during the licensing of the facility or the mechanisms of NPDES permitting and associated 316(a) and (b) determinations. They either were found acceptable or mitigated. For some plants with once-through cooling systems, the large volumes of water withdrawn, heated, and discharged back to the receiving water may cause adverse effects to fish and shellfish populations during the license renewal term. Because impacts of entrainment of fish and shellfish, impingement, and thermal discharge effects could be small, moderate, or large, depending on the plant, these are Category 2 issues for plants with once-through cooling systems. These issues will need to be analyzed in the supplemental NEPA document at the time of license renewal.

4.3 COOLING TOWERS

This section introduces cooling towers and their emissions (Section 4.3.1) and then evaluates the impacts of the emissions on surface water and groundwater (Section 4.3.2), aquatic ecology (Section 4.3.3), agricultural crops (Section 4.3.4), terrestrial ecology (Section 4.3.5, which also includes bird collisions with cooling towers), and human health (Section 4.3.6). Impacts of cooling-tower noise are also addressed (Section 4.3.7). Each section that evaluates impacts (Sections 4.3.2–4.3.7) provides a conclusion that defines the significance of the impacts. These conclusions are based on reviews of cooling-tower data available for towers at specific nuclear plants as well as for other cooling towers (e.g., those at coal-fired plants).

4.3.1 Introduction

Mechanical- and natural-draft wet cooling towers transfer waste heat to the atmosphere primarily by evaporating water. Natural-draft towers are generally up to 160 m (520 ft) in height, whereas mechanical-draft towers are generally less than 30 m (100 ft) tall (Roffman and Van Vleck 1974). Because of the large cooling capacity of natural-draft towers, only one such tower is required for each reactor unit; but two or more mechanical-draft towers are required for equivalent cooling.

Most of the water lost from a cooling tower escapes to the atmosphere as water vapor in the exhaust flow. About 10 percent of the vapor recondenses after release, forming the visible part of the plume leaving the tower (Golay et al. 1986). Drift droplets of cooling water are also entrained in the air stream inside the tower and escape directly into the atmosphere. A particulate solid drift material remains after droplet evaporation. The drift contains varying amounts of salts, biocides, and microorganisms.

Natural-draft towers release drift and moisture high into the atmosphere where they are dispersed over long distances. Local impacts are more likely to occur with mechanical-draft towers because the plume is not dispersed over as great an area. The visible moisture plume from a natural-draft cooling tower may be 20 to 30 percent longer than that from comparable mechanical-draft towers (Roffman and Van Vleck 1974). Icing of vegetation and roads can occur near mechanical draft towers when fog is present and temperatures are below freezing. Much of the drift eventually deposits on the earth. The atmospheric transport of drift and the

amount of deposition to the earth has been estimated for most nuclear plants through the use of computer models. Actual measurements of drift deposition have been collected at only a few nuclear plants. These measurements indicate that, beyond about 1.5 km (1 mile) from nuclear plant cooling towers, salt deposition is not significantly above natural background levels.

4.3.2 Surface Water Quality and Use

Sections 4.3.2 and 4.3.3 review the past and ongoing impacts on aquatic resources caused by the operation of nuclear power plants with cooling towers. Any ongoing impacts will probably continue into the license renewal term because the cooling system design and operation will not change as a result of license renewal. Judgments about the significance of these issues during the license renewal terms are based on published information, agency consultation, and information provided by the utilities (Appendix F) applicable to every nuclear power plant in the United States. The conclusions drawn in Sections 4.3.2 and 4.3.3 apply to all nuclear power plants with cooling towers.

4.3.2.1 Water Use

Two factors may cause water-use and water-availability issues to become important for some nuclear power plants that use cooling towers. First, the relatively small rates of cooling water withdrawal and discharge allowed some power plants with cooling towers to be located on small bodies of water that are susceptible to droughts or competing water uses. Second, closed-cycle cooling systems evaporate cooling water, and consumptive water losses may represent a substantial proportion of the flows in small rivers. Loss of a substantial portion of flow from a small stream as a result of evaporative losses from a cooling tower will reduce the amount of habitat for fish and aquatic invertebrates. Off-stream water uses, such as power plant consumption, must be regulated to ensure that important in-stream uses, such as habitat for aquatic organisms, boating, angling, and waste assimilation, are not compromised.

Consumptive water use can adversely impact riparian vegetation and associated animal communities by reducing the amount of water in the stream that is available for plant growth, maintenance, and reproduction. Riparian vegetation is defined as streamside vegetation that is structurally and floristically distinct from adjacent upland plant communities (Taylor 1982). Riparian vegetation has important ecological functions; and its importance as a resource has been widely recognized and reviewed (e.g., Brinson et al. 1981; Johnson et al. 1985). Briefly, riparian vegetation stabilizes stream channels and floodplains. It influences biogeochemical cycles, water temperature and quality, and the duration and magnitude of flooding. Riparian vegetation also provides diverse cover, food, water, reproductive habitat, and migration corridors for many aquatic and terrestrial animals. As a result, riparian zones often support a wide variety and high density of wildlife (deer, small mammals, songbirds, raptors, reptiles, and amphibians), especially in arid or urbanized areas. Riparian vegetation may be adversely affected by dewatering in a number of ways (Taylor 1982), including decreases in the width of the riparian corridor, changes in species and community diversity, increased susceptibility to flooding, changes in tree canopy cover, lower tree basal area, and lower seedling densities. Impacts to wildlife occur as a

direct or indirect result of degradation of riparian habitats. Such dewatering effects are most apparent in the arid and semi-arid West; in the eastern United States, dewatering effects generally involve more subtle changes in community composition because of the higher precipitation, humidity, and soil moisture and the lower water stress conditions that prevail.

Limerick Generating Station, located on the Schuylkill River at Pottstown, Pennsylvania, is an example of a plant with a closed-cycle cooling system that is subject to water availability constraints because of in-stream-flow requirements in a smaller river, controversy over water use related to interbasin transfer, competing water uses, and water-related agreements between utilities. Aquatic resource issues identified include (1) water quality and low-flow problems in the Schuylkill River; (2) water availability conflicts with downstream water users; (3) increased in-stream flow requirements, particularly with respect to continuing efforts to improve the water quality of the Schuylkill River and to reintroduce American shad into the river; and (4) concerns over saltwater movement upstream in the Delaware River as the result of upstream water use (Margaret A. Reilly, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee May 24, 1990; D. T. Guise, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990).

Limerick is in one of the fastest growing regions in Pennsylvania, which is experiencing heavy residential development and water demands for domestic, existing industrial, and developing industrial uses (Joseph Hoffman, letter to V. R. Tolbert, ORNL, Oak Ridge, Tennessee, August 27, 1990). Limerick is permitted to withdraw up to 13 percent of the minimum flow of the Schuylkill River and a major portion of the flow of Perkiomen Creek for cooling tower makeup. Only 5 percent of the 1.8–2.0 m^3/s (65–70 ft^3/s) withdrawn from the Schuylkill River when the flow is greater than 15 m^3/s (530 ft^3/s) is returned to the river. This loss of in-stream flow is viewed as a significant contribution to the water quality and low-flow problems in the Schuylkill River (Dennis T. Guise, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990). This water-use issue may be exacerbated as efforts to reintroduce the American shad into the Schuylkill River continue. In addition to the water use from the Schuylkill River, 2 m^3/s (71 ft^3/s) of water is diverted from the Delaware River to the East Branch of Perkiomen Creek via the Point Pleasant Diversion at a rate of 2 m^3/s (71 ft^3/s); this interbasin transfer affects the achievement of the 85 m^3/s (3000 ft^3/s) minimum flow objective in the Delaware River at Trenton. The effects of the diversion are being debated through an NPDES permit appeal before the Pennsylvania Environmental Hearing Board (Dennis T. Guise, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990).

The Palo Verde NGS offers another example of competing water uses that may affect continued operation of nuclear facilities that use cooling towers. Palo Verde currently uses treated effluent from the cities of Phoenix and Tolleson for cooling tower makeup water. The blowdown from the cooling towers discharges to on-site lined evaporation ponds [Arizona Public Service Company response to NUMARC survey (NUMARC 1990)]. In the absence of the power plant, part of the municipal effluent would be used for commercial purposes and the remainder discharged to the Gila River, where it would be used for groundwater recharge, irrigation, and support of riparian

habitat (Jack Bale, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, May 31, 1990). According to the Arizona Game and Fish Department (Donald Turner, Arizona Game and Fish Department letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 29, 1990), if Palo Verde uses all of its allocation, the flow from the Gila River downstream to Gillespie Dam will be reduced, the water tables will drop significantly, and aquatic habitat and riparian vegetation will be destroyed. Sixty-nine percent of the water flowing in the Gila and Salt rivers downstream from the Ninety-First Avenue treatment plant is discharged by the treatment plant. Most if not all of the water produced by the treatment plant is committed to Palo Verde. When all three units of the plant were operating, flow in the river was significantly reduced, pools and ponds dried up, and numerous fish die-offs occurred (Donald Turner, Arizona Game and Fish Department, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 29, 1990).

Nuclear facilities on small bodies of water may experience water-use constraints related to availability. For example, during temporary drought periods, power plants with cooling towers may have to curtail operations if evaporative water losses exceed the capacity of small, multiple-use source bodies of water. Byron Station in Illinois withdraws water from the Rock River to supply natural-draft cooling towers. By agreement with the Illinois Department of Conservation, the withdrawal for makeup is limited to 3.5 m^3/s (125 ft^3/s) and net water consumption is limited to no more than 9 percent of the flow below 19 m^3/s (679 ft^3/s) [Commonwealth Edison Company response to NUMARC survey (NUMARC 1990)]. Duane Arnold Energy Center on the Cedar River in Iowa uses mechanical-draft cooling towers for condenser cooling and could also experience water availability constraints. The state of Iowa Department of Natural Resources currently has no water-use concerns with operation of Duane Arnold (Larry J. Wilson, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, May 22, 1990); however, the plant may possibly experience future constraints on the availability of water for consumptive use, because the surface water withdrawals within the state are projected to increase by 19 percent from 1985 to 2005 (Thamke 1990). Within Linn County, where Duane Arnold is located, water use is also projected to increase (Brian Tormee, telephone interview with V. R. Tolbert, ORNL, Oak Ridge, Tennessee, September 4, 1990).

Consultations with regulatory and resources agencies indicate that water use conflicts are already a concern at two closed-cycle nuclear power plants (Limerick and Palo Verde) and may be a problem in the future at Byron Station and the Duane Arnold Energy Center. Because water use conflicts may be small or moderate during the license renewal period, this is a Category 2 issue for nuclear plants with closed-cycle cooling systems. Related to this, the effects of consumptive water use on in-stream and riparian communities could also be small or moderate, depending on the plant, and is also a Category 2 issue.

4.3.2.2 Water Quality

Although cooling towers are considered to be closed-cycle cooling systems, concentration of dissolved salts in the makeup water—which results from evaporative water loss—requires the discharge of a certain percentage of the

mineral-rich stream (blowdown) and its replacement with fresh water (makeup). The quantities of blowdown are relatively small compared with the discharges from once-through systems, typically on the order of 10 percent. Water quality impacts could occur from the elevated temperatures of the blowdown or from the concentration and discharge of chemicals added to the recirculating cooling water (to prevent corrosion and biofouling, regulate pH, etc.). A unit of water may reside in the cooling circuit for 3 to 20 cycles before being lost to evaporation or released in the blowdown stream (Coutant 1981). The concentration of total dissolved solids in the cooling tower blowdown averages 500 percent of that in the makeup water, a concentration factor that can be tolerated by most freshwater biota (ORNL/NUREG/TM-226). Dilution of the low-volume blowdown by the receiving water also reduces water quality impacts of heat and contaminants discharged from closed-cycle cooling systems.

Because of strict regulation of chemical discharges from steam-electric power plants (e.g., EPA regulations per 40 CFR Part 423), water treatment systems for cooling tower blowdown have been developed. Many of these systems recapture chemical additives for recycling in the cooling system (Coutant 1981). As noted in Section 4.2, all nuclear power plants are required to obtain an NPDES permit to discharge effluents. These permits are renewed every 5 years by the regulatory agency, either EPA or, more commonly, the state's water quality permitting agency. The periodic NPDES permit renewals provide the opportunity to require modification of power plant discharges or to alter discharge monitoring in response to water quality concerns. Utility responses to the NUMARC survey (Table F.2) indicate that such changes have been made during the plants' operation to correct water quality problems.

Impacts of cooling tower discharges are considered to be of small significance if water quality criteria (e.g., NPDES permits) are not consistently violated. In considering the effects of closed-cycle cooling systems on water quality, the staff evaluated the same issues that were evaluated for open-cycle systems (Table 4.1): altered current patterns, altered salinity gradients, temperature effects on sediment transport capacity, altered thermal stratification of lakes, scouring from discharged cooling water, eutrophication, discharge of chlorine and other biocides, discharge of other chemical contaminants, and discharge of sanitary wastes. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, discharge of cooling tower effluents has not been a problem at existing nuclear plants. Although occasional violations of NPDES permits have occurred at many plants (e.g., minor spills), water quality impacts have been localized and temporary. Effects are considered to be of small significance for all plants. Cumulative impacts to water quality would not be expected because the small amounts of chemicals released by these low-volume discharges are readily dissipated in the receiving waterbody. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of cooling towers discharges on receiving water quality is anticipated. Effects of cooling tower discharges could be reduced by operating additional wastewater treatment systems, or by reducing the plant's generation rate. However, because the effects of cooling

tower discharges on water quality are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Effects of cooling tower discharges on water quality are all Category 1 issues.

4.3.3 Aquatic Ecology

Cooling towers have been suggested as mitigative measures to reduce known or predicted entrainment and impingement losses (see, for example, Barnthouse and Van Winkle 1988). The relatively small volumes of makeup and blowdown water needed for closed-cycle cooling systems result in concomitantly low entrainment, impingement, and discharge effects (see Section 4.2.2 for a more complete discussion of these effects regarding once-through cooling systems). Studies of intake and discharge effects of closed-cycle cooling systems have generally judged the impacts to be insignificant (NUREG/0720; NUREG/CR-2337). None of the resource agencies consulted for this GEIS (Appendix F) expressed concerns about the impacts of closed-cycle cooling towers on aquatic resources.

However, even low rates of entrainment and impingement at a closed-cycle cooling system can be a concern when an unusually important resource is affected. Such aquatic resources would include threatened or endangered species or anadromous fish that are undergoing restoration. For example, concern about potential impacts of the Washington Nuclear Project (WNP-2) on chinook salmon has been raised by the Washington Department of Fisheries (Cynthia A. Wilson, Washington Department of Fisheries, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 5, 1990). Although entrainment, impingement, and thermal discharges are not believed to be a problem at WNP-2, the importance of the Columbia River salmon stocks are such that the resource agency feels that monitoring should continue. Similarly, the Pennsylvania Fish Commission has expressed concern about future entrainment and impingement of American shad by the Limerick Generating Station, the Susquehanna Steam Electric Station, Three Mile Island Nuclear Station, and Peach Bottom Atomic Power Station (Dennis T. Guise, Pennsylvania Fish Commission, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990). In all cases, losses of American shad at these power plants are minimal or nonexistent, but periodic monitoring has been recommended to ensure that no future problems occur as the anadromous fish restoration efforts continue.

It is unlikely that the small volumes of water withdrawn and discharged by closed-cycle cooling systems would interfere with the future restoration of aquatic biota or their habitats. Effects of operation of closed-cycle cooling systems on aquatic organisms are considered to be of small significance if changes are localized and populations in the receiving waterbody are not reduced. In considering the effects of closed-cycle cooling systems on aquatic ecology, the staff evaluated the same issues that were evaluated for open-cycle systems (Table 4.1): impingement of fish and shellfish, entrainment of fish and shellfish early life stages, entrainment of phytoplankton and zooplankton, thermal discharge effects, cold shock, effects on movement and distribution of aquatic biota, premature emergency of aquatic insects, stimulation of nuisance organisms, losses from predation, parasitism, and disease, gas supersaturation of low

dissolved oxygen in the discharge, and accumulation of contaminants in sediments or biota. Based on reviews of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, these potential effects have not been shown to cause reductions in the aquatic populations near any existing nuclear power plants. None of the regulatory and resource agencies expressed concerns about the cumulative effects on aquatic resources of closed cycle cooling system operations at this time, although some recommended continued monitoring in view of efforts to restore fish populations. Effects of all of these issues are considered to be of small significance for all plants. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of cooling towers on aquatic biota is anticipated. Effects of entrainment, impingement, and discharges from closed-cycle cooling systems could be reduced by reducing the plant's generation rate, or by operating additional wastewater treatment systems. However, because the effects of cooling tower withdrawals and discharges on aquatic organisms are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. The effects of closed-cycle cooling system operation on aquatic biota are all Category 1 issues.

4.3.4 Agricultural Crops and Ornamental Vegetation

The issue addressed by this section is the extent to which the productivity of agricultural crops near nuclear plants may be reduced by exposure to salts or other effects (e.g., icing, increased humidity) resulting from cooling-tower operation. The approach to evaluating this issue was as follows: first, based on a literature review, potential impacts of salts in general (whether from cooling towers or other sources such as wind-blown salts near seashores) are described according to the rate of salt deposition to earth and the relative sensitivity of different types of crops (Section 4.3.4.1); then, the data generated by monitoring programs at a representative subset of specific nuclear plants were reviewed (Section 4.3.4.2). The subset includes 10 of the 11 nuclear power plants with mechanical-draft cooling towers. Mechanical-draft towers are the focus of this section because impacts of drift deposition and icing are more likely to occur near these towers than at natural-draft towers. Drift from natural-draft towers is released at greater heights, disperses more widely, and therefore deposits on earth at lower rates or concentrations. Data were also found and reviewed for 8 of the 17 plants with natural-draft cooling towers (Table 4.1). The coal-fired Chalk Point Plant was also included in the analysis because extensive monitoring of cooling-tower-drift effects has been conducted there and because this plant uses brackish water for cooling and represents a case with comparatively high potential for drift impacts from natural-draft towers. The only nuclear plant that has a natural-draft tower and uses brackish water for cooling is Hope Creek in New Jersey. It is included among the plants that were reviewed.

The following standard of significance is applied to the effects of cooling tower operation on agricultural crops and ornamental vegetation. The impact is of small significance if under expected operational conditions measurable productivity losses (either quantity or

quality of yield) do not occur for agricultural crops; and measurable damage (either visual or to plant function) does not occur for ornamental vegetation.

4.3.4.1 Overview of Impacts

4.3.4.1.1 Ambient Salts and Cooling-Tower Drift

Agricultural crops can be affected by chemical salts and biocides in cooling tower drift and drift-induced or plume-induced ice formation. Increased fogging, cloud cover, and relative humidity resulting from cooling-tower operation have little potential to affect crops, and adverse effects have not been reported. Generally, drift from cooling towers using fresh water has low salt concentrations and, in the case of mechanical draft towers, falls mostly within the immediate vicinity of the towers (ANL/ES-53), representing little hazard to vegetation off-site. Typical amounts of salt or total dissolved solids in freshwater environments are around 1000 ppm (ANL/ES-53). In arid environments, competition for water resources can result in the use of relatively low-quality or saline water for cooling, and the potential for drift-induced damage to surrounding vegetation may be greater (McBrayer and Oakes 1982). For example, source water for cooling at Palo Verde in Arizona is withdrawn from an onsite reservoir containing treated sewage effluent of relatively high salinity. As a result, cooling tower basin water also had high salinity levels including 10,000 to 26,000 ppm total dissolved solids, 3,400 to 7,000 ppm Cl^-, and 2,700 to 8,600 ppm Na^+ (NUS-5241). High salt levels also occur at plants on the coasts or coastal bays. Brackish cooling water used by the Chalk Point coal-fired plant in Maryland contained 11,000 to 26,000 ppm total soluble salts and 6,600 to 18,000 ppm Cl^- (Mulchi and Armbruster 1983). Nuclear plants with cooling towers use fresh water, except for the Hope Creek Plant in New Jersey, which uses saline water. At the Crystal River Plant, Florida, which currently uses brackish water in once-through cooling, a helper cooling tower has been constructed to cool water in a canal that receives discharge from five fossil and one nuclear units.

Talbot (1979) has concluded that adequate estimates of natural background levels of atmospheric salt loading (naturally occurring drift) and rates of deposition thereof are not available for points remote from oceans. In field measurements at a wet cooling tower, A. Backhaus et al. (1988) estimated that up to 60 percent of the chemical contents in the sample came from atmospheric aerosols and not from the tower. Therefore, observed deposition is not all drift from cooling towers (Talbot 1979). Recent work (ORNL/TM-11121) has quantified background aerosol deposition for a dozen sites throughout the country, but deposition for most locations remains poorly known.

Salts from cooling towers are deposited on vegetation by (1) wind-driven impaction, (2) droplet and particulate fallout, and (3) rainfall (Talbot 1979; CONF-740302, 1975b). In high-salt environments such as a windy seashore, impaction is usually the most important process, delivering 10 times more salt to vegetation than does fallout. Increasing wind speeds and salt concentrations increase impaction, hence increasing vegetation injury (Talbot 1979). In most humid environments, rainwater will wash off salts deposited on vegetation (ANL/ES-53), but exposure can be significant during periods between rainfalls.

4.3.4.1.2 Effects of Salt Drift

Plants damaged by salt drift may have acute symptoms, including necrotic or discolored tissue, stunted growth, or deformities (Talbot 1979; Hoffman et al. 1987). Chronic effects are less obvious but may include some degree of chlorosis and reduced growth (Talbot 1979) or increased susceptibility to disease and insect damage (Hosker and Lindberg 1982).

Climatic conditions affect plants' ability to tolerate salt (Talbot 1979; Maas 1985). The degree of injury is related to the salt content in the leaves, but hot or dry weather conditions and water stress are critical in inducing injury (most crops can tolerate greater salt stress during relatively cool and humid weather) (Maas 1985).

Among the factors that affect the plant's foliar accumulation of salt are physical characteristics of the leaves (Maas 1985; CONF-740302, 1975d; Taylor 1980), type and concentration of salt, ambient temperature and humidity, and length of time the leaf remains wet (Maas 1985). Because salt on foliage is apparently absorbed from solution, high humidity, which retards evaporation, enhances salt uptake (CONF-740302, 1975d; McCune et al. 1977; Talbot 1979; Grattan et al. 1981). Because precipitation and dew affect salt deposition, uptake, and resultant injury, dose exposure is difficult to predict (Talbot 1979; Grattan et al. 1981; McCune et al. 1977; EPA-600/3-76-078).

Plant species and crop varieties vary significantly in their tolerance to drift deposition and to soil salinity (Talbot 1979; Maas 1985). In general, salt uptake, plant injury, and reduction in crop yield have been shown to increase with increasing levels of airborne salt or deposition and with time of exposure (CONF-740302, 1975b; Mulchi and Armbruster 1981; Maas; Grattan et al.; EPA-600/3-76-078). Some plants, however, have shown a slight increase in vegetative productivity [e.g., tobacco at < 4 kg/ha (3.6 lb/acre) per week (Mulchi and Armbruster 1983) and cotton at 8 kg/ha (7 lb/acre per week) (Hoffman et al. 1987)]. Based on experimental exposures, a yield reduction of 10 percent has been estimated for deposition levels as low as 4.7 kg/ha (4.2 lb/acre) per week to corn, a species sensitive to foliar salt injury (Mulchi and Armbruster 1981). Relationships between experimental levels of salt deposition, foliar concentrations of sodium and chloride, and corn yield show that yield may be slightly reduced even at rates as low as 2 kg/ha (1.8 lb/acre) per week (Mulchi and Armbruster 1981). Also, bush beans can have reduced yield depending on the age of plants, with older plants being most sensitive (EPA-600/3-76-078). Deposition rates near nuclear-plant towers, according to available deposition data (Section 4.3.5.1.2), appear to be generally below the rates that would affect sensitive agricultural crops.

Talbot (1979) tabulated salt deposition amounts known to induce acute toxicity symptoms in vegetation (Table 4.2). Corn was the most sensitive crop, showing injury above 1.8 kg/ha (1.6 lb/acre) per week; the least sensitive was pinto beans, showing injury above 253 kg/ha (226 lb/acre) per week. Armbruster and Mulchi (1984) showed that foliar salt deposition of 3.2 to 8.8 kg/ha (2.9 to 7.9 lb/acre) per week increased foliar chloride content and damaged foliage of corn, with the higher deposition reducing the yield of grain by as much as 11 percent. They found similar results for soybeans, with bean yields

Table 4.2 Estimates of salt-drift deposition rates estimated to cause acute injury to vegetation

Species	Deposition above which injury is expected (kg/ha/week)
Crops and ornamental plants	
Zea mays (corn)	1.82
Glycine hispida var York (soybean)	7.28
Gossypium hirsutum (cotton)	8.0
Medicago sativa (alfalfa)	15.7
Forsythia intermedia var spectabilis (forsythia)	189.6
Phaseolus vulgaris var Pinto (pinto bean)	252.8
Albizzia julibrissin rosea (mimosa)	379.2
Koelreutaria paniculata (golden rain tree)	568.8
Native species	
Cornus florida (flowering dogwood)	1.2 (in Maryland) 47.4 (in New York)
Fraxinus americana (white ash)	1.3 (in Maryland) 18.9 (in New York)
Tsuga canadensis (Canadian hemlock)	9.4
Pinus strobus (white pine)	189.6
Quercus prinus (chestnut oak)	379.2
Robinia pseudoacacia (black locust)	379.2
Acer rubrum (red maple)	474.0
Hammamelis virginiana (witch hazel)	1042.8

Source: Adapted from Talbot 1979 and Hoffman et al. 1987.
Note: To convert kg/ha to lb/acre, multiply by 0.8924.

reduced by as much as 7 percent at the highest deposition rate.

W. C. Hoffman et al. (1987) experimentally exposed cotton and cantaloupe in the arid environment near Palo Verde to foliar salt deposition rates of 8 to 415 kg/ha (7 to 370 lb/acre) per year total salt and alfalfa to depositions up to 829 kg/ha (740 lb/acre) per year. They found foliar injury in alfalfa only at the highest deposition level but no injury to cantaloupe or cotton despite increases in foliar Na^+ and Cl^-. Yields of cantaloupe and alfalfa were not reduced, but 415 kg/ha (370 lb/acre) per year reduced cotton boll production and seed cotton yield by approximately 25 percent.

The burning quality of tobacco is known to be adversely affected by elevated Cl^-. Experiments have shown that burning quality, or length of time the leaf will burn, is impaired by increasing experimental doses of salt deposition (Mulchi and Armbruster 1983). A 17 percent reduction in burning quality was estimated for a Cl^- deposition of 5 kg/ha (4.5 lb/acre) per week, based on regression relationships of deposition, leaf chloride concentration, and leaf burn (Mulchi and Armbruster 1983).

Field studies of the effects of salt drift have been conducted at the Turkey Point plant and the coal-fired Chalk Point plant. Hindawi et al. (EPA-440/5-86-001) investigated field exposures of bean and corn plants to saltwater drift from a test cooling tower and power spray module at the Turkey Point plant. Salt concentrations in tissues of bean and corn plants increased with time during three weeks of exposure and decreased exponentially with distance from the salt drift source. Some injury to leaves was visible at the site of greatest exposure.

The coal-fired Chalk Point plant has a relatively high potential impact from natural-draft cooling towers because brackish water is used for cooling. Other than the Hope Creek plant, all nuclear plants with natural-draft towers use fresh water for cooling. Deposition rates at Chalk Point were measured at 12 monitoring sites at distances of from 1.6 km to 9.6 km (1 to 6 miles) from the towers during their initial 5 years of operation (Mulchi et al. 1982). No increased deposition resulting from cooling-tower operation was detected at these distances. Deposition rates at the sites ranged from about 0.5 to 1.2 kg/ha (0.4 to 1 lb/acre) per month for NaCl, which comprises most of the solids in the brackish cooling water. Monitoring sites, which were established to study effects on agricultural crops, were not located in areas closer to the towers because no active cropland was in these areas and because the plant, located on a peninsula on the Patuxent River, is bounded by water except to the north and north-northwest. Most drift probably deposits in the river.

A study of tobacco plants 3 years after Chalk Point cooling towers began operating failed to find any increase in leaf salt content that could be attributed to drift (Mulchi and Armbruster 1983). Chloride levels in tobacco and chloride and sodium levels in corn and soybeans at 1.6 km (1 mile), the closest distance crops were grown to the Chalk Point towers, were within the range of preoperational values and were no higher than levels found up to 9.6 km (6 miles) from the towers (Mulchi et al. 1982; Mulchi and Armbruster 1983).

4.3.4.1.3 Effects on Soils

Drift deposition also has the potential to damage vegetation by soil salinization. Soil salinization does not usually occur in areas where rainfall is sufficient to leach salts from the soil profile. In arid regions, however, such as at Palo Verde, cooling tower drift has the potential to increase soil salinity and thus affect native and agricultural plants (McBrayer and Oakes 1982). Salinity of irrigated soils in arid regions may also be increased by drift, even though such soils already have a high salinity resulting from salts in irrigation water and high evaporation rates. Responses of crop plants to soil salinity appear to be poorly correlated to their tolerance to foliar-applied salts (Grattan et al. 1981; Maas 1985).

In an experiment in a more humid environment, salts were applied to soils to simulate drift deposition from the Chalk Point coal-fired plant with brackish water cooling towers. One-time applications of 14–112 kg/ha (13–100 lb/acre) NaCl affected leaf Cl^- in corn and soybeans but resulted in no visible damage or reduction in yield (Armbruster and Mulchi 1984). These soil salt treatments also increased soil pH and extractable cations (Armbruster and Mulchi 1984), but leaching by winter precipitation returned soil to pretreatment status.

In humid environments, effects of drift deposition on soils appear transitory if they can be detected at all. Field measurements of the effects of the operating cooling towers at Chalk Point showed no changes in soil chemical elements at distances of 1.6 to 9.6 km (1 to 6 miles) (Mulchi et al. 1982). In a study of five saltwater cooling towers near Galveston Bay, Texas, salt deposition up to 746 kg/ha/year was found within 100 m (328 ft) of the towers, with levels decreasing to <52 kg/ha (46 lb/acre) per year at 434 m (1424 ft) (Wiedenfeld et al. 1978). Weekly deposition ranged from 4.27 kg/ha (3.81 lb/acre) per week to 58.8 kg/ha (52.5 lb/acre) per week. In the survey, salt content of the soil at 104 m (341 ft) from the towers returned to previous levels when towers were shut down during the winter.

4.3.4.2 Plant-Specific Operational Data

Annual reports of environmental monitoring for vegetation damage at nuclear plants were reviewed. Vegetation monitoring included detailed measurements of vegetation structure and composition on permanent plots, aerial infrared photography with subsequent field surveys for vegetation injury, or general surveillance. Vegetation damage ranging from foliar chlorosis to defoliation can be identified on false-color infrared aerial photographs (NUREG/CR-1231). Vegetation monitoring for drift effects has been conducted at 18 nuclear plants. Most of the nuclear plants are not located close to agricultural areas, but six of the plants monitored crops, pasture, orchards, or ornamental vegetation. None reported visible damage to ornamental vegetation or reduction in crop yield (Table 4.3).

A detailed study at Palo Verde in Arizona showed that, after 6 years of operation, no change in agricultural soils attributable to cooling tower emissions occurred. Although significant increases or decreases occurred in some soil parameters at some monitoring locations, these changes appear unrelated to cooling-tower operation and were believed to have been caused by irrigation management, cropping, and fertilizer application. At the conclusion of the 6-year study, no significant effects on

Table 4.3 Results of nuclear facility monitoring for cooling-tower drift effects on terrestrial vegetation

Plant	Vegetation effects	Type of monitoring
	Natural draft	
Arkansas	No visible damage; no foliar chemical changes after one year	Aerial photography; foliar chemistry; orchard, native trees
Beaver Valley	No visible damage	Aerial photography; soil pH and conductivity; native vegetation
Byron	No visible damage	Aerial photography; crops; woody, ornamental, and native vegetation
Callaway	No visible damage	Aerial photography; permanent vegetation plots; native trees
Davis-Besse	No visible damage	Aerial photography; soil chemistry; native vegetation
Hope Creek	No visible damage after one year; no foliar chemical changes after one year	Ground survey; foliar chemistry; soil chemistry; native vegetation
Three Mile Island	No visible damage	Visual inspection; crops and native vegetation
Trojan	No visible damage	Aerial photography; pasture, ornamental and native vegetation
	Mechanical draft	
Catawba	Possible ice damage to loblolly pine < 61 m (200 ft) from towers	Aerial photography; ground survey; native trees
Duane Arnold	No visible damage	Visual inspection; native vegetation
Edwin I. Hatch	No visible damage	Aerial photography; permanent vegetation plots; native vegetation

Table 4.3 (continued)

Plant	Vegetation effects	Type of monitoring
Joseph Farley	No visible damage	Aerial photography; native vegetation
Palisades	Severe ice damage < 61 m (200 ft) from towers; some icing beyond 250 m (820 ft); sulfate injury < 150 m (492 ft) from towers; change in vegetation caused by damage to trees	Aerial photography; permanent vegetation plots; native vegetation
Palo Verde	No visible damage; foliar salt concentrations increased on site	Aerial photography; foliar chemistry; soil chemistry; crops and native vegetation
Prairie Island	Frequent ice damage to oaks adjacent to towers; change in canopy structure caused by ice damage; reduced viability in acorns from oaks near towers	Aerial photography; ground survey; acorn viability survey; native vegetation
River Bend	No visible damage	Aerial photography; permanent vegetation plots; native vegetation
Fort Saint Vrain	No visible damage	Aerial photography; crops; native vegetation
Washington	No foliar chemical changes	Foliar chemistry; soil chemistry; native vegetation

crops or native vegetation had been noted, and the study was discontinued (Halliburton NUS 1992).

At the Palisades plant in Michigan, concern was expressed by owners of nearby fruit orchards about possible effects of elevated humidity on the incidence of disease, particularly apple scab, in their orchards. The concern was that increased humidity could result in the need for increased applications of disease-control sprayings and thus increase orchard operating costs. NRC staff recommended a survey program to assess impacts of cooling-tower moisture on yield, quality, and frequency of disease-control sprayings (NRC 1978). Weather conditions encouraging apple scab are temperatures of 17 to 24°C (63 to 75°F) and

>85 percent relative humidity for 9 h or more. A study was conducted to determine these weather conditions near Palisades cooling towers and in more distant areas (Ryznar et al. 1980). Long-term weather records from weather stations outside the influence of the Palisades cooling towers were analyzed. In addition, a network of meteorological stations was established in the vicinity of the Palisades plant. No increase in weather occurrences favoring apple scab was observed that could be related to Palisades operation.

4.3.4.3 Conclusion

Monitoring results from the sample of nuclear plants and from the coal-fired Chalk Point plant, in conjunction with the literature review and information provided by the natural resource agencies and agricultural agencies in all states with nuclear power plants, have revealed no instances where cooling tower operation has resulted in measurable productivity losses in agricultural crops or measurable damage to ornamental vegetation. Because ongoing operational conditions of cooling towers would remain unchanged, it is expected that there would continue to be no measurable impacts on crops or ornamental vegetation as a result of license renewal. The impact of cooling towers on agricultural crops and ornamental vegetation will therefore be of small significance. Because there is no measurable impact, there is no need to consider mitigation. Cumulative impacts on crops and ornamental vegetation are not a consideration because deposition from cooling tower drift is a localized phenomenon and because of the distance between nuclear power plant sites and other facilities that may have large cooling towers. This is a Category 1 issue.

4.3.5 Terrestrial Ecology

This section addresses the impact of cooling tower drift on natural plant communities (Section 4.3.5.1) and the impact of bird mortality resulting from collisions with natural-draft cooling towers (Section 4.3.5.2).

4.3.5.1 Effects of Cooling-Tower Drift

This section addresses the extent to which natural plant communities near nuclear plants are affected by exposure to salts, icing, or other effects (e.g., fogging and increased humidity) caused by operation of cooling towers. The approach to evaluating this issue is the same as that used for evaluating the impact on agricultural crops in Section 4.3.4.

4.3.5.1.1 Overview of Impacts

The potential impacts of cooling tower operation on native vegetation are similar to those for agricultural crops, including salt-induced leaf damage, growth and seed yield reduction, and ice-induced damage (see Section 4.3.4). In addition, native vegetation may suffer changes in community structure (Talbot 1979) in response to ice damage or differences in species tolerances to drift. Increased fogging and relative humidity near cooling towers have little potential to affect native vegetation, and no such impacts have been reported.

The following standard of significance is applied to the effects of cooling tower operation on natural plant communities. The impact is of small significance if no measurable degradation (not including short-term, minor, and localized impacts) of natural plant communities results from cooling tower operation.

Species vary in their sensitivity to soil salinity and foliar salt deposition, and their tolerances of drift deposition are not well known. Curtis et al. (PPSP) determined that experimental exposure to saline cooling-tower drift for one growing season resulted in foliar damage to vegetation when leaf Cl^- levels were between 3145 and 9000 μg/g dry weight. These investigators also found that several species of trees growing under field conditions were not always as sensitive to salt deposition as they were under greenhouse conditions. Actual sensitivities of native trees may therefore be less than those shown in Table 4.2. Age of leaves also affects sensitivity to deposition. McCune et al. 1977 found that the youngest leaves of deciduous woody species and the year-old needles of conifers were more susceptible than leaves of other ages. Seasonal deposition, therefore, has the potential to affect these species groups differently. The most sensitive native species, flowering dogwood, shows injury from deposition above 1.2 kg/ha (1.1 lb/acre) per week, and the least sensitive species, witch hazel, shows injury above 1042.8 kg/ha (930.6 lb/acre) per week (Talbot 1979). Deposition rates near nuclear plant cooling towers, according to available deposition data, appear to be generally below the rate that would adversely affect dogwood.

Talbot (1979) reviewed studies of vegetation damage at nine industrial cooling tower installations. Three of the six installations having mechanical draft towers (one saltwater and two freshwater) produced some damage to native vegetation within 215 m (705 ft). Natural draft towers at three sites had no reported visible effects on vegetation. Natural draft cooling towers using brackish water at the coal-fired Chalk Point plant resulted in elevated chloride concentrations in vegetation after 1 year of tower operation (PPSP-CPCTP-18), but symptoms of salt toxicity in native trees had not been observed after 2 years of operation (Lauver et al. 1978), after which monitoring was terminated because of the absence of significant effects (C. L. Mulchi, University of Maryland, personal communication with H. Quarles, ORNL, Oak Ridge, Tennessee, March 15, 1995).

Impacts on native vegetation as a result of soil salinization (Section 4.3.4) are not expected except possibly in arid environments. Although according to McBrayer and Oakes (1982), the predicted annual salt deposition of 25 to 50 kg/ha (22 to 51 lb/acre) near the Palo Verde cooling towers could increase soil salinity enough to alter distribution of certain species because natural soil salinity is already close to their salt tolerances, a monitoring study conducted over the first 6 years of cooling tower operation showed no significant effects on native vegetation or crops (Halliburton NUS 1992).

4.3.5.1.2 Plant-Specific Operational Data

Vegetation monitoring at nuclear plants is described in Section 4.3.4. Of the 18 plants reviewed, visible vegetation damage resulting from cooling tower operation was reported for only the Catawba, Palisades, and Prairie Island plants, all with mechanical-draft towers (Table 4.3). At these facilities, damage has been reported primarily within 150 m of the towers. Although no vegetation damage was reported at Palo Verde, increased foliar salt concentrations were found on-site (Halliburton NUS 1992).

At the Catawba Plant a few loblolly pine trees adjacent to the cooling towers were

apparently damaged by ice. Damage to the trees consisted of some browning of needles on trees nearest the towers.

At Palisades, monitoring conducted in response to observed vegetation damage included chloride and sulfate deposition and visual observation of damage. Vegetation damage resulted primarily from sulfate and was more extensive than at any other nuclear facility because, at Palisades' unique location, the tops of the cooling towers are lower than the tops of forested dunes on the site. This unique position of the cooling towers contributes to interception of cooling tower emissions by dune vegetation. Vegetation injury ranged from visible signs to severe necrosis of leaves to near-total defoliation in areas with maximum impact. In 1975, severe icing from drift interception also caused extensive damage by breaking branches as well as trunks of trees (Rochow 1978). Approximately 8 ha (20 acres) was affected by sulfates and icing, including about 6 ha (15 acres) of forest. Sulfate damage resulted from addition of sulfuric acid to the cooling water. However, this practice was discontinued, thus significantly reducing the impacts; and the severe icing in 1975 may have resulted from unusual weather conditions combined with a possible cooling tower malfunction (Ryznar et al. 1980).

Vegetation damage was found to correlate with elevated rates of sulfate deposition from the Palisades towers (Rochow 1978); chloride deposition, however, was less than 1.0 g/m^2/month in areas of extensive vegetation damage and did not correlate with the damage. Sulfate deposition rates were 0.61 g/m^2/month between 700 and 1609 m (2296 and 5278 ft) and 9.0 g/m^2/month within 50 m (164 ft) of the tower. About 75 percent of the sulfate fell out within 145 m (129 ft) of the towers (Rochow 1978). Heaviest damage to vegetation was in areas receiving more than 5 g/m^2/month sulfate, but areas receiving 2 to 5 g/m^2/month also were heavily damaged. Areas receiving 1 to 2 g/m^2/month were damaged primarily in the upper portions of trees.

Monitoring at Prairie Island included aerial photography, ground surveys of vegetation, and acorn viability monitoring. Viability of acorns collected from red oak trees located near the mechanical-draft towers was low, although acorn production appeared normal. Icing from plume downwash, which occurred frequently, may have damaged developing embryos in the acorns, which take 2 years to develop (Richardson 1976; Richardson 1978). Ice also damaged some of the trees growing adjacent to the towers. Because the towers at Prairie Island have not been used for cooling during the winter since 1984, icing damage has been eliminated.

Monitoring at Palo Verde included drift deposition, soil chemistry, salt concentrations in vegetation, and aerial photography. Drift deposition up to 95.6 kg/ha (85.3 lb/acre) per year has occurred on the site within 1.6 km (1 mile) of the cooling towers. Amounts of approximately 25 to 50 kg/ha (22 to 45 lb/acre) per year were predicted to alter soil salinity enough to affect vegetation over the long term (McBrayer and Oakes 1982). Increases in soil sodium, potassium, or chloride content have been reported, but increases also occurred in some sites that were distant from the towers (Halliburton NUS 1992). Observed changes in soil chemistry at Palo Verde appeared to be unrelated to cooling tower operation, and no effects on vegetation were reported.

4.3.5.1.3 Conclusion

Monitoring results from the sample of nuclear plants and from the Chalk Point plant, in conjunction with the literature review and information provided by the natural resource agency and agricultural agencies in all states with nuclear power plants, have revealed no instances where cooling tower operation has resulted in measurable degradation of the health of natural plant communities. Observed vegetation damage caused by icing and cooling-tower drift at mechanical draft towers usually is minor and localized in small ares (e.g., Catawba and Prairie Island). Damage to native vegetation has not occurred at Chalk Point coal plant and the Hope Creek nuclear plant, which use brackish water for cooling and represent a comparatively high probability of impact from operation of natural draft towers. Therefore, damage at other nuclear plants with natural draft towers is unlikely. Damage from operation of mechanical-draft towers at Palisades was more extensive than for the other nuclear plants, but was limited to about 8 ha (20 acres) on the site. The damage resulted from Palisades unique location, the addition of sulfuric acid to cooling water, and possibly from a cooling tower malfunction combined with unusual weather conditions. The use of sulfuric acid was discontinued, significantly reducing the impact. Cooling tower drift in the arid environment at Palo Verde has not affected native species through soil salinization: no actual damage was reported over a 6 year study of cooling tower operation (Halliburton NUS 1992). The only potential mitigation measures would be to change to another cooling system or to modify the cooling towers to reduce the amount of drift. Because the impacts of cooling tower drift on native plants are expected to be of small significance at all plants and because the potential mitigation measures would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. Cumulative impacts on natural plant communities are not a consideration because of the distance between nuclear power plant sites and other facilities that may have large cooling towers. This is a Category 1 issue.

4.3.5.2 Bird Collisions with Cooling Towers

This section addresses the significance of avian mortality resulting from collisions of birds with natural-draft cooling towers at nuclear plants. Natural-draft towers, which are tall structures, cause some mortality, whereas mechanical-draft towers cause negligible mortality and are not addressed here. This issue was evaluated by reviewing the general literature for avian collision mortality associated with all types of man-made objects, as well as the monitoring studies conducted at six nuclear plants. The literature review is presented in Section 4.5.6.2. The significance of the mortality caused by cooling towers is determined by examining the actual numbers and species of birds killed and comparing this mortality with the total avian mortality resulting from other man-made objects and with the abundance of bird populations near the towers.

4.3.5.2.1 Overview of Impacts

Throughout the United States, millions of birds are killed annually when they collide with man-made objects, including radio and TV towers, windows, vehicles, smoke stacks, cooling towers, and numerous other objects. An overview of collision mortality for all types of man-made objects is

included in the discussion of transmission lines in Section 4.5.6.2.

Avian mortality due to man-made structures is of concern if the stability of the local population of any bird species is threatened or if the reduction in the numbers within any bird population significantly impairs its function within the local ecosystem. Avian mortality resulting from collisions of birds with cooling towers is considered to be of small significance if the losses do not threaten the stability of local populations of any species and if there is no noticeable impairment of its function within the local ecosystem.

4.3.5.2.2 Plant-Specific Analysis

Monitoring of bird collisions has been done at several nuclear plants with natural draft cooling towers, including the Susquehanna plant near Berwick on the Susquehanna River in eastern Pennsylvania, the Davis-Besse plant on the shore of Lake Erie in north central Ohio, the Beaver Valley plant on the Ohio River in extreme western Pennsylvania, the Trojan Plant on the Columbia River in extreme northwestern Oregon, the Three Mile Island plant near Harrisburg in southeastern Pennsylvania, and the Arkansas Nuclear One plant on Dardanelle Lake in northwestern Arkansas. The following information was obtained from nuclear plant annual monitoring reports and from a few other sources, as cited.

At the Susquehanna plant, surveys were conducted on weekdays during spring and fall migration from 1978 through 1986. This plant's natural draft towers are 165 m (540 ft) tall and illuminated at the top with 480-V aircraft warning strobe lights. About 1500 dead birds (total for all survey years) of 63 species were found that had apparently collided with the cooling towers. Others were probably lost in the tower basin water during plant operation. Most of the birds were passerines (songbirds). Fewer collisions seemed to occur during plant operation, when cooling tower plumes and noise may have frightened birds away from the towers. From 1984 through 1986, eight dead bats were also found, including little brown myotis, red bat, and big brown bat.

At Davis-Besse, extensive surveys for dead birds were conducted from fall 1972 to fall 1979. Early morning surveys at the 152-m (499-ft-) tall cooling tower were made almost daily from mid-April to mid-June and from the first of September to late October. After the tower began operating in the fall of 1976, some dead birds were lost through the water outlets of the tower basin. A total of 1554 dead birds were found, an average of 196 per year. The dead birds included 1222 at the cooling tower, 222 around Unit 1 structures, and 110 at the meteorological tower. Most were night-migrating passerines, particularly warblers, vireos, and kinglets. Waterfowl that were abundant in nearby marshes and ponds suffered little collision mortality. Most collision mortalities at the cooling tower occurred during years when the cooling tower was not well illuminated (1974 to spring 1978). After completion of Unit 1 structures and the installation of many safety lights around the buildings in the fall of 1978, collision mortality was significantly reduced (average of 236 per year from 1974 through 1977, 135 in 1978, and 51 in 1979). Diffusion of light from these safety lights may illuminate the cooling tower in such a way that birds can see and avoid it. Lights at nuclear plants may not confuse birds to the extent sometimes caused by lights on radio or TV towers (Section 4.5.6.2). Lights illuminating

the Pilgrim Nuclear Station in Massachusetts apparently were not a problem to migrating birds, which were monitored by radar. The orientation, flight speed, and altitude of these birds appeared unaffected by the lights, although on one of nine nights, flight direction at the station was different from that in a control area and flight altitude was higher (Marsden et al. 1980).

At Beaver Valley, surveys were conducted in spring and fall from 1974 through 1978 at the natural draft tower. A total of 27 dead birds were found. At the Trojan Plant, surveys were conducted weekly in 1984 and 1988 at the 152-m 499-ft-) tall cooling tower, meteorological tower, switch yard, and generation building. No dead birds were found. At the 113-m (371-ft-) tall cooling towers at Three Mile Island, a total of 66 dead birds were found from 1973 through 1975 (Temme and Jackson 1979). No dead birds were found at Arkansas Nuclear One, where monitoring at the natural-draft tower was done twice weekly from October 15 through April 15 in 1978–79 and 1979–80.

4.3.5.2.3 Conclusion

Existing data on cooling-tower collision mortality suggest that cooling towers cause only a very small fraction of the total bird collision mortality (see Section 4.5.6.2 for a review of this mortality). The relatively few nuclear plants having natural-draft towers in the United States (approximately 32 units), combined with the relatively low bird mortality at individual natural draft towers, shows that (1) these nuclear plant towers are not greatly affecting bird populations (see Section 4.5.6.2.1) and (2) their contribution to the cumulative effects of bird collision mortalities is very small. Mechanical-draft cooling towers, which are not nearly as tall as natural-draft towers, and other facilities pose little risk to migrating birds.

Local bird populations are apparently not being significantly affected by collision with cooling towers. Waterfowl and other birds that are commonly present as permanent or summer residents around nuclear plants do not frequently collide with the towers. Instead, a very high percentage of the collision mortalities occur during the spring and fall bird migration periods and involve primarily birds migrating at night. Studies that have been conducted at six nuclear plants, in conjunction with literature reporting total collision mortality (Section 4.5.6.2), show that (1) avian mortality associated with cooling towers is a very small part of the total mortality and (2) local bird populations are not being significantly reduced. Data on collision mortality were found for only 6 of the 20 nuclear plants with natural-draft cooling towers. Collision mortality at one or more of these plants may be greater than at the plants where surveys were conducted.

Avian mortality resulting from collisions of birds with cooling towers involves sufficiently small numbers for any species that it is unlikely that the losses would threaten the stability of local populations or result in a noticeable impairment of the function of a species within local ecosystems. There is no reason to believe that the annual mortality rate resulting from collision of birds with any cooling tower would be different during the license renewal term. Thus, avian mortality resulting from collision with cooling towers is of small significance. A potential method of mitigating avian morality would be to illuminate natural draft cooling towers at night. Because it is unlikely that the numbers of birds killed from collision with

cooling towers are large enough to affect local population stability or impair the function of a species within the local ecosystem, consideration of further mitigation is not necessary. Because any contributions of cooling tower collisions to overall bird mortality have already been expressed in species populations, it is not expected that there will be any incremental or cumulative impact on bird populations from cooling tower collision mortality due to relicensing of current nuclear plants. The cumulative effect of bird mortality is further considered with transmission lines in Section 4.5.6.2. Avian mortality resulting from collision with cooling towers is a Category 1 issue.

4.3.6 Human Health

Some microorganisms associated with cooling towers and thermal discharges can have deleterious impacts on human health. Their presence can be enhanced by thermal additions. These microorganisms include the enteric pathogens *Salmonella* sp. and *Shigella* sp. as well as *Pseudomonas aeruginosa* and the thermophilic fungi (Appendix D). Tests for these pathogens are well established, and factors germane to their presence in aquatic environs are known and in some cases controllable. Other aquatic microorganisms normally present in surface waters have only recently been recognized as pathogenic for humans. Among these are Legionnaires' disease bacteria (*Legionella* sp.) and free-living amoebae of the genera *Naegleria* and *Acanthamoeba*, the causative agents of various, although rare, human infections. Factors affecting the distribution of *Legionella* sp. and pathogenic free-living amoebae are not well understood. Simple, rapid tests for their detection and procedures for their control are not yet available. The impacts of nuclear plant cooling towers and thermal discharges are considered of small significance if they do not enhance the presence of microorganisms that are detrimental to water and public health.

Potential adverse health effects on workers due to enhancement of microorganisms are an issue for steam-electric plants that use cooling towers. Potential adverse health effects on the public from thermally enhanced microorganisms is an issue for the nuclear plants that use cooling ponds, lakes, or canals and that discharge to small rivers. These plants are all combined in the category of small river (average flow less than 2830 m^3/s (100,000 ft^3/s) in Tables 5.18 and 5.19. These issues were evaluated by reviewing what is known about the organisms that are potentially enhanced by operation of the steam-electric plants.

Because of the reported cases of fatal *Naegleria* infections associated with cooling towers, the distribution of these two pathogens in the power plant environs was studied in some detail (Tyndall et al. 1983; see also Appendix D). In response to these various studies (Appendix D), many electric utilities require respiratory protection for workers when cleaning cooling towers and condensers. However, no Occupational Safety and Health Administration (OSHA) or other legal standards for exposure to microorganisms exist at present. Also, for worker protection, one plant with high concentrations of *Naegleria fowleri* in the circulating water successfully controlled the pathogen through chlorination before its yearly downtime operation (Tyndall et al. 1983).

Changes in the microbial population and in the use of bodies of water may occur after the operating license is issued and the

application for license renewal is filed. Ancillary factors may also change, including average temperature of water resulting from climatic conditions. Finally, the long-term presence of a power plant may change the natural dynamics of harmful microorganisms within a body of water by raising the level of *N. fowleri*, which are indigenous to the soils. Increased populations of *N. fowleri* may have significant adverse impacts. On entry into the nasal passage of a susceptible individual, *N. fowleri* will penetrate the nasal mucosa. The ensuing infection results in a rapidly fatal form of encephalitis. Fortunately, humans in general are resistant to infection with *N. fowleri*. Hallenbeck and Brenniman (1989) have estimated individual annual risks for primary amebic meningoencephalitis caused by the free living *N. fowleri* to swimmers in fresh water, to be approximately 4×10^{-6}. Heavily used lakes and other fresh bodies of water may merit special attention and possibly routine monitoring for *N. fowleri*.

Thermophilic organisms may or may not be influenced by the operation of nuclear power plants. The issue is largely unstudied. However, NRC recognizes a potential health problem stemming from heated effluents. Occupational health questions are currently resolved using proven industrial hygiene principles to minimize worker exposures to these organisms in mists of cooling towers. NRC anticipates that all plants will continue to employ proven industrial hygiene principles so that adverse occupational health effects associated with microorganisms will be of small significance at all sites, and no mitigation measures beyond those implemented during the current term license would be warranted. Aside from continued application of accepted industrial hygiene procedures, no additional mitigation measures are expected to be warranted as a result of license renewal. This is a Category 1 issue.

Public health questions require additional consideration for the 25 plants using cooling ponds, lakes, canals, or small rivers (all under the small river category in Tables 5.18 and 5.19) because the operation of these plants may significantly enhance the presence of thermophilic organisms. The data for these sites are not now at hand and it is impossible to predict the level of thermophilic organism enhancement at any given site with current knowledge. Thus the impacts are not known and are site-specific. Therefore, the magnitude of the potential public health impacts associated with thermal enhancement of *N. fowleri* cannot be determined generically. This is a Category 2 issue.

4.3.7 Noise Impacts

When noise levels are below the levels that result in hearing loss, impacts have been judged primarily in terms of adverse public reactions to the noise. Generally, power plant sites do not result in off-site levels more than 10 dB(A) above background. However, some sites have calculated impacts to critical receptors at this level and above. Noise level increases larger than 10 dB(a) would be expected to lead to interference with outdoor speech communication, particularly in rural areas or low-population areas where the day-night background noise level is in the range of 45–55 dB(A). Generally, surveys around major sources of noise such as large highways and airports have found that, when the day-night level increases beyond 60 to 65 dB(A) (FICN 1992), noise complaints increase significantly. Noise

levels below 60 to 65 dB(A) are considered to be of small significance.

The principal sources of noise from plant operations are natural-draft and mechanical-draft cooling towers, transformers, and loudspeakers. Other occasional noise sources may include auxiliary equipment such as pumps to supply cooling water from a remote reservoir. Generally, these noise sources are not perceived by a large number of people off-site.

In most cases, the sources of noise are sufficiently distant from critical receptors outside the plant boundaries that the noise is attenuated to nearly ambient levels and is scarcely noticeable. However, during the original license application process, some of the sites identified critical receptors near plant boundaries that would experience noise levels greater than 10 dB above ambient. Those levels would increase the difficulty in outdoor speech communication. (The noise would require that people speak louder to communicate.) In no case is the off-site noise level from a plant sufficient to cause hearing loss.

Natural-draft and mechanical-draft cooling towers emit noise of a broadband nature, whereas transformers emit noise of a specific tonal nature at harmonics of the 60-Hz primary frequency. The frequencies with important intensities are 120, 240, 360, and 480 Hz. Loudspeakers emit noise at audible frequencies, generally below 5000 Hz. Because of the broadband character of the cooling towers, the noise associated with them is largely indistinguishable and less obtrusive than transformer noise or loudspeaker noise. Transformer noise is distinct because of its specific low frequencies. These low frequencies are not attenuated with distance and intervening materials as much as higher frequencies are; thus, low frequencies are more noticeable and obtrusive. However, at most sites employing cooling towers, transformer noise is masked by the broadband cooling tower noise. Loudspeakers would be a more intermittent source of noise.

Cooling tower and transformer noises do not change appreciably with time. No change in noise levels or their attendant impacts would be expected during the license renewal term.

License renewal does not add to the extent of noise impacts, either in frequency distribution or in intensity. No major changes in the noise profile of power plants is anticipated. The only possible source of added impacts would be the result of additional people who build homes near enough to the site that they are affected by noise. At the noise levels anticipated, no cumulative biological impacts are expected.

During the license renewal term, noise impacts will be the same as during the initial license term. These impacts were found to be generally not noticed by the public, thus noise impacts are of small significance. Consideration was given to mitigating these noise impacts. Because the principal sources of noise are cooling towers, transformers, and loudspeakers, these sources would be the focus of noise reduction efforts. Reduction in loudspeaker noise could be accomplished by restricting such use to emergencies only and using personal electronic pagers to contact personnel. Mitigation of the low-frequency noise from cooling towers or transformers is much more difficult and would require shielding by massive concrete structures or earthen berms.

Because these noise reduction methods would be costly and given that there have been few complaints and the noise impacts are so small, no additional mitigation measures are warranted for license renewal. This is a Category 1 issue.

4.4 COOLING PONDS

4.4.1 Introduction

Power plants that use cooling ponds compose a unique subset of closed-cycle systems in that they operate as once-through power plants [i.e., large condenser flow rates (Table 2.1)] that withdraw from and discharge to relatively small bodies of water created for the plant. Cooling ponds reduce the heat load to natural bodies of water from power plant operations without the construction and operational expenses of cooling towers. The natural body of water is not relied on for heat dissipation but is used as a source of makeup water to replace that lost to evaporation and as a receiving stream for discharges from the cooling pond.

4.4.1.1 Types of Cooling Ponds

The range of power plants that use cooling ponds or lakes represents a gradation from closed-cycle power plants sited on small cooling ponds to once-through power plants sited on large, multipurpose reservoirs. For the purpose of this section, a cooling pond will be defined as "a man-made impoundment that does not impede the flow of a navigable system and that is used primarily to remove waste heat from condenser water prior to recirculating the water back to the main condenser" (ORNL/NUREG/TM-226). Under this definition, nine nuclear power plants use cooling ponds: Braidwood, Clinton, Dresden, La Salle, H. B. Robinson, South Texas, Virgil C. Summer, Wolf Creek, and Turkey Point (actually an extensive system of canals for recirculating water). Effects of other power plants located on large, multipurpose reservoirs (e.g., Comanche Peak and William B. McGuire) are included in the analysis of once-through cooling systems in Section 4.2.

The surface areas of the cooling ponds associated with these nine plants range from 629 to 2924 ha (1573 to 7310 acres). Braidwood, Clinton, Dresden, La Salle, and South Texas all use large cooling ponds that rely on nearby rivers for makeup water. Both H. B. Robinson and Clinton recycle their heated effluent in cooling ponds that are impoundments of relatively small creeks. The Virgil C. Summer plant dissipates waste heat to Monticello Reservoir, which in turn receives makeup water from Parr Reservoir. Wolf Creek recycles its condenser cooling water through a cooling pond that receives its makeup water from nearby John Redmond Reservoir. Turkey Point recirculates condenser cooling water through a complex series of canals.

4.4.1.2 Cooling Pond Emissions and Effluents

Power plants sited on cooling ponds do not have unique effluents or emissions. The examples considered in this section represent open-cycle condenser cooling systems that use the man-made pond to recirculate cooling water. Discharges to natural waters are used primarily to control the buildup of dissolved solids, analogous to blowdown from cooling towers, and may or may not have elevated temperatures. The types of emissions and effluents are the same as those considered for once-through cooling systems in Section 4.2.