U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1437
Supplement 55

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Supplement 55

Regarding Braidwood Station, Units 1 and 2

Draft Report for Comment

Office of Nuclear Reactor Regulation

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Draft Report for Comment

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Any interested party may submit comments on this report for consideration by the NRC staff. Comments may be accompanied by additional relevant information or supporting data. Please specify the report number **NUREG-1437, Supplement 55,** in your comments, and send them by the end of the comment period specified in the *Federal Register* notice announcing the availability of this report.

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Federal Rulemaking Website: Go to http://www.regulations.gov and search for documents filed under Docket ID **NRC-2013-0169**. Address questions about NRC dockets to Carol Gallagher at 301-415-3463 or by e-mail at Carol.Gallagher@nrc.gov.

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COVER SHEET

Responsible Agency: U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation. There are no cooperating agencies involved in the preparation of this document.

Title: *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 55, Regarding Braidwood Station, Units 1 and 2, Draft Report for Comment* (NUREG-1437). Braidwood Station (Braidwood), Units 1 and 2, are located in Will County, Illinois.

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ABSTRACT

This supplemental environmental impact statement (SEIS) has been prepared in response to an application submitted by Exelon Generation Company, LLC (Exelon), to renew the operating license for Braidwood Station (Braidwood), Units 1 and 2, for an additional 20 years.

This SEIS includes the preliminary analysis that evaluates the environmental impacts of the proposed action and alternatives to the proposed action. Alternatives considered include: new nuclear, coal-integrated gasification combined cycle, natural gas combined cycle, combination alternative (wind power, natural gas combined cycle, and solar power), and purchased power.

The U.S. Nuclear Regulatory Commission (NRC) staff's preliminary recommendation is that the adverse environmental impacts of license renewal for Braidwood are not so great that preserving the option of license renewal for energy-planning decisionmakers would be unreasonable. This recommendation is based on the following:

- the analysis and findings in NUREG–1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*;
- the Environmental Report submitted by Exelon;
- consultation with Federal, State, local, and Tribal government agencies;
- the NRC staff's environmental review; and
- consideration of public comments received during the scoping process.

TABLE OF CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

BACKGROUND

By letter dated May 29, 2013, Exelon Generation Company, LLC (Exelon), submitted an application to the U.S. Nuclear Regulatory Commission (NRC) to issue renewed operating licenses for Braidwood Station, Units 1 and 2 (Braidwood), for an additional 20-year period.

Pursuant to Title 10 of the *Code of Federal Regulations* 51.20(b)(2) (10 CFR 51.20(b)(2)), the renewal of a power reactor operating license requires preparation of an environmental impact statement (EIS) or a supplement to an existing EIS. In addition, 10 CFR 51.95(c) states that, in connection with the renewal of an operating license, the NRC shall prepare an EIS, which is a supplement to the Commission's NUREG-1437, *Generic Environmental Impact Statement (GEIS) for License Renewal of Nuclear Plants*.

Upon acceptance of Exelon's application, the NRC staff began the environmental review process described in 10 CFR Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions," by publishing a notice of intent to prepare a supplemental EIS (SEIS) and conduct scoping. In preparation of this SEIS for Braidwood, the NRC staff performed the following:

- conducted public scoping meetings on August 21, 2013, in Fossil Ridge library in Will County, Illinois;
- conducted a site audit at Braidwood on November 19, 2013;
- reviewed Exelon's Environmental Report (ER) and compared it to the GEIS;
- consulted with Federal, state, and local agencies;
- conducted a review of the issues following the guidance set forth in NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1, Revision 1: Operating License Renewal*; and
- considered public comments received during the scoping process.

PROPOSED FEDERAL ACTION

Exelon initiated the proposed Federal action—issuance of renewed power reactor operating licenses—by submitting an application for license renewal of Braidwood, for which the existing licenses (NPF-72 and NPF-77) expire on October 17, 2026, and December 18, 2027, respectively. The NRC's Federal action is the decision whether or not to renew the licenses for an additional 20 years. In accordance with 10 CFR 2.109, if a licensee of a nuclear power plant files an application to renew an operating license at least 5 years before the expiration date of that license, the existing license will not be deemed to have expired until the safety and environmental reviews are completed and the NRC has made a final decision to either deny the application or issue a renewed license for the additional 20 years.

PURPOSE AND NEED FOR THE PROPOSED FEDERAL ACTION

The purpose and need for the proposed action (issuance of renewed licenses) is to provide an option that allows for power generation capability beyond the term of the current nuclear power plant operating license to meet future system generating needs. Such needs may be determined by other energy-planning decisionmakers, such as state, utility (plant owner), and,

where authorized, Federal agencies (other than NRC). This definition of purpose and need reflects the NRC's recognition that, unless there are findings in the safety review required by the Atomic Energy Act or findings in the National Environmental Policy Act (NEPA) environmental analysis that would lead the NRC to reject a license renewal application, the NRC does not have a role in the energy-planning decisions as to whether a particular nuclear power plant should continue to operate.

ENVIRONMENTAL IMPACTS OF LICENSE RENEWAL

The SEIS evaluates the potential environmental impacts of the proposed action. The environmental impacts from the proposed action are designated as SMALL, MODERATE, or LARGE. As set forth in the GEIS, Category 1 issues are those that meet all of the following criteria:

- The environmental impacts associated with the issue are determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.
- A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts, except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal.
- Mitigation of adverse impacts associated with the issue is considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

> **SMALL:** Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
>
> **MODERATE:** Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
>
> **LARGE:** Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

For Category 1 issues, no additional site-specific analysis is required in this SEIS unless new and significant information is identified. Chapter 4 of this SEIS presents the process for identifying new and significant information. Site-specific issues (Category 2) are those that do not meet one or more of the criteria for Category 1 issues; therefore, an additional site-specific review for these non-generic issues is required, and the results are documented in the SEIS.

Neither Exelon nor the NRC identified information that is both new and significant related to Category 1 issues that would call into question the conclusions in the GEIS. This conclusion is supported by the NRC's review of the applicant's ER and other documentation relevant to the applicant's activities, the public scoping process and substantive comments raised, and the findings from the environmental site audit conducted by the NRC staff. The NRC staff, therefore, relies upon the conclusions of the GEIS for all Category 1 issues applicable to Braidwood.

Table ES-1 summarizes the Category 2 issues relevant to Braidwood, as well as the NRC staff's findings related to those issues. If the NRC staff determined that there were no Category 2 issues applicable for a particular resource area, the findings of the GEIS, as documented in Appendix B to Subpart A of 10 CFR Part 51, are incorporated for that resource area.

Table ES–1. Summary of NRC Conclusions Relating to Site-Specific Impacts of License Renewal

Resource Area	Relevant Category 2 Issues	Impacts
Surface Water Resources	Surface water use conflicts	SMALL
Groundwater Resources	Radionuclides released to groundwater	SMALL
Terrestrial Resources	Effects on terrestrial resources (non-cooling system impacts)	SMALL
	Water use conflicts with terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river)	SMALL
Aquatic Resources	Impingement and entrainment of aquatic organisms	SMALL to MODERATE
	Thermal impacts on aquatic organisms	SMALL to MODERATE
	Water use conflicts with aquatic resources	SMALL
Special Status Species	Threatened or endangered species	No effect to May affect, but not likely to adversely affect [a]
Historic and Cultural	Historic and cultural resources	No adverse effect[b]
Human Health	Microbiological hazards to the public health	SMALL
	Electric shock hazards	SMALL
Environmental Justice	Minority and low-income populations	See note below[c]
Cumulative Impacts	Surface Water	SMALL to MODERATE
	Ground Water	MODERATE to LARGE
	Terrestrial resources	MODERATE to LARGE
	Aquatic resources	MODERATE
	Environmental Justice	See note below[c]
	Global Climate Change	MODERATE
	All other resource areas	SMALL

[a]For Federally protected species, the NRC reports the effects from continued operation of Braidwood during the license renewal period in terms of its Endangered Species Act (ESA) findings of “no effect,” “may affect, but not likely to adversely affect,” or “may affect, and is likely to adversely affect.”

[b]The National Historic Preservation Act of 1966, as amended (NHPA) requires Federal agencies to consider the effects of their undertakings on historic properties.

[c]There would be no disproportionately high and adverse impacts to minority and low-income populations and subsistence consumption from continued operation of Braidwood during the license renewal period and from cumulative impacts.

SEVERE ACCIDENT MITIGATION ALTERNATIVES

Since the staff had not previously considered severe accident mitigation alternatives (SAMAs) for Braidwood in an environment impact statement or related supplement or in an environmental assessment (to reduce the likelihood or potential consequences of a variety of highly uncommon but potentially serious accidents at Braidwood), 10 CFR 51.53(c)(3)(ii)(L) requires that a consideration of alternatives to mitigate severe accidents must be provided in the course of the license renewal review. SAMAs are potential ways to reduce the risk or potential impacts of uncommon, but potentially severe accidents, and they may include changes to plant components, systems, procedures, and training.

The NRC staff reviewed Exelon's ER evaluation of potential SAMAs. Based on the staff's review, the NRC staff concluded that none of the potentially cost-beneficial SAMAs relate to adequately managing the effects of aging during the period of extended operation. Therefore, they need not be implemented as part of the license renewal, pursuant to 10 CFR Part 54, "Requirements for renewal of operating licenses for nuclear power plants."

ALTERNATIVES

The NRC staff considered the environmental impacts associated with alternatives to license renewal. These alternatives include other methods of power generation and not renewing the Braidwood operating license (the no-action alternative). The feasible and commercially viable replacement power alternatives considered were:

- new nuclear,
- coal-integrated gasification combined cycle (IGCC),
- natural gas combined-cycle (NGCC),
- combination alternative (wind power, natural gas combined cycle, and solar power), and
- purchased power.

The NRC staff initially considered a number of additional alternatives for analysis as alternatives to the license renewal of Braidwood; these were later dismissed because of technical, resource availability, or commercial limitations that currently exist and that the NRC staff believes are likely to continue to exist when the existing Braidwood licenses expire. The no action alternative and the effects it would have were also considered by the NRC staff.

Where possible, the NRC staff evaluated potential environmental impacts for these alternatives located both at the Braidwood site and at some other unspecified alternate location. Alternatives considered, but dismissed, were:

- energy efficiency and conservation,
- solar power,
- wind power,
- biomass,
- hydroelectric power,
- wave and ocean energy,
- fuel cells,

- delayed retirement,
- geothermal power,
- municipal solid waste,
- petroleum, and
- super critical pulverized coal (SCPC).

The NRC staff evaluated each alternative using the same resource areas that were used in evaluating impacts from license renewal.

PRELIMINARY RECOMMENDATION

The NRC staff's preliminary recommendation is that the adverse environmental impacts of license renewal for Braidwood are not so great that preserving the option of license renewal for energy-planning decisionmakers would be unreasonable. This recommendation is based on the following:

- the analyses and findings in the GEIS;
- the ER submitted by Exelon;
- the NRC staff's consultation with Federal, state, and local agencies;
- the NRC staff's independent environmental review; and
- the NRC staff's consideration of public comments received during the scoping process.

ABBREVIATIONS AND ACRONYMS

°C	degree(s) Celsius
°F	degree(s) Fahrenheit
μm	micrometer(s)
^{14}C	carbon-14 (an isotope of carbon)
AADT	annual average daily traffic
ac	acre(s)
ac/MW	acre(s) per megawatt
ACC	averted cleanup and decontamination costs
ACHP	Advisory Council on Historic Preservation
ADAMS	Agencywide Documents Access and Management System
AEA	Atomic Energy Act of 1954
AEC	U.S. Atomic Energy Commission
AEL	Alternative Energy Law
AFW	auxiliary feedwater
AIU	Ameren Illinois Utilities
ALARA	as low as reasonably achievable
AMSAC	ATWS mitigating system actuation circuitry
AMSL	above mean sea level
ANS	American Nuclear Society
AOC	averted offsite property damage costs
AOE	averted occupational exposure
AOSC	averted onsite costs
AP	auxiliary power
APE	area of potential effect
APE	averted public exposure
API	American Petroleum Institute
AQCR	Air Quality Control Region
ARES	alternative retail electric suppliers
ASME	American Society of Mechanical Engineers
ATWS	anticipated transient(s) without scram
AWEA	American Wind Energy Association
AWT	Association of Water Technologies

BACT	best available control technology
BEA	Bureau of Economic Analysis
BGE	Baltimore Gas and Electric Company
BGEPA	Bald and Golden Eagle Protection Act
bgs	below ground surface
BLH	BLH Technologies, Inc.
BLM	Bureau of Land Management
BLS	Bureau of Labor Statistics
BMP	best management practice
BOEM	Bureau of Ocean Energy Management
BP	before present
BPA	Bonneville Power Authority
Braidwood	Braidwood Station, Units 1 and 2
BSER	best system of emission reduction
BTA	Best Technology Available
BTU	British thermal units
BWR	boiling water reactor
CAA	Clean Air Act
CAES	compressed air energy storage
CAIR	Clean Air Interstate Rule
CAP	Community Advisory Panel
CCS	carbon capture and sequestration/storage
CCW	component cooling water
CDC	Centers for Disease Control and Prevention
CDF	core damage frequency
CDII	Channahon Dresden Island Illinois
CDL	Cropland Data Layer
CEC	Commission for Environmental Cooperation
CED	Center for Economic Development
CEQ	Council on Environmental Quality
CET	containment event tree
CFE	early containment failure
CFR	Code of Federal Regulations
cfs	cubic foot (feet) per second
CH_4	methane

CLB	current licensing basis (bases)
cm	centimeter(s)
CMA	Chicago Metropolitan Area
CMAP	Chicago Metropolitan Agency for Planning
CO	carbon monoxide
CO_2	carbon dioxide
CO_2/MWh	carbon dioxide per megawatt hour
CO_2e	carbon dioxide equivalent(s)
COE	cost of enhancement
COL	Combined License
ComEd	Commonwealth Edison Company
CPI	Consumer Price Index
CPUE	catch-per-unit-effort
CRA	Conestoga-Rovers & Associates
CRMP	Cultural Resource Management Plan
CSAPR	Cross-State Air Pollution Rule
CsI	cesium iodide
CsOH	cesium hydroxide
CSP	concentrating solar power
CUSD	Community Unit School District
CVCS	chemical and volume control system
CWA	Clean Water Act
CWS	cooling water system
DAW	dry active waste
dB	decibel(s)
dBA	decibels adjusted
DCEO	Illinois Department of Commerce and Economic Opportunity
DLOOP	dual unit loss(es) of offsite power
DMR	Discharge Monitoring Report
DMS	demand side management
DMS	Diverse Mitigation System
DNPS	Dresden Nuclear Power Station
DNR	[Illinois] Department of Natural Resources
DO	dissolved oxygen
DOE	Department of Energy

DSM	demand-side management
DTS	dry transfer system
E&E	Ecology and Environment, Inc.
EA	environmental assessment
EAV	equalized assessed value
ECCS	emergency core cooling system
EcoCAT	Ecological Compliance Assessment Tool
EDPR	EDP Renewables
EFH	essential fish habitat
EIA	Energy Information Administration
EIS	environmental impact statement
ELF	extremely low frequency
Elv.	Elevation
EMF	electromagnetic field
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
EPRI	Electric Power Research Institute
EPT	Ephemeroptera, Plecoptera, and Trichoptera
EPZ	emergency planning zone
ER	Environmental Report
ERCOT	Electric Reliability Council of Texas
ESA	Endangered Species Act of 1973, as amended
ESF	engineered safety feature
ESFAS	engineered safety features actuation system
ESI	Ecological Specialists, Inc.
ESRP	environmental standard review plan
ESW	emergency service water
ET	Earth Tech, Inc.
EU	electric utilities
Exelon	Exelon Generation Company, LLC
F&O	fact and observation
FAA	Federal Aviation Administration
FCT	Fuel Cell Technologies

FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FES	Final Environmental Statement
FES-C	Final Environmental Statement for Braidwood Construction
FES-O	Final Environmental Statement for Braidwood Operation
FESOP	Federally Enforceable State Operating Permit
FHA	Fuel Handling Accident
FHWA	Federal Highway Administration
FIVE	fire-induced vulnerability evaluation
FONSI	finding of no significant impact
FPIE	full power, internal events
fps	foot (feet) per second
FR	Federal Register
FRA	Federal Railroad Administration
FRN	*Federal Register* notice
FT	feet above mean sea level (AMSL)
ft	foot (feet)
ft^3	cubic foot (feet)
fps	foot (feet) per second
FW	feedwater
FWS	U.S. Fish and Wildlife Service
g C_{eq}/kWh	grams of carbon equivalent per kilowatt-hour
gal	gallon(s)
GEIS	*Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437
GHG	greenhouse gas
GI	gastrointestinal
GI	generic issue
GL	generic letter
GLA	Great Lakes Archaeological Research Center
gpd	gallon(s) per day
gpm	gallon(s) per minute
GW	gigawatt
GWh	gigawatt hour(s)

GWP	global warming potential
GWPS	gaseous waste processing system
H_2O	water
ha	hectare(s)
ha/MW	hectare(s) per megawatt
HAI	healthcare-associated infections
HCLPF	high confidence in low probability of failure
HDPE	high density polyethylene
HDR	HDR Engineering, Inc.
HEP	human error probability
HFC	hydrofluorocarbon
HFE	human failure event
HFO	high winds, floods, and other
HIC	high-integrity container
HMTA	Hazardous Materials Transportation Act of 1975
HRA	human reliability analysis (analyses)
HRSG	heat recovery steam generator
HSR	high-speed rail
HTGR	high-temperature gas-cooled reactor
HUD	U.S. Department of Housing and Urban Development
HX	heat exchanger
IAC	Illinois Administrative Code
IBI	Index of Biological Integrity
IBRC	Indiana Business Research Center
ICEC	Illinois Clean Energy Coalition
IDCEO	Illinois Department of Commerce and Economic Opportunity
IDPH	Illinois Department of Public Health
IDNR	Illinois Department of Natural Resources
IDOT	Illinois Department of Transportation
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IEMA	Illinois Emergency Management Agency
IEPA	Illinois Environmental Protection Agency
IGCC	integrated gasification combined cycle
IGNN	Illinois Government News Network

IHPA	Illinois Historic Preservation Agency
ILCS	Illinois Compiled Statutes
ILGA	Illinois General Assembly
INAI	Illinois Natural Areas Inventory
INDNR	Indiana Department of Natural Resources
INEEL	Idaho National Engineering and Environmental Laboratory
INHS	Illinois Natural History Survey
IPA	integrated plant assessment
IPaC	Information, Planning, and Conservation System
IPCC	Intergovernmental Panel on Climate Change
IPE	individual plant examination
IPEEE	individual plant examination(s) of external events
IRSF	Interim Radwaste Storage Facility
ISBE	Illinois State Board of Education
ISFSI	independent spent fuel storage installation
ISGS	Illinois State Geological Survey
ISLOCA	interfacing-systems loss-of-coolant accident
ISM	Illinois State Museum
ISO	independent [transmission] system operator
ISO	International Organization for Standardization
ITA	Illinois Transportation Archaeological Research Program
JHEP	joint human error probability
JOAAP	Joliet Army Ammunition Plant
kg	kilogram(s)
kHz	kilohertz
km	kilometer(s)
km^2	square kilometer(s)
kV	kilovolt(s)
kW	kilowatt(s)
kWe	kilowatt(s) electrical
kWh	kilowatt hour(s)
$kWh/m^2/day$	kilowatt hour(s) per square meter per day
L	liter(s)
L/min	liter(s) per minute
L/sec	liter(s) per second

lb	pound(s)
Ldn	day-night average sound level—the 24-hour A-weighted equivalent sound level, with a 10-decibel penalty applied to nighttime levels
LER	large, early release
LERF	large early release frequency
LLC	limited liability company
LLRW	low-level radioactive waste
LLW	low-level [radioactive] waste
LMFW	loss of main feedwater
LOCA	loss-of-coolant accident
LOE	line(s) of evidence
LOOP	loss(es) of offsite power
LOS	level(s) of service
Lpd	liter(s) per day
LRA	license renewal application
LRMP	land resource management plan
LRWS	liquid radwaste system
m	meter(s)
m/s	meter(s) per second
m^3	cubic meter(s)
m^3/d	cubic meter(s) per day
m^3/s	cubic meter(s) per second
m^3/y	cubic meter(s) per year
MAAP	Modular Accident Analysis Program
MACCS2	MELCOR Accident Consequence Code System version 2
MACR	maximum averted cost-risk
MAE Center	Mid-America Earthquake Center
MATS	Mercury and Air Toxics Standards
MBTA	Migratory Bird Treaty Act
MCC	motor control center
MCR	main control room
MDNR	Minnesota Department of Natural Resources
mg/L	milligram(s) per liter
mgd	million gallons per day

mgy	million gallons per year
mGy	milligray
mi	mile(s)
mi^2	square mile(s)
MiSA	Micropolitan Statistical Area
MISO	Midcontinent Independent System Operator, Inc.
mm	millimeter(s)
MMT	million metric tons
MODNR	Missouri Department of Natural Resources
MOV	motor-operated valve
MPCA	Minnesota Pollution Control Agency
mph	mile(s) per hour
mrad	millirad
mrem	millirem
MSA	Magnuson–Stevens Fishery Conservation and Management Act, as amended through 2006
mSv	millisievert
MT	metric ton(s)
MUDS	makeup water demineralizer system
MUR	measurement uncertainty recapture
MW	megawatt(s)
MWe	megawatt(s) electrical
MWh	megawatt hour(s)
MWt	megawatt(s) thermal
N_2O	nitrous oxide
NA	not applicable
NAA	nonattainment area
NAAQS	National Ambient Air Quality Standards
NARUC	National Association of Regulatory Utility Commissioners
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NCADAC	National Climate Assessment and Development Advisory Committee
NCDC	National Climatic Data Center
NCES	National Center for Education Statistics

NCZVED	National Center for Zoonotic, Vector-Borne, and Enteric Diseases
NEA	Nuclear Energy Agency
NEAC	[DOE] Nuclear Energy Advisory Committee
NEI	Nuclear Energy Institute
NEIS	Nuclear Energy Information Service
NEPA	National Environmental Policy Act
NERI	Nuclear Energy Research Initiative
NESC®	National Electrical Safety Code®
NETL	National Energy Technology Laboratory
NGCC	natural-gas-fired combined-cycle
NGNP	Next Generation Nuclear Plant
NH_3	ammonia
NHPA	National Historic Preservation Act of 1966, as amended
NIEHS	National Institute of Environmental Health Sciences
NMFS	National Marine Fisheries Service (of NOAA)
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOED	Notice of Enforcement Discretion
NOI	Notice of Intent
NO_x	nitrogen oxide(s)
NP	National Park
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	U.S. Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NRHP	National Register of Historic Places
NRIS	National Register Information System
NRR	Nuclear Reactor Regulation
NSC	National Safety Council
NSPS	New Source Performance Standards
NSR	New Source Review
O_3	ozone
ODCM	Offsite Dose Calculation Manual
OECD	Organisation for Economic Co-operation and Development
OECR	offsite economic cost risk

OTEC	Ocean Thermal Energy Conversion
OWR	[Illinois Department of Natural Resources or DNR] Office of Water Resources
oz	ounce(s)
PAM	primary amebic meningoencephalitis
Pb	lead
PC	pulverized coal
PCB	polychlorinated biphenyl
pCi/L	picocurie(s)/liter
PDS	plant damage state
PECO	PECO Energy Company [an Exelon company, formerly Philadelphia Electric Company]
PEIS	programmatic environmental impact statement
PFC	perfluorocarbon
PHS	pumped hydroelectric storage
PIAT	payment(s) in addition to taxes
PIMW	potentially infectious medical waste
PJM	central Atlantic and Midwestern regional electric distribution network
PM	particulate matter
PM_{10}	particulate matter with aerodynamic diameters of 10 microns or less
$PM_{2.5}$	particulate matter with aerodynamic diameters of 2.5 microns or less
PNNL	Pacific Northwest National Laboratory
PORV	power-operated relief valve
PRA	probabilistic risk assessment
PSA	probabilistic safety assessment
PSD	Prevention of Significant Deterioration
psi	pound(s) per square inch
PTE	potential to emit
PV	photovoltaic
PWR	pressurized-water reactor
RAI	request for additional information
RCP	reactor coolant pump
RCRA	Resource Conservation and Recovery Act of 1976, as amended

RCS	reactor coolant system
RDS	Research and Development Solutions, LLC
rem	roentgen equivalent(s) man
REMP	radiological environmental monitoring program
RGPP	Radiological Groundwater Protection Plan
RHR	Regional Haze Rule
RHR	residual heat removal
RKm	river kilometer(s)
RM	river mile(s)
ROI	region(s) of influence
ROW	right-of-way
RPC	replacement power cost
RPV	reactor pressure vessel
RRW	risk reduction worth
RTO	regional transmission organization
RWSPG	[Northeastern Illinois] Regional Water Supply Planning Group
RWST	refueling water storage tank
SAFSTOR	a period of safe storage of the stabilized and defueled facility followed by final decontamination, dismantlement, and license termination
SAMA	severe accident mitigation alternative
SAT	system auxiliary transformer
SBO	station blackout
SCPC	supercritical pulverized coal
SCR	selective catalytic reduction
SDWIS	Safe Drinking Water Information System
SECPOP2000	Sector Population, Land Fraction, and Economic Estimation Program
SEIS	supplemental environmental impact statement
SER	safety evaluation report
SERC	Southeastern Electric Reliability Council
SF_6	sulfur hexafluoride
SG	steam generator
SGTR	steam generator tube rupture
SHPO	State Historic Preservation Officer
SI	safety injection

SIP	State Implementation Plan
SMA	seismic margin assessment
SMITTR	surveillance, monitoring, inspection, testing, trending, and recordkeeping
SNL	Sandia National Laboratories
SO_2	sulfur dioxide
SOARCA	State-of-the-Art Reactor Consequence Analyses
SO_x	sulfur oxide(s)
SPDES	State Pollutant Discharge Elimination System
SR	supporting requirement
SSA	South Suburban Airport
SSC	structure, system, and component
SSEL	Safe Shutdown Equipment List
Sv	sievert
SW	service water
SWPPP	Stormwater Pollution Prevention Plan
SX	essential service water
t	ton(s)
T&RM	Training and Reference Material
TAC	Technical Assignment Control
TCEQ	Texas Commission on Environmental Quality
TEEIC	Tribal Energy and Environmental Information Clearinghouse
TEP	Threatened, Endangered, and Proposed
TES	thermal energy storage
Tg	teragram(s)
TMDL	total maximum daily load
tpy	ton(s) per year
TS	technical specification
TSP	total suspended particulates
TSS	transmission substation
U.S.	United States
U.S.C.	United States Code
UFSAR	Updated Final Safety Analysis Report
UNL	University of Nebraska—Lincoln
UP	Union Pacific

USACE	United States Army Corps of Engineers
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
V	volt(s)
VEGP	Vogtle Electric Generating Plant
VOC	volatile organic compound
WA	Wilderness Area
WAW	wet active waste
WCAP	Westinghouse Commercial Atomic Power
WCD	Waste Confidence Decision
WGFD	Wyoming Game and Fish Department
WHC	Wildlife Habitat Council
WJE	Wiss, Janney, Elstner Associates, Inc.
WNS	white-nose syndrome
WOE	weight of evidence
yd	yard(s)
yd^3	cubic yard(s)
YOY	young of the year
yr	year(s)
Δ	change of quantity

1.0 INTRODUCTION

U.S. Nuclear Regulatory Commission (NRC) environmental protection regulations in Part 51 of Title 10 of the *Code of Federal Regulations* (10 CFR 51) implement the National Environmental Policy Act (NEPA). Section 51.20 of 10 CFR requires the preparation of an environmental impact statement (EIS) for the issuance or renewal of a nuclear power plant operating license.

The Atomic Energy Act of 1954 (AEA) specifies that licenses for commercial power reactors can be granted for up to 40 years. NRC regulations (10 CFR 54.31) allow for an option to renew a license for up to an additional 20 years. The initial 40-year licensing period was based on economic and antitrust considerations rather than on technical limitations of the nuclear facility.

The decision to seek a license renewal rests entirely with nuclear power facility owners and, typically, is based on the facility's economic viability and the investment necessary to continue to meet NRC safety and environmental requirements. The NRC makes the decision to grant or deny license renewal based on whether the applicant has demonstrated that the environmental and safety requirements in the agency's regulations can be met during the period of extended operation.

1.1 Proposed Federal Action

Exelon Generation Company, LLC (Exelon) requested the proposed Federal action by submitting an application for license renewal of Braidwood Station (Braidwood), Units 1 and 2, for which the existing licenses (NPF-72 and NPF-77) expire on October 17, 2026, and December 18, 2027, respectively. The NRC's proposed Federal action is the decision whether to issue the renewed licenses for an additional 20 years.

1.2 Purpose and Need for the Proposed Federal Action

The purpose and need for the proposed action (issuance of a renewed license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by other energy-planning decisionmakers. This definition of purpose and need reflects the NRC's recognition that, unless there are findings in the safety review required by the AEA or findings in the NEPA environmental analysis that would lead the NRC to reject a license renewal application (LRA), the NRC does not have a role in the energy-planning decisions of State regulators and utility officials as to whether a particular nuclear power plant should continue to operate.

1.3 Major Environmental Review Milestones

Exelon submitted an Environmental Report (ER) as part of its LRA (Exelon 2013) in May 2013. After reviewing the LRA and ER for sufficiency, the NRC staff published a *Federal Register* Notice of Acceptability and Opportunity for Hearing (78 FR 44603) on July 24, 2013. Then, on July 31, 2013, the NRC published another notice in the *Federal Register* (78 FR 46379) on the intent to conduct scoping, thereby beginning the 60-day scoping period.

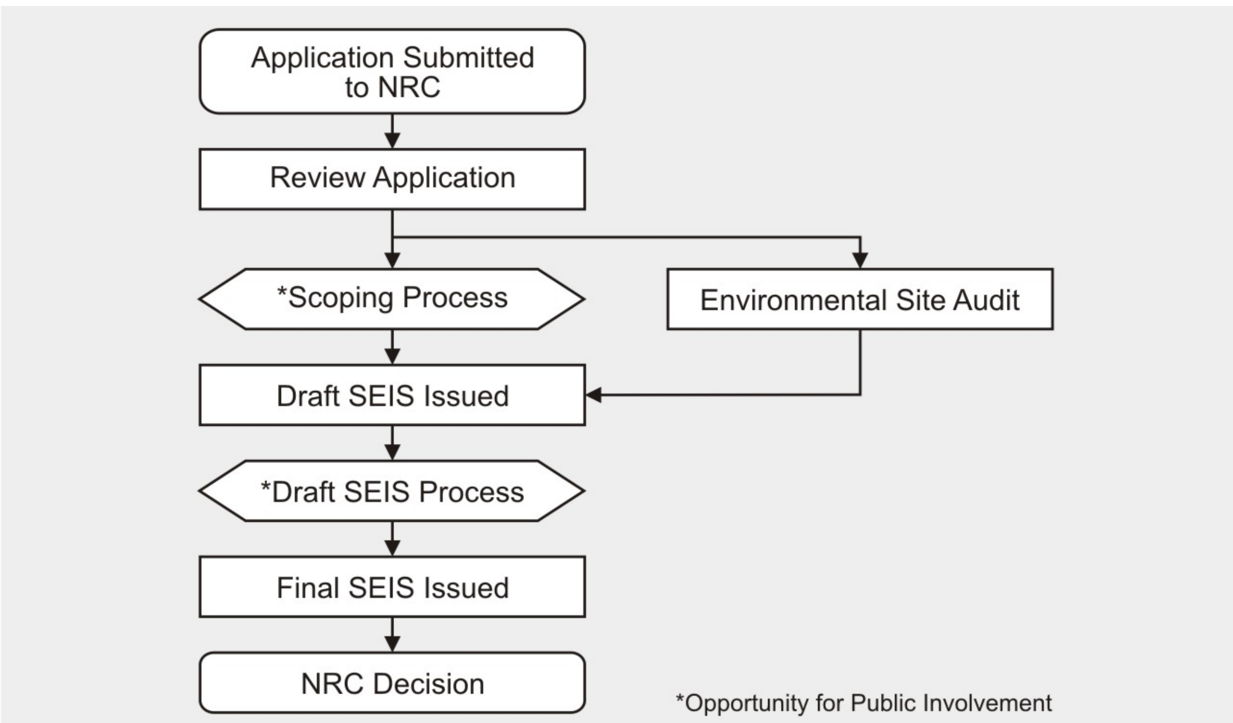
The NRC staff held two public scoping meetings on August 21, 2013, in Will County, Illinois. The comments received during the scoping process are presented in their entirety in "Environmental Impact Statement Scoping Process, Summary Report, Braidwood Station, Units 1 and 2, Will County," published in 2014 (NRC 2014). The staff presents comments

considered to be within the scope of the environmental license renewal review and the NRC responses in Appendix A of this supplemental environmental impact statement (SEIS).

In order to independently verify information provided in the ER, the NRC staff conducted a site audit at Braidwood, Units 1 and 2, in November 2013. During the site audit, the staff met with plant personnel, reviewed specific documentation, toured the facility, and met with interested Federal, State, and local agencies. A summary of that site audit and the attendees is contained in the Audit Summary Report, published in December 2013 (NRC 2013b).

Upon completion of the scoping period and site audit, the NRC staff compiled its findings in the draft SEIS. This document is made available for public comment for 45 days. During this time, the staff will host public meetings and collect public comments. Based on the information gathered, it will amend the draft SEIS findings, as necessary, and publish the final SEIS for license renewal. Figure 1–1 shows the major milestones of the NRC's license renewal application environmental review.

Figure 1–1. Environmental Review Process



The NRC has established a license renewal review process that can be completed in a reasonable period with clear requirements to assure safe plant operation for up to an additional 20 years of plant life. The NRC staff conducts the safety review simultaneously with the environmental review. The staff documents the findings of the safety review in a safety evaluation report (SER). The findings in the SEIS and the SER are both factors in the NRC's decision to either grant or deny the issuance of a renewed license.

1.4 Generic Environmental Impact Statement

The NRC staff performed a generic assessment of the environmental impacts associated with license renewal to improve the efficiency of its license renewal review. The *Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants* (GEIS), NUREG-1437, Revision 1 (NRC 2013), documented the results of the staff's systematic approach to evaluate the environmental consequences of renewing the licenses of individual nuclear power plants and operating them for an additional 20 years. The staff analyzed in detail and resolved those environmental issues that could be resolved generically in the GEIS.

The GEIS establishes separate environmental impact issues for the NRC staff to independently verify. Of these issues, the NRC staff determined that some generic issues are generic to all plants (Category 1). Other issues do not lend themselves to generic consideration (Category 2 or uncategorized). The staff evaluated these issues on a site-specific basis in a SEIS. Appendix B to Subpart A of 10 CFR 51 provides a summary of the staff findings in the GEIS.

For each potential environmental issue, in the GEIS, the NRC staff performs the following:

- describes the activity that affects the environment,
- identifies the population or resource that is affected,
- assesses the nature and magnitude of the impact on the affected population or resource,
- characterizes the significance of the effect for both beneficial and adverse effects,
- determines whether the results of the analysis apply to all plants, and
- considers whether additional mitigation measures would be warranted for impacts that would have the same significance level for all plants.

The NRC's standard of significance for impacts was established using the Council on Environmental Quality (CEQ) terminology for "significant." The NRC established three levels of significance for potential impacts—SMALL, MODERATE, and LARGE, as defined below.

SMALL: Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

MODERATE: Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE: Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

> **Significance** indicates the importance of likely environmental impacts and is determined by considering two variables: **context** and **intensity**.
>
> **Context** is the geographic, biophysical, and social context in which the effects will occur.
>
> **Intensity** refers to the severity of the impact, in whatever context it occurs.

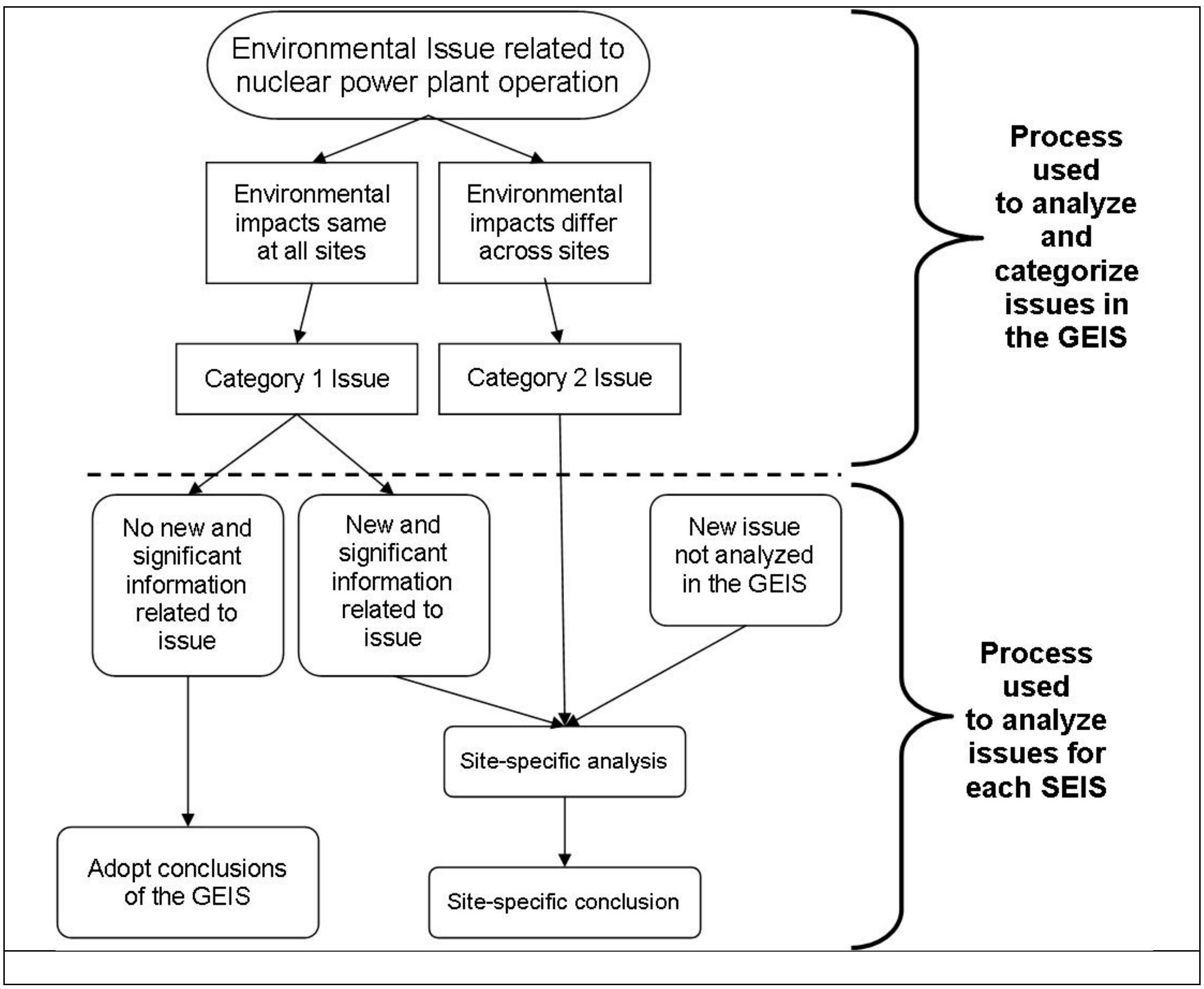
The GEIS includes a determination of whether the analysis of the environmental issue could be applied to all plants and whether additional mitigation measures would be warranted. Issues are assigned a Category 1 or a Category 2 designation. As set forth in the GEIS, Category 1 issues are those that meet the following criteria:

- The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.

- A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal).
- Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

For generic issues (Category 1), no additional site-specific analysis is required in the SEIS unless new and significant information is identified. The process for identifying new and significant information is presented in Section 4.14. Site-specific issues (Category 2) are those that do not meet one or more of the criteria of Category 1 issues; therefore, additional site-specific review for these issues is required. A site-specific analysis is required for 17 of those 78 issues evaluated in the GEIS. The results of that site-specific analysis are documented in the SEIS. Figure 1–2 illustrates the evaluation of environmental issues for license renewal.

Figure 1–2. Environmental Issues Evaluated for License Renewal



1.5 Supplemental Environmental Impact Statement

The SEIS presents an analysis that considers the environmental effects of the continued operation of Braidwood, Units 1 and 2, alternatives to license renewal, and mitigation measures for minimizing adverse environmental impacts. Chapter 4 contains analysis and comparison of the potential environmental impacts from alternatives while Chapter 5 presents the recommendation of the NRC on whether or not the environmental impacts of license renewal are so great that preserving the option of license renewal would be unreasonable. The final recommendation will be made after consideration of comments received on the draft SEIS during the public comment period.

In the preparation of the SEIS for Braidwood, Units 1 and 2, the NRC staff carried out the following activities:

- reviewed the information provided in Exelon's ER;
- consulted with other Federal, State, local agencies, and tribal nations;
- conducted an independent review of the issues during site audit; and
- considered the public comments received for the review (during the scoping process and, subsequently, on the draft SEIS).

New information can be identified from many sources, including the applicant, the NRC, other agencies, or public comments. If a new issue is revealed, it is first analyzed to determine whether it is within the scope of the license renewal environmental evaluation. If the new issue is not addressed in the GEIS, the NRC staff would determine the significance of the issue and document the analysis in the SEIS.

> **New and significant information** must be both new and bear on the proposed action or its impacts, presenting a seriously different picture of the impacts from those envisioned in the GEIS (i.e., impacts of greater severity than impacts considered in the GEIS, considering their intensity and context).

1.6 Decision to Be Supported by the SEIS

The decision to be supported by the SEIS is whether or not to renew the operating licenses for Braidwood for an additional 20 years. The NRC decision standard is specified in 10 CFR 51.103(a)(5):

> In making a final decision on a license renewal action pursuant to Part 54 of this chapter, the Commission shall determine whether or not the adverse environmental impacts of license renewal are so great that preserving the option of license renewal for energy planning decisionmakers would be unreasonable.

There are many factors that the NRC takes into consideration when deciding whether to renew the operating license of a nuclear power plant. The analyses of environmental impacts evaluated in the GEIS would provide the NRC's decisionmaker (in this case, the Commission) with important environmental information for use in the overall decisionmaking process. There are also decisions outside the regulatory scope of license renewal that cannot be made on the basis of the final GEIS analysis. These decisions concern the following issues: changes to plant cooling systems, disposition of spent nuclear fuel, emergency preparedness, safeguards and security, need for power, and seismicity and flooding (NRC 2013a).

1.7 Cooperating Agencies

During the scoping process, no Federal, State, or local agencies were identified as cooperating agencies in the preparation of this SEIS.

1.8 Consultations

The Endangered Species Act of 1973, as amended (ESA); the Magnuson–Stevens Fisheries Management Act of 1996, as amended; and the National Historic Preservation Act (NHPA) of 1966 require that Federal agencies consult with applicable State and Federal agencies and groups prior to taking action that may affect endangered species, fisheries, or historic and archaeological resources, respectively. The NRC consulted with the following agencies and groups:

- State Historic Preservation Office (SHPO),
- U.S. Fish and Wildlife Service (FWS),
- Ho-Chunk Nation,
- Miami Tribe of Oklahoma,
- Peoria Tribe of Indians of Oklahoma,
- Citizen Potawatomi Nation,
- Sac and Fox Tribe of the Mississippi in Iowa (Meskwaki),
- Sac and Fox Nation of Missouri in Kansas and Nebraska,
- Sac and Fox Nation,
- Pokagon Band of Potawatomi,
- Forest County Potawatomi,
- Hannahville Indian Community, Band of Potawatomi,
- Prairie Band of Potawatomi Nation,
- Winnebago Tribe of Nebraska,
- Kickapoo Tribe in Kansas, and
- Kickapoo Tribe of Oklahoma.

The Tribes were selected based on their historical and cultural ties with the local areas. Appendix C provides a listing of the consultation documents.

1.9 Correspondence

Appendix D contains a chronological list of all documents sent and received during the environmental review, including consultation documents listed in Section 1.8.

1.10 Status of Compliance

Exelon is responsible for complying with all NRC regulations and other applicable Federal, State, and local requirements. Appendix F of the GEIS describes some of the major applicable Federal statutes.

There are numerous permits and licenses issued by Federal, State, and local authorities for activities at Braidwood, Units 1 and 2. Appendix B contains further discussion about Braidwood status of compliance.

1.11 Related Federal and State Activities

The NRC reviewed the possibility that activities of other Federal agencies might impact the renewal of the operating license for Braidwood. There are no Federal projects that would make it necessary for another Federal agency to become a cooperating agency in the preparation of this supplemental EIS. There are no known American Indian lands within 50 mi (80 km) of Braidwood. There are three Federally owned facilities within 50 mi of Braidwood: (1) Joliet Army Ammunition Plant, (2) Argonne National Laboratory, and (3) Fermi National Accelerator Laboratory.

The NRC is required under Section 102(2)(C) of NEPA to consult with and obtain the comments from any Federal agency that has jurisdiction by law or special expertise with respect to any environmental impact involved in the subject matter of the EIS. For example, during the course of preparing the SEIS, the NRC consulted with the FWS. A complete list of key consultation correspondences is listed in Appendix C.

1.12 References

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy*, Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

10 CFR Part 54. *Code of Federal Regulations*, Title 10, *Energy*, Part 54, "Requirements for renewal of operating licenses for nuclear power plants."

78 FR 37282. U.S. Nuclear Regulatory Commission. "Revisions to environmental review for renewal of nuclear power plant operating licenses." *Federal Register* 78(119):37282–37324. June 20, 2013.

78 FR 44603. U.S. Nuclear Regulatory Commission. "Byron Nuclear Station, Units 1 and 2, and Braidwood Nuclear Station, Units 1 and 2; Exelon Generation Company, LLC." *Federal Register* 78(142):44603–44605. July 24, 2013.

78 FR 46379. U.S. Nuclear Regulatory Commission. "Exelon Generation Company, LLC, license renewal application for Braidwood Station, Units 1 and 2." *Federal Register* 78(147):46379–46381. July 31, 2013.

[AEA] Atomic Energy Act of 1954, as amended. 42 U.S.C. §2011 et seq.

[ESA] Endangered Species Act of 1973, as amended. 16 U.S.C. §1531 et seq.

[Exelon] Exelon Generation Company, LLC. 2013. "Braidwood Station, Units 1 and 2, Docket Nos. 50–456, 50–457, License Renewal Application." May 29, 2013. ADAMS No. ML131550528.

Magnuson–Stevens Fishery Conservation and Management Act, as amended. 16 U.S.C. §1801 et seq.

[NEPA] National Environmental Policy Act of 1969, as amended. 42 U.S.C. §4321 et seq.

[NHPA] National Historic Preservation Act of 1966. 16 U.S.C. §470 et seq.

[NRC] U.S. Nuclear Regulatory Commission. 2013a. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. Washington, DC: NRC. NUREG-1437, Revision 1, Volumes 1, 2, and 3. June 2013. 1,535 p. ADAMS Nos. ML13106A241, ML13106A242, and ML13106A244.

[NRC] U.S. Nuclear Regulatory Commission. 2013b. Letter from T. Tran, Project Manager, to M. Gallagher, Vice President, Nuclear Licensing Projects, Exelon Generating Company, LLC. Subject: Summary of site audit related to the review of the license renewal application for Braidwood Station, Units 1 and 2. December 3, 2013. ADAMS No. ML13318A238.

[NRC] U.S. Nuclear Regulatory Commission. 2014. Environmental Impact Statement Scoping Process, Summary Report, Braidwood Station, Units 1 and 2, Will County, IL. Washington, DC: NRC. 2014. ADAMS No. ML13337A503.

2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

Although the U.S. Nuclear Regulatory Commission's (NRC's) decisionmaking authority in license renewal is limited to deciding whether or not to renew a nuclear power plant's operating license, the NRC's implementation of the National Environmental Policy Act (NEPA) requires consideration of the environmental impacts of potential alternatives to renewing a plant's operating license. While the ultimate decision about which alternative (or the proposed action) to carry out falls to utility (or plant owners), state, or Federal officials (not the NRC or non-NRC), comparing the impacts of renewing the operating license to the environmental impacts of alternatives allows the NRC to determine whether the environmental impacts of license renewal are so great that preserving the option of license renewal for energy-planning decisionmakers would be unreasonable (Title 10 of the *Code of Federal Regulations* (10 CFR) 51.95(c)(4)).

Energy-planning decisionmakers and owners of the nuclear power plant ultimately decide whether the plant will continue to operate, and economic and environmental considerations play important roles in this decision. In general, the NRC's responsibility is to ensure the safe operation of nuclear power facilities and not to formulate energy policy or encourage or discourage the development of alternative power generation. The NRC does not engage in energy-planning decisions and makes no judgment as to which energy alternatives evaluated would be the most likely alternative in any given case.

The remainder of this chapter provides: (1) a description of the proposed action, (2) a description of alternatives to the proposed action (including the no-action alternative), and (3) alternatives to Braidwood Station, Units 1 and 2 (Braidwood), license renewal that the staff considered and eliminated from detailed study. Chapter 4 of this plant-specific supplemental environmental impact statement (SEIS) compares the impacts of renewing the operating licenses of Braidwood and continued plant operations to the environmental impacts of alternatives.

2.1 Proposed Action

As stated in Chapter 1, the NRC's proposed Federal action is the decision of whether to renew the Braidwood operating licenses for an additional 20 years. For the NRC to determine the impacts from continued operation of Braidwood, an understanding of that operation is needed. A description of normal power plant operations during the license renewal term is provided in Section 2.1.1. Braidwood is a two-unit, nuclear-powered steam-electric generating facility. The nuclear reactor for each unit is a pressurized water reactor (PWR), producing a reactor core rated thermal power of 3,645 megawatts thermal (Braidwood licenses, NPF-72 and NPF-77).

2.1.1 Plant Operation During the License Renewal Term

Most Braidwood operation activities during license renewal term would be the same as or similar to those occurring during the current license term. Section 2.1.1 of the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437, Volume 1, Revision 1, (GEIS) (NRC 2013a) summarizes the general types of activities that are carried out during the operation of a nuclear power plant such as Braidwood, as follow:

- reactor operation;
- waste management;
- security;

- office and clerical work;
- laboratory analysis;
- surveillance, monitoring, and maintenance; and
- refueling and other outages (unanticipated).

As stated in the Environmental Report (ER), Braidwood will continue to operate in the same manner as during the current license term except for, as appropriate, additional aging management programs to address structures and components aging, in accordance with 10 CFR Part 54. The ER further states Braidwood operation during the license renewal term is documented in the Braidwood Updated Final Safety Analysis Report (UFSAR) as required by NRC requirements.

2.1.2 Refurbishment and Other Activities Associated With License Renewal

The GEIS (NRC 2013a) states: "NRC assumed that licensees would need to conduct major refurbishment activities to ensure the safe and economic operation of nuclear plants beyond the current license term." The major refurbishment class of activities characterized in the GEIS is intended to encompass actions that typically take place only once in the life of a nuclear plant, if at all (e.g., replacement of steam generators for PWR).

As a result of its refurbishment evaluation, Exelon did not identify the need to undertake any major refurbishment or replacement activities associated with license renewal to support the continued operation of Braidwood beyond the end of the existing operating license. Therefore, the staff does not discuss refurbishment activities as part of the proposed action in Chapter 4.

However, Exelon identified two hypothetical refurbishment activities that may occur during the period of continued operation:

- steam generator replacement for Unit 2 and
- reactor pressure vessel head replacement for both or either unit.

The staff discusses the impacts of these hypothetical refurbishments as part of the cumulative impact in Chapter 4 (Section 4.16).

2.1.3 Termination of Nuclear Power Plant Operation and Decommissioning After the License Renewal Term

The impacts of decommissioning are described in the *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities: Regarding the Decommissioning of Nuclear Power Reactors*, NUREG-0586 (NRC 2002a). The majority of the activities associated with plant operations would cease with reactor shutdown. Some activities (e.g., security and oversight of spent nuclear fuel) would remain unchanged, while others (waste management, office and clerical work, laboratory analysis, and surveillance, monitoring, and maintenance) would continue at reduced or altered levels. Systems dedicated to reactor operations would cease operations; however, impacts from their physical presence may continue if not removed after reactor shutdown. For sites such as Braidwood, with more than one unit, shared systems may operate at reduced capacities. Impacts associated with dedicated systems that remain in place or shared systems that continue to operate at normal capacities would remain unchanged.

Decommissioning would occur whether Braidwood was shut down at the end of its current operating licenses or at the end of the period of extended operation, and the decommission plan requires NRC approval. There are no site-specific issues related to decommissioning. In the

GEIS, the NRC staff concluded that impacts of terminating operation and decommissioning are SMALL (Category 1) on all resources for nuclear power plants.

2.2 Alternatives

The NRC has the obligation to consider reasonable alternatives to the proposed action of renewing the license for a nuclear reactor. In addition to the no-action alternative, a reasonable alternative (power replacement) must be commercially viable on a scale capable of producing baseload power and must be operational prior to the expiration of the reactor's operating license(s), or expected to become commercially viable or expected to produce baseload power and be operational prior to the expiration of the reactor's operating license(s).

The GEIS incorporated the latest information on replacement power alternatives; however, rapidly evolving technologies will inevitably outpace the information presented in the GEIS. Additionally, the range of reasonable alternatives will also vary by location because of availability of renewable energy resources, current status of infrastructure and technology within the region, and local laws and regulations that may promote or inhibit certain energy producing technologies. As such, a site-specific analysis of alternatives must be performed for each SEIS, taking into account changes in technology and science.

2.2.1 No-Action Alternative

This section examines the environmental effects that would occur if NRC takes no action. "No-action" in this SEIS means that the NRC does not issue renewed operating licenses for Braidwood, and the licenses expire at the end of the current terms. If the NRC takes no action, the two units would shut down at or before the end of the current licenses. After shutdown, plant owners would initiate decommissioning in accordance with 10 CFR 50.82.

The no-action alternative examines those impacts that arise directly as a result of plant shutdown. The environmental impacts from decommissioning and related activities are addressed in several other documents, including the *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*, NUREG-0586, Supplement 1 (NRC 2002); the license renewal GEIS, Chapter 4 (NRC 2013a); and Chapter 4 of this SEIS. These analyses either directly address or bound the environmental impacts of decommissioning whenever Exelon ceases operating Braidwood.

Even if NRC grants renewed operating licenses, Braidwood will eventually shut down, and the environmental effects addressed in Chapter 4 under the no-action alternative will occur at that time. As with decommissioning effects, shutdown effects are expected to be similar whether they occur at the end of the current licenses or at the end of renewed licenses.

Termination of operations at Braidwood would result in the total cessation of electrical power production. Unlike the alternatives described in Section 2.2.2, the no-action alternative does not provide a means of delivering baseload power to meet future electric system needs. Assuming that a need currently exists for the power generated by Braidwood, the no-action alternative would likely create a need for replacement power. That need could be met by installation of additional generating capacity, adoption or expansion of energy conservation and energy efficiency programs, purchased power, or some combination of measures to offset and replace the power currently generated by Braidwood.

Although the NRC's authority extends only to the decision of whether to renew the Braidwood operating licenses, the staff describes the replacement power alternatives in the following sections to represent reasonable options for energy-planning decisionmakers, should NRC choose not to renew the Braidwood licenses.

2.2.2 Replacement Power Alternatives

For replacement power alternatives, the NRC staff selected alternatives based on the reviews of energy technologies that are either currently a commercially viable source of producing baseload power, or can be expected to become a commercially viable source of baseload power before the expiration of the reactors' operating licenses. The NRC staff's analysis assumed that an alternative must be available (able to be constructed, permitted, and connected to the grid) by the time the current Braidwood licenses expire.

The NRC staff eliminated alternatives that cannot meet future system needs or whose costs do not justify inclusion in the range of reasonable alternatives. For example, energy technologies that are not practical because of geographical location or for other reasons are identified but not evaluated in detail. Alternatives that the NRC staff has dismissed from further analysis are discussed in Section 2.3.

To determine the reasonableness of various alternatives, the NRC staff reviewed the information in the GEIS, which presents an overview of some energy technologies. Because many energy technologies are continually evolving in capability and cost and vary by geographic area, and because regulatory structures have changed to either promote or impede development of particular alternatives, the analyses in this chapter may include updated information from the following sources:

- Energy Information Administration (EIA),
- other offices within the U.S. Department of Energy (DOE),
- U.S. Environmental Protection Agency (EPA),
- industry sources and publications, and
- information submitted by Exelon in its ER.

In addition, the NRC reviewed energy relevant statutes, regulations, and policies to ensure that the alternatives analysis is consistent with State and regional energy policies. The NRC staff also reviewed the current generation capacity mix and electricity production data within the region where Braidwood is located.

Based on the results of the information review, the NRC staff considered 16 energy technology options and alternatives to the proposed action (listed in the text box) and then narrowed the range of reasonable alternatives to the five alternatives to be evaluated in depth. These are discussed in Sections 2.2.2.1 through 2.2.2.5.

The NRC staff evaluated the environmental impacts for each reasonable alternative in Chapter 4 of this SEIS. This evaluation considers the impacts across several categories: land use and visual resources, air quality and noise, geologic environment, water resources,

Alternatives Evaluated in Depth:

- new nuclear,
- coal-integrated gasification combined cycle,
- natural gas combined cycle,
- combination alternative (wind power, natural gas combined cycle, and solar power), and
- purchased power.

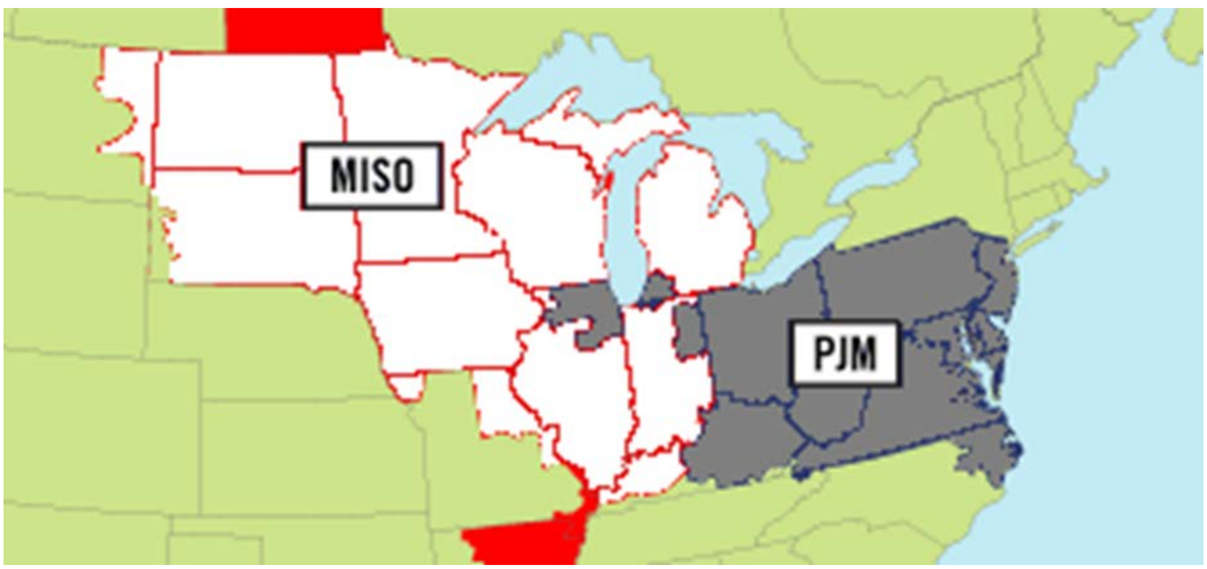
Other Alternatives Considered but Dismissed:

- energy efficiency and conservation,
- wind power,
- solar power,
- hydroelectric power,
- wave and ocean energy,
- geothermal power,
- municipal solid waste,
- biomass,
- oil-fired power,
- fuel cells, and
- delayed retirement.

ecological resources, historic and cultural resources, socioeconomics, human health, environmental justice, and waste management. The order of presentation for the five reasonable alternatives is not meant to imply increasing or decreasing level of impact. Nor does it imply that an energy-planning decisionmaker would be more likely to select any given alternative.

Region of Influence. The region of influence defines the geographical scope of the staff's alternative analysis. Braidwood is owned and operated by Exelon and provides electricity through Commonwealth Edison Company (ComEd) (Exelon 2013). ComEd operates under the PJM Interconnection, a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in 13 states across the Midwest and Northeast (Exelon 2013). ComEd provides service to 3.8 million customers across northern Illinois. Its service territory borders Iroquois County to the south, the Wisconsin border to the north, the Iowa border to the west, and the Indiana border to the east (ComEd 2013). However, electricity consumption in Illinois is not limited to electricity that is generated within the state. Although northern Illinois relies on electricity from ComEd, the rest of Illinois and surrounding states, which are not part of the PJM Interconnection, are part of the Midcontinent Independent System Operator, Inc. (MISO) (See Figure 2–1) (Exelon 2013).

Figure 2–1. Territories of the MISO and PJM Interconnection



Source: FERC 2014

If renewed licenses were not issued, replacement power for Braidwood would be required in northern Illinois. Electricity could be replaced by generation sources from a variety of locations. Electricity could be transported from within the PJM Interconnection; however, the PJM Interconnection in Illinois is geographically distant from the rest of the PJM region (see Figure 2.2-1). It is also possible that electricity within MISO could be purchased by PJM, and efforts are currently being made to increase coordination and deliverability between the RTOs (PJM 2013b). In addition, the State of Illinois has a renewable portfolio standard that includes a geographic eligibility requirement stipulating that eligible renewable resources must be procured from facilities located in Illinois or states that adjoin Illinois (Wisconsin, Indiana, Iowa, Kentucky, Michigan, and Missouri) (ILGA 2011). Renewable resources can only be obtained from other regions of the country if they are not available in Illinois or in adjoining states (ILGA 2011).

Therefore, because replacement power would be required in northern Illinois and any renewable energy resources would need to be procured from adjoining states, the NRC staff evaluated the impacts of locating replacement power facilities within the States of Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri, and Wisconsin. These seven states constitute the region of influence (ROI) for the NRC staff's alternative analyses. The NRC assumes that replacement power would either be produced in northern Illinois within the PJM region, or would be purchased by PJM from MISO.

In 2012, electric generators in the ROI had a net summer generating capacity of approximately 179,000 megawatts (MW). This capacity included units fueled by coal (49 percent), natural gas (27 percent), nuclear (11 percent), and wind (6.6 percent) (EIA 2014b).

In 2011, the electric industry in the ROI provided approximately 744 million megawatt hours (MWh) of electricity. Electricity produced in the ROI was dominated by coal (67 percent) and nuclear (21 percent). While natural gas makes up nearly 30 percent of the installed generating capacity in the ROI, it provides only 6 percent of electricity in the region. Non-hydroelectric renewable energy produced 1.3 percent of the electricity in the ROI (EIA 2014a).

Renewable Energy Legislation in the Region of Influence. Renewable energy legislation in Illinois allows the purchase of electricity generation in adjoining states; therefore, any legislation targeting renewable energy in these states could impact a state's incentive to develop renewable resources. Five states in the ROI (Illinois, Iowa, Missouri, Wisconsin, and Michigan) have legally mandated renewable energy legislation. The State of Indiana has a voluntary program, and Kentucky does not have any renewable energy requirements. The paragraphs below briefly outline each state's program, including renewable energy goals and benchmarks.

In August 2007, Illinois adopted a renewable portfolio standard that requires the State's utilities to produce at least 25 percent of their power from renewable sources by 2025, 75 percent of which must come from wind. Solar Photovoltaic must comprise 6 percent of the annual requirement for calendar year 2015 and thereafter. Other eligible sources include biomass and existing hydroelectric power (DSIRE 2012a). The law also includes an energy efficiency standard that requires utilities to implement cost-effective energy efficiency measures to meet energy savings of 2 percent by calendar year 2015 and thereafter (ILGA 2011). For electric utilities (including ComEd), eligible resources must be located in Illinois; resources can be purchased from adjoining states only if there are insufficient in-State resources (ILGA 2011).

Iowa's Alternative Energy Production Law requires the state's two investor-owned utilities to generate a combined total of 105 megawatts (MW) of their generating capacity from renewable-energy sources. A 2007 order allows the utilities to participate in renewable energy credit trading programs by distinguishing between renewable electricity production capacity used to comply with Iowa law and that which can be used to satisfy other states' renewable portfolio standards (DSIRE 2012c).

Missouri adopted a renewable portfolio standard that requires investor-owned utilities to increase their use of renewable sources by 15 percent by 2021 and includes a provision specifying that 2 percent of the renewable portfolio standard requirement must be met by solar energy. Resources can be purchased from outside of Missouri, but renewable energy generated in State receives a multiplier of 1.25 compared to out-of-State generation (DSIRE 2013b).

Wisconsin's renewable portfolio standard requires utilities to produce 10 percent of their electricity from renewable sources by 2015. Included in the renewable portfolio standard is a provision that allows electricity providers to create and sell or transfer renewable resource

credits and renewable energy certificates. Renewable energy generated outside of Wisconsin is eligible, provided that the electricity is distributed to Wisconsin customers (DSIRE 2012d).

Michigan enacted a Renewable Energy Standard in 2008 that requires utilities to generate 10 percent of their retail electricity sales from renewable energy resources by 2015. The standard also allows energy efficiency and advanced cleaner energy systems to meet part of the requirement. Renewable energy credits can be purchased from in-state or out-of-state facilities, provided that the facilities are located within the retail electric service territory of a utility as recognized by the Michigan Public Service Commission (DSIRE 2013a).

Indiana does not have a mandatory renewable or alternative energy portfolio standard. On July 9, 2012, Indiana adopted a Clean Energy Portfolio Standard, which sets a voluntary goal of 10 percent clean energy by 2025, based on the amount of electricity supplied by the utility in 2010. Unlike many of the other ROI states, up to 30 percent of the goal may be met with clean coal technology, nuclear energy, combined heat and power systems, natural gas that displaces electricity from coal, clean coal technology, and net-metered distributed generation facilities. Fifty percent of qualifying energy must come from within the State (DSIRE 2012b).

Kentucky is the only state in the ROI that does not have mandatory or voluntary renewable energy requirements.

Given known technology and technological and demographic trends, the EIA predicts that 32 percent of electricity in the United States will be generated by coal in 2040 (EIA 2013b). In all the Midwest case projections, coal accounts for 42 percent in 2040 (EIA 2013b). Natural gas generation rose from 16 percent in 2000 to 24 percent in 2011 and is projected to increase to 35 percent in 2040, surpassing coal as the largest share of U.S. electric power generation (EIA 2013b, 2013d). Electricity generation from renewable energy is expected to grow from 13 percent of total generation in 2011 to 16 percent in 2040. However, there are uncertainties that could affect this forecast, particularly the implementation of policies aimed at reducing greenhouse gas emissions that would have a direct effect on fossil-fuel-based generation technologies (EIA 2013b).

Alternatives Evaluated in Depth. The remainder of this section describes the replacement power alternatives to license renewal that are evaluated in depth. These include a new nuclear alternative in Section 2.2.2.1; a coal-integrated gasification combined cycle (-IGCC) alternative in Section 2.2.2.2; a natural-gas-fired combined-cycle (NGCC) in Section 2.2.2.3; a combination natural gas, wind, and solar power alternative in Section 2.2.2.4; and a purchased power alternative in Section 2.2.2.5. Table 2–1 summarizes key design characteristics of the alternative technologies evaluated in depth. The environmental impacts of these alternatives are evaluated in Chapter 4.

Table 2–1. Summary of Replacement Power Alternatives and Key Characteristics Considered in Depth

	New Nuclear Alternative	Coal-IGCC	NGCC Alternative	Combination Alternative
Summary of Alternative	Two-unit nuclear plant, each with 1,120 MWe for a total of 2,240 MWe	Four 618-MWe units for a total of 2,472 MWe	Five 560-MWe units, for a total of 2,800 MWe	One 360-MWe NGCC unit; a 1,813-MWe wind farm; and a 227-MWe solar photovoltaic facility, for a total of 2,400 MWe
Location	An existing nuclear plant site or retired coal plant site. New transmission line(s) and other infrastructure upgrades may be required. Some facilities (i.e., support buildings, potable water supply, sanitary discharge structures) could be shared with existing plant.	An existing plant site or retired coal plant site. New transmission line(s) and other infrastructure upgrades may be required. Some facilities (i.e., support buildings, potable water supply, sanitary discharge structures) could be shared with existing plant.	An existing plant site or retired coal plant site. New transmission line(s) and other infrastructure upgrades may be required; would require construction of a new or upgraded pipeline. Some facilities (i.e., support buildings, potable water supply, sanitary discharge structures) could be shared with existing plant.	Spread across multiple sites throughout the ROI
Cooling System	Closed-cycle with natural draft cooling towers. Cooling water withdrawal—54 mgd consumptive water use—40 mgd (NRC 2008).	Closed-cycle with mechanical draft cooling towers. Cooling water withdrawal—25 mgd; consumptive water use—20 mgd (NETL 2013a).	Closed-cycle with mechanical draft cooling towers. Cooling water withdrawal—17 mgd ; consumptive water use—13 mgd (NETL 2013a).	For NGCC portion, closed-cycle with mechanical draft cooling towers. Cooling water would be 15% of that required for NGCC alternative. Minimal water use for wind and solar.

	New Nuclear Alternative	Coal-IGCC	NGCC Alternative	Combination Alternative
Land Requirements	355 ac (144 ha) (NRC 2008); 520 ac (210 ha) for uranium mining and processing [(a)] (NRC 2013c)	2,000 ac (800 ha) for the major permanent facilities; 1,100 ac (450 ha) per year for mining (DOE 2010c)	94 ac (38 ha) for the plant, including pipelines (Exelon 2013); 10,080 ac (4,079 ha) for gas extraction and collection (NRC 1996)	Wind farms would require 3,376 ac (1,366 ha) to 10,127 ac (4,098.3 ha) (Western and FWS 2013); solar photovoltaic facilities would require 6,749 ac (2,731 ha) (Ong et al. 2013). For NGCC portion, land use would remain the same at 94 ac (38 ha) (Exelon 2013).
Work Force	3,500 workers during peak construction; 812 workers during operations (NRC 2008)	4,600 workers during peak construction; 420 workers during operations (DOE 2010c)	1,783 workers during peak construction; 94 workers during operations (Exelon 2013)	Solar photovoltaic—600 workers during peak construction, 60 workers during operations; wind—931 workers during construction, 566 workers during operations (DOE 2010b). The number of construction and operations workers would be less than the standalone alternative but would not be a linear reduction because of the need for a minimum number of workers regardless of the size of the NGCC plant.

[(a)] Normalized to model light water reactor annual fuel requirement. Forty-six percent of this land requirement is temporarily committed land.

Sources: DOE 2010b, 2010c; Exelon 2013; NETL 2013a; NRC 1996, 2008, 2013c; Ong et al. 2013; Western and FWS 2013

1 *2.2.2.1 New Nuclear Alternative*

2 In this section, NRC staff describes the new nuclear alternative. NRC staff evaluates the
3 environmental impacts from this alternative in Chapter 4.

The NRC staff considered the construction of a new nuclear plant to be a reasonable alternative to license renewal. For example, nuclear generation currently provides 21 percent of electricity generation in the ROI (EIA 2014a). Twelve nuclear power plants operate in the ROI; six plants have received renewed licenses and three additional plants have applied for renewed licenses from the NRC (including Braidwood) (NRC 2013a). In addition, there is an interest in new nuclear power plant development in the region; combined license (COL) applications have been filed for two new nuclear power plants in the ROI. On July 24, 2008, Union Electric Company submitted a COL application for Callaway Nuclear Power Plant Unit 2 (Callaway Unit 2) in Callaway County, Missouri, on the existing Callaway site (AmerenUE 2009). However, that application has since been suspended (NRC 2009b). An application was also filed in September 2008 for Enrico Fermi Atomic Power Plant, Unit 3 (Fermi Unit 3), in Monroe County, Michigan, on the existing Fermi site. The NRC staff published the Final Environmental Impact Statement for Fermi 3 in January 2013 (NRC 2013a). Although the State of Indiana does not currently have any nuclear power plants, its voluntary clean energy initiative includes nuclear as an eligible technology (DSIRE 2012b).

For alternative analysis, the NRC staff assumed that there is sufficient time for Exelon to prepare and submit an application, build, and operate two new nuclear units before the Braidwood licenses expire in October 2026 and December 2027. For example, the NRC staff review of a COL application that references a certified design takes about 30 months. Noncertified designs would take 48 to 60 months to review (NRC 2009a). The recently licensed Vogtle Electric Generating Plant, Units 3 and 4 (Vogtle Units 3 and 4), nuclear power plant anticipates a construction schedule of 6 to 7 years (Southern 2013).

In evaluating the new nuclear alternative, the NRC staff assumed that two new nuclear reactors would be installed on an existing nuclear or coal power plant site, allowing for the maximum use of existing ancillary facilities such as support buildings and transmission infrastructure. In 1987, Illinois passed a moratorium preventing the construction of new nuclear power plants within the State. Unless the moratorium is lifted, any new nuclear alternative would have to be located elsewhere in the ROI. For the purposes of this analysis, the NRC relied on the Vogtle Units 3 and 4 COL EIS for technological parameters for the new nuclear alternative because the Vogtle Units 3 and 4 COL considers two new nuclear reactor units with similar output as Braidwood and is representative of the reactors that could be constructed in the ROI before Braidwood's licenses expire (NRC 2011). As such, the NRC staff assumed two Westinghouse AP1000 reactors with a net electrical output of 2,240 megawatts electrical (MWe) would replace Braidwood's current reactors for this alternative. The NRC staff estimated that 324 acres (ac) (131 hectares (ha)) of additional land would be required on a long-term basis for permanent facilities, and an additional 31 ac (12.5 ha) would be disturbed for temporary facilities, a laydown area, and storage of dredge material (NRC 2008).

The heat rejection demands of a new nuclear alternative would be similar to those of Braidwood. The new reactors may require a new cooling system (including natural draft cooling towers and intake and discharge structures). The NRC staff assumes that water requirements for the new nuclear alternative would be similar to current water use at Braidwood. The existing transmission lines leaving the site, as well as construction and drinking water wells, are expected to serve the replacement reactor with few modifications required. A new onsite transmission line may be required if insufficient transmission occurs on the site. Construction materials would be delivered via rail spur, truck, or barge, or all three depending on the specific site location. It is possible that modifications would be required to deliver such materials depending on the existing infrastructure at the site; modifications could include new rail lines or access roads.

The NRC staff also considered the installation of multiple small modular reactors as an alternative to renewing the Braidwood licenses. The NRC established the Advanced Reactor Program in the Office of New Reactors because of considerable interest in small modular reactors along with anticipated license applications by vendors. Small modular reactors are approximately 300 MW or less, would have lower initial capacity than large-scale units, and would have siting flexibility for locations that are not large enough to accommodate traditional nuclear reactors (DOE undated). As of January 2014, no applications for small modular reactors have been submitted to the NRC. The DOE has estimated that the technology may achieve commercial operation by 2021 to 2025 (DOE undated). Because small modular reactors are not expected to be operational at a commercial scale until near the time Braidwood's licenses expire, it is unlikely that eight new small modular reactors (the number of units required to replace Braidwood's current output) could be constructed in the ROI; therefore, this analysis focused on nuclear generation by larger nuclear units.

2.2.2.2 Coal (Integrated Gasification Combined Cycle) Alternative

In this section, the NRC staff describes the IGCC alternative. The NRC staff evaluates the environmental impacts from this alternative in Chapter 4.

Coal provides the greatest share of electrical power in the ROI, and in 2010, coal represented 46 percent of installed generation capacity and accounted for 69 percent of all electricity generated in the ROI (EIA 2012a). Integrated gasification combined cycle is an emerging technology that generates electricity from coal and combines modern coal gasification technology with both gas-turbine and steam-turbine power generation. The technology is cleaner than conventional pulverized coal plants because major pollutants can be removed from the gas stream before combustion. An IGCC power plant consists of coal gasification and combined-cycle power generation. Coal gasifiers convert coal into a gas (synthesis gas, also referred to as syngas) which fuels the combined-cycle power generating units. The combined-cycle system for a 618-MWe IGCC power plant includes two combustion turbines, two heat recovery steam generators, and a steam turbine. The combined-cycle units combust gas in one or more combustion turbines, and the resulting hot exhaust gas is then used to heat water into steam to drive a steam turbine. The steam turbine then uses the heat from the gas turbine's exhaust through a heat recovery steam generator to produce additional electricity (DOE 2010c). This two-cycle process has high rates of efficiency since the exhaust heat that would otherwise be lost is captured and reused. In addition, the power plant would reduce sulfur dioxide, nitrogen oxides, mercury, and particulate emissions by removing constituents from the syngas before combustion. Nearly 100 percent of the nitrogen from the syngas would be removed prior to combustion in the gas turbines and would result in lower nitrogen oxide emissions compared to conventional coal-fired power plants (DOE 2010c).

Integrated gasification combined cycle power plants have been in operation since the mid-1990s. The Wabash Rice IGCC repowering project in Indiana and the Polk Power Station in Florida are two examples of operating IGCC plants. Recently, there has been an increased interest in new IGCC projects, and multiple new projects have been proposed or have recently begun operations in the United States. The Duke Energy Edwardsport Generation Station in Indiana is a 618-MWe IGCC power plant in the ROI that began commercial operation in June 2013. Duke Energy estimates that the IGCC plant will produce 10 times as much power as the retired coal plant it replaced, with 70 percent fewer emissions of sulfur dioxide, nitrogen oxides, and particulates. The IGCC plant will reduce carbon emissions per MWh by nearly half (Duke Energy 2013). In addition, the Edwardsport Generation Station has potential for carbon capture and geologic sequestration; space has been reserved at the site for carbon dioxide capture equipment (NETL 2013b).

Many IGCC power plants have been designed with a carbon capture system to further reduce carbon dioxide emissions. The Kemper County IGCC project in east-central Mississippi proposes to use a carbon capture system to reduce carbon dioxide emissions by almost 70 percent by removing carbon from the syngas postgasification (DOE 2010c). According to a 2013 NETL report, nine IGCC projects totaling over 4,000 MW are currently active; these projects are either in the planning stages or have begun construction. Thirteen projects have been proposed and subsequently cancelled for a variety of reasons, including air quality issues, state laws and regulations, redirected focus on gas-fired generation and renewables, and unanticipated rising costs (NETL 2013c).

Integrated gasification combined cycle technology and proposed projects have experienced a number of setbacks and opposition, hindering the technology's ability to fully integrate into the energy market. The most significant roadblock is IGCC's high capital cost compared to conventional coal-fired power plants. Cost overruns have been experienced at both the Edwardsport IGCC project and the Kemper County IGCC project. FutureGen, an IGCC plant featuring carbon capture and storage (CCS), lost DOE financial support because of escalating cost estimates (Reuters 2012). Other issues include but are not limited to:

- construction timeline overruns,
- limited track record for reliable performance, and
- opposition from an environmental perspective (Rosenberg 2004).

Despite these issues, the NRC staff considers IGCC technology to be a reasonable source of baseload power to replace Braidwood by the time its licenses expire in 2026 and 2027, for the following reasons:

- existence of active IGCC plants within the ROI and
- how well the technology aligns with recent regulatory actions targeting fossil fuel-fired electric utility steam generating units.

Specifically, on January 8, 2014, EPA issued a proposed rule for carbon pollution that would apply performance standards to utility boilers and IGCC units based on partial implementation of a CCS system as the best method of emission reduction. The proposed emission limit for these sources is 1,100 lb carbon dioxide per megawatt hour (CO_2/MWh). The proposed rule cites a number of IGCC projects and concludes that the projects are "consistent with the EIA modeling which projects that few, if any, new coal-fired units would be built in this decade and that those that are built would include CCS" (79 FR 1430). Therefore, for alternative analysis, the NRC staff considers IGCC power plants as a reasonable alternative to Braidwood because the Edwardsport IGCC project in Indiana is currently in operation and the Kemper IGCC project in Mississippi is under construction. The technology parameters for these plants are considered to be the current state of technology and are used here to describe a hypothetical IGCC power plant located on an existing power plant site within the ROI.

To replace the electricity that Braidwood generates, the NRC staff considered four IGCC units, each with a net capacity of 618 MWe. Various coal sources are available to coal-fired power plants in the ROI. For the purpose of this evaluation, the NRC staff assumes that the IGCC alternative would burn a subbituminous coal, based on the type of coal used in electric plants in Illinois. NRC staff presumes that coal burned in Illinois will be representative of coal that would be burned in an IGCC alternative regardless of where it may be located (EIA 2012b). The IGCC units would reduce sulfur dioxide, nitrogen oxides, mercury, and particulate emissions by removing constituents from the syngas. The removal of nearly 100 percent of the nitrogen from the syngas prior to combustion in the gas turbines would result in significantly lower nitrogen

oxide emissions compared to conventional coal-fired power plants (DOE 2010c). In addition, the units would be designed with the potential to add carbon capture systems at a later date. In a carbon capture system, carbon dioxide emissions would be compressed and piped off site where it could be sold for beneficial use or geologic storage. Additional discussion of air quality impacts associated with the IGCC alternative is presented in Chapter 4.

The IGCC alternative would be located at an existing site (such as an existing power plant site) to maximize availability of infrastructure and reduce other environmental impacts. Depending on the specific site location, there might be a need to construct new intake and discharge facilities and a new cooling system. The IGCC alternative would use about the same amount of water as Braidwood and a similar amount as the Edwardsport IGCC plant. The NRC staff assumes the cooling system would use a closed-cycle system with mechanical draft cooling towers. This system would withdraw 25 million gallons per day (mgd) (95 million liters per day (Lpd)) of water and consume 20 mgd (76 million Lpd). Onsite visible structures could include the boilers, exhaust stacks, intake/discharge structures, mechanical draft cooling towers, transmission lines, and an electrical switchyard. Construction materials would be delivered via rail spur, truck, or barge, or all three depending on the specific site location. Modifications may be required to deliver such materials; modifications could include new rail lines or access roads.

The NRC staff also initially considered, but subsequently dismissed the use of supercritical pulverized coal (SCPC) as an alternative to renewing the Braidwood licenses (see Section 2.3).

2.2.2.3 Natural Gas Combined Cycle Alternative

In this section, the NRC staff describes the natural-gas-fired combined-cycle (NGCC) alternative. The NRC staff evaluates the environmental impacts from this alternative in Chapter 4.

Natural gas represents nearly 30 percent of installed generation capacity in the ROI, but provides only 6 percent of all electrical power in the ROI (EIA 2014a, 2014b). Nationwide, the percentage of power generated by natural gas is expected to rise by 2040, although the actual rise in natural gas generation will depend on future natural gas prices (EIA 2013b). For its analysis, the NRC staff considers the construction of an NGCC power plant to be a reasonable alternative to license renewal because it is a feasible, commercially available option for providing electrical generating capacity beyond the expiration of Braidwood's current licenses.

Baseload NGCC power plants have proven their reliability and can have capacity factors as high as 85 percent. In an NGCC system, electricity is generated using a gas turbine that burns natural gas. A steam turbine uses the heat from the gas turbine's exhaust through a heat recovery steam generator to produce additional electricity. This two-cycle process has high rates of efficiency since the exhaust heat that would otherwise be lost is captured and reused. Like other fossil fuel sources, NGCC power plants are a source of greenhouse gases, including carbon dioxide. An NGCC power plant, however, produces significantly fewer greenhouse gases per unit of electrical output than conventional coal-powered plants.

To replace the electricity that Braidwood generates, the NRC staff considered five NGCC units, each with a net capacity of 560 MWe (NETL 2007). The NRC staff assumes that each plant configuration consists of two combustion turbine generators, two heat recovery steam generators, and one steam turbine generator with mechanical draft cooling towers for heat rejection. To minimize the plant's nitrogen oxide emissions, the power plant incorporates a selective catalytic reduction system (NETL 2007).

This 2,800 MWe NGCC plant would consume 124 billion cubic feet (ft^3) (3,500 million cubic meters (m^3)) of natural gas annually, assuming an average heat content of 1,021 British thermal unit(s) per cubic feet (BTU/ft^3) (EIA 2013c). Natural gas would be extracted from the ground

through wells, then treated to remove impurities and blended to meet pipeline gas standards before being piped through the state pipeline system to the plant site. This NGCC alternative would produce relatively little waste, primarily in the form of spent catalysts used for control of nitrogen oxide emissions.

The NGCC alternative would be located at an existing power plant site to maximize availability of infrastructure and reduce other environmental impacts. Depending on the specific site location, there might be a need to construct new intake and discharge facilities and a new cooling system. Because NGCC power plants generate much of their power from a gas-turbine combined-cycle plant and the overall thermal efficiency of this type of plant is high, an NGCC alternative would require less cooling water than Braidwood. This system would withdraw 17 mgd of water (64 million Lpd) and consume 13 mgd (49 million Lpd). The NRC staff assumes the cooling system would use a closed-cycle system with mechanical-draft cooling towers. Onsite visible structures could include the cooling towers, exhaust stacks, intake/discharge structures, transmission lines, natural gas pipelines, and an electrical switchyard. Construction materials would be delivered via rail spur, truck, or barge, or all three depending on the specific site location. Modifications may be required to deliver such materials; modifications could include new rail lines or access roads.

2.2.2.4 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

In this section, NRC staff describes the environmental impacts of a combination alternative to the continued operation of Braidwood consisting of an NGCC facility constructed at an existing power plant site, operating in conjunction with land based wind farms as well as solar energy facilities, all of which would be located within the ROI. The NRC staff evaluates the environmental impacts from this alternative in Chapter 4.

To serve as an effective baseload power alternative to the Braidwood reactors, this combination alternative must be capable of providing an equivalent amount of baseload power. For the purpose of this evaluation and based on location-feasibility reasonableness, the NRC staff presumes that 15 percent of the annual power producing potential of the Braidwood reactors would be replaced by an NGCC plant, 75 percent would be replaced by wind farms, and the remaining 10 percent would come from solar photovoltaic facilities.

<u>NGCC Portion of the Combination Alternative</u>

To produce its required share of power, the NGCC portion, operating at an expected capacity factor of 85 percent (NETL 2007), would need to have a nameplate rating of approximately 425 MWe.

In 2013, the EIA reported that natural gas-fired power plants are generally used infrequently for shorter periods of time to meet peak demand. Capacity factors for natural gas plants averaged less than 5 percent during offpeak demand hours for most regions of the country. Natural gas is used for these “peaker plants” because natural gas combustion turbines can respond quickly, so they tend to be used to meet short-term increases in electricity demand (EIA 2013d). A report prepared by CITI Research stated that gas-fired power plants can help overcome the intermittent nature of renewable energy (CITI 2012). The peaking aspect of natural gas-fired power plants makes these plants an ideal addition to an otherwise renewable energy combination alternative.

NRC staff assumed that one new NGCC unit of the type described in Section 2.2.2.3 would be constructed and installed at an existing power plant site with a total net capacity of approximately 360 MWe. The appearance of an NGCC unit would be similar to that of the full NGCC alternative considered in Section 2.2.2.3, although only one unit would be constructed. The NRC staff assumed that the NGCC portion of this alternative, which is assumed to be

located at an existing power plant site, would use existing electrical switchyards, substations, and transmission lines. Depending on the existing site conditions, it is possible that intake and discharge structures of the existing cooling system could continue in service, but would be connected to a new closed-cycle cooling system. For the purposes of this analysis, the NRC staff assumes that the NGCC portion of the combination would use mechanical draft cooling towers.

Wind Portion of the Combination Alternative

The NRC staff assumed that the wind-generated power from this combination alternative would come from land-based wind farms which would be located in the ROI within the states of Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri or Wisconsin. The wind portion, assuming a capacity factor of 30 percent, would require a nameplate capacity of 6,042 MWe (Western and FWS 2013).

The American Wind Energy Association (AWEA) reports a total of more than 60,000 MW of installed wind energy capacity nationwide as of March 31, 2013 (AWEA 2013). As of March 2013, Texas is by far the leader in installed land-based capacity with 12,214 MW. Two states in the ROI have the third- and fourth-largest installed capacity: Iowa with 5,133 MW, followed by Illinois with 3,568 MW (AWEA 2013). The installed wind capacity in the ROI has been increasing annually by 1,000 MWe to 2,500 MWe in each of the past 6 years, for a total of over 11,000 MWe of additional wind capacity from 2007 to 2012 (DOE 2013a). Therefore, NRC staff considers 6,042 MW of wind energy to be a reasonable amount by the time the Braidwood licenses expire in 2026 and 2027. As is the case with other renewable energy sources, the feasibility of wind resources serving as alternative baseload power is dependent on the location (relative to expected load centers), value, accessibility, and constancy of the resource. Wind energy must be converted to electricity at or near the point where it is extracted, and there are limited energy storage opportunities available to overcome the intermittency and variability of wind resource availability. At the current stage of wind energy technology development, wind resources in wind power class 3 and higher are suitable for most utility-scale applications (NREL 2014). Wind power class 3 is defined as having a wind speed of 15.7 miles per hour (mph) (7.0 meters per second (m/s)) and a wind density of 500 watts per square meter at 164 ft (50 m) (NREL 2014). Individual wind turbine capacity increased from 0.71 MW in 1999 to 1.79 MW in 2010. The size of turbine most frequently installed in the United States in recent years is the 1.5-MW turbine (Western and FWS 2013). For the purposes of this analysis, the NRC staff assumes wind turbines with a capacity of 1.79 MW. The capacity factors of land-based wind farms are lower than offshore wind farms (Western and FWS 2013). For the wind portion of the combination alternative, the NRC staff assumed a capacity factor of 30 percent, resulting in an estimated total net capacity of 1,813 MWe. Wind turbines must be well-separated from each other to avoid interferences to wind flowing through the wind farm, resulting in wind farms requiring substantial amounts of land. Wind turbines may require as much as 1 to 3 ac (0.4 to 1.2 ha) of land for each turbine (Western and FWS 2013). Based on the size of the turbines and amount of land required between each turbine, approximately 3,376 turbines and 3,376 to 10,127 ac (1,366 to 4,098 ha) would be required for the wind portion of the combination alternative.

Wind energy's intermittency affects its viability and value as a baseload power source. However, the variability of wind-generated electricity can be lessened if the proposed wind farms were located at a large distance from one another and allowed to operate as interconnected wind farms, an aggregate controlled from a central point. Distance separation ensures that the two wind farms will not simultaneously experience the same climate, and power will likely be produced at some of the wind farms at any given time (Archer and Jacobson 2007).

Solar Photovoltaic Portion of the Combination Alternative

The solar portion of the combination alternative would be generated through one or more solar photovoltaic energy facilities located in the ROI. Assuming a capacity factor of 19 percent, the solar energy facilities would need a collective nameplate rating of 1,193 MWe. Solar photovoltaic technologies could be installed on building roofs at existing residential, commercial, or industrial sites or at larger standalone solar facilities.

Nationwide, growth in large solar photovoltaic facilities (greater than 5 MW) has resulted in an increase from 70 MW in 2009 to over 700 MW installed capacity in 2011. As of January 2012, it is estimated that more than 11,000 MW of large solar photovoltaic projects have signed power purchase agreements (Mendelsohn et al. 2012). Over 9,000 MW of those solar projects are 50 MW or greater, although most are located in the southwestern United States (Mendelsohn et al. 2012). As described in Section 2.2.2, two states in the ROI (Missouri and Illinois) have renewable energy legislation that includes requirements for solar photovoltaic technology. Missouri's renewable portfolio standard includes a provision specifying that 2 percent of the renewable portfolio standard requirement must be met by solar energy by 2021. Illinois' renewable portfolio standard specifies that solar photovoltaic must comprise 6 percent of the annual requirement for the year 2015-2016 and thereafter. As of 2010, only 9 MW of solar energy capacity had been installed in the ROI.

Photovoltaic solar resources in the ROI range from 4.0 to 5.0 kilowatt hours per square meter per day (kWh/m^2/day). The most viable solar resources are located in Missouri, Iowa, and southern Illinois and Indiana (NREL 2013a). Economically viable solar resources are considered to be 6.75 kWh/m2/day and greater (BLM and DOE 2010). As is the case with wind energy sources, the feasibility of solar energy resources serving as alternative baseload power is dependent on the location, value, accessibility, and constancy of the resource. Solar photovoltaic uses solar panels to convert solar radiation into usable electricity. Solar cells are formed into solar panels by solar manufacturers which can then be linked into photovoltaic arrays to generate electricity. The electricity generated can be stored, used directly, fed into a large electricity grid, or combined with other electricity generators as a hybrid plant. Solar photovoltaic can generate electricity whenever there is sunlight, regardless of whether or not the sun is directly shining on solar panels. Therefore, solar photovoltaic technologies do not need to directly face and track the sun which has allowed solar photovoltaic systems to have broader geographical use than concentrated solar power (Ardani and Margolis 2011a). Because the ROI contains average solar photovoltaic resources and solar photovoltaic is a commercially available option for providing electrical generating capacity, the NRC staff considers the construction of solar photovoltaic facilities to be a reasonable alternative to license renewal when combined with wind and NGCC.

For the purposes of this analysis, the NRC staff assumes solar photovoltaic facilities with a capacity factor of 19 percent (Ardani and Margolis 2011). Solar photovoltaic facilities may require 6.2 ac (2.5 ha)/MW of land (NRC 2013a). Although not all of this land would be cleared of vegetation and permanently impacted, the area (6.2 ac) represents the land enclosed in the total site boundary of the solar facility (Ong et al. 2013). For the solar portion of this combination alternative, approximately 7,397 ac (2,993 ha) would be required to support an installed net capacity of 227 MWe. In this analysis, the NRC staff does not speculate on the number and size of individual solar facilities, nor their location within the ROI. However, as stated above, some of the output could be realized by solar photovoltaic installations on building roofs at existing residential, commercial, or industrial sites or at larger standalone solar facilities. As long as rooftop or building-integrated solar photovoltaic installations remain popular, effects to land use would be relatively minor. Solar photovoltaic systems do not require water for cooling purposes, but a small amount of water is needed to clean the panels and for potable

water for the workforce. Impacts identified in the Solar Energy Programmatic Environmental Impact Statement (PEIS) (BLM and DOE 2010, 2012) among other technical reports, provide information used in the analyses presented in the impact sections in Chapter 4.

2.2.2.5 Purchased Power

In this section, the NRC staff describes purchased power as an alternative to the continued operation of Braidwood.

The impacts from purchased power would depend substantially on the generation technologies used to supply the purchased power. Impacts from operation of other electricity generators would likely occur in the ROI. As discussed in Section 2.2.2, replacement power for Braidwood would be required in northern Illinois and could come from anywhere within Illinois or adjoining states in either the PJM or MISO RTOs. Given the large geographic area, multiple RTOs within the ROI, and wide-ranging generating facilities, the NRC staff considers purchased power to be a feasible source of baseload power to replace Braidwood by the time the licenses expire in 2026 and 2027.

Purchased power would likely come from the most common types of electricity generation within the ROI: coal, natural gas, nuclear, and wind. Each of these power sources is discussed as an alternative to license renewal of Braidwood and is identified in Sections 2.2.2.1 to 2.2.2.4. Construction and operational impacts from these sources of electricity generation are considered in Chapter 4. Unlike the alternatives considered in Chapter 4, however, facilities from which power would be purchased would not likely be constructed solely to replace Braidwood. Purchased power may, however, require new transmission lines (which may require new construction). Purchased power also may rely on older and less-efficient power plants operating at higher capacities than they currently operate or new facilities that would be constructed. During operations, impacts from nuclear, coal-fired, and natural gas-fired plants, wind, and solar energy projects would be similar to those described under the new nuclear, coal, natural gas, and combination alternatives detailed in Chapter 4 for all resource areas. Impacts to air quality from the operations of existing coal and natural gas-fired plants would likely be greater than the operations of new plants because older plants are more likely to be less efficient and without modern emissions controls. Impacts to other resource areas from the operation of existing power plant facilities would likely be less than those for new plants because existing facilities would not require new construction.

2.3 Alternatives Considered but Dismissed

Alternatives to Braidwood license renewal that were considered and eliminated from detailed analysis are presented in this section. These alternatives were eliminated because of technical, resource availability, or current commercial limitations. Many of these limitations will continue to exist when the current Braidwood licenses expire.

2.3.1 Energy Conservation and Energy Efficiency

Energy conservation can include reducing energy demand through behavioral changes or altering the shape of the electricity load and usually does not require the addition of new generating capacity. Conservation and energy efficiency programs are more broadly referred to as demand-side management (DSM).

Conservation and energy efficiency programs can be initiated by a utility, by transmission operators, by the state, or by other load-serving entities. The State of Illinois’ renewable portfolio standard includes an energy efficiency portfolio standard that requires utilities to reduce electric usage by 2 percent of demand by 2015 (DSIRE 2012a), which is equivalent to

4 million MWh, only 20 percent of the amount that would be required to offset Braidwood's current electrical generation.

In general, residential electricity consumers have been responsible for the majority of peak load reductions, and participation in most programs is voluntary. Therefore, the existence of a program does not guarantee that reductions in electricity demand would occur. The GEIS concludes that, while the energy conservation or energy efficiency potential in the United States is substantial, there are likely no cases where an energy efficiency or conservation program has been implemented expressly to replace or offset a large baseload generation station (NRC 2013b). While significant energy savings are possible in the ROI through DSM and energy efficiency programs, conservation and energy efficiency programs are not likely to replace Braidwood as a standalone alternative, and therefore the NRC staff does not consider conservation and energy efficiency to be a reasonable alternative to license renewal.

2.3.2 Solar

Solar power, including solar photovoltaic and concentrated solar power technologies, produces power generated from sunlight. Photovoltaics convert sunlight directly into electricity using solar cells made from silicon or cadmium telluride. Concentrating solar power uses heat from the sun to boil water and produce steam to drive a turbine connected to a generator to produce electricity (NREL 2013b). To be considered a viable alternative, a solar alternative must replace the amount of electricity Braidwood provides. Assuming a capacity factor of 19 percent (Ardani and Margolis 2011), approximately 12,400 MWe of electricity would need to be generated by solar energy facilities in the seven-state ROI.

In 2011, 14 MWh of electricity was generated from solar energy in the ROI (EIA 2014b). The National Renewable Energy Laboratory (NREL) within DOE reports that the states in the ROI receive solar insolation of 4.0–5.0 kWh/m^2/day, which is considered low to average (NREL 2013a). For utility-scale development, insolation levels below 6.5 kWh/m^2/day are not considered economically viable given current technologies (BLM and DOE 2010). There is more potential for solar development using local photovoltaic applications, such as rooftop solar panels, than through utility-scale solar facilities. In addition, a solar facility can only generate electricity when the sun is shining. Energy storage can be used to overcome intermittency for concentrating solar power facilities; however, current and foreseeable storage technologies that have been paired with solar power facilities have a much smaller capacity than would be necessary to replace Braidwood. Taking all of the factors above into account, it is unlikely that solar photovoltaic or concentrated solar power technologies could serve as baseload power in the ROI to replace Braidwood's current electricity output. Given the modest levels of solar energy available throughout the ROI, the lack of substantial installed solar capacity in the ROI, and the weather-dependent intermittency of solar power, the NRC staff concludes that a solar power energy facility in the ROI would not be a reasonable alternative to license renewal. The NRC staff evaluated an alternative of solar power in combination with wind and an NGCC plant in Section 2.2.2.4.

2.3.3 Wind

Two states in the ROI have the third- and fourth-largest installed capacity in the Nation: Iowa with 5,133 MW, followed by Illinois with 3,568 MW (AWEA 2013). The installed wind capacity in the ROI has been increasing annually by 1,000 MWe to 2,500 MWe in each of the past 6 years, for a total of over 11,000 MWe of additional wind capacity from 2007 to 2012 (DOE 2013a). All of the wind energy facilities and the electricity generation from wind currently being produced in the ROI are land-based. To be considered a viable alternative, a wind alternative must

replace the amount of electricity Braidwood provides. Assuming a capacity factor of 30 percent for land-based wind and 40 percent for offshore wind, a range of 5,665 to 7,553 MWe of electricity would need to be generated by some combination of land-based and offshore wind energy facilities in the seven-state ROI.

As is the case with other renewable energy sources, the feasibility of wind resources serving as alternative baseload power is dependent on the location (relative to expected load centers), value, accessibility, and constancy of the resource. Wind energy must be converted to electricity at or near the point where it is extracted, and there are limited energy storage opportunities available to overcome the intermittency and variability of wind resource availability. Although wind power is intermittent and individual facilities are unable to provide baseload power, it has been proposed that multiple interconnected wind installations separated by long distances could function as a virtual power plant and provide baseload power, since individual facilities would be exposed to different weather and wind conditions. To date, however, no states or utilities operate arrays of wind installations as virtual power plants.

Given the amount of wind capacity necessary to replace Braidwood and the intermittency of wind power, the NRC staff finds a completely wind-based alternative to be unreasonable. However, the NRC staff also concludes that, when used in combination with other technologies with inherently higher capacity factors, wind energy can provide a viable alternative. The NRC staff evaluated such a possible combination as described in Section 2.2.2.4.

Offshore Wind. The United States currently does not have any offshore wind farms in operation; however, approximately 20 projects representing more than 2,000 MW of capacity are in the planning and permitting process as of 2010 (Musial and Ram 2010). Offshore wind projects have been developed in Europe, most of which are located close to shore and in shallow water below 98.4 ft (30.0 m) in depth. Total worldwide installed capacity has been estimated at 2,377 MW (Musial and Ram 2010).

While wind data suggest there is potential for offshore wind farms in the Great Lakes, project costs likely limit the future potential of large-scale projects (Tidball et al. 2010). Tidball et al. (2010) estimated that offshore project costs would run approximately 200 to 300 percent higher than land-based systems. Also, based on current prices for wind turbines, the 20-year levelized cost of electricity produced by an offshore wind farm would be above the current production costs from existing power generation facilities. In addition to cost, other barriers include the immature state of the technology, limited resource area, and high risks and uncertainty (Tidball et al. 2010). As no offshore wind capacity yet exists in either the Great Lakes or on the Atlantic Coast and as none appears likely to exist on a large commercial scale in the Great Lakes by 2026 (given the current state of development), the NRC staff finds that offshore wind will not be a reasonable alternative to Braidwood during the license renewal term.

Wind Power With Storage. Energy storage is one possible way to overcome intermittency. Besides pumped hydroelectric facilities, compressed air energy storage (CAES) is the technology most suited for storage of large amounts of energy. In CAES systems, electricity generated during low-demand periods can be stored by using a compressor to pressurize and store air, and during high-demand periods, the compressed air can be used to drive a turbine to generate electricity. A 2011 DOE report analyzed various power generation sources, including wind, coupled with CAES systems (DOE 2011b). The report considered siting criteria, using 1) proximity to natural gas lines, high-voltage transmission, and a market for wholesale electric power and 2) availability of geology and wind resources. The results show that within the ROI there is potential for one CAES site in northwest Iowa. Without detailed wind-speed data, specific site information, and detailed information on the energy-storage capacity of the potential CAES site, it is difficult to estimate how much wind capacity would be necessary and whether or

not it could provide for an all-wind alternative. Furthermore, the NRC staff is not aware of a CAES project coupled with wind generation that is providing baseload power. Therefore, the NRC staff concludes that the use of CAES in combination with wind turbines to replace the Braidwood power plant is unlikely.

Conclusion Summary. Despite the relatively high reliability demonstrated by modern turbines, the recent technological advancements in turbine design and wind farm operation, and wind energy's dramatic market penetrations of recent years, empirical data on wind farm capacity factors and wind energy's limited ability to store power for delayed production of electricity give reasons for the NRC staff to conclude that wind energy—on shore, off shore, or a combination thereof—could not serve as a discrete alternative to the baseload power supplied by the Braidwood reactors. However, the NRC staff also concludes that, when used in combination with other technologies with inherently higher capacity factors, wind energy can provide a viable alternative. The NRC staff evaluated such a possible combination as described in Section 2.2.2.4.

2.3.4 Biomass

Biomass resources used for biomass-fired generation include agricultural residues, animal manure, wood wastes from forestry and industry, residues from food and paper industries, municipal green wastes, dedicated energy crop, and methane from landfills (IEA 2007). Using biomass-fired generation for baseload power depends on the geographic distribution, available quantities, constancy of supply, and energy content of biomass resources. For this analysis, the NRC staff assumed that biomass would be combusted for power generation in the electricity sector. Biomass is also used for space heating in residential and commercial buildings and can be converted to a liquid form for use in transportation fuels (Haq undated).

In the GEIS, the NRC staff indicated a wood waste facility could provide baseload power and operate with capacity factors between 70 and 80 percent (NRC 2013b). Although the ROI currently produces electricity from biomass fuels, the plants operating within the ROI generated 569 MWe in 2010 (EIA 2012a). Based on the relatively low electricity generation currently produced at biomass plants, it is unlikely that these plants, or the construction of several new biomass plants, could increase capacity by adding 2,400 MWe of electricity from biomass-fired generation by the time Braidwood's licenses expire in 2026 and 2027.

For utility-scale biomass electricity generation, the NRC staff assumes that the technologies used for biomass conversion would be similar to fossil fuel plants including the direct combustion of biomass in a boiler to produce steam (NRC 2013b). Biomass generation is generally more cost-effective when cofired with coal plants (IEA 2007). Biomass-fired generation plants generally are small and can reach capacities of 50 MWe, meaning that over 40 new facilities would be required before the Braidwood licenses expire. After reevaluating current technologies, the NRC staff finds biofuel-fired alternatives as still unable to reliably replace the Braidwood capacity. For this reason, the NRC staff does not consider biofuels to be a reasonable alternative to Braidwood license renewal.

2.3.5 Hydroelectric

Hydroelectric power uses the force of water to turn turbines, which spin a generator to produce electricity. In a run-of-the-river system, the force of a river current provides the force to create the needed pressure for the turbine. In a storage system, water is accumulated in reservoirs created by dams and is released as needed to generate electricity.

DOE's Idaho National Engineering and Environmental Laboratory (INEEL) (now Idaho National Laboratory) completed a comprehensive survey of hydropower resources in 1997. The ROI has hydroelectric generating potential of 1,954 MW, adjusting for environmental, legal, and institutional constraints (INEEL 1998). These constraints could include (1) scenic, cultural, historical, and geological values; (2) Federal and state land use; and (3) legal protection issues such as Wild and Scenic legislation, and Threatened or Endangered Fish and Wildlife legislative protection. A separate assessment by DOE of nonpowered dams (dams that do not produce electricity) concluded that there is potential for a total of 4,185 MW of electricity in the ROI (Hadjerioua et al. 2012). These nonpowered dams serve various purposes such as providing water supply to inland navigation.

The EIA reported that the states comprising the ROI generated 2,262 MW electricity from hydroelectric power in 2012 (EIA 2014a). To replace Braidwood's current output, hydroelectric generation across the ROI would need to double by 2026. Although there is potential for anywhere between 1,954 MW and 4,185 MW of hydroelectric power, it is unlikely that the maximum levels of development would occur across the entire ROI by the time Braidwood's licenses expire in 2026 and 2027 given that the generating capacity of hydroelectric power is projected to continue to decrease in generating capacity through 2040 (EIA 2013a). Given the decrease in projected power generation from hydroelectric facilities, the NRC staff does not consider hydroelectric power to be a reasonable alternative to Braidwood license renewal.

2.3.6 Wave and Ocean Energy

Waves, currents, and tides are often predictable and reliable, making them attractive candidates for potential renewable energy generation. There are four major technologies that may be suitable to harness wave energy: (1) terminator devices, which range from 500 kilowatts (kW) to 2 MW; (2) attenuators; (3) point absorbers; and (4) overtopping devices (BOEM undated). Point absorbers and attenuators use floating buoys to convert wave motion into mechanical energy, driving a generator to produce electricity. Overtopping devices trap a portion of a wave at a higher elevation than the sea surface; waves then enter a tube, compressing air that is used to drive a generator which produces electricity (NRC 2013b). Some designs are undergoing demonstration testing at commercial scales, but none are currently used to provide baseload power (BOEM undated).

The Great Lakes do not experience large tides, and there is limited energy output for wave technologies in the Great Lakes. The Electric Power Research Institute (EPRI) published a document that assessed ocean wave energy resources in the United States. The Great Lakes were not included in the analysis, suggesting that the resource potential is not great enough to use on a commercial scale (EPRI 2011). Consequently, the limited resource availability and infancy of the technologies in the Great Lakes support the NRC staff's conclusion that wave and ocean energy technologies are not feasible substitutes for Braidwood license renewal.

2.3.7 Fuel Cells

Fuel cells oxidize fuels without combustion and its environmental side effects. Fuel cells use a fuel (e.g., hydrogen) and oxygen to create electricity through an electrochemical process. The only byproducts (depending on fuel characteristics) are heat, water, and carbon dioxide (depending on hydrogen fuel type) (DOE 2010a). Hydrogen fuel can come from a variety of hydrocarbon resources. Natural gas typically is used as the hydrogen source.

Presently, fuel cells are not economically or technologically competitive with other alternatives for electricity generation. The EIA projects that fuel cells may cost $6,835 per installed kW (total overnight capital costs, 2010 dollars), which is high compared to other alternative technologies

analyzed in this section (EIA 2010). More importantly, fuel cell units are likely to be small in size (approximately 10 MWe). It would be prohibitively costly to replace the power Braidwood provides; it would require approximately 230 units and modifications to the existing transmission system. Given the immature status of fuel cell technology and high cost, the NRC staff does not consider fuel cells to be a reasonable alternative to Braidwood license renewal.

2.3.8 Delayed Retirement

A delayed retirement alternative would consider deferring the retirement of generating facilities in Illinois and its six adjoining states which include MISO and PJM RTOs.

To maintain reliable operations, electric systems must be able to meet peak load requirements. To ensure sufficient capacity, this must also include a planning reserve margin (FERC 2013). The projected MISO reserve margin for 2021 is 18.6 percent, which exceeds the reserve margin requirement of 17.4 percent. However, pending EPA regulations may lead to increased coal plant retirements at a faster pace than projected. In that case, 3,000 MW to 12,600 MW of plant retirements could decrease the projected reserves anywhere from 16.22 to 6.9 percent, well below the reserve margin requirement (MISO 2011).

PJM is facing similar constraints due, in large part, to retirements of coal plants given air quality regulations (PJM 2013a). This indicates an emerging reliability problem potentially affecting major population centers within the PJM region in the near future (PJM 2013a). Because the current generation mix has not resulted in the long-term commitment of generation needed for reliability, generation retirements that have occurred with short notice have created unanticipated reliability problems for PJM (PJM 2013a).

The 2014 Annual Energy Outlook is predicting that there will be more coal plant retirements before 2016 than previously predicted. These accelerated retirements are driven by low natural gas prices, slow growth in electricity demand, and the requirements of the Mercury and Air Toxics Standards which will require significant reductions in plant emissions (EIA 2014). Exelon also expects increased generation retirements for a variety of reasons, including increased operating costs for older facilities, increased environmental regulations and competition, and decreased load (Exelon 2010). As generators are required to adhere to future regulations, some power plant owners may opt for early retirement of older units rather than incurring the cost of compliance. Exelon has stated that some of its nuclear fleet may be retired early because of low wholesale energy prices and current energy policy (Bloomberg 2014). Because of the uncertain regulatory environment and concerns expressed by MISO and PJM regarding the retirement pace of coal power plants, the NRC staff does not consider delayed retirement to be a reasonable alternative to Braidwood license renewal.

2.3.9 Geothermal

Geothermal technologies extract the heat contained in geologic formations to produce steam to drive a conventional steam turbine generator. Facilities producing electricity from geothermal energy have demonstrated capacity factors of 95 percent or greater, making geothermal energy a potential source of baseload electric power. However, the feasibility of geothermal power generation to provide baseload power depends on the regional quality and accessibility of geothermal resources. Utility-scale geothermal energy generation requires geothermal reservoirs with a temperature above 200 °F (93 °C). Utility-scale power plants range from small 300 kilowatts electrical to 50 MWe and greater (TEEIC undated). Geothermal resources are concentrated in the Western United States. Specifically, these resources are found in Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming (USGS 2008). In general, most assessments of geothermal

resources have been concentrated on these Western states. Geothermal resources are used in the ROI for heating and cooling purposes, but no electricity is currently being produced from geothermal resources in the ROI (EIA 2012a). Given the low resource potential in the ROI, the NRC staff does not consider geothermal to be a reasonable alternative to Braidwood license renewal.

2.3.10 Municipal Solid Waste

Energy recovery from municipal solid waste converts nonrecyclable waste materials into usable heat, electricity, or fuel through combustion (EPA 2013a). The three types of combustion technologies include mass burning, modular systems, and refuse-derived fuel systems (EPA 2013b). Mass burning is currently the method used most frequently in the United States. The heat released from combustion is used to convert water to steam, which is used to drive a turbine generator to produce electricity. Ash is collected and taken to a landfill, and particulates are captured through a filtering system (EPA 2013b). As of 2010, approximately 86 waste-to-energy plants are in operation in 25 states, processing more than 28 million tons of waste per year (EPA 2013a). These waste-to-energy plants have an aggregate capacity of 2,720 MWe, and although some plants have expanded to handle additional waste and produce more energy, no new plants have been built in the United States since 1995 (EPA 2013a). The average waste-to-energy plant produces about 50 MWe, with some reaching 77 MWe, and can operate at capacity factors greater than 90 percent (Michaels 2010). Indiana has one waste recovery facility that produces steam; Iowa has one waste-to-energy facility that produces 10 MW of electricity; Michigan has three facilities that produce a total of 89.7 MW of electricity; and Wisconsin has two facilities that generate a total of 32.3 MW of electricity (Michaels 2010). In total, as of 2010, the ROI had a municipal solid waste generating capacity of 132 MW. More than 46 average-sized plants would be necessary to provide the same level of output as Braidwood, almost doubling the national waste-to-energy generation.

The decision to burn municipal waste to generate energy is usually driven by the need for an alternative to landfills rather than energy considerations. Given the improbability that additional stable supplies of municipal solid waste would be available to support approximately 46 new facilities and that so few existing plants operate in the ROI, the NRC staff does not consider municipal solid waste combustion to be a reasonable alternative to Braidwood license renewal.

2.3.11 Petroleum

In the ROI, the percent of electricity from oil-fired generation was 0.5 percent in 2010 and had a generating capacity of 5,942 MW (EIA 2012a).

The variable costs of oil-fired generation tend to be greater than those of the nuclear or coal fired operations, and oil-fired generation tends to have greater environmental impacts than natural gas-fired generation. The high cost of oil has resulted in a steady decline in its use for electricity generation (EIA 2013b). Given the high cost of oil and the small generating capacity from oil-fired power plants in the ROI, the NRC staff does not consider oil-fired generation a reasonable alternative to Braidwood license renewal.

2.3.12 Super Critical Pulverized Coal

In general, super critical pulverized coal (SCPC) power plants are feasible, commercially available options for providing electrical generating capacity. Baseload coal units have proven their reliability and can sustain capacity factors as high as 79 percent. Pulverized coal power generation uses crushed coal that is fed into a boiler where it is burned to create heat. The heat produces steam that is used to spin one or more turbines to generate electricity. Among the

technologies available, pulverized coal boilers producing supercritical steam (SCPC boilers) are increasingly common for new coal-fired plants given their high operating temperatures and pressures which increase thermal efficiencies and overall reliability. Supercritical pulverized coal facilities consume less fuel per unit output, reducing environmental impacts (NETL undated).

As described in Section 2.2.2.2, the EPA has issued a proposed rule for carbon pollution that would apply to new fossil fuel-fired power plants, including SCPC facilities. The action proposes performance standards and has identified a CCS system as the best method of emission reduction. The proposed emission limit for these sources is 1,100 lb CO_2/MWh. The EIA modeling projects that if the proposed rule is implemented, few, if any, new coal-fired units would be built and that those that are built would include CCS (79 FR 1430). If this rule becomes final, any new coal-fired power plants would likely require CCS in order to achieve the 1,100 lb CO_2/MWh emission limit.

In addition, given known technology and technological and demographic trends, EIA predicts that by 2040 natural gas will surpass coal as the largest share of U.S. electric power generation (EIA 2013b). This does not consider the proposed EPA rule described above, but indicates a general trend away from coal-fired facilities in favor of natural gas-fired power plants due to falling natural gas prices. MISO projects that the pending EPA regulations could lead to increased coal plant retirements and estimates retirements between 3,000 MW and 12,600 MW, which could have a large impact on MISO's reserve margin in the future (MISO 2011).

Although SCPC plants are currently the most widely used source of electricity generation within the ROI, given the potential for stringent air quality regulations and trends towards natural gas-fired power plants, the NRC staff does not consider SCPC to be a reasonable alternative to Braidwood license renewal. Instead, the NRC staff describes an IGCC plant under the coal alternative in Section 2.2.2.2 for analysis.

2.4 Comparison of Alternatives

In this chapter, the NRC staff considered the following alternatives to Braidwood license renewal: new nuclear generation; coal-IGCC generation; NGCC generation; a combination alternative of natural gas, wind, and solar; and purchased power. No-action alternative and its impacts also were considered. Table 2–2 provides a summary of the impacts analyzed in Chapter 4.

The environmental impacts of the proposed action (issuing renewed Braidwood operating licenses) would be SMALL for all impact categories, except for the issues of "Chronic effects of electromagnetic fields (EMFs)" and "Offsite radiological impacts of spent nuclear fuel and high-level waste disposal" which both have an impact level of "Uncertain Impact" and the issue of "Offsite radiological impacts – collective impacts from other than the disposal of spent fuel and high-level waste" to which the NRC has not assigned an impact level. The environmental impacts from all other alternatives would be larger than those of the proposed license renewal, as indicated in Table 2–2.

Table 2–2. Summary of Environmental Impacts of Proposed Action and Alternatives

Alternative	Air Quality	Noise	Groundwater and Surface Water Resources	Aquatic Resources	Terrestrial Resources	Human Health	Environmental Justice	Land Use	Visual Resources	Socioeconomics	Transportation	Historic and Cultural Resources	Waste Management
License renewal	SMALL	SMALL	SMALL	SMALL to MODERATE	SMALL	SMALL	NA[2]	SMALL	SMALL	SMALL	SMALL	NA[1]	SMALL
New nuclear at an existing site	SMALL	SMALL	SMALL to MODERATE	SMALL	SMALL to MODERATE	SMALL	NA[2]	SMALL	SMALL to MODERATE	SMALL to LARGE	SMALL to LARGE	SMALL	SMALL
NGCC at an existing site	MODERATE	SMALL	SMALL	SMALL to MODERATE	SMALL to MODERATE	SMALL	NA[2]	SMALL	SMALL to MODERATE	SMALL to LARGE	SMALL to LARGE	SMALL to MODERATE	SMALL
IGCC at an existing site	MODERATE	SMALL to MODERATE	SMALL	SMALL to MODERATE	MODERATE	SMALL	NA[2]	SMALL to MODERATE	SMALL to MODERATE	SMALL to LARGE	SMALL to LARGE	SMALL	SMALL to MODERATE
Combination alternative (NGCC, Wind, and Solar)	SMALL to MODERATE	SMALL to MODERATE	SMALL	SMALL	SMALL to MODERATE	SMALL	NA[2]	SMALL to MODERATE	SMALL to LARGE	SMALL	SMALL to MODERATE	SMALL to LARGE	SMALL
Purchased power alternative	SMALL to MODERATE	SMALL to MODERATE	SMALL	SMALL	SMALL	SMALL	NA[2]	SMALL	SMALL	SMALL to LARGE	SMALL to LARGE	SMALL to LARGE	SMALL to MODERATE
No-action alternative	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	NA[2]	SMALL to MODERATE	SMALL	SMALL to LARGE	SMALL	NA[1]	SMALL

(1) The NRC staff concludes that there would be no adverse effect on historic and cultural resources for license renewal or the no-action alternatives.

(2) Except for No-Action alternative, there are no disproportionately high and adverse human health and environmental effects on minority and low-income populations. The No-Action alternative could disproportionately affect minority and low-income populations.

In conclusion, the environmentally preferred alternative is the license renewal of Braidwood. All other alternatives capable of meeting the needs currently served by Braidwood entail potentially greater impacts than the proposed action of license renewal of Braidwood. To make up the lost generation if a renewed license is not issued (the no-action alternative), one or a combination of alternatives would be implemented, all of which have greater impacts than the proposed action. Hence, the NRC staff concludes that the no-action alternative will have environmental impacts greater than or equal to the proposed license renewal action.

2.5 References

10 CFR Part 50. *Code of Federal Regulations*, Title 10, *Energy*, Part 50, "Domestic licensing of production and utilization facilities."

10 CFR Part 51. *Code of Federal Regulations,* Title 10, *Energy,* Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions."

10 CFR Part 54. *Code of Federal Regulations*, Title 10, *Energy*, Part 54, "Requirements for renewal of operating licenses for nuclear power plants."

79 FR 1430. U.S. Environmental Protection Agency. "Standards of performance for greenhouse gas emissions from new stationary sources: electric utility generating units." *Federal Register* 79(5):1430–1519. January 8, 2014.

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3.0 AFFECTED ENVIRONMENT

Braidwood Station (Braidwood) is located in Will County, Illinois. The plant consists of two reactor units. Each nuclear reactor is a pressurized water reactor (PWR) with steam generators producing steam that turns turbines to generate electricity. For purposes of the evaluation in this report, the “affected environment” is the environment that currently exists at and around Braidwood. Because existing conditions are at least partially the result of past construction and operation at the plant, the impacts of these past and ongoing actions and how they have shaped the environment are presented here. The facility and its operation are described in Section 3.1. The affected environment is presented in Section 3.2 to 3.13.

3.1 Description of Nuclear Power Plant Facilities and Operation

Braidwood is a two-unit, nuclear-powered steam electric generating facility that began commercial operation in July 1988 (Unit 1) and October 1988 (Unit 2). The nuclear reactor for each unit is a Westinghouse PWR, producing a reactor core rated thermal power of 3,586 megawatts thermal. Generally, U.S. Nuclear Regulatory Commission (NRC) staff drew information about Braidwood facilities and operation from Exelon’s Environmental Report (ER), Updated Final Safety Analysis Report, and Braidwood licenses. In this supplemental environmental impact statement (SEIS), the use of “Braidwood” is referring to the site (including the station) where the “Braidwood Station, Units 1 and 2” are located. The use of “Exelon” is referring to the applicant (Exelon Generation Company, LLC) who submitted the license renewal application (LRA).

3.1.1 External Appearance and Setting

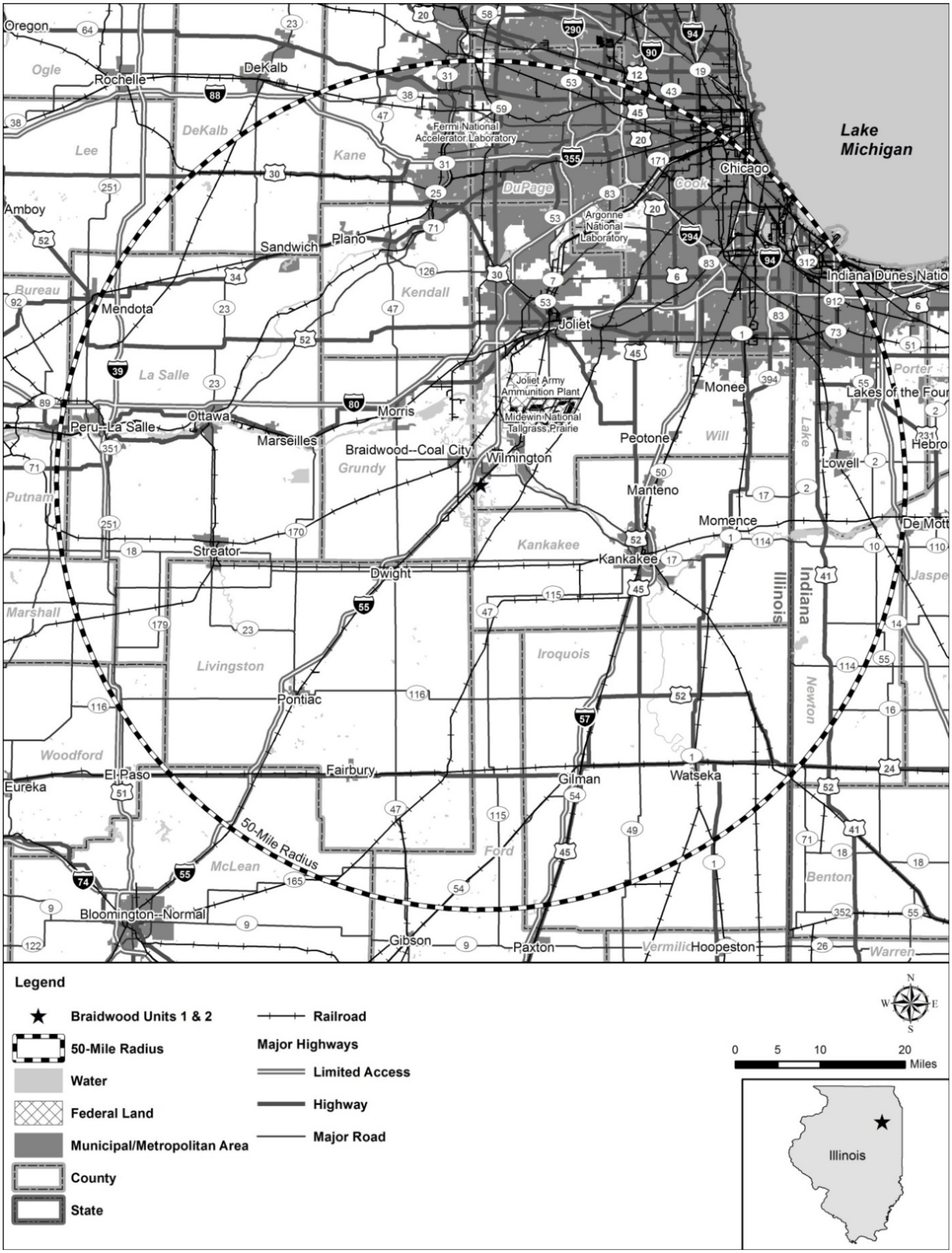
Braidwood Station is located approximately 80 to 97 km (50 to 60 mi) southwest of the Chicago Metropolitan Area (CMA), and 32 to 40 km (20 to 25 mi) south-southwest of Joliet. The site is located on the Kankakee plain in an area where former farmlands were displaced by strip coal mining (Exelon 2013a, 2013b, 2013c). The Kankakee River is approximately 8 km (5 mi) east of the eastern site boundary.

The Braidwood site occupies an area of approximately 1,804 hectares (ha) (4,457 acres (ac)). It has a cooling pond of approximately 1,030 ha (2,540 ac). Figures 3–1 and 3–2 are extracted from the ER, which show the Braidwood 50-mi and 6-mi Radius Maps, respectively**.** The pond is used to dissipate waste heat from the reactor. The public has access to the cooling pond as a result of a 1981 long-term lease agreement between Exelon Generation and the Illinois Department of Natural Resources (IDNR). The cooling pond is part of the Mazonia-Braidwood State Fish and Wildlife Area. It is managed jointly by Exelon Generation and the IDNR (Exelon 2013a, 2013b, 2013c). The cooling pond takes makeup water from and discharges (blowdown) to the Kankakee River. A right-of-way (ROW) for the water intake and discharge pipes runs from the northeast site boundary approximately 8 km (5 mi), east to the Kankakee River (Exelon 2013a, 2013b, 2013c).

The nuclear generating facilities are located in the northwest quadrant of the site and include the two reactor containment buildings and related structures (e.g., auxiliary and turbine buildings), a switchyard, administration buildings, warehouses, and other features (Exelon 2013a, 2013b, 2013c).

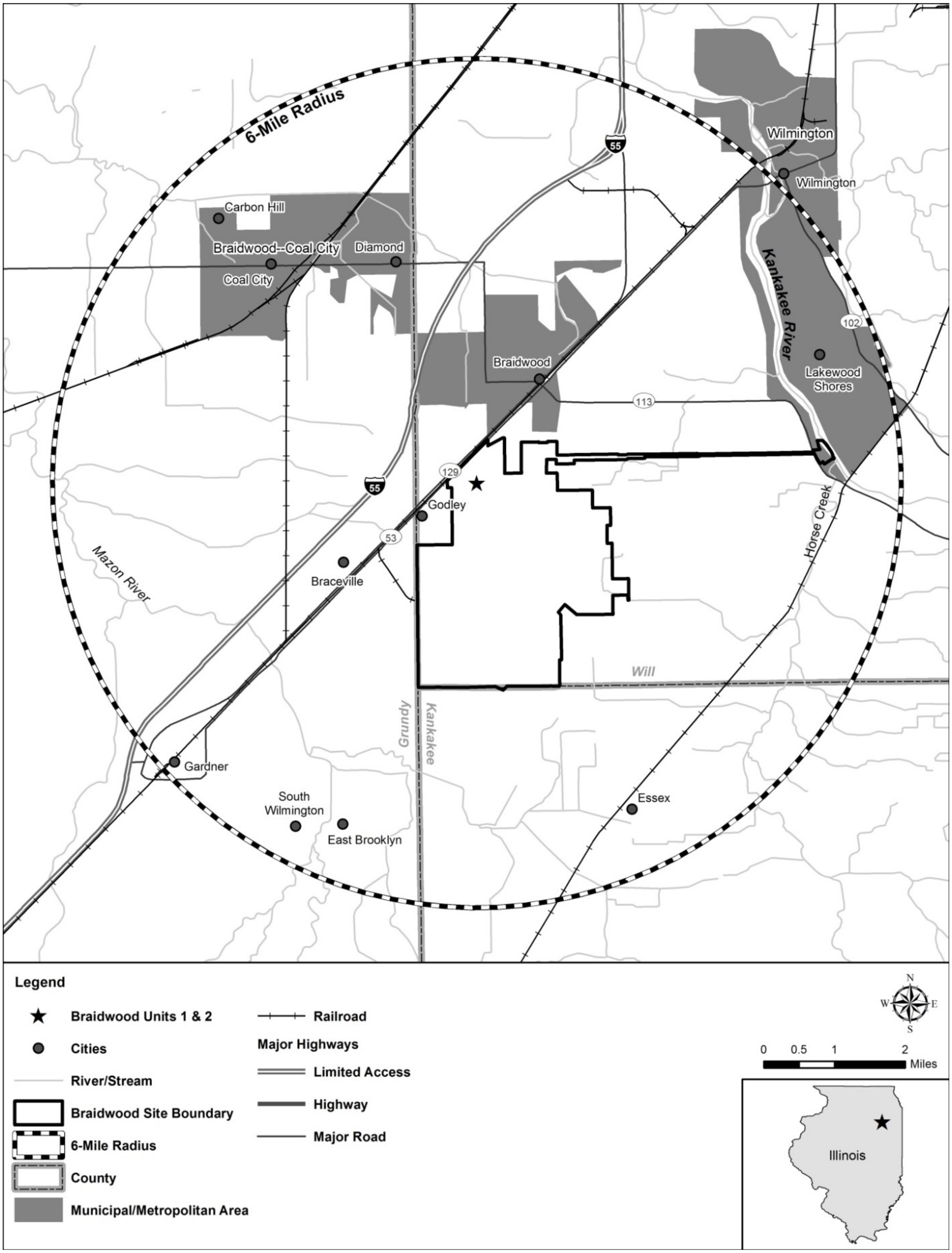
One Braidwood 345-kilovolt (kV) transmission line ROW provides connection from Braidwood to a substation near Crete, Illinois, and the electric grid (Exelon 2013a, 2013b, 2013c).

Figure 3–1. Braidwood 50-mi (80-km) Radius Map



Source: Exelon 2013e

Figure 3–2. Braidwood 6-mi (10-km) Radius Map



Source: Exelon 2013e

3.1.2 Nuclear Reactor Systems

The nuclear steam supply system at Braidwood is a four-loop Westinghouse PWR. The reactor core heats water, which is pumped to four steam generators where the heat boils the water on the shell-side into steam that is routed to the turbines. The steam turns the turbines, which are connected to the electrical generator. The Unit 1 steam generators were replaced in 1998. The ER indicates that the Unit 2 steam generators have not been replaced.

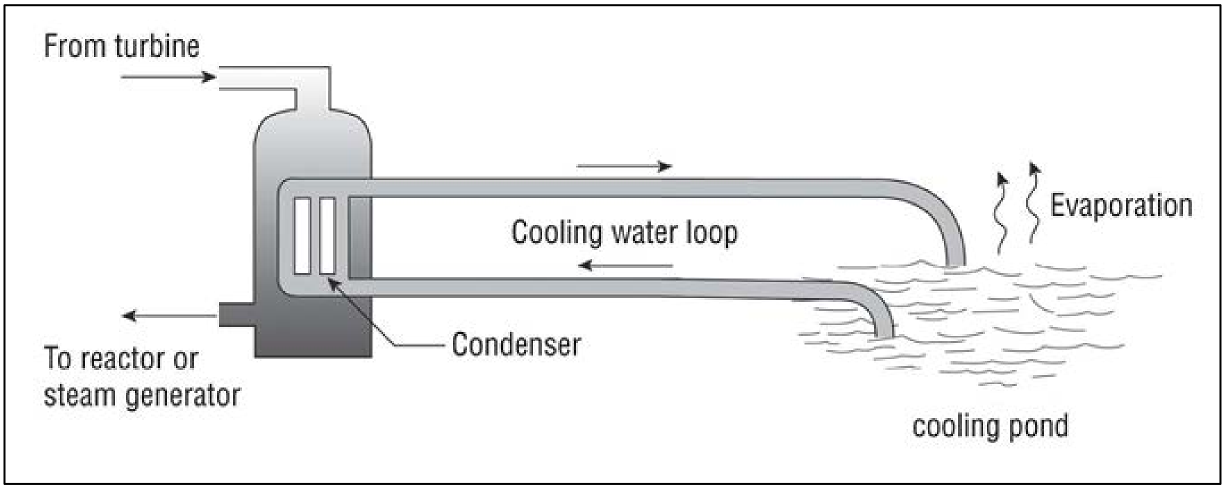
The nuclear fuel is low-enriched uranium dioxide with enrichments to a nominal 5 percent by weight uranium-235 and an allowable fuel burnup levels not to exceed 60,000 megawatt-days per metric ton uranium. Braidwood operates on an 18-month refueling cycle.

The reactor, steam generators, and related systems are enclosed in a containment building. The containment building is a steel-lined post-tensioned, reinforced concrete cylinder with a slab base and a shallow dome. A welded steel liner is attached to the inside face of the concrete shell to ensure a high degree of leak tightness. In addition, the thick concrete walls serve as a radiation shield to limit personnel exposure to less than NRC regulated limits. In addition, the containment systems would ensure the off-site doses resulting from postulated accidents are below NRC guidelines.

3.1.3 Cooling and Auxiliary Water Systems

Braidwood uses a closed-cycle cooling system that includes an artificial cooling pond for heat dissipation. In this type of closed-cycle system, the cooling pond serves as the primary source of water to cool plant condensers and other system components as well as the primary receiving body for excess heat, which is dissipated through mixing and evaporation. Water that is not lost to evaporation is either recirculated through the system as cooling water or discharged as blowdown (i.e., water that is periodically rinsed from the cooling system to remove impurities and sediment that may degrade plant performance) to a secondary receiving water body. Water lost to evaporation or discharged as blowdown must be replaced; this water is referred to as makeup water. Figure 3–3 provides a basic schematic diagram of a closed-cycle cooling system with a cooling pond. All of Braidwood’s systems withdraw makeup water from and discharge blowdown to the Kankakee River. Unless otherwise cited, the description of Braidwood’s cooling and auxiliary water systems is derived from the ER (Exelon 2013e).

Figure 3–3. Closed-Cycle Cooling System With Cooling Pond



Source: Modified from NRC 2013a, Figure 3.1-4

Cooling Pond. Braidwood's cooling pond was created in 1980 and 1981 by pumping water from the Kankakee River into the site's former strip mine spoils. It is approximately 2,540 ac (1,030 ha) in size and accounts for approximately 57 percent of the site acreage. The pond typically holds 22,300 acre-feet (27.5 million cubic meters (m^3)) of water. Cooling water is withdrawn from the cooling pond through the lake screen house, which is located at the north end of the pond. Heated water returns to the cooling pond through a discharge canal west of the lake screen house intake that is separated from the intake by a dike. This and other dikes throughout the cooling pond aid in heat dissipation by slowing water circulation and increasing the time water resides in the pond between discharge and intake. The average residence time for cooling pond water is approximately four days (AEC 1974).

The essential cooling pond is the portion of the cooling pond that serves as the ultimate heat sink; it encompasses a 99-ac (40-ha) excavated area of the pond directly in front of the lake screen house. The essential cooling pond is capable of supplying Braidwood's cooling system with 30 days of station operation without additional makeup water.

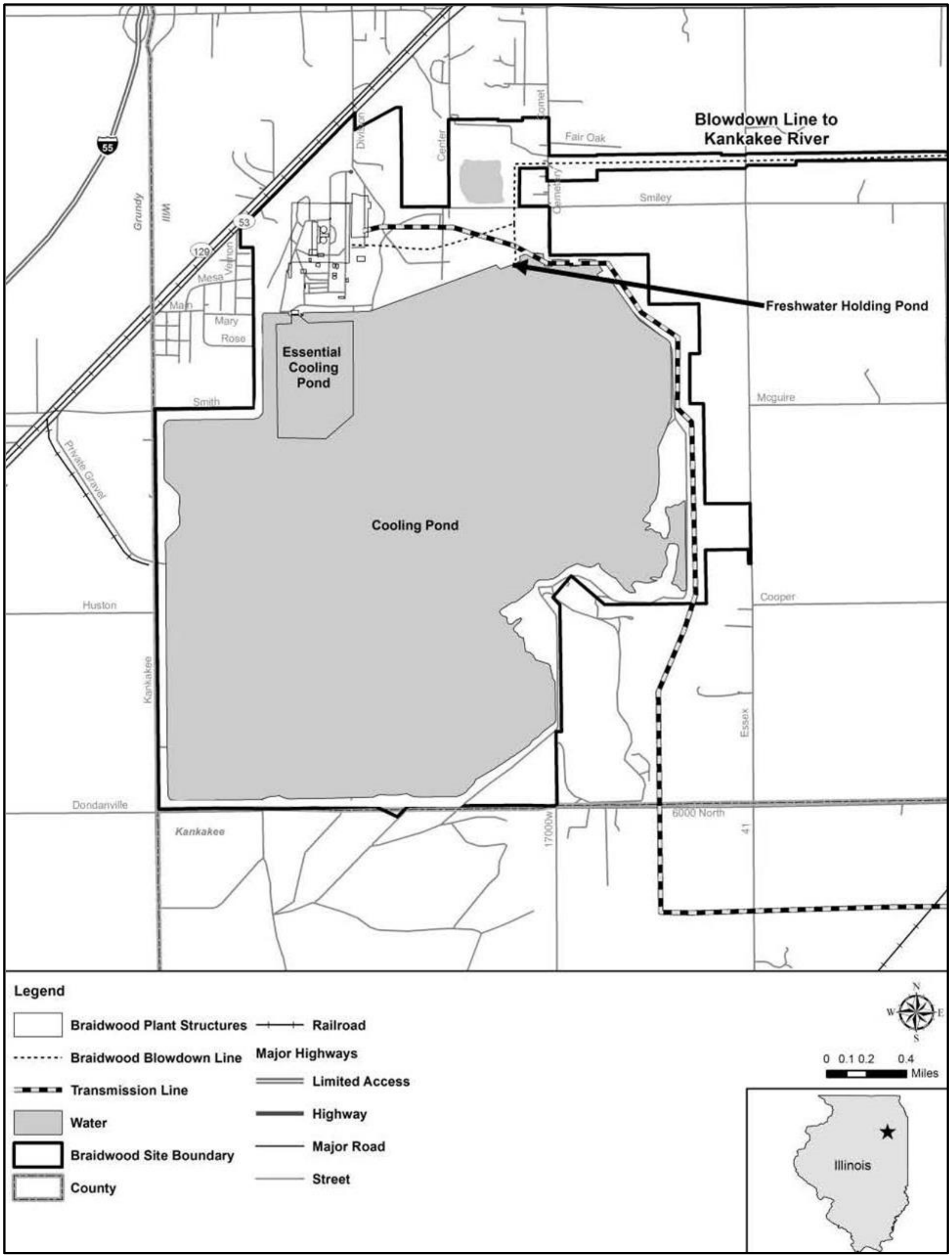
The Kankakee River serves as the source of makeup water for the cooling pond. The river also receives continuous blowdown from the cooling pond. Figure 3–4 depicts the cooling pond, essential cooling pond, and the blowdown line to the Kankakee River. Figure 3-5 shows Braidwood plant layout.

The State of Illinois classifies the cooling pond as a treatment facility for the dissipation of waste heat. Therefore, the station's National Pollutant Discharge Elimination System (NPDES) permit (IEPA 1997) does not contain water quality standards applicable to the cooling pond. However, the IDNR regulates Exelon's operation and maintenance of the cooling pond through Permit No. NE2000125 (IDNR 2000).

Kankakee River Makeup and Blowdown. Cooling pond makeup water from the Kankakee River is drawn into a river screen house on the south bank of the river. Water enters the river screen house through an intake bay equipped with bar grills, 3/8-in.-mesh travelling screens, and trash rakes to prevent debris and aquatic biota from entering the system (Exelon 2014e). Water velocity at the river screen house ranges from 0.32 to 0.48 foot per second (fps) (0.10 to 0.15 meter per second (m/s)). These velocities are within the 0.5-fps (0.15-m/s) intake velocity set by the U.S. Environmental Protection Agency (EPA) for protection of aquatic organisms

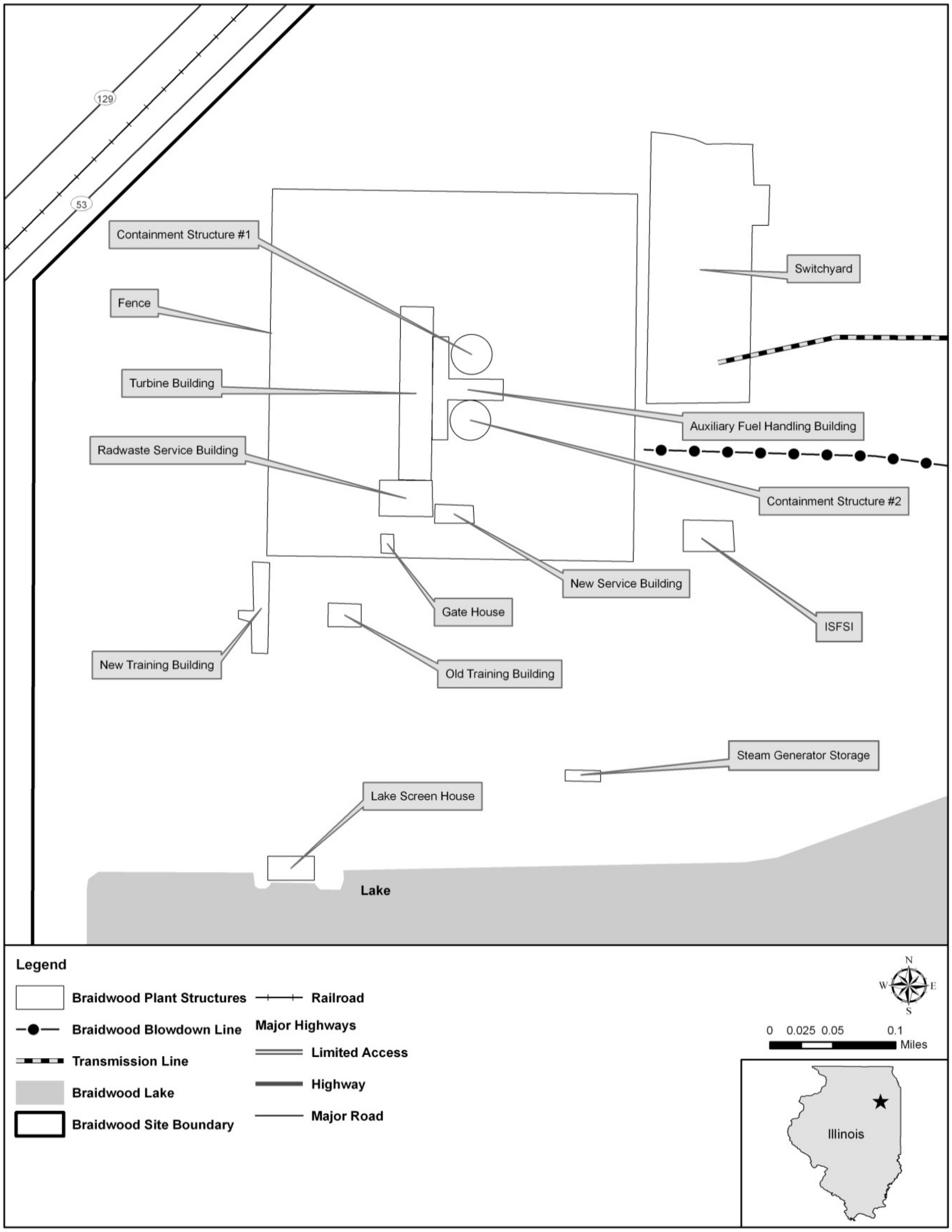
(79 FR 48300). Debris and biota collected in the intake bay are deposited into trash baskets, the contents of which are transferred to an independent contractor for offsite disposal. The river screen house does not contain a fish return system (Exelon 2014e). From the river screen house, circulating water pumps route water to the site via underground pipes that connect to a small freshwater holding pond on the northeast shoreline of the cooling pond (see Figure 3–4). During normal operations, two of three circulating water pumps typically operate and withdraw 3,028 liters per second (L/sec) (48,000 gallons per minute (gpm)) of water. Withdrawal volume is limited to a maximum of 4,531 L/sec (160 cubic feet per second (cfs)) by an agreement with the State of Illinois (IDOT 1977a, 1977b). Once river water reaches the site, the water is collected in the cooling pond for use in Braidwood’s cooling and auxiliary water systems.

1 **Figure 3–4. Braidwood Cooling Pond and Kankakee River Blowdown Line**



2
3 Source: Exelon 2013e, Figure 3.1-1

1 **Figure 3–5. Braidwood Plant Layout**



2

3 Source: Exelon 2013e, Figure 3.1-2

Cooling pond blowdown returns to the Kankakee River via a blowdown pipeline that discharges water approximately 500 ft (150 m) downstream of the river screen house. Water enters the river through a submerged multi-port diffuser at mid-river, which is regulated under Braidwood's NPDES permit (IEPA 1997) as Outfall 001. The permit limits blowdown discharges to the river to a 30-day average of 54 million liters per day (Lpd) or 14.3 million gallons per day (mgd). The permit also limits the thermal characteristics of blowdown. Special Condition 3A stipulates that at the edge of Braidwood's thermal mixing zone, discharges from Outfall 001 shall not cause the Kankakee River water to rise above natural temperatures by more than 2.8 °C (5 °F) (IEPA 1997). Special Condition 3B stipulates that temperatures at the edge of the mixing zone shall not exceed the monthly maximum limits of 90 °F (32 °C) from April through November and 60 °F (16 °C) from December through March for more than one percent of the hours in a 12-month period and at no time shall water temperatures exceed the monthly maximum limits by more than 3 °F (1.7 °C) (IEPA 1997). Section 3.5.1 discusses the NPDES permit and characteristics of the Kankakee River in more detail.

Circulating Water System. The circulating water system provides cooling water to the main condensers to cool the Braidwood reactor cores. Prior to entering the system, water passes into the lake screen house through two separate intake bays, each of which are equipped with bar grills, 3/8-in.-mesh travelling screens, and trash rakes to prevent debris and aquatic biota from entering the system (Exelon 2014e). Water velocity at the lake house traveling screen is about 2.37 fps (0.72 m/s) assuming clean screens and a low water depth of 20.7 ft (6.3 m) (Exelon 2014e). As with the river screen house, the lake screen house does not include a fish return system. From the lake screen house, six circulating water pumps (three for each unit) draw water into the circulating water system. During normal operations, two pumps per unit pump 41,640 L/sec (660,000 gpm) of water for use in the system. In addition, any debris or aquatic biota collected (i.e., neither the lake screen house traveling screen nor the river screen house traveling screen has a fish return system) at the river screen house is disposed of offsite (Exelon 2014e).

Following use for cooling, heated water is returned to the cooling pond through the discharge canal. Upon exiting the plant, circulating water temperatures are maintained below approximately 123 °F (50.5 °C). Exelon measures the cooling pond's average and maximum temperatures by grab sample taken several times a week in front of the trash racks at the lake screen house. During the period from 2004 through 2013, the annual average temperatures at the sampling point ranged from 66.4 °F (19.1 °C) (in 2007) to 71.2 °F (21.8 °C) (in 2012) (Exelon 2014g). The maximum temperature for this period was 99.3 °F (37.4 °C), which was recorded on July 19, 2013 (Exelon 2014g).

Nonessential Service Water System. The nonessential service water system provides cooling water for non-safety related equipment. It has three dedicated pumps that draw cooling pond water from the lake screen house. Each pump is rated at 2,208 L/sec (35,000 gpm). During normal operations, two pumps are in service (one per unit) with the third available as a backup for either unit. Water from this system returns to the cooling pond through the discharge canal.

Essential Service Water System. The essential service water system removes heat from safety-related equipment necessary for safe shutdown of the reactor. This system includes four pumps (two per unit) in the auxiliary building that draw water from the cooling pond. Each pump is rated at 1,514 L/sec (24,000 gpm). Water returns to the cooling pond through the discharge canal.

Cooling and Auxiliary Water Monitoring and Treatment. Exelon monitors, cleans, and treats the Kankakee river intake and discharge equipment, the cooling pond intake and discharge

equipment, and each water system to prevent corrosion, scaling (i.e., the build-up of inorganic nutrients, such as calcium, magnesium, and silica), and biofouling.

Exelon personnel routinely monitor the river screen house for excessive sedimentation or macro-biological fouling in the intake bays and silt accumulation on the Kankakee River bottom in front of the bar grills (Exelon 2014e). If personnel identify the potential need for maintenance, divers further inspect conditions and perform follow-up maintenance on an "as needed" basis (Exelon 2014e). In the case of excessive sedimentation, Exelon will periodically dredge the river in front of the makeup water intake bay to maintain adequate makeup water flow. Most recently, Exelon (2009d) submitted a dredging permit application to the United States Army Corps of Engineers (USACE) in 2009 to mechanically dredge 1,000 cubic yards (760 m^3) of accumulated river sediments for a 0.14-ac (570-m^3) area in front of the river screen house. The USACE (2009) authorized the dredging in June 2009, and the permit was effective through June 1, 2011.

Divers inspect the river discharge structure on an annual basis to evaluate the need for maintenance (Exelon 2014e). Generally, maintenance on the discharge structure can be completed without impeding the flow of blowdown to the Kankakee River. Dredging is not performed near the discharge structure because the multi-port diffuser flushes sediments away from the area (Exelon 2014e).

Within the cooling pond, Exelon follows a company procedure (No. CY-BR-120-4130) to address macrobiological challenges, including bryozoan deposition and growth, aquatic plant growth, and biofouling by mussels and clams (Exelon 2014k). Divers inspect for and, as needed, physically remove bryozoan colonies from the lake screen house bays once per year (Exelon 2014k). An Exelon vendor inspects for aquatic plant growth twice per year and plants may be controlled or eliminated, as appropriate (Exelon 2014k). To control biofouling, Exelon continuously treats the circulating water and service water systems, when in service, with sodium hypochlorite for up to 2 hours (120 minutes) per day per unit (ComEd 2000; Exelon 2014i). In accordance with Special Condition 4 of the NPDES permit (IEPA 1997), water discharged to the Kankakee River may not contain more than an instantaneous maximum concentration of 0.2 mg/L of residual chlorine or 0.05 mg/L of residual oxides, as measured at Outfall 001. As needed, sodium biosulfite is added to water prior to discharge to remove residual chlorine and maintain compliance with NPDES permit limitations (Exelon 2014i). The NPDES permit stipulates that chlorinated or brominated water may not be discharged from each unit's main cooling condensers for more than 2 hours per day. Exelon also conducts regular inspections for zebra mussels and nuisance bryzoan and, as needed, performs mechanical cleaning of the affected equipment (Exelon 2014k).

3.1.4 Radioactive Effluent, Waste, and Environmental Monitoring Programs

As part of normal operations and as a result of equipment repairs and replacements due to normal maintenance activities, nuclear power plants routinely generate both radioactive and nonradioactive wastes. Nonradioactive wastes include hazardous and nonhazardous wastes. There is also a class of waste, called mixed waste that is both radioactive and hazardous. The systems used to manage (i.e., treat, store, and dispose of) these wastes are described in this section. Waste minimization and pollution prevention measures commonly employed at nuclear power plants are also discussed in this section.

All nuclear plants were licensed with the expectation that they would release radioactive material to both the air and water during normal operation. However, NRC regulations require that gaseous and liquid radioactive releases from nuclear power plants must meet the radiation dose-based limits specified in Title 10 of the *Code of Federal Regulations* (CFR) Part 20, and

the as low as is reasonably achievable (ALARA) criteria in Appendix I to 10 CFR Part 50. Regulatory limits are placed on the radiation dose that members of the public can receive from radioactive effluents released by a nuclear power plant. All nuclear power plants use radioactive waste management systems to control and monitor radioactive wastes.

Braidwood uses liquid, gaseous, and solid waste processing systems to collect and process, as needed, radioactive materials produced as a by-product of plant operations. The liquid and gaseous radioactive effluents are processed to reduce the levels of radioactive material prior to discharge into the environment. This is to ensure that the dose to members of the public from radioactive effluents is reduced to levels that are ALARA in accordance with NRC's regulations. The radioactive material removed from the effluents is converted into a solid form for eventual disposal at a licensed radioactive disposal facility (Exelon 2013e).

Braidwood has a radiological environmental monitoring program (REMP) to assess the radiological impact, if any, to the public and the environment from radioactive effluents released during operations at Braidwood. The REMP measures the aquatic, terrestrial, and atmospheric environment for radioactivity, as well as the ambient radiation. In addition, the REMP measures background radiation (i.e., cosmic sources, global fallout, and naturally occurring radioactive material, including radon) (Teledyne 2013).

Braidwood has an Offsite Dose Calculation Manual (ODCM) that contains the methods and parameters used to calculate offsite doses resulting from radioactive liquid and gaseous effluents and the scope and requirements for the REMP. The ODCM addresses the type of samples (i.e., gaseous and liquid effluents, environmental samples of drinking water, vegetation, food products, ambient radiation levels, etc.), sampling frequency, type of analysis, and lower limit of detection (i.e., sensitivity) for the analysis. These controls ensure that radioactive effluents released from the plant meet NRC and EPA regulatory dose standards and that the environment is monitored for radioactivity (Exelon 2013i).

3.1.4.1 Liquid Waste Processing Systems

Radioactive liquids are controlled and processed by the liquid radwaste system (LRWS) for either recycle for use in the plant or for release to the environment. The LRWS is designed to control and process radioactive liquid waste designated for release into the environment so that radioactivity levels are within NRC and EPA standards.

The LRWS consists of two subsystems: the steam generator blowdown system and the non-blowdown subsystem. The non-blowdown subsystem treats waste streams from the auxiliary building equipment drains and floor drains, the chemical waste drains, the regeneration waste drains, the laundry drains, the turbine building equipment and floor drains (if contaminated) and the condensate polisher sump when its stream is contaminated.

The radioactive liquid waste processing system is shared by both units. However, each liquid radioactive waste stream is collected in its own storage tank. The liquid waste is periodically sampled and analyzed to determine the level of radioactivity and thus, the appropriate amount of processing to reduce the radioactivity below NRC and EPA standards. The radioactivity in the liquid waste is reduced using filtration, demineralization, evaporation, chemical or ultraviolet treatment, and reverse osmosis. After processing, the purified effluent can either be reused or released to the Kankakee River via the blowdown line. A radiation detector monitors the liquid in the discharge line to ensure radioactivity levels meet NRC and EPA standards (Exelon 2013e).

Dose estimates for members of the public from the radioactive liquid effluent are calculated based on the amounts of radioactivity in the liquid, aquatic transport models, and exposure pathways (i.e., consumption of contaminated water and fish). Exelon submits an annual

radiological effluent release report to the NRC that contains a detailed presentation of the radioactive liquid effluents released from Braidwood Units 1 and 2 and the resultant calculated doses. The NRC staff reviewed 5 years of radioactive effluent release data; 2008 through 2012 (Exelon 2009c, 2010c, 2011b, 2012b, 2013d). A 5-year period provides a data set that covers a range of activities that occur at a nuclear power plant such as refueling outages, routine operation, and maintenance activities that can affect the generation of radioactive effluents. The NRC staff compared the data against NRC dose limits and looked for indication of adverse trends (i.e., increasing dose levels) over the period of 2008 through 2012. The following summarizes the calculated annual doses from radioactive liquid effluents released during 2012:

Unit 1. The total-body dose to an offsite member of the public from Braidwood Unit 1 radioactive liquid effluents was 2.41×10^{-2} millirem (mrem) (2.41×10^{-4} millisievert (mSv)), which is well below the 3 mrem (0.03 mSv) dose criterion in Appendix I to 10 CFR Part 50.

- The organ dose (adult gastrointestinal (GI)-tract) to an offsite member of the public from Braidwood Unit 1 radioactive liquid effluents was 3.43×10^{-2} mrem (3.43×10^{-4} mSv), which is well below the 10 mrem (0.1 mSv) dose criterion in Appendix I to 10 CFR Part 50.

Unit 2. The total-body dose to an offsite member of the public from Braidwood Unit 2 radioactive liquid effluents was 2.41×10^{-2} mrem (2.41×10^{-4} mSv), which is well below the 3 mrem (0.03 mSv) dose criterion in Appendix I to 10 CFR Part 50.

- The organ dose (adult GI-tract) to an offsite member of the public from Braidwood Unit 2 radioactive liquid effluents was 3.43×10^{-2} mrem (3.43×10^{-4} mSv), which is well below the 10 mrem (0.1 mSv) dose criterion in Appendix I to 10 CFR Part 50.

Based on its review of Braidwood's radioactive liquid effluent data (release data from Braidwood effluent control program), the staff concluded that radiation doses to members of the public were controlled within NRC's and EPA's radiation protection standards contained in Appendix I to 10 CFR Part 50, 10 CFR Part 20, and 40 CFR Part 190. No adverse trends were observed in the dose levels.

3.1.4.2 Gaseous Waste Processing System

The gaseous waste processing system (GWPS) is designed to remove radioactive fission product gases from the reactor coolant and minimize the amount of radioactive material released into the environment.

The GWPS consists of two waste-gas compression packages, six holding tanks, and associated piping, valves, and instrumentation. Radioactive gaseous wastes are generated during plant operation and include the following activities: removing gas from the liquid reactor coolant, purging the volume control tank, displacing the cover gases in tanks as they fill up with liquid waste, purging various equipment and pipes, operating the boron recycle system, and performing surveillance activities that involve sampling and analysis of plant systems containing radioactive material. Radioactive gases are collected in one of six holding tanks and stored temporarily to allow for radioactive decay. When the plant is ready to release the radioactive gaseous effluent, the gas is sampled and analyzed in accordance with the requirements in the ODCM prior to being released into the atmosphere to ensure the radioactivity levels are within NRC and EPA radiation protection standards. Radioactive gaseous effluents are released into the atmosphere in a controlled and monitored manner through the plant vent. The radioactive gaseous waste sampling and analysis program specifications provided in the ODCM address the gaseous release type, sampling frequency, minimum analysis frequency, type of activity analysis, and lower limit of detection (i.e., sensitivity) for the radiation monitor (Exelon 2013e).

Dose estimates for members of the public are calculated based on radioactive gaseous effluent release data, atmospheric transport models, and exposure pathways (i.e., inhalation and ingestion of radioactive material from the air or on food products). Exelon's annual radioactive material release report contains a detailed presentation of the radioactive gaseous effluents released from Braidwood and the resultant calculated doses. The NRC staff reviewed 5 years of radioactive effluent release data; 2008 through 2012 (Exelon 2009c, 2010c, 2011b, 2012b, 2013d). A 5-year period provides a data set that covers a range of activities that occur at Braidwood such as refueling outages, non-refueling outage years, routine operation, and maintenance activities that can affect the generation of radioactive effluents. The NRC staff compared the data against NRC dose limits and looked for indication of adverse trends (i.e., increasing dose levels) over the period of 2008 through 2012. The following summarizes the calculated doses from radioactive gaseous effluents released during 2012 (Exelon 2013d):

Unit 1:

- The air dose at the site boundary from gamma radiation in gaseous effluents from Braidwood Unit 1 was 4.41×10^{-6} millirad (mrad) (4.41×10^{-8} milligray (mGy)), which is well below the 10 mrad (0.1 mGy) dose criterion in Appendix I to 10 CFR Part 50.
- The air dose at the site boundary from beta radiation in gaseous effluents from Braidwood Unit 1 was 1.72×10^{-5} mrad (1.72×10^{-7} mGy), which is well below the 20 mrad (0.2 mGy) dose criterion in Appendix I to 10 CFR Part 50.
- The dose to an organ (child bone) from radioactive iodine, radioactive particulates, and carbon-14 from Braidwood Unit 1 was 1.11 mrem (0.01 mSv), which is well below the 15 mrem (0.15 mSv) dose criterion in Appendix I to 10 CFR Part 50.

Unit 2:

- The air dose at the site boundary from gamma radiation in gaseous effluents from Braidwood Unit 2 was 4.41×10^{-6} mrad (4.41×10^{-8} mGy), which is well below the 10 mrad (0.1 mGy) dose criterion in Appendix I to 10 CFR Part 50.
- The air dose at the site boundary from beta radiation in gaseous effluents from Braidwood Unit 2 was 1.72×10^{-5} mrad (1.72×10^{-7} mGy), which is well below the 20 mrad (0.2 mGy) dose criterion in Appendix I to 10 CFR Part 50.
- The dose to an organ (child bone) from radioactive iodine, radioactive particulates, and carbon-14 from Braidwood Unit 2 was 1.11 mrem (0.01 mSv), which is well below the 15 mrem (0.15 mSv) dose criterion in Appendix I to 10 CFR Part 50.

Based on its review of Braidwood's radioactive gaseous effluent data (release data from Braidwood effluent control program), the staff concluded that radiation doses to members of the public were controlled within NRC's and EPA's radiation protection standards contained in Appendix I to 10 CFR Part 50, 10 CFR Part 20, and 40 CFR Part 190. No adverse trends were observed in the dose levels.

3.1.4.3 Solid Waste Management

Radioactive solid low-level radioactive waste (LLW) is generated by the removal of radioactive material from liquid waste streams, filtration of gaseous effluents, and removal of contaminated equipment and waste material from various areas within the radiation controlled areas of the plant.

Radioactive solid waste is collected from throughout the two Braidwood units, packaged, and stored temporarily onsite until it can be shipped offsite for treatment, if needed, and disposed of in a licensed LLW disposal facility. Low-level radioactive waste is classified as Class A, Class B, Class C, or greater than Class C depending on the types and amounts of radioactivity it contains. The waste is further divided into two categories: dry active waste (DAW) and wet active waste (WAW). Class A waste contains the smallest amounts of radioactivity and includes both DAW and WAW. Classes B and C contain higher levels of radioactivity than Class A and are normally WAW, such as spent resins from demineralizers and filter cartridges. The majority of LLW generated at Braidwood is Class A waste. Classes B and C wastes make up a low percentage by volume of the total LLW generated at Braidwood.

The DAW is composed of material that is either equipment, or tools, or both that are broken or cannot be decontaminated and reused within the plant or waste such as used air filters, miscellaneous paper trash, rags, contaminated clothing, and laboratory glassware and sample containers. The WAW is typically composed of used deep bed demineralizer resins and disposable cartridge filter elements. The LLW is typically packaged in drums or large metal boxes that are sealed and staged for transport to a licensed LLW disposal facility in accordance with NRC regulations in 10 CFR Parts 20, 61, and 71 (Exelon 2013e).

Braidwood, on an infrequent basis, generates small quantities of mixed waste (i.e., waste having both a hazardous component and a radioactive component). The Illinois Environmental Protection Agency (IEPA) regulates the hazardous component of the waste and the Illinois Emergency Management Agency Division of Nuclear Safety and NRC regulate the radioactive component. The mixed waste is stored temporarily on site in the DAW storage area in accordance with Illinois Administrative Code (IAC) 35 Part 726, Standards for the Management of Specific Hazardous Waste and Specific Types of Hazardous Waste Management Facilities (IEPA 2013f) and NRC's 10 CFR Part 20. The mixed waste is transported to a licensed offsite facility for treatment and disposal (Exelon 2013e).

Braidwood uses Waste Control Specialists, LLC (WCS), to treat and dispose of its LLW in an LLW disposal facility. The facility is licensed by the State of Texas and is located in Andrews County, Texas.

3.1.4.4 Radioactive Waste Storage

With the availability of the WCS disposal facility, existing onsite LLW handling and staging areas are expected to handle the temporary storage of LLW generated during the license renewal term. Exelon stated in its ER that radioactive solid waste processing capability is adequate to handle the maximum expected volume of LLW generated during refueling and maintenance outages during the license renewal term. No long-term storage of LLW is expected. However, in the event of temporary delays in transportation or interruption in LLW disposal capability, Braidwood has the capability to store its LLW for approximately 2 years (Exelon 2013e).

Braidwood stores its spent nuclear fuel in a spent fuel pool and also maintains an independent spent fuel storage installation (ISFSI) onsite within a restricted area. Spent fuel transfers to the ISFSI began in 2011. The ISFSI is used to safely store spent fuel in licensed and approved dry cask storage containers. The installation and monitoring of this facility is governed by NRC requirements in 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste." The Braidwood ISFSI would remain in place until the U.S. Department of Energy (DOE) takes possession of the spent fuel and removes it from the site for permanent disposal. Expansion of the onsite spent fuel storage capacity may be required during the license renewal term (Exelon 2013e).

3.1.4.5 Radiological Environmental Monitoring Program

Exelon conducts a REMP to assess the radiological impact to the public and the environment from the operations at Braidwood.

The REMP measures the aquatic, terrestrial, and atmospheric environment for radioactivity, as well as the ambient radiation by sampling air, water, milk, foods, soil, fish, and shoreline sediment. The REMP also measures background radiation (i.e., cosmic sources, global fallout, and naturally occurring radioactive material, including radon) and cumulative radiological impacts from other nuclear power plants that may be nearby. The radiation detection devices and analysis methods used to determine ambient radiation levels and radioactivity in environmental samples are very sensitive and accurate.

In addition to the REMP, Braidwood has an onsite groundwater protection program designed to monitor the onsite plant environment for detection of leaks from plant systems and pipes containing radioactive liquid (Exelon 2013e). Information on the ground water protection program is contained in section 3.5.2 of this document.

The NRC staff reviewed 5 years of annual radiological environmental monitoring data; 2008 through 2012 (Teledyne 2009, 2010, 2011, 2012, 2013). A 5-year period provides a data set that covers a range of activities that occur at Braidwood such as refueling outages, routine operation, and maintenance activities that can affect the generation and release of radioactive effluents into the environment. The NRC staff looked for indication of adverse trends (i.e., build-up of radioactivity levels) over the period of 2008 through 2012.

The NRC staff's review of Exelon's data showed no indication of an adverse trend in radioactivity levels in the environment. The data showed that there was no measurable impact to the environment from operations at Braidwood.

3.1.4.6 Reasonably Foreseeably Radiological Projects at Braidwood

In its ER, Exelon stated that no refurbishment activities are necessary or planned to support the continued operation of Braidwood during the license renewal term. Nevertheless, Exelon discussed the potential impacts associated with the hypothetical replacement of the Unit 2 steam generators and reactor pressure vessel heads for both units (Exelon 2013e). If Exelon conducts these potential refurbishment activities during the license renewal term, Exelon is required to maintain its radiation protection program to limit radiation dose to its workers and members of the public in accordance with NRC and EPA radiation protection standards.

Based on the NRC staff's review of the radioactive waste management program discussed in Section 3.1.4 and the radiation protection program discussed in Section 3.11.1 of this document, the NRC staff expects that Braidwood would conduct the hypothetical refurbishment activities in accordance with NRC and EPA radiation protection standards.

3.1.5 Nonradiological Waste Management Systems

Like any other industrial facility, nuclear power plants generate wastes that are not contaminated with either radionuclides or hazardous chemicals. These wastes include trash, paper, wood, and sewage.

Braidwood has a nonradioactive waste management program to handle its nonradioactive hazardous and nonhazardous wastes. The waste is collected in central collection areas within the plant site and managed in accordance with Exelon's procedures. The materials are received in various forms and packaged to meet regulatory requirements prior to final disposition at an offsite facility licensed to receive and manage the waste. Listed below is a summary of the types of waste materials generated and managed at Braidwood.

- Braidwood is registered as a small quantity hazardous waste generator; however, hazardous wastes are managed according to large quantity generator standards. The amount of hazardous wastes generated are only a small percentage of the total wastes generated; consisting of paints and paint-related materials, spent and off-specification and shelf-life expired chemicals, laboratory chemical wastes, and occasional project-specific wastes. Braidwood has contracts in place to transfer hazardous waste to licensed off-site treatment and disposal facilities.
- Braidwood's nonhazardous wastes include potentially infectious medical waste (PIMW), regulated asbestos-containing material, used oil, grease, antifreeze, adhesives, and other petroleum-based liquids. PIMW is generated at a health facility onsite and can include used and unused hypodermic needles and syringes, as well as items contaminated with human blood. PIMW is considered a unique special waste category in Illinois and transportation and disposal of this waste is regulated under 35 IAC 1420.
- Universal wastes (e.g., batteries, pesticides, mercury-containing equipment, bulbs (lamps)) are recycled when possible, according to Exelon procedures and Illinois regulations.
- General plant trash is collected in dumpsters and transported to a state-licensed regional landfill permitted to accept solid wastes. General trash typically consists of garbage, paper, plastic, packing materials, leather, rubber, glass, soft drink and food cans, dead animals and fish, floor sweepings, ashes, wood, textiles, and scrap metal.

Exelon operated a sewage treatment package plant onsite prior to 2012. Effluent discharge to the Kankakee River was regulated under NPDES permit IL0048321. Operation of the sewage treatment plant ceased in October 2012. Since then, sewage has been routed to the City of Braidwood Sewage Treatment Plant, which discharges to an unnamed tributary of Claypool Ditch. This effluent discharge is regulated under the town's NPDES permit IL0054992 (Exelon 2013e).

3.1.6 Utility and Transportation Infrastructure

The following sections briefly describe the existing utility and transport infrastructure at Braidwood.

3.1.6.1 Electricity

Electrical service to Braidwood is supplied by other offsite power plants, as needed. The onsite 345-kV switchyard provides independent offsite power to Braidwood from the grid, as needed (Exelon 2013g). Exelon also maintains four diesel generators (two per reactor unit), each of which is capable of generating 5,500 kilowatts (kW) in the event of total loss of auxiliary power from offsite sources (Exelon 2013h). For operation, much of the time, Braidwood consumes its own generation fed back from the grid.

3.1.6.2 Fuel

Braidwood Fuel Oil System includes four 25,000-gallon (gal) (85-m^3) diesel oil storage tanks for Unit 1's diesel generators and two 50,000-gal (190-m^3) storage tanks for Unit 2's diesel generators (Exelon 2010a).

3.1.6.3 Water

Section 3.1.1 describes Braidwood's cooling and auxiliary water systems. In addition to water needed for cooling, Braidwood requires potable water for sanitary purposes and everyday use by personnel (e.g., drinking, showering, cleaning, laundry, toilets, and eye washes). Braidwood uses a deep water-supply well that draws water from the Ironton-Galesville deep sand aquifer for its potable water system (Exelon 2013g). This well also supplies water to the make-up demineralizer system (Exelon 2013g). Section 3.5.2 describes site groundwater use in more detail.

3.1.6.4 Transportation Systems

The Braidwood site includes extensive paved surfaces, parking lots, and roads connecting power plant infrastructure. Illinois State Routes 53, 113, and 129 provide direct access to the site, and Interstate 55 lies less than 3 km (2 mi) west-northwest of the site (Exelon 2013g). SEIS Section 3.10.6 describes local transportation systems, including roadway access, in more detail. The Canadian National Railway (formerly Illinois Central Railroad) maintains a railroad spur on site that connects Braidwood with the Illinois Central Gulf Railroad.

3.1.6.5 Power Transmission Systems

For license renewal, the NRC (2013a) evaluates those transmission lines that connect the nuclear power plant to the substation where electricity is fed into the regional power distribution system and transmission lines that supply power to the nuclear plant from the grid. Regarding power transmission systems at Braidwood, the plant's main power transformers connect to an intermediate, onsite transmission line that runs from the plant to an onsite 345-kV switchyard that lies east of the reactor containment buildings. This switchyard connects the plant to the Mid-America Interpool Network (i.e., the regional grid) (Exelon 2010a, 2014d). No separate transmission lines supply offsite power to Braidwood from the grid (Exelon 2013g). Commonwealth Edison Company (ComEd) owns and operates all transmission lines associated with Braidwood (Exelon 2013g).

3.1.7 Nuclear Power Plant Operation and Maintenance

Maintenance activities conducted at Braidwood include inspection, testing, and surveillance to maintain the current licensing basis of the facility and to ensure compliance with environmental and safety requirements. Various programs and activities currently exist at Braidwood to maintain, inspect, test, and monitor the performance of facility equipment. These maintenance activities include inspection requirements for reactor vessel materials, boiler and pressure vessel inservice inspection and testing, and maintenance of water chemistry.

Additional programs include those carried out to meet technical specification (TS) surveillance requirements, those implemented in response to the NRC generic communications, and various periodic maintenance, testing, and inspection procedures. Certain program activities are carried out during the operation of the unit, while others are carried out during scheduled refueling outages. Braidwood must periodically discontinue the production of electricity for refueling, periodic inservice inspection, and scheduled maintenance. The Braidwood reactor units are on staggered 18-month refueling cycles.

3.2 Land Use and Visual Resources

3.2.1 Land Use

The Braidwood site encompasses 4,457 ac (1,804 ha) in Will County, Illinois, approximately 80 km (50 mi) southwest of the CMA (Exelon 2013e). The site is located on the Kankakee plain, and the Kankakee River lies approximately 5 mi (8 km) east of the site (Exelon 2013e). The natural vegetative communities for this area are tallgrass prairie and deciduous forest. However, the Braidwood site was already highly disturbed at the time of Braidwood construction and consisted of a mixture of coal strip-mine spoil, cultivated fields, fallow fields, and open woodlands (AEC 1974). Much of the strip-mine spoils on the site were flooded to create a 2,540-ac (1,028-ha) artificial cooling pond, which provides Braidwood with a source of cooling water. Several large islands occur within the pond. The reactor containment buildings and related structures, a switchyard, administration buildings, warehouses, the makeup/blowdown pipeline corridor, and a river screen house occupy the developed portions of the site. The remainder of the site consists of small forested tracts, old fields, early successional grasslands, and areas leased for agriculture and recreation. Table 3–1 provides a breakdown of site acreage by land use. Figures 3–4 and 3–5 depict the site layout.

Table 3–1. Braidwood Site Acreage by Land Use

Land Use	Acres (Hectares)	Percentage (%)
Developed for industrial use	264 (107)	5.9
Cooling pond	2,540 (1,028)	57.0
Natural areas		
Leased for recreation	1,280 (518)	28.7
Leased for agriculture	67 (27)	1.5
Unleased forest, old fields, and early successional grasslands	306 (124)	6.9
Total	**4,457 (1,804)**	**100**

Sources: Exelon 2013e, 2014

The cooling pond is part of the Mazonia-Braidwood State Fish and Wildlife Area, which Exelon and the IDNR jointly manage. Much of the cooling pond is accessible to the public for fishing, waterfowl hunting, and fossil collecting through a 1981 lease agreement between Exelon and IDNR (IDNR 2014d). The Mazonia-Braidwood State Fish and Wildlife Area also includes IDNR-owned lands adjacent to the Braidwood site to the south and southwest of the cooling pond.

The Braidwood site is accessible from Illinois State Routes 53, 113, and 129. The site also includes a railroad spur, which connects to the Illinois Gulf Railroad (Exelon 2013e).

Will County, in which Braidwood is located, encompasses 537,000 ac (217,000 ha) (USCB 2014h). The county's Land Resource Management Plan (Will County 2011) classifies the current land uses within the county as: agricultural (60 percent), developed (20 percent), and vacant (20 percent). Will County is one of the fastest-growing counties in the CMA. From 1990 to 2000, the population grew by more than 40 percent (from 350,000 individuals to just over 500,000), and the population is expected to grow by another 60 percent (to over 800,000 individuals) in the next 20 years (Will County 2011). Despite such growth, the County's

Land Resource Management Plan (Will County 2011) concludes that the county has more capacity for growth than there is demand.

3.2.2 Visual Resources

Braidwood is situated on flat to rolling topography. Predominant features at the Braidwood site include the two reactor containment buildings, the auxiliary building, the turbine building, administration buildings, warehouses, the makeup/blowdown pipeline corridor, the river screen house, the switchyard, an ISFSI, and the cooling pond (Exelon 2013e).

The most noticeable feature of the site is the cooling pond, which occupies the majority (57 percent) of the site. However, the cooling pond is not readily visible from offsite locations. The reactor containment buildings and switchyard are the most visible structures from offsite. The rolling topography and small forested tracts on and near the site provides some visual screening.

3.3 Meteorology, Climatology, Air Quality, and Noise

3.3.1 Meteorology and Climatology

The Braidwood site is located in Will County in northeastern Illinois, approximately 55 mi (90 km) southwest of the CMA and 23 mi (36 km) south-southwest of Joliet, Illinois. Local towns near the Braidwood site include the town of Godley (1 mi (1.6 km)), Braidwood (2 mi (3.2 km)), and Wilmington (6 mi (9.6 km)). The Kankakee River is about 5 mi (8 km) east of the Braidwood site's eastern boundary. The land area of Braidwood and surrounding area is former farmland that was subsequently used for strip coal mining (Exelon 2013b).

The climate of the region is continental and marked by strong seasonality in temperature, which is characteristic of an inland location. During fall, winter, and spring, the polar jet stream is located near or over northeastern Illinois which causes large scale synoptic storms to move through the area bringing precipitation, winds, and often dramatic temperature changes (NOAA 2005). Lake Michigan has an influence on the climate of northeastern Illinois. During the summer months, the lake causes a stabilizing effect on the atmosphere which tends to lower temperature and reduce precipitation when winds blow from the north or northeast. During winter, the lake keeps temperatures higher than surrounding areas and enhances precipitation by producing lake-effect snow when winds blow from the north or northeast (NOAA 2005).

The staff obtained climatological data collected at the Channahon Dresden Island Illinois (CDII) climate observation station, 11 mi (17.7 km) northwest of Braidwood. Additionally, Exelon maintains a 320-ft (97.5-m) high meteorological tower at Braidwood. The tower base is approximately 600 ft (183 m) above sea level and is located 0.4 mi (0.7 km) northeast of Braidwood (as measured from a point midway between Unit 1 and Unit 2). The tower measures wind speed and direction, temperature, and dew point (Exelon 2014c). Data from these stations was used to characterize the region's climate and is presented below.

For the period 1981 to 2010 from the CDII climate observation station, the coldest weather occurred in January (monthly mean temperature of 23.2 °F (−4.9 °C)), and the warmest occurred in July (monthly mean temperature 73.7 °F (23.2 °C)) (NOAA 2014a). At the Braidwood meteorological tower, the average monthly temperature over the period 1974 to 2012 was 50.2 °F (10.1 °C); the coldest month was January (monthly mean temperature of 23.7 °F (−4.6 °C), and the warmest month was July (monthly mean temperature 73.0 °F (22.8 °C)) (Exelon 2014c).

Annual meteorological reports from the Braidwood meteorological tower provided wind direction and speed data and precipitation (Exelon 2014c). Wind direction and speed data for the last 5 years (2008 through 2012) are shown in Table 3–2. Precipitation data for the same period measured at the Braidwood tower site are also shown in Table 3–2. For comparison, average annual precipitation for the 1981 to 2010 period as measured at the CDII climate observation station, was 92.7 cm (36.5 in.); the lowest monthly mean rainfall occurred in February (4.04 cm (1.59 in.)) with the highest monthly mean occurring in June and July (10.6 cm (4.17 in.) each month) (NOAA 2014a).

Table 3–2. Wind Direction, Wind Speed, and Precipitation Data for 2008 Through 2012 from the Braidwood Tower

Year	Prevailing Wind Direction	Annual Wind Speed Category (mph)	Annual Precipitation (inches)	Maximum 24-Hour Precipitation (inches)	Maximum 1-Hour Precipitation (inches)
2008	W	3.6 to 7.5	33.4	3.04	1.08
2009	WNW	3.6 to 7.5	47.05	2.37	1.06
2010	W	3.6 to 7.5	34.2	2.33	1.07
2011	W	3.6 to 7.5	36.7	2.87	0.85
2012	S	3.6 to 7.5	30.6	3.78	1.70

W = west; WNW = west-northwest; S = south

Source: Exelon 2014c

Severe weather associated with thunderstorm activity occurs in Will County during the summer. Severe thunderstorms may produce tornadoes, hail, and high wind gusts. Severe winter weather conditions can also occur in the area in the form of heavy snowfall, high winds causing blowing and drifting snow and blizzard conditions, and ice storms. For the period January 1, 1996, through October 31, 2013, the following number of days with severe events was recorded in Will County (NOAA 2014b):

- Hail – 91 days;
- Tornadoes – 10 days (16 separate tornado events);
- Thunderstorm Wind above 50 knots – 110 days (4 days with winds above 70 knots);
- Blizzard – 4 days;
- Heavy Snow – 10 days;
- Ice Storm – 2 days; and
- General Winter Storm classification event – 22 days.

3.3.2 Air Quality

Under the Clean Air Act (CAA), the Environmental Protection Agency (EPA) has set primary and secondary National Ambient Air Quality Standards (NAAQS, 40 CFR 50) for six common criteria pollutants to protect public health and the environment. The NAAQS criteria pollutants include carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and

particulate matter (PM). PM is further categorized by size—PM_{10} (diameter of 10 micrometers or less) and $PM_{2.5}$ (diameter of 2.5 micrometers or less).

The EPA designates areas of "attainment" and "nonattainment" with respect to the NAAQS. Areas that have insufficient data to determine designation status are denoted as "unclassifiable." Areas that were once in non-attainment, but are now in attainment, are called "maintenance" areas; these areas are under a 10-year monitoring plan to maintain the attainment designation status.

Air quality designations are generally made at the county level. For the purpose of planning and maintaining ambient air quality with respect to the NAAQS, the EPA has developed Air Quality Control Regions (AQCRs). AQCRs are intrastate or interstate areas that share a common airshed (40 CFR 81). The Braidwood site is located in Will County, IL; this county, along with Cook, DuPage, Grundy, Kane, Kankakee, Kendall, Lake, and McHenry counties in Illinois and Lake County and Porter counties in Indiana are in the Metropolitan Chicago Interstate AQCR (40 CFR 81.14). With regards to the NAAQS criteria pollutants, Will County is designated as nonattainment for the 2008 8-hour ozone NAAQS and 2010 sulfur dioxide NAAQS (partial county designation) and designated maintenance area for the annual 1997 $PM_{2.5}$ NAAQS. States have primary responsibility for ensuring attainment and maintenance of the NAAQS (40 CFR 81.314; EPA 2015). Under section 110 of the CAA (42 U.S.C. 7410) and related provisions, States are to submit, for EPA approval, State Implementation Plans (SIPs) that provide for the timely attainment and maintenance of the NAAQS.

Existing air emission sources at Braidwood are regulated under a Federally Enforceable State Operating Permit (FESOP) (I.D. No. 197816AAB) issued by the IEPA. A source is eligible for a FESOP (also known as "synthetic minor" air permit) if the potential to emit from the source triggers CAA Permit Program requirements, but maximum actual emissions are below, or can be restricted to remain below, major source thresholds. Braidwood's FESOP was issued May 29, 2001, and expired April 29, 2007. Exelon filed a timely renewal application on October 30, 2006, and received correspondence from IEPA indicating continued operation was allowed during the renewal application. No further correspondence regarding the renewal application has been received by Exelon (Exelon 2014c). Regulated air pollutants including sulfur dioxide, carbon monoxide, nitrogen oxide, carbon dioxide, and particulates are emitted at the Braidwood site from four large diesel generators, various small diesel engines (less than 600 horsepower) used for electric generation and water pumping, two diesel engine auxiliary feedwater pumps, a rad-waste volume reduction system, fuel storage tanks, and two auxiliary boilers. Emissions during the last 5 years (2008 to 2012) are shown in Table 3–3 (Exelon 2014a). For each pollutant, Braidwood is classified as a minor emission source.

Table 3–3. Estimated Air Emissions for Permitted Combustion Sources at Braidwood

Year	NO_x (T)[(a)]	CO (T)[(a)]	SO_x (T)[(a)]	$PM_{2.5}$ (T)[(a)]	PM_{10} (T)[(a)]	VOC (T)[(a)]	CO_2e (T)[(a)]
2008	25.9	6.9	0.05	0.48	0.47	0.75	1,311
2009	27.1	7.2	0.06	0.48	0.50	0.79	1,361
2010	21.9	5.8	0.09	0.39	0.41	0.65	1,111
2011	21.4	5.7	0.11	0.38	0.39	0.62	1,132
2012	21.6	5.7	0.11	0.38	0.40	0.63	1,110

[(a)] To convert T to MT, multiply by 0.91.

NO_x = nitrogen oxides; CO = carbon monoxide; SO_x = sulfur oxides; $PM_{2.5}$ = particulate matter with a diameter of 2.5 micrometers or less; PM_{10} = particulate matter with an aerodynamic diameter between 2.5 and 10 micrometers; VOC = volatile organic compound; CO_2e = carbon dioxide equivalent(s)

Source: Exelon 2014a

On October 30, 2009, the EPA published a rule for the mandatory reporting of greenhouse gases (GHGs) from sources that in general emit 25,000 metric tons or more of carbon dioxide equivalents (CO_2e)[1] per year in the United States (74 FR 56260). Most small industrial facilities fall below the 25,000 metric ton threshold and are not required to report GHG emissions to EPA. On June 3, 2010, the EPA promulgated the Prevention of Significant Deterioration (PSD) and Title V GHG Tailoring Rule (75 FR 31514). Beginning January 2, 2011,[2] operating permits issued to major sources of GHG under the prevention of significant deterioration (PSD) or Title V Federal permit programs must contain provisions requiring the use of best available control technology to limit the emissions of GHGs if those sources would be subject to PSD or Title V permitting requirements because of their non-GHG pollutant emission potentials and their estimated GHG emissions are at least 75,000 tons per year of CO_2e. As discussed above, Braidwood is a synthethic minor source. GHG emissions from combustion sources at Braidwood are below the GHG Mandatory Reporting and Tailoring Rules thresholds; therefore, the NRC staff anticipates that Braidwood would be exempted from GHG emission limits.

The EPA promulgated the Regional Haze Rule (RHR) to improve and protect visibility in national parks and wilderness areas from haze, which is caused by numerous, diverse sources located across a broad region (40 CFR 51.308-309). Specifically, 40 CFR 81 Subpart D lists mandatory Class I Federal Areas where visibility is an important value. The RHR requires States to develop SIPs to reduce visibility impairment at Class I Federal Areas. The closest Federal Class 1 area to Braidwood is the U.S. Fish & Wildlife Service Mingo Wilderness Area, approximately 500 km (300 mi) southwest of the Braidwood site. Generally, minor emissions sources, such as Braidwood, that are located more than 100 km (62 mi) from a Class I area are considered to have no effect on a Class I area. The air pollutant emissions from Braidwood would not have any adverse impact at the Mingo Wilderness Class I area due to the minor

[1] Carbon dioxide equivalents (CO_2e) is a metric used to compare the emissions of GHG based on their Global warming potential (GWP). GWP is a measure used to compare how much heat a GHG traps in the atmosphere. GWP is the total energy that a gas absorbs over a period of time, compared to carbon dioxide. Carbon dioxide equivalent is obtained by multiplying the amount of the GHG by the associated GWP. For example, the GWP of CH_4 is estimated to be 21; therefore, one ton of CH_4 emission is equivalent to 21 tons of CO_2 emissions.

[2] On June 23, 2014, the U.S. Supreme Court issued a decision that the EPA may not treat GHGs as an air pollutant for purposes of determining whether a source is a major source required to obtain a PSD or Title V permit, but could continue to require PSD and Title V permits, otherwise required based on emissions of conventional pollutants. In July 2014, the EPA issued a memorandum in response to the Supreme Court's decision and acknowledged that, while the decision is pending judicial action, the EPA will no longer require PSD or Title V permits for GHG-emitting sources that are not sources subject to PSD or Title V permits based on emissions of conventional pollutants (nitrogen oxides, carbon monoxide, etc.) (EPA 2014b).

source emission levels and the large distance separating the Braidwood site from the Mingo Wilderness Area.

3.3.3 Noise

Any pressure variation that the human ear can detect is considered as sound, and noise is defined as unwanted sound. Sound is described in terms of amplitude (perceived as loudness) and frequency (perceived as pitch). Sound pressure levels are typically measured by using the logarithmic decibel (dB) scale. A-weighting (denoted by dBA) is widely used to account for human sensitivity to frequencies of sound (i.e., less sensitive to lower and higher frequencies and most sensitive to sounds between 1 and 5 kHz), which correlates well with a human's subjective reaction to sound (ASA 1983, 1985). Table 3–4 presents common noise sources found in many locations and their respective noise levels.

Table 3–4. Common Noise Sources and Noise Levels

Source	Noise Level (dBA)
Jet Plane (at 100 ft distance)	130
Diesel truck (at 30 ft distance)	100
Food blender (at 3 ft distance)	90
Car (50 mph at 50 ft distance)	65
Conversation	55
Threshold of hearing	0

Sources: MMSHT 2008, SFU undated

Nuclear power generation is an industrial process that can generate noise. Noise sources at the Braidwood site include circulating water make-up pumps, main steam valves, water discharge system, transmission lines, PA system, security drills, and transformers (Exelon 2014c; NRC 2013a). Exelon identified the nearest residence in each of 16 sectors (each sector covering 22.5 degrees) around Braidwood during their annual land use survey. The nearest noise receptors from the station are located in sectors to the southwest, and west through north-northwest. Residences in these sectors are 0.4 mi (0.64 km) from Braidwood's reactor buildings. Noise levels from the plant may be occasionally heard at these receptors but are barely noticeable above other noise sources common to residential area activity, and noise from traffic on Illinois state highway 53 and the Union Pacific (UP) rail line.

Braidwood has received a few noise complaints related to the cooling water discharge system into the Kankakee River. Prior to 2011, this system produced noticeable noise at the discharge location. In 2011, a new diffuser was installed for water discharge into the Kankakee River which, among other environmental benefits, has nearly eliminated noise from the discharge location. In 2010 Braidwood also received noise complaints related to steam releases that can have a 26 to 36 hour duration. As a result of the noise complaints related to steam releases, Braidwood notifies the public about the impending activity and the potential for noise via their notification system (Exelon 2014c). The notification system alerts residences and other locations within 1 mi of Braidwood prior to planned activities that may affect the surrounding area. This practice has reduced noise complaints during subsequent years (Exelon 2014c).

In addition to noise sources from the Braidwood site, noise sources around the Braidwood site include local traffic, nearby community activities and events, and rail line. Illinois state highway 53 and the UP rail line, which hosts freight and passenger trains on a daily basis, are

on the western edge of Godley. This section of the rail line is part of the Illinois high-speed rail (HSR) plan. According to the HSR environmental impact statement, existing train traffic passing along the section of track near Godley produces day-night (Ldn) noise levels of approximately 60 decibels at 300 ft from the tracks (IDOT and FRA 2013).

The EPA uses a threshold level of 55 dBA to protect against excess noise during outdoor activities. However, according to EPA, this threshold does "not constitute a standard, specification, or regulation," but was intended to provide a basis for State and local governments establishing noise standards (EPA 1974). The Federal Housing Administration has established noise assessment guidelines and finds that noise 65 dBA or less are acceptable (HUD 2014). The Will County Code of Ordinances contains noise regulations in Title IX (General Regulations), Chapter 93 (Public Nuisances), sections 93.080 through 93.087 (Will County 2014). The Will County noise ordinance adopts by reference the noise regulations found in Title 35 IAC, Subtitle H (Noise), Chapter 1 (Pollution Control Board), Part 900 (General Provisions) and Part 901 (Sound Emission Standards and Limitations for Property Line Noise Sources) (35 IAC H). These noise regulations have allowable octave-band sound levels according to emitting and receiving land class and time of day.

3.4 Geologic Environment

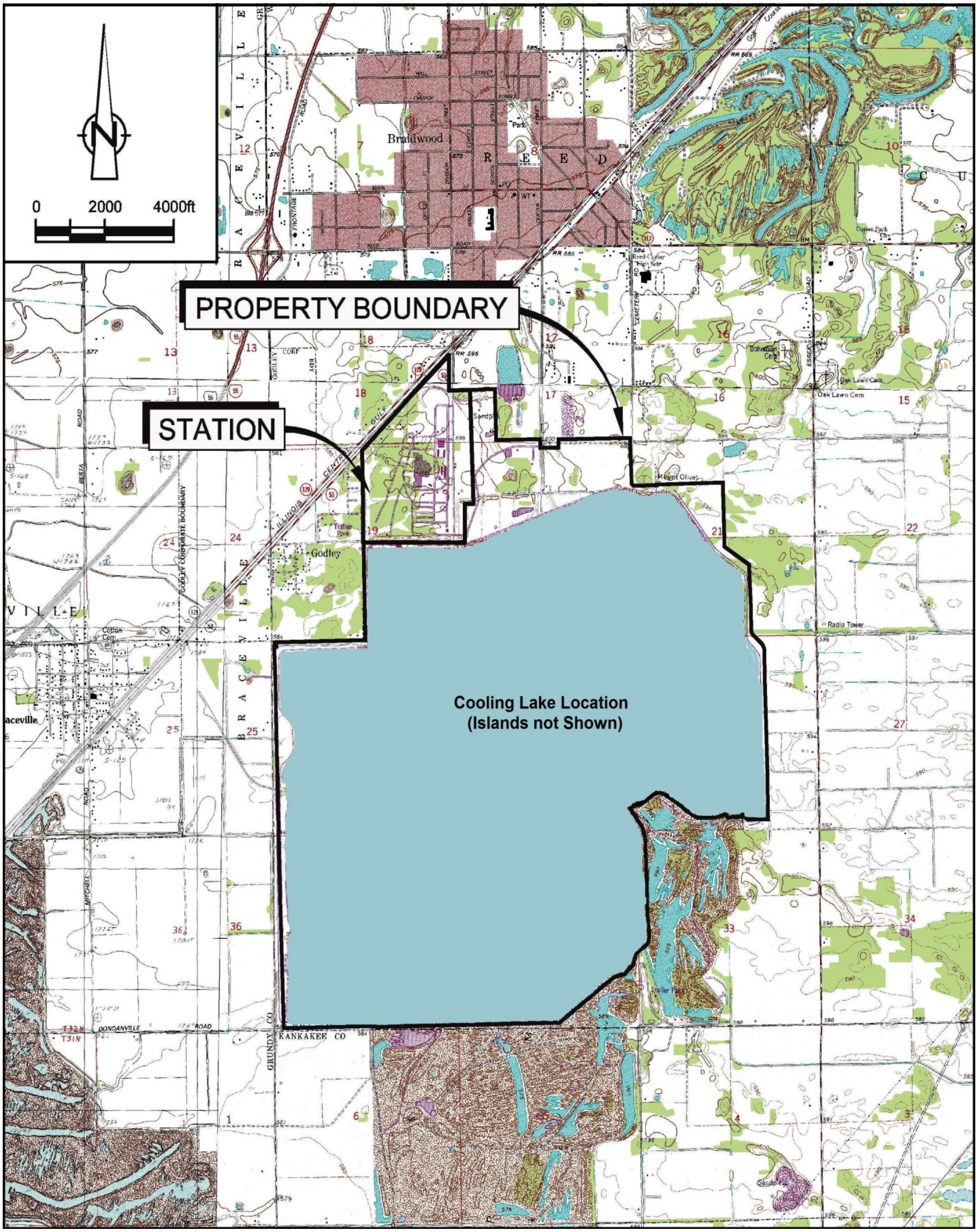
This section describes the current geologic environment of the Braidwood site and vicinity, including landforms, geology, soils, and seismic conditions.

3.4.1 Physiography and Geology

The Braidwood site is located in an area which contains non-lithified (not solid rock) glacial deposits overlying a bedrock surface. These deposits formed during successive periods of glaciation. The topography, in general, slopes gently to the north toward the Illinois River (Figure 3–6). The Cooling Lake immediately adjacent to and south of the station was formed from prior coal strip mining operations. Large areas of former coal strip mined land occurs north and south of the station and a number of small excavations (now water filled ponds) occur north and northeast of the plant site (CRA 2006b) (Figure 3–6). The underlying bedrock was largely formed in ancient seas prior to glacial activity and consists of 4,500 ft (1,372 m) of dolomite, sandstone, and shale rock (See Section 3.5.2.1). In turn, these rocks are underlain by granites and possibly metamorphic rocks to a great depth (Frankie and Nelson 2003).

Coal mining in the area ceased in 1974, when it was no longer economical to continue mining. North and northeast of the station, the surficial formation has been mined for its sand content (See Section 3.5.2.1). This same formation underlies the generating station. Access to this formation as a source of sand is readily available outside the station over a wide area.

Figure 3–6. Braidwood Site Topography



Source: Modified from CRA 2011

3.4.2 Soils

The soils at Braidwood have developed from sandy glacial outwash (water from a glacial ice) deposits and lake deposits. The soils are established on relatively flat topography and can be characterized as fine sand and sandy loams. These soils are moderately to well drained and have moderate to rapid permeability (CRA 2006b; USDA 2013). Because of their large sand component they are not considered as suitable for prime farmland and because of the high water table they may require dewatering to be used for farming.

3.4.3 Seismic Setting

The only reported injury from an earthquake that occurred in Illinois happened on April 12, 1883, when an old frame house was shaken down, resulting in slight injury to the inhabitants. A number of earthquakes (USGS 2012a, 2013a, 2013b) have originated within Illinois and include:

- May 26, 1909, a large earthquake knocked over many chimneys in Aurora and swayed buildings in Chicago.
- July 18, 1909, an earthquake knocked down chimneys in Petersburg.
- August 14, 1965, a sharp local earthquake knocked down chimneys at Elco, Unity, Olive Branch, and Olmstead.
- November 9, 1968, a magnitude 5.3 earthquake was felt over a large area.

Dozens of earthquakes originating outside Illinois have been felt inside the State without causing damage. These earthquakes originated in Missouri, Arkansas, Kansas, Nebraska, Tennessee, Indiana, Ohio, Michigan, Kentucky, and Canada. However, southern Illinois could experience major damage should a large magnitude earthquake occur in the New Madrid Seismic Zone (located in southern Illinois and neighboring states) (MODNR 2014; USGS 2009). The site is located in northeast Illinois that has a very small probability of experiencing damaging earthquakes (FEMA 2013; MAE Center 2009). The NRC requires every nuclear plant to be designed for site-specific ground motions that are appropriate for its location.

3.5 Water Resources

3.5.1 Surface Water Resources

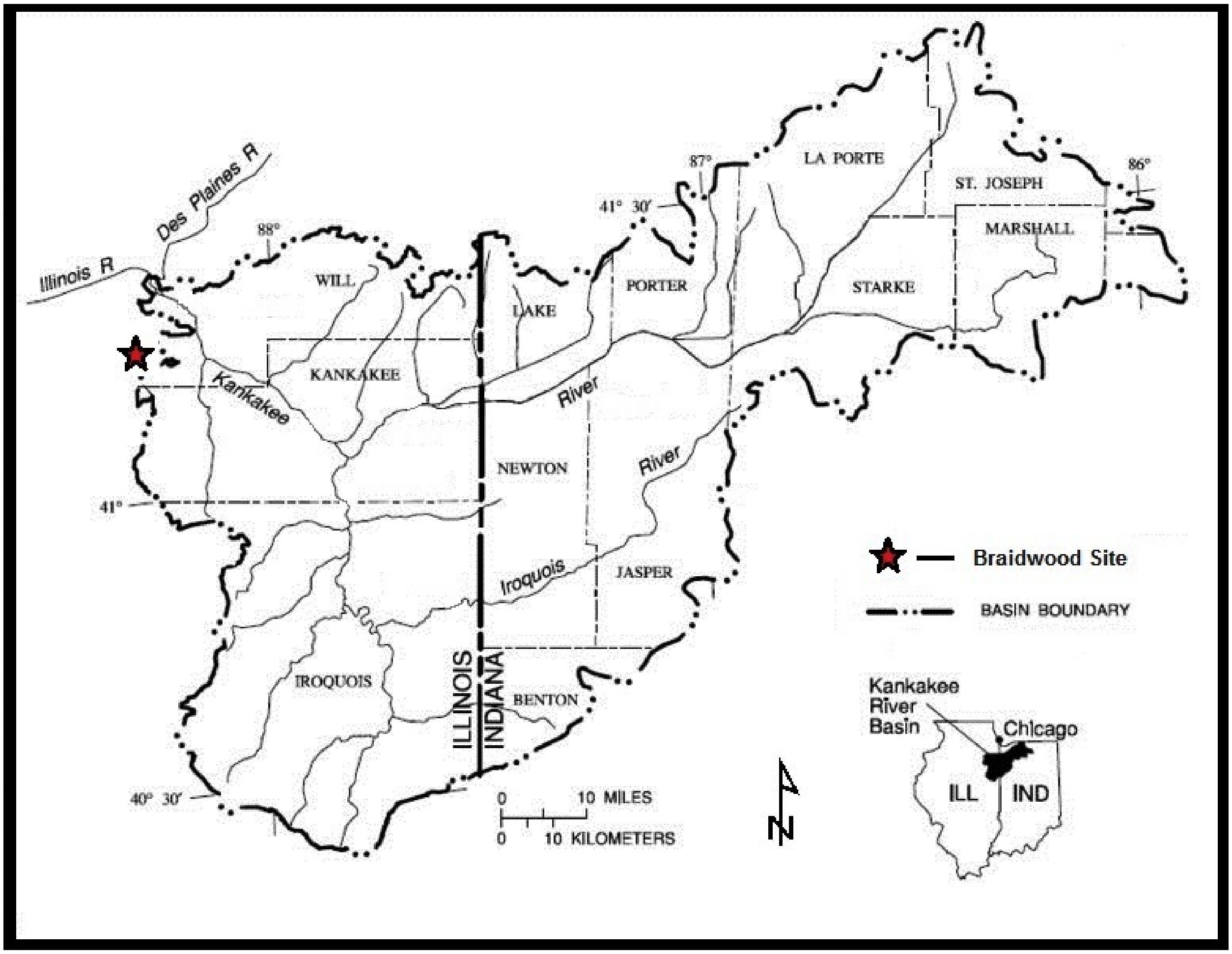
This section describes the current surface water resources within and near the Braidwood Station. Surface water encompasses all water bodies that occur above the ground surface, including rivers, streams, lakes, ponds, and man-made reservoirs or impoundments.

3.5.1.1 Surface Water Hydrology

The Braidwood site is situated in the Upper Illinois/Mazon River watershed. The Mazon River is approximately 33 mi long and the basin drains an area of 455 square miles (mi^2). The Mazon River empties into the Illinois River near Morris, Illinois (IDNR 2014e). While the site is located in the Mazon River watershed, it consumes surface water from the Kankakee River Basin. The Kankakee River is located about 5 mi (8 km) to the east of Braidwood. The river originates near South Bend, Indiana and flows west into Illinois near Momence, Illinois, until it joins the Des Plaines River to ultimately form the Illinois River. In total, the Kankakee River is approximately 150 mi long and the basin drains an area of 5,165 mi^2 (see Figure 3–7). The Illinois portion of the Kankakee River runs for about 59 mi and drains an area of 2,168 mi^2 (Bhowmik and Demissie 2000). There are three dams along the river's main stem in Momence,

Wilmington, and Kankakee, IL. The largest tributary to the Kankakee River is the Iroquois River; the Iroquois River is 94 mi long and has a drainage area of 2,137 mi^2.

Figure 3–7. Kankakee River Basin



Source: Modified from Phipps et al. 1995

Makeup water for Braidwood's cooling pond is withdrawn from the Kankakee River through an intake structure (river screen house). The U.S. Geological Survey (USGS) maintains a gaging station on the Kankakee River in Wilmington, IL (station 05527500) located approximately 14 km (8.8 mi) downstream from Braidwood's intake structure. River discharge data have been collected at this site since 1932. Because of its location and long period of record data, this gauge was chosen to be representative of long-term river flow characteristics in the vicinity of Braidwood. The mean annual discharge measured at the USGS gage at Wilmington, for water years 1934 through 2012, is 4,805 cfs (136 cubic meters per second (m^3/s)) (USGS 2012b). Over this period of time the highest annual mean discharge was 10,380 cfs (294 m^3/s) in 1993 and the lowest annual mean discharge was 1,407 cfs (40 m^3/s) in 1964 (USGS 2012b).

Braidwood's storm water discharges are released into the Mazon River. The storm water drainage system directs runoff from the plant's protected area and surrounding Exelon-owned land to three outfalls designated in the site's NPDES permit. Exelon implements and maintains a Stormwater Pollution Prevention Plan (SWPPP) to comply with Special Condition 9 of the

site's Illinois-issued NPDES permit (IEPA 2014c). The site's NPDES permit is further discussed in Section 3.5.1.3.

Braidwood's cooling pond is approximately 1,030 ha (2,540 ac) (Exelon 2013a, 2013b, 2013c). The cooling pond is available for public access for fishing, waterfowl hunting, and fossil collecting as a result of an agreement between Exelon and the IDNR. The cooling pond is further discussed in Section 3.1.3.

3.5.1.2 Surface Water Use

Braidwood withdraws surface water from the Kankakee River to provide makeup water to the cooling pond that is lost to evaporation and seepage. Cooling pond blowdown is discharged back to the Kankakee River via a multi-port diffuser at a point located about 152 m (500 ft.) downstream of the plant's intake at the river screen house.

Table 3–5 summarizes Braidwood's surface water withdrawals for the period 2008 to 2012. Based on the staff's review of Braidwood's Illinois State Water Survey submittals, Braidwood's surface water withdrawals have averaged 16,806.3 million gallons per year (mgy) (64 million cubic meters per year (m^3/y)). This is equivalent to an average withdrawal rate of 71 cfs. Return discharges to the Kankakee River have averaged 8,445.9 mgy (32 million m^3/y). This is equivalent to an average discharge rate of 36 cfs. The average consumptive rate for this period of time was 8,360.4 mgy (31.6 million m^3/y) or 35 cfs.

Table 3–5. Annual Surface Water Withdrawals and Return Discharges to the Kankakee River, Braidwood Station

Year	Withdrawals (mgy)	mgd	Discharges (mgy)	mgd
2008	14,819.8	41	7,550.3	21
2009	15,935.0	44	9,407.5	26
2010	18,159.6	50	8,893.2	24
2011	16,754.2	46	8,550.8	23
2012	18,364.3	50	7,827.9	21
Average	16,806.6	46	8,445.9	23

Note: Reported values are rounded. To convert million gallons per year (mgy) to million cubic meters (m^3), divide by 264.2.

mgd = million gallons per day

Source: Exelon 2014c

Braidwood's surface water withdrawals are subject to an April 1977 construction permit (No. 15039) from the Illinois Department of Transportation (IDOT), Division of Water Resources (now the IDNR). The provisions of this permit limit Braidwood's maximum makeup withdrawal rate from the river to 160 cfs (71,808 gpm or 4.5 m^3/s). The provisions specify to stop withdrawing water from the river when the flow rate falls below 422 cfs (189,394 gpm or 12 m^3/s) (Exelon 2014c). Braidwood has operating procedures to comply with these provisions and stipulate actions that plant personnel must take during conditions of low river flow (Exelon 2013b).

3.5.1.3 Surface Water Quality and Effluents

The Illinois Pollution Control Board, a sister Agency to the Illinois EPA, promulgates water quality standards in Illinois. Two Sections of Title 35 of the IAC (35 IAC 302; 35 IAC 303)

contain the standards applicable to lakes and streams. Procedures to be followed in using water quality standards to set NPDES permit limits are found in Section 309 (35 IAC 309). Designated uses prescribed by 35 IAC 303 are those uses specified in water quality standards for each lake, river, stream, and groundwater resource. In designating uses for a water body, the Illinois Pollution Control Board takes into consideration the use and value of the water body for public water supply; for propagation of fish, shellfish, and wildlife; and for recreational, agricultural, industrial, and navigational purposes.

The Kankakee River and Mazon River are designated as “general use water” by the Illinois Pollution Control Board. Waters in the general use category must meet water quality standards protective of aquatic life, wildlife, agricultural use, secondary contact use, as well as most industrial uses and aesthetic quality (35 IAC 303.201). These standards pertain to pH, phosphorus, dissolved oxygen, radioactivity (gross beta, strontium-90, and radium-226 and -228), and various chemical constituents (metals and organic compounds), fecal coliform, and other toxic substances (as appropriate).

Section 303(d) of the Federal Clean Water Act (CWA) requires the State of Illinois and other states to identify all “impaired” waters for which effluent limitations and pollution control activities are not sufficient to attain water quality standards in such waters. The 303(d) list includes those water quality limited stream segments that require the development of total maximum daily loads (TMDLs) to assure future compliance with water quality standards. The IEPA has identified an 8.22-mi-long segment of the Kankakee River adjacent to the Braidwood plant site as impaired and not meeting designated uses, or water quality standards, or both (IEPA 2014b). This segment is listed due to contamination from polychlorinated biphenyls (PCBs) and mercury (impairing fish consumption use), as well as for phenols (impairing public water supplies).

An 18.7-mi segment (IL_DV-04) of the Mazon River, which includes the segment that receives storm water discharge from Braidwood, is also identified as impaired. This segment is listed due to contamination from polychlorinated biphenyls (PCBs) and mercury (impairing fish consumption use) and fecal coliform (impaired primary-contact recreation or nuisance for recreation use). Special Condition 6 of the station’s NPDES permit prohibits the discharge of PCBs in plant effluents (IEPA 2014c).

To operate a nuclear power plant, licensees must comply with the CWA, including associated requirements imposed by the EPA or the state, as part of the NPDES permitting system under Section 402 of the CWA as well as state water quality certification requirements under Section 401 of the CWA. The EPA or the state, not the NRC, sets the limits for effluents and operational parameters in plant-specific NPDES permits. Nuclear power plants cannot operate without a valid NPDES permit and a current Section 401 Water Quality Certification. The State of Illinois has been delegated responsibility by the U.S. EPA for administration of the NPDES program in Illinois. NPDES permits are issued by the IEPA on a 5-year cycle.

Braidwood is currently operating under NPDES Permit No. IL0048321, issued on July 31, 2014 (IEPA 2014c). The NPDES permit specifies the discharge standards and monitoring requirements for effluent chemical and thermal quality and for stormwater discharges through the plant’s outfalls to the Kankakee River and Mazon River. The plant’s outfalls are identified in Figure 3–8, and Table 3–6 summarizes the outfalls discharges.

Figure 3–8. Braidwood NPDES Outfall Locations

Note: A01= outfall 001(a); C01= outfall 001(c); D01=outfall 001(d); E01= outfall 001(e)

Source: Modified from Exelon 2014c

Table 3–6. National Pollutant Discharge Elimination System-Permitted Outfalls, Braidwood Station [(a)]

Outfall	Average Flow [(b)] Rate (mgd)	Description
001	14.638	Cooling Pond Blowdown line; continuous discharge to the Kankakee River
001(a)	0.081	Wastewater Treatment Plant Effluent; discharge to the Kankakee River
001(c)	0.003	Radwaste Treatment System Effluent; continuous discharge to the Kankakee River
001(d)	0.028	Demineralizer Regenerant Wastes; continuous discharge to the Kankakee River
001(e)	No discharge	River Intake Screen Backwash
002	Intermittent	North Site Stormwater Runoff Basin; discharges to the Mazon River
003	Intermittent	South Site Stormwater Runoff Basin; discharges to the Mazon River
004	Intermittent	Switchyard Area Runoff; discharges to the Mazon River

[(a)] Special Conditions 4 and 11 of the NPDES permit restrict temperature changes in the river and require Exelon to monitor the temperature of its discharge and provide the results in its monthly DMRs.

[(b)] To convert million gallons per day (mgd) to million cubic meters (m^3), divide by 264.2.

Sources: Exelon 2014c; IEPA 1995, 2013b, 2014c

Exelon has prepared an SWPPP for Braidwood to manage its stormwater discharges in compliance with Special Condition 9 of the NPDES permit. The NPDES permit requires Exelon to monitor the flow rate, pH, chlorine and bromine concentration, and temperature of its cooling system blowdown discharge to the Kankakee River through its primary outfall (outfall 001). Monitoring results are reported in monthly Discharge Monitoring Reports (DMRs) submitted to the State. Braidwood has received no notices of violation associated with NPDES permitted discharges during the 2008 through 2012 time period. However, a review of DMRs from 2008 through 2012 indicates that five occurrences of noncompliance with NPDES permit limits or conditions occurred for short periods of time (Exelon 2014c):

- July 2009: sewage treatment plant effluent (outfall 001(b))[3] exceeded the 30-day average concentration for biochemical oxygen demand
- April 2011: sewage treatment plant effluent (outfall 001(b)) exceeded the 30-day average concentration for biochemical oxygen demand
- May 2011: demineralizer regenerant wastes effluent (outfall 001(d)) exceeded the daily maximum limit for total suspended solids
- March 2012: cooling pond blowdown line effluent (outfall 001) exceeded the limit for temperature
- November 2012: cooling pond blowdown line effluent (outfall 001) exceeded the limit for maximum pH

[3] In October 2012, Braidwood's sewage treatment plant ceased operation, and sewage was rerouted directly into the City of Braidwood Sewage Treatment Plant (Exelon 2014c). Outfall 001(b) has been removed from the July 31, 2014, Reissued NPDES Permit (IEPA 2014c).

Exelon notified the IEPA regarding the noncompliances listed above. With respect to the March 2012 exceedance, the IEPA granted Braidwood a provisional variance from the NPDES water discharge permitted temperature limits due to warm weather conditions (IEPA 2012). During the variance, as required by IEPA, Exelon continuously monitored the discharge and receiving water temperatures and visually inspected all discharge areas at least three times a day. Furthermore, Exelon identified and implemented corrective actions to prevent future occurrences subsequent to these noncompliances (Exelon 2014c).

Section 401 of the CWA requires an applicant for a Federal license to conduct activities that may cause a discharge of regulated pollutants into navigable waters to provide the licensing agency with water quality certification from the state. This certification implies that discharges from the project or facility to be licensed will comply with CWA requirements and will not cause or contribute to a violation of state water quality standards. If the applicant has not received Section 401 certification, the NRC cannot issue a license unless that state has waived the requirement. The NRC recognizes that some NPDES-delegated States explicitly integrate their 401 certification process with NPDES permit issuance. Braidwood's NPDES permit does not explicitly convey water quality certification under CWA Section 401.

The Chicago District of the USACE sent a letter to Exelon in July 2012 stating that no permit was required from the USACE and that it had no objection to renewing the Section 401 certification for Braidwood (Exelon 2013b). Previously, by letter dated May 18, 2012, Exelon submitted an application to the IEPA Bureau of Water Pollution Control requesting certification that renewal of the plant's NRC operating licenses would not violate state water quality standards (Exelon 2013b). In May 2013, the IEPA Division of Water Pollution Control responded to the Exelon request and sent a letter to the NRC regarding Braidwood's 401 certification, providing the 401 certification subject to inclusion of two conditions into the NRC license for Braidwood (IEPA 2013e). In November 2014, NRC staff responded to IEPA, noting that since the two conditions are license requirements either because they are imposed as a matter of law or they state existing statutory provisions, no further NRC action is needed with respect to these two conditions: (1) Exelon must obtain CWA Section 402 (NPDES) permits from the State in accordance with 33 U.S.C. § 1342, and (2) a 401 certification does not authorize activities that require authorizations under Section 404 of the CWA, 33 U.S.C. § 1344 (i.e., the permits for discharges of dredged or fill material, which are issued by the USACE) (NRC 2014).

In order to maintain Braidwood's surface water intake system at the river screen house, Exelon conducts dredging to remove accumulated river sediment. There is no prescribed frequency for dredging, and divers are used to periodically examine the area to assess the need. Dredging was performed in 2009 (Exelon 2014c). Similarly, Braidwood's diffuser discharge structure is inspected annually by divers to evaluate the need for maintenance. Dredging is conducted in accordance with USACE Nationwide Permits in accordance with Section 10 of the Rivers and Harbors Act and Section 404 of the CWA. In the USACE letter to Exelon in July 2012, there is no mention of dredging maintenance.

3.5.2 Groundwater Resources

This section describes the current groundwater resources at the Braidwood site and vicinity.

3.5.2.1 Site Description and Hydrogeology

The site is located in an area which contains glacially deposited material overlying a bedrock surface. These deposits are the Equality Formation and the underlying Wedron Clay Till. The Equality Formation, hereafter called the "Upper Aquifer" (Figure 3–9), is approximately 20 ft (6.1 m) thick and is a uniform fine-grained sand. Figure 3-9 shows an illustration of the

Geologic Cross-Section. The Upper Aquifer is a water-table (unconfined) aquifer and locally is used as a source of potable water. The water table occurs near the land surface. The depth to water ranges from 5 to 15 ft (1.5 to 4.6 m). In some areas, this aquifer has been mined as a source of sand to build roads. As these pits were excavated below the water table, they are now water filled ponds (Section 3.4.1) (CRA 2006b).

The Wedron Clay Till underlies the Upper Aquifer. The Wedron Clay Till is a silty clay and ranges from 15 to 20 ft (4.6 to 6.1 m) thick. The Wedron Clay has a very low permeability (transmits water very poorly) and is considered an aquitard. The Wedron Clay is underlain by the bedrock. The bedrock that underlies the Wedron Clay is the Francis Creek Shale. This shale is approximately 40 to 50 ft (12.2 to 15.2 m) thick and because of its low permeability is considered an aquitard. Beneath the Wedron Clay is a siltstone/conglomerate. It is about 10 ft (3 m) thick. Beneath this siltstone conglomerate is the Colchester Coal (No. 2) Seam, which averages 3 ft (1 m) thick.

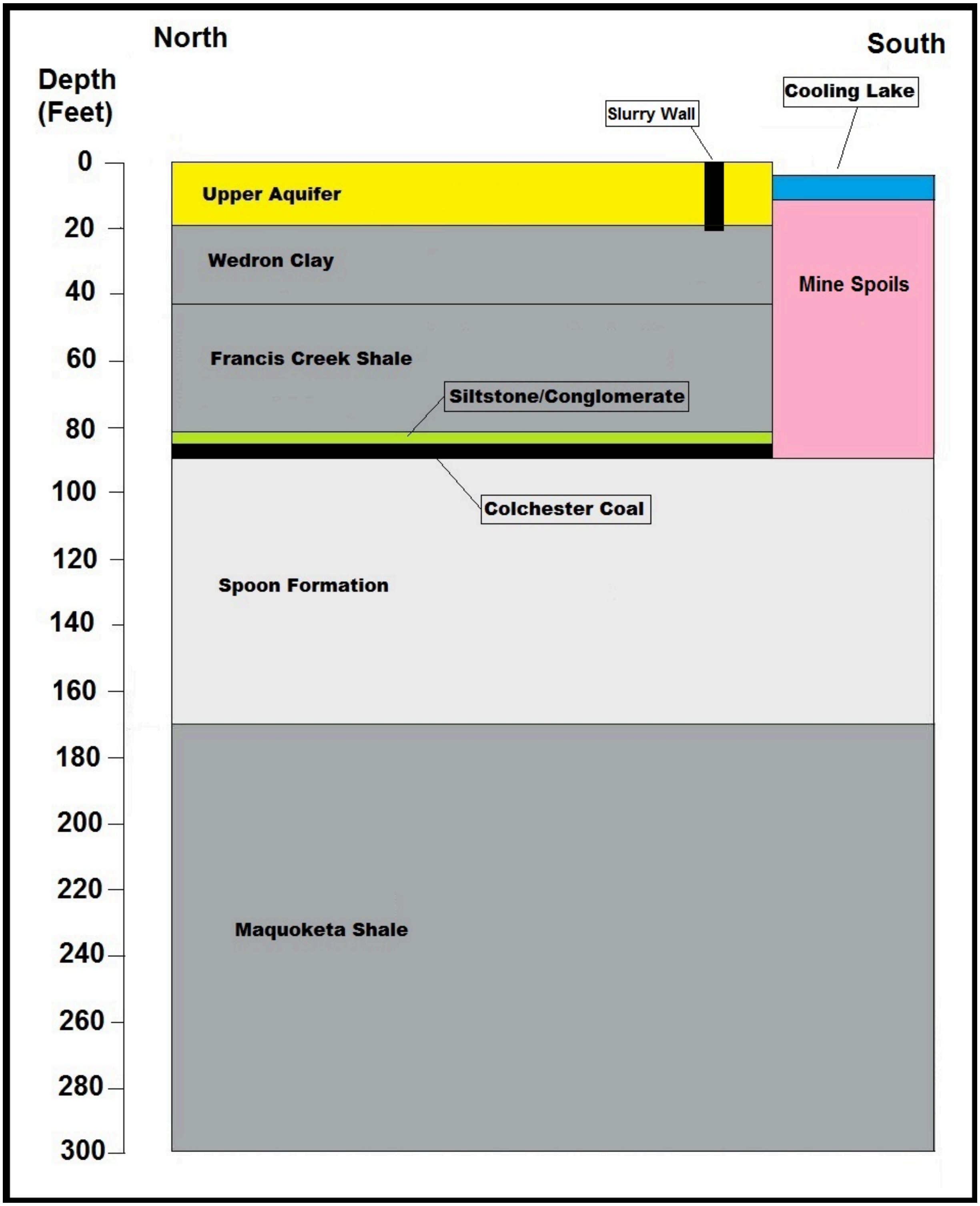
The Colchester Coal Seam is underlain by the Spoon Formation. This formation is made up of limestone rock, with a thickness of 80 ft (24.4 m) to 90 ft (27.4 m). This formation is underlain by the Maquoketa Shale with a thickness of at least 120 ft (37 m). The Maquoketa Shale is considered an aquitard and is laterally continuous throughout the area. It overlies the Galena-Platteville Dolomite, St. Peter Sandstone aquifer, the Knox Megagroup, and the Ironton–Galesville aquifer. Regionally, these units are hydraulically connected and hereafter they are called the "Deep Aquifer" (Figure 3–10). Within the Deep Aquifer, the St. Peter Sandstone aquifer and the Ironton-Galesville aquifer are the most productive aquifers and are used as a source of water (see Section 3.5.2.2) (Exelon 2013j).

The Upper Aquifer is recharged by local precipitation, and discharges to nearby ponds, streams, and strip mines. At the site, the lateral direction of groundwater flow in this aquifer is generally from south to north (Exelon 2013j). The Deep Aquifer is hydraulically isolated from the Upper Aquifer by the Wedron Clay Till and the Maquoketa Shale. This aquifer is not recharged locally. It is recharged in areas where the Maquoketa Shale is not found. These areas are located west and northwest of the site in north-central Illinois (Burch 2008) (Figure 4-1, in Cumulative Impact Section). Lateral groundwater flow in the Deep Aquifer beneath the Braidwood site is toward the northeast (Burch 2002; Exelon 2013j).

Mining the Colchester Coal (No. 2) Seam was previously a significant activity in the local area, but today mining of this coal seam is no longer profitable. Coal was discovered in the Coal City area in 1854. Underground mining began in the 1870s. Strip-mining began in the 1920s and continued until 1974. Both abandoned underground and strip mines can be found within 1 to 1.5 mi (1.6 to 2.4 km) in all directions from the site (Illinois State Geological Survey 2012; Obrad 2006; Obrad and Chenoweth 2007).

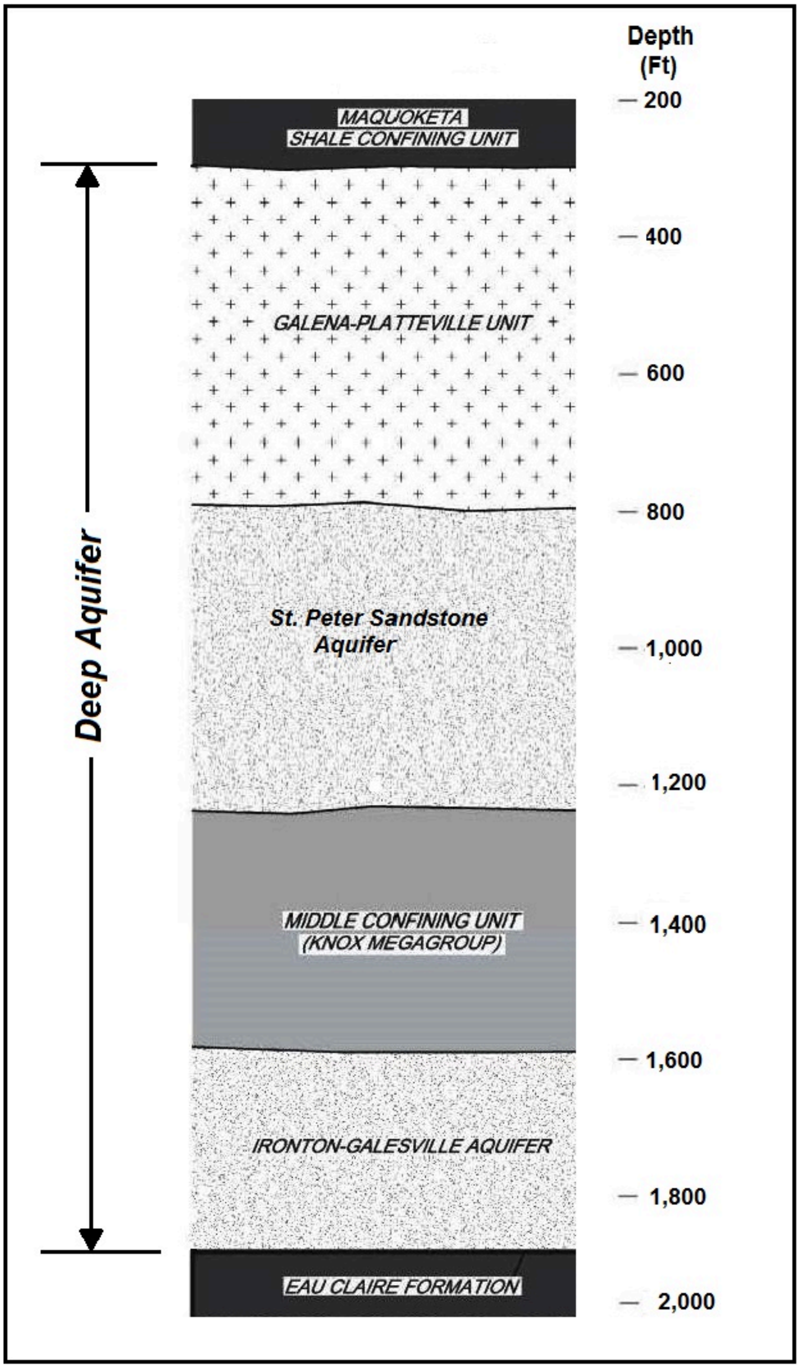
Coal mining activities stopped above the Spoon Formation. As a result the Maquoketa Shale was undisturbed by mining activities and remains a significant barrier (aquitard) to the vertical movement of groundwater. Mining never occurred beneath the station. However the coal seam (or vein) was strip mined over a large area south and east of the station. This strip mine operated until 1974. The strip mine was excavated to a depth of about 100 ft (30.5 m) below ground surface. As each new cut was excavated into the earth the geologic materials that overlay the coal were placed into the previously mined cut. This had the effect of filling most of the former coal mine excavation with the rock layers which previously overlay the coal.

Figure 3–9. Illustrative Geologic Cross-Section



Source: NRC Staff–Generated Graphic

Figure 3–10. Generalized Geologic Column of Deep Aquifer



Source: Modified from CRA 2010

The cooling lake for the Braidwood Station was constructed from this former coal mine operation and from adjacent farmland. As previously explained, while mining went to a depth of 100 ft (30.5 m) most of the old excavations were filled with geologic units that overlay the coal (mine spoils). As a result, the average depth of the cooling lake is only 8 ft (2.4 m) (CRA 2006b; Larimore and Skelly 1984). Dikes were constructed around and in this area. These dikes in association with existing spoil banks were designed to contain and guide water flow through the cooling pond. To reduce lateral water losses out the sides of the cooling lake and into the

Equality Formation, a slurry wall of low permeability material was built around the entire cooling lake when the facility was constructed. This slurry wall was constructed from the land surface and into the top of the Wedron Clay Till (CRA 2006a, 2006b). The cooling pond was completely filled with water pumped from the Kankakee River from December 1, 1980, to February 18, 1981.

A small abandoned underground coal mine is located 0.25 mi (0.4 km) east of the facility. From 1904 to 1909, vertical shafts and a long-wall mining technique were used to extract coal from the Colchester Coal (No. 2) Seam. The underground mine went to a depth of 81 ft (24.7 m) and covered 33 ac (13.4 ha) (Obrad 2006).

3.5.2.2 Groundwater Use

Groundwater in the site area is mainly extracted from two primary aquifers; the Upper Aquifer and the Deep Aquifer (CRA 2006b). However, a small number of local water wells supplying private residences may extract water from the Siltstone Conglomerate or from the Spoon Formation (Exelon 2013j).

Within 1 mi (1.6 km) from the center of the plant buildings there are approximately 40 private wells (Figure 3–11) (CRA 2010). Many of these wells are screened within the Upper Aquifer. The Deep Aquifer, made up of the St. Peter Sandstone and the Ironton–Galesville aquifer, is used by both public and private water users (Exelon 2013j). Within 1 mi (1.6 km) of the site, six private wells are completed in the Deep Aquifer.

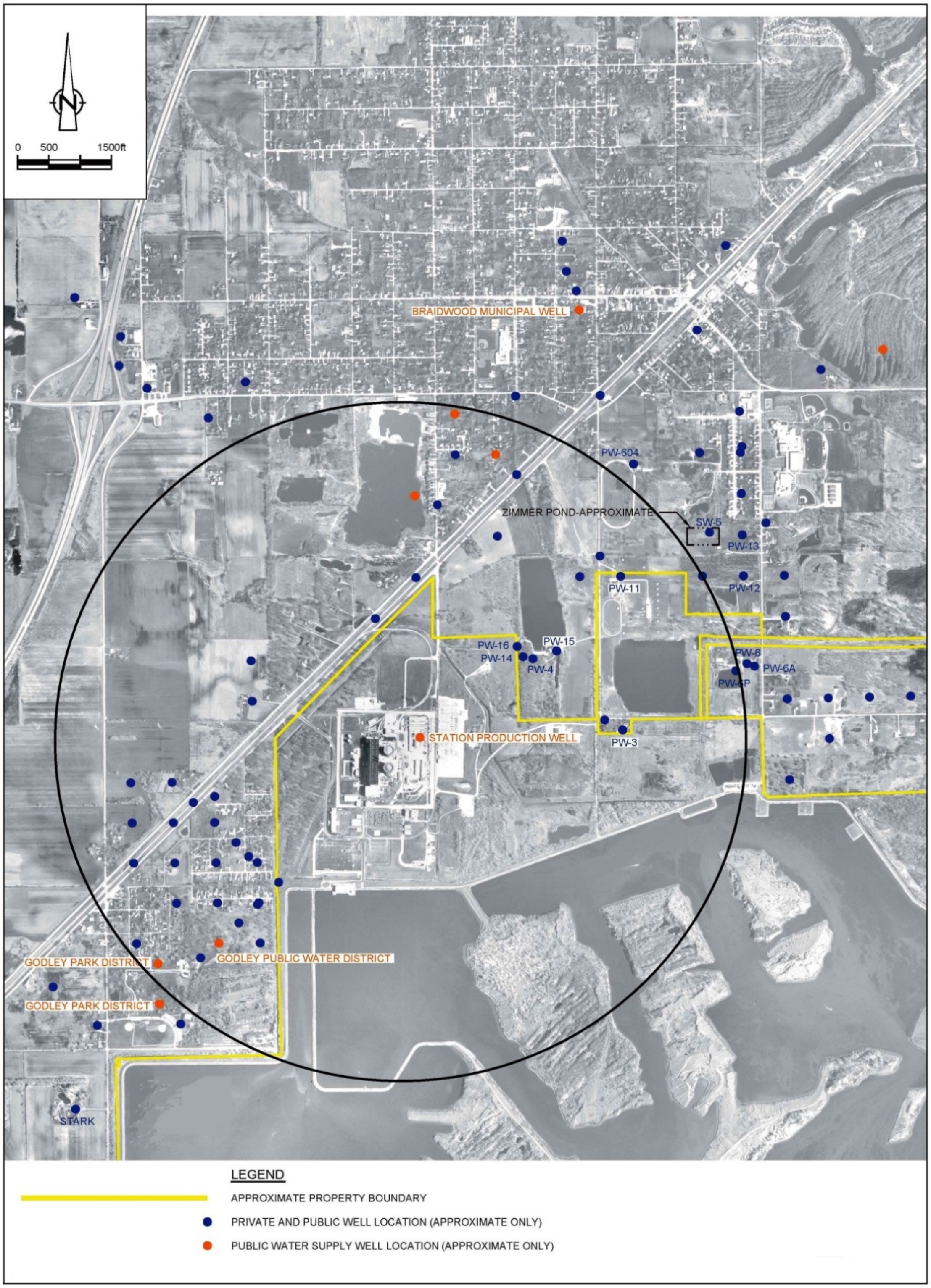
The nearest public water supply wells to the site are owned by the Godley Public Water District. These wells are located approximately 0.86 to 1 mi (1.4 to 1.6 km) southwest of Braidwood and are completed into the St. Peter Sandstone of the Deep Aquifer (Figure 3–11) (CRA 2010; Exelon 2013j). Together these wells average a combined production rate of 34,840 gallons per day (gpd) (131,900 Lpd) (Exelon 2013j).

The next nearest public water supply well is located approximately 1.4 mi (2.2 km) north-northeast of the site and belongs to the City of Braidwood (Figure 3–11). This well pumps water at an average rate of 1.8 mgd (6.8 million Lpd) (Exelon 2013j). The City of Braidwood also owns the next closest public water well. This well is located approximately 2.5 mi (4.0 km) north of the site. Pumping rates for this well are not available (Exelon 2013j). Both wells are completed into the Ironton–Galesville Aquifer of the Deep Aquifer (Exelon 2013j).

The plant obtains water from an onsite well completed into the Deep Aquifer. This well is cased to a depth of 1,200 ft (365.7 m) and obtains water from the Ironton-Galesville Aquifer. Water from this well is used to supply the plant potable water system and make-up demineralizer system at a rate of approximately 83,000 gpd or (314,000 Lpd) (Exelon 2013j).

Figure 3–11. Public and Private Water Wells Near Braidwood Station

(The circle has a 1-mi radius.)



Source: Modified from CRA 2010

3.5.2.3 Groundwater Quality

The water quality of both the Upper Aquifer and the Deep Aquifer is acceptable for public use and consumption.

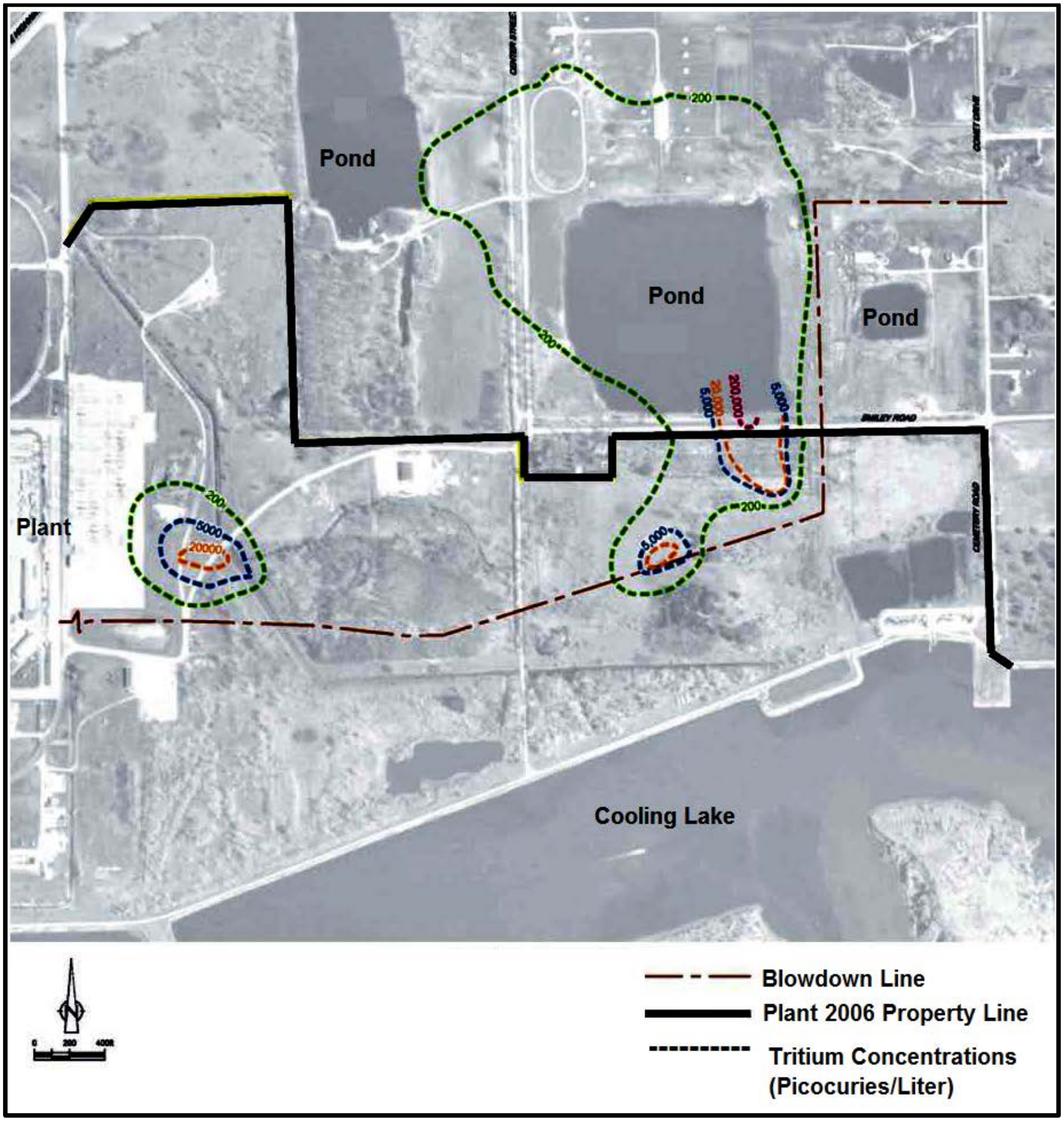
Controlled effluent from plant operations, which may include radionuclides produced in the reactor coolant system, may be released to the Kankakee River via the discharge or “blowdown” pipeline. Before the effluent is released into the pipeline it is sampled, analyzed, and processed to ensure the liquid released complies with NRC and EPA regulations. In 2005, Exelon determined that water from the blowdown pipeline had been released by three malfunctioning vacuum breaker valves located along a section of the pipeline approximately 0.5 mi (0.8 km) east of the plants eastern boundary. Exelon determined that water containing tritium had been released from the pipeline in 1996, 1998, 2000, 2003, and 2005. The water released from the blowdown pipeline infiltrated into the groundwater in the Upper Aquifer (Figure 3-12) (CRA 2006a; Exelon 2013j).

The highest on-site tritium concentration, detected in Upper Aquifer groundwater was 282,000 picocuries per liter (pCi/L), and the highest offsite concentration (230,000 pCi/L) was found in a monitoring well located immediately adjacent to the 2005 Braidwood property line. Only one private well was found to contain tritium above the lower limit of detection (200 pCi/L) (CRA 2006a). The maximum concentration of tritium in this well was 1,524 pCi/L. This concentration is well below EPA’s safe level for public drinking water of 20,000 pCi/L (CRA 2006a, Table 6.4).

The blowdown pipeline was evaluated for structural integrity. Vacuum breakers along the blowdown pipeline were repaired or permanently closed, and groundwater monitoring wells were installed along the pipeline. Continuous monitoring systems were installed in the operating vacuum breaker boxes to warn of any wastewater releases from the vacuum breakers. Remediation of the contaminated groundwater began in 2006, principally by pumping water from a small Braidwood-owned pond (a former sand borrow pit). This lowered the water table in the Upper Aquifer around the pond, which in turn caused contaminated groundwater to flow into the pond. Water from the pond was pumped into the repaired blowdown pipe, where it was combined with water obtained from the Braidwood cooling pond and then discharged to the Kankakee River in compliance with NRC regulations (Exelon 2013j).

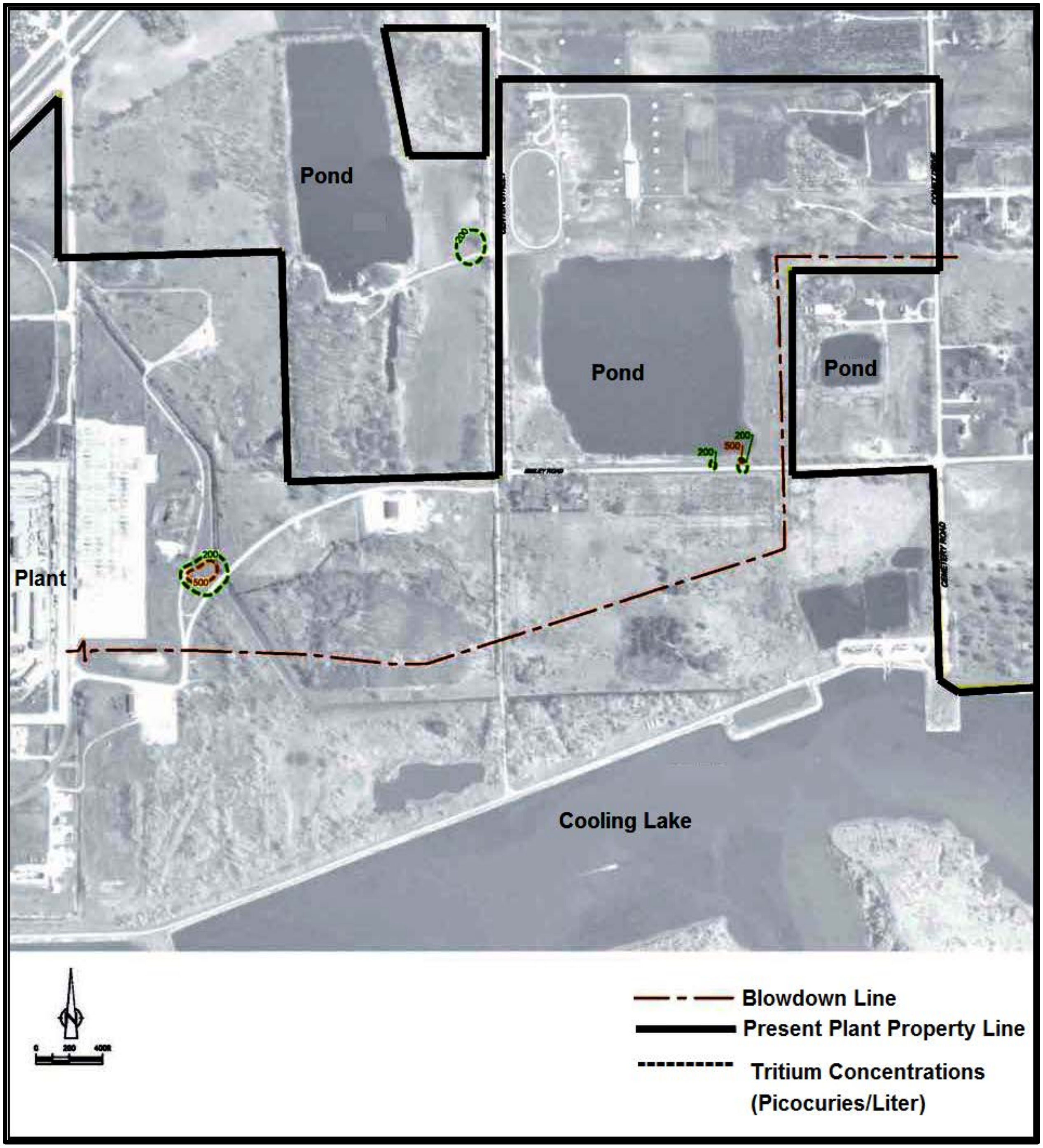
Both off-site and on-site groundwater contamination in the Upper Aquifer has been successfully remediated. In 2013, the Illinois EPA determined that the contamination in the Upper Aquifer had been successfully remediated and that active groundwater remediation could be terminated (CRA 2011; Exelon 2009b, 2010b, 2011a, 2012c, 2012d, 2013c, 2013j; IEPA 2013b, 2013c, 2013d). At the end of active remediation, the size of the area contaminated had been reduced by 97 percent and the highest concentrations of tritium had been reduced by 99 percent (Exelon 2013j). Figure 3–12 shows tritium 2006 concentrations from areas of the Upper Aquifer impacted by the releases from the blowdown pipeline and Figure 3–13 shows 2012 tritium concentrations near the end of active remediation.

Figure 3–12. Tritium Concentrations in the Upper Aquifer in 2006



Source: Modified from Exelon 2013j

Figure 3–13. Tritium Concentrations in the Upper Aquifer in 2012



Source: Modified from Exelon 2013j

In accordance with a Nuclear Energy Institute Industry Groundwater Protection Initiative, hydrogeologic investigations were conducted by an independent consultant in 2006 and 2011 (CRA 2006a, 2011). As part of these investigations, groundwater samples were collected and analyzed for tritium, strontium-89 and -90, and gamma-emitting radionuclides. In addition to the areas where leaks had occurred from the blowdown pipeline, in 2006, tritium was also detected in both the Upper Aquifer and construction-fill adjacent to the west side of the plant buildings.

The source of the tritium is believed to be from historical releases that infiltrated into the groundwater (CRA 2011; Exelon 2013j). The concentration in the groundwater from these releases ranged from just above the detection limit of 200 pCi/L to a high of 1,040 pCi/L (CRA 2006a). All of these values are well below the Environmental Protection Agency's safe level for public drinking water (20,000 pCi/L).

Much more data was available for the 2011 study. Tritium in groundwater within the site was not detected above the EPA safe level for public drinking water. Tritium concentrations in all offsite private and public wells were determined to be below the lower limit of detection (CRA 2011). The report concluded that tritium is not migrating off the Braidwood property at detectable concentrations. Tritium and other radionuclides above the lower limit of detection have not been found in wells that monitor the bedrock or bedrock aquifers (CRA 2011). Tritium concentrations within the site have continued to remain well below the EPA safe level for public drinking and no other radionuclides have been detected above their baseline values (Teledyne 2012, 2013).

3.6 Terrestrial Resources

3.6.1 Braidwood Ecoregion

Braidwood lies within the Illinois/Indiana Prairies Level IV Ecoregion. This ecoregion encompasses 19,557 mi^2 (50,652 square kilometers (km^2) in eastern and central Illinois and western Indiana (Woods et al. 2006). It is composed of vast glaciated, flat to rolling plains with terminal and recessional moraines, prairie potholes, and old lake beds. Historically, tallgrass prairie covered the majority of the land surface. Oak-hickory forests were common on moraines and floodplains, and marshes and wet prairies occurred in poorly drained areas. Beginning in the nineteenth century, agricultural land began to replace the natural vegetation, and it is now the dominant land type (Woods et al. 2006). Prairie remnants lack many natural ecosystem functions due to their small size, and areas of prairie restoration often lack forbs or are overly dominated by big bluestem (*Andropogon gerardii*) or Indiangrass (*Sorghastrum nutans*) (IDNR 2005). Historically, forests were dominated by oak (*Quercus* spp.), hickory (*Carya* spp.), elm (*Ulmus* spp.), ash (*Fraxinus* spp.), beech (*Fagus* spp.), and maple (*Acer* spp.) species (CEC 2008). Remaining forests are highly fragmented and are experiencing species composition shifts to sugar maple (*A. saccharum*) and other mesophytic species due to fire suppression (IDNR 2005). Many of the wetlands areas have been drained for row crops, and agriculture now accounts for over 75 percent of land use within this ecoregion (IDNR 2005).

Table 3–7 lists representative wildlife for this ecoregion, as well as species that the IDNR considers to be "critical" to the conservation and restoration of the region's native habitats; species that are indicative of ecosystem health (known as "indicator species"); and species that are native to the region, but are now extirpated or imperiled.

The IDNR maintains the *Illinois Wildlife Action Plan* (IDNR 2005), which addresses native habitat and species decline and contains a statewide conservation plan.

Table 3–7. Wildlife in the Illinois and Indiana Prairies Level IV Ecoregion

Wildlife representative of the ecoregion		
American black bear (*Ursus americanus*)	**eastern bluebird** (*Sialia sialis*)	**North American porcupine** (*Erethizon dorsatum*)
American redstart (*Setophaga ruticilla*)	**eastern chipmunk** (*Tamias striatus*)	**raccoon** (*Procyon lotor*)
bobcat (*Lynx rufus*)	**eastern gray squirrel** (*Sciurus carolinensis*)	**tree sparrow** (*Passer montanus*)
Canada warbler (*Cardellina canadensis*)	**gray fox** (*Urocyon cinereoargenteus*)	**white-footed mouse** (*Peromyscus leucopus*)
coyote (*Canis latrans*)	**indigo bunting** (*Passerina cyanea*)	**white-tailed deer** (*Odocoileus virginianus*)
Wildlife critical to the conservation and restoration of the ecoregion's native habitats		
American badger (*Taxidea taxus*)	**Henslow's sparrow** (*Ammodramus henslowii*)	**northern harrier** (*Circus cyaneus*)
eastern massasauga[(a)] (*Sistrurus catenatus*)	**Illinois chorus frog** (*Pseudacris streckeri illinoensis*)	**ornate box turtle** (*Terrapene ornata ornata*)
four-toed salamander (*Hemidactylium scutatum*)	**Indiana bat**[(b)] (*Myotis sodalis*)	**red squirrel** (*Sciurus vulgaris*)
gray bat (*Myotis grisescens*)	**Kirtland's snake** (*Clonophis kirtlandii*)	**short-eared owl** (*Asio flammeus*)
Wildlife indicative of ecosystem health (indicator species)		
black rat snake (*Elaphe obsoleta obsoleta*)	**eastern meadowlark** (*Sturnella magna*)	**prairie vole** (*Microtus ochrogaster*)
black-capped chickadee (*Poecile atricapillus*)	**great blue heron** (*Ardea herodias*)	**red-headed woodpecker** (*Melanerpes erythrocephalus*)
eastern box turtle (*Terrapene carolina carolina*)	**horned lark** (*Eremophila alpestris*)	**red-tailed hawk** (*Buteo jamaicensis*)
eastern kingbird (*Tyrannus tyrannus*)	**prairie king snake** (*Lampropeltis calligaster calligaster*)	**tufted titmouse** (*Baeolophus bicolor*)
Extirpated or imperiled wildlife		
American bison (*Bison bison*)	**Blanding's turtle** (*Emys blandingii*)	**Franklin's ground-squirrel** (*Poliocitellus franklinii*)

[(a)] The eastern massasauga is a candidate for listing under the Endangered Species Act of 1973, as amended (ESA). It and other Federally listed species are discussed in Section 3.8.

[(b)] The Indiana bat is Federally listed as endangered under the ESA. While the Indiana bat occurs within the Illinois and Indiana Prairies Level IV Ecoregion, the FWS (2014b) indicates that it does not occur in Will County.

Sources: CEC 1997; IDNR 2005; Wiken et al. 2011

3.6.2 Summary of Past Braidwood Site Surveys and Reports

Commonwealth Edison Company, the company that constructed and first operated Braidwood, conducted baseline preconstruction surveys of the terrestrial vegetation and wildlife in autumn of 1972 and continued these surveys seasonally through the winter, spring, and summer of 1973. The results of these surveys were recorded in the ER for Braidwood construction (ComEd 1973b). ComEd conducted follow-up surveys from 1974 through 1975, the results of which appeared in the ER for Braidwood operation (ComEd 1985). In September 2005, a Wildlife Habitat Council (WHC) biologist conducted a 1-day site assessment that included a species inventory of plants, mammals, birds, insects, and fish as part of Exelon's application for

a Wildlife at Work Certification (Exelon 2013j). The site assessment is included in Exelon's 2013 Wildlife Management Plan for Braidwood (Exelon 2013f). These surveys, as well as the Final Environmental Statement for Braidwood Construction (FES-C) (AEC 1974) and the ER for license renewal (Exelon 2013g) inform the description of the terrestrial resources on the Braidwood site in the following sections.

3.6.3 Braidwood Site

The Braidwood site encompasses 4,457 ac (1,804 ha) in Will County, Illinois (Exelon 2013g). The majority of the site consists of the cooling lake and plant buildings and infrastructure. Small forested tracts of land occur east and west of the developed portion of the site, and several large islands occur within the cooling pond (Exelon 2013g). The Braidwood site was highly disturbed prior to construction and operation of the site, and the majority of natural areas were previously coal strip-mine spoils or cultivated fields. Strip mining within the boundaries of the Braidwood site began in the early 1940s, and the U.S. Forest Service (USFS) undertook reclamation of the site beginning in the late 1940s and continuing through the early 1960s as part of a statewide program to address strip-mine spoils (ComEd 1973b). Following the passage of reclamation laws in the State of Illinois, Peabody Coal Company began systematic plantings on the site in the 1960s through early 1970s. The company topped and seeded spoil ridges with grasses and forbs. American sycamore (*Platanus occidentalis*), eastern red cedar (*Juniperus virginiana*), and eastern cottonwood (*Hibiscus tiliaceus*) trees were hand-planted, but mortality of these species was high. Black locust (*Robinia pseudoacacia*), autumn olive (*Elaeagnus umbellata*), Russian olive (*E. angustifolia*), and various pines (*Pinus* spp.) were later planted with higher success rates (ComEd 1973b). The natural vegetative communities for the Braidwood site are tallgrass prairie and deciduous forest characterized by sassafras (*Sassafras albidum*), white oak (*Quercus alba*), red oak (*Q. rubra*), black oak (*Q. velutina*), and Hortulan plum (*Prunus hortulana*) (ComEd 1973b, 1985). The Braidwood site was highly disturbed prior to Braidwood construction and operation. For this reason, the preoperational surveys determined that no such communities existed on the site (ComEd 1973b, 1985).

The Braidwood site currently includes 264 ac (107 ha) of land developed for industrial use and 1,653 ac (699 ha) of natural areas (Exelon 2014f). Exelon (2014f) leases 67 ac (27 ha) of natural areas to private individuals for agricultural use and 1,280 ac (518 ha) to the IDNR for recreational use. The cooling pond occupies the remaining 2,540 ac (1,028 ha) of the site. Section 3.2 describes the current land uses on the Braidwood site in more detail.

Exelon maintains a WHC-certified Wildlife Management Plan (Exelon 2013f) for the Braidwood site. The plan outlines the goals and projects of Exelon's Wildlife at Work program, which includes ecological management of the cooling pond (referred to as "Braidwood Lake" in the plan) through fish population management, underwater habitat restoration, and shoreline habitat restoration. Exelon's shoreline habitat restoration efforts have included water willow (*Justicia americana*) plantings in 2008, and the plan indicates that Exelon will consider planting other native shoreline plants, in consultation with IDNR, in the future (Exelon 2013f). Exelon will also evaluate the potential for controlling and removing some of the non-native invasive common reed (*Phragmites australis*) with mechanical methods and aquatic-safe herbicides. Non-native species are not currently being controlled (Exelon 2013f). Exelon first received WHC certification for its plan in 2005 (Exelon 2014h), and the WHC most recently renewed Exelon's certification in October 2013 (WHC 2013). WHC certification lasts for two-year periods. Exelon intends to seek WHC recertification and continue to implement wildlife protection programs during the proposed license renewal term (Exelon 2014h).

3.6.3.1 Vegetation

Cultivated Fields. At the time of Braidwood construction, approximately 1,021 ac (413 ha) of the site was cultivated for soybeans (*Glycine max*), wheat (*Triticum* spp.), and alfalfa (*Medicago sativa*) on a rotating basis (ComEd 1973b). ComEd (1973b, 1985) reported that weeds such as black nightshade (*Solanum americanum*), common thistle (*Cirsium* spp.), asters (*Aster* spp.), and ivy-leafed morning glory (*Ipomoea hederacea*) were also present in these areas. Today, Exelon continues to lease 67 ac (27 ha) of the Braidwood site for agricultural use (Exelon 2014f).

Fallow Fields and Grasslands. ComEd (1973b) reports that approximately 471 ac (191 ha) of fallow fields occurred in the western portion of the site. Prior to ComEd's purchase of the site, these fields had likely been cultivated for wheat. During baseline terrestrial surveys, these fields were composed of various annual and herbaceous perennials with localized stands of alfalfa, frostweed (*Aster pilosus*), late boneset (*Eupatorium serotinum*), and common ragweed (*Ambrosia artemisiifolia*). Exelon (2014f) indicates that 306 ac (124 ha) of forest, old fields, or early successional grasslands remain on the site today, but the specific acreage of remaining fields and grasslands is unavailable.

Woodlands. During baseline surveys, approximately 395 ac (160 ha) of the Braidwood site consisted of open woodlands. ComEd (1973b) indicates that these woodlands occupied thin strips between cultivated fields in the northwest corner of the site. Red and white oak dominated the overstory vegetation, and the understory included sassafras, prairie willow (*Salix humilis*), and hazelnut (*Corylus americana*). Cinnamon ferns (*Osmundastrum cinnamomeum*) were present in localized stands. The average canopy height was 35 to 40 ft (11 to 12 m) and ground cover was between 60 to 75 percent. Other areas of the site supported small communities of red oak, eastern cottonwood, osage orange (*Maclura pomifera*), silver maple (*Acer saccharinum*), and sugar maple. Lombardy poplar (*Populus italica*) had also been planted as windbreaks in certain areas. Exelon (2014f) indicates that 306 ac (124 ha) of forest, old fields, or early successional grasslands remain on the site today, but the specific acreage of remaining forest is unavailable.

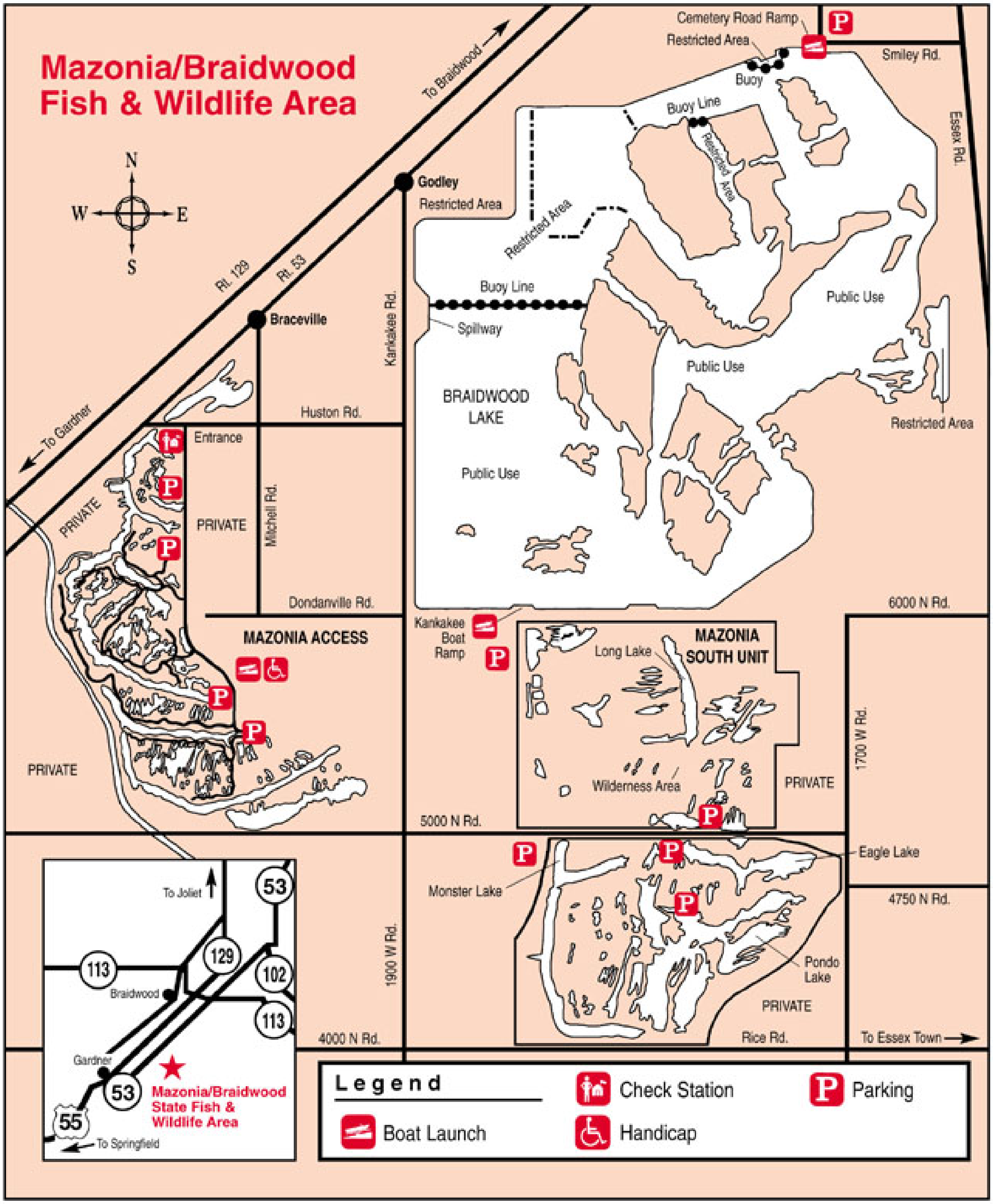
The woodland species recorded by the WHC during the 2005 site assessment varied somewhat from those species reported during baseline surveys. Silver maple, eastern cottonwood, willow, oak species, and raspberry were reported in both preoperational surveys and in the 2005 inventory. The 2005 inventory also reported the following additional species in wooded areas: chicory (*Cichorium intybus*), eastern red cedar, and burr oak (*Quercus macrocarpa*). Because the methodology for the 2005 species inventory is unknown, it is unclear whether additional forest species reported in the baseline surveys no longer occur on the site or whether they were simply not observed or reported in 2005.

Strip-Mine Spoils. Approximately 2,433 ac (985 ha) of the site consisted of strip-mine spoils during preoperational terrestrial surveys (ComEd 1973b). These areas were characterized by long ridges separated by deep gullies that contained intermittent ponds. The majority (80 percent) of the strip-mine spoils were bare prior to Braidwood construction, and vegetation on ridge tops was dominated by those species planted during reclamation. Naturally occurring forbs included Russian thistle (*Salsola pestifer*), sweet clover (*Melilotis officinalis*), and goosefoot (*Chenopodium berlandieri*), and the most commonly occurring grasses were bromegrass (*Bromus inermis*) and foxtail (*Setaria faberii*). Marshy, sloped areas were dominated by broad-leaved cattail (*Typha latifolia*) and black willow (*Salix nigra*), and drainages supported threeawn grass (*Aristida* spp.), spike-rush (*Eleocharis ovate*), great bulrush (*Scirpus acutus*), and pondweed (*Potamogeton natans*). Those areas that had been mined earliest (in the 1940s) supported a more diverse community of black willow, black locust, quaking aspen

(*Populus tremuloide*), and understory species including poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), frost grape (*Vitis vulpina*), sweet clover, and black raspberry (*Rubus occidentalis*).

During Braidwood construction, the strip-mine spoils were flooded to create the cooling pond. The cooling pond includes large islands with trees and shrubs, which represent the remaining former strip-mine terrestrial habitat. Figure 3–14 is a map of the Mazonia–Braidwood State Fish and Wildlife Area, which depicts the network of islands within the cooling pond (labeled "Braidwood Lake" in the figure).

Figure 3–14. Mazonia–Braidwood Fish and Wildlife Area



Source: IDNR 2014d

3.6.3.2 Animals

Mammals. The baseline surveys documented mammals on the site based on observations of tracks, droppings, or individuals during the autumn of 1972 and 1973. ComEd (1973b, 1985) reported 24 species of mammals as occurring on the Braidwood site. White-tailed deer (*Odocoileus virginianus*), cottontail rabbit (*Sylvilagus floridanus*), red (*Vulpes vulpes*) and gray (*Urocyon cinereoargenteus*) foxes, deer mice (*Peromyscus maniculatus*), and North American voles (*Scalopus aquaticus*) were observed in most site habitats. ComEd (1985) noted that strip-mine spoils, though sparsely vegetated, supported a diversity of mammals typical of marshes, ponds, or other semi-aquatic habitats, such as muskrat (*Ondatra zibethica*), beaver (*Castor canadensis*), and otter (*Lutra canadensis*).

The 2005 WHC site assessment reported seven mammal species as occurring on the Braidwood site (Exelon 2013f): groundhog (*Marmota monax*), striped skunk (*Mephitis mephitis*), white-tailed deer, raccoon (*Procyon lotor*), eastern gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), and red fox. Six of these species were also reported in the baseline surveys, and one species (the eastern chipmunk) did not appear in baseline surveys. It is possible that the creation of the cooling pond, which flooded most of the strip-mine spoils, affected the diversity of mammals on the site. However, Exelon's Wildlife Management Plan (Exelon 2013j) does not specify the methodology of the 2005 site assessment, so a meaningful comparison between the baseline surveys and the 2005 data is not possible.

Birds. The baseline surveys documented birds on the site by visual observations and bird calls during four seasons in two survey years (1972-1973 and 1973-1974). A total of 91 migratory and resident species were identified. The greatest species diversity was found in woodlands (48 species), and fallow fields held the least diversity of birds (6 species). Several waterfowl—including mallard (*Anas platyrhynchos*), black duck (*A. rubripes*), blue-winged teal (*A. discors*), and wood duck (*Aix sponsa*)—and shorebird species—including green heron (*Butorides virescens*), sora rail (*Porzana carolina*), upland sandpiper (*Bartramia longicauda*), and least bittern (*Ixobrychus exilis*)—were observed in the ponds formed between strip-mine spoil ridges. Strip-mine spoils were inhabited by birds typical of open or edge habitats. Many species of migratory songbirds occurred on the site on spring and fall survey days including eastern bluebird (*Sialia sialis*), cedar waxwing (*Bombycilla cedrorum*), eastern meadowlark (*Sturnella magna*), American goldfinch (*Carduelis tristis*), indigo bunting (*Passerina cyanea*), black-capped chickadee (*Poecile atricapillus*), eight species of warblers, and nine species of sparrows. Year-long residents included bobwhite (*Colinus virginianus*), ring-necked pheasant (*Phasianus colchicus*), mourning dove (*Zenaida macroura*), horned lark (*Eremophila alpestris*), blue jay (*Cyanocitta cristata*), American crow (*Corvus brachyrhynchos*), field sparrow (*Spizella pusilla*), and song sparrow (*Melospiza melodia*). Birds of prey included the eastern screech owl (*Megascops asio*), osprey (*Pandion haliaetus*), and six species of hawks.

The 2005 WHC site assessment reported 27 bird species as occurring on the Braidwood site (Exelon 2013f). Eighteen of these species were also reported in the baseline surveys. Notable additions not reported in the baseline surveys include the bald eagle (*Haliaeetus leucocephalus*), American kestrel (*Falco sparverius*), and wild turkey (*Meleagris gallopavo*). As indicated previously, Exelon's Wildlife Management Plan (Exelon 2013j) does not specify the methodology of the 2005 site assessment, so a meaningful comparison between the baseline surveys and the 2005 data is not possible.

Amphibians and Reptiles. The baseline surveys documented amphibians and reptiles on the site during spring, summer, and fall of the two survey years (1972-1973 and 1973-1974). A total of 27 species were recorded on the site with the greatest diversity of species occurring in strip-mine spoil habitat (ComEd 1972, 1985). Cricket frogs (*Acris crepitans*) were the most

abundant species, and cricket frogs, chorus frogs (*Pseudacris* spp.), and American toads (*Bufo americanus*) were present at all sampling locations. Aquatic turtles—including the painted turtle (*Chrysemys picta marginataxbelli*), common snapping turtle (*Chleydra serpentina*), Blanding's turtle, and spiny softshell turtle (*Trionyx spiniferus*)—inhabited ponds between strip-mine spoil ridges. The ornate box turtle (*Terrapene ornate*), a terrestrial turtle, was also present. Observed snakes included the eastern garter (*Thamnophis sirtalis*), eastern hognose (*Heterodon platirhinos*), eastern yellow-bellied racer (*Coluber constrictor flaviventris*), northern water snake (*Nerodia sipedon*). Other species of note included the eastern tiger salamander (*Ambystoma tigrinum*), five-lined skink (*Eumeces fasciatus*), and six-lined race runner (*Cnemidophorus sexlineatus*).

The 2005 habitat assessment did not include amphibians or reptiles.

3.6.3.3 Important Species and Habitats

<u>Important Species</u>. The IDNR (2013b) identifies 58 State-listed terrestrial species (39 plants, 9 birds, 5 reptiles, 3 insects, 1 mammal, and 1 amphibian) as occurring in Will County. In March 2012, Exelon further refined this list of species when it generated an IDNR Ecological Compliance Assessment Tool (EcoCAT) report that included Illinois Natural Heritage Database information on species that could potentially be affected by the proposed license renewal. The EcoCAT reported is included in Appendix C of the ER (Exelon 2013g). The report indicates that four terrestrial State-listed species may occur on or near the Braidwood site: the ornate box turtle, Blanding's turtle (*Emys blandingii*), Oklahoma grass pink orchid (*Calopogon oklahomensis*), and pale-green orchid (*Platanthera flava* var. *herbiola*). Of these, ComEd (1973b, 1985) indicates that the ornate box turtle and Blanding's turtle were observed during baseline surveys of the Braidwood site. No State-listed species were identified in the 2005 habitat assessment. Federally protected species are discussed in Section 3.8.

The ornate box turtle is listed as threatened in Illinois (IDNR 2013b). It inhabits prairies and sandy, treeless grasslands, and open woodlands with loose soils suitable for burrowing (WGFD 2010). The Blanding's turtle is listed as endangered in Illinois (IDNR 2013b). It inhabits wetland complexes with rich aquatic vegetation and adjacent sandy uplands as well as ephemeral wetlands and backwater pools (MDNR 2014a). The Braidwood site may provide some marginal habitat for these two species, but it is unlikely to support large populations of either turtle because of the lack of optimal habitat.

The Oklahoma grass pink orchid is a State-endangered terrestrial orchid that inhabits a variety of habitats, including seasonally dry-mesic prairie, upland prairie, open woodlands, and bogs edges (IDNR 2013b). The U.S. Fish and Wildlife Service (FWS) indicates that in Illinois, 7 to 42 historic populations occurred in the state, of which, 1 to 2 still exist (76 FR 61307). One of these populations occurs in Braidwood Dunes and Savanna Nature Preserve, which lies approximately 2 mi (2.4 km) northeast of the Braidwood site. Illinois Nature Preserves are high-quality natural areas that provide permanent protection to habitats and native biota within the preserves. The FWS recognize Illinois Nature Preserves as providing appropriate protection for the continued existence of Oklahoma grass pink orchid (76 FR 61307).

The pale-green orchid is a State-threatened terrestrial orchid that inhabits wet woods and meadows with sandy soil and high leaf litter (IDNR 2013b; NatureServe 2014b). The IDNR (2014a) indicates that this species also occurs northeast of the Braidwood site in the Braidwood Dunes and Savanna Nature Preserve.

In addition to State-listed species, in a letter to NRC, the FWS (2013d) indicated that the bald eagle, which is Federally protected under the Bald and Golden Eagle Protection Act (BGEPA) and Migratory Bird Treaty Act (MBTA), has nested on one of the cooling pond islands in the

past. The BGEPA and MBTA provide certain protections to bald and golden (*Aquila chrysaetos*) eagles and migratory birds, respectively. The FWS Chicago Ecological Services Field Office provided technical assistance to Exelon to ensure that the eagles were protected and that Exelon appropriately complied with the BGEPA. In its ER, Exelon (2013g) indicated that bald eagles have not nested on the cooling pond in recent years.

<u>Important Habitats</u>. In its Illinois Natural Areas Inventory (INAI), the IDNR (2013a) identifies 38 Will County sites as Category I ("high quality natural community and natural community restorations"), Category II ('specific suitable habitat for state-listed species or state-listed species relocations"), Category III ("State-dedicated Nature Preserves, Land and Water Reserves, & Natural Heritage Landmarks"), or a combination of the three categories. The 2012 EcoCAT report (Appendix C in Exelon 2013g) indicates that two of these sites lie near the Braidwood site: Braidwood Dunes and Savanna Nature Preserve and Godley Railroad Prairie.

The Braidwood Dunes and Savanna Nature Preserve (INAI Site No. 0935) lies 2 mi (2.4 km) northeast of the Braidwood site. It is 314 ac (127 ha) in size and includes dry-mesic sand savanna remnant habitat with prairie, sedge meadow, and marsh habitats representative of the Kankakee Sand Area Section of the Grand Prairie Natural Division (IDNR 2014a). The IDNR (2013a) designates this INAI site as Category I, II, and III.

The Godley Railroad Prairie (INAI Site No. 0898) in Will County encompasses 235 ac (95 ha). The IDNR (2013a) designated this INAI as Category I.

The Mazonia-Braidwood State Fish and Wildlife Area, which Exelon and the IDNR jointly manage, includes the Braidwood cooling pond as well as IDNR-owned lands adjacent to the Braidwood site to the south and southwest of the cooling pond. In total, the wildlife area consists of 2,640 ac (1,068 ha) of land. The IDNR (2014d) manages the area to enhance habitat for sport fish, waterfowl, and State-listed threatened and endangered species.

3.7 Aquatic Resources

The aquatic communities of interest for the Braidwood site occur in the Kankakee River and in the site's artificial cooling pond. The Kankakee River lies 5 mi (8 km) east of the site. It supplies makeup water to Braidwood's cooling system and receives cooling system blowdown. The cooling pond is the site's main source of cooling water and ultimate heat sink. Section 3.1.3 describes the cooling system in detail, and Section 3.5.1 describes the surface water characteristics of Kankakee River and the cooling pond.

3.7.1 Aquatic Ecosystem Descriptions

3.7.1.1 Kankakee River

The Kankakee River is a tributary of the Illinois River. It flows southwest from its headwaters near South Bend, St. Joseph County, Indiana, and continues into Illinois through Kankakee and Will Counties to its confluence with the Des Plaines River near Channahon, Illinois. At this point, the Kankakee and Des Plains River together form the Illinois River. The total length of the Kankakee River is approximately 140 mi (225 km), of which 59 mi (95 km) is in Illinois (Pescitelli and Rung 2008). The river's width varies from 200 to 800 ft (60 to 240 m) with depths of up to 15 ft (6 m) (IDNR 1998).

The river's watershed drains a total of 2,989 mi^2 (4,810 km^2) in northwestern Indiana, 2,169 mi^2 (3,490 km^2) in northeast Illinois, and 7 mi^2 (11 km^2) in southwest Michigan (INDNR 1990). Major tributaries include the Iroquois River, Singleton Ditch, Trim Creek, Baker Creek/Exline Slough,

Rock Creek, Horse Creek, Forked Creek, and Prairie Creek. Agriculture accounts for 75 percent of land use in the watershed (Pescitelli and Rung 2008).

In Indiana, the Kankakee River was extensively channelized in the late 1800s and early 1900s. Within Illinois, the river remains largely unmodified with the exception of three dams: a small side channel dam at Momence in Kankakee County and a larger dam at the city of Kankakee—both of which are upstream of Braidwood—as well as an overflow dam at Wilmington downstream of Braidwood in Will County (Bhowmik and Demissie 2000). The river in the vicinity of Braidwood includes numerous riffles, small pools, and islands and the river bottom is composed of gravel, cobble, and sand (Pescitelli and Rung 2008).

The Kankakee River basin supports a large diversity of aquatic biota, including 84 species of fish, 37 mussels, 14 crustaceans, and a variety of aquatic macroinvertebrates. Common fish include the spotfin shiner (*Cyprinella spiloptera*), red shiner (*C. lutrensis*), rosyface shiner (*Notropis rubellus*), striped shiner (*Luxilus chrysocephalus*), sand shiner (*N. stramineus*), grass pickerel (*Esox americanus vermiculatus*), shorthead redhorse (*Moxostoma macrolepidotum*), smallmouth bass (*Micropterus dolomieu*), longear sunfish (*Lepomis megalotis*), and banded darter (*Etheostoma zonale*). Within Kankakee River tributaries, creek chub (*Semotilus* spp.), bluntnose minnow (*Pimephales notatus*), red shiner, rock bass (*Ambloplites rupestris*), and johnny darter (*Etheostoma nigrum*) are prevalent. The most common species of mussels are the mucket (*Actinonaias ligamentina*), pimpleback (*Quadrula pustulosa*), threeridge (*Amblema plicata*), fatmucket (*Lampsilis siliquoidea*), white heelsplitter (*Lasmigona complanata*), and plain pocketbook (*Lampsilis cardium*) (IDNR 1998).

The IEPA (2014b) has rated the Kankakee River in the vicinity of Braidwood as fully supporting aquatic life. The IDNR has designated the Kankakee River from Momence in Kankakee County to the Des Plains Wildlife Conservation Area in Will County as a Biologically Significant Stream because it supports one of the state's most diverse aquatic communities (Page et al. 1991). This designation includes the portion of the river affected by Braidwood operation. Silted pools separated by solid bedrock runs support several State-listed fish, including pallid shiner (*N. amnis*; State-endangered), weed shiner (*N. texanus*; State-endangered), western sand darter (*Ammocrypta clarum*; State-endangered), river redhorse (*Moxostoma carinatum*; State-threatened), and a diversity of mussels, including the Federally endangered sheepnose (*Plethobasus cyphyus*) (Page et al. 1991). The blacknose shiner (*N. heterolepis*) and the northern brook lamprey (*Ichthyomyzon fossor*), both of which are State-endangered, are thought to have been extirpated from the river (Page et al. 1991). Section 3.7.5 addresses State-listed species, and Section 3.8 discusses Federally listed species in detail.

3.7.1.2 Braidwood Cooling Pond

Braidwood's 2,540-ac (1,030-ha) cooling pond was created in 1980 and 1981 by pumping water from the Kankakee River into the site's former strip mine spoils. In the fall of 1981, the Illinois Department of Conservation (now the IDNR) entered into a long-term lease agreement with ComEd (the constructor and original operator of Braidwood) to allow general public access to the cooling pond for fishing, waterfowl hunting, and fossil collecting (IDNR 2014d). The leased portion of the cooling pond is part of the Mazonia–Braidwood State Fish and Wildlife Area, which also includes IDNR-owned lands adjacent to the Braidwood site to the south and southwest of the cooling pond. Exelon and the IDNR continue to jointly manage this area to enhance habitat for sport fish, waterfowl, and State-listed species (IDNR 2014d).

Since the beginning of the lease agreement, the IDNR has stocked the cooling pond with a variety of game species, including largemouth bass (*Micropterus salmoides*), smallmouth bass, blue catfish (*Ictalurus furcatus*), striped bass (*Morone saxatilis*), crappie (*Poxomis* spp.), walleye, and tiger muskellunge (*Esox masquinongy* × *lucius*). Because of the high water

temperatures experienced in the summer months, introductions of warm-water species, such as largemouth bass and blue catfish, have been more successful than introductions of cool-water species, such as walleye and tiger muskellunge (Exelon 2013e). High summer temperatures have also contributed to a number of fish kills in the cooling pond. Section 3.7.4 discusses these events.

3.7.2 Aquatic Surveys and Monitoring

3.7.2.1 Kankakee River

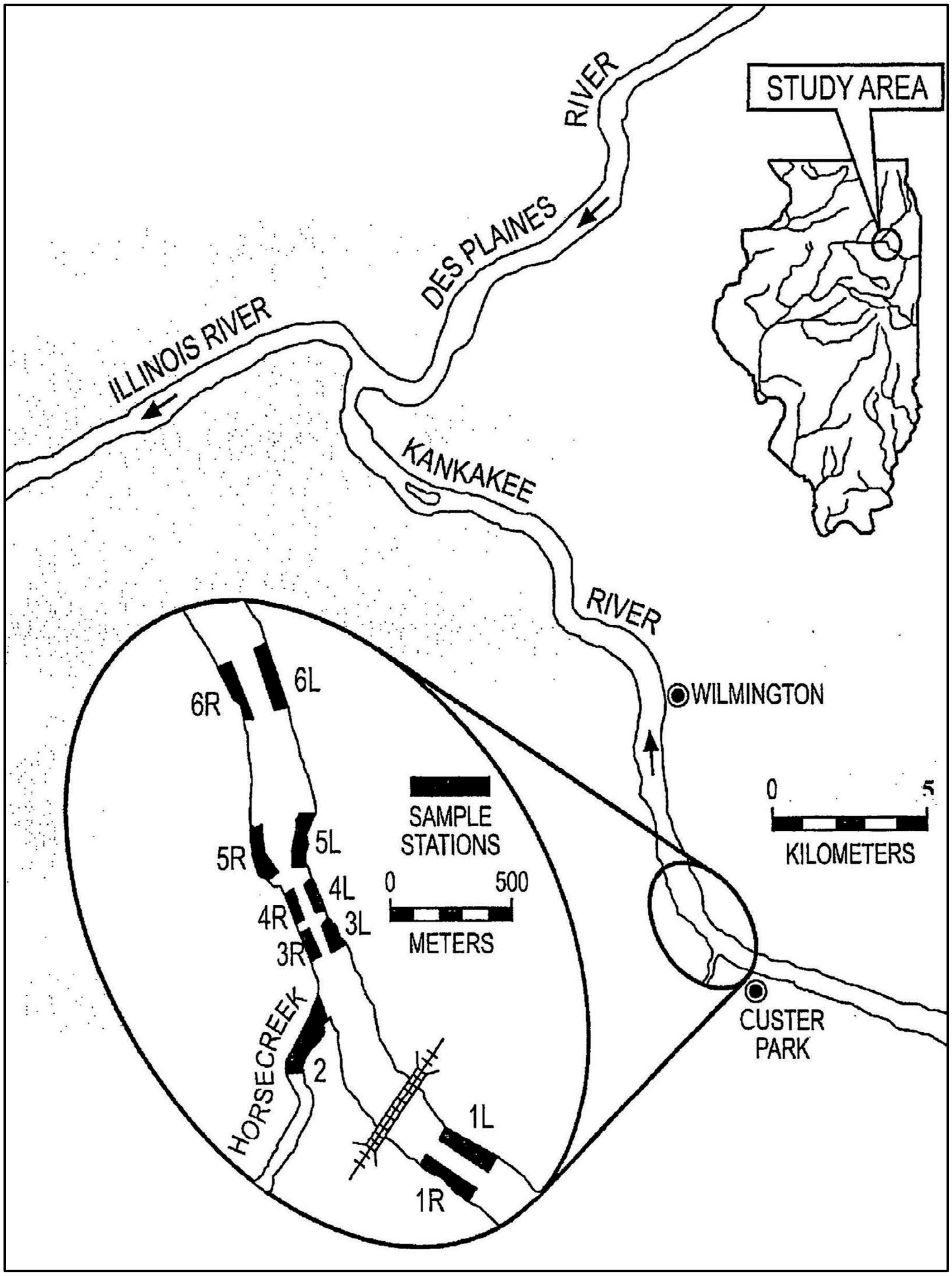
Preoperational monitoring of the Kankakee River aquatic resources began in 1972 when Westinghouse Electric Corporation initiated a monitoring program within a 2.5-km (1.5-mi) reach of the Kankakee River and its tributary, Horse Creek, approximately 23.5 km (14.6 mi) upstream from the confluence of the Kankakee and Des Plaines Rivers (HDR 2013b). Eleven sampling locations (listed in Table 3–8 lists and illustrated in Figure 3–15) were established as part of the program, and the same locations continue to be sampled today. Results of the first study, conducted from October 1972 through November 1973, as well as the projected impacts of construction on aquatic resources were described in ComEd's 1973 ER (ComEd 1973a) and the U.S. Atomic Energy Commission's 1974 FES-C (AEC 1974). Three additional sampling periods (1974-1975, 1977-1979, and 1981-1982), as well as the projected impacts of operation, were addressed in ComEd's 1983 ER and the NRC's 1984 Final Environmental Statement for Braidwood operation (FES-O) (NRC 1984).

Table 3–8. Braidwood Aquatic Survey Sampling Locations

Sampling Location(s)	Description	Representative Conditions
1L, 1R	South/left (L) and north/right (R) banks of the Kankakee River 1 km (0.6 mi) upstream of the makeup water intake point	Representative of upstream areas uninfluenced by Braidwood operations
2	In Horse Creek 150 m (500 ft) upstream from its confluence with the Kankakee River	Representative of a potential fish spawning area for the Kankakee River
3L, 3R	Left and right banks of the Kankakee River in the area of Braidwood's makeup water intake point at the river screen house	Representative of areas that may be affected by withdrawal of makeup water
4L, 4R	Left and right banks of the Kankakee River in the area of Braidwood's discharge point	Representative of areas that may be affected by thermal and chemical attributes of blowdown
5L, 5R	Left and right banks of the Kankakee River 300 m (1000 ft) downstream of the discharge point	Representative of nearfield recovery from any impacts associated with blowdown
6L, 6R	Left and right banks of the Kankakee River 1.6 km (1.0 mi) downstream of the discharge point	Representative of farfield recovery from any impacts associated with blowdown

Source: HDR 2009

Figure 3–15. Kankakee River Fish Sampling Locations



Source: HDR 2014

Beginning in 1977, the Illinois Natural History Survey (INHS) conducted annual fish sampling of the Braidwood Station Aquatic Monitoring Area. INHS continued surveys through 1990. Since 1991, various private companies have performed the sampling; most recently HDR Engineering, Inc. (HDR), has conducted annual sampling since 2005. The description of Kankakee River aquatic communities in Section 3.7.3 relies on available sampling program data (HDR 2009, 2011b, 2013b; Larimore and Peterson 1989).

In 2008, Exelon commissioned two studies (ESI 2009; HDR 2008) to determine the presence of State-listed fish and mussel species near the Braidwood makeup water discharge channel on the Kankakee River. These studies supported Exelon's assessment of potential impacts to aquatic biota that could result from replacing the discharge channel with a multi-port discharge diffuser, a project that was later completed in 2010. The studies are considered in the description of Kankakee River aquatic communities in Sections 3.7.3 and the discussion of important species and habitats in Section 3.7.5.

In support of the LRA, Exelon commissioned EA Engineering, Science, and Technology, Inc. (EA Engineering 2012), to perform benthic macroinvertebrate sampling in the Kankakee River at locations upstream and downstream of Braidwood. EA Engineering conducted the sampling in 2011, and it included artificial substrate samplers, grab samples, and kick net samples along several river transects. Also in support of the LRA, HDR (2014) compiled aquatic monitoring data for the period 1991 through 2013. Section 3.7.3 discusses the results of these studies.

A number of impingement and entrainment studies have been conducted to determine the impacts of Braidwood's cooling system on Kankakee River aquatic organisms. Several preoperational studies are described in the FES-O (NRC 1984). Operational studies include a 1988-1989 impingement and entrainment study (EA Engineering 1990) and a 1991 impingement study (summarized in EA Engineering 2012). Exelon also commissioned EA Engineering (2012) to perform historical fish and benthos comparisons that consider impingement and entrainment to support preparation of the LRA. These studies are discussed in the NRC's assessment of impacts to aquatic resources in Section 4.7.

3.7.2.2 Braidwood Cooling Pond

The IDNR has conducted fish surveys of the cooling pond since 1980 when the cooling lake was first impounded with Kankakee River water. The IDNR continued to conduct surveys annually from 1980 through 1992, in 1994, and every other year from 1997 through 2007. HDR (2010) summarizes the results of these surveys.

Beginning in 2009, Exelon commissioned HDR (2010, 2011a, 2012, 2013a) to begin sampling the cooling pond and to create a set of procedures that could predict conditions that would create a high likelihood for fish kill events following several events between 2001 and 2007 (discussed in detail in Section 3.7.4). HDR continues these surveys today.

These studies inform the description of the cooling pond's aquatic communities in Section 3.7.3.

3.7.3 Aquatic Communities near Braidwood

3.7.3.1 Kankakee River

<u>Phytoplankton</u>. Phytoplankton are microscopic floating photosynthetic organisms that form one base of aquatic food webs by producing biomass from inorganic compounds. As primary producers, phytoplankton play key ecosystem roles in the distribution, transfer, and recycling of nutrients and minerals.

Kankakee River phytoplankton community characteristics were assessed during 1972-1973 preoperational surveys and summarized in the FES-C (AEC 1974). Phytoplankton was again assessed during three additional preoperational sampling periods (1974-1975, 1977-1979, and 1981-1982) and summarized in the FES-O (NRC 1984). During 1972-1973, 1-liter dip samples were taken biweekly in October and November 1972 and monthly from December 1972 through September 1973. Samples were collected at mid-stream along the transects listed in Table 3–8 (ComEd 1973a). Diatoms were the most abundant phytoplankton, particularly from December through April (AEC 1974). Other phytoplankton present included blue-green algae, which was

most abundant in early October; green algae, which was most prevalent in late October and November; and flagellates (Euglenophyta), which were most prevalent in February. The FES-C concluded that the Kankakee River phytoplankton community in the vicinity of Braidwood is characteristic of temperate zone rivers. The FES-O (NRC 1984) notes that during the 1974-1975 monitoring period, samples yielded five phyla and 200 species of phytoplankton. Most species belonged to the phyla Bacillariophyta (diatoms) or Chlorophyta (green algae). Diatoms again dominated the phytoplankton community in both Kankakee River and Horse Creek samples. The NRC staff is not aware of any additional phytoplankton surveys that may have been conducted in the vicinity of Braidwood since the plant began operating in 1988.

Periphyton. Periphyton includes a mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that attach to submerged surfaces. Like phytoplankton, periphyton are primary producers and provide a source of nutrients to many bottom-feeding organisms.

The river's periphyton community was assessed during 1972-1973 preoperational surveys and summarized in the FES-C (AEC 1974). Artificial substrate diatometer and drain tile samples were collected in eight months in 1972 and 1973 along the transects listed in Table 3–8 approximately 20 ft (6 m) from either shore (ComEd 1973a). The FES-C provides little information on periphyton beyond stating that diatoms were more numerous than either green or blue-green algae. The FES-C also notes that several species that are tolerant of organic enrichment, including the diatoms *Gomphonema olivaceum*, *Navicula crytocella*, *Nitzschia filiformis*, and *Nitzschia palea*, were present. Additional periphyton monitoring was conducted in 1974-1975, 1977-1979, and 1981-1982. The FES-O (NRC 1984) notes that diatoms dominated each of these sample periods and that over 400 diatom species were identified across the 11 sample sites. The NRC staff is not aware of any additional periphyton surveys that may have been conducted in the vicinity of Braidwood since the plant began operating in 1988.

Zooplankton. Zooplankton are small animals that float, drift, or weakly swim in the water column and include ichthyoplankton (fish eggs and larvae) with no or limited swimming ability and larvae of benthic invertebrates. Zooplankton are important trophic links between primary producers (e.g., phytoplankton and periphyton) and carnivores (e.g., fish).

Kankakee River zooplankton community characteristics were assessed during 1972-1973 preoperational surveys and summarized in the FES-C (AEC 1974). Samples were collected biweekly in October and November 1972 and monthly from December 1972 through September 1973 via metered surface tows with 202-micron (μ) mesh plankton nets at mid-stream along the transects listed in Table 3–8 (ComEd 1973a). Species diversity and abundance was greatest in the spring when over 125 species were identified (AEC 1974). Glochidia (freshwater mussel larvae), crustaceans in the family Cyclopidae and the order Ostracoda were most abundant in spring samples, while the mayfly *Stenonema* was most abundance in fall samples (AEC 1974). The FES-O (NRC 1984) does not provide any additional information on the results of subsequent periods of zooplankton monitoring.

The NRC staff is not aware of any additional zooplankton surveys that may have been conducted in the vicinity of Braidwood since the plant began operating in 1988.

Benthic Macroinvertebrates. Benthic macroinvertebrates include aquatic annelids (aquatic worms, flatworms, and leeches), mollusks, crustaceans, and insect larvae that inhabit aquatic sediments. They accelerate detrital decomposition and nutrient cycling, and serve as a food source for fish and other aquatic biota.

During the preoperational monitoring period, the INHS collected seasonal Hester-Dendy (HD) and Ponar grab or kick net samples of benthic macroinvertebrates from the Kankakee River in 1979. The samples were collected at eight river locations (1L, 1R, 4L, 4R, 5L, 5R, 6L, and 6R;

see Table 3–8) in June, August, September (HD samples) and May, August, and November (grab and kick net samples). The August collections, which incorporated all gear types, yielded 82 taxa, of which 29 were larvae of mayflies (order Ephemeroptera), stoneflies (order Plecoptera), or caddisflies (order Trichoptera). Dominant taxa included caddisflies (*Cheumatopsyche* spp., *Hydropsyche phalerata, Maccaffertium integrum*); mayflies in the genera *Hexagenia*, *Isonychia*, *Stenacron*, and *Tricorythodes*; midges in the genera *Polypedilum* and *Tanytarsus*; and oligochaete worms (family Naididae). Species richness and density was greatest near the Braidwood discharge point (location 4R) in HD samples and downstream of the discharge point (location 5L) in grab samples. (EA Engineering 2012)

In 2011, EA Engineering (2012) conducted benthic macroinvertebrate sampling at five river locations (1L, 4L, 4R 5L, and 5R; See Table 3–8). HD samples were collected at four locations (all but 5L) and Ponar grab or kick net samples were taken at all five locations. The sampling yielded a total of 72 taxa, of which 24 were midges (family Chironomidae), 15 were mayflies (order Ephemeroptera), and 6 were mollusks (class Bivalvia). Eleven taxa of Ephemeroptera, Plecoptera, and Trichoptera (EPT) were identified. In HD samples, taxa richness was highest at locations 1L and 4R (30 taxa), followed by location 5R (27 taxa), and location 4L (20 taxa). Density was highest at location 4R and lowest at location 5R. Dominant taxa included mayflies (*Baetis intercalaris*, *Caenis* spp., *Stenacron* spp., and *Tricorythodes* spp.), midges (*Dicrotendipes neomodestus*, *Chironomus* spp., and *Glyptotendipes* spp.), flatworms (class Turbellaria), oligochaete worms (family Naididae), the amphipod crustacean *Hyalella azteca*, and freshwater snails in the genus *Pleurocera*.

EA Engineering (2012) concluded that the benthic community had remained similar in the 32 years between the 1979 and 2011 samples. Species richness and density was similar for individual locations across the two sample years, and in both years, taxa that tend to be less tolerant of environmental stressors were generally more abundant at upstream locations, while tolerant species were more abundant downstream. Both surveys attributed these longitudinal differences to differences in substrate composition at upstream and downstream locations.

The largest difference between the two studies appears to be the EPT richness. EPT taxa are generally considered to be intolerant of environmental stress. Thus, a relatively high EPT richness typically represents a high quality benthic community. In 1979, 29 EPT taxa were collected, while in 2011, only 11 EPT taxa were collected. The change in EPT richness appears to contradict EA Engineering's (2012) conclusions because it signals a possible degradation in water quality. Section 3.5.1 addresses surface water quality.

<u>Fish</u>. Preoperational fish monitoring began in 1972. However, the only available information is on the 1974-1975 and 1981-1982 sample years. The FES-O (NRC 1984) indicates that during this period, 38 species of fish were collected from the Kankakee River, and 46 species were collected from both the Kankakee River and Horse Creek at the 11 sampling survey locations listed in Table 3–8. Gear types included electrofishing, seining, baited hoop netting, and gill netting (ComEd 1973a). The majority of the fish belonged to the families Cyprinidae (minnows, shiners, and carp), Centrarchidae (sunfish), and Catostomidae (suckers), which accounted for 33, 24, and 14 percent of the total number of species collected, respectively (NRC 1984). Other families present included Aphredoderidae (pirate perch), Atherinidae (silversides), Clupeidae (herring), Esocidae (pike), Ictaluridae (catfish), Lepisosteidae (gar), Percidae (perch), and Salmonidae (trout). Within Kankakee River sample sites, the most abundant species (accounting for 5 percent or more of the total collection) were bluegill (*Lepomis macrochirus*), rock bass, mimic shiner (*Notropis volucellus*), spotfin shiner, shorthead redhorse, white crappie (*Pomoxis annularis*), and spottail shiner (*Notropis hudsonius*). Several years later in 1981 to 1982, 51 taxa were collected. Cyprinids (33.1 percent), catostomids (26.2 percent), and

centrarchids (21.1 percent) continued to dominate samples. Table 3–9 lists the number of individuals collected and relative abundance in 1981-1982 by family and species.

Kankakee River fish surveys have continued since Braidwood began operating, as described in Section 3.7.2.1. Exelon's current Kankakee River sampling program includes electrofishing and seine samples from the 11 locations identified in Table 3–8 during the first and third weeks of August of each year. Electrofishing is conducted with a boat-mounted, boom-type electrofisher. River locations 1, 5, and 6 are sampled for 30 minutes over a distance of 500 ft (150 m), which represents one unit effort, and locations 3 and 4 are sampled for 15 minutes over 250 ft (75 m). Location 2 (Horse Creek) is electrofished from the stream mouth to a point 1,000 ft (300 m) upstream for 30 minutes. Shoreline seining is performed with 25 ft x 4 ft (7.6 m x 1.2 m) nets with 3/16-in. (4.8-mm) mesh and a 4-ft x 4-ft (1.2-m x 1.2-m) bag of 3/16-in. (4.8-mm) mesh. Two seine hauls are made at each location during each sampling effort. Collections are taken across 15 m (50 ft) of shoreline in a downstream direction, and the second haul is taken upstream of the first (HDR 2009).

Since 1977, 84 species in 19 families have been collected from the Kankakee River and Horse Creek (HDR 2013b). In the past 5 data years (2009 through 2013), HDR (2014) has collected 69 species of fish in 15 families. The most commonly collected species during this period (both sampling gear types, all sampling locations) were spotfin shiner (37.1 percent), longear sunfish (28.5 percent), bullhead minnow (*Pimephales vigilax*; 21.7 percent), bluntnose minnow (16.5 percent), sand shiner (13.6 percent), and largemouth bass (6.9 percent). Two State-listed species were collected during electrofishing samples: two pallid shiner (State-endangered) in 2011 and one river redhorse (State-threatened) in 2009. Table 3–10 lists the number and relative abundance of individuals collected by gear type, family, and species from 2009 through 2013.

Common carp (*Cyprinus carpio*) have consistently dominated sample biomass since 1993 in all but three years. Other significant biomass contributors include gizzard shad (*Dorosoma cepedianum*), channel catfish (*Ictalurus punctatus*), smallmouth bass, redhorse spp., carpsucker spp. (*Carpiodes* spp.), buffalo spp. (*Ictiobus* spp.), and longear sunfish.

Several species have become more abundant in recent years. HDR (2013b) indicates that largemouth bass, blackstripe topminnow (*Fundulus notatus*), brook silverside (*Labidesthes sicculus*), bluegill, and walleye have consistently increased in sample abundance. The appearance of an increasing number of walleye is likely due to IDNR's recent stocking efforts in the Kankakee River (HDR 2013b). Walleye steadily increased in numbers over the 2009-2013 period from 8 individuals (0.5 percent of individuals collected) in 2009 to 50 individuals (2.2 percent) in 2013.

Historically, the Kankakee River aquatic community in the vicinity of Braidwood was dominated by insectivores and piscivores of intermediate pollution tolerance (as defined in Barbour et al. (1999)). In recent years, insectivores and omnivores of intermediate to high pollution tolerance have dominated the community. Rock bass and white crappie, which were prevalent piscivores in preoperational monitoring sampling, only accounted for 1.8 and 0.3 percent of individuals collected from 2009-2013, while bluntnose minnow and bullhead minnow, both omnivores, have accounted for a combined 23.2 percent of collected individuals in recent years (2009-2013). The increased prevalence of bluntnose minnow and spotfin shiner accounts for the majority of the shift to more pollution-tolerant species. The mimic shiner and rosyface shiner, which are pollution intolerant, were prevalent in preoperational studies, but have only accounted for 0.1 and 0.7 percent of the total catch from 2009-2013.

Table 3–9. Fish Collected in the Kankakee River and Horse Creek by Family and Species, 1981–1982

Family and Species[(a)]	Common Name	Number of Individuals Collected	Relative Abundance (%)
Cyprinidae		**355**	**33.1**
Cyprinella spiloptera	spotfin shiner	41	3.8
Cyprinus carpio	common carp	49	4.6
Luxilus chrysocephalus	striped shiner	83	7.7
Moxostoma spp.	redhorse spp.	2	0.2
Notemigonus crysoleucas	golden shiner	6	0.6
Notropis spp.	minnow spp.	2	0.2
Notropis amnis	pallid shiner	2	0.2
Notropis buccatus	silverjaw minnow	1	0.1
Notropis rubellus	rosyface shiner	70	6.5
Notropis stramineus	sand shiner	21	2.0
Notropis volucellus	mimic shiner	4	0.4
Phenacobius mirabilis	suckermouth minnow	12	1.1
Pimephales notatus	bluntnose minnow	47	4.4
Pimephales vigilax	bullhead minnow	14	1.3
Semotilus atromaculatus	creek chub	1	0.1
Catostomidae		**281**	**26.2**
Ambloplites rupestris	rock bass	43	4.0
Carpiodes cyprinus	quillback	43	4.0
Esox lucius	northern pike	10	0.9
Hypentelium nigricans	northern hogsucker	18	1.7
Ictiobus cyprinellus	bigmouth buffalo	2	0.2
Moxostoma anisurum	silver redhorse	46	4.3
Moxostoma duquesnei	black redhorse	3	0.3
Moxostoma erythrurum	golden redhorse	83	7.7
Moxostoma macrolepidotum	shorthead redhorse	22	2.1
Moxostoma carinatum	river redhorse	10	0.9
Noturus flavus	stonecat	1	0.1
Centrarchidae		**226**	**21.1**
Lepomis cyanellus	green sunfish	75	7.0
Lepomis cyanellus × macrochirus	green sunfish × bluegill hybrid	3	0.3
Lepomis humilis	orangespotted sunfish	19	1.8
Lepomis hybrid	sunfish hybrid	1	0.1
Lepomis macrochirus	bluegill	10	0.9
Lepomis megalotis	longear sunfish	50	4.7
Lepomis spp.	sunfish spp.	13	1.2
Lythrurus umbratilis	redfin shiner	8	0.7
Micropterus salmoides	largemouth bass	26	2.4
Pomoxis annularis	white crappie	11	1.0
Pomoxis nigromaculatus	black crappie	10	0.9

Family and Species[a]	Common Name	Number of Individuals Collected	Relative Abundance (%)
Percidae		**126**	**11.8**
Etheostoma nigrum	johnny darter	20	1.9
Micropterus dolomieu	smallmouth bass	100	9.3
Percina maculata	blackside darter	5	0.5
Sander vitreum	walleye	1	0.1
Clupeidae		**66**	**6.2**
Dorosoma cepedianum	gizzard shad	66	6.2
Moronidae		**9**	**0.8**
Ameiurus natalis	yellow bullhead	1	0.1
Catostomus commersoni	white sucker	8	0.7
Amiidae		**2**	**0.2**
Amia calva	bowfin	2	0.2
Ictaluridae		**2**	**0.2**
Campostoma anomalum	stoneroller	1	0.1
Ictalurus punctatus	channel catfish	1	0.1
Lepisosteidae		**2**	**0.2**
Lepisosteus osseus	longnose gar	2	0.2
Esocidae		**1**	**0.1**
Esox americanus	grass pickerel	1	0.1
Fundulidae		**1**	**0.1**
Fundulus notatus	blackstripe topminnow	1	0.1
Umbridae		**1**	**0.1**
Umbra limi	central mudminnow	1	0.1

[a] Families ordered by decreasing relative abundance, and species within each family ordered alphabetically.

Source: NRC 1984

Another major change in the aquatic community is the significant shift in species distribution towards cyprinids. Cyprinids accounted for 33.1 percent of total collected individuals in 1982, while they accounted for an average of 57.2 percent of fish collected over the 2009-2013 period. Centrarchid abundance has increased slightly from 21.1 percent to 28.8 percent between 1982 and 2009-2013. Catostomids, which accounted for 26.2 percent of the total catch in 1982, have only comprised an average of 5.0 percent in recent years. Percids have also decreased in relative abundance (see Figure 3–16).

Species composition has also changed. Three families have appeared in recent years that were not present in preoperational sampling: Scianidae (freshwater drum) began appearing in monitoring samples in the early 1990s and Poeciliidae (mosquitofish) and Petromyzontidae (lamprey) began appearing in samples in 2008 and 2010, respectively (HDR 2014). One family (Amiidae or bowfin) has not appeared in samples since Braidwood began operating, and another family (Umbridae or mudminnows) has not appeared in samples since 2001.

Table 3–10. Fish Collected in the Kankakee River Monitoring Samples by Family and Species, 2009–2013

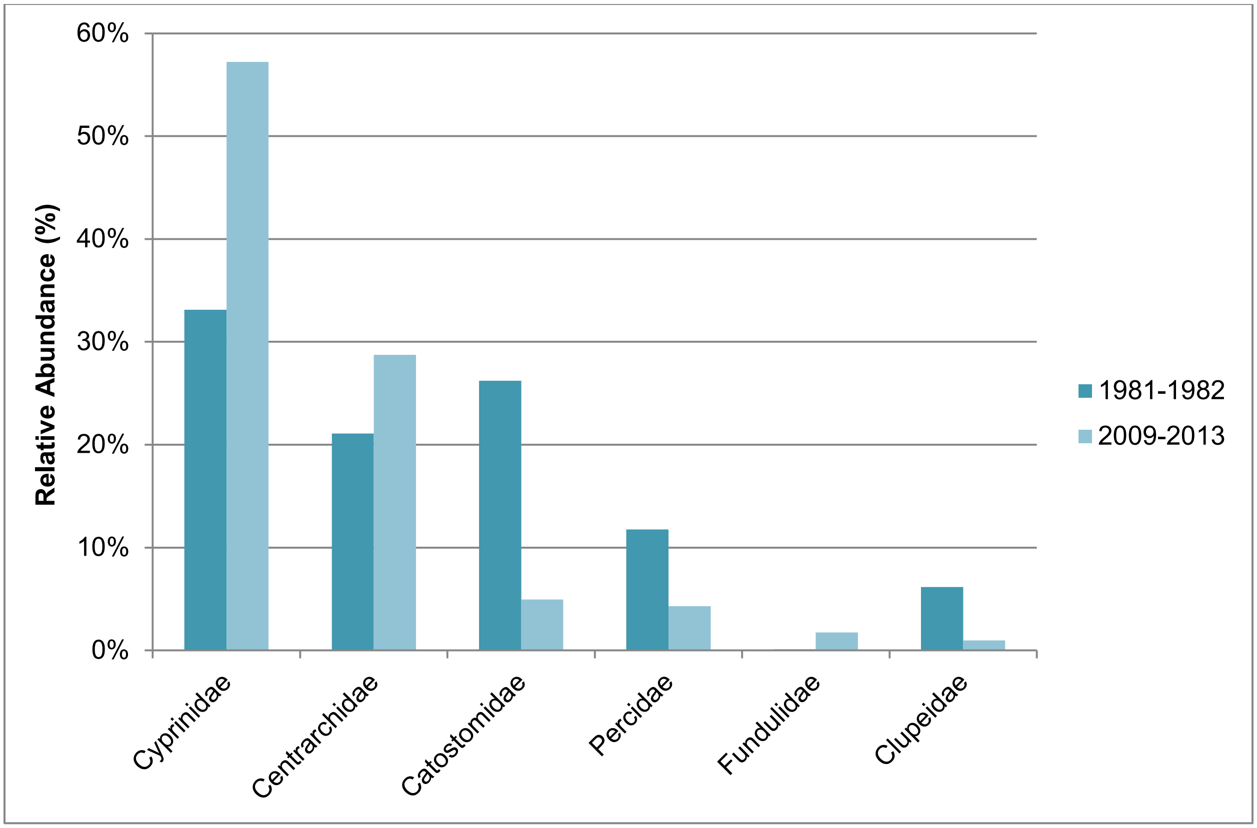
		Electrofishing		Seining		All Gear Types	
Species	**Common Name**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Cyprinidae		**4,467**	**43.7**	**6,246**	**73.4**	**10,713**	**57.2**
Cyprinella spiloptera	spotfin shiner	1,206	11.8	3,000	35.3	4,206	22.5
Cyprinus carpio	common carp	52	0.5	2	<0.1	54	0.3
Lepomis microlophus	redear sunfish	1	<0.1	–	–	1	<0.1
Luxilus chrysocephalus	striped shiner	100	1.0	123	1.4	223	1.2
Minytrema melanops	spotted sucker	7	0.1	–	–	7	<0.1
Moxostoma spp.	redhorse spp.	46	0.5	25	0.3	71	0.4
Nocomis biguttatus	hornyhead chub	2	<0.1	7	0.1	9	<0.1
Notemigonus crysoleucas	golden shiner	1	<0.1	–	–	1	<0.1
Notropis amnis	pallid shiner	4	<0.1	–	–	4	<0.1
Notropis atherinoides	emerald shiner	1	<0.1	2	<0.1	3	<0.1
Notropis buchanani	ghost shiner	50	0.5	22	0.3	72	0.4
Notropis rubellus	rosyface shiner	33	0.3	96	1.1	129	0.7
Notropis stramineus	sand shiner	1,068	10.5	472	5.6	1,540	8.2
Notropis volucellus	mimic shiner	10	0.1	3	<0.1	13	0.1
Pimephales notatus	bluntnose minnow	1,041	10.2	836	9.8	1,877	10.0
Pimephales promelas	fathead minnow	23	0.2	6	0.1	29	0.2
Pimephales vigilax	bullhead minnow	821	8.0	1,646	19.4	2,467	13.2
Semotilus atromaculatus	creek chub	1	<0.1	6	0.1	7	<0.1
Centrarchidae		**3,869**	**37.9**	**1,512**	**17.8**	**5,381**	**28.8**
Ictiobus bubalus	smallmouth buffalo	8	0.1	–	–	8	<0.1
Lepomis cyanellus	green sunfish	94	0.9	6	0.1	100	0.5
Lepomis gibbosus	pumpkinseed	4	<0.1	–	–	4	<0.1
Lepomis humilis	orangespotted sunfish	173	1.7	41	0.5	214	1.1
Lepomis hybrid	sunfish hybrid	1	<0.1	–	–	1	<0.1
Lepomis macrochirus	bluegill	343	3.4	59	0.7	402	2.1
Lepomis macrochirus × megalotis	bluegill × longear sunfish hybrid	1	<0.1	–	–	1	<0.1
Lepomis megalotis	longear sunfish	2,553	25.0	682	8.0	3,235	17.3
Lepomis spp.	sunfish spp.	84	0.8	385	4.5	469	2.5
Lythrurus umbratilis	redfin shiner	15	0.1	45	0.5	60	0.3
Micropterus salmoides	largemouth bass	576	5.6	203	2.4	779	4.2
Noturus gyrinus	tadpole madtom	1	<0.1	3	<0.1	4	<0.1
Pomoxis annularis	white crappie	4	<0.1	44	0.5	48	0.3
Pomoxis nigromaculatus	black crappie	12	0.1	44	0.5	56	0.3

		Electrofishing		Seining		All Gear Types	
Species	**Common Name**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Catostomidae		**892**	**8.7**	**38**	**0.4**	**930**	**5.0**
Ambloplites rupestris	rock bass	315	3.1	28	0.3	343	1.8
Carpiodes carpio	river carpsucker	35	0.3	1	<0.1	36	0.2
Carpiodes cyprinus	quillback	7	0.1	1	<0.1	8	<0.1
Carpiodes spp.	carpsucker spp.	2	<0.1	5	0.1	7	<0.1
Cyprinella lutrensis	red shiner	2	<0.1	1	<0.1	3	<0.1
Esox lucius	northern pike	12	0.1	–	–	12	0.1
Hypentelium nigricans	northern hogsucker	6	0.1	–	–	6	<0.1
Ictiobus cyprinellus	bigmouth buffalo	5	<0.1	–	–	5	<0.1
Morone mississippiensis	yellow bass	2	<0.1	–	–	2	<0.1
Moxostoma anisurum	silver redhorse	119	1.2	2	<0.1	121	0.6
Moxostoma duquesnei	black redhorse	7	0.1	–	–	7	<0.1
Moxostoma erythrurum	golden redhorse	371	3.6	–	–	371	2.0
Moxostoma macrolepidotum	shorthead redhorse	7	0.1	–	–	7	<0.1
Moxostoma carinatum	river redhorse	1	<0.1	–	–	1	<0.1
Noturus flavus	stonecat	1	<0.1	–	–	1	<0.1
Percidae		**506**	**5.0**	**301**	**3.5**	**807**	**4.3**
Etheostoma nigrum	johnny darter	46	0.5	226	2.7	272	1.5
Etheostoma zonale	banded darter	8	0.1	2	<0.1	10	0.1
Micropterus dolomieu	smallmouth bass	273	2.7	43	0.5	316	1.7
Percina caprodes	logperch	9	0.1	14	0.2	23	0.1
Percina maculata	blackside darter	24	0.2	15	0.2	39	0.2
Percina phoxocephala	slenderhead darter	9	0.1	1	<0.1	10	0.1
Sander vitreum	walleye	137	1.3	–	–	137	0.7
Fundulidae		**114**	**1.1**	**215**	**2.5**	**329**	**1.8**
Fundulus notatus	blackstripe topminnow	114	1.1	215	2.5	329	1.8
Atherinopsidae		**73**	**0.7**	**112**	**1.3**	**185**	**1.0**
Labidesthes sicculus	brook silverside	73	0.7	112	1.3	185	1.0
Clupeidae		**159**	**1.6**	**23**	**0.3**	**182**	**1.0**
Dorosoma cepedianum	gizzard shad	159	1.6	23	0.3	182	1.0
Ictaluridae		**65**	**0.6**	**29**	**0.3**	**94**	**0.5**
Ameiurus melas	black bullhead	1	<0.1	1	<0.1	2	<0.1
Ictalurus punctatus	channel catfish	58	0.6	28	0.3	86	0.5
Pylodictis olivaris	flathead catfish	6	0.1	–	–	6	<0.1
Esocidae		**27**	**0.3**	**16**	**0.2**	**43**	**0.2**
Esox americanus	grass pickerel	27	0.3	16	0.2	43	0.2
Sciaenidae		**27**	**0.3**	**–**	**<0.1**	**27**	**0.1**
Aplodinotus grunniens	freshwater drum	27	0.3	–	–	27	0.1

		Electrofishing		Seining		All Gear Types	
Species	**Common Name**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Lepisosteidae		**10**	**0.1**	**3**	**<0.1**	**13**	**0.1**
Lepisosteus osseus	longnose gar	10	0.1	3	<0.1	13	0.1
Moronidae		**6**	**0.1**	**2**	**<0.1**	**8**	**<0.1**
Ameiurus natalis	yellow bullhead	4	<0.1	1	<0.1	5	<0.1
Catostomus commersoni	white sucker	–	–	1	<0.1	1	<0.1
Morone americana	white perch	2	<0.1	–	–	2	<0.1
Poeciliidae		**–**	**<0.1**	**5**	**0.1**	**5**	**<0.1**
Gambusia affinis	mosquitofish	–	–	5	0.1	5	<0.1
Aphredoderidae		**–**	**<0.1**	**1**	**<0.1**	**1**	**<0.1**
Aphredoderus sayanus	pirate perch	–	–	1	<0.1	1	<0.1
Petromyzontidae		**1**	**<0.1**	**–**	–	**1**	**<0.1**
Petromyzontidae spp.	lamprey spp.	1	<0.1	–	–	1	<0.1
Source: HDR 2014							

During a 2008 special study associated with the discharge canal replacement, HDR (2008) sampled fish in conjunction with the annual Kankakee River sampling program to determine the presence of State-listed species in the vicinity of the discharge channel. HDR collected samples by electrofishing and seining on August 4 and 5, 2008. HDR also preformed mussel sampling, the methods and results of which are described later in this section. During the study, two pallid shiner were collected by electrofishing at locations 5L and 5R approximately 975 ft (300 m) downstream from the discharge channel (600 ft (180 m) downstream of the currently functioning discharge diffuser) in areas of deeper water neighboring a sand bar. One river redhorse was collected by electrofishing at location 1L approximately 3,250 ft (1,000 m) upstream of the discharge channel (3,000 ft (900 m) upstream of the currently functioning discharge diffuser). No State-listed species were collected during seining. The pallid shiner and river redhorse are described in more detail in Section 3.7.5.

Figure 3–16. Comparison of Relative Abundance of Most Prevalent[a] Fish Families in Historic and Recent Kankakee River Monitoring Samples



[a] Families that constituted 1.0 percent or less of both historic and recent monitoring samples are not represented in this figure.

Sources: HDR 2014; NRC 1984

<u>Mussels</u>. The FES-O (NRC 1984) indicates that 15 species of mussels were collected from the Kankakee River in the vicinity of Braidwood during preoperational surveys. The majority of mussels were collected in shallow riffles with fast currents, and the predominant species was the mucket. The remaining 14 species are unspecified, but a 1978 study (Suloway 1981) conducted at 13 sites throughout the Kankakee River in Illinois provides insight as to what species were likely present prior to Braidwood operation. Suloway (1981) recorded 20 species among 1,006 live individuals collected in samples. The mucket was the most abundantly collected species, and the fatmucket, which occurred at all sample sites, was the most widely distributed species.

HDR (2008) conducted the first operational mussel survey near Braidwood in 2008 as part of a special study on the presence of State-listed species that could be affected by installation of the multi-port discharge diffuser (described previously). HDR conducted the survey in two phases, both of which occurred on August 8, 2008. In the first phase, six people hand-picked mussels along the shoreline for 2.5 hours each, and in the second phase, nine 220-m (720-ft) brail (a collection device for mussels) runs were conducted in the center of the river. Live individuals were recorded by area and returned to the river upstream of the discharge channel.

HDR (2008) collected 212 live individuals of 15 species and shells of an additional 8 species (see Table 3–11). Mucket, the most commonly collected species, comprised the majority (54.2 percent) of live individuals. Threeridge (*Amblema plicata*) was the second most commonly collected species (13.2 percent) followed by flutedshell (*Lasmigona costata*; 6.1 percent) and pimpleback (*Quadrula pustulosa*; 5.6 percent). The remaining 11 species each accounted for less than 5 percent of live collections. Three live purple wartyback (*Cyclonaias tuberculata*), a State-threatened species, were collected. Of the eight species collected as shells, one dead sheepnose (*Plethobasus cyphyus*), a Federally endangered species, was collected (see Section 3.8 for a discussion of Federally listed species) and relict shells of two State-threatened species, spike (*Elliptio dilatata*) and black sandshell (*Ligumia recta*), were collected (Section 3.7.5 discusses these State-listed species in more detail).

The majority of individuals were collected from hand-picking along the south shore upstream of the effluent pipe (156 live individuals). Hand-picking on the south shore downstream of the discharge and brail runs in the center of the river yielded the remaining live individuals. No mussels were found on the north shore, which HDR (2008) attributed to unsuitable habitat conditions. Table 3–12 lists the habitat attributes, collection method, and number of individuals and species collected at each surveyed location.

In October 2008, Ecological Specialists, Inc. (ESI 2009), conducted a more comprehensive dive study to better characterize and map the distribution of freshwater mussels near the Braidwood discharge channel. The study included semi-quantitative, quantitative, and qualitative sampling methods. Ecological Specialists (ESI 2009) used semi-qualitative sampling to assess mussel distribution by surveying five 200-m (670-ft) transects perpendicular to river flow starting approximately 20 to 40 m (65 to 130 ft) upstream of the multi-port discharge diffuser (which had yet to be constructed at the time) (see Figure 3–17). A diver collected all mussels within 1 m (3.2 ft) of the line in 10-m (33-ft) sections for a total of 20 samples per transect. Based on the quantitative samples, qualitative samples were taken in areas with higher mussel density or where State-listed species had been identified.

Table 3–11. Mussels Collected in the Kankakee River Near the Braidwood Discharge by Species, 2008

Species [(a)]	Common Name	No. Collected in August 2008 [(b)]	No. Collected in October 2008 [(b)]	Status [(c)]
Actinonaias ligamentina	mucket	115 L	97 L	–
Amblema plicata	threeridge	28 L	13 L	–
Lasmigona costata	flutedshell	13 L	1 L	–
Quadrula pustulosa	pimpleback	12 L	1 L	–
Lasmigona complanata	white heelsplitter	10 L	–	–
Utterbackia imbecillis	paper pondshell	7 L	1 L	–
Lampsilis siliquoidea	fatmucket	5 L	–	–
Pleurobema sintoxia	round pigtoe	5 L	–	–
Cyclonaias tuberculata	purple wartyback	3 L	1 L	ST
Lampsilis cardium	plain pocketbook	3 L	2 L	–
Leptodea fragilis	fragile papershell	3 L	2 L	–
Pyganodon grandis	giant floater	3 L	–	–
Quadrula metanevra	monkeyface	2 L	1 L	–
Quadrula quadrula	mapleleaf	2 L	–	–
Venustaconcha ellipsiformis	ellipse	1 L	2 L	–
Alasmidonta marginata	elktoe	D	–	–
Fusconaia flava	Wabash pigtoe	D	1 L	–
Megalonaias nervosa	washboard	D	2 L	–
Plethobasus cyphyus	sheepnose	D	–	FE, SE
Potamilus alatus	pink heelsplitter	D	–	–
Elliptio dilatata	spike	R	2 L	ST
Ligumia recta	black sandshell	R	–	ST
Strophitus undulatus	creeper	R	–	–

[(a)] Species ordered by decreasing number of individuals collected in the August 2008 survey.

[(b)] L = live; D = dead (valves with tissue present or shiny nacre and intact periostracum); R = relict (valves with chalky nacre and worn periostracum); – = none collected

[(c)] FE = Federally endangered; SE = State-endangered in Illinois; ST = State-threatened in Illinois; – = species is not Federally or State-listed as endangered or threatened

Sources: ESI 2009; HDR 2008; IDNR 2011

Table 3–12. Mussels Collected in the Kankakee River Near the Braidwood Discharge by Location, August 2008

Location	Habitat Attributes	Collection Method	No. Live Individuals Collected	No. Species Collected
River channel	habitat not assessed due to water depth (>2 m)	Brail Run	20	3
South shore upstream of Braidwood discharge	silted-sand with small patches of mud and gravel	Hand-picking	156	15
North shore	mud and rip-rap	Hand-picking	0	0
South shore downstream of Braidwood discharge	silted-sand with large fluctuations in water temperature	Hand-picking	36	5

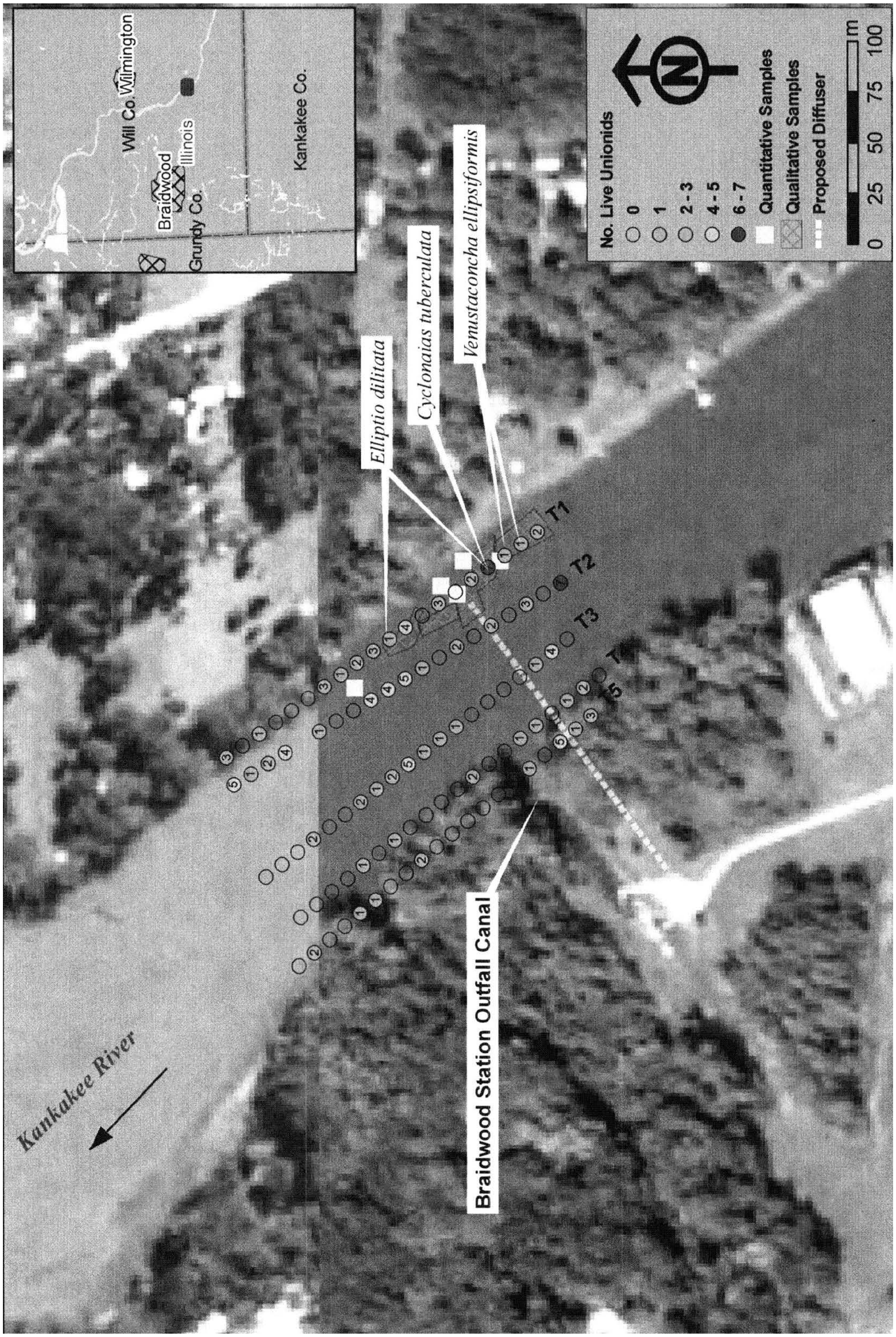
Source: HDR 2008

Ecological Specialists (ESI 2009) collected 126 live individuals of 13 species (see Table 3–11). Mucket was again the most collected species. No unique species were present that had not been collected in the August 2008 survey. Three live State-listed individuals (one purple wartyback and two spike) were collected from upstream portions of the survey transects. In the previous survey, spike had only been collected as relict shells. No black sandshell or sheepnose were collected in the October 2008 survey. Ecological Specialists (ESI 2009) concluded that the mussel community in the vicinity of the Braidwood discharge exhibits moderate to high species richness and relatively low abundance due to lack of suitable substrate. No juveniles or other indications of recruitment were observed during the survey, which suggests that the mussels in the vicinity of Braidwood likely come from larger, stable, and reproducing upstream populations.

Species diversity within the mussel community appears to be relatively high and to have remained similar since Braidwood began operation. Available literature indicates that 20 species were identified as occurring in the Illinois portions of the Kankakee River in the late 1970s (Suloway 1981). The 2008 Braidwood surveys (ESI 2009; HDR 2008) identified 23 species (live individuals of 18 species and shells of 5 additional species). Only three species of mussels from 1978 were not collected in 2008, and it is unknown whether these species historically occurred in the reach of the river near Braidwood. The Braidwood surveys also yielded a higher species diversity than a 2010 INHS mussel survey of the Kankakee River basin (Price et al. 2012). Table 3–13 compares species identified during the historical and recent mussel surveys.

Species abundance, however, appears to be lower in the vicinity of Braidwood than in other regions of the Kankakee River. During the hand-picking portion of the August 2008 survey (HDR 2008), 192 individuals were collected in 15 man-hours, which yields a catch-per-unit-effort (CPUE) of 12.8. Suloway (1981) collected 1,006 individuals in 37 man-hours, which yields a CPUE of 27.2, and Price et al. (2012) reported a CPUE of 40.0 at mainstem locations. HDR (2008) indicates that the lower species abundance near Braidwood is likely the result of unsuitable or marginal habitat.

Figure 3–17. Braidwood Mussel Sampling Locations, 2009 Survey



Source: ESI 2009

1 **Table 3–13. Historic and Recent Mussel Species Collected in the Kankakee River**

		Location of Study on the Kankakee River[b]		
Species[a]	**Common Name**	**Throughout Illinois, 1978[c]**	**In the Vicinity of Braidwood, 2008[d]**	**Upstream and Downstream of Braidwood, 2010[e]**
Actinonaias ligamentina	mucket	x	x	x
Alasmidonta marginata	elktoe	x	D	x
Amblema plicata	threeridge	x	x	
Cyclonaias tuberculata	purple wartyback	x	x	x
Elliptio dilatata	spike	x	x	R
Fusconaia flava	Wabash pigtoe	x	x	x
Lampsilis cardium	plain pocketbook		x	x
Lampsilis ovata	pocketbook	x		
Lampsilis siliquoidea	fatmucket	x	x	
Lasmigona complanata	white heelsplitter	x	x	x
Lasmigona compressa	creek heelsplitter	x		
Lasmigona costata	flutedshell	x	x	x
Leptodea fragilis	fragile papershell		x	x
Ligumia recta	black sandshell	x	R	x
Megalonaias nervosa	washboard	x	x	x
Plethobasus cyphyus	sheepnose		D	
Pleurobema cordatum	Ohio pigtoe	x		
Pleurobema sintoxia	round pigtoe		x	x
Potamilus alatus	pink heelsplitter		D	
Pyganodon grandis	giant floater	x	x	R
Quadrula metanevra	monkeyface	x	x	x
Quadrula pustulosa	pimpleback	x	x	x
Quadrula quadrula	mapleleaf	x	x	R
Strophitus undulatus	creeper		R	
Truncilla trancata	deertoe			x
Utterbackia imbecillis	paper pondshell	x	x	
Venustaconcha ellipsiformis	ellipse	x	x	D
Total number of species collected		**20**	**23**	**18**

[a] Some species' names differ from those in Suloway (1981) to reflect the most current taxonomy.

[b] x = live individuals collected during study; D = dead shells collected; R = relict shells collected

[c] Suloway (1981) surveyed 13 locations in the Kankakee River in Kankakee and Will Counties, Illinois, in the fall of 1978.

[d] HDR (2008) and Ecological Specialists (ESI 2009) surveyed mussels within the Kankakee River in the vicinity of the Braidwood makeup water discharge channel in August and October 2008, respectively.

[e] Price et al. (2012) surveyed 21 sites in the Kankakee River and its tributaries from June through September 2010. Only those species collected at Sites 5 and 6, which are the closest upstream and downstream sampling locations to Braidwood, are included in this table.

Sources: ESI 2009; HDR 2008; Price et al. 2012; Suloway 1981

3.7.3.2 Braidwood Cooling Pond

In 1980, the IDNR began annual fish sampling of the Braidwood cooling pond, as described in Section 3.7.2.2. Sampling continued through 1992, in 1994, and every other year from 1997 through 2007. Table 3–14 lists the fish species IDNR collected during these surveys by relative abundance. Information on the IDNR surveys described in this section is obtained from summaries in HDR (2010). Survey materials and methods for the IDNR surveys are unavailable.

IDNR has collected 47 species in the Braidwood cooling pond. Common carp, gizzard shad, largemouth bass, and bluegill have consistently been among the most abundant species in the cooling pond. Channel catfish have also become relatively abundant during the operational period. Bluegill, which can tolerate high temperatures with relatively high survival according to Banner and Van Arman (1973), have noticeably increased in relative abundance from 9.6 percent of preoperational samples to 23.5 percent of operational survey samples. By family, clupids (primarily gizzard shad), centrarchids, and cyprinids have consistently been the most abundant throughout both sampling periods. One State-endangered river redhorse individual was collected in 1999 during the operational period.

Since 2009, HDR (2010, 2011a, 2012, 2013a) has sampled fish populations in the cooling pond by electrofishing, trap netting, and gill netting in July and August of each year at the locations identified in Figure 3–18. Electrofishing is conducted at eight locations (E-1 through E-8) with a boat-mounted, boom-type electrofisher. Each location is sampled for 30 minutes during daytime hours (30 minutes after sunrise to 30 minutes before sunrise). Trap nets are set at eight locations (TN-1 through TN-8) during late afternoon or early evening and left to collect fish overnight for approximately 12 hours. Two 125-ft (38.1-m)-long and 6-ft (1.8-m)-deep gill nets are used to collect fish at two locations (GN-1 and GN-2) at depths of 6 to 10 ft (1.8 to 3.1 m) for 60 to 90 minutes. Table 3–15 lists the number and relative abundance of each species collected by HDR for the available years (2009 through 2012).

HDR has collected 34 species representing 10 families between 2009 and 2012. HDR collected several species that had not been previously collected in the cooling pond (shortnose gar, bigmouth buffalo, smallmouth buffalo, fathead minnow, rosyface shiner, and shovelnose tiger catfish), while other species that had been previously collected by the IDNR did not appear in HDR's collections. Common carp, gizzard shad, and largemouth bass remained abundant in samples, though these species have declined in relative abundance compared to the IDNR survey periods. Bluegill has continued to increase in abundance and was the most abundant species collected over the four-year period. Gizzard shad, one of the most frequently affected species during periods of elevated pond temperatures, have decreased in abundance dramatically in recent years and comprised only 5.0 percent of total catch over the four-year period. IDNR-stocked warm water game species, such as largemouth bass and blue catfish, have persisted in small numbers, while cooler water stocked species, such as walleye and tiger muskellunge, no longer appear in collections. HDR did not collect the State-endangered river redhorse.

Table 3–14. Fish Collected During Braidwood Cooling Pond Surveys by Relative Abundance, 1980–2007

		Pre-operational (1980–1987)[b]		Operational (1988–2007)[c]		Total	
Species [a]	**Common Name**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Dorosoma cepedianum	gizzard shad	4,160	27.4	16,110	37.3	20,270	34.7
Lepomis macrochirus	bluegill	1,462	9.6	10,139	23.5	11,601	19.9
Cyprinus carpio	common carp	4,328	28.6	7,068	16.3	11,396	19.5
Micropterus sahnoides	largemouth bass	2,225	14.7	3,028	7.0	5,253	9.0
Ictalurus punctatus	channel catfish	85	0.6	3,561	8.2	3,646	6.2
Dorosoma petenense	threadfin shad	564	3.7	363	0.8	927	1.6
Lepomis cyanellus	green sunfish	462	3.0	353	0.8	815	1.4
Cyprinella spiloptera	spotfin shiner	10	<0.1	603	1.4	613	1.0
Carpiodes cyprinus	quillback	271	1.8	258	0.6	529	0.9
Perca flavescens	yellow perch	401	2.6	74	0.2	475	0.8
Labidesthes sicculus	brook silverside	150	1.0	299	0.7	449	0.8
Ameiurus melas	black bullhead	319	2.1	-	-	319	0.5
Sander vitreum	walleye	151	1.0	156	0.4	307	0.5
Aplodinotus grunniens	freshwater drum	45	0.3	209	0.5	254	0.4
Percina caprodes	logperch	-	-	226	0.5	226	0.4
Micropterus dolomieu	smallmouth bass	-	-	163	0.4	163	0.3
Pomoxis annularis	white crappie	118	0.8	28	<0.1	146	0.3
Notropis stramineus	sand shiner	6	<0.1	121	0.3	127	0.2
Lepomis hybrid	sunfish hybrid	72	0.5	50	0.1	122	0.2
Pimephales notatus	bluntnose minnow	11	<0.1	105	0.2	116	0.2
Pomoxis nigromaculatus	black crappie	61	0.4	51	0.1	112	0.2
Notemigonus crysoleucas	golden shiner	88	0.6	5	<0.1	93	0.2
Ameiurus natalis	yellow bullhead	56	0.4	15	<0.1	71	0.1
Notropis atherinoides	emerald shiner	3	<0.1	50	0.1	53	<0.1
Esox americanus	grass pickerel	39	0.3	-	-	39	<0.1
Lepomis megalotis	longear sunfish	-	-	37	<0.1	37	<0.1
Luxilus cornutus	common shiner	31	0.2	4	<0.1	35	<0.1
Moxostoma macrolepidotum	shorthead redhorse	1	<0.1	32	<0.1	33	<0.1
Morone saxatilis	striped bass	2	<0.1	28	<0.1	30	<0.1
Esox masquinongy × lucius	tiger muskellunge	11	<0.1	17	<0.1	28	<0.1
Lepisosteus osseus	longnose gar	3	<0.1	13	<0.1	16	<0.1
Pylodictis olivaris	flathead catfish	-	-	15	<0.1	15	<0.1

Species [(a)]	Common Name	Pre-operational (1980–1987)[(b)] No.	Pre-operational (1980–1987)[(b)] %	Operational (1988–2007)[(c)] No.	Operational (1988–2007)[(c)] %	Total No.	Total %
Luxilus chrysocephalus	striped shiner	14	<0.1	-	-	14	<0.1
Pimephales vigilax	bullhead minnow	-	-	11	<0.1	11	<0.1
Moxostoma erythrurum	golden redhorse	2	<0.1	8	<0.1	10	<0.1
Carassius auratus	goldfish	-	-	7	<0.1	7	<0.1
Fundulus notatus	blackstripe topminnow	-	-	6	<0.1	6	<0.1
Ambloplites rupestris	rock bass	-	-	5	<0.1	5	<0.1
Percina phoxocephala	slenderhead darter	-	-	5	<0.1	5	<0.1
Lepomis microlophus	redear sunfish	-	-	4	<0.1	4	<0.1
Moxostoma anisurum	silver redhorse	1	<0.1	2	<0.1	3	<0.1
Lepomis humilis	orangespotted sunfish	-	-	3	<0.1	3	<0.1
Carpiodes velifer	highfin carpsucker	2	<0.1	-	-	2	<0.1
Morone mississippiensis	yellow bass	1	<0.1	1	<0.1	2	<0.1
Etheostoma nigrum	johnny darter	2	<0.1	-	-	2	<0.1
Lythrurus umbratilis	redfin shiner	-	-	1	<0.1	1	<0.1
Moxostoma carinatum	river redhorse	-	-	1	<0.1	1	<0.1
Total Number		**15,157**		**43,235**		**58,392**	
Total Species		**34**		**42**		**47**	

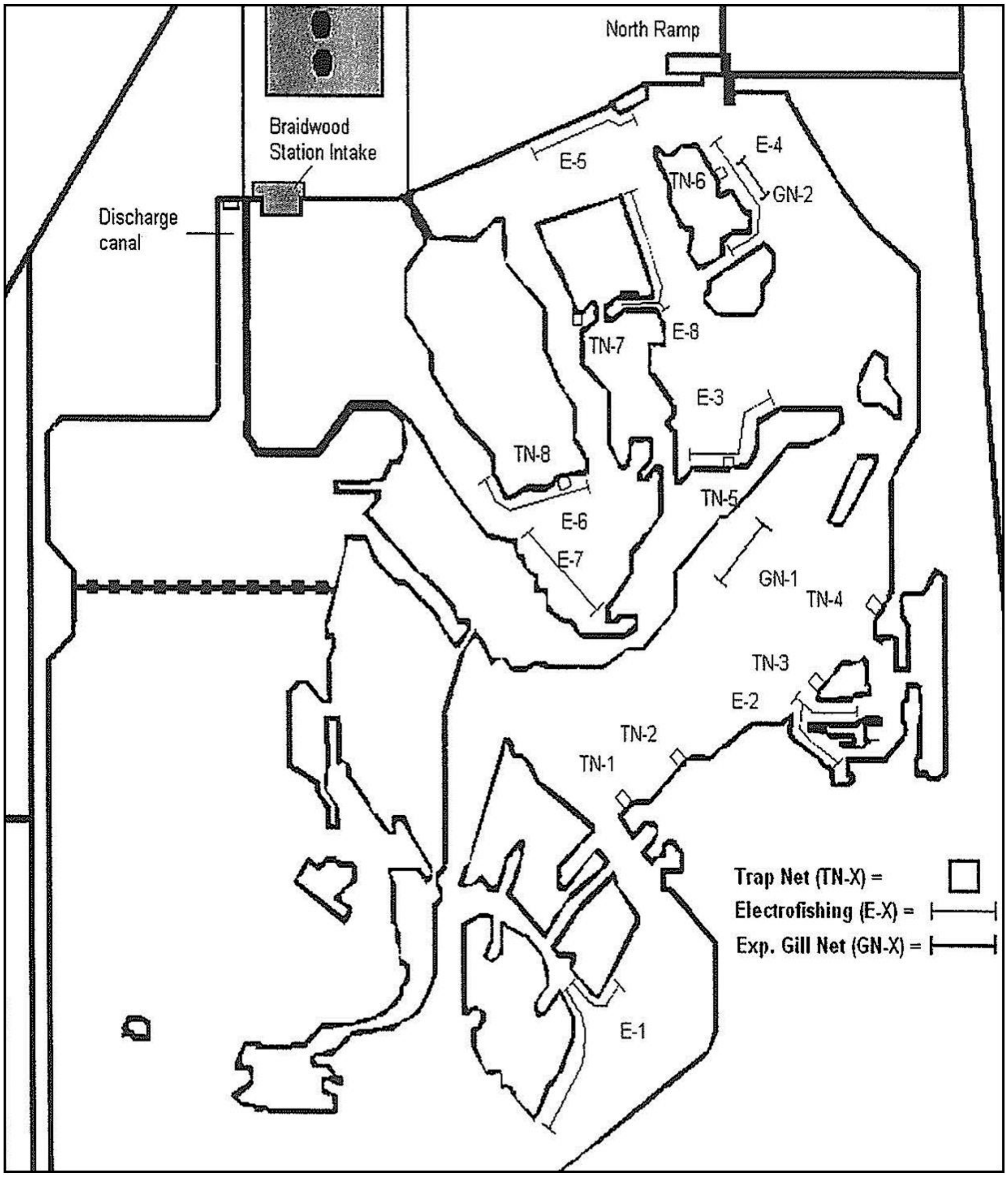
(a) Species ordered by decreasing total relative abundance.

(b) The preoperational period includes 8 surveys that were conducted annually from 1980 through 1987.

(c) The operational period includes 12 surveys that were conducted annually from 1988 through 1992, in 1994, and every other year from 1997 through 2007.

Source: HDR 2010

1 **Figure 3–18. Cooling Pond Fish Sampling Locations**



2

3 Source: HDR 2010

Table 3–15. Fish Collected During Braidwood Cooling Pond Surveys by Relative Abundance, 2009–2012

Species[a]	Common Name	No. Collected	Relative Abundance (%)
Lepomis macrochirus	bluegill	2,499	28.4
Ictalurus punctatus	channel catfish	1,387	15.8
Dorosoma petenense	threadfin shad	1,130	12.9
Cyprinus carpio	common carp	801	9.1
Cyprinella spiloptera	spotfin shiner	644	7.3
Pimephales vigilax	bullhead minnow	555	6.3
Dorosoma cepedianum	gizzard shad	435	5.0
Pimephales notatus	bluntnose minnow	357	4.1
Micropterus sahnoides	largemouth bass	336	3.8
Lepomis megalotis	longear sunfish	165	1.9
Lepomis cyanellus	green sunfish	145	1.7
Ictalurus furcatus	blue catfish	74	0.8
Lepomis microlophus	redear sunfish	51	0.6
Notropis stramineus	sand shiner	46	0.5
Luxilus chrysocephalus	striped shiner	34	0.4
Labidesthes sicculus	Brook silverside	26	0.3
Notropis rubellus	rosyface shiner	21	0.2
Lepomis hybrid	sunfish hybrid	17	0.2
Lepisosteus osseus	longnose gar	9	0.1
Micropterus dolomieu	smallmouth bass	9	0.1
Aplodinotus grunniens	freshwater drum	9	0.1
Pylodictis olivaris	flathead catfish	8	<0.1
Pimephales promelas	fathead minnow	7	<0.1
Lepomis spp.	sunfish spp.	5	<0.1
Ictiobus bubalus	smallmouth buffalo	3	<0.1
Ameiurus natalis	yellow bullhead	3	<0.1
Lepomis humilis	orangespotted sunfish	3	<0.1
Gambusia affinis	mosquitofish	2	<0.1
Lepisosteus platostomus	shortnose gar	1	<0.1
Luxilus cornutus	common shiner	1	<0.1
Ictiobus cyprinellus	bigmouth buffalo	1	<0.1
Pseudoplatystoma spp.	tiger shovelnose catfish	1	<0.1
Morone saxatilis hybrid	striped bass hybrid	1	<0.1
Pomoxis nigromaculatus	black crappie	1	<0.1
Total Collected		**8,787**	

[a] Species are ordered by relative abundance (highest to lowest).

Sources: HDR 2010, 2011a, 2012, 2013a

3.7.4 Cooling Pond Fish Kill Events

Since 2001, six fish kill events have occurred in the Braidwood cooling pond. A brief description of each event follows.

July 22, 2001

Exelon staff identified a fish kill of approximately 700 fish due to high temperatures in the cooling pond. Pond temperatures peaked at 98.4 °F (36.9 °C) (Exelon 2001a), which is above the upper thermal tolerance for most of the fish species in the lake with the exception of juvenile bluegill, which can tolerate temperatures of up to 102.6 °F (39.2 °C) for 24-hour periods with relatively high survival (Banner and Van Arman 1973). An IDNR representative performed an onsite inspection on July 23, 2001, and determined that the fish kill was attributable to high temperatures resulting from Braidwood operation (Exelon 2001a).

August 27, 2001

A second fish kill occurred in August of the same year. Exelon staff identified an unspecified number of dead fish, most of which were gizzard shad, in the cooling pond on August 27, 2001. The following day, an independent lake specialist assessed cooling pond temperature, oxygen, and pH levels. The fish kill was attributed to a sudden increase in cooling water temperatures resulting from operation of Braidwood's cooling system coupled with depleted oxygen levels in the lake (Exelon 2001b).

June 28, 2005

Exelon (2005) reported a fish kill of approximately 10,000 fish. Specific species were not identified, but Exelon (2005) indicated that temperatures in the pond exceeded the upper thermal tolerances of threadfin shad (*Dorosoma petenense*) and gizzard shad. An IDNR representative performed an assessment of the cooling pond the following day and determined that the fish kill was attributable to high temperatures associated with Braidwood operation.

August 21, 2007

A Braidwood plant employee noted a large number of dead fish near the circulating water intake during inspection of the intake area and cooling pond banks. The following day, an Exelon Fishery Specialist observed several thousand dead gizzard shad and threadfin shad and several dozens of channel catfish throughout the cooling pond while performing dissolved oxygen measurements at various locations in the pond. The Exelon Fishery Specialist, in consultation with an IDNR biologist, concluded that die-off and decay of phytoplankton during the several days preceding the fish kill event triggered a rapid decline in dissolved oxygen concentrations, which then suffocated a large number of fish. Braidwood personnel concluded that the fish kill was not directly attributable to plant operations (Exelon 2014j).

June 24, 2009

Exelon (2009a) reported a fish kill of a few thousand gizzard shad and an unspecified number of various game fish species on June 24, 2009. An IDNR representative performed an assessment of the cooling pond the following day and determined that the fish kill was attributable to high temperatures associated with Braidwood operation.

July 7 and 8, 2012

Prolonged hot weather in northern Illinois from July 4 through July 8, 2012, caused ultimate heat sink (i.e., essential portion of the cooling pond) temperatures to exceed the TS limit of 100 °F

(38 °C) on July 7 and 8. The NRC approved a Notice of Enforcement Discretion that allowed Exelon to operate for a period of 18 hours with ultimate heat sink temperatures of up to 102 °F (38.9 °C) (NRC 2012). During this time, Braidwood personnel found approximately 3,000 dead gizzard shad and 100 dead bass, catfish, and carp in the cooling pond (Exelon 2014j).

3.7.5 Important Species and Habitats

3.7.5.1 State-Listed Species

IDNR lists 31 fish and 25 mussel species as State-endangered or threatened (IDNR 2011). Of these, information from the IDNR (2013) indicates that 14 species (9 fish, 5 mussels) occur in Will County, and available aquatic surveys (ESI 2009; HDR 2008, 2014; IDNR 1998; Price et al. 2012) indicate that 10 of these species (5 fish, 5 mussels) occur within the Kankakee River and its tributaries (see Table 3–16).

Table 3–16. State-Listed Aquatic Species in the Kankakee River Basin

			Recorded Occurrences[b]			
Species	**Common Name**	**State Status[a]**	**Kankakee River Area Assessment, 1998[c]**	**Kankakee River Basin Fish Survey, 2005[d]**	**Kankakee River Freshwater Mussel Survey, 2010[e]**	**Braidwood Aquatic Monitoring Surveys, 1991–2013 for fish and 2008 for mussels[f]**
Fish						
Ammocrypta clara	western sand darter	SE	x			
Hybopsis amnis	pallid shiner	SE	x			x
Moxostoma carinatum	river redhorse	ST	x	x		x
Notropis chalybaeus	ironcolor shiner	ST	x	x		
Notropis texanus	weed shiner	SE	x			
Mussels						
Alasmidonta viridis	slippershell	ST	x		R	
Cyclonaias tuberculata	purple wartyback	ST			x	x
Elliptio dilatata	spike	ST	x		x	x
Ligumia recta	black sandshell	ST			x	x
Plethobasus cyphyus[g]	sheepnose	SE	x		x	

[a] SE = State-endangered in Illinois; ST = State-threatened in Illinois
[b] x = live individuals collected during study; R = relict shells collected
[c] IDNR 1998
[d] Pescitelli and Rung 2008
[e] Price et al. 2012
[f] ESI 2009; HDR 2008, 2014
[g] The sheepnose is Federally endangered. Section 3.8 discusses this species.

Sources: ESI 2009; HDR 2008, 2014; IDNR 1998; Pescitelli and Rung 2008; Price et al. 2012

In May 2009, Exelon applied for an incidental take authorization with the IDNR for State-listed species that had the potential to be affected by the replacement of the discharge channel with a multi-port discharge diffuser (Mostardi Platt 2009). In December 2009, the IDNR (2009) issued Exelon an incidental take permit for western sand darter, pallid shiner, river redhorse, purple wartyback, spike, black sandshell, and sheepnose. The incidental take permit prohibited construction activities from occurring during the spring spawning season and required relocation of state-listed freshwater mussels prior to the commencement of construction. In July 2010, Ecological Specialists (ESI 2010) collected and relocated 911 live mussels within the area that had the potential to be impacted by construction. Relocated mussels included 16 State-listed mussels (8 purple wartyback and 8 black sandshell) (ESI 2010). Exelon completed installation of the new discharge diffuser in December 2010 (Exelon 2013e). The 2009 incidental take permit also requires Exelon to complete a follow-up survey of fish and mussels near the construction area 5 years after completion of construction. The ER (Exelon 2013e) indicates that this survey will be undertaken in 2016. The State-listed species included in the incidental take permit are discussed individually below. The sheepnose, which was Federally listed as endangered in 2012, is discussed in Section 3.8.

Western Sand Darter. The western sand darter is a small perch that inhabits sandy runs of clear to moderately turbid rivers in areas of coarse sand or fine gravel (NatureServe 2014a). Barbour et al. (1999) classify the species as an insectivore that is intolerant of pollution and other environmental stressors. Although the species was included in the incidental take permit for the 2010 construction of the Braidwood discharge diffuser (IDNR 2009), it has not been collected during preoperational or operational surveys (HDR 2014; Larimore and Peterson 1989; NRC 1984) or during impingement and entrainment studies (EA Engineering 2010).

Pallid Shiner. The pallid shiner is a small, short-lived minnow that inhabits medium to large rivers in areas of slow-moving waters with mud, sand, gravel, and rocky substrate (MDNR 2014b). Barbour et al. (1999) classify the species as an insectivore that is intolerant of pollution and other environmental stressors. Pallid shiner have consistently appeared in both preoperational and operational aquatic monitoring surveys (HDR 2014; NRC 1984). HDR (2014) indicates that the species generally accounts for less than 0.1 percent of total individuals collected each year during Braidwood surveys. The species was most prevalent in 1991 (152 individuals collected) and was absent from samples in 1993, 2009, 2010, and 2012 (HDR 2014). EA Engineering (1990) also collected pallid shiner in impingement samples taken in 1988 and 1989. EA Engineering (1990) estimated that about 73 individuals are impinged annually and that most impingement occurs from mid-April through early June. Impingement is discussed in detail in Section 4.7.

River Redhorse. The river redhorse inhabits large river systems, including impoundments and pools, in areas of moderate to swift current and clean gravel substrate (NatureServe 2014f). Barbour et al. (1999) classify the species as an insectivore that is intolerant of pollution and other environmental stressors. River redhorse were collected in preoperational surveys (NRC 1984) and have occasionally appeared in operational surveys (HDR 2014). Between 1991 and 2013, a total of 13 individuals were collected across 8 of the 23 years (HDR 2014). The species was most abundant in 1993 samples, during which five individuals were collected. In the past 10 years, HDR (2014) has collected only one individual in 2009. EA Engineering (1990) also collected river redhorse in impingement samples taken in 1988 and 1989, which are discussed in detail in Section 4.7.

Purple Wartyback. The purple wartyback is a freshwater mussel that inhabits medium to large rivers in gravel or mixed sand and gravel substrates (Cummings and Mayer 1992). It is distributed throughout southern Ontario, the upper Mississippi River drainage, and south to

Arkansas and Missouri (NatureServe 2013c). The species has been recorded as occurring in the Kankakee River basin since the early 1900s (Baker 1906) and most recently, Price et al. (2012) found live individuals or shells at six sites within the river's mainstem during a 2010 mussel survey. As previously discussed, within the vicinity of Braidwood, HDR (2008) and Ecological Specialists (ESI 2009) collected a total of four live individuals upstream of Braidwood's discharge during 2008 studies associated with construction of the Braidwood discharge diffuser (see Table 3–11), and Ecological Specialists (ESI 2010) relocated eight individuals in July 2010 prior to the commencement of construction.

Spike. The spike is a freshwater mussel that inhabits shoals of medium streams to large rivers, reservoirs, and lakes with sand and gravel substrates (MDNR 2014c). It is distributed throughout the eastern United States, the Mississippi River system, and portions of the Great Lakes (NatureServe 2013d). The species has been recorded as occurring in the Kankakee River basin since the early 1900s (Baker 1906) and most recently, Price et al. (2012) found live individuals or shells at six sites within the river's mainstem during a 2010 mussel survey. As previously discussed, within the vicinity of Braidwood, HDR Engineering (HDR 2008) and Ecological Specialists (ESI 2009) collected relict shells of the species in August 2008 and two live individuals in October 2008 (see Table 3–11). The relict shells were collected along the southern shore of the river both upstream and downstream of Braidwood's discharge point; the location of the live individuals was unspecified. Ecological Specialists (ESI 2010) did not identify any spike individuals during July 2010 mussel relocations.

Black Sandshell. The black sandshell is a freshwater mussel that inhabits riffles of medium to large rivers in gravel or firm sand substrates (Cummings and Mayer 1992). It is distributed throughout the eastern and central United States in the Great Lakes basin and in the Mississippi River drainage to Louisiana (NatureServe 2013e). The species has been recorded as occurring in the Kankakee River basin since the early 1900s (Baker 1906). Most recently, Price et al. (2012) collected live individuals or shells at all surveyed mainstem sites during a 2010 mussel survey. As previously discussed, within the vicinity of Braidwood, HDR (2008) collected relict shells of the species in August 2008 (see Table 3–11). Ecological Specialists (ESI 2009) did not identify the species in its follow-up study in October 2010, nor was it collected and relocated in July 2010 (ESI 2010) prior to the commencement of the discharge diffuser construction.

3.7.5.2 Important Habitats

The Kankakee River State Park lies approximately 10 mi (16 km) southeast and downstream from the Braidwood site. The park is open to the public for smallmouth bass, channel catfish, walleye and northern pike fishing (IDNR 2014c). Within the park, the IDNR established the Kankakee River Nature Preserve in 1966. The preserve comprises a 135-ac (55-ha) area that includes an island in the middle of the river, and the IDNR has designated the portion of the river bordered by the preserve as a Biologically Significant Stream because it supports one of the State's most diverse aquatic communities (IDNR 2014b; Page et al. 1991).

3.7.6 Non-Native Species

Several non-native species, including the common carp, Asian clam (*Corbicula fluminea*), and rusty crayfish (*Orconectes rusticus*), have been introduced into the Kankakee River (IDNR 1998).

Common carp feed by rooting through substrates for insects, crustaceans, and benthic worms. This behavior can dislodge shallowly rooted plants, which causes decreased food or shelter for species that rely upon aquatic vegetation, increased water turbidity, and decreased water clarity. The IDNR (1998) indicates that the effect of the species in Illinois is difficult to determine because the species has been present in Illinois waters since the earliest recorded surveys.

Common carp were present in the vicinity of the site prior to Braidwood operation (AEC 1974; NRC 1984) and have consistently dominated annual operational monitoring sample biomass since 1993 (HDR 2013b).

The Asian clam was first documented in the Kankakee River in 1978 (IDNR 1998). The species competes with native mussels for limited food and habitat resources. Asian clams have occurred in the vicinity of Braidwood since the plant began operating (NRC 1984), and Exelon treats its cooling water system to prevent biofouling (see Section 3.1.3).

The rusty crayfish, which was likely introduced by fishers as bait, outcompetes native crayfish, including the ecologically similar White River crayfish (*Procambarus acutus*). No surveys have assessed crustacean populations in the vicinity of Braidwood, so it is unknown whether this species occurs in the vicinity of the site.

3.8 Federally Protected Species and Habitats

Because NRC's issuance of a renewed license for power plants is a Federal action, the NRC's National Environmental Policy Act (NEPA) process considers species and habitats that are protected under Federal acts and possibly affected by license renewal. Federal acts that protect species and habitats possibly affected by the renewal of a nuclear plant license include the Endangered Species Act of 1973, as amended (ESA); the BGEPA of 1940, as amended; the MBTA of 1918, as amended; the Magnuson-Stevens Fishery Conservation and Management Act, as amended (MSA); and the Marine Mammal Protection Act of 1972, as amended. Of these, the NRC has direct responsibilities only under the ESA and MSA. No species protected under the MSA, which protects habitat for certain marine and anadromous fish species, occur near Braidwood. Species protected under the ESA are discussed in this section, and species protected under other Federal acts where the NRC has no direct responsibilities and under state acts are discussed in sections for terrestrial and aquatic resources.

Section 7(a)(2) of the ESA states that each Federal agency shall, in consultation with the Secretary (Secretary of Commerce or Secretary of the Interior), insure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat. In fulfilling these requirements, each agency is to use the best scientific and commercial data available. This section of the Act sets out the consultation process, which is further implemented by regulation (50 CFR 402). The ESA makes it unlawful for a person to take a listed animal without a permit, where "take" under the ESA is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." Through regulations, the term "harm" is defined as "an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering (50 CFR 17.3). Listed plants are not protected from take, although collecting or maliciously harming them on Federal land is illegal.

The FWS and the National Marine Fisheries Service (NMFS) jointly administer the ESA. The FWS manages the protection of and recovery efforts for listed terrestrial and freshwater species, and the NMFS manages the protection of and recovery efforts for listed marine and anadromous species, of which none occur in the Kankakee River.

3.8.1 Action Areas

The ESA regulations at 50 CFR 402.02 define “action area” to mean all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action. The action area helps frame the ESA effects analysis because species that occur within the action area may be affected by the Federal action, while species that do not occur within the action area would likely not be affected by the Federal action. Depending on biology, different species may require different action areas.

Braidwood occupies about 1804 ha (4,457 ac) in Will County, Illinois, including a 1030-ha (2,540-ac) cooling pond created by flooding portions of a former strip mine (Exelon 2013e). A ROW for the water intake and discharge pipes runs from the northeast site boundary approximately 8 km (5 mi) east to the Kankakee River, which is the source of the cooling pond’s makeup water and the receiving body for the cooling pond’s discharge. Braidwood is connected to the regional grid at the onsite 345-kV Braidwood switchyard (Exelon 2013e). Under the 2013 generic environmental impact statement (GEIS) (NRC 2013a), only the transmission lines going to the onsite switchyard that connects Braidwood to the regional grid are in scope for this license renewal environmental review.

For Federally protected terrestrial species, the action area is the site, including the water intake and discharge pipe ROW, and areas immediately around the site that could include natural populations affected by plant operations. Within the action area, Federally listed terrestrial species could experience impacts such as habitat disturbance associated with refurbishment or other ground-disturbing activities, cooling tower drift, collisions with cooling towers and transmission lines, exposure to radionuclides, and other direct and indirect impacts associated with station, cooling system, and in-scope transmission line operation and maintenance (NRC 2013a).

For Federally protected aquatic species, the action area is the site and the Kankakee River in the area affected by water withdrawal and discharge as well as the range of any species affected by water withdrawal and discharge. The license renewal of nuclear plants action can affect Federally listed aquatic species in several ways, such as impingement or entrainment of individuals into the cooling system, alteration of the riverine environment through water level reductions, changes in dissolved oxygen, gas supersaturation, eutrophication, thermal discharges from cooling system operation, habitat loss or alteration from dredging, and exposure to radionuclides (NRC 2013a).

3.8.2 Federally Protected Species and Habitats Considered

On September 11, 2013, NRC sent a letter to FWS requesting concurrence with a list of Federally-listed species for Braidwood (NRC 2013c). On September 24, 2013, FWS (2013d) replied with a letter that included scoping comments and comments on the NRC’s list of Federally-listed species for Braidwood. Following release of the 2013 GEIS, which redefines the in-scope area of transmission lines for the purposes of NEPA, the NRC decided to change geographic scope of the Braidwood SEIS to follow the 2013 GEIS in regard to transmission lines. This change of in-scope area changed the list of listed species compared to NRC’s September 11 letter to FWS. Because the FWS’s Rock Island Field Office no longer responds to species list requests (FWS 2013a), NRC staff did not submit a revised list to FWS. The NRC compiled the list of species in Table 3–17 from the FWS’s Endangered Species Program online database (FWS 2014a, 2014c).

Table 3–17. Federally Listed Species in Will County, Illinois

Group	Federally Listed Species	Common Name	Federal Status[a]	Habitat
Clams and Mussels	*Plethobasus cyphyus*	sheepnose mussel	E	Shallow areas in larger rivers and streams
	Epioblasma triquetra	snuffbox	E	Small to medium-sized creeks and some larger rivers, in areas with a swift current
Insects	*Somatochlora hineana*	Hine's emerald dragonfly	E	Spring-fed wetlands, wet marshes, and marshes
Plants	*Platanthera leucophaea*	eastern prairie fringed orchid	T	Mesic prairie, wetlands, sedge meadows, marsh edges, and bogs with full sun and little to no woody encroachment
	Hymenopsis herbacea	lakeside daisy	T	Dry, rocky prairies
	Delea foliosa	leafy prairie clover	E	Prairie remnants on thin soil over limestone
	Asclepias meadii	Mead's milkweed	T	Late successional tallgrass prairie, tallgrass prairie converted to hay meadow, and glades or barriers with thin soil
	Proposed Species			
Mammals	*Myotis septentrionalis*	northern long-eared bat		Winter: caves and mines. Summer: mature forests.
	Candidate Species			
Reptiles (snakes)	*Sistrurus catenatus*	eastern massasauga		Graminoid-dominated plant communities (fens, sedge meadows, peatlands, wet prairies, open woodlands, and shrublands)
Insects	*Papaipema eryngii*	rattlesnake-master borer moth		Undisturbed prairie and woodland openings that contain their only food plant, rattlesnake-master
	Critical Habitat			
	None			

[a] E=endangered; T=threatened

Sources: FWS 2014a, 2014c

Sheepnose Mussel (*Plethobasus cyphyus*). The FWS listed the sheepnose mussel (also called just sheepnose) as endangered on March 13, 2012, with an effective date of April 12, 2012 (77 FR 14914). The sheepnose mussel is a freshwater mussel in the family Unionidae.

According to Parmalee and Bogan (1998), adult mussels may reach 11 to 12 cm (4.3 to 4.8 in) in length. Adult mussels are found partially or completely buried in the substrate. They are suspension feeders and eat bacteria, algae, microscopic animals, and detritus (77 FR 14914). It is found in large rivers in gravel or mixed sand and gravel (INHS 2013). Further, in unimpounded rivers, sheepnose mussels can be found in less than 0.6 m (2 ft) of water and in relatively fast currents. In reservoirs, sheepnose mussels occupy depths of 3.6 to 4.6 m (12 to 15 ft) (Parmalee and Bogan 1998), though they have also been reported at depths exceeding 6 m (20 ft) (77 FR 14914). Sheepnose mussels are long-lived and can live nearly 100 to 200 years (FWS 2013h).

Like other unionids, sheepnose has an unusual life cycle. After fertilization, the eggs live in special gill chambers of the females and develop into microscopic larvae called glochidia. Females brood the glochidia. When the glochidia are ready, the female expels the glochidia, which then must attach to the host fish's gills or fins to complete development by enclosing themselves in a cyst (encysting). They drop off the host fish as newly transformed juveniles. The sauger (*Sander canadensis*) is the only known fish host for sheepnose mussel glochidia.

The sheepnose mussel is found across the Southeast and the Midwest, although it has been eliminated from about two-thirds of its range. Today, the sheepnose mussel is found in Alabama, Illinois, Indiana, Iowa, Kentucky, Minnesota, Mississippi, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin.

<u>Snuffbox (*Epioblasma triquetra*)</u>. Snuffbox is a freshwater mussel belonging to the family Unionidae that the FWS designated as endangered through its range in 2012 (77 FR 8632). Unless otherwise cited, information for the present summary is from the FWS's listing document (77 FR 8632). Adults are small to medium sized mussels: males attain lengths up to 7.0 cm (2.8 in.) and females 4.5 cm (1.8 in.). The shells are somewhat triangular in females and oblong or ovate in males, with the anterior of the shell being rounded and the posterior truncated. The shells are solid and thick and typically smooth and yellowish or yellowish-green in young individuals and become darker with age. Snuffbox reproductive and maximum ages are unknown, but unionids are generally long-lived and maximum ages can exceed that of humans.

Juveniles and adults live in the substrate of small to medium-sized creeks with swift currents with riffles and in sand, gravel, and pebbles of wave-washed lake shores. Except when spawning, they live in burrows that are deep into the substrate. The adults are suspension feeders that consume algae, bacteria, detritus, and microscopic animals. They may also deposit-feed on particles in the sediment.

Snuffbox has separate male and female individuals. Like other unionids, snuffbox has an unusual life cycle, although all the details are not known for snuffbox. After fertilization, the eggs live in special gill chambers of the females and develop into microscopic larvae called glochidia. Females may brood the glochidia from September to May. When the glochidia are ready, female snuffbox move to the surface and may attract host fish, whereupon the female expels the glochidia, which then must attach to the host fish's gills or fins to complete development by enclosing themselves in a cyst (encysting). They drop off the host fish as newly transformed juveniles.

Different unionid species require different host fishes. In the laboratory, juvenile snuffbox have successfully transformed on logperch (*Percina caprodes*), blackside darter (*P. maculata*), rainbow darter (*Etheostoma caeruleum*), Iowa darter (*E. exile*), blackspotted topminnow (*Fundulus olivaceous*), mottled sculpin (*Cottus bairdii*), banded sculpin (*Cottus carolinae*), Ozark sculpin (*Cottus hypselurus*), largemouth bass (*Micropterus salmoides*), and brook stickleback (*Culaea inconstans*). Tiemann (2010) reports that logperch may be the predominant host fish in Illinois, and logperch populations have been declining there.

The snuffbox was once widespread and occurred in 210 lakes and streams in 18 states and 1 Canadian province, and today, extant (currently existing) populations are known from 79 streams in 14 states and 1 Canadian province. Many of these extant populations are small, highly fragmented, and restricted to short stream reaches, and 25 of the 79 extant populations are represented by only one or two recent live or fresh-dead individuals. The primary cause of the reduction in range has been the modification and destruction of river and stream habitats. This is due primarily to construction of impoundments because dams interrupt a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, and energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; decreasing stability due to subsequent sedimentation; blocking host fish passage; and isolating mussel populations from fish hosts. Other causes include modification or destruction of habitat due to dredging and channelization, chemical contamination from industrial and agricultural sources, legacy pollutants in sediments, mining runoff in some areas (e.g., gravel mining along the Kankakee River), siltation, draining of wetlands, removal of riparian areas, development in flood plains, invasive species, and reduction of fish host populations from all of the above (77 FR 8632; Tiemann 2010). Regarding cumulative effects, the warming due to climate change can increase the toxicity of many contaminants to freshwater mussels.

In Illinois, the snuffbox is presently known only in the Kankakee and Embarras Rivers. Fresh-dead individuals were found in Will County (where Braidwood is located) in 1988 and Kankakee County in 1991, and only relic shells have been found in the Kankakee River since then. If an extant Kankakee River population exits, it most likely is small, localized, and of doubtful viability, and Tiemann (2010) considers the snuffbox to be functionally extinct in Illinois.

<u>Hine's Emerald Dragonfly (*Somatochlora hineana*)</u>. Hine's emerald dragonfly has emerald-green eyes and a dark brown and metallic green body, with yellow stripes on its sides. Its body is about 2.5 in. (6.4 cm) long, and its wingspan is about 3.3 in. (84 cm). It has probably been extirpated in Alabama, Indiana, and Ohio, and today can only be found in Illinois, Michigan, Missouri, and Wisconsin. This dragonfly lives in calcareous (high in calcium carbonate) spring-fed marshes and sedge meadows overlaying dolomite bedrock.

Adults, which live only about 3 to 4 weeks, catch and eat smaller flying insects, including mosquitoes, biting flies, and gnats. The adult males defend small breeding territories, and pursue and mate with females who enter their territories. The females lay eggs in shallow water. Later in the season or the following spring, immature dragonflies, called nymphs, hatch from the eggs. The nymphs live in the water for 2 to 4 years, eat smaller aquatic insects, and shed their skins many times as they grow. In turn, the nymphs are important food for fish. FWS reviews (FWS 2006, 2013b) provide more information on this species.

The FWS listed Hine's emerald butterfly as an endangered species in 1995 (60 FR 5267), designated critical habitat for it in 2007 (72 FR 51102) and revised the critical habitat designation in 2010 (75 FR 21394). FWS did not designate critical habitat on or immediately adjacent to the Braidwood site, and Exelon (2013e) reports that the nearest designated critical habitat to the Braidwood site is about 37 km (23 mi) away. Exelon (2013e) reports no observations of this species on the Braidwood site.

<u>Eastern Prairie Fringed Orchid (*Platanthera leucophaea*)</u>. The eastern prairie fringed orchid is 1 of at least 200 North American orchid species and is a perennial herb. Plants are about 8 to 40 in. (0.2 to 1 m) tall. An upright leafy stem carries a flower cluster called an inflorescence. The 3- to 8-in. (76- to 200-cm) lance-shaped leaves sheath the stem. Each plant has one single flower spike composed of 5 to 40 creamy white flowers, and the blossoms often rise just above

the height of the surrounding grasses and sedges. Blooming occurs in late June and early July. Night-flying hawkmoths (family Sphingidae) pollinate the nocturnally fragrant flowers.

This species typically inhabits tallgrass prairies east of the Mississippi River that have calcareous silt loam soils and calcareous wetlands with open portions of fends, sedge meadows, marshes, and bogs. While once numerous and wide spread, populations have declined with the disappearance of eastern prairies by conversion of habitat for crop fields, grazing, intensive and continuous hay mowing, drainage, and related human uses. Other reasons for the decline include succession to woody vegetation, competition from non-native species, and over-collection. Remaining populations tend to be small, unprotected, and unmanaged. The FWS designated the eastern prairie fringed orchid as an endangered species in 1989 (54 FR 39857) and in 2012 initiated a 5-year status review of the listing (77 FR 38762). In addition to the FWS listing document, another source of information is an FWS fact sheet (FWS 2013g). FWS did not designate critical habitat for this species. Exelon (2013e) reports no observations of this species on the Braidwood site.

Lakeside Daisy (*Hymenopsis* (also *Tetraneurus*) *herbacea*). Lakeside daisy is a member of the Asteraceae (also called Compositae) family, a large group of plants with over 23,000 species that includes asters, daisies, and sunflowers. It is an herbaceous, spring-blooming perennial with yellow blossoms. This plant is found in dry, rocky prairie grassland underlain by limestone, and it requires open sites with full sun. Fire suppression practices have eliminated the wildfires that once regularly cleared prairie grasslands of the encroaching woods, and the expansion of shrubs and trees threatens the daisy. Other threats to the species include habitat destruction by quarrying, over collection, off-road vehicles, and herbivory by rabbits, deer, and weevils (FWS 2013c).

While it may once have been widespread in the Great Lakes region, it is now found in only a few sites in the U.S. Although lakeside daisy has been reported from Will County, Illinois, where Braidwood is located, the FWS (53 FR 23742) considers the Illinois populations to be extirpated. The FWS listed the lakeside daisy as a threatened species in 1988 (53 FR 23742). FWS did not designate critical habitat. Exelon (2013e) reports no observations of lakeside daisy on the Braidwood site.

Leafy Prairie-Clover (*Delea foliosa*). The FWS listed the leafy prairie-clover as endangered throughout its range in 1991 (56 FR 19953), when it was known to be present only in two sites in Alabama, nine sites in Tennessee, and three sites in Illinois. The FWS did not designate critical habitat for leafy prairie-clover. The species is perennial and a member of the pea family (Fabaceae). The plants grow erect stems about 0.5-m (1.5-ft) tall, on the end of which grow small purple flowers in dense spikes. Flowering begins in August, and seeds ripen in early October, after which the above-ground portion of the plant dies while the below ground portion survives the winter (56 FR 19953).

This plant is typically found in dry prairies, often in dolomitic soils. In Illinois, leafy prairie-clover was originally known from six counties in the northeastern part of the state, but by 1991 only three populations were known in the state, all in Will County (where Braidwood is located) in prairie remnants along the Des Plaines River (56 FR 19953). The USFS (undated a) lists the reasons for its decline as plant and habitat loss from inundation by dams, road work, and ROW management, including herbicide effects; botanical and horticultural collection; off-road vehicle impacts to plants and habitat; predation by deer and rabbits; encroachment of woody plants; and severe drought. Its habitat is being lost as dolomite prairies are being converted to industrial, commercial, and residential uses (USFS undated b). Recovery efforts by a partnership of the FWS (Chicago Field Office), the USFS, the Forest Preserve District of Will County, the Department of the Army (Joliet Training Area), the IDNR, the Forest Preserve

District of Kane County, and Midewin National Tallgrass Prairie are underway in northeastern Illinois (USFS undated b). Exelon (2013e) reports no observations of this species on the Braidwood site.

<u>Mead's Milkweed (*Asclepias meadii*)</u>. Mead's milkweed is a long-lived prairie perennial herb belonging to the family Asclepiadaceae (milkweeds), which is part of the subclass Asteridae (asters). It has a slender, unbranched stalk that at maturity carries an umbrella-like cluster of greenish, cream-colored flowers. It may take 15 years or more to mature from a germinating seed to a flowering plant. This milkweed requires moderately wet to moderately dry upland tallgrass prairie or glade-and-barren habitat characterized by vegetation adapted for drought and fire.

The historic range of Mead's milkweed included much of the eastern tallgrass prairie of the central U.S. It is now restricted to sites in 34 counties in southern Illinois, south-central Iowa, eastern Kansa, and Missouri. Recovery actions include land management for existing populations and reintroductions.

It is threatened by the destruction of tall grass prairie due to agricultural expansion, urban growth, and agricultural practices such as mowing and grazing that are detrimental to the plant's reproductive cycle. The tallgrass prairie habitat required by Mead's milkweed is being eliminated by plowing, conversion to grazing, and development. Habitat fragmentation may help explain the loss of genetic diversity and failure of the plants to mature, as smaller habitat fragments support lower numbers of plants that may not attract sufficient numbers and types of pollinators (FWS 2013e).

The FWS designated Mead's milkweed as a threatened species in 1988. The FWS (53 FR 33992) did not designate critical habitat because "no benefit to the species can be identified that would outweigh the potential threat of vandalism or collection, which might be exacerbated by the publication of a detailed critical habitat map." Exelon (2013e) reports no observations of Mead's milkweed on the Braidwood site.

<u>Northern Long-Eared Bat (*Myotis septentrionalis*)</u>. In December 2013, the FWS (78 FR 72058) found that listing of the northern long-eared bat as an endangered species under the ESA was warranted. Earlier in October 2013, the FWS (78 FR 61046) had found that it could not determine critical habitat for this species. The following information is from those listing documents. The northern long-eared bat is a medium-sized bat species with average adult body weights of 5 to 8 g (0.2 to 0.3 oz), adult body lengths between 77 to 95 mm (3.0 to 3.7 in.) and wingspans between 228 and 258 mm (8.9 to 10.2 in.). Adult fur is typically brown, darker on top than below. The range includes much of the eastern and north central United States (it occurs in 39 states) and all Canadian provinces west to the southern Yukon Territory and eastern British Columbia. Throughout the majority of this range, however, it is patchily distributed, and historically it was less common in the southern and western part of its range than in the northern portion. The bats gather and hibernate in winter in areas called hibernacula, typically mines and caves, where they are now usually found only in low numbers. They migrate out of the hibernacula in summer, when they forage at night and roost during daylight in small numbers in live and dead trees and change roosts often. Their diet includes moths, flies, leafhoppers, caddisflies, and beetles, although the diet differs geographically and seasonally, and an individual can consume 3,000 insects each night. Mating occurs in the autumn and birthing in May or June. Mature forests are an important habitat type for northern long-eared bats, although they occasionally act as forager over forest clearings and along roads. The northern long-eared bat has experienced a sharp decline, estimated at approximately 99 percent from hibernacula data, in the northeastern portion of its range due to the recent emergence of a fungal disease known as white-nose syndrome (WNS; currently

called *Geomycetes destructans*), and FWS expects similar declines in the western part of its range as this disease spreads. Human activities that threaten this species include constructing physical barriers at cave accesses and destruction of habitat through mining, flooding, vandalism, development, timber harvest, and other activities. Surveys in Shawnee National Forrest in Illinois, about 300 mi south of Braidwood, consistently catch northern long-eared bats. FWS has confirmed the presence of WNS in Illinois. Exelon (2013e) plans no landscape-changing activities that might require an ESA conference on northern long-eared bats.

<u>Eastern Massasauga (*Sistrurus catenatus*)</u>. The FWS (76 FR 66370) lists the eastern massasauga, a rattlesnake, as a candidate species. A candidate species is one for which FWS has on file sufficient information on biological vulnerability and threats to support a proposal to list as endangered or threatened, but for which preparation and publication of a proposal is precluded by higher priority listing actions. Candidate species do not receive the Federal protection afforded to threatened and endangered species. In 2011, FWS reviewed and changed the priority of eastern massasauga as a candidate species (76 FR 66370) when recent information indicated that it was a distinct species rather than one of three subspecies of massasauga.

The eastern massasauga is a small, thick-bodied rattlesnake that occupies shallow wetlands and adjacent upland habitat in portions of Illinois, Indiana, Iowa, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and Ontario. The current range resembles the historical range, but populations have decreased. About 40 percent of the counties that it previously occupied no longer support populations, and FWS considers less than 35 percent of the remaining populations secure. The FWS lists threats to this species as “habitat modification, habitat succession, incompatible land management practices, illegal collection for the pet trade, and human persecution” (76 FR 66370).

In Illinois, eastern massasauga has been historically recorded for Cook, DuPage, Lake, and Will Counties. The FWS Chicago Field office is working with the IDNR to establish an Illinois Eastern Massasauga Recovery Team to work on conserving remaining Illinois populations of this species (FWS 2013f). Exelon (2013e) reports no observations of this species on the Braidwood site.

<u>Rattlesnake-master Borer Moth (*Papaipema eryngii*)</u>. Rattlesnake-master borer moths (also called *Eryngium* stem borers) feed exclusively on a prairie plant, rattlesnake-master (*Eryngium yuccifolium*), from which the moth derives its name. On August 14, 2013, the FWS identified the rattlesnake-master borer moth as a candidate species for listing as an endangered or threatened species (78 FR 49422, 78 FR 70104). The following information is from those listing documents. Females drop their eggs near rattlesnake-mast plants in mid-October, where the eggs overwinter in leaf litter. The young larvae hatch between mid-May and June and feed on the leaves of the host plant. Later larval stages burrow into the stem or root, where they actively bore and create a chamber where they may remain until they pupate. The boring activities may kill the host plant or prevent it from flowering. Adults emerge from mid-September to mid-October and fly through mid- to late October. Adults make a single short mating flight per year and do not disperse widely. Their nocturnal habits make them hard to observe, so that adult feeding habits are unknown. Their biology suggests that they likely feed on dew or oozing sap for moisture.

Rattlesnake-master borer moths require a habitat of undisturbed prairie and woodland openings that contain their only food plant, rattlesnake-master. The moth is currently known to occur in five States: Illinois, Arkansas, Kentucky, North Carolina, and Oklahoma. Because its food plant ranges across 26 States, the historical range was no doubt much larger. Between 82 and

99 percent of original tallgrass prairie habitat has been lost, with most prairie destruction occurring between 1840 and 1900, and most of the remaining high-quality prairies are small and scattered across the landscape. Although the rattlesnake-master borer moth is common in such remnant prairies, it occurs at low densities. The continuing effects of habitat fragmentation and isolation of small populations are a threat to the rattlesnake-master borer moth across its range. Documented and predicted climate-related changes indicate increased future threats from increased severity and frequency of droughts, floods, fires, and other climate-related changes.

The State of Illinois has the most rattlesnake-master borer moth sites of any state: 10 known sites in 8 counties (Will, Cook, Grundy, Livingston, Kankakee, Marion, Effingham, and Fayette). Two sites occur in Will County, in which Braidwood is located. FWS considers one of the sites to harbor an extant population but is unsure of the status on the other site because the most recent survey (2008) found no sign of the species and it may now be extirpated. Exelon (2013e) reports no observations of this species on the Braidwood site.

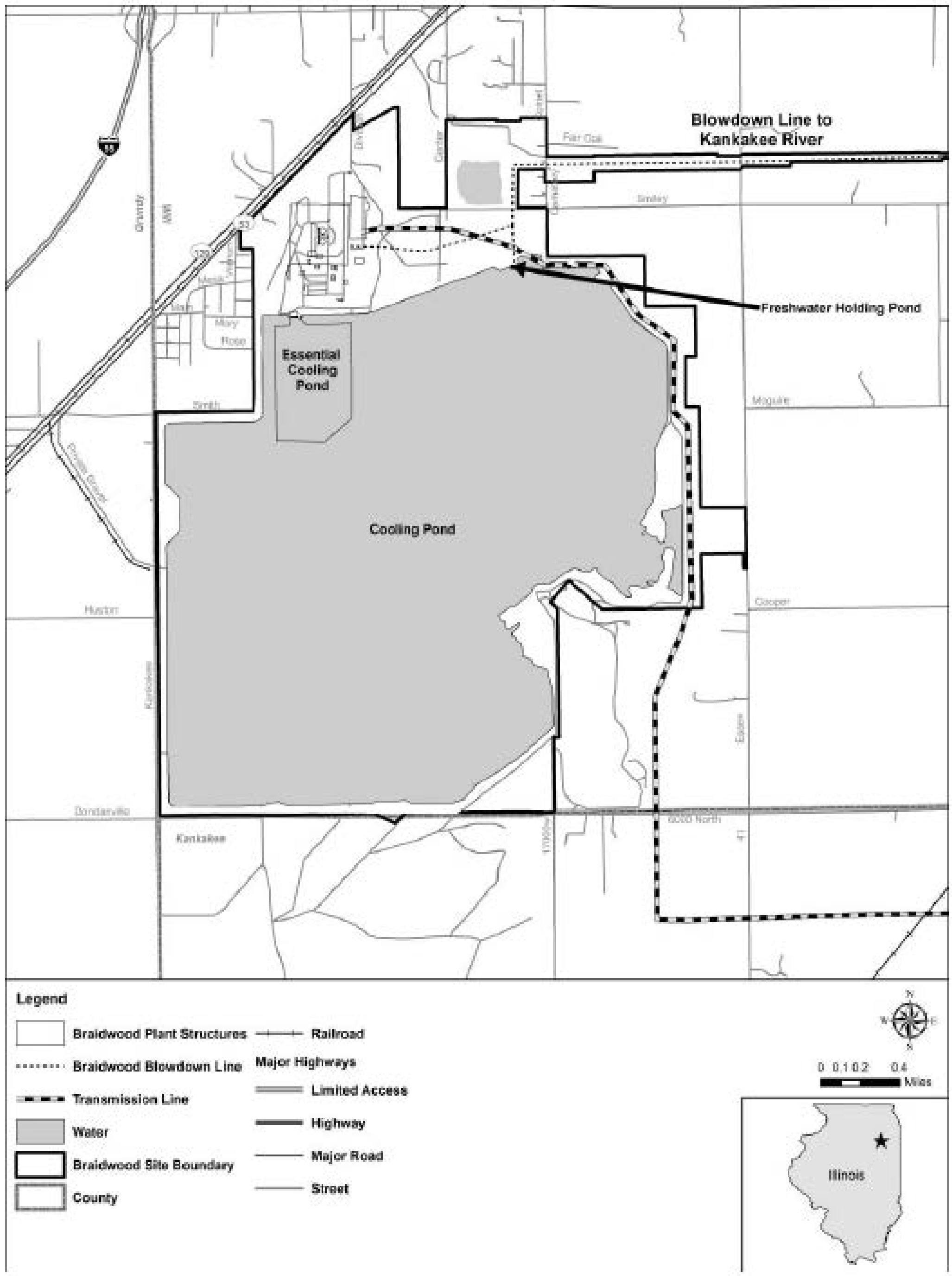
Summary of the Occurrence of Listed Species Within the Action Area. The ten species listed in Table 3-17 are under the FWS's jurisdiction within Will County, although the information is not specific to the Braidwood site. For the several species identified for Will County (Table 3-17), the NRC staff did not identify any within the action area after review of the ER (Exelon 2013e), a site visit that included discussions with site staff and review of on-site documents, and published and online sources. Sections 3.6 Terrestrial Resources and 3.7 Aquatic Resources summarize the ecological surveys performed on and near the Braidwood site that would detect protected species. Exelon (2013e) reports that the only species on Table 3-17 observed on or near the Braidwood site was a "fresh-dead" sheepnose mussel collected in the Kankakee River in the vicinity of the Braidwood discharge diffuser in 2008.

3.9 Historic and Cultural Resources

This section discusses the cultural background and the known historic and cultural resources found on and in the vicinity of Braidwood. The discussion is based on a review of historic and cultural resource surveys and other background information on the region surrounding Braidwood. In addition, a records search was performed via the Illinois Historic Preservation Agency (IHPA) (Pauketat 1993) to obtain the most updated information about historic and cultural resources in the region.

The Area of Potential Effect (APE) is the area at the Braidwood power plant site, the transmission lines up to the first substation, and immediate environs that may be affected by the license renewal decision and land-disturbing activities associated with continued reactor operations. For this analysis, the first substation (345 kV Braidwood switchyard) is located on the Braidwood site (Exelon 2014b). The APE may extend beyond the immediate environs in instances where land-disturbing maintenance and operations activities during the license renewal term or refurbishment activities could potentially have an effect. See Figure 3–19.

Figure 3–19. Braidwood Site Property



Source: Exelon 2013e, Figure 3.1-1

3.9.1 Cultural Background

Human occupation in the vicinity of Braidwood site is generally characterized according to the following chronological sequence (Pauketat 1993):

- Paleo-Indian Period (12,000 – 10,000 before present (BP)),
- Archaic Period (10,000 – 3,000 BP),
- Woodland Period (3,000 – 1,100 BP),
- Mississippian Period (1,100 – 400 BP (ca. A.D. 900 – 1600)), and
- Protohistoric/Historic Period (400 – present (ca. A.D. 1600 – present)).

Paleo-Indian Period (12,000 – 10,000 B.P.). The earliest evidence of people living in Illinois dates to the Paleo-Indian Period. Paleo-Indian sites are generally found upland or on river terraces and are characterized by specific types of projectile points (i.e., fluted Clovis and Folsom points) and stone tools such as gravers, scrapers or large blades. These artifacts often occur in association with mastodon remains, suggesting a reliance on megafauna (e.g., mammoth, ground sloth, and saber-tooth tiger) for subsistence along with plants, small game, birds, and amphibians. Social organization consisted of small, highly nomadic bands of hunter-gathers, leaving Paleo-Indian sites with little detailed archaeological information (Neusius and Gross 2007; Pauketat 1993).

Archaic Period (10,000 – 3,000 B.P.). The Archaic Period was a time of major climatic shifts as colder environments transitioned to warmer environments similar to modern conditions. In response to this shift, new technologies and subsistence strategies were developed during this time. The Archaic Period is often divided into early, middle, and late subperiods. The Early Archaic Period is characterized by a shift from nomadic to sedentary settlement patterns, with central base camps located on river terraces and smaller hunting camps located in upland areas. This subperiod also shows an increased reliance on wild plant foods, small game, and aquatic resources. The Middle Archaic Period is characterized by an increased number of settlement sites on high stream terraces, which may reflect population increases. While subsistence and settlement patterns remained fairly similar to the Early Archaic Period, artifact assemblages suggest increased exploitation of aquatic resources as well as new artifacts (e.g., pecked and ground stone tools used for intensive processing of nuts; banner stones that signaled the innovation of a new projectile technology called the atlatl or spear-thrower; and grooved axes). The Late Archaic Period is characterized by an increase in the number and size of settlement sites, which indicates an increase in population and a more sedentary lifestyle. New features of Late Archaic artifact assemblages, such as crude ceramic vessels, represent a shift towards increased reliance on horticulture as a subsistence strategy, although hunting and gathering would have continued (Fagan 2005; Neusius and Gross 2007; Pauketat 1993).

Woodland Period (3,000 – 1,100 B.P.). The Woodland Period is also often divided into early, middle, and late periods. However, the distinction between the early and middle period is not fixed. The Woodland Period is marked by an increase in more permanent settlements, changes in burial practices, increased cultivation of plants such as sunflowers and cucurbits (i.e., squashes, gourds, melons, etc.), and a rise in the manufacture and use of pottery (Fagan 2005). During the Middle Woodland Period, the large and complex Hopewell Culture emerged in the northeastern and midwestern United States, including Illinois. This culture is characterized by settlement in villages, increased reliance on intensive horticulture, burial mounds, and long distance trade networks. These long distance networks allowed the trade of exotic materials, such as marine shells from the Gulf Coast, obsidian from the Rocky Mountains, copper from Lake Superior, and mica from the Appalachian Mountains far outside their immediate locations. Evidence of the Illinois Hopewell culture is found primarily in the bluffs and floodplains of the Illinois River Valley. The burial mounds of this period often included central features, lined with logs, and filled with grave goods. Different burial treatments within the mounds point to social stratification within society, but through sex and age rather than

hereditary lineage (Neusius and Gross 2007). The Late Woodland Period is characterized by an increase in settlement sites, which suggests (a) a rise in population, or (b) a change in settlement patterns from large, centralized village sites to smaller, dispersed habitation sites, or both. Late Woodland Period artifact assemblages are characterized by an increase in thin-walled plain ceramic types and stemmed and side-notched projectile points. The sudden appearance of very small, thin triangular projectile points between 1,300 and 1,400 BP indicates the invention of bow-and-arrow technology and suggests a corresponding change in hunting techniques (Fagan 2005).

Mississippian Period (1,100 – 400 B.P. (ca. A.D. 900 – 1600)). The Mississippian Period is characterized by major changes in settlement, subsistence patterns, and social structure. Large highly centralized chiefdoms with permanent settlements sites supported by numerous satellite villages emerged during this period. The platform mound, a new ceremonial earthen mound appeared in association with these permanent settlements. Platform mounds, burial mounds, and defensive structures, such as moats and palisades, were often constructed in clusters in settlements of this period and were common in the larger river valleys of the Midwest. Mississippian Period subsistence relied heavily on maize agriculture, as well as hunting and gathering. Long distance trading increased and craft specialists produced highly specialized lithic and ceramic artifacts, beadwork and shell pendants (Fagan 2005). Examples of Mississippian Period occupation within Will County is the Fisher site, 16.5-ac village site containing habitation and burial features, and the Briscoe Mounds, a site containing two burial mounds estimated to have been constructed between A.D. 1000 and A.D. 1200 (WJE 2009). In southern Wisconsin and northern Illinois, the emerging Mississippian culture was blended with the receding Woodland culture to produce the Oneota tradition. The Oneota cultural complex is marked by permanent villages, produced unique ceramic artifacts, and relied on a mixed subsistence strategy of hunting and gathering, though cultivation of maize was practiced. Burial traditions varied from the mounds of the Woodland Period to non-mounded cemeteries near villages (Exelon 2013; Neusius and Gross 2007).

Protohistoric/Historic Period (A.D. 1600 – Present). The end of the Mississippian Period is characterized by severe social, political, and demographic changes that resulted from indirect and direct contact with Europeans. In particular, it is believed that the introduction of European infectious diseases such as smallpox, yellow fever, typhoid, and influenza severely decimated Native American populations, which had no immunity to these diseases. The spread of these diseases, which were fatal to large numbers of Native Americans, resulted in the widespread abandonment of villages and a concurrent collapse of Native American socioeconomic networks, such that by the time of widespread European contact and settlement, the Mississippian chiefdoms were gone (Fagan 2005). In 1832 in Will County, approximately one-third of the Native American population in the region died during a smallpox epidemic (WJE 2009). During the historic period, Illinois was primarily populated with a confederation of tribes known as the Illinois, or Illiniwek, and the Miami tribe. During the 1700s and early 1800s, new tribes migrated to Illinois, including the Iroquois, Fox (Mesquakie), Ioway, Kickapoo, Mascouten, Piankashaw, Potawatomi, Sauk, Shawnee, Wea, and Winnebago. Competition for resources led to sporadic war among the Illinois, surrounding tribes, and European immigrants to the area for approximately the next 120 years (ISM 2002). In 1673, the expedition of Father Jacques Marquette and Louis Jolliet traveled along the Mississippi River and up the Illinois River to Will County claiming the region for France. French influence in the Illinois territory began to wane by the mid-1700s during the French and Indian War and in 1763 the French ceded land east of the Mississippi to the British who controlled the region until the Revolutionary War. Illinois became part of the Northwestern Territory at the close of the American Revolution. On January 12, 1836, Will County was created (WJE 2009). The area surrounding the

Braidwood site has principally been used for agriculture and coal mining from this period onward (Exelon 2013e).

3.9.2 Braidwood Historic and Cultural Resources

Braidwood historic and cultural resources include prehistoric era and historic era archaeological sites, historic districts, and buildings, as well as any site, structure, or object that may be considered eligible for listing on the National Register of Historic Places (NRHP). Historic and cultural resources also include traditional cultural properties that are important to a living community of people for maintaining their culture. "Historic property" is the legal term for a historic or cultural resource that is eligible for listing on the NRHP.

A review of databases maintained by the National Park Service indicates that there are 35 properties listed in the NRHP within Will County, including one that has been designated a National Historic Landmark (IHPA 2013). These historic properties reflect the historic cultural contexts for the Braidwood property and include a prehistoric mound and historic buildings, structures and districts dating from the mid-18th through mid-20th centuries. However, none of the historic properties are located within the boundaries of the Braidwood property (IHPA 2013). The closest NRHP eligible site is in Wilmington, Illinois, approximately 6 mi (9 km) to the northeast.

In 1973, Phase I archaeological surveys were undertaken by the Illinois State Museum (ISM) for all lands purchased by ComEd for the proposed construction of Braidwood Units 1 and 2. These surveys identified 16 prehistoric era archaeological sites within the area. Sites were primarily debris scatters, composed of lithics, fire-cracked rock, and ceramics. Survey methods were mostly at the surface reconnaissance level, though subsurface surveys were conducted for two sites, which yielded a projectile point and Late-Woodland era pottery sherds. Surveyors concluded that construction at Braidwood would destroy the 16 sites found during the survey, via plant construction or reservoir inundation. However, the destruction would not be of a significant impact on the overall archaeological resources of Will County. Collections of the existing sites were made and site locations were recorded at the ISM. None of the sites were deemed eligible for the NRHP (McMillan 1973).

A search of the Illinois State Archaeological Site Files, a database maintained by the Illinois State Historic Preservation Officer, by NRC staff identified the 16 archaeological sites noted in the 1973 Phase I survey performed by the ISM (ISM 2014). No other cultural resources within the current confines of the Braidwood site were identified.

3.10 Socioeconomics

This section describes current socioeconomic factors that have the potential to be directly or indirectly affected by changes in operations at Braidwood. Braidwood, and the communities that support it, can be described as a dynamic socioeconomic system. The communities supply the people, goods, and services required to operate the nuclear power plant. Power plant operations, in turn, supply wages and benefits for people and dollar expenditures for goods and services. The measure of a community's ability to support Braidwood operations depends on its ability to respond to changing environmental, social, economic, and demographic conditions.

3.10.1 Power Plant Employment and Expenditures

The socioeconomics region of influence (ROI) is defined by the areas where Braidwood employees and their families reside, spend their income, and use their benefits, thus affecting the economic conditions of the region. Exelon Generation employs a permanent workforce of

approximately 885 employees and 20 long-term contract employees (Exelon 2013a, 2014a). Approximately 80 percent of Braidwood employees reside in a three-county area in northeastern Illinois in Will, Grundy, and Kankakee Counties. Most of the remaining 20 percent of the workforce are spread among 12 other counties in Illinois and 6 counties outside of Illinois, with numbers ranging from 1 to 37 employees per county (Exelon 2014a). Given the residential locations of Braidwood employees, the most significant effects of plant operations are likely to occur in Will, Grundy, and Kankakee counties. Table 3–18 summarizes the Braidwood workforce geographic distribution. The focus of the socioeconomic impact analysis in this SEIS is, therefore, on the impacts of continued Braidwood operations on these three counties, also termed the ROI.

Table 3–18. Exelon Generation Employees Residence by County

County	Number of Employees	Percentage of Total
Cook	36	4
DuPage	37	4
Grundy	216	24
Kankakee	95	11
Will	356	40
Other counties	145	17
Total	**885**	**100**

Source: Exelon 2014a

Exelon purchases goods and services to facilitate Braidwood operations. While specialized equipment and services are procured from a wider region, some proportion of the goods and services used in plant operations are acquired from within the ROI. These transactions fuel a portion of the local economy, as jobs are provided and additional local purchases are made by plant suppliers.

The Braidwood units are on staggered 18-month refueling intervals. During refueling outages, site employment typically increases by an average of 1,400 temporary workers for approximately 20 days (Exelon 2013a). Outage workers are drawn from all regions of the country; however, the majority would be expected to come from Illinois, Wisconsin, and other Midwestern states.

3.10.2 Regional Economic Characteristics

This section presents information on employment and income in the Braidwood socioeconomic ROI. The three-county ROI is predominantly rural and agricultural. Agricultural and forested land comprises the majority of the land use in Will, Grundy, and Kankakee Counties. Urban developed land only makes up about 10, 32, and 10 percent of total land area of each county, respectively (NASS 2014).

3.10.2.1 Employment and Income

From 2000 to 2012, the labor force in the Braidwood ROI increased approximately 28 percent to just over 454,000. The number of employed persons increased by about 21 percent over the same period, to approximately 410,000. Consequently, the number of unemployed people in the ROI has increased nearly 187 percent in the same period, to over 42,800, or about 9.4 percent of the current workforce – up from 4.2 percent in 2000 (BLS 2014).

According to the U.S. Census Bureau's (USCB's) 2008–2012 American Community Survey 5-Year Estimates, the educational, health, and social services industry represented the largest employment sector in the socioeconomic ROI (22.2 percent) followed by manufacturing (12.3 percent) and retail (11.8 percent). A list of employment by industry in each county of the ROI is provided in Table 3–19.

Table 3–19. Employment by Industry in the Braidwood ROI (5-year estimates 2008–2012)

Industry	Will	Grundy	Kankakee	Total	Percent
Total employed civilian workers	324,409	23,258	50,106	397,773	–
Agriculture, forestry, fishing, hunting, and mining	1,385	342	998	2,725	0.7
Construction	20,801	1,947	3,074	25,822	6.5
Manufacturing	39,165	2,852	6,935	48,952	12.3
Wholesale Trade	11,599	724	1,937	14,260	3.5
Retail Trade	38,425	2,872	5,982	47,279	11.8
Transportation, warehousing, and utilities	24,523	2,300	2,946	29,769	7.4
Information	6,682	294	644	7,620	1.9
Finance, insurance, real estate, rental, and leasing	23,392	1,103	2,876	27,371	6.8
Professional, scientific, management, administrative, and waste management services	35,101	1,552	2,837	13,226	9.9
Educational, health, and social services	70,314	4,720	13,572	88,606	22.2
Arts, entertainment, recreation, accommodation, and food services	26,517	2,665	4,192	33,374	8.3
Other services (except public administration)	14,370	971	2,324	17,665	4.4
Public administration	12,135	926	1,789	14,850	3.7

Source: USCB 2014c

Major employers in Will County, the county in which Braidwood is located, are listed in Table 3–20. Provena St. Joseph Medical Center is shown as the largest employer in the county.

Estimated income information for the Braidwood ROI is presented in Table 3–21. According to the USCB's 2008–2012 American Community Survey 5-Year Estimates, Will County had a median household income and per capita income higher than the State of Illinois. Grundy County had a higher median household income than the State of Illinois, but a lower per capita income. Kankakee County had a lower median household income and per capita income than the State of Illinois. Kankakee has the highest percentages of persons (16.1 percent) living below the official poverty level when compared to the other two counties and the State of Illinois as a whole. Will and Grundy Counties had 7.7 and 8.6 percent, respectively, and the State of Illinois as a whole had 13.7 percent. The percentage of families living below the poverty level in Will and Grundy Counties (5.9 and 6.5 percent, respectively) was lower than the percentage of families in Kankakee County and the State of Illinois as a whole (12.5 percent and 10 percent, respectively) (USCB 2014c).

Table 3–20. Top 10 Employers in Will County in 2012

Employer (City or Village)	Industry/Product/Service	Number of Employees
Provena St. Joseph Medical Center (Joliet)	Health care	2,673
Silver Cross Hospital (New Lenox)	Health care	1,800
Caterpillar, Inc. (Joliet)	Manufacturing of construction and mining equipment	1,500
Harrah's Joliet Casino (Joliet)	Casino and entertainment facility	1,100
Midwest Generation (Joliet)	Energy production	987
Southern Wine & Spirits of Illinois (Bolingbrook)	Wine and spirits distributor	900
Quantum Foods, Inc. (Bolingbrook)	Meat production and distribution	700
Comcast Cable Call Center	Customer service	700
Applied Systems (University Park)	Information services	700
RR Donnelly (Bolingbrook)	Information services	700

Source: Will County 2012

Table 3–21. Estimated Income Information for the Braidwood ROI (5-year estimates 2008–2012)

	Will	Grundy	Kankakee	Illinois
Median household income (dollars)[(a)]	76,352	63,840	49,994	56,853
Per capita income (dollars)[(a)]	30,407	28,075	23,535	29,519
Individuals living below the poverty level (percent)	7.7	8.6	16.1	13.7
Families living below the poverty level (percent)	5.9	6.5	12.5	10.0

[(a)] In 2012 inflation adjusted dollars

Source: USCB 2014c

3.10.2.2 Unemployment

According to the USCB's 2008-2012 American Community Survey 5-Year Estimates, the unemployment rates (averaged estimates) were: Will County, 6.5 percent; Grundy County, 7 percent; and Kankakee County, 7.2 percent. Comparatively, the State of Illinois's unemployment rate during this same time period was 9.9 percent (USCB 2014c).

3.10.3 Demographic Characteristics

According to the 2010 Census, an estimated 191,099 people lived within 20 mi (32 km) of Braidwood, which equates to a population density of 152 per mi^2 (Exelon 2013a). This translates to a Category 4, "least sparse" population density using the GEIS measure of sparseness (greater than or equal to 120 persons per mi^2 within 20 mi). An estimated 4,968,734 people live within 50 mi (80 km) of Braidwood with a population density of 634 persons per mi^2 (Exelon 2013a). This translates to a Category 4 density, using the GEIS measure of proximity (more than 190 people per mi^2 within 50 mi (80 km) of the plant).

Therefore, Braidwood is located in a high-population area based on the GEIS sparseness and proximity matrix.

Table 3–22 shows population projections and percent growth from 1970 to 2060 in the three-county Braidwood ROI. The population in the ROI has increased over the previous 2 decades (2000 and 2010). Based on State forecasts, the population is expected to continue to increase at a moderate to high rate due in part to the close proximity of the ROI to Chicago. Population projections for years 2020 and 2030 shown in the table were developed by the Illinois Department of Commerce and Economic Opportunity (DCEO 2012) and are based on projected 2000 population census estimates (see Table 3–23). As a result, the projected 2020 and 2030 population estimates may be overstated, as actual population data from the 2000 and 2010 decennial census were lower than the 2000 and 2010 population estimates projected by the DCEO.

Table 3–22. Population and Percent Growth in Braidwood ROI Counties 1970–2010, 2012 (estimated), and Projected for 2020–2060

	Will County		Grundy County		Kankakee County	
Year	Population	Percent Growth	Population	Percent Growth	Population	Percent Growth
1970	249,498	-	26,535	–	97,250	–
1980	324,460	30.0	30,582	15.3	102,926	5.8
1990	357,313	10.1	32,337	5.7	96,255	−6.5
2000	502,266	40.6	37,353	15.5	103,833	7.9
2010	677,560	34.9	50,063	34.0	113,449	9.3
2012	681,591	0.6	50,208	0.2	112,847	−0.5
2020	907,625	33.1	46,454	−7.4	119,655	6.0
2030	1,093,207	20.4	50,414	8.5	126,509	5.7
2040	1,308,444	19.7	49,328	−2.2	132,931	5.1
2050	1,516,268	15.9	49,504	0.4	139,461	4.9
2060	1,724,091	13.7	49,679	0.4	145,991	4.7

Sources: Decennial population data for 1970-2010, and estimated 2012 (USCB 2014g); projections for 2020-2030 by Illinois Department of Commerce and Economic Opportunity (DCEO 2012); 2040-2060 calculated

Table 3–23. Illinois Department of Commerce and Economic Opportunity (DCEO) Population Projections for 2000–2030

	Will County		Grundy County		Kankakee County	
Year	Population	Percent Growth	Population	Percent Growth	Population	Percent Growth
2000	503,162	–	18,694	–	104,010	–
2010	706,639	40.4	20,689	10.6	110,659	6.3
2020	907,625	28.4	22,960	10.9	119,655	8.1
2030	1,093,207	20.4	24,686	7.5	126,509	5.7

Source: DCEO 2012

The 2010 Census demographic profile of the three-county ROI population is presented in Table 3–24. According to the 2010 Census, minorities (race and ethnicity combined) comprised 30.6 percent of the total three-county population. The largest minority populations in the three-county ROI are Hispanic or Latino (14.3 percent) and Black or African American (10.9 percent).

Table 3–24. Demographic Profile of the Population in the Braidwood ROI in 2010

	Will	Grundy	Kankakee	ROI
Total Population	677,560	50,063	113,449	841,072
Race (percent of total population, Not-Hispanic or Latino)				
White	67.2	88.9	73.4	69.4
Black or African American	11.0	1.2	15.0	10.9
American Indian & Alaska Native	0.1	0.1	0.2	0.1
Asian	4.5	0.6	0.9	3.8
Native Hawaiian & Other Pacific Islander	0.0	0.0	0.0	0.0
Some other race	0.1	0.0	0.1	0.1
Two or more races	1.3	0.8	1.4	1.3
Ethnicity				
Hispanic or Latino	105,817	4,096	10,167	120,080
Percent of total population	15.6	8.2	9.0	14.3
Minority population (including Hispanic or Latino ethnicity)				
Total minority population	221,418	5,505	30,123	257,046
Percent minority	32.7	11.0	26.6	30.6

Source: USCB 2014f

3.10.3.1 Transient Population

Within 50 mi (80 km) of Braidwood, colleges and recreational opportunities attract daily and seasonal visitors who create a demand for temporary housing and services. In 2013, approximately 49,000 students attended colleges and universities within 50 mi (80 km) of Braidwood (NCES 2013).

Based on the 2008−2012 American Community Survey (ACS) estimates, approximately 22,965 seasonal housing units are located within 50 mi (80 km) of Braidwood. Of those, 1,615 were located in the Braidwood ROI. Table 3–25 presents information about seasonal housing for the counties located all or partly within 50 mi (80 km) of Braidwood.

Table 3–25. 2007-2011 Estimated Seasonal Housing in Counties Located Within 50 Miles of Braidwood

County [(a)]	Total Housing Units	Vacant Housing Units: for Seasonal, Recreational, or Occasional Use	Percent
	Illinois		
Bureau	15,712	219	1.4
Cook	2,178,739	15,363	0.7
DeKalb	40,932	305	0.7
Dupage	356,37	991	0.3
Ford	6,265	26	0.4
Grundy	***19,919***	***295***	***1.5***
Iroq ois	13,460	206	1.5
Kane	181,587	399	0.2
Kankakee	***45,175***	***445***	***1.0***
Kendall	40,002	82	0.2
LaSalle	49,924	731	1.5
Lee	15,049	373	2.5
Livingston	15,863	52	0.3
Mclean	69,691	431	0.6
Marshall	5,922	373	6.3
Putnam	3,083	326	10.6
Will	***237,175***	***875***	***0.4***
Woodford	15,155	137	0.9
County Subtotal	**3,310,023**	**21,629**	**1.7**
	Indiana		
Jasper	13,165	130	1.0
Lake	208,913	1,123	0.5
Newton	6,023	83	1.4
County Subtotal	**228,101**	**1,336**	**1.0**
Total	**3,538,124**	**22,965**	**0.9%**

[(a)] Counties within 50 mi (80 km) of Braidwood with at least one block group located within the 50-mi (80-km) radius

Source: USCB 2014a

3.10.3.2 Migrant Farm Workers

Migrant farm workers are individuals whose employment requires travel to harvest agricultural crops. These workers may or may not have a permanent residence. Some migrant workers follow the harvesting of crops, particularly fruit, throughout rural areas of the United States. Others may be permanent residents near Braidwood and travel from farm to farm harvesting crops.

Migrant workers may be members of minority or low-income populations. Because they travel and can spend a significant amount of time in an area without being actual residents, migrant workers may be unavailable for counting by census takers. If uncounted, these workers would be “underrepresented” in USCB minority and low-income population counts.

Information about migrant farm and temporary labor was collected in the 2007 Census of Agriculture. Table 3–26 supplies information about migrant farm workers and temporary farm

labor (less than 150 days) within 50 mi (80 km) of Braidwood. According to the 2007 Census of Agriculture, approximately 11,700 farm workers were hired to work for less than 150 days and were employed on 3,707 farms within 50 mi (80 km) of Braidwood. The county with the highest number of temporary farm workers (1,014) on 223 farms was DeKalb County, Illinois (NASS 2012).

Table 3–26. Migrant Farm Workers and Temporary Farm Labor in Counties Located Within 50 Miles of Braidwood

County[a]	Number of Farms with Hired Farm Labor[b]	Number of Farms Hiring Workers for Less Than 150 Days[b]	Number of Farm Workers Working for Less Than 150 Days[b]	Number of Farms Reporting Migrant Farm Labor[b]
Illinois				
Bureau	321	278	786	4
Cook	77	50	363	3
DeKalb	269	223	1,014	16
DuPage	34	28	318	4
Ford	145	128	308	0
Grundy	***120***	***101***	***312***	***3***
Iroquois	407	343	953	8
Kane	231	172	798	13
Kankakee	***233***	***211***	***899***	***23***
Kendall	111	94	371	11
LaSal e	402	338	760	9
Lee	242	203	462	10
Livingston	371	323	816	9
Mclean	410	361	823	4
Marshall	97	86	207	3
Putnam	27	26	141	0
Will	***222***	***185***	***602***	***12***
Woodford	205	191	607	4
County Subtotal	**3,924**	**3,341**	**10,540**	**136**
Indiana				
Jasper	206	163	646	5
Lake	122	97	349	15
Newton	118	106	262	6
County Subtotal	**446**	**366**	**1,257**	**26**
Total	**4,370**	**3,707**	**11,797**	**162**

[a] Counties within 50 mi of Braidwood with at least one block group located within the 50-mi radius

[b] Table 7. Hired farm Labor—Workers and Payroll: 2007

Source: 2007 Census of Agriculture — County Data (NASS 2012)

In the 2002 Census of Agriculture, farm operators were asked for the first time whether or not they hired migrant workers—defined as a farm worker whose employment required travel—to do work that prevented the migrant workers from returning to their permanent place of residence the same day. A total of 162 farms, in the 50-mi radius of the Braidwood, reported hiring migrant workers in the 2007 Census of Agriculture. Kankakee County, Illinois, reported the most farms with migrant farm labor (23 farms) (NASS 2012).

3.10.4 Housing and Community Services

This section presents information regarding housing and local public services, including education and water supply.

3.10.4.1 Housing

Table 3–27 lists the total number of occupied and vacant housing units, vacancy rates, and median value in the ROI. Based on USCB's 2008–2012 ACS 5-Year Estimates, there were approximately 302,000 housing units in the socioeconomic region, of which approximately 281,000 were occupied. The median values of owner-occupied housing units in the ROI range from $149,000 in Kankakee County to about $228,000 in Will County. The vacancy rate in Grundy and Kankakee Counties were similar (9.7 and 9.0, respectively), while Will County, where Braidwood is located, was 6.3 percent (USCB 2014d).

Table 3–27. Housing in the Braidwood ROI (2008−2012, 5-year estimate)

	Will	Grundy	Kankakee	ROI
Total housing units	237,175	19,919	45,175	302,269
Occupied housing units	222,092	17,987	41,068	281,147
Total vacant housing units	15,083	1,932	4,107	21,122
Percent total vacant	6.3	9.7	9.0	6.9
Owner occupied units	185,671	13,691	28,406	227,768
Median value (dollars)	228,900	186,500	149,200	564,600
Owner vacancy rate (percent)	1.9	2.0	2.3	1.3 (avg)
Renter occupied units	36,421	4,296	12,662	45,421
Median rent (dollars/month)	960	889	781	707
Rental vacancy rate (percent)	6.7	9.4	6.7	5.4 (avg)

Source: USCB 2014d

3.10.4.2 Education

There are 12 public school districts in Grundy County and an average daily total enrollment of approximately 12,650 students during the 2010–2011 school year. Kankakee County has 12 public school districts and an average daily total enrollment of approximately 19,000 students. In Will County, the county in which Braidwood is located, there are 29 public school districts with 116,000 students enrolled (ISBE 2012).

3.10.4.3 Public Water Supply

Table 3–28 lists the largest public water systems, their maximum design yields (i.e., pump capacity), reported annual average usage, and population served in Will, Grundy, and Kankakee Counties. The discussion of public water supply systems is limited to major municipal water systems in the local area.

Table 3–28. Local Public Water Supply Systems (in million gallons per day (mgd))

Public Water System	County	Source	Usage (mgd)	Pump Capacity (mgd)	Population Served[(a)]
Crest Hill	Will	Groundwater	1.97	3.82	14,889
Frankfort	Will	Groundwater	3.44	9.74	24,648
Illinois American-Homer Township	Will	Purchased Surface Water	1.90	10.08	22,038
Illinois American-West Suburban	Will	Purchased Surface Water	8.97	26.64	66,429
Joliet	Will	Groundwater	15.00	31.61	147,433
Lockport	Will	Groundwater	3.34	9.89	24,839
Mokena	Will	Purchased Surface Water	1.76	9.30	18,669
New Lenox	Will	Purchased Surface Water	2.18	17.86	24,394
Plainfield	Will	Purchased Surface Water	3.10	32.40	8,259
Romeoville	Will	Groundwater	4.35	12.57	52,000
Shorewood	Will	Groundwater	1.29	6.04	16,000
Minooka	Grundy	Groundwater	1.05	5.70	10,925
Morris	Grundy	Groundwater	1.46	2.88	12,000
Aqua-Illinois Kankakee	Kankakee	Surface Water	11.6	22.0	78,738

NA = Not available

(a) Safe Drinking Water Search for the State of Illinois (EPA 2014a)

Sources: EPA 2014a; Exelon 2013a

Public water suppliers in Will County obtain water from groundwater or purchase surface water from another water supplier. In Grundy County, most public water suppliers obtain water from groundwater. In Kankakee County, with the exception of the largest public water supplier, Aqua Illinois-Kankakee, most public water suppliers use groundwater (Exelon 2013a). Aqua Illinois-Kankakee obtains its water supply from the Kankakee River, Lake Vermilion, Vermilion River and groundwater (Aqua 2014). Braidwood gets its potable water from one deep groundwater well and is not connected to a public water system (Exelon 2013a).

Northeastern Illinois has not experienced water supply shortages. However, as the CMA continues to expand, State legislators have called for development of regional water supply plans throughout northeastern Illinois. To address future water supply planning issues, the Chicago Metropolitan Agency for Planning (CMAP), in conjunction with the IDNR, formed the Northeastern Illinois Regional Water Supply Planning Group (RWSPG). The RWSPG was tasked with a 3-year mission culminating in a final report addressing water supply and drought planning and management for an 11-county region. In this report, Will, Grundy, and Kankakee County were identified as priority planning areas (CMAP 2010). CMAP is currently implementing recommendations from RWSPG's final report (CMAP 2014).

3.10.5 Tax Revenues

Property taxes paid by Exelon Generation for Braidwood are generally determined using the equalized assessed value (EAV) set by the county assessor, and the tax levy and rates set by each taxing district. Periodically, Exelon Generation enters into negotiations (which may result in a "settlement agreement") with Will County and the other taxing districts to set the EAV for Braidwood. Negotiations can consider, but are not limited to, property valuation approaches, tax "triggers" (or limits), and payments in addition to taxes (PIAT). Exelon's last settlement agreement for Braidwood was signed on March 12, 2008, and covered tax years 2007 through 2011, which included negotiated triggers or tax limits. If tax levies exceeded these negotiated triggers, Exelon Generation could reduce Braidwood's property tax obligation by the amounts in excess of the triggers. Exelon Generation also agreed to make PIAT (additional payments) to specific tax recipients. These payments are not considered tax payments in the traditional sense. They have fewer limitations for use and provide additional benefits for recipients. In accordance with the 2008 settlement agreement, Exelon Generation made PIAT payments of $3,711,150 in 2008 and the $3,643,566 in 2009 (Exelon 2013a). Table 3–29 lists the larger of the PIAT payments (2008) and their recipients. Reed-Custer School District 255U received the majority of the PIAT payment, with 68.2 percent of the total payment.

Table 3–29. PIAT Payments and Recipients, 2008

Tax Recipients	Dollars	Percent of Total
Fossil Ridge Public Library District	91,004	2.5
Godley Park District	188,585	5.2
Reed Township Mosquito Abatement District	19,483	0.5
Reed-Custer School District 255U	2,486,545	68.2
Will County/Will County Building Commission	339,460	9.3
Reed Township	24,334	0.7
Reed Township Road District	30,088	0.8
Will County Forest Preserve	101,759	2.8
Braidwood Fire Protection District	214,563	5.9
Joliet Junior College	147,745	4.1
Total	**3,643,566**	**100.0**

Source: Exelon 2013a

Exelon Generation and the taxing bodies have not entered into another settlement agreement, although negotiations have begun. Negotiations are in the early stages, and PIAT payments may be included as part of any future settlement agreement. Exelon Generation expects the recipients would remain the same as those listed in Table 3–29, because those are the taxing institutions that levy tax on the two power block Property Index Numbers (PINs). The settlement agreements have historically only settled the EAV for the two power block PINs (Exelon 2014a).

The Will County Assessor set the EAV for the 2012 tax year to be $470 million. Exelon Generation believes the higher EAV overvalues Braidwood because an independent appraiser set the 2012 value of the station at $2 billion, which equates to an EAV of approximately $333.3 million. On this basis, Exelon Generation appealed the 2012 assessment to Will County Board of Review. Upon an unfavorable ruling by the Board of Review, Exelon Generation then appealed the assessment to the Illinois Property Tax Appeal Board. The company will continue

to negotiate with the taxing bodies to reach a settlement agreement, and in its absence, will appeal any assessment that does not reflect a valuation of the plant that they believe is fair (Exelon 2013a, 2014a).

Pending the outcome of such actions, Exelon Generation has paid the tax assessed for 2012 (an increase of more than $3 million over the prior year, see Table 3–30). This increase was based on the EAV set by the assessor for the three combined power block PINs. Exelon Generation actually pays property taxes on 78 land parcels or PINs at Braidwood. The total taxes paid by Exelon Generation include taxes for all of the PINs (Exelon 2013a, 2014a).

As previously discussed, the Will County Treasurer collects the property tax payment and disperses it to various institutions within the county to partially fund their operating budgets. These include, but are not limited to, the Will County Forest Preserve, Braidwood Fire District, Will County, Reed Custer School District 255-U (255U), and the Godley Park District (Exelon RAI). From 2008 through 2012, Will County's total adjusted property tax levies ranged from approximately $1.5 to $1.6 billion annually (see Table 3–30). From 2008 through 2012, Braidwood's total property tax payments (after tax triggers and not including PIAT payments) represented 1.2 to 1.4 percent of Will County's total adjusted property tax levy (see Table 3–30).

Table 3–30. Property Tax Payment Comparison, All Taxing Districts Combined

Year	Total Combined Taxing District Levy - Will County (after adjustments) (billions of dollars)	Braidwood Property Tax Payment (after tax triggers have been applied and not including PIAT payments) (millions of dollars)	Braidwood Payment as Percent of Total District Levy (percent)
2008	1.5	18.5	1.2
2009	1.5	19.3	1.2
2010	1.6	20.4	1.3
2011	1.6	20.5	1.3
2012	1.6	24.5	1.4

Sources: Exelon 2013a, 2014a

The recipient of the largest percentage of Braidwood's property tax payment is the Reed-Custer School District 255U (Exelon 2013a). Table 3–31 compares Braidwood's property tax payments (after tax triggers and not including PIAT payments) to the Braidwood Reed-Custer School District 255U's adjusted total property tax levies. From 2008 through 2012, Braidwood's property tax payments to the school district represented 67 to 79.5 percent of the school district's total adjusted property tax levies (see Table 3–31).

Exelon Generation pays property taxes directly to Will County in accordance with tax bills received from Will County each year. Each bill shows all of the taxing bodies that are imposing a tax on each tax parcel. As the Braidwood property is large, some of its tax parcels fall within multiple taxing districts. Exelon Generation, however, has no control over how the tax money is allocated to the respective taxing districts. Each district has the ability to levy against all taxpayers within its respective district according to its own charter and according to state law. The Will County Treasurer then allocates the tax money according to predetermined levies once all taxes have been collected (Exelon 2014a).

Table 3–31. Property Tax Payment Comparison, Reed-Custer School District 255U

Year	Total Reed Custer School District 255U Levy (after adjustments) (millions of dollars)	Reed Custer School District 255U Portion of Braidwood Property Tax Payment (after tax triggers have been applied and not including PIAT payments) (millions of dollars)	Braidwood Payment as Percent of Total District Levy (percent)
2008	15.8	12.4	78.1
2009	16.4	12.7	77.7
2010	17.3	13.8	79.5
2011	20.1	13.5	67
2012	21.4	16	75

Sources: Exelon 2013a, 2014a

The following tables show the total levy for each taxing body and the amount paid by Exelon Generation to each taxing body. The tables also show the percentage of total revenue represented by Exelon Generation's tax payment for the tax years 2011 and 2012 (see Tables 3–32 and 3–33, respectively). The 2012 data are preliminary and the total levies for any one of the taxing bodies within Will County may change when the tax year closes (Exelon 2013a, 2014a).

Although variations in tax levies are not completely under its control, Exelon Generation expects that Braidwood's annual property tax payments will remain relatively constant through the license renewal period. In 1998, Braidwood replaced the Unit 1 steam generators. Because the replacement was considered one-for-one, the Station's assessed value was unaffected. Exelon Generation expects that any future one-for-one replacement projects will also not affect the station's assessed value (Exelon 2013a).

1 **Table 3–32. 2011 Property Tax Payment Comparison, Each Taxing District Individually**

Taxing Body	Total Taxing District Levy (dollars)	Taxing District Portion of Braidwood Property Tax Payment (dollars)	Braidwood Payment as Percent of Taxing District Levy (percent)
Will County Forest Preserve	33,991,038	726,125	2
Will County Building Commission	4,015,499	85,779	2
Reed Township Town Funds	170,009	122,365	72
Reed Township Road Funds	178,530	144,527	81
Braidwood Fire District	1,546,592	1,113,239	72
Essex Fire District	15,106	3,646	24
Custer Township Town Funds	84,196	2,034	2
Custer Township Road Funds	200,060	4,857	2
Custer Fire District	70,096	1,944	3
School District 255-U	20,141,090	13,594,795	67
Joliet Junior Community College 525	40,559,603	1,056,376	3
Godley Park District	936,736	865,880	92
Village of Braceville Road and Bridge	160	91	57
Braidwood Park District	154,986	7,122	5
Fossil Ridge Public Library	636,060	429,327	67
Reed Township Mosquito Abatement	131,964	94,997	72
Will County	107,435,329	2,295,036	2
Claypool Drainage District	96,479	276	0.2
Braidwood Park District	154,986	7,122	5

Source: Exelon 2014a

Table 3–33. 2012 Property Tax Payment Comparison, Each Taxing District Individually

Taxing Body	Total Taxing District Levy (dollars)	Taxing District Portion of Braidwood Property Tax Payment (dollars)	Braidwood Payment as Percent of Taxing District Levy (percent)
Will County Forest Preserve	35,103,179	886,752	3
Will County Building Commission	4,003,154	101,125	3
Reed Township Town Funds	177,882	140,903	79
Reed Township Road Funds	189,927	167,040	88
Braidwood Fire District	1,649,412	1,306,774	79
Essex Fire District	15,907	4,041	25
Custer Township Town Funds	86,815	2,255	3
Custer Township Road Funds	201,819	5,304	3
Custer Fire District	72,233	1,987	3
School District 255-U	21,476,914	16,039,297	75
Joliet Junior Community College 525	42,887,756	1,320,350	3
Godley Park District	1,249,133	1,234,838	99
Village of Braceville Road and Bridge	115	43	38
Braidwood Park District	158,705	7,548	5
Fossil Ridge Public Library	673,848	503,240	75
Reed Township Mosquito Abatement	138,820	109,961	79
Will County	107,557,817	2,717,021	3
Claypool Drainage District	96,278	276	0.2

Source: Exelon 2014a

3.10.6 Local Transportation

Major freeways serving Will County include interstates I-55, I-57, and I-80. Other major roadways serving the county state routes are: 1, 7, 50, 53, 59, 102, 113, 126, 171, and 394; and U.S. Highways 6, 30, 45, and 52. Road access to Braidwood is via State Highway 53, a rural northeast-southwest two-lane highway. Braidwood has one access road which intersects State Highway 53 approximately 2 mi (3 km) southwest of the City of Braidwood. In the City of Braidwood, State Highway 53 intersects State Highway 113, which in turn intersects State Highway 129. State Highway 129 runs north, eventually intersecting I-55. Employees traveling from the west, northwest, north, northeast, and east to the Braidwood site would use some combination of these routes. Employees traveling from the west, southwest, south, and southeast to the Braidwood site would use a combination of I-55 and State Highway 53.

Exelon Generation employees report that there has been no traffic congestion in the area during normal operations (Exelon 2013a).

During major refueling or maintenance outages, there is congestion at the intersection of State Highways 53 and 113, and the intersection of State Highways 113 and 129 in the City of Braidwood. To lessen outage congestion, local law enforcement is used to direct traffic during shift changes and periods of high activity (Exelon 2013a).

Table 3–34 lists commuting routes to the Braidwood site and average annual daily traffic (AADT) volume values. The AADT values represent traffic volumes for a 24-hour period factored by both the day of the week and the month of the year.

Table 3–34. Major Commuting Routes in the Vicinity of Braidwood: 2012 Average Annual Daily Traffic Count

Roadway and Location	Average Annual Daily Traffic (AADT)[(a)]
The section of Highway 53 between the City of Braidwood and the Village of Godley	3,450
On Highway 53, at the intersection of Highway 113 in the City of Braidwood	5,050[(b)]
On Highway 113, at the intersection of Highway 53, in the City of Braidwood	6,100-7,500[(b)]
On I-55, at the intersection of W. Kennedy Rd, west of the City of Braidwood	20,800-24,800
On I-55, at the intersection of West Division Street, northeast of the Village of Godley	24,800

[(a)] Unless otherwise indicated, all AADTs represent traffic volume during the average 24-hour day during 2012.
[(b)] AADTs in 2011.

Source: IDOT 2014

3.11 Human Health

3.11.1 Radiation Protection Program

As required by NRC regulation, 10 CFR 20.1101, Exelon has a radiation protection program designed to protect onsite personnel, including employees, contractor employees, visitors, and offsite members of the public from radiation and radioactive material generated at Braidwood.

The radiation protection program is extensive and includes, but is not limited to the following:

- Organization and Administration (i.e., a Radiation Protection Manager who is responsible for the program and having trained and qualified workers),
- Implementing procedures,
- ALARA Program to minimize dose to workers and members of the public,
- Dosimetry Program (i.e., measure radiation dose of plant workers),

- Radiological Controls (i.e., protective clothing, shielding, filters, respiratory equipment, and individual work permits with specific radiological requirements),
- Radiation Area Entry and Exit Controls (i.e., locked or barricaded doors, interlocks, local and remote alarms, personnel contamination monitoring stations),
- Posting of Radiation Hazards (i.e., signs and notices alerting plant personnel of potential hazards),
- Record Keeping and Reporting (i.e., documentation of worker dose and radiation survey data),
- Radiation Safety Training (i.e., classroom training and use of mock-ups to simulate complex work assignments),
- Radioactive Effluent Monitoring Management (i.e., control and monitor radioactive liquid and gaseous effluents released into the environment),
- Radioactive Environmental Monitoring (i.e., sampling and analysis of environmental media, such as air, water, vegetation, food crops, direct radiation, and milk to measure the levels of radioactive material in the environmental that may impact human health), and
- Radiological Waste Management (i.e., control, monitor, process, and dispose of radioactive solid waste).

Regarding the radiation exposure to Braidwood personnel, the NRC staff reviewed the data contained in NUREG-0713, Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities 2011: Forty-Fourth Annual Report (NUREG-0713, Volume 33). This report, which was the most recent available at the time of this review, summarizes the worker's radiation dose data through 2011 that are maintained in the NRC's Radiation Exposure Information and Reporting System database. Nuclear power plants are required by 10 CFR 20.2206 to report their occupational exposure data to the NRC annually (NRC 2013b).

NUREG-0713 contains data on the trends in radiation dose received by workers at nuclear power plants as well as other industries licensed by the NRC to produce, use, or possess radioactive material. These other industries include: industrial radiography, manufacturing and distribution of radioactive material, independent spent fuel storage facilities, fuel cycle licensees for the fabrication, processing and uranium enrichment, and uranium fluoride production plants. The NRC staff used the data in NUREG-0713 to compare Braidwood's occupational dose to the data on the 3-year average collective dose for other nuclear power plants. The 3-year average collective dose is one of the metrics that the NRC uses in the Reactor Oversight Program (i.e., NRC reactor inspection program) to evaluate the effectiveness of a nuclear power plant's radiation protection program to maintain worker doses that are ALARA. Collective dose is the sum of the individual doses received by workers at a nuclear plant over a one year time period. The annual collective dose at each plant varies based on the amount of work performed inside the radiation areas of the plant (i.e., maintenance work and refueling outages). There are no NRC or EPA standards for collective dose; as previously stated, it is a comparative value used in the NRC's reactor inspection program to assess performance. Based on the data for operating PWRs like those at Braidwood, the 3-year average annual collective dose per all PWRs for the period 2009 – 2011 was 59.712 person-rem (0.597 person-sievert). In comparison, Braidwood reported an annual collective dose per reactor of 46.015 person-rem (0.460 person-sievert).

In addition, as reported in NUREG-0713 for 2011, Braidwood measured the dose of 3,165 workers. There were 2,094 workers with no measurable dose; 859 workers that had less than 0.100 rem (0.001 sievert (Sv)); 192 workers had between 0.100 rem (0.001 Sv) but less than 0.250 rem (0.002 Sv) and 20 workers had between 0.250 rem (0.002 Sv) but less than 0.500 rem (0.005 Sv). No worker at Braidwood received a dose of 0.500 rem (0.005 Sv) or greater. The NRC's annual worker dose limit in 10 CFR 20.1201 is 5.0 rem (0.05 Sv). Braidwood maintained its worker's doses within NRC dose limits.

3.11.2 Chemical Hazards

The use, storage, and discharge of chemicals, biocides, and sanitary wastes, as well as minor chemical spills are regulated by state and Federal environmental agencies. Chemical hazards to Braidwood's workers during the license renewal term are expected to be minimized by implementing good industrial hygiene practices as required by Federal and State regulations. Discharges of chemical and sanitary wastes are monitored and controlled as part of the Braidwood's NPDES permit IL0048321 to minimize impacts to the public and the environment (Exelon 2013e).

3.11.3 Microbiological Hazards

Nuclear plants that have cooling towers and that discharge thermal effluents to cooling ponds, lakes, canals, or rivers, such as Braidwood, have the potential to promote the increased growth of thermophilic microorganisms, which could result in adverse health effects for plant workers and the public. Microorganisms of particular concern include several types of bacteria (*Legionella* spp., *Salmonella* spp., *Shigella* spp., and *Pseudomonas aeruginosa*) and the free-living amoeba *Naegleria fowleri*.

Nuclear plant workers can be exposed to *Legionella* spp. when performing maintenance activities on plant cooling systems if workers inhale cooling tower vapors because vapors are often within the optimum temperature range for *Legionella* growth. Plant personnel most likely to come in contact with *Legionella* aerosols would be workers who clean biofilms off of condenser tubes, cooling towers, and related system components or equipment. Exposure of the public to *Legionella* from nuclear plant operations is generally not a concern because *Legionella* exposure would be confined to a small area of the site within the protected area. In the case of Braidwood, which does not have cooling towers, exposure of workers to *Legionella* is unlikely.

The public can be exposed to the thermophilic microorganisms *Salmonella*, *Shigella*, *P. aeruginosa*, and *N. fowleri* during swimming, boating, or other recreational uses of freshwater. If a nuclear plant's thermal effluent enhances the growth of thermophilic microorganisms, recreational users could experience an elevated risk of exposure when using waters near the plant's discharge.

3.11.3.1 Thermophilic Microorganisms of Concern

Legionella is a genus of common warm water bacteria that occurs in lakes, ponds, and other surface waters, as well as some groundwater sources and soils. The bacteria are pathogenic to humans when aerosolized and inhaled into the lungs. Approximately two to five percent of those exposed in this way to *Legionella* develop an acute bacterial infection of the lower respiratory tract known as Legionnaires' disease (Pearson 2003). Optimal growth occurs in stagnant surface waters with biofilms or slimes that range in temperature from 35 to 45 °C (95 to 113 °F), though the bacteria can persist in waters from 20 to 50 °C (68 to 122 °F) (Pearson 2003). Elderly and immunocompromised individuals are most susceptible to

Legionnaires' disease (Pearson 2003). According to data from the Centers for Disease Control and Prevention (CDC 2011a) from 2000 through 2009, New England and Mid-Atlantic states generally had the highest number of reported legionellosis cases each year.

Approximately 2,000 serotypes of *Salmonella* spp. cause the bacterial infection salmonellosis in humans. Of these, the serotypes Typhimurium and Enteritidis are the most common in the United States (CDC 2010a). Salmonellosis is most common in summer months, and it is transmitted through contact with food, water, or animals contaminated with human or animal feces (CDC 2010a). The bacteria have an optimal growth temperature of 37 °C (98.6 °F) but can grow at temperatures ranging from 6 to 46 °C (43 to 115 °F) (Albrecht 2013a). Studies examining the persistence of *Salmonella* spp. outside of a host have found that *Salmonella* can survive for several months in water and in aquatic sediments (Moore et al. 2003).

Shigella is a genus of bacteria species that causes shigellosis (i.e., bacterial dysentery), which is spread through consuming fecal-contaminated food or water or by swimming in contaminated water. Its optimum growth temperature is 37 °C (98.6 °F), though it can grow in water temperatures ranging from 10 to 40 °C (50 to 104 °F) (Albrecht 2013b). Shigellosis is most common in summer months and among toddlers age 2 to 4 in childcare settings (CDC 2013e).

Pseudomonas aeruginosa is a free-living bacterium found in soil, water, and plant surfaces. It is most commonly linked to infections transmitted in healthcare settings. However, as a waterborne pathogen, it can cause ear infections (i.e., "swimmer's ear"), eye infections, and skin rashes after exposure to contaminated hot tubs, swimming pools, or other recreational waters (CDC 2013a). Its optimum growth temperature is 37 °C (98.6 °F), though it can grow at temperatures as high as 42 °C (107.6 °F) (Todar 2004). *P. aeruginosa* almost exclusively infects immunocompromised individuals or already injured or inflamed sites on the skin (Todar 2004).

Naegleria fowleri is a free-living amoeba that occurs in warm lakes, rivers, or hot springs. It is the causative agent of human primary amoebic meningoencephalitis (PAM). Infection occurs when contaminated freshwater enters the nose, and the amoeba migrates to brain tissue; the ensuing illness is usually fatal (CDC 2013b). *N. fowleri* grows best at higher temperatures up to 46 °C (115 °F) (CDC 2013b), though it has also been isolated from thermally altered waters surrounding power plant discharges at temperatures ranging from 35 to 41 °C (95 to 105.8 °F) (Stevens et al. 1977).

3.11.3.2 Prevalence of Waterborne Diseases Associated with Recreational Waters

From 2002 through 2011, the CDC (2003, 2004a, 2005, 2006a, 2007, 2008a, 2009, 2010b, 2011b, 2012) reported an average of 2,774 cases of Legionnaires' disease per year, of which between 28 and 151 per year were reported from Illinois. Although *Legionella* is often present in the cooling tower vapors of power plants, cases of Legionnaires' disease from this type of exposure are rare due to workers' use of appropriate respiratory protection, and as indicated above, this type of exposure does not apply to Braidwood because the cooling system does not include cooling towers.

The Illinois Department of Public Health (IDPH) indicates that approximately 1,500 to 2,000 cases of salmonellosis are reported in the state each year (IDPH 2009). However, the overwhelming majority of salmonellosis cases are foodborne (CDC 2010a). The CDC reports biannually on waterborne disease outbreaks associated with recreational waters. A review of the past 10 available data years (1999 through 2008) of these reports indicates that no outbreaks or cases of waterborne *Salmonella* infection from recreational waters occurred in the United States during this timeframe (CDC 2002, 2004b, 2006b, 2008b, 2011c). From 2006 to

2013, all CDC-reported salmonellosis outbreaks have been caused by contaminated produce, meats, or prepared foods or through contact with contaminated animals (CDC 2013d).

Approximately 1,300 confirmed cases of shigellosis are reported in Illinois each year (IDPH 2013). CDC reports (2002, 2004b, 2006b, 2008b, 2011c) indicate that less than a dozen shigellosis outbreaks have been attributed to lakes, reservoirs, and other recreational waters in the past 10 available data years (1999 through 2008). None of these cases were in Illinois.

Infections attributed to *Pseudomonas aeruginosa* are most commonly contracted in pools, spas, and hot tubs. No cases of infection linked to contaminated recreational waters in the United States have been reported within the past 10 available data years (1999 through 2008) (CDC 2002, 2004b, 2006b, 2008b, 2011c).

The *N. fowleri*-caused disease, PAM, is rare in the United States. Since 1962, between zero and eight cases of PAM have been reported to the CDC annually, and no cases have been reported in Illinois (CDC 2013c).

3.11.4 Electromagnetic Fields

Based on the GEIS, the Commission found that electric shock resulting from direct access to energized conductors or from induced charges in metallic structures has not been found to be a problem at most operating plants and generally is not expected to be a problem during the license renewal term. However, a site-specific review is required to determine the significance of the electric shock potential along the portions of the transmission lines that are within the scope of this SEIS.

In the GEIS, the NRC found that without a review of the conformance of each nuclear plant transmission line with National Electrical Safety Code (NESC) criteria, it was not possible to determine the significance of the electric shock potential (IEEE 2002). Evaluation of individual plant transmission lines is necessary because the issue of electric shock safety was not addressed in the licensing process for some plants. For other plants, land use in the vicinity of transmission lines may have changed, or power distribution companies may have chosen to upgrade line voltage. To comply with 10 CFR 51.53(c)(3)(ii)(H), the applicant must provide an assessment of the impact of the proposed action on the potential shock hazard from the transmission lines if the transmission lines that were constructed for the specific purpose of connecting the plant to the transmission system do not meet the recommendations of the NESC for preventing electric shock from induced currents. The NRC uses the NESC criteria and the applicant's adherence to these during the current operating license as its baseline to assess the potential human health impact of the induced current from an applicant's transmission lines. As discussed in the GEIS, the issue of electric shock is of small significance for transmission lines that are operated in adherence with the NESC criteria.

In its ER, Exelon stated that one 345-kV transmission line was specifically constructed from Braidwood to a substation near Crete, Illinois to connect Braidwood to the electric grid at the time of initial plant construction. This is the only transmission line considered to be in-scope for the Braidwood license renewal environmental review. Subsequent to initial plant construction, a new transmission substation (TSS) was constructed at Davis Creek, within the Braidwood-to-Crete ROW approximately 6 mi (10 km) northwest of Kankakee, Illinois. After construction of the Davis Creek TSS, the original Crete TSS was retired and the lines were extended northward to a new Crete TSS. The transmission line segment from Braidwood to the new Davis Creek TSS became known as the Braidwood-to-Davis-Creek transmission line.

In its ER, Exelon stated that, for the purpose of electric shock evaluation for license renewal, the portion of the present-day transmission line extending from Braidwood through the Davis Creek TSS to the former location of the original Crete TSS is called the Braidwood-to-Crete (retired) transmission line.

Exelon identified spans on the Braidwood-to-Crete (retired) transmission line it considered to be the worst-case span. The worst case span is the configuration where the potential for induced-current shock would be greatest. Using the worst-case span, Exelon calculated the electric field strength and induced current using the Electric Power Research Institute computer code, ACDCLINE. The input parameters included the design features of the limiting-case scenario and the maximum vehicle size under the lines (a tractor-trailer). The analysis identified five locations along the Braidwood-to-Crete (retired) transmission line that exceed the NESC's 5-milliampere standard. Exelon's analysis noted that every location above 5-milliampere standard also contains a 765 kV transmission line that is not within the scope of this review. The induced current at locations where only the Braidwood-to-Crete (retired) transmission line is present ranged from 0.5 to 2.9 milliamperes. The calculated induced current where the 765 kV line is also present ranges from 2.2 to 5.5 milliamperes. Exelon concluded that its Braidwood-to-Crete (retired) transmission line meets the NESC criteria (Exelon 2013e).

Exelon's energy subsidiary company, ComEd, is the owner and operator of the Braidwood-to-Crete (retired) transmission line and the 765-kV transmission line. ComEd's surveillance and maintenance program includes performing routine inspections and aerial patrols to check for encroachments, broken conductors, or any other evidence of clearance issues. Exelon stated in its ER that ComEd plans to continue using the 765-kV transmission line, even after Braidwood is decommissioned (Exelon 2013e).

3.11.5 Other Hazards

Two additional human health issues are addressed in this section: physical occupational hazards and electric shock hazards.

Nuclear power plants are industrial facilities that have many of the typical occupational hazards found at any other electric power generation utility. Workers at or around nuclear power plants would be involved in some electrical work, electric power line maintenance, repair work, and maintenance activities and exposed to some potentially hazardous physical conditions (e.g., falls, excessive heat, cold, noise, electric shock, and pressure). The issue of physical occupational hazards is generic to all nuclear power plants.

The Occupational Safety and Health Administration (OSHA) is responsible for developing and enforcing workplace safety regulations. OSHA was created by the Occupational Safety and Health Act of 1970 (29 USC 651 et seq.), which was enacted to safeguard the health of workers. With specific regard to nuclear power plants, plant conditions which result in an occupational risk, but do not affect the safety of licensed radioactive materials, are under the statutory authority of OSHA rather than the NRC as set forth in a Memorandum of Understanding (53 FR 43950, October 31, 1988) between the NRC and OSHA. Occupational hazards can be minimized when workers adhere to safety standards and use appropriate protective equipment; however, fatalities and injuries from accidents can still occur.

Exelon's maintains a worker safety program at Braidwood. In 2010, Exelon was awarded the Green Cross for Safety Medal by the National Safety Council (NSC). The award recognized Exelon's outstanding safety achievements in the workplace and off-the-job safety (NSC 2010).

3.12 Environmental Justice

Under Executive Order (EO) 12898 (59 FR 7629), Federal agencies are responsible for identifying and addressing, as appropriate, disproportionately high and adverse human health and environmental impacts on minority and low-income populations. In 2004, the Commission issued a *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040), which states, "The Commission is committed to the general goals set forth in EO 12898, and strives to meet those goals as part of its NEPA review process."

The Council on Environmental Quality (CEQ) provides the following information in *Environmental Justice: Guidance Under the National Environmental Policy Act* (CEQ 1997):

> **Disproportionately High and Adverse Human Health Effects.**
>
> Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts on human health. Adverse health effects may include bodily impairment, infirmity, illness, or death. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant (as employed by NEPA) and appreciably exceeds the risk or exposure rate for the general population or for another appropriate comparison group. [CEQ 1997]
>
> **Disproportionately High and Adverse Environmental Effects.**
>
> A disproportionately high environmental impact that is significant (as employed by NEPA) refers to an impact or risk of an impact on the natural or physical environment in a low-income or minority community that appreciably exceeds the environmental impact on the larger community. Such effects may include ecological, cultural, human health, economic, or social impacts. An adverse environmental impact is an impact that is determined to be both harmful and significant (as employed by NEPA). In assessing cultural and aesthetic environmental impacts, impacts that uniquely affect geographically dislocated or dispersed minority or low-income populations or American Indian tribes are considered. [CEQ 1997]

The environmental justice analysis assesses the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations that could result from the operation of Braidwood during the renewal term. In assessing the impacts, the following definitions of minority individuals and populations and low-income population were used (CEQ 1997):

> **Minority individuals**
>
> Individuals who identify themselves as members of the following population groups: Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, or two or more races, meaning individuals who identified themselves on a Census form as being a member of two or more races, for example, [White] and Asian.
>
> **Minority populations**
>
> Minority populations are identified when (1) the minority population of an affected area exceeds 50 percent or (2) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis.

Low-income population

Low-income populations in an affected area are identified with the annual statistical poverty thresholds from the Census Bureau's Current Population Reports, Series P60, on Income and Poverty.

3.12.1 Minority Population

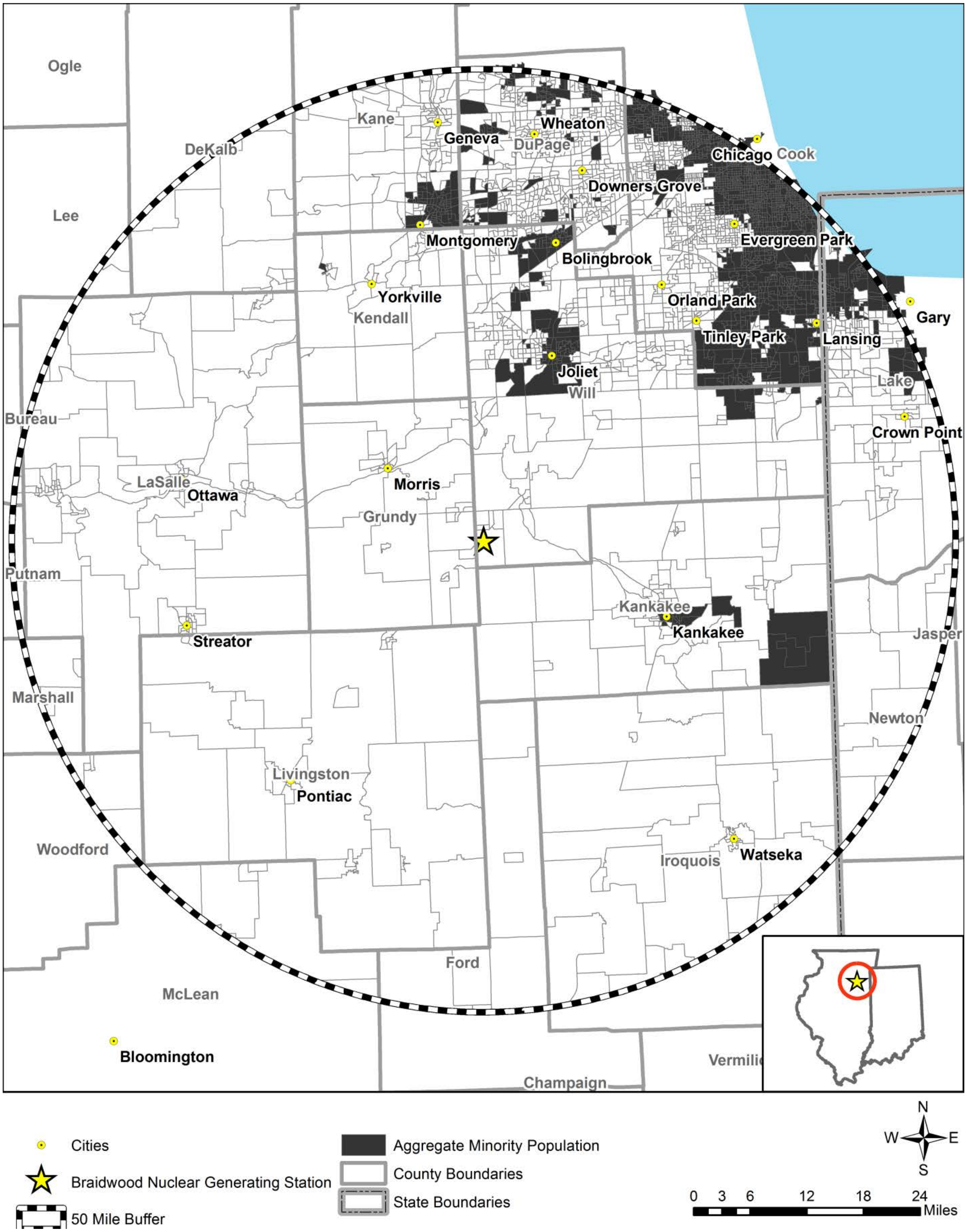
According to 2010 Census data, approximately 48 percent of the population residing within a 50-mi (80-km) radius of Braidwood (in contrast to the ROI data) identified themselves as minority individuals. The largest minority group was Black or African American (22 percent), followed by Hispanic or Latino (of any race) (21 percent) (USCB 2014f).

According to 2010 Census data, minority populations in the socioeconomic ROI (Will, Grundy, and Kankakee counties) composed 30.6 percent of the total three-county population (see Table 3–24). Figure 3–20 shows predominantly minority population block groups, using 2010 Census data for race and ethnicity, within a 50-mi (80-km) radius of Braidwood.

Census block groups were considered minority population block groups if the percentage of the minority population within any block group exceeded 48 percent (the percent of the minority population within the 50-mi radius of Braidwood). A minority population exists if the percentage of the minority population within the block group is meaningfully (statistical significant consideration) greater than the minority population percentage in the 50-mi (80-km) radius. Approximately 1,716 of the 3,648 census block groups located within the 50-mi (80-km) radius of Braidwood have meaningfully greater minority populations (USCB 2014f).

As shown in Figure 3–20, the nearest minority population block groups (race and ethnicity) are mostly clustered near Joliet, Kankakee, and the Chicago metropolitan statistical area. None of the block groups near Braidwood have meaningfully greater minority populations.

1 **Figure 3–20. Minority Block Groups Within a 50-mi Radius of Braidwood**



2

3 Source: USCB 2014f

3.12.2 Low-Income Population

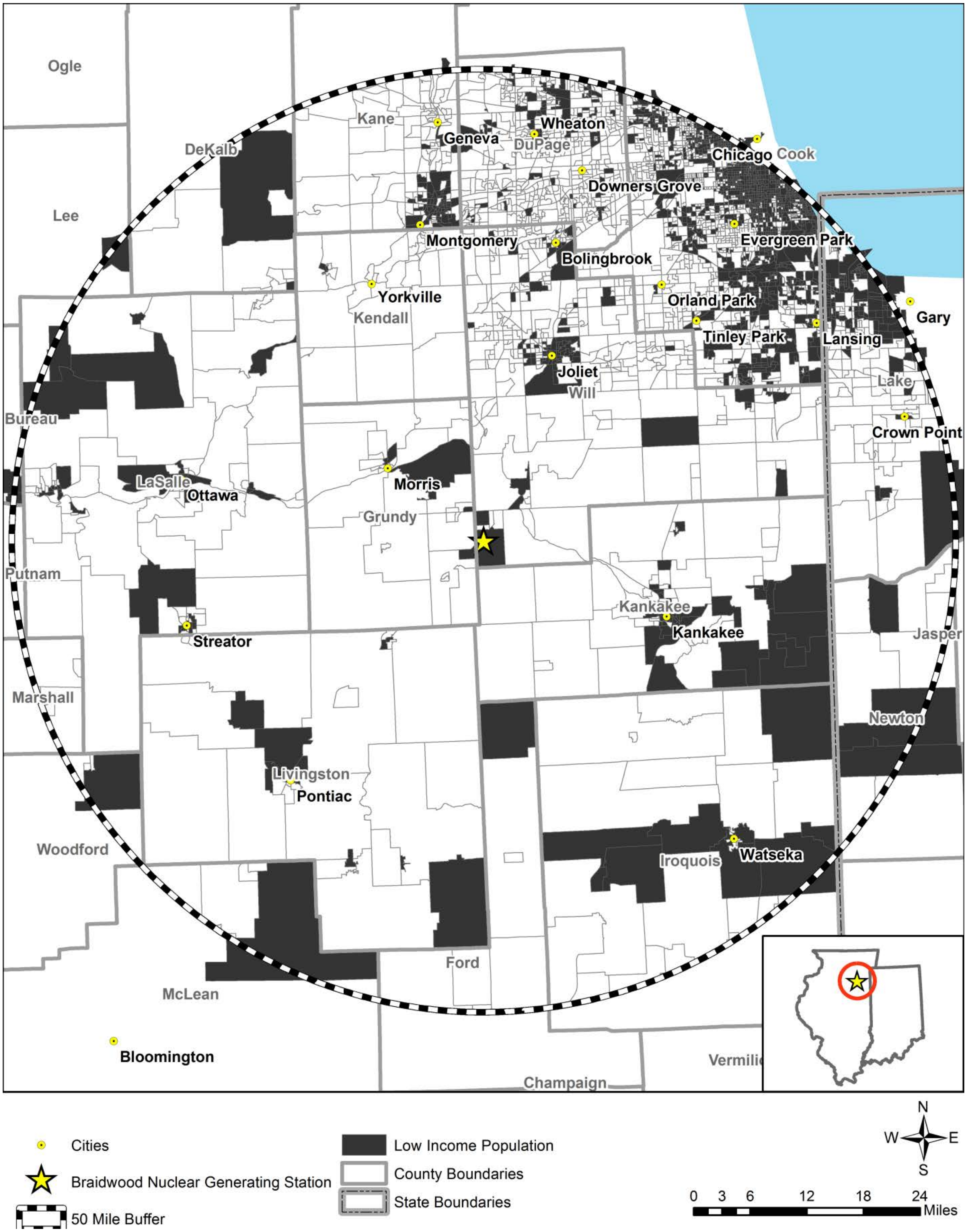
According to USCB's 2008–2012 American Community Survey 5 Year Estimates an average of 7.9 percent of families and 13.5 percent of individuals residing in the 16 counties within a 50-mi (80-km) radius of Braidwood were identified as living below the Federal poverty threshold (USCB 2014b). The 2012 Federal poverty threshold was $23,942 for a family of four.

According to the USCB's 2008–2012 American Community Survey 5-Year Estimates, Will County had a median household income and per capita income higher than the State of Illinois. Grundy County had a higher median household income than the State of Illinois, but a lower per capita income. Kankakee County had a lower median household income and per capita income than the State of Illinois. Kankakee has the highest percentages of persons (16.1 percent) living below the official poverty level when compared to the other two counties and the State of Illinois as a whole. Will and Grundy Counties had 7.7 and 8.6 percent, respectively, and the State of Illinois as a whole had 13.7 percent. The percentage of families living below the poverty level in Will and Grundy Counties (5.9 and 6.5 percent, respectively) was lower than the percentage of families in Kankakee County and the State of Illinois as a whole (12.5 percent and 10 percent, respectively) (USCB 2014c).

Figure 3–21 shows the location of predominantly low-income population block groups within a 50-mi (80-km) radius of Braidwood. Census block groups were considered low-income population block groups if the percentage of individuals living below the Federal poverty threshold within any block group exceeded 13.5 percent (the percent of the individuals living below the Federal poverty threshold within the 50-mi radius of Braidwood). Approximately 1,472 of the 3,648 census block groups located within the 50-mi (80-km) radius of Braidwood have meaningfully (statistical significant consideration) greater low-income populations (USCB 2014e).

Several census block groups including the block group where Braidwood is located are considered low-income block groups. In addition to these groups, as shown in Figure 3–21, the nearest low-income population block groups are mostly clustered near Chicago, Joliet, and Morris, Illinois.

1 **Figure 3–21. Low-Income Block Groups Within a 50-mi Radius of Braidwood**



2

3 Source: USCB 2014e

3.13 Waste Management and Pollution Prevention

3.13.1 Radioactive Waste

As discussed in Section 3.1.4 of this SEIS, Braidwood uses liquid, gaseous, and solid waste processing systems to collect and treat, as needed, radioactive materials produced as a by-product of plant operations. Radioactive materials in liquid and gaseous effluents are reduced prior to being released into the environment so that the resultant dose to members of the public from these effluents is well within NRC and EPA dose standards. Radionuclides that can be efficiently removed from the liquid and gaseous effluents prior to release are converted to a solid waste form for disposal in a licensed disposal facility.

3.13.2 Nonradioactive Waste

Waste minimization and pollution prevention are important elements of operations at all nuclear power plants. The licensees are required to consider pollution prevention measures as dictated by the Pollution Prevention Act (Public Law 101-508) and Resource Conservation and Recovery Act of 1976, as amended (PL 94-580) (NRC 2013).

As described in Section 3.1.5, Braidwood has a nonradioactive waste management program to handle this nonradioactive waste. In addition to managing its nonradioactive waste, Exelon has programs in place to minimize the generation of this waste. Braidwood implements a waste minimization plan to reduce, to the extent feasible, waste generated, treated, accumulated, or disposed. In addition to a focus on recycling operations, Exelon's waste minimization plan focuses on identifying waste reduction opportunities and preventing waste before it happens. Exelon implements best management practices for solid, special, hazardous, mixed waste, and chemicals to control and minimize waste generation to the maximum extent practicable (Exelon 2012a).

Braidwood has an SWPPP that identifies potential sources of pollution that may affect the quality of storm water discharges from each permitted outfall. The SWPP plan also describes practices that are used to reduce pollutants in storm water discharges to assure compliance with the site's NPDES permit. As part of Braidwood's Spill Prevention Control and Countermeasure Plan, measures are in place to monitor areas within the site that have the potential for spills of regulated substances, such as oil (Exelon 2013e).

3.14 References

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4.0 ENVIRONMENTAL CONSEQUENCES AND MITIGATING ACTIONS

4.1 Evaluation of Braidwood License Renewal and Alternatives to License Renewal

In this chapter, the U.S. Nuclear Regulatory Commission (NRC) staff (or the staff) evaluates the environmental consequences of the proposed action (i.e., license renewal of Braidwood Station, Units 1 and 2 (Braidwood)), including the (1) impacts associated with continued operations similar to those that have occurred during the current license terms; (2) impacts of various alternatives to the proposed action (e.g., Coal-integrated Gasification Combined Cycle (IGCC) and Natural-gas-fired Combined-cycle (NGCC)); (3) impacts from the termination of nuclear power plant operations and decommissioning after the license renewal term (with emphasis on the incremental effect caused by an additional 20 years of operation); (4) impacts associated with the uranium fuel cycle; (5) impacts of postulated accidents (design-basis accidents and severe accidents); (6) cumulative impacts of the proposed action; and (7) resource commitments associated with the proposed action, including unavoidable adverse impacts, the relationship between short term use and long-term productivity, and irreversible and irretrievable commitment of resources. The NRC also considers new and potentially significant information on environmental issues related to operation during the renewal term.

The *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS) (NRC 2013e) identifies 78 issues to be evaluated in the license renewal environmental review process. Generic issues (Category 1) rely on the analysis presented in the GEIS, unless otherwise noted. Applicable site-specific issues (Category 2) have been analyzed for Braidwood and assigned a significance level of SMALL, MODERATE, or LARGE. Section 1.4 of this supplemental environmental impact statement (SEIS) provides an explanation of the criteria for Category 1 and Category 2 issues, as well as the definitions of SMALL, MODERATE, and LARGE. Resource-specific impact significance level definitions are provided where applicable.

4.2 Land Use and Visual Resources

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on land use and visual resources.

4.2.1 Proposed Action

Section 3.2 of this SEIS describes land use and visual resources in the vicinity of the Braidwood site. The four generic (Category 1) issues that apply to land use and visual resources during the proposed license renewal period appear in Table 4–1. The GEIS (NRC 2013f) discusses these issues in Section 4.2.1. The GEIS does not identify any site-specific (Category 2) land use or visual resource issues.

The NRC staff did not identify any new and significant information related to the generic (Category 1) issues listed above during the review of the applicant's Environmental Report (ER) (Exelon 2013c), the site audit, or the scoping process. Therefore, the NRC expects no impacts associated with these issues beyond those discussed in the GEIS. The GEIS concludes that the impact level for each of these issues is SMALL.

Table 4–1. Land Use and Visual Resource Issues

Issue	GEIS Section	Category
Land Use		
Onsite land use	4.2.1.1	1
Offsite land use	4.2.1.1	1
Offsite land use in transmission line right-of-ways (ROWs)[a]	4.2.1.1	1
Visual Resources		
Aesthetic impacts	4.2.1.2	1

[a] This issue applies only to the in-scope portion of electric power transmission lines, which are defined as transmission lines that connect the nuclear power plant to the substation where electricity is fed into the regional power distribution system and transmission lines that supply power to the nuclear plant from the grid.

Source: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51

4.2.2 No-Action Alternative

4.2.2.1 Land Use

If Braidwood were to shut down, the impacts to land use would remain similar to those during operations until the plant is fully decommissioned. Temporary buildings and staging or laydown areas may be required during large component and structure dismantling. Braidwood is likely to have sufficient space within previously disturbed areas for these needs, and therefore, no additional land would need to be disturbed that would result in changes to current land uses. In NUREG–0586, *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, Supplement 1* (NRC 2002d), NRC concludes generically that land use during decommissioning activities would be SMALL. For Braidwood, the continuation of the lease agreement between Exelon Generation Company, LLC (Exelon), and the Illinois Department of Natural Resources (IDNR) for the Mazonia-Braidwood State Fish and Wildlife Area could be affected by decommissioning. Loss of these lands as a State-managed area could result in land use changes depending upon any future use of the site. In addition, the GEIS (NRC 2013f) notes that land use impacts could occur in other areas beyond the immediate nuclear plant site as a result of the no-action alternative if new power plants are needed to replace lost capacity. The NRC staff concludes that the no-action alternative could, but may not necessarily, alter land use noticeably. Thus, the NRC staff concludes that the impacts of the no-action alternative on land use during the proposed license renewal term would be SMALL to MODERATE.

4.2.2.2 Visual Resources

If Braidwood were to shut down, visual resource impacts would be similar to those experienced during operations until the site is fully decommissioned. As indicated in Section 3.2.2, the majority of site buildings are not tall, and the rolling topography and small forested tracts on and near the Braidwood site provide visual screening. Construction equipment associated with decommissioning could create some visual impacts, but these impacts would be temporary and localized. Therefore, the NRC staff concludes that the impacts of the no-action alternative on visual resources would be SMALL.

4.2.3 New Nuclear Alternative

4.2.3.1 Land Use

The new nuclear alternative assumes that the new facility would be built at an existing nuclear or retired coal plant site within the region of influence (ROI) but outside of Illinois. Construction of the new nuclear plant would require an estimated 324 acres (ac) (131 hectares (ha)) for permanent buildings and facilities and an additional 31 ac (12.5 ha) for temporary facilities and laydown areas. The NRC staff assumes that this alternative would use existing onsite structures and previously disturbed areas to the extent practicable to minimize development of undisturbed land. Thus, this alternative would not significantly affect existing land uses. Given the land requirements, it is expected that some undisturbed lands would be affected, which would result in the conversion of natural areas to industrial land. No additional land use changes would result from operation of the nuclear facility. The NRC staff concludes that the impacts to land use from construction and operation of a new nuclear alternative would be SMALL.

4.2.3.2 Visual Resources

Because the facility would be located on an existing site, visual resources impacts of most new buildings and infrastructure would be minimal. If proposed, the construction of natural draft cooling towers would be the largest visual impact because both the towers themselves and the plume could be visible from a distance. The magnitude of this impact would vary based on the topography of the chosen site and surrounding area. The NRC staff concludes that the impacts to visual resources from construction and operation of a new nuclear alternative would be SMALL to MODERATE.

4.2.4 Coal (Integrated Gasification Combined Cycle) Alternative

4.2.4.1 Land Use

The IGCC alternative assumes that the new facility would be built at an existing energy-producing site or a retired coal plant site in Illinois or another state within the ROI. Construction of the facility would require 2,000 ac (809 ha) of land. The NRC staff assumes that this alternative would use existing onsite structures and previously disturbed areas to the extent practicable to minimize new development in undisturbed areas. However, because the footprint of the facility would be large, it is likely that construction would require clearing of lands that are currently in a different land use, such as agricultural, forested, or other natural areas. The impacts of this would vary widely based on the specific site selection and land uses that would be lost due to construction. No additional land use changes would result from operation of the IGCC facility. The NRC staff concludes that the impacts to land use from construction and operation of an IGCC alternative would be SMALL to MODERATE, primarily due to the potential for conversion of land to industrial use during construction.

4.2.4.2 Visual Resources

Because the facility would be located on an existing site, visual resources impacts would be minimal. The mechanical draft cooling towers would likely not be significantly taller than other buildings on the site. However, the plume created from operation of the towers could create noticeable visual impacts depending on the topography of the chosen site and surrounding area. The NRC staff concludes that the impacts to visual resources from construction and operation of an IGCC alternative would be SMALL to MODERATE.

4.2.5 Natural Gas Combined Cycle Alternative

4.2.5.1 Land Use

The NGCC alternative assumes that the facility would be built at an existing energy-producing site or a retired coal plant site in Illinois or another state within the ROI. The facility would require 94 ac (38 ha) of land for the plant and associated pipelines. Because the footprint of the facility would be relatively small, the entire construction footprint could likely be sited in already developed areas of the site, which would minimize land use changes. No additional land use changes would result from operation of the new NGCC facility. The NRC staff concludes that the impacts to land use from construction and operation of an NGCC alternative would be SMALL.

4.2.5.2 Visual Resources

Because the facility would be located on an existing site, visual resources impacts would be minimal. The mechanical draft cooling towers would likely not be significantly taller than other buildings on the site. However, the plume created from operation of the towers could create noticeable visual impacts depending on the topography of the chosen site and surrounding area. The NRC staff concludes that the impacts to land use and visual resources from construction and operation of a new nuclear alternative would be SMALL to MODERATE.

4.2.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

4.2.6.1 Land Use

The NGCC component of this alternative would require the same amount of land as the NGCC alternative (94 ac (38 ha)), but the NGCC component would likely make better use of existing infrastructure because it would be sited at an existing power plant in Illinois or another state within the ROI and could use buildings and structures that are already in place and operational for the existing facility. Land use impacts would be similar to or less than those described in Section 4.2.5 for the NGCC alternative and would, therefore, be SMALL.

The wind component of the combination alternative would require 3,376 ac (1,366 ha) to 10,127 ac (4,098 ha) at sites across the ROI. However, the majority of this land would only be temporarily disturbed during construction. Permanently disturbed land would hold the wind turbines, access roads, and transmission lines. Land used for equipment laydown and turbine component assembly and erection could be returned to its original state. Given the large footprint of the wind component, land use could be affected. However, some land uses, such as agriculture, could continue once the wind turbines are operational. Land use impacts for the wind component would range from SMALL to MODERATE depending on the amount and types of land that would be affected by wind turbine construction.

The solar component would require 6,749 ac (2,731 ha) of land across the ROI. The majority of solar installations could be installed on building roofs at existing residential, commercial, or industrial sites or at larger standalone solar facilities, and thus, it is possible that little land would be required for construction. However, the exact magnitude of impacts on land use would depend on the amount of land that is required to be converted for construction of solar installations. Unlike wind power, solar-powered installations often cannot be co-located with existing land uses (such as in a crop-producing agricultural field). The impacts of the solar component of this alternative on land use would range from SMALL to MODERATE depending on the amount and types of land that would be affected by construction of the solar installations.

The NRC staff concludes that the impacts of the combination alternative on land use would be SMALL to MODERATE. This range is primarily the result of the variability in land required for the wind and solar components of the alternative.

4.2.6.2 Visual Resources

Visual resource impacts for the NGCC component of this alternative would be similar to or less than those described in Section 4.2.5 for the NGCC alternative and would, therefore, be SMALL. Visual resources would be significantly affected by construction of the wind component. Although specific effects would vary based on the topography and remoteness of the wind turbine locations, the visual impact of wind energy is often one of the most significant impacts and could range from MODERATE to LARGE. The visual impacts of the solar component would also vary based on the topography of the area but are expected to be minimal because individual solar installations are not tall or expansive. Thus, the impacts of the solar component would likely be SMALL. Overall, the NRC concludes that the impacts of the combination alternative on visual resources would be SMALL to LARGE.

4.2.7 Purchased Power

4.2.7.1 Land Use

The purchased power alternative would have wide-ranging impacts that are hard to specifically assess because this alternative could include a mixture of coal, natural gas, nuclear, and wind across many different sites in the ROI. This alternative would likely have little to no construction impacts because it would include power from already-existing power generating facilities (e.g., from excess capacity or peak capacity). The construction of additional transmission lines, as needed, could affect land uses if the lines require the clearing of new transmission line corridors. The types of operational impacts would be similar to the effects discussed in the preceding alternative sections. This alternative would be more likely to intensify already existing effects (impacts) at power generating facilities than create wholly new effects on land use. Existing facilities would likely have best management practices (BMPs) and other procedures in place to ensure that effects to the environment during operations are minimized. The NRC staff concludes that the impacts on land use from the purchased power alternative would be SMALL.

4.2.7.2 Visual Resources

The purchased power alternative would not result in the construction of any buildings or facilities or any other changes to existing visual resources. Thus, the NRC staff concludes that the purchased power alternative would have no impact on visual resources, and as such, it would be SMALL.

4.3 Air Quality and Noise

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on air quality and noise.

4.3.1 Proposed Action

Section 3.3 describes the meteorological, air quality, and noise conditions in the vicinity of Braidwood. Title 10 of *Code of Federal Regulations* (CFR) Part 51, Subpart A, Appendix B, Table B-1 lists a summary of findings on National Environmental Policy Act (NEPA) issues for license renewal of nuclear power plants. Two Category 1 air quality issues are applicable to Braidwood, “air quality impacts (all plants)” and “air quality effects of transmission lines” (see

Table 4–2). There are no Category 2 issues for air quality. One Category 1 noise issue is applicable to Braidwood, "noise impacts"; there are no Category 2 issues for noise.

Table 4–2. Air Quality and Noise

Issue	GEIS Section	Category
Air quality impacts (all plants)	4.3.1.1	1
Air quality effects of transmission lines	4.3.1.1	1
Noise impacts	4.3.1.2	1

Source: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51

4.3.1.1 Air Quality

Section 3.3.2 discusses the air quality conditions in the vicinity of Braidwood as well as air emissions resulting from operation of Braidwood. The Category 1 issue "air quality effects of transmission lines" considers the production of ozone and oxides of nitrogen; the GEIS found that minute and insignificant amounts of ozone and nitrogen oxides are generated during transmission. The Category 1 issue "air quality impacts (all plants)," considers the air quality impacts from continued operation and refurbishment associated with license renewal. The GEIS concludes that the impact of refurbishment activities on air quality during the license renewal term would be SMALL for most plants, but could be cause for concern at plants located in or near air quality nonattainment or maintenance areas (NRC 2013d).

The NRC staff did not identify any new and significant information during the review of Exelon's ER in the license renewal application (LRA) (Exelon 2013a), the site audit, or during the scoping process. As a result, no information or impacts related to these issues were identified that would change the conclusions presented in the GEIS. Therefore, there are no impacts related to these issues beyond those discussed in the GEIS.

4.3.1.2 Noise

Section 3.3.3 discusses the noise conditions in the vicinity of Braidwood as well as noise sources resulting from operation of Braidwood. One Category 1 noise issue is applicable to Braidwood, "noise impacts" (see Table 4–2). The 1996 GEIS (NRC 1996) concluded that noise was not a problem at operating plants and was not expected to be a problem at any nuclear plant during the license renewal term, and the 2013 GEIS did not identify new information that would alter this conclusion; therefore, offsite (beyond the Braidwood site boundary) noise impacts are expected to be SMALL. The NRC staff did not identify any new and significant information during the review of Exelon's ER in the LRA (Exelon 2013a), the site audit, or during the scoping process. As a result, no information or impacts related to these issues were identified that would change the conclusions presented in the GEIS. Therefore, there are no impacts related to these issues beyond those discussed in the GEIS. The GEIS concludes that the impact level related to these issues is SMALL.

4.3.2 No-Action Alternative

4.3.2.1 Air Quality

When the plant stops operating, there would be a reduction in emissions from activities related to plant operation such as use of stationary combustion sources (e.g., diesel generators, auxiliary boilers, diesel engine auxiliary feedwater (AFW) pumps) and vehicle traffic

(e.g., workers and delivery). Therefore, if emissions decrease, the impact on air quality from shutdown (decommissioning) of the Braidwood Station would be SMALL.

4.3.2.2 Noise

When the plant stops operating, there will be no noise from activities related to plant operation such as circulating water make-up pumps, main steam valves, water discharge system, and vehicle traffic (e.g., workers and delivery). In other words, noise levels around the site would be back to the background levels before the Braidwood Station was built. Therefore, if noise sources are reduced, the impact on ambient noise levels would also be reduced and would be SMALL.

4.3.3 New Nuclear Alternative

4.3.3.1 Air Quality

Because of the moratorium preventing the construction of new nuclear power plants within Illinois, the new nuclear alternative would be located elsewhere in the ROI. The ROI is defined as the states of Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri, and Wisconsin. The reactor would be installed on an existing nuclear or coal power plant site in the ROI, allowing for the maximum use of existing ancillary facilities such as support buildings and transmission infrastructure.

Within the ROI states, the majority of the area is designated as attainment for all pollutants. However, existing air quality conditions range from attainment to nonattainment areas within the ROI. Nonattainment areas within the ROI are primarily associated with the heavily urbanized areas near Chicago, IL, and St. Louis, MO (EPA 2014c). Therefore, it is possible that the new nuclear alternative could be located in an air quality area meeting all current National Ambient Air Quality Standards (NAAQS) or in a location not meeting one or more current NAAQS (nonattainment). It is also possible that air quality attainment/nonattainment designations may change prior to the development of the new nuclear alternative within the ROI.

<u>Construction</u>

Construction of the new nuclear plant would result in temporary impacts on local air quality. During construction, air quality would be affected by the release of criteria pollutants (nitrogen oxides, sulfur dioxide, carbon monoxide, particulate matter (PM)) and greenhouse gases (GHGs) from combustion of fuel in construction vehicles and equipment, workforce commuting vehicles, and material delivery vehicles (i.e., engine exhaust and fugitive dust). Greenhouse gas emissions during construction would result primarily from the consumption of fossil fuels in the operation of construction vehicles and equipment and from the operation of delivery vehicles and vehicles used by the commuting workforce. Greenhouse gas emissions are controlled by using fuels that meet U.S. Environmental Protection Agency (EPA) requirements in all vehicles and equipment and keeping all vehicles and equipment maintained in accordance with manufacturers' specifications. Some releases of volatile organic compounds (VOCs) would be expected from onsite vehicle and equipment fueling activities and from the use of cleaning agents and corrosion control coatings. Ground disturbance—such as from ground-clearing and cut-and-fill activities, movement of construction vehicles on unpaved and disturbed land surfaces, and delivery and stockpiling of materials used in construction (e.g., sand and gravel)—would produce fugitive dust releases.

Construction lead times for nuclear plants are anticipated to be 7 years (NRC 2013j). Air emissions would be intermittent and vary based on the level and duration of a specific activity throughout the construction phase. Construction of a new nuclear plant would be expected to employ BMPs, if necessary, to reduce construction-related air quality impacts to acceptable

levels. State and Federal permits and regulated practices for managing air emissions from construction equipment and temporary stationary sources and vehicle inspection and traffic management plans will limit potential impacts on air quality from building a nuclear power plant. Since air emission from construction activities would be limited, local, and temporary, the NRC staff concludes that the overall air quality impacts associated with construction of a new nuclear alternative would be SMALL.

Operation

Operation of a new nuclear generating plant would result in similar air emissions to those of the existing Braidwood site. Sources of air emissions can include stationary combustion sources (e.g., emergency diesel generators, pumps, auxiliary boilers) and mobile sources (worker vehicles, onsite heavy equipment and support vehicles, and delivery of materials and disposal of wastes). The new nuclear power plant would likely use natural draft cooling towers as opposed to a once-through cooling system as currently used at Braidwood and will result in additional PM as drift.

In general, most stationary combustion sources at a nuclear power plant would operate only for limited periods, often for periodic maintenance testing. Thus, emissions from stationary combustion sources would fall far below the threshold for major sources (100 tons per year (tons/yr)) and threshold for mandatory GHG reporting (25,000 metric tons (MT) per year). In contrast, cooling towers would operate continuously for the entire year. However, a nuclear power plant located in the ROI would use cooling water taken from a nearby river or lake, which would have relatively low concentrations of total dissolved solids. In addition, the modern cooling towers would be equipped with drift eliminators to minimize the loss of cooling water from the tower via drift. Thus, PM emissions from cooling towers are anticipated to be minimal.

Air pollutants emitted from stationary combustion sources (e.g., criteria pollutants, VOCs, hazardous air pollutants (HAPs), and GHGs) and from cooling towers (PM as drift) associated with operations of a nuclear power plant would be permitted in accordance with State and Federal regulatory requirements. The new nuclear plant would be required to apply for and obtain an air quality permit to operate from the state air regulatory authority for the state in which the plant would be located. The permit would be similar to the synthetic minor source air permit issued by the Illinois Environmental Protection Agency (IEPA) currently governing operation of Braidwood's air emission sources. Section 51.307 in Subpart P of 40 CFR Part 51 contains the visibility protection regulatory requirements, including the review of the new sources that may affect visibility in any Federal Class I area. If a new nuclear plant were located near a mandatory Class I area, additional air pollution control requirements may be required.

Air emissions for combustion sources from a new nuclear plant are expected to be similar to what is emitted at Braidwood:

- sulfur dioxide (SO_2): 0.06 tons (0.05 MT) per year,
- nitrogen oxides (NO_x): 28 tons (25 MT) per year,
- carbon monoxide (CO): 7.2 tons (6.5 MT) per year,
- particulate matter (PM_{10}): 0.50 tons (0.45 MT) per year, and
- carbon dioxide equivalents (CO_2e): 1,361 tons (1,230 MT) per year.

A new nuclear plant would have slightly higher total PM_{10} emissions due to the use of natural draft cooling towers. During operation, air quality impacts would also include releases of criteria pollutants from vehicles used by the commuting workforce and vehicles (primarily trucks) used to deliver supplies and equipment to the site.

The NRC staff evaluated potential impacts on air quality associated with criteria pollutants and GHG emissions from operating a new nuclear alternative. Based on its review (discussed above), the NRC staff determined that the impacts would be minimal. Therefore, the NRC staff concludes that the impacts of operation of a new nuclear alternative on air quality from emissions of criteria pollutants and GHGs would be SMALL.

Conclusion

The NRC staff concludes that the air quality impacts associated with construction and operation of a new nuclear alternative would be SMALL.

4.3.3.2 Noise

Construction

Construction of a new nuclear power plant is similar to that of other large industrial projects and involves many noise-generating activities. In general, noise emissions vary with each phase of construction, depending on the level of activity, the mix of construction equipment for each phase, and site-specific conditions. Noise propagation to receptors is affected by several factors, including source-receptor configuration, land cover, meteorological conditions (temperature, relative humidity, and vertical profiles of wind and temperature), and screening (such as topography and natural or man-made barriers). Typical construction equipment, such as dump trucks, loaders, bulldozers, graders, scrapers, air compressors, generators, and mobile cranes, would be used, and pile driving and blasting activities would take place during the construction of a new nuclear power plant. Another noise source includes commuter, delivery, and support vehicular traffic traveling within, to, and from the facility.

Noise is produced by the equipment and vehicles used to construct the facility. Construction equipment and vehicles produce engine noise during operation within the construction site; delivery vehicles also produce noise outside the construction site on roads in the vicinity of the site. Noise is also produced during demolition of any existing structures, excavation and transport of soil, transport of construction materials, preparation of building materials for installation (cutting, hammering, grinding, etc.), and construction of the buildings and equipment.

Noise emissions from construction equipment are predicted to be in the 85 to 100 decibels adjusted (dBA) range (Knauer and Pedersen 2011); however, noise levels attenuate rapidly with distance such that at half-a-mile distance from construction equipment, 85 to 90 dBA noise levels can drop to 51 to 61 dBA (NRC 2002a). Additionally, noise abatement and controls can be incorporated to reduce noise impacts. Accounting for attenuation from the construction site and noise controls, predicted noise levels can be less than Housing and Urban Development’s acceptable noise level guideline of 65 dBA. Based on the temporary nature of construction activities, consideration of noise attenuation from the construction site to residences, the location and characteristics (i.e., ground cover), and good noise control practices, the NRC staff concludes that the potential noise impacts of construction activities from a new nuclear alternative would be SMALL.

Operation

During the operation phase, noise sources from the new nuclear power plant would come from cooling towers, main steam valves, transformers, turbines, and auxiliary equipment such as standby generators or auxiliary boilers, and vehicular traffic (commuting, delivery, support), similar to those for Braidwood discussed in Section 3.3.3 of this SEIS. Although the plant layout and the distance from primary noise sources to the nearby receptors at Braidwood might be different from those at a new nuclear alternative and the new nuclear alternative will likely have cooling towers, the NRC staff does not expect noise impacts for a new nuclear plant to be any

greater than that analyzed for the existing Braidwood site. Therefore, the noise impacts of a new nuclear plant located within the ROI region would be SMALL.

Conclusion

The NRC staff concludes that the noise impacts associated with operation and construction of a new nuclear alternative would be SMALL.

4.3.4 Coal (Integrated Gasification Combined Cycle) Alternative

4.3.4.1 Air Quality

The IGCC alternative consists of 2,472 MWe of new generation produced by four 618 MWe IGCC units. The IGCC plant would be installed (or located) on one or more existing nuclear or coal power plant sites in the ROI, allowing for the maximum use of existing ancillary facilities, such as support buildings and transmission infrastructure. The ROI and existing air quality discussion in Section 4.3.3.1 also applies to the IGCC alternative. It is possible that the IGCC alternative could be located in an air quality area meeting all current NAAQS (attainment), or in a location not meeting one or more current NAAQS (nonattainment), depending on the availability of suitable sites for development. It is also possible that air quality attainment/nonattainment designations may change prior to the development of the IGCC alternative within the ROI. For instance, if the IGCC alternative were to be located at the Braidwood site, Will County would be designated as nonattainment for the 2008 8-hour ozone (marginal) NAAQS and 2010 sulfur dioxide NAAQS (partial county designation) and designated maintenance area for the 1997 $PM_{2.5}$ NAAQS (40 CFR 81.314; EPA 2015).

Construction

Construction of an IGCC plant would be similar to that of other large industrial projects and involves many activities similar to those for a new nuclear alternative presented in Section 4.3.3.1. Construction of an IGCC plant would result in the release of various criteria pollutants (PM, nitrogen oxides, carbon monoxide, and sulfur dioxide), VOCs, HAPs, and GHGs from operation of internal combustion engines in construction vehicles, equipment, delivery vehicles, and vehicles used by the commuting construction workforce. In addition, soil disturbance activities such as earthmoving and material handling would generate fugitive dust. Release of VOCs will result from the onsite storage and dispensing of vehicle and equipment fuels. Air emissions would be intermittent and vary based on the level and duration of a specific activity throughout the construction phase. Construction lead times for IGCC plants are estimated to be 3 years (NETL 2007). Impacts would be localized, intermittent, and short-lived, and adherence to well-developed and well-understood construction BMPs would mitigate such impacts. The NRC staff concludes that construction-related impacts on air quality from an IGCC alternative would be of relatively short duration and would be SMALL.

Operation

The sources of air emissions during operation of the IGCC include heat recovery steam generator (HRSG) stacks, the wet gas sulfuric acid system exhaust, acid gas removal process startup/shutdown vents, startup stacks, flares, material handling equipment, and mechanical draft cooling towers (DOE 2010b; EPA 2006; NETL 2007). The HRSG stacks would release the most emissions. Auxiliary boilers and firewater pumps would also generate emissions on an infrequent basis.

Compared to conventional coal-fired power plants, the proposed IGCC power plant would reduce sulfur dioxide, nitrogen oxide, mercury, and PM emissions by removing constituents from the syngas (DOE 2010b). The IGCC alternative would also result in lower nitrogen oxide

emissions since nearly 100 percent of the fuel-bound nitrogen from the syngas would be removed from the syngas before combustion in the gas turbine. Sulfur removal technology would remove more than 99 percent of the sulfur in the syngas. The use of sulfide-activated carbon could remove more than 92 percent of mercury from the syngas. More than 99.9 percent of particulate emissions would be removed from the syngas using high-temperature, high-pressure filtration.

Various Federal and state regulations aimed at controlling air pollution would affect an IGCC alternative located in the seven-state ROI. A new 2,472-MWe IGCC plant (or multiple plants in different locations totaling 2,472 MWe) would qualify as a new major source of criteria pollutants and GHGs and would require a Prevention of Significant Deterioration (PSD) of air quality review under New Source Review (NSR) regulations (42 U.S.C. § 7401 et seq. (Clean Air Act (CAA))), as implemented by the applicable state regulatory authority. If the IGCC alternative is located in an air quality area designated nonattainment, emissions of the nonattainment pollutant would be reviewed under nonattainment NSR.

The NSR air permit application review process would include evaluation of all potentially applicable air quality regulations, identify those that apply to the IGCC plant, and develop control, compliance, reporting, and recordkeeping requirements to demonstrate compliance with applicable regulations. The new IGCC plant would be required to secure a Title V operating permit from the state agency. Analysis regarding NAAQS compliance would be conducted at the specific site location. The IGCC plant would need to comply with applicable New Source Performance Standards, such as the standards of performance for electric utility steam generating units set forth in 40 CFR Part 60, Subpart Da (electric utility steam generating units).

If the IGCC alternative were located close to a mandatory Class I area, additional air pollution control requirements would be necessary (Subpart P of 40 CFR Part 51) as mandated by the Regional Haze Rule. Within the ROI, there are five Class I Federal areas, including: Mammoth Cave National Park (NP) in Kentucky (40 CFR 81.411), Isle Royale NP and Seney Wilderness Area (WA) in Michigan (40 CFR 81.414), and Hercules-Glades WA and Mingo WA in Missouri (40 CFR 81.416). The rule could apply to the IGCC alternative, but would depend on specific site locations(s). If an IGCC plant was located close to a mandatory Class I area, additional air pollution analyses, and permitting and control requirements would potentially apply.

Air emissions for the IGCC alternative were estimated based on data presented in Table 4.3-1 in the GEIS (NRC 2013f). The resulting IGCC emissions are estimated to be as follows:

- sulfur dioxide (SO_2)— 820 tons (740 MT) per year,
- nitrogen oxides (NO_x)— 3,000 tons (2,720 MT) per year,
- particulate matter (PM_{10})— 480 tons (435 MT) per year,
- carbon monoxide (CO)— 2,045 tons (1,850 MT) per year, and
- carbon dioxide equivalents (CO_2e)— 14.3 million tons (13.0 million MT) per year.

The IGCC alternative would produce 820 tons (740 MT) of sulfur dioxide and 3,000 tons (3,000 MT) per year of nitrogen oxide. The IGCC plant would have to comply with Title IV of the CAA (42 U.S.C. § 7651) reduction requirements for sulfur oxide and nitrogen oxide, which are the main precursors of acid rain and the major causes of reduced visibility. Title IV establishes maximum sulfur oxide and nitrogen oxide emission rates from the existing plants and a system of sulfur oxide emission allowances that can be used, sold, or saved for future use by the new plants. The new plant would be subjected to the continuous monitoring requirements of sulfur

dioxide and nitrogen oxide as specified in 40 CFR Part 75. The Clean Air Interstate Rule [4] (CAIR) requires 27 states (including Indiana, Iowa, Michigan, Missouri, Kentucky, and Wisconsin) to improve air quality requiring power plants to reduce sulfur dioxide and nitrogen oxide emissions (EPA 2014c). A new IGCC plant would be subject to these additional rules and regulations.

The IGCC alternative would emit approximately 14.3 million tons (approximately 13.0 million MT) per year of carbon dioxide equivalent emissions. The plant would be subjected to the continuous monitoring requirements for carbon dioxide, as specified in 40 CFR Part 75. On July 12, 2012, EPA issued a final rule tailoring the criteria that determine which stationary sources and modifications to existing projects become subject to permitting requirements for GHG emissions under the PSD and Title V Programs of the CAA (77 FR 41051). Beginning January 2, 2011,[5] operating permits issued to major sources of GHG under the PSD or Title V Federal permit programs must contain provisions requiring the use of best available control technology (BACT) to limit the emissions of GHGs if those sources would be subject to PSD or Title V permitting requirements because of their non-GHG pollutant emission potentials and their estimated GHG emissions are at least 75,000 tons/yr of carbon dioxide equivalents. If the IGCC alternative meets PSD or Title V permitting requirements for non-GHG pollutant emissions and the GHG emission thresholds established in the rule, then GHG emissions from this alternative would be regulated under the PSD and Title V permit programs.

In response to the Consolidated Appropriations Act of 2008 (Public Law 110-161), EPA issued final mandatory GHG reporting regulations for major sources effective in December 2009 (EPA 2012b). Major sources are defined as those emitting more than 25,000 tons/yr of all GHGs. An IGCC alternative would be subject to these reporting regulations with or without carbon capture. On January 8, 2014, the EPA issued a new proposal for GHG emissions from new fossil fuel-fired electric utility steam generating units (79 FR 1430). It also proposes standards of performance for IGCC units that burn coal. The performance standards are based on partial implementation of carbon capture and sequestration (CCS) as the best system of emission reduction (BSER). Although the proposed rule has not been finalized, the IGCC alternative analysis includes an option for future implementation of CCS.

An IGCC alternative also would be subject to the Mercury and Air Toxics Standards (MATS) final rule, finalized by EPA on December 16, 2011 (EPA 2012c). MATS sets standards for emissions of heavy metals (mercury, arsenic, chromium, and nickel) and acid gases (hydrochloric acid and hydrofluoric acid). Mercury is the most prominent HAP emitted and is subject to regulation by the MATS rule. New IGCC units are required to meet a mercury emission limit of 0.003 pounds per gigawatt hour (40 CFR Part 63 Subpart UUUUU). NRC staff estimates that an IGCC alternative replacing the electrical output of Braidwood would generate from 0.03 tons (0.02 MT) of mercury per year.

[4] The Clean Air Interstate Rule (CAIR) was first issued by EPA in 2005; however, the Federal rule was vacated by the D.C. Circuit Court on February 8, 2008. In December 2008, the U.S. Court of Appeals for the D.C. Circuit reinstated the rule, allowing it to remain in effect but also requiring EPA to revise the rule and its implementation plan. On July 6, 2010, EPA proposed replacing CAIR with the Cross-State Air Pollution Rule (CSAPR) for control of sulfur dioxide and nitrogen oxide emissions that cross state lines, the regulations of which would be implemented in 2011 and finalized in 2012. However, CSAPR was vacated by the D.C. Circuit Court on August 21, 2012. On April 29, 2014, the U.S. Supreme Court reversed the D.C. Circuit opinion vacating CSAPR. EPA is reviewing the opinion and CAIR remains in effect.

[5] On June 23, 2014, the U.S. Supreme Court issued a decision that EPA may not treat GHGs as an air pollutant for purposes of determining whether a source is a major source required to obtain a PSD or Title V permit, but could continue to require PSD and Title V permits, otherwise required based on emissions of conventional pollutants. In July 2014, EPA issued a memorandum in response to the Supreme Court's decision and acknowledged that while the decision is pending judicial action, EPA will no longer require PSD or Title V permits for GHG-emitting sources that are not sources subject to PSD or Title V permits based on emissions of conventional pollutants (nitrogen oxides, carbon monoxide, etc.) (EPA 2014d).

The impact from sulfur dioxide and nitrogen oxide emissions would be significant and subject to a Title V permit. GHG emissions also would be noticeable and significant; GHG emissions would be much larger than the threshold in EPA's GHG Tailoring Rule and GHG emissions may be regulated under the PSD and Title V permit programs. The NRC staff concludes that the air quality impacts associated with operation of an IGCC alternative would be MODERATE.

Conclusion

The NRC staff concludes that the overall air quality impacts associated with construction and operation of an IGCC alternative would be MODERATE.

4.3.4.2 Noise

Construction

Construction of an IGCC plant is similar to that of other large industrial projects, and construction-related noise sources would be virtually the same as those for construction of the nuclear alternative. However, the construction period for the IGCC alternative would be shorter and the level of activities scattered over a wide area would be less extensive compared with construction of a nuclear alternative. Consequently, with construction-related noise for the nuclear alternative as a bounding condition, the NRC staff concludes that construction-related noise associated with the IGCC alternative would be SMALL.

Operation

Operation of an IGCC plant would introduce mechanical sources of noise that would be audible offsite. Continuous sources include the mechanical equipment associated with normal plant operations and mechanical draft cooling towers. Intermittent sources include the equipment related to coal handling, solid waste disposal, transportation related to coal and lime/limestone delivery, use of outside loudspeakers, and the commuting of plant employees. Noise associated with rail delivery of coal and lime/limestone would extend beyond the plant site boundary and would be most significant for residents living in the vicinity of the facility and along the rail route. Noise impacts associated with rail delivery are predicted to be in the 80 to 96 dBA range (NRC 2002a). At this sound level range, transportation-related noise has the potential to be noticeable and cause an adverse community response as this noise source can reach beyond the plant site boundary. The NRC staff concludes that the potential impacts of noise on residents in the vicinity of the facility of IGCC alternative and the rail line are considered to range from SMALL to MODERATE, depending on the distance from primary noise sources to nearby sensitive receptors.

Conclusion

The NRC staff concludes that the overall potential impacts of noise associated with construction and operation of the IGCC alternative and the rail line are considered to range from SMALL to MODERATE.

4.3.5 Natural Gas Combined Cycle Alternative

4.3.5.1 Air Quality

This alternative includes the construction and operation of five NGCC 560-MW units (total 2,800 MW) and a capacity factor of 85 percent. These sites could be located at an existing power plant site in the ROI. Some infrastructure upgrades may be required and would require construction of a new or upgraded pipeline. Using existing power plant sites maximizes availability of infrastructure and reduces disruption to land and populations.

Construction

Construction of an NGCC power plant would be similar to that of other large industrial projects. Construction of an NGCC power plant would result in the release of various criteria pollutants (PM, nitrogen oxides, carbon monoxide, and sulfur dioxide), VOCs, HAPs, and GHGs from the operation of internal combustion engines in construction vehicles, equipment, delivery vehicles, and vehicles used by the commuting construction workforce. In addition, onsite soil disturbance activities such as earthmoving and material handling would generate fugitive dust. Releases of VOCs will also result from the onsite storage and dispensing of vehicle and equipment fuels. Air emissions would be intermittent and vary based on the level and duration of a specific activity throughout the construction phase. Gas-fired power plants are constructed relatively quickly; construction lead times for NGCC plants are around 2 to 3 years (Dujardin 2005; EIA 2011). Impacts would be localized, intermittent, and short-lived, and adherence to well-developed and well-understood construction BMPs would mitigate such impacts. Therefore, the NRC staff concludes that construction-related impacts on air quality from an NGCC alternative would be of relatively short duration and would be SMALL.

Operation

Operation of the NGCC plant would result in significant emissions of certain criteria pollutants, including carbon monoxide, nitrogen oxide, and PM. The sources of air emissions during operation include gas turbines through HRSG stacks and mechanical draft cooling towers. Auxiliary boilers and emergency generators would also generate emissions on an infrequent basis.

Various Federal and state regulations aimed at controlling air pollution would affect an NGCC alternative located in the seven-state ROI. It is possible that the NGCC alternative could be located in an air quality area meeting all current NAAQS (attainment), or in a location not meeting one or more current NAAQS (nonattainment), depending on the availability of suitable sites for development. For instance, if the NGCC alternative were to be located at the Braidwood site, Will County is designated as nonattainment for the 2008 8-hour ozone (marginal) NAAQS and 2010 sulfur dioxide NAAQS (partial county designation) and designated maintenance area for the 1997 $PM_{2.5}$ NAAQS (40 CFR 81.314; EPA 2015). An NGCC plant would be subject to the NSR permitting program to ensure air emissions are minimized and the local air quality is not substantially degraded (EPA 2013b). The new NGCC plant would be required to secure a Title V operating permit from the state agency. The NGCC plant would need to comply with the standards of performance for stationary combustion turbines set forth in 40 CFR Part 60 Subpart KKKK. If the NGCC alternative were located close to a mandatory Class I area, additional air pollution control requirements would be required (Subpart P of 40 CFR Part 51) as mandated by the Regional Haze Rule. A detailed discussion of these Federal and state regulations is provided in Section 4.3.4.1.

Air emissions for the NGCC alternative were estimated based on data presented in Table 4.3-2 in the GEIS and EPA emission factors (NRC 2013, EPA 2000). The estimate is based on using advanced F class gas turbines at one or multiple sites within the ROI. The resulting NGCC emissions are estimated to be as follows:

- sulfur dioxide (SO_2)— 380 tons (350 MT) per year,
- nitrogen oxides (NO_x)— 600 tons (540 MT) per year,
- particulate matter (PM_{10})— 210 tons (190 MT) per year,
- carbon monoxide (CO)— 1,690 tons (1,530 MT) per year, and

- carbon dioxide equivalents (CO_2e)— 7.9 million tons (7.2 million MT) per year.

The NGCC alternative would produce 380 tons (350 MT) per year of sulfur dioxide and 600 tons (540 MT) per year of nitrogen oxide. The new plant would be subjected to the continuous monitoring requirements of sulfur dioxide and nitrogen oxide as specified in 40 CFR Part 75. Under the Federal Acid Rain Program, a new natural gas-fired plant would have to comply with Title IV of the CAA reduction requirements for sulfur dioxide and nitrogen oxides, which are the main precursors of acid rain and the major cause of reduced visibility. The CAIR requires 27 states (including Indiana, Iowa, Michigan, Missouri, Kentucky, and Wisconsin) to improve air quality requiring power plants to reduce sulfur dioxide and nitrogen oxide emissions (EPA 2014c). A new NGCC plant would be subject to these additional rules and regulations.

The NGCC alternative would emit approximately 7.9 million tons (approximately 7.2 million MT) per year of carbon dioxide equivalents. The plant would be subjected to the continuous monitoring requirements for carbon dioxide, as specified in 40 CFR Part 75. On July 12, 2012, EPA issued a final rule tailoring the criteria that determine which stationary sources and modification to existing projects become subject to permitting requirements for GHG emissions under the PSD and Title V Programs of the CAA (77 FR 41051). Beginning January 2, 2011, operating permits issued to major sources of GHG under the PSD or Title V Federal permit programs must contain provisions requiring the use of BACT to limit the emissions of GHGs (if those sources would be subject to PSD or Title V permitting requirements because of their non-GHG pollutant emission potentials and their estimated GHG emissions are at least 75,000 tons/yr of carbon dioxide equivalents). If the NGCC alternative meets PSD or Title V permitting requirements for non-GHG pollutant emissions and the GHG emission thresholds established in the rule, then GHG emissions from this alternative would be regulated under the PSD and Title V permit programs. In response to the Consolidated Appropriations Act of 2008 (Public Law 110-161), EPA issued final mandatory GHG reporting regulations for major sources effective in December 2009 (EPA 2012b). Major sources are defined as those emitting more than 25,000 tons/yr of all GHGs. An NGCC alternative would be subject to these reporting regulations with or without carbon capture. On January 8, 2014, the EPA issued a new proposal for GHG emissions from new fossil fuel-fired electric utility steam generating units (79 FR 1430). It also proposes standards of performance for natural gas-fired stationary combustion turbines based on modern, efficient NGCC technology as the BSER. Although the proposed rule has not been finalized, the IGCC alternative analysis includes an option for future implementation of CCS.

In December 2000, EPA issued regulatory findings on emissions of HAPs from electric utility steam-generating units (65 FR 79825). These findings indicated that natural gas-fired plants emit HAPs such as arsenic, formaldehyde, and nickel and stated that:

> [t]he impacts due to hazardous air pollutants (HAP) emissions from natural gas-fired electric utility steam generating units were negligible based on the results of the study. The Administrator finds that regulation of HAP emissions from natural gas-fired electric utility steam generating units is not appropriate or necessary.

Mercury is not emitted from NGCC power plants due to the lack of mercury in natural gas used as fuel.

Considerable air emissions are emitted from operations of the NGCC alternative. The impacts from nitrogen oxide and sulfur dioxide emissions would be significant and subject to a Title V permit. GHG emissions also would be noticeable and significant; carbon dioxide emissions would be much larger than the threshold in EPA’s GHG Tailoring Rule. The NRC staff

concludes that the overall air quality impacts associated with operation of an NGCC alternative would be MODERATE.

Conclusion

The NRC staff concludes that the overall air quality impacts associated with construction and operation of an NGCC alternative would be MODERATE.

4.3.5.2 Noise

Construction

The construction-related noise sources for an NGCC alternative would be virtually the same as those for construction of the IGCC alternative. Construction vehicles and equipment associated with the construction of the NGCC plant would generate noise; these impacts would be intermittent and last only through the duration of plant construction. Noise emissions from common construction equipment would be in the 85 to 100 dBA range (Knauer and Pedersen 2011). However, noise abatement and controls can be incorporated to reduce noise impacts. The NRC staff concludes that construction-related noise impacts associated with the NGCC alternative would be SMALL.

Operation

Noise impacts from operations would include cooling towers (water pumps, cascading water, or fans), transformers, turbines, pumps, compressors, exhaust stack, the combustion inlet filter house, condenser fans, high-pressure steam piping, and vehicles (Saussus 2012). Pipelines delivering natural gas fuel could be audible off site near gas compressor stations, but such noise impacts would be similar to impacts already occurring in the vicinity of the existing pipeline to which the new NGCC site would connect. Most noise-producing equipment is located inside the power block buildings and no outside fuel-handling activities will occur. Minor offsite noise source could be pipeline compressor stations. The NRC staff concludes that operation-related noise impacts from the NGCC alternative would be SMALL.

Conclusion

The NRC staff concludes that construction and operation-related noise impacts from the NGCC alternative would be SMALL.

4.3.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

The combination alternative relies on NGCC, wind, and solar generating capacity. The total installed solar photovoltaic (PV) capacity is 1,193 MW, the total installed wind capacity is 6,042 MW of onshore wind, and the total installed capacity for NGCC is 267 MW in this alternative. All portions of the combination alternative would be located in Illinois or other adjoining states in the ROI (Indiana, Iowa, Michigan, Missouri, Kentucky, and Wisconsin).

The NGCC alternative would require one 267-MW unit. For the NGCC portion of the combination alternative, it is assumed that sites would be located at an existing power plant site which maximizes availability of infrastructure and reduces disruption to land and populations. Most of the wind farms would likely be located on open agricultural cropland, which would remain largely unaffected by the wind turbines. The solar portion requires 1,193 MW and it is assumed that some of the capacity would be from small units and may be installed on building roofs or on existing residential, commercial, or industrial sites.

4.3.6.1 Air Quality

Construction

Air emissions associated with the construction of the NGCC portion of the combination alternative are similar to the NGCC alternative but reduced considerably because its electricity output is approximately 10 percent that of the NGCC alternative. As discussed in Section 4.3.5.1, construction activities for an NGCC alternative would cause some temporary impacts to air quality from dust generation during operation of the earthmoving and material handling equipment and exhaust emissions from worker vehicles and construction equipment. These emissions include criteria pollutants, VOCs, GHGs, and small amounts of HAPs. However, these impacts would be localized, intermittent, and short-lived, and adherence to well-developed and well-understood construction BMPs would mitigate such impacts. The NRC staff concludes that construction-related impacts on air quality from an NGCC portion of the combination alternative would be of relatively short duration and would be SMALL.

Only a small percentage of site land (5 percent or less) would be disturbed by construction activities because wind turbines need to be separated from one another in order to maximize energy production and avoid wake turbulences created by upwind turbines. Construction of the wind portion of the combination alternative would involve a number of activities, including road and staging/laydown area construction, land clearing, topsoil stripping, earthmoving operations, grading, ground excavation, drilling, foundation treatment, wind turbine erection, ancillary building/structure construction, and electrical and mechanical installation. For most wind energy facilities, the site preparation phase would last for only a few months, followed by a year-long construction phase (depending on size of the wind energy facility) (Tegen 2006). Air emissions associated with construction activities result from fugitive dust from soil disturbances and engine exhaust from heavy equipment and vehicular traffic. These emissions include criteria pollutants, VOCs, GHGs, and HAPs. Dust suppression methods and other mitigation measures could reduce impacts from fugitive dust. The wind portion of the combination alternative would have no power block, for which intensive construction activities would occur. Accordingly, the number of heavy equipment and workforce, level of activities, and construction duration would be substantially lower than other alternatives. Therefore, the NRC staff concludes that the overall air quality impacts associated with construction of the wind portion of the combination alternative would be SMALL.

Construction of the solar portion of the combination alternative would cause temporary impacts to air quality from fugitive dust from soil disturbances and engine exhaust from heavy equipment and from vehicular traffic. Air emissions associated with construction activities include criteria pollutants, VOCs, GHGs, and HAPs to a lesser amount. Dust suppression methods and other mitigation measures could reduce impacts from fugitive dust. The solar PV portion of combination alternative would have no power block, for which intensive construction activities would occur. Accordingly, the number of heavy equipment and workforce, level of activities, and construction duration would be substantially lower than those for other alternatives. Therefore, the NRC staff concludes that the overall air quality impacts associated with construction of the solar PV portion of the combination alternative would be SMALL.

Operation

Air emissions associated with the operation of the NGCC portion of the combination alternative are similar to the NGCC alternative in Section 4.3.5.1 but reduced proportionally because its electricity output is approximately 13 percent that of the NGCC alternative. Section 4.3.5 discusses the various State and Federal regulations that would control the construction and operation of an NGCC plant. The same regulatory controls discussed in Section 4.3.5 would apply to air emissions from the NGCC under this alternative.

Air emissions for the NGCC alternative were estimated based on data presented in Table 4.3-2 in the GEIS and Energy Information Administration (EIA) emission factors (EIA 1999; NRC 2013f). The estimate is based on using advanced F class gas turbines at one or multiple sites within the ROI. The resulting NGCC emissions are estimated to be as follows:

- sulfur dioxide (SO_2)— 50 tons (45 MT) per year,
- nitrogen oxides (NO_x)— 80 tons (70 MT) per year,
- particulate matter (PM_{10})— 30 tons (25 MT) per year,
- carbon monoxide (CO)— 220 tons (200 MT) per year, and
- carbon dioxide equivalents (CO_2e)— 1.0 million tons (0.9 million MT) per year.

Annual emissions of sulfur dioxide and nitrogen oxide would be lower than the major source threshold, while those of carbon monoxide would exceed major source threshold. The overall air quality impacts associated with operation of the NGCC portion of the combination alternative would be SMALL to MODERATE.

In general (taking into account full operation and maintenance activities), air emissions associated with the operation of solar energy facilities are negligible because no fossil fuels are burned to generate electricity. Emissions from the operation of wind energy facilities would include minor dust and engine exhaust emissions from vehicles and heavy equipment associated with site inspections, maintenance activities, and wind erosion from cleared land and access roads. Small amounts of emissions would be produced during the operation of diesel emergency generators but would be used on an infrequent basis. The types of emission sources and pollutants during operation would be similar to those during construction, but much fewer emissions would be released during operation. The NRC staff concludes that the overall air quality impacts associated with the operation of the wind portion of the combination alternative would be SMALL.

In general, air emissions associated with the operation of solar energy facilities are negligible because no fossil fuels are burned to generate electricity. Emissions from solar fields would include fugitive dust and engine exhaust emissions from vehicles and heavy equipment associated with site inspections, maintenance activities (mirror washing, replacement of broken mirrors), and wind erosion from cleared lands and access roads. The types of emission sources and pollutants during operation would be similar to those during construction, but much fewer emissions would be released during operation. These emissions should not cause exceedances of air quality standards or have any impacts on climate change. The NRC staff concludes that the overall air quality impacts associated with the operation of the solar PV portion of the combination alternative would be SMALL.

Conclusion

The overall air quality impacts associated with construction and operation of the combination alternative would be SMALL to MODERATE.

4.3.6.2 Noise

Construction

The construction-related noise sources for the NGCC portion of the combination alternative would be virtually the same as those for construction of the NGCC alternative. The construction period for the NGCC portion would be shorter, and the level of construction activities would be less extensive than the NGCC alternative. Consequently, the NRC staff concludes that

construction-related noise associated with the NGCC portion of combination alternative would be SMALL.

Construction of the wind portion of the combination alternative would involve a number of activities, as described above. The wind portion of the combination alternative would have no power block, for which intensive construction activities would occur. Accordingly, the number of heavy equipment and workforce, level of activities, and construction duration would be substantially lower than other alternatives. Considering these factors, the NRC staff concludes that construction-related noise associated with the wind portion of combination alternative would be SMALL.

Construction of the solar PV portion of the combination alternative would involve a number of activities. The solar PV portion of the combination alternative would have no power block for which intensive construction activities would occur. Accordingly, the number of heavy equipment and workforce, level of activities, and construction duration would be substantially lower than other alternatives. Considering these factors, the NRC staff concludes that construction-related noise associated with the solar PV portion of combination alternative would be SMALL.

Operation

Besides noise from the power block area, cooling towers, and vehicular traffic, operation-related noise for the NGCC would include limited outdoor waste-handling activities. Pipelines delivering natural gas fuel could be audible off site near gas compressor stations, but such sound impacts would be similar to impacts already occurring in the vicinity of the existing pipeline to which the new NGCC site would connect. Most noise-producing equipment is located inside the power block buildings and no outside fuel-handling activities will occur. Minor offsite noise source could be pipeline compressor stations. The NRC staff concludes that operation-related noise from the NGCC portion of combination alternative would be SMALL.

Noise impacts from wind generation operations would include aerodynamic noise from the turbine rotors and mechanical noise from the turbine drivetrain components. Noise levels are dependent on the wind and atmospheric conditions, which vary with time, and on site-specific conditions: the number and size of wind turbines, their layout, distance to the nearby sensitive receptors, land cover, and topography. Wind turbine noise levels can reach 105 dBA; however, studies show that at approximately 1,000 ft. (300 m) from a wind turbine, noise levels can reach 43 dBA (GE 2010; Hessler 2011). Therefore, masking effects of background noise should be taken into consideration. Unless noise from wind turbines is masked by high background levels (e.g., near major highways or industrial complexes), it can be noticeable and annoying at farther distances. One study indicated that, for the same A-weighted sound level, proportions of respondents annoyed by wind turbine noise are higher than for other community noise, such as aircraft, road, or railway traffic, and that the proportion annoyed increases more rapidly (higher rate over time) (Pedersen and Persson Waye 2004). Therefore, the NRC staff concludes that operation-related noise from the wind portion of the combination alternative would be SMALL to MODERATE, depending on the layout and location of the wind facility and the distance to nearby sensitive receptors.

The solar PV potion of the combination alternative would have no power block and cooling towers, and thus there would be a minimal number of noise sources with low-level noises. Noise sources include small-scale cooling systems to dissipate heat from solar module assemblies, solar tracking devices, inverters, transformers, and vehicle traffic for maintenance and inspection. Because of minimal noise-generating activities, noise from a solar PV facility would be typically anticipated to be inaudible or barely perceptible at the facility boundaries. Considering the minimum number of sources with low-noise levels and the area size of solar PV

facility, the NRC staff concludes that operation-related noise from the solar PV portion of combination alternative would be SMALL.

Conclusion

The noise impacts associated with construction and operation of the combination alternative would be SMALL to MODERATE.

4.3.7 Purchased Power

4.3.7.1 Air Quality

Estimated air emissions from operations of the proposed action and five alternatives are presented in Table 4–3. In general, air emissions from the proposed action and the new nuclear alternative would be lowest, while the IGCC alternative would release the highest emissions, followed by the NGCC alternative. Air emissions from the combination alternative would fall between the nuclear alternative and the NGCC alternative. It is apparent that the IGCC and NGCC alternatives will produce significantly greater air pollutant emissions than those associated with the proposed action (license renewal of Braidwood), new nuclear alternative, or the combination alternative. Air emissions from purchased power will vary and depend on the type of technology and if the purchased power is from existing or newly constructed technology. If purchased power is solely from coal-fired plants, air emissions would be higher than purchased power from nuclear power (source of less emission). It is assumed that purchased power will come from a combination of technologies. In 2012, coal, natural gas, and nuclear power accounted for 37-, 30-, and 19-percent shares, respectively, of total U.S. electricity generation (EIA 2014). Using these percent shares for the purchased power alternative, the NRC staff estimates that air emissions will be greater than the NGCC alternative, but less than the IGCC alternative. However, actual emissions may be greater or less than what is estimated in Table 4–3 and will depend on the technology from which the purchased power comes.

Table 4–3. Estimated Direct Air Emissions From Operation of the Proposed Action and Alternatives (Ton/Year)

	Proposed Action [a]	New Nuclear [b]	IGCC	NGCC	Combination [c]	Purchased Power [d]
NO_x	28	28	3,000	600	80	1,290
SO_2	0.06	0.06	820	380	50	420
PM_{10}	0.50	0.50	480	210	30	240
CO	7.2	7.2	2,045	1,690	220	1,270
CO_2e	1,361	1,361	14.3×10^6	7.9×10^6	1.0×10^6	7.7×10^6

[a] Highest annual emissions from the Braidwood Station during the 2008–2012 period

[b] Assumed air emissions from the Braidwood Station

[c] Assumed air emissions only from the NGCC portion of the combination alternative

[d] Assumed air emissions were estimated by assuming that purchased power coal accounted for a 37% share, natural gas a 30% share, nuclear a 19% share, and renewable a 14% share of electricity generation.

Key: CO = carbon monoxide, CO_2e = carbon dioxide equivalents, NO_x = nitrogen oxides, SO_2 = sulfur dioxide

Conclusion

Purchased power would come from common types of existing technology (coal, natural gas, and nuclear) within the ROI, and it is not likely that new facilities would be constructed to replace Braidwood. Construction of new transmission lines would result in additional amounts of air emissions. Air emissions associated with the construction of transmission lines would be from operation of the earthmoving and material handling equipment and exhaust emissions from worker vehicles and construction equipment. These emissions include criteria pollutants, VOCs, GHGs, and HAPs. However, these impacts would be temporary and not likely to be high. For purchased power from existing plants, the impact on air quality is expected to be SMALL as there would be no change in existing plant operations.

If new facilities were to be constructed for purchased power, the impact on air quality would depend on the plant technology constructed, since air emissions can vary substantially, as can be observed from the alternative air quality discussions provided above. For instance, natural gas- and coal-fired plants emit higher amounts of nitrogen oxides, sulfur oxides, PM, and carbon dioxide than nuclear plants. Purchased power from new nuclear plants would not have noticeable impacts on air quality. New natural gas- and coal-fired plants would have noticeable impacts on air quality as a result of the higher amounts of air emissions. Therefore, impacts on air quality from purchased power of new plants would be SMALL to MODERATE.

4.3.7.2 Noise

Purchased power from existing electricity generating facilities would not have noticeable impacts on noise as there would be no change in existing plant operations. Purchased power from new generating facilities could have impacts on noise. Construction and operation of new facilities could result in additional noise sources including mechanical equipment associated with normal plant operations and vehicular traffic. Additionally, construction of new transmission lines could increase noise levels. Increase in noise levels from construction of new transmission lines and new facilities would be dependent on the distance of residents to the noise sources. Noise levels from operation will also be dependent on the type of technology (e.g., operation of nuclear or wind power). Therefore, impacts from purchased power on noise would be SMALL to MODERATE (transmission lines).

Conclusion

As discussed in the sections above, noise levels and impacts from operation of the NGCC and New Nuclear combination alternatives would not be greater than those associated with operation of the Braidwood site and are expected to be SMALL. Noise levels and impacts from operation of the IGCC, Combination, and purchased power are expected to be SMALL to MODERATE. Noise levels for these three alternatives are dependent on the distance of residents to the noise sources unique to the technology. For instance, the IGCC alternative will introduce noise associated with rail delivery predicted to be in the 80 to 96 dBA range. The wind power portion of the Combination alternative will introduce wind turbine noise levels that can reach 105 dBA.

4.4 Geologic Environment

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on geologic and soil resources.

For all alternatives to the proposed action (with the exception of the no-action alternative), impacts to geology and soil resources would occur during construction and no additional land would be disturbed during operations. During construction, sources of aggregate material, such

as crushed stone and sand and gravel, would be required to construct buildings, foundations, roads, and parking lots. The NRC staff assumes that these resources would likely be obtained from commercial suppliers using local or regional sources. Land clearing during construction and the installation of power plant structures and impervious surfaces would expose soils to erosion and alter surface drainage. Best management practices would be implemented in accordance with applicable permitting requirements so as to reduce soil erosion. These practices would include the use of sediment fencing, staked hay bales, check dams, sediment ponds, riprap aprons at construction and laydown yard entrances, mulching and geotextile matting of disturbed areas, and rapid reseeding of temporarily disturbed areas. Removed soils and any excavated materials would be stored on site for redistribution such as for backfill at the end of construction. Construction activities would be temporary and localized. Therefore, for all the alternatives to the proposed action, construction impacts would be SMALL.

4.4.1 Proposed Action

Section 3.4 describes the local and regional geologic environment of the Braidwood site. Section 3.4.1 discusses the current geologic environment of the Braidwood site and vicinity.

Table B-1 of 10 CFR Part 51, Subpart A, Appendix B, lists a summary of findings on NEPA issues for license renewal of nuclear power plants. Table 4–4 identifies issues related to geology and soils that are applicable to the Braidwood Station during the renewal term. One Category 1 geology and soil issue is applicable to Braidwood. There are no Category 2 issues for geology and soils.

Table 4–4. Geology and Soils Issues

Issue	GEIS Section	Category
Geology and Soils	4.4.1	1

Source: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51

The NRC staff did not identify any new and significant information associated with the Category 1 geology and soils issue identified in Table 4–4 during the review of the applicant's ER, the site audit, the scoping process, or the evaluation of other available information. As a result, no information or impacts related to these issues were identified that would change the conclusions presented in the GEIS (NRC 2013f). For these geology and soil issues, the GEIS concludes that the impacts are SMALL. It is expected that there would be no incremental impacts (in comparison to environmental base line in Chapter 3) related to these Category 1 issues during the renewal term beyond those discussed in the GEIS; therefore, the impacts associated with these issues by the proposed action would be SMALL.

4.4.2 No-Action Alternative

There would not be any impacts to the geology and soils at the Braidwood site with shutdown of the facility. With the shutdown of the facility no additional land would be disturbed. Therefore, impacts would be SMALL.

4.4.3 New Nuclear Alternative

This alternative would be located at an existing or retired plant site. As such, it would be located in an area where the soils have already been disturbed by previous activities at the site. As discussed earlier in this Section 4.4, the impacts on the geology and soil resources would occur

during construction, and the impacts of this alternative on geology and soil resources would be SMALL.

4.4.4 Coal (Integrated Gasification Combined Cycle) Alternative

This alternative would be located at an existing or retired plant site. As such, it would be located in an area where the soils have already been disturbed by previous activities at the site. As discussed earlier in this Section 4.4, the impacts on the geology and soil resources would occur during construction, and the impacts of this alternative on geology and soil resources would be SMALL.

4.4.5 Natural Gas Combined Cycle Alternative

This alternative would be located at an existing or retired plant site. As such, it would be located in an area where the soils have already been disturbed by previous activities at the site. As discussed earlier in this Section 4.4, the impacts on the geology and soil resources would occur during construction, and the impacts of this alternative on geology and soil resources would be SMALL.

4.4.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

The natural gas part of this alternative would be located at an existing or retired plant site. As such, it would be located in an area where the soils have already been disturbed by previous activities at the site. The solar PV and the windfarm part of this alternative requires a large amount of land (up to 19,790 ac (8,009 ha)). However, much of the land would be undisturbed as only a small area would be disturbed by road and facility construction. In addition, some of the PV and windfarm facilities may be located at an existing or retired plant site, where the soils have already been disturbed by previous activities at the site. As discussed earlier in this Section 4.4, the impacts on the geology and soil resources would occur during construction and the impacts of this alternative on geology and soil resources would be SMALL.

4.4.7 Purchased Power

The impacts of this alternative are likely to be bounded by the impact descriptions of the other alternatives. Purchased power is likely to come from existing facilities, or if new facilities are constructed, it would likely be from one of the previously discussed alternatives. These alternatives have SMALL impacts. Therefore the impact of this alternative on geology and soil resources would be SMALL.

4.5 Water Resources

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on surface water and groundwater resources.

For all the alternatives (with the exception of the No-Action Alternative) discussed in this section, while they would be located at an existing or retired site (or both), construction activities will alter the surface water drainage features at the site, and stormwater runoff from construction areas and spills and leaks from construction equipment could potentially affect downstream surface water quality. Nevertheless, it is anticipated that appropriate soil erosion and sediment control measures, as described in Section 4.4 of this SEIS, would be observed. Application of BMPs in accordance with a State-issued National Pollutant Discharge Elimination System (NPDES) general permit, including appropriate waste management, water discharge,

stormwater pollution prevention plan, and spill prevention practices, would prevent or minimize and surface water or groundwater quality impacts during construction.

For the new nuclear power plants, IGCC, and NGCC alternatives, NRC assumes that any existing intake and discharge infrastructure at an alternative site location would be refurbished and used to maximize use of existing facilities. This would reduce construction related impacts on surface water quality. Any dredge-and-fill operations would be conducted under a permit from the U.S. Army Corps of Engineers and State-equivalent permits requiring the implementation of BMPs to minimize impacts. During construction, the dewatering of excavations is unlikely to consume enough water to affect offsite surface water or groundwater bodies. Surface water and groundwater withdrawals would be subject to applicable State water appropriation and/or registration requirements. The NRC staff assumes construction water would be obtained from groundwater or purchased from a commercial water utility. Therefore, for all the alternatives to the proposed action, construction impacts on groundwater and surface water resources would be SMALL.

For the new nuclear power plants, IGCC, and NGCC alternatives, after the facility is constructed and operational, groundwater from onsite wells would be used as a source of potable water and for fire protection. Water for cooling would be obtained from surface water. Cooling water treatment additives used by these three alternatives would essentially be the same.

For all the alternatives, surface water and groundwater withdrawals would be subject to State-issued permits. Effluent discharges and storm water discharges would be subject to a State-issued NPDES permit. To prevent and respond to accidental non-nuclear releases to surface water, facility operations would be conducted in accordance with a spill prevention, control, and countermeasures plan; storm water pollution prevention plan; or equivalent plans and associated BMPs and procedures. Therefore, for all the alternatives to the proposed action, operational impacts on groundwater and surface water “quality” would be SMALL.

4.5.1 Proposed Action

As further discussed below, the impact by the proposed action on water resources are SMALL.

4.5.1.1 Surface Water Resources

The Category 1 (generic) and Category 2 surface water use and quality issues applicable to Braidwood Units 1 and 2, are discussed in the following sections and listed in Table 4–5. Surface water resources-related aspects and conditions relevant to the Braidwood site are described in Section 3.5.1.

Table 4–5. Surface Water Resources Issues

Issue	GEIS Section	Category
Surface water use and quality (non-cooling system impacts)	4.5.1.1	1
Altered current patterns at intake and discharge structures	4.5.1.1	1
Scouring caused by discharged cooling water	4.5.1.1	1
Discharge of metals in cooling system effluent	4.5.1.1	1
Discharge of biocides, sanitary wastes, and minor chemical spills	4.5.1.1	1
Surface water use conflicts (plants with cooling ponds or cooling towers using makeup water from a river)	4.5.1.1	2
Effects of dredging on surface water quality	4.5.1.1	1
Temperature effects on sediment transport capacity	4.5.1.1	1

Sources: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51 (78 FR 37282); NRC 2013f

Generic Surface Water Resources

The NRC staff did not identify any new and significant information with regard to the Category 1 (generic) surface water issues based on review of the Braidwood ER (Exelon 2013), the public scoping process, or as a result of the environmental site audit. As a result, no information or impacts related to these issues were identified that would change the conclusions presented in the GEIS. Therefore, it is expected that there would be no incremental impacts related to these Category 1 issues during the renewal term beyond those discussed in the GEIS. For these surface water issues, the GEIS concludes that the impacts are SMALL.

Surface Water Use Conflicts

This section presents the NRC staff's review of plant-specific (Category 2) surface water use conflict issue as listed in Table 4–3.

Plants With Cooling Ponds or Cooling Towers Using Makeup Water From a River

For nuclear power plants utilizing cooling towers or cooling ponds supplied with makeup water from a river, the potential impact on the flow of the river and its availability to meet the demands of other users is a Category 2 issue. This designation requires a plant-specific assessment, including the related potential impacts on terrestrial (riparian) ecological communities and with aquatic (in stream) communities. Sections 4.6.1 and 4.7.1 further discuss the impacts of the proposed action on terrestrial and aquatic resources, respectively.

In evaluating the potential impacts resulting from surface water use conflicts associated with license renewal, the NRC staff uses as its baseline the surface water resource conditions as described in Section 3.1.3 and 3.5.1 of this SEIS. These baseline conditions encompass the defined hydrologic (flow) regime of the surface water(s) potentially affected by continued operations as well as the magnitude of surface water withdrawals for cooling and other purposes (as compared to relevant appropriation and permitting standards).

The mean annual discharge for Kankakee River (see Section 3.5.1.1) measured at the U.S. Geological Survey (USGS) gage at Wilmington, for water years 1934 through 2012, is 4,805 cubic feet per second (cfs) (136 cubic meters per second (m^3/s)) (USGS 2012). As described in Section 3.5.1.2, the average annual consumption for the Braidwood site from the

Kankakee River is 41 cfs (1.14 m^3/s). This results in a rate of consumption of 0.9 percent of Kankakee River's average flow. Compared to the lowest annual mean flow recorded for the Kankakee River at the USGS gage at Wilmington, this consumption rate is 2.9 percent of the volume of water flowing in the river. However, the provisions of Braidwood's intake construction permit (issued by the Illinois Department of Transportation (IDOT), Division of Water Resources—now the IDNR) limits the maximum makeup withdrawal rate from the river to 160 cfs (71,808 gallons per minute (gpm) or 4.5 m^3/s) and requires Exelon to stop withdrawing water from the Kankakee River when the flow rate falls below 422 cfs (12 m^3/s) (Exelon 2014i). In accordance with these provisions, if Braidwood needs to cease withdrawing makeup water from the Kankakee River, cooling pond water levels will be drawn down temporarily.

Water use for irrigation, public water supply systems, and the power plant industry is withdrawn from the Kankakee River (Knapp 1992). In 2005, the public water systems withdrew approximately 13 million gallons per day (mgd) (24.2 cfs, 10,861 gpm, 0.69 m^3/s) from the Kankakee River (ISWS 2012). There are a total of 17 major effluent return flows to streams in the Illinois portion of the Kankakee watershed, most of which are from public wastewater treatment facilities (Knapp 1992). While Illinois does not withdraw water from the Kankakee River for irrigation use, Indiana does withdraw from the Kankakee River for irrigation water use. Dresden Nuclear Power Station, Units 2 and 3, withdraw water from the Kankakee River, and net withdrawals vary between 46 cfs (1.3 m^3/s, 30 mgd) to 88 cfs (2.5 m^3/s, 57 mgd) (NRC 2004).

As discussed above, major sources of water use from the Kankakee River include the public water supply systems and power plant industry. In adding the consumptive rates of these sources and comparing this rate (153 cfs) to the mean annual river flow of 4,805 cfs of the Kankakee River, surface flows in the Kankakee River appears well able to meet the current consumptive demand. For these reasons, the NRC staff concludes that the impact on surface water resources from continued withdrawals during the license renewal term would be SMALL.

4.5.1.2 Groundwater Resources

Table 4–6 identifies issues related to groundwater that are applicable to Braidwood Station during the renewal term. Section 3.5.2 describes groundwater resources at the Braidwood Station.

Table 4–6. Groundwater Issues

Issue	GEIS Section	Category
Groundwater Contamination and Use (Non-Cooling System Impacts)	4.5.1.2	1
Groundwater Use Conflicts (Plants with Closed-Cycle Cooling Systems that Withdraw Makeup Water from a River)	4.5.1.2	2
Groundwater Quality Degradation (Plants with Cooling Ponds at Inland Sites)	4.5.1.2	2
Radionuclides Released to Groundwater	4.5.1.2	2

Source: Table B-1 in Appendix B, Subpart A to 10 CFR Part 51

The NRC staff did not identify any new and significant information associated with the Category 1 groundwater issues identified in Table 4–6 during the review of the applicant's ER, the site audit, the scoping process, or the evaluation of other available information. As a result, no information or impacts related to these issues were identified that would change the

conclusions presented in the GEIS (NRC 2013f). For these issues, the GEIS concludes that the impacts are SMALL. Therefore, it is expected that there would be no incremental impacts related to these Category 1 issues during the renewal term beyond those discussed in the GEIS and therefore the impacts associated with these issues by the proposed action would be SMALL.

The three Category 2 issues (see also Table 4–6) related to groundwater during the renewal term are discussed in the following text.

Groundwater Use Conflicts (Plants Using Cooling Towers or Cooling Ponds and Withdrawing Makeup Water From a Small River)

This issue looks at the potential impact of the consumption of river water on the availability of groundwater supplies. The Braidwood site uses a cooling pond and withdraws water from a small river. In turn, the cooling pond loses water to the atmosphere by evaporation. As a result, less water is returned to the Kankakee River than is withdrawn. This issue evaluates the impact of river water consumption and lowered river water levels on groundwater supplies.

The Kankakee River alluvium is hydrologically connected to the Upper Aquifer. As described in Section 4.5.1.1, there is a low impact by plant water consumption on river flows over the period of licensing. This means that river water levels are unlikely to be significantly impacted, which in turn means that local aquifers adjacent to the river are very unlikely to suffer dewatering. Therefore, the NRC staff concludes that impacts to groundwater use would be SMALL.

Groundwater Use Conflicts (Plants With Closed-Cycle Cooling Systems That Withdraw Makeup Water From a River)

This issues looks at the potential for closed cycle inland unlined cooling ponds to degrade the surrounding groundwater quality and reach off-site wells. The water in the cooling pond has high concentrations of total dissolved solids, alkalinity, hardness, sulfates, magnesium, calcium, and total phosphorus (Exelon 2014i; Teledyne 2013). The water quality in the cooling pond reflects the net result of Kankakee River water additions, water chemistry adjustments by the plant, high temperatures, losses to evaporation, and water discharges back to the Kankakee River. Radionuclides are not discharged to the cooling pond. Tritium concentrations in the cooling pond have not been detected above baseline values (Teledyne 2013).

As discussed in Section 3.5.2.1, the cooling pond was built with a slurry wall to isolate the pond from the Upper Aquifer. The slurry wall surrounding the cooling pond would prevent or greatly reduce any water movement between the Upper Aquifer and the cooling pond. Accordingly, the Upper Aquifer will not be either recharged or dewatered (i.e., no change) by water in the cooling pond.

The bottom of the cooling pond is filled with low-permeability shale, clay and siltstone mine spoils from former coal strip mining activities mine spoils (Teledyne 2013). As discussed in Section 3.5.2.1, coal mining activities stopped above the Spoon Formation. As a result the Maquoketa Shale was undisturbed by mining activities and remains a significant barrier (aquitard) to the vertical movement of groundwater from the cooling pond into the Deep Aquifer. Therefore, the impact of the cooling pond on groundwater quality would be SMALL.

Radionuclides Released to Groundwater

This issue looks at potential contamination of groundwater from the release of radioactive liquids from plant systems into the environment. Section 3.5.2.3 of this document contains a description of tritium contamination in groundwater. In evaluating the potential impacts on groundwater quality associated with license renewal, the NRC staff uses as its baseline the existing groundwater conditions as described in Section 3.5.2.3 of this SEIS. These baseline

conditions encompass the existing quality of groundwater potentially affected by continued operations (as compared to relevant State or EPA primary drinking water standards) as well as the current and potential onsite and offsite uses and users of groundwater for drinking and other purposes. The baseline also considers other downgradient or in-aquifer uses and users of groundwater.

Historical releases of liquids containing tritium have not impacted groundwater quality beyond the site boundary. Both off-site and on-site groundwater contamination that resulted from the failure of three vacuum breaker valves on the discharge pipeline has been successfully remediated. Tritium concentrations in groundwater near the plant buildings remain below EPA's safe level for public drinking water.

Present and future Braidwood operations are not expected to impact the quality of groundwater in any aquifers that are a current or potential future source of water for offsite users. Therefore, the NRC staff concludes that the impacts on groundwater use and quality during the Braidwood license renewal term would be SMALL.

4.5.2 No-Action Alternative

4.5.2.1 Surface Water Resources

With the cessation of operations, the temperature of the cooling pond would drop. Lower temperatures would likely result in reduced evaporation rates, some changes in general pond chemistry, and during winter, partial or entire pond surface freezing.

The cooling pond was built with a slurry wall to hydraulically isolate the pond from the Upper Aquifer (see Section 3.5.2.1). After it was built, the cooling pond was filled with water from the Kankakee River. The slurry wall prevents or limits the inflow of groundwater as a source of recharge. As a result, water levels in the cooling pond would largely be driven by whichever is larger: water losses by evaporation or water gains from direct precipitation into the pond. Exelon owns the cooling pond and it is not known at this time what would become of the cooling pond after the site is decommissioned.

During operations, water losses from the pond have been made up with the addition of water obtained from the Kankakee River. The rate of consumptive use of Kankakee River water would greatly decrease and eventually cease. Wastewater discharges to the Kankakee River would be reduced considerably. Shutdown would reduce the impacts on Kankakee water use and quality. Therefore, the impact of this alternative on surface water resources would be SMALL.

4.5.2.2 Groundwater Resources

With the cessation of operations, the consumption of groundwater would be much less and there should be little or no impacts on groundwater quality. The slurry wall (see Section 3.5.2.1) surrounding the cooling pond would prevent or greatly reduce any water movement between the Upper Aquifer and the cooling pond. Accordingly, the Upper Aquifer will not be either recharged or dewatered (i.e., no change) by water in the cooling pond. Therefore, the impact of this alternative on groundwater resources would be SMALL.

4.5.3 New Nuclear Alternative

4.5.3.1 Surface Water Resources

As discussed earlier in this Section 4.5, construction impacts for all alternatives to the proposed action on surface water resources would be SMALL. The operational impacts for all alternatives to the proposed action on surface water quality would be SMALL.

The operation of the two new nuclear units would consume 40 mgd (151,416 cubic meters per day (m^3/d)) of surface water. As discussed in Sections 3.1.3 and 3.5.1.2, this alternative consumes 16 percent more surface water than the proposed action, which consumes approximately 34.2 mgd (129,461 m^3/d). Therefore, while the impacts of this alternative on surface water quality would be SMALL the operational impact on surface water availability would be SMALL to MODERATE.

4.5.3.2 Groundwater Resources

As discussed earlier in this Section 4.5, construction impacts for all alternatives to the proposed action on groundwater resources would be SMALL. Operational impacts for all alternatives to the proposed action on groundwater quality would be SMALL. During operations, the consumptive use of groundwater would be similar to the proposed action. Therefore, the impacts of this alternative on groundwater resources would be SMALL.

4.5.4 Coal (Integrated Gasification Combined Cycle) Alternative

4.5.4.1 Surface Water Resources

As discussed earlier in this Section 4.5, construction impacts for all alternatives to the proposed action on surface water resources would be SMALL. The operational impacts for all alternatives to the proposed action on surface water quality would be SMALL.

When operable, this alternative would consume 20 mgd (75,708 m^3/d) of surface water. This alternative would consume 41 percent less surface water than the proposed action, which consumes 34.2 mgd (129.461 m^3/d) (Sections 3.1.3 and 3.5.1.2) and the impacts on surface water availability would be SMALL. Therefore, the impact of this alternative on surface water resources would be SMALL.

4.5.4.2 Groundwater Resources

As discussed in Section 4.5, construction impacts for all alternatives to the proposed action on groundwater resources would be SMALL. Also as discussed in Section 4.5 operational impacts for all alternatives to the proposed action on groundwater quality would be SMALL. During operations, the consumptive use of groundwater would be similar to the proposed action and the impacts on groundwater availability would be SMALL. Therefore, the impacts of this alternative on groundwater resources would be SMALL.

4.5.5 Natural Gas Combined Cycle Alternative

4.5.5.1 Surface Water Resources

As discussed in Section 4.5, construction impacts for all alternatives to the proposed action on surface water resources would be SMALL. Also as discussed in Section 4.5, the operational impacts for all alternatives to the proposed action on surface water quality would be SMALL.

During operations, this alternative would consume 13 mgd (49,210 m^3/d) of surface water. This alternative would consume 61 percent less surface water than the proposed action, which consumes 34.2 mgd (129.461 m^3/d) (Sections 3.1.3 and 3.5.1.2) and the impacts on surface

water availability would be SMALL. Therefore, the impact of this alternative on surface water resources would be SMALL.

4.5.5.2 Groundwater Resources

As discussed in Section 4.5, construction impacts for all alternatives to the proposed action on groundwater resources would be SMALL. Also as discussed in Section 4.5, operational impacts for all alternatives to the proposed action on groundwater quality would be SMALL. During operations, the consumptive use of groundwater would be similar to the proposed action and the impacts on groundwater availability would be SMALL. Therefore, the impacts of this alternative on groundwater resources would be SMALL.

4.5.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

4.5.6.1 Surface Water Resources

As discussed in Section 4.5, construction impacts for all alternatives to the proposed action on surface water resources would be SMALL. Also as discussed in Section 4.5, the operational impacts for all alternatives to the proposed action on surface water quality would be SMALL.

It is estimated that when operable the natural gas alternative would consume 2 mgd (7,571 m^3/d) of surface water. This alternative would consume 94 percent less surface water than the proposed action, which consumes 34.2 mgd (129.461 m^3/d) and the impacts on surface water availability would be SMALL. Therefore, the impact of this alternative on surface water resources would be SMALL.

4.5.6.2 Groundwater Resources

As discussed in Section 4.5, construction impacts for all alternatives to the proposed action on groundwater resources would be SMALL. Also as discussed in Section 4.5, operational impacts for all alternatives to the proposed action on groundwater quality would be SMALL. During operations the consumptive use of groundwater would be much smaller than the proposed action and the impacts on groundwater availability would be SMALL. Therefore, the impacts of this alternative on groundwater resources would be SMALL.

4.5.7 Purchased Power

4.5.7.1 Surface Water Resources

The impacts of this alternative on surface water resources are likely to be bounded by the impact descriptions for the other alternatives. Purchased power is likely to come from existing facilities or if new facilities are constructed it would likely be from one of the previously discussed alternatives. These alternatives have SMALL impacts. Therefore, the impact of this alternative on surface water resources would be SMALL.

4.5.7.2 Groundwater Resources

The impacts of this alternative on groundwater resources are likely to be bounded by the impact descriptions for the other alternatives. Purchased power is likely to come from existing facilities or if new facilities are constructed it would likely be from one of the previously discussed alternatives. These alternatives have SMALL impacts. Therefore, the impact of this alternative on surface water resources would be SMALL.

4.6 Terrestrial Resources

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on terrestrial resources.

4.6.1 Proposed Action

Section 3.6 of this SEIS describes terrestrial resources on and in the vicinity of the Braidwood site. The generic (Category 1) and site-specific (Category 2) issues that apply to terrestrial resources during the proposed license renewal period appear in Table 4–7. The GEIS (NRC 2013f) discusses these issues in Section 4.6.1.1.

Table 4–7. Terrestrial Resource Issues

Issue	GEIS Section	Category
Effects on terrestrial resources (non-cooling system impacts)	4.6.1.1	2
Exposure of terrestrial organisms to radionuclides	4.6.1.1	1
Cooling system impacts on terrestrial resources (plants with once-through cooling systems or cooling ponds)	4.6.1.1	1
Cooling tower impacts on vegetation (plants with cooling towers)	4.6.1.1	[a] N/A
Bird collisions with plant structures and transmission lines [b]	4.6.1.1	1
Water use conflicts with terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river)	4.6.1.1	2
Transmission line right-of-way (ROW) management impacts on terrestrial resources [b]	4.6.1.1	1
Electromagnetic fields on flora and fauna (plants, agricultural crops, honeybees, wildlife, livestock)[b]	4.6.1.1	1

[a] This issue does not apply because the Braidwood cooling system does not include cooling towers.

[b] This issue applies only to the in-scope portion of electric power transmission lines, which are defined as transmission lines that connect the nuclear power plant to the substation where electricity is fed into the regional power distribution system and transmission lines that supply power to the nuclear plant from the grid.

Source: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51

4.6.1.1 GEIS Category 1 Issues

The NRC staff did not identify any new and significant information related to the generic (Category 1) issues listed above during the review of the applicant's ER (Exelon 2013c), the site audit, or the scoping process. Therefore, the NRC staff expects no impacts associated with these issues beyond those discussed in the GEIS. The GEIS concludes that the impact level for each of these issues is SMALL.

4.6.1.2 Impacts on Terrestrial Resources (Non-Cooling System Impacts)

In the GEIS (NRC 2013f), the NRC staff determined that noncooling system effects on terrestrial resources is a Category 2 issue (see Table 4–7) that requires site-specific evaluation during each license renewal review. According to the GEIS, non-cooling system impacts can include those impacts that result from landscape maintenance activities, stormwater management, elevated noise levels, and other ongoing operations and maintenance activities that would occur

during the renewal period and that could affect terrestrial resources on and near the Braidwood site.

Section 3.6 indicates that approximately 1,280 ac (518 ha) of the Braidwood site (37 percent) remains as natural areas that are either leased for agricultural use, leased to the IDNR for recreational use, or are unmanaged (Exelon 2014d). The majority of site landscape maintenance is performed within the protected area and not within natural areas on the site (Exelon 2014f). Typically, only removal of trees and shrubs that pose a safety or security threat are removed from natural areas. Leased lands are maintained by the leasee and in accordance with the standing lease. As described in Section 3.6, Exelon and the IDNR manage some of the natural areas on the site for recreational purposes and restoration of native shoreline plants.

Stormwater drainages direct Braidwood site runoff to three NPDES-permitted stormwater outfalls, all of which flow through an unnamed drainage ditch along the western boundary of the Braidwood property, past the Village of Godley, into the Mazon River (Exelon 2013c). Special Condition 9 of the NPDES permit requires Exelon to develop and implement a Stormwater Pollution Prevention Plan (Exelon 2013c). This plan identifies sources of pollution that could affect the quality of stormwater and describes practices that Exelon uses to reduce such pollutants. Areas with spill potential, such as areas around tanks that contain oil, are further monitored under the Braidwood Station Spill Prevention Control and Countermeasure Plan (Exelon 2013c). Collectively, these measures ensure that the effects to terrestrial resources from pollutants carried by stormwater would be small during the proposed license renewal term.

The GEIS (NRC 2013f) indicates that elevated noise levels could be a non-cooling system impact to terrestrial resources. However, the GEIS also concludes that generic noise impacts would be small because noise levels would remain well below regulatory guidelines for offsite receptors during continued operations and refurbishment associated with license renewal. The NRC staff did not identify any information during its review that would indicate that noise impacts to terrestrial resources at Braidwood would be unique or require separate analysis.

Other operations and maintenance activities that could occur in the future include the replacement of the Unit 1 steam generators. While Exelon has previously replaced the Unit 2 steam generators, Exelon has not replaced the Unit 1 steam generators. Exelon has no plans to replace the Unit 1 steam generators at this time, but Exelon may choose to replace them prior to the end of the 40-year initial license term. Because steam generator replacement is not necessary for safe operation during license renewal, the NRC does not consider it part of the proposed action. As such, the impacts of Unit 1 steam generator replacement on terrestrial resources are discussed in Section 4.15.4 (cumulative impacts) rather than in this section. Exelon (2014g) is planning no other land-disturbing activities or construction unrelated to possible Unit 1 steam generator replacement. No disturbances to natural habitats would occur during license renewal, and Exelon does not expect any changes in operations or changes to existing land uses during the proposed license renewal period. As such, no measurable impacts to the terrestrial environment are expected during the license renewal period.

When new activities that could impact the environment occur at Braidwood, Exelon follows several procedures to ensure that potential environmental effects are considered and appropriately addressed. Exelon maintains a procedure (No. EN-AA-103) that requires Exelon staff to screen proposed activities, such as maintenance activities, operational changes, procedure changes, and other facility activities, to determine if the activity warrants further evaluation for environmental impact or risk (Exelon 2014e). If the activity warrants further evaluation, Exelon Procedure No. EN-AA-103-0001 provides guidance to Exelon staff on performing such an evaluation and determining the environmental and regulatory impacts of the

activity (Exelon 2014e). This procedure also requires that implementation of the activity be halted until any environmental impacts are addressed.

Based on the NRC staff's independent review, the staff concludes that the landscape maintenance activities, stormwater management, elevated noise levels, and other ongoing operations and maintenance activities that Entergy might undertake during the renewal term would primarily be confined to disturbed areas of the Braidwood site. These activities would not have noticeable effects on terrestrial resources, nor would they destabilize any important attribute of the terrestrial resources on or in the vicinity of the Braidwood site. Therefore, the staff expects non-cooling system impacts on terrestrial resources during the license renewal term to be SMALL.

4.6.1.3 Water Use Conflicts With Terrestrial Resources

In the GEIS (NRC 2013f), the NRC staff determined that effects of water use conflicts on terrestrial resources is a Category 2 issue (see Table 4–7) that requires site-specific evaluation during each license renewal review. Water use conflicts occur when the amount of water needed to support terrestrial riparian communities is diminished as a result of demand for agricultural, municipal, or industrial use; decreased water availability due to droughts; or a combination of these factors.

According to USGS data from the nearest surface water gaging stations (USGS Station No. 05520500 at Momence, Illinois; 54.2 km [33.7 mi] upstream of Braidwood), the average annual flow of the Kankakee River near Braidwood in the past 10 data years (2002 through 2012) has ranged from 1,619 cfs; 45,850 liters per second (L/sec) or 727,000 gpm) in 2006 to 3,583 cfs (101,500 L/sec or 1.61 million gpm) in 2008 (USGS 2014). Normally, Braidwood's circulating water system withdraws 3,028 L/sec (48,000 gpm) of makeup water (Exelon 2013c). Thus, Braidwood has consumed between 3.0 and 6.6 percent of the Kankakee River's flow each year for the past 10 years. In times where the river flow is low, Exelon has an agreement with the IDNR to limit Kankakee River water consumption such that withdrawal of makeup water does not cause the Kankakee River flow to drop below 12,517 L/sec (442 cfs) (Exelon 2013c). Exelon maintains procedures to comply with these withdrawal restrictions, which would continue during the proposed license renewal term (Exelon 2013c).

The amount of Kankakee River water Braidwood consumes is minor in comparison to the flow of water past the plant, and regulatory mechanisms are in place to ensure that Braidwood does not consume an amount that would be harmful to riparian communities during low river flow conditions. The terrestrial resources near the plant (described in Section 3.6) do not appear to be affected by the consumption of water from the river. The NRC staff concludes that water use conflicts would not occur from the proposed license renewal or would be so minor that the effects on terrestrial resources would be undetectable. Thus, the NRC staff concludes that the impacts of water use conflicts on terrestrial resources during the proposed license renewal term would be SMALL.

4.6.2 No-Action Alternative

If Braidwood were to shut down, the impacts to terrestrial ecology would remain similar to those during operations until the plant is fully decommissioned. Temporary buildings and staging or laydown areas may be required during large component and structure dismantling. Braidwood is likely to have sufficient space within previously disturbed areas for these needs, and therefore, no additional land disturbances would occur on previously undisturbed land. Adjacent lands may experience temporary increases in erosional runoff, dust, or noise, but these impacts could be minimized with the implementation of standard BMPs (NRC 2002). In NUREG–0586, *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*,

Supplement 1 (NRC 2002), the NRC concludes generically that impacts to terrestrial ecology during decommissioning activities would be SMALL. In the case of Braidwood, the continuation of the lease agreement between Exelon and the IDNR for the Mazonia-Braidwood State Fish and Wildlife Area could be affected by decommissioning. Loss of these lands as a State-managed area could result in impacts to terrestrial resources depending upon any future land use of the site. Reclamation of the site following decommissioning could create terrestrial habitat in areas currently used as industrial areas. The GEIS (NRC 2013f) notes that terrestrial resource impacts could occur in other areas beyond the immediate nuclear plant site as a result of the no-action alternative if new power plants are needed to replace lost capacity. The NRC staff concludes that the no-action alternative is unlikely to noticeably alter or have more than minor effects on terrestrial resources. Thus, the NRC staff concludes that the impacts of the no-action alternative on terrestrial resources during the proposed license renewal term would be SMALL.

4.6.3 New Nuclear Alternative

The new nuclear alternative assumes that the new facility would be built at an existing nuclear or retired coal plant site within the ROI but outside of Illinois. Construction of the new nuclear plant would require an estimated 324 ac (131 ha) for permanent buildings and facilities and an additional 31 ac (12.5 ha) for temporary facilities and laydown areas. The NRC staff assumes that this alternative would use existing onsite structures and previously disturbed areas to the extent practicable to minimize new development in undisturbed areas. However, given the land requirements, it is expected that some undisturbed areas would be affected, which would directly impact terrestrial resources. During construction, terrestrial species could experience habitat loss or fragmentation, loss of food resources, and altered behavior due to noise and other construction-related disturbances. Erosion and sedimentation from clearing, leveling, and excavating land could affect adjacent riparian and wetland habitats, if present. Implementation of appropriate BMPs would minimize these effects. This alternative could also require construction of new transmission lines or upgrades to existing lines. Because the new nuclear facility would be located on an existing energy-producing site, transmission lines could likely be co-located within existing transmission line corridors to minimize land disturbance. Although construction activities could noticeably alter terrestrial resources through habitat loss or fragmentation, construction is unlikely to destabilize any important attributes of the terrestrial environment. The exact magnitude of impacts would vary based on the chosen location of the facility and the amount and types of undisturbed habitat that would be affected by construction of the alternative, and thus, impacts of construction could range from SMALL to MODERATE.

During operation, impacts would be similar in type and magnitude to those assessed in Section 4.6.1 for continued operation of Braidwood under the proposed renewal term and would, therefore, be SMALL.

The NRC concludes that the impacts of construction and operation of the new nuclear alternative on terrestrial resources would be SMALL to MODERATE.

4.6.4 Coal (Integrated Gasification Combined Cycle) Alternative

The IGCC alternative assumes that the new facility would be built at an existing energy-producing site or a retired coal plant site in Illinois or another state within the ROI. The facility would require 2,000 ac (809 ha) of land to construct the facility. The NRC staff assumes that this alternative would use existing onsite structures and previously disturbed areas to the extent practicable to minimize new development in undisturbed areas. However, because the footprint of the facility would be large, it is likely that construction would require clearing of

previously undisturbed terrestrial habitats. This would result in habitat loss and fragmentation and loss of food resources. Terrestrial species may also alter their behaviors due to noise and other construction-related disturbances. Erosion and sedimentation from clearing, leveling, and excavating land could affect adjacent riparian and wetland habitats, if present. Implementation of appropriate BMPs would minimize these effects. This alternative could also require construction of new transmission lines or upgrades to existing lines. Because the IGCC facility would be located on an existing energy-producing site, any new transmission lines could likely be co-located within existing transmission line corridors to minimize land disturbance. Depending on the site and terrestrial habitats present, construction activities could noticeably alter or destabilize attributes of the terrestrial environment due to the large land requirements of the facility. The exact magnitude of impacts would vary based on the chosen location of the facility and the amount and types of undisturbed habitat that would be affected by construction of the alternative. The NRC staff expects that impacts of construction would be MODERATE.

The GEIS (NRC 2013f) concludes that impacts to terrestrial resources from operation of fossil energy alternatives would essentially be similar to those from continued operations of a nuclear facility. Unique impacts would include periodic maintenance dredging if coal is delivered by barge, which could create noise, dust, and sedimentation. Dredging and delivery of coal to the site could introduce minerals and trace elements to water resources on which terrestrial biota rely. Such minerals could also bioaccumulate in nearby riparian or wetland habitats. Air emissions during operation would include sulfur oxides and nitrogen oxides, which can combine with water vapor and create sulfuric and nitric acids. These acids would then be released back into the environment through precipitation, which could affect the acidity levels of water resources and have detrimental effects to plant foliage. Acid precipitation has the potential to destabilize the terrestrial environment by creating conditions that are too acidic for certain plants or animals. The IGCC facility would also emit various GHGs during operation, which is an effect that can have far-reaching consequences because GHGs contribute to climate change. The effects of climate change on terrestrial resources are discussed in Section 4.13.3.2. The various air emissions during operation of the IGCC facility could create noticeable impacts that could destabilize certain attributes of the terrestrial environment, and therefore, the operational impacts would be MODERATE.

The NRC concludes that the impacts of construction and operation of the IGCC alternative on terrestrial resources would be MODERATE.

4.6.5 Natural Gas Combined Cycle Alternative

The NGCC alternative assumes that the facility would be built at an existing energy-producing site or a retired coal plant site in Illinois or another state within the ROI. The facility would require 94 ac (38 ha) of land for the plant and associated pipelines. Because the footprint of the facility would be relatively small, the entire construction footprint could likely be sited in already developed areas of the site, which would minimize impacts to terrestrial habitats and species. However, the level of direct impact would vary based on the specific location of new buildings and infrastructure on the site. During construction, terrestrial species could experience habitat loss or fragmentation, loss of food resources, and altered behavior due to noise and other construction-related disturbances. Erosion and sedimentation from clearing, leveling, and excavating land could affect adjacent riparian and wetland habitats, if present. Implementation of appropriate BMPs would minimize these effects. This alternative could also require construction of new transmission lines or upgrades to existing lines. Because the NGCC facility would be located on an existing site, any new transmission lines could likely be co-located within existing transmission line corridors to minimize land disturbance. Similarly, any new pipelines could be co-located within existing pipeline corridors. Although construction activities

could noticeably alter terrestrial resources, primarily through habitat loss or fragmentation, construction is unlikely to destabilize any important attributes of the terrestrial environment. The exact magnitude of impacts would vary based on the chosen location of the facility and the amount and types of undisturbed habitat that would be disturbed for construction of the alternative, and thus, impacts of construction could range from SMALL to MODERATE.

The GEIS (NRC 2013f) concludes that impacts to terrestrial resources from operation of fossil energy alternatives would essentially be similar to those from continued operations of a nuclear facility. Unique impacts would include air emissions of GHGs such as nitrogen oxides, carbon dioxide, and methane, all of which can have far-reaching consequences because they contribute to climate change. The effects of climate change on terrestrial resources are discussed in Section 4.13.3.2. Although the impacts of operating the NGCC alternative may be noticeable, they are unlikely to destabilize any important attribute of the terrestrial environment, and would, therefore, be SMALL.

The NRC concludes that the impacts of construction and operation of the NGCC alternative on terrestrial resources would be SMALL to MODERATE.

4.6.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

The NGCC component of this alternative would require the same amount of land as the NGCC alternative (94 ac [38 ha]), but the NGCC component would likely make better use of existing infrastructure because it would be sited at an existing power plant in Illinois or another state within the ROI and could use buildings and structures that are already in place and operational for the existing facility. The types of impacts on the terrestrial environment would be similar to those discussed in Section 4.6.5, but the NRC staff expects the magnitude of impacts to be less because of the use of existing infrastructure. Thus, the construction and operation of the NGCC component of the combination alternative would be SMALL.

The wind component of the combination alternative would require 3,376 ac (1,366 ha) to 10,127 ac (4,098 ha) at sites across the ROI. However, the majority of this land would only be temporarily disturbed during construction. Permanently disturbed land would hold the wind turbines, access roads, and transmission lines. Land used for equipment laydown and turbine component assembly and erection could be returned to its original state. Use of BMPs would ensure that disturbed lands were appropriately restored to reduce the long-term impacts to the terrestrial environment. Operation of wind turbines could uniquely affect terrestrial species through mechanical noise, collision with turbines and meteorological towers, and interference with migratory behavior. Bat and bird mortality from turbine collisions is an ongoing concern for operating wind farms; however, recent developments in turbine design have reduced the potential for bird and bat strikes. The NRC staff expects that this component has the potential to noticeably alter terrestrial resources, primarily through the loss of habitat and bird and bat mortalities associated with wind turbine operation. However, it is unlikely that the wind component would destabilize any important attribute of the terrestrial environment, and thus, impacts would be MODERATE.

The solar component would require 6,749 ac (2,731 ha) of land across the ROI. The majority of solar installations could be installed on building roofs at existing residential, commercial, or industrial sites or at larger stand-alone solar facilities, and thus, it is possible that little terrestrial habitat would be disturbed during construction. However, the exact magnitude of impacts on terrestrial resources would depend on the amount of terrestrial habitat that is lost or fragmented during construction of solar installations. Operation would have no measurable effects on the terrestrial environment. Overall impacts from construction and operation of this component of

the alternative would range from SMALL to MODERATE depending on the locations of solar installations and the amount of terrestrial habitat affected.

The NRC staff concludes that the impacts of the combination alternative on terrestrial resources would be SMALL to MODERATE.

4.6.7 Purchased Power

The purchased power alternative would have wide-ranging impacts that are hard to specifically assess because this alternative could include a mixture of coal, natural gas, nuclear, and wind across many different sites in the ROI. This alternative would likely have little to no construction impacts because it would include power from already-existing power generating facilities. The construction of additional transmission lines would require implementation of BMPs to minimize erosion and sedimentation that could affect riparian areas and wetlands. The types of operational impacts would be similar to the effects discussed in the preceding alternative sections. This alternative would be more likely to intensify already existing effects at power generating facilities than create wholly new effects on terrestrial species and habitats. Existing facilities would likely have BMPs and other procedures in place to ensure that effects to the environment during operations are minimized. The NRC staff concludes that the impacts on terrestrial resources from the purchased power alternative would be SMALL.

4.7 Aquatic Resources

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on aquatic resources.

Section 3.1.3 of this SEIS describes the Braidwood cooling and auxiliary water systems, and Section 3.7 describes the aquatic resources of interest. The generic (Category 1) and site-specific (Category 2) issues that apply to aquatic resources at Braidwood during the proposed license renewal period appear in Table 4-8. The GEIS (NRC 2013f) discusses these issues in Section 4.6.1.2.

Table 4–8. Aquatic Resource Issues

Issue	GEIS Section	Category
All plants		
Entrainment of phytoplankton and zooplankton	4.6.1.2	1
Infrequently reported thermal impacts	4.6.1.2	1
Effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication	4.6.1.2	1
Effects of non-radiological contaminants on aquatic organisms	4.6.1.2	1
Exposure of aquatic organisms to radionuclides	4.6.1.2	1
Effects of dredging on aquatic organisms	4.6.1.2	1
Effects on aquatic resources (non-cooling system impacts)	4.6.1.2	1
Impacts of transmission line right-of-way (ROW) management on aquatic resources [a]	4.6.1.2	1
Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses	4.6.1.2	1
Plants with once-through cooling systems or cooling ponds		
Impingement and entrainment of aquatic organisms	4.6.1.2	2
Thermal impacts on aquatic organisms	4.6.1.2	2
Plants with cooling ponds or cooling towers using makeup water from a river		
Water use conflicts with aquatic resources	4.6.1.2	2

[a] This issue applies only to the in-scope portion of electric power transmission lines, which are defined as transmission lines that connect the nuclear power plant to the substation where electricity is fed into the regional power distribution system and transmission lines that supply power to the nuclear plant from the grid.

Source: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51

4.7.1 Proposed Action

4.7.1.1 GEIS Category 1 Issues

The GEIS concludes that the nine Category 1 issues listed in Table 4–8 would have a SMALL impact on aquatic resources during the license renewal term for all plants. For these issues, no additional plant-specific analysis is required unless new and significant information is identified.

During its review, the NRC staff considered Exelon’s ER, aquatic surveys and studies performed at Braidwood and in the Kankakee River, and available scientific literature; participated in a site audit; and considered Federal and State agency and public comments received during the scoping process. The NRC staff did not identify any new and significant information related to any of the Category 1 issues. Therefore, no site-specific analysis is required for these issues, and there would be no impacts associated with these issues beyond those discussed in the GEIS.

4.7.1.2 Impingement and Entrainment of Aquatic Organisms

In the GEIS (NRC 2013f), the NRC determined that impingement and entrainment of aquatic organisms is a Category 2 issue (see Table 4–8) that requires site-specific evaluation during

each license renewal review for plants with once-through cooling systems or cooling ponds, such as Braidwood.

Impingement is the entrapment of all life stages of fish and shellfish on the outer part of an intake structure or against a screening device during periods of water withdrawal (40 CFR 125.83). Impingement can kill organisms immediately or contribute to a slower death resulting from exhaustion, suffocation, injury, and other physical stresses. The potential for injury or death is generally related to the amount of time an organism is impinged, its susceptibility to injury, and the physical characteristics of the screen washing system and fish return (if present) of the plant.

Entrainment is the incorporation of all life stages of fish and shellfish with intake water flow entering and passing through a cooling-water intake structure and into a cooling water system (CWS) (40 CFR 125.83). Organisms susceptible to entrainment are generally of smaller size than those susceptible to impingement and include ichthyoplankton (fish eggs and larvae), larval stages of shellfish and other macroinvertebrates, zooplankton, and phytoplankton. Entrained organisms may experience physical trauma and stress, pressure changes, excess heat, and exposure to chemicals, all of which may result in injury or death (Mayhew et al. 2000).

A particular species can be subject to both impingement and entrainment if some individuals are impinged on screens while others pass through the screens and are entrained. For instance, adult individuals could be impinged, while juveniles could be entrained if they are small enough to pass through the intake screen openings.

At Braidwood, aquatic organisms may be impinged or entrained at two locations. Organisms that inhabit the Kankakee River may be impinged or entrained when makeup water is drawn from the river, through the river screen house, and into the cooling pond. Organisms that inhabit the cooling pond may be impinged or entrained when water is drawn from the pond, through the lake screen house, and into the CWS. A 1988 Braidwood entrainment survival study (EA Engineering 1990) indicates that some entrained organisms from the Kankakee River can survive the stresses of the makeup water intake and colonize the cooling pond. However, organisms that are entrained by passing through the cooling pond's lake screen house and into the Braidwood CWS are subject to mechanical, thermal, and toxic stresses that make survival unlikely.

This section's analysis uses a retrospective assessment of the present and past impacts to the aquatic ecosystem resulting from Braidwood operation in order to provide a prospective assessment for the future impacts over the proposed license renewal term (i.e., through 2046 for Unit 1 and through 2047 for Unit 2). The timeframe and geographic extent are two components of the assessment that bound the analysis. The timeframe defines how far back and how far forward the analysis will extend. In assessing the level of impact, the staff looked at the projected effects in comparison to a baseline condition. In agreement with NEPA guidance (CEQ 1997), the baseline of the assessment is the condition of the resource without the action (i.e., under the no-action alternative). Under the no-action alternative, the plant would shut down, and the resource would conceptually return to its condition without the plant, which is not necessarily the same as the condition before the plant was constructed. The timeframe for analyzing ecological resources extends far enough into the past to understand trends and to determine whether the resource is stable, which the NRC definitions of impact levels require. For assessing direct and indirect impacts, the geographic boundaries depend on the biology of the species under consideration.

The NRC staff used a modified weight-of-evidence (WOE) approach to evaluate the effects of impingement and entrainment on the aquatic resources in the Kankakee River and Braidwood cooling pond. NRC chose this approach because EPA recommends a WOE approach for

ecological risk assessment (EPA 1998). The WOE approach is a useful tool due to the complex nature of assessing risk (or impact), and NRC has used this approach in other evaluations of the effects of nuclear power plant cooling systems on aquatic communities (e.g., NRC 2010, 2011, 2013e). Menzie et al. (1996) defines WOE as "…the process by which multiple measurement endpoints are related to an assessment endpoint to evaluate whether significant risk of harm is posed to the environment." In the present WOE approach, the NRC staff examined five lines of evidence (LOE) to determine if operation of Braidwood is contributing to adverse impacts on aquatic resources in the Kankakee River or Braidwood cooling pond. The lines of evidence are as follows:

LOE	Description
1	Results of impingement studies performed at Braidwood
2	Results of entrainment studies performed at Braidwood
3	A review of available Kankakee River fish sampling data
4	A review of available Kankakee River freshwater mussel surveys
5	Consideration of engineered designs and operational controls that affect impingement and entrainment rates

LOE 1: Impingement Studies

Three studies have been conducted to evaluate impingement resulting from Braidwood's makeup water withdrawals from the Kankakee River. Commonwealth Edison Company (ComEd) commissioned an impingement study during filling of the cooling pond from December 1980 through February 1981 (summarized in NRC 1984). EA Engineering (1990) conducted an impingement and entrainment study from October 1988 through October 1989. EA Engineering also conducted an impingement study from April through June 1991 (summarized in EA Engineering 2012). No studies have been conducted that assess impingement and entrainment resulting from withdrawal of cooling water from the cooling pond (Exelon 2014l).

1980-1981 Kankakee River Impingement Study

The NRC's Final Environmental Statement for Braidwood Operation (FES-O; NRC 1984) summarizes the results of the first impingement study, which was conducted from December 1, 1980, through February 21, 1981, during filling of the cooling pond and before Braidwood operation. The FES-O does not include a discussion of study methods. During the study, eight fish constituted 75 percent of the total number of fish impinged:

	Percent (%) of Total Impinged
rock bass	17.9
rosyface shiner	11.6
channel catfish	11.1
bluegill	8.4
smallmouth bass	8.2
bullhead minnow	6.3
white crappie	6.1
orangespotted sunfish	5.9

The total estimated impingement for the period (December through February) was 1,201 individuals representing 32 species (see Table 4–9). Most impinged fish were young-of-the-year (YOY). The NRC (1984) noted that the study correlated with the period of the year where impingement was expected to be highest due to low water temperatures that reduced fish swimming speeds.

Although the relative abundance of fish impinged during the 1980-1981 study period was generally proportional to the relative abundance of fish collected during 1981-1982 river sampling period (discussed in Section 3.7), some differences are apparent (see Table 4–10). Centrarchids were the most commonly impinged family. Sunfishes may be more susceptible to impingement because individuals tend to aggregate in shallower, warmer waters with aquatic plants, such as in the vicinity of the river screen house. Clupids, which accounted for 6.2 percent of river samples, were rarely impinged. Gizzard shad (*Dorosoma cepedianum*, a clupid) grow rapidly, and YOY may have been large enough to swim against the intake current and avoid impingement given that the study was conducted in the winter. Ictalurids, which were rare in river samples, accounted for 11.3 percent of impinged fish. Two families appeared in impingement samples that did not appear in river samples: Aphredoderidae (pirate perch (*Aphredoderus savanus*)) and Atherinopsidae (brook silverside (*Labidesthes sicculus*)).

Based on the study, the NRC (1984) concluded that operation of Braidwood would have minimal effects on Kankakee River fish because of the low numbers of the various species impinged during the study and the generally high natural mortality rates of YOY fish, which constituted the majority of impingement.

1 **Table 4–9. Estimated Fish Impingement by Abundance, Dec. 1980–Feb. 1981**

Species [(a)]	Common Name	Number of Individuals	Relative Abundance (%)
Ambloplites rupestris	rock bass	214.7	17.9
Notropis rubellus	rosyface shiner	139.2	11.6
Ictalurus punctatus	channel catfish	133.8	11.1
Lepomis macrochirus	bluegill	101.0	8.4
Micropterus dolomieu	smallmouth bass	98.8	8.2
Pimephales vigilax	bullhead minnow	76.2	6.3
Pomoxis annularis	white crappie	73.8	6.1
Lepomis humilis	orangespotted sunfish	70.9	5.9
Lepomis cyanellus	green sunfish	51.0	4.2
Pomoxis nigromaculatus	black crappie	50.2	4.2
Cyprinella spiloptera	spotfin shiner	39.6	3.3
Notropis stramineus	sand shiner	35.6	3.0
Noturus flavus	stonecat	20.8	1.7
Lepomis gibbosus	pumpkinseed	16.4	1.4
Notropis spp.	Notropis spp.	15.3	1.3
Lepomis microlophus	redear sunfish	7.6	0.6
Notemigonus crysoleucas	golden shiner	7.0	0.6
Pimephales notatus	bluntnose minnow	7.0	0.6
Lepomis punctatus	spotted sunfish	4.6	0.4
Phenacobius mirabilis	suckermouth minnow	4.6	0.4
Dorosoma cepedianum	gizzard shad	4.6	0.4
Ameiurus natalis	yellow bullhead	4.6	0.4
Micropterus sahnoides	largemouth bass	2.3	0.2
Pimephales promelas	fathead minnow	2.3	0.2
Carpiodes cyprinus	quillback	2.3	0.2
Ameiurus melas	black bullhead	2.3	0.2
Etheostoma zonale	banded darter	3.0	0.2
Perca flavescens	yellow perch	2.3	0.2
Aphredoderus savanus	pirate perch	2.3	0.2
Labidesthes sicculus	brook silverside	2.3	0.2
Esox americanus	grass pickerel	2.3	0.2
Lepisosteus osseus	longnose gar	2.3	0.2
TOTAL		**1,201.0**	**100.0**

[(a)] Species are ordered by decreasing abundance.

Source: NRC 1984

Table 4–10. Relative Abundance of Fish Families Collected in Kankakee River Sampling, 1981–1982, and Impingement Sampling, 1980–1981

Family [a]	Relative Abundance (%)	
	River Sampling	Impingement Sampling
Centrarchidae	34.4	56.9
Cyprinidae	33.1	27.8
Catostomidae	22.2	1.9
Clupeidae	6.2	0.4
Percidae	2.4	0.4
Moronidae	0.8	0.4
Ictaluridae	0.2	11.3
Lepisosteidae	0.2	0.2
Amiidae	0.2	-
Esocidae	0.1	0.2
Fundulidae	0.1	-
Umbridae	0.1	-
Aphredoderidae	-	0.2
Atherinopsidae	-	0.2

[a] Families ordered by decreasing relative abundance in river samples

Source: NRC 1984

1988-1989 Kankakee River Impingement Study

EA Engineering (1990) initiated a second study in 1988, the first year of Braidwood operation, and it included both entrainment and impingement components. For the impingement portion of the study, EA Engineering collected samples on 132 sample days between October 11, 1988, and October 4, 1989. For each sample, impinged fish were collected in the river screen house baskets over a 24-hour period. Before each sample period, the traveling screens were manually rotated, and station personnel removed all debris from the trash baskets. At the end of each sample period, station personnel manually operated each traveling screen to remove all impinged fish. All fish collected in the trash baskets were identified, counted, weighed, and measured. During the study period, EA Engineering collected three samples per week with the exception of holidays, periods in which makeup water was not pumped from the Kankakee River, and periods where there were mechanical problems at the intake.

EA Engineering collected 17,680 individuals of 59 species (see Table 4–11). The most prevalently impinged fish were as follows:

	Individuals Collected	Percent (%) of Total Impinged
gizzard shad	12,220	69.1
rock bass	1,816	10.3
smallmouth bass	553	3.1
longear sunfish	544	3.1

The remaining 55 species each comprised less than 2 percent of the total collected individuals. Two state-listed species were collected: pallid shiner (*Notropis amnis*; 16 individuals) and river redhorse (*Moxostoma carinatum*; 2 individuals). Species richness was highest in March (47 species) and January (45 species). Total catch and catch-per-unit effort was highest in December 1988 at 6,310 individuals and 26.1 fish/hour. Catch was lowest in August, which was due to the lack of river water withdrawal from August 1 through 22. EA Engineering determined that that the majority of impinged fish were YOY based on length frequency distributions for the seven most common non-minnow species—gizzard shad, rock bass (*Ambloplites rupestris*), smallmouth bass (*Micropterus dolomieu*), longear sunfish (*Lepomis megalotis*), bluegill (*Lepomis macrochirus*), shorthead redhorse (*Moxostoma macrolepidotum*), and silver redhorse (*Moxostoma anisurum*).

EA Engineering estimated the total annual impingement for the study period with the assumption that for each week, impingement on unsampled days would be the average of the sampled days. Weekly estimates were then added together to yield annual estimates. The total estimated impingement during the 12-month study period was 53,111 fish, the majority of which (51 percent; 26,870 individuals) occurred from mid-December to mid-January. EA Engineering included species-specific estimates for the three most commonly impinged species:

	Estimated Annual Impingement	Percent (%) of Total Impinged
gizzard shad	36,608	68.9
rock bass	5,129	9.7
smallmouth bass	1,594	3.0

EA Engineering also estimated that Braidwood impinged 73 pallid shiner during the sample period. All impingement of this species occurred from mid-April through early June. Although collected in impingement samples, EA Engineering made no annual estimate for river redhorse.

While the 1980-1981 study had estimated that 1,201 fish would be impinged between December and February, the 1988–1989 study estimated a much larger number (32,821 fish). Gizzard shad accounted for much of this difference: the first study estimated that 5 individuals were impinged from December 1980 through February 1981, while the second study estimated that 28,969 gizzard were impinged during the same 3-month period in 1988 and 1989. For all other species, the two studies' estimates also vary greatly: an estimated 1,196 nongizzard shad individuals were impinged during the first study period versus an estimated 3,852 nongizzard shad individuals during the second study period. EA Engineering (1990) notes that in 1988, record low flows were observed in many Midwestern streams, including the Kankakee River, which likely yielded greater impingement losses than would occur in a typical year because a larger portion of the river was withdrawn for makeup water.

1 **Table 4–11. Fish Collected in Impingement Samples by Abundance,**
2 **Oct. 1988–Oct. 1989**

Species [(a)]	Common Name	Individuals Collected	Relative Abundance (%)
Dorosoma cepedianum	gizzard shad	12,220	69.1
Ambloplites rupestris	rock bass	1,816	10.3
Micropterus dolomieu	smallmouth bass	553	3.1
Lepomis megalotis	longear sunfish	544	3.1
Notropis rubellus	rosyface shiner	300	1.7
Cyprinella spiloptera	spotfin shiner	238	1.3
Labidesthes sicculus	brook silverside	190	1.1
Lepomis macrochirus	bluegill	175	1.0
Pimephales notatus	bluntnose minnow	170	1.0
Notropis volucellus	mimic shiner	149	0.8
Moxostoma macrolepidotum	shorthead redhorse	119	0.7
Lepomis cyanellus	green sunfish	104	0.6
Luxilus chrysocephalus	striped shiner	97	0.5
Noturus flavus	stonecat	90	0.5
Pimephales vigilax	bullhead minnow	82	0.5
Moxostoma anisurum	silver redhorse	80	0.5
Lepomis humilis	orangespotted sunfish	72	0.4
Notemigonus crysoleucas	golden shiner	70	0.4
Pimephales promelas	fathead minnow	51	0.3
Ictalurus punctatus	channel catfish	47	0.3
Percina maculata	blackside darter	44	0.2
Micropterus sahnoides	largemouth bass	43	0.2
Nocomis biguttatus	hornyhead chub	40	0.2
Pomoxis nigromaculatus	black crappie	40	0.2
Percina caprodes	logperch	36	0.2
Pomoxis annularis	white crappie	31	0.2
Lepomis spp.	*Lepomis* spp.	29	0.2
Moxostoma erythrurum	golden redhorse	28	0.2
Carpiodes cyprinus	quillback	27	0.2
Cyprinus carpio	common carp	22	0.1
Notropis stramineus	sand shiner	20	0.1
Ameiurus melas	black bullhead	17	<0.1
Notropis amnis	pallid shiner	16	<0.1
Ameiurus natalis	yellow bullhead	14	<0.1
Notropis atherinoides	emerald shiner	13	<0.1
Aplodinotus grunniens	freshwater drum	9	<0.1
Ictiobus bubalus	smallmouth buffalo	7	<0.1
Perca flavescens	yellow perch	7	<0.1
Esox americanus	grass pickerel	6	<0.1

Species [a]	Common Name	Individuals Collected	Relative Abundance (%)
Hypentelium nigricans	northern hogsucker	6	<0.1
Moxostoma spp.	*Moxostoma* spp.	6	<0.1
Notropis buchanani	ghost shiner	5	<0.1
Phenacobius mirabilis	suckermouth minnow	5	<0.1
Minytrema melanops	spotted sucker	3	<0.1
Ameiurus nebulosus	brown bullhead	3	<0.1
Etheostoma nigrum	johnny darter	3	<0.1
Etheostoma zonale	banded darter	3	<0.1
Percina phoxocephala	slenderhead darter	3	<0.1
Lepisosteus osseus	longnose gar	2	<0.1
Esox lucius	northern pike	2	<0.1
Cyprinella lutrensis	red shiner	2	<0.1
Lythrurus umbratilis	redfin shiner	2	<0.1
Cyprinella spiloptera × *lutrensis*	spotfin × red shiner	2	<0.1
Carpiodes spp.	*Carpiodes* spp.	2	<0.1
Moxostoma carinatum	river redhorse	2	<0.1
Moxostoma duquesnei	black redhorse	2	<0.1
Noturus gyrinus	tadpole madtom	2	<0.1
Morone mississippiensis	yellow bass	2	<0.1
Lepomis hybrid	sunfish hybrid	2	<0.1
Carassius auratus	goldfish	1	<0.1
Catostomus commersoni	white sucker	1	<0.1
Aphredoderus savanus	pirate perch	1	<0.1
Fundulus notatus	blackstripe topminnow	1	<0.1
Etheostoma caeruleum	rainbow darter	1	<0.1
Total		**17,680**	**100.0**

[a] Species ordered by decreasing relative abundance

Source: EA Engineering 1990

Gizzard shad, the most commonly impinged species, was also the second most common species to be collected in an August 1988 Illinois Natural History Survey of the Kankakee River (Larimore and Peterson 1989). In northern portions of the species range, such as Illinois, individuals typically live to 5 to 7 years (Williamson and Nelson 1985). Fecundity typically peaks at 2 to 3 years of age, and fecundity has been reported as ranging from 12,500 eggs per female of age two in Acton Lake, Ohio (Williamson and Nelson 1985) to 378,900 eggs per female in western Lake Erie (Bodola 1966). Egg mortality rates are generally high in freshwater broadcast-spawning species, such as gizzard shad (Dahlberg 1979), and gizzard shad YOY are particularly susceptible to mortality caused by sudden or extreme changes of temperature, making winter die-offs common in northern waters when temperatures fall below 3.3 °C (38 °F) (Williamson and Nelson 1985). Because 78 percent of gizzard shad impingement occurred between early December and early February, many of the individuals were likely already stressed or weakened by cold temperatures. EA Engineering (1990) noted that a large percentage of the fish impinged at the Braidwood Station were likely already dead or would

have died regardless of being impinged at the intake based on findings from impingement studies at other facilities. This hypothesis is supported by the low intake velocities (measured at an average of 0.30 to 0.37 foot per second (fps) (0.09 to 0.11 meter per second (m/s)) during the study year). These velocities are within the 0.5-fps (0.15-m/s) intake velocity recommended by the EPA for protection of aquatic organisms (79 FR 48300), and thus, healthy fish should have been able to avoid impingement.

EA Engineering (1990) concluded that the annual impingement of 5,129 rock bass YOY and 1,594 smallmouth bass YOY also represents a small loss as female rock bass lay between 2,000 to 11,000 eggs per year (Wallus and Simon 2008) and smallmouth bass lay between 2,000 to 21,000 eggs per year (Brown et al. 2009). As with gizzard shad, because healthy fish would be able to avoid the low intake velocities, most impinged individuals would likely be already stressed or weakened.

Little is known about the spawning habits of the State-endangered pallid shiner (Kwak 1991), so a comparison of the impingement of 73 YOY to the average fecundity of an adult female is not possible. Impacts to the species are partially mitigated through Special Condition 8 in the Braidwood NPDES permit (IEPA 2014d). As a result of the 1988-1989 impingement study, the IEPA determined that pumping restrictions were appropriate to address entrainment (discussed later in this section). In 1991, IEPA incorporated a condition (Special Condition 8) into Braidwood’s NPDES permit that limits Kankakee River makeup water withdrawals during the peak entrainment period (the last 3 weeks in May and the first week in June). During this period, the NPDES permit restricts withdrawals to only those needed to fill the freshwater holding pond and to maintain efficient operation of the cooling pond. Withdrawals are prohibited during night hours (one hour before sunset through one hour after sunrise).

Because pallid shiner are susceptible to impingement during this period, Special Condition 7 also reduces the likelihood that this species would be impinged. For instance, from April 19 through June 6, 1989, EA Engineering collected 16 pallid shiner individuals in impingement samples, and an estimated 73 individuals were impinged in total during this time period. Had the special condition been in place during the 1988-1989 impingement study, withdrawals would have been restricted from May 11 through June 7, 1989. During this period, EA Engineering collected 10 of the 16 impinged pallid shiner. Thus, had Special Condition 7 been in place during the study, the total estimated number of pallid shiner impinged would have been reduced by 62.5 percent from 73 individuals to about 27 individuals. Although not collected during the impingement study, Kankakee River monitoring data indicates that pallid shiner are also known to be present in the vicinity of Braidwood through mid-August and as late as November (Kwak 1991), and it is unknown how many impingements of pallid shiner have occurred during these months since the 1988-1989 study. Nevertheless, Special Condition 7 likely acts to greatly reduce, though not eliminate, the potential for impingement of pallid shiner. Specific population estimates are unavailable for the Kankakee River. However, in its Kankakee River Area Assessment, the IDNR (1998) indicates that the pallid shiner is “on the verge of extinction” in Illinois and that the Kankakee River population is the only large population remaining in the state. Based on this information, any losses of pallid shiner to impingement at Braidwood could result in a decreased ability for the Illinois population to survive and reproduce.

Impacts to the State-threatened river redhorse are difficult to quantify from the 1988–1989 impingement study because only two individuals were collected, and EA Engineering does not provide a species-specific entrainment estimate or discuss the species in detail in its results. The two individuals were collected on January 3 and June 6, 1989, which indicates that the species is likely present in the vicinity of Braidwood and susceptible to impingement the majority of the year. Had Special Condition 8 been in place during the study, only one individual would have been impinged. Thus, this condition may act to reduce the number of river redhorse

impinged, but given the small sample size, it is unclear to what extent. The Illinois Endangered Species Protection Act (520 ILCS 10/1 et seq.) defines threatened species as those that are "…likely to become endangered in the wild in Illinois within the foreseeable future." The Illinois Endangered Species Protection Board most recently reviewed the species' status in 2011 and determined that it remained threatened (Mankowski 2012). Because the river redhorse is not in danger of extinction at this time, the small losses from impingement at Braidwood are unlikely to destabilize or noticeably alter the population in Illinois. If the species' status changes during the proposed license renewal term, impingement at Braidwood could contribute more significantly to endangering the Illinois population's continued existence.

The 1988–89 impingement study provides evidence that impingement from Braidwood operations would only have a minor effect on most Kankakee River aquatic biota because impingement would not destabilize or noticeably alter the aquatic community in the vicinity of Braidwood. This conclusion is based on the fact that only a small number of fish would be impinged annually compared to the populations in the river; the majority of losses would be gizzard shad during winter months when temperature-related die-offs of this species are common; and most impinged individuals would already be stressed or weakened before impingement. Impacts to the state-listed pallid shiner and river redhorse, specifically, are partially mitigated by Special Condition 8 in the Braidwood NPDES permit. However, continued impingement of small numbers of pallid shiner—estimated to be as high as 73 individuals per year by EA Engineering (1990)—could result in a decreased ability for the Illinois population of this species to survive and reproduce. Impingement of river redhorse, which the 1988–1989 study indicates is relatively rare, is unlikely to have more than a minor effect on the Illinois population of this species.

1991 Kankakee River Impingement Study

Braidwood's 1991 renewed NPDES permit required impingement collections to be made whenever the river screen house makeup pumps operated between April and June 1991. During that period, the makeup water pumps operated on 49 days (14 days in April, 12 days in May, and 23 days in June), and EA Engineering collected and recorded all impinged fish during this time with similar methodology as in the 1988–1989 study. EA Engineering (2012) summarizes the results of the 1991 study.

EA Engineering collected 813 fish of 42 species (see Table 4–12). The most prevalently impinged fish were:

	Individuals Collected	Percent (%) of Total Impinged
common carp	535	65.8
stonecat	37	4.6
longear sunfish	33	4.1
rock bass	28	3.4

The remaining species each comprised less than 2 percent of the total collected individuals. One pallid shiner was collected, and no river redhorse were present during the 3-month period.

Table 4–12. Fish Collected in Impingement Samples by Abundance, April–June 1991

Species [a]	Common Name	Number Collected	Relative Abundance (%)
Cyprinus carpio	common carp	535	65.8
Noturus flavus	stonecat	37	4.6
Lepomis megalotis	longear sunfish	33	4.1
Ambloplites rupestris	rock bass	28	3.4
Pimephales promelas	fathead minnow	19	2.3
Carpiodes carpio	river carpsucker	15	1.8
Notemigonus crysoleucas	golden shiner	13	1.6
Pimephales vigilax	bullhead minnow	10	1.2
Lepomis cyanellus	green sunfish	10	1.2
Lepomis humilis	orangespotted sunfish	8	1.0
Lepomis macrochirus	bluegill	7	0.9
Ictalurus punctatus	channel catfish	5	0.6
Pomoxis annularis	white crappie	5	0.6
Pomoxis nigromaculatus	black crappie	4	0.5
Micropterus dolomieu	smallmouth bass	2	0.2
Esox lucius	northern pike	2	0.2
Notropis amnis	pallid shiner	1	0.1
Unspecified species	unspecified species	79	9.8
Total		**813**	**100.0**

[a] Species ordered by decreasing relative abundance

Source: EA Engineering 2012

Overall, a significantly smaller number of fish were impinged in 1991 than was estimated during the previous impingement study. In the 1988-1989 study, EA Engineering (1990) calculated that 3,907 fish would be impinged from April through June, while the 1991 study only collected 813 fish (20.8 percent of the previous estimate). Because the NPDES permit required that sampling be conducted whenever pumping occurred, the 813 fish collected in 1991 represents the actual number of fish impinged during the 3-month period. EA Engineering (2012) attributed the lower numbers to differences in river flow that might affect the distribution of fishes in the river, differences in local population abundances near the plant intake, or other unknown factors. Based on the 1991 study, EA Engineering (2012) concluded that impingement in the spring months does not appear to have adverse effects on any species because impingement rates are so low.

LOE 1 Conclusion

Based on the available impingement studies, intake of makeup water from the Kankakee River appears to have a minor effect on the aquatic community in the vicinity of Braidwood and that impingement is not likely to noticeably alter or destabilize any important attributes of the community. Impacts to the Kankakee River aquatic community as a whole, therefore, would be SMALL during the proposed license renewal term. Continued impingement of the State-endangered pallid shiner, however, may create a noticeable effect on this species'

population in Illinois, and thus, impacts of the proposed license renewal to this species would be MODERATE.

Although fish and aquatic biota are also impinged at the lake screen house when cooling pond water is drawn into Braidwood's cooling system, the impacts of impingement on the aquatic community within the cooling pond are unknown because they have not been addressed in studies.

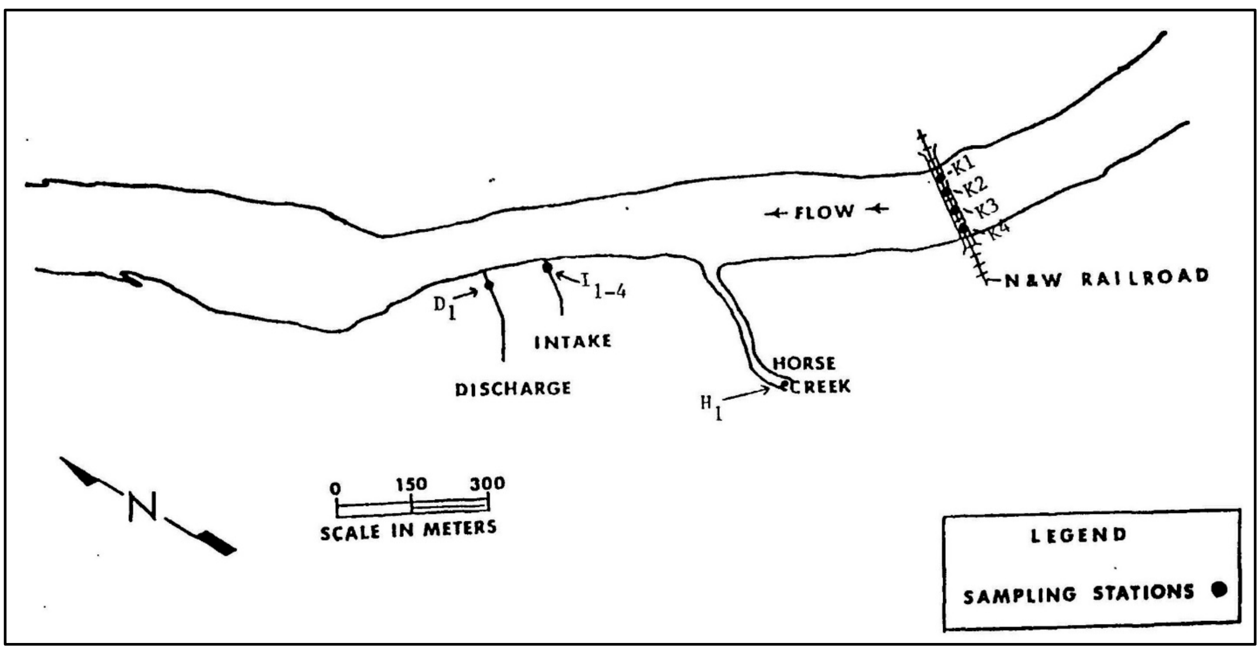
LOE 2: Entrainment Studies

One study has been conducted to evaluate entrainment resulting from Braidwood's withdrawal of makeup water from the Kankakee River. EA Engineering (1990) conducted the study from April through September 1988 in conjunction with the previously discussed 1988–1989 impingement and entrainment study. No studies have been conducted that assess entrainment resulting from withdrawal of cooling water from the cooling pond (Exelon 2014l).

1988 Entrainment Study

EA Engineering (1990) collected ichthyoplankton samples on 22 sample days between April 19 and September 13, 1988, at four locations: the Kankakee River, Horse Creek, the Braidwood intake, and the Braidwood discharge (see Figure 4–1). All samples were taken with conical plankton nets (2.5 m (8.2 ft) in length with a 0.5-m (1.5-ft) opening and Number 0 (505-micron (μ)) mesh), and each location was sampled as follows.

Figure 4–1. Braidwood Ichthyoplankton Sampling Locations



Source: EA Engineering 1990

Kankakee River. Collections were taken at four points (K1, K2, K3, and K4) from a boat anchored in position. Each location was sampled two times per 24-hour period (day and night) at two depths (surface and bottom), and two replicates were taken of each sample. This resulted in 32 samples each sample day. Collection times varied from 6 to 47 minutes,

depending on water velocity, to yield sample volumes of 40 cubic meters (m^3) (130 cubic feet (ft^3)).

Horse Creek. Collections were taken 1.2 km (0.7 mi) upstream of the creek mouth at one location (H1). Four replicate samples were taken both day and night resulting in eight samples each sample day. Collections were made by hand, and collection times varied from 7 to 35 minutes to yield sample volumes of 40 m^3 (130 ft^3).

Braidwood Intake. Collections were taken by suspending plankton nets each of the two intake forebays between the trash racks and traveling screens. Each intake bay was sampled at two locations (I1, I2, I3, and I4) and at two depths (surface and bottom) twice per 24-hours period (day and night). This resulted in 16 samples per sample day; however, low current velocities during the sample period prohibited collection of all 16 samples on many of the sampling days.

Braidwood Discharge. Collections were taken by suspending plankton nets in the discharge channel to the river approximately 10 m (33 ft) downstream of the outfall structure at one location (D1). Two replicates were collected per sample period, and collection time ranged from 8 to 35 minutes to yield a 40-m^3 (130-ft^3) sample volume. The discharge was only sampled through June 28 (rather than through September 13 as with the other locations). It should be noted that this sample location no longer exists because Exelon replaced the discharge canal with a multiport diffuser in 2010.

The four locations yielded 853 samples. EA Engineering sorted and identified each sample to the lowest practical taxonomic group. Both eggs and larvae were measured to the nearest 0.1 mm, and larvae were categorized as yolk-sac, post yolk-sac, or juveniles. The samples yielded 7,197 larvae and 271 eggs. Table 4–13 summarizes the characteristics of the eggs collected, and Table 4–14 lists the number and relative abundance of larvae collected by family, taxa, and location.

Within Kankakee River and Horse Creek samples, eggs and larvae were most abundant at night and in late May. For the period of May 10 through June 7, 1988, an estimated 4 to almost 10 million larvae were present in the river each week. EA Engineering determined that the majority of eggs collected at both river and creek sites were those of cyprinids. Within intake samples, the majority of eggs were common carp (*Cyprinus carpio*). Cyprinid eggs and one percid egg were also present. River, Horse Creek, and intake larvae samples were dominated by cyprinids, catostomids, and percids in the following distributions:

Percent (%) Composition	Kankakee River	Horse Creek	Braidwood Intake
Cyprinids	44.4	17.6	54.1
Catostomids	34.9	74.8	16.3
Percids	12.4	5.2	19.3

Table 4–13. Summary of Eggs Collected in Entrainment Samples, 1988

	Sample Location			
	Kankakee River	**Horse Creek**	**Braidwood Intake**	**Braidwood Discharge**
Sample Summary				
Total samples taken	406	136	264	52
Total sample days	19	17	18	11
Sample days in which eggs were present	5	5	10	5
Egg Characteristics				
Total collected	41	89	271	182
Average density	$0.12/10m^3$	$<0.2/10m^3$	$0.44/10m^3$	$1.8/10m^3$
Maximum density	$0.64/10m^3$	$1.9/10m^3$	$2.35/10m^3$	$5.6/10m^3$
Date of earliest collection	May 24	May 10	Apr 26	May 17
Date of latest collection	Jul 19	Jun 21	Jul 19	Jun 28
Date of highest density	Jul 19	May 31	May 17	May 31
Diameter range	1.3-2.0 mm	1.0-2.5 mm	1.0-2.0 mm	0.8-2.3 mm
Taxa present	Cyprinid	Cyprinid	Carp (majority); other cyprinids; and darter spp. (one egg)	Centrarchid (90 percent), gizzard shad, freshwater drum, and cyprinid

Source: EA Engineering 1990

Over 90 percent of eggs collected in discharge samples were centrarchids. Eggs of gizzard shad, freshwater drum (*Aplodinotus grunniens*), and cyprinids were also present. Larvae samples were dominated by gizzard shad (39.1 percent) and crappie (*Pomoxis* spp.; 33.1 percent). Cyprinid, percid, and catostomid larvae, which were the most prevalent groups at other sample sites, only accounted for 2.1, 1.7, and 0.8 percent, respectively. Because discharge samples represented water drawn from the cooling pond, through the discharge canal, and into the Kankakee River, the differences in species composition exhibited in discharge samples are attributable to the different species composition present in the cooling pond. As discussed in Section 3.7.1.2, the IDNR stocks the pond with a number of species that do not occur in the Kankakee River.

EA Engineering preliminarily predicted that 20 percent or less of eggs and larvae would be entrained at the Braidwood intake assuming withdrawal of 20 percent of river flow at the plant's maximum pumping rate of 50,000 gpm (100 cfs) during low flow conditions of 500 to 600 cfs (220,000 to 270,000 gpm). Using ichthyoplankton densities from the collected samples and USGS river flow data, EA Engineering determined actual and worst case scenario entrainment as follows. The worst case scenario assumed that Braidwood would withdraw river water 24 hours a day, 7 days a week at the maximum capacity pump rate (50,000 gpm [100 cfs]) over the sample period. Table 4–15 lists the estimated ichthyoplankton drift and entrainment in 1988.

Table 4–14. Numbers and Relative Abundance of Larvae Collected in Entrainment Samples by Family and Location, 1988

		Sampling Location and Catch						Total	
		Kankakee River		Horse Creek		Braidwood Intake			
Species [a]	**Common Name**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Catostomidae		**904**	**34.9**	**5,304**	**74.8**	**1,200**	**16.8**	**7,408**	**44.0**
Hypentelium or *Moxostoma* spp.	Catostomid D [b]	538	20.8	5,188	73.2	908	12.7	6,634	39.4
unidentified subfamily Ictiobinae	unidentified subfamily Ictiobinae	301	11.6	11	0.2	126	1.8	438	2.6
other and unidentified *Catostomid* spp.	other and unidentified *Catostomid* spp.	65	2.5	105	1.5	166	2.3	336	2.0
Cyprinidae		**1,151**	**44.4**	**1,244**	**17.6**	**3,863**	**54.1**	**6,258**	**37.2**
Cyprinus carpio	Common carp	467	18.0	10	0.1	1,187	16.6	1,664	9.9
Notropis spp.	*Notropis* spp.	299	11.5	49	0.7	765	10.7	1,113	6.6
other and unidentified Cyprinids	other and unidentified Cyprinids	385	14.9	1,185	16.7	1,911	26.7	3,481	20.7
Percidae		**320**	**12.4**	**368**	**5.2**	**1,377**	**19.3**	**2,065**	**12.3**
Percina spp.	*Percina* spp.	173	6.7	42	0.6	1,001	14.0	1,216	7.2
other and unidentified Percids	other and unidentified Percids	147	5.7	326	4.6	376	5.3	849	5.0
Centrarchidae		**154**	**5.9**	**149**	**2.1**	**551**	**7.7**	**854**	**5.1**
Lepomis spp.	*Lepomis* spp.	149	5.8	149	2.1	547	7.7	845	5.0
other and unidentified Centrarchids	other and unidentified Centrarchids	5	0.2	-	-	4	<0.1	9	<0.1
Other and Unidentified Families		**61**	**2.4**	**22**	**0.3**	**156**	**2.2**	**239**	**1.4**
other and unidentified species	other and unidentified species	61	2.4	22	0.3	156	2.2	239	1.4
Total		**2,590**	**100.0**	**7,087**	**100.0**	**7,147**	**100.0**	**16,824**	**100.0**

[a] Only those taxa that constituted 5.0% or more of the sample at one or more sample sites are listed individually. All other taxa are grouped as “other or unidentified” within the appropriate family.

[b] Catostomid D refers to individuals in the genera *Hypentelium* and *Moxostoma*, for which a positive separation could not be made due to overlapping characteristics in the larval stage.

Source: EA Engineering 1990

Table 4–15. Estimated Ichthyoplankton Drift and Entrainment, 1988

Number of Individuals (in millions)					
	Drift in Kankakee River	Entrainment at Braidwood Intake		Percent (%) Entrained at Intake	
	Actual	Actual [(a)]	Worst Case [(b)]	Actual	Worst Case
Eggs	0.8	0.7	1.0	83.9	121.8
Larvae	37.7	5.8	11.2	15.5	29.8
Total	**38.5**	**6.5**	**12.2**	**16.9**	**31.8**

[(a)] The actual case is the estimated number of eggs and larvae that were entrained during the sample period (April 19–September 13) based on the actual total weekly volume of water withdrawn from the Kankakee River each week during the period.

[(b)] The worst case represents the estimated number of eggs and larvae that would be entrained if the plant were to withdraw Kankakee River water 24 hours a day, 7 days a week at the maximum capacity pump rate (50,000 gpm) over the sample period.

Source: EA Engineering 1990

EA Engineering preliminarily predicted that 20 percent or less of eggs and larvae would be entrained at the Braidwood intake assuming withdrawal of 20 percent of river flow at the plant's maximum pumping rate of 50,000 gpm (100 cfs) during low flow conditions of 500 to 600 cfs (220,000 to 270,000 gpm). Using ichthyoplankton densities from the collected samples and USGS river flow data, EA Engineering determined actual and worst case scenario entrainment as follows. The worst case scenario assumed that Braidwood would withdraw river water 24 hours a day, 7 days a week at the maximum capacity pump rate (50,000 gpm [100 cfs]) over the sample period. Table 4–15 lists the estimated ichthyoplankton drift and entrainment in 1988.

Individuals (in millions)	Eggs	Larvae	Total
Present in river	0.8	37.7	38.5
Entrained (actual)	0.7	5.8	6.5
Entrained (worst case)	1.0	11.2	12.2
Percent (%) Entrained			
Actual	83.9	15.5	16.9
Worse Case	121.8	29.8	31.8

Egg entrainment was particularly high in both the actual (83.9 percent) and worst case (121.8 percent) scenarios. EA Engineering determined that two factors could have made the estimated entrainment rate appear higher than the actual entrainment rate. First, Horse Creek could be significantly contributing to Kankakee River egg drift. Because river samples were taken upstream of the confluence of Horse Creek (see Figure 4–1), this is a reasonable contributing factor. Second, EA Engineering determined that spawning may be taking place near or immediately upstream of the intake. Several taxa were present in intake egg samples that were not present in Kankakee River or Horse Creek samples (see Table 4–13), which supports this explanation. The river also includes a large, deep, slack-water area between the mouth of Horse Creek and the intake, which could serve as a spawning area for species that prefer to spawn in slower-moving waters. EA Engineering concluded that egg entrainment may create noticeable effects on a number of species, including common carp, cyprinids, and

darters, but that such effects would likely be restricted to the portion of the population near Braidwood.

To determine whether the loss of 15.5 to 29.8 percent of larvae would be significant, EA Engineering considered several factors. First, EA Engineering considered whether the larvae captured in the samples were indicative of the larval populations susceptible to entrainment. For taxa that were common in samples, such as catostomids, cyprinids, and percids, the samples were found to be reasonably representative. For rare and occasional species, including ictalurids, esocids, and most centrarchids, EA Engineering determined that samples would greatly underestimate the abundance of these taxa's presence in the river. Horse Creek contributed an additional 10 percent to the number of larvae present in upstream samples. Spawning near the intake, which is assumed to be a contributing factor to egg entrainment, would also significantly contribute to the amount of larvae present near the intake. Thus, river samples taken during the study likely underestimated total larvae present in the vicinity of the Braidwood intake that were susceptible to entrainment.

Second, EA Engineering considered how the estimated entrainment losses at Braidwood would affect fish populations throughout the 58 mi (93 km) portion of the Kankakee River in Illinois based on methods discussed in Goodyear (1977). This area was chosen because the entire length of the river within Illinois is meandering, well-vegetated, and rocky, and it is reasonable to assume that this area could serve as a source of recruitment for losses of fish in the vicinity of Braidwood. Of the 58 mi (93 km), 14.5 mi (23.3 km) are located downstream of Braidwood. Larvae produced in this portion of the river would not be at risk of entrainment. EA Engineering determined that upstream of Braidwood, larvae within the 24.5 mi (39.4 km) portion of the river above the dam in Kankakee, Illinois are also not at risk of entrainment. Thus, only larvae that occur within a 19-mi (30.6-km) stretch (33 percent) of the river in Illinois are at risk of entrainment. Based on this information, EA Engineering calculated that Braidwood would entrain 5.1 percent of all larvae in the Illinois portion of the Kankakee River under the actual case scenario (15.5 percent larvae in the vicinity of Braidwood entrained during the 1988 study × 33 percent of the river in Illinois in which larvae are susceptible to entrainment) and 9.8 percent under the worst case scenario (29.8 percent entrained during the study × 33 percent of the river in which larvae are susceptible to entrainment).

Third, EA Engineering considered how larval entrainment would affect different taxa groups based on biological or ecological criteria. EA Engineering determined that the groups least likely to be affected would be:

Taxa Least Likely to be Impacted	Reason
catostomids, gizzard shad, common cyprinids (i.e., spotfin shiner, bluntnose minnow)	Larvae are abundant, taxa have high fecundity, and larvae are entrained less frequently than expected
centrarchids, esocids, ictalurids	Larvae are not susceptible to the drift and/or have abundant populations in the river

EA Engineering determined that the groups most likely to be affected would be:

Taxa Most Likely to be Impacted	Reason
Percina spp.	Larvae abundance is disproportionately high in entrainment samples in comparison to river population
most darters	Larvae enter the drift regularly and taxa has low fecundity
pallid shiner, ghost shiner, mimic shiner	Taxa are rare or uncommon and largely restricted to the lower Kankakee River

Darters were determined to be the group most likely to experience impacts from larval entrainment at Braidwood because they have low populations in the river, produce relatively few eggs, and are disproportionately represented in the drift. Uncommon cyprinids restricted to the lower Kankakee River, such as the State-endangered pallid shiner, are likely to be disproportionately affected by larval entrainment, as well. Although impingement samples included pallid shiner, ghost shiner, and mimic shiner, larvae of these species were not identified in entrainment samples. It is possible, however, that these species were present as unidentified cyprinids, which accounted for 26.7 percent of larvae collected at the intake (see Table 4–14).

EA Engineering also conducted larval survival studies, which EA Engineering factors into its conclusions as a source of ichthyoplankton to the river that could mitigate losses from entrainment. Discharged larvae originate in the cooling pond, travel through the river screen house, and enter the Kankakee River with cooling pond blowdown. EA Engineering determined that 75 percent of larvae survive the discharge pathway from the cooling pond to the river.

Although it is possible that cooling pond larvae discharged into the river supplement some entrainment losses, the NRC will not consider the survival study in its conclusions for a number of reasons. First, the discharge survival study included only a small sample size (103 total larvae) because it was conducted on only 3 sample days in June and July 1988 during daylight hours. The larvae survivorship samples also yielded a significantly different species composition than the 52 ichthyoplankton drift samples collected between April 19 and June 28, 1988, and discussed previously in this section. Samples taken during the peak entrainment period (in May at night) would have yielded larger samples that were more representative of the actual species composition. Second, larval samples were sorted and identified within 20 minutes of collection. Thus, it is unknown how many of the larvae counted as “live” in the samples may have died in the hours following entrainment due to physical or thermal stresses experienced prior to discharge into the river. Third, while EA Engineering concluded that 75 percent of larvae would survive discharge into the river, this number is skewed by the large number of *Lepomis* postlarvae (79 postlarvae; 76.7 percent) collected in survivorship samples and the high survivorship of these individuals (80 percent). The only other live larvae collected were of *Poxomis* spp. (3 postlarvae and 1 juvenile; 3.9 percent) with a survivorship rate of 33 percent. By dividing the total number of live larvae by the total number of larvae collected in all entrainment samples taken at the discharge (not just the survivorship samples), however, the result is a much different overall survival rate:

$$\frac{\text{92 } \textit{Lepomis} \text{ larvae (0.8 survivorship)} + \text{213 } \textit{Poxomis} \text{ larvae (0.33 survivorship)}}{\text{734 total larvae collected}} = 19.6\% \text{ overall survivorship}$$

For these reasons, NRC has not factored EA Engineering's survivorship study into its conclusions below.

LOE 2 Conclusion

Based on the one entrainment study that has been conducted at Braidwood, it is difficult to determine whether entrainment of eggs and larvae has a detectable impact on fish populations in the Kankakee River. The study's egg entrainment estimates are not useful in determining impacts to the fish community as a whole because they did not account for the contribution of spawning in Horse Creek or near the intake. Nevertheless, EA Engineering determined that entrainment of eggs may create noticeable effects on a number of species, including common carp, cyprinids, and darters and that such effects would likely be restricted to the portion of the population near Braidwood. Because the impacts are noticeable but not likely to destabilize the resource, impacts from egg entrainment appear to be MODERATE for these species.

Larval entrainment would only affect a small portion of the Kankakee River fish populations in Illinois—5.1 to 9.8 percent when adjusted for the portion of the populations in the river susceptible to entrainment—and many populations, including catostomids, gizzard shad, common cyprinids, centrarchids, esocids, and ictalurids, would likely not be noticeably affected. Thus, impacts from larval entrainment would be SMALL for these groups. Species that have low populations in the river or are restricted to the lower Kankakee River, produce relatively few eggs, and/or are disproportionately represented in the drift are more likely to experience noticeable effects as a result of larval entrainment. This includes *Percina* spp., darters, and less common cyprinids, such as the State-endangered pallid shiner. Impacts from larval entrainment would be MODERATE for these groups.

Although eggs and larval fish are also entrained at the lake screen house when cooling pond water is drawn into Braidwood's cooling system, the impacts of entrainment on the aquatic community within the cooling pond are unknown because they have not been addressed in studies.

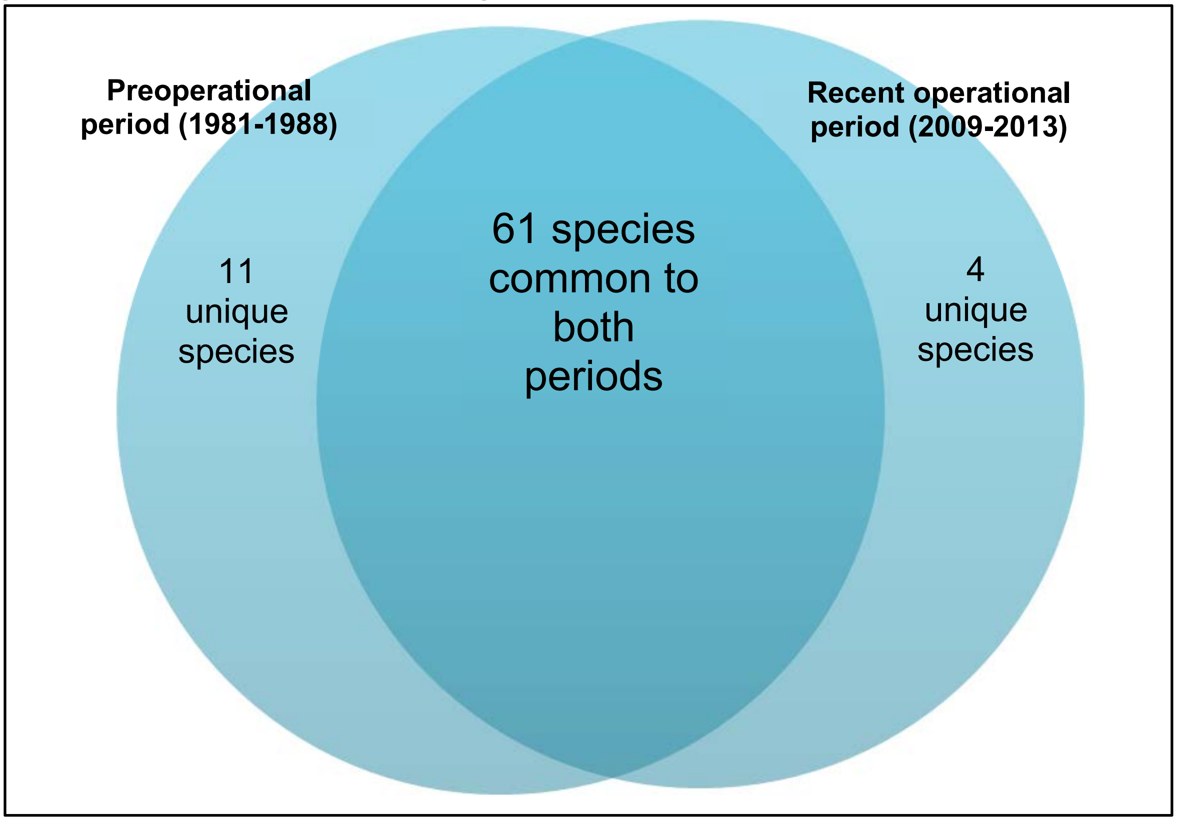
<u>LOE 3: Kankakee River Fish Sampling Data</u>

Impingement and entrainment from the withdrawal of makeup water from the Kankakee River has removed individuals from the river ecosystem since Braidwood began operating in 1988. Over this period of time, the aquatic community may have changed in a number of ways, including species richness (the number of species present), species composition (the kinds of species present), and species evenness (the relative abundance of species). This line of evidence (LOE) compares the community characteristics prior to and during operations to determine whether changes have occurred and if such changes can be attributed to Braidwood operations.

One way to determine whether species richness and composition has changed is to calculate the Jaccard index (or Jaccard similarity coefficient). This index provides a simple snapshot of species presence or absence. The index is calculated as $J = a /(a+b+c)$, where J is the index value, a is the number at both sites, b is the number at the second site only, and c is the number at the first site only (Pielou 1977). A coefficient of 1.0 indicates that the exact same species are present in both samples, while a coefficient of zero would indicate that none of the species in either sample appear in the other sample (i.e., each sample has completely unique species). The NRC staff calculated the Jaccard similarity coefficient to compare the fish collected in studies conducted during the preoperational period with the fish collected during the last 5 years of monitoring data (2009-2013). Section 3.7.2.1 and Tables 4–9 and 4–11 identify the species considered. Only unique species or taxa groups were included (e.g., *Notropis volucellus*, but not unidentified *Notropis* spp.). In total, 76 species or hybrids appeared in either the

preoperational period, the recent operational period, or both. Of these, 61 species appeared in both periods, 11 species were unique to the preoperational period, and 4 species were unique to the recent operational period (see Figure 4–2, NRC staff generated graphic). The NRC staff calculated the Jaccard similarity coefficient to be 0.80. This coefficient indicates that the aquatic community has remained relatively similar, and thus, impingement and entrainment over the 26 years of Braidwood operations has not noticeably altered species richness or composition.

Figure 4–2. Species Richness During Preoperational and Recent Operational Periods



Section 3.7.3.1 discusses several changes in species evenness since Braidwood began operating, and Figure 3–13 in Section 3.7.3.1 illustrates the shift in relative abundance of the most prevalent fish families in historic and recent Kankakee River monitoring samples. The major changes include a significant increase in the relative abundance of cyprinids and a decrease in the abundance of catostomids. Cyprinids accounted for 33.1 percent of total collected individuals in 1982, while they accounted for an average of 57.2 percent of fish collected over the 2009–2013 period. Catostomids, which accounted for 22.2 percent of the total catch in 1982, have only comprised an average of 3.2 percent in recent years. Centrarchids and clupids have also decreased in abundance (34.4 to 32.2 percent and 6.2 to 1.0 percent, respectively).

To determine whether these changes could be attributable to Braidwood operations or whether they are merely a reflection of changes in species abundance throughout the Kankakee River in Illinois, NRC staff considered the relative abundances of fish families captured during a 2005 Kankakee River survey performed by IEPA and IDNR staff (Pescitelli and Rung 2008). The 2005 survey included boat electrofishing, backpack electrofishing, electric seining, and standard seining at 13 locations on the mainstem of the Kankakee River form July 19 to July 22, 2005. Surveyors collected 5,630 fish representing 14 families and 68 species from all gear times

combined. Figure 4–3 compares the relative abundance of the most prevalent fish families collected during the 2005 survey with the abundance of the same families during 1981–1982 preoperational fish surveys (NRC 1984) and the 5 most recent years of operational fish sampling data (HDR 2014).

While a strict comparison cannot be made because no mainstem surveys are available from the preoperational period, several changes in the relative abundance of fish families in the vicinity of Braidwood do not appear to be correlated with the more recent river-wide abundance of those same families. For instance, the 2005 mainstem survey yielded a much more even distribution of catostomids (26.1 percent), percids (25.9 percent), and cyprinids (20.7 percent) than recent Braidwood collections. Cyprinids have by far been the most abundant family in recent Braidwood collections, while catostomids and clupids have decreased in abundance and are proportionately much rarer in the vicinity of Braidwood than in Kankakee mainstem collections. Centrarchids have decreased slightly in abundance between preoperational surveys and recent years, although they appear to still be more abundant in the vicinity of Braidwood than in the Kankakee mainstem.

Figure 4–3. Relative Abundance of Most Prevalent Fish Families in the Kankakee River Over Time

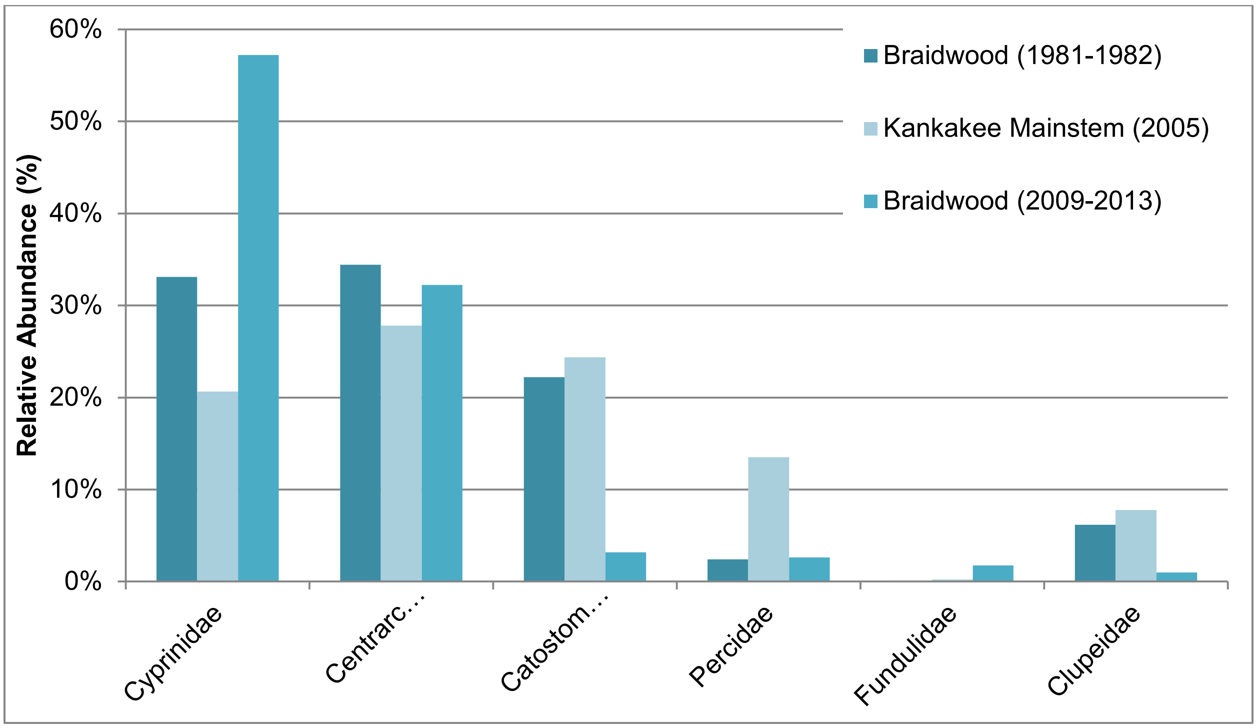


Figure data sources: HDR 2014; NRC 1984; Pescitelli and Rung 2008

Impingement and entrainment may be contributing the apparent local decline of clupids and catostomids. Gizzard shad (a clupid) was the most commonly impinged species in the 1988 to 1989 impingement discussed as part of LOE 1 (EA Engineering 2012). Although EA Engineering (1990) concluded that this species was unlikely to be affected by impingement, the decline in the relative abundance of clupids in recent years indicates that impingement of YOY and juveniles could be creating unanticipated effects. For catostomids, EA Engineering (2012) most commonly collected eggs of carp in entrainment samples taken at the Braidwood intake (see LOE 2). The decline of catostomids supports EA Engineering's (2012) conclusion

that egg entrainment may create noticeable effects on a number of species, including common carp.

LOE 3 Conclusion

While the species richness and composition has remained similar over the period of Braidwood operations, recent Braidwood survey information indicates that species evenness is significantly different than during the preoperational monitoring period. The relative abundance of cyprinids have noticeably increased, while the relative abundances of clupids and catostomids have noticeably decreased. It is possible that impingement of clupids and entrainment of catostomid eggs could be contributing to the decline in the relative abundance of these taxa. Thus, this LOE indicates that impingement and entrainment may be creating a MODERATE effect on the aquatic community in the vicinity of Braidwood.

LOE 4: Mussel Surveys

Freshwater mussel eggs, juveniles, and adults are generally not susceptible to impingement or entrainment because they live on bottom substrates rather than in the water column. Some species' glochidia (the larval stage) require attachment to a fish host to mature. For these species, impingement or entrainment of glochidia is possible if the host fish is impinged.

Based on a review of possible host species, it does not appear that impingement of host fish is noticeably altering the mussel population in the vicinity of Braidwood. Table 4–16 lists the most commonly occurring mussel species near Braidwood and their host fish. Host fish species for each of these mussels were present in 1980–1981 and 1988–1989 impingement samples (see Tables 4–9 and 4–11). Section 3.7.3.1 discusses several mussel surveys conducted in the vicinity of Braidwood (Belt 2009; HDR 2008) as well as throughout the Kankakee River basin (Price et al. 2012; Suloway 1981). As indicated in that section, species diversity within the mussel community appears to be relatively high in the vicinity of Braidwood and has remained similar since Braidwood began operating. Species abundance appears to be lower in the vicinity of Braidwood than in other regions of the Kankakee River. Because no preoperational mussel surveys were done in the vicinity of Braidwood, it is not possible to determine whether this is the result of Braidwood operations or other factors. HDR Engineering indicates that the lower species abundance is likely the result of unsuitable or marginal habitat near Braidwood (HDR 2008).

Table 4–16. Host Fish of Common Kankakee River Mussels

Species	Common Name	Host Fish
Actinonaias ligamentina	mucket	sawfish, bluegill, bass, crappie, perch
Lasmigona complanata	white heelsplitter	common carp, bass, crappie
Lasmigona costata	flutedshell	common carp
Quadrula pustulosa	pimpleback	channel catfish, bullhead, sturgeon
Utterbackia imbecillis	paper pondshell	sunfish spp.

Source: Hess 2014

LOE 4 Conclusion

No noticeable changes in the mussel community have occurred since Braidwood began operating. Thus, impingement and entrainment of mussel glochidia through impingement of host fish appears to have a SMALL impact on the mussel community in the vicinity of Braidwood.

LOE 5: Engineered Design and Operational Controls

In August 2014, the EPA published a final rule establishing requirements under section 316(b) of the Clean Water Act (CWA) for cooling water intake structures at existing facilities (79 FR 48300). The final rule indicates that two basic approaches can reduce impingement and entrainment mortality: (1) flow reduction and (2) including technologies into the cooling water intake design that gently exclude organisms or collect and return organisms without harm to the water body. The EPA also notes that two additional approaches can reduce impingement and entrainment, but that these technologies may not be available to all facilities. The two additional approaches are: relocating the facility's intake to a less biologically rich area in a water body and reducing the intake velocity. The Braidwood CWS on the Kankakee River incorporates several of these approaches.

Flow Reduction

Reducing the amount of water that is withdrawn for cooling purposes from a water body reduces the number of aquatic organisms that are drawn through the intake structure and subject to impingement or entrainment. Because Braidwood uses a cooling pond-based heat-dissipation system, the majority of cooling water needed for plant operation is drawn from the cooling pond rather than the Kankakee River. The cooling pond system is similar to a closed-cycle cooling system in that water in the pond continues to be recirculated through the plant for cooling and only makeup water (water lost to evaporation or discharged as blowdown) is drawn directly from the Kankakee River. Depending on the quality of the makeup water, closed-cycle cooling systems can consume significantly less water than if the same facility were to use a once-through cooling system.

Braidwood's intake flow is also controlled by an agreement with the IDNR that was made in 1977 upon issuance of a permit to construct the river screen house and blowdown discharge canal (IDOT 1977). The agreement limits Kankakee River makeup withdrawal volume to a maximum of 160 cfs (4,531 L/sec), and in times where the river flow is low, Exelon must limit Kankakee River water consumption such that withdrawal of makeup water does not cause river flow to drop below 442 cfs (12,517 L/sec) (IDC 1977).

The most recently issued Braidwood NPDES permit (IEPA 2014d) requires further withdrawal reductions during the peak entrainment period each year. Special Condition 8 requires that during the last 3 weeks in May and first week in June, Kankakee River withdrawals be made only during the day (between one hour after sunrise and one hour before sunset). Pumping during the day must also be limited to only those occasions where additional water is needed to fill the freshwater holding pond and to maintain efficient operation of the cooling pond.

Technologies That Exclude or Collect and Return Organisms

The Braidwood cooling system has several technologies that help exclude organisms from becoming impinged or entrained. Water enters the river screen house through an intake bay equipped with bar grills, 3/8-in. (9.5-mm) mesh travelling screens, and trash rakes to prevent debris and aquatic biota from entering the system (Exelon 2014c). The space between the

trash racks and the traveling screens allow fish to swim downstream and exit the intake structure. The EPA indicates that, ideally, traveling screens would be used with a fish handling and return system (79 FR 48300). Braidwood's river screen house does not contain a fish return system (Exelon 2014c). However, the space between the trash racks and traveling screens, paired with the low intake velocity (discussed below), should allow some fish to swim away and escape impingement.

Location of the Facility's Intake

Location of the intake system is another design factor that can affect impingement and entrainment because locating intake systems in areas with high biological productivity or sensitive biota can negatively affect aquatic life (EPA 2004). As discussed in Section 3.7, the IEPA (2014b) has rated the Kankakee River in the vicinity of Braidwood as fully supporting aquatic life, and the IDNR has designated the Kankakee River from Momence in Kankakee County to the Des Plains Wildlife Conservation Area in Will County as a Biologically Significant Stream because it supports one of the state's most diverse aquatic communities (Page et al. 1991). Thus, the location of the Braidwood intake is not a factor that is likely to result in reductions in entrainment and impingement mortality.

Intake Flow

Water velocity associated with the intake structure greatly influences the rate of impingement and entrainment. The higher the approach velocity, through-screen velocity, or both, the greater the number of organisms that will be impinged or entrained. At an approach velocity of 0.5 ft/s (0.15 m/s) or less, most fish can swim away and escape from the intake current (79 FR 48300). As indicated in Section 3.1.3, water velocity at the river screen house ranges from 0.32 to 0.48 fps (0.10 to 0.15 m/s), depending on river level, when both units are operating (Exelon 2013c). Thus, the river screen house intake velocities are within the 0.5-fps (0.15-m/s) intake velocity recommended by the EPA for protection of aquatic organisms.

LOE 5 Conclusion

While flow control measures, including the IDNR agreement and NPDES Permit Special Condition 8, and low intake velocities reduce the effects of impingement and entrainment mortality at Braidwood, the lack of a fish return system and high biological significance of the Kankakee River in the vicinity of Braidwood could contribute to impingement and entrainment effects. This LOE does not conclusively indicate whether impingement or entrainment at Braidwood is creating detectable effects on the Kankakee River aquatic community. Thus, this LOE, considered alone, is inconclusive.

<u>Summary of Impingement and Entrainment Conclusion</u>

Based on past and present impacts to aquatic resources resulting from Braidwood operation, the NRC concludes that impingement and entrainment associated with the proposed license renewal would result in SMALL to MODERATE impacts on aquatic resources in the Kankakee River. MODERATE impacts would primarily result from the following:

- impingement of the State-endangered pallid shiner (LOE 1) and clupids (LOE 3);
- entrainment of common carp, cyprinids, and darter eggs (LOE 2, 3); and
- entrainment of *Percina*, darter, pallid shiner, and other less common cyprinid larvae (LOE 2).

The NRC cannot make a determination on the impact of impingement and entrainment on the aquatic resources in the cooling pond because no studies exist on impingement and entrainment at the lake screen house.

Impingement and entrainment impacts are presently mitigated through special conditions of the NPDES permit (discussed under LOE 1) and the existing engineered design and operational controls (discussed under LOE 5). During the proposed license renewal term, impacts would be further reduced through the IDNR's implementation of new requirements contained in the final CWA 316(b) regulations, which were published in August 2014 (79 FR 48300) and discussed in LOE 5. The new regulations require the EPA or the State, as applicable, to ensure that the location, design, construction, and capacity of existing power generation facilities with cooling water intake structures reflect the best technology available to minimize harmful adverse environmental impacts. For Braidwood, the IEPA would ensure Exelon's adherence to the CWA 316(b) regulations through the NPDES permit renewal process. Braidwood's current NPDES permit expires in July 2019. Although the NRC has no authority over the NPDES permitting process, the NRC staff assumes that this mitigation is reasonably certain to reduce existing impacts because it is required by Federal regulation. The applicant has proposed no additional mitigation as part of license renewal to reduce adverse environmental impacts associated with impingement and entrainment.

4.7.1.3 Thermal Impacts on Aquatic Organisms

In the GEIS (NRC 2013f), the NRC determined that thermal impacts on aquatic organisms is a Category 2 issue (see Table 4-8) that requires site-specific evaluation during each license renewal review for plants with once-through cooling systems or cooling ponds, such as Braidwood.

The NRC staff used a modified WOE approach to evaluate thermal impacts on the aquatic resources in the Kankakee River and Braidwood cooling pond. The NRC staff examined the five lines of evidence as follows.

LOE	Description
1	Results of past NRC reviews on thermal impacts of Braidwood operations
2	A review of regulatory controls on thermal effluents
3	Results of a 2010 thermal study conducted at Braidwood
4	Consideration of fish kills at Braidwood
5	A review of available cooling pond monitoring data

<u>LOE 1: Past NRC Reviews</u>

The NRC (1984) previously assessed the potential thermal impacts of Braidwood operations in the FES-O. The NRC determined that the thermal plume would be relatively small. The 2 °F (1.1 °C) isotherm would range from 0.52 ac (0.21 ha) in April to 5.4 ac (2.2 ha) in October, and in all months, the 5 °F (2.8 °C) isotherm would occupy an area of less than 0.5 ac (0.2 ha), and the 10 °F (5.6 °C) isotherm would occupy an area of less than 0.1 ac (0.4 ha). Limitations set forth by the Illinois Administrative Code (IAC) and NPDES permit (discussed in LOE 2) would also limit thermal additions to the river. Thus, the NRC (1984) concluded that juvenile and adult fish would be able to avoid the thermal plume. Impacts to the phytoplankton community were determined to be minor and of minimal duration because the residence time within the plume is short and the regeneration time of phytoplankton is rapid. The NRC determined that benthic organisms would not be significantly affected by blowdown discharge. The NRC also concluded that cold water shock would not create significant effects because blowdown discharged to the river originates from the cooling pond, which would cool slowly upon station shutdown.

The NRC (1984) characterized the cooling pond as a "stressed system" and determined that Braidwood operation would have an adverse effect on aquatic organisms in the pond during periods when pond temperatures exceed 30 °C (86 °F). The NRC noted that while it was possible that fish could avoid high temperatures by taking refuge in deeper, cooler areas of the cooling pond, high temperatures would also create algal blooms and subsequent periods of algal die-off, which would reduce dissolved oxygen in the water column and likely kill fish that would have otherwise been able to withstand the higher temperatures. The NRC determined that the effects of thermal additions to the cooling pond were discountable because the State had not identified the pond as a fishery resource and because the applicant had indicated that the pond would only be used for cooling purposes. However, since that time, the IDNR has regularly stocked the lake with game fish and the pond is managed as part of the Mazonia-Braidwood State Fish and Wildlife Area. The pond also provides quality habitat, food, and water to waterfowl and migrating birds. The NRC, therefore, no longer considers effects to the cooling pond to be discountable.

LOE 1 Conclusion

The NRC's past review of the thermal impacts resulting from Braidwood operation indicate that the impacts to the Kankakee River aquatic community would be minor and unnoticeable, and therefore, SMALL. The impacts to the cooling pond aquatic community, however, were determined be noticeable and adverse. The FES-O does not provide enough information to assess whether these impacts would destabilize the community. Thus, the NRC concludes that thermal impacts on the cooling pond aquatic community would be MODERATE.

LOE 2: Regulatory Controls

The IAC and the Braidwood NPDES permit (IEPA 2014d) impose regulatory controls on Braidwood's thermal effluent that ensure that impacts on the aquatic environment are reduced or mitigated.

Title 35, *Environmental Protection*, Section 302, "Water Quality Standards," of the IAC contains stipulations pertaining to effluent temperature as well as mixing zones and zones of initial dilution. The following limitations and requirements included in Section 302 pertain to effluent temperature and serve to protect aquatic biota from the effects of such effluents.

> The maximum temperature rise shall not exceed 2.8 °C (5 °F) above natural receiving water body temperatures. [35 IAC 302.211(d)]
>
> Water temperature at representative locations in the main river shall at no time exceed 33.7 °C (93 °F) from April through November and 17.7 °C (63 °F) in other months. [35 IAC 302.211(e)]

Several IAC stipulations pertaining to mixing zones also protect aquatic biota from thermal effluents.

> Mixing is not allowed in waters which include a tributary stream entrance. [35 IAC 302.102(b)(2)]
>
> Mixing is not allowed in waters containing mussel beds, endangered species habitat, fish spawning areas, areas of important aquatic life habitat, or any other natural features vital to the well-being of aquatic life. [35 IAC 302.102(b)(4)]
>
> Mixing must allow for a zone of passage for aquatic life. [35 IAC 302.102(b)(6)]
>
> The area and volume of mixing must not contain more than 25 percent of the cross-sectional area or volume of a stream and must not intersect any body of water in such a manner that the maintenance of aquatic life in the body of water as a whole would be adversely affected. [35 IAC 302.102(b)(7) and (8)]

> The area and volume in which mixing occurs must be as small as is practicable, and in no circumstances larger than 26 ac (11 ha). [35 IAC 302.102(b)(12)]

The Braidwood NPDES permit (IEPA 2014d) also contains requirements related to thermal effluents. Special Condition 4 of the permit mirrors the temperature requirements at 35 IAC 302.211 listed above. Additionally, the special condition requires that water temperature at the edge of the mixing zone not exceed 60 °F from December through March during more than one percent of the hours in a 12-month period and that at no time shall the water temperature at such locations exceed the maximum limits by more than 3 °F (i.e., 63 °F).

In the past 5 years, Braidwood has reported one noncompliance with Special Condition 4 to the IEPA. In March 2012, blowdown water discharged as effluent to the Kankakee River at Outfall 001 exceeded the permitted temperature limits at points beyond the mixing zone edge due to a period of extremely warm weather and little to no precipitation in Illinois (Exelon 2014l). On March 19, 2012, ambient water temperature upstream of Braidwood was recorded at 67.5 °F on March 19, 2012 (IEPA 2012b). Accordingly, any thermal addition to the river would have exceeded the permitted limit of 63 °F. On March 22, 2012, the IEPA (2012b) granted a provisional variance from the requirements of the special condition that allowed temperatures to increase to a maximum of 70 °F at the edge of the mixing zone from March 21 through March 31, 2012. The provisional variance required Exelon to monitor the river for adverse environmental effects, such as fish mortalities. Exelon has not reported any such effects to the IEPA or NRC as a result of the variance.

LOE 2 Conclusion

Braidwood thermal effluent is limited by the IAC and the Braidwood NPDES permit to ensure that it does create adverse effects on the aquatic communities in the Kankakee River. In the past 5 years, Exelon applied for and the IEPA granted one provisional variance to allow higher-than-permitted temperatures at the edge of the discharge mixing zone caused by a period of extremely warm weather and little to no precipitation. Exelon reported no fish kills or other events to the IEPA or the NRC that would indicate adverse environmental effects resulting from the provisional variance. The NRC depends on the State to enforce the regulatory controls in place at Braidwood and effectively ensure that any environmental effects to Kankakee River aquatic communities are not detectable or so minor as to neither destabilize nor noticeably alter the community. Thus, this LOE indicates that thermal impacts to Kankakee River aquatic organisms would be SMALL during the proposed license renewal term.

<u>LOE 3: Thermal Modeling</u>

In 2009, Exelon commissioned HydroQual Environmental Engineers and Scientists, Inc., to develop a model that would assess the mixing zone and thermal impact of replacing the Braidwood discharge canal with a multi-port diffuser, a project that was later completed in 2010. As part of the modeling, Thuman (2009a) developed a CORMIX model for several different diffuser configurations; only the 7-port diffuser is discussed here as this was the configuration that was installed. The CORMIX simulation indicated that under normal blowdown rates (1,199 L/sec [19,000 gpm]) and extreme low river flow, the largest area that would experience the IAC's maximum allowable temperature rise of 2.8 °C (5.0 °F) would occur in March and would extend approximately 64 ft (19.6 m) downstream. With lower or higher blowdown rates, the area of water exhibiting a 2.8 °C (5.0 °F) rise ranged from 48 to 72 ft (14.5 to 22 m).

The CORMIX model also indicated that under no scenario did the thermal plume exceed 25 percent of the cross-sectional area of the river, in accordance with 35 IAC 302.102(b)(8). Thuman (2009a) estimated the cross sectional area to vary from 9.3 percent of the river's

cross-sectional area (in April) to 24.8 percent (in November). The surface area of the plume was determined to be 0.22 ac (0.1 ha).

LOE 3 Conclusion

The available thermal model indicates that Braidwood's thermal effluent complies with the requirements of the IAC. As indicated in the previous LOE, the NRC relies on the State through its NPDES permitting process to ensure that thermal effluents do not create adverse effects on aquatic communities. Thus, this LOE is consistent with LOE 2's conclusion of SMALL.

<u>LOE 4: Fish Kills</u>

Since 2001, Exelon has identified six fish kill events in the Braidwood cooling pond; Section 3.7.4 describes these events. Exelon (2013c) attributes most of the fish kills to high temperatures in the cooling lake associated with operation of the Braidwood cooling system. Each event resulted in the mortality of several hundred to several thousand fish. The largest of these events occurred in June 2005 and included approximately 10,000 dead fish (Exelon 2005). Affected species have included gizzard shad, threadfin shad (*Dorosoma petenense*), channel catfish (*Ictalurus punctatus*), carp, bass, and other unspecified game fish species. The NRC expects that fish kills would continue during the proposed license renewal period based on HDR Engineering's (2013) assessment, which states that "there are no practical or simple solutions that could prevent the occurrence of fish die-offs at Braidwood Lake."

Exelon has not reported any fish kills on the Kankakee River since Braidwood began operating.

LOE 4 Conclusion

No fish kills have occurred on the Kankakee River. Thus, this LOE indicates that the effects of the thermal discharge on Kankakee River aquatic biota are not detectable and, therefore, SMALL.

Information on fish kills in the cooling pond indicates noticeable effects that are likely to persist while Braidwood is operational. This LOE does not provide enough information to determine if fish kills have destabilized any important attribute of the resource. Therefore, this LOE indicates that the effects of the thermal discharge on cooling pond aquatic biota are MODERATE.

<u>LOE 5: Cooling Pond Fish Sampling Data</u>

Section 3.7.3.2 discusses Braidwood cooling pond fish sampling that IDNR has conducted since 1980 and HDR Engineering has conducted since 2009. The sampling data indicate that the cooling pond's species composition has noticeably shifted towards heat-tolerant species. In particular, bluegill, which accounted for 9.6 percent of preoperational samples, increased to 23.5 percent during the IDNR operational samples (1988–2007) and to 28.4 percent in HDR Engineering operational samples (2009–2012). Gizzard shad, one of the most frequently affected species during periods of elevated pond temperatures, has decreased in abundance dramatically; it was the most abundant species in preoperational surveys, while it only accounted for 5.0 percent of HDR Engineering's 2009–2012 samples. IDNR-stocked warm water game species, such as largemouth bass and blue catfish, have persisted in small numbers, while cooler water stocked species, such as walleye and tiger muskellunge, a usually sterile hybrid of true muskellunge (*Esox masquinongy*) and the northern pike (*Esox lucius*), appear to no longer be present in the pond. HDR Engineering (2013) notes that with the exception of common carp and channel catfish, survival of many of the species in the cooling pond is limited by elevated water temperatures in the summer months.

LOE 5 Conclusion

This LOE indicates that the cooling pond's aquatic community has noticeably changed over the course of Braidwood's operation. The effects of IDNR stocking and other management efforts on fish may be contributing to this effect. However, fish sampling data paired with the fish kill information in LOE 4 indicate that operation of the Braidwood cooling system is also a contributing factor. Therefore, this LOE indicates that the effects of the thermal discharge on cooling pond aquatic biota are likely MODERATE.

Summary of Thermal Impacts Conclusion

Based on past and present impacts to aquatic resources resulting from Braidwood operation, the NRC concludes that thermal impacts associated with the proposed license renewal would result in SMALL impacts to aquatic resources in the Kankakee River and MODERATE impacts to aquatic resources in the cooling pond.

The applicant has proposed no mitigation to reduce adverse environmental impacts associated with thermal discharges to the cooling pond. Further, because the State considers the cooling pond to be a wastewater treatment facility, it is not subject to limitations of the CWA.

4.7.1.4 Water Use Conflicts With Aquatic Resources

In the GEIS (NRC 2013f), the NRC determined that effects of water use conflicts on aquatic resources is a Category 2 issue (see Table 4-8) that requires site-specific evaluation during each license renewal review. Water use conflicts occur when the amount of water needed to support aquatic resources is diminished as a result of demand for agricultural, municipal, or industrial use or decreased water availability due to droughts, or a combination of these factors.

According to USGS data from the nearest surface water gaging station (USGS Station No. 05520500 at Momence, Illinois; 54.2 km [33.7 mi] upstream of Braidwood), the average annual flow of the Kankakee River near Braidwood in the past 10 data years (2002 through 2012) has ranged from 1,619 cfs; 45,850 L/sec or 727,000 gpm) in 2006 to 3,583 cfs (101,500 L/sec or 1.61 million gpm) in 2008 (USGS 2014). Normally, Braidwood's circulating water system withdraws 3,028 L/sec (48,000 gpm) of makeup water (Exelon 2013c). Thus, Braidwood has consumed between 3.0 and 6.6 percent of the Kankakee River's flow each year for the past 10 years. In times where the river flow is low, Exelon has an agreement with the IDNR to limit Kankakee River water consumption such that withdrawal of makeup water does not cause the Kankakee River flow to drop below 12,517 L/sec (442 cfs) (Exelon 2013c). Exelon maintains procedures to comply with these withdrawal restrictions, which would continue during the proposed license renewal term (Exelon 2013c).

The amount of Kankakee River water Braidwood consumes is minor in comparison to the flow of water past the plant, and regulatory mechanisms are in place to ensure that Braidwood does not consume an amount that would be harmful to aquatic biota during low flow conditions. The NRC staff did not identify any information that indicates that the Kankakee River biota are affected by the loss of river water consumed by Braidwood's makeup water withdrawals. The NRC staff concludes that water use conflicts would not occur from the proposed license renewal or would be so minor that the effects on aquatic resources would be undetectable. Thus, the NRC staff concludes that the impacts of water use conflicts on aquatic resources during the proposed license renewal term would be SMALL.

4.7.2 No-Action Alternative

If Braidwood were to cease operating, impacts to aquatic ecology would decrease or stop following reactor shutdown. Some withdrawal of water from the Kankakee River would continue

during the shutdown period as the fuel is cooled, although the amount of water withdrawn would decrease over time. The reduced demand for cooling water would substantially decrease the effects of impingement, entrainment, and thermal effluents. These effects would likely stop following the removal of fuel assemblies from the reactor cores. Given the small area of the thermal plume in the Kankakee River under normal operating conditions, effects from cold shock are unlikely. The cooling pond, however, would likely experience shifts in the relative abundances in fish populations because less heat-tolerant species would no longer be stressed by thermal additions to the pond.

The continuation of the lease agreement between Exelon and the IDNR for the Mazonia-Braidwood State Fish and Wildlife Area could be affected by decommissioning. Loss of these lands as a State-managed area could result in impacts to aquatic resources in the cooling pond depending upon any future land use of the site. The GEIS (NRC 2013f) notes that aquatic resource impacts could occur in other areas beyond the immediate nuclear plant site as a result of the no-action alternative if new power plants are needed to replace lost capacity.

NUREG–0586, *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*, Supplement 1, (NRC 2002d) concludes generically that impacts to aquatic ecology during decommissioning activities would be SMALL for facilities at which the decommissioning activities would be limited to existing operational areas. In the case of Braidwood, the NRC staff did not identify any effects that would have more than minor effects on aquatic resources. Thus, the NRC staff concludes that the impacts of the no-action alternative on aquatic resources during the proposed license renewal term would be SMALL.

4.7.3 New Nuclear Alternative

Construction of a new nuclear alternative would occur at an existing nuclear power plant site (other than the Braidwood site) or a retired coal plant site. Construction activities could degrade water quality of nearby streams, ponds, or rivers through erosion and sedimentation; result in loss of habitat through pond or wetland filling; or result in direct mortality of aquatic organisms from dredging or other in-water work. Due to the short-term nature of construction activities, these effects would likely be relatively localized and temporary. Siting the plant on an existing site could make use of existing transmission lines, roads, parking areas, and other infrastructure, which would limit the amount of habitat disturbance that would be required. Less habitat disturbance would create less erosion and sedimentation. The construction of intake and discharge structures could result in direct mortality of individuals as well as water quality degradation. Appropriate permits would ensure that water quality impacts would be addressed through mitigation or BMPs, as stipulated in the permits. The U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, or the State would oversee applicable permitting, including a CWA Section 404 permit, Section 401 certification, and Section 402(p) NPDES general stormwater permit. The NRC (2013b) has completed the review of one combined license application to build and operate a new nuclear plant in the ROI (Enrico Fermi 3 in Michigan) and concluded that construction would have SMALL impacts on aquatic resources. Without more specific details on the location of the new nuclear alternative, the NRC staff finds it reasonable to adopt its previous construction conclusions regarding Enrico Fermi 3 for the construction portion of this alternative.

Operational impacts would include those listed in Table 4-8, and the GEIS (NRC 2013f) conclusions of SMALL for Category 1 issues in the table would apply during the operational phase of the new nuclear alternative. Because this alternative would use a closed-cycle system, impingement, entrainment, and thermal effects would also be SMALL. Water use conflicts with aquatic resources would depend on the site location, water body, and specific

aquatic community present and cannot be determined without more specific details on the location of this alternative.

The NRC staff concludes that the impacts to aquatic resources from construction and operation of a new nuclear alternative would be SMALL.

4.7.4 Coal (Integrated Gasification Combined Cycle) Alternative

Construction of an IGCC alternative would occur at the Braidwood site or another existing power plant site in the ROI. The GEIS (NRC 2013f) indicates that the impacts of new power plant construction on ecological resources would be qualitatively similar. Thus, those impacts discussed under the new nuclear alternative would apply during the construction phase. Because the IGCC alternative would require significantly more land than the new nuclear alternative (2,000 ac [202 ha] versus 355 ac [144 ha]), the magnitude of impacts would likely be greater and could create noticeable effects on aquatic resources. Thus, construction impacts would be MODERATE.

Operation of the IGCC alternative would require less cooling water than Braidwood because the plant would operate with a closed-cycle system. Accordingly, impingement, entrainment, and thermal effects on aquatic resources would likely be smaller than for continued operation of Braidwood, though the exact magnitude would depend upon the water body and specific aquatic communities present. Chemical discharges from the cooling system would be similar to those at Braidwood. Operation would require coal deliveries, cleaning, and storage, which would require periodic dredging (if coal is delivered by barge); create dust, sedimentation, and turbidity; and introduce trace elements and minerals into the water. Air emissions from the IGCC units would include small amounts of sulfur dioxide, particulates, and mercury that would settle on water bodies or be introduced into the water from soil erosion. If the IGCC plant was located on the same water body (the Kankakee River) in the vicinity of the Braidwood site, overall operational impacts would be less than for the continued operation of Braidwood because of the reduced impingement, entrainment, and thermal effects. However, without knowing the location of the IGCC plant, the associated water body, aquatic species, and their interactions within the ecosystem, the NRC staff cannot assume that overall impacts of operation of an IGCC plant would be less than those for the continued operation of Braidwood, which were determined to be SMALL for some issues and MODERATE for others.

The NRC staff concludes that the impacts to aquatic resources from construction of an IGCC plant would be MODERATE and the impacts of operation would be within the range of SMALL to MODERATE.

4.7.5 Natural Gas Combined Cycle Alternative

Construction of an NGCC alternative would occur at the Braidwood site or another existing power plant site in the ROI. The GEIS (NRC 2013f) indicates that the impacts of new power plant construction on ecological resources would be qualitatively similar. Thus, those impacts discussed under the new nuclear alternative would apply during the construction phase. Construction of new pipelines, if necessary, could impact previously undisturbed habitats. This impact would vary depending on the location of the plant and would be more likely to impact terrestrial resources than aquatic resources. Because the NGCC alternative would be built on an existing power plant site, new pipelines could be collocated in existing corridors to reduce impacts. Overall, construction impacts would be SMALL.

Operation of the NGCC alternative cooling system would be qualitatively similar to the IGCC alternative but would result in smaller impacts because the NGCC alternative would consume

about half as much cooling water. Air emissions from the NGCC units would include nitrogen oxide, carbon dioxide, and particulates that would settle on water bodies or be introduced into the water from soil erosion. If the NGCC plant was located on the same water body (the Kankakee River) in the vicinity of the Braidwood site, overall operational impacts would be less than for the continued operation of Braidwood due to the reduced impingement, entrainment, and thermal effects. However, without knowing the location of the NGCC plant, the associated water body, aquatic species, and their interactions within the ecosystem, the NRC staff cannot assume that overall impacts of operation of an NGCC plant would be less than those for the continued operation of Braidwood, which were determined to be SMALL for some issues and MODERATE for others.

The NRC staff concludes that the impacts to aquatic resources from construction of an IGCC plant would be SMALL and the impacts of operation would be within the range of SMALL to MODERATE.

4.7.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

The NGCC portion of this alternative could be located at the Braidwood site or another existing power plant site in the ROI. Construction and operation impacts would be qualitatively similar to those discussed for the NGCC alternative, but would be much less in magnitude because of the smaller footprint of the plant, reduced cooling water consumption, and lowered air emissions. The wind and solar portions of the alternative, which account for 90 percent of the alternative's power generation, would not require cooling or consumptive water use during operation, and thus, would not affect aquatic resources. The NRC staff concludes that the impacts on aquatic resources from the combination alternative would be SMALL.

4.7.7 Purchased Power

The purchased power alternative would have wide-ranging impacts that are hard to specifically assess because this alternative could include a mixture of coal, natural gas, nuclear, and wind across many different sites in the ROI. This alternative would likely have little to no construction impacts because it would include power from already-existing power generating facilities, and the types of operational impacts would be similar to the effects discussed in the preceding alternative sections. This alternative would be more likely to intensify already existing effects at power generating facilities than create wholly new effects on aquatic species and habitats. Existing facilities would likely have permits with appropriate mitigation, BMPs, or other procedures in place to ensure that effects to the environment during operations are minimized. The NRC staff concludes that the impacts on aquatic resources from the purchased power alternative would be SMALL.

4.8 Special Status Species and Habitats

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on special status species and habitats.

Section 3.8 of this SEIS describes the special status species and habitats that have the potential to be affected by the proposed action. The discussion of species and habitats protected under the Endangered Species Act of 1973, as amended (ESA), includes a description of the action area as defined by the ESA section 7 regulations at 50 CFR 402.02. The action area encompasses all areas that would be directly or indirectly affected by the proposed Braidwood license renewal.

Table 4–17 lists the one site-specific (Category 2) issue related to special status species and habitats applicable to Braidwood. Appendix C contains information on the NRC staff's section 7 consultation with the U.S. Fish and Wildlife Service (FWS) for the proposed action.

Table 4–17. Special Status Species and Habitat Issues

Issue	GEIS Section	Category
Threatened, endangered, and protected species, critical habitat and essential fish habitat	4.6.1.3	2

Source: Table B–1 in Appendix B, Subpart A, to 10 CFR Part 51

<u>Correspondence</u>

NRC staff identified no Federally listed species or essential fish habitat (EFH) under NMFS jurisdiction that would occur near Braidwood. On September 11, 2013, NRC (2013h) sent a letter to FWS requesting concurrence with a list of Federally listed species that might occur in the action area for Braidwood. On September 24, 2013, FWS (2013) replied with a letter that included scoping comments and comments on the NRC's list of Federally-listed species for Braidwood. Following release of the 2013 GEIS, which redefines the in-scope area of transmission lines for the purposes of NEPA (staff's review), the NRC decided to change geographic scope of the Braidwood SEIS (related to transmission lines) to follow the 2013 GEIS in regard to transmission lines. This change of in-scope area altered the list of listed species compared to NRC's September 11 letter to FWS.

FWS's (2013) comments note the possible presence of the Federally listed mussels, sheepnose (*Plethobasus cyphyus*) and snuffbox (*Epioblasma triquetra*), and requests that NRC give particular attention "to potential impacts from water quality (including temperature) and water quantity that may result from proposed operations" on those species. FWS (2013) also notes that northern long-eared bat (*Myotis septentrionalis*) is found in the project vicinity.

4.8.1 Special Status Species and Habitats Impacts of License Renewal (Proposed Action)

<u>Analysis and Determination of Effects</u>

The NRC staff concludes that of the Federally listed species identified in Section 3.8, none outside of the three species identified by FWS (2013 LC) would occur in the action area based on habitat requirements, life history, wildlife and fish surveys and studies, and other available information. In addition, no designated or proposed critical habitat under the ESA occurs in the action area. The NRC staff concludes that the proposed action would have no effect on those Federally listed species. Concurrence from the FWS is not required in the case of no effect determinations. Assessment for the three species identified by FWS (2013) for special consideration follow.

Endangered Sheepnose and Snuffbox Mussels

These freshwater mussels species are Federally listed as endangered. They are both members of the family Unionidae, members of which have similar life histories in which eggs are brooded by the females, larvae are typically expelled into fish and must attach to the host fish's gills or fins to complete development, after which they drop off the fish host as they transform to juveniles, and thereafter the juveniles and adults live in the river or stream substrate. Because

the larvae are attached to host fish and juveniles and adults live in the river bottom, they are not directly susceptible to entrainment or impingement by power plants. Larvae are indirectly susceptible if the host fish species is susceptible. All life stages are directly or indirectly susceptible to dredging and to power plant effluents due to temperature and current alterations and chemical contaminants.

In conjunction with Exelon's proposal to replace Braidwood's cooling pond discharge, then a shoreline discharge channel, with a diffuser pipe placed on the bottom of and extending across the Kankakee River, HDR Engineering (2008) sampled the potentially affected Kankakee River reach for fish and freshwater mussels during August 4 – 8, 2008. The Kankakee River supports some of Illinois' most diverse and abundant mussel populations (HDR 2008; Page et al. 1992), and HDR Engineering's (2008) literature review identified 27 extant and 40 historical species from the river. HDR Engineering's mussel sampling included 15 person-hours of hand picking along the shoreline and nine 220-m (240-yd) brail (a type of sampling gear used for freshwater mussels) transects. HDR Engineering concluded that the Kankakee River in the immediate vicinity of the Braidwood Station discharge channel, like the Kankakee River in general, supports a diverse and abundant mussel fauna.

The habitat at the south shore upstream of the discharge channel was silted-sand with small patches of mud and gravel, which is conducive for large mussel populations, while the habitat at the north shore was mud and rip-rap, not conducive for freshwater mussel populations. The habitat along the south shore downstream of the discharge channel was silted-sand with large fluctuations in water temperature mostly unsuitable for freshwater mussels. HDR Engineering (2008) could not sample or assess habitat in the center channel, which was over 2-m (about 2 yd) deep, but did find mussels in river channel areas upstream of the Braidwood Station discharge channel. HDR Engineering reported collecting a total of 212 live individuals from 15 species alive during the survey. The collections included one fresh-dead sheepnose and no snuffbox individuals or shells.

Ecological Specialists, Inc. (Belt 2009), conducted a mussel survey in October 2008 to supplement the HDR Engineering survey. The supplemental survey employed divers sampling along transects about 100 yards (about 100 m) above and below Exelon's then proposed diffuser pipe location and was designed to include depths greater than 2 yards (about 2 m) and to provide information on distribution of species and the composition of the mussel community that could not be obtained by HDR Engineering's brail sampling methods. Ecological Specialists, Inc., reported collecting no sheepnose and no snuffbox individuals or shells. They also recorded water depth and substrate type (Wentworth scale) at sampling sites. They found that mussel species were scattered throughout the survey area without observable correlation of habitat with distribution, so that any species might occur throughout their sampling area.

Price et al. (2012) sampled 20 sites in the Kankakee River for freshwater mussels from June through September 2010. The methods were hand grabbing and visual detection (e.g., trails, siphons, exposed shell) when water conditions permitted for 4 hours at each site in all available habitat types present at a site including riffles, pools, slack water, and areas of differing substrates. They found no snuffbox and concluded, based on their own survey and historical records, that the species had been extirpated from the Kankakee River. They found sheepnose at two sites.

Page et al. (1992) found that at that time no live snuffbox had been reported for 30 years and that the species was probably extirpated in the Kankakee River drainage. Subsequent mussel sampling studies (Belt 2009; HDR 2008; Price et al. 2012) reached a similar conclusion. The NRC staff concludes that the species has probably been extirpated from the Kankakee River so that continued operation of Braidwood would have **no effect** on snuffbox.

Price et al. (2012) reported live sheepnose in the Kankakee River, and HDR Engineering (2008) found a recently dead individual near the Braidwood's then proposed diffuser pipe location in the river. Ecological Specialists, Inc. (Belt 2009), found that mussel species in the Kankakee River near the diffuser pipe were scattered throughout the survey area with observable correlation of habitat with distribution so that mussel species might occur throughout the sampling area. The FWS (77 FR 14914) found that decline of the species is primarily the result of habitat loss and degradation, and the main causes specifically include impoundments, channelization, chemical contaminants, mining, and sedimentation. Imminent threats also include climate change, temperature alterations, exotic species, and population fragmentation and isolation (77 FR 14914). Compared to the historical distribution, the presently fragmented populations are more susceptible to extirpation from single catastrophic events, such as toxic chemical spills, and also have a more limited ability to recolonize historically occupied streams and river reaches (77 FR 14914).

Sheepnose larvae are indirectly susceptible to impingement and entrainment of host fish, and the only known host species for sheepnose is sauger. Juvenile and adult sauger were not reported in surveys of the Kankakee River near the Braidwood intake or impingement collections in 1988 and 1989, and eggs and larvae were not reported from samples in the river or from entrainment collections in the same years (EA Engineering 1990). Monitoring studies of fish in the Kankakee River near Braidwood in the last 5 years also has not reported sauger in the collections (e.g., HDR 2009, 2013, 2014). Assuming that the results reflect future conditions, the indirect effect of impingement and entrainment on sheepnose host species from now until 20 years beyond the expiration of Braidwood's present operating licenses is likely to be insignificant. Some unionid species may have one host species, and others more than one, and future studies may identify additional sheepnose host species that might modify this conclusion.

Sheepnose are also susceptible from direct and indirect effects (through host fish species) of Braidwood's effluent due to temperature and current alterations and to chemical contaminants. The IEPA, not the NRC, regulates the discharge through its Illinois NPDES permitting program to insure protection of aquatic species, and Braidwood must have an Illinois NPDES permit to operate. In view of these observations, the NRC staff concludes that snuffbox may occur near Braidwood but that the continued operation of Braidwood **may, but is not likely to, adversely affect** the species.

Proposed Northern Long-Eared Bat

On October 2013, FWS (78 FR 61046) found that listing of this species is warranted, and it proposes to list the northern long-ear bat as an endangered species throughout its range. The FWS also found that it could not determine critical habitat for this species at this time. Although FWS has not made the decision of whether or not to list this species as threatened or endangered, Federal agencies must confer with the Service [FWS or NMFS] on any action that is likely to jeopardize the continued existence of any proposed species (50 CFR 402.10(a)). The present assessment initiates the conference or informal discussions between NRC and FWS and presents the NRC staff's effects assessment. If the proposed species is subsequently listed prior to the completion of the Federal action, the NRC must review the action to determine whether formal consultation is required (50 CFR 402.10(c)).

The FWS reports that surveys in Shawnee National Forrest in Illinois, about 300 mi south of Braidwood, consistently catch northern long-eared bats, and FWS (2013) states that they may be found on the Braidwood site. Winter hibernacula do not occur on the Braidwood site, but they migrate out of the hibernacula in summer, when they forage at night and roost during daylight in small numbers in live and dead trees and change roosts often.

Regarding a conference for northern long-ear bat, the FWS (78 FR 61046) says that:

> Federal agency actions within the species' habitat that may require conference or consultation or both…include management and any other landscape-altering activities on Federal lands administered by the U.S. Fish and Wildlife Service, U.S. Forest Service, NPS, and other Federal agencies; issuance of section 404 Clean Water Act (33 U.S.C. 1251 et seq.) permits by the U.S. Army Corps of Engineers; and construction and maintenance of roads or highways by the Federal Highway Administration.

Over the duration of the proposed license renewal term, Exelon (2013c) reports no plans for landscape-altering activities, such as those that might adversely affect northern long-ear bats.

The FWS (78 FR 61046) identified the primary threat to northern long-ear bat as white nose syndrome, a disease caused by the fungus *Geomyces destructans*, and other sources of mortality to the species include wind-energy development, habitat modification, destruction and disturbance (e.g., vandalism to hibernacula, roost tree removal), effects of climate change, and contaminants.

Exelon (2013c) states in its assessment for Indiana bats (*Myotis sodalis*) that the Braidwood property offers no undisturbed natural habitat, no large blocks of mature forest, and no high quality roost habitat for bats, and in fact is "a noisy (PA [public address] system, pumps, diesels, heavy equipment), lighted industrial facility" where Indiana bats are not likely to be found. Compared to Indiana bats, however, northern long-ear bats are more opportunistic in roost selection and may roost in live trees, man-made structures, and other places where Indiana bats might not roost (78 FR 61046). Exelon (2014d) describes the Braidwood site as occupying about 4,457 ac (1,804 ha) with the following land uses: 2,540 ac (1,030 ha) of water, 264 ac (107 ha) in industrial use (including makeup-blowdown pipeline and river screen house), 67 ac (27 ha) in agriculture, 1,280 ac (518 ha) of former strip mine areas leased for recreation, and 306 ac (124 ha) of former strip mine and re-vegetated areas not used for recreation. This site would probably not provide prime habitat for long-ear bats even though they are more opportunistic than Indiana bats in roost selection.

Because FWS has identified the northern long-ear bat as potentially occurring on the Braidwood site; because FWS has identified the primary threat to northern long-ear bat as the disease white-nose syndrome, which is typically spread in the winter hibernacula and such hibernacula do not occur on the Braidwood site; because the Braidwood site has and would harbor little summer roost habitat; because that habitat has not been nor would be prime habitat for summer roosting; and because Exelon plans no landscape-altering activities, the NRC staff considers any adverse effects from the proposed relicensing of Braidwood would be small and insignificant. The staff concludes that the proposed action **may, but is not likely to, adversely affect** northern long-ear bat.

All Species

If in the future, a Federally listed species is observed on the Braidwood site, the NRC has the obligation under the ESA to initiate section 7 consultation. Braidwood's Unit 1 and Unit 2 operating licenses, Appendix B, "Environmental Protection Plan" (NRC 2014a, 2014b) require Exelon to report to the NRC within 24 hours any "unusual or important event that indicates or could result in significant environmental impact causally related to plant operation." The licenses give the specific example of "mortality or unusual occurrence of any species protected by the Endangered Species Act of 1973." Additionally, the NRC's regulations containing notification requirements require that operating nuclear power reactors report to the NRC within 4 hours "any event or situation, related to…protection of the environment, for which a news

release is planned or notification to other government agencies has been or will be made" (10 CFR 50.72(b)(2)(xi)). Such notifications include reports regarding Federally listed species, as described in Section 3.2.12 of NUREG 1022, "Event Reporting Guidelines for 10 CFR 50.72 and 50.73" (NRC 2013c).

Special Status Species and Habitats Impacts Summary

Table 4–18 summarizes the NRC staff's findings.

Table 4–18. Federally Listed Species in Will County, Illinois

Group	Federally Listed Species	Common Name	Federal Status [a]	Finding
Clams and Mussels	*Plethobasus cyphyus*	sheepnose mussel	E	May, but not likely to adversely affect
	Epioblasma triquetra	snuffbox	E	No effect
Insects	*Somatochlora hineana*	Hine's emerald dragonfly	E	No effect
Plants	*Platanthera leucophaea*	eastern prairie fringed orchid	T	No effect
	Hymenopsis herbacea	lakeside daisy	T	No effect
	Delea foliosa	leafy prairie clover	E	No effect
	Asclepias meadii	Mead's milkweed	T	No effect
	Proposed Species			
Mammals	*Myotis septentrionalis*	northern long-eared bat		May, but not likely to adversely affect
	Candidate Species			
Reptiles (snakes)	*Sistrurus catenatus*	eastern massasauga		Not applicable
Insects	*Papaipema eryngii*	rattlesnake-master borer moth		Not applicable
	Critical Habitat			
	None			Not applicable

[a] E = endangered; T = threatened

4.8.2 No-Action Alternative

Under the no-action alternative, the plant would shut down. Federally listed species and designated critical habitat can be affected not only by operation of nuclear power plants but also by activities during shutdown. The ESA action area for the no-action alternative would most likely be the same as discussed in Section 3.8. The plant would require substantially less cooling water, so potential impacts to aquatic species and habitats discussed in Section 4.8.1 would be reduced, although the plant would still require some cooling water for some time. Changes in land use and other shutdown activities might affect terrestrial species differently than under continued operation.

Under the no-action alternative, NRC would assess the need for ESA consultation for plant shutdown. The ESA forbids "take" of a listed species, where "take" means "harass, harm,

pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." In the case of a take, ESA section 7 requires that NRC initiate consultation with the FWS or NMFS. The implementing regulations at 50 CFR 402.16 also direct Federal agencies to reinitiate consultation in circumstances where (a) the incidental take limit in a biological opinion is exceeded, (b) new information reveals effects to Federally listed species or designated critical habitats that were not previously considered, (c) the action is modified in a manner that causes effects not previously considered, or (d) new species are listed or new critical habitat is designated that may be affected by the action. An ESA section 7 consultation could identify impacts on Federally listed species or critical habitat, require monitoring and mitigation to minimize such impacts, and provide a level of exempted takes. Regulations and guidance regarding the ESA section 7 consultation process are provided in 50 CFR Part 402 and in the Endangered Species Consultation Handbook (FWS and NMFS 1998).

The effects on ESA-listed aquatic species would likely be smaller than the effects under continued operation but would depend on the listed species and habitats present when the alternative is implemented. The types and magnitudes of adverse impacts to terrestrial ESA-listed species would depend on the shutdown activities and the listed species and habitats present when the alternative is implemented. Therefore, the NRC cannot forecast a particular level of impact for this alternative.

4.8.3 New Nuclear Alternative

This alternative entails shutdown and decommissioning of Braidwood and construction of a new nuclear unit at an alternative industrial location. Section 4.8.2 discusses ESA considerations for the shutdown of Braidwood.

Because the new nuclear alternative would be built on an existing power plant site outside of Illinois, which has restrictions on new nuclear power plant construction, the special status species and habitats affected by the action would be different than those considered under the proposed action. Because the NRC would be the licensing agency under this alternative, the ESA would require NRC to initiate consultation with the FWS and NMFS, as applicable, prior to construction to ensure that the construction and operation of the new nuclear plant would not adversely affect any Federally listed species or adversely modify or destroy designated critical habitat. Section 4.8.2 discusses general ESA considerations.

No EFH designated under the Magnuson–Stevens Act (MSA), which applies to only certain commercially harvested marine species, occurs within the ROI of this alternative, and no EFH consultation, which applies only to actions of Federal agencies, would be required. Because the types and magnitudes of adverse impacts to ESA-listed species would depend on the proposed site, plant design, operation, and species and habitats listed when the alternative is implemented, the NRC cannot forecast a particular level of impact for this alternative.

4.8.4 Coal (Integrated Gasification Combined Cycle) Alternative

This alternative entails shutdown and decommissioning of Braidwood and construction of a new IGCC facility at either the Braidwood site or an alternative industrial location. Section 4.8.2 discusses ESA considerations for the shutdown of Braidwood.

Unlike the new nuclear alternative, the NRC does not license IGCC facilities, and the NRC would not be responsible for initiating section 7 consultation if listed species or habitats might be adversely affected under this alternative. The facilities themselves would be responsible for protecting listed species because the ESA forbids "take" of a listed species, where "take" means

"harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct."

If the IGCC alternative were to be built on the Braidwood site, the ESA action area might be different, and the activities and structures associated with the site would be different than those described under continued operation. If the IGCC alternative were to be built a site other than the Braidwood site, the listed species and habitats affected by the action would be different than those identified for Braidwood. Because the types and magnitudes of adverse impacts to ESA-listed species would depend on the proposed site, plant design, operation, and species and habitats listed when the alternative is implemented, the NRC cannot forecast a particular level of impact for this alternative.

4.8.5 Natural Gas Combined Cycle Alternative

This alternative entails shutdown and decommissioning of Braidwood and construction of a new NGCC facility at either the Braidwood site or an alternative industrial location. Section 4.8.2 discusses ESA considerations for the shutdown of Braidwood.

Unlike the new nuclear alternative, the NRC does not license NGCC facilities, and the NRC would not be responsible for initiating section 7 consultation if listed species or habitats might be adversely affected under this alternative. The facilities themselves would be responsible for protecting listed species because the ESA forbids "take" of a listed species, where "take" means "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct."

If the NGCC alternative were to be built on the Braidwood site, the ESA action area might be different, and the activities and structures associated with the site would be different than those described under continued operation. If the NGCC alternative were to be built a site other than the Braidwood site, the listed species and habitats affected by the action would be different than those identified for Braidwood. Because the types and magnitudes of adverse impacts to ESA-listed species would depend on the proposed site, plant design, operation, and species and habitats listed when the alternative is implemented, the NRC cannot forecast a particular level of impact for this alternative.

4.8.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

This alternative entails shutdown and decommissioning of Braidwood and construction of a new non-nuclear facilities at the Braidwood site and alternative industrial locations. Section 4.8.2 discusses ESA considerations for the shutdown of Braidwood.

The combination alternative would involve construction and operation of wind turbines and solar PV systems throughout the ROI as well as an NGCC plant at an existing power plant site other than the Braidwood site. Unlike the new nuclear alternative, the NRC does not license NGCC, wind, or solar facilities, and the NRC would not be responsible for initiating section 7 consultation if listed species or habitats might be adversely affected under this alternative. The facilities themselves would be responsible for protecting listed species because the ESA forbids "take" of a listed species, where "take" means "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct."

If part of the combination alternative were to be built on the Braidwood site, the ESA action area might be different, and the activities and structures associated with the site would be different than those described under continued operation. If parts of the combination alternative were to be built on a site or sites other than the Braidwood site, the listed species and habitats affected by the action would be different than those identified for Braidwood. Because the types and

magnitudes of adverse impacts to ESA-listed species would depend on the proposed site, plant design, operation, and species and habitats listed when the alternative is implemented, the NRC cannot forecast a particular level of impact for this alternative.

4.8.7 Purchased Power

Because the purchased power alternative might include a mixture of coal, natural gas, nuclear, and wind across many different sites in the ROI, the special status species and habitats affected by the action would be different than those considered under continued operation. Because the types and magnitudes of adverse impacts to ESA-listed species would depend on the proposed sites, plant designs, operation, and species and habitats listed at the various sites when the alternative is implemented, the NRC cannot forecast a particular level of impact for this alternative. As with the other alternatives discussed previously, the facilities themselves, and not the NRC, would be responsible for initiating section 7 consultation if listed species or habitats might be adversely affected under this alternative.

4.9 Historic and Cultural Resources

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on historic and cultural resources.

The National Historic Preservation Act of 1966, as amended (NHPA) requires Federal agencies to consider the effects of their undertakings on historic properties, and renewing the operating license of a nuclear power plant is an undertaking that could potentially affect historic properties. Historic properties are defined as resources eligible for listing in the National Register of Historic Places (NRHP). The criteria for eligibility are listed in 36 CFR Part 60.4 and include: (1) association with significant events in history; (2) association with the lives of persons significant in the past; (3) embodiment of distinctive characteristics of type, period, or construction; and (4) sites or places that have yielded, or are likely to yield, important information.

The historic preservation review process (Section 106 of the NHPA) is outlined in regulations issued by the Advisory Council on Historic Preservation (ACHP) in 36 CFR Part 800.

4.9.1 Proposed Action

In accordance with the provisions of the NHPA, the NRC is required to make a reasonable effort to identify historic properties included in or eligible for inclusion in the NRHP in the Area of Potential Effect (APE). The APE for a license renewal action is the area at the power plant site, the transmission lines up to the first substation and immediate environs that may be affected by the license renewal decision, and land-disturbing activities associated with continued reactor operations. For Braidwood, the first substation is located on-site at the 345-kV Braidwood Station switchyard (Exelon 2013a, 2014b).

If historic properties are present within the APE, the NRC is required to contact the State Historic Preservation Office (SHPO), assess the potential impact, and resolve any possible adverse effects of the undertaking (license renewal) on historic properties. In addition, the NRC is required to notify the SHPO if historic properties would not be affected by license renewal or if no historic properties are present. The SHPO is part the Illinois Historic Preservation Agency (IHPA).

This section provides the NRC's assessment of the potential effects from the proposed license renewal of Braidwood Units 1 and 2. Section 3.9 describes potentially affected historic and cultural resources and historic properties near the Braidwood site.

Consultation

In accordance with 36 CFR 800.8(c), on August 8, 2013, the NRC initiated consultations on the proposed action by writing to the ACHP and IHPA (NRC 2013a, b). Also on August 8, 2013, the NRC initiated consultation with the following 14 Federally recognized Tribes (NRC 2013i) (see Appendix C for a copy of these letters):

- Ho-Chunk Nation;
- Miami Tribe of Oklahoma;
- Peoria Tribe of Indians of Oklahoma;
- Citizen Potawatomi Nation;
- Sac and Fox Tribe of the Mississippi in Iowa/Meskwaki;
- Sac and Fox Nation of Missouri in Kansas and Nebraska;
- Sac and Fox Nation;
- Pokagon Band of Potawatomi;
- Forest County Potawatomi;
- Hannahville Indian Community, Band of Potawatomi;
- Prairie Band of Potawatomi Nation;
- Winnebago Tribe of Nebraska;
- Kickapoo Tribe in Kansas; and
- Kickapoo Tribe of Oklahoma.

By letter, the NRC provided information about the proposed action, defined the APE, and indicated that the NHPA review would be integrated with the NEPA process, according to 36 CFR 800.8. NRC invited participation in the identification and possible decisions concerning historic properties and also invited participation in the scoping process. In September 2013, the NRC received a determination from the IHPA stating no objection to the undertaking and that no historic properties would be affected (Haaker 2013) (see Appendix C).

Exelon currently has no planned physical changes or license renewal-related ground-disturbing activities at the Braidwood site (Exelon 2013a). As described in Section 3.9, there are no historic properties or known NRHP-eligible historic or cultural resources located within the Braidwood APE. Of the 4,457 ac of land composing the Braidwood site, only 67 ac have the observable potential to contain undiscovered historic or cultural resources. The remaining acres are heavily disturbed due to power plant construction (e.g., power block, blowdown pipeline) and operation; are former strip mine land which has been repurposed or revegetated; or part of the man-made cooling pond excavated by ComEd (Exelon 2014b). The Illinois Inventory of Archaeological Sites has not identified any areas in the immediate vicinity of the Braidwood site as having archaeological resource potential (IHPA 2014). However, Exelon has established a draft Cultural Resource Management Plan (CRMP) to ensure historic and cultural resources are considered prior to any ground disturbing activities at Braidwood. The CRMP instructs Exelon's staff on how to evaluate land disturbing activity for possible impacts to historic and cultural resources and identifies previously disturbed areas of the Braidwood property and any areas

with the potential to contain undiscovered resources (Exelon 2014b). If historic or cultural resources are inadvertently discovered during operational activities, the CRMP directs Exelon staff to stop work, protect exposed resources, and contact Exelon environmental personnel to take appropriate action (Exelon 2013a). Supplemental cultural resource surveys may be performed on the affected areas based on consultation with the SHPO. Day-to-day maintenance of the Braidwood site follows guidelines based on the type of land use, and less developed areas are not regularly landscaped unless specially requested (Exelon 2014b). Cultural resource training is not currently required for Braidwood staff members (Exelon 2014b).

Based on (1) no current NRHP-eligible historic properties in the APE, (2) tribal input (SEIS Appendices A and C), (3) Exelon's draft CRMP, (4) the fact that no license renewal-related physical changes or ground-disturbing activities would occur, (5) IHPA input, and (6) cultural resource assessment, license renewal would not affect any known historic properties (36 CFR Section 800.4(d)(1)). Exelon could reduce the risk of potential impacts to historic and cultural resources located on or near the Braidwood site by finalizing their draft CRMP, with input from the SHPO, and by providing training on cultural resources for Exelon staff engaged in planning and executing ground-disturbing activities.

4.9.2 No-Action Alternative

Not renewing the operating licenses and terminating reactor operations would have no effect on historic properties and cultural resources on or in the immediate vicinity of Braidwood. A separate environmental review would be conducted to determine the impacts of decommissioning activities on historic properties and cultural resources.

4.9.3 New Nuclear Alternative

Any land areas potentially affected by the construction of the new nuclear alternative power plant would need to be surveyed to identify and record historic and archaeological cultural resources. An inventory of a previously disturbed former plant industrial site may still be necessary if the site has not been previously surveyed or to verify the level of previous disturbance and to evaluate the potential for intact subsurface cultural resources to be present. Power plant developers would need to survey all potentially affected land areas associated with operation of the alternative (e.g., including land required for new roads, transmission corridors, other right-of-ways (ROWs)). Any cultural resources found during these surveys would need to be recorded and evaluated for eligibility for listing on the NRHP. Mitigation of adverse effects would need to be considered if eligible resources properties were encountered. Areas with the greatest sensitivity (relative to cultural resource impacts) and most significant cultural resources should be avoided. Visual impacts on significant cultural resources, such as the historic property viewsheds near the proposed power plant site, should also be assessed and evaluated.

The potential for impacts to historic and cultural resources from the new nuclear alternative would vary greatly depending on the location of site selected for the proposed new nuclear power plant site. Construction of cooling towers for this alternative has the potential to impact the viewshed of historic properties within the area. However, given the preference to use a previously disturbed former power plant site, avoidance of further potential impacts to historic and cultural resources should be possible and effectively managed under current laws and regulations. Therefore, the impacts on historic and cultural resources from the construction and operation of a new nuclear alternative power plant would be SMALL.

4.9.4 Coal (Integrated Gasification Combined Cycle) Alternative

Any areas potentially affected by the construction of the IGCC alternative would need to be surveyed to identify and record historic and cultural resources. If the IGCC alternative is located on the existing Braidwood site, previously disturbed areas known to not contain historic and cultural resources could be used. If the alternative is sited on the approximately 67 ac (27 ha) of undisturbed land on the Braidwood site, a survey and inventory for potential historic and cultural resources should be performed. An inventory of a previously disturbed former plant site, other than Braidwood, may still be necessary if the site has not been previously surveyed or to verify the level of disturbance and evaluate the potential for intact subsurface resources. Any resources found in these surveys would need to be evaluated for eligibility on the NRHP, and mitigation of adverse effects would need to be addressed if eligible resources were encountered. Areas with the greatest sensitivity should be avoided. Visual impacts on significant cultural resources, such as the historic property viewshed of historic properties near the proposed power plant site, should also be assessed and evaluated.

The potential for impacts on historic and cultural resources from the IGCC alternative would vary greatly depending on the location of the proposed site. Given that the preference is to use a previously disturbed former plant site and no major infrastructure upgrades are necessary, avoidance of significant historic and cultural resources should be possible and effectively managed under current laws and regulations. Therefore, the impacts on historic and archaeological resources from the IGCC alternative would be SMALL.

4.9.5 Natural Gas Combined Cycle Alternative

Any areas potentially affected by the construction of the NGCC alternative would need to be surveyed to identify and record historic and cultural resources. If the NGCC alternative is located on the existing Braidwood site, previously disturbed areas known to not contain historic and cultural resources could be used. If the alternative is sited on the approximately 67 ac (27 ha) of undisturbed land on the Braidwood site, a survey and inventory for potential historic and cultural resources should be performed. An inventory of a previously disturbed former plant site, other than Braidwood, may still be necessary if the site has not been previously surveyed or to verify the level of disturbance and evaluate the potential for intact subsurface resources. Plant operators would need to survey all areas associated with operation of the alternative (e.g., a new pipeline, roads, transmission corridors, other ROWs). Any resources found in these surveys would need to be evaluated for eligibility on the NRHP, and mitigation of adverse effects would need to be addressed if eligible resources were encountered. Areas with the greatest sensitivity should be avoided. Visual impacts on significant cultural resources, such as the historic property viewsheds of historic properties near the proposed power plant site, should also be assessed and evaluated.

The potential for impacts on historic and cultural resources from the NGCC alternative would vary greatly depending on the location of the proposed site. Given that the preference is to use a previously disturbed former plant site, avoidance of significant historic and cultural resources should be possible and effectively managed under current laws and regulations. However, historic and archaeological resources could potentially be affected, depending on the resource richness of the land required for a new pipeline. Therefore, the impacts on historic and archaeological resources from the NGCC alternative would be SMALL to MODERATE.

4.9.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

Areas potentially affected by the construction of the NGCC, wind, and solar PV alternative would need to be surveyed to identify and record historic and archaeological resources. Any resources found in these surveys would need to be evaluated for eligibility on the NRHP and mitigation of adverse effects would need to be addressed if eligible resources were encountered. If the NGCC portion of this alternative is located on the existing Braidwood site, previously disturbed areas known to not contain historic and cultural resources could be used. If the alternative is sited on the approximately 67 ac (27 ha) of undisturbed land on the Braidwood site, a survey and inventory for potential historic and cultural resources should be performed. If any portion of the alternative is sited on a previously disturbed former plant site, other than Braidwood, a survey may still be necessary if the site has not been previously surveyed or to verify the level of disturbance and evaluate the potential for intact subsurface resources. Plant operators would need to survey all areas associated with operation of the alternative (e.g., new pipeline, roads, transmission corridors, other ROWs). Areas with the greatest sensitivity should be avoided. Visual impacts on significant cultural resources, such as the historic property viewsheds of historic properties near the proposed power plant site, should also be assessed and evaluated.

Impacts to historic and cultural resources from the NGCC portion of this alternative are similar to the NGCC alternative in Section 4.9.5. The potential for impacts on historic and cultural resources from the wind portion of this alternative would vary greatly, depending on the location of the proposed sites. Areas with the greatest sensitivity could be avoided or effectively managed under current laws and regulations. However, construction of wind farms and their support infrastructure have the potential to notably impact historic and archaeological resources because of earthmoving activities (e.g., grading and digging) and the aesthetic changes they may bring to the viewshed of historic properties located nearby. The impacts of the construction of a new solar PV alternative on historic and cultural resources will vary depending on the form of the solar capacity installed. Rooftop installations minimize land disturbance and the modifications necessary to the transmission system, thereby minimizing impacts to historic and cultural resources. Land-based installations are larger than rooftop installations and will require some degree of land disturbance for installation purposes, potentially causing greater impacts to historic and archaeological resources. Aesthetic changes caused by the installation of both forms could have a noticeable effect on the viewshed of nearby historic properties. Using previously disturbed sites for land-based installations and co-locating any new transmission lines with existing ROWs could minimize impacts to historic and archaeological resources. Areas with the greatest sensitivity could be avoided or effectively managed under current laws and regulations. Therefore, depending on the resource richness of the sites chosen for the NGCC, wind, and solar PV alternative, the impacts could range from SMALL to LARGE.

4.9.7 Purchased Power

No direct impacts on historic and cultural resources are expected from purchased power. If new transmission lines were needed to convey power to the PJM Interconnection area, historic and cultural resource surveys would need to be performed. However, transmission lines would likely be collocated with existing ROWs minimizing any impacts to historic and cultural resources.

Indirectly, construction of new nuclear, coal-fired, and natural gas–fired plants, wind energy projects and any new transmission lines to support increased demand in the purchased power alternative could affect historic and cultural resources. Any areas potentially affected by the construction would need to be surveyed to identify and record historic and cultural resources. Resources found in these surveys would need to be evaluated for eligibility on the NRHP and

mitigation of adverse effects would need to be addressed if eligible resources were encountered. Plant operators would need to survey all areas associated with operation of the alternative (e.g., roads, transmission corridors, other ROWs). The potential for impacts on historic and cultural resources would vary greatly depending on the location of the proposed sites; however, using previously disturbed sites could greatly minimize impacts to historic and cultural resources. Areas with the greatest sensitivity could be avoided or effectively managed under current laws and regulations. Therefore, depending on the resource richness of the sites chosen, the impacts could range from SMALL to LARGE.

4.10 Socioeconomic

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on socioeconomic (impact).

4.10.1 Proposed Action

The Category 1 (generic) socioeconomic NEPA issues in 10 CFR Part 51, Appendix B to Subpart A, Table B-1, applicable to the license renewal of Braidwood Units 1 and 2 are shown in Table 4–19. No Category 2 socioeconomic NEPA issues were identified during the review conducted for the 2013 GEIS revision (NRC 2013g). Socioeconomic effects of ongoing reactor operations at Braidwood have become well established as regional socioeconomic conditions have adjusted to the presence of the nuclear power plant. These conditions are described in Section 3.10. Any changes in employment and tax payments caused by license renewal and any associated refurbishment activities could have a direct and indirect impact on community services and housing demand, as well as traffic volumes in the communities around a nuclear power plant.

Table 4–19. Category 1 Socioeconomic NEPA Issues Affected by License Renewal

Issue	GEIS Section
Employment and income, recreation and tourism	4.8.1.1
Tax revenues	4.8.1.2
Community services and education	4.8.1.3
Population and housing	4.8.1.4
Transportation	4.8.1.5

The supplemental site-specific socioeconomic impact analysis for the license renewal of Braidwood Units 1 and 2 included a review of the Exelon ER, scoping comments, other information records, and a data gathering site visit to Braidwood. NRC staff did not identify any new and significant information during the review that would result in impacts that would exceed the predicted socioeconomic impacts evaluated in the GEIS, and no additional socioeconomic NEPA issues were identified beyond those listed in Table B-1.

In addition, Exelon indicated in its ER that they have no plans to add non-outage workers during the license renewal term and that increased maintenance and inspection activities could be managed using the current workforce. Consequently, people living in the vicinity of Braidwood are not likely to experience any changes in socioeconomic conditions during the license renewal term beyond what is currently being experienced. Therefore, the impact of continued reactor operations during the license renewal term would not exceed the socioeconomic impacts predicted in the GEIS. For these issues, the GEIS predicted that the impacts would be SMALL for all nuclear plants.

4.10.2 No-Action Alternative

Not renewing the operating licenses and terminating reactor operations would have a noticeable impact on socioeconomic conditions in the communities located near Braidwood. The loss of jobs and income would have an immediate socioeconomic impact. Some, but not all, of the approximately 905 employees (885 Exelon and 20 long-term contract employees) would begin to leave after reactor operations are terminated; and overall tax revenue generated by plant operations would be reduced (Exelon 2013a). Exelon pays annual property taxes to a number of taxing entities within, and including, Will County. The Will County Treasurer collects Braidwood's property tax payment and disperses it to the various taxing entities to partially fund their respective operating budgets. The taxing entities to which Exelon pays taxes include, but are not limited to, Will County Forest Preserve, Braidwood Fire District, Will Count, Reed Custer School District 255-U, and the Godley Park District (Exelon 2013a). The loss of tax revenue could reduce or eliminate some public and educational services. Indirect employment and income generated by plant operations would also be reduced.

Former Braidwood workers and their families could leave in search of employment elsewhere. The increase in available housing along with decreased demand could cause housing prices to fall. Since the majority of employees reside in Will, Grundy, and Kankakee counties, socioeconomic impacts from the termination of reactor operations would be concentrated in these counties, with a corresponding reduction in purchasing activity and tax revenue in the regional economy. Income and revenue losses from the termination of reactor operations at Braidwood would directly affect Will County and nearby communities most reliant on income from power plant operations. The impact of the job loss, however, may not be as noticeable in local communities given the amount of time required for decommissioning. The socioeconomic impacts from the termination of nuclear plant operations (which may not entirely cease until after decommissioning) would, depending on the jurisdiction, range from SMALL to LARGE.

Traffic congestion caused by commuting workers and truck deliveries on roads in the vicinity of Braidwood would be reduced after power plant shutdown. Most of the reduction in traffic volume would be associated with the loss of jobs. The number of truck deliveries to Braidwood would be reduced until decommissioning. Traffic-related transportation impacts would be SMALL as a result of the shutdown of the nuclear power plant.

4.10.3 New Nuclear Alternative

Socioeconomic impacts are defined in terms of changes to the demographic and economic characteristics and social conditions of a region. For example, the number of jobs created by the construction and operation of a power plant could affect regional employment, income, and expenditures.

Two types of jobs would be created by this alternative: (1) construction jobs, which are transient, short in duration, and less likely to have a long-term socioeconomic impact; and (2) power plant operations jobs, which have the greater potential for permanent, long-term socioeconomic impacts. Workforce requirements for the construction and operation of a new nuclear power plant were evaluated to measure their possible effects on current socioeconomic conditions.

Exelon estimated the construction workforce would peak at 3,500 workers (NRC 2008). The relative economic effect of this many workers on the local economy and tax base would vary with the greatest impacts occurring in the communities where the majority of construction workers would reside and spend their income. As a result, local communities could experience a short term economic "boom" from increased tax revenue and income generated by

construction expenditures and the increased demand for temporary (rental) housing and public as well as commercial services.

After construction, local communities could experience a return to preconstruction economic conditions. Based on this information and given the number of workers, socioeconomic impacts during construction in communities near an existing nuclear power plant or retired coal site could range from MODERATE to LARGE.

An estimated 812 workers would be required during nuclear power plant operations (NRC 2008). Some Braidwood operations workers could transfer to the new nuclear power plant. Local communities near the new nuclear power plant would experience the economic benefits from increased tax revenue and income generated by operational expenditures and demand for housing and public as well as commercial services. The amount of property tax payments under the new nuclear alternative may also increase if additional land is required to support this alternative.

This alternative would also result in a loss of approximately 905 relatively high-paying jobs at Braidwood and a corresponding reduction in purchasing activity and revenue contributions to the regional economy. Should Braidwood cease operations, there would be an immediate socioeconomic impact to local communities and businesses from the loss of jobs (some, but not all, of the 905 employees would begin to leave), and tax payments may be reduced. In addition, the housing market could also experience increased vacancies and decreased prices if operations workers and their families move out of the region. The impact of the job loss, however, may not be noticeable in local communities given the amount of time required for decommissioning of the existing Braidwood station facilities. Based on this information and given the number of operations workers, socioeconomic impacts during nuclear power plant operations on local communities could range from SMALL to MODERATE.

Transportation impacts associated with construction and operation of a new nuclear power plant would consist of commuting workers and truck deliveries of construction materials to the power plant site. During periods of peak construction activity, up to 3,500 workers could be commuting daily to the construction site (NRC 2008). Workers commuting to the construction site would arrive via site access roads and the volume of traffic on nearby roads could increase substantially during shift changes. In addition to commuting workers, trucks would be transporting construction materials and equipment to the work site, thereby increasing the amount of traffic on local roads. The increase in vehicular traffic would peak during shift changes, resulting in temporary levels of service (LOS) impacts and delays at intersections. Materials could also be delivered by rail or barge, depending on the location. Traffic-related transportation impacts during construction would likely range from MODERATE to LARGE.

Traffic-related transportation impacts on local roads would be greatly reduced after the completion of the power plant. Transportation impacts would include daily commuting by the operating workforce, equipment and materials deliveries, and the removal of commercial waste material to offsite disposal or recycling facilities by truck. Traffic on roadways would peak during shift changes, resulting in temporary LOS impacts and delays at intersections. Overall, at the new nuclear power plant site, transportation impacts would be SMALL to MODERATE during operations.

4.10.4 Coal (Integrated Gasification Combined Cycle) Alternative

As explained in Section 4.10.2.2, two types of jobs would be created by this alternative: (1) construction jobs, which are transient, short in duration, and less likely to have a long-term socioeconomic impact; and (2) power plant operations jobs, which have the greater potential for permanent, long-term socioeconomic impacts. Workforce requirements for the construction and

operation of the IGCC alternative were evaluated to measure their possible effects on current socioeconomic conditions.

The construction workforce could peak at 4,600 workers (DOE 2010b), if the four new units are constructed at four different locations. Fewer construction workers would be required if multiple units are constructed at the same existing power plant site. The relative economic effect of this many workers on the local economy and tax base would vary with the greatest impacts occurring in the communities where the majority of construction workers would reside and spend their income. As a result, local communities could experience a short term economic “boom” from increased tax revenue and income generated by construction expenditures and the increased demand for temporary (rental) housing and public as well as commercial services.

After construction, local communities could experience a return to preconstruction economic conditions. Based on this information and given the number of workers, socioeconomic impacts during construction in communities near an existing power plant site could range from MODERATE to LARGE.

An estimated 420 workers would be required during power plant operations (DOE 2010b), if the four new units are operated at four different locations. Fewer workers would be required if multiple units are operated at the same site. Local communities would experience the economic benefits from increased tax revenue and income generated by operational expenditures and demand for housing and public as well as commercial services. The amount of property tax payments under the IGCC alternative may also increase if additional land is required to support this alternative.

This alternative would also result in a loss of approximately 905 relatively high-paying jobs at Braidwood and a corresponding reduction in purchasing activity and revenue contributions to the regional economy. Should Braidwood cease operations, there would be an immediate socioeconomic impact to local communities and businesses from the loss of jobs (some, but not all, of the 905 employees would begin to leave), and tax payments may be reduced. In addition, the housing market could also experience increased vacancies and decreased prices if operations workers and their families move out of the region. The impact of the job loss, however, may not be noticeable in local communities given the amount of time required for decommissioning of the existing Braidwood station facilities. Based on this information and given the number of operations workers, socioeconomic impacts during IGCC power plant operations on local communities could range from SMALL to MODERATE.

Transportation impacts associated with construction and operation of the four-unit, IGCC power plants would consist of commuting workers and truck deliveries of construction materials to the power plant site. During periods of peak construction activity, up to 4,600 workers could be commuting daily to one or more construction sites. Workers commuting to the construction site would arrive via site access roads and the volume of traffic on nearby roads could increase substantially during shift changes. In addition to commuting workers, trucks would be transporting construction materials and equipment to the work site, thereby increasing the amount of traffic on local roads. The increase in vehicular traffic would peak during shift changes, resulting in temporary LOS impacts and delays at intersections. Materials could also be delivered by rail or barge, depending on location. Traffic-related transportation impacts during construction would likely range from MODERATE to LARGE.

Traffic-related transportation impacts on local roads would be greatly reduced after the completion of the power plant. The estimated maximum number of operations workers commuting daily to one or more power plant sites could be 420 (DOE 2010b). Fewer workers would be required if multiple units are operated at the same site. Frequent coal and limestone deliveries and ash removal by rail would add to the overall transportation impact. The increase

in traffic on roadways would peak during shift changes, resulting in temporary LOS impacts and delays at intersections. Onsite coal storage would make it possible to receive several trains per day at a site with rail access. If the IGCC power plant is located on navigable waters, coal and other materials could be delivered by barge. Coal and limestone delivery and ash removal via rail would cause LOS impacts due to delays at railroad crossings. Overall, transportation impacts would be SMALL to MODERATE during IGCC power plant operations.

4.10.5 Natural Gas Combined Cycle Alternative

As explained in Section 4.10.2.2, two types of jobs would be created by this alternative: (1) construction jobs, which are transient, short in duration, and less likely to have a long-term socioeconomic impact; and (2) power plant operations jobs, which have the greater potential for permanent, long-term socioeconomic impacts. Workforce requirements for the construction and operation of the NGCC alternative were evaluated to measure their possible effects on current socioeconomic conditions.

The construction workforce would peak at 1,783 workers (Exelon 2013a). The relative economic effect of this many workers on the local economy and tax base would vary with the greatest impacts occurring in the communities where the majority of construction workers would reside and spend their income. As a result, local communities could experience a short term economic “boom” from increased tax revenue and income generated by construction expenditures and the increased demand for temporary (rental) housing and public as well as commercial services.

After construction, local communities could experience a return to preconstruction economic conditions. Based on this information and given the number of workers, socioeconomic impacts during construction in communities near an existing power plant site could range from MODERATE to LARGE.

An estimated 94 workers would be required during power plant operations (Exelon 2013a). Local communities would experience the economic benefits from increased tax revenue and income generated by operational expenditures and demand for housing and public as well as commercial services. The amount of property tax payments under the NGCC alternative may also increase if additional land is required to support this alternative.

This alternative would also result in a loss of approximately 905 relatively high-paying jobs at Braidwood and a corresponding reduction in purchasing activity and revenue contributions to the regional economy. Should Braidwood cease operations, there would be an immediate socioeconomic impact to local communities and businesses from the loss of jobs (some, but not all, of the 905 employees would begin to leave), and tax payments may be reduced. In addition, the housing market could also experience increased vacancies and decreased prices if operations workers and their families move out of the region. The impact of the job loss, however, may not be noticeable in local communities given the amount of time required for decommissioning of the existing Braidwood station facilities. Based on this information and given the number of operations workers, socioeconomic impacts during NGCC power plant operations on local communities could range from SMALL to MODERATE.

Transportation impacts associated with construction and operation of a five-unit, NGCC power plant would consist of commuting workers and truck deliveries of construction materials to the power plant site. During periods of peak construction activity, up to 1,783 workers could be commuting daily to the construction site. Workers commuting to the construction site would arrive via site access roads and the volume of traffic on nearby roads could increase substantially during shift changes. In addition to commuting workers, trucks would be transporting construction materials and equipment to the work site, thus increasing the amount

of traffic on local roads. The increase in vehicular traffic would peak during shift changes, resulting in temporary LOS impacts and delays at intersections. Pipeline construction and modification of existing natural gas pipeline systems could also have a temporary impact. Materials also could be delivered by barge or rail, depending on location. Traffic-related transportation impacts during construction would likely range from MODERATE to LARGE.

Traffic-related transportation impacts would be greatly reduced after completing the installation of the NGCC alternative. Transportation impacts would include daily commuting by the operating workforce, equipment and materials deliveries, and the removal of commercial waste material to offsite disposal or recycling facilities by truck. The operations workforce of 94 workers would likely not be noticeable relative to total traffic volumes on local roadways. Since fuel is transported by pipeline, the transportation infrastructure would experience little to no increased traffic from plant operations. Overall, given the relatively small operations workforce estimate of 94 workers, transportation impacts would be SMALL during power plant operations.

4.10.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

As explained in Section 4.10.2.2, two types of jobs would be created by this alternative: (1) construction jobs, which are transient, short in duration, and less likely to have a long-term socioeconomic impact; and (2) operations jobs, which have the greater potential for permanent, long-term socioeconomic impacts. Workforce requirements for the construction and operation of the NGCC, wind, and solar generation components of this combination alternative were evaluated to estimate their possible effects on current socioeconomic conditions.

Fewer workers would be required to construct the single NGCC unit at an existing power plant site than the full-power NGCC alternative. Installation of an estimated 3,376 wind turbines would likely be done in stages and could employ up to 931 construction workers (DOE 2010a). Additional workers would be required to install solar PV systems on existing buildings or structures at already-developed residential, commercial, or industrial sites. Similar to the wind farms, installation would likely be done in stages and could employ up to 600 construction workers (DOE 2010a).

Conversely, a small number of operations workers would be needed to operate the single NGCC unit and additional small numbers of workers would be required to maintain the wind farms and PV systems. Local communities could experience the economic benefits from increased tax revenue and income generated by operational expenditures and demand for housing and public as well as commercial services. The amount of property tax payments under the wind and solar PV components may also increase if additional land is required to support this combination alternative.

This combination alternative would also result in a loss of approximately 905 relatively high-paying jobs at Braidwood and a corresponding reduction in purchasing activity, tax payments, and revenue contributions would occur in the surrounding regional economy. Should Braidwood cease operations, there would be an immediate socioeconomic impact to local communities and businesses from the loss of jobs (some, but not all, of the 905 employees would begin to leave), and tax payments may be reduced. In addition, the housing market could also experience increased vacancies and decreased prices if operations workers and their families move out of the region. The impact of the job loss, however, may not be noticeable in local communities given the amount of time required for decommissioning of the existing Braidwood station facilities. Based on this information and given the relatively small numbers of construction and operations workers, socioeconomic impacts during construction and operations on local communities would be SMALL.

Transportation impacts during the construction and operation of the NGCC unit as well as the wind and solar components of this combination alternative would be less than the impacts for any of the previous alternatives discussed. This is because the construction workforce for each component and the volume of materials and equipment needing to be transported to the respective construction site would be smaller than for any one of the individual replacement power alternatives. In other words, the transportation impacts would not be concentrated as in the other alternatives, but spread out over a wider area.

Workers commuting to the construction site would arrive via site access roads and the volume of traffic on nearby roads could increase during shift changes. In addition to commuting workers, trucks would be transporting construction materials and equipment to the work site, thereby increasing the amount of traffic on local roads. The increase in vehicular traffic would peak during shift changes, resulting in temporary LOS impacts and delays at intersections. Transporting heavy and oversized components on local roads could have a noticeable impact over a large area. Some components and materials could also be delivered by rail or barge, depending on location. Traffic-related transportation impacts during construction could range from SMALL to MODERATE at the NGCC power plant, wind farms and solar installations; depending on current road capacities and average daily traffic volumes.

During operations, transportation impacts would be less noticeable during shift changes and maintenance activities. Given the small numbers of operations workers, the LOS traffic impacts on local roads from NGCC, wind farm, and solar PV operations would be SMALL.

4.10.7 Purchased Power

Purchased power from existing power generating facilities would not have any socioeconomic impact, because there would be no change in power plant operations or workforce. If the amount of purchased power exceeds the available supply, new electrical power generating facilities would be needed. Construction and operation of a new electrical power generating facility to supply purchased power could cause noticeable socioeconomic impacts in the communities located near the new facility. The intensity of the impact would depend on the number of workers required to build and operate the new electrical power generating facility and the amount of increased demand for housing and public services.

Whether or not there would be a socioeconomic impact would depend on whether a new electrical power generating facility was needed to supply purchased power. If a new power generating facility is needed, socioeconomic impacts would range anywhere from SMALL to LARGE.

Similarly, purchased power from existing power generating facilities would also not have any transportation impact, because there would be no change in power plant operations or workforce. Construction and operation of a new electrical power generating facility could cause noticeable transportation impacts depending on the number of workers and truck deliveries required to build and operate the new electrical power generating facility. Traffic volumes could increase noticeably on local roads during shift changes.

Whether or not there would be a transportation impact would depend on whether a new electrical power generating facility was needed to supply purchased power. If a new power generating facility is needed, transportation impacts would range anywhere from SMALL to LARGE.

4.11 Human Health

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on human health.

4.11.1 Proposed Action

4.11.1.1 Normal Operating Conditions

The human health issues applicable to Braidwood are discussed below and are listed in Table 4–20 for Category 1, Category 2, and uncategorized issues. Table B-1 of Appendix B to Subpart A of 10 CFR Part 51 contains more information on these issues.

Table 4–20. Human Health Issues

Issues	GEIS Section	Category
Radiation exposures to the public	4.9.1.1.1	1
Radiation exposures to plant workers	4.9.1.1.1	1
Human health impact from chemicals	4.9.1.1.2	1
Microbiological hazards to the plant workers	4.9.1.1.3	1
Microbiological hazards to the public	4.9.1.1.3	2
Chronic effects of electromagnetic fields (EMFs)	4.9.1.1.4	[a] N/A
Physical occupational hazards	4.9.1.1.5	1
Electric shock hazards	4.9.1.1.5	2

[a] N/A (not applicable) The categorization and impact finding definition does not apply to this issue.

Source: Table B-1 in Appendix B, Subpart A, to 10 CFR Part 51

<u>Category 1 Issues</u>

The NRC staff did not identify any new and significant information during its review of Exelon's ER, the site audit, or the scoping process for the Category 1 issues listed in Table 4-20. Therefore, there are no impacts related to these issues beyond those discussed in the GEIS. For these Category 1 issues, the GEIS concluded that the impacts are SMALL (NRC 2013f).

Microbiological Hazards to Plant Workers

In the GEIS (NRC 2013f), NRC staff determined that effects of thermophilic microbiological organisms on plant workers is a generic (Category 1) issue (see Table 4–20). The GEIS concludes that the impact of this issue would be SMALL for all sites because occupational health impacts are expected to be controlled by continued application of accepted industrial hygiene practices to minimize worker exposures as required by permits and Federal and State regulations.

The NRC staff did not identify any new and significant information during the review of Exelon's ER, the NRC staff's site audit, the scoping process, and the evaluation of other available information. Therefore, the staff does not expect any impacts related to this issue during the proposed renewal term beyond those discussed in the GEIS. As indicated above, the GEIS concludes that the impact level for this issue is SMALL.

Chronic Effects of Electromagnetic Fields (EMFs)

In the GEIS, the chronic effects of 60-Hz electromagnetic fields from power lines were not designated as Category 1 or 2, and will not be until a scientific consensus is reached on the health implications of these fields.

The potential for chronic effects from these fields continues to be studied and is not known at this time. The National Institute of Environmental Health Sciences (NIEHS) directs related research through the U.S. Department of Energy (DOE).

The report by NIEHS (NIEHS 1999) contains the following conclusion:

> The NIEHS concludes that ELF-EMF (extremely low frequency-electromagnetic field) exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern.

This statement is not sufficient to cause the NRC staff to change its position with respect to the chronic effects of EMFs. The NRC staff considers the GEIS finding of "UNCERTAIN" still appropriate and will continue to follow developments on this issue (NRC 2013f).

<u>Category 2 Issues</u>

Electric Shock Hazards

Based on the GEIS, the Commission found that electric shock resulting from direct access to energized conductors or from induced charges in metallic structures has not been found to be a problem at most operating plants and generally is not expected to be a problem during the license renewal term. However, a site-specific review is required to determine the significance of the electric shock potential along the portions of the transmission lines that are within the scope of this SEIS (NRC 2013f).

As discussed in Section 3.11.4 of this SEIS, Exelon performed an evaluation of its 345-kilovolt (kV) transmission line connecting Braidwood with the electric grid to determine whether the line conforms to the National Electrical Safety Code (NESC) criteria for induced electric shock. Exelon's evaluation concluded that its transmission line conforms to the NESC criteria.

Because Braidwood's transmission line conforms to the NESC criteria during its current license term and is expected to continue to conform to the standard during the license renewal term, the NRC staff concludes that the potential impact from acute electric shock during the license renewal term would be SMALL.

Microbiological Hazards to the Public

In the GEIS (NRC 2013f), the NRC staff determined that effects of thermophilic microorganisms on the public for plants using cooling ponds, lakes, or canals or cooling towers that discharge to a river is a Category 2 issue (see Table 4–20) that requires site-specific evaluation during each license renewal review.

In order to determine whether the continued operations of Braidwood could promote increased growth of thermophilic microorganisms, and thus have an adverse effect on the public, the NRC staff considered several factors: the thermophilic microorganisms of concern; Braidwood's thermal effluent characteristics; Exelon's chlorination procedures; recreational use of Braidwood Lake and the Kankakee River; and input from the Illinois Department of Public Health (IDPH).

Section 3.11.3 describes the thermophilic microorganisms that the GEIS identified to be of potential concern at nuclear power plants and summarizes data from the Centers for Disease Control and Prevention (CDC) on the prevalence of waterborne diseases associated with these microorganisms that have been linked to recreational water use in the past 10 available data years (1999 through 2008). CDC data indicate that no outbreaks or cases of waterborne *Salmonella* or *Pseudomonas aeruginosa* infection from recreational waters have occurred in the United States during this timeframe. *Shigella* and *Naegleria fowleri* infections linked to exposure in recreational waters were rarely reported, and none of the reported cases occurred in Illinois. Public exposure to aerosolized *Legionella* from nuclear plant operations is generally not a concern because such exposure would be confined to a small area of the site to which the public would not have access. Based on the information presented in Section 3.11.3, the thermophilic organisms most likely to be of potential concern at Braidwood are *Shigella* and *N. fowleri*.

Braidwood's circulating water system and two service water systems discharge heated water to the site's artificial cooling pond through a discharge canal at the north end of the pond. Braidwood also continuously discharges blowdown to the Kankakee River, and this discharge (designated as Outfall 001) is subject to the limitations set forth in the site's NPDES permit (IEPA 2014d). The permit limits blowdown discharges to the river to a 30-day average of 54 million liters per day (Lpd) or 14.3 mgd. Sections 3.1.3 and 3.5.1 describe the cooling system and surface water characteristics, respectively.

Prior to mixing with the cooling pond, circulating water discharge temperatures exiting the plant are maintained below approximately 123 °F (50.6 °C) (Exelon 2013c). Because discharged water is higher in temperature than the maximum tolerance of both *Shigella* (104 °F (40.0 °C)) or *N. fowleri* (105.8 °F (41.00 °C)), these organisms are unlikely to be present in discharged waters. The circulating water system's discharge to the cooling pond is also unlikely to create a thermal environment that would enhance the survival of thermophilic microorganisms, if already present in the cooling pond. Exelon measures the cooling pond's average and maximum temperatures by grab sample taken several times a week in front of the trash racks at the lake screen house. During the period from 2004 through 2013, the annual average temperatures at the sampling point ranged from 19.1 °C (66.4 °F) (in 2007) to 21.8 °C (71.2 °F) (in 2010) (Exelon 2014h). These temperatures are below the optimal growth temperature of both *Shigella* (37 °C (98.6 °F)) and *N. fowleri* (46.1 °C (115 °F)). In 2 years during the time period, maximum daily temperatures reached those within 1 °F (0.6 °C) of *Shigella*'s optimal growth temperature: Exelon (2014h) recorded temperatures of 37.3 °C (99.1 °F) on June 29, 2005, and 37.4 °C (99.3 °F) on July 19, 2013. Although these temperatures could reasonably enhance survival or growth of *Shigella*, the short duration (1 day) and periodicity (twice in 10 years) of these temperatures are unlikely to have produced a measurable effect on the *Shigella* population, if present in the pond. Thus, thermal additions to the cooling pond as a result of Braidwood operations are unlikely to enhance the growth or survival of thermophilic organisms.

For blowdown to the Kankakee River, Special Conditions 4C and 4D of the NPDES permit limit water temperatures at Outfall 001. Special Condition 4C stipulates that at the edge of Braidwood's thermal mixing zone, discharges from Outfall 001 shall not cause the Kankakee River water to rise above natural temperatures by more than 2.8 °C (5 °F). Special Condition 4D stipulates that temperatures at the edge of the mixing zone shall not exceed the

monthly maximum limits of 90 °F (32 °C) from April through November and 60 °F (16 °C) from December through March for more than 1 percent of the hours in a 12-month period and at no time shall water temperatures exceed the monthly maximum limits by more than 1.7 °C (3 °F). These limits are consistent with Title 35, *Environmental Protection*, Section 302, "Water Quality Standards," of the IAC, which stipulates that for thermal effluents, the maximum temperature rise shall not exceed 2.8 °C (5 °F) above natural receiving water body temperatures and that the water temperature at representative locations in the main river shall at no time exceed 33.7 °C (93 °F) from April through November and 17.7 °C (63 °F) in other months (35 IAC 302.211). In recent years, the average maximum monthly discharge temperature in summer months (calculated from Exelon's monthly discharge monitoring reports for 2008 through 2013) has been 92.6 °F (33.7 °C), which is slightly lower than the NPDES permit limit of 93 °F (33.7 °C) (Exelon 2014j). This temperature is below the optimal growth temperature both *Shigella* and *N. fowleri*, and thus, would not enhance the growth or survival of these thermophilic organisms, if present in Kankakee River water.

In addition to temperature limitations, the IAC prohibits the area and volume of thermal mixing from being more than 25 percent of the cross-sectional area or volume of stream flow (35 IAC 302.102). In 2009, Exelon commissioned a thermal mixing zone analysis (Thuman 2009b). The analysis determined that Braidwood's thermal mixing zone meets the IAC's criteria: the surface area of the thermal mixing zone was estimated to be 0.1 ha (0.22 ac), which is a small fraction of the allowable area (10.5 ha or 26 ac) under the IAC water quality standard. Thus, the IAC's thermal mixing limitations effectively minimize the area and volume over which microorganisms could experience enhanced growth or survival in the Kankakee River near the Braidwood discharge.

Chlorine is an effective disinfectant for water containing the microorganisms of concern. The EPA (EPA 1999a) reports that chlorination at concentrations of 1 to 2 milligrams per liter (mg/L) in water at a pH of 6.0 to 8.0 can effectively eliminate health hazards caused by bacteria, including *Shigella*. The CDC (CDC 2013) reports that chlorine at a concentration of 1 ppm (1 mg/L) added to 77 °F (25 °C) clear water at a pH of 7.5 will reduce the number of viable *N. fowleri* trophozoites by 99.99 percent in 12 minutes.

Exelon treats water entering the circulating water system and service water systems with sodium hypochlorite for up to 120 minutes per day per unit to control biofouling (ComEd 2000; Exelon 2014c). Water discharged to the Kankakee River may not contain more than an instantaneous maximum concentration of 0.2 mg/L of residual chlorine or 0.05 mg/L of residual oxides, as measured at Outfall 001, per Special Condition 5 of the NPDES permit (IEPA 2014d). As needed, sodium biosulfite is added to water prior to discharge to remove residual chlorine and maintain compliance with NPDES permit limitations (Exelon 2014a). Although Exelon chlorinates station water at lower concentrations than those indicated by EPA and the CDC as most effectively eliminating the microorganisms of concern, chlorination of the system is likely to prevent some increased growth and survival of microorganisms that might otherwise result from operation of Braidwood.

Both the cooling pond and the Kankakee River are used for recreational purposes. The cooling pond is part of the Mazonia–Braidwood State Fish and Wildlife Area, which Exelon and the IDNR jointly manage. It is open to the public for fishing from March 1st until ten days prior to the opening of waterfowl season, which typically begins in late October (Exelon 2013c). Portions of the cooling pond within the exclusion zone, which includes the essential cooling pond, are off limits to the public, and these areas are clearly marked with buoys or signs (Exelon 2013c). Within public access areas, swimming, wading, water-skiing, and sailing are prohibited, which further reduces the potential for human exposure to the microorganisms of concern, if present in the cooling pond.

As discussed above, Braidwood's thermal mixing zone in the Kankakee River is relatively small (0.1 ha (0.22 ac)), and the temperature limitations set forth in the NPDES permit are lower than those that would promoted increased growth or survival of thermophilic microorganisms. In accordance with the IAC, the discharge is not located near any public access areas because thermal mixing is prohibited "in water adjacent to bathing beaches, bank fishing areas, boat ramps or dockages or any other public access area" (35 IAC 302.102(b)(3)). Given the small area of thermally altered waters and the unlikelihood of the water to create conditions favorable to thermophilic microorganisms, exposure of recreational Kankakee River users to elevated concentrations of the microorganisms of concern is unlikely.

The environmental standard review plan for license renewal (NRC 2013k) directs NRC staff to consult with the state public health department—in this case, the IDPH—regarding concerns about the potential for waterborne disease outbreaks associated with license renewal. Appendix E of the ER (Exelon 2013c) includes copies of correspondence between Exelon and IDPH regarding this issue. In a January 2013 letter to IDPH, Exelon provided a brief assessment that concluded that the license renewal "would not contribute to any increase in adverse effects on public health from exposure to *N. fowleri* or any other thermophilic pathogen in the Rock River." The IDPH responded in a March 2013 letter and indicated that its staff does not have the expertise necessary to adequately evaluate Exelon's assessment. Accordingly, the NRC staff did not separately contact the IDPH during its license renewal review.

<u>Conclusion</u>

The thermophilic microorganisms *Shigella* and *N. fowleri* have been linked to waterborne outbreaks in recreational waters within the United States. However, based on these microorganisms' temperature tolerances, *Shigella* and *N. fowleri* are unlikely to be present in the vicinity of Braidwood. Additionally, Exelon's chlorination procedures and the small thermal mixing zones in the cooling pond and Kankakee River make exposure of recreational water users to elevated levels of these microorganisms unlikely. The NRC staff concludes that the impacts of thermophilic microorganisms on the public are SMALL for Braidwood license renewal.

4.11.1.2 Environmental Impacts of Postulated Accidents

This section describes the environmental impacts from postulated accidents that Braidwood might experience during the period of extended operation. The term "accident" refers to any unintentional event outside the normal plant operational envelope that results in a release or the potential for release of radioactive materials into the environment. The two classes of postulated accidents listed in Table 4–21 are contained in Table B-1 of Appendix B to Subpart A of 10 CFR Part 51 and are evaluated in detail in the GEIS. These two classes of accidents are design-basis accidents (DBAs) and severe accidents.

Table 4–21. Issues Related to Postulated Accidents

Issue	GEIS Section	Category
DBAs	4.9.1.2	1
Severe accidents	4.9.1.2	2

Source: Table B-1 in Appendix B, Subpart A, to 10 CFR Part 51

Design-Basis Accidents

DBAs are those accidents that both the nuclear power plant licensee and the NRC staff evaluate for all nuclear power plants to ensure that they can withstand normal and abnormal transients and a broad spectrum of postulated accidents, without undue hazard to the health and safety of the public. These postulated accidents are not expected to occur during the life of the plant but are evaluated to establish the design basis for the preventive and mitigative safety systems of the nuclear power plant. A licensee is required to maintain the acceptable design and performance criteria throughout the licensed life for operation of a reactor, including the license renewal term. Part 50 and Part 100 of Title 10 of the CFR describe the acceptance criteria for DBAs (NRC 2013f).

Exelon stated in its ER (Exelon 2013c) that it is not aware of any new and significant information related to DBAs associated with the renewal of Braidwood. The NRC staff has not found any new and significant information during its independent review of the Exelon ER, the site audit, or the scoping process. Therefore, the NRC staff concludes that there are no impacts related to DBAs, beyond those discussed in the GEIS. For this Category 1 issue, the GEIS concludes that the impacts are SMALL.

Severe Accidents

Severe nuclear accidents are those that are more severe than DBAs because they could result in substantial damage to the reactor core, whether or not there are serious offsite consequences. The GEIS assessed the effects of severe accidents during the period of extended operation, using the results of existing analyses and site-specific information to conservatively predict the environmental impacts of severe accidents for each plant during the period of extended operation.

The impacts from severe accidents initiated by external phenomena such as tornadoes, floods, earthquakes, fires, and sabotage were specifically considered in the GEIS. The GEIS evaluated existing impact assessments at selected nuclear power plants in the United States and concluded that the risk is SMALL. The GEIS also performed an analysis of sabotage, in connection with license renewal, and concluded that the core damage and radiological release from such acts would be no worse than the damage and release expected from internally initiated events. The GEIS concludes that the risk from sabotage at existing nuclear power plants is SMALL and, additionally, that the risks from other external events are adequately addressed by a generic consideration of internally initiated severe accidents (NRC 2013f).

The NRC found that:

> The probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to ground water, and societal and economic impacts from severe accidents are small for all plants. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives. [78 FR 37282, 78 FR 46255]

The NRC staff found no new and significant information related to postulated accidents during the review of Exelon's ER (Exelon 2013c), the site visit, or the scoping process. Therefore, as discussed in the GEIS, the probability-weighted consequences of severe accidents are SMALL.

4.11.1.3 Severe Accident Mitigation Alternatives (SAMAs)

Section 51.53(c)(3)(ii)(L) requires that license renewal applicants consider alternatives to mitigate severe accidents if the NRC staff has not previously evaluated SAMAs for the applicant's plant in an EIS or related supplement or in an environmental assessment (EA). The purpose of this consideration is to ensure that plant changes (i.e., hardware, procedures, and

training) with the potential for improving severe accident safety performance are identified and evaluated. SAMAs have not been previously considered for Braidwood; therefore, the remainder of this section addresses those alternatives.

Overview of SAMA Process

This section presents a summary of the SAMA evaluation for Braidwood conducted by Exelon and the NRC staff's review of that evaluation. The NRC staff performed its review with contract assistance from Pacific Northwest National Laboratory. The NRC staff's review is available in full in Appendix F; the Exelon's SAMA evaluation is available in full in the ER.

The SAMA evaluation for Braidwood was conducted using a four-step approach. In the first step, Exelon quantified the level of risk associated with potential reactor accidents using the plant-specific probabilistic risk assessment (PRA) and other risk models.

In the second step Exelon examined the major risk contributors and identified possible ways (SAMAs) of reducing that risk. Common ways of reducing risk are changes to components, systems, procedures, and training. Exelon identified 35 potential SAMAs for Braidwood. Exelon performed an initial screening to determine if any SAMAs could be eliminated because (a) they are not applicable to Braidwood due to design differences, (b) they have already been implemented at Braidwood or their intent is achieved by other means, or (c) they have estimated implementation costs that would exceed the dollar value associated with completely eliminating all severe accident risk at Braidwood related to power generation operations. One SAMA was eliminated based on this screening, leaving 34 for further evaluation. This SAMA (eliminated during screening) was also further evaluated after considering analysis uncertainties.

In the third step Exelon estimated the benefits and the costs associated with each of the SAMAs. Estimates were made of how much each SAMA could reduce risk. Those estimates were developed in terms of dollars in accordance with NRC guidance for performing regulatory analyses (NRC 1997). The cost of implementing the proposed SAMAs was also estimated.

In the fourth step, the costs and benefits of each of the remaining SAMAs were compared to determine whether the SAMA was cost-beneficial, meaning the benefits of the SAMA were greater than the cost (a positive cost benefit). Exelon concluded in its ER that several of the SAMAs evaluated are potentially cost-beneficial (Exelon 2013c). No additional potentially cost-beneficial SAMAs were identified in response to NRC staff inquiries regarding estimated benefits for certain SAMAs and lower-cost alternatives (Exelon 2014k).

Finally, the potentially cost-beneficial SAMAs are evaluated to determine if they are in the scope of license renewal, (i.e., they are subject to aging management). This evaluation considers whether the systems, structures, and components (SSCs) associated with these SAMAs: (1) perform their intended function without moving parts or without a change in configuration or properties and (2) that these SSCs are not subject to replacement based on qualified life or specified time period. The potentially cost-beneficial SAMAs identified for Braidwood do not relate to adequately managing the effects of aging during the period of extended operation; therefore, they need not be implemented as part of license renewal in accordance with 10 CFR Part 54, "Requirements for renewal of operating licenses for nuclear power plants." Exelon's SAMA analyses for Braidwood and the NRC's review are discussed in more detail below.

Estimate of Risk

Exelon submitted an assessment of SAMAs for Braidwood as part of the ER (Exelon 2013c). This assessment was based on the most recent Braidwood PRA available at that time, a plant-specific offsite consequence analysis performed using the MELCOR Accident Consequence Code System 2 (MACCS2) computer program, and insights from the Braidwood

individual plant examination (ComEd 1994, 1997a) and individual plant examination of external events (ComEd 1997b).

The scope of the Level 1 PRA model includes both internal events and a limited fire PRA. However, the fire PRA is not fully integrated with the most recent internal events model and is an interim implementation of NUREG–6850 (EPRI and NRC 2005). Hence, Exelon performed a separate assessment of the risk (and risk reduction) for internal and fire events.

The baseline core damage frequency (CDF) for the purpose of the SAMA evaluation is approximately 3.6×10^{-5} per year for Unit 1 and 3.5×10^{-5} per year for Unit 2 for internal events (including internal flooding events). The total fire CDF for Unit 2 is approximately 5.9×10^{-5} per year. The Unit 1 fire CDF was reported as lower than the Unit 2 fire CDF, and so the Unit 2 fire CDF was used in the SAMA evaluation. Exelon accounted for the potential risk reduction benefits associated with internal events by quantifying the benefits using the internal events model. For internal event-related SAMAs, Exelon accounted for the potential risk reduction benefits associated with external events (e.g., seismic and fire events) by multiplying the estimated benefits for internal events by a factor of 3.0. For fire-related SAMAs, Exelon separately estimated the risk reduction benefits using the fire risk model. The breakdown of CDF by initiating event for Braidwood is provided in Table 4–22 for internal events.

Table 4–22. Braidwood Core Damage Frequency (CDF) for Internal Events

Initiating Event	Unit 1 CDF (per year)	Unit 1 Percent CDF Contribution	Unit 2 CDF (per year)	Unit 2 Percent CDF Contribution
Loss of Essential Service Water (SX)	1.3×10^{-5}	36	1.3×10^{-5}	37
Small Loss-of-Coolant Accident (LOCA)	6.4×10^{-6}	18	6.3×10^{-6}	18
Internal Flooding	5.7×10^{-6}	16	5.6×10^{-6}	16
Loss of Component Cooling Water (CCW)	3.2×10^{-6}	9	3.2×10^{-6}	9
Loss of Auxiliary Power (AP)	2.1×10^{-6}	6	1.4×10^{-6}	4
Other Initiating Events	1.8×10^{-6}	5	1.8×10^{-6}	5
Medium Loss-of-Coolant Accident (LOCA)	1.4×10^{-6}	4	1.4×10^{-6}	4
Steam Generator Tube Rupture (SGTR)	1.4×10^{-6}	4	1.8×10^{-6}	5
General Transient and Loss of Main Feedwater (LMFW)	7.1×10^{-7}	2	7.0×10^{-7}	2
Total (Internal Events)[a]	**3.6×10^{-5}**	**100**	**3.5×10^{-5}**	**100**

[a] Column totals may be different due to round off.

As shown in these tables, internal event CDF is dominated by loss of essential service water (SX), small loss-of-coolant accident, internal flooding, and loss of component cooling water (CCW) for both units.

Exelon estimated the dose to the population within 50 mi (80 km) of the Braidwood site to be approximately 1.14 person-sievert (Sv) (114 person-rem) per year (Exelon 2013c) for internal events. The breakdown of the total population dose and offsite economic cost by containment release mode is summarized in Table 4–23. Containment overpressure accidents, interfacing

system loss-of-coolant accident, and steam generator tube rupture (SGTR) are the dominant contributors to population dose risk from internal events.

Table 4–23. Breakdown of Population Dose and Offsite Economic Cost by Containment Release Mode [(a)]

Containment Release Mode	Population Dose (Person-rem [(b)] Per Year)	Percent Contribution	Offsite Economic Cost ($/yr)	Percent Contribution
Containment over-pressure (late)	87.3	77	687,000	83
Interfacing system LOCA	15.5	14	54,400	7
Steam generator tube rupture	9.05	8	61,800	8
Containment isolation failure	1.18	1	3,800	<1
Containment intact	0.33	<1	300	<1
Early containment failure	0.29	<1	2,000	<1
Basemat melt-through (late)	0.06	<1	62	<1
Total [(c)]	**114**	**100**	**810,000**	**100**

[(a)] Values in table derived from Table F.3-9 of the ER

[(b)] One person-rem = 0.01 person-Sv

[(c)] Column totals may be different due to round off.

The NRC staff has reviewed Exelon's data and evaluation methods and concludes that the quality of the risk analyses is adequate to support an assessment of the risk reduction potential for candidate SAMAs. Accordingly, the staff based its assessment of offsite risk on the CDFs and offsite doses reported by Exelon.

Potential Plant Improvements

Once the dominant contributors to plant risk were identified, Exelon searched for ways to reduce that risk. In identifying and evaluating potential SAMAs, Exelon considered insights from the plant-specific PRA and SAMA analyses performed for other operating plants that have submitted LRAs. This search included reviewing insights from the plant-specific risk studies, considering insights from the Braidwood PRA Group, and reviewing plant improvements considered in the IPE, IPEEE, and previous SAMA analyses. Exelon identified 35 potential risk-reducing improvements (SAMAs) to plant components, systems, procedures, and training. A detailed cost-benefit analysis was performed for each of the SAMAs.

The staff concludes that Exelon used a systematic and comprehensive process for identifying potential plant improvements for Braidwood and that the set of potential plant improvements identified by Exelon is reasonably comprehensive and, therefore, acceptable.

Evaluation of Risk Reduction and Costs of Improvements

Exelon evaluated the risk reduction potential of the candidate SAMAs. The SAMA evaluations were performed using realistic assumptions with some conservatism. Exelon estimated the costs of implementing the candidate SAMAs through the development of Braidwood-specific cost estimates, the use of other licensees' estimates for similar improvements, and, in some cases, combinations of these two sources. The cost estimates conservatively did not include the cost of replacement power during extended outages required to implement the modifications.

The staff reviewed Exelon's bases for calculating the risk reduction for the various plant improvements and concludes that the rationale and assumptions for estimating risk reduction are reasonable and generally conservative (i.e., the estimated risk reduction is higher than what would actually be realized). Accordingly, the staff based its estimates of averted risk for the various SAMAs on Exelon's risk reduction estimates.

The staff reviewed the bases for the applicant's cost estimates. For certain improvements, the staff also compared the cost estimates to estimates developed elsewhere for similar improvements, including estimates developed as part of other licensees' analyses of SAMAs for operating reactors. The staff found the cost estimates to be reasonable, and generally consistent with estimates provided in support of other plants' analyses.

The staff concludes that the risk reduction and the cost estimates provided by Exelon are sufficient and appropriate for use in the SAMA evaluation.

<u>Cost-Benefit Comparison</u>

The cost benefit analysis performed by Exelon was based primarily on NUREG/BR–0184 (NRC 1997) and was executed consistent with this guidance. NUREG/BR–0058 has recently been revised to reflect the agency's revised policy on discount rates. Revision 4 of NUREG/BR–0058 states that two sets of estimates should be developed—one at 3 percent and one at 7 percent (NRC 2004). Exelon provided both sets of estimates (Exelon 2013c, 2014k) and based its decisions on potentially cost-beneficial SAMAs on these values.

Exelon identified 18 potentially cost-beneficial SAMAs in the baseline analysis contained in the ER. The potentially cost-beneficial SAMAs are:

- SAMA 3 – Auto Start of Standby SX Pump
- SAMA 5 – Modify the Startup Feedwater pump to Start Using the AMSAC SG Low-Low-Low Level Signal to Mitigate AFW Failure
- SAMA 6 – Enhance Plant Procedures to Explicitly Confirm Adequate _SX007 Throttling
- SAMA 7 – Establish Flow to the RH HX on RH Pump Start
- SAMA 8 – Install Kill Switches for the Fire Protection Pumps in the MCR
- SAMA 9 – Install Flow Restrictors in Fire Protection Pipes
- SAMA 10 – Alter Ductwork Between the Aux BLDG Room and the SX Pump Room
- SAMA 11 – Implement DMS
- SAMA 13 – Alternate AFW Cooling with Seal Protection
- SAMA 15 – Resolve Regulatory Issues and Complete Implementation of the Inter Unit AFW Cross-tie
- SAMA 16 – Install High Flow Sensors on the Non-Essential Service Water System
- SAMA 19 – Replace MOVs in the RHR Discharge Line with Valves That Can Isolate an ISLOCA Event
- SAMA 25 – Install a Filtered Containment Vent
- SAMA 26 – DMS Using a Dedicated Generator, Self-Cooled Charging Pump, and a Portable AFW Pump

- SAMA 27 – Protect RH.SI and CVCS Cubicle Cooling Fan Cables in Fire Zone 11.3-0
- SAMA 28 – Install Fire Barriers around MCC 134X
- SAMA 29 – Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment
- SAMA 33 – Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Division 11 ESF Switchgear Room

Exelon performed additional analyses to evaluate the impact of parameter choices and uncertainties on the results of the SAMA assessment (Exelon 2013c, 2014k). If the benefits are increased by a factor of 2.29 (which was reduced to 1.97 in response to an NRC staff RAI) to account for uncertainties, eight additional SAMA candidates were determined to be potentially cost-beneficial:

- SAMA 1 – Install Diesel Driven SX Pump in a New Dedicated Building
- SAMA 2 – Replace the Positive Displacement Pump with a Self-Cooled, Auto Start Pump
- SAMA 4 – Install “No Leak” Seals
- SAMA 22 – Install the Same High Flow Isolation Logic Used on Valve_CC685 on Valve_CC9438
- SAMA 31 – Install Fire Barriers around MCCs 132X5 and 132X
- SAMA 32 – Install Fire Barriers around MCC 131X2
- SAMA 34 – Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Aux Building Elevation 426′ of the General Area
- SAMA 35 – Unit 2 SAMA - Install Cable Wrap to Protect 2AF005A, B, C, and D in the Division 21 Containment Electrical Penetrations Area

Exelon stated in the ER that the 26 SAMAs determined to be cost-beneficial in the ER baseline and uncertainty evaluations have been submitted to the Braidwood Plant Health Committee for further implementation consideration (Exelon 2013c).

The staff concludes that, with the exception of the potentially cost-beneficial SAMAs discussed above, the costs of the SAMAs evaluated would be higher than the associated benefits when they are considered independently.

Conclusions

The staff reviewed Exelon’s analysis and concluded that the methods used and the implementation of those methods was sound. The treatment of SAMA benefits and costs support the general conclusion that the SAMA evaluations performed by Exelon are reasonable and sufficient for the license renewal submittal.

Based on its review of the SAMA analysis, the staff finds acceptable Exelon’s identification of areas in which risk can be further reduced in a cost-beneficial manner through the implementation of all or a subset of potentially cost-beneficial SAMAs. Given the potential for cost-beneficial risk reduction, the staff considers that further evaluation of these SAMAs by Exelon is warranted. Additionally, the NRC staff evaluated the 26 potentially cost-beneficial SAMAs to determine if they are in the scope of license renewal, (i.e., they are subject to aging management). This evaluation considers whether the systems, structures, and components (SSCs) associated with these SAMAs: (1) perform their intended function without moving parts

or without a change in configuration or properties and (2) that these SSCs are not subject to replacement based on qualified life or specified time period. The NRC staff determined that these SAMAs do not relate to adequately managing the effects of aging during the period of extended operation. Therefore, they need not be implemented as part of the license renewal pursuant to 10 CFR Part 54.

4.11.2 No-Action Alternative

Human health risks would be smaller following plant shutdown. The two reactor units, which are currently operating within regulatory limits, would emit less gaseous, liquid, and solid radioactive material to the environment. In addition, following shutdown, the variety of potential accidents at the plant (radiological or industrial) would be reduced to a limited set associated with shutdown events and fuel handling and storage. In Section 4.11.1, the NRC staff concluded that the impacts of continued plant operation on human health would be SMALL, except for "Chronic effects of electromagnetic fields (EMFs)," for which the impacts are UNCERTAIN. In Section 4.11.1.2, the NRC staff concluded that the impacts of accidents during operation were SMALL. Therefore, as radioactive emissions to the environment decrease, and as the likelihood and types of accidents decrease following shutdown, the NRC staff concludes that the risk to human health following plant shutdown would be SMALL.

4.11.3 New Nuclear Alternative

<u>Construction</u>

Impacts on human health from construction of two new nuclear units would be similar to impacts associated with the construction of any major industrial facility. Compliance with worker protection rules would control those impacts on workers at acceptable levels. Construction of new nuclear units would increase traffic on local roads, which could affect the health of the general public. Human health impacts would be the same whether the new facility is located on greenfield sites, other existing power plant sites, or at the existing Braidwood nuclear plant site. Impacts from construction on the general public would be minimal since limiting active construction area access to authorized individuals is expected. Personal protective equipment, training, and engineered barriers would protect the workforce. Therefore, the impacts on human health from the construction of two new nuclear units would be SMALL (NRC 2013f).

<u>Operation</u>

The human health effects from the operation of two new nuclear power plants would be similar to those of the existing Braidwood units. As presented in Section 4.11.1.1, impacts on human health from the operation of Braidwood would be SMALL, except for "Chronic effects of electromagnetic fields (EMFs)," for which the impacts are UNCERTAIN. Therefore, the impacts on human health from the operation of two new nuclear plants would be SMALL.

4.11.4 Coal (Integrated Gasification Combined Cycle) Alternative

<u>Construction</u>

Impacts on workers are expected to be similar to those experienced during construction of any major industrial facility. Impacts from construction of combustion-based renewable energy facilities are expected to be the same as those for construction of fossil fuel facilities. Construction would increase traffic on local roads, which could affect the health of the general public. Human health impacts would be the same for all facilities whether located on greenfield sites, other existing power plant sites, or at an existing nuclear plant. Personal protective equipment, training, and engineered barriers would protect the workforce (NRC 2013f).

Therefore, the impacts on human health from the construction of an IGCC facility would be SMALL.

Operation

The IGCC alternative introduces worker risks from coal and limestone mining, worker and public risk from coal and lime/limestone transportation, worker and public risk from disposal of coal-combustion waste, and public risk from inhalation of stack emissions. In addition, human health risks are associated with the management and disposal of coal combustion waste. Coal combustion generates waste in the form of ash, and equipment for controlling air pollution generates additional ash and scrubber sludge. Human health risks may extend beyond the facility workforce to the public depending on their proximity to the coal combustion waste storage and/or disposal facility. The character and the constituents of coal combustion waste depend on both the chemical composition of the source coal and the technology used to combust it. Generally, the primary sources of adverse consequences from coal combustion waste are from exposure to sulfur oxide and nitrogen oxide in air emissions and radioactive elements such as uranium and thorium as well as the heavy metals and hydrocarbon compounds contained in fly ash and bottom ash, and scrubber sludge (NRC 2013f).

Regulatory agencies, including the EPA and state agencies, base air emission standards and requirements on human health impacts. These agencies also impose site-specific emission limits as needed to protect human health. Given the regulatory oversight exercised by the EPA and state agencies, the NRC staff concludes that the human health impacts from radiological doses and inhaled toxins and particulates generated from the IGCC alternative would be SMALL (NRC 2013f).

4.11.5 Natural Gas Combined Cycle Alternative

Construction

Impacts on workers are expected to be similar to those experienced during construction of any major industrial facility. Impacts from construction of combustion-based renewable energy facilities are expected to be the same as those for construction of fossil fuel facilities. Construction would increase traffic on local roads, which could affect the health of the general public. Human health impacts would be the same for all facilities whether located on greenfield sites, other existing power plant sites, or at an existing nuclear plant. Compliance with worker protection rules and personal protective equipment, training, and engineered barriers would protect the workforce (NRC 2013f). Impacts from construction on the general public would be minimal since crews would limit active construction area access to authorized individuals. Therefore, the NRC staff concludes that the impacts on human health from the construction of an NGCC facility would be SMALL.

Operation

Impacts from the operation of an NGCC facility introduces public risk from inhalation of gaseous emissions. The risk may be attributable to nitrogen oxide emissions that contribute to ozone formation, which in turn contribute to health risk. Regulatory agencies, including the EPA and state agencies, base air emission standards and requirements on human health impacts. These agencies also impose site-specific emission limits as needed to protect human health. Given the regulatory oversight exercised by the EPA and state agencies, the NRC staff concludes that the human health impacts from the NGCC alternative would be SMALL.

4.11.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

Construction

Impacts on human health from construction of a combination of NGCC, wind, and solar PV alternatives would be similar to effects associated with the construction of any major industrial facility. Compliance with worker protection rules and personal protective equipment, training, and engineered barriers would protect the workforce (NRC 2013f). Impacts from construction on the general public would be minimal since crews would limit active construction area access to authorized individuals. Based on the above, the NRC staff concludes that the Impacts on human health from the construction of the NGCC, wind, and solar alternative would be SMALL.

Operation

Operational hazards at an NGCC facility are discussed in Section 4.11.5.

Operational hazards at a wind facility for the workforce include working at heights, near rotating mechanical or electrically energized equipment, and working in extreme weather. Potential impacts to workers and the public include ice thrown from rotor blades and broken blades thrown caused by mechanical failure. Potential impacts also include EMF exposure, aviation safety (hazard related), and exposure to noise and vibration from the rotating blades.

Operational hazards at a solar PV facility may involve exposure to airborne toxic metals (e.g., cadmium) and silicon if the PV cell loses its integrity from a fire. Workers could also inhale silicon dust if the PV cell was smashed by an object or from a fall to the ground. However, based on worker and environmental protection rules, it is expected that remediation of toxic material would occur. Such remediation would minimize the impact to workers and the environment.

Therefore, given the expected compliance with worker and environmental protection rules and the use of personal protective equipment, training, and engineered barriers, the NRC staff concludes that the potential human health impacts would be SMALL.

4.11.7 Purchased Power

Purchased power is expected to come from the types of electricity generation available within the ROI: coal, natural gas, nuclear, and wind. The human health impacts from the operation of these types of power plants are discussed in sections 4.11.3, 4.11.4, 4.11.5, and 4.11.6. Based on the information in those sections, the NRC staff concludes that the human health impacts of the purchased power alternative using coal, natural gas, nuclear, and wind would be SMALL.

4.12 Environmental Justice

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on environmental justice.

The NRC addresses environmental justice matters for license renewal by (1) identifying the location of minority and low-income populations that may be affected by the continued operation of the nuclear power plant during the license renewal term, (2) determining if there would be any potential human health or environmental effects to these populations and special pathway receptors, and (3) determining if any of the effects may be disproportionately high and adverse. Adverse health effects are measured in terms of the risk and rate of fatal or nonfatal adverse impacts on human health. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant and exceeds the risk or exposure rate for the general population or for

another appropriate comparison group. Disproportionately high environmental effects refer to impacts or risks of impacts on the natural or physical environment in a minority or low-income community that are significant and appreciably exceed the environmental impact on the larger community. Such effects may include biological, cultural, economic, or social impacts.

4.12.1 Proposed Action

Figures 3.12-1 and 3.12-2 show the location of predominantly minority and low-income population block groups residing within a 50-mi (80-km) radius of Braidwood. This area of impact is consistent with the impact analysis for public and occupational health and safety, which also focuses on populations within a 50-mi (80-km) radius of the plant. Chapter 4 presents the assessment of environmental and human health impacts for each resource area.

Potential impacts on minority and low-income populations (including migrant workers or Native Americans) would mostly consist of socioeconomic and radiological effects; however, radiation doses from continued operations during the license renewal term are expected to continue at current levels, and they would remain within regulatory limits. Section 4.9.1.2 of this SEIS discusses the environmental impacts from postulated accidents that might occur during the license renewal term, which include both design-basis and severe accidents. In both cases, the Commission has generically determined that impacts associated with design-basis accidents are small because nuclear plants are designed and operated to successfully withstand such accidents, and the probability weighted consequences of severe accidents are small.

Therefore, based on this information and the analysis of human health and environmental impacts presented in Chapter 4 of this SEIS, there would be no disproportionately high and adverse human health and environmental effects on minority and low-income populations from the continued operation of Braidwood during the license renewal term.

As part of addressing environmental justice concerns associated with license renewal, the NRC also assessed the potential radiological risk to special population groups (e.g., migrant workers or Native Americans) from exposure to radioactive material received through their unique consumption practices and interaction with the environment, including subsistence consumption of fish, native vegetation, surface waters, sediments, and local produce; absorption of contaminants in sediments through the skin; and inhalation of airborne radioactive material released from the plant during routine operation. This analysis is presented below.

<u>Subsistence Consumption of Fish and Wildlife</u>

The special pathway receptors analysis is an important part of the environmental justice analysis because consumption patterns may reflect the traditional or cultural practices of minority and low-income populations in the area, such as migrant workers or Native Americans.

Section 4-4 of Executive Order 12898 (published in the *Federal Register* (FR) at 59 FR 7629 in 1994) directs Federal agencies, whenever practical and appropriate, to collect and analyze information about the consumption patterns of populations that rely principally on fish and/or wildlife for subsistence and to communicate the risks of these consumption patterns to the public. In this SEIS, the NRC considered whether there were any means for minority or low-income populations to be disproportionately affected by examining impacts on American Indian, Hispanics, migrant workers, and other traditional lifestyle special pathway receptors. The assessment of special pathways considered the levels of radiological and nonradiological contaminants in native vegetation, crops, soils and sediments, groundwater, surface water, fish, and game animals on or near Braidwood.

The following is a summary discussion of Exelon's radiological environmental monitoring programs that assess the potential impacts from the subsistence consumption of fish and wildlife near the Braidwood site.

Exelon has an ongoing comprehensive Radiological Environmental Monitoring Program (REMP) to assess the impact of Braidwood operations on the environment. To assess the impact of nuclear power plant operations, samples are collected annually from the environment and analyzed for radioactivity. A plant effect would be indicated if the radioactive material detected in a sample was significantly larger than background levels. Two types of samples are collected. The first type, a control sample, is collected from areas that are beyond the measurable influence of the nuclear power plant or any other nuclear facility. These samples are used as reference data to determine normal background levels of radiation in the environment. These samples are then compared with the second type of samples, indicator samples, collected near the nuclear power plant. Indicator samples are collected from areas where any contribution from the nuclear power plant will be at its highest concentration. These samples are then used to evaluate the contribution of nuclear power plant operations to radiation or radioactivity levels in the environment. An effect would be indicated if the radioactivity levels detected in an indicator sample was significantly larger than the control sample or background levels.

Samples of environmental media are collected from the aquatic, atmospheric, and terrestrial pathways in the vicinity of Braidwood. The aquatic pathways include surface water, public water, well water, fish, and shoreline sediment. Atmospheric pathways include samples of air particulate and airborne iodine from eight different locations around Braidwood. The terrestrial pathways include airborne particulates, milk, and food products (i.e., cabbage, beets and beet greens, kohlrabi, potatoes, rhubarb leaves, onions, and turnips). During 2012, 1,602 analyses were performed on 1,368 samples of environmental media at Braidwood showed no significant or measurable radiological impact above background levels from site operations (Teledyne 2013).

<u>Conclusion</u>

Based on the radiological environmental monitoring data from Braidwood, the NRC finds that no disproportionately high and adverse human health impacts would be expected in special pathway receptor populations in the region as a result of subsistence consumption of water, local food, fish, and wildlife. Continued operation of Braidwood would not have disproportionately high and adverse human health and environmental effects on these populations.

4.12.2 Environmental Impacts of Alternatives to the Proposed Action

As discussed in Section 4.12, the environmental justice impact analysis evaluates the potential for disproportionately high and adverse human health and environmental effects on minority and low-income populations. Some of these potential effects have been identified in resource areas discussed in this SEIS. For example, increased demand for rental housing during replacement power plant construction could disproportionately affect low-income populations. Minority and low-income populations are subsets of the general public residing in the vicinity of all the alternatives listed below, and all are exposed to the same hazards generated by each alternative.

4.12.2.1 No-Action Alternative

Impacts on minority and low-income populations would depend on the number of jobs and the amount of tax revenues lost by communities in the immediate vicinity of the power plant after

Braidwood ceases operations. Not renewing the operating licenses and terminating reactor operations would have a noticeable impact on socioeconomic conditions in the communities located near Braidwood. The loss of jobs and income would have an immediate socioeconomic impact. Some, but not all, of the approximately 905 employees would begin to leave after reactor operations are terminated; and overall tax revenue generated by plant operations would be reduced. The reduction in tax revenue would decrease the availability of public services in Will County. This could disproportionately affect minority and low-income populations that may have become dependent on these services. Effects could be high or adverse depending on the needs of the individual impacted. See also Appendix J of NUREG–0586, Supplement 1 (NRC 2002c), for additional discussion of these impacts.

4.12.2.2 New Nuclear Alternative

Potential impacts to minority and low-income populations from the construction and operation of a new nuclear power plant would mostly consist of environmental and socioeconomic effects (e.g., noise, dust, traffic, employment, and housing impacts). Noise and dust impacts from construction would be short-term and primarily limited to onsite activities. Minority and low-income populations residing along site access roads would be affected by increased commuter vehicle traffic during shift changes and truck traffic. However, these effects would be temporary during certain hours of the day and would not likely be high and adverse. Increased demand for rental housing during construction could affect low-income populations. However, given the proximity of some existing nuclear power plant sites to metropolitan areas, many construction workers could commute to the site, thereby reducing the potential demand for rental housing.

Potential impacts to minority and low income populations from new nuclear power plant operations would mostly consist of radiological effects; however, radiation doses are expected to be well below regulatory limits. All people (including minority and low income populations) living near the nuclear power plant would be exposed to the same potential effects from power plant operations, and any impacts would depend on the magnitude of the change in ambient air quality conditions. Permitted air emissions are expected to remain within regulatory standards.

Based on this information and the analysis of human health and environmental impacts presented in this SEIS, the construction and operation of a new nuclear power plant would not have disproportionately high and adverse human health and environmental effects on minority and low-income populations.

4.12.2.3 Coal (Integrated Gasification Combined Cycle) Alternative

Potential impacts to minority and low-income populations from the construction and operation of a new IGCC plant at an existing power plant site would consist of environmental and socioeconomic effects (e.g., noise, dust, traffic, employment, and housing impacts). Noise and dust impacts from construction would be short-term and primarily limited to onsite activities. Minority and low-income populations residing along site access roads would be affected by increased commuter vehicle traffic during shift changes and truck traffic. However, these effects would be temporary during certain hours of the day and would not likely be high and adverse. Increased demand for rental housing during construction could affect low-income populations. However, given the proximity of some existing power plant sites to metropolitan areas, many construction workers could commute to the site, thereby reducing the potential demand for rental housing.

Emissions from the operation of an IGCC plant could affect minority and low income populations as well as the general population living in the vicinity of the new power plant. However, all would be exposed to the same potential effects from IGCC power plant operations and any

impacts would depend on the magnitude of the change in ambient air quality conditions. Permitted air emissions are expected to remain within regulatory standards.

Based on this information and the analysis of human health and environmental impacts presented in this SEIS, the construction and operation of a new IGCC plant would not have disproportionately high and adverse human health and environmental effects on minority and low-income populations.

4.12.2.4 Natural Gas Combined Cycle Alternative

Potential impacts to minority and low-income populations from the construction and operation of a new NGCC plant at an existing power plant site would mostly consist of environmental and socioeconomic effects (e.g., noise, dust, traffic, employment, and housing impacts). Noise and dust impacts from construction would be short-term and primarily limited to onsite activities. Minority and low-income populations residing along site access roads would be affected by increased commuter vehicle traffic during shift changes and truck traffic. However, these effects (impacts) would be temporary (only during certain hours of the day) and would not likely be high and adverse. Increased demand for rental housing during construction could affect low-income populations in the vicinity of the Braidwood site. However, given the proximity of some existing power plant sites to metropolitan areas, many construction workers could commute to the site, thereby reducing the potential demand for rental housing.

Emissions from the operation of an NGCC plant could affect minority and low income populations as well as the general population living in the vicinity of the new power plant. However, all would be exposed to the same potential effects from NGCC power plant operations, and any impacts would depend on the magnitude of the change in ambient air quality conditions. Permitted air emissions are expected to remain within regulatory standards.

Based on this information and the analysis of human health and environmental impacts presented in this SEIS, the construction and operation of a new NGCC plant would not have disproportionately high and adverse human health and environmental effects on minority and low-income populations.

4.12.2.5 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

Potential impacts to minority and low-income populations from the construction and operation of a new NGCC plant, wind turbines, and solar PV installations would mostly consist of environmental and socioeconomic effects (e.g., noise, dust, traffic, employment, and housing impacts). Noise and dust impacts from construction would be short-term and primarily limited to onsite activities. Minority and low-income populations residing along site access roads would be affected by increased commuter vehicle traffic during shift changes and truck traffic. However, these effects would be temporary during certain hours of the day and would not likely be high and adverse. Increased demand for rental housing during construction could affect low-income populations. However, given the small number of construction workers and the possibility that many workers could commute to these construction sites, the potential need for rental housing would not be significant.

Minority and low income populations living in close proximity to wind farm and solar PV power generating installations could be disproportionately affected by maintenance and operations activities. However, everyone would be exposed to the same operational effects, and any effects would depend on the magnitude of change from current conditions. Operational impacts from the wind turbines and solar PV installations would mostly be limited to noise and aesthetic effects. The general public living near the wind farms and solar PV installations would also be exposed to the same effects.

Based on this information and the analysis of human health and environmental impacts presented in this SEIS, the construction and operation of a new NGCC plant, wind farms, and solar PV installations would not have disproportionately high and adverse human health and environmental effects on minority and low-income populations.

4.12.2.6 Purchased Power

Purchased power from existing power generating facilities would not likely have any disproportionately high and adverse effects on minority populations, because there would be no change in power plant operations or workforce. However, low-income populations could be disproportionately affected by increased utility bills because of the cost of purchased power, although programs are available to assist low-income families in paying for increased electrical costs.

If the amount of purchased power exceeds the available supply, new electric power generating facilities would be needed. Construction and operation of a new power generating facility to supply purchased power could create new human health and environmental effects in communities located near the new facility. Minority and low-income populations residing in the vicinity of the new electric power generating facility are subsets of the general population, and all would be exposed to the same hazards generated by construction activities and facility operations.

Some potential human health and environmental effects have already been described for other replacement power alternatives in this SEIS. Potential impacts from the construction of a new power generating facility would mostly consist of environmental effects (e.g., increased noise, dust, traffic, employment, and housing demand). Noise and dust impacts from construction would be short-term and primarily limited to onsite activities. Minority and low-income populations residing along site access roads would be affected by increased commuter vehicle traffic during shift changes and truck traffic. However, these effects would be temporary during certain hours of the day and would not likely be high and adverse. Increased demand for rental housing during construction could affect low-income populations. However, depending on the location of the new power generating facility and the possibility of construction workers commuting to the construction site, the potential need for rental housing may not be significant.

Minority and low income populations living in close proximity to power generating facilities could also be disproportionately affected by maintenance and operations activities. However, everyone living near the power plant site would be exposed to the same operational effects, and any effects would depend on the magnitude of change from current conditions. Operational impacts for all new power generating facilities would mostly be limited to noise and aesthetic effects. Emissions from fossil-fueled power generating facilities could create disproportionate human health effects in minority and low income populations living in the vicinity of the new power plant. However, all populations would be exposed to the same potential human health and environmental effects from power plant operations and any impacts would depend on the magnitude of the change in ambient air quality conditions. In addition, permitted air emissions would be expected to remain within regulatory standards.

Based on this information and the analysis of human health and environmental effects presented in this SEIS, the construction and operation of a new power generating facility may not have disproportionately high and adverse human health and environmental effects on minority and low-income populations.

4.13 Waste Management and Pollution Prevention

This section describes the potential impacts of the proposed action (license renewal) and alternatives to the proposed action on waste management and pollution prevention.

4.13.1 Proposed Action

The waste management issues applicable to Braidwood are discussed below and listed in Table 4–24. Table B-1 of Appendix B to Subpart A of 10 CFR Part 51 contains more information on these issues.

Table 4–24. Waste Management Issues

Issue	GEIS Section	Category
Low-level waste storage and disposal	4.11.1.1	1
Onsite storage of spent nuclear fuel	4.11.1.2[(a)]	1
Offsite radiological impacts of spent nuclear fuel and high-level waste disposal	4.11.1.3	1
Mixed-waste storage and disposal	4.11.1.4	1
Nonradioactive waste storage	4.11.1.4	1

[(a)] The environmental impacts of this issue for the period beyond the licensed life for reactor operations are discussed in NUREG-2157 (NRC 2014d).

Source: Table B-1 in Appendix B, Subpart A, to 10 CFR Part 51

The NRC staff's evaluation of the environmental impacts associated with spent nuclear fuel is addressed in two issues in Table 4-24, "Onsite storage of spent nuclear fuel" and "Offsite radiological impacts of spent nuclear fuel and high-level waste disposal." However, as explained later in this section, these two issues now incorporate the generic environmental impact determinations codified in the revised 10 CFR 51.23 pursuant to the Continued Storage Rule (79 FR 56238)[6].

The NRC staff did not identify any new and significant information related to waste management issues listed in Table 4-24 during its review of the applicant's ER (Exelon 2013), the site visit, or the scoping process. Therefore, there are no impacts related to these issues beyond those discussed in the GEIS (NRC 2013d) and the *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel*, Volumes 1 and 2 (NUREG–2157) (NRC 2014d). During the license renewal term for these Category 1 issues, the GEIS concludes that the impacts are SMALL.

4.13.1.1 10 CFR 51.23 (Continued Storage Rule) and 10 CFR 51, Subpart A, Table B-1 (License Renewal)

The NRC's findings regarding the environmental impacts associated with the renewal of a power reactor operating license are contained in Table B-1, "Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants." The table is located in Appendix B to Subpart A of 10 CFR Part 51, "Environmental Effect of Renewing the Operating License of a

[6] 79 FR 56238. U.S. Nuclear Regulatory Commission. "Continued Storage of Spent Nuclear Fuel." *Federal Register* 79 (182):56238–56263. September 19, 2014.

Nuclear Power Plant"[7] (Table B-1). In 1996, as part of the 10 CFR Part 51 license renewal rulemaking, the NRC determined that offsite radiological impacts of spent nuclear fuel and high-level waste disposal would be a Category 1 (generic) issue with no impact level assigned (61 FR 28467, 28495; June 5, 1996). The NRC analyzed the EPA generic repository standards and dose limits in existence at the time and concluded that offsite radiological impacts warranted a Category 1 determination (61 FR 28467, 28478; June 5, 1996). In its 2009 proposed rule, the NRC stated its intention to reaffirm that determination (74 FR 38117, 38127; July 31, 2009).

For the offsite radiological impacts resulting from spent fuel and high-level waste disposal and the onsite storage of spent fuel, which will occur after the reactors have been permanently shut down, the NRC's Waste Confidence Decision and Temporary Storage Rule (WCD and rule) (10 CFR 51.23) historically represented the Commission's generic determination that spent fuel can continue to be stored safely and without significant environmental impacts for a period of time after the end of the licensed life for operation. This generic determination meant that the NRC did not need to consider the storage of spent fuel after the end of a reactor's licensed life for operation in NEPA documents that support its reactor and spent fuel storage application reviews.

The NRC first adopted the WCD and rule in 1984. The NRC amended the decision and rule in 1990, reviewed them in 1999, and amended them again in 2010, as published in the FR (49 FR 34685, 34694; 55 FR 38472, 38474; 64 FR 68005; and 75 FR 81032 and 81037). The WCD and rule are codified in 10 CFR 51.23.

On December 23, 2010, the Commission published in the FR a revision of the WCD and rule to reflect information gained from experience in the storage of spent fuel and the increased uncertainty in the siting and construction of a permanent geologic repository for the disposal of spent fuel and high-level waste (75 FR 81032 and 81037). In response to the 2010 WCD and rule, the States of New York, New Jersey, Connecticut, and Vermont—along with several other parties—challenged the Commission's NEPA analysis in the decision, which provided the regulatory basis for the rule. On June 8, 2012, the United States Court of Appeals, District of Columbia Circuit in *New York* v. *NRC*, 681 F.3d 471 (D.C. Cir. 2012), vacated the NRC's WCD and rule, after finding that it did not comply with NEPA.

In response to the court's ruling, the Commission, in CLI-12-16 (NRC 2012a), determined that it would not issue licenses that rely upon the WCD and rule until the issues identified in the court's decision are appropriately addressed by the Commission. In CLI-12-16, the Commission also noted that the decision not to issue licenses only applied to final license issuance; all licensing reviews and proceedings should continue to move forward.

In addition, the Commission directed in SRM-COMSECY-12-0016 (NRC 2012b) that the NRC staff proceed with a rulemaking that includes the development of a generic EIS to support a revised WCD and rule and to publish both the EIS and the revised decision and rule in the FR within 24 months (by September 2014). The Commission indicated that both the EIS and the revised WCD and rule should build on the information already documented in various NRC studies and reports, including existing EAs that the NRC developed as part of the 2010 WCD and rule. The Commission directed that any additional analyses should focus on the issues identified in the court's decision. The Commission also directed that the NRC staff provide ample opportunity for public comment on both the draft EIS and the proposed WCD and rule.

[7] The Commission issued Table B-1 in June 1996 (61 FR 28467; June 5, 1996). The Commission issued an additional rule in December 1996 that made minor clarifying changes to, and added language inadvertently omitted from, Table B-1 (61 FR 66537; December 18, 1996). The NRC revised Table B-1 and other regulations in 10 CFR Part 51, relating to the NRC's environmental review of a nuclear power plant's license renewal application in a 2013 rulemaking (78 FR 37282; June 20, 2013).

As discussed above, in *New York* v. *NRC*, 681 F.3d 471 (D.C. Cir. 2012), the court vacated the Commission's WCD and rule (10 CFR 51.23). In response to the court's *vacatur*, the Commission developed a revised rule and associated *Generic Environmental Impact Statement for Continued Storage of Spent-Nuclear Fuel* (NUREG-2157). Before the issuance of the revised 10 CFR 51.23 and NUREG–2157, the NRC issued the 2013 final license renewal rule, which amended Table B-1—along with other 10 CFR Part 51 regulations—and stated that upon finalization of the revised Waste Confidence rule and accompanying technical analyses,[8] the NRC would make any necessary conforming amendments to Table B-1 (78 FR 37282, 37293; June 20, 2013).

On August 26, 2014, the Commission approved the Continued Storage Rule and associated *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel* (NUREG-2157, NRC 2014d). Subsequently, on September 19, 2014, the NRC published the final rule (79 FR 56238) in the FR along with NUREG-2157 (79 FR 53238, 56263). The Continued Storage Rule adopts the generic impact determinations made in NUREG-2157 and codifies the NRC's generic determinations regarding the environmental impacts of continued storage of spent nuclear fuel beyond a reactor's operating license (i.e., those impacts that could occur as a result of the storage of spent nuclear fuel at at-reactor or away-from-reactor sites after a reactor's licensed life for operation and until a permanent repository becomes available). As directed by 10 CFR 51.23(b), the impacts assessed in NUREG-2157 regarding continued storage are deemed incorporated by rule into this license renewal SEIS.

In the Continued Storage Rule, the NRC made conforming changes to the two environmental issues in Table B-1 that were impacted by the vacated Waste Confidence rule: "Onsite spent fuel" and "Offsite radiological impacts (spent fuel and high-level waste disposal)."[9] Although NUREG-2157 (the technical basis for the Continued Storage Rule) does not include high-level waste disposal in the analysis of impacts, it does address the technical feasibility of a repository in Appendix B of NUREG-2157 and concludes that a geologic repository for spent fuel is technically feasible and the same analysis applies to the feasibility of geologic disposal for high-level waste.

The Commission revised the Table B-1 finding for "Onsite storage of spent nuclear fuel" to add the phrase "during the license renewal term" to make clear that the SMALL impact is for the license renewal term only. Some minor clarifying changes were also made to the paragraph. The first paragraph of the column entry now reads, "During the license renewal term, SMALL. The expected increase in the volume of spent nuclear fuel from an additional 20 years of operation can be safely accommodated onsite during the license renewal term with small environmental impacts through dry or pool storage at all plants."

In addition, a new paragraph is added to address the impacts of onsite storage of spent fuel during the continued storage period. The second paragraph of the column entry reads, "For the period after the licensed life for reactor operations, the impacts of onsite storage of spent nuclear fuel during the continued storage period are discussed in NUREG-2157 and as stated in § 51.23(b), shall be deemed incorporated into this issue." The changes reflect that this issue covers the environmental impacts associated with the storage of spent nuclear fuel during the license renewal term as well as the period after the licensed life for reactor operations.

The Table B-1 entry for "Offsite radiological impacts of spent nuclear fuel and high-level waste disposal" also was revised to reclassify the impact determination as a Category 1 issue with no

[8] At the time of the 2013 final license renewal rule, the Continued Storage Rule was referred to as Waste Confidence.

[9] These two issues were renamed ''Onsite storage of spent nuclear fuel' and ''Offsite radiological impacts of spent nuclear fuel and high-level waste disposal,'' respectively, by the 2013 license renewal rule. See "Revisions to Environmental Review for Renewal of Nuclear Power Plant Operating Licenses," 78 FR 37282–37324 (June 20, 2013).

impact level assigned. The finding column entry for this issue includes reference to EPA's radiation protection standards for the high-level waste and spent nuclear fuel disposal component of the fuel cycle. Although the status of a repository, including a repository at Yucca Mountain, is uncertain and outside the scope of the generic environmental analysis conducted to support the Continued Storage Rule, the NRC believes that the current radiation standards for Yucca Mountain are protective of public health and safety and the environment.

The changes to these two issues finalize the Table B-1 entries that the NRC had intended to issue in its 2013 license renewal rulemaking, but was unable to because the 2010 Waste Confidence rule had been vacated.

NUREG-2157 concludes that deep geologic disposal remains technically feasible, while the bases for the specific conclusions in Table B-1 are found elsewhere (e.g., the 1996 rule that issued Table B-1 and the 1996 license renewal GEIS, which provided the technical basis for that rulemaking, as reaffirmed by the 2013 rulemaking and final license renewal GEIS). Based on the Continued Storage Rule, these two issues were revised accordingly in Table B-1.

4.13.1.2 CLI-14-08: Holding That Revised 10 CFR 51.23 and NUREG-2157 Satisfy NRC's NEPA Obligations for Continued Storage and Directing Staff to Account for Environmental Impacts In NUREG-2157

In CLI-14-08 (NRC 2014c), the Commission held that the revised 10 CFR 51.23 and associated NUREG-2157 cure the deficiencies identified by the court in *New York* v. *NRC* and stated that the rule satisfies the NRC's NEPA obligations with respect to continued storage for initial, renewed, and amended licenses for reactors.

As the Commission noted in CLI-14-08, the NRC staff must account for these environmental impacts before finalizing its licensing decision in this proceeding. To account for these impact determinations, the generic environmental impact determinations made pursuant to the Continued Storage Rule and the associated NUREG-2157 are deemed incorporated into this SEIS.

The NRC staff relies on the Continued Storage Rule and its supporting generic environmental impact statement (i.e., NUREG-2157) to provide the NEPA analyses of the environmental impacts of spent fuel storage at the reactor site or at an away-from-reactor storage facility beyond the licensed life for reactor operations. By virtue of revised 10 CFR 51.23, the impact determinations in NUREG–2157 regarding continued storage complete the analysis of the environmental impacts associated with spent fuel storage beyond the licensed life for reactor operations, and are deemed incorporated into this SEIS, as further described below.

4.13.1.3 At-Reactor Storage

The analysis in NUREG-2157 concludes that the potential impacts of at-reactor storage during the short-term timeframe (the first 60 years after the end of licensed life for operations of the reactor) would be SMALL (Section 4.20 of NUREG-2157). Further, the analysis in NUREG-2157 states that disposal of the spent fuel by the end of the short-term timeframe is the most likely outcome (see Section 1.2 of NUREG-2157).

However, the analysis in NUREG-2157 also evaluated the potential impacts of continued storage if the fuel is not disposed of by the end of the short-term timeframe. The analysis in NUREG–2157 determined that the impacts to historic and cultural resources from at-reactor storage during the long-term timeframe (the 100-year period after the short-term timeframe) and the indefinite timeframe (the period after the long-term timeframe) are dependent on factors that are unpredictable this far in advance and therefore concluded those impacts would be SMALL to LARGE (see Section 4.12 of NUREG-2157). Among other things, as discussed in

NUREG-2157, the NRC cannot accurately determine at this time what resources may be present or discovered at a continued storage site a century or more in the future and whether those resources will be historically or culturally significant to future generations. Additionally, impacts greater than SMALL could occur if the activities to replace an independent spent fuel storage installation (ISFSI) and the dry transfer system (DTS) adversely affect cultural or historic resources and the effects cannot be mitigated. As discussed in NUREG-2157, given the minimal size of an ISFSI and DTS, and the large land areas at nuclear power plant sites, licensees should be able to locate these facilities away from historic and cultural resources. Potential adverse effects on historic properties or impacts on historic and cultural resources could also be minimized through development of agreements, license conditions, and implementation of the licensee's historic and cultural resource management plans and procedures to protect known historic and cultural resources and address inadvertent discoveries during construction and replacement of these facilities. However, it may not be possible to avoid adverse effects on historic properties under the NHPA or impacts on historic and cultural resources under NEPA, and therefore, the analysis in NUREG-2157 concluded that impacts would be SMALL to LARGE (see Section 4.12.2 of NUREG-2157).

The analysis in NUREG-2157 also concludes that the impacts of nonradioactive waste in the indefinite timeframe would be SMALL to MODERATE, with the higher impacts potentially occurring if the waste from repeated replacement of the ISFSI and DTS exceeds local landfill capacity (see Section 4.15 of NUREG-2157). Although the NRC concluded that nonradioactive waste disposal would not be destabilizing (or LARGE), the range reflects uncertainty regarding whether the volume of nonradioactive waste from continued storage would contribute to noticeable waste management impacts over the indefinite timeframe when considered in the context of the overall local volume of nonradioactive waste.

As previously discussed, the NRC found in NUREG-2157 that disposal of the spent fuel is most likely to occur by the end of the short-term timeframe. Therefore, disposal during the long-term timeframe is less likely, and the scenario depicted in the indefinite timeframe—continuing to store spent nuclear fuel indefinitely—is unlikely. As a result, the most likely impacts of the continued storage of spent fuel are those considered in the short-term timeframe. In the unlikely event that fuel remains on site into the long-term and indefinite timeframes, the associated impact ranges in NUREG-2157 reflect the accordingly greater uncertainties regarding the potential impacts over these very long periods of time. Taking into account the impacts that the NRC considers most likely, which are SMALL; the greater uncertainty reflected in the ranges in the long-term and indefinite timeframes compared to the greater certainty in the SMALL findings; and the relative likelihood of the timeframes, the staff finds that the impact determinations for at-reactor storage presented in NUREG-2157 are deemed incorporated into this SEIS pursuant to 10 CFR 51.23.

4.13.1.4 Away-From-Reactor Storage

In NUREG-2157, the NRC concluded that a range of potential impacts could occur for some resource areas if the spent fuel from multiple reactors is shipped to a large (roughly 40,000 MT uranium) away-from-reactor ISFSI (see Section 5.20 of NUREG-2157). The ranges for some resources are driven by the uncertainty regarding the location of such a facility and the local resources that would be affected.

For away-from-reactor storage, the unavoidable adverse environmental impacts for most resource areas is SMALL across all timeframes, except for air quality, terrestrial resources, aesthetics, waste management, and transportation where the impacts are SMALL to MODERATE. Socioeconomic impacts range from SMALL (adverse) to LARGE (beneficial) and historic and cultural resource impacts could be SMALL to LARGE across all timeframes. The

potential MODERATE impacts on air quality, terrestrial wildlife, and transportation are based on potential construction-related fugitive dust emissions, terrestrial wildlife direct and indirect mortalities, terrestrial habitat loss, and temporary construction traffic impacts. The potential MODERATE impacts on aesthetics and waste management are based on noticeable changes to the viewshed from constructing a new away-from-reactor ISFSI, and the volume of nonhazardous solid waste generated by assumed facility ISFSI and DTS replacement activities for the indefinite timeframe, respectively. The potential LARGE beneficial impacts on socioeconomics are due to local economic tax revenue increases from an away-from-reactor ISFSI.

The potential impacts to historic and cultural resources during the short-term storage timeframe would range from SMALL to LARGE. The magnitude of adverse effects on historic properties and impacts on historic and cultural resources largely depends on where facilities are sited, what resources are present, the extent of proposed land disturbance, whether the area has been previously surveyed to identify historic and cultural resources, and if the licensee has management plans and procedures that are protective of historic and cultural resources. Even a small amount of ground disturbance (e.g., clearing and grading) could affect a small but significant resource. In most instances, placement of storage facilities on the site can be adjusted to minimize or avoid impacts on any historic and cultural resources in the area. However, the NRC recognizes that this may not always be possible. The NRC's site-specific environmental review and compliance with the NHPA process could identify historic properties, identify adverse effects, and potentially resolve adverse effects on historic properties and impacts on other historic and cultural resources. Under the NHPA, mitigation does not eliminate a finding of adverse effect on historic properties. The potential impacts to historic and cultural resources during the long-term and indefinite storage timeframes would also range from SMALL to LARGE. This range takes into consideration routine maintenance and monitoring (i.e., no ground-disturbing activities), the absence or avoidance of historic and cultural resources, and potential ground-disturbing activities that could affect historic and cultural resources. The analysis also considers uncertainties inherent in analyzing this resource area over long timeframes. These uncertainties include any future discovery of previously unknown historic and cultural resources, resources that gain significance within the vicinity and the viewshed (e.g., nomination of a historic district) due to improvements in knowledge, technology, and excavation techniques and changes associated with predicting resources that future generations will consider significant. If construction of a DTS and replacement of the ISFSI and DTS occurs in an area with no historic or cultural resource present or construction occurs in a previously disturbed area that allows avoidance of historic and cultural resources, then impacts would be SMALL. By contrast, a MODERATE or LARGE impact could result if historic and cultural resources are present at a site and, because they cannot be avoided, are impacted by ground-disturbing activities during the long-term and indefinite timeframes.

Impacts on Federally listed species, designated critical habitat, and EFH would be based on site-specific conditions and determined as part of consultations required by the ESA and the Magnuson-Stevens Fishery Conservation and Management Act.

Continued storage of spent nuclear fuel at an away-from-reactor ISFSI is not expected to cause disproportionately high and adverse human health and environmental effects on minority and low-income populations. As indicated in the Commission's policy statement on environmental justice, should the NRC receive an application for a proposed away-from-reactor ISFSI, a site-specific NEPA analysis would be conducted, and this analysis would include consideration of environmental justice impacts. Pursuant to 10 CFR 51.23, the impact determinations for away-from-reactor storage presented in NUREG-2157 are deemed incorporated into this SEIS.

4.13.1.5 Cumulative Impacts of Continued Storage

NUREG-2157 examines the incremental impact of continued storage on each resource area analyzed in NUREG-2157 in combination with other past, present, and reasonably foreseeable future actions. NUREG-2157 indicates ranges of potential cumulative impacts for multiple resource areas (see Section 6.5 of NUREG-2157). However, these ranges are primarily driven by impacts from activities other than the continued storage of spent fuel at the reactor site; the impacts from these other activities would occur regardless of whether spent nuclear fuel is stored during the continued storage period. In the short-term timeframe, which is the most likely timeframe for the disposal of the fuel, the potential impacts of continued storage for at-reactor storage are SMALL and would, therefore, not be a significant contributor to the cumulative impacts. In the longer timeframes for at-reactor storage, or in the less likely case of away-from-reactor storage, some of the impacts from the storage of spent nuclear fuel could be greater than SMALL. As noted in NUREG-2157, other Federal and non-Federal activities occurring during the longer timeframes include uncertainties as well. It is primarily these uncertainties (i.e., those associated with activities other than continued storage) that contribute to the ranges of potential cumulative impacts discussed throughout Chapter 6 of NUREG-2157 and summarized in Table 6-4 of NUREG-2157. Because, as stated above, the impacts from these other activities would occur regardless of whether continued storage occurs, the overall cumulative impact conclusions in NUREG-2157 would still be the stated ranges regardless of whether there are impacts of continued storage from any individual licensing action.

Taking into account the impacts that the NRC considers most likely, which are SMALL; the uncertainty reflected by the ranges in some impacts; and the relative likelihood of the timeframes, the impact determinations for cumulative impacts presented in NUREG-2157 are deemed incorporated into this SEIS pursuant to 10 CFR 51.23.

4.13.1.6 Conclusion

Based on the information discussed above, the impacts of continued storage of spent nuclear fuel are those presented in NUREG-2157 and are deemed incorporated into this SEIS pursuant to 10 CFR 51.23. In addition, the revised 10 CFR 51.23 and NUREG-2157 have gone through the rulemaking process that involved significant input from the public. Therefore, the NRC staff concludes that the information in NUREG-2157 provides the appropriate NEPA analyses of the potential environmental impacts associated with the continued storage of spent fuel beyond the licensed life for reactor operations at the Braidwood Station, Units 1 and 2.

The NRC staff concludes that the revised 10 CFR 51.23, which adopts the generic impact determination regarding continued storage from NUREG-2157, satisfies the NRC's NEPA obligations with respect to continued storage of spent nuclear fuel, as it pertains to the issues, "Onsite storage of spent nuclear fuel" and "Offsite radiological impacts of spent nuclear fuel and high-level waste disposal" for the environmental review associated with the license renewal for Braidwood.

4.13.2 No-Action Alternative

If the no-action alternative were implemented, Braidwood would cease operation at the end of the initial operating licenses, or sooner, and enter decommissioning. The plants, which are currently operating within regulatory limits, would generate less spent nuclear fuel and emit less gaseous and liquid radioactive effluents into the environment. In addition, following shutdown, the variety if potential accidents at the plants (radiological and industrial) would be reduced to a limited set associated with shutdown events and fuel handling and storage. In Section 4.11 of this SEIS, the NRC staff concluded that the impacts of continued operations on human health would be SMALL. In Section 4.11 of this SEIS, the NRC staff concluded that the impacts of

accidents would be SMALL. In Section 4.14.2 of this SEIS the NRC staff concludes that the impacts from decommissioning would be SMALL. Therefore, as radioactive emissions to the environment decrease, and the likelihood and variety of accidents decrease following shutdown and decommissioning, the NRC staff concludes that the risk to human health following plant shutdown would be SMALL.

4.13.3 New Nuclear Alternative

Construction

Construction-related nonradioactive waste would be generated during construction activities, and would be recycled or disposed of in approved landfills.

Operation

During normal plant operations, routine plant maintenance, and cleaning activities would generate radioactive low-level waste (LLW), spent nuclear fuel, and high-level waste as well as nonradioactive waste. Sections 3.1.4 and 3.1.5 discuss radioactive and nonradioactive waste management at Braidwood. Quantities of radioactive and nonradioactive waste generated by two new nuclear units would be comparable to that generated at Braidwood.

The GEIS concluded that the generation and management of solid radioactive and nonradioactive waste during the license renewal term are not expected to result in significant environmental impacts. Based on this information, the waste impacts from the new nuclear alternative would be SMALL (NRC 2013f).

4.13.4 Coal (Integrated Gasification Combined Cycle) Alternative

Construction

Construction-related debris would be generated during plant construction activities, and would be recycled or disposed of in approved landfills.

Operation

Coal combustion generates waste in the form of fly ash and bottom ash. In addition, equipment for controlling air pollution generates additional ash, spent selective catalytic reduction (SCR) catalyst, and scrubber sludge. The management and disposal of the large amounts of coal combustion waste is a significant part of the operation of a coal-fired power generating facility.

Although an IGCC facility is likely to use offsite disposal of coal combustion waste, some short-term storage of coal combustion waste (either in open piles or in surface impoundments) is likely to take place onsite, thus establishing the potential for leaching of toxic chemicals into the local environment.

The impacts of managing the substantial amounts of solid waste, especially fly ash and scrubber sludge generated during operation of this alternative would be MODERATE (NRC 1996). The amount of the construction waste would be small compared to the amount of waste generated during the operational stage and much of it could be recycled (i.e., marketed for beneficial use). Therefore, the staff concludes that the overall waste management impacts from construction and operation of this alternative would be SMALL to MODERATE.

4.13.5 Natural Gas Combined Cycle Alternative

Construction

Construction-related debris would be generated during plant construction activities, and would be recycled or disposed of in approved landfills.

Operation

Waste generation from NGCC technology would be minimal. The only significant waste generated at an NGCC power plant would be spent SCR catalyst, which is used to control nitrogen oxide emissions.

The spent catalyst would be regenerated or disposed of offsite. Other than spent SCR catalyst, waste generation at an operating natural gas-fired plant would be limited largely to typical operations and maintenance nonhazardous waste. Overall, the NRC staff concludes that waste impacts from the NGCC alternative would be SMALL.

4.13.6 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

Construction

Construction-related debris would be generated during construction activities, and would be recycled or disposed of in approved landfills.

Operation

Waste generation from NGCC technology is discussed in Section 4.13.5.

Waste generation from a combination of wind and solar PV alternatives would be minimal, consisting of debris from routine maintenance and the disposal of worn or broken parts. Based on this information, the NRC staff concludes that waste impacts from the construction and operation of a combination wind and solar PV alternative would be SMALL.

4.13.7 Purchased Power

The types of waste generated by the alternative electricity generation sources (i.e., coal, natural gas, nuclear, and wind) used in the purchased power alternative are discussed in Sections 4.13.3, 4.13.4, 4.13.5, and 4.13.6. Depending on types of power-generation plants used to provide the electricity for the purchased power alternative, the NRC staff concludes that the waste management impacts would range from SMALL to MODERATE.

4.14 Evaluation of New and Potentially Significant Information

New and significant information is information that must be new, based on a review of the GEIS (NRC 2013a), presenting a seriously different picture of the impacts from those envisioned in the GEIS (i.e., impacts of greater severity than impacts considered in the GEIS, considering their intensity and context).

In accordance with 10 CFR 51.53(c), the ER that the applicant submits must provide an analysis of the Category 2 issues in Table B–1 of 10 CFR Part 51, Subpart A, Appendix B. Additionally, it must discuss actions to mitigate any adverse impacts associated with the proposed action and environmental impacts of alternatives to the proposed action. In accordance with 10 CFR 51.53(c)(3), the ER does not need to contain an analysis of any Category 1 issue unless there is new and significant information on a specific issue.

The NRC process for identifying new and significant information is described in NUREG–1555, Supplement 1, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1: Operating License Renewal* (NRC 2013k). The search for new information includes:

- review of an applicant's ER and the process for discovering and evaluating the significance of new information;
- review of public comments;
- review of environmental quality standards and regulations;
- coordination with Federal, state, Tribal, and local environmental protection and resource agencies; and
- review of technical literature.

New information that the staff discovers is evaluated for significance using the criteria set forth in the GEIS. For Category 1 issues, in which new and significant information is identified, reconsideration of the conclusions for those issues is limited in scope to assessment of the relevant new and significant information. The scope of this assessment does not include those facets of an issue that are not affected (or relevant to) by the new information.

The NRC staff reviewed the discussion of environmental impacts associated with operation during the renewal term in the GEIS and has conducted its own independent review, including a public involvement process (e.g., public meetings) to identify new and significant issues for the Braidwood LRA environmental review. The NRC staff has not identified new and significant information on environmental issues related to operation of Braidwood during the renewal term. The NRC staff also determined that information provided during the public comment period did not identify any new issue that requires site-specific assessment.

4.15 Impacts Common to All Alternatives

This section describes the impacts that are considered common to all alternatives discussed in this SEIS, including the proposed action and replacement power alternatives. The continued operation of a nuclear power plant and replacement fossil fuel power plants both involve mining, processing, and the consumption of fuel, which results in comparative impacts (NRC 2013f). The termination of operations and the decommissioning of both a nuclear power plant and replacement fossil fueled power plants are also discussed in the following sections, as well as GHG emissions.

4.15.1 Fuel Cycles

This section describes the environmental impacts associate with the fuel cycles of the proposed action and replacement power alternatives. Most replacement power alternatives employ a set of steps in the utilization of its fuel source, which can include extraction, transformation, transportation, and combustion. Emissions generally occur at each stage of the fuel cycle (NRC 2013f).

4.15.1.1 Uranium Fuel Cycle

The uranium fuel cycle issues applicable to Braidwood are discussed below and listed in Table 4–25 for Category 1 issues. Table B-1 of Appendix B to Subpart A of 10 CFR Part 51 contains more information on these issues.

Table 4–25. Issues Related to the Uranium Fuel Cycle

Issue	GEIS Section	Category
Offsite radiological impacts – individual impacts from other than the disposal of spent fuel and high-level waste	4.12.1.1	1
Offsite radiological impacts – collective impacts from other than the disposal of spent fuel and high-level waste	4.12.1.1	1
Nonradiological impacts of the uranium fuel cycle	4.12.1.1	1
Transportation	4.12.1.1	1

Source: Table B-1 in Appendix B, Subpart A, to 10 CFR Part 51

The uranium fuel cycle includes uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials, and management of LLWs and high-level wastes related to uranium fuel cycle activities. The generic potential impacts of the radiological and nonradiological environmental impacts of the uranium fuel cycle and transportation of nuclear fuel and wastes are described in detail in NUREG–1437, *Generic Environmental Impact Statement* (GEIS) *for License Renewal of Nuclear Plants* (NRC 2013f).

The NRC staff did not identify any new and significant information related to the uranium fuel cycle issues listed in Table 4-25 during its review of the applicant's ER (Exelon 2013), the site visit, or the scoping process. Therefore, there are no impacts related to these issues beyond those discussed in the GEIS. For these Category 1 issues, the GEIS concludes that the impacts are SMALL, except for the issue, "Offsite radiological impacts - collective impacts," which the NRC has not assigned an impact level. This issue assesses the 100-year radiation dose to the U.S. population (i.e., collective effects or collective dose) from radioactive effluent released as part of the uranium fuel cycle for a nuclear power plant during the license renewal term compared to the radiation dose from natural background exposure. It is a comparative assessment for which there is no regulatory standard to base an impact level.

4.15.1.2 Replacement Power Fuel Cycles

Fossil Fuel Energy Alternatives

Fuel cycle impacts for a fossil-fuel-fired plant result from the initial extraction of fuel, cleaning and processing of fuel, transport of fuel to the facility, and management and ultimate disposal of solid wastes from fuel combustion. These impacts are discussed in more detail in Section 4.12.1.2 of the GEIS (NRC 2013f) and can generally include:

- significant changes to land use and visual resources;
- impacts to air quality, including release of criteria pollutants, fugitive dust, VOCs, and coalbed methane in the atmosphere;
- noise impacts;
- geology and soil impacts due to land disturbances and mining;
- water resource impacts, including degradation of surface water and groundwater quality;
- ecological impacts, including loss of habitat and wildlife disturbances;
- historic and cultural resources impacts within the mine footprint;

- socioeconomic impacts from employment of both the mining workforce and service and support industries;
- environmental justice impacts;
- health impacts to workers from exposure to airborne dust and methane gases; and
- the generation of coal and industrial wastes.

New Nuclear Energy Alternatives

Fuel cycle impacts for a nuclear plant result from the initial extraction of fuel, transport of fuel to the nuclear facilities, and management and ultimate disposal of spent fuel. The environmental impacts of the uranium fuel cycle are discussed above, in Section 4.14.1.1.

Renewable Energy Alternatives

The term “fuel cycle” has varying degrees of relevance for renewable energy facilities. The term has meaning for renewable energy technologies that rely on combustion of fuels such as biomass grown or harvested for the express purpose of power production. The term is somewhat more difficult to define for renewable technologies such as wind, solar, geothermal, and ocean wave and current. Those natural energy resources exist regardless of any effort to harvest them for electricity production. The common technological strategy for harvesting energy from such natural resources is to convert the kinetic or thermal energy inherent in that resource to mechanical energy or torque. The torque is then applied directly (e.g., as in the case of a wind turbine) or indirectly (e.g., for those facilities that utilize conventional steam cycles to drive turbines that drive generators) to produce electricity. However, because those renewable technologies capture very small fractions of the total kinetic or thermal energy contained in those resources, impacts from the presence or absence of the renewable energy technology are often indistinguishable (NRC 2013f).

4.15.2 Terminating Power Plant Operations and Decommissioning

This section describes the environmental impacts associated with the termination of operations and the decommissioning of a nuclear power plant and replacement power alternatives. All operating power plants will terminate operations and be decommissioned at some point after the end of their operating life or after a decision is made to cease operations. For the proposed action, license renewal would delay this eventuality for an additional 20 years beyond the current license period.

4.15.2.1 Existing Nuclear Power Plant (Proposed Action)

Environmental impacts from the activities associated with the decommissioning of any reactor before or at the end of an initial or renewed license are evaluated in Supplement 1 of NUREG-0586, *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities Regarding the Decommissioning of Nuclear Power Reactors* (NRC 2002b). Additionally, the incremental environmental impacts associated with decommissioning activities resulting from continued plant operation during the renewal term are discussed in the GEIS (NRC 2013f).

Table 4–26 lists the Category 1 issues in Table B-1 of 10 CFR Part 51, Subpart A, Appendix B that are applicable to Braidwood’s decommissioning following the license renewal term.

Table 4–26. Issues Related to Decommissioning

Issue	GEIS Section	Category
Radiation doses	4.12.2.1	1
Waste management	4.12.2.1	1
Air quality	4.12.2.1	1
Water quality	4.12.2.1	1
Ecological resources	4.12.2.1	1
Socioeconomic impacts	4.12.2.1	1

Source: Table B-1 in Appendix B, Subpart A, to 10 CFR Part 51

Decommissioning would occur whether Braidwood were shut down at the end of its current operating license or at the end of the period of the license renewal term. Exelon stated in its ER (Exelon 2013) that it is not aware of any new and significant information on the environmental impacts of Braidwood during the license renewal term. The staff has not found any new and significant information during its independent review of Exelon's ER, the site visit, or the scoping process. Therefore, the NRC staff concludes that there are no impacts related to these issues, beyond those discussed in the GEIS (license renewal). For all of these issues, the NRC staff concluded in the GEIS that the impacts are SMALL (NRC 2013f).

4.15.2.2 Replacement Power Plants

Fossil Fuel Energy Alternatives

The environmental impacts from the termination of power plant operations and decommissioning of a fossil-fuel-fired plant are dependent on the facility's decommissioning plan. General elements and requirements for a fossil fuel plant decommissioning plan are discussed in Section 4.12 of the GEIS (license renewal) and can include the removal of structures to at least 3 ft (1 m) below grade, removal of all coal, combustion waste, and accumulated sludge, removal of intake and discharge structures, and the clean-up and remediation of incidental spills and leaks at the facility. The decommissioning plan outlines the actions necessary to restore the site to a condition equivalent in character and value to the greenfield or existing industrial site on which the facility was first constructed (NRC 2013f). A Greenfield site is a vacant land that has never been developed or was formerly occupied by farms or low-density development that left the land free of environmental contamination. A Greenfield site is typically located in suburban or ex-urban areas and can be less costly to develop than an existing industrial site that is often located in urban areas.

The environmental consequences of decommissioning are discussed in the GEIS (license renewal) and can generally include:

- short-term impacts on air quality and noise from the deconstruction of facility structures;
- short-term impacts on land use and visual resources;
- long-term reestablishment of vegetation and wildlife communities;
- socioeconomic impacts due to decommissioning workforce and the long-term loss of jobs; and
- elimination of health and safety impacts on operating personnel and general public.

New Nuclear Alternatives

Termination of operations and decommissioning impacts for a nuclear plant include all activities related to the safe removal of the facility from service and the reduction of residual radioactivity to a level that permits release of the property under restricted conditions or unrestricted use and termination of a license (NRC 2013f). The environmental impacts of the uranium fuel cycle are discussed above, in Section 4.15.1.1.

Renewable Alternatives

Termination of power plant operation and decommissioning for renewable energy facilities would be similar to the impacts discussed for fossil-fuel-fired plants above. Decommissioning would involve the removal of facility components and operational wastes and residues to restore the site to a condition equivalent in character and value to the site on which the facility was first constructed (NRC 2013f).

4.15.3 Greenhouse Gas Emissions and Climate Change

The following sections discuss: (a) GHG emissions released from operation of Braidwood and alternatives and (b) the environmental impacts that could occur from changes in climate conditions. The cumulative impacts of GHG emissions on climate are discussed in Section 4.16.11, Global Climate Change.

4.15.3.1 Greenhouse Gas Emissions From the Proposed Project and Alternatives

Gases found in the Earth’s atmosphere that trap heat and play a role in Earth’s climate are collectively termed GHGs. Greenhouse gases include carbon dioxide, methane, nitrous oxide, water vapor, and fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride. Earth’s climate responds to changes in concentration of GHG in the atmosphere as GHGs affect the amount of energy absorbed and heat trapped by the atmosphere. Increasing GHG concentration in the atmosphere generally increases Earth’s surface temperature. Atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have significantly increased since 1750 (Solomon et al. 2007). Carbon dioxide, methane, nitrous oxide, HFCs, PFCs, and sulfur hexafluoride (termed long-lived GHGs) are well-mixed throughout Earth’s atmosphere and their impact on climate is long lasting as a result of their long atmospheric lifetime (74 FR 66496). Carbon dioxide is of primary concern for global climate change due to its long atmospheric lifetime and it is the primary gas emitted as a result of human activities. Climate change research indicates that the cause of the Earth’s warming over the last 50 years is the buildup of GHGs in the atmosphere resulting from human activities (USGCRP 2014).

4.15.3.2 Existing Nuclear Power Plant (Proposed Action)

Plant operations at Braidwood release GHG emissions (primarily carbon dioxide) from stationary combustion sources, such as diesel generators, auxiliary boilers, AFW pumps, and diesel engines. Mobile combustion sources include vehicle traffic, such as worker and delivery vehicles. Other sources include fluorinated gases used in refrigeration systems and in electrical transmission and distribution systems. These fluorinated gases are typically emitted in small quantities but their impacts could be substantial because of their high global warming potential.

The GHG emissions generated directly and indirectly by an entity can be classified into three “Scopes,” based on the source of the emissions (EPA 2013a). Scope 1 GHG emissions are direct emissions that are owned or controlled by the entity, which include emissions from fossil fuels burned onsite, emissions from entity-owned or agency-leased vehicles, and other direct sources. Scope 2 GHG emissions are indirect emissions resulting from the generation of

electricity, heating and cooling, or steam generated off site but purchased by the reporting entity. Scope 3 GHG emissions are indirect emissions from sources not owned or directly controlled by the reporting entity but related to the entity's activities such as vendor supply chains, delivery services, outsourced activities, and employee travel and commuting. Greenhouse gas emissions from nuclear power plants, including Braidwood, belong to all three Scopes. Annual total GHG emissions at Braidwood are presented in Table 4–27 for the 2008-2012 period (based on the specific fuel-mix (energy related) that is purchased by Braidwood, related to indirect emission). Total (direct plus indirect) GHG emissions include permitted combustion sources (diesel generators and auxiliary boilers), fugitive gas emissions, direct fluorinated gases, indirect purchased electricity, and ozone depleting substances from refrigerants. However, total emissions do not include GHG emissions from mobile sources because Exelon does not compile site-specific data for such sources (Exelon 2014i). There are approximately 890 employees at Braidwood and about 80 percent of the employees live in Will, Grundy, or Kankakee Counties in Illinois (within 50 mi of Braidwood Station). The NRC staff estimates annual GHG emissions resulting from employee vehicles to be approximately 8,400 MT carbon dioxide equivalents.

Table 4–27. Estimated GHG Emissions From Operations at Braidwood Station

Year	CO_2e (MT/year)
2008	20,413
2009	20,888
2010	25,040
2011	25,815
2012	35,029

Source: Exelon 2014i

4.15.3.3 No-Action Alternative

The no-action alternative represents a decision by the NRC not to renew the operating license of a nuclear power plant beyond the current operating license term. At some point, all nuclear plants will terminate operations and undergo decommissioning. Under the no-action alternative, plant operations for Braidwood would terminate at or before the end of the current license term (NRC 2013f). When the plant stops operating, there will be a reduction in GHG emissions from activities related to plant operation, such as use of diesel generators and employee vehicles. Greenhouse gas emissions are anticipated to be less than the emissions presented in Table 4–27.

4.15.3.4 New Nuclear Alternative

As discussed in Section 2.2.2.1, the NRC staff evaluated the new nuclear power plant alternative that would consist of two units with an approximate generating capacity of 1,120 MWe each. The GEIS presents lifecycle GHG emissions associated with nuclear power generation. As presented in Tables 4.12-4 through 4.12-6 of the GEIS, lifecycle [10] GHG emissions from nuclear power generation can range from 1 to 288 g carbon equivalent per kilowatt-hour (C_{eq}/kWh). Operations of nuclear power plants do not burn fossil fuels to generate

[10]Lifecycle carbon emissions analyses consider construction, operation, decommissioning, and associated processing of fuel (gas, coal, etc.).

electricity and so do not directly emit GHG emissions. Sources of GHG emissions include stationary combustion sources (e.g., emergency diesel generators, auxiliary boilers) and mobile sources (worker vehicles, onsite heavy equipment and support vehicles, and delivery of materials and disposal of wastes). As discussed in Section 4.3.3.1, it is anticipated that air emissions from a new nuclear power plant would be similar to those from Braidwood.

4.15.3.5 Coal (Integrated Gasification Combined Cycle) Alternative

As discussed in Section 2.2.2.2, the NRC staff evaluated the IGCC plant alternative that would consist of four units with a total output of 2,472 MWe. The IGCC alternative would release GHGs. The NRC staff estimates that operation of four IGCC units will directly emit about 14.3 million tons (approximately 12.9 million MT) per year of carbon dioxide equivalents. Emissions were estimated for the IGCC alternative without CCS. Among the alternatives, GHG emissions are the highest from IGCC plants. As described in Chapter 2, the IGCC alternative assumes that the plants may install CCS technology at some point in the future, which would reduce carbon dioxide emissions considerably. The DOE's National Energy Technology Laboratory (NETL) performed a study to establish the cost and performance for a range of carbon dioxide capture levels (up to 97 percent) for new IGCC power plant (NETL 2013a). The study identified technical configurations that were tailored to achieve a specific level of carbon capture.

4.15.3.6 Natural Gas Combined Cycle Alternative

As discussed in Section 2.2.2.3, the NRC staff evaluated an NGCC alternative that consists of five NGCC 560-MWe units (total 2800 MW). The GEIS presents lifecycle GHG emissions associated with natural gas power generation. As presented in Table 4.12-5 of the GEIS, lifecycle GHG emissions from natural gas can range from 120 to 930 g C_{eq}/kWh. The NRC staff estimates that operation of the NGCC alternative directly will emit about 7.9 million tons (approximately 7.2 million MT) per year of carbon dioxide equivalent emissions.

4.15.3.7 Combination of Interconnected Wind Farms, Solar Photovoltaic, and Natural Gas

For the combination alternative, it is assumed that the majority of the GHG emissions result from the NGCC portion only because renewable portions (wind and solar PV) do not burn fossil fuels to generate electricity. The NGCC portion of the combination alternative would consist of 360 MWe of generating capacity. The NRC staff estimates that operation of the combination alternative will directly emit 1.0 million tons (0.9 million MT) per year of carbon dioxide equivalents.

4.15.3.8 Purchased Power

Purchased power would come from common types of existing technology (coal, natural gas, and nuclear) within the ROI and it is not likely that new facilities would be constructed to replace Braidwood. GHG emissions from purchased power will vary and depended on the type and combination of technology purchased power comes from. In 2012, coal, natural gas, and nuclear power accounted for 37, 30, and 19 percent share, respectively, of total U.S. electricity generation (EIA 2014). Using these percent shares for the purchased power alternative, the NRC staff estimates 7.7 million tons (6.9 million MT) per year of carbon dioxide equivalents will be emitted. However, GHG emissions may be greater or less than this estimate and will depend on the technology from which the purchased power comes from.

4.15.3.9 Summary of GHG Emissions From the Proposed Action and Alternatives

Table 4–28 presents the direct uncontrolled GHG emissions from operation of the proposed action and alternatives. GHG emissions from the proposed action (continued operation at Braidwood) and the new nuclear alternative would be lowest. The IGCC alternative would

release the highest emissions, followed by the NGCC alternative. GHG emissions from the combination alternative would be about one-tenth of the NGCC alternative. GHG emissions for the IGCC, NGCC, combination, and purchased power alternatives are higher than those for the proposed action and a new nuclear alternative by several orders of magnitude.

Table 4–28. Direct Uncontrolled GHG Emissions From Operation of the Proposed Action and Alternatives

Technology	CO_2e (MT/year)
Braidwood Station continued operation	1,230
New Nuclear	1,230
NGCC	13.0×10^6
IGCC	7.2×10^6
Combination Alternative [a]	1.0×10^6
Purchased Power [b]	6.9×10^6

[a] Only NGCC portion of GHG emissions are presented.
[b] Assumed 10% NGCC, 80% Wind, and 10% Solar in generating capacity

4.15.3.10 Climate Change Impacts to Resource Areas

Climate change is the decades or longer change in climate measurements (temperature, precipitation, etc.) that has been observed on a global, national, and regional level (EPA 2012; Solomon et al. 2007; USGCRP 2014). Climate change can vary regionally, spatially, and seasonally depending on local, regional, and global factors. Just as the regional climate differs throughout the world, the impacts of climate change can vary between locations.

On a global level, from 1880 to 2012, average surface temperatures increased by 0.85 °C, and an increase in annual average precipitation (ranging from 1.01 to 2.77 mm/year per decade) has been observed for the 1901 to 2008 time period (Stocker et al. 2013). The observed global change in average surface temperature and precipitation has been accompanied by an increase in sea surface temperatures, a decrease in global glacier ice, increase in sea level, and changes in extreme weather events. Such extreme events include an increase in frequency of heat waves, heavy precipitation, and minimum and maximum temperatures (EPA 2012a; Karl et al. 2009; Solomon et al. 2007; USGCRP 2014).

In the United States, the U.S. Global Change Research Program (USGCRP) reports that from 1895 to 2012, average surface temperature has increased by 1.3 °F to 1.9 °F (0.72 to 1.06 °C), and since 1900, average annual precipitation has increased by 5 percent (USGCRP 2014). On a seasonal basis, warming has been the greatest in winter and spring. From 1895 to 2001, an increase in the length of the freeze-free season, the period between the last occurrence of 0 °C (32 °F) in the spring and first occurrence of 0 °C (32 °F) in the fall has been observed for the contiguous United States; between 1991 and 2011 the average freeze-free season was 10 days longer than between 1901 and 1960 (USGCRP 2014). Since the 1970s, the United States has warmed at a faster rate as the average surface temperature rose at an average rate of 0.17 to 0.25 °C (0.31 to 0.45 °F) per decade. In addition, the year 2012 was the warmest on record (USGCRP 2014). Observed climate related changes in the United States include increases in the frequency and intensity of heavy precipitation, earlier onset of spring snowmelt and runoff, rise of sea level in coastal areas of the U.S., increase in occurrence of heat waves, and a

decrease in occurrence of cold waves (EPA 2012a; Karl et al. 2009; NOAA 2013a; USGCRP 2014).

Temperature data indicates that the Midwest region, where Braidwood is located, experienced a 0.06 ˚C (0.11 ˚F) per decade increase in annual mean temperature during the 1900-2010 period (NOAA 2013b). Temperature data for the recent past indicates an increased rate of warming for the Midwest: 0.12 C (0.22 F) per decade for the 1950–2010 time period and a 0.26 ˚C (0.47 F) temperature increase for the 1979-2010 time period. Average annual precipitation data for the Midwest exhibits an increasing trend of 0.31 inches per decade for the long term period (1895–2011) (NOAA 2013b). Precipitation data over the 1958–2007 period exhibit clear trends toward more very heavy precipitation events (defined as the heaviest 1 percent of all daily events) for the nation as a whole, and particularly in the Northeast and Midwest. At Braidwood, for the 1973–2013 period, an upward trend in ambient annual average temperature has also been observed (Exelon 2014i).

Future GHG emission concentration and climate models are commonly used to project possible climate change. Climate models indicate that over the next few decades, temperature increases will continue due to current GHG emissions concentrations in the atmosphere (USGCRP 2014). Over the longer term, the magnitude of temperature increases and climate change effects will depend on both past and future GHG emission scenarios (Karl et al. 2009; Solomon et al. 2007; USGCRP 2014). Climate models project a continued increase in global surface temperatures, more frequent and long-lasting heat waves, continued increase in sea level, continued decline in arctic sea ice, an increase in heavy precipitation events, and an increased frequency of severe droughts.

For the license renewal period of Braidwood, climate model simulations (between 2021–2050 relative to the reference period (1971-1999)) indicate an increase in annual mean temperature in the Midwest region of 2.5–3.5 ˚F (NOAA 2013b). The predicted increase in temperature during this time period occurs for all seasons with the largest increase occurring in the summertime (June, July, and August). Climate model simulations (for the time period 2021–2050) suggest spatial differences in annual mean precipitation changes for the Midwest with northern areas experiencing an increase in precipitation and the southern areas experiencing a decrease in precipitation. For Illinois, the models indicate a 0-3 percent increase in annual mean precipitation with fall, winter, and spring seasons experiencing precipitation change increases and the summer season experiencing a decrease in precipitation. However, these changes in precipitation were not significant and the models indicate changes that are less than normal year to year variations (NOAA 2013b). While future regional changes in precipitation are difficult to predict, the USGCRP reports that storm tracks are expected to shift northward, increases in heavy precipitation events will continue, the number of dry days between rainfalls will increase, and an increase in drought is expected (USGCRP 2014).

Changes in climate have broader implications for public health, water resources, land use and development, and ecosystems. For instance, changes in precipitation patterns and increase in air temperature can affect water availability and quality, distribution of plant and animal species, and land-use patterns and land-cover, which can in turn affect terrestrial and aquatic habitats. The sections below discuss how future climate change may impact air quality, water resources, land-use, terrestrial resources, aquatic resources, and human health in the region of interest for Braidwood Station. Although there is uncertainty in the exact future climate change scenario, the discussions provided below demonstrate the potential implications of climate change on resources.

Air Quality

Air pollutant formation partially depends on the temperature and humidity of the atmosphere and is a result of the interactions between hourly changes in the physical and dynamic properties of the atmosphere, atmospheric circulation features, wind, topography, and energy use (Parry et al. 2007). In addition, air pollutant concentrations (i.e., after formation) are sensitive to winds, temperature, humidity, and precipitation (74 FR 66496). Hence, climate change can impact air quality as a result of the changes in meteorological conditions.

Ozone has been found to be particularly sensitive to climate change (EPA 2009; USGCRP 2014). Ozone is formed as a result of the chemical reaction of nitrogen oxides and VOCs in the presence of heat and sunlight. Sunshine, high temperatures, and air stagnation are favorable meteorological conditions to higher levels of ozone (EPA 2009). The emission of ozone precursors also depends on temperature, wind, and solar radiation (Parry et al. 2007); both nitrogen oxide and biogenic VOC emissions are expected to be higher in a warmer climate (EPA 2009). Warmer climate and weaker air circulation are conducive to higher ozone levels. Regional air quality modeling indicates that the northern regions of the United States can experience an increase in ozone concentration by the year 2050, but an increase in $PM_{2.5}$ concentration around the Great Lakes region (Tagaris et al. 2009; USGCRP 2014). However, air quality projections (particularly ozone and $PM_{2.5}$) are uncertain and indicate that concentrations are driven primarily by emissions rather than by physical climate change (Stocker et al. 2013). The combination of higher temperatures, stagnant air masses, sunlight, and emissions of precursors may make it difficult to meet ozone National Ambient Air Quality Standards (Karl et al. 2009).

Land Use

Anthropogenic land use is both a contributor to climate change as well as a receptor of climate change impacts (Dale 1997). As described previously in this section, the Midwest will likely experience rising temperatures and heavier precipitation events during the proposed license renewal period. Agriculture (the major land use in the vicinity of Braidwood) and growing urban areas will further exacerbate these changes by continuing to inhibit natural ecosystem functions that could moderate climate change effects. For instance, air temperatures and near-surface moisture levels change in areas where natural vegetation is converted to agricultural use, and in the Midwest, higher temperatures have been observed as a result of converting land to agricultural use (USGCRP 2014). The USGCRP (2014) indicates that land use changes, such as the continued expansion of urban areas, paired with climate change effects, such as heavier precipitation events, can exacerbate climate change effects, including reduced water filtration into the soil and increased surface runoff. While anthropogenic land uses will contribute to climate change in these and other ways, land uses will also be affected by climate change in several ways. For instance, plant winter hardiness zones are likely to shift one-half to one full zone by the end of the proposed license renewal period (USGCRP 2014). This will affect the ability to grow certain crops as the Midwest will likely contain plants now associated with the Southeast by the end of the century (USGCRP 2014). Water availability will likely affect urban areas, which are growing rapidly in the Midwest. Will County, in which Braidwood is located, is expected to grow by 60 percent in the next 20 years (Will County 2011). This growth will likely lead to water use conflicts as climate change reduces water availability and the growing population requires more water.

Water Resources

Predicted changes in the timing, intensity, and distribution of precipitation would be likely to result in changes in surface water runoff affecting water availability across the Midwest. As discussed above, the Midwest may experience increased precipitation during the fall, winter

and spring. As cited by the USGCRP, the loss of moisture from soils because of higher temperatures, as is projected for the Midwest, along with evapotranspiration from vegetation is likely to increase the frequency, duration, and intensity of droughts across the region into the future (Karl et al. 2009; USGCRP 2014); such conditions can reduce the amount of water available for surface runoff and streamflow. Runoff and streamflow at a regional scale for the Midwest region indicate no clear trend during the last half century; however, annual runoff and river flow are projected to increase in the upper Midwest (USGCRP 2014). Climate change impacts on groundwater availability depend on basin geology, frequency and intensity of high-rainfall periods, recharge, soil moisture, and groundwater–surface water interactions (USGCRP 2014). Precipitation and evapotranspiration are key drivers in aquifer recharge. Although exact responses in groundwater storage and flow to climate change are not well-understood, recent studies have started to consider the effects that climate change have on groundwater resources (USGCRP 2014).

Terrestrial Resources

As described above, the Midwest will likely experience rising temperatures and heavier precipitation events during the proposed license renewal period. As the climate changes, terrestrial resources will either need to be able to tolerate the new physical conditions or shift their population range to new areas with a more suitable climate. Scientists currently estimate that species are shifting their ranges at a rate of between 6.1 to 11 m (20 to 36 ft) in elevation per decade and 6.1 to 16.9 km (3.8 to 10.5 mi) in latitude per decade (Chen et al. 2011; Thuiller 2007). While some species may readily adapt to a changing climate, others may be more prone to experience adverse effects. For example, species whose ranges are already limited by habitat loss or fragmentation or who require very specific environmental conditions may not be able to successfully shift their ranges over time. Migratory birds that travel long distances may also be disproportionately affected because they may not be able to pick up on environmental clues that a warmer, earlier spring is occurring in the United States while overwintering in tropical areas. Fraser et al. (2013) found that songbirds overwintering in the Amazon did not leave their winter sites earlier, even when spring sites in the Eastern United States experienced a warmer spring. As a result, the song birds missed periods of peak food availability. Habitat ranges for forest systems in the Midwest, such as paper birch, balsam fir, and black spruce, are projected to decline across the Midwest as they shift northward, and species that are common farther south, such as oaks and pines, will expand their range north into the Midwest region (USGCRP 2014). Special status species and habitats, such as those that are Federally protected by the ESA, would likely be more sensitive to climate changes because these species' populations are already experiencing threats that are endangering their continued existence throughout all or a significant portion of their ranges. Climate changes could also favor nonnative, invasive species and promote population increases of insect pests and plant pathogens, which may be more tolerant to a wider range of climate conditions.

Aquatic Resources

The potential effects of climate change, whether from natural cycles or man-made activities could result in changes that would affect aquatic resources in the Kankakee River. Raised air temperatures could result in higher water temperatures in the river and its tributaries. Higher water temperatures would increase the potential for thermal effects on aquatic biota and could exacerbate existing environmental stressors, such as excess nutrients, sedimentation, and lowered dissolved oxygen associated with eutrophication (NCADAC 2013). The Midwest will likely experience an increased frequency of extreme rainfall events, which will cause erosion and could lead to a decline in water quality (USGCRP 2014). Species that require cleaner waters, such as freshwater mussels, could experience further population declines. The USGCRP (2014) predicts habitat loss and local extinctions of fish and other aquatic species

throughout the United States from the combined effects of water withdrawal and climate change. Shifts in species assemblages and distributions are also likely as climate change continues (USGCRP 2014), which could alter the balance of the aquatic community in the Kankakee River. As discussed above under "terrestrial resources," special status species, such as those that are Federally protected under the ESA, would be more sensitive to climate changes. Invasions of non-native species that thrive under a wide range of environmental conditions could further disrupt the current composition of aquatic communities (NRC 2013f).

Historic and Cultural Resources

Increases in river and lake water levels because of changes in meteorological conditions due to climate change could result in the loss of historic and cultural resources from flooding, erosion, or inundation. Because of water-level changes, some resources could be lost before they could be documented or otherwise studied. However, the limited extent of climate change that may occur during the 20-year license renewal term would not likely result in any significant loss of historic and cultural resources at Braidwood.

Socioeconomics

Rapid changes in climate conditions could have an impact on the availability of jobs in certain industries. For example, tourism and recreation are major job creators in some regions, bringing billions of dollars to regional economies. Across the nation, fishing, hunting, and other outdoor activities make important economic contributions to rural economies and are also a part of the cultural tradition. A changing climate would mean reduced opportunities for some activities in some locations and expanded opportunities for others. Hunting and fishing opportunities could also change as animals' habitats shift and as relationships among species are disrupted by their different responses to climate change (USGCRP 2014).

Water-dependent recreation could also be affected (Karl et al. 2009). The USGCRP reports that increasing heat and humidity associated with climate change in parts of the Midwest region by the year 2050 could create unfavorable conditions for summertime outdoor recreation and tourism activity (USGCRP 2014). However, the limited extent of climate change that may occur during the 20-year license renewal term would not likely to cause any significant changes in socioeconomic conditions in the vicinity of Braidwood.

Human Health

Increasing temperatures due to changes in climate conditions could have an impact on human health. However, changes in climate conditions that may occur during the license renewal term will not result in any change to the impacts discussed in Section 4.11 from Braidwood's radioactive and nonradioactive effluents.

Environmental Justice

Rapid changes in climate conditions could disproportionately affect minority and low-income populations. The USGCRP (Karl et al. 2009) indicates that "infants and children, pregnant women, the elderly, people with chronic medical conditions, outdoor workers, and people living in poverty are especially at risk from a variety of climate-related health effects." Examples of these effects include increased heat stress, air pollution, extreme weather events, and diseases carried by food, water, and insects. The greatest health burdens related to climate change are likely to fall on the poor, especially those lacking adequate shelter and access to other resources such as air conditioning. Elderly people on fixed incomes, who are more likely to be poor, are more likely to have debilitating chronic diseases or limited mobility. In addition, the elderly have a reduced ability to regulate their own body temperature or sense when they are too hot. According to the USGCRP (Karl et al. 2009), they "are at greater risk of heart failure,

which is further exacerbated when cardiac demand increases in order to cool the body during a heat wave." The USGCRP study also found that people taking medications, such as diuretics for high blood pressure, have a higher risk of dehydration (Karl et al. 2009). The USGCRP (2014) study reconfirmed the previous report findings regarding the risks of climate change on low-income populations, and also warns that climate change could affect the availability and access to local plant and animal species, thus impacting the people that have historically depended on them for food or medicine. However, minority and low-income populations at Braidwood are not likely to experience disproportionately high and adverse impacts from climate change, based on the expected small or slow change, effectively, in the environment during the 20-year license renewal term.

4.16 Cumulative Impacts of the Proposed Action

The NRC staff considered potential cumulative impacts in the environmental analysis of continued operation Braidwood during the 20-year license renewal period. Cumulative impacts may result when the environmental effects associated with the proposed action are overlaid or added to temporary or permanent effects associated with other past, present, and reasonably foreseeable actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time. It is possible that an impact that may be SMALL by itself could result in a MODERATE or LARGE cumulative impact when considered in combination with the impacts of other actions on the affected resource. Likewise, if a resource is regionally declining or imperiled, even a SMALL individual impact could be important if it contributes to or accelerates the overall resource decline.

For the purposes of this cumulative analysis, past actions are those before the receipt of the LRA. Present actions are those related to the resources at the time of current operation of the power plant, and future actions are those that are reasonably foreseeable through the end of plant operation, including the period of extended operation. Therefore, the analysis considers potential impacts through the end of the current license terms as well as the 20-year renewal license term. The geographic area over which past, present, and reasonably foreseeable actions would occur depends on the type of action considered and is described below for each resource area.

To evaluate cumulative impacts, the incremental impacts of the proposed action, as described in Sections 4.1 to 4.13, are combined with other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. The NRC staff used the information provided in the ER; responses to requests for additional information; information from other Federal, State, and local agencies; scoping comments; and information gathered during the visits to the Braidwood site to identify other past, present, and reasonably foreseeable actions. To be considered in the cumulative analysis, the NRC staff determined if the project would occur within the noted geographic areas of interest and within the period of extended operation, was reasonably foreseeable, and if there would be a potential overlapping effect with the proposed project. For past actions, consideration within the cumulative impacts assessment is resource and project-specific. In general, the effects of past actions are included in the description of the affected environment in Chapter 3, which serves as the baseline for the cumulative impacts analysis. However, past actions that continue to have an overlapping effect on a resource potentially affected by the proposed action are considered in the cumulative analysis.

Other actions and projects identified during this review and considered in the NRC staff's analysis of the potential cumulative effects are described in Appendix E. Not all actions or

projects listed in Appendix E are considered in each resource area due to the uniqueness of the resource and its geographic area of consideration.

4.16.1 Air Quality and Noise

This section addresses the direct and indirect effects of license renewal on air quality and noise when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. As described in Section 4.3.1, the incremental impacts on air quality and noise levels from the proposed license renewal would be SMALL.

4.16.1.1 Air Quality

The geographic area considered in the cumulative air quality analysis is the county of the proposed action as air quality designations for criteria air pollutants are generally made at the county level. Counties are further grouped together based on a common air shed—known as an air quality control region (AQCR)—to provide for the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS). Braidwood is located in Will County, Illinois. Air quality in Will County is under the jurisdiction of the Illinois EPA (IEPA). Will County is designated as a non-attainment area for the 2008 8-hour ozone (marginal) NAAQS and 2010 sulfur dioxide NAAQS (partial county designation) and designated maintenance area for the 1997 $PM_{2.5}$ NAAQS (40 CFR 81.314; EPA 2015). Within the nonattainment area, air pollutant emission sources, both stationary and mobile, are prevalent, especially in and close to the Chicago Metropolitan Area (CMA).

As noted in Section 3.3, the IEPA's Air Pollution Control Program has primary responsibility for regulating air emission sources within Illinois and Will County and in developing plans to achieve and maintain attainment with the NAAQS. The IEPA conducts ambient air monitoring in the State to assess compliance with the NAAQS. In 2012, the IEPA operated 75 sites throughout Illinois with approximately 170 monitors (IEPA 2012a).

Existing emission sources at Braidwood are regulated under a Federally Enforceable State Operating Permit (I.D. No. 197816AAB). As discussed in Section 3.3, regulated air pollutants—including sulfur dioxide, carbon monoxide, nitrogen oxide, carbon dioxide, and particulates—are emitted at the Braidwood site from four large diesel generators, various small diesel engines (<600 horsepower) used for electric generation and water pumping, two diesel engine AFW pumps, a rad-waste volume reduction system, fuel storage tanks and two auxiliary boilers. Emissions during the last 5 years (2008 to 2012) are shown in Table 3.3.2-1 in Section 3.3.2. For each pollutant, Braidwood is classified as a minor emission source. A minor source classification typically indicates that the facility has little to no potential for significantly impacting air quality or interfering with plans to achieve compliance with the NAAQS in nonattainment areas (IEPA 2014c). Since there will be no refurbishment related activities, the NRC staff expects similar emissions during the license renewal period. Accordingly, the incremental impacts on air quality (during the period of extended operation) from the proposed license renewal would be SMALL. Therefore, cumulative changes to air quality in Will County and AQCR would be the result of changes to present-day emissions as well as future projects and actions within the county.

<u>Cumulative Impacts</u>

Appendix E provides a list of present and reasonably foreseeable projects that could contribute to cumulative impacts to air quality. The following existing operating nuclear power stations are in the region:

- Clinton, Unit 1, in DeWitt County;
- Byron Station, Units 1 and 2, in Ogle County;
- LaSalle County Station, Units 1 and 2, in LaSalle County; and
- Dresden Station, Units 2 and 3, in Grundy County.

Similar to Braidwood, these stations are also classified as minor emission sources, are distant (located in a different county or air shed from Braidwood) and unlikely to contribute to a cumulative impact due to their minor emission status and distance from Braidwood.

There are no plans for refurbishment of structures or components at the Braidwood site for license renewal. However, Unit 1 and 2 reactor pressure vessel head replacement (assumed to occur during a 7-day period with 340 additional workers) and Unit 2 steam generator replacement (estimated to require an additional 500 workers for 90 days) may occur at Braidwood. The main contributors to air quality impacts associated with these activities would be fugitive dust generation from construction activities, work to open containment to replace the steam generators and related equipment, and exhaust emissions from motorized equipment and vehicles of temporary workers. The additional vehicle air emissions resulting from the additional workforce for steam generator replacement activities (used as bounding conditions since steam generator replacement will require a larger number of workers and has longer activity duration) would be temporary and are estimated to result in an additional 3.3 tons of volatile organic compounds, 9.8 tons of nitrogen oxides, 0.04 tons of sulfur dioxide, and 0.40 tons of $PM_{2.5}$ (direct emissions) being emitted, which do not exceed the de minimis levels of 100 tons/yr for nitrogen oxides, volatile organic compounds, sulfur dioxide, or particulate matter set forth in 40 CFR 93.153(b). Steam generator replacement and pressure head replacement are not expected to occur simultaneously, and pressure vessel head replacement would require a lower additional workforce than what would be needed for steam generator replacement (Exelon 2013c). Therefore, vehicle emissions from the additional workforce needed for vessel head and steam generator replacement are not expected to exceed the de minimis levels set forth in 40 CFR 93.153(b).

Development and activities associated with regional growth of housing, business, and industry, as well as associated vehicular traffic can increase air emissions. As discussed in Section 2.3, Will County is one of the fastest-growing counties in the Chicago metropolitan area and population is expected to grow by another 60 percent in the next 20 years. Regional air quality conditions could deteriorate from the effects of the growth of the county as growth gives rise to dust, exhaust, and emissions that can degrade air quality. The air quality effects of development are monitored through the statewide ambient air quality monitoring network. If degradation in air quality is observed, the IEPA can develop air quality control programs to mitigate the effects of development. Any new stationary sources of emissions that would be established in the region would be required to apply for an air permit from the IEPA. Prior to issuing an air permit to a new source (or to an existing source that proposes to undergo significant modification), IEPA will examine the potential air quality impacts using various modeling tools to assess any potential changes to compliance with the NAAQS.

EPA’s Enforcement and Compliance History Online database identifies 33 facilities that are major sources of air emissions in Will County (EPA 2014b). Two existing large coal-fired electric generating facilities are the Joliet Station Power Plant, located approximately 18 mi (29 km) north-northeast of Braidwood and the Will County Power Station, located approximately 28 mi (45 km) to the north-northeast. Both facilities are regulated by the IEPA through the Operating Permit program. In 2008, Joliet Station emitted 7,514 tons of nitrogen oxide and 18,281 tons of sulfur dioxide; Will County Power Station emitted 7,192 tons of nitrogen oxide

and 16,497 tons of sulfur dioxide (EPA 2014a). These two sources are the dominant emission sources within a 30-mi (50-km) radius of Braidwood.

Climate change can impact air quality as a result of changes in meteorological conditions. Air pollutant formation partially depends on the temperature and humidity of the atmosphere and is a result of the interactions between hourly changes in the physical and dynamic properties of the atmosphere, atmospheric circulation features, wind, topography, and energy use (IPCC 2009). As discussed in Section 4.14.3.2, ozone levels have been found to be particularly sensitive to climate change influences (EPA 2007). Sunshine, high temperatures and air stagnation are favorable meteorological conditions leading to higher levels of ozone (EPA 2009). Air quality projections (particularly ozone and $PM_{2.5}$) are uncertain and indicate that concentrations are driven primarily by emissions rather than by physical climate change (Stocker et al. 2013). The combination of higher temperatures, stagnant air masses, sunlight, and emissions of precursors may make it difficult to for Will County to continue to meet ozone National Ambient Air Quality Standards (USGCRP 2009). States, however, must continue to comply with the CAA and ensure air quality standards are met.

Conclusion

Because of the small quantity of emissions from Braidwood, the distance between existing emission sources in the region and no expected emissions increase associated with license renewal, the potential for Braidwood to contribute to a cumulative impact with other air pollutant sources is SMALL. The NRC staff concludes that, combined with the emissions from other past, present, and reasonably foreseeable future actions, cumulative impacts on air quality from hazardous and criteria air pollutant emissions from Braidwood-related actions would be SMALL.

4.16.1.2 Noise

Section 3.3.3 presents a summary of noise sources at Braidwood and site vicinity. Noise emission sources from Braidwood include such things as circulating water make-up pumps, main steam valves, water discharge system, transmission lines, security drills, and transformers. In 2011, Braidwood redesigned its blowdown water discharge into the Kankakee River to reduce noise associated with the water discharge location, which was the subject of noise complaints. This action reduced the number of noise complaints Braidwood received. The surrounding land use in the immediate vicinity of the Braidwood site is residential and open land. Occasional train activity on the nearby rail line and truck traffic on nearby roads may cause a temporary noise increase while trains and trucks pass by the Braidwood site, with noise levels returning to background once the train or vehicle exits the area.

Cumulative Impacts

Ongoing or foreseeable future projects in and around the Braidwood Station as identified in Appendix E would increase noise levels in the vicinity of their noise sources. For instance, activities at the Braidwood site related to steam generator replacement or reactor pressure vessel head replacement, if they occur, would increase noise levels as a result of construction activities related to the storage facility, motorized equipment, and increased vehicles. Construction equipment, for instance, can result in noise levels in the range of 85–90 dBA; however, noise levels attenuate rapidly with distance such that at half-a-mile distance from construction equipment noise levels can drop to 51-61 dBA (NRC 2002). Additional noise from construction activities would be temporary and intermittent and the majority of work activities would occur inside of buildings. Therefore, the NRC concludes that offsite noise levels will not be noticeable to nearby receptors and there are no long-term changes expected to existing noise levels associated with license renewal. Furthermore, as indicated in Appendix E, most of the projects considered for cumulative impacts are not located in Will County and only a few are

located within 1 mi from Braidwood. Generally, as distance is doubled from a point source, noise levels decrease by 6 dBA (MPCA 2014). Therefore, noise levels from present and future actions of these projects (not in Will County) are not anticipated to contribute to noise impacts in the vicinity of Braidwood.

Conclusion

Cumulative impacts on noise environment are expected to be SMALL and remain minor during the license renewal term.

Air and Noise Cumulative Impact Summary

Cumulative impacts to air quality and noise are estimated based on the information available in the Braidwood Station ER and the NRC staff's independent evaluation. Other past, present, and reasonably foreseeable future activities exist in the geographic areas of interest (local for noise; local and regional for criteria pollutants) that could affect air quality and noise resources. The cumulative impacts on the emissions of criteria pollutants from Braidwood Station and other projects would be minimal. The NRC staff concludes that cumulative impacts from other past, present, and reasonably foreseeable future actions on air quality and noise resources in the geographic areas of interest would be SMALL. The incremental contribution of impacts on air quality and noise resources from plant operations at Braidwood Station would be SMALL.

4.16.2 Geology and Soils

This section addresses the direct and indirect effects of license renewal on geology and soils when added to the aggregate effects of other past, present, and reasonably foreseeable future actions.

As noted in Section 4.4.1, the NRC staff concludes that the impact from license renewal on geology and soils would be SMALL.

Cumulative Impacts

The cumulative impacts on the geologic environment primarily relate to land disturbance and the potential for soil erosion and loss, as well as the projected consumption of geologic resources. Exelon has no plans to conduct refurbishment or replacement actions and ongoing operation and maintenance activities at the Braidwood site are expected to be confined to previously disturbed areas. Any use of geologic materials, such as aggregates, to support operation and maintenance activities would be procured from local and regional sources. Thus, activities associated with continued operations are not expected to affect the geologic environment. The NRC staff presumes that construction activities, as identified in Appendix E, would use material from local and regional sources as these materials are abundant in the region. These identified projects are of such a scale as to not be likely to impact regional sources and supplies of the identified resources. Furthermore, construction activities would need to be conducted in accordance with State and local requirements and development activities would be subject to BMPs for soil erosion and sediment control, which would serve to minimize soil erosion and loss.

Conclusion

Considering ongoing activities, past activities, and reasonably foreseeable actions, the NRC staff concludes that the cumulative impacts on geology and soils during the Braidwood license renewal term would be SMALL.

4.16.3 Water Resources

This section addresses the direct and indirect effects of license renewal on surface water and groundwater when added to the aggregate effects of other past, present, and reasonably foreseeable future actions.

As described in Sections 4.5.1.1 and 4.5.1.2, the incremental impacts on water resources from continued operations of Braidwood, during the license renewal term would be SMALL.

NRC staff also conducted an assessment of other projects and actions for consideration in determining their cumulative impacts on water resources (see Appendix E). The geographic area considered for the surface water resources component of the cumulative impact spans the Illinois portion of the Kankakee River basin (see Figure 3.5-1). For groundwater, the geographic area of interest is comprised of the local groundwater basin relative to the Braidwood site, the Cambrian-Ordovician aquifer. As such, this review focused on those projects and activities that would (1) withdraw water or discharge water to the Kankakee River or (2) would use groundwater from Cambrian-Ordovician aquifer.

4.16.3.1 Surface Water Resources

The Kankakee River serves both public water supply systems and the nuclear plant industry. Consumers Illinois Water Company and the City of Wilmington began withdrawing water from the Kankakee River in 1886 and 1990, respectively (Knapp 1992). These public water systems withdraw approximately 13 mgd (24.2 cfs, 10,861 gpm, 0.69 m^3/s) from the Kankakee River and it is projected that withdrawals in 2050 will increase to approximately 17 mgd (31.6 cfs, 14,182 gpm, 0.89 m^3/s) (ISWS 2012; City of Kankakee 2014). This is a 30 percent increase in projected public water supply withdrawals. Dresden Nuclear Power Station, Units 2 and 3 (listed in Appendix E) are currently operating and withdrawal water from the Kankakee River. Total current consumptive rates from public water supply systems and nuclear plants (Braidwood and Dresden) are approximately 3 percent of the Kankakee River average flow (see Section 4.5.1.1.2). Furthermore, various wastewater discharges to the Kankakee River Basin are identified in Appendix E. There are a total of 17 major effluent return flows to streams in the Illinois portion of the Kankakee watershed and the average return flow from these sources is 35 cfs (22.6 mgd, 15,708 gpm or 1.0 m^3/s) (Knapp 1992).

<u>Cumulative Impacts</u>

There are no proposed refurbishment activities associated with the license renewal of Braidwood; however, Exelon has indicated that during the period of license renewal there is a possibility for Unit 2 steam generator replacement and pressure vessel head replacement for both units. Steam generator and pressure vessel head replacement activities will require water for concrete production, dust control, and facility and equipment cleaning. However, water consumption for these non-cooling water related activities is anticipated to be negligible and temporary. Construction related activities would occur on previously disturbed land and are expected to be managed by a Stormwater Pollution Prevention Plan and implementation of BMPs.

In 2006, northeastern Illinois was selected as a priority water supply planning area. The northeastern Illinois region includes an 11-county area (including Will County, where Braidwood is located) and encompasses the Kankakee River Basin. In 2010, a regional water plan was developed to guide future use, manage water demand, and protect water supplies by the Chicago Metropolitan Agency for Planning (CMAP). The surface waters of the Kankakee River watershed were identified as a future source of water for the suburban areas of northeastern Illinois due to increased demand resulting from future population growth in these areas, in particular the city of Joliet (CMAP 2010; ISWS 2012). Significant increases in water demand

are also expected in the western and southern parts of the Chicago metropolitan region, which currently use Lake Michigan water, inland surface waters, and deep groundwater aquifers. The deep aquifer system and Lake Michigan water supply are now at or near their sustainable or legally mandated limits (Wehrmann and Knapp 2006). As the CMA grows and moves closer to the Kankakee River, the river will be viewed increasingly as a regional source of water (Wehrmann and Knapp 2006). As further discussed in Section 4.15.3.1, over pumping of the regional Cambrian-Ordovician Aquifer System has long been recognized as a regional problem. Proposed corrective actions have included increased reliance on the Kankakee River as a source of water. The City of Joliet has identified the Kankakee River as a likely source of water to replace over pumping of the regional aquifer by its wells (Wehrmann and Knapp 2006). The water plan recommends surface and groundwater modeling of the Kankakee River watershed to support water supply efforts in the future (CMAP 2010).

As discussed in Section 3.5.1.3, a segment of the Kankakee River near Braidwood does not meet designated uses or water quality standards (or both) and is listed as impaired (IEPA 2014a). Various segments (totaling 58 mi (93 km)) of the Kankakee River have been designated by the IEPA as impaired because of contamination from mercury, PCB's, or phenols (impairing water supply use). However, water treatment technology can be utilized to ensure water quality standards are met and protect water quality. For instance, the Kankakee River Metropolitan Agency, as part of Illinois' Clean Water Initiative, will upgrade the wastewater treatment plant to prevent pollutants from entering the Kankakee River from effluent discharges and protect water quality (IGNN 2014). Furthermore, compliance with the CWA and IEPA regulations impose limitations on discharges to ensure water quality does not decline.

Climate change can impact surface water as a result of changes in temperature and precipitation. As discussed in Section 4.14.3.2, the climate model simulations for the Midwest region indicate an increase in annual mean temperature. Increased precipitation results in increases in runoff and streamflow. However, higher temperatures increase evaporation that contributes to dry conditions and can reduce the amount of water available for surface runoff and streamflow (USGCRP 2009). Precipitation and evapotranspiration rates will be key drivers in determining future Kankakee River flow. The USGCRP (2014) reports that runoff and streamflow for the Midwest will increase. Additionally, higher air surface temperatures can lead to high cooling pond temperatures and an increase in evaporation of Braidwood's cooling pond; this can subsequently result in additional makeup water withdrawals from the Kankakee River and higher temperature discharges to the Kankakee River. However, as discussed in Section 3.5.1.2, Braidwood is limited to a withdrawal rate of 160 cfs (71,808 gpm or 4.5 m^3/s) in accordance with the permit issued by IDOT, and Braidwood's NPDES permit places limits the temperature of the effluent versus the temperature of the river water during a given season. Furthermore, cooling pond temperature data obtained from Exelon between 2004 and 2013 does not display an increasing trend in cooling pond temperatures (Exelon 2014i).

<u>Conclusion</u>

Given current water demand and use of the Kankakee River, increased regional demand and the potential increased reliance on the Kankakee River as a source of water, and impacts of climate change, the NRC staff concludes that the cumulative impacts on surface water resources during the license renewal term would be SMALL to MODERATE. The regional impact will be influenced by climate change and future water demand and actions taken in the Kankakee River to address water supplies.

4.16.3.2 Ground Water Resources

This section addresses the direct and indirect effects of license renewal on groundwater use and quality when added to the aggregate effects of other past, present, and reasonably foreseeable future actions.

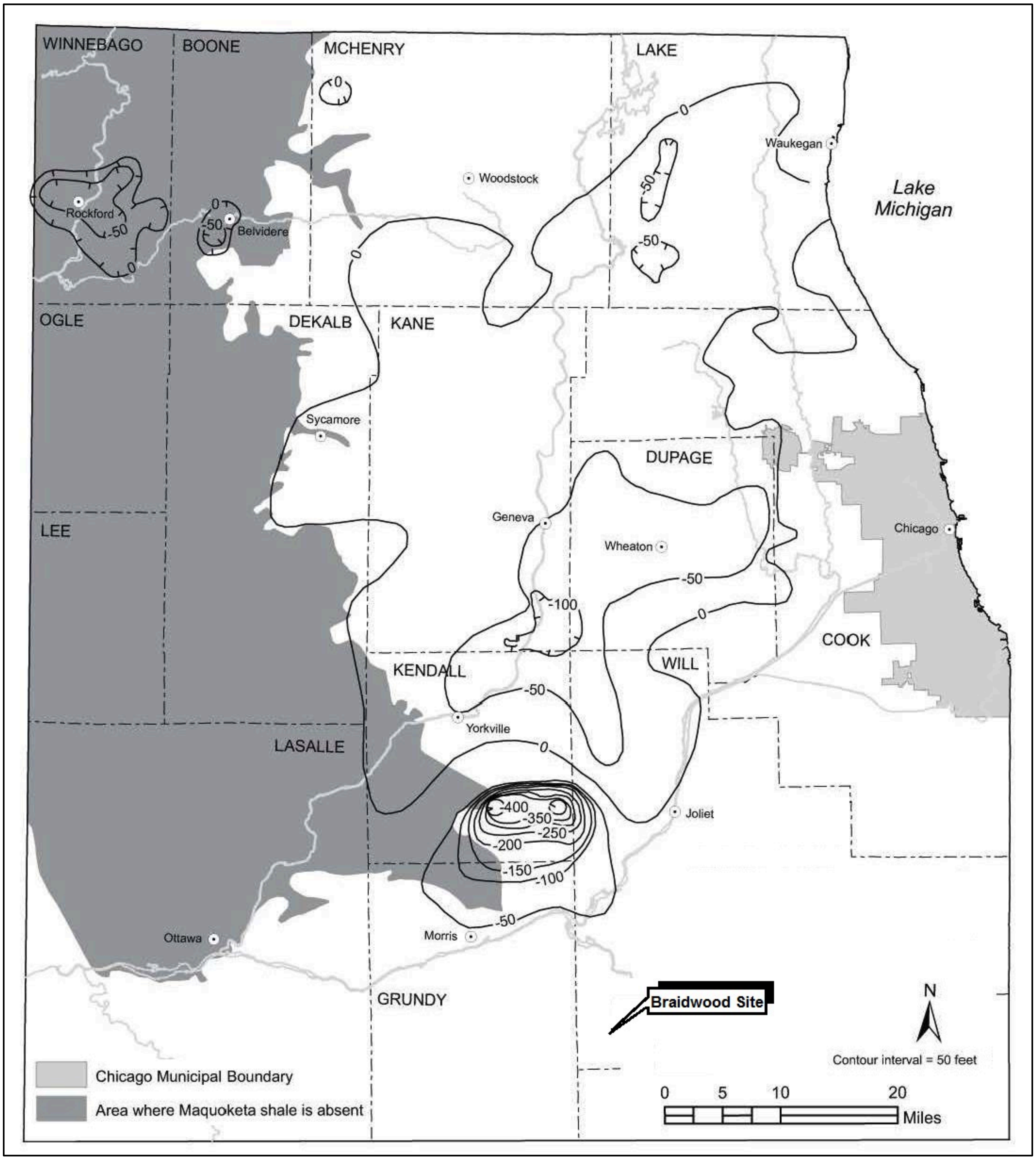
All groundwater consumed at the Braidwood site is obtained from a single well completed in the Deep Aquifer (see Section 3.5.2.2). The Deep Aquifer makes up most of the regional Cambrian-Ordovician Aquifer System. The Cambrian-Ordovician Aquifer System is a major source of water in the Chicago Metropolitan Region. In Will County most of the public water is obtained from this aquifer (50 percent in 1983) (Woller and Sandersone 1983). It was estimated that in 2003, Joliet obtained 14,340,000 gpd (54,282,804 Lpd) from this aquifer system (Burch and Wehrmann 2007).

In the Chicago Metropolitan Region, extensive use of the Cambrian-Ordovician Aquifer System has caused water levels in this system to drop (Burch 2002, 2008). Since 1865, groundwater (potentiometric) levels declined by 500 ft (152.4 m) or more over a broad area of the Chicago region. During this same time period, some groundwater levels in the Joliet area declined 850 to 900 ft (244 to 274 m) (Burch 2007). Up to 400 ft (122 m) of this decline in the Joliet area occurred between 2000 and 2007 in wells located in southeastern Kendall county that supply Joliet, Illinois with public water (Figure 4–4) (Burch 2008).

Over pumping of the Cambrian-Ordovician Aquifer System has long been recognized as a regional problem (CMAP 2010; Konikow 2013; Schicht and Moench 1971; Walton et al. 1960). Groundwater consumption projections suggest that by 2050, the continued drawdown of groundwater levels has a high potential to cause adverse impacts in southeastern Kane County and northern Will County. These impacts include decreasing well yields, increasing pumping expenses, increases in salinity in deep well water, and increased concentrations of radium, barium, and arsenic (ISWS 2012). Aurora and Joliet appear to be most at risk from projected future water demand scenarios (CMAP 2010, ISWS 2012). Suggested corrective actions include increased use of water from Lake Michigan, from Rivers, from near surface aquifers, and more efficient use of currently available water (CMAP 2010; USGS 2005).

Managing water extraction from the Cambrian-Ordovician Aquifer is anticipated to continue to be a long term regional concern. The contribution by the plant to the consumptive use of water obtained from the Cambrian-Ordovician Aquifer is SMALL.

1 **Figure 4–4. Changes in Deep Sandstone Wells in Northeast Illinois Between 2000 and 2007**



2

3 Modified from Burch 2008

4 Cumulative Impacts

5 Consumptive use would continue to be SMALL, even if groundwater consumption temporarily
6 increases during steam generator or reactor pressure vessel head replacement. However, for

cumulative impacts, when combined with groundwater consumption by the Chicago Metropolitan Region, the impact to consumptive groundwater use is MODERATE to LARGE.

Contamination of groundwater obtained from shallow aquifers will be more of a concern if shallow aquifers, such as the Upper Aquifer, are increasingly accessed as a source of water in the Chicago Metropolitan Region during the license renewal term. This is because the groundwater in shallow aquifers is more vulnerable to contamination from surface-derived contaminants (such as road salt, agrichemicals, petrochemicals, and other man made pollutants) than the groundwater in deep aquifers. Future increases in land development may accelerate the degradation of shallow aquifers from surface-derived contaminants. Preventing the contamination of near surface aquifers is likely to be a long-term regional concern. As further described in Sections 3.5.2.3 and 4.5.1.2.1, at Braidwood, a program is in place to safeguard groundwater quality, and it would be employed during steam generator or reactor pressure vessel head replacement. Therefore, while the impact by the plant to near surface aquifer water quality degradations is SMALL, the cumulative impact of future regional land development on near surface aquifer water quality is MODERATE.

Conclusion

Considering ongoing activities and reasonably foreseeable actions, the NRC staff concludes that the cumulative impacts to groundwater use and quality during the Braidwood license renewal term would be MODERATE to LARGE.

4.16.3.3 Water Resource Conclusion Summary

Considering ongoing activities and reasonably foreseeable actions, the NRC staff concludes that cumulative impact of the proposed license renewal when combined with other past, present, and reasonably foreseeable future activities on surface water resources would be SMALL to MODERATE, while impacts to groundwater resources would be MODERATE to LARGE. While the Braidwood facility is not expected to impact surface or groundwater resources, increased regional demand on both surface and groundwater resources is expected to grow throughout the license renewal term.

4.16.4 Terrestrial Ecology

This section addresses past, present, and future actions that could result in cumulative impacts on the terrestrial species and habitats described in Section 3.6. For purposes of this analysis, the geographic extent considered in this cumulative terrestrial resource analysis depends on the particular cumulative impacts being discussed. Direct and indirect impacts from Braidwood operation are largely limited to the Braidwood site and immediate vicinity. However, projects or actions located beyond this geographic area could directly or indirectly affect terrestrial resources in this area. Section 4.6 of this SEIS concludes that the impact from the proposed license renewal would not noticeably alter the terrestrial environment and would be SMALL.

As discussed in Section 3.6, the Braidwood site was highly disturbed prior to construction and operation of Braidwood, and the majority of natural areas were previously coal strip-mine spoils or cultivated fields. Strip mining within the boundaries of the Braidwood site began in the early 1940s, and various reclamation projects took place on the site from the 1950s through the early 1970s (ComEd 1973). Due to the highly disturbed condition of the site, preoperational surveys determined that no terrestrial climax communities existed on the site (ComEd 1973, 1985). During Braidwood construction, terrestrial habitat was further reduced: 2,540 ac (1,028 ha) of land was flooded to create the facility's cooling pond, and an additional 264 ac (107 ha) was cleared for industrial use (Exelon 2013c, 2014i).

In the broader area—the Illinois/Indiana Prairies Level IV Ecoregion—native prairies and wetlands have been converted to agricultural land, which now accounts for over 75 percent of land use within the ecoregion (IDNR 2005). Habitat loss, in general, can negatively affect breeding success, dispersal success, predation rate, and other animal behaviors (Fahrig 2003). Habitat fragmentation (the breaking up of a larger area of habitat into smaller patches of smaller total area) can also negatively affect terrestrial biota. In a study of breeding bird communities in 24 Illinois grassland fragments, Herkert (1994) found that fragmentation was likely a factor in Midwestern grassland bird population declines. A study conducted in 2012 on the partridge pea (*Chamaecrista fasciculate*) (Mannouris and Byers 2013) concludes that native prairie plant species that occur in smaller, isolated prairie fragments are likely to suffer a reduction in genetic fitness. The IDNR (2005) indicates that habitat loss, fragmentation, and fire suppression in Illinois native forests is causing species composition shifts to sugar maple (*Acer saccharum*) and other mesophytic species.

<u>Cumulative Impacts</u>

Energy Production and Development

Four nuclear power plant sites with seven operating reactors lie within 50 mi (80 km) of the Braidwood site (see Appendix E). Because the effects of these facilities would primarily be limited to the terrestrial resources on each facility's site and immediate vicinity, the operation of these facilities would not result in cumulative effects to the terrestrial resources affected by Braidwood operation.

Two wind farms operate near Braidwood: Top Crop I Wind Farm lies southwest of Braidwood and includes 68 units in La Salle and Livingston Counties, and Grand Ridge Wind Farm lies south of Braidwood and includes 66 units in La Salle County. An additional 132 wind-powered units are currently under construction in Grundy County as part of Top Crop II Wind Farm. All of these wind farms lie within approximately 25 mi (40 km) of the Braidwood site. Operation of wind farms can result in direct mortality of birds and bats through collision with turbine blades as well as indirect effects, such as avoidance of an area, habitat disruption, reduced nesting or breeding density, habitat abandonment, and behavioral effects (Stewart et al. 2005, 2007). Given that the majority of bird and bat species are migratory, effects of wind farms on bird and bat populations can be far-reaching.

Two other energy-producing facilities occur in the region: the coal- and natural gas-fired Joliet Station, which lies 18 mi (29 km) northeast of Braidwood in Joliet, Illinois, and the coal-fired Will County Station, which lies 27 mi (43 km) northeast of Braidwood in Romeoville, Illinois. Air emissions from these facilities include GHGs such as nitrogen oxides, carbon dioxide, and methane, all of which can have far-reaching consequences because they cumulatively contribute to climate change. The effects of climate change on terrestrial resources are discussed in Section 4.13.3.2.

Development, Urbanization, and Habitat Fragmentation

As the region surrounding the Braidwood site becomes more developed, habitat fragmentation will increase and the amount of forested, prairie, and wetland habitat is likely to decline further. Transmission lines and associated corridors established to connect Braidwood and other energy-producing facilities to the regional electric grid represent past habitat fragmentation because some of the corridors split otherwise continuous tracts of habitat. Construction of transmission lines associated with new energy projects may also result in habitat fragmentation if the lines are not co-located within existing corridors or sited within previously developed

areas. Edge species that prefer open or partially open habitats will likely benefit from the fragmentation, while species that require interior forest or wetland habitat will likely decline.

Continued urbanization in the future will likely include construction of additional housing units and associated commercial buildings; roads, bridges, and rail; and water or wastewater treatment and distribution facilities and associated pipelines. Increased development will likely decrease the overall availability and quality of terrestrial habitats. Species that require larger ranges, especially predators, will likely suffer reductions in their populations. Similarly, species with threatened or endangered Federal or State status or otherwise declining populations would be more sensitive to declines in habitat availability and quality. Native prairie plants will likely continue to experience reductions in genetic fitness, as previously discussed.

Nature Preserves and State Parks

State parks and wildlife refuges located near Braidwood (Appendix E) provide valuable habitat to native wildlife, migratory birds, and protected terrestrial species and habitats. As fragmentation and conversion continues in the future, these protected areas will become ecologically more important because they provide large, continuous areas of minimally disturbed habitat. The Braidwood Dunes and Savanna Nature Preserve, which lies approximately 2 mi (2.4 km) northeast of the Braidwood site, provides particularly high-quality habitat and protection to native biota, including the State-endangered Oklahoma grass pink orchid (*Calopogon oklahomensis*) and State-threatened pale-green orchid (*Platanthera flava* var. *herbiola*) (see Section 3.6).

<u>Conclusion</u>

NRC staff concludes that the cumulative impacts on terrestrial resources in the vicinity of the Braidwood site are MODERATE to LARGE based on past, present, and reasonably foreseeable future actions. This level of impact is primarily the result of past habitat alteration and loss on the Braidwood site and within the larger Illinois/Indiana Prairies Level IV Ecoregion. The environmental effects of these actions are clearly noticeable and have destabilized important attributes of certain terrestrial communities. The loss of genetic fitness of native prairie species and the species composition shifts observed in native Illinois forests are demonstrative of such effects. The incremental, site-specific impact from the continued operation of Braidwood during the license renewal period would be an unnoticeable (SMALL) or minor contributor to cumulative impacts on terrestrial resources.

4.16.5 Aquatic Ecology

This section addresses the direct and indirect effects of license renewal on aquatic resources when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. Section 4.7 of this document finds that the direct and indirect impacts on aquatic resources from the proposed license renewal when considered in the absence of the aggregate effects would be SMALL for some issues and MODERATE for others. The cumulative impact is the total effect on the aquatic resources of all actions taken, no matter who has taken the actions (the second principle of cumulative effects analysis in CEQ 1997).

<u>Cumulative Impacts</u>

The geographic extent considered in this cumulative aquatic resource analysis depends on the particular cumulative impacts being discussed. During Braidwood impingement and entrainment studies (discussed in Section 4.7), EA Engineering determined that the entire length of the Kankakee River in Illinois could serve as a source of recruitment for fish losses resulting from Braidwood operation. The Illinois portion of the river is meandering,

well-vegetated, and rocky, and it is reasonable to assume that similar species exist throughout. Accordingly, the NRC staff assumes that direct and indirect impacts from the Braidwood site are limited to the Illinois portion of the Kankakee River, which consists of 58 river miles (RM) (93 river kilometers (RKm)) in Kankakee and Will Counties, and that effects to aquatic resources that could result from continued operation of Braidwood and other actions could not be meaningfully discerned or described beyond the geographic area (i.e., the Illinois portion of the Kankakee River). However, for this cumulative impacts analysis, projects or actions located outside of this area could directly or indirectly affect the aquatic resources in this area. This section focuses on the cumulative effects of such actions. The baseline, or benchmark, for assessing cumulative impacts on aquatic resources takes into account the preoperational environment as recommended by the EPA (1999b) for its review of NEPA documents.

Past River Channelization and Damming

The Kankakee River in Illinois has remained largely unmodified with the exception of three dams: a small side channel dam at Momence in Kankakee County, a larger dam at the city of Kankakee, and an overflow dam at Wilmington downstream of Braidwood in Will County (Bhowmik and Demissie 2000). In the vicinity of Braidwood, the numerous riffles, small pools, and islands and varied substrates support a large diversity of aquatic biota, including several State-listed fish and mussels. The IDNR has designated the Kankakee River from Momence in Kankakee County to the Des Plains Wildlife Conservation Area in Will County as a Biologically Significant Stream because it supports one of the state's most diverse aquatic communities (Page et al. 1991). In Indiana, the Kankakee River was extensively channelized in the late 1800s and early 1900s. Today the channel is essentially man-made, and it extends straight for many miles between small bends (Bhowmik and Demissie 2000). The loss of microhabitats such as riffles, pools, and meandering bends through channelization in Indiana has likely affected the species composition, richness, and diversity in Indiana. This, in turn, has likely affected fish populations in Illinois because the Indiana portion of the river may no longer provide spawning grounds or serve as a source of recruitment.

Energy Development

Four nuclear power plant sites with seven operating reactors lie within 50 mi (80 km) of the Braidwood site (see Appendix E). Because the effects of these facilities would primarily be limited to the water body from which they draw cooling water and none of these facilities draw from the Kankakee River, the operation of these facilities (other than Braidwood) would not result in cumulative effects to the aquatic resources affected by Braidwood operation.

Two other energy-producing facilities occur in the region: the coal- and natural gas-fired Joliet Station, which lies 18 mi (29 km) northeast of Braidwood in Joliet, Illinois, and the coal-fired Will County Station, which lies 27 mi (43 km) northeast of Braidwood in Romeoville, Illinois. Both facilities are located on the Des Plains River. The Kankakee and Des Plains Rivers meet near Channahon, Illinois, and together form the Illinois River. Because direct effects to the aquatic environments caused by these facilities would likely be confined to the Des Plains River, the continued operation of these facilities during the proposed license renewal term would not result in direct impacts on Kankakee River aquatic communities. Air emissions from these facilities include GHGs such as nitrogen oxides, carbon dioxide, and methane, all of which can have far-reaching consequences because they cumulatively contribute to climate change. The effects of climate change on aquatic resources are discussed in Section 4.13.3.2.

Two wind farms also operate near Braidwood and a third is under construction (see Appendix E). These facilities would not have detectable impacts on Kankakee River aquatic

resources because, in general, they will not require water during operation and have no air emissions.

Future Urbanization and Transportation Development

Future urbanization in the vicinity of Braidwood will likely include construction of new housing units and associated commercial buildings; roads, bridges, and rail; and water or wastewater treatment (or both) and distribution facilities and associated pipelines. Known future development projects include improvements to the Jane Addams Memorial Tollway (I-90) and construction of South Suburban Airport (see Appendix E). Continued development of the area has the potential to increase the rate and volume of stormwater runoff and reduce groundwater recharge. If not managed appropriately, such development could result in increased flooding, higher and more frequent storm-related flows, and low flows of longer duration in streams. The increased runoff rates and high channel velocities from inappropriately managed sites could result in excessive bank erosion and associated sedimentation and stream degradation in the Kankakee River and its tributaries. As a result, aquatic biota populations may experience habitat degradation or loss, reduced food or prey availability, and increased susceptibility to exotic species invasions. Such potential impacts can be mitigated through implementation of BMPs that address stormwater quality, quantity, and discharge. Stormwater BMPs are often required by state and local regulations, which would ensure that impacts to aquatic resources resulting from future development would be appropriately mitigated.

Wildlife Preserves, Parks, and Recreational Areas

Several wildlife preserves, parks, and recreation sites lie within the vicinity of Braidwood (see Appendix E) including the Mazonia State Fish and Wildlife Area, part of which lies within the Braidwood site. The continued preservation of these areas will protect aquatic habitats and as land development continues, these areas will become ecologically more important because they will provide large areas of unfragmented natural habitat.

Illinois Wildlife Conservation Plan

The State of Illinois maintains a Comprehensive Wildlife Conservation Plan and Strategy (IDNR 2005), which is implemented by the IDNR and numerous Federal, State, local, and private partners. The plan addresses long-range landscape-level planning initiatives, which include projects to address declining wildlife populations and conservation and restoration of ecologically important, sensitive, and rare habitats. As part of the plan, the IDNR intends to restore in-stream habitat and natural processes in the Kankakee River in both Illinois and Indiana by restoring channelized stream portions, stabilizing stream banks, managing drainage practices to moderate water flows, and protecting and restoring remnant savanna, sand prairie, wetland, and other riparian habitats (IDNR 2005). Commitment to this plan will ensure that high-quality aquatic habitats are protected or restored such that the river will continue to support a diversity of aquatic life in the future.

Conclusion

Although the Illinois portion of the Kankakee River has remained a diverse ecosystem with many microhabitats and supportive of a diversity of aquatic life, the NRC cannot conclude with certainty that the future impacts of energy-generating facilities, urbanization, and transportation development will not result in detectable impacts on the aquatic environment. Continued protection of aquatic habitats through wildlife preserves, parks, and recreational areas, as well as the implementation of the Illinois Wildlife Conservation Plan will likely mitigate such effects, and, therefore, the NRC finds it reasonable to assume that these activities will ensure that future

actions do not destabilize important attributes of the aquatic resources in the Illinois portion of the Kankakee River. Accordingly, the NRC staff concludes that the cumulative impacts on aquatic resources in the Kankakee River are MODERATE based on past, present, and reasonably foreseeable future actions.

4.16.6 Historic and Cultural Resources

This section addresses the direct and indirect effects of license renewal on historic and cultural resources when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. The geographic area considered in this analysis is the APE associated with the proposed undertaking, as described in Section 3.9.

The archaeological record for the region indicates prehistoric and historic occupation of the Braidwood site and its immediate vicinity. The construction of Braidwood Units 1 and 2 resulted in destruction of cultural resources within the Braidwood site and surrounding area.

<u>Cumulative Impacts</u>

Other historic land development in the vicinity of Braidwood also resulted in impacts on, and the loss of, cultural resources on the Braidwood site and its immediate vicinity. However, there remains the possibility for additional historic or cultural resources to be located within the Braidwood site. The present and reasonably foreseeable projects which could affect these resources reviewed in conjunction with license renewal are noted in Appendix E of this document. Direct impacts would occur if historic and cultural resources in the APE were physically removed or disturbed. Indirect visual or noise impact could occur from new construction or maintenance. The following projects are located within the geographic area considered for cumulative impacts:

- Unit 2 steam generator replacement,
- Units 1 and 2 reactor pressure vessel head replacement, and
- future urbanization in the immediate vicinity of Braidwood.

As described in Section 4.9, no known cultural resources would be adversely affected by Braidwood Unit 1 and 2 license renewal activities as no associated changes or ground-disturbing activities will occur (Exelon 2013a). Unit 2 steam generator replacement, Unit 1 and 2 reactor pressure vessel head replacement, and future urbanization all have the potential to result in impacts on cultural resources through inadvertent discovery during ground-disturbing activities. However, as discussed in Section 4.9, Exelon has established draft procedures to ensure cultural resources are considered in project planning during normal operation of Braidwood.

<u>Conclusion</u>

The NRC staff concludes that the cumulative impact of the proposed license renewal on historic and cultural resources, when combined with other past, present, and reasonably foreseeable future activities would be SMALL.

4.16.7 Socioeconomics

This section addresses socioeconomic factors that have the potential to be directly or indirectly affected by changes in operations at Braidwood in addition to the aggregate effects of other past, present, and reasonably foreseeable future actions.

The primary geographic area of interest considered in this cumulative analysis is Will, Grundy, and Kankakee counties, where approximately 80 percent of Braidwood employees reside (see

Table 3.8.10-1). This is where the economy, tax base, and infrastructure would most likely be affected because Braidwood workers and their families reside, spend their incomes, and use their benefits within these counties.

Cumulative Impacts

As discussed in Section 4.8.10 of this SEIS, continued operation of Braidwood during the license renewal term would have no impact on socioeconomic conditions in the region beyond those already being experienced. Since Exelon has no plans to hire additional workers during the license renewal term, overall expenditures and employment levels at Braidwood would remain relatively constant and unchanged with no additional demand for permanent housing and public services. In addition, as employment levels and tax payments would not change, there would be no population or tax revenue-related land-use impacts. Therefore, the only contributory effects would come from reasonably foreseeable future planned activities at Braidwood, unrelated to the proposed action (license renewal), and other reasonably foreseeable planned offsite activities. For example, residential development is forecast for the Braidwood area, but not to the point that population densities will be significant.

Unit 2 Steam Generator Replacement

Exelon indicated that the Unit 2 steam generator replacement would occur during the license renewal term. Exelon estimates that steam generator replacement would occur during a 90-day period paralleling (coinciding with) a refueling outage or other scheduled maintenance outage. Steam generator replacement would require approximately 500 personnel, in addition to the 1,400 personnel required for refueling (Exelon 2013c). These additional workers would create a short-term increase in the demand for temporary (rental) housing, an increased use of public water and sewer services, and transportation impacts on access roads in the immediate vicinity of Braidwood. Given the short amount of time needed to replace the steam generator, the additional number of refueling outage and steam generator replacement workers and truck deliveries needed to support this one-time replacement, steam generator replacement could have a temporary cumulative effect on socioeconomic conditions in the vicinity of the nuclear plant. However, since the number of non-outage workers at Braidwood would not change after steam generator replacement, there would be no long-term cumulative socioeconomic impacts in the region.

Units 1 and 2 Reactor Pressure Vessel Head Replacement

Exelon indicated that the reactor vessel heads would be replaced before the license renewal term. Exelon estimates that each vessel head replacement would require a one-time increase of 340 outage workers for one week. If the vessel heads were replaced simultaneously, the number of outage workers would remain at 340, but an additional week of work would be necessary (Exelon 2013c). These additional workers would create a short-term increase in the demand for temporary (rental) housing, an increased use of public water and sewer services, and transportation impacts on access roads in the immediate vicinity of Braidwood. Given the short amount of time needed to replace the vessel head and the additional number of workers and truck deliveries needed to support this one-time replacement of the vessel head, vessel head replacement could have a temporary cumulative effect on socioeconomic conditions in the vicinity of the nuclear plant. However, since the number of non-outage workers at Braidwood would not change after reactor vessel head replacement, there would be no long-term cumulative socioeconomic impacts in the region.

Conclusion

When combined with other past, present, and reasonably foreseeable future activities, there will be no additional contributory effect on socioeconomic conditions from the continued operation of Braidwood during the license renewal period beyond what is currently being experienced. Increases in the Braidwood workforce during steam generator and vessel head replacement would be temporary and have no long-term socioeconomic impact to the region. Therefore, the NRC staff concludes that the cumulative socioeconomic impact would be SMALL in the immediate vicinity of Braidwood.

4.16.8 Human Health

The NRC and EPA established radiological dose limits for protection of the public and workers from both acute and long-term exposure to radiation and radioactive materials. These dose limits are codified in 10 CFR Part 20 and 40 CFR Part 190. As discussed in Section 4.11.1, the NRC staff concluded impacts to human health from the continued operations of Braidwood are SMALL.

Cumulative Impacts

For the purposes of this analysis, the geographical area considered is the area included within an 80-km (50-mi) radius of the Braidwood plant site. There are four other nuclear power plants within the applicable geographical area; LaSalle County Station, Units 1 and 2 and Dresden Nuclear Power Station, Units 2 and 3. In addition to storing its spent nuclear fuel in a storage pool, Braidwood also stores some of its spent nuclear fuel in an onsite ISFSI (Exelon 2013c).

EPA regulations in 40 CFR Part 190 limit the dose to members of the public from all sources in the nuclear fuel cycle, including nuclear power plants, fuel fabrication facilities, waste disposal facilities, and transportation of fuel and waste. As discussed in Section 3.1.4.5, Braidwood has a radiological environmental monitoring program (REMP). This program measures radiation and radioactive materials in the environment from Braidwood, its ISFSI, and other nuclear power plants, and other sources (i.e., medical and industrial facilities using radioactive material). As discussed in Section 4.11.1, the NRC staff reviewed the radiological environmental monitoring data for the 5-year period from 2008 to 2012 as part of the cumulative impacts assessment. The NRC staff reviewed Braidwood REMP data. The data showed no indication of an adverse trend in radiation or radioactivity levels in the environment from Braidwood, its ISFSI, other nuclear power plants, or other sources. The data showed that there was no measurable impact to the environment from the operations at Braidwood or any other facility using radioactive material.

In addition, as discussed in Section 3.1.4.6 of this SEIS, Exelon stated in its ER that it may replace the Braidwood Unit 2 steam generators and reactor pressure vessel heads for both units (Exelon 2013c). If Exelon conducts these potential refurbishment activities during the license renewal term, Exelon is required to maintain its radiation protection program to limit radiation dose to its workers and members of the public in accordance with NRC and EPA radiation protection standards.

Based on Braidwood's radiation protection program, the staff expects the dose to plant workers and members of the public from these potential projects would continue to be a small fraction of NRC and EPA's radiation protection standards. The NRC and the State of Illinois will regulate any future development or actions in the vicinity of the Braidwood site that could contribute to cumulative radiological impacts.

Conclusion

Based on the NRC staff's review of Braidwood's REMP data, radioactive effluent release data, and Braidwood's expected continued compliance with Federal radiation protection standards during continued operation and the potential refurbishment activities, and regulation of any future development or actions in the vicinity of the Braidwood site by the NRC and the State of Illinois, the NRC staff concludes that the cumulative impacts would be SMALL.

4.16.9 Environmental Justice

The environmental justice cumulative impact analysis assesses the potential for disproportionately high and adverse human health and environmental effects on minority and low-income populations that could result from past, present, and reasonably foreseeable future actions, including Braidwood operations during the renewal term. Adverse health effects are measured in terms of the risk and rate of fatal or nonfatal adverse impacts on human health. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant and exceeds the risk or exposure rate for the general population or for another appropriate comparison group. Disproportionately high environmental effects refer to impacts or risks of impacts on the natural or physical environment in a minority or low-income community that are significant and appreciably exceed the environmental impact on the larger community. Such effects may include biological, cultural, economic, or social impacts. Some of these potential effects have been identified in resource areas presented in preceding sections of this SEIS.

Minority and low-income populations are part of the general public residing in the area and all would be exposed to the same hazards generated from Braidwood operations. As previously discussed in this chapter, the impact from license renewal for all resource areas (e.g., land, air, water, ecology, and human health) would be SMALL. Therefore, as discussed in Section 4.12 of this SEIS, there would be no disproportionately high and adverse impacts on minority and low-income populations from the continued operation of Braidwood during the license renewal term.

Cumulative Impacts

Because Exelon has no plans to hire additional workers during the license renewal term (other than outages), employment levels at Braidwood would remain relatively constant, and there would be no additional demand for housing or increased traffic. Based on this information and the analysis of human health and environmental impacts presented in the preceding sections, it is not likely there would be any disproportionately high and adverse contributory effect on minority and low-income populations from the continued operation of Braidwood during the license renewal term. Therefore, the only contributory effects would come from the other reasonably foreseeable future planned activities at Braidwood, unrelated to the proposed action (license renewal), and other reasonably foreseeable planned offsite activities.

Unit 2 Steam Generator Replacement

Potential impacts to minority and low-income populations would mostly consist of environmental and socioeconomic effects (e.g., traffic, employment, and housing impacts). Noise and dust impacts from power plant modifications would be temporary and limited to onsite activities. Minority and low-income populations residing along site access roads could experience increased commuter vehicle traffic during shift changes. Increased demand for inexpensive rental housing during steam generator-related power plant modifications could disproportionately affect low-income populations; however, because of the short duration of the

work and the availability of housing, impacts to minority and low-income populations would be of short duration and limited. Radiation doses from plant operations after power plant modifications are not expected to change and will remain within regulatory limits.

Based on this information and the analysis of human health and environmental impacts presented in this section of the SEIS, Unit 2 steam generator replacement would not have disproportionately high and adverse human health and environmental effects on minority and low-income populations residing in the vicinity of Braidwood.

Units 1 and 2 Reactor Pressure Vessel Head Replacement

Similar to steam generator replacement, potential impacts to minority and low-income populations from reactor pressure vessel head replacement would mostly consist of environmental and socioeconomic effects (e.g., traffic, employment, and housing impacts). Noise and dust impacts from power plant modifications would be temporary and limited to onsite activities. Minority and low-income populations residing along site access roads could experience increased commuter vehicle traffic during shift changes. Increased demand for inexpensive rental housing during steam generator-related power plant modifications could disproportionately affect low-income populations; however, because of the short duration of the work and the availability of housing, impacts to minority and low-income populations would be of short duration and limited. Radiation doses from plant operations after power plant modifications are not expected to change and will remain within regulatory limits.

Based on this information and the analysis of human health and environmental impacts presented in this section of the SEIS, Unit 1 and 2 reactor pressure vessel head replacement would not have disproportionately high and adverse human health and environmental effects on minority and low-income populations residing in the vicinity of Braidwood.

Conclusion

The NRC staff concludes that the contributory effects of this action, when combined with other past, present, and reasonably foreseeable future activities considered, would not cause any disproportionately high and adverse human health and environmental effects on minority and low-income populations residing in the vicinity of Braidwood.

4.16.10 Waste Management

This section describes waste management impacts from Braidwood during the license renewal term when added to the cumulative impacts of other past, present, and reasonably foreseeable future actions. For the purpose of this cumulative impacts analysis, the area within a 50-mi (80-km) radius of Braidwood was considered.

The NRC staff concluded, in Section 4.11.1, that the potential human health impacts from Braidwood's waste during the license renewal term would be SMALL.

Cumulative Impacts

As discussed in Sections 3.1.4 and 3.1.5, Exelon maintains waste management programs for radioactive and nonradioactive waste generated at Braidwood and is required to comply with Federal and state permits and other regulatory requirements for the management of waste material. The nuclear power plants and other facilities within a 50-mi (80-km) radius of Braidwood are also required to comply with appropriate NRC, EPA, and state requirements for the management of radioactive and nonradioactive waste. For cumulative impacts analysis, waste management activities at Braidwood are expected to be stable during the license renewal term and comply with Federal and State requirements for radioactive and nonradioactive waste.

Adequate disposal options at licensed disposal facilities are expected to handle the cumulative volume of radioactive and nonradioactive waste generated by Braidwood and other facilities. If access to a disposal facility is temporarily unavailable, the waste will be safely stored in accordance with NRC, EPA, and state requirements.

Conclusion

Based on the above information, the NRC staff concludes that the potential cumulative impact from radioactive and nonradioactive waste would be SMALL.

4.16.11 Global Climate Change

This section addresses the impact of GHG emissions resulting from continued operation of Braidwood Station on global climate change when added to the aggregate effects of other past, present, and reasonably foreseeable future actions.

The impacts of climate change on air, water, and ecological resources are discussed in Section 4.14.3. Climate is influenced by both natural and human-induced factors; the observed global warming (increase in Earth's surface temperature) in the 21^{st} century has been attributed to the increase in GHG emissions resulting from human activities (USGCRP 2009). Climate model projections indicate that future climate change is dependent on current and future GHG emissions (Parry et al. 2007; USGCRP 2009). As described in Section 4.14.3.1, operations at Braidwood emit GHG emissions directly and indirectly. Therefore, it is recognized that GHG emissions from continued Braidwood Station operation may contribute to climate change.

Cumulative Impacts

The cumulative impact of a GHG emission source on climate is global. GHG emissions are transported by wind and become well mixed in the atmosphere as a result of their long atmospheric time. Therefore, the extent and nature of climate change is not specific to where GHGs are emitted. In April 2013, EPA published the official U.S. inventory of GHG emissions, which identifies and quantifies the primary anthropogenic sources and sinks of GHGs. The EPA GHG inventory is an essential tool for addressing climate change and participating with the United Nations Framework Convention on Climate Change to compare the relative global contribution of different emission sources and GHGs to climate change. In 2011, the United States emitted 6,702 teragrams (Tg) (6,702 million metric tons (MMT) of carbon dioxide equivalents, and since 1990, emissions increased at an average annual rate of 0.4 percent (EPA 2013c). In 2010 and 2011, the total amount of carbon dioxide equivalent emissions related to electricity generation was 2,303 Tg (2,303 MMT) and 2,201 Tg (2,201 MMT), respectively (EPA 2013c). The EIA reported that, in 2010, electricity production alone in Illinois was responsible for 94 MMT carbon dioxide equivalents (EIA 2013). Facilities that emit 25,000 MT carbon dioxide equivalents or more per year are required to annually report their GHG emissions to the EPA. These facilities are known as direct emitters and the data is publicly available in EPA's facility-level information on GHGs tool (FLIGHT). In 2012, FLIGHT identified four facilities in Ogle County, Illinois where the Braidwood Station is located, that emitted a total of 0.33 MT carbon dioxide equivalents (EPA 2014e). In 2012, FLIGHT identified 291 facilities in Illinois that emitted a total of 130.3 MMT carbon dioxide equivalents (EPA 2014e).

Appendix E provides a list of present and reasonable foreseeable projects that could contribute to GHG emissions. Permitting and licensing requirements and other mitigative measures can minimize the impacts of GHG emissions. For instance, in 2012 the EPA issued a final GHG Tailoring Rule to address GHG emissions from stationary sources under the CAA permitting requirements; the GHG Tailoring Rule establishes when an emission source will be subject to

permitting requirements and control technology to reduce GHG emissions. On June 25, 2013, President Obama set forward a plan to reduce carbon pollution. The Climate Action Plan will reduce carbon pollution, prepare the United States for the impacts of climate change, and lead international efforts to combat global climate change. Future actions and steps taken to reduce GHG emissions will lessen the impacts on climate change.

EPA's U.S. inventory of GHG emissions, illustrates the diversity of GHG sources emitters, such as electricity generation, industrial processes, and agriculture. Direct GHG emissions resulting from operations at Braidwood range from 941 to 1,503 MT carbon dioxide equivalents (Table 4–29) and total emissions range from 10,872 to 13,962 MT carbon dioxide equivalents. In comparing Braidwood Station's GHG emission contribution to different emissions sources, whether it be total U.S. GHG emissions, emissions from electricity production in Illinois, or emissions on a county level, GHG emissions from Braidwood are minor relative to these inventories; this is evident as presented in Table 4–29. The emissions impact of a single source on climate change requires that a climate model account for that specific source emissions to project the magnitude and extent of climate change. Climate models indicate that short-term climate change (through the year 2030) is dependent on past GHG emissions. Therefore, climate change is projected to occur with or without present and future GHG emissions from Braidwood. The NRC staff concludes that the impact from the contribution of GHG emissions from continued operation of Braidwood on climate change would be SMALL. As discussed in Section 4.14.3.2, climate change and climate-related changes have been observed on a global level and climate models indicate that future climate change will depend on present and future GHG emissions. With continued increases in GHG emission rates, climate models project that Earth's average surface temperature will continue to increase and climate-related changes will persist. Therefore, the cumulative impact of GHG emissions on climate change is noticeable but not destabilizing.

Table 4–29. Comparison of GHG Emission Inventories

Source	CO_2e MMT/year
Global Fossil Fuel Combustion Emissions (2011)[(a)]	31,800
U.S. Emissions (2011)[(b)]	6,702
Illinois (2012)[(c)]	130.3
Ogle County, Illinois (2012)[(c)]	0.33
Braidwood Station Emissions (2008–2012)[(d)]	0.010–0.013

[(a)] Source: IEA (2012)
[(b)] Source: EPA (2013a)
[(c)] GHG emissions account only for direct emitters, those facilities that emit 25,000 MT or more a year (EPA 2014e).
[(d)] Emissions include direct and indirect emissions from operation of Braidwood (Exelon 2013b).

Sources: EPA 2014e, 2013c; Exelon 2013b; IEA 2012

Conclusion

The NRC staff concludes that the cumulative impacts from the proposed license renewal and other past, present, and reasonably foreseeable projects would be MODERATE.

4.16.12 Summary of Cumulative Impacts

The NRC staff considered the potential impacts resulting from the operation of Braidwood during the period of extended operation and other past, present, and reasonably foreseeable future actions near Braidwood. The preliminary determination is that the potential cumulative impacts would range from SMALL to LARGE, depending on the resource. Table 4–30 summarizes the cumulative impacts on resource areas.

Table 4–30. Summary of Cumulative Impacts on Resource Areas

Resource Area	Cumulative Impact
Air Quality and Noise	Past, present, and reasonably foreseeable future activities exist in the geographic areas of interest (local for noise; local and regional for criteria pollutants) that could affect air quality and noise resources. However, the incremental contribution of impacts on air quality and noise resources from plant operations at Braidwood Station would be minimal. The NRC staff concludes that cumulative impacts from other past, present, and reasonably foreseeable future actions on air quality and noise resources in the geographic areas of interest would be SMALL.
Geology and Soils	Any use of geologic materials such as aggregates to support operation and maintenance activities would be procured from local and regional sources. These materials are abundant in the region and geologic conditions are not expected to change during the license renewal term. Thus, activities associated with continued operations are not expected to affect the geologic environment. Considering ongoing activities and reasonably foreseeable actions, the NRC staff concludes that the cumulative impacts on geology and soils during the Braidwood license renewal term would be SMALL.
Water Resources	Considering ongoing activities and reasonably foreseeable actions, the NRC staff concludes that cumulative impacts of the proposed license renewal when combined with other past, present, and reasonably foreseeable future activities on surface water resources would be SMALL to MODERATE, while impacts to groundwater resources would be MODERATE TO LARGE. While the Braidwood facility is not expected to impact surface or groundwater resources, increased regional demand on both surface and groundwater resources is expected to grow throughout the license renewal term.
Terrestrial Ecology	NRC staff concludes that the cumulative impacts on terrestrial resources in the vicinity of the Braidwood site are MODERATE to LARGE based on past, present, and reasonably foreseeable future actions. This level of impact is primarily the result of past habitat alteration and loss on the Braidwood site and within the larger Illinois/Indiana Prairies Level IV Ecoregion. The environmental effects of these actions are clearly noticeable and have destabilized important attributes of certain terrestrial communities. The loss of genetic fitness of native prairie species and the species composition shifts observed in native Illinois forests are demonstrative of such effects. The incremental, site-specific impact from the continued operation of Braidwood during the license renewal period would be an unnoticeable or minor contributor to cumulative impacts on terrestrial resources.
Aquatic Ecology	The NRC staff concludes that the cumulative impacts on aquatic resources in the Kankakee River are MODERATE based on past, present, and reasonably foreseeable future actions. The NRC staff cannot conclude with certainty that future impacts of energy-generating facilities, urbanization, and transportation development will not result in detectable impacts on the aquatic environment of the Illinois portion of the Kankakee River. Continued protection of aquatic habitats through wildlife preserves, parks, and recreational areas, as well as the implementation of the Illinois Wildlife Conservation Plan will likely mitigate such effects, and, therefore, the NRC finds it reasonable to assume that these activities will ensure that future actions do not destabilize important attributes of the aquatic resources in the Illinois portion of the Kankakee River.
Cultural Resources	As described in Section 4.9, no cultural resources would be adversely affected by Braidwood license renewal activities as no associated changes or ground-disturbing activities will occur. Exelon has established draft procedures to ensure cultural resources are considered in project planning during normal operation of Braidwood. Therefore, the NRC staff concludes that the cumulative impact of the proposed license renewal when combined other past, present, and reasonable foreseeable future activities on historic and cultural resources would be SMALL.

Resource Area	Cumulative Impact
Socioeconomics	When combined with other past, present, and reasonably foreseeable future activities, there will be no additional contributory effect on socioeconomic conditions from the continued operation of Braidwood during the license renewal period beyond what is currently being experienced. Increases in the Braidwood workforce during steam generator and vessel head replacement would be temporary and have no long-term socioeconomic impact to the region. Therefore, the NRC staff concludes that the cumulative socioeconomic impact would be SMALL in the immediate vicinity of Braidwood.
Human Health	Based on the NRC staff's review of Braidwood's REMP data, radioactive effluent release data, and Braidwood's expected continued compliance with Federal radiation protection standards during continued operation and the potential refurbishment activities, and regulation of any future development or actions in the vicinity of the Braidwood site by the NRC and the State of Illinois, the NRC staff concludes that the cumulative impacts would be SMALL.
Environmental Justice	The NRC staff concludes that the contributory effects of this action, when combined with other past, present, and reasonably foreseeable future activities considered, would not cause any disproportionately high and adverse human health and environmental effects on minority and low-income populations residing in the vicinity of Braidwood.
Waste Management	NRC staff concludes that the potential cumulative impacts from radioactive and nonradioactive waste during the license renewal term would be SMALL. Waste management activities at Braidwood are expected to be stable during the license renewal term and comply with Federal and State requirements for radioactive and nonradioactive waste. Adequate disposal options at licensed disposal facilities are expected to handle the cumulative volume of radioactive and nonradioactive waste generated by Braidwood and other facilities.
Global Climate Change	Continued increases in GHG emission rates, climate models project that Earth's average surface temperature will continue to increase and climate-related changes will persist. Therefore, the cumulative impact of GHG emissions on climate change is noticeable but not destabilizing. The NRC staff concludes that the cumulative impacts from the proposed license renewal and other past, present, and reasonably foreseeable projects would be MODERATE.

4.17 Resource Commitments Associated With the Proposed Action

4.17.1 Unavoidable Adverse Environmental Impacts

Unavoidable adverse environmental impacts are impacts that would occur after implementation of all workable mitigation measures. Carrying out any of the energy alternatives considered in the SEIS, including the proposed action, would result in some unavoidable adverse environmental impacts.

Minor unavoidable adverse impacts on air quality would occur due to emission and release of various chemical and radiological constituents from power plant operations. Nonradiological emissions resulting from power plant operations are expected to comply with EPA emissions standards, though the alternative of operating a fossil-fueled power plant in some areas may worsen existing attainment issues. Chemical and radiological emissions would not exceed the national emission standards for HAPs.

During nuclear power plant operations, workers and members of the public would face unavoidable exposure to radiation and hazardous and toxic chemicals. Workers would be exposed to radiation and chemicals associated with routine plant operations and the handling of nuclear fuel and waste material. Workers would have higher levels of exposure than members of the public, but doses would be administratively controlled and would not exceed standards or administrative control limits. In comparison, the alternatives involving the construction and operation of a non-nuclear power generating facility would also result in unavoidable exposure to hazardous and toxic chemicals to workers and the public.

The generation of spent nuclear fuel and waste material, including low-level radioactive waste (LLRW), hazardous waste, and nonhazardous waste would be unavoidable. Hazardous and nonhazardous wastes would be generated at non-nuclear power generating facilities. Wastes generated during plant operations would be collected, stored, and shipped for suitable treatment, recycling, or disposal in accordance with applicable Federal and state regulations. Because of the costs of handling these materials, power plant operators would be expected to carry out all activities and optimize all operations in a way that generates the smallest amount of waste possible.

4.17.2 Relationship Between Short-Term Use of the Environment and Long-Term Productivity

The operation of power generating facilities would result in short-term uses of the environment, as described in Chapters 3 and 4. "Short-term" is the period of time that continued power generating activities take place.

Power plant operations require short-term use of the environment and commitment of resources and commit certain resources (e.g., land and energy), indefinitely or permanently. Certain short-term resource commitments are substantially greater under most energy alternatives, including license renewal, than under the no-action alternative because of the continued generation of electrical power and the continued use of generating sites and associated infrastructure. During operations, all energy alternatives entail similar relationships between local short-term uses of the environment and the maintenance and enhancement of long-term productivity.

Air emissions from power plant operations introduce small amounts of radiological and nonradiological constituents to the region around the plant site. Over time, these emissions would result in increased concentrations and exposure, but they are not expected to impact air quality or radiation exposure to the extent that public health and long-term productivity of the environment would be impaired.

Continued employment, expenditures, and tax revenues generated during power plant operations directly benefit local, regional, and state economies over the short term. Local governments investing project-generated tax revenues into infrastructure and other required services could enhance economic productivity over the long term.

The management and disposal of spent nuclear fuel, LLRW, hazardous waste, and nonhazardous waste requires an increase in energy and consumes space at treatment, storage, or disposal facilities. Regardless of the location, the use of land to meet waste disposal needs would reduce the long-term productivity of the land.

Power plant facilities are committed to electricity production over the short term. After decommissioning these facilities and restoring the area, the land could be available for other future productive uses.

4.17.3 Irreversible and Irretrievable Commitments of Resources

This section describes the irreversible and irretrievable commitment of resources that have been noted in the SEIS. Resources are irreversible when primary or secondary impacts limit the future options for a resource. An irretrievable commitment refers to the use or consumption of resources that are neither renewable nor recoverable for future use. Irreversible and irretrievable commitment of resources for electrical power generation include the commitment of land, water, energy, raw materials, and other natural and man-made resources required for power plant operations. In general, the commitment of capital, energy, labor, and material resources is also irreversible.

The implementation of any of the energy alternatives considered in the SEIS would entail the irreversible and irretrievable commitment of energy, water, chemicals, and—in some cases—fossil fuels. These resources would be committed during the license renewal term and over the entire life cycle of the power plant, and they would be unrecoverable.

Energy expended would be in the form of fuel for equipment, vehicles, and power plant operations and electricity for equipment and facility operations. Electricity and fuel would be purchased from offsite commercial sources. Water would be obtained from existing water supply systems. These resources are readily available, and the amounts required are not expected to deplete available supplies or exceed available system capacities.

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5.0 CONCLUSION

This draft supplemental environmental impact statement (SEIS) contains the environmental review of the application for renewed operating licenses for Braidwood Station, Units 1 and 2 (Braidwood), submitted by Exelon Generation Company, LLC (Exelon), as required by the *Code of Federal Regulations* (CFR), Part 51 of Title 10 (10 CFR Part 51), the U.S. Nuclear Regulatory Commission's (NRC's) regulations that implement the National Environmental Policy Act (NEPA). This chapter presents conclusions and recommendations from the site-specific environmental review of Braidwood. Section 5.1 summarizes the environmental impacts of license renewal; Section 5.2 presents a comparison of the environmental impacts of license renewal and energy alternatives; and Section 5.3 presents the NRC staff conclusions and recommendation.

5.1 Environmental Impacts of License Renewal

The NRC staff's review of site-specific environmental issues in this SEIS leads to the conclusion that issuing renewed licenses at Braidwood would have SMALL to MODERATE impacts for the Category 2 issues applicable to license renewal at Braidwood. The NRC staff considered mitigation measures for each Category 2 issue, as applicable. The NRC staff concluded that no additional mitigation measure is warranted.

5.2 Comparison of Alternatives

In Chapter 4, the staff considered the following alternatives to Braidwood license renewal:

- no-action alternative,
- natural gas combined-cycle alternative,
- super-critical pulverized coal alternative,
- new nuclear alternative, and
- combination alternative (wind, solar).

Based on the summary of environmental impacts provided in Table 2–2, the NRC staff concluded that the environmental impacts of renewal of the operating licenses for Braidwood would be smaller than those of feasible and commercially viable alternatives. The no-action alternative—the act of shutting down Braidwood on or before its licenses expires—would have SMALL environmental impacts in most areas with the exception of land use and socioeconomic impacts, which would have SMALL to MODERATE and SMALL to LARGE environmental impacts, respectively. Continued operations would have SMALL to MODERATE environmental impacts for Aquatic Resources, and SMALL impacts is all other areas. The staff concluded that continued operation of the existing Braidwood units is the environmentally preferred alternative.

5.3 Recommendation

The NRC staff's preliminary recommendation is that the adverse environmental impacts of license renewal for Braidwood are not so great that preserving the option of license renewal for energy-planning decisionmakers would be unreasonable. This recommendation is based on the following:

- the analysis and findings in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*,
- the Environmental Report submitted by Exelon,
- consultation with Federal, State, and local agencies,
- the NRC staff's environmental review, and
- consideration of public comments received during the scoping process.

6.0 LIST OF PREPARERS

This supplemental environmental impact statement (SEIS) was prepared by members of the Office of Nuclear Reactor Regulation (NRR) with assistance from other U.S. Nuclear Regulatory Commission (NRC) organizations and contract support from Pacific Northwest National Laboratory (PNNL), Ecology and Environment, Inc. (E&E), and BLH Technologies, Inc. (BLH). Table 6–1 lists the NRC staff who contributed to the development of the SEIS. Ecology and Environment, Inc., provides contract support for air quality, meteorology (climatology), and alternative reviews. PNNL provides contract support for severe accident mitigation alternative (SAMA) reviews. BLH provides contract support for technical editing reviews.

Table 6–1. List of Preparers

Name	Affiliation	Function or Expertise
NRC		
B. Wittick	NRR	Management oversight
D. Wrona	NRR	Management oversight
T. Tran	NRR	Project management
J. Rikhoff	NRR	Socioeconomic and environmental justice
S. Klementowicz	NRR	Human health
K. Folk	NRR	Hydrology (surface water)
M. Moser	NRR	Aquatic ecology
B. Grange	NRR	Terrestrial ecology and land use
R. Hoffman	NRR	Air quality, meteorology (climatology), and alternative
J. Parillo	NRR	SAMA
E. Larson	NRR	Cultural resource
W. Ford	NRR	Geology, soil, and hydrology (groundwater)
D. Logan	NRR	Threatened and endangered species
National Laboratory Personnel[(a)]		
R. Schmitt	PNNL	SAMA
Commercial Contractors		
D. Kassel	E&E	Alternative
B. Wattle	E&E	Air quality and meteorology (climatology)
M. Chambers	BLH	Technical editing

[(a)] PNNL is operated by Battelle for the U.S. Department of Energy

7.0 LIST OF AGENCIES, ORGANIZATIONS, AND PERSONS TO WHOM COPIES OF THIS SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT ARE SENT

Name	Affiliation
R. Nelson	Advisory Council on Historic Preservation
J. Greendeer	Tribal Nation—Ho-Chunk Nation
D. Lankford	Tribal Nation— Miami Tribe of Oklahoma
J. Froman	Tribal Nation—Peoria Tribe of Indians in Oklahoma
T. Melius (FWS)	U.S. Fish & Wildlife Service
L. Clemency (FWS)	U.S. Fish & Wildlife Service
A. Haaker	Illinois Historic Preservation Agency (State Historic Preservation Officer (SHPO) Office)
J. Barrett	Tribal Nation—Citizen Potawatomi Nation
J. Bender	Tribal Nation—Sac and Fox Tribe of the Mississippi in Iowa/Meskwaki
B. Robidoux	Tribal Nation—Sac and Fox Nation of Missouri in Kansas and Nebraska
G. Thurman	Tribal Nation—Sac and Fox Nation
J. Warren	Tribal Nation—Pokagon Band of Potawatomi
H. Frank	Tribal Nation—Forest County Potawatomi
K. Meshigaud	Tribal Nation—Hannahville Indian Community, Band of Potawatomi
S. Ortiz	Tribal Nation—Prairie Band of Potawatomi Nation
J. Blackhawk	Tribal Nation—Winnebago Tribe of Nebraska
S. Cadue	Tribal Nation—Kickapoo Tribe in Kansas
G. Salazar	Tribal Nation—Kickapoo Tribe of Oklahoma
EIS Scoping Participant	**Affiliation**
Bill Rulien	Braidwood Mayor Office
Lawrence Walsh	Will County Executive
Herbert Brooks, Jr.	Will County Board
Seth Jansen	U.S. Congressman Kinzinger Office
Rich Girof	Braidwood Police Department
Mark Kanavos	Exelon
Mike Gallagher	Exelon
John Grueling	Will County Center for Economic Development
Tom Wolf	IL Chamber of Commerce
Don Moran	Will County Board member, Union Sheet Metal Workers, and IL State Rifle Association
James King	REED-Custer (CUSD255), Community Unit School District #255
Doug O'Brien	IL Clean Energy Coalition
Irfan Khan	Exelon
Dee deGroh	Community Advisory Panel (CAP)

EIS Scoping Participant (continued)	**Affiliation**
Angie Hutton	Braidwood Chamber of Commerce
Chris Rosso	Exelon
Dave Kraft	Nuclear Energy Information Service - Chicago
Sue Rezin	Illinois State Senator, 38th District Office
Greg Ridenour	U.S. Congressman Kinzinger Office
Denis Forrest	Community - Exelon
Philip O’Connor	Proactive Strategies, Inc.
Steve Quigley	Will County Governmental League
Frank Antos	CAP
Nancy Ammer	Grundy Economic Development
Alan Keller	Illinois Environmental Protection Agency
Tom Zimmer	Braidwood resident
Shawn Cirton	U.S. Fish and Wildlife Service
Anne Haaker	SHPO Office
Kent Collier	Kickapoo Tribe of Oklahoma
David A. Kraft	Nuclear Energy Information Service

8.0 INDEX

APPENDIX A
COMMENTS RECEIVED ON THE BRAIDWOOD STATION ENVIRONMENTAL REVIEW

COMMENTS RECEIVED ON THE BRAIDWOOD STATION ENVIRONMENTAL REVIEW

A.1 Comments Received During the Scoping Period

The scoping process began on July 31, 2013, with the publication of the U.S. Nuclear Regulatory Commission (NRC) notice of intent to conduct scoping in the *Federal Register* (78 FR 46379). The scoping process included two public meetings held at the Fossil Ridge library in Will County, Illinois, on August 21, 2013. Approximately 60 members of the public attended the meetings. After the NRC staff prepared statements related to the license renewal process, the meetings were open for public comments. Attendees provided oral statements that were recorded and transcribed by a certified court reporter. Any written statements submitted at the public meeting are documented in the transcript of the meetings. Transcripts of the two meetings are attachments to the scoping meeting summary, dated September 28, 2013 (Agencywide Documents Access and Management System (ADAMS) No. ML13248A191). In addition to the comments received during the public meetings, comments were also received electronically and through the mail.

Each commenter was given a unique identifier so that every comment could be traced back to its author. Table A–1 identifies the individuals who provided comments and the Commenter ID associated with each person's set of comments.

Specific comments were categorized and consolidated by topic. Comments with similar specific objectives were combined to capture the common essential issues raised by participants. Comments fall into one of the following general groups:

- Specific comments that address environmental issues within the purview of the NRC environmental regulations related to license renewal (Category 1 and Category 2 issues, or not addressed in NUREG-1437). The comments also address alternatives to license renewal and related Federal actions.

- General comments (expression) in support of or opposed to nuclear power or license renewal, or comments regarding the renewal process, the NRC's regulations, and the regulatory process.

- Comments that address issues that do not fall within or are specifically excluded from the purview of NRC environmental regulations related to license renewal. These comments typically address issues such as the need for power, emergency preparedness, security, current operational safety issues, and safety issues related to operation during the renewal period.

The comments that are general or outside the scope of the environmental review for Braidwood Station (Braidwood) license renewal are not included here but can be found in the scoping summary report (ADAMS No. ML13281A537). To maintain consistency with the scoping summary report, the unique identifier used in that report for each set of comments is retained in this Appendix A.

Table A–1. Individuals Providing Comments During the Scoping Comment Period

Commenter	Commenter ID	Affiliation (if stated)	ADAMS No.
Bill Rulien	Braidwood 1	Braidwood Mayor Office	ML13248A191
Lawrence Walsh	Braidwood 2	Will County Executive	ML13248A191, ML13247A009
Herbert Brooks, Jr.	Braidwood 3	Will County Board	ML13248A191
Seth Jansen	Braidwood 4	U.S. Congressman Kinzinger Office	ML13248A191
Rich Girof	Braidwood 5	Braidwood Police Department	ML13248A191
Mark Kanavos	Braidwood 6	Exelon	ML13248A191
Mike Gallagher	Braidwood 7	Exelon	ML13248A191
John Grueling*	Braidwood 8	Will County Center for Economic Development	ML13248A191
Tom Wolf	Braidwood 9	IL Chamber of Commerce	ML13248A191
Don Moran*	Braidwood 10	Will County Board member, Union Sheet Metal Workers, and IL State Rifle Association	ML13248A191
James King	Braidwood 11	REED-Custer (CUSD)	ML13248A191
Doug Obrien	Braidwood 12	IL Clean Energy Coalition (ICEC)	ML13248A191
Irfan Khan	Braidwood 13	Exelon	ML13248A191
Dee deGroh	Braidwood 14	Community Advisory Panel (CAP)	ML13248A191
Angie Hutton	Braidwood 15	Braidwood Chamber of Commerce	ML13248A191
Chris Rosso	Braidwood 16	Exelon	ML13248A191
Dave Kraft*	Braidwood 17	Nuclear Energy Information Service—Chicago	ML13248A191
Sue Rezin	Braidwood 18	State Senator, 38th District Office	ML13248A191, ML13248A271
Greg Ridenour	Braidwood 19	U.S. Congressman Kinzinger Office	ML13248A191
Denis Forrest	Braidwood 20	Community - Exelon	ML13248A191
Philip O’Connor	Braidwood 21	Proactive Strategies, Inc.	ML13248A191
Steve Quigley	Braidwood 22	Will County Governmental League	ML13248A191
Frank Antos	Braidwood 23	CAP	ML13248A191
Nancy Ammer*	Braidwood 24	Grundy Economic Development	ML13248A191
Alan Keller	Braidwood 25	Illinois Environmental Protection Agency (May 22, 2013, prior to the scoping period)	ML13207A105
Tom Zimmer	Braidwood 26	Braidwood resident	ML13263A219

Commenter	Commenter ID	Affiliation (if stated)	ADAMS No.
Shawn Cirton	Braidwood 27	Fish and Wildlife Service	ML13269A373
Anne Haaker	Braidwood 28	Office of the State Historic Preservation Officer	ML13269A369
Kent Collier	Braidwood 29	Kickapoo Tribe of Oklahoma	ML13274A239
David A. Kraft	Braidwood 30	Nuclear Energy Information Service	ML13277A305

* Scoping participant who provided mailing address or e-mail address and requested to be on the NRC distribution list.

Applicable scoping comments are grouped in the following categories and presented in the following order:

- Alternatives to License Renewal of Braidwood,
- Socioeconomic Impact of Braidwood,
- Water Usage or Hydrology,
- Human Health,
- Terrestrial or Aquatic Ecology, and
- Climate Change.

A.1.1 Alternatives to License Renewal of Braidwood, Units 1 and 2

The comments in this category are in Section 5 of the scoping summary report and labeled with the following identifiers: 1-1, 4-2, 7-1, 9-1, 10-2, 11-2, 12-1, 19-2, 1-3, 7-2, 10-4, 12-3, 21-1, and 30-3. The comments listed below are extracted from the original sources in Section 5 of the scoping summary report.

Comment 1-1: I was about ten years old, I used to get my dad’s newspaper and read it. And I started to learn about the first commercial nuclear power plant in the whole country that started producing power. And it was just an amazing thing to me with no fuel and no pollution. And that plant was started by Commonwealth Edison. That’s our little Dresden plant over there. They were on the cutting edge of this technology.

Now, when I was about 20, I built my first solar collector. And I also decided to build and experimented with some wind generators. Didn’t take me too long to figure out when the wind don’t blow, it would make great supplemental power, but could never be reliable as a source of power.

In the 43 years since then, almost nothing has changed. If you want reliable, safe, massed produced pollution free power, you’re going to get it from a nuclear power plant. So, as far as we can see in the future, that’s what our future holds for us.

Comment 4-2: While many areas of Illinois struggle to meet clean air standards, the generating station at Braidwood offers affordable, abundant energy with a fraction of the greenhouse gas emissions as other conventional energy sources.

Comment 7-1: We also took a look at the environmental aspects and impacts of continuing to operate Braidwood. We looked at all aspects of continuing impacts of the plant on the

environment. And our conclusion is that the impacts on the environment are small. And I use the term small in the sense of the regulation. The regulations define small as the environmental effects are not detectible or are minor.

We also reviewed the alternatives if Braidwood would not have its license renewed and another source of electric generation would have to be installed either here on site or someplace else to generate that replacement electricity. We concluded that any other means of generating the replacement electricity would have more have an impact on the environment than the continued operation of Braidwood.

<u>Comment 9-1</u>: To maintain an abundant and diverse electricity supply and to be able to provide that supply at competitive rates, Illinois relies heavily on its fleet of nuclear generation stations.

Illinois has more nuclear power generation than any state in the country. Nearly 45 percent of Illinois' electricity is produced from nuclear power and 90 percent of Illinois' carbon-free electricity is produced from nuclear power. If you want to impress your friends at a cocktail party, test that trivia on the number one state for nuclear. They very rarely guess Illinois.

Whether or not you agree with President Obama's recent push on making America a leader in reducing carbon emissions, every kind of energy generation is looking to improve its cost, efficiency, reliability, and yes, its carbon footprint. While coal and gas remain viable, an important source of electricity and our renewable sector continues to grow, Illinois' nuclear industry combines capacity, reliability, and efficiency without carbon emissions.

At the same time, nuclear generation employs thousands of Illinoisians and [in]jects billions of dollars into our state's economy every year. In today's political world, it's hard to get any kind of serious energy policy going and it's hard to predict how new technologies will affect future electricity generation opportunities, but it doesn't take a nuclear physicist, and I'm not a nuclear physicist, but it doesn't take one to figure out that a diverse reliable supply of electricity will create cost competitive power that our economy and our businesses need to thrive.

So, in that light, because Braidwood has been a key part of Illinois' nuclear fleet, which has in turn been a critical part of Illinois' electricity infrastructure, because Exelon has shown itself to be an excellent, responsible owner and operator of the Braidwood generation facility and its other nuclear plants in Illinois and across the country, and because Braidwood is such a benefit for the community in terms of employment, tax revenue, direct and indirect spending and community involvement, for all those reasons and more, the Illinois Chamber of Commerce strongly supports this application and hopes you see fit to grant Exelon the license renewal.

<u>Comment 10-2</u>: As Illinois struggles in today's competitive business market, we cannot afford to ignore any of the things that help us put us on better footing. One of the building blocks to economic development is affordable and reliable electricity. The Illinois's diverse network of electricity generation coming from coal, wind, and nuclear gives us an advantage in enticing new and retaining existing businesses to the area.

Unlike the rolling blackouts experienced in California during 2000 and 2001, our local electrical generation and transmission systems have provided consistent reliable electricity and have done so with diminishing cost to consumers as compared to the CPI.

I remember cooling my first home, a tiny 900 square foot house with summer monthly electric bills of over $200 in the mid-80s. Today, I live in a modest town home about three times that large and pay about $150 in summer months to cool it. Quite the bargain compared to nearly 30 years ago, especially when considered next to the cost associated with fueling your car or paying for health care.

<u>Comment 11-2</u>: And I also would like to say on a personal note that the reason I mentioned that I grew up and was born eight miles from here is because I used to play on the spoils for the coal mining that was done there. It's probably illegally but back then nobody said anything about it. We played in those lakes, we played on those spoils. And when I go back there to this day and visit my relatives, and I see all of the red lights flashing from all of the windmills, it kind of makes me sick to my stomach to see what has happened to some of the environmental, you talk about environmental impact, that to me, when you drive south of DeWitt and you see all of those windmills, and then you realize that the generation from those windmills is slight in comparison to the small footprint of this plant.

<u>Comment 12-1</u>: And the benefits derived from Braidwood and the other nuclear plants in Illinois are not limited to the economy. It's an enormous benefit that the generation of 18 million megawatts of electricity at Braidwood last year produced no carbon air admissions.

Earlier this year, NASA's Goddard Institute sought to quantify the real impact of nuclear power's carbon emissions free operations. The Goddard study found that replacing nuclear power with fossil fuel generation would lead to an estimated 76,000 deaths per year globally, primarily as a result of increased cardio and pulmonary disease.

And this is even more important here in Illinois. The Chicago metropolitan area is designated a non-attainment area by the EPA due to air pollution. And this situation would be greatly acerbated without the existence of the Braidwood generating station which produces enough electricity to power two million homes without adding to this environmental problem.

And I think it's also important to note we're talking a great deal about two parts of our environment. We're talking about ecosystem and the impacts that we traditionally think of as environmental. We talk about emissions and we talk about impacts on the air and the water.

<u>Comment 19-2</u>: While many areas of Illinois struggle to meet clean air standards, the generating station at Braidwood offers affordable, abundant energy with a fraction of the greenhouse gas emissions as other conventional energy sources. As Americans' and Illinoisans' demand for energy rises, nuclear generating stations like Braidwood will be vital to meeting the energy needs of our citizens.

<u>Comment 1-3</u>: When I was about 10 years old I used to read my dad's newspaper, and the first commercial nuclear power plant in about 1960 came online, and it was an amazing thing to me. It produced power with almost no fuel, no pollution. Commonwealth Edison, the parent company of Exelon, was the cutting edge of technology, the company that brought that to us.

When I was about 20, I built a solar collector, and I also experimented with a wind generator. It didn't take too long to realize when the breeze quit that it was great supplemental power but it wasn't something you could really rely on as a source of power. In the 43 years since then, there hasn't been anything much that's changed. If you want reliable, mass produced pollution free electric power, nuclear power is the proven technology and the way to go for now, and as far as we can see into the future.

<u>Comment 7-2</u>: We've also reviewed the alternatives if Braidwood would not have its license renewed and another source of electric generation would have to be installed, either here on site or someplace else to generate the replacement electricity organization studying the impacts of climate change, sought to quantify the impact of nuclear power's carbon free emissions. Goddard's study found that replacing nuclear power with [fossil] fuel generation, would lead to approximately 76,000 deaths globally every year, primarily as a result of increased cardio and pulmonary disease.

This is even more important here in Illinois, as we all know the Chicago metropolitan area is designated as a non-attainment area by the EPA due to air pollution, and this situation would be greatly exacerbated without the existence of the Braidwood Generating Station, which produces energy to power up to two million homes, without adding to our existing environmental problems.

We concluded that any other means of generating the replacement electricity would have more an impact to the environment than the continued operation of Braidwood.

<u>Comment 10-4</u>: As Illinois struggles in today's competitive business market, we cannot afford to ignore any of the things that helped put us on a better footing. One of the building blocks to economic development is affordable and reliable electricity. Illinois' diverse network of electricity generation coming from coal, wind and nuclear gives us an advantage in enticing new and retaining existing businesses to the area.

Unlike the rolling blackouts experienced in California during 2000 and 2001, our local electric generation and transmission systems have provided consistent, reliable electricity and have done so with a diminishing cost to consumers, as compared to the CPI.

I remember cooling my first home, a tiny, 900 square foot house, with summer monthly electric bills of over $200 in the mid 80's. Today I live in a modest town home about three times that large and I pay about $150 in the summer months to cool it, quite the bargain compared to nearly 30 years ago, especially if considered next to the costs associated with fuel in your car or paying for healthcare.

<u>Comment 12-3</u>: And the benefits derived at Braidwood and other nuclear plants are not limited to the economy. It's an enormous benefit that the generation of 18 million megawatts of electricity at Braidwood last year produced no carbon air emissions. And that's an objective, that's a goal we all want to strive to in our country.

Earlier this year NASA's Goddard Institute, which is a leading research organization studying the impacts of climate change, sought to quantify the impact of nuclear power's carbon free emissions. Goddard's study found that replacing nuclear power with foss[i]l fuel generation, would lead to approximately 76,000 deaths globally every year, primarily as a result of increased cardio and pulmonary disease.

This is even more important here in Illinois, as we all know the Chicago metropolitan area is designated as a non-attainment area by the EPA due to air pollution, and this situation would be greatly exacerbated without the existence of the Braidwood Generating Station, which produces energy to power up to two million homes, without adding to our existing environmental problems.

<u>Comment 21-1</u>: Second, in an era in which there's been both great uncertainty about the economics as well as the environmental aspects of fossil fuels, these two stations have had the advantage of a low cost, non-fossil fuel supply and all of the intended consequences of that.

<u>Comment 30-3</u>:

<u>Incomplete and faulty analysis in Section 7.0 - Alternatives to the Proposed Action</u>

In reviewing the scenarios Exelon examined to come up with its evaluations concerning the viability of options replacing the power output of Braidwood, we find that Exelon uses information that is perhaps not current, and leaves out significant other real world options for consideration and analysis:

- <u>Role of renewables too narrow, inaccurate, inappropriate</u>: Exelon tends to treat the renewable energy resources as if they are just some variant of

traditional fossil and nuclear plants. They are not. As a result they analyze these renewables solely in ways amenable to their own narrow view of functioning, which is not necessarily the best or optimal use of the particular renewable energy resource. For example only centralized energy station use of both wind and solar are considered, with no consideration of “distributed generation” in any meaningful way. Pairing up one renewable with natural gas is the only permutation analyzed, when pairing up of solar with wind to compliment the strengths of both is ignored. Further, it is not clear the degree to which the operational efficiencies of these renewables either in the present or the future is accurately analyzed.

Improvements in technology, higher wind towers, increased solar panel efficiencies, etc. are all very real prospects even before the 2024/26 license expirations of the two Braidwood nuclear reactors. We believe that this section needs a serious revision, perhaps from an outside independent consultant to more accurately reflect both the real, and the realistically anticipated world of renewable energy contributions.

- Anachronistic business model used exclusively: The Exelon ER examines the contributions of all competitors to the Braidwood nuclear plant - not just the renewables - on the assumption that Braidwood can only be replaced by “baseload” power. While indeed that is the way things are structured at present, current trends and real world energy discussions are starting to envision the end of this business model and approach. The notion of “distributed power” has been around for over a decade. Recently FERC officials have seriously talked about “baseload” being a concept of the past, which technological developments in both generation and grid dispatching will render increasingly meaningless. Some major US utilities are even setting up exploration of a non-baseload oriented system in trial increments within their existing systems.

  The purpose of the license extension proceeding for Braidwood is NOT to analyze its past performance and compare it to the present; it is to look at its present performance and extrapolate that out an additional 20 years (31 and 33 years from now), attempting to envision the energy world at that time to see if the “present” can compete or even function in that world. Insufficient attention has been paid to this analysis in the Exelon ER. Section 7 reads like a convenient cherry-picked self-fulfilling prophecy.

  Even Exelon itself cannot think that the business model is uses today will be the one that Braidwood will operate in from 2024 to 2044. A way to prove that is to ask: does Exelon TODAY operate with the business model it had in 2002 (11 years AGO)? This was just a handful of years out from utility deregulation and unbundling of utilities here in Illinois. Exelon did not even exist. Its predecessor’s predecessor was just in the process of selling off its coal plants.

  Before these critiques are summarily dismissed by NRC as out of the scope of this docket, we would remind you that a “nuclear safety culture” demands that kind of “out of the box” thinking and analysis to “...ensure protection of people and the environment.” You said so yourselves. Analyzing the functioning of Braidwood in the energy world of the future will have serious

implications for Exelon's analysis of socio-economic impacts. Until that analysis is done, their "small" conclusions must be held in serious doubt.

Recommendation: Order Exelon to re-examine its Section 7 comparisons, incorporating: 1) distributed generation and decline of the "baseload power" business model; 2) better data on the capabilities of wind and solar, based on expected improvements in technology, or better and more optimal use decisions; 3) expected upgrades, improvements and additions of grid and dispatching systems in the MISO and PJM Interconnection areas.

Response: *These comments provide information for consideration in the staff's environmental analysis of the alternatives to license renewal, including the alternative of not renewing the operating license—also known as the "no-action" alternative. In Chapters 2 and 4 of this supplemental environmental impact statement (SEIS), the staff discusses the alternatives to license renewal. In addition, in Chapter 4 of this SEIS, the staff considered other alternatives that were subsequently dismissed for reasons of technical, resource availability, or commercial limitations.*

A.1.2 Socioeconomic Impact of Braidwood, Units 1 and 2

The comment in this category is in Section 5 of the scoping summary report and labeled with the following identifier: 30-2.

Comment 30-2 (a):

Analysis of socio-economic impacts are incomplete. No analysis of impacts of early or unexpected closure are considered or provided.

The Exelon ER documents a significant local tax impact for the presence of the Braidwood Nuclear Station, yet only addresses the positive impacts. No mention or analysis of negative impacts resulting from abrupt, planned, or unexpected early closure of Braidwood is presented. This is a significant omission.

According to the Exelon ER Braidwood represents less than 2% of the Will County total tax base, roughly $20 million annually for the years 2008 through 2010. However, it accounts for upwards of 78% of the Reed-Custer School District 255U's adjusted property tax levy. These are not insignificant amounts for the local communities around Braidwood, as opposed to the county as a whole. Their abrupt disappearance would wreak local economic havoc on the affected governmental and essential service entities' ability to operate; while leaving Will County as a whole largely unaffected.

The ER either fails to recognize or mention at all some of the possible events that could result in such a situation:

- Unexpected major accident, resulting in immediate and presumably premature closure
- NRC ordered shut down
- Exelon's unilateral decision to close the plant on economic or other grounds, as it did at Zion, resulting in an immediate loss of about 55% of Zion's tax base
- Devaluation through sale, as occurred at the Clinton station, resulting in enormous loss of tax base
- Eventual old-age, license expiration closure (the outcome most hoped for)

Exelon even provides a possible indication of the kinds of circumstances that would lead it to close Braidwood on economic grounds. Section 3.2 on Refurbishment indicates that Exelon is well aware that Braidwood Unit 2 may need a steam generator replacement during the extended operational lifetime. It is also tracking the potential for reactor vessel head replacements at its operating PWRs at both Byron and Braidwood. Should either or both of these conditions emerge at a time of deflated energy prices, or at a time Exelon acknowledges might occur as early as 2024 when renewables are much more cost competitive and approaching base load capabilities (Sec. 7.2, page 7-9), or as the result of multi-season drought curtailing water availability - Exelon being a business will certainly make the calculations it made when it closed Zion, and decide if Braidwood should continue to operate.

In this omission the ER makes the same mistake the U.S. Government made when it invaded Iraq - *it had no exit strategy.* To simply assume that the only socio-economic effects of Braidwood's presence will be positive ones is simply irrational.

Finally, the Exelon ER is somewhat dismissive of the effects that Braidwood seems to have on local property values. Exelon seems to focus primarily on "property value," as opposed to salability, which anecdotally seems to be of much greater concern in the communities directly surrounding the reactor site. It matters little what your property is "worth" if you are trying to sell it to move out of the area and can't. Such figures should be easy to obtain from local realtors, and should be included in t[h]e ER.

Response*: Information about Exelon's tax payments is described in Chapter 3 in the SEIS, and the socioeconomic impacts of station closure and the termination of reactor operations due to the expiration of the Braidwood operating licenses is described as part of the no action alternative in Chapter 4 in the SEIS. The impacts of closing (or decommissioning a nuclear power plant) are also described in the Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities: Regarding the Decommissioning of Nuclear Power Reactors, (NUREG-0586). The environmental consequences of closing or decommissioning of Braidwood would be addressed in a separate environmental NEPA review.*

Regarding cost competitiveness, as stated in Title 10 of the Code of Federal Regulations (10 CFR) 51.45(c), "Environmental reports prepared at the license renewal stage under § 51.53(c) need not discuss the economic or technical benefits and costs of either the proposed action or alternatives except if these benefits and costs are either essential for a determination regarding the inclusion of an alternative in the range of alternatives considered or relevant to mitigation. In addition, environmental reports prepared under § 51.53(c) need not discuss issues not related to the environmental effects of the proposed action [license renewal] and its alternatives." Comment petitioning to issue, amend, or rescind the license renewal rule is governed by 10 CFR 2.802, "Petition for Rulemaking," and is beyond the scope of this environmental review for Braidwood license renewal.

<u>Comment 30-2 (b)</u>:

Recommendation: Planning for some kind of eventual closure must be made long before it happens to minimize economic and service disruptions to the entities whose tax base will be affected. Debate about the license extension serves as a good reminder of this fact, and an opportunity to take action. We recommend that dependent governmental and taxing entities begin formal negotiations with Exelon to establish an escrowed "closure mitigation fund," based on some mutually agreeable assessment and payment structure, so that dependent entities will have some kind of temporary funds available to soften the economic blow of closure, and not radically disrupt essential services. Salability of property should be investigated and reported more directly, especially in the communities adjacent to the plant.

Response: *This portion of the comment is directed at dependent governmental and taxing entities. The staff will not respond to this comment.*

A.1.3 Water Usage or Hydrology

The original sources for the comments in this category (water usage) can be found in Section 5 of the scoping summary report and are labeled with the following identifiers: 6-2, 6-6, 25-1, 26-1, and 30-1. These comments are extracted from the original sources.

<u>Comment 6-2</u>: Radiation monitors are staged in over 40 locations within a [10-mile] radius of our station to monitor any radiation of those levels and ensure the safety of the community.

We've also had great success in our tritium re-mediation efforts. In the last [7] years, Braidwood has made significant progress. [Hydrogeologists] have confirmed that re-mediation is having the intended effect. As of today, the square footage of land [affected] by tritium has been reduced by 97 percent. And the highest concentrations of tritium in the ground have been reduced by 99 percent. We will continue to monitor and we still retain the ability to re-mediate via pumping should it become necessary.

Braidwood's environmental management systems are certified under the strictest criteria of the International Organization of Standardization or ISO. Specifically, we receive the ISO 14001 re-certification which is an industry recognition of our environmental efforts.

This is an internationally recognized benchmark for environmental management. The ISO 14001 certification requires a commitment to excellence in meeting our regulatory requirements in the prevention of pollution and continuous improvement of our environmental systems.

<u>Comment 6-6</u>: We have a comprehensive on-site environmental groundwater protection program for monitoring and detecting the presence of radioactivity in the ground water before it has a chance to migrate off of our property. This program includes 19 on-site monitoring wells designed to protect, detect and alert us of any unusual events, levels of radiation in the groundwater, so that we can assess and address any changes quickly.

We have detailed procedures that outline how we test all the water leaving our station. Radiation monitors are staged at 40 locations within a [10-mile] radius around the [plant] to monitor any radiation levels and dose to ensure the safety of the community.

We also have had great success in our tritium remediation efforts. In the last [7] years Braidwood has made significant progress. Hydrogeologists have confirmed that remediation is having the intended effect. As of today the square footage of land affected by tritium has been reduced by 96 percent, and the highest concentrations of tritium in the groundwater have been reduced by 99 percent. We'll continue to monitor and retain the ability to remediate via pumping, should that become necessary.

Braidwood's environmental management systems are certified under the strictest criteria, the International Organization of Standardization, or ISO, specifically we have received the ISO 14001 [standard] certification, an industry standard recognition. This is an internationally recognized benchmark for environmental management. The ISO 14000['s] certification requires a commitment to excellence in meeting our regulatory requirements, and the prevention of pollution and continuous improvement in our environmental programs and systems.

<u>Comment 26-1</u>: We live approximately 1800 ft from Braidwood nuclear remediation pond. When they pump down their pond, our pond levels also drop. We have talked to other neighbors who have the same problem. One was paid and told not to say anything by Exelon. Also when they 1st began pumping, they were sued by Forest Preserve District for draining their

wet lands killing wildlife. Forest Preserve won lawsuit. Also, the property Exelon purchased next to my home is not maintained. I have talked to them about it and they said they would only cut vegetation once a year. I feel all the above is an environmental and health issue. Also, I feel that all the previous tritium spills of thousands of gallons and steam releases of tritium should be taken into consideration before the 20 year license extension is given.

Comment 30-1:

The ER submitted by Exelon is incomplete in not providing evidence that it has examined the projected effects of predicted Illinois climate disruption on future operations. NRC regulations are inadequate for not requiring this examination.

Consideration of climate disruption projections is not an extraordinary request. Many other sections of Exelon's applications require them to project into the future their analysis of how Braidwood will be operating at some future date. An issue that could well determine whether Braidwood has sufficient water to either operate or sufficiently cool safety-related functions at the plant should not be cavalierly dismissed; it should be at the top of the list for evaluation.

Current climate models suggest that Illinois will gradually assume a climate resembling that of East Texas or Mississippi by mid-Century (within the period of operational life extension of Braidwood), depending on whether one is running a low- or high- emissions model. Summer temperatures are expected to increase on average from 3.30 F to 8.60 F. While total precipitation is expected to remain about the same, seasonal variation will increase, and frequency of heavy precipitation events-measured in terms of number of days per year with more than 2 inches of rain, and annual maximum 24-hr, 5-day and 7-day rainfall totals--is likely to continue to increase, particularly closer to the Great Lakes, a factor which will have implications in the Comments below.

The implications of these projections do not seem to be incorporated into the ER analysis provided by Exelon, which invariably result in the conclusion of "small" impact. The ER clearly states that the Kankakee River is a "small river" by definition. It is essential for the adequate functioning of the ultimate heat sink for the reactors - the cooling pond. Increased evaporation and less recharge in a climate disrupted Illinois will add stress to the pond, which according to the Exelon ER experienced 5 fish kills from 2001 to 2007. [Sec. 2.2.4.4., p. 2-15], as a result of high water temperatures and low dissolved oxygen levels in summer. These conditions are expected to worsen over time in stressed waterways.

Make-up water for the mechanical draft cooling tower system relies on the Kankakee River. Decreased volume and flow rates expected under projected climate disruption models for Illinois could have an adverse effect on cooling functions at Braidwood.

Exelon's historic penchant to request license variances on water use and thermal discharge from IEPA [Illinois Environmental Protection Agency] suggests the possibility for greater effect than is characterized in the Exelon ER document. The alternative would be curtailment of operation, which also does not appear factored into the Exelon ER in any manner.

Recommendation: NRC should require a more thorough projection of water use at Braidwood, based on the best possible climate modeling for Illinois between now and mid-century. Because this variation in climate disruption and its effects are local/regional, it falls outside the scope of a generic analysis or regulation.

Response: *These comments provided input (or data) for the staff's environmental analysis of water resource impacts of Braidwood on local and regional communities. These comments are related to Braidwood's water usage of the Kankakee River. The staff discusses water usage impacts in Chapters 3 and 4 of the SEIS.*

Clean Water Act Section 401 certification

Comment 25-1: This Agency [IEPA] received a request on May 22, 2012[,] from Exelon Generating Company requesting necessary comments concerning the renewal of the Nuclear Regulatory Commission operating licenses for the Braidwood Generating Stations Units 1 and 2 in Will County. We offer the following comments.

This Agency [IEPA] hereby issues certification under Section 401 of the Clean Water Act (PL 95-217), subject to the applicant's compliance with the following conditions:

(1) The applicant shall be responsible for obtaining NPDES permits required for wastewater or stormwater discharges to waters of the State from the proposed activity.

(2) This certification does not cover future activities that require a federal authorization under Section 404 of the Clean Water Act.

This certification becomes effective when the Nuclear Regulatory Commission includes the above conditions # 1 through # 2 as conditions of the requested license issued under the Atomic Energy Act of 1954.

This certification does not grant immunity from any enforcement action found necessary by this Agency [IEPA] to meet its responsibilities in prevention, abatement, and control of water pollution.

Response*: This comment provided input (or data) for the staff's environmental analysis of water resource impacts of Braidwood on local and regional communities. This comment addresses Clean Water Act (CWA) Section 401 matters. The staff discusses impacts on water resource in Chapters 3 and 4 of the SEIS. In addition, the NRC staff responded to the Illinois EPA in an NRC letter (ADAMS No. ML14220A382).*

The NRC understands the importance of the CWA and a delegated State's role in implementing the statute. As early as 1984, the Commission recognized that in revising its regulations, NRC licenses are subject to conditions deemed imposed by the CWA as a matter of law and that the NRC need not duplicate the U.S. Environmental Protection Agency's or a delegated State agency's water quality reviews.[11] *To explicitly recognize that conditions are deemed imposed by the CWA and to obviate the need to undertake amendments to incorporate conditions imposed by statute that could be subject to frequent changes by certifying States, the Commission added 10 CFR 50.54(aa)*[12] *to specifically provide that each 10 CFR Part 50 "license shall be subject to all conditions deemed imposed as a matter of law by section 401(a)(2) and 401(d) of the CWA (33 U.S.C.A. 1341(a)(2) and (d)), as amended)." To keep informed of the environmental effects of NRC licensing actions, the Commission relies on reporting requirements of National Pollutant Discharge Elimination System (NPDES) permits to alert the NRC of environmental effects of NRC licensing action. As the Commission stated, "The NRC's role in the water quality area is limited to regulating radiological discharges into aquatic bodies and NEPA matters such as weighing aquatic impacts in NEPA analyses which NRC is required to make before reaching a major Federal licensing decision."*[13]

Because the two 401 certification conditions are license requirements either because they are imposed as a matter of law or they state existing statutory provisions, no further NRC action is

[11] 49 FR 9352, 9359-60. "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions and Related Conforming Amendments." March 12, 1984.

[12] 49 FR 9352, 9360.

[13] 49 FR 9352, 9380.

needed with respect to these two conditions. Specifically, (1) Exelon must obtain a CWA Section 402 (NPDES) permit from the State in accordance with 33 U.S.C. § 1342, and (2) a 401 certification does not authorize activities that require an authorization under Section 404 of the CWA, 33 U.S.C. § 1344 (i.e., the permits for discharges of dredged or fill material, which are issued by the U.S. Army Corps of Engineers). Appendix B, paragraph 3.2 of the current Braidwood licenses further requires that Exelon provides the NRC with copies of any NPDES permit or State certification (or changes to those documents) within 30 days of approval. If the licenses are renewed, this requirement will be carried over to the renewed licenses for Braidwood Units 1 and 2.

A.1.4 Human Health

The original sources for the comments in this category (Human Health or Radiation Impact) can be found in Section 5 of the scoping summary report and are labeled with the following identifiers: 6-1, 8-3, 15-1, 6-5, 8-6, and 15-3. These comments are extracted from the original sources.

<u>Comment 6-1</u>: I'm proud to say that we've been a key part of this community for over 25 years. Braidwood generating station operates in a manner that preserves the environment. We maintain a comprehensive radiological monitoring program that extensively monitors the air and the water and the food products around the facility that ensures that we are not adversely impacting the environment.

We also have a comprehensive on-site environmental ground water protection program that can monitor and detect the presence of radioactivity in ground water before it has a chance to migrate off-site. This program includes 19 on-site wells designed to detect and alert us of any unusual level of radiation in the ground water so that we can address any changes that we see quickly. We have detailed procedures which outline how we test all water leaving our station.

<u>Comment 8-3</u>: The CED recognizes that a good environmental steward Exelon is at their Braidwood facility. The radiological monitoring and the ground water protection programs in place today give the community a sense of safety and environmental protection that we expect from a world-class facility like Braidwood.

<u>Comment 15-1</u>: Exelon has been here a long time and they've been a good neighbor. And with the exception of the tritium leak, they did take care of it, maybe not like some people want it, but it has been taken care of. It did open the communication up a lot.

<u>Comment 6-5</u>: Braidwood Generating Station operates under the manner that preserves the environment. We maintain a comprehensive, radiological monitoring program that extensively monitors the air, water and food products around the facility to ensure that we did not adversely impact the environment.

<u>Comment 8-6</u>: The CED [Center for Economic Development] recognizes what a good environmental steward Exelon has been and will continue to be at their Braidwood facility. The radiological monitoring and the groundwater protection programs in place today give the community a sense of safety and environmental protection we expect from a world class facility like Braidwood.

<u>Comment 15-3</u>: And there was an issue with the tritium, and as being a good neighbor, which they promised when they started, they did remediate the area, they bought the property that was impacted, and with that they took aggressive action so that it doesn't happen again. And with that they also opened up great communications.

Response: *These comments provided information for the staff's consideration in its description of and evaluation of (a) impacts to human health, and (b) environmental impacts related to possible radioactive leaks from Braidwood Station.*

Radiation doses to members of the public from the current operations of Braidwood are discussed in the SEIS in Chapters 3 and 4. In these chapters, the staff reviewed the radioactive releases from Braidwood (i.e., radioactive gaseous and liquid effluents, radiation from radioactive waste storage buildings, radiological impacts from refueling and maintenance activities, and tritium leaks) and the results of Braidwood's radiological environmental monitoring program (REMP) (i.e., analysis of air, water (surface, ground, and drinking), sediment, vegetation, and aquatic and terrestrial biota for radioactivity).

A.1.5 Terrestrial or Aquatic Ecology

The original sources for the comments in this category can be found in Section 5 of the scoping summary report and are labeled with the following identifiers: 6-3 and 6-7. These comments are extracted from the original sources.

Comment 6-3: Last year, the Wildlife Habitat Council recognized Braidwood generating station's commitment to the environmental stewardship by awarding us the Wildlife at Work certification. This distinction was awarded for our commitment to ensuring the continuance of healthy wildlife in and around our plant, and our fish habitat restoration project. The project places artificial habitats in the Braidwood lake the greatly benefit the fish throughout their life. It has greatly enhanced the fishery.

Comment 6-7: Last year the Wildlife Habitat Counsel recognized Braidwood Generating Station's commitment to the environmental stewardship by awarding us the Wildlife award certification. This distinction was awarded to our commitment for ensuring that the continuance of the healthy wildlife around our planet, through our fish habitat restoration project. This project places artificial habitats in the Braidwood Lake, and that greatly benefits the fish throughout their life, and greatly enhances the fishery.

Response: *These comments provided information for the staff's consideration in its description of and evaluation of impacts to aquatic and terrestrial resources at Braidwood. The staff discusses terrestrial and aquatic resources in Chapters 3 and 4 of the SEIS.*

A.1.6 Climate Change

The original source for the comment in this category can be found in Section 5 of the scoping summary report and is labeled with the following identifier: 30-4. The comment is extracted from the original source.

Comment 30-4:

Sec. 5.0 - Assessment of New and Significant Information

Since, "...The environmental report must contain any new and significant information regarding the environmental impacts of license renewal of which the applicant is aware." (10 CFR 51.53(c)(3)(iv)), and Exelon and NRC have now been made [aware] of new information not previously analyzed, the law requires that this information be researched, and reported in a revised ER.

Since the climate disruption issues raised above are uniquely local in their manifestation and effects, a generic ruling on them is both inappropriate and would be inaccurate.

Since no apparent investigation has been done concerning either the effects of climate disruption, or the effects of abrupt closure on socio-economic factors, results would certainly "...lead to an impact finding that presents a seriously different picture of the environmental impact of the proposed project in comparison with what was previously envisioned." (Sec. 5.1, page 5-3)

Response: *This comment provided information for the staff's consideration in its description of and evaluation of climate change impacts at Braidwood. The staff discusses climate change (climatology) impacts to individual resource areas in Chapters 3 and 4. The staff provides responses to socioeconomic concerns about abrupt closure of Braidwood in Section A.1.2.*

APPENDIX B
APPLICABLE REGULATIONS, LAWS, AND AGREEMENTS

APPLICABLE REGULATIONS, LAWS, AND AGREEMENTS

The Atomic Energy Act (AEA) authorizes the U.S. Nuclear Regulatory Commission (NRC) to enter into agreement with any state to assume regulatory authority for certain activities. For example, in accordance with Section 274 of the AEA, as amended, the State of Illinois assumed regulatory responsibility over the following nuclear material usages:

- byproduct materials as defined in Section 11e.(1) of the Act,
- byproduct materials as defined in Section 11e.(2) of the Act,
- source materials, and
- special nuclear materials in quantities not sufficient to form a critical mass.

The Illinois Emergency Management Agency (IEMA) administers the Illinois Agreement State Program. In addition to implementing some Federal programs, state legislatures develop state laws, which are subject to applicable Federal statutes and regulations. State laws supplement, as well as implement, Federal laws for protection of air, water quality, and groundwater. State legislation may address solid waste management programs, locally rare or endangered species, and historic and cultural resources.

The Clean Water Act (CWA) allows for primary enforcement and administration through state agencies, provided the state program is at least as stringent as the Federal program. The state program must conform to the CWA and to the delegation of authority for the Federal National Pollutant Discharge Elimination System (NPDES) Program from the U.S. Environmental Protection Agency (EPA) to the state. In accordance with the CWA, for surface water, the primary mechanism to control water pollution is the requirement that directs dischargers (e.g., point source dischargers) to obtain an NPDES permit or, in the case of states where the authority has been delegated from EPA, a State Pollutant Discharge Elimination System (SPDES) permit.

B.1 Federal and State Environmental Requirements

Certain environmental requirements may have been delegated to state authorities for implementation, enforcement, or oversight by the applicable Federal agencies in exercising the agencies' regulations. Table B-1 provides a list of Braidwood licenses and permits needed for compliance with the major requirements of the Illinois environmental laws that affect the license renewal of Braidwood Station (Braidwood). These licenses and permits are addressed in this supplemental environmental impact statement (SEIS), pursuant to the NRC Environmental Standard Review Plan, including applicable Tribal consultation.

Table B–1. Licenses and Permits

Permit	Number	Dates	Responsible Agency
License to operate Braidwood, Unit 1	NPF-72	Issued: 07/02/1987 Expires: 10/17/2026	NRC
License to operate Braidwood, Unit 2	NPF-77	Issued: 05/20/1988 Expires: 12/18/2027	NRC
Hazardous materials shipments registration	040801750001SU	Issued: 06/09/2010 Expired: 06/30/2013	U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration
Shipments of low-level radioactive waste	IL0106	Issued: Not applicable Expires: Not applicable	Illinois Emergency Management Agency, Division of Nuclear Safety
License to deliver radioactive material to processing facility in Tennessee	T-IL005-L11	Issued: 01/1/2011 Expires: (Renewed Annually)	Tennessee Department of Environment and Conservation
Permit to deliver radioactive material to disposal facility in Utah	0110000031	Issued: 05/21/2011 Expires: (Renewed Annually)	Utah Department of Environmental Quality
Illinois Pollutant Discharge Elimination System Permit	IL0048321 (IEPA 1997 and ComEd 2000)	Issued: 07/31/2014 Expired: 07/31/2019	Illinois Environmental Protection Agency, Division of Water Pollution Control
Air Permit (auxiliary boilers and emergency generators)	Application #79020011 ID# 197816AAB	Issued: 05/29/2001 Expired: 04/29/2007 Renewal submitted: 10/30/2006	Illinois Environmental Protection Agency, Division of Air Pollution Control
Registration of Industrial and Hazardous Waste	ILD000806505	Issued: Not applicable Expires: Not applicable	Illinois Environmental Protection Agency, Bureau of Land
Potable Water System	IL3081869	Issued: Not applicable Expires: Not applicable	Illinois Department of Health, Division of Environmental Health

Source: Braidwood License Renewal Application (Exelon 2010)

B.2 References

Several operating permit applications may be prepared and submitted. Regulatory approval, permits, or both would be received before license renewal approval by the NRC. As a convenient source of references of environmental requirements, Table B-2 lists representative Federal, state, and local approvals by the responsible agencies applicable to license renewal.

Table B–2. Federal, State, and Local Laws and Other Requirements

Braidwood is subject to other requirements regarding various aspects of their environmental program. Representative examples of those requirements are briefly described below.

License, Permit, or Other Required Approval (or Submittal)	Responsible Agency	Authority	Relevance
Air Quality Protection			
Required for sources that are not exempt and are major sources, affected sources subject to the Acid Rain Program, sources subject to new source performance standards, or sources subject to National Emission Standards for Hazardous Air Pollutants	U.S. EPA or IEPA	Federal Clean Air Act (42 USC 7401), 40 CFR 70, and Illinois Administrative Code 35 IAC 201	Nuclear power plants are subject to 40 CFR Part 61, Subpart H, "National Emissions Standards for Emissions of Radionuclides," which is included in the terms and conditions of the Title V Operating Permit.
Water Resources Protection			
NPDES Permit—Construction Site Stormwater—required before making point source discharges of storm water from a construction project that disturbs more than 2 ha (5 ac) of land	U.S. EPA or IEPA	CWA (33 USC 1251 et seq.); 40 CFR Part 122; Illinois Administrative Code, Title 35, Part 309	Any plant refurbishment involving construction of more than 2 ha (5 ac) of land would require a Stormwater Pollution Prevention Plan and Construction Site Storm Water Discharge Permit.
NPDES Permit—Industrial Facility Stormwater—required before making point source discharges of storm water from an industrial site	U.S. EPA or IEPA	CWA (33 USC 1251 et seq.); 40 CFR Part 122; Illinois Administrative Code Title 35, Part 309	Stormwater would be discharged from the nuclear power plants during operations. Stormwater would discharge through existing outfalls covered by the permit.
NPDES Permit—Process Water Discharge—required before making point source discharges of industrial process wastewater	U.S. EPA or IEPA	CWA (33 USC 1251 et seq.); 40 CFR Part 122 ; Illinois Administrative Code Title 35, Part 309	Processed industrial wastewater would be discharged through existing outfalls covered by the permit.
Spill Prevention Control and Countermeasures Plan—required for any facility that could discharge diesel fuel in harmful quantities into navigable waters or onto adjoining shorelines	U.S. EPA or IEPA	CWA (33 USC 1251 et seq.); 40 CFR Part 112	A Spill Prevention Control and Countermeasures Plan is required at nuclear power plants storing large volumes of diesel fuel or other petroleum products or both.

License, Permit, or Other Required Approval (or Submittal)	Responsible Agency	Authority	Relevance
CWA, Section 401, Water Quality Certification—required to be submitted to the agency responsible for issuing any Federal license or permit to conduct an activity that may result in a discharge of pollutants into waters of a state	U.S. EPA or IEPA	CWA, Section 401 (33 USC 1341)	Certification for operation of a nuclear power plant may require a Federal license or permit (e.g., a CWA, Section 404, Permit or a CWA, Section 401, Water Quality Certification).
New Underground Storage Tanks System Registration—required within 30 days of bringing a new underground storage tank system into service	U.S. EPA or IEPA	Resources Conservation and Recovery Act (RCRA), as amended, Subtitle I (42 USC 6991a-6991i); 40 CFR §280.22	This registration is required if new underground storage tank systems would be installed during refurbishment at a nuclear power plant.
Above Ground Storage Tank Permit—required to install, remove, repair, or alter any stationary tank for the storage of flammable or combustible liquids	Applicable State Fire Marshall		This permit is required if new above-ground diesel fuel storage tanks would be installed during refurbishment at a nuclear power plant. In accordance with Braidwood Environmental Report (ER), there is no plan for new diesel fuel storage.
Waste Management & Pollution Prevention			
Registration and Hazardous Waste Generator Identification Number—required before a person who generates over 100 kg (220 lb) per calendar month of hazardous waste ships the hazardous waste off site	U.S. EPA or IEPA	RCRA, as amended (42 USC 6901 et seq.), Subtitle C	Generators of hazardous waste must notify EPA that the wastes exist and require management in compliance with RCRA.

License, Permit, or Other Required Approval (or Submittal)	Responsible Agency	Authority	Relevance
Hazardous Waste Facility Permit—required if hazardous waste will undergo nonexempt treatment by the generator; be stored on site for longer than 90 days by the generator of 1,000 kg (2,205 lb) or more of hazardous waste per month; be stored on site for longer than 180 days by the generator of between 100 and 1,000 kg (220 and 2,205 lb) of hazardous waste per month; be disposed of onsite; or be received from off site for treatment or disposal	U.S. EPA or IEPA	RCRA, as amended (42 USC 6901 et seq.), Subtitle C	Hazardous wastes are usually not disposed of on site at nuclear power plants. Hazardous wastes generated on site are not generally stored for more than 90 days. However, should a nuclear power plant store wastes on site for greater than 90 days for characterization, profiling, or scheduling for treatment or disposal, a Hazardous Waste Facility Permit would be required.
Emergency Planning & Response			
List of Material Safety Data Sheets—submission required for hazardous chemicals (as defined in 29 CFR Part 1910) that are stored on site in excess of their threshold quantities	State and local emergency planning agencies (IEMA)	Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), Section 311 (42 USC 11021); 40 CFR §370.20	Nuclear power plant operators are required to submit list of Material Safety Data Sheets to state and local emergency planning agencies.
Annual Hazardous Chemical Inventory Report—submission required when hazardous chemicals have been stored at a facility during the preceding year in amounts that exceed threshold quantities	State and local emergency response agencies (IEMA); local fire department	EPCRA, Section 312 (42 USC 11022); 40 CFR §370.25	If hazardous chemicals have been stored at a nuclear power plant during the preceding year in amounts that exceed threshold quantities, plant operators would be required to submit an Annual Hazardous Chemical Inventory Report.
Notification of Onsite Storage of an Extremely Hazardous Substance—submission required within 60 days after onsite storage begins of an extremely hazardous substance in a quantity greater than the threshold planning quantity	State and local emergency response agencies (IEMA)	EPCRA, Section 304 (42 USC 11004); 40 CFR §355.30	If an extremely hazardous substance stored at a nuclear power plant in a quantity greater than the threshold planning quantity, plant operators would prepare and submit the Notification of Onsite Storage of an Extremely Hazardous Substance.
Annual Toxics Release Inventory Report—required for facilities that have 10 or more full-time employees and are assigned certain standards	U.S. EPA or IEPA	EPCRA, Section 313 (42 USC 11023); 40 CFR Part 372	If required, nuclear power plant operators would prepare and submit a Toxics Release Inventory Report to EPA.

License, Permit, or Other Required Approval (or Submittal)	Responsible Agency	Authority	Relevance
Industrial Classification codes			
Transportation of Radioactive Wastes and Conversion Products Packaging, Labeling, and Routing Requirements for Radioactive Materials—required for packages containing radioactive materials that will be shipped by truck or rail	U.S. Department of Transportation	Hazardous Material Transportation Act (HMTA) (49 USC 1501 et seq.); AEA, as amended (42 USC 2011 et seq.); 49 CFR Parts 172, 173, 174, 177, and 397	When shipments of radioactive materials are made, nuclear power plant operators would comply with U.S. Department of Transportation packaging, labeling, and routing requirements.
Biotic Resource Protection			
Threatened and Endangered Species Consultation—required between the responsible Federal agencies and affected states to ensure that the project is unlikely to jeopardize the continued existence of any species listed at the Federal or state level as endangered or threatened or result in destruction of critical habitat of such species	U.S. Fish and Wildlife Service (FWS) and other applicable state agencies (listed in Appendix D of this SEIS)	Endangered Species Act of 1973, as amended (16 USC 1531 et seq.)	The NRC would consult with the FWS and state agencies regarding the impact of license renewal on threatened or endangered species or their critical habitat.
CWA, Section 404, (Dredge and Fill) Permit—required to place dredged or fill material into waters of the U.S., including areas designated as wetlands, unless such placement is exempt or authorized by a Nationwide permit or a regional permit (A notice must be filed if a Nationwide or regional permit applies.)	USACE	CWA (33 USC 1251 et seq.); 33 CFR Parts 323 and 330	Any dredging or placement of fill material into wetlands within the jurisdiction of the USACE at a nuclear power plant would require a Section 404 permit.

License, Permit, or Other Required Approval (or Submittal)	Responsible Agency	Authority	Relevance
Cultural Resources Protection			
Archaeological and Historical Resources Consultation—required before a Federal agency approves a project in an area where archaeological or historic resources might be located	State Historic Preservation Officer or Tribal Historic Preservation Officer or both (listed in Appendix D of this SEIS)	National Historic Preservation Act of 1966, as amended (16 USC 470 et seq.); Archaeological and Historical Preservation Act of 1974 (16 USC 469–469c-2); Antiquities Act of 1906 (16 USC 431 et seq.); Archaeological Resources Protection Act of 1979, as amended (16 USC 470aa-mm)	The NRC would consult with the State or Tribal Historic Preservation Officers or both and applicable Indian tribes (e.g., tribes that have historical ties to the land) regarding the impacts of license renewal and the results of archaeological and architectural surveys of nuclear power plant site.

APPENDIX C
CONSULTATION CORRESPONDENCE

CONSULTATION CORRESPONDENCE

C.1 National Historic Preservation Act of 1966 Consultation

The National Historic Preservation Act (NHPA) requires Federal agencies to consider the effects of their undertakings on historic properties and consult with applicable state and Federal agencies, tribal groups, and individuals and organizations with a demonstrated interest in the undertaking before taking action. Historic properties are defined as resources that are eligible for listing on the National Register of Historic Places. The historic preservation review process (Section 106 of the National Historic Preservation Act of 1966, as amended) is outlined in regulations issued by the Advisory Council on Historic Preservation (ACHP) in Title 36 of *Code of Federal Regulations* (CFR), Part 800. In accordance with 36 CFR 800.8(c), the U.S. Nuclear Regulatory Commission (NRC) has elected to use the National Environmental Policy Act (NEPA) process to comply with its obligations under Section 106 of the NHPA.

Table C–1 lists the chronology of consultations and consultation documents related to the NRC Section 106 review. The NRC staff is required to consult with the noted agencies and organizations in accordance with the statutes listed above.

Table C–1. NHPA Correspondence

Date	Sender and Recipient	Description	ADAMS Accession No.[a]
8/8/13	M. Wong (NRC) to A. Haaker, Illinois Historic Preservation Agency	Request for scoping comments/notification of Section 106 review	ML13191B089
8/8/13	M. Wong (NRC) to R. Nelson, ACHP	Request for scoping comments/notification of Section 106 review	ML13186A174
8/13/13	M. Wong (NRC) to J. Greendeer, Ho-Chunk Nation	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to D. Lankford, Miami Tribe of Oklahoma	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to J. Froman, Peoria Tribe of Indians in Oklahoma	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to J. Barrett, Citizen Potawatomi Nation	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to A. Sanache, Sac and Fox Tribe of the Mississippi in Iowa/Meskwaki	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to M. Dougherty, Sac and Fox Nation of Missouri in Kansas and Nebraska	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to G. Thurman, Sac and Fox Nation	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to M. Wesaw, Pokagon Band of Potawatomi	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to H. Frank, Forest County Potawatomi	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to K. Meshigaud, Hannahville Indian Community, Band of Potawatomi	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to S. Ortiz, Prairie Band of Potawatomi Nation	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to J. Blackhawk, Winnebago Tribe of Nebraska	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to S. Cadue, Kickapoo Tribe in Kansas	Request for scoping comments/notification of Section 106 review	ML13227A388
8/13/13	M. Wong (NRC) to G. Salazar, Kickapoo Tribe of Oklahoma	Request for scoping comments/notification of Section 106 review	ML13227A388
9/4/13	A. Haaker, Illinois Historic Preservation Agency to C. Bladey (NRC)	Section 106 determination	ML13269A369

[a] These documents can be accessed through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://adams.nrc.gov/wba/.

C.2 Endangered Species Act of 1973 and Magnuson–Stevens Fisheries Management Act of 1996 Consultation

The NRC must comply with the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq., herein referred to as ESA) when authorizing, funding, or carrying out Federal actions, such as the proposed action that this supplemental environmental impact statement (SEIS) addresses, which is whether to issue a renewed license for the continued operation of Braidwood Station, Units 1 and 2, for an additional 20 years beyond the current license terms. Under the ESA, the NRC must consult under section 7 of the ESA with the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS), as appropriate, to ensure the protection of listed species and designated critical habitat. The regulations that implement section 7 (50 CFR 402) describe the consultation procedures that Federal agencies must follow in order to fully comply with the act. Depending on the project, the NRC may need to consult with the FWS, NMFS, or both. In the case of Braidwood, no species under NMFS's jurisdiction occur within the action area, and so the NRC staff consulted only with the FWS.

The ESA section 7 implementing regulations at 50 CFR 402.06 allow Federal agencies to fulfill their obligations under section 7 of the ESA in conjunction with the requirements of the National Environmental Policy Act of 1969, as amended (NEPA). In such cases, the Federal agency must include the results of its consultation with FWS or NMFS in the NEPA document (i.e., this SEIS). A chronology of the section 7 consultation is provided below, and Table C–2 lists the correspondence related to the NRC's review of the Braidwood license renewal application pursuant to section 7 of the ESA. This table will be updated upon issuance of the final SEIS, as applicable, to include correspondence between the issuance of the draft and final SEISs.

Additional information regarding Federally listed species appears in Chapters 3 and 4 of this SEIS. Section 3.8 describes the action area and the Federally listed species and habitats that have the potential to occur in the action area. Section 4.8 provides an assessment of the potential effects of the proposed license renewal on each of these species and the NRC's effect determinations, which are consistent with those identified in Section 3.5 of *Endangered Species Consultation Handbook* (FWS and NMFS 1998).

<u>Chronology of Section 7 Consultation</u>

After receiving the license renewal application, the NRC staff considered whether any Federally listed species or habitats occur within the vicinity of Braidwood that could be affected by the proposed license renewal. The NRC staff compiled a list of these species and habitats and requested the FWS's concurrence with this list in accordance with the ESA section 7 regulations at 50 CFR 402.12(c) in a letter dated September 11, 2013 (NRC 2013). On September 24, 2013, FWS (2013b) replied with a letter that included scoping comments and comments on the NRC's list of Federally-listed species for Braidwood. Following this correspondence and during the NRC staff's determination of the action area (described in Section 3.8), the NRC has further refined the list of species that may be affected by the proposed Braidwood license renewal. Because the FWS's Rock Island Field Office no longer responds to species list requests (FWS 2013a), NRC staff did not send a revised species list request to FWS. The NRC compiled the list of species from the FWS's Endangered Species Program online database (FWS 2014a, 2014b).

NRC staff presents an assessment of the effects of the proposed action on Federally listed species in Sections 3.8 and 4.8 of this SEIS and intends to send FWS a copy of this SEIS when it is issued.

Table C–2. Section 7 Consultation Correspondence

Date	Sender and Recipient	Description	ADAMS No.[a]
9/11/13	M. Wong (NRC) to T. Melius (FWS)	Request for Concurrence with List of Federally-listed Species and Habitats for the Proposed Braidwood Station, Units 1 and 2, License Renewal	ML13226A549
9/24/13	L. Clemency (FWS) to C. Bladey (NRC)	No subject. Included comments on NRC's preliminary List of Federally listed Species and Habitats for the Proposed Braidwood Station, Units 1 and 2, License Renewal	ML13269A373

[a] These documents can be accessed through the NRC's Agencywide Documents Access and Management System (ADAMS) at the following URL: http://adams.nrc.gov/wba/.

C.3 References

36 CFR Part 800. *Code of Federal Regulations*, Title 36, *Parks, Forests, and Public Property*, Part 800, "Protection of historic and cultural properties."

50 CFR Part 402. *Code of Federal Regulations*, Title 50, *Wildlife and Fisheries*, Part 402, "Interagency Cooperation—Endangered Species Act of 1973, as amended."

[ESA] Endangered Species Act of 1973, as amended. 16 U.S.C. § 1531 et seq.

[FWS] U.S. Fish and Wildlife Service. 2013a. E-mail from J. Duyvejonck, Rock Island Field Office, to B. Grange, U.S. Nuclear Regulatory Commission. Subject: Byron Illinois license renewal. August 30, 2013. ADAMS No. ML13246A385.

[FWS] U.S. Fish and Wildlife Service. 2013b. Letter from L. Clemency, Field Supervisor, to C. Bladey, Chief, Rules, Announcements, and Directives Branch, U.S. Nuclear Regulatory Commission. Subject: NOI comments. September 24, 2013. ADAMS No. ML13269A373.

[FWS] U.S. Fish and Wildlife Service. 2014a. "Illinois Threatened and Endangered Species; Illinois County Distribution; Federally Endangered, Threatened, and Candidate Species." October 2013. Available at <http://www.fws.gov/midwest/endangered/lists/illinois-cty.html> (accessed 24 February 2014).

[FWS] U.S. Fish and Wildlife Service. 2014b. Information, Planning, and Conservation System (IPaC), Version 1.4. Natural Resources of Concern. (Accessed 24 February 2014).

[FWS and NMFS] U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. *Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act*. March 1998. 315 p. Available at <http://www.fws.gov/endangered/esa-library/pdf/esa_section7_handbook.pdf> (accessed 8 July 2013).

[NEPA] National Environmental Policy Act of 1969, as amended. 42 U.S.C. § 4321 et seq.

[NHPA] National Historic Preservation Act of 1966, as amended. 16 U.S.C. §470 et seq.

[NRC] U.S. Nuclear Regulatory Commission. 2013. Letter from M. Wong, Branch Chief, to T. Melius, Midwest Regional Director, U.S. Fish and Wildlife Service. Subject: Request for concurrence with list of Federally-listed species and habitats for the proposed Braidwood Station, Units 1 and 2, license renewal. September 11, 2013. ADAMS No. ML13226A549.

APPENDIX D
CHRONOLOGY OF ENVIRONMENTAL REVIEW CORRESPONDENCE

CHRONOLOGY OF ENVIRONMENTAL REVIEW CORRESPONDENCE

This appendix contains a chronological listing of correspondence between the U.S. Nuclear Regulatory Commission (NRC) and external parties as part of its environmental review for the Braidwood Station (Braidwood). All documents, with the exception of those containing proprietary information, are available electronically from the NRC's Public Electronic Reading Room, which is found on the Internet at the following web address: http://www.nrc.gov/reading-rm.html. From this site, the public can gain access to the NRC's Agencywide Documents Access and Management System (ADAMS), which provides text and image files of NRC's public documents. The ADAMS accession number for each document is included below.

D.1 Environmental Review Correspondence

Table D–1 lists the environmental review correspondence in date order beginning with the request by Exelon Generation Company, LLC (Exelon), to renew the operating licenses for Braidwood.

Table D–1. Environmental Review Correspondence

Date	Correspondence Description	ADAMS No.
05/29/13	Braidwood, Units 1 and 2 - Environmental Report, Part 1	ML13155A424
05/29/13	Braidwood and Byron, Units 1 and 2 - Application for Renewed Operating Licenses	ML13155A387
05/29/13	Braidwood, Units 1 and 2 - Environmental Report, Part 2	ML13155A426
05/29/13	Braidwood and Byron, Units 1 and 2 - Information to Support NRC Staff Review of the Application for Renewed Operating Licenses	ML13155A388
06/06/13	Letter—Receipt and Availability of the LRA for the Byron and Braidwood Nuclear Stations	ML13144A099
06/10/13	Press Release-13-051: NRC Announces Public Availability of License Renewal Application for Braidwood and Byron Nuclear Power Plants in Illinois	ML13161A381
06/24/13	Advisement of Leadership Changes for Exelon Generation Company	ML13177A019
07/16/13	Determination of Acceptability And Sufficiency for Docketing, Proposed Review Schedule, and Opportunity for a Hearing Regarding the Application From Exelon Generation Company, LLC, for Renewal of the Operating Licenses for Byron Nuclear Station, Unit 1	ML13134A142
07/18/13	FRN - License Renewal Application; Notice of Docketing and Opportunity to Request a Hearing and to Petition for Leave to Intervene	ML13134A156
07/24/13	Press Release-13-062: NRC Announces Hearing Opportunity on License Renewal Application for Byron and Braidwood Nuclear Plants in Illinois	ML13207A291
07/24/13	Braidwood notice of intent to prepare environmental impact statement	ML13178A244
08/05/13	08/21/2013 Forthcoming Meeting to Discuss the License Renewal Process and Environmental Scoping for Exelon Generation Company, LLC, Braidwood Nuclear Station Units 1 and 2	ML13193A361
08/06/13	Braidwood, Units 1 and 2, Notification of Intent to Prepare an Environmental Impact Statement and Conduct Scoping Process for License Renewal	ML13193A299
08/08/13	Braidwood Station, Units 1 and 2, License Renewal Application Review	ML13191B089
08/12/13	Press Release-13-066: NRC Public Meetings to Discuss Environmental Reviews of Byron, Braidwood Nuclear Plant License Renewals	ML13224A318
08/13/13	Request for Scoping Comments Concerning the Braidwood Nuclear Generating Station, Units 1 and 2, License Renewal Application Review	ML13227A388
08/16/13	Braidwood Station Units 1 and 2, License Renewal Process and Environmental Scoping Meeting	ML13227A249
08/21/13	Comment (3) by Sue Rezin Supporting Extension of Braidwood Nuclear Generating Station License	ML13248A271
08/27/13	Comment (1) of Nancy Schultz Voots & Lawrence M. Walsh on Behalf of the County Board Will County, Illinois, Supporting of the Renewal of the Operating License of the Exelon Generation Braidwood Nuclear Generating Station	ML13247A009
08/28/13	Comment (2) of Tom Zimmer Opposing Braidwood Nuclear Plant License Extension for 20 Years Due to Environmental and Health Issue Hazardous	ML13263A219
09/04/13	Comment (00004) of Anne E. Haaker, on Behalf of IL Historic Preservation Agency on License Renewal for Braidwood Station	ML13269A369
09/05/13	0821NRC2-154-Afternoon	ML13247A541
09/11/13	Braidwood, FWS Letter Scoping and Species List	ML13226A549
09/16/13	Comment (6) of Kent Collier on Behalf of Kickapoo Tribe of Oklahoma Supporting the Renewal Application of Braidwood Station, Units 1 and 2 License	ML13274A239

Date	Correspondence Description	ADAMS No.
10/29/13	License Renewal Environmental Site Audit re Byron and Braidwood Stations - Severe Accident Mitigation Alternative (TAC Nos. MF1834/1835, MF1790/1791, MF1832/1833, and MF1792/1793)	ML13270A116
11/07/13	License Renewal Environmental Site Audit Regarding Braidwood Station (TAC Nos. ME1832/1833, MF1792/1793)	ML13270A126
12/03/13	Summary of Site Audit Related to the Review of the License Renewal Application for Braidwood Station, Units 1 and 2 (TAC Nos. MF1832, MF1833, and MF1792, MF1793)	ML13318A238
12/13/13	Audit Trip Report SAMA	ML13312A317
12/18/13	Draft Byron and Braidwood SAMA RAIs E-mail	ML14002A472
12/18/13	Draft Byron and Braidwood SAMA RAIs	ML14002A473
12/21/13	RAI Braidwood Nuclear Station	ML13354B937
01/07/14	Request for Additional Information for the Review of the Byron and Braidwood Application - Severe Accident Mitigation Alternative Review (TAC NOS. MF1790, MF1791, MF1792, & MF1793).	ML13318A208
01/21/14	Braidwood Station, Units 1 and 2, Response to NRC Request for Additional Information, Dated December 20, 2013, Related to Byron and Braidwood Station, Units 1 and 2 License Renewal Application, Braidwood Station Applicant's Environmental Report.	ML14022A132
01/24/14	Byron and Braidwood SAMA RAI Conference Call Summary.	ML14007A240
01/31/14	Braidwood Station Kankakee River Fish Monitoring Program, 1991-2013 - Tables Requested by the NRC to Describe the Number of Fish Caught by Sampling Gear and Species at Each Monitoring Location.	ML14030A269
02/04/14	Braidwood, Units 1 & 2 and Byron Units 1 & 2, Response to NRC Requests for Additional Information for the Severe Accident Mitigation Alternatives Review, dated January 6, 2014 License Renewal Application.	ML14035A512
03/04/14	Summary Of Telephone Conference Call Held On February 12, 2014, Between The U.S. Nuclear Regulatory Commission And Exelon Generation Company, LLC, Concerning Requests For Additional Information Pertaining To The Braidwood Station License Renewal Application.	ML14050A101
03/31/14	Requests for Additional Information for Review of Braidwood Station, License Renewal Application.	ML14079A617
04/02/14	Requests For Additional Information For The Review Of The Braidwood Station License Renewal Application Environmental Report.	ML14087A432
04/03/14	Issuance of Environmental Scoping Summary Report Associated with the Staff's Review of the Application By Exelon Generation Company, LLC, for Renewal of the Operating Licenses for Braidwood Station, Units 1 and 2, (TAC NO. MF1832, MF1833, MF1792).	ML13337A506 (package)
04/15/14	Summary Of Telephone Conference Call Held On March 31, 2014 Between The U.S. NRC And Exelon Generation Company, LLC, Concerning Requests For Additional Information Pertaining To The Braidwood Station, License Renewal Application.	ML14092A356
04/30/14	Response to NRC Request for Additional Information dated April 2, 2014, Related to the Byron and Braidwood Stations, Units 1 and 2 License Renewal Application, Braidwood Station Applicant's Environmental Report.	ML14122A065
05/01/14	Summary of Telephone Conference Call Held on April 16, 2014, Between the U.S. Nuclear Regulatory Commission & Exelon Generation Company, LLC, Concerning Requests for Additional Information Pertaining to the Braidwood Station, License Renewal Application.	ML14114A671

Date	Correspondence Description	ADAMS No.
05/05/14	Schedule Revision for Environmental Review of Byron and Braidwood Nuclear Stations License Renewal Application - Environmental Review Schedule (TAC Nos. MF1790, MF1791, MF1792, And MF1793).	ML14104B131
05/12/14	Update to Chapter 9 of Byron and Braidwood Stations, Units 1 and 2 License Renewal Application, Braidwood Station Applicant's Environmental Report.	ML14132A140
08/15/14	Braidwood, Units 1 and 2 - Renewal of National Pollutant Discharge Elimination System (NPDES) Permit No. IL0048321.	ML14227A712
10/08/14	Amendment to Exelon Generation, LLC Response dated April 30, 2014 to NRC Request for Additional Information dated April 2, 2014, related to Byron & Braidwood Units 1 & 2 License Renewal Application, Braidwood Station Applicant's Environmental Report.	ML14281A019
10/17/14	Schedule Revision For The Environmental Review Of The Byron Station And Braidwood Station License Renewal Application Environmental Review Schedule (TAC Nos. MF1790, MF1791, MF1792, And MF1793).	ML14275A003

APPENDIX E
ACTIONS AND PROJECTS CONSIDERED IN CUMULATIVE ANALYSIS

ACTIONS AND PROJECTS CONSIDERED IN CUMULATIVE IMPACT ANALYSIS

Table E–1 identifies projects considered in the U.S. Nuclear Regulatory Commission (NRC) staff's analysis of cumulative impacts related to the environmental analysis of the continued operation of Braidwood. Potential cumulative impacts associated with these actions and projects are addressed in Section 4.16 of this SEIS. However, not all projects listed in this appendix are considered in each resource area, as appropriate (i.e., due to the uniqueness of the resource and its geographic area of consideration).

Table E–1. Projects Considered in Cumulative Impact Analysis

Project Name	Summary of Project	Location	Status
Nuclear Projects			
Clinton Power Station, Unit 1	Nuclear power plant, 1 1,067-MWe General Electric Type 6 reactor	DeWitt County, IL, approximately 77 mi (124 km) southwest. 50-mi radius overlaps with Braidwood.	Operational (NRC 2014a)
Byron Station, Units 1 and 2	Nuclear power plant, 2 1,121-MWe Westinghouse 4-loop reactors	Ogle County, IL, approximately 80 mi (129 km) northwest. 50-mi radius overlaps with Braidwood.	Operational (NRC 2014b, 2014c)
LaSalle County Station, Units 1 and 2	Nuclear power plant, 2 1,200-MWe General Electric Type 5 reactors	LaSalle County, IL, approximately 23 mi (37 km) west	Operational (NRC 2014d, 2014e)
Dresden Nuclear Power Station, Units 2 and 3	Nuclear power plant, 2 867-MWe General Electric Type 3 reactors	Grundy County, IL, approximately 12 mi (20 km) north	Operational (NRC 2014f, 2014g)
Dresden Nuclear Power Station, Unit 1	Nuclear power plant NA (not applicable or available)	Grundy County, IL, approximately 12 mi (20 km) north	Shut down in October 1978 and is currently in SAFSTOR. No dismantlement activities are under way. All spent fuel from DNPS Unit 1 transferred to the onsite Independent Spent Fuel Storage Installation (NRC 2014h)
Wind Projects			
Top Crop I Wind Farm	68-unit wind farm with 102 MW generating capacity	Grundy, LaSalle and Livingston Counties, IL, approximately 20 mi (33 km) west	Operational (EDPR 2014)
Top Crop II Wind Farm	132-unit wind farm with 198 MW generating capacity	Grundy County, IL, approximately 17 mi (28 km) west	Operational (EDPR 2014)
Grand Ridge Wind Farm	66-unit wind farm with 99 MW generating capacity	Marseilles, IL, approximately 26 mi (42 km) northwest	Operational (Boldt 2014)

Project Name	Summary of Project	Location	Status
Fossil Fuel Projects			
Joliet Station	3-unit 1,358-MW coal and natural gas facility	Joliet, IL, approximately 22 mi (35 km) north	Operational, NPDES Permit Nos. IL0002216 and IL0064254 (EPA 2014a)
Will County Station	4-unit 1,092-MW coal facility	Romeoville, IL, approximately 30 mi (48 km) north	Operational, NPDES Permit No. IL0002208 (IEPA 2013)
Landfills			
Prairie View Landfill	Permitted landfill area of 631 ac and a permitted disposal area of 223 ac. Design capacity of 30,196,438 yd^3.	Wilmington, IL, approximately 7 mi (11 km) northeast	Operational until 2027, NPDES Permit No. IL0078662 (Will County 2010)
Laraway Recycling and Disposal Facility	Permitted landfill area of 225 ac and a permitted disposal area of 32.2 ac. Design capacity of 1,185,400 yd^3.	Joliet, IL, approximately 22 mi (35 km) north	Operational until 2045, NPDES Permit No. IL0063479 (IEPA 2010)
Water Supply and Treatment Facilities			
City of Godley, wastewater treatment	Water treatment with discharge to Mazon River, tributary of Illinois River	Approximately 1 mi (2 km) southwest	Operational, NPDES Permit No. IL0078816 (EPA 2014b)
City of Godley, water supply	Withdraws groundwater from Ancell aquifer St. Peter Sandstone	Approximately 1 mi (2 km) southwest	Operational (EPA 2014c)
City of Braidwood, water supply	Withdraws groundwater from Ironton–Galesville deep sandstone aquifer	Approximately 1.4 mi (2.2 km) north-northeast	Operational (EPA 2014c)
City of Braidwood, wastewater treatment	Water treatment with discharge to a tributary of Claypool Ditch, with drainage to the Mazon River, a tributary of the Illinois River	Approximately 1.4 mi (2.2 km) north-northeast	Operational, NPDES Permit No. IL0054992 (EPA 2014b)
Various minor NPDES wastewater discharges	Various businesses with smaller wastewater dischargers to Kankakee River Basin	Within 50 mi (31 km)	Operational (EPA 2014b)
Transportation			
South Suburban Airport	Proposed 809-ha (2,000-ac) commercial service airport	Peotone, IL, approximately 24 mi (39 km) southwest	Components of master plan and environmental analysis submitted to the State. Construction expected sometime during the license renewal term for Braidwood (SSA 2013).

Project Name	Summary of Project	Location	Status
Remediation Sites			
Joliet Army Ammunition Plant	14-ha (36-ac) facility used from early 1940s through 1977 to load, assemble, and package high-explosive artillery shells, bombs, mines, and small-arms ammunition. Other activities on site included testing of ammunition, washout and renovation of shells, and burning and demolition of explosives.	Joliet, IL, approximately 22 mi (35 km) northeast	Ongoing remediation under the purview of the U.S. Army. Land use controls are restricting land uses; portions are now under productive reuse by the U.S. Forest Service (Midewin National Tallgrass Prairie), the Veteran's Administration (Abraham Lincoln National Cemetery), the County of Will (500-ac landfill), and productive uses through commercial and industrial redevelopment (EPA 2013).
Parks and Recreation Sites			
Braidwood Dunes and Savanna Nature Preserve	127 ha (315 ac) near Braidwood, IL, part of Kankakee Sands preservation system and protects a diversity of habitats, including prairie, savanna, and wetland.	Approximately 4 mi (6 km) northeast	Operational. Managed by Forest Preserve District of Will County (IDNR 2014a).
Mazonia State Fish and Wildlife Area	447 ha (1,107 ac) contains more than 200 water impoundments ranging from 0.3 ha (0.75 ac) to 12 ha (30 ac) in size for recreational fishing. Managed primarily for sport fish and waterfowl. Includes Braidwood Lake, owned by Commonwealth Edison, a partially perched, cooling lake.	Approximately 2 mi (4 km) southwest	Operational. Managed by Illinois Department of Natural Resources (DNR); Braidwood Lake is leased to the Illinois DNR by Commonwealth Edison (IDNR 2014b).
Midewin National Tallgrass	7,689 ha (19,000 ac) federal tallgrass prairie preserve east of the Mississippi River. Located on former Joliet Army Ammunition Plant.	Near Wilmington, IL, approximately 7 mi (11 km) northeast	Operational. Managed by U.S. Department of Agriculture Forest Service (USFS 2014).
Kankakee River State Park	1,618 ha (4,000 ac) along the Kankakee River. Hiking, fishing, and camping occur within the park.	Approximately 12 mi (19 km) west	Operational. Managed by Illinois Department of Natural Resources (IDNR 2014c).

Project Name	Summary of Project	Location	Status
Braidwood Projects			
Unit 2 steam generator replacement	Assumed to occur during normal refueling outage. 500 additional workers specific to replacement. All work to occur on previously disturbed land on site.	Braidwood site	Assumed to occur prior to the end of the 40-year initial license term (Exelon 2013)
Units 1 and 2 reactor pressure vessel head replacement	Assumed to occur during normal refueling outage. 340 additional workers specific to replacement.	Braidwood site	Assumed to occur during licensing term (Exelon 2013)
Other Projects			
Future Urbanization	Construction of housing units and associated commercial buildings; roads, bridges, and rail; and water and/or wastewater treatment and distribution facilities and associated pipelines as described in local land-use planning documents	Throughout region	Construction would occur in the future, as described in State and local land-use planning documents.

Sources: Boldt 2014; EDPR 2014; EPA 2013, 2014a, 2014b, 2014c; Exelon 2013; IDNR 2014a, 2014b, 2014c; IEPA 2010, 2013; NRC 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g, 2014h; SSA 2013; USFS 2014; Will County 2010

E.1 References

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[EPA] U.S. Environmental Protection Agency. 2013. “Region 5 Cleanup Sites: Joliet Army Ammunition Plant.” November 14, 2013. Available at <http://www.epa.gov/region05/cleanup/jolietarmy/index.html> (accessed July 2014).

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[IDNR] Illinois Department of Natural Resources. 2014a. “Illinois Nature Preserves and Commission: Braidwood Dunes and Savanna.” 2014. Available at <http://www.dnr.illinois.gov/inpc/pages/area3willbraidwooddunesandsavanna.aspx>(accessed July 2014).

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[NRC] U.S. Nuclear Regulatory Commission. 2014c. “Byron Station, Unit 2.” May 8, 2014. Available at <http://www.nrc.gov/info-finder/reactor/byro2.html> (accessed July 2014).

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APPENDIX F
U.S. NUCLEAR REGULATORY COMMISSION STAFF EVALUATION OF SEVERE ACCIDENT MITIGATION ALTERNATIVES FOR BRAIDWOOD STATION, UNITS 1 AND 2, IN SUPPORT OF LICENSE RENEWAL APPLICATION REVIEW

U.S. NUCLEAR REGULATORY COMMISSION STAFF EVALUATION OF SEVERE ACCIDENT MITIGATION ALTERNATIVES FOR BRAIDWOOD STATION, UNITS 1 AND 2, IN SUPPORT OF LICENSE RENEWAL APPLICATION REVIEW

F.1 Introduction

Exelon Generation Company, LLC (Exelon), submitted an assessment of severe accident mitigation alternatives (SAMAs) for the Braidwood Station, Units 1 and 2 (Braidwood), as part of the Environmental Report (ER) (Exelon 2013a). This assessment is based on the most recent Braidwood probabilistic risk assessment (PRA) available at that time, a plant-specific offsite consequence analysis performed using the MELCOR Accident Consequence Code System 2 (MACCS2) computer code, and insights from the Braidwood individual plant examination (IPE) (ComEd 1994, 1997a) and individual plant examination of external events (IPEEE) (ComEd 1997b). In identifying and evaluating potential SAMAs, Exelon considered SAMAs that addressed the major contributors to core damage frequency (CDF) and release frequency at Braidwood, as well as SAMA candidates for other operating plants that have submitted license renewal applications. Exelon initially identified 35 potential SAMAs. This list was reduced to 34 unique SAMA candidates by eliminating SAMAs that are not applicable to Braidwood due to design differences, that have already been implemented at Braidwood or the intent achieved by other means, or that have excessive implementation costs. One additional candidate SAMA was also further evaluated after accounting for analysis uncertainties. Exelon assessed the costs and benefits associated with each of the 35 potential SAMAs and concluded in the ER that 26 of the candidate SAMAs evaluated are potentially cost-beneficial. Exelon has submitted all 26 potentially cost-beneficial SAMAs to the Braidwood Plant Health Committee for further implementation consideration.

Based on a review of the SAMA assessment and plant audit trip conducted November 4, 5, and 6, 2013, the U.S. Nuclear Regulatory Commission (NRC) staff issued requests for additional information (RAIs) to Exelon by letter dated January 6, 2014 (NRC 2014). Key questions concerned: (a) the disposition of internal and external review comments on the PRA model, (b) the modeling of systems shared between units, (c) additional details on the Levels 2 and 3 PRA models, (d) the scope and status of the Braidwood fire PRA model, (e) the estimated seismic CDF, (f) the identification of candidate SAMAs, (g) the basis for the SAMA cost estimates, and (h) the results of the uncertainty analysis. Exelon submitted additional information by letter dated February 4, 2014 (Exelon 2014). In the responses, Exelon provided a discussion of the conduct of the PRA model self-assessment and the resolution of review findings, a discussion of the modeling of shared systems and the incorporation of opposite unit equipment unavailability, clarification of Levels 2 and 3 PRA modeling details and assumptions, further details on the Braidwood fire PRA, analysis of additional SAMAs, updated SAMA cost information, and revised SAMA benefit analyses to fully account for seismic events and uncertainty. Exelon's responses addressed the NRC staff's concerns and did not result in the identification of additional potentially cost-beneficial SAMAs.

An assessment of SAMAs for Braidwood is presented below.

F.2 Estimate of Risk for Braidwood

Exelon's estimates of offsite risk at Braidwood are summarized in Section F.2.1. The summary is followed by the NRC staff's review of Exelon's risk estimates in Section F.2.2.

F.2.1 Exelon's Risk Estimates

Exelon combined two distinct analyses to form the basis for the risk estimates used in the SAMA analysis: (1) the Braidwood Levels 1 and 2 PRA models, both, are essentially (effective-change majority) new models developed since the IPE models, and (2) a supplemental analysis of offsite consequences and economic impacts (essentially a Level 3 PRA model), developed specifically for the SAMA analysis. The SAMA analysis is based on the most recent Braidwood Level 1 and Level 2 PRA model, available at the time of the ER, which is referred to as the Braidwood PRA (Revision BB011b1). The scope of this Braidwood PRA includes internal floods but does not include external events.

The Braidwood CDF is approximately 3.6×10^{-5} per year for Unit 1 and 3.5×10^{-5} per year for Unit 2 (Exelon 2013a). Exelon did not explicitly include the contribution from external events within the Braidwood SAMA risk estimates; however, it did account for the potential risk reduction benefits associated with external events by multiplying the estimated benefits for internal events by a factor of 2.8. This is discussed further in Sections F.2.2 and F.6.2.

The breakdown of CDF by initiating event is provided in Table F–1 (Exelon 2013a). As shown in this table, events initiated by loss of essential service water (SX), small loss-of-coolant accident (LOCA), and internal flooding are the dominant contributors to the CDF for both units.

Table F–1. Braidwood Core Damage Frequency (CDF) for Internal Events

Initiating Event	Unit 1 CDF (per year)	Unit 1 Percent CDF Contribution	Unit 2 CDF (per year)	Unit 2 Percent CDF Contribution
Loss of Essential Service Water (SX)	1.3×10^{-5}	36	1.3×10^{-5}	37
Small Loss-of-Coolant Accident (LOCA)	6.4×10^{-6}	18	6.3×10^{-6}	18
Internal Flooding	5.7×10^{-6}	16	5.6×10^{-6}	16
Loss of Component Cooling Water (CCW)	3.2×10^{-6}	9	3.2×10^{-6}	9
Loss of Auxiliary Power (AP)	2.1×10^{-6}	6	1.4×10^{-6}	4
Other Initiating Events	1.8×10^{-6}	5	1.8×10^{-6}	5
Medium LOCA	1.4×10^{-6}	4	1.4×10^{-6}	4
Steam Generator Tube Rupture (SGTR)	1.4×10^{-6}	4	1.8×10^{-6}	5
General Transient and Loss of Main Feedwater	7.1×10^{-7}	2	7.0×10^{-7}	2
Total (Internal Events)[(a)]	**3.6×10^{-5}**	**100**	**3.5×10^{-5}**	**100**

[(a)] Column totals may be different due to round off.

In addition, in the ER, Exelon identified that station blackout (SBO) contributes (a) 7.1×10^{-7} per year, or 2.0 percent, for Unit 1 and (b) 1.1×10^{-6} per year, or 3.0 percent, for Unit 2, to the total internal events CDF. In response to the NRC staff RAI, Exelon identified that anticipated transients without scram (ATWS) contribute 1.6×10^{-7} per year or 0.4 and 0.5 percent of the total CDF for Units 1 and 2, respectively (Exelon 2014).

The Braidwood Level 2 PRA model that forms the basis for the SAMA evaluation is a new model and stated by Exelon to represent the current state of the art (Exelon 2013a). The

Level 2 model utilizes a single containment event tree (CET) to assess the accident progression following a core damage event and contains both phenomenological and systemic events. The Level 1 core damage sequences are binned into plant damage states (PDSs). These PDSs provide the interface between the Level 1 and Level 2 CET analysis. Each PDS bin is then entered into the CET. The CET is linked directly to the Level 1 event trees and CET nodes are evaluated using supporting fault trees and logic rules.

The result of the Level 2 PRA is a set of 13 release or source term categories, with their respective frequency and release characteristics. The results of this analysis for Braidwood are provided in Table F.2-8 of the ER (Exelon 2013a). The categories were defined based on the similarity of scenario release characteristics and ultimate containment failure mode. This resulted in six release categories with large early releases (LERs), four with late releases, two with small early releases, and one for an intact containment. The frequency of each release category was obtained by summing the frequency of the individual accident progression CET endpoints binned into the release category. Source terms were developed for each of the 13 release categories using the results of Modular Accident Analysis Program (MAAP) Version 4.0.6 computer code calculations (Exelon 2013a).

The offsite consequences and economic impact analyses use the MACCS2 (NRC 1998) code to determine the offsite risk impacts on the surrounding environment and public. Inputs for these analyses include plant-specific and site-specific input values for core radionuclide inventory, source term and release characteristics, site meteorological data, projected population distribution (within a 80-km (50-mi)) radius) for the year 2047, emergency response evacuation modeling, and economic data. The core radionuclide inventory corresponds to the end-of-cycle values for Braidwood operating at 3,645 megawatts thermal (MWt). The magnitude of the onsite impacts (in terms of cleanup and decontamination costs and occupational dose) is based on information provided in NUREG/BR–0184 (NRC 1997a).

In the ER, Exelon estimated the dose to the population within 80 km (50 mi) of the Braidwood site to be approximately 1.14 person-sieverts (Sv) (114 person-roentgen equivalents man (rem)) per year (Exelon 2013a). In addition, Exelon estimated the annual offsite economic cost impact to be $810,000 per year. The breakdown of the total population dose and offsite economic cost by containment release mode is summarized in Table F–2. Late failures due to containment overpressure events (such as loss of containment heat removal due to loss of power or cooling water) and large early release frequency (LERF) accidents caused by unisolated interfacing-systems loss-of-coolant accident (ISLOCA) dominate the population dose risk (PDR) at Braidwood. Late containment overpressure failures are dominant in the offsite economic cost impact.

Table F–2. Breakdown of Population Dose and Offsite Economic Cost by Containment Release Mode [(a)]

Containment Release Mode	Population Dose (Person-rem [(b)] Per Year)	Percent Contribution	Offsite Economic Cost ($/yr)	Percent Contribution
Containment overpressure (late)	87.3	77	687,000	83
ISLOCA	15.5	14	54,400	7
SGTR	9.05	8	61,800	8
Containment isolation failure	1.18	1	3,800	<1
Containment intact	0.33	<1	300	<1
Early containment failure	0.29	<1	2,000	<1
Basemat melt-through (late)	0.06	<1	62	<1
Total [(c)]	**114**	**100**	**810,000**	**100**

(a) Values in table derived from Table F.3-9 of the ER

(b) One person-rem = 0.01 person-Sv

(c) Column totals may be different due to round off.

F.2.2 Review of Exelon's Risk Estimates

Exelon's determination of offsite risk at the Braidwood site is based on the following three major elements of analysis:

(1) the Level 1 risk model that supersedes the 1994/1997 IPE submittals (ComEd 1994, 1997a), a new interim internal fire analysis (approved by Exelon for interim use) and the seismic and other external event analyses of the 1997 IPEEE submittal (ComEd 1997b);

(2) the new Level 2 risk model; and

(3) the MACCS2 analyses performed by Exelon to translate fission product source terms and release frequencies from the Level 2 PRA model into offsite consequence measures.

Each of these analyses was reviewed by NRC staff to determine the acceptability of Braidwood's risk estimates for the SAMA analysis, as summarized below.

F.2.2.1 Internal Events CDF Model

The NRC staff's review of the Braidwood IPE is described in an NRC letter dated December 3, 1997 (NRC 1997b). Based on a review of the original and modified IPE submittal, the NRC staff concludes that the Braidwood IPE has met the intent of generic letter (GL) 88-20 (NRC 1988). The NRC staff review indicated that while no definition of a vulnerability was provided by the staff or Exelon, Exelon did identify one potential vulnerability (used by Exelon for plant management) and one enhancement. These are discussed in Section F.3.2.

There have been numerous revisions to the Braidwood PRA since the original 1994 IPE submittal. A listing of the complete revision history of the Braidwood PRA since the original IPE submittal was provided in the ER (Exelon 2013a) and is summarized in Table F–3 below. A comparison of the internal events CDF between the 1997 modified IPE and the current PRA

model indicates there has been very little change in the total CDF (from 3×10^{-5} per year for both units to 3.6×10^{-5} per year for Unit 1 and 3.5×10^{-5} per year for Unit 2).

Table F–3. Summary of Major PRA Models and Corresponding CDF and LERF Results [(a)]

PRA Model	Summary of Significant Changes From Prior Model	CDF (per year)		LERF (per year)	
		Unit 1	Unit 2	Unit 1	Unit 2
Original IPE (6/1994)	• IPE submittal	2.7×10^{-5} (same model)		2.6×10^{-6} (same model)	
Modified IPE [(b)] (3/1997)	• Numerous modifications based on NRC concerns on Braidwood IPE similar to those on other Commonwealth Edison IPEs	3.0×10^{-5} (same model)		Not Available	
Revision 0 (10/1999)	• Changed PRA model from support state model to linked fault tree model involving extensive changes to all event trees and fault trees • Updated all data	4.9×10^{-5}	4.9×10^{-5}	3.8×10^{-6}	3.8×10^{-6}
Revision 1 (10/2000)	• Changed SX pump success criterion from two pumps to one pump	4.6×10^{-5}	4.6×10^{-5}	4.9×10^{-6}	4.9×10^{-6}
Revision 3a (8/2001)	• Revised loss of offsite power (LOOP)/DLOOP Event Tree • Internal flooding analysis incorporated • Incorporation of plant mods to CV pump lube oil cooler • Incorporation of plant mod that removed auxiliary feedwater (AFW) pump 1B dependency on instrument air	3.2×10^{-5}	3.1×10^{-5}	4.6×10^{-6}	4.6×10^{-6}
Revision 4 (2/2002)	• Significant model enhancements to the following systems: reactor protection system, engineered safety features actuation system (ESFAS), CCW, power-operated relief valves (PORVs), AFW and instrument power • Updated containment failure likelihood	3.1×10^{-5}	3.1×10^{-5}	4.6×10^{-6}	4.9×10^{-6}
Revision 5 (12/2002)	• Changed small LOCA and transient accident modeling • Addressed miscellaneous model issues • Incorporated updated failure and unavailability data, HEPs and support system initiating event frequencies	3.8×10^{-5}	3.8×10^{-5}	4.2×10^{-6}	4.5×10^{-6}
Revision 5B (6/2003)	• Reevaluated the plant-specific data • Performed full convergence analysis and a human failure dependency analysis • Incorporated new SX success criteria • Revised the model so that automatic quantification can be performed using ORAM-Sentinel and PSALINK program	5.4×10^{-5}	5.4×10^{-5}	4.7×10^{-6}	5.4×10^{-6}
Revision 5F (12/2006)	• Model revised to incorporate conditional dual unit LOOP for most initiators • Updated some LERF binning • Changed modeling of ESFAS testing • Added RWST switchover channel testing and common cause	5.4×10^{-5}	5.4×10^{-5}	5.0×10^{-6}	5.8×10^{-6}
Revision 6C (5/2008)	• Extensive model update including changes to AFW success criteria, revisions to human error probability to reflect procedure changes and operator interviews, revised internal flooding analysis, updated data analysis, and changes to emergency service water and CCW modeling	3.6×10^{-5}	3.5×10^{-5}	2.9×10^{-6}	3.4×10^{-6}
Revision 6E3 (5/2010)	• Revised RCP seal LOCA model • Incorporated revised feed and bleed success criteria • Incorporated AFW unit crosstie modification • Revised human reliability assessment	1.6×10^{-5}	1.5×10^{-5}	1.4×10^{-6}	1.6×10^{-6}
Revision BB011a (6/2012)	• Updated internal flooding analysis • Incorporated new data analysis • Incorporated new human reliability dependency and preinitiator analysis • Removed credit for AFW unit crosstie modification	4.3×10^{-5}	4.3×10^{-5}	2.7×10^{-6}	3.3×10^{-6}
Revision BB011b (11/2012)	• Improved modeling of ESW and CCW systems • Incorporated new operator actions for use of emergency service water and CCW systems	3.6×10^{-5}	3.5×10^{-5}	2.5×10^{-6}	3.1×10^{-6}
Revision BB011b1 (12/2012)	• LERF model replaced with Level 2 model based on methodology of WCAP-16341-P	3.6×10^{-5}	3.5×10^{-5}	1.1×10^{-6}	1.0×10^{-6}

[(a)] Except for Modified IPE information, information in table is based on ER Table F.2-1 with some intermediate models not included.

[(b)] Information from ComEd 1997a.

The CDF value from the 1997 modified IPE (3×10^{-5} per year) is in the middle range of the CDF values reported in the IPEs for Westinghouse four-loop plants. Figure 11.6 of NUREG-1560 shows that the IPE-based total internal events CDF for Westinghouse four-loop plants ranges from 2×10^{-6} per year to 2×10^{-4} per year, with an average CDF for the group of 6×10^{-5} per year (NRC 1997c). It is recognized that other plants have updated the values for CDF subsequent to the IPE submittals to reflect modeling and hardware changes. The current internal events CDF results for Braidwood (3.6×10^{-5} per year for Unit 1 and 3.5×10^{-5} per year for Unit 2) are comparable to those results for other plants of similar vintage and characteristics.

The NRC staff considered the peer review performed for the Braidwood PRA and the potential impact of the review findings on the SAMA evaluation. In the ER (Exelon 2013a), Exelon briefly described the results of the 1999 Westinghouse Owners Group peer review of Revision 0 of the Braidwood PRA. Exelon stated that the 27 significance-level A (expected impact to be significantly nonconservative) and level B (expected impact to be nonconservative but small) facts and observations (F&Os) generated during the peer review have been closed out. In response to an NRC staff RAI to describe (a) what is meant by "closed out," (b) how this is verified, and (c) if these F&Os were considered in the 2012 self-assessment and the corrections incorporated in the PRA that was used for the SAMA analysis, Exelon provided a description of the process used to track and close out F&Os as well as other potential model changes. In the ongoing model-update process, the model and document changes associated with each F&O, as well as the decision to not change the model or documentation, are reviewed and approved with each official model approval in accordance with Exelon procedures. The approved dispositions of all peer review F&Os were incorporated in the SAMA PRA. Exelon stated that "changes due to the peer review F&Os were fully considered as part of the 2012 self-assessment" (Exelon 2014).

The NRC staff has determined that Exelon's disposition of the peer review findings is consistent with the guidance in Nuclear Energy Institute (NEI) 05-01 (NEI 2005) and that the final resolution of the findings provides reasonable assurance of minimal impact to the results of the SAMA analysis.

The NRC staff noted in an RAI that ER Table F.2-1 (describing changes made to each PRA revision) states PRA Revision 5A "[r]evised the model and data to address the PRA quality issues raised by CR#00142080 (1/30/03) against Rev. 5 model," and requested Exelon to identify the underlying quality-process issues and the corrective actions taken (NRC 2014). In response to the RAI, Exelon stated:

> The underlying process issue that allowed these technical quality issues to occur was a premature approval of the model prior to full review as required by the work process procedure. Exelon T&RM ER-AA-600-1015, 'FPIE PRA Model Update,' provides specific process and review criteria for a new model to be officially approved. [Exelon 2014]

Further:

> This process was not followed adequately for Revision 5, resulting in the CR. To help ensure that the review items are performed prior to model approval, the Quantification Notebook for each official model of record (including the current model of record) now includes confirmation that the reviews required by ER-AA-600-1015 were performed to check for these and other quality issues. The Quantification Notebook documenting the listed reviews is internally independently reviewed. Signatures of the author, reviewers, and approver confirm this review has been performed, and approval of the Quantification Notebook signifies official approval of the updated model. [Exelon 2014]

Exelon indicated that there had been several self-assessments of the Braidwood PRA, with the latest in 2012 of Revision BB011a against the Capability Category II requirements of the 2009 revision of the American Society of Mechanical Engineers (ASME) and American Nuclear Society (ANS) PRA standard (ASME and ANS 2009). Exelon further clarified in its response to an RAI that the self-assessment considered the guidance in Regulatory Guide 1.200, Revision 2 (NRC 2009), and it was performed consistent with the NEI 00-02 (NEI 2006) self-assessment process (Exelon 2014).

This self-assessment identified 2 supporting requirements (SRs) that were classified as not being met and 22 that were considered as meeting only the Capability Category I requirements. The ER provided a tabulation of the issues related to the SRs that did not meet Capability Category II and the potential impact on the SAMA analysis. All but four of the SRs not meeting Capability Category II were associated with requirements for the LER analysis. This was a result of the self-assessment being performed on the BB011a LERF-only model. These LER issues were addressed in a subsequent assessment as discussed in Section F.2.2.3 below. For the four non-LER issues identified in the self-assessment, Exelon concluded that not meeting the Capability Category II requirements would have no meaningful impact on the SAMA analysis. The NRC staff concurs with this conclusion.

The NRC staff noted in an RAI that the list of CDF contribution by initiating event (see Table F–1 above) included a contribution due to loss of AP but did not explicitly include a contribution due to a LOOP (NRC 2014). Exelon indicated that the loss of AP is a loss of an internal AP bus and is modeled the same as the loss of any other support system. The LOOP contribution is included in the “Other” category and is 0.9 percent and 1.0 percent of the total internal events CDF for Units 1 and 2, respectively. These values are for the LOOP initiating event only and do not include the contribution from LOOP that are the consequences of other initiating events. Both single unit and dual unit loss of offsite power (DLOOP) events are included in the Braidwood PRA (Exelon 2014).

The freeze date for the inclusion of plant specific data for the model was December 2010. In response to an NRC staff RAI concerning actual or planned changes to Braidwood hardware or operation since the freeze date, Exelon listed a number of modifications being considered, all of which were considered as SAMAs in the license renewal analysis. In addition Exelon stated that “no potential changes in fuel cycle or fuel management are known that would affect the SAMA analysis” (Exelon 2014).

To confirm as-built modeling in Exelon’s analysis, the NRC staff notes that, as indicated at the November 2013 audit and stated in an RAI response (Exelon 2014), Exelon is planning to install no-leakage reactor coolant pump (RCP) seals at Braidwood. The staff confirmed that this planned change is not included in the baseline SAMA analysis, but is evaluated appropriately as a candidate SAMA.

In response to an NRC staff RAI to identify the systems that are shared or can be crosstied between units and describe the modeling including the treatment of unavailability during outages of the other unit, Exelon indicated that the service water (SW), CCW, AFW, AP direct current power, and instrument air/service air systems are shared or could be crosstied between Braidwood units and stated that:

> The Braidwood PRA is a fully integrated two-unit model, so all components from each unit and those shared between units are explicitly modeled. Unit-specific components which can be used by the opposite unit are linked into the opposite unit’s fault tree logic structure.

Further, it is indicated that unavailability is modeled with both normal maintenance terms as well as outage maintenance terms for all shared components except those needed during normal full

power and outage operations. The normal unavailability is based on unavailable hours during normal power operation while the outage unavailability is based on unavailable hours (a) during an outage and (b) during total time as defined by the event progression (Exelon 2014).

During the reviews of the Braidwood ER SAMA analysis and that from the similar Byron Station analysis (Exelon 2013b), the NRC staff noted some differences in PRA results between the two sites and asked Exelon, in an RAI, to explain the reasons for these differences. The staff asked if the reasons suggest design or operating changes that might be cost-beneficial for one site or the other (NRC 2014). For sequences resulting from RCP seal LOCAs following Loss of CCW with failure to establish emergency core cooling system (ECCS) recirculation cooling but with successful cooldown and depressurization, for which the Byron CDF is considerably larger than that for Braidwood, Exelon indicated that the difference is due to a different normal valve alignment at Byron which requires additional operator actions (NRC 2014). For sequences resulting from random nonisolable small LOCAs with failure to establish ECCS recirculation cooling but with successful cooldown and depressurization, for which the Braidwood CDF is considerably larger than that for Byron, Exelon indicated that the difference is primarily because at Braidwood Station, SX007 SW valves must be throttled open to establish an appropriate flow rate through the component cooling heat exchangers (HXs). This requirement for Braidwood results from Braidwood SW being taken from the Braidwood cooling pond (lake), whose water temperature varies throughout the year. At Byron, the SX007 valves do not need manipulation during an accident (Exelon 2014). The potential for SAMAs suggested by these differences is discussed in Section F.3.2.

Given the following current conditions—(a) an early revision of the Braidwood internal events PRA model has been peer-reviewed, (b) a more recent revision was subjected to a self-assessment using the 2009 revision of the ASME PRA standard and the guidance in Regulatory Guide 1.200, Revision 2, (c) the assessment was performed consistent with the NEI 00-02 self-assessment process and the review findings were adequately resolved, and (d) Exelon has satisfactorily addressed NRC staff questions regarding the PRA—the NRC staff concludes that the internal events Level 1 PRA model is of sufficient quality to support the SAMA evaluation.

F.2.2.2 External Events

As indicated above, the Braidwood PRA used for the SAMA analysis does not include external events. In the absence of such an analysis, Exelon used the Braidwood IPEEE and other analyses to identify the highest risk accident sequences and the potential means of reducing the risk posed by those sequences and to estimate the benefit of potential SAMAs, as discussed below and in Section F.3.2.

The Braidwood IPEEE was submitted in June 1997 (ComEd 1997b), in response to Supplement 4 of GL 88-20 (NRC 1991a). The submittal included a seismic margin assessment (SMA), a fire assessment using the Electric Power Research Institute (EPRI) fire-induced vulnerability evaluation (FIVE) guidance (EPRI 1992), and a screening analysis for other (high winds, floods, and other (HFO)) external events. ComEd did not explicitly provide a definition of a vulnerability and did not identify any vulnerabilities in the seismic, fire, or HFO areas. However, a number of seismic issues were identified during ComEd’s IPEEE development, which were identified as “outliers” (related to statistical likelihood). As indicated in the ER, for example, these are generally items with potential seismically induced interaction issues for which it was difficult to calculate a High Confidence of Low Probability of Failure value; therefore, these require further evaluation. In its safety evaluation report (NRC 2001), the NRC staff concludes that the applicant’s IPEEE process is capable of identifying the most likely

severe accidents and severe accident vulnerabilities for external events and, therefore, that the Braidwood IPEEE has met the intent of Supplement 4 to GL 88-20.

The Braidwood IPEEE seismic analysis was a focused-scope SMA following NRC guidance (NRC 1991a, 1991b). The SMA approach is deterministic in nature and does not result in probabilistic risk information. The SMA was performed using a Safe Shutdown Equipment List (SSEL) with plant walkdowns in accordance with the guidelines and procedures documented in EPRI Report NP-6041-SL (EPRI 1991). Two success paths, each capable of mitigating the effects of a seismically induced small break LOCA, were identified based on a review of the guidance and plant documentation. The components on the SSEL were then evaluated for seismic capacity.

The components and associated structures in which they are housed were evaluated based on the screening criteria of NP-6041-SL. The review of major structures was based primarily on a review of the design bases augmented by a walkdown to identify any anomalous conditions. Masonry block walls were evaluated and qualified to the seismic design basis loads in compliance with the plant's seismic evaluation criteria. Mechanical and electrical equipment that did not meet the screening criteria were considered SMA outliers. If the equipment had anchorage that was not judged robust by the walkdown team, the high confidence in low probability of failure (HCLPF) anchorage evaluation was calculated to obtain an anchorage seismic capacity.

A number of outliers were identified. The majority of the outliers involved seismic interaction concerns that were resolved through some corrective actions. Others were resolved either by conservative deterministic failure margin capacity analysis to show the capacity well beyond review-level earthquake demand or by maintenance/modifications. These outliers were considered further in the Phase I SAMA identification discussed in Section F.3 below.

For the purposes of the SAMA evaluation, Exelon assumed a seismic CDF of 1×10^{-6} per year in the development of the external events multiplier (Exelon 2013a). Since the SMA approach used in the IPEEE does not involve the determination of seismic CDF and Exelon did not provide a basis for the value used, the NRC staff asked Exelon to consider the impact on the SAMA analysis if a seismic CDF from the generic issue (GI) 199 risk assessment (NRC 2010a) for the Braidwood site was used instead of the assumed seismic CDF of 1×10^{-6} per year. Exelon indicated that using the "weakest link" (bounding scenario) seismic CDF value (7.3×10^{-6} per year) from GI 199, the external events multiplier would increase from 2.8 to 3.0. Exelon reevaluated the SAMAs using this larger multiplier (Exelon 2014). This is discussed in more detail below.

The Braidwood IPEEE included an internal fire analysis employing EPRI's FIVE methodology (EPRI 1992). However, this has been superseded by the 2008 Braidwood Fire PRA, which is stated by Exelon to be an interim implementation of NUREG/CR–6850 (EPRI and NRC 2005). Interim implementation status is because not all needed analyzing tasks are completely addressed or implemented in the model. The 2008 Braidwood fire PRA was used in the SAMA analysis for determining the fire contribution to the external events multiplier as well as for identifying potential SAMAs to mitigate the internal fire risk.

While the Braidwood fire PRA is a risk assessment as compared to the IPEEE fire analysis, which is a screening analysis, it was not used directly in the SAMA analysis quantification. Exelon indicated that this was due to the fire model's not being fully integrated with the most recent Levels 2 and 3 analyses and the fire model's being based on Revision 6C of the internal events PRA rather than the current Revision BB11b1 model used for the internal events SAMA analysis.

In response to an NRC staff RAI (request) to provide more information on the quality and development of the 2008 Braidwood Fire PRA, Exelon indicated that the fire PRA development tasks do not have any specific quality assurance activities (Exelon 2014). However, there are internal processes that are used to ensure that the tasks are being performed and reviewed by knowledgeable personnel. This is accomplished by the use of certification guides for analysis in addition to each document's having three levels of signatures—preparer, reviewer, and approver—commensurate with quality assurance expectation for PRA. In addition, Exelon briefly discussed several conservatisms and nonconservatisms in the current model. The major conservatism identified is in the fire modeling task, which uses generic treatments of the zone of influence and no credit is given for fire severity. The nonconservatisms identified include not accounting for the effects of hot gas layers and the limited modeling of multiple spurious operations. The human reliability analysis (HRA) is identified as having potentially both conservative and nonconservative impacts on the results. A flow chart method is used for determining the human error probabilities (HEPs). The HEPs are generic in nature and modified based on certain parameters that may not be accurate given the actual fire.

In addition, the HEPs may be higher due to the unavailability of cues to give the operators a chance to respond to the event or, in some cases, timing constraints (Exelon 2014).

The NRC staff notes that, while the 2008 Braidwood Fire PRA is still under development and has not been peer reviewed, the SAMA evaluation should be performed using the best available information (consistent with NEPA requirements) on risk insights. Considering that the 2008 Braidwood Fire PRA model is a more current analysis of the fire risk at Braidwood than the IPEEE fire analysis and therefore is the best currently available fire risk information, the NRC staff concludes that the use of the fire PRA model provides an acceptable basis (best available information) for identifying and evaluating SAMA candidates.

The major (CDF greater than 1×10^{-6} per year) fire core damage contributors for each unit are listed in Tables F–4(a) and F–4(b). This information was used by Exelon to identify potential SAMAs for the fire events and to evaluate the benefit of any SAMA uniquely directed at reducing the fire risk. This is discussed in Sections F.3 and F.4 below.

As seen in Table F–4(b), the Unit 2 results include a CDF for fire in the Unit 1 containment. It is stated in the ER that the fire-induced failures are Unit 1 equipment and the fire is modeled as requiring a Unit 2 shutdown without the availability of untraced equipment, such as the main feedwater (FW) system. In response to an NRC staff RAI which noted that Unit 2 containment fires did not appear in the Unit 1 results, Exelon explained that the fire model considers the impact of a fire in each of the site's fire zones for each unit, even if the fire zone is in the opposite unit. The Unit 1 results also include Unit 2 containment fires as contributors, but these fires were below the review threshold used in the ER. The Braidwood fire PRA, which is an interim model, conservatively assumes failure of the equipment for which the cable routing is not known, which includes the main FW system (Exelon 2014).

The ER indicated that the 2008 Braidwood fire PRA utilized fire ignition frequencies from NUREG/CR–6850 rather than the later data from EPRI 1016735 (EPRI 2008). The NRC staff notes that the use of the updated fire ignition frequencies in EPRI 1016735 is endorsed by the NRC in NUREG/CR–6850 Supplement 1 (EPRI and NRC 2010). To account for this, the results of the 2008 Braidwood fire PRA were reduced by a factor of 1.262, which was obtained from the results of a sensitivity study performed for the Byron fire PRA. The total fire CDF for Braidwood is then 7.5×10^{-5} per year (for Braidwood Unit 2), the higher of the two units, divided by 1.262 or 5.94×10^{-5} per year (Exelon 2013a).

Table F–4(a). Major Braidwood Unit 1 Contributors to Fire CDF

Fire Zone	Fire Zone Description	CDF (per year)
1-1	Unit 1 containment	7.0×10^{-6}
11.3-1	Unit 1 containment pipe penetration area	5.7×10^{-6}
11.3-0	Auxiliary building general area, Elevation (Elv.) 364	5.7×10^{-6}
11.4c-0	Radwaste and remote shutdown panel control room	5.3×10^{-6}
11.6-1	Division 12 containment electrical penetrations area	3.7×10^{-6}
5.2-1	Division 11 engineered safety feature (ESF) switchgear room	3.2×10^{-6}
5.6-1	Division 11 miscellaneous electric equipment room and battery room	3.2×10^{-6}
5.5-1	Unit 1 auxiliary electric equipment room	2.5×10^{-6}
5.6-2	Division 21 Miscellaneous electric equipment room and battery room	2.1×10^{-6}
5.1-1	Division 12 ESF switchgear room	1.5×10^{-6}
11.6c-0	Auxiliary building laundry room	1.5×10^{-6}
18.12-0	Lake screen house	1.3×10^{-6}
11.6-0	Auxiliary building general area, Elv. 426	1.2×10^{-6}
11.5a-1	Division 11 containment electrical penetrations area	1.1×10^{-6}

In response to an NRC staff RAI concerning the applicability of the Byron sensitivity study result to Braidwood, Exelon indicated that this reduction factor was applied to the total fire CDF but not to the individual fire zone results listed in Table F–4. Exelon also provided the results of a sensitivity study of the impact of the EPRI 1016735 fire ignition frequencies on the CDF for each of the Braidwood major fire zones identified in Table F–4. This study indicated that, for Unit 2, the total CDF for the major fire zones was reduced from 4.89×10^{-5} per year to 3.54×10^{-5} per year or a reduction factor of 1.38 while a reduction factor of 1.37 was similarly found for Unit 1 (Exelon 2014). Both of these reduction factors are higher than the 1.262 reduction factor used in the SAMA evaluation.

While the above Braidwood sensitivity study was only performed on the major fire zones representing about 65 percent of the total fire CDF, the NRC staff considers these results to provide a reasonable representation of the significant contributors to fire CDF at Braidwood and therefore sufficient to support the use of the 1.262 reduction factor for the total Braidwood fire CDF. Considering that a SAMA evaluation should be performed using the best available risk information, the NRC staff concurs that the use of the 2008 Braidwood fire PRA adjusted as described above rather than the IPEEE fire analysis for the development of the external events multiplier in the SAMA evaluation is appropriate. The NRC staff also concludes that the use of the individual fire zone results without adjustment for ignition frequency is conservative and acceptable for SAMA identification and cost-benefit evaluation purposes.

The Exelon IPEEE analysis of high winds and tornadoes, external floods, and transportation and other nearby facility accidents (HFO events) followed the screening and evaluation approaches specified in Supplement 4 to GL 88-20 (NRC 1991a). For these events, the IPEEE concluded that the Braidwood design conforms to the 1981 Standard Review Plan criteria (NRC 1981) and therefore the contribution to CDF from these events meets the IPEEE screening criterion of 1×10^{-6} per year in NUREG–1407 (NRC 1991b). The IPEEE did not identify any vulnerabilities or enhancements.

Table F–4(b). Major Braidwood Unit 2 Contributors to Fire CDF

Fire Zone	Fire Zone Description	CDF (per year)
5.2-2	Division 21 ESF switchgear room	7.8×10^{-6}
11.4C-0	Radwaste and remote shutdown panel control room	6.1×10^{-6}
1-2	Unit 2 containment	4.9×10^{-6}
5.6-1	Division 11 Miscellaneous electric equipment room and battery room	4.6×10^{-6}
5.6-2	Division 21 Miscellaneous electric equipment room and battery room	3.7×10^{-6}
11.6-2	Division 22 containment electrical penetrations area	3.4×10^{-6}
5.5-2	Unit 2 auxiliary electric equipment room	3.1×10^{-6}
5.2-1	Division 11 ESF switchgear room	2.2×10^{-6}
11.6-0	Auxiliary building general area, Elv. 426	1.7×10^{-6}
11.5A-2	Division 21 containment electrical penetrations area	1.6×10^{-6}
11.4-0	Auxiliary building general area, Elv. 383	1.4×10^{-6}
18.12-0	Lake screen house	1.3×10^{-6}
11.5-0	Auxiliary building general area, Elv. 401	1.2×10^{-6}
1-1 A	Unit 1 Containment	1.2×10^{-6}
11.6C-0	Auxiliary building laundry room	1.2×10^{-6}
18.10E-2	System auxiliary transformers 242-1 and 242-2	1.1×10^{-6}
8.10E-1	System auxiliary transformers 142-1 and 142-2	1.1×10^{-6}
8.6-0	Turbine building operating floor	1.0×10^{-6}

Based on the aforementioned results, Exelon indicated in the ER that the total external events CDF is approximately 6.3×10^{-5} per year. This value is based on a seismic CDF of 1.0×10^{-6} per year, a fire CDF of 5.9×10^{-5} per year, a high wind CDF of 1.0×10^{-6} per year, an external flooding CDF of 1.0×10^{-6} per year, and a transportation and other nearby accidents CDF of 1.0×10^{-6} per year. The total external events CDF of 6.3×10^{-5} per year is 1.8 times the Unit 2 internal events CDF of 3.5×10^{-5} per year. The total CDF (internal and external events) is then 9.8×10^{-5} per year or 2.8 times the Unit 2 internal events CDF.

Therefore, the ER used an external events multiplier of 2.8 in the SAMA analysis to account for the impact of external events on the benefits determined from the internal events PRA.

As discussed above, the GI 199 risk assessment gives a seismic CDF for Braidwood of 7.3×10^{-6} per year. Use of this value yields a total external events CDF of 7.0×10^{-5} per year and a total internal plus external events CDF of approximately 1.05×10^{-4} per year, which is approximately 3.0 times the Unit 1 internal events CDF. In response to an NRC staff RAI, Exelon used this higher external events multiplier to update a cost-benefit analysis (Exelon 2014).

The NRC staff: (a) agrees with the applicant's overall conclusion concerning the use of a multiplier to represent the impact of external events and (b) finds that the applicant's use of a multiplier of 3.0 in response to an NRC staff RAI will reasonably account for external events in the SAMA evaluation. This is discussed further in Section F.6.2.

F.2.2.3 Level 2 Fission Product Release Analysis

The NRC staff reviewed the general process used by Exelon to translate the results of the Level 1 PRA into containment releases, as well as the results of the Level 2 analysis, as described in the ER and in response to NRC staff RAIs (Exelon 2014). The results of the Level 2 analysis are provided in ER Table F.2-8 (release category frequencies) and Table F.2-7 (timing and magnitude of release).

The current Level 2 model is essentially a completely new model, replacing the prior LERF model, and was developed specifically for the SAMA analysis. Exelon stated that the current Braidwood Level 2 model is a state-of-the-art Level 2 analysis structure designed to address the Category II requirements of Regulatory Guide 1.200 (NRC 2009) and the ASME PRA Standard (ASME and ANS 2009).

Exelon stated that the Level 2 model is generally consistent with the "Simplified Level 2 Modeling Guidelines," Westinghouse Commercial Atomic Power (WCAP)-16341-P (Westinghouse 2005). This WCAP provides a common and standardized method for pressurized-water reactors (PWRs) with large dry containments to produce an analysis that generally meets Capability Category II of the ASME PRA standard. The guidance particularly addresses the latest understanding for induced SGTRs, direct containment heating, and other important Level 2 phenomena. While the WCAP is focused on modeling the LERF for the ASME standard, it includes guidance for including intact, small, and late releases to provide a more complete, though still standardized, Level 2 analysis.

In response to an NRC staff RAI to identify areas where the Braidwood model differs from that in WCAP-16341-P, Exelon indicated that the differences include (Exelon 2014):

- No credit for recovery of alternating current power or diesel generator repair after core damage.
- Modeling of potential hot leg rupture following an induced tube rupture, such that the release to the environment is substantially reduced, based on recent research results from the State-of-the-Art Reactor Consequence Analyses (SOARCA) project (Bixler et al. 2013).
- Use of a combined CET rather than separate SBO and non-SBO CETs. This is a modeling choice and has no effect on the overall model since recovery of offsite power is not credited.
- Crediting a human action to maintain a sufficient water pool over the steam generator (SG) tubes to scrub releases in SGTR events. While not specifically included in the WCAP methodology, WCAP-16341-P does identify that this type of scrubbing is possible.

Plant damage states provide the interface between the Level 1 and Level 2 analyses. Each Level 1 accident sequence that leads to core damage consists of a unique combination of an initiating event followed by the success or failure of various plant systems (including operator actions). The Level 1 sequences that result in core damage are grouped into PDS bins. Each bin collects all of those sequences for which: (a) the progression of core damage, (b) the release of fission products from the fuel, (c) the status of the containment and its safeguards systems, and (d) the potential for mitigating the potential radiological source terms are similar.

The PDS bins for Braidwood are characterized by the status of containment bypass due to SGTR or ISLOCA, reactor coolant system (RCS) pressure, and the availability of feedwater (AFW).

For Braidwood a single detailed CET evaluates the accident progression following a core damage event and analyzes each PDS bin as a group. The Braidwood CET (shown in ER Figure F.2-4) is stated to be based on the CETs provided in WCAP-16341-P. While the function of the CET is essentially the same as the WCAP CETs, some changes were made to accommodate the capabilities and features of the Braidwood PRA model. The event tree begins with one or more core damage sequences. The CET then asks a number of questions to determine the characteristics of a release if one were to occur. Each question is modeled as a top event in the event tree and the outcome is based on previous work for Braidwood (including logic taken from the existing model), recent accident progression research, and the guidance provided in the WCAP.

The NRC staff noted in an RAI that ER Section F.2.3.2 indicated that containment failure due to direct containment heating is “0.000” and asked to clarify how this, and other early containment failure (CFE) probabilities, are included in the Level 2 models (NRC 2014). In response to the RAI, Exelon indicated that the “0.000” containment failure probability is not a typo but is the value reported from WCAP-16341-P, which in turn quotes the value from NUREG/CR-6338, “Resolution of Direct Containment Heating Issue for all Westinghouse Plants with Large Dry Containments or Subatmospheric Containments.” The WCAP notes that the NUREG provides only three significant digits. The 0.000 value applies to all sequences and all combinations of hydrogen burns, steam explosion, or direct containment heating—or some combination of the three. Therefore, the probability of CFE at Braidwood is negligible for any sequence. However, in order to maintain flexibility in the model for sensitivity analyses, the CFE probability is maintained in the model and assigned a probability of 0.001 for any cause or combination of causes (Exelon 2014).

Each CET end state represents a radionuclide release to the environment and is assigned to a release category. Four general release categories were defined: intact, late release, small early release, and LER. Because there are a large number of Level 2 sequences that contribute to each general release category with varying release characteristics, the general release categories were then subsequently subdivided into 13 detailed release categories.

The LER categories are for the containment bypass or failure conditions that lead to the release. These are unisolated ISLOCAs, containment isolation failures, CFEs, noninduced SGTRs with and without FW, and pressure or thermal induced SGTRs. The late release categories are for containment overpressure failure and “basemat” melt through, each with or without FW. The small early release categories are for SGTRs with FW available resulting in water level above the SG tubes and thermally induced SGTRs shortly followed by hot-leg failure.

Exelon developed the accident progression and associated release characteristics for each release category by using the results of MAAP Version 4.0.6 computer code calculations. A representative sequence was selected for each detailed release, considering both the likelihood of the scenario and its potential consequences. Since source terms are not always available for each sequence making up a release category, the selection of the representative sequence was based on judgment as to the potential consequences. Exelon stated that the sequence that is judged to be associated with a higher potential source term is used as the representative sequence unless there is: (a) another sequence that accounts for a majority of the release category frequency and (b) the sequence with the “higher” source term that accounts for less than about 10 percent of the release category frequency. In those cases, the “majority” sequence would be chosen as representative (Exelon 2013a). Table F.2-6 of the ER describes the representative sequence used for each release category. Table F.3-8 of the ER describes and justifies the MAAP case for each representative sequence and provides the resulting key event timings. In response to an NRC staff RAI, Exelon stated that the input for the MAAP

cases specified the fission product mass, as recommended by the MAAP Users Group Bulletin, "MAAP-FLASH #68" (Exelon 2014).

The above listed tables indicate that for several release categories, the run duration of the MAAP analysis was quite long (200, 800, and 1,600 hours). Exelon stated that this duration was necessary to achieve a plateau of the release fractions, with primary attention paid to cesium iodide (CsI) and cesium hydroxide (CsOH) release fractions. In response to NRC staff RAIs as to the reason this was necessary and to identify conservatisms in the analysis, Exelon indicated that the run time for various MAAP calculations was established based on: (a) the timing for the onset of core damage, (b) the timing for either containment failure or containment bypass, and (c) consideration of revaporization of fission products that initially deposited within the RCS (particularly on the SG tubes where, after the SG dries out and the tube temperature increases, the deposited fission products become available for release late in the event). The run times were selected to make sure to capture this revaporization phenomenon (Exelon 2014).

Exelon provided plots of the CsI release as a function of time for a number of release categories by Exelon in response to the RAI. In many cases, the plots show a stable (steady state) total release from the containment is achieved well before the end of the run. For the dominant release category (LATE-CHR-NOAFW), which contributes 58 percent of the PDR and 79 percent of the offsite economic cost risk (OECR), the CsI reaches a stable value at 600 hours. For CsOH (which is stated by Exelon to be the primary driver for long-term dose and costs), the release is slower and the release fraction is still increasing at a slow rate even at 1,600 hours.

The NRC staff notes that the above cited times of 600 hours (25 days) and 1,600 hours (67 days) are relatively long, compared with the time that is expected for additional onsite and offsite resources (mitigation measures) to be available to mitigate the releases. This has a significant impact on the release fractions. For example, for the dominant release category, at 72 hours or 3 days after declaration of a general emergency, the CsI release fraction is 37 percent of the value used in the consequence analysis, while the CsOH release fraction is only 7 percent of the value used in the consequence analysis. Alternatively, if the releases were terminated at 144 hours or 6 days after declaration of a general emergency, the CsI release would be 63 percent and the CsOH release would be 16 percent of the values used in the consequence analysis for the dominant release category. Use of these lower release fractions would result in a significant reduction in both PDR and OECR.

In response to the NRC staff's RAI to identify the major factors that contribute to the OECR and to discuss their realism (or conservatism), in addition to discussing the conservatism involved in using the release fractions for very long run times, Exelon identified conservative modeling involving the chemical form of cesium (Cs). NUREG/CR–7110 (Bixler et al. 2013) indicates that only a small fraction of the Cs is in the form of CsI and that the dominant chemical form will be cesium molybdate (a compound containing an oxoanion with molybdenum) with the remaining Cs in the form of CsOH. The Braidwood SAMA analyses conservatively assume that the dominant Cs chemical form is CsOH. Cesium molybdate has a very low vapor pressure and would therefore be expected to remain deposited (retained) on structures (e.g., the tubes in an SG, instead of being released) for a longer time, relative to CsOH. The result of this assumption is a conservative SAMA assessment (Exelon 2014).

The NRC staff noted in an RAI that the analysis of sequences involving containment isolation failure did not allow for CFE due to such phenomenology as hydrogen explosion or direct containment heating (NRC 2014). In response to the RAI, Exelon indicated that, while hydrogen explosion and direct containment heating are potential failure modes for the containment

isolation failure sequences (Release Category LERF-CI), the probability of CFE due to these mechanisms is 1×10^{-3}. While the CFE CsI release fraction may be about 20 times larger than the CsI release fraction for containment isolation, the frequency is 1,000 times less. Furthermore, the potential contribution from the fraction of isolation failures that result in CFE represents only about 1 percent of the other CFE frequency (Release Category LERF-CFE). Rebinning the CFE contributions from the LERF-CI release category into the LERF-CFE release category results in no measurable change to the reported PDR and OECR values and, therefore, would have no impact on the SAMA analysis (Exelon 2014).

In response to an NRC staff RAI to describe the steps taken to ensure the technical adequacy of the revised Braidwood Level 2 PRA model, Exelon indicated that for the initial completion of the updated Level 2 model included in Revision BB011b1 of the PRA, an internal review was conducted examining accident sequence modeling, fault tree modeling, and cutset reviews. The documentation of the BB011b1 model also includes a self-assessment (roadmap) against Capability Category II of the ASME PRA Standard. This self-assessment (roadmap) concluded that all applicable LER (or LERF) SRs were met at Capability Category II. The signatures of the preparer and the reviewer confirm the internal review and agreement with the conclusion of the self-assessment (roadmap). The new Level 2 model replaced the simplified (generally conservative) previous LERF model. Reductions in LERF come from several improvements, including credit for: (a) an operator action to keep an SG full to scrub a release from a SGTR and (b) reduced CFE probabilities (Exelon 2014).

The NRC staff has reviewed the Level 2 methodology and determined that: (a) Exelon has satisfactorily addressed NRC staff RAIs and (b) the Level 2 model was assessed by Exelon against the LER safety requirements of the ASME PRA standard and found to meet the Capability Category II requirements. Therefore, the NRC staff concludes that the Level 2 PRA is of sufficient quality to support the SAMA evaluation.

F.2.2.4 Level 3 Offsite Consequence Analysis

The NRC staff reviewed the process used by Exelon to extend the containment performance (Level 2) portion of the PRA to an assessment of offsite consequences (Level 3 PRA). This included consideration of the source terms used to characterize fission product releases for the applicable containment release categories and the major input assumptions used in the offsite consequence analyses. The MACCS2 code (Version 1.13.1) was utilized to estimate offsite consequences (NRC 1998). Plant-specific input to the code includes: (a) the source terms for each source term category and the reactor core radionuclide inventory (both discussed above), (b) site-specific meteorological data, (c) projected population distribution within an 80-km (50-mi) radius for the year 2047, (d) emergency evacuation modeling, and (e) economic data. As indicated in the ER, the reactor core radionuclide inventory used in the consequence analysis was based on end-of-cycle power of 3,645 MWt. The current rated power for Braidwood is 3,586.6 MWt and the core radionuclide inventory was based on this power (Exelon 2008). Exelon has submitted a license amendment requesting a Measurement Uncertainty Recapture (MUR) power uprate from 3,586.6 MWt to 3,645 MWt (Exelon 2011). The proposed uprate was included in the MACCS2 analysis by scaling the base core inventory by the power uprate ratio (1.0163). This information is provided in Section 3.5 of Attachment F to the ER (Exelon 2013a). Exelon performed a sensitivity study assuming the current rated power of 3,586.6 MWt. The decrease in power of 1.63 percent resulted in a decrease in both PDR and cost risk of 1 percent each.

Exelon modeled all releases as being from midheight of the reactor containment building and at 1×10^{7} (10 megawatts) thermal content, except for intact containment (which maintained zero energy for the purpose of release height analysis). Exelon performed sensitivity studies using

zero plume energy (Exelon 2013a). With zero plume heat, the dose risk and cost risk decrease by 3 percent and 8 percent, respectively. Exelon performed sensitivity studies for plume release height and deposition velocity (Exelon 2013a). Release height set to ground level resulted in a decrease in dose risk of 2 percent and a decrease in cost risk of 4 percent. Release height set to the top of containment resulted in an increase in dose risk of 2 percent and an increase in cost risk of 2 percent. The deposition velocity was reduced from 0.01 meters per second (m/s) (0.03 foot per second (fps)) to 0.005 m/s (0.016 fps) (a factor of 2), which resulted in a decrease in PDR of 10 percent and decrease in cost risk of 21 percent. In response to an NRC staff RAI, Exelon provided additional values and assumptions associated with the MACCS2 model input, including: rainfall, mixing height, building wake effects, plume energy, land fraction, region index, watershed index, growing season, fraction of farmland, and shielding and protection factors (Exelon 2014). Based on the information provided, the staff concurs and concludes that the release parameters used are acceptable for the purposes of the SAMA evaluation, consistent with the review criteria in the standard review plan.

Exelon used site-specific meteorological data for the 2010 calendar year as input to the MACCS2 code. The development of the meteorological data is discussed in Section 3.7 of Attachment F to the ER. The data were collected from onsite and local meteorological monitoring systems. In response to an NRC staff RAI (Exelon 2014), Exelon clarified that only mixing layer height was based on other meteorological data. The mixing layer height was based on a U.S. Environmental Protection Agency study (Holzworth 1972); this is identified in Section F.3.7 of the ER. Missing data were filled in by substituting data from a different elevation, interpolation, power law, or substituting data from the previous or subsequent day. Sensitivity analyses were performed using MACCS2 and the meteorological data for the years 2008 and 2009 (Exelon 2013a). The year 2008 data resulted in a decrease in dose risk of 2 percent and a decrease in cost risk of 3 percent. The year 2009 data resulted in a decrease in dose risk of 3 percent and no change in cost risk. The NRC staff notes that previous SAMA analyses overall results have shown little sensitivity to year-to-year differences in meteorological data; therefore, the NRC staff concludes that the use of the 2010 meteorological data in the SAMA analysis is reasonable.

The population distribution used as input to the MACCS2 analysis was estimated for the year 2047 using year 2000 census data as accessed by SECPOP2000 (Sector Population, Land Fraction, and Economic Estimation Program) (Bixler et al. 2003) as a starting point. The transient population was included in the 16-km (10-mi) emergency planning zone (EPZ), and in the population projection from years 2000 to 2047. In addition, special facilities population was also included in the initial year 2000 population estimate. In response to an NRC staff RAI, Exelon provided the year 2000 transient, special facility, and residential population distributions (Exelon 2014). These are presented in Tables 4b-1 and 4c-1 of the RAI response. A 30-year population growth rate was estimated using the year 2000 SECPOP2000 data and population growth estimates from the Illinois (DCEO 2012) and Indiana (IBRC 2012) county population projections to year 2030. The year 2030 population estimate was then scaled to year 2046 using this growth rate to obtain the population distribution in 2046. The NRC staff noted that Section 2.6.1 of the ER contained year 2010 census population, but the SAMA analysis used year 2000 census data for estimating population growth. In response to an NRC staff RAI, Exelon compared a projected year 2010 population to the recently available year 2010 census population for result sensitivity determination. The projected population within the 80-km (50-mi) radius was approximately 6 percent higher than the census population (Exelon 2014). The baseline population was determined for each of 160 sectors, consisting of 16 directions for each of 10 concentric distance rings to a radius of 80 km (50 mi) surrounding the site. Individual county growth rates were applied at each grid element. Some grid elements include land from multiple counties. A weighted growth rate was used for those grid elements based on the

fraction of land in that grid element associated with each county. Counties that were projected to have negative growth rates were conservatively assumed to have zero growth rates. In response to an NRC staff RAI, Exelon stated that three recently publicized SECPOP2000 code errors were accounted for in the Braidwood analysis (Exelon 2014). Exelon performed a sensitivity study for the year 2047 population by increasing the population by 30 percent (uniformly). The resulting dose risk increased by 30 percent and cost risk increased by 29 percent. The NRC staff concurs with the results and considers the methods and assumptions for estimating population reasonable and acceptable (within acceptable sensitivity) for purposes of the SAMA evaluation, consistent with the review criteria in the standard review plan.

The emergency evacuation model was modeled as a single evacuation zone and stated to extend out 16 km (10 mi) from the plant (the EPZ) (ET 2003). Exelon assumed that 95 percent of the population would evacuate. This assumption is conservative relative to the NUREG-1150 study (NRC 1990) that assumes evacuation of 99.5 percent of the population within the EPZ. The evacuated population was assumed to move at an average radial speed of approximately 4.2 m/s (9.4 miles per hour (mph)) with a delayed start time of 115 minutes after declaration of a general emergency (Exelon 2013a). The evacuation speed is a time-weighted average value accounting for season, day of week, time of day, and weather conditions (ET 2003). A general emergency declaration was assumed to occur when plant conditions degraded to the point when it was judged that there was a credible risk to the public. In response to an NRC staff RAI, Exelon clarified that the evacuation study (ET 2003) does not associate specific events with the evacuation time study (Exelon 2014). Exelon performed sensitivity studies for the evacuation speed and delay time to evacuation. The evacuation speed was reduced by 67 percent to 1.4 m/s (3.1 mph). The resulting dose risk increased by 5 percent and the change in cost risk was negligible. The evacuation delay time was increased by a factor of 2 to 230 minutes. The resulting dose risk increased by 0.7 percent and the change in cost risk was negligible. The NRC staff concurs and concludes that the evacuation assumptions and analysis are reasonable and acceptable for the purposes of the SAMA evaluation.

Site-specific agriculture and economic parameters were developed manually using data in the 2007 National Census of Agriculture (USDA 2009) and 2007 data from the Bureau of Economic Analysis (BEA 2012) for each of the 21 counties surrounding Braidwood, to a distance of 80 km (50 mi). Economic values were updated to July 2012 using the consumer price index from the Bureau of Labor Statistics (BLS 2012). The values used for each of the 160 sectors were the data from each of the surrounding counties multiplied by the fraction of that county's area that lies within that sector. Food ingestion was modeled using the new MACCS2 ingestion pathway model COMIDA2 (NRC 1998). For Braidwood, approximately 1.4 percent of the total PDR is due to food ingestion (1.6 person-rem/year) (Exelon 2013a). In response to an NRC staff RAI, Exelon stated that input parameters used were based on food production parameters derived from annual food consumption of an average individual, and that food ingestion dose limits were based on 1998 Food and Drug Administration Guidance (Exelon 2014). Generic economic data applied to the region as a whole were revised from the MACCS2 sample problem input to account for cost escalation since 1986 (the year that input was first specified). Taking into account the U.S. Consumer Price Index (CPI), a factor of 2.09 (CPI of 229.1 divided by CPI of 109.6), representing cost escalation from 1986 (CPI index of 109.6) to July 2012 (CPI index of 229.1), was applied to parameters describing cost of evacuating and relocating people, land decontamination, and property condemnation.

Exelon performed a sensitivity study for the economic rate of return, resettlement planning, and generic economic inputs. The rate of return was modified to 3 percent and 12 percent (from

7 percent). The decrease in rate of return (by approximately 57 percent) resulted in an increase in population dose of 1 percent and a decrease in cost risk of 9 percent. The increase in rate of return (by approximately 71 percent) resulted in a decrease in population dose of 1 percent and an increase in cost risk of 11 percent. In response to an NRC staff RAI, Exelon provided clarification that the rate of return on property impacts the estimated property that is condemned (or reclaimed) (Exelon 2014). Changes in property reclamation will result in changes in dose consequences to those who occupy the property after it has been reclaimed. Resettlement planning was modified assuming: (a) no "Intermediate Phase" and (b) a 1-year "Intermediate Phase" (in lieu of 6 months). No "intermediate phase" resulted in an increase in dose risk of 17 percent and a decrease in cost risk of 40 percent. A 1-year "intermediate phase" resulted in a decrease in dose risk of 13 percent and an increase in cost risk of 41 percent. Key generic economic input parameters to MACCS2 were modified as shown in Table F.7-1 of the ER. In general the input variables were increased by a factor of 2. The increase in these economic parameters resulted in a decrease in dose risk of approximately 4 percent and an increase in cost risk of approximately 52 percent.

The NRC staff concludes that the methodology used by Exelon to estimate the offsite consequences for Braidwood provides an acceptable basis from which to proceed with an assessment of risk reduction potential for candidate SAMAs. Accordingly, the NRC staff based its independent assessment of offsite risk on the CDF and offsite population doses and offsite economic costs reported by Exelon.

F.3 Potential Plant Improvements

The process for identifying potential plant improvements, an evaluation of that process, and the improvements evaluated in detail by Exelon are discussed in this section.

F.3.1 Process for Identifying Potential Plant Improvements

Exelon's process for identifying potential plant improvements (SAMAs) consisted of the following elements:

- review of the most significant basic events from the current, plant-specific PRA including the 2008 Braidwood fire analysis;
- review of selected cost-beneficial SAMAs from selected plants;
- review of potential plant improvements identified in the Braidwood IPE and IPEEE; and
- insights from the PRA group.

Based on this process, an initial set of 35 candidate SAMAs, referred to as Phase I SAMAs, was identified. In Phase I of the evaluation, Exelon performed a qualitative screening of the initial list of SAMAs and eliminated SAMAs from further consideration using the following criteria:

- The SAMA is not applicable to Braidwood plant design.
- The SAMA has already been implemented or its intent met at Braidwood.
- The SAMA has estimated implementation costs that would exceed the dollar value associated with completely eliminating all severe accident risk at Braidwood.

Based on this screening, one SAMA was eliminated leaving 34 for further evaluation. The results of the Phase I screening analysis are provided in Table F.5-3 of the ER (Exelon 2013a).

The remaining SAMAs, referred to as Phase II SAMAs, are listed in Table F.6-1 of the ER (Exelon 2013a). In Phase II, a detailed evaluation was performed for each of the 34 SAMA candidates, as discussed in Sections F.4 and F.6 below. To account for the potential impact of external and internal flooding events, the estimated benefits based on internal events were multiplied by a factor of 2.8 as discussed in Section F.2.2.2. Also as discussed in Section F.2.2.2, this multiplier was increased to 3.0 in response to an NRC staff RAI (Exelon 2014).

F.3.2 Review of Exelon's Process

Exelon's efforts to identify potential SAMAs focused primarily on areas associated with internal initiating events. The initial list of SAMAs generally addressed the accident sequences considered to be important to CDF (i.e., importance list review) from functional, initiating event, and risk reduction worth (RRW) perspectives at Braidwood.

Exelon provided in the ER a tabular listing of the Level 1 PRA basic events sorted according to their RRW (Exelon 2013a). The SAMAs impacting these basic events would have the greatest potential for reducing risk. In the ER, Exelon indicates that the review of these events down to an RRW of 1.006 would correspond to a potential benefit of $100,000 if a SAMA to mitigate this event were 100 percent effective. This value is Exelon's estimate of the cost of a procedure change along with any necessary engineering analysis and training. As Exelon noted, this value of the RRW does not include the potential impact of external events. This was stated as not included because the Braidwood fire results were reviewed separately for potential SAMAs and the fire model is in an interim state. Exelon used an RRW cutoff of 1.005 based on the availability of an earlier SAMA review that used this as a cutoff.

The RRW cutoff of 1.005 corresponds to about a half percent change in CDF given 100-percent reliability of the SAMA. The NRC staff estimates that this equates to a benefit of approximately $249,000 (after the benefits have been multiplied by a factor of 3.0 to account for external events).

In response to an NRC staff RAI to justify not extending the review down to an RRW value which would encompass failures whose mitigation would have a benefit, accounting for both internal and external events, of $100,000 as determined in the Braidwood Phase II cost-benefit analysis, Exelon discusses the guidance given in NEI's SAMA guidance document (NEI 2005). This document, which is endorsed by the NRC, indicates that the SAMA analysis should use the Probabilistic Safety Analysis importance to "identify plant-specific SAMA candidates by reviewing dominant risk contributors (to both CDF and population dose) in the Level 1 and Level 2 PSA models." While acknowledging that the definition of "dominant risk contributors" is open to interpretation, Exelon indicates that the guidance does not indicate that the identification process should be an exhaustive search for all plant enhancements that might be cost-beneficial. Exelon points out that the PRA Applications Guide (EPRI 1995) defines risk-significant events to be those events with RRW values of 1.010 and greater. As indicated above, the Braidwood importance review was carried out down to an RRW value of 1.005 (Exelon 2014).

Relative to the use of RRW cutoff criterion in SAMA analysis, the NRC staff disagrees with the practice of reviewing basic events down to an RRW of 1.005 based solely on the definition of risk-significant events from the PRA Applications Guide (EPRI 1995). Rather, the intent of the SAMA analysis, as discussed in NEI 05-01 (NEI 2005), is to perform a review of the risk-significant contributors to the level necessary to identify potential cost-beneficial enhancements. The minimum cost of a potentially cost-beneficial enhancement was determined by Exelon to be $100,000 for Braidwood and, hence, this should be the basis for the

importance review. Based on additional explanation provided by Exelon, the NRC staff notes (as discussed above) that Exelon performed a separate review of the important contributors to fire risk. Hence, the staff agrees that the RRW cutoff for the internal events Level 1 and Level 2 importance review need not consider the contribution from fire events. The NRC staff estimates that an RRW of 1.005 equates to a benefit of approximately $108,000 (after the benefits have been multiplied by a factor of 1.3 to account for nonfire external events only). Exelon also notes in the ER that this benefit would be further reduced with implementation of SAMA 15 (cross-tie AFW between Units 1 and 2 to provide steam generator makeup), which Exelon states is currently being implemented at Braidwood (Exelon 2013a). Based on Exelon's separate review of the significant contributors to fire risk, and Exelon's implementation of SAMA 15 at Braidwood, the NRC staff concludes that Exelon's review of Braidwood's PRA importance analysis down to an RRW of 1.005 is adequate for the purpose of the SAMA assessment.

Exelon also provided in the ER tabular listings of the Level 2 PRA basic events for the combined LERF categories and the combined Late Release categories, which in total contribute approximately 95 percent of the population dose-risk and the OECR. Exelon used an RRW cutoff of 1.005 when reviewing these basic events for SAMA candidates. The Level 2 sequences for the intact release category were not included in the review so as to prevent high frequency–low consequence events from biasing the importance listing.

Exelon's review of the Level 1 and Level 2 importance lists resulted in the identification of 25 SAMA candidates. Exelon used the importance list review to identify the equipment failure scenarios most important to Braidwood risk, by examining the reasons for the importance through sequence and system analysis.

Although not identified to mitigate any specific Level 2 basic event, Exelon identified an additional SAMA candidate (SAMA 25 Install a Filtered Containment Vent) as a "General Late Release Mitigation Method" (Exelon 2013a).

The Exelon review of the late release categories importance list identified SAMA 24, to provide a reactor vessel cooling system to prevent vessel melt through, as a means of mitigating basemat melt through. The NRC staff noted that based on the Braidwood IPE (ComEd 1994), plant procedures were implemented to direct reactor cavity flooding in core damage scenarios to provide a means of exterior vessel cooling (NRC 1997b). Based on the IPE implementation of cavity flooding, the NRC staff requested in an RAI clarification on why the additional cooling system in SAMA 24 was required to perform this function (NRC 2014). Exelon noted that for cases where core damage occurred, there was a concern that it might not be possible to perform cavity flooding in the time available to prevent vessel failure. Preventing reactor vessel melt through not only prevents basemat melt through but also prevents CFEs such as that due to direct containment heating. A fast-acting system might therefore have added benefit. These additional failures were assumed to be mitigated by SAMA 24 in the ER cost-benefit analysis. The NRC staff considers this description of SAMA 24 and explanation of its potential benefit reasonable.

Exelon reviewed the cost-beneficial Phase II SAMAs from prior SAMA analyses for six Westinghouse PWR sites to aid in the identification of additional SAMA candidates. Many of the industry Phase II SAMAs were already represented by other SAMAs in the Braidwood list, were known not to impact important plant systems or be relevant to the Braidwood design, or were judged not to have the potential to be close contenders for Braidwood. As a result, most of the SAMAs in these prior analyses were not added to the Braidwood SAMA list. However, Exelon's review resulted in the identification of one additional SAMA candidate.

The NRC staff noted in an RAI that the NRC staff's evaluation of the Indian Point, Units 2 and 3, SAMA analysis (NRC 2010b) identified 13 potentially cost-beneficial SAMAs, whereas the

Braidwood review considered only 7 of the 13 SAMAs (NRC 2014). In response to the RAI, Exelon assessed the additional six Indian Point SAMAs and concluded that each was either not applicable to the Braidwood design, has been implemented at Braidwood, or is already addressed by a Braidwood candidate SAMA (Exelon 2014).

In its review of industry cost-beneficial SAMAs, Exelon noted that two Vogtle SAMAs (SAMAs 6 and 16) (NRC 2008) that were originally cost-beneficial were, upon further evaluation of the cost and benefit, judged not to be cost-beneficial at Vogtle. In response to an NRC staff RAI to consider if these SAMAs would be applicable or potentially cost-beneficial at Braidwood, Exelon determined that the failure being mitigated by Vogtle SAMA 6 (involving adding a bypass line around the cooling tower return valve) is not a significant risk contributor for Braidwood and the SAMA would not be cost-beneficial. For Vogtle SAMA 16 (involving nonexplicit improvements in ISLOCA procedures), Exelon determined that the intent of this SAMA is already met by existing Braidwood ISLOCA procedures that are constantly trained on and improved by the plant staff (Exelon 2014). Based on this additional information, the NRC staff finds acceptable and concludes that Vogtle SAMAs 6 and 16 have been adequately considered for applicability and are unlikely to be cost-beneficial at Braidwood.

Exelon considered the potential plant improvements described in the IPE in the identification of plant-specific candidate SAMAs for internal events. As described in the ER, while the Braidwood IPE did not identify any vulnerabilities or provide a definitive list of enhancements, the report did describe a multisite review of IPE and Accident Management insights. The ER indicated that the IPE did discuss two enhancements, both of which have been implemented at Braidwood (Exelon 2013a).

The NRC staff noted in an RAI that, according to the NRC staff safety evaluation report for the IPE (NRC 1997b), the transmittal of the modified Braidwood IPE indicated that a potential vulnerability involving a unit loss of emergency service water (ESW) due to internal flooding had been identified and that a modification was being considered (NRC 2014). In response to the RAI, Exelon indicated that this modification had not been implemented but is included as SAMA 10, alter the ductwork between the auxiliary building sump drain room and the SX pump room, in the SAMA analysis (Exelon 2014).

In response to an NRC staff RAI, Exelon indicated that as part of routine work, PRA groups identify major contributors to plant risk and, in some cases, the groups have identified specific changes that could reduce risk. As part of the SAMA identification process, the site PRA group was questioned to determine if they have identified any such changes. For Braidwood, the PRA group did not identify any plant enhancements that were not already identified by the SAMA identification process (Exelon 2014).

In response to an NRC staff RAI to describe the steps taken to identify SAMAs involving improvements in procedures, training or available cues for the important human errors, Exelon indicated that the HRA quantifications are reviewed to identify the major contributors to the HEP and to determine if there are any practical means of reducing those contributors. Braidwood SAMAs 7 and 8 are examples of the results of this process (Exelon 2014).

As discussed above in Section F.2.2.1, the NRC staff noted some differences in PRA results for the Braidwood site compared to the Byron site. Exelon indicated that for certain sequences resulting from random nonisolable small LOCAs with failure to establish ECCS recirculation cooling but with successful cooldown and depressurization, for which the Braidwood CDF is considerably larger than that for Byron, the difference is primarily because at Braidwood the SX007 SW valves must be throttled open to establish an appropriate flow rate through the component cooling HXs. This requirement results from SW's being taken from the Braidwood cooling pond (lake), whose water temperature varies throughout the year. At Byron, the

SX007 valves do not need manipulation during an accident. In response to an NRC staff RAI, Exelon pointed out that a low-cost potentially cost-beneficial SAMA, SAMA 6, was developed to address the SX007 valve throttling issue (Exelon 2014).

Based on this information, the NRC staff concludes that the set of SAMAs evaluated in the ER, together with those identified in response to NRC staff RAIs, adequately addresses the major contributors to internal event CDF.

As discussed above, risk insights from the 2008 Braidwood Fire PRA were used to identify SAMA candidates. Since the fire model was not fully integrated with the most recent Levels 2 and 3 analyses and the model was based on Revision 6C of the internal events PRA rather than the current Revision BB11b1 model, it could not be used directly in the identification of SAMAs. However, the fire contributors that are potentially significant to risk were reviewed to identify potential SAMAs. In the ER Exelon considered and evaluated the fire zones with a CDF contribution greater than the IPEEE screening threshold of 1.0×10^{-6} per year for potential SAMAs. These fire zones are listed in Table F–4.

The major fire scenario results for each zone were reviewed and grouped together to help identify target equipment that is common to multiple scenarios in a given fire zone. In response to an NRC staff RAI, Exelon defined major fire scenarios as those contributing 10 percent or more to the fire zone frequency (Exelon 2014). The major scenarios of each of the important fire zones are described and potential SAMAs identified in Section F.5.1.6.1 of the ER. This review indicated that a number of the previously identified internal events SAMAs would also mitigate fire-initiated accidents. In addition, Exelon's review resulted in the identification of eight additional SAMA candidates. One SAMA—SAMA 30, automate swap to recirculation mode, previously identified from the Level 1 importance review—was also identified to mitigate fire-initiated accidents.

The NRC staff noted in an RAI that the 1.0×10^{-6} per year screening threshold used in the fire SAMA identification review corresponds to a benefit threshold of $474,000 (NRC 2014). In response to the RAI to provide assurance that use of this threshold does not result in missing some potentially cost-effective SAMAs, Exelon provided the results of an assessment of the impact of lowering the threshold to that corresponding to a fire RRW of 1.01. Based on the fire ignition frequency adjusted total Braidwood fire CDF of 5.9×10^{-5} per year, an RRW of 1.01 corresponds to a fire CDF of 5.9×10^{-7} per year. Based on this lower threshold, Exelon identified three additional Unit 2 fire zones to be considered for potential SAMAs. No additional Unit 1 fire zones were above this threshold. For the first two Unit 2 fire zones, Exelon discussed the fire scenarios and noted that previously identified candidate SAMAs would mitigate the fire risk from these zones. For the third zone, fire zone U2:3.4A-2, Unit 2 Cable Riser Area, Elv. 451′, having a fire CDF of 6.5×10^{-7} per year, one additional SAMA candidate to install a low-flow seal injection pump, or to install cable wrap or fire barriers, was identified and evaluated and determined to not be cost-beneficial (Exelon 2014). This is discussed further in Section F.6.2.

The staff considered the best available information for its independent analysis. While the fire PRA model is still under development, it is the best available information at the time of this review. Therefore, the NRC staff concludes that the screening RRW of 1.01 for identifying potential fire-mitigating SAMAs reasonable.

Regarding fire zone 11.6c-0 (the auxiliary building laundry room), the NRC staff asked Exelon to consider a SAMA to move the laundry to another facility if the fire source in the fire zone is due to laundry room operation (NRC 2014). In response to the RAI, Exelon indicated that the laundry equipment has been removed from that room and this room no longer serves that function (Exelon 2014).

In response to an NRC staff RAI to describe the extent to which new or improved Braidwood fire procedures to mitigate the important fires have been considered in the SAMA analysis, Exelon responded that review of the fire procedures to identify improvements in the fire response is an iterative task that is performed as part of the fire PRA development process and is not within the scope of the SAMA analysis. Unlike SAMAs to modify Abnormal Operating Procedures and Emergency Operating Procedures, the identification of fire response enhancement requires coordination with the fire modeling team and procedure writers to ensure the actions are consistent with existing procedures and that the proposed changes are appropriate for the failure modes caused by the fire events (Exelon 2014). Although the NRC staff does not agree that identifying improvements to the fire procedures is beyond the scope of a SAMA analysis, since the applicant's fire PRA model is still under development and will be separately approved, as appropriate, the NRC staff concludes that further enhancement to the fire procedures is not necessary for the Braidwood SAMA evaluation for license renewal.

As discussed in Section F.2.2.2, although the IPEEE did not identify any fundamental vulnerabilities or weaknesses related to external events, a number of "outliers" were identified from the IPEEE seismic assessment (ComEd 1997b). These "outliers" were addressed in the ER and described as "generally items with potential seismically induced interaction issues for which it was difficult to calculate a High Confidence of Low Probability of Failure value" (Exelon 2013a). Exelon described each of the items and their disposition concluding that no additional SAMAs were needed to address these items.

As stated earlier, the Exelon IPEEE analysis of other external hazards (high winds, tornadoes, external floods, and other external events) did not identify opportunities for improvements for these events.

The NRC staff notes that the Braidwood external flooding design and capability, seismic design and capability, and the IPEEE seismic "outliers" were assessed in the engineering walkdowns and evaluations required for the response to the Fukushima Near-Term Task Force's Recommendation 2.3 (Exelon 2012a, 2012b; NRC 2012).

The NRC staff questioned Exelon about potentially lower cost alternatives to some of the SAMAs evaluated, as listed in an RAI (NRC 2014), including:

- A SAMA to modify procedures to avoid clearing of RCS cold leg water seals in the event of core damage. In response to the RAI, Exelon explained that this improvement has already been implemented at Braidwood because the Braidwood procedures direct an "RCP bump" to inject reactor coolant line water into the reactor vessel only if the SG level is greater than 10 percent, which avoids the clearing of the RCS cold leg seal (Exelon 2014).

- An SG PORV gagging device for use after an SGTR and stuck-open SG PORV as an alternate to SAMA 14. In response to the RAI, Exelon explained that the Braidwood design includes isolation valves with manual handwheels upstream of the SG PORVs, hence the ability to stop flow through a stuck-open PORV exists without the need for the gagging device (Exelon 2014).

- Install "reduced leakage" RCP seals similar to those evaluated for Vogtle SAMA 7 (NRC 2008) as an alternative to the "no-leakage" seals evaluated as Braidwood SAMA 4. In response to the RAI, Exelon explained that this is not a viable alternative for Braidwood because a decision has already been made to implement SAMA 4 at Braidwood, Exelon has already made awards for the replacement of the RCP seals, and the cost of engineering and analysis has

already exceeded the cost given for the Vogtle “reduced leakage” RCP seals (Exelon 2014).

- Installation of additional flood alarms to assist in mitigating important internal flood scenarios. In response to the RAI, Exelon reviewed the internal flooding events and determined that internal flooding alarms already existed, were evaluated in an existing SAMA (SAMA 16), or determined that the flooding sequences are not risk significant (Exelon 2014).

The NRC staff notes that the set of SAMAs submitted is not all-inclusive and that additional less expensive, design alternatives can be postulated. Based on the best available information and its independent review, the NRC staff concludes that the benefits of any additional modifications are unlikely to exceed the benefits of the modifications evaluated and that the alternative improvements would not likely cost less than the least expensive alternatives evaluated, when the subsidiary costs associated with maintenance, procedures, and training are considered.

In summary, the NRC staff concludes that Exelon used a systematic and comprehensive process for identifying potential plant improvements for Braidwood, and that the set of potential plant improvements (SAMA) identified by Exelon is reasonably comprehensive and, therefore, acceptable. The SAMA search included reviewing insights from the plant-specific risk studies and reviewing plant improvements considered in previous SAMA analyses. While explicit treatment of external events in the SAMA identification process was limited, the NRC staff has determined that the prior implementation of plant modifications and the absence of external event vulnerabilities reasonably justifies examining primarily the internal events risk results for this purpose.

F.4 Risk Reduction Potential of Plant Improvements

Exelon evaluated the risk-reduction potential of the 35 SAMAs retained for the Phase II evaluation in the ER (Exelon 2013a). The SAMA evaluations were generally performed by Exelon in a realistic or conservative fashion that overestimates the benefit of the SAMA. In most cases the failure likelihood of the added equipment is taken to be optimistically low, thereby overestimating the benefit of the SAMA. In other cases it was assumed that the SAMA eliminated all of the risk associated with the proposed enhancement. The NRC staff notes that this bounding approach overestimates the benefit and is conservative.

Exelon used model requantification to determine the potential benefits for most of the SAMAs. The CDF, population dose reductions, and offsite economic cost reductions were estimated using the Braidwood PRA model. The changes made to the model to quantify the impact of each SAMA are described in Section F.6 of the ER for each SAMA. Table F–5 summarizes the assumptions used to estimate the risk reduction for each of the evaluated SAMAs, the estimated risk reduction in terms of percent reduction in CDF, population dose, and offsite economic cost, and the estimated total benefit (present value) of the averted risk. The determination of the benefits for the various SAMAs is further discussed in Section F.6.

The NRC staff reviewed the assumptions used in evaluating the benefit or risk reduction estimate of each of the SAMAs as described in the ER Section F.6. In response to an NRC staff RAI, Exelon clarified that for SAMA 14, automating the refueling water storage tank (RWST) makeup, it is conservative to assume, for both SGTR and non-SGTR sequences, that transitioning to recirculation mode and terminating break flow (i.e., controlled cooldown) is required. The human errors associated with both of these scenarios are reduced by a factor of 10 as a result of the additional time available due to this SAMA (Exelon 2014). In response to another NRC staff RAI, Exelon clarified that for SAMA 15, inter-unit AFW crosstie, no credit is

taken for this during dual-unit events since each unit may require the use of its own AFW pump, realistically (Exelon 2014). The NRC staff considers the assumptions, as clarified, to be reasonable and acceptable for purposes of the SAMA evaluation.

For those SAMAs identified in the ER which specifically mitigate fire risk (i.e., SAMAs 27, 28, 29, 31, 32, 33, 34, and 35), a bounding estimate of the SAMA benefits was made. Exelon conservatively assumed that all of the fire risk, or fire CDF, associated with the fire zones affected by the SAMA is eliminated. (Because PDR and OECR were not directly calculated, this is noted as “Not Estimated” in Table F–5). These SAMAs were assumed to have no additional benefits in internal events. The NRC staff notes that this approach is not necessarily conservative for SAMAs, in which the benefit is dominated by the reduction in PDR or OECR and not CDF. However, the NRC staff concludes that since all of the fire mitigating SAMAs identified in the ER were determined by Exelon to be potentially cost-beneficial, further evaluation of these SAMAs is not necessary.

The NRC staff has reviewed Exelon’s bases for calculating the risk reduction for the various plant improvements and concludes that the rationale and assumptions for estimating risk reduction are reasonable and generally conservative (i.e., the estimated risk reduction is higher than what would actually be realized). Accordingly, the NRC staff based its independent estimates of averted risk for the various SAMAs on Exelon’s risk reduction estimates.

1 Table F–5. SAMA Cost and Benefit Screening Analysis for Braidwood Station [a]

Analysis Case and Applicable SAMAs[a]	Modeling Assumptions	% Risk Reduction			Total Benefit ($)[b]		Cost ($)[c]
		CDF	Population Dose	OECR	Baseline (Internal + External)	Baseline With Uncertainty	
1 – Diesel Driven SX Pump	Reduce the probability of RCP seal failure on loss of SX. Auto-start failure of diesel pump is 1×10^{-2}.	55	78	87	41M	81M	>15M
2 – Replace the Positive Displacement Pump with a Self-Cooled, Auto-Start Pump	Reduce the probability of RCP seal failure on loss of SX. Seal injection pump failure is 1×10^{-3}; transfer switch is 100% reliable.	46	19	6	5.4M	11M	>2.8M
3 – Auto-Start of Standby SX Pump	Reduce the probability of loss of cooling to critical loads on failure of standby SX to start. Auto-start failure is 1×10^{-4}.	20	12	6	4.1M	8.2M	>565K
4 – Install "No Leak" RCP Seals	Reduce the probability of RCP seal for loss of seal cooling. Seal failure probability is reduced by a factor of 1,000.	47	20	7	6.1M	12M	>6.5M
5 – Modify the Startup Feedwater Pump to Start Using the ATWS Mitigating System Actuation Circuitry (AMSAC) SG Low-Low-Low Level Signal to Mitigate AFW Failure	Modify FW pump start logic to require failure of both the automated start function and manual operator action. Auto-start failure is 1×10^{-4}.	11	29	39	18M	35M	>328K
6 – Enhance Plant Procedures to Explicitly Confirm Adequate _SX007 Throttling	Reduce HEP for verification of adequate RHR (to 6×10^{-4}). Joint human error probability (JHEP) is reduced by about a factor of 5.	15	<1	<1	673K	1.3M	100K
7 – Establish Flow to the Residual Heat Removal (RHR) Heat Exchanger (HX) on RHR Pump Start	Modify procedures to preclude the need for continuous action statement to protect RH pumps. Reduce HEP from 7.3×10^{-4} to 1.4×10^{-4}.	3	<1	<1	118K	233K	100K
8 – Install Kill Switches for the Fire Protection Pumps in the Main Control Room (MCR)	Reduce the HEP for termination of fire pump flow. Action time is assumed to be 1 minute per pump.	4	2	1	784K	1.5M	>217K

Analysis Case and Applicable SAMAs[a]	Modeling Assumptions	% Risk Reduction			Total Benefit ($)[b]		Cost ($)[c]
		CDF	Population Dose	OECR	Baseline (Internal + External)	Baseline With Uncertainty	
9 – Install Flow Restrictors in Fire Protection Pipes	**Aux building fire break flow is reduced to 1,000 gpm (4,000 L/min), and is adequate to meet fire suppression requirements. The increase in available time to terminate flow reduces the flood mitigation factor to 1.2×10^{-4}.**	**9**	**5**	**2**	**1.7M**	**3.3M**	**>174K**
10 – Alter Ductwork Between the Aux Building (BLDG) Room and the SX Pump Room	**Completely eliminate the "T1" flooding scenario. Flood mitigation factors for normal service water (SW) and SX floods are simplified to HEP for termination of flooding before reaching Elv. 364′.**	**13**	**12**	**11**	**5.5M**	**11M**	**>660K**
11 – Implement diverse mitigation system (DMS)	**A portable 480-V generator is aligned to support diesel driven AFW makeup or a portable SG makeup pump. Failure probability for this function is 1×10^{-2}. Cognitive failure to diagnose the need for secondary cooling, and any dependent combinations, are assumed to fail DMS.**	**70**	**77**	**84**	**41M**	**80M**	**>7.3M**
12 – Modify Practices for System Auxiliary Transformer (SAT) Maintenance or Enhance Procedures	Completely eliminate risk of dual SAT out of service.	4	12	16	7.1M	14M	70M
13 – Alternate AFW Cooling with Seal Protection	**Eliminate SX dependence for motor driven AFW pump operation. Reduce the probability of RCP seal failure on loss of SX. Seal injection pump failure is 1×10^{-3}; transfer switch is 100% reliable.**	**66**	**77**	**85**	**41M**	**81M**	**>3M**

Analysis Case and Applicable SAMAs[a]	Modeling Assumptions	% Risk Reduction			Total Benefit ($)[b]		Cost ($)[c]
		CDF	Population Dose	OECR	Baseline (Internal + External)	Baseline With Uncertainty	
14 – Automating RWST Makeup	Reduce HEPs for transition to recirculation mode and terminate break flow on SGTR by a factor of 10. Reduce impacted JHEPs to 0 or by a factor of 10.	1	<1	<1	161K	318K	3.8M
15 – Resolve Regulatory Issues and Complete Implementation of the Inter-Unit AFW Cross-tie	**The AFW crosstie action execution failure probability is reduced to 2.4×10^{-2}.**	**3**	**2**	**3**	**1.3M**	**2.6M**	**0K**
16 – Install High Flow Sensors on the Non-Essential Service Water System	**Completely eliminate all risk associated with SW flood event scenarios.**	**2**	**6**	**8**	**3.5M**	**6.9M**	**>496K**
17 – Use AMSAC for Alternate Low SG Level AFW Initiation	Eliminate the independent manual AFW initiation human failure events (HFEs) in conjunction with all associated JHEPs. The AMSAC logic is 100% reliable.	<1	<1	<1	57K	112K	>490K
18 – Automate Refill of the Diesel Driven AFW Pump Fuel Oil Day Tank	Eliminate the independent HFE and all dependent combinations to refill the AFW pump fuel oil day tank.	1	<1	<1	330K	651K	>804K
19 – Replace Motor-Operated Valves (MOVs) in the RHR Discharge Line with Valves That Can Isolate an ISLOCA Event	**Completely eliminate all risk from the ISLOCA events occurring in the RHR discharge lines.**	**<1**	**10**	**5**	**2.9M**	**5.8M**	**900K**
20 – Disallow On-line RHR HX Maintenance	Completely eliminate all risk associated with RHR HX maintenance.	<1	0	<1	49K	96K	20M
21 – Install an Emergency Isolation Valve in Each of the RHR Suction Lines	Completely eliminate all risk from the ISLOCA events occurring in the RHR discharge lines.	<1	3	1	745K	1.5M	1.6M
22 – Install the Same High Flow Isolation Logic Used on Valve_CC685 on Valve_9438	**Completely eliminate all risk from the ISLOCA events occurring in the RCP thermal barrier cooling HXs.**	**0**	**<1**	**<1**	**170K**	**335K**	**250K**
23 – Install a Passive Hydrogen Ignition System	Completely eliminate all containment failures due to hydrogen detonation.	0	<1	<1	116K	230K	760K

Analysis Case and Applicable SAMAs[a]	Modeling Assumptions	% Risk Reduction			Total Benefit ($)[b]		Cost ($)[c]
		CDF	Population Dose	OECR	Baseline (Internal + External)	Baseline With Uncertainty	
24 – Provide a Reactor Vessel Exterior Cooling System	Completely eliminate relocation of the core to the containment floor, and eliminate all CFEs. Allow scrubbing to maximize averted cost.	0	<1	<1	124K	246K	>1.2M
25 – Install a Filtered Containment Vent	**The filtered vent reduces the consequential dose and offsite economic cost associated with containment overpressure failures by a factor of 10.**	**0**	**72**	**76**	**35M**	**69M**	**5.7M**
26 – DMS Using a Dedicated Generator, Self Cooled Charging Pump, and a Portable AFW Pump	**Indefinite AFW makeup capability and an alternate high-pressure injection function capable of providing alternate seal injection to prevent RCP seal LOCAs. The frequency of seal LOCA sequences is reduced by a factor of 100.**	**69**	**77**	**84**	**41M**	**80M**	**2.4M**
27 – Protect RH Safety Injection (SI) and Chemical and Volume Control System (CVCS) Cubicle Cooling Fan Cables in Fire Zone 11.3-0	**Completely eliminate all of the risk associated with fire zone 11.3-0.**	[b] **16**	**Not Estimated**		**2.6M**	**5.2M**	**975K**
28 – Install Fire Barriers Around MCC 134X	**Completely eliminate all of the risk associated with fire zone 11.6-0.**	[b] **10**	**Not Estimated**		**1.7M**	**3.4M**	**975K**
29 – Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment	**Completely eliminate all of the risk associated with fire zone 5.6-1.**	[b] **9**	**Not Estimated**		**1.5M**	**2.9M**	**555K**
30 – Automate Swap to Recirculation Mode	Completely eliminate the contribution from the failure to swap to recirculation mode.	**1**	**<1**	**<1**	**90K**	**178K**	**>1.2M**
31 – Install Fire Barriers Around MCCs 132X5 and 134X	**Completely eliminate all of the risk associated with fire zone 11.6-0.**	[b] **3**	**Not Estimated**		**557K**	**1.1M**	**975K**
32 [d] – Install Fire Barriers Around MCC 132X5	Completely eliminate all of the risk associated with fire zone 11.5a-1.	[b] 3	Not Estimated		488K	960K	975K

Analysis Case and Applicable SAMAs[a]	Modeling Assumptions	% Risk Reduction			Total Benefit ($)[b]		Cost ($)[c]
		CDF	Population Dose	OECR	Baseline (Internal + External)	Baseline With Uncertainty	
33 – Install Cable Wrap on the 141 to 241 4-kV Cross-Tie Cable in the Division 11 ESF Switchgear Room	**Completely eliminate all of the risk associated with fire zone 5.2-1 (Unit 2).**	[b] **6**	**Not Estimated**		**1M**	**2.0M**	**975K**
34 – Install Cable Wrap on the 141 to 241 4-kV Cross-Tie Cable in the Aux Building Elevation 426′ of the General Area	**Completely eliminate all of the risk associated with fire zone 11.6-0 (Unit 2).**	[b] **5**	**Not Estimated**		**813K**	**1.6M**	**975K**
35 – Install Cable Wrap to Protect 2AF005A, B, C and D in the Division 21 Containment Electrical Penetrations Area	**Completely eliminate all of the risk associated with fire zone 11.5a-2 (Unit 2).**	[b] **5**	**Not Estimated**		**761K**	**1.5M**	**975K**

[a] SAMAs in bold are potentially cost-beneficial.

[b] The risk reduction for fire-mitigating SAMAs was estimated by the NRC staff, utilizing information provided in the ER, as the ratio of the reduction in fire CDF divided by the total fire CDF of 5.94×10^{-5} per year.

[c] The estimated benefits and implementation costs were revised in response to NRC staff RAIs 3.d, 6.a, and 6.f (Exelon 2014).

[d] SAMA 32 was determined to be potentially cost-beneficial in the ER (Exelon 2013a), but was subsequently determined to not be cost-beneficial in response to NRC staff RAI 3.d (Exelon 2014).

Sources: Exelon 2013a, 2014

F.5 Cost Impacts of Candidate Plant Improvements

In the ER, Exelon estimated the costs of implementing the candidate SAMAs through the development of Braidwood-specific cost estimates, the use of industry estimates, and, in some cases, combinations of these two sources. It was also noted that Braidwood-specific implementation costs do include contingency costs for unforeseen difficulties, but do not account for any replacement power costs (RPCs) that may be incurred due to consequential shutdown time unless specifically noted. In response to an NRC staff RAI, Exelon stated that a consulting firm was used to develop “order of magnitude” cost estimates for the SAMA implementation (Exelon 2014). Details such as cost of equipment, demolition, scaffolding, overtime, consumables, freight, engineering, etc. were used to develop the costs. Exelon provided the components of the cost estimates associated with: (a) developing supporting procedures, (b) providing lifelong training, and (c) applicable simulator updates.

Exelon also identified in the RAI response that the cost estimates for several SAMAs (2, 3, 4, 5, 8, 9, 10, 11, 13, 16, 17, and 18) were for both Units 1 and 2 rather than for a single unit (Exelon 2014). Revised implementation cost estimates for each of these SAMAs was provided on a per unit basis. The corrected implementation costs were utilized in an updated cost-benefit analysis and are reflected in Table F–5. Detailed cost estimates were not developed for SAMAs that were judged to have implementation costs that far exceeded the estimated benefit.

In response to an NRC staff RAI concerning savings due to sharing of costs between units and between the Byron and Braidwood sites, Exelon clarified that since implementation costs were developed on a “per site” basis, cost sharing between units was accounted for in the updated analysis by dividing the “per-site” costs in half to obtain the “per-unit” costs (Exelon 2014). Cost sharing, however, was not considered between sites. Exelon explained that if cost sharing between sites was possible, engineering costs at the first sister plant are estimated to be generally 75 percent to 80 percent of the original costs if the modifications are identical. Exelon indicated that sharing of costs between sites is not appropriate because:

- It is not necessarily true that a SAMA implemented at one site will necessarily be implemented at the other site.
- While cost sharing between sites could reduce some implementation costs, any reductions in cost would be offset if other costs were also accounted for, such as inflation and RPCs.
- The SAMA designs are conceptual, and the cost estimates provided are “order of magnitude” estimates. Changes in the per-site engineering costs of 12 percent to 13 percent are expected to be within the margin of error.
- Actual installation costs are generally larger than estimated installation costs.
- The impact of accounting for inter-site cost sharing is bounded by the results of the CDF uncertainty analysis, which is discussed in Section F.6.2.

The NRC staff agrees that the amount of cost savings due to sharing of cost between sites is highly uncertain. For its independent analysis, the NRC staff also considers the potential cost savings due to SAMA implementation at more than one site (in the cost-benefit analysis). For this consideration, the results of the cost-benefit analysis summarized in Table F–5 indicate that, if the amount of savings suggested by Exelon is realized, SAMA 21 and possibly SAMA 18 would become cost-beneficial. However, considering the above points (high uncertainty in the data) and in particular that both of these SAMAs are shown not cost-beneficial at Byron (similar reactor design except for the cooling tower instead of cooling pond) and hence no inter-site cost

savings would be realized, the NRC staff concludes that further consideration of these two SAMAs is not warranted.

Exelon estimated the minimum cost of making a change to a procedure and for conducting the necessary training on a procedure change to be $100,000. In response to an NRC staff RAI, Exelon stated that, although potentially lower cost estimates could be developed for procedure changes, all SAMAs associated with procedure changes were found to be cost-beneficial (Exelon 2014). Since all SAMAs associated with procedure change were found to be potentially cost-beneficial, reducing the cost of a procedure change to less than $100,000 would have no impact on the SAMA analysis results, and, based on this, the NRC staff finds this RAI response acceptable.

For SAMAs 12 and 20, the NRC staff requested in an RAI additional explanation for why the implementation cost estimates for these SAMAs assumed an extended outage time rather than assuming maintenance was performed in parallel with other outage activities (NRC 2014). For SAMA 12, Exelon responded that the SAT is the primary source of power to systems supporting spent fuel pool cooling when the fuel is in the spent fuel pool (Exelon 2014). At Braidwood, SAT work has not been performed during refueling outages as the refueling unit's SAT is protected during the entire outage. Shutdown risk procedures do not allow for SAT work any time fuel is in the reactor vessel. The SAT protection could be removed during defueled conditions when the core fuel is in the spent fuel pool. However, the standard template for the defueled window is only 32 hours. The proposed SAT maintenance typically requires approximately 14 days to complete, requiring the outage to be extended. In addition, non-ESF buses are powered by the SAT that is needed during the outage. Reconfiguration of the SAT would hamper the ability to perform other normal outage work. For SAMA 20, Exelon responded that the primary driver is that any work on an RH train be performed during the defueled window (Exelon 2014). When fuel is in the reactor vessel, both RH trains are desired to be in service. In addition, while pump suction and HX work could be done on line, the inability to vent the RH pump discharge requires that this work be performed during an outage. However, the standard template for the defueled window is only 32 hours. The proposed RH maintenance typically requires approximately 4 to 5 days to complete, requiring the outage to be extended. Based on this additional information, the NRC staff considers the estimated costs for SAMAs 12 and 20 to be reasonable and acceptable for purposes of the SAMA evaluation.

For certain improvements, the NRC staff compared the cost estimates to estimates developed elsewhere for similar improvements, including estimates developed as part of other licensees' analyses of SAMAs for operating reactors.

For SAMA 1, install a dedicated diesel-driven SX pump, the NRC staff noted that the cost estimate from the Limerick SAMA analysis used as the basis for the cost estimate included large HXs and safety-related equipment (PECO 1989). The NRC staff questioned in an RAI whether non-safety-grade equipment could be considered, and that large HXs significantly increase cost but are not needed in SAMA 1 (NRC 2014). In response to the RAI, Exelon reevaluated the cost estimate for SAMA 1, and provided the updated cost, which is included in Table F–5.

Given that Exelon followed the guidance in NEI 05-01 (NEI 2005) and satisfactorily addressed NRC questions regarding cost estimates, the NRC staff concludes that the cost estimates provided by Exelon are sufficient and appropriate for use in the SAMA evaluation.

F.6 Cost-Benefit Comparison

Exelon's cost-benefit analysis and the NRC staff's review are described in the following sections.

F.6.1 Exelon's Evaluation

The methodology used by Exelon was based primarily on NRC's guidance for performing cost-benefit analysis, (i.e., NUREG/BR-0184, *Regulatory Analysis Technical Evaluation Handbook*) (NRC 1997a). The guidance involves determining the net value for each SAMA, according to the following formula:

Net Value = (APE + AOC + AOE + AOSC) – COE, where

APE = present value of averted public exposure ($)

AOC = present value of averted offsite property damage costs ($)

AOE = present value of averted occupational exposure costs ($)

AOSC = present value of averted onsite costs ($)

COE = cost of enhancement ($)

If the net value of a SAMA is negative, the cost of implementing the SAMA is larger than the benefit associated with the SAMA and it is not considered cost-beneficial. Exelon's derivation of each of the associated costs is summarized below.

NUREG/BR-0058 has recently been revised to reflect the agency's policy on discount rates. Revision 4 of NUREG/BR-0058 states that two sets of estimates should be developed, one at 3 percent and one at 7 percent (NRC 2004). Exelon provided a base set of results using the 3-percent discount rate and sensitivity studies using the 7-percent discount rate (Exelon 2013a).

<u>Averted Public Exposure (APE) Costs</u>

The APE costs were calculated using the following formula:

APE = Annual reduction in public exposure (Δ person-rem/year)

× monetary equivalent of unit dose ($2,000 per person-rem)

× present value conversion factor (15.04 based on a 20-year period with a 3-percent discount rate)

As stated in NUREG/BR-0184 (NRC 1997a), the monetary value of the public health risk after discounting does not represent the expected reduction in public health risk due to a single accident. Rather, it is the present value of a stream of potential losses extending over the remaining lifetime (in this case, the renewal period) of the facility. Thus, it reflects the expected annual loss due to a single accident, the possibility that such an accident could occur at any time over the renewal period, and the effect of discounting these potential future losses to present value. For the purposes of initial screening, which assumes elimination of all severe accidents, Exelon calculated an APE of approximately $3,420,000 for the 20-year license renewal period (Exelon 2013a).

Averted Offsite Property Damage Costs (AOC)

The AOC were calculated using the following formula:

AOC = Annual CDF reduction

× offsite economic costs associated with a severe accident (on a per-event basis)

× present value conversion factor

This term represents the sum of the frequency-weighted offsite economic costs for each release category, as obtained for the Level 3 risk analysis. For the purposes of initial screening, which assumes elimination of all severe accidents caused by internal events, Exelon calculated an OECR of about $810,000 based on the Level 3 risk analysis (Exelon 2013a). This results in a discounted value of approximately $12,200,000 for the 20-year license renewal period.

Averted Occupational Exposure (AOE) Costs

The AOE costs were calculated using the following formula:

AOE = Annual CDF reduction

× occupational exposure per core damage event

× monetary equivalent of unit dose

× present value conversion factor

Exelon derived the values for averted occupational exposure from information provided in Section 5.7.3 of the regulatory analysis handbook (NRC 1997a). Best estimate values provided for immediate occupational dose (3,300 person-rem) and long-term occupational dose (20,000 person-rem over a 10-year cleanup period) were used. The present value of these doses was calculated using the equations provided in the handbook in conjunction with a monetary equivalent of unit dose of $2,000 per person-rem, a real discount rate of 3 percent, and a time period of 20 years to represent the license renewal period. For the purposes of initial screening, which assumes elimination of all severe accidents caused by internal events, Exelon calculated an AOE of approximately $22,100 for the 20-year license renewal period (Exelon 2013a).

Averted Onsite Costs

Averted onsite costs (AOSC) include: (a) averted cleanup and decontamination costs (ACC) and (b) averted power replacement costs. Repair and refurbishment costs are considered for recoverable accidents only and not for severe accidents. Exelon derived the values for AOSC based on information provided in Section 5.7.6 of NUREG/BR-0184, the regulatory analysis handbook (NRC 1997a).

Exelon divided this cost element into two parts—the onsite cleanup and decontamination cost, also commonly referred to as ACC, and the RPC.

ACC were calculated using the following formula:

ACC = Annual CDF reduction

× present value of cleanup costs per core damage event

× present value conversion factor

The total cost of cleanup and decontamination subsequent to a severe accident is estimated in NUREG/BR-0184 to be $1.5 billion (undiscounted). This value was converted to present costs over a 10-year cleanup period and integrated over the term of the proposed license extension.

For the purposes of initial screening, which assumes elimination of all severe accidents caused by internal events, Exelon calculated ACC of approximately $696,000 for the 20-year license renewal period.

Long-term RPCs were calculated using the following formula:

RPC = Annual CDF reduction
× present value of replacement power for a single event
× factor to account for remaining service years for which replacement power is required
× reactor power scaling factor

Exelon based its calculations on a Braidwood net output of 1,197 megawatts electrical (MWe) and scaled up from the 910 MWe reference plant in NUREG/BR-0184 (NRC 1997a). Therefore, Exelon applied a power scaling factor of 1197⁄910 to determine the RPCs.

For the purposes of initial screening, which assumes elimination of all severe accidents caused by internal events, Exelon calculated an RPC of approximately $259,000 and AOSC of approximately $955,000 for the 20-year license renewal period.

Using the above equations, Exelon estimated the total present dollar value equivalent associated with completely eliminating severe accidents from internal events at Braidwood to be about $16,575,743, also referred to as the maximum averted cost-risk (MACR). The internal events MACR is rounded to next highest thousand ($16,576,000) for SAMA calculations. Use of a multiplier of 2.8 to account for external events increases the value to $46.4 million and represents the dollar value associated with completely eliminating all internal and external event severe accident risk for Braidwood. This is referred to as the modified MACR.

Exelon's Results

If the implementation costs for a candidate SAMA exceeded the calculated benefit, the SAMA was considered not to be cost-beneficial. In the baseline analysis contained in the ER (using a 3-percent discount rate), Exelon identified 18 potentially cost-beneficial SAMAs (SAMAs 3, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 25, 26, 27, 28, 29, and 33). Based on consideration of uncertainty analysis, Exelon identified an additional eight potentially cost-beneficial SAMAs (SAMAs 1, 2, 4, 22, 31, 32, 34, and 35), resulting in 26 SAMAs in total. In response to NRC staff RAIs, Exelon provided the results of revised baseline and uncertainty analyses to account for: (a) updated SAMA implementation cost estimates, (b) a revised multiplier of 3.0 to account for external events, and (c) revisions to the uncertainty analysis (Exelon 2014). Exelon did not identify any additional cost-beneficial SAMAs as a result of the revised baseline and uncertainty analyses.

The potentially cost-beneficial SAMAs for Braidwood are as follows:

- SAMA 1 – Diesel Driven SX Pump
- SAMA 2 – Replace the Positive Displacement Pump with a Self Cooled, Auto Start Pump
- SAMA 3 – Auto Start of Standby SX Pump
- SAMA 4 – Install "No Leak" Seals
- SAMA 5 – Modify the Startup Feedwater pump to Start Using the AMSAC SG Low-Low-Low Level Signal to Mitigate AFW Failure

- SAMA 6 – Enhance Plant Procedures to Explicitly Confirm Adequate _SX007 Throttling
- SAMA 7 – Establish Flow to the RH HX on RH Pump Start
- SAMA 8 – Install Kill Switches for the Fire Protection Pumps in the MCR
- SAMA 9 – Install Flow Restrictors in Fire Protection Pipes
- SAMA 10 – Alter Ductwork Between the Aux BLDG Room and the SX Pump Room
- SAMA 11 – Implement DMS
- SAMA 13 – Alternate AFW Cooling with Seal Protection
- SAMA 15 – Resolve Regulatory Issues and Complete Implementation of the Inter-Unit AFW Cross-tie
- SAMA 16 – Install High Flow Sensors on the Non-Essential Service Water System
- SAMA 19 – Replace MOVs in the RHR Discharge Line with Valves That Can Isolate an ISLOCA Event
- SAMA 22 – Install the Same High Flow Isolation Logic Used on Valve_CC685 on Valve_CC9438
- SAMA 25 – Install a Filtered Containment Vent
- SAMA 26 – DMS Using a Dedicated Generator, Self Cooled Charging Pump, and a Portable AFW Pump
- SAMA 27 – Protect RH SI and CVCS Cubicle Cooling Fan Cables in Fire Zone 11.3-0
- SAMA 28 – Install Fire Barriers Around MCC 134X
- SAMA 29 – Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment
- SAMA 31 – Install Fire Barriers Around MCCs 132X5 and 132X
- SAMA 32 – Install Fire Barriers Around MCC 131X2
- SAMA 33 – Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4-kV Cross-tie Cable in the Division 11 ESF Switchgear Room
- SAMA 34 – Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4-kV Cross-tie Cable in the Aux Building Elevation 426′ of the General Area
- SAMA 35 – Unit 2 SAMA - Install Cable Wrap to Protect 2AF005A, B, C, and D in the Division 21 Containment Electrical Penetrations Area

The potentially cost-beneficial SAMAs and Exelon’s plans for further evaluation of these SAMAs are discussed in more detail in Section F.6.2.

F.6.2 Review of Exelon's Cost-Benefit Evaluation

The cost-benefit analysis performed by Exelon was based primarily on NUREG/BR–0184 (NRC 1997a) and discount rate guidelines in NUREG/BR-0058 (NRC 2004) and was executed consistent with this guidance.

The NRC staff noted that SAMAs identified primarily on the basis of the internal events analysis could provide benefits in certain external events, in addition to their benefits in internal events (internal flooding events were included in the PRA model). Exelon accounted for the potential risk reduction benefits associated with external events by applying a multiplier to the estimated benefits for internal events. In the analysis reported in the ER, Exelon multiplied the estimated benefits for internal events by a factor of 2.8, incorporating an external events multiplier of 1.8 to account for external events (Exelon 2013a). As discussed above, 18 SAMAs were determined to be potentially cost-beneficial in Exelon's baseline analysis (SAMAs 3, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 25, 26, 27, 28, 29, and 33). As discussed in Section F.2.2.2, in response to an NRC staff RAI, Exelon provided a revised baseline evaluation by applying a multiplier of 3.0 [(fire CDF of 5.94×10^{-5} per year + seismic CDF of 1.0×10^{-6} per year + external flooding CDF of 1.0×10^{-6} per year + high winds CDF of 1.0×10^{-6} per year + transportation and nearby facility accident CDF of 1.0×10^{-6} per year)$/$(internal events CDF of 3.50×10^{-5} per year) + 1] to account for external events (Exelon 2014). The results of this revised evaluation are provided in Table F–5. No additional potentially cost-beneficial SAMAs were identified as a result of this revised evaluation (using a multiplier of 3.0 and a 3-percent discount rate), which incorporated the revised SAMA implementation costs discussed in Section F.5.

Exelon considered the impact that possible increases in benefits from analysis uncertainties would have on the results of the SAMA assessment. In the ER, Exelon presents the results of an uncertainty analysis of the internal events CDF, which indicates that the 95th percentile value is a factor of 2.29 times the point estimate CDF for Braidwood. Exelon considered whether any additional Phase I SAMAs might be retained for further analysis if the benefits from internal and external events were increased by a factor of 2.29. One additional SAMA (SAMA 12) was identified. Exelon also considered the impact on the Phase II screening if the estimated benefits from internal and external events were increased by a factor of 2.29. As discussed above (with these considerations), 8 additional SAMAs (SAMAs 1, 2, 4, 22, 31, 32, 34, and 35) were determined to be potentially cost-beneficial in Exelon's analysis.

In an RAI, the NRC staff noted that the mean CDF (for BB011a) was lower than the point estimate (usually the mean CDF is greater than the point estimate due to the correlation of uncertainties) (NRC 2014). In response to the NRC staff RAI, Exelon responded that many of the largest contributors to the Braidwood PRA results are human probabilities related, JHEPs, or flood mitigation events (including operator errors) that are not correlated events. In addition, several contributors with large failure probabilities were assigned lognormal distributions with relatively high error factors. These factors can act to reduce the mean relative to the point estimate. Exelon recalculated the uncertainty analysis using revised error factors for selected events and determined that the revised 95th percentile value is a factor of 1.97 times the point estimate CDF for Braidwood. Since all Phase I SAMAs were retained in the Phase I analysis in the ER (after considering analysis uncertainties), the revised uncertainty analysis was performed for all SAMAs identified in the ER. Exelon also considered the impact on the Phase II screening if the estimated benefits from internal and external events were increased by this uncertainty factor of 1.97 (in addition to the multiplier of 3.0 for external events and revised SAMA implementation costs discussed in Section F.5). No additional SAMAs were found to be cost-beneficial as a result of this revised evaluation (using a 3-percent discount rate), although one SAMA, SAMA 32, was found to no longer be cost-beneficial (Exelon 2014). Although

determined to no longer be cost-beneficial in this revised evaluation, Exelon did not withdraw this SAMA from further implementation consideration in the RAI response. The results of this revised evaluation are provided in Table F–5.

Exelon provided the results of additional sensitivity analyses in the ER, including the use of a 7-percent discount rate and variations in MACCS2 input parameters (as discussed in Section F.2.2.4). Exelon determined that these analyses did not identify any additional potentially cost-beneficial SAMAs (Exelon 2013a). In an RAI, the NRC staff requested Exelon to explain why the MACCS2 sensitivity case for economic rate of return resulted in a change in dose consequence (NRC 2014). In response to the RAI, Exelon provided clarification that the rate of return on property impacts the estimated property that is condemned (or reclaimed). Changes in property reclamation will result in changes in dose consequences to those who occupy the property after it has been reclaimed (Exelon 2014). The NRC staff considers this explanation reasonable.

Exelon stated in the ER that SAMA 15, Resolve Regulatory Issues and Complete Implementation of the Inter-Unit AFW Cross-Tie to Improve AFW Reliability, was in the final stages of implementation at Braidwood at the time of the ER submittal and was, therefore, included as a SAMA rather than being included in the base PRA model. A sensitivity analysis was provided in the ER in which SAMA 15 was incorporated into the base PRA model and the Phases I and II SAMAs were reevaluated. This reevaluation did not alter the conclusions of either the Phase I screening analysis or the Phase II cost-benefit analysis.

Exelon also stated in the ER that many of the SAMAs address similar areas of plant risk and that implementation of one SAMA may result in other SAMAs no longer being cost-beneficial. Exelon further noted that SAMA 11, Implement diverse mitigation system or DMS, would mitigate many of the largest contributors to Braidwood risk, and that it may be fully or partially implemented at Braidwood for reasons other than the results of the SAMA analysis (specifically, it includes capabilities to address insights from the Fukushima Dai-ichi accident). Exelon reevaluated the cost-beneficial SAMAs assuming both SAMA 15 and SAMA 11 are implemented in an attempt to optimize a reduced set of SAMAs that would address the largest risk contributors. As a result, 15 SAMAs were determined to no longer be cost-beneficial (SAMAs 1, 2, 3, 4, 8, 9, 10, 13, 16, 25, 26, 27, 31, 32, and 35) (Exelon 2013a). The NRC staff notes that SAMA 4 is effectively implemented in this analysis since installing “no leak” RCP seals is one element of SAMA 11.

As discussed in Section F.3.2, in response to an NRC staff RAI, Exelon identified one additional SAMA candidate to install a low-flow seal injection pump to mitigate both a fire-induced RCP seal LOCA and a head vent LOCA, or to install cable wrap or fire barriers to prevent the fire damage, due to a transient fire in fire zone U2:3.4A-2 (Unit 2 Cable Riser Area, Elv. 451). Exelon estimated the implementation cost to be: (a) at least $2.9 million to install a low-flow seal injection pump (same as SAMA 2, which was to mitigate the RCP seal LOCA only) or (b) about $1 million to install cable wrap or fire barriers (same as SAMA 35). The risk reduction benefit from eliminating all fire risk in fire zone U2:3.4A-2, which has a fire CDF of 6.5×10^{-7} per year, was estimated by Exelon to be about $302,000 in the baseline and $595,000 after accounting for uncertainties. Based on this result, Exelon concluded that this SAMA was not cost-beneficial in either the baseline or uncertainty analysis.

As discussed above, the determination of risk reduction for a fire-specific SAMA from the mitigated fire CDF is not necessarily conservative since it is possible that a SAMA could have a greater impact on person-rem and OECR than on the CDF. The description of the fire scenario in fire zone U2:3.4A-2 indicates that the ignition source is a transient fire with the largest contributor from welding and cutting activities. The fire results in failure of a number of

Division 1 systems including a seal LOCA. Based on this description, the NRC staff noted the use of updated ignition frequencies would reduce the fire CDF for this zone as would the planned installation of the "no leak" RCP seals. Considering this as well as the previously discussed conservatism in the Level 2 fission product release fractions for the risk-dominant release categories, the NRC staff concludes that it is unlikely that the new SAMA candidate for fire zone U2:3.4A-2 would be cost-beneficial, even after accounting for the potential nonconservatism in the analysis.

Exelon stated in the ER that the 26 SAMAs (SAMAs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 22, 25, 26, 27, 28, 29, 31, 32, 33, 34, and 35) determined to be cost-beneficial in the ER baseline and uncertainty evaluations have been submitted to the Braidwood Plant Health Committee for further implementation consideration (Exelon 2013a).

Given that Exelon has satisfactorily addressed the NRC staff questions regarding Exelon's cost-benefit evaluations, the NRC staff concludes that the cost-benefit evaluations are of sufficient quality to support the SAMA evaluation. For the SAMA evaluation, the NRC staff concurs and concludes that, with the exception of the potentially cost-beneficial SAMAs discussed above (SAMAs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 22, 25, 26, 27, 28, 29, 31, 32, 33, 34, and 35), the costs of the other SAMAs evaluated would be higher than their associated benefits.

F.7 Conclusions

Exelon initially compiled a list of 35 SAMAs based on a review of: (a) the most significant basic events from the plant-specific PRA and insights from the Braidwood PRA group, (b) insights from the plant-specific IPE and IPEEE, and (c) Phase II SAMAs from license renewal applications for other plants. An initial qualitative screening removed SAMA candidates that: (a) are not applicable to Braidwood due to design differences, (b) have already been implemented at Braidwood or the intent achieved by other means, or (c) have excessive implementation costs. Based on this screening, one SAMA was eliminated leaving 34 candidate SAMAs for evaluation. The one candidate SAMA initially screened was further evaluated after accounting for analysis uncertainties.

For all 35 SAMA candidates, benefit and cost estimates were developed as shown in Table F–5. The cost-benefit analyses in the ER showed that 18 of the SAMA candidates were potentially cost-beneficial in the baseline analysis (SAMAs 3, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 25, 26, 27, 28, 29, and 33). Exelon performed additional analyses to evaluate the impact of parameter choices and uncertainties and in response to NRC staff RAIs on the results of the SAMA assessment. As a result, eight additional SAMAs were identified as potentially cost-beneficial (SAMAs 1, 2, 4, 22, 31, 32, 34, and 35). Exelon has indicated that all 26 potentially cost-beneficial SAMAs will be submitted to the Braidwood Plant Health Committee for further implementation consideration.

The NRC staff reviewed the Exelon analysis and concludes that the methods used and the implementation of those methods were sound. The treatment of SAMA benefits and costs supports the general conclusion that the SAMA evaluations performed by Exelon are reasonable and sufficient for the license renewal submittal. Although the treatment of SAMAs for external events was somewhat limited, the NRC staff determined that the likelihood of additional cost-beneficial enhancements in this area was minimized by: (a) utilization of an interim Braidwood fire PRA to identify SAMA candidates, (b) resolution of suggested plant improvements that were identified as a result of the IPEEE process, and (c) inclusion of a multiplier to account for external events.

Based on the NRC staff's review of Exelon's SAMA evaluations, including Exelon's response to NRC staff questions regarding the evaluations, the NRC staff concludes that Exelon has adequately identified areas in which risk can be further reduced in a cost-beneficial manner through the implementation of the identified and potentially cost-beneficial SAMAs. Given the potential for cost-beneficial risk reduction, the NRC staff agrees that further evaluation by Exelon of the 26 candidate SAMAs identified by Exelon as being potentially cost-beneficial in the ER is warranted.

Additionally, the NRC staff evaluated the identified potentially cost-beneficial SAMAs to determine if they are in the scope of license renewal, (i.e., they are subject to aging management). This evaluation considers whether the systems, structures, and components associated with these SAMAs: (1) perform their intended function without moving parts or without a change in configuration or properties and (2) are not subject to replacement based on qualified life or specified time period. The NRC staff determined that these SAMAs do not relate to adequately managing the effects of aging during the period of extended operation. Therefore, they need not be implemented as part of license renewal in accordance with Title 10 of the *Code of Federal Regulations* (CFR), Part 54, "Requirements for renewal of operating licenses for nuclear power plants."

F.8 References

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10. SUPPLEMENTARY NOTES

Docket Nos. 50-456 and 50-457

11. ABSTRACT (200 words or less)

This supplemental environmental impact statement has been prepared in response to an application by Exelon Generation Company, LLC (Exelon) to renew the operating licenses for Braidwood Station (Braidwood), Units 1 and 2, for an additional 20 years. This supplemental environmental impact statement (SEIS) includes the preliminary analysis that evaluates the environmental impacts of the proposed action and alternatives to the proposed action. Alternatives considered include: new nuclear generation, coal-integrated gasification combined cycle, natural gas combined-cycle generation, combination (wind power, natural gas combined cycle, and solar power) alternative, purchased power, and not renewing the license (the no action alternative). The U.S. Nuclear Regulatory Commission (NRC) staff's preliminary recommendation is that the adverse environmental impacts of license renewal for Braidwood are not so great that preserving the option of license renewal for energy-planning decisionmakers would be unreasonable. This recommendation is based on the following:

-the analysis and findings in NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants;"
-the environmental report submitted by Exelon;
-consultation with Federal, State, local, and Tribal government agencies;
-the NRC staff's environmental review; and
-consideration of public comments received during the scoping process.

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Braidwood	14. SECURITY CLASSIFICATION
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Regarding Braidwood Station, Units 1 and 2

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