UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR OPERATIONS, INC.; ENTERGY NUCLEAR INDIAN POINT 2, LLC; ENTERGY NUCLEAR INDIAN POINT 3, LLC; HOLTEC INTERNATIONAL; and HOLTEC DECOMMISSIONING INTERNATIONAL, LLC; APPLICATION FOR ORDER CONSENTING TO TRANSFERS OF CONTROL OF LICENSES AND APPROVING CONFORMING LICENSE AMENDMENTS (Indian Point Nuclear Generating Station)	Docket Nos.: 50-3 50-247 50-286 72-051

DECLARATION OF TIMOTHY B. RICE

I, Timothy B. Rice, declare and state as follows:

1. I have worked as a Health Physicist in the New York State Department of Environmental Conservation (DEC or Department) for more than 25 years. Currently I am working in a title classified as Environmental Radiation Specialist 3 (ERS3) and serving as Chief of the Radioactive Materials Management Section within the Division of Materials Management. My section is responsible for overseeing the identification, characterization, and remediation of radiologically contaminated sites throughout New York State, and it is in this capacity that I am familiar with the Indian Point Nuclear Generating Station (Indian Point). My section is additionally

responsible for permitting transporters of low-level radioactive waste in the State, making determinations on issues of disposal of radioactive waste, and adjudicating the detection of radioactive materials in solid waste streams.

2. I have worked on many radiological environmental characterization and remediation sites for the Department, including at Indian Point Units 1 and 2 and at three other nuclear power reactors in the state. I have also worked at several research reactor sites, including: the Cintichem medical isotope production facility, the SUNY Buffalo research reactor, the Brookhaven National Laboratory High-flux Beam Reactor and Graphite Research Reactor; at defense related installations at the Seneca Army Depot, Knolls Atomic Power Laboratory facilities and associated sites, and at the West Valley commercial spent nuclear fuel reprocessing center in Cattaraugus County, New York. I was also responsible for overseeing the monitoring and maintenance of two former low-level radioactive waste disposal facilities—the state-licensed Disposal Area at the West Valley site, and the Cornell University Radiation Disposal Site (RDS)—and the radiological closure of the RDS. In the course of my duties I located, identified and characterized numerous instances of radiological environmental contamination and oversaw characterization and remediation activities at many of these contaminated sites.

3. I have more than thirty-seven years of experience working in the fields of environmental radiation and personnel monitoring and protection, including thirteen years in the private sector working as a Radiation Safety Officer for a tritium light manufacturer, and as a senior health physics technician and Environmental

Associate for a research reactor and "hot lab" facility. My responsibilities have included personnel bioassay and dosimetry, providing health physics coverage for personnel working at the Cintichem combined reactor and hot lab facility, the collection, preparation and analysis of operational and environmental samples, updating health physics and environmental program policies and procedures, updating and expanding the Cintichem site environmental monitoring program and developing and managing a 24/7 radiological analytical laboratory to support both the environmental monitoring and decommissioning efforts. In that context I identified environmental contamination and traced it back to a failed ventilation system that became a significant contributing factor in the decision to decommission that facility. *See* Rice Exhibit A, Curriculum Vitae.

4. In my opinion, and based on more than twenty years of investigating numerous radiological incidents at Indian Point that have contaminated structures and spread radiological contamination through drainage systems and groundwater at the site, Holtec has not demonstrated it has sufficient and accurate information regarding site contamination upon which to base its Post Shutdown Decommissioning Activities Report and Site-Specific Decommissioning Cost Estimate for Indian Point Nuclear Generating Station Units 1, 2, and 3 (December 19, 2019) (PSDAR). Holtec' s PSDAR submission to the NRC makes only passing reference to the legacy of radiological and environmental contamination known at the site. Based on my experience at Indian Point, and involvement with radiological decommissioning of other sites in New York, it is my professional opinion that Holtec will likely uncover

significant additional radiological contamination that will increase the scope, remedial needs and cost of the decommissioning process at Indian Point.

New York's Regulatory Authority and Responsibilities

5. Pursuant to section 274 of the federal Atomic Energy Act, the Nuclear Regulatory Commission can relinquish to a state portions of its regulatory authority, specifically to license and regulate byproduct materials (radioisotopes); source material (uranium and thorium in quantities not sufficient to form a critical mass); and certain quantities of special nuclear material. The mechanism for the transfer of NRC's authority to a state is an agreement signed by the governor of the state and the chair of the Commission, in accordance with section 274b of the Act. New York entered into such an agreement with the Atomic Energy Commission in 1962. *See* Rice Exhibit B, Agreement.

6. Under the Act, the NRC retains regulatory authority over all aspects of the use of radioactive materials at all licensed reactor sites within New York State, including nuclear power reactors such as Indian Point. The NRC is therefore the sole regulator of the use and environmental discharge of, and environmental contamination by, radioactive materials at Indian Point and other licensed reactor sites in New York. That said, state environmental regulations apply to radiological contamination that has migrated off NRC-regulated sites. Additionally, property released from NRC licensing authority reverts to agreement-state authority for radioactive materials usage or contamination.

7. New York implements its authority as an agreement state through licensing the use of radioactive materials, permitting their environmental discharges, permitting transporters of low-level radioactive waste (LLRW), regulating the disposal of LLRW, and overseeing the characterization and remediation of radiologically contaminated properties. The Department is one of three agencies, including the New York State Department of Health and the New York City Department of Health and Mental Hygiene, that make up the New York agreement state program.

8. Agreement state programs are afforded the opportunity to accompany NRC staff during inspections of NRC licensees in their respective states. The Department's radiation program staff can and does accompany NRC personnel on select inspections of NRC licensees in New York, particularly where the Department determines that NRC licensed facilities present conditions of special interest or concern for the environment and citizens of the state. In that context, I and other Department staff, and representatives from the State Department of Health, have accompanied NRC on numerous inspections of Indian Point regarding known or suspected radiological environmental releases or contamination events.

The Indian Point Nuclear Power Station

9. The Indian Point site consists of 239 acres of land located on the eastern shore of the Hudson River in the Village of Buchanan, Westchester County. It is approximately 2.5 miles south of the City of Peekskill and approximately 24 miles north of New York City. The site contains three nuclear power reactors, a 275 MW Babcock & Wilcox pressurized water reactor (Unit 1) in SAFESTOR since 1976, two

Westinghouse 1,000 MW 4-loop pressurized water reactors (Units 2 and 3) that are still in operation at this time; their associated spent fuel pools and turbine halls; individual tertiary cooling water withdrawal structures in the Hudson River; the combined discharge canal on the Hudson River; an independent spent fuel storage installation (ISFSI, also known as a dry cask storage pad) serving all three reactors; ancillary support structures; and the site electrical transmission infrastructure. There are also two below-grade high-volume natural gas transmission lines that enter the site from the west, south of Indian Point Unit 3 where they emerge from beneath the Hudson River, exiting the site to the east on their way to supplying gas to the New England States. *See* Rice Exhibit C, Indian Point Aerial View.

10. Indian Point generates electricity for the regional electrical grid by utilizing the heat from the nuclear fission of enriched-uranium fuel (splitting the nucleus of the very large uranium-235 atom into new, smaller radioisotopes called fission products) to produce steam that spins turbines and electrical generators. The radioactive fission products must be contained within the active fuel in the reactor core, and within spent fuel in the fuel pool and ISFSI, in order to protect the public and the environment from radiological contamination. At Indian Point, roughly one third of the uranium fuel in a reactor is replaced every two years after which it is offloaded from the reactor core and stored in a water-filled spent fuel pool. Eventually, the oldest fuel in the pool is transferred to storage casks and then to the Indian Point ISFSI north of Unit 2 for long-term storage. It will remain on the ISFSI until the

federal government approves a permanent fuel repository or authorizes a centralized interim storage facility. *See* Rice Exhibit D, Indian Point Unit 2 Systems Diagram.

11. Reactor coolant and spent fuel pool water are routinely treated to reduce radiological contaminants in the water and to remove particulate contamination. However, these treatment systems are ineffective in removing tritium (H-3, radioactive hydrogen) from the water, resulting in tritium concentrations in the millions of picocuries per liter (pCi/l) in the pool water. Based on my experience, the detection of tritium concentrations above background levels in the soil or groundwater at nuclear reactor sites usually indicates the presence of a leak from either the reactor containment structures or spent fuel pools, and associated systems.

12. In my capacity with the Department, I have direct knowledge of numerous known radiological environmental contamination incidents at Indian Point. These incidents have been associated primarily with the operation of Units 1 and 2 and involved leaks of contaminated water from the reactor systems and spent fuel pools to site groundwater and, ultimately, to the Hudson River. These leaks have left a legacy of contamination in the systems and concrete of the structures themselves, and have similarly contaminated the fill, concrete, and bedrock beneath and around the Unit 1 and Unit 2 reactors and spent fuel pool buildings. The shared underground storm and process drain systems have also spread contamination at the site. Two known on-site groundwater contamination plumes of primarily tritium and radioactive strontium (Strontium-90, Sr-90) extend downgradient to the Hudson River from

both the Unit 1 and Unit 2 spent fuel pools. *See* Rice Exhibit E, Hydrogeologic Site Investigation Report, 2008, at 91, 101.

13. I have been involved in Department investigations of Indian Point contamination throughout my tenure through accompaniment of NRC inspection activities. In 1994, I participated in an NRC inspection looking into a report of significant concentrations of radioactivity in the Sphere Foundation Drain Sump located in the lowest levels of the Chemical Systems Building adjacent to the Unit 1 spent fuel pools. The investigation found that tritium and other fission and activation products were escaping from degraded stainless steel-clad fuel assemblies, contaminating the Unit 1 spent fuel pool water, and making their way into building drain systems through leaks from the unlined fuel pools. In response, improvements to the drainage systems around and beneath the Unit 1 complex were made to collect and contain this leaking contaminated fuel pool water, and a water treatment system was installed to remove radiological contaminants from the fuel pool water. In addition, water flow was redirected from the drain sump that had historically flowed through a storm drain south of Unit 1, into drains in a utility tunnel leading more directly to the common site discharge canal. Even after these modifications, however, I expressed our concern to the NRC inspectors and licensee staff that at least some contaminated water in the drain system was not being collected and was continuing to reach site groundwater, which flows west towards the Hudson River.

14. The investigation of this incident also uncovered the presence of Sr-90 contamination in soils around the storm drain leading from the south side of Unit 1.

The sphere foundation drain sump had been discharging to this storm drain since construction of the facility in the early 1960s. *See* Rice Exhibit E at 111–113.

15. In 2005 the current licensee, Entergy, reported to the state and other site stakeholders that they had identified a previously unknown leak of tritium-contaminated water from the Unit 2 spent fuel pool while excavating to bedrock immediately adjacent to its exterior. The purpose of the excavation was the installation of a new crane system to support spent fuel transfers from the pool to the ISFSI. During the excavation, Entergy contractors observed water seeping from hairline cracks in the concrete pool wall, and testing disclosed the water was contaminated with tritium. Later investigations also subsequently identified and repaired a pinhole leak in a weld in the transfer canal portion of the Unit 2 spent fuel pool that, according to the licensee report to the NRC, had likely existed since construction of the spent fuel pool in 1976. *See* Rice Exhibit E at 94.

16. The Department participated in the initial NRC investigation into the extent of tritium contamination from the Unit 2 spent fuel pool. This investigation entailed the sampling and testing of existing and newly-drilled groundwater monitoring wells. Testing revealed an extensive Sr-90 groundwater plume originating from the Unit 1 building complex, attributable to the long-standing Unit 1 spent fuel pool water leak.

17. Spent fuel was transferred from the Unit 1 pool to dry cask storage, and the Unit 1 pool was drained in November of 2008, ending any active ongoing releases of radioactive material from the pool complex. However, in my opinion contamination

likely remains within the leakage pathways in the facility concrete as well as in the building drainage system, surrounding fill, preconstruction concrete mud mats, and bedrock fractures around and beneath Unit 1.

18. Analytical results reported in the 2008 Hydrogeologic Site Investigation for Indian Point clearly show the presence of the accumulation of less mobile fission product and activation products around and downgradient of Unit 1 (monitoring wells 38, 42, 50, 53, 57, 58.) The results show cesium-137 (Cs-137) as high as 102,000 pCi/l, nickel-63 (Ni-63) as high as 5,120 pCi/l, and cobalt-60 (Co-60) as high as 88 pCi/l, all in monitoring well 42. *See* Exhibit E, Table 5.1 Groundwater Analytical Data. In my opinion, these data clearly show that activation and fission products in leaking Unit 1 spent fuel pool water have left a legacy of subsurface radiological contaminants in this area of the site. In my opinion, determining the extent of this contamination in the groundwater, bedrock, fill, and structural concrete in and around Unit 1 is crucial to the development of an adequate decommissioning plan and decommissioning cost estimate for the Indian Point site.

19. The Hydrogeologic Site Investigation data also clearly show that areas of radiological contamination dispersed across much of the Indian Point site. These data include the presence of Cs-137 in multiple monitoring wells adjacent to both Units 1 and 2, in the Unit 2 transformer yard, along the Unit 1 utility tunnel, in one well upgradient of the Unit 3 containment (though downgradient of the Unit 1 drain system in which Sr-90 was detected earlier), and in monitoring well 38 immediately along the lower end of the discharge canal (possibly due to contaminated groundwater

flow along the outer (eastern) side of the canal wall). *See* Exhibit E, Table 5.1 Groundwater Analytical Data. In my opinion, these data are another strong indicator of the likely existence of additional as-yet unidentified areas of subsurface radiological contamination within the controlled area of Indian Point.

20. To summarize, there is a long history of facility and environmental radiological contamination in, around, and downgradient of the Unit 1 reactor and spent fuel pool. The known areas of fission product contamination are already quite extensive, though they have not yet been well characterized. Contamination exists in the structural concrete in and around the pool, drain systems in, under, and around the fuel storage building/chemical services building, primary auxiliary building, and reactor containment, as well as in underlying fill and bedrock, and the groundwater plume leading to the Hudson River.

21. There is an extensive groundwater contamination plume containing primarily Sr-90 and tritium present around and beneath the Unit 1 reactor, spent fuel, chemical services, and adjacent primary auxiliary buildings that extends to and into the Hudson River. Less mobile fission and activation products remain closer to the Unit 1 structures, within and surrounding those structures and in construction fill, the construction mud mat, and in bedrock underlying, surrounding, and downgradient of them. The primary source of this contamination is a long-standing leak from the Unit 1 spent fuel pool that was not addressed in a timely manner and never adequately contained.

22. There is also a history of facility and environmental contamination in and around Unit 2. The previously discussed spent fuel pool leaks led to contamination of the concrete surfaces in contact with the fuel pool liner and contamination of the concrete within the pool walls due to the presence of cracks in the concrete. The leaks have also allowed contaminated pool water to flow into the surrounding environment resulting in contamination of surrounding fill and bedrock and an extensive groundwater plume of tritium. That plume flows into the Hudson River and has also entered the site storm drain system. Additionally, long-standing operator neglect of maintenance and misuse of facility floor drains has led to internal contamination of areas of Unit 2 and the primary auxiliary building. This has occurred through drain overflows onto facility floors, the draining of that water down through several levels of the buildings, and leakage of that water into the surrounding fill, soil and bedrock through structural joints and shrinkage cracking.

23. I am not directly aware of any evidence of radiological environmental contamination associated with the operation of Unit 3. However, historic site contamination and the radiological leaks from the adjacent Units 1 and 2 have led to environmental contamination in the vicinity of Unit 3 by way of the site storm drain system. *See* Rice Exhibit F, NRC Inspection Report, May 13, 2008 (ML081340425).

24. Further, in preparation for the construction of Unit 3 during the mid-1970s, Con Edison excavated a Unit 1 septic leach field, and the resulting radiologically contaminated soil was disposed of in an on-site impoundment at the southern end of the property. In their 2006 response to the Nuclear Energy Institute

groundwater questionnaire discussed above, Entergy identified this on-site disposal location as the site of one of a number of inadvertent radioactive liquid releases and "other smaller inadvertent releases and spills" that have also occurred (along with the already mentioned Unit 1 and 2 pool releases, storm drain infiltration and other events). *See* Rice Exhibit G, Entergy Ground Water Protection Baseline Information, July 31, 2006 (ML062220228).

Unknown Radiological Contamination at Indian Point

25. If Holtec performs decontamination and decommissioning of Indian Point, the Department expects they will find potentially significant additional areas of contamination that will need to be remediated. In my opinion, without a comprehensive characterization of the known areas of sub-surface structural and environmental contamination, and realistic planning for addressing other previously unknown areas of contamination in need of remediation, Holtec cannot develop an adequate decommissioning plan or decommissioning cost estimate for Indian Point.

26. In my experience, the decommissioning of large or complex sites with substantial areas of known radiological contamination ordinarily uncovers additional unanticipated areas of radiological contamination. These areas of previously unknown contamination can result in the need for expansion of the scope of decommissioning plan and decontamination efforts and increases in the amount of waste that needs to be managed and disposed. These occurrences often result in project delays and significant decommissioning cost overruns.

27. Examples of this in New York include the former Cintichem reactor and hot lab facility located in Orange County, and the High-Flux Beam Reactor (HFBR) at Brookhaven National Laboratory. Both facilities had to address leaking concrete spent fuel pools similar to that of Indian Point Unit 1. In the case of Cintichem, they also encountered leaking water management systems like what has occurred at Indian Point. In both cases the discovery of previously unanticipated radiological environmental contamination had significant consequences. In the case of Cintichem, decommissioning continued for years longer than planned and resulted in significant cost overruns. In the case of the Brookhaven HFBR, characterization to determine the existence and extent of the fuel pool leak resulted in years of costly management of an extensive tritium groundwater plume, and eventually the closure of the reactor itself.

Conclusions

28. Numerous radiological environmental contamination events have occurred at the Indian Point site since operations commenced in the early 1960s, and the co-location of the three reactors and spent fuel pools, and the use of shared systems and infrastructure, has spread the contamination throughout much of the site. In their PSDAR, Holtec only mentions the Entergy Historical Site Assessment in passing and places little emphasis on a need to perform a comprehensive assessment of radiological environmental contamination on the site. Nor do they appear to take the known or likely yet-to-be-identified environmental contamination into account in the development of a decommissioning plan or decommissioning cost estimate for the

site. In its PSDAR, Holtec does not even appear to acknowledge that there is a need to consider a comprehensive characterization or remediation of radiological contamination in subsurface soils, fill, groundwater, and bedrock; they appear to only commit to the identification and removal of any contamination within the below grade portions of the actual structures.

29. In my opinion, no truly informed conclusions can be drawn at this time regarding the impact of site radiological contamination on radiological doses of future site users. Without a comprehensive environmental characterization of the site, the PSDAR and site-specific decommissioning cost estimate developed by Holtec very likely underestimates the extent of radiological environmental contamination, and also the costs associated with necessary decommissioning.

30. In my opinion, prior to granting any license amendment or transfer for decommissioning, the NRC must have sufficient information to make regulatory decisions regarding whether the scope and extent of proposed decommissioning as outlined in the PSDAR will result in a decommissioning plan that is adequate to protect public health and safety. To that end, the NRC should direct Entergy and/or Holtec to carry out a comprehensive radiological environmental assessment of the Indian Point site to properly account for the extent and ramifications of on-site radiological contamination. The results associated with this assessment should be included in a revised PSDAR and used to develop a comprehensive decommissioning plan, including establishing appropriately conservative derived concentrations guidance limits (DCGLs) applicable to both structural and environmental site contamination.

31. I, Timothy B. Rice, have read the above declaration, consisting of sixteen pages, and certify under penalty of perjury that the foregoing is true and correct. Executed this 7th day of February, 2020.

Timothy B. Rice

TIMOTHY B. RICE

DECLARATION OF TIMOTHY B. RICE
LIST OF EXHIBITS

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Exhibit G	Entergy Ground Water Protection Baseline Information, July 31, 2006 (ML062220228)

Exhibit A

Curriculum Vitae of Timothy B. Rice

Curriculum Vitae
Timothy B. Rice

EDUCATION

AS Forestry and Environmental Science
Herkimer County Community College, 1981
BA Environmental Science
SUNY Plattsburgh, 1981
(Research Scholarship to Miner Institute)
NYU Radiation Health course, 1982

ADDITIONAL EDUCATION

Harvard School of Public Health
- Environmental Radiation Surveillance
- Radioactivity in the Environment

Oak Ridge Associated Universities
- 5-Week Applied Health Physics
- Environmental Monitoring
- Radiation Surveys in Support of Decommissioning

DOE
- DOE/ANL Decommissioning Course
- Radworker II – West Valley Demonstration Project
- L-Security Clearance - Knolls Atomic Power Lab
- Applied Radioactive Waste Management

EPA
- Hazardous Waste Operations and Emergency Response 40-hr & 8-hr annually > 2019
- MARSSIM
- MARLAP
- MARSAME
- NESHAPS Subpart H – Hanford, WA

FEMA
- IS-301 Radiological Emergency Response
- RERO-Radiological Emergency Response Operations

OTHER
- Supervisor of Hazardous Waste Operations
- Dose Assessment and Plume Modeling Training – Various

WORK HISTORY

2009 - Present – Radioactive Materials Management Section Chief, NYS DEC
-DEC Representative on the Conference of Radiation Control Program Directors
Management of program responsible for permitting LLRW transporters, oversite of FUSRAP remedial efforts, coordination with NRC for environmental issues at federally licensed nuclear/RAM facilities, permitting LLRW disposal facilities, identification and characterization of RAM and TENORM contaminated sites,

consultation with Solid Waste program for rad monitoring at landfills including alarm response and isotope identification, determinations for disposal of radiologically contaminated waste, and technical support to NYS Homeland Security radiation detection and interdiction program.

1998 - Environmental Radiation Specialist 2, NYS DEC
-Radiation program environmental monitor for the West Valley site.
-NYS representative on DOE High-level Radioactive Waste Tank Working Group
-NYS representative on DOE State and Tribal Government Working Group
Responsible for program coverage of environmental issues at New York nuclear power generation facilities, including environmental contamination issues at Indian Point, and the three upstate nuclear facilities.

1994 - Environmental Radiation Specialist 1, NYS DEC
Field work including radiological site investigations, management and interpretation of radiological site characterization project data, accompaniment of ERS-2 for inspections of two LLRW disposal sites in New York including the Cornell University Radiation Disposal Site (RDS) and the West Valley State-licensed Disposal Site (SDA). Investigated fuel pool leaks at Indian Point U-1 and Brookhaven National Laboratory High-flux Beam Reactor.

May 1988 – May 1994 – Environmental Associate, Cintichem Inc
Responsible for expansion and operation of environmental monitoring program and on-site analytical laboratory, including: effluent and environmental monitoring and records management, offsite dose calculations, maintenance and operation of NaI, HPGe, and Alpha-beta systems supporting site environmental and decommissioning programs, management of environmental TLD program, interaction with regulators, preparation of DMR's and radiological effluent reports, periodic land-use census, training and supervision of environmental and laboratory technicians. Training coordinator for industrial first-aid squad. Developed and maintained env program procedures. Performed environmental special-investigations that identified radiological ground, surface, and drinking water contaminations that identified/verified major hot lab ventilation and sitewide water management system malfunctions that contributed to site closure and decommissioning. Expanded and supervised 24/7 analytical lab supporting facility decommissioning. Oversight of radiological analysis for, and authorized batch water releases from, process and decommissioning activities.

Sept. 1984 – May 1988 – Senior Health Physics Technician, Cintichem Inc. (Commercial reactor, hot lab, and medical isotope production facility) – Collected and analyzed routine air, water and wipe test samples; routine and special project contamination and air quality management; HP coverage for manned entries of hot cells and other high-hazard operations, Performed the first-in-a-generation manned entry in to the reactor holdup tank to perform initial tank condition assessment and

radiation survey, prepared and processed personnel TLDs, supervised junior HP technicians, extensive revision of Health Physics Manual, member of emergency response Radiological Assessment Team.

April 1982 – Sept. 1984 – Radiation/Safety Supervisor, Self-Powered Lighting
Responsible for industrial safety, radiation safety, and environmental monitoring for a tritium light manufacturer including: revision and implementation of company Radiation Safety Manual, receipt and control of 8,000 Ci gaseous H-3 shipments and transfers to DU storage traps, filling of lights from storage traps, and air discharge minimization. Personnel dosimetry and exposure control, facility contamination control. In-plant air sampling, stack and environmental sampling and analysis. Operation and expansion of environmental monitoring program (pursuant to DEC CO), Heath Physics coverage for decontamination and decommissioning of portions of manufacturing facility.

Aug. 1981 – Feb. 1982 Environmental Lab Technician, Lawler, Matusky and Skelly Engineers
Atomic absorption and wet chemistry analysis of sediments, potable, surface, and waste waters using EPA approved methods.

Exhibit B

Agreement Between the U.S. AEC and State of New York, 1962

AGREEMENT BETWEEN THE UNITED STATES ATOMIC ENERGY COMMISSION AND THE STATE OF NEW YORK FOR DISCONTINUANCE OF CERTAIN COMMISSION REGULATORY AUTHORITY AND RESPONSIBILITY WITHIN THE STATE PURSUANT TO SECTION 274 OF THE ATOMIC ENERGY ACT OF 1954, AS AMENDED

WHEREAS, The United States Atomic Energy Commission (hereinafter referred to as the Commission) is authorized under Section 274 of the Atomic Energy Act of 1954, as amended, (hereinafter referred to as the Act) to enter into agreements with the Governor of any State providing for discontinuance of the regulatory authority of the Commission within the State under Chapters 6, 7, and 8, and Section 161 of the Act with respect to byproduct materials, source materials, and special nuclear materials in quantities not sufficient to form a critical mass; and

WHEREAS, The Governor of the State of New York is authorized under Section 462 of the New York State Atomic Energy Law to enter into this Agreement with the Commission; and

WHEREAS, The Governor of the State of New York certified on July 20, 1962, that the State of New York (hereinafter referred to as the State) has a program for the control of radiation hazards adequate to protect the public health and safety with respect to the materials within the State covered by this Agreement, and that the State desires to assume regulatory responsibility for such materials; and

WHEREAS, information as to the Radiation Control Program within the State of New York was submitted to the Commission on July 20, 1962, August 20, 1962 and October 8, 1962; and

WHEREAS, The Commission found on October 12, 1962, that the program of the State for the regulation of the materials covered by this Agreement is compatible with the Commission's program for the regulation of such materials and is adequate to protect the public health and safety; and

WHEREAS, The State and the Commission recognizes the desirability and importance of cooperation between the Commission and the State in the formulation of standards for protection against hazards of radiation and in assuring that State and Commission programs for protection against hazards of radiation will be coordinated and compatible; and

WHEREAS, The Commission and the State recognize the desirability of reciprocal recognition of licenses and exemption from licensing of those materials subject to this Agreement; and

NOW, THEREFORE, It is hereby agreed between the Commission and Governor of the State, acting in behalf of the State, as follows:

ARTICLE I

Subject to the exceptions provided in Articles II, III, and IV, the Commission shall discontinue, as of the effective date of this Agreement, the regulatory authority of the Commission in the State under Chapters 6, 7, and 8, and Section 161 of the Act with respect to the following materials:

A. Byproduct materials;

B. Source materials; and

C. Special nuclear materials in quantities not sufficient to form a critical mass.

ARTICLE II

This Agreement does not provide for discontinuance of any authority and the Commission shall retain authority and responsibility with respect to regulation of:

A. The construction and operation of any production or utilization facility;

B. The export from or import into the United States of byproduct, source, or special nuclear material, of any production or utilization facility;

C. The disposal into the ocean or sea of byproduct, source, or special nuclear waste materials as defined in regulations or orders of the Commission;

D. The disposal of such other byproduct, source, or special nuclear material as the Commission from time to time determines by regulation or order should, because of the hazards or potential hazards thereof, not be so disposed of without a license from the Commission.

ARTICLE III

Notwithstanding this Agreement, the Commission may from time to time by rule, regulation, or order, require that the manufacturer processor, or producer of any equipment, device, commodity, or other product containing source, byproduct, or special nuclear material shall not transfer possession or control of such product except pursuant to a license or an exemption from licensing issued by the Commission.

ARTICLE IV

This Agreement shall not affect the authority of the Commission under subsection 161 b. or i. of the Act to issue rules, regulations, or orders to protect the common defense and security, to protect restricted data or to guard against the loss or diversion of special nuclear material.

ARTICLE V

The Commission will use its best efforts to cooperate with the State and other agreement States in the formulation of standards and regulatory programs of the State and the Commission for protection against hazards of radiation and to assure that State and Commission programs for protection against hazards of radiation will be coordinated and compatible. The State will use its best efforts to cooperate with the Commission and other agreement States in the formulation of standards and regulatory program of the State and the Commission for protection against hazards of radiation and to assure that the State's program will continue to be compatible with the program of the Commission for the regulation of like materials. The State and the Commission will use their best efforts to keep each other informed of proposed changes in their respective rules and regulations and licensing, inspection and enforcement policies and criteria, and to obtain the comments and assistance of the other party thereon.

ARTICLE VI

The Commission and the State agree that it is desirable to provide for reciprocal recognition of licenses for the materials listed in Article I licensed by the other party or by any agreement State. Accordingly, the Commission and the

State agree to use their best effort to develop appropriate rules, regulations, and procedures by which such reciprocity will be accorded.

ARTICLE VII

The Commission and the State recognize that the limits on their respective rights, powers and responsibilities under the Constitution, with respect to protection against radiation hazards arising out of the activities licensed by the Commission within the State, are not precisely clear. The Commission and the State agree to work together to define, within a reasonable time, the limits of, and to provide mechanisms for accommodating, such responsibilities of both parties. Without prejudice to the respective rights, powers and responsibilities of Federal and State authority, the State undertakes to obtain promptly and to maintain in effect while such cooperative endeavors are in progress, a modification of the Health, Sanitary and Industrial Codes which are to become effective within the State as of October 15, 1962, so as to exempt (except for registration; notification; inspection, not including operational testing but including sampling which would not substantially interfere with or interrupt any Commission licensed activities; and routing and scheduling of material in transit) licensees of the Commission from so much of such Codes as pertain to protection against radiation hazards arising out of activities licensed by the Commission within the State. While such cooperative endeavors are in progress, the existence or nonexistence of the exemptions and exceptions referred to above shall not prejudice the exercise by the Commission or the State, in an emergency situation presenting a peril to the public health and safety, of any constitutional rights and powers the Federal Government or the State may have now or in the future. If such cooperative endeavors do not result in

a definition, within a reasonable time, of the limits of, and provision of mechanisms for accommodating, the responsibilities of the Commission and the State with respect to protection against radiation hazards arising out of the activities licensed by the Commission within the State, then the existence or nonexistence of the exemptions and exceptions referred to above shall not prejudice the exercise by the Commission or the State of any constitutional rights and powers the Federal Government or the State may have now or in the future.

ARTICLE VIII

The Commission, upon its own initiative after reasonable notice and opportunity for hearing to the State, or upon request of the Governor of the State, may terminate or suspend this Agreement and reassert the licensing and regulatory authority vested in it under the Act if the Commission finds that such termination or suspension is required to protect the public health and safety.

ARTICLE IX

This Agreement shall become effective on October 15, 1962, and shall remain in effect unless, and until such time as it is terminated pursuant to Article VII.

Done at Washington, District of Columbia, in triplicate, this 15th day of October, 1962.

FOR THE UNITED STATES ATOMIC ENERGY COMMISSION

/s/ Glenn T. Seaborg

Glenn T. Seaborg, Chairman

Done at Albany, State of New York, in triplicate, this 15th day of October, 1962.

FOR THE STATE OF NEW YORK

/s/ Nelson A. Rockefeller,

Nelson A. Rockefeller, Governor

Exhibit C

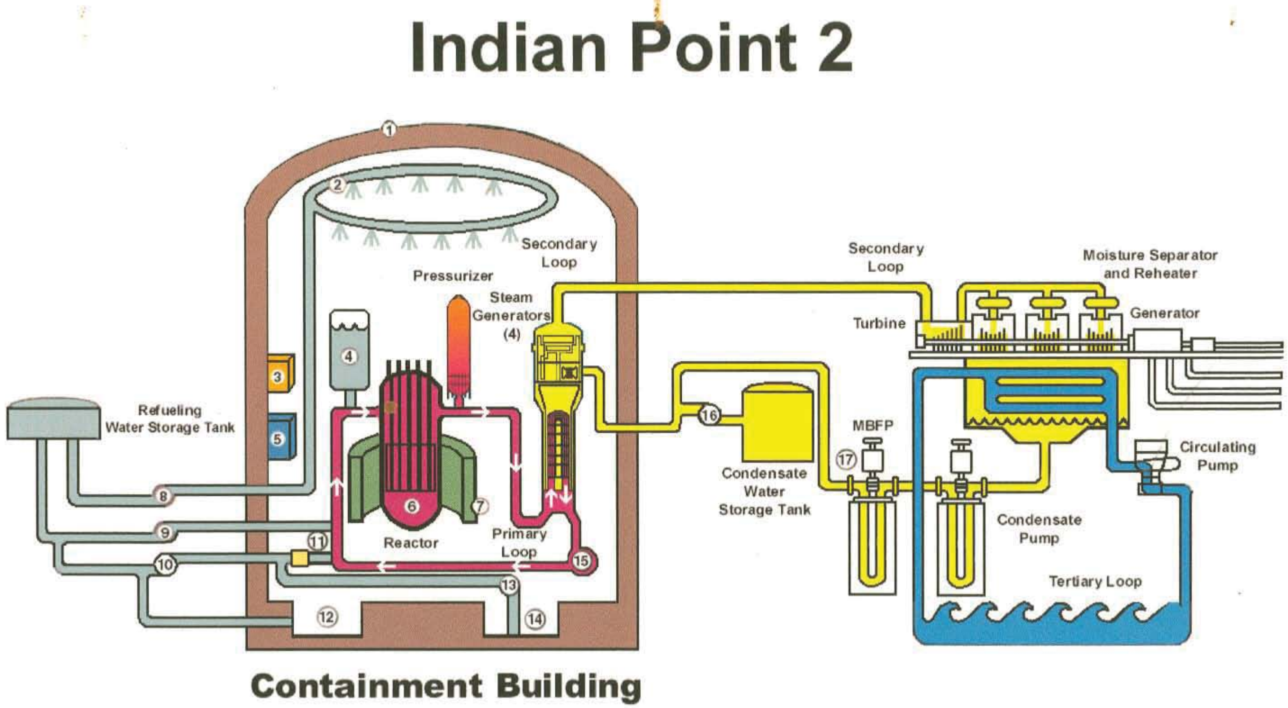
Indian Point Nuclear Power Station – Aerial View

EXHIBIT C – Indian Point Nuclear Power Station Aerial View

Exhibit D

Indian Point Unit 2 Systems Diagram

EXHIBIT D – Indian Point Unit 2 Systems Diagram



1	Containment	10	Residual Heat Removal Pumps (2)
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Exhibit E

GZA GeoEnvironmental, Inc. Hydrogeologic Site Investigation Report, January 7, 2008 (ML080320450)

GZA
GeoEnvironmental, Inc.

Engineers and Scientists

January 7, 2008
File No. 41.0017869.10

Mr. Robert Evers
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Buchanan, NY 10511-0308

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Norwood
Massachusetts
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781-278-3700
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Subject: Hydrogeologic Site Investigation Report
Indian Point Energy Center
Buchanan, New York

Dear Mr. Evers:

GZA GeoEnvironmental, Inc. (GZA) is pleased to provide the attached Hydrogeologic Site Investigation Report for the Indian Point Energy Center. The report provides a summary of the investigative methods, findings/conclusions and recommendations for work conducted from September 2005 through the end of September 2007.

If you have any questions, please contact either David or Matt.

GZA appreciates the opportunity to provide continued support to Enercon Services and Entergy.

Sincerely,

GZA GEOENVIRONMENTAL, INC.

David M. Winslow, Ph.D., P.G.
Associate Principal

Matthew J. Barvenik, LSP
Senior Principal

Michael Powers, P.E.
Senior Principal

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APPENDICES

ACRONYMS

ADT	Aquifer Drilling and Testing
AGS	Advanced Geological Services
ALARA	As Low As Reasonably Achievable
AREOR	Annual Radiological Environmental Operating Report
ATV	Acoustical Televiewer
CSS	Containment Spray Sump
CSB	Chemical Systems Building
CSM	Conceptual Site Model
EPA	Environmental Protection Agency
EVS	Environmental Visualization Software
GA	Geophysical Applications, Inc.
GPR	Ground Penetrating Radar
GZA	GZA GeoEnvironmental, Inc.
IP	Indian Point
IP1-CSB	Indian Point Unit 1 Chemical Systems Building
IP1-FHB	Indian Point Unit 1 Fuel Handling Building
IP1-SFDS	Indian Point Unit 1 Sphere Foundation Drain Sump
IP1-SFPS	Indian Point Unit 1 Spent Fuel Pool
IP1-CB	Indian Point Unit 1 Containment Building
IP2-FSB	Indian Point Unit 2 Fuel Storage Building
IP2-PAB	Indian Point Unit 2 Primary Auxiliary Building
IP2-SFP	Indian Point Unit 2 Spent Fuel PoolS
IP2-TB	Indian Point Unit 2 Turbine Generator Building
IP2-TY	Indian Point Unit 2 Transformer Yard
IP2-VC	Indian Point Unit 2 Vapor Containment
K	Hydraulic Conductivity
NGVD 29	National Geodetic Vertical Datum of 1929
NYSDEC	New York State Department of Environmental Conservation
MGM	Million Gallons per Minute
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NEI	Nuclear Energy Institute
NCD	North Curtain Drain
NRC	Nuclear Regulatory Commission
OCA	Owner Controlled Area
OTV	Optical Televiewer
RWST	Reactor Water Storage Tank
RQD	Rock Quality Designation
SFDS	Sphere Foundation Drain Sump
SFP	Spent Fuel Pool
SOP	Standard Operating Procedure
SSC	Structures, Systems and Components
TGB	Turbine Generator Building
TY	Transformer Yard
USGS	United States Geological Survey
VC	Vapor Containment

EXECUTIVE SUMMARY

This report presents the results of a two-year comprehensive hydrogeologic site investigation of the Indian Point Energy Center (Site) conducted by GZA GeoEnvironmental, Inc. (GZA). The study was initiated in response to an apparent release of Tritium to the subsurface, initially discovered in August of 2005 during Unit 2 construction activities associated with the Independent Spent Fuel Storage Installation Project. These investigations were subsequently expanded to include areas of the Site where credible potential sources of leakage might exist, and encompassed all three reactor units. Ultimately, these investigations traced the contamination back to two separate structures, the Unit 2 and Unit 1 Spent Fuel Pools (SFPs). The two commingled plumes, resulting from these SFPs releases, have been fully characterized and their extent, activity and impact determined. The two primary radionuclide contaminants of interest were found to be Tritium and Strontium. Other contaminants, Cesium, Cobalt, and Nickel, have been found in a subset of the groundwater samples, but always in conjunction with Tritium or Strontium. Therefore, while the focus of the investigation was on Tritium and Strontium, it inherently addresses the full extent of groundwater radionuclide contamination. The investigations have further shown that the contaminated groundwater can not migrate off-property to the North, East or South. The plumes ultimately discharge to the Hudson River to the West.

Throughout the two years of the investigation, the groundwater mass flux and radiological release to the Hudson River have been assessed. These assessments, along with the resulting Conceptual Site Model, have been used by Entergy to assess dose impact. At no time have analyses of existing Site conditions yielded any indication of potential adverse environmental or health risk. In fact, radiological assessments have consistently shown that the releases to the environment are a small percentage of regulatory limits.

SOURCES OF CONTAMINATION

As stated above, the investigations found that the groundwater contamination is the result of releases from the Unit 2 and the Unit 1 SFPs. Our studies found no evidence of any release from Unit 3.

The predominant radionuclide found in the plume from the Unit 2 SFP pool is Tritium. The releases were due to: 1) historic damage in 1990 to the SFP liner, with subsequent discovery and repair in 1992; and 2) a weld imperfection in the stainless steel Transfer Canal liner identified by Entergy in September 2007, and repaired in December 2007. To the extent possible, the Unit 2 pool liner has been fully tested and repairs have been completed. The identified leakage has therefore been eliminated and/or controlled by Entergy. Specifically, Entergy has: 1) confirmed that the damage to the liner associated with the 1992 release was repaired by the prior owner and is no longer leaking; 2) installed a containment system (collection box) at the site of the leakage discovered in 2005, which precludes further release to the groundwater; and 3) after an exhaustive

liner inspection, identified a weld imperfection in the Transfer Canal liner that was then prevented from leaking by draining the canal. The weld was then subsequently repaired by Entergy in mid-December 2007. Therefore, all identified Unit 2 SFP leaks have been addressed. Water likely remains between the Unit 2 SFP stainless steel liner and the concrete walls, and thus additional active leaks can not be completely ruled out. However, if they exist at all, the data indicate they must be small and of little impact to the groundwater.

The Unit 1 plume is characterized by Strontium from legacy leakage of the Unit 1 fuel pools. At present, the Unit 1 pools have been drained with the exception of the Unit 1 West Fuel Pool which still contains spent fuel. This West Pool leaks water under the fuel building and is responsible for the Unit 1 Strontium groundwater plume discovered in 2006. Prior to that time, the previous owner had identified leakage from the West Fuel Pool in the 1990's and was managing the leakage by collecting it from a re-configured footing drain that surrounded the fuel building. However, based on the groundwater investigation, it has been determined that the pool leakage management program was not successful in collecting all of the leakage. As a result, uncollected contaminants released from the Unit 1 Spent Fuel Pools, past and present, have been observed during the groundwater investigation effort at various locations near the site of Unit 1. In response to the finding that the leak collection system was not functioning as believed, Entergy promptly initiated a program to reduce the concentration of radionuclides in the Unit 1 West Pool's water, beginning in April 2006, via enhanced demineralization water treatment. The planned fuel removal and pool draining will completely eliminate this release source by year end 2008.

EXTENT OF CONTAMINATION

The groundwater contamination is, and will remain, limited to the Indian Point Energy Center property, because the migration of Site contaminants is controlled by groundwater flow, which, in turn, is governed by the post-construction hydrogeologic setting. Plant construction required reduction in bedrock surface elevations and installation of foundation drains. These man-made features have lowered the groundwater elevations beneath the facility, redirecting groundwater to flow to the West towards the Hudson River; and not to the North, East or South. Because of the nature and age of the releases, groundwater contaminant migration rates, and interdictions by Entergy to eliminate/control releases, the groundwater contaminant plumes have reached their maximum spatial extent and should now decrease over time.

LONG TERM MONITORING

Long term groundwater monitoring is ongoing; a network of multi-level groundwater monitoring installations has been established at the facility. These "wells" are located downgradient of, and in close proximity to, both existing and potential release locations. Groundwater testing is performed quarterly on the majority of these wells, with the rest remaining on standby to provide added detail, if required. The resulting information is provided on a yearly basis to the Nuclear Regulatory Commission

(NRC). The information is used to assess changes in groundwater relative to dose impact assessment and to detect future releases, should they occur.

In addition to the groundwater samples from the network of monitoring wells, Entergy obtained various off-Site samples of environmental media including off-Site wells, reservoirs and the Hudson River. In addition, Entergy participated in a fish sampling program with the NRC and New York State Department of Environmental Conservation (NYSDEC). None of the samples analyzed, including the samples split with regulatory agencies, detected any radioactivity in excess of environmental background levels.

GZA believes that the recommended remediation technology discussed below will cause the concentrations of radionuclides in the groundwater plumes to decrease over time. The continued monitoring of groundwater is expected to demonstrate that trend and support the conclusion that the identified leaks have been terminated. However, GZA expects that contaminant concentrations will fluctuate over time due to natural variations in groundwater recharge and that a potential future short term increase in concentrations does not, in and of itself, indicate a new leak. It is further emphasized that the groundwater releases to the river are only a small percentage of the regulatory limits, which are of no threat to public health.

PROPOSED REMEDIATION

GZA has recommended the following corrective measures to Entergy, which they are implementing:

1. Repair the identified Unit 2 Transfer Canal liner weld imperfection (completed December 2007).
2. Continue source term reduction in the Unit 1 West Pool via the installed demineralization system (ongoing until completion of No. 3 below).
3. Remove the remaining Unit 1 fuel and drain the West Pool (in-process).
4. Implement long term groundwater monitoring (in-process).

The proposed remediation technology is source elimination/control (Nos. 1 and 3 above) with subsequent Monitored Natural Attenuation, or MNA. MNA is a recognized and proven remedial approach that allows natural processes to reduce contaminant concentrations. The associated monitoring is intended to verify that reductions are occurring in an anticipated manner. The Indian Point Energy Center Site is well suited for this approach because: 1) interdictions to eliminate or reduce releases have been made; 2) the nature and extent of contamination is known; 3) the contaminant plumes have reached their maximum extent; and 4) the single receptor of the contamination, the Hudson River, is monitored, with radiological assessments consistently demonstrating that the releases to the environment are a small percentage of regulatory limits, and no threat to public health or safety.

1.0 INTRODUCTION

This report presents the results of hydrogeological studies performed by GZA GeoEnvironmental, Inc. (GZA) at the Indian Point Energy Center (IPEC) in Buchanan, New York (Site). See **Figure 1.1**[1] for a Locus Plan. The report was prepared by GZA under the terms of an agreement with Enercon Services, Inc. for Entergy Nuclear Northeast, and describes services completed between September 2005 (the beginning of our services) and September 2007.

Our investigations were conducted in a cooperative and open manner. Entergy provided full and open access and there were regular and frequent meetings with representatives of the United States Nuclear Regulatory Commission (NRC), the United States Geological Survey (USGS), and the New York State Department of Environmental Conservation (NYSDEC). Further, we presented our preliminary findings at a number of external stakeholder and public meetings.

From the onset of the investigations, GZA routinely computed the groundwater mass flux[2] and associated radiological release to the Hudson River. Using these data, the potential impacts of releases to the river were assessed by Entergy and compared to existing regulatory thresholds. At no time did these analyses yield any indication of potential adverse environmental or health risk as assessed by Entergy as well as the principal regulatory authorities. In fact, radiological assessments have consistently shown that the releases to the environment are a small percentage of regulatory limits, and no threat to public health or safety. In this regard, it is also important to note that the groundwater is not used as a source of drinking water on or near the Site.

This report documents two years of comprehensive hydrogeological investigations. The text of the report describes Site conditions, GZA's investigations, and findings, and presents conclusions and recommendations. Supporting information is provided in tables, on figures and in appendices. To understand how we formed our opinions, it is important to review the report in its entirety, including **Appendix A** Limitations.

1.1 PURPOSE

The overall purpose of our services was to identify the nature and extent of radiological groundwater contamination that originates at IPEC, and assess the hydrogeological implications of that contamination. More specifically, our objectives were to:

- Identify the nature and extent of radiological groundwater contamination;
- Establish the sources of the radiological groundwater contamination;

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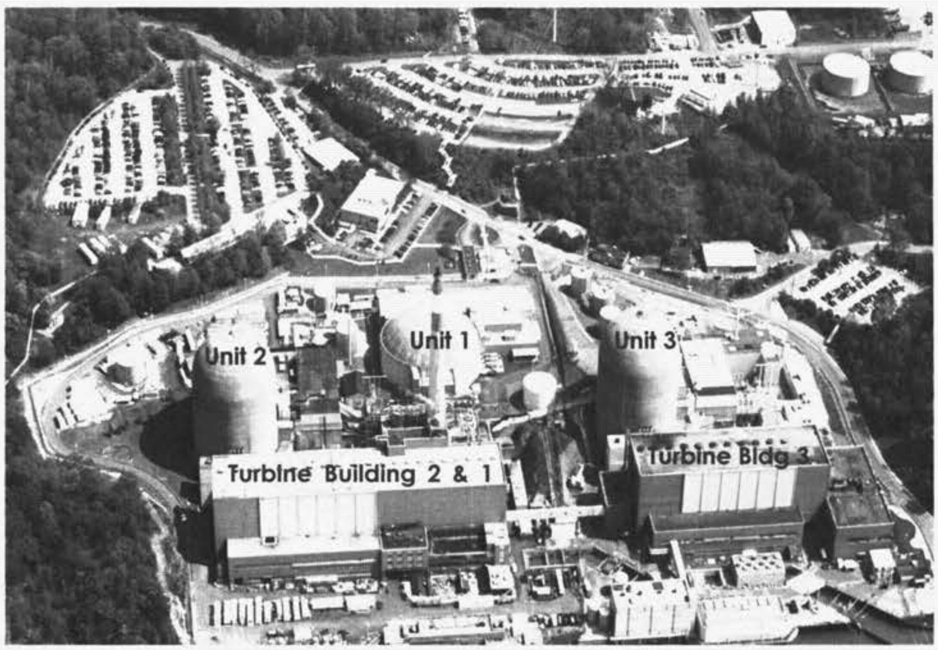
[1] Figures referenced by specific number are contained as full size drawings in Volume 3 of this report. Additional smaller scale figures, photographs, etc. are embedded within the text for immediate reference.
[2] Flux (or mass flux) is defined as the amount of groundwater that flows through a unit subsurface area per unit time.

- Evaluate the mechanisms controlling the groundwater transport of radiological contamination;
- Estimate both the mass of groundwater transporting contaminants, and the radiological activity associated with these contaminant pathways;
- Develop a groundwater monitoring network that addresses IPEC's short term and long term needs, and is consistent with the Nuclear Energy Institute's (NEI's) Groundwater Protection Initiative; and
- Recommend, as required, appropriate remedial measures.

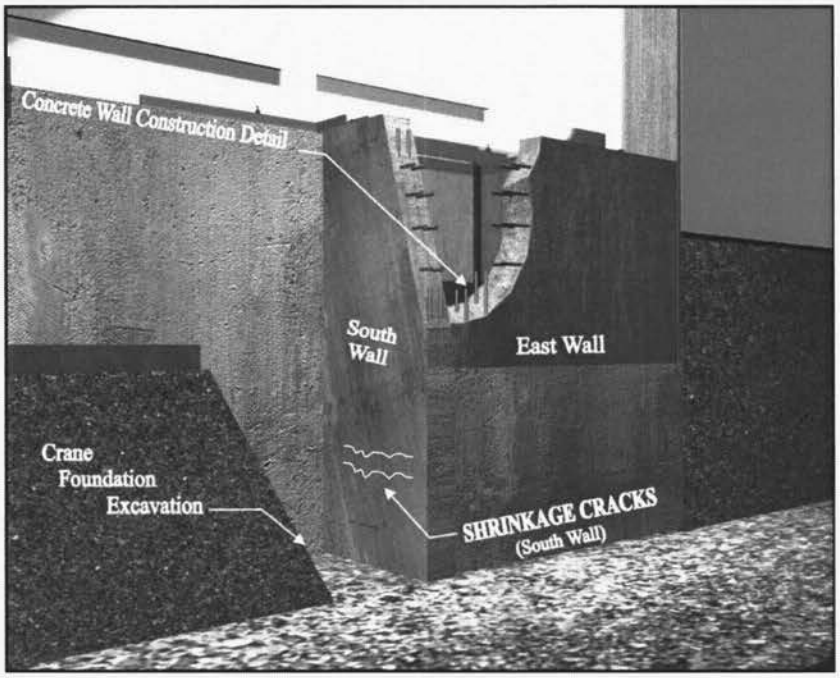
1.2 BACKGROUND

In August 2005, Entergy was excavating in the Unit 2 Fuel Storage Building (IP2-FSB) Loading Bay, adjacent to the South wall of the Spent Fuel Pool (IP2-SFP), in preparation for installation of gantry crane foundations required for the Independent Spent Fuel Storage Installation Project (see **Figure 1.2** and the following illustration).



IPEC LOOKING EAST FROM ABOVE THE HUDSON RIVER

While removing existing backfill material from along the South wall of the SFP, two shrinkage cracks in the concrete pool wall (about 1/64" wide) were observed (refer to **Section 8.1** for additional information). The concrete wall in the area of these cracks appeared damp.



UNIT 2 SFP SHRINKAGE CRACKS IDENTIFIED IN SEPTEMBER 2005

Initially, a temporary, plastic membrane collection device was installed to facilitate water retention and sampling as there was no visibly free-flowing liquid. Analyses of the collected moisture indicated that it had the radiological and chemical characteristics of IP2-SFP water. The primary radioactive constituent was Tritium. This finding initiated work to terminate the known release from these shrinkage cracks. Permanent containment of the release, and prevention of any further migration into the subsurface, was accomplished by installing a waterproof physical containment ("collection box") over the two shrinkage cracks prior to backfilling the gantry crane foundations and SFP wall. This containment was then piped to a permanent collection point such that any future leakage from the crack could be monitored[3]. In addition, Entergy also began extensive investigations of the stainless steel liner in the Unit 2 Fuel Pool itself, as well as the integral Transfer Canal. Subsurface investigations were also started to evaluate if the groundwater had become contaminated from the release.

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[3] Subsequent monitoring has indicated that the leakage from the crack, which had only been typically as high as 1.5 L/day (peak of about 2 L/day) from its discovery through the fall of 2005, has since fallen off dramatically. (L=liters).

As part of these early investigations, Entergy sampled groundwater on September 29, 2005 from a nearby existing downgradient monitoring well, MW-111. This monitoring well is located between the IP2-SFP and the downgradient Hudson River to the West (see **Figure 1.3** for well location). The analysis results, reported on October 5, 2005, indicated an elevated Tritium concentration. The elevated Tritium in MW-111 was consistent with a release from the shrinkage cracks that had migrated into the on-Site groundwater. Entergy therefore began an extensive investigation to understand the extent of the Unit 2 groundwater contamination and potential impacts to the environment.

Although the early subsurface investigations were focused primarily on potential sources of contamination, the project team also reviewed: regional hydrogeological information, plant design/construction details, and available Site-specific groundwater monitoring results. This early work led to three conclusions:

- The recently identified shrinkage cracks had resulted in releases of Tritium to the groundwater;
- It was unlikely that contaminated groundwater was migrating off-property to the North, East or South; and
- Tritium-contaminated groundwater likely had, and would continue to, migrate to the Hudson River to the West.

In response to these three early conclusions, Entergy tasked GZA with developing a network of groundwater monitoring wells. The primary objectives for this network were to facilitate comprehensive investigation of the IP2-SFP Tritium release location, as well as evaluate the potential for releases at other locations across the Site. Additional objectives included:

- Monitoring of the southern boundary of the Site (previously identified by others as downgradient);
- Monitoring attenuation of the contaminant plume(s) identified on-Site;
- Early detection of leaks in areas of ongoing active operations, should they occur in the future; and
- Monitoring of the groundwater adjacent to the Hudson River to provide the required groundwater data for Entergy's radiological impact evaluations.

The groundwater monitoring network ultimately developed by GZA, and supported by Entergy, was comprised of shallow and deep installations at 59 monitoring locations. These installations were completed in both soil overburden and bedrock. The installations generally include multi-level instrumentation which allows acquisition of depth-discrete groundwater samples and automatic recording of depth-specific groundwater elevations via electronic pressure transducers. The wells were drilled in a phased manner, with resulting

data being used to modify and guide the work of subsequent investigations. This iterative progression is in accordance with the Observational Method[4] approach (see **Section 2.0**).

During the course of the expanded investigations in 2006, Strontium-90 was detected in, and downgradient of, the western portion of the Unit 2 Transformer Yard (IP2-TY). While the transformer yard is located immediately downgradient of the Unit 2 Spent Fuel Pool (IP2-SFP), the source of this Strontium in the groundwater could not reasonably be associated with a release from the IP2-SFP. This conclusion was particularly appropriate when evaluated in light of the sampling data from the upgradient transformer yard wells and ultimately from wells directly adjacent to the SFP itself. The ongoing subsurface investigation program was therefore further expanded to encompass not only the IP2-SFP source area, but also other potential sources across the entire Site, including Units 1 and 3. These subsequent phases of investigation ultimately established the retired Unit 1 plant as the source of the Strontium contamination identified[5] in the groundwater. More specifically, the Unit 1 fuel storage pool complex, where historic legacy pool leakage was known to exist, was confirmed as the Strontium source. This fuel pool complex is collectively termed the Unit 1 Spent Fuel Pools (IP1-SFPs). Following detection of radionuclides in the groundwater associated with IP1-SFPs, Entergy accelerated efforts to reduce activity in the IP1-SFPs, along with acceleration of the already ongoing planning for the subsequent fuel rod removal and complete pool drainage.

As indicated above, later phases of the investigations encompassed the entire Site, including all three Units (IP1, IP2 and IP3). These investigations found no evidence of releases to the groundwater from the IPEC Unit 3 plant complex. In this regard, it is important to note that the design and construction of the IP3-SFP incorporates a secondary leak detection telltale drain system, in addition to the primary stainless steel liner. The earlier Unit 1 and Unit 2 SFPs were not designed with this feature.

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[4] a. *Use of the Observational Method in the Investigation and Monitoring of a Spent Fuel Pool Release*, Barvenik, et. al., NEI Groundwater Workshop, Oct. 2007.

b. *Use of the Observational Method in the Remedial Investigation and Cleanup of Contaminated Land*, Dean, A.R. and M.J. Barvenik, The Seventh Geotechnique Symposium - Geotechnical Aspects of Contaminated Land, sponsored by the Institution of Civil Engineers, London, Volume XLII, Number 1, March 1992.

c. Advantages and Limitations of the Observational Method in Applied Soil Mechanics, Peck, R.B., Geotechnique 1969, No. 2, 171-187.

[5] In addition to Strontium, other radionuclides (Nickel, Cobalt and Cesium) were also sporadically detected in groundwater. These other radionuclides were continuously assessed within the context of the overall hydrologic model. Based upon their occurrence, Strontium, in combination with Tritium, provides full delineation of radiological groundwater plumes at the IPEC Site.

2.0 SCOPE OF SERVICES

This section outlines the scope of our two-plus year-long investigation. Consistent with well established hydrogeologic practices, GZA followed the Observational Method. That is, GZA developed a Conceptual Site Model (see **Section 3.0**) that described our understanding of groundwater flow and contaminant transport at IPEC, and performed investigations to test the validity of our model. In response to test data, we revised the model and/or performed additional testing to clarify findings. This iterative, step-wise phased approach allows for better focused testing, and a more comprehensive review of data. It also reduces the chances of missing critical information, and generally completes studies in less time. GZA executed the scope in three phases.

2.1 PHASE I

Phase I investigations commenced in September 2005. Consistent with the concerns raised by the observed IP2-SFP crack leakage, the Phase I investigation program focused on: 1) Identifying the groundwater flow paths which would intercept potential releases from IP2-SFP; and 2) Evaluating groundwater contaminant fate and transport mechanisms in this area of the facility. This work included:

- Identification, retrieval and evaluation of historic geologic, hydrogeologic and geotechnical reports to form the basis of our initial Conceptual Site Model (CSM);
- Development of an initial CSM;
- Identification, retrieval and evaluation of historic facility Site plans and construction details pursuant to the impact of man-made features on groundwater flow directions and Tritium migration, with subsequent refinement of the CSM;
- Installation of nine groundwater monitoring wells, a number of which contained multiple sampling levels, in the area of the Tritium release;
- Installation of four stilling wells[6], three within the Discharge Canal and one in the Hudson River, to allow groundwater elevations to be compared to these surface water elevations (to evaluate if the Hudson River is the ultimate discharge point for any potential IP2-SFP release);
- Performance of elevation and location surveys to establish reference points for groundwater elevation measurement;
- Installation of electronic pressure transducers in newly drilled boreholes and previously existing wells to continuously monitor groundwater elevation fluctuations, as influenced by climatic/seasonal variability, tidal influences and the drilling of nearby boreholes (to assess interconnections between boreholes at different locations);
- Geophysical borehole testing to provide further bedrock fracture identification, location and groundwater flow information;

[6] Stilling wells are typically constructed of slotted pipe or well screen. They are placed in surface water bodies to house pressure transducers for water level measurement. Their purpose is to dampen-out high frequency pressure fluctuations in the water body, typically due to flow-induced turbulence, such that more representative readings can be obtained. Stilling wells are not included as monitoring wells with reference to numbers of monitoring wells installed.

- Packer testing of specific bedrock boreholes to provide initial depth-specific groundwater samples, measurement of depth-specific groundwater elevations and flow capacity of the fracture zones;
- Completion of the boreholes as screened overburden wells, open bedrock wells, or multi-level monitoring wells as appropriate for the subsurface conditions encountered;
- Testing of open bedrock and screened boreholes to measure formation groundwater flow capacity;
- Ground Penetrating Radar (GPR) analysis of the key locations to evaluate top of bedrock elevations relative to preferential groundwater flow through soil backfill;
- Sampling of groundwater from the monitoring wells and analyzing the samples for Tritium and gamma emitters; and
- Computation of the groundwater flux and radiological activity to the Hudson River for use by Entergy in their dose computations.

2.2 PHASE II

Phase II investigations commenced in January 2006. The focus of this work was to: 1) Confirm initial findings; 2) Better estimate the quantity of contaminated groundwater at the facility that discharges to the Hudson River; and 3) Establish a network of wells suitable for identifying potential leaks at all three units across the Site and for long term monitoring of groundwater. This phase of work included:

- Re-evaluation of our CSM to guide the selection of borehole locations and establish testing requirements;
- Identification of accessible areas from which to drill boreholes to measure groundwater elevations and the contaminant concentrations;
- Drilling of 23 additional boreholes through soil and bedrock to depths of up to 200 feet, including coring to provide bedrock core samples for inspection (to locate fractures in the bedrock which likely conduct groundwater flow);
- Performance of elevation and location surveys to establish reference points for groundwater elevation measurement;
- Installation of electronic pressure transducers in newly drilled boreholes to continuously monitor groundwater elevation fluctuations, as influenced by climatic/seasonal variability, tidal influences and the drilling of nearby boreholes (to assess interconnections between boreholes at different locations);
- Geophysical borehole testing to provide further bedrock fracture identification, location and groundwater flow information;
- Packer testing of specific bedrock boreholes to provide depth-specific groundwater samples, measurement of depth-specific groundwater elevations and flow capacity of the fracture zones;
- Completion of the boreholes as screened overburden wells, open bedrock wells, or multi-level monitoring wells as appropriate for the subsurface conditions encountered;
- Conducting tests on open bedrock and screened boreholes to measure formation groundwater flow capacity;
- Ground Penetrating Radar (GPR) analysis of the key locations to evaluate top of bedrock elevations relative to preferential groundwater flow through soil backfill;

- Sampling of groundwater from the monitoring wells and analyzing the samples for Tritium and additional radionuclides of interest (including Strontium, gamma emitters, Nickel-63 and transuranics); and
- Re-computing the groundwater flux and radiological activity to the Hudson River (based on the more current data and refined CSM) for use by Entergy in their dose computations.

2.3 PHASE III

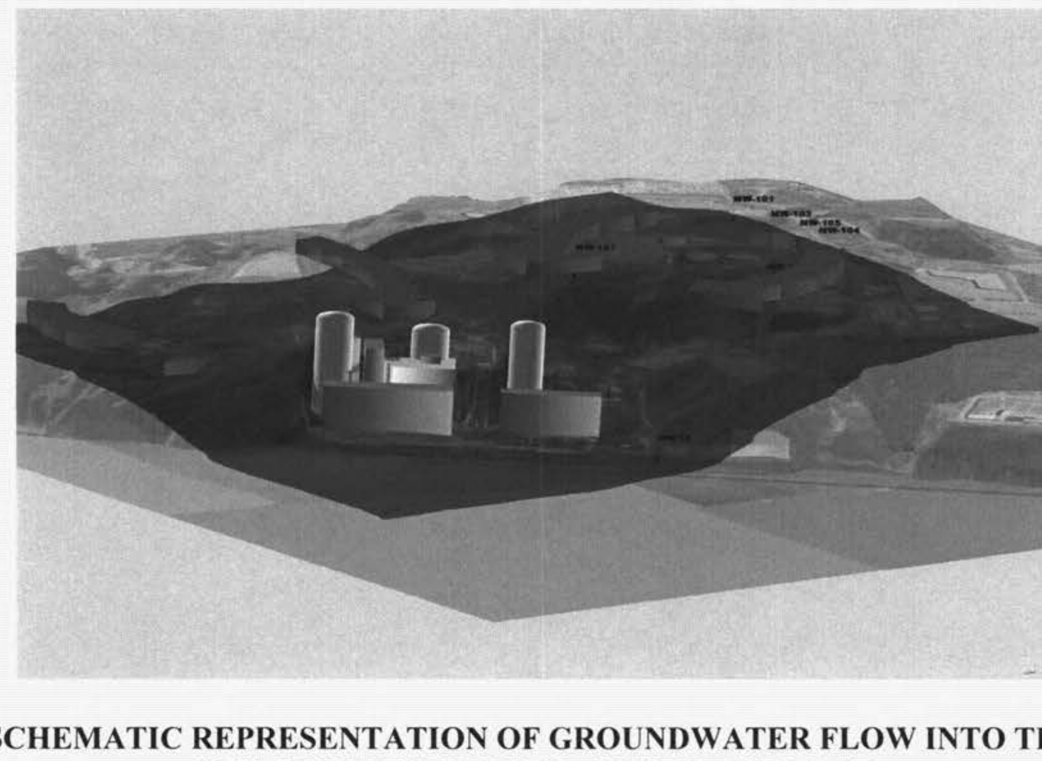
Phase III investigations commenced in June 2006. The focus of the Phase III work was to:
1) Better delineate the extent of Strontium detected during Phase II investigations; and
2) Improve characterization of bedrock aquifer properties to allow evaluation of remedial alternatives. This phase of work included:

- Re-evaluation of our CSM to guide the selection of borehole locations and establish testing requirements;
- Installation of additional wells (MW-53 through MW-67 and U1-CSS) to further delineate the horizontal extent of groundwater contamination (this work was begun in Phase II);
- Installation of deep wells (MW-54, -60, -61, -62, -63, -66, and -67) to establish the vertical extent of contamination;
- Conducting hydraulic tests on boreholes and completed wells to assess the transmissivity of bedrock fracture zones and overburden;
- Installation of electronic pressure transducers in newly drilled boreholes and existing wells to continuously monitor groundwater elevation fluctuations due to climatic/seasonal variability, tidal influences and the drilling of nearby boreholes (to assess interconnections between boreholes at different locations);
- Geophysical borehole testing to provide further bedrock fracture identification, location and groundwater flow information;
- Packer testing of specific bedrock boreholes to provide depth-specific groundwater samples, measurement of depth-specific groundwater elevations and flow capacity of the fracture zones;
- Completion of the boreholes as screened overburden wells, open bedrock wells, or multi-level monitoring wells as appropriate for the subsurface conditions encountered;
- Conducting a 72-hour Pumping Test to assess hydraulic properties of the bedrock as well as to assess the feasibility of managing Tritium-contaminated groundwater through hydraulic containment;
- Performance of a tracer test to better assess contaminant migration and transport mechanisms, particularly in the unsaturated zone;
- Sampling of groundwater from the monitoring wells and analyzing the samples for radionuclides; and
- Re-computing the groundwater flux and radiological activity to the Hudson River (based on the more current data and refined CSM) for use by Entergy in their dose computations.

3.0 CONCEPTUAL HYDROGEOLOGIC MODEL

This section, together with associated figures, constitutes our Conceptual Site Model (CSM). The key components of the model consisted of: the hydrogeologic setting; general groundwater flow patterns; identified contaminant sources; contaminants of potential concern; and identified receptors. GZA used the CSM to guide our investigations, identify and fill data gaps, assess the reasonableness of findings, and develop parameters controlling contaminant transport. It was an iterative process and, as studies progressed, we modified the CSM to better fit observed conditions. With completion of the investigations and further refinement of the CSM, our CSM was consistent with both the Site-specific project data and published data for the area.

The CSM incorporates our understanding of Site construction practices as they influence contaminant migration. Critical in this regard is that, according to construction plans, lean concrete was used as backfill material for foundation walls in a number of locations, primarily associated with Unit 1 structures. We also note that in some areas where construction plans show soil backfill, we found that lean concrete was actually used. This is likely due to the relatively low cost of concrete during the 1950's and the uniqueness of the construction for these first nuclear power plants. At the subsequently constructed Units 2 and 3, it appears soil or blast rock was the material most commonly used as backfill against foundation walls.



SCHEMATIC REPRESENTATION OF GROUNDWATER FLOW INTO THE SITE FROM THE NORTH, SOUTH, AND EAST

3.1 HYDROGEOLOGIC SETTING

The Site watershed is limited in areal extent. GZA assumed that the top of the watershed defines a no-flow boundary in the aquifer. The distance from the upgradient no-flow boundary located at the top of the watershed, to the river, is on the order of 2,200 feet (see **Figure 3.1**). This length limits the volume of precipitation available for aquifer recharge. Recharge is further limited by the density of structures and areal extent of paving, which induces direct run-off. An average annual recharge rate of 5.5 inches per year was initially selected[7] as representative for the Site area, which is the USGS estimated average in Westchester County where IPEC is located.

3.2 GENERAL GROUNDWATER FLOW PATTERNS

Groundwater flow takes place in three dimensions. In general, flow at the top of the watershed is largely downward and flow near the river's edge is largely upward. In the mid-section of the watershed, flows are predominantly horizontal. Based on the location of the Site in the watershed and information indicating that the top of the bedrock is more fractured, GZA initially estimated, and later confirmed that the bottom of the local groundwater flow to be at or above elevation -200 feet (National Geodetic Vertical Datum of 1929[8], NGVD 29)[9]. Note that temporal and spatial variations in areal recharge rates, rock heterogeneities, and tidal influences cause local variations from these general flow patterns. In fact, Site groundwater flow patterns in some areas are dominated by shallow anthropogenic Site features. These features include pumping from building foundation drains, foundation walls, subsurface utilities, and flows in the intake structures and Discharge Canal.

Based upon the regional topography, Site topography (see **Figure 3.2**), anthropogenic influences, and the geostructural setting, even at the initial stages of the investigations GZA expected that groundwater would flow into IPEC from the North, East and South, and then discharge to the Hudson River, with portions of the flow being intercepted by the cooling water intake and Discharge Canal (see **Figure 3.3**). However, based on our review of reports available at the start of the investigations, it was unclear what the role that anisotropic bedrock structure played in groundwater migration. That is, there was information suggesting groundwater flows would have a primarily southern component (see **Section 6.4** for a description of the regional area and Site-specific geologic setting).

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[7] As discussed in **Section 6.0**, the initial average areal recharge rate of 5.5 inches/year was subsequently increased somewhat as we refined our CSM.

[8] The National Geodetic Vertical Datum of 1929 (NGVD 29) is the renamed Sea Level Datum of 1929. The datum was renamed because it is a hybrid model, and *not a pure model of mean sea level*, the geoid, or any other equipotential surface. NGVD 29, which is based on "an averaging" of multiple points in the US and Canada, is the vertical "sea level" control datum established for vertical control surveying in the United States of America by the General Adjustment of 1929. The datum is used to measure elevation or altitude above, and depression or depth below, "mean sea level" (MSL). It is noted that there is no single MSL, because it varies from place to place and over time.

[9] During a mid-phase of the work, we concluded that the bottom of the local groundwater flow may be deeper, more likely between elevations -200 to -350 feet NGVD 29. This conjecture was based on the observed vertical distribution of heads, bedrock fracture patterns, and the observed contaminant concentrations at the time. We therefore increased our drilling depth to 350 feet (multi-level monitoring well installation MW-67) to investigate this issue. Subsequently, the most recent data better fit with a 200-foot-deep flow model.

Based on our studies, including a full-scale Pumping Test and tidal response testing, we have shown that in the area of groundwater contamination, and on the scale of the contaminant plumes, the direction and quantity of groundwater flow can be estimated using an equivalent porous media model. We state this recognizing that an individual bedrock zone may represent flow in a single or limited number of fractures which over a relatively short distance is not representative of average conditions. In terms of our equivalent porous media model, this condition represents an aquifer heterogeneity. However, over sufficient volumes of bedrock (which is the case for the work at IPEC), the bedrock groundwater flux can be estimated based on an equivalent porous media model using Darcy's Law[10].

3.3 IDENTIFIED CONTAMINANT SOURCES

GZA, in conjunction with facility personnel, conducted a review of available construction drawings, aerial photographs, prior reports, and documented releases, and interviewed Entergy personnel to identify potential groundwater contaminant sources.

That review, in conjunction with the observed distribution of contaminants, identified IP2-SFP and IP1-SFPs, along with legacy piping associated with Unit 1, as sources of the radiological groundwater contamination. The locations of these structures are shown on **Figure 3.4.** No release was identified in the Unit 3 area. This finding is consistent with, and reflects, changes in construction practices over time[11]. Refer to **Section 8.0** for additional information pursuant to source area description.

3.4 CONTAMINANTS OF INTEREST

Throughout this report, Tritium and Strontium are discussed as the principal radiological constituents associated with the groundwater contamination investigation performed at IPEC. Both radionuclides served as the most representative contaminant tracer tools from the perspective of frequency of observed occurrence, as well as contaminant transport[12] across the Site. Other radionuclides (primarily Cs-137, Ni-63, Co-60) were more sporadically identified and isolated to specific locations within the Site. These radionuclides are encompassed by the Unit 2 (Tritium) and Unit 1 (Strontium) plumes. We also note these other radionuclides carry a smaller potential radiological impact as compared to Strontium. These contaminants were also continuously assessed within the context of the overall site hydrological model as well as the plume information gleaned from the Unit 1 and Unit 2 plume data. All detected radionuclides have been

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[10] *Interpretation of Hydraulic Tests and Implications Towards Representative Elementary Volume for Bedrock Systems*, Thomas Ballerstero, October 2003, AGU San Francisco.

[11] The absence of Unit 3 sources is attributed to the design upgrades incorporated in the more recently constructed IP3-SFP.

[12] A combination of Tritium and Strontium allow full characterization of radiological groundwater plume nature and extent at the IPEC Site given their divergent behavior in the subsurface. Tritium is completely conserved in the groundwater with no partitioning to natural or anthropogenic subsurface materials. It, therefore, moves with and as fast as the groundwater, and thus serves as an indicator of the leading edge of a recent release. Strontium provides strong partitioning characteristics and long half-life. It is, therefore, an indicator of older, historic releases.

accounted for by Entergy in their dose assessment analyses (radiological impact evaluations). Accounting for these data was performed via USNRC Annual Reporting documents that have been made public (year-end 2005 and 2006) and will continue to be reported on (Refer to RG1.21 report). Additional discussion of the identified sources of contaminants and the properties affecting contaminant migration are provided in **Sections 8.0** and **9.0.**

3.5 IDENTIFIED RECEPTORS

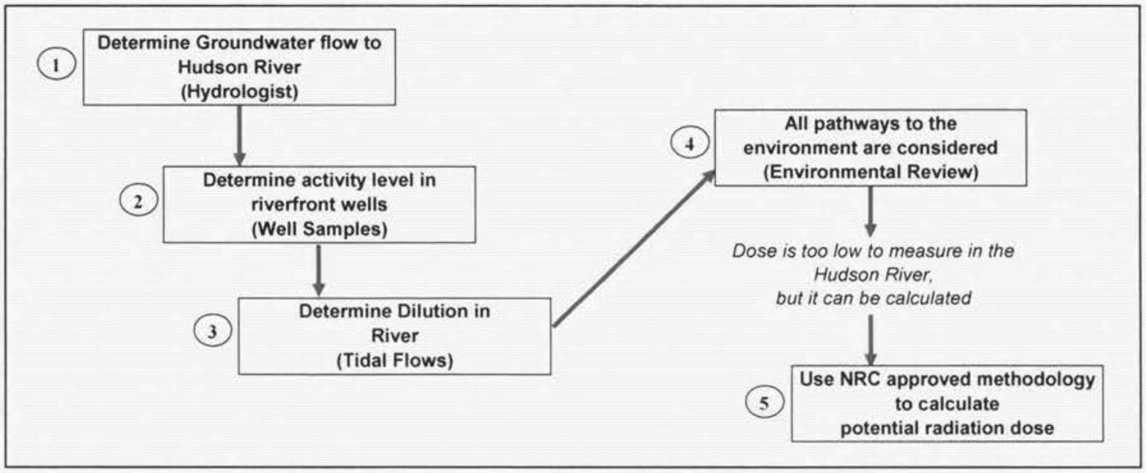
The NRC has set forth guidance for calculations of radiation dose to the public, and IPEC follows this guidance for radioactive effluents, including those from groundwater. IPEC is required to perform an environmental pathway analysis to determine the possible ways in which radioactivity released to the Hudson River can cause radiation dose. Receptors for radioactive releases to the environment are considered to be actual or hypothetical individuals exposed to radioactive materials either directly or indirectly.

Title 10 of the Code of Federal Regulations, Part 50 (10CFR50) Appendix I states: "*Account shall be taken of the cumulative effect of all sources and pathways within the plant contributing to the particular type of effluent being considered.*" 10CFR50 Appendix I provides numerical guidelines on liquid releases of radioactivity, such that releases "*will not result in an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 3 millirems to the total body or 10 millirems to any organ.*"

IPEC has reviewed the potential pathways that result in dose to the public and are viable for the Site. Potential pathways considered included drinking water consumption, aquatic foods, exposure to shoreline sediments, swimming, boating, and irrigation. As discussed below, drinking water is not a viable pathway for releases to the Hudson River. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I" provides guidance and acceptable methodologies for calculating radiation dose from environmental releases. The NRC guidance uses the maximum exposed individual approach, where doses are calculated to hypothetical individuals in each of four age groups (infant, child, teen, and adult). Maximum individuals are characterized as "maximum" with regard to food consumption and occupancy. Regulatory Guide 1.109 describes a pathway as "significant" if a conservative evaluation yields an additional dose increment of at least 10 percent of the total from all pathways. Based on the above description, the only significant pathway for liquid releases is for consumption of aquatic foods; i.e., Hudson River fish and invertebrates.

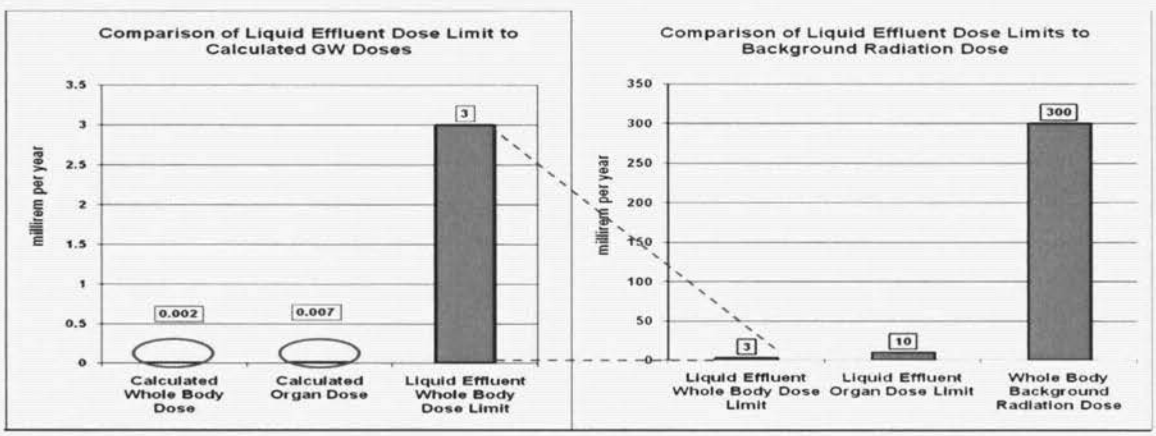
The specific methodology used to calculate doses from liquid radioactive effluents is based on NRC guidance and is contained in the Indian Point Offsite Dose Calculation Manual (ODCM). The volume of groundwater traversing the site and discharging into the Hudson River, as estimated by GZA using the data as presented in this groundwater report, is used in conjunction with measured concentrations of radionuclides in groundwater to estimate the total amount of radionuclides to the Hudson River, and their potential dose impact. In 2005 and 2006, groundwater releases resulted in a small fraction of the offsite dose limits established by the NRC for each site. This dose is calculated from measured

radionuclides in groundwater, using the methodology in the ODCM. A simplified description of the methodology is shown in the figure below.



SIMPLIFIED GROUNDWATER DOSE CALCULATION METHODOLOGY

Radiation doses are reported annually by IPEC in an NRC-required Annual Radioactive Effluent Report. An overview of the results is shown in the figure below.



COMPARISON OF BACKGROUND, DOSE LIMITS, AND CALCULATED GROUNDWATER DOSE – 2006

For the purposes of this study, the migration of contaminated groundwater is the pathway of interest. The contaminants of interest are not volatile; therefore, they remain in the subsurface bedrock, soil and groundwater until discharge to the river.

There is no current or reasonable anticipated use of groundwater at the IPEC. According to the NYSDEC[13], there are no active potable water wells or other production wells on the

[13] Early in the investigative process, the NYSDEC requested that the New York State Department of Health assess the presence of drinking water supply wells in the vicinity of the Site. The NYSDEC informed Entergy and GZA that no drinking water supply wells were located on the East side of the Hudson River in the vicinity of the Site in June 2006.

East side (Plant side) of the Hudson River in proximity to the IPEC[14]. Drinking water in the area (Town of Buchanan and City of Peekskill) is supplied by the communities and is sourced from surface water reservoirs located in Westchester County and the Catskills region of New York. The nearest of these reservoirs (Camp Field Reservoir) is located 3.3 miles North-Northeast of the Site and its surface water elevation is hundreds of feet above the IPEC, in a cross-gradient direction and several watersheds away. In addition, groundwater flow directions on the Site are to the West towards the Hudson River. Therefore, it is not possible for the contaminated groundwater at IPEC to ever impact these drinking water sources.

Groundwater beneath the IPEC flows to the Hudson River and therefore flows through portions of the river bank and river bottom. The river bank at the Site consists of sections of vertical bulkheads and some rip-rap outside of the contaminated flow zone. The size of the Hudson River and the hydraulic properties of the underlying bedrock preclude natural or pumping-induced migration of contaminated groundwater to the West side of the river. Therefore, conditions at the IPEC pose no threat to potable water supplies.

In summary, the only pathway of significance for groundwater is through consumption of fish and invertebrates in the Hudson River, and the calculated doses are less than 1/100 of the federal limits. As described above, potable water is not a viable pathway and no dose calculations are necessary in that regard.

GZA utilized Environmental Data Resources, Inc. to conduct a search for public water supply wells within 1 mile of the Site. According to records maintained by the USEPA, there were no water supply wells located within the search radii.

[14] According to the Rockland County Department of Health, there are municipal drinking water supply wells operated in Rockland County. GZA formally requested, through a Freedom of Information Law Application (F01-07-004), information regarding the elevation of groundwater in these wells to assess if there was any potential for IPEC to impact these wells. The information was not made available to GZA for security reasons. The closest active drinking water well in Rockland County is over 4.5 miles Southwest of the Site on the West side of the Hudson River.

4.0 FIELD INVESTIGATIONS

This section provides a description of our field activities. The studies were conducted in three phases between October 2005 and September 2007. Field activities were performed, in accordance with general industry practice and regulatory guidelines, to develop and validate our CSM (see **Section 3.0**).

The field exploration program was developed by GZA in cooperation with Enercon and Entergy. A team of GZA engineers, geologists and scientists was present to observe and document drilling efforts, classify soil and rock samples, direct field testing (packer tests, etc.) and collect other hydrogeologic data. Borehole development, well installation and packer testing were performed by GZA and the drilling contractor, Aquifer Drilling and Testing (ADT), New Hyde Park, New York. The exploration program also included the use of geophysical exploration techniques to help identify underground utilities, evaluate the location of the bedrock surface, and evaluate the nature of bedrock fractures in select boreholes. Advanced Geological Services (AGS) and Geophysical Applications, Inc. (GA), both under GZA's oversight, conducted this work.

The following provides a broad overview of our investigations. Refer to subsequent subsections for more information.

Geological Reconnaissance

- Review of Relevant Geological Literature and Previous Reports
- Site Reconnaissance to Observe Outcrops of Bedrock
- Geostructural Logging of the Rock Wall within the IP2-FSB Crane Foundation Excavation

Test Drilling - Planning, Execution, Post-Drill Activity

- Review of Existing Utility Plans
- Surface Geophysical Utility Surveys (to further locate utilities)
- Vacuum Excavation of 39 boreholes (for safety; to reduce risk of encountering underground utilities or structures)
- Test Boring Advancement (bedrock borings, overburden borings)
- Borehole Development (to remove rock cuttings and drill water; preparation for hydraulic testing in boreholes)
- Borehole Geophysical Surveys (to evaluate fractures along the borehole wall)

Monitoring Well Installations

- Bedrock Wells
- Open Rock Wells
- Waterloo Systems
- Nested Wells
- Overburden Wells
- Wellhead Completion

- Wellhead Elevation Surveying

Hydraulic Testing to Evaluate Hydraulic Conductivity of Bedrock

- Specific Capacity Testing
- Rising Head Hydraulic Conductivity Testing (pneumatic and hydraulic slug tests)
- Bedrock Packer Hydraulic Conductivity Testing
- A Pumping Test (a 72 hour Pump Test to evaluate the hydraulic properties of the bedrock)

Water Sampling

- On-Site Sampling of Groundwater, Surface Water and Facility Water
- Off-Site Sampling of Groundwater and Surface Water

Groundwater Elevation Monitoring and Pressure Transducer Data

- Installation of In-Situ and Geokon Transducers
- Data Retrieval

Organic Dye Tracer Testing

- Injection Well Construction
- Tracer Introduction
- Sampling Methods

Geophysical Testing – Identification of Preferential Groundwater Flow Paths

- Ground Penetrating Radar Surveys at Unit 2, Unit 3 and the Owner Controlled Area (OCA) Access Road
- Seismic Refraction, GPR and Electromagnetic Surveys between the Protected Area and southern Warehouse

As-built locations of the explorations are shown on **Figure 1.3**. **Table 4.1** provides a summary of well locations and installation details. The following sections describe the key aspects of the completed work. Explorations logs, test records and additional information are presented in the Appendices.

4.1 GEOLOGIC RECONNAISSANCE

To develop a preliminary understanding of the subsurface conditions expected to occur beneath the Site, GZA reviewed USGS publications relating to the local and regional geology as well as available Site-specific geologic reports. GZA further conducted a reconnaissance of the Site to identify the type of bedrock exposed, relative fracture density and locations of expected overburden. Specifically included was the logging of the rock wall in the construction excavation at Unit 2 (refer to **Section 6.0** for additional detail on Site Geology). This information was used to help design the subsurface investigation methods.

4.2 TEST DRILLING

Forty-seven borings were completed by GZA as part of this program, forty-two of these borings were converted to monitoring installations, one was converted to a recovery well and one was converted to a tracer injection point[15]. Boring logs for the bedrock borings and the additional overburden borings are provided in **Appendix B**. Boring locations and elevations are provided in **Table 4.1**. Final sampling elevations are also provided in **Table 4.1**. Test Boring/Monitoring Installation locations are shown on **Figure 1.3**. In viewing the figure, note that test boring designations are the same as the monitoring installation[16] designations (see **Section 4.3.4**). In addition, a tracer injection point was installed along the side of the casing of MW-30 (see **Section 7.0** for details).

Prior to advancement of the borings, a utility identification and clearance program was implemented to reduce the risk of encountering underground utilities, and to maintain the safety of on-Site personnel during drilling activities. GZA personnel, AGS personnel and Site personnel first performed a reconnaissance of the proposed boring locations. Site personnel then utilized Site plans to assess the potential presence of subsurface utilities in the area of the proposed boring locations. Following this initial screening, AGS personnel performed a surface geophysical survey of the area around the proposed boring locations using GPR and radiofrequency utility locating equipment. The results of the survey were marked on the ground surface using spray paint. Entergy personnel performed a final reconnaissance prior to approving the locations.

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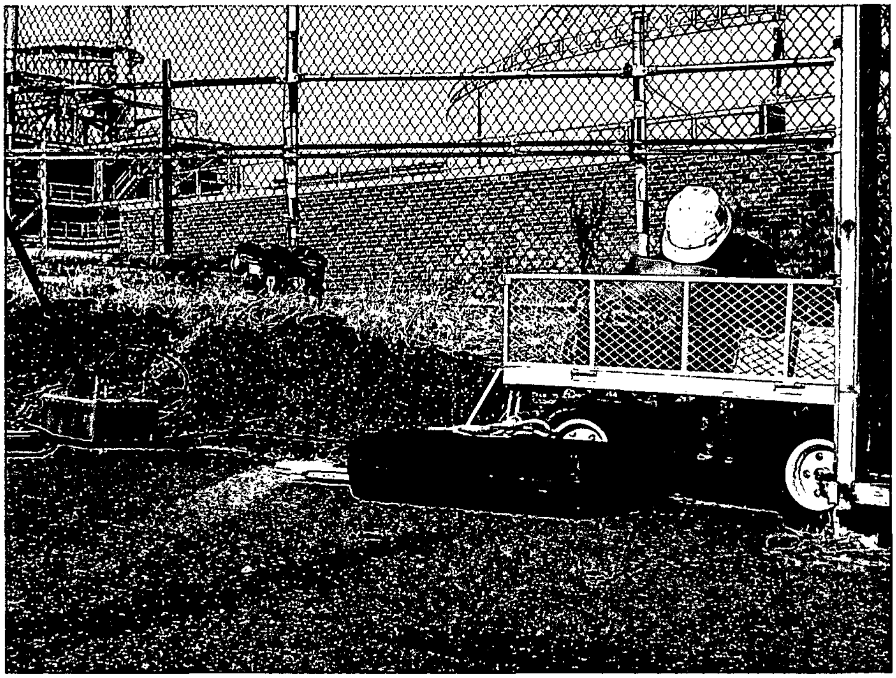
[15] Borings are defined as test sites that were excavated with hand held or mechanical drilling devices. Monitoring installations are defined as boreholes (or wellbores) that were completed to allow groundwater monitoring and generally include multiple monitoring levels over the depth of the boring (either "nested well" casings within one borehole or Waterloo multi-level completions). In several instances, a monitoring installation location designation, such as MW-49, may have two discrete borings, in which case it is counted as two installations, but represented on the figures as a single location for clarity. Attempted borings which met refusal and had to be re-drilled are not included in the boring count.

[16] *Monitoring installations* are commonly referred to as *Monitoring wells*, which in this usage, may include multiple, individual well casings. This generic usage is also used herein.

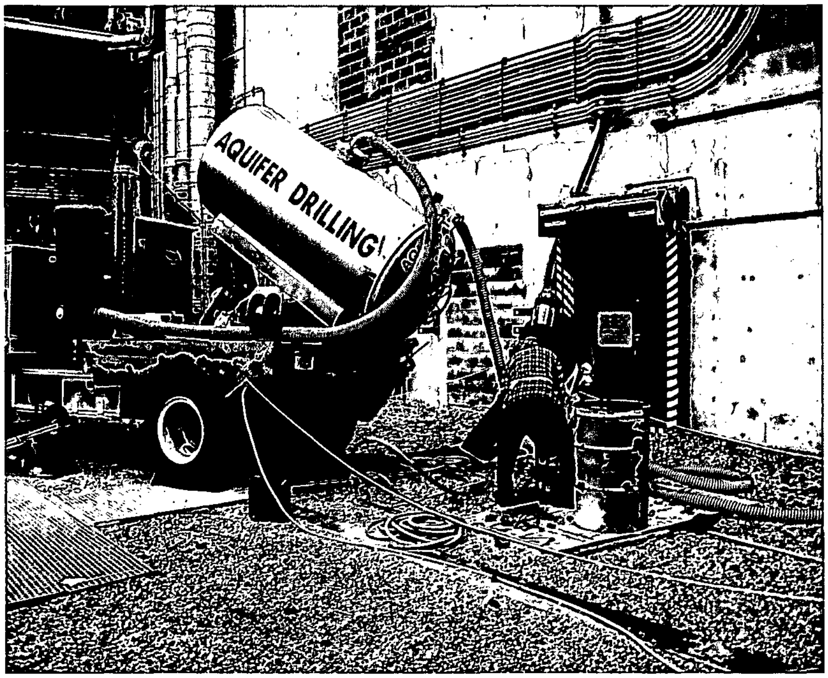


SURFACE GEOPHYSICAL SURVEY

At thirty nine of the boring locations, overburden was vacuum-excavated until bedrock was encountered, or to the practical limits of the vacuum excavation technique. To further reduce the risk associated with the drilling program, during advancement of the borings to bedrock, a downhole magnetometer was utilized every two feet to assess the presence of metallic objects potentially related to subsurface utilities.

The test borings were performed by ADT with a combination of three drill rigs: a track-mounted CME LC55 rotary drill rig, a truck-mounted CME 75 rotary drill rig, and an electric track-mounted Davie DK 515 rotary drill rig. The original program consisted of advancing borings into bedrock to desired terminal depths using wire line HQ direct rotary coring techniques. This resulted in a nominal 3.85-inch diameter borehole. Where overburden was present, either a four-inch or six-inch casing was installed into the rock and grouted in place.

At certain locations where overburden occurred beyond the bottom of the vacuum-excavated test pits, soil samples were collected at 5-foot intervals, from the bottom of the vacuum-excavated test pit, using a 2-inch outside diameter (OD) split-spoon sampler driven by a 140-pound hammer falling 30 inches, to characterize soils. These samples were visually classified using the Burmister Classification System. At all locations, either vacuum-excavated test pits or hand-excavated test pits were performed to clear utilities prior to advancing boreholes. Grab samples were collected during the advancement of the test pits to visually characterize the overburden soils.



VACUUM EXCAVATION

During the drilling program, rigorous field protocols were implemented to limit the risk of cross-contamination. All down-hole drilling tools, testing equipment, and well materials were steam cleaned or pressure washed prior to use on the Site, subsequent to the completion of a boring, and prior to leaving the Site. Water used during drilling, testing and well installations was drawn from the Buchanan, New York public water supply from on-Site connections. Waste water, waste soil, and decontamination wash water were placed in 55-gallon drums and transferred to Site personnel for proper disposal.

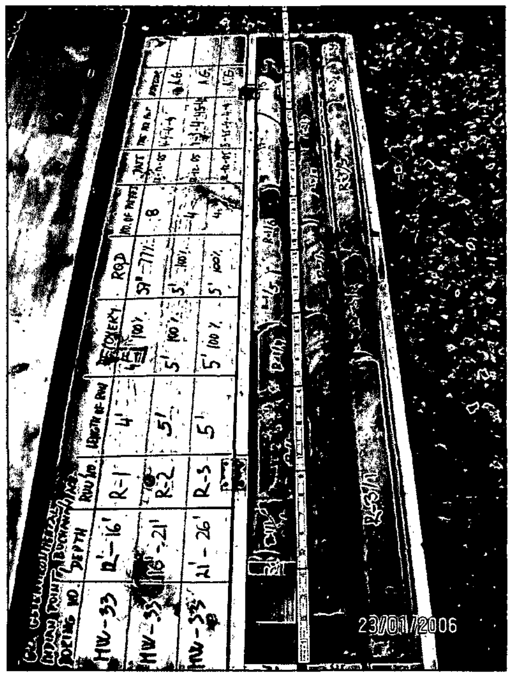
4.2.1 Bedrock Borings

Thirty-eight of the borings were drilled in bedrock, including U1-CSS which was installed horizontally through the East wall of the Unit 1 Containment Spray Sump using hand coring techniques. The borings were completed using rotary techniques with water as the drilling fluid and either permanent 4-inch or temporary 6-inch casing to keep the borehole open through overburden soils. Once rock was encountered, it was cored using HQ-size double-tube core barrels with diamond studded bits in general accordance with ASTM D2113 [6]. Core runs were generally 5 feet in length, with a nominal 3 inch diameter. Shorter or incomplete runs were made when the drilling team believed the core barrel to be blocked.

The rock samples were classified and logged by GZA field personnel, and the descriptions and rock quality designations were reviewed and checked by a Senior GZA Geologist. Rock classification was based on the International Society of Rock Mechanics (ISRM) System with adaptation to suit the identified rock and structure.

The rock core was logged as soon as practical after it was extracted from the core barrel. The following information was generally noted for each core run:

- Depth of core run
- Percent core recovery
- Rock Quality Designation (RQD)
- Rock type, including color, texture, degree of weathering and hardness
- Character of discontinuities, joint spacing, orientation, roughness and alteration
- Nature of joint infilling materials, where encountered
- Presence of apparently water-filled fractures



BEDROCK CORE OBTAINED FROM DRILLING USED FOR EVALUATION OF FRACTURES

During rock coring activities, potable water was used as a drilling fluid to cool and lubricate the core barrel and remove cuttings from the borehole. The drilling fluid was circulated down the borehole around the core that had been cut, flowed between the core and core barrel, and exited through the bit. The drilling fluid then circulated up the annular space and was discharged at the land surface to a mud tub. The volume of water lost during drilling was recorded and later, during development, an attempt was made to remove the amount lost to the formation.

In addition, drilling parameters, such as the type of drilling equipment, core barrel and casing size, drilling rate, and groundwater condition were recorded. Cumulatively, this information provided insights relative to rock conditions, and the potential for the transport of groundwater migration in bedrock fractures.

Bedrock borings ranged in depth from 30 feet below ground surface at MW-33, -34 and -35 to 350 feet below ground surface at MW-67. As described below in **Section 4.4**,

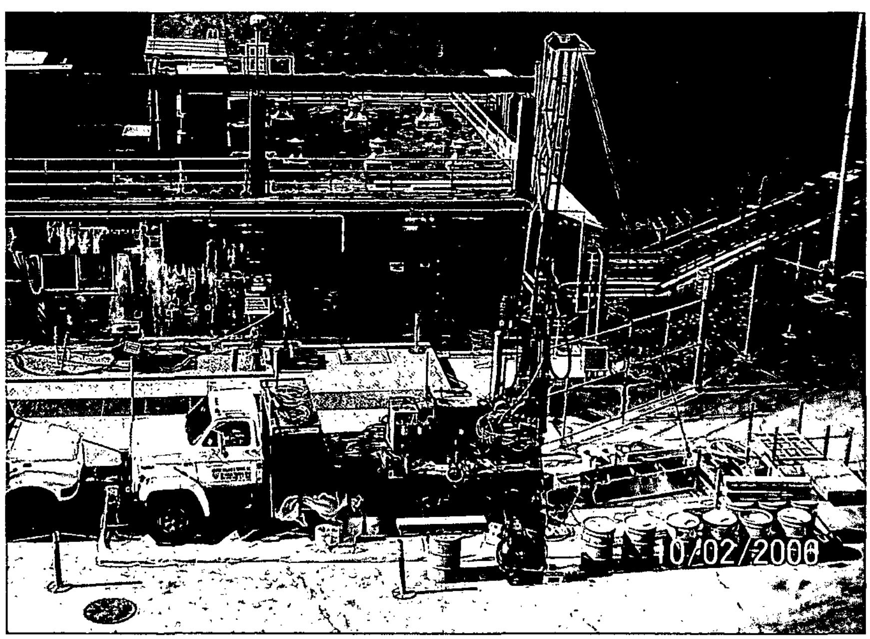
the majority of the rock borings were completed as monitoring well locations. One exception was MW-61, which was abandoned when a length of HQ casing separated in the borehole due to drilling difficulties related to a 70-foot length of clay-filled fault gouge, and could not be retrieved. The boring was subsequently grouted and a second boring, designated MW-66, was advanced approximately 10 feet East of the MW-61 location.

As discussed earlier, one boring, U1-CSS, was installed using a hand-held coring machine through the East wall of the IP1-CSS. This borehole was advanced horizontally approximately 70 inches into the bedrock to the East of the Superheater Building.

4.2.2 Overburden Borings

In areas where groundwater was encountered in the overburden deposits, overburden (soil) borings were drilled to further evaluate water quality in the shallow aquifer. Five borings, designated MW-49, -52, -62, -63, and -66 were advanced immediately adjacent to the bedrock boring of the same name. In addition, three overburden borings, designated MW-38 and MW-64, were advanced at stand alone locations. MW-38 was advanced to assess groundwater quality and migration pathways along the Discharge Canal. MW-64 was advanced to determine the backfill material and construction properties of the Discharge Canal as it runs beneath the Superheater Building, and was terminated at a depth of 3 feet when concrete was encountered beneath the slab of the building. Additionally, a tracer injection well (T1-U1-1) was installed within overburden above the North Curtain Drain (NCD) along the North wall of the IP1-FHB.

Seven of the borings were advanced using water rotary techniques and temporary six-inch casing. MW-64 was advanced using a concrete core until lean concrete was encountered under the building slab. Seven of the borings were completed as single monitoring wells.



ADVANCEMENT OF BORINGS ALONG RIVERFRONT

4.2.3 Borehole Development

After drilling was completed and prior to conducting hydraulic tests within a borehole, borehole development was conducted to remove rock cuttings from the borings, which could otherwise restrict water flow into the fractures and alter packer testing results, as well as to remove drilling water lost to the formation during drilling. The boreholes were developed either by pumping and surging with a 3.7-inch surge block and a Grundfos Redi-Flo 2 submersible pump, or by pumping with a submersible pump along the length of the borehole. Sufficient water was pumped out of the borehole to account for water lost during drilling and until well water was visually free of turbidity.

4.2.4 Borehole Geophysical Analysis

Upon completion of borehole development, a suite of geophysical surveys was conducted in select boreholes (borehole geophysics was biased towards the deeper boreholes) by GA of Holliston, Massachusetts to obtain information on the presence of water bearing fractures in the rock. This work took place between November 2005 and July 2007, and involved twenty-three borings MW-30, -31, -32, -33, -34, -39, -40, -51, -52, -53, -54, -55, -56, -57, -58, -59, -60, -62, -63, -65, -66, -67 and RW-1.

GA performed fluid resistivity, temperature and conductivity logging; heat pulse flow meter logging; and optical and acoustical televiewer logging (OTV/ATV). A Mount Sopris model 4MXA or 4MXB logging winch equipped with a Mount Sopris model MGX-11 electronics console recorded conventional logs at each well. All conventional log data was recorded at 0.1-foot depth increments.

Fluid temperature and fluid resistivity logs were recorded during the first downward logging run at each borehole using a Mount Sopris caliper probe with a fluid temperature/fluid resistivity subassembly. These fluid logs were obtained using a downward logging speed of approximately 4 to 5 feet per minute. Caliper data were subsequently recorded while pulling the same probe upward at approximately 10 feet per minute.

ATV data were obtained using an Advanced Logic Technologies (ALT) model AB140 acoustical televiewer probe with a Mount Sopris winch and an ALT model Abox electronics console. ATV data were recorded at 0.01-foot depth intervals with 288 pixels for a 360-degree scan around the borehole wall. Logging speeds were approximately 4 feet per minute with this probe.

OTV data were recorded using an ALT model OB140 probe, also with a Mount Sopris winch and the ALT electronics console. OTV data were stored at depth increments of 0.007 feet, with 288 pixels for each 360-degree scan around the borehole wall. OTV logging speeds were also approximately 4 feet per minute.

A pair of centralizer assemblies positioned the ATV and OTV probes near the middle of each borehole. Each centralizer included four stainless steel bow springs, clamped to the probe housings with brass compression fittings, at positions recommended

by the probe manufacturer to minimize the risk of interference with the probes' three internal component magnetometers.

Flowmeter data were recorded with a Mount Sopris model HPF-2293 heat-pulse flowmeter probe at specific depths selected from field graphs of the caliper, fluid temperature and fluid resistivity logs. Flowmeter data were initially recorded under ambient conditions. The same test depths were subsequently repeated while pumping at 0.4 to 0.75 gallons per minute (gpm) with a Grundfos, Fultz or Whale pump. The pump was positioned a few feet below the observed static water level in each well. In some cases, the pump was operated so as to maintain the water level some number of feet below the static level (if the well produced little water and the water level was constantly dropping while pumping).

A detailed description of the geophysical logging results for each borehole is included in **Appendix C.**

4.3 WELL INSTALLATIONS

Bedrock and overburden monitoring installations were constructed in boreholes to allow for future recording of groundwater levels and the collection of groundwater quality samples. Further, we installed nested piezometers in single boreholes to screen multiple levels of bedrock and overburden within a single borehole and alleviate the need for multiple borings in areas not easily accessed. For specific well installation details, refer to the well construction logs provided in **Appendix D**. In addition, eighteen monitoring wells were previously installed at the Site prior to this investigation and included: MW-101, MW-103, MW-104, MW-105, MW-107, MW-108, MW-109, MW-110, MW-111, MW-112, U3-1, U3-2, U3-3, U3-4S, U3-4D, U3-T1, U3-T2 and I-2.

4.3.1 Bedrock Wells

Following borehole advancement and testing, GZA evaluated the rock cores, geophysical logs, and other hydrologic and radionuclide test data to assess fracture spacing and potential yield. Using these data, GZA selected intervals within the boreholes to be completed as permanently screened monitoring wells. The selected well screen intervals were intended to span hydraulically active zones within the bedrock.

4.3.1.1 Open Rock Wells

Four bedrock borings, designated MW-33, -34, -35 and -46, were left as open borehole monitoring points. MW-46 is located in the Unit 3 Transformer Yard (IP3-TY), and MW-33, -34 and -35 are located in the Unit 2 Transformer Yard (IP2-TY) where the water table spans the hydraulically active shallow bedrock. The wetted lengths of the borehole were appropriate for one sampling zone at these locations.

Recovery well RW-1, located in the IP2-FSB truck bay, is also an open borehole. The borehole was installed and a Pumping Test conducted (described in **Section 4.4.4**) to test the feasibility of using hydraulic containment in the vicinity of Unit 2, should it be found appropriate. This location was used as the pumping well during the Pumping

Test. During the interim between completion of the Pumping Test and completion of a hydraulic containment system, a series of temporary packers were installed in the borehole to prevent or limit non-ambient, downward migration of radionuclides through the borehole. RW-1 was also used as a monitoring point during the tracer test.

MW-66 is an open borehole to 200 feet below grade. A Flute liner system was installed in the borehole in September 2007 to limit the vertical migration of contaminants until such time as either a multi-level monitoring well is completed or the boring is abandoned.

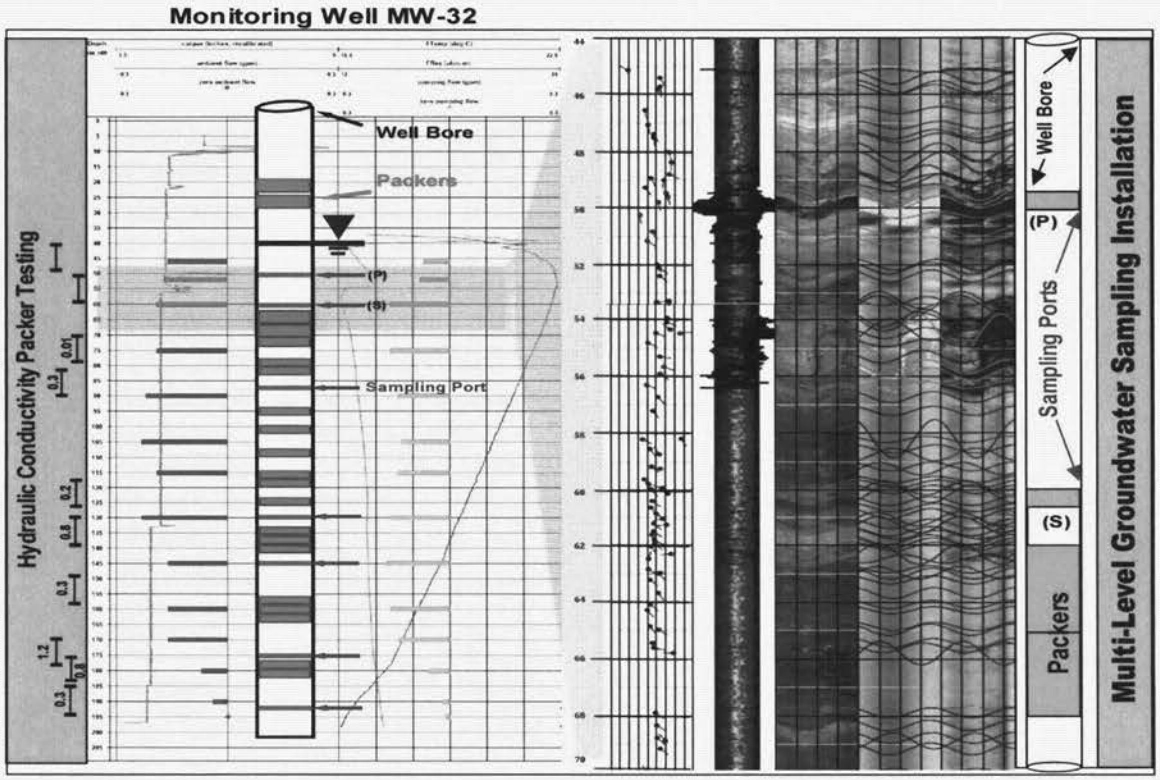
U1-CSS is an open borehole advanced horizontally into the bedrock behind the East wall of the Superheater Building. A watertight flange was mounted to the concrete wall of the IP1-CSS and steel piping was extended vertically upward through the floor of the Superheater Building. The well was completed as a standpipe with shut-off valves and overflow bypass in case of any artesian effect.

4.3.1.2 Waterloo Multi-Level Completion Wells

Twelve borehole locations, designated MW-30, -31, -32, -39, -40, -51, -52, -54, -60, -62, -63, and -67, were completed with Waterloo multi-level sampling systems. The Waterloo system uses modular components which form a sealed casing string of various casing lengths, packers, ports, a base plug and a surface manifold. This configuration allows accurate placement of ports at precise monitoring zones. Stainless steel sampling pumps are connected to the stem of each port and individually connect that monitoring zone to the surface. The Waterloo systems are constructed of 2-inch-diameter Schedule 80 PVC risers with 3-foot-long packers that inflate to fill a 4-inch borehole.

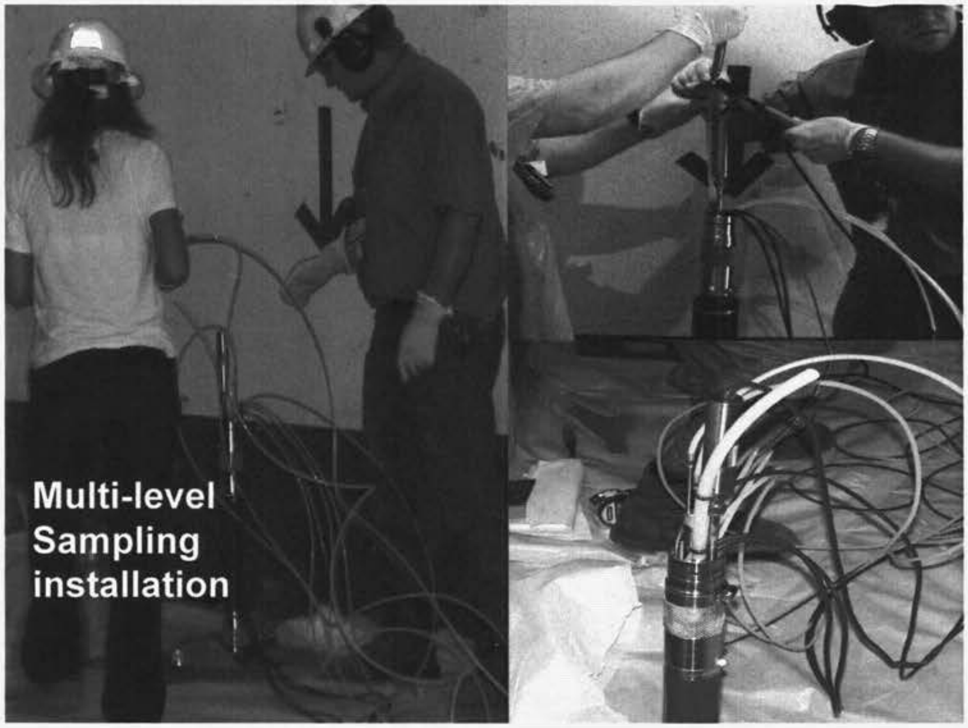
Multiple levels of monitoring ports were installed in each borehole. In several cases, redundant ports were also installed (typically, within approximately two feet of each other). In the borehole, the associated sampling zones are isolated from each other by a series of packers. The monitoring ports are constructed from stainless steel. Each monitoring port has two openings: one for sampling and one for monitoring piezometric pressures. A sampling pump and pressure transducer are dedicated to each monitoring port. Each sampling pump is individually connected to the surface manifold by 0.25-inch nylon tubing. In general, monitoring ports were placed within sampling zones adjacent to the fractures that were observed to be the most hydraulically active. Sampling zone lengths were varied with the objective of making them less than ten feet in length, but longer where either: 1) more low transmissivity fractures were required to allow enough flow for reasonable sampling times, and/or 2) two conductive fractures needed to be captured within a single sampling zone given that the total number of monitoring ports was limited to seven per borehole. Packers were placed at locations where the data (geophysical logging, packer testing, rock core photographs, etc.) indicated that the bedrock was the least fractured. In areas where packer placement could not avoid all fractures, zones with nearly horizontal fractures were favored. The overall objective of packer placement was to achieve a vertical borehole conductivity equal to or less than that of the original bedrock removed from the borehole.

A schematic of the data and analysis process used to design the multi-level installations is included below.



EXAMPLE OF DATA AND ANALYSES USED TO DESIGN MULTILEVEL INSTALLATION

The manifold completes the system at the surface. It organizes, identifies, and coordinates the sample tubing, air drive line tubing, and/or transducer cables from each monitoring zone (see photo below of tubing and cabling during system assembly and installation). The manifold allows connection to each transducer in turn, and a simple, one-step connection for operation of pumps. Dedicated pumps allow individual zones to be purged separately; the manifold also allows for the purging of many zones simultaneously from one borehole to reduce sampling times.



SAMPLING PORTS, TUBING AND CABLING FOR MULTI- LEVEL SYSTEM ASSEMBLY AND INSTALLATION

4.3.1.3 Nested Wells

Nested monitoring wells were installed in 18 locations, designated MW-36, -37, -41, -42, -43, -44, -45, -47, -48, -49, -50, -53, -55, -56, -57, -58, -59, and -65. In general, the nested wells consisted of the installation of one or more one-inch diameter Schedule 80 PVC wells screened at varying intervals in bedrock and a two-inch Schedule 80 PVC well in the shallow West sampling zone of the boring, either in the bedrock or overburden.

In general, well screens consisting of 0.02-inch slotted PVC pipe were installed at lengths between 2 and 10 feet. Once the screened intervals were selected, the PVC well point was lowered into the boring to the desired depth. Appropriately sized filter pack material was placed from one foot below the screened interval to a minimum of one foot above the screened interval. The depth of the filter pack was measured on several occasions during installation to assess the affects of bridging and verify that the filter pack material was placed at the required depths. The intervals between well screens were sealed using bentonite pellets.

4.3.2 Overburden Wells

Three wells, MW-38, -49-26, -52-12 were completed as either two-inch diameter or four-inch diameter groundwater monitoring wells. The wells were constructed of Schedule 40 PVC screen and solid riser to ground surface. A 0.02-inch slot size was selected for the

well screens based on existing knowledge of the Site soil conditions. From field observations, the shallow groundwater table was expected to be influenced by daily tidal fluctuations of approximately 2.7 feet. Consequently, well screens were installed such that the top of the screens were above mean high-tide water levels and of sufficient length to accommodate groundwater sampling needs. The annular space around the screen and riser was backfilled with #2 filter sand to approximately 2 feet above the top of the screen. The remaining annular space was backfilled with bentonite and grout.

In order to sample two intervals in deep fill and overburden deposits observed near the Hudson River (in borings at MW-62, -63, and -66), GZA installed two one-inch Schedule 40 PVC wells, or one one-inch and one two-inch well, at these three locations. One of the well screens spanned the tidally influenced shallow water table, and one at the top of rock in a more gravel-rich layer beneath silty, historic, river bottom sediments.

In addition, GZA installed one tracer injection well situated in the overburden above the Unit 1 North Curtain Drain. This well is constructed of two-inch Schedule 40 PVC. The screened interval was backfilled with #2 filter sand to approximately 2 feet above the screen. The remaining annular space was backfilled with bentonite grout. A second tracer injection point was completed adjacent to MW-30's casing.

4.3.3 Wellhead Completion

To protect the monitoring installations against damage and the elements, most installations were finished at the ground surface with an 8-inch or 12-inch flush mount protective casing with a concrete pad. To accommodate the multi-purge, sampling manifold of the Waterloo Systems well installations, the wellheads were completed with a 2 foot by 2 foot by 2 foot well vault. The well vaults were concreted in-place by Entergy subcontractors after the completion of the rock borings. The well vaults are equipped with hinged diamond plate steel lids that are rated for truck wheel loads.

4.3.4 Well Nomenclature

GZA designated names to newly installed monitoring installations[17], typically with the prefix "MW-". Nomenclature of single-interval installations, such as MW-33, were designated a number typically indicative of the order in which locations were selected prior to drilling. Nomenclature of installations containing Waterloo systems or nested piezometers, such as MW-30-69, were designated a number followed by a monitoring depth interval. In Waterloo installations, the depth interval suffix is indicative of the depth to the sampling port from the top of the well casing. In nested piezometers, the monitoring depth interval suffix is indicative of the depth to the bottom of the piezometer from the top of the well riser. These depths are rounded to the nearest foot.

Throughout the course of the investigation, alterations were made to well casings and adjacent ground surfaces due to equipment installation, hydraulic conductivity testing,

[17] *Monitoring installations* are commonly referred to as *Monitoring wells*, which in this usage, may include multiple, individual well casings. This generic usage is also used herein.

well vault installation, and Site construction activities. In May 2007, GZA reassigned the names of multilevel installations to maintain the above described nomenclature basis as an easily verifiable tool in the field. Changes in installation nomenclature are provided in **Table 4.2**. It should be noted that the provided groundwater and tracer test analytical data, piezometric data, well construction and development logs, transducer installation logs, sampling logs, hydraulic conductivity testing logs, and survey reports dated prior to May 2007 reference the original designated installation nomenclature.

4.3.5 Wellhead Elevation Surveying

As-built surveys of the newly installed monitoring installations were performed in December 2005, March 2006, April 2006, November 2006, January 2007, and May 2007 by Badey and Watson, Inc. **Figure 1.3** reflects the surveyed locations. The survey results are summarized in **Appendix E** and in **Table 4.1**. Note that **Appendix E** survey reports dated prior to May 2007 reference original installation nomenclature. **Table 4.3** includes changes in casing and ground surface elevations and dates of alterations and resurveys throughout the course of the investigation. Elevations are reported with respect to the National Geodetic Vertical Datum of 1929 (NGVD 29)[18], which is also the datum used by the plant.

4.4 HYDRAULIC TESTING

Four types of in situ tests were performed on existing and newly installed monitoring wells to characterize hydrogeologic properties of the bedrock and overburden, and facilitate the selection of well screen and piezometric sampling intervals. These included short duration specific capacity tests, rising head hydraulic conductivity tests, bedrock packer hydraulic conductivity tests, and the Pumping Test. The following sections describe the equipment and procedures used during this testing program.

4.4.1 Short Duration Specific Capacity Tests

A total of eight specific capacity tests and eight extraction tests were performed to assess hydraulic conductivity (K). See **Table 4.4** for a summary of hydraulic conductivity data.

The testing was conducted by pumping water from the well at a constant rate in order to achieve "measurable drawdown" within the well that would stabilize after a relatively short period of time. "Measurable drawdown" was considered between 1.5 and 10 feet for the purposes of this study. Once drawdown apparently stabilized, pumping was allowed to continue at a constant rate for at least thirty additional minutes before pumping ceased.

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[18] The National Geodetic Vertical Datum of 1929 (NGVD 29) is the renamed Sea Level Datum of 1929. The datum was renamed because it is a hybrid model, and *not a pure model of mean sea level*, the geoid, or any other equipotential surface. NGVD29, which is based on "an averaging" of multiple points in the US and Canada, is the vertical "sea level" control datum established for vertical control surveying in the United States of America by the General Adjustment of 1929. The datum is used to measure elevation or altitude above, and depression or depth below, "mean sea level" (MSL). It is noted that there is no single MSL, because it varies from place to place and over time.

If measurable drawdown within the well could not be achieved, and the maximum capacity of the pump was reached, pumping was allowed to continue at a constant rate for approximately thirty minutes, and the pump was turned off. If the characteristics of the monitoring well and immediately surrounding hydrogeology did not allow for a more suitable method of hydraulic testing, the well was characterized as having a K value "greater than" the value estimated at the maximum pumping rate.

If stabilized drawdown within the well could not be achieved, and the water level in the well continued to decline after attempts to minimize pumping rate to the minimum pumping capability of the pump, the pump was turned off. If alternative methods of testing could not be appropriately implemented due to well characteristics, water levels during the recovery period of this test were analyzed and interpreted for K values.

A Grundfos II Readi-Flo submersible pump or peristaltic pump was used for specific capacity testing, and drawdown was measured using an electronic water level meter and/or pressure transducers. Flow rates were either measured using an in-line flow meter, or estimated by measuring the time required to fill a calibrated container. Transducer-logged water level measurements were typically recorded at thirty second or one minute intervals, while manual water level measurements were typically logged every one to five minutes. The entire pumping duration for each test was typically between thirty and ninety minutes.

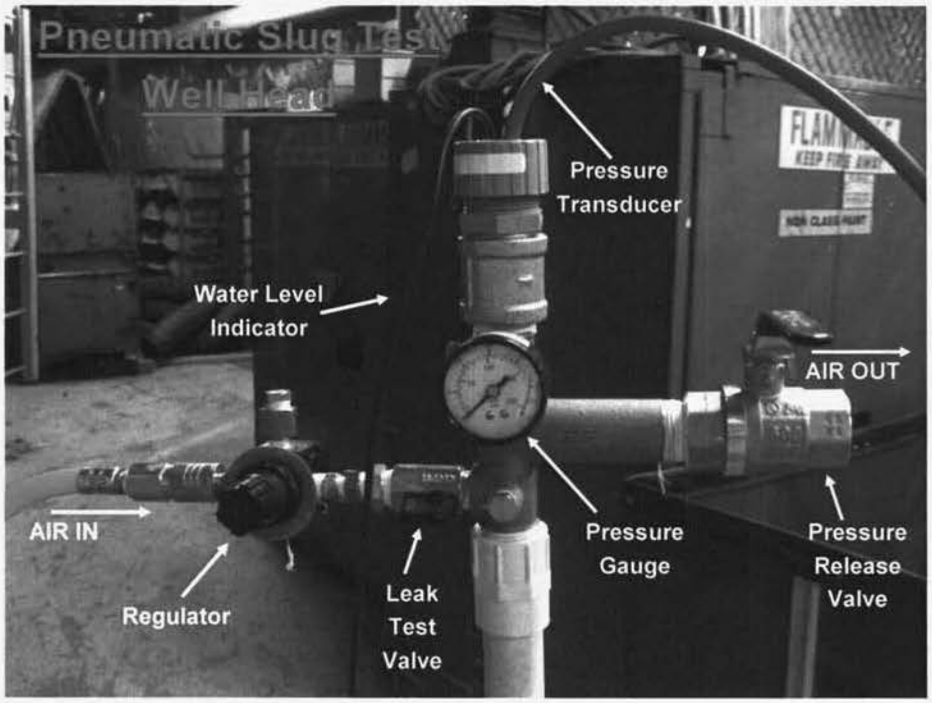
GZA performed specific capacity tests between January 2006 and April 2007. Measurements were also recorded during borehole development. The logs are included in **Appendix F**.

4.4.2 Rising Head Hydraulic Conductivity Tests

A total of forty-three rising head hydraulic conductivity tests were performed at eighteen monitoring wells at the Site. Rising head K tests (slug tests) were performed in MW-36-41, -36-53, -37-57, -41-64, and -42-51 via traditional slug testing. Pneumatic slug tests were performed in monitoring wells MW-53-120, -55-24, -55-24, -55-35, -55-54, -56-85, -57-20, -57-45, -58-65, -59-31, -59-45, -59-68, and -65-80. Hydraulic conductivity (and transmissivity) estimates were then calculated from those results. The calculations for the hydraulic conductivity estimates are provided in **Appendix G**.

At each of the traditional slug tested monitoring wells, the resting (static) water level was measured along with the depth and diameter of the well. A pressure transducer was installed within the screened portion of the tested well to record water level measurements at 10 second intervals. Pressure transducers in immediately adjacent wells also recorded water level measurements at 10 second to one minute intervals. During the first part of the slug test a rod (slug) of approximately 7 feet long was quickly inserted into the tested well below the water table in order to nearly instantaneously displace a volume of water equivalent to the volume of the slug. The raised head of the water column was then dissipated back down to its initial static level. When equilibration at static water level was reached a rising head test was conducted. The slug was quickly withdrawn from the monitoring well, resulting in a nearly instantaneous decline in the water level within the tested well. The lowered head of the water column recovered to its initial static water level.

At each of the pneumatic slug tested wells, static water level was recorded, as well as the depth and diameter of the well. Pressure transducers were installed within the screened portion of the tested well and in adjacent wells to record water level measurements at 1 to 3 second intervals. A pneumatic slug test well head was attached and sealed to the top of the tested well (see enclosed photo below). The well head was then pressurized using compressed air in order to lower the water column to a predetermined depth that was measured using pressure transducers. The water column was not permitted to decline below the top of the well screen. When pressure transducer readings stabilized and the water level in the well was below the water level indicated, the air pressure was instantaneously released through a valve on the pneumatic slug test well head, and the water column was allowed to recover to its initial static water level.



PNUEMATIC SLUG TEST WELL HEAD INSTRUMENTATION

Slug test logs are provided in **Appendix H**. Estimated K values are provided in **Table 4.4**. **Figure 4.1** represents a diagram of the pneumatic slug test well head.

4.4.3 Bedrock Packer Extraction Hydraulic Conductivity Testing

Under the direction of GZA personnel, ADT conducted 186 packer hydraulic conductivity tests between November 2005 and August 2007 in boreholes MW-30, -31, -32, -39, -40, -51, -52, -54, -60, -62, -63, -66 and -67.

PACKER TESTING OF MW-30 WITHIN IP2-SFP EXCAVATION

Bedrock packer hydraulic conductivity testing (packer testing) was performed to estimate the equivalent hydraulic conductivity of the bedrock in the vicinity of the borehole locations. The use of packers permitted the localization of a specific depth interval within a bedrock borehole for sampling and hydraulic conductivity testing. The primary hydraulic conductivity of unfractured marble is insignificant. Bedrock groundwater flow, therefore, is controlled by fractures in the rock formation. However, not all rock fractures are hydraulically active. Accordingly, packer tests were used to assess which rock zones have the ability to transmit measurable quantities of groundwater, and to estimate the equivalent hydraulic conductivities of those fractures.

During packer testing, water samples were collected for Tritium analysis for each tested interval in all boreholes except MW-40. Water samples were also collected for Strontium analysis for every other tested interval in boreholes MW-54, -60, -62, -63, -66, and -67.

Prior to the initiation of packer testing at the Site, the packer assembly was pressure tested. Also, prior to the start of packer testing at each borehole, all downhole equipment was disassembled and steam cleaned. The submersible pump was removed from the packer assembly and decontaminated using a fresh water and Alconox solution. A quality assurance/quality control (QA/QC) sample was collected from this pump after the decontamination process was completed. After reassembly of the packer equipment, packers and air lines were tested for leaks.

Packer tests were performed using an assembly composed of two inflatable bladders, or "packers", with a length of perforated pipe making up the 10-foot test zone between the two packers. A Grundfos Rediflo II submersible pump was placed within this 10-foot-long test zone. Pressure transducers were positioned above, within and below the test zone.

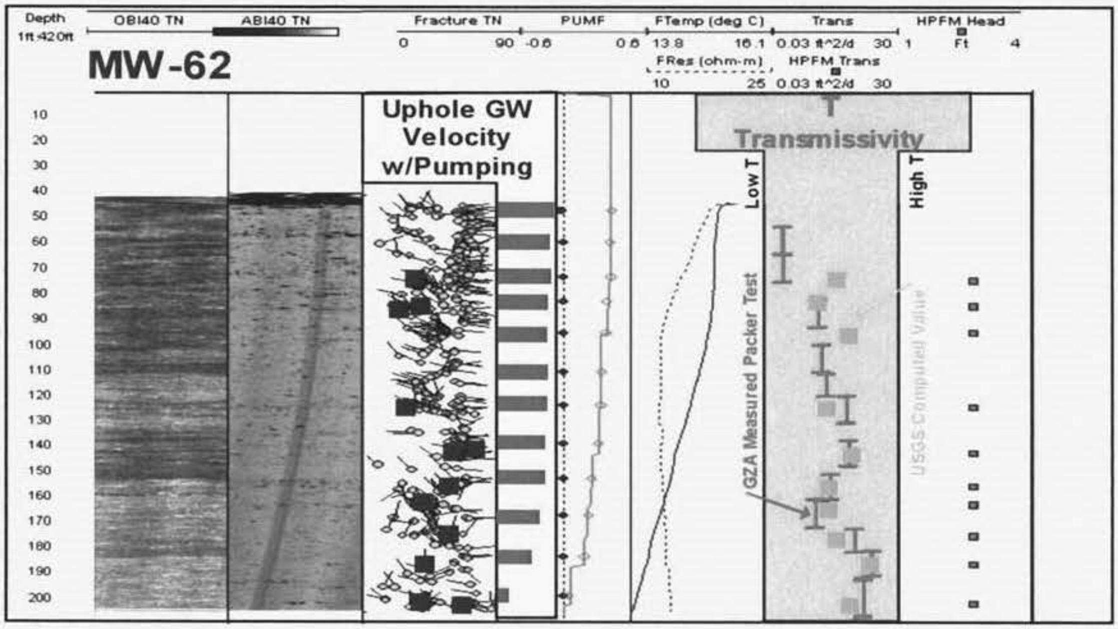
Using a drill rig hoist, the packer assembly was lowered on two-inch-diameter Schedule 80 pipe to the appropriate test depths within each tested borehole. See **Figure 4.2** for a schematic of the packer test assemblage.

Water levels above, within, and below the tested zone were recorded at ten second intervals using pressure transducers. Packers were inflated with 160-195 psi of nitrogen, and water levels were allowed to equilibrate. Once pressures had equilibrated, the pump was turned on and the tested zone was slow purged for at least ten minutes at a rate of 2 to 10 gallons per hour (gph). During this initial purge, a sample was collected for Tritium analysis in boreholes MW-30, MW-31, MW-32, MW-39, MW-51 and MW-52. Immediately following this initial purging period, the pumping rate was increased to a rate of 0.5 to 4 gallons per minute (gpm) in order to achieve drawdown of approximately 10 to 30 feet within the tested zone.

During drawdown, pressure transducer data was observed and compared to assess the potential for cross-zone communication, either through fractures interconnecting around the packer or incomplete seals by the packers. If significant drawdown could not be achieved, a short term sustained yield test was conducted. Once significant drawdown was achieved, or sustained yield was maintained for at least 30 minutes, a sample was collected for Tritium analysis. The pump was turned off, and the water level within the test zone was allowed to recover for either 30 minutes or until 80 percent recovery was achieved. For test zones in which sufficient recovery had been achieved, a final sample was collected for Tritium analysis. This sample was collected from all packer test zones except in borehole MW-40. In some test zones, as noted above, an additional sample was collected for Strontium analysis. After samples were retrieved, the packers were deflated and pressure transducer data was collected.

Packer test intervals and test pressures were measured in the field and recorded by GZA personnel along with all pertinent testing data. Hydraulic conductivity calculations and methodologies are presented in **Appendix G**. Packer test result summary sheets are presented in **Appendix I**. **Table 4.4** summarizes hydraulic conductivity data collected during packer testing.

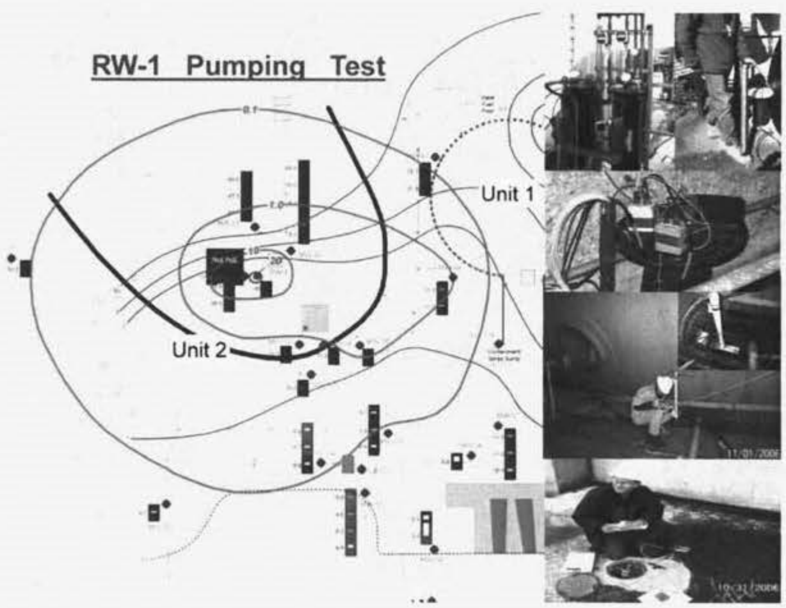
In addition to the analyses referenced above, depth-specific borehole transmissivity values were also computed by the USGS using the heat pulse flow meter data collected during the geophysical logging. These data generally confirmed the packer testing values computed as discussed above (see figure below for an example comparison). In some cases however, these two methods did not correlate well, as reflective of the limitations inherent with each method. For example, the heat pulse flow meter analyses yielded lower transmissivity values where the packer testing transducer data indicated leakage around the packers. In other cases, the heat pulse flow meter analyses proved to be too insensitive to measure lower transmissivity values.



COMPARISON OF PACKER TESTING TO HEAT PULSE FLOW METER ANALYSIS OF TRANSMISSIVITY

4.4.4 Pumping Test

GZA conducted a step drawdown, constant rate drawdown, and aquifer recovery test in recovery well RW-1 near the IP2-SFP as shown on **Figure 1.3**. Collectively, these tests are referred to as the "Pumping Test." The Pumping Test was performed in general accordance with our Standard Operating Procedure (SOP) dated October 11, 2006 and submitted as part of the "Pumping Test Report" dated and submitted to Entergy on December 8, 2006. A schematic of the Pumping Test data, testing and pumping equipment, and data monitoring is provided below.



EQUIPMENT, MONITORING AND DATA FROM PUMPING TEST OF RW-1

Prior to the Pumping Test, GZA installed select instrumentation including flow meters, precision gauges, and valving at the well head to control flow and to collect samples, and transducers in wells and drains to measure water level response to pumping.

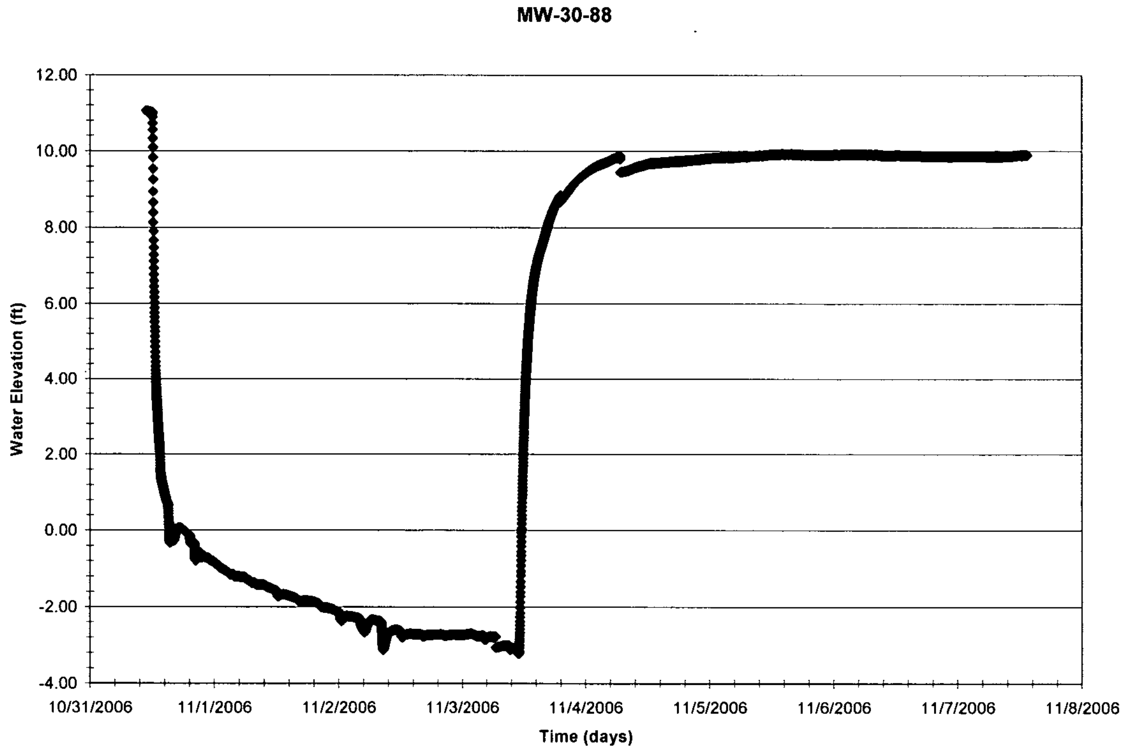
GZA conducted the Pumping Test by extracting groundwater from RW-1 at the following average flow rates:

Test Name	Begin Date	End Date	Pumping Rate at RW-1
Step Drawdown	10/25/2006	10/25/2006	2 gpm for 88 minutes 4 gpm for 77 minutes 5 gpm for 63 minutes 7 gpm for 28 minutes
Constant Rate Drawdown	10/31/2006	11/3/2006	4 gpm for 71 hours
Recovery	11/3/2006	11/6/2006	No pumping

PUMPING TEST SUMMARY TABLE

During the Pumping Test, we monitored and recorded the following:

- Water level elevations with 75 pressure transducers at 44 groundwater monitoring wells at the Site. Water levels in the 15 primary monitoring wells (i.e., I-2, MW-30, -31, -32, -33, -34, -35, -36, -37, -42, -47, -51, -52, -53, and -111) were monitored once per minute. The remaining 29 wells (MW-38, -39, -41, -43, -44, -45, -46, -48, -49, -50, -54, -55, -56, -57, -58, -59, -60, -62, -63, -65, -108, -109, U3-2, U3-3, U3-C1, U3-T1, U3-T2, U3-4D, and U3-4S) were monitored hourly.
- Water quality parameters; we also collected groundwater samples for Tritium and Strontium analysis during the step drawdown and constant rate drawdown test at RW-1.
- Flow rates at the IP1-NCD and IP1-SFDS, and the IP2-Curtain Drain; generally at the frequency and using the methods stated in the SOP.
- Precipitation via data available from the on-Site meteorological tower or via information available at www.wunderground.com for the surrounding area.



EXAMPLE OF TIME VS DRAWDOWN CURVE FOR MW-30

The Pumping Test activities are further detailed in our December 8, 2006 report. The results of the Pumping Test are described in **Section 6.0**.

4.5 WATER SAMPLING

Sampling of on-Site groundwater and surface water sources and off-Site groundwater and surface water sources was conducted during the period of this study. The locations and methods of sampling are described in the following sections. The results of the sampling are discussed in **Section 10.0**.

4.5.1 On-Site Groundwater Sampling

On-Site groundwater sampling commenced in August 2005, upon observation of the moist shrinkage cracks in the IP2-SFP wall. Through May 2007, sampling was conducted primarily by Entergy personnel. During this period, GZA personnel collected groundwater samples only during packer testing and when conducting low flow groundwater sampling at monitoring wells MW-30 and MW-42. After May 2007, GZA personnel conducted all groundwater sampling. Over 700 groundwater samples were collected during the study.

GZA and Entergy personnel collected groundwater samples using traditional purge techniques, modified purge techniques, or low flow sampling techniques. Groundwater samples were collected from specific intervals in monitoring wells MW-30 and the 2-inch diameter well-screened interval of MW-42 using low flow purging and sampling methods described in the USEPA's Low Flow Purging and Sampling Guidance document. These sampling techniques are described in the following sections.

4.5.1.1 Purging

At the early stages of the project, Entergy personnel sampled open borehole wells and nested piezometers by purging the traditional 3 to 5 times the volume of water standing in the well casing[19]. This was accomplished with either a dedicated submersible pump, a peristaltic pump with dedicated tubing, or a Waterra foot-valve pump with dedicated tubing. As the investigation proceeded, GZA became concerned that the standardly-required purge volume could force unrepresentative displacement of contaminants in the low conductivity bedrock through sampling-induced drawdown in the wells. We therefore reduced the purge volume, for wells not low flow-sampled, to 1.5 well volumes for the remainder of the investigation. This modification to the sampling procedures was discussed with the regulators. By May 2007, low flow sampling procedures had been adopted and implemented for all wells.

4.5.1.2 Low Flow Sampling

The low flow sampling method allows collection of groundwater samples representative of ambient flow conditions at discrete sampling zones, while limiting the accumulation of wastewater, mobilization of contaminants, and turbidity of samples by reducing pumping rate and drawdown. GZA collected low flow groundwater samples using peristaltic pumps, Grundfos Readiflo II submersible pumps, and several models of submersible pumps manufactured by Proactiv. Low flow samples were also collected at discrete sampling intervals of deeper boreholes using Solinst Multilevel Waterloo sampling systems. The use of Waterloo systems for low flow sample collection is summarized in the following section. With the exception of wells MW-30 and MW-42, GZA began low flow sampling in May 2007. GZA collected samples from MW-30 and MW-42 using low flow techniques starting in January 2006.

GZA collected low flow samples by slowly pumping from a predetermined well depth while monitoring water quality parameters, including pH, specific conductance, temperature, turbidity, dissolved oxygen, and oxygen reduction potential (ORP). Water quality parameters were monitored using a Horiba U22 water quality meter with an in-line flow-through cell. Pumping rates were typically between 100 and 400 ml per minute, and drawdown within the well was typically limited to between 0.1 and 1.0 foot.

GZA recorded water quality parameters, water level, and flow rate every five to ten minutes during a pre-sampling purge which lasted generally between one half hour and three hours. Samples were collected upon stabilization of water quality parameters listed above. Low flow sampling logs are provided in **Appendix J**. Note that sampling logs dated prior to May 2007 reference original well nomenclature.

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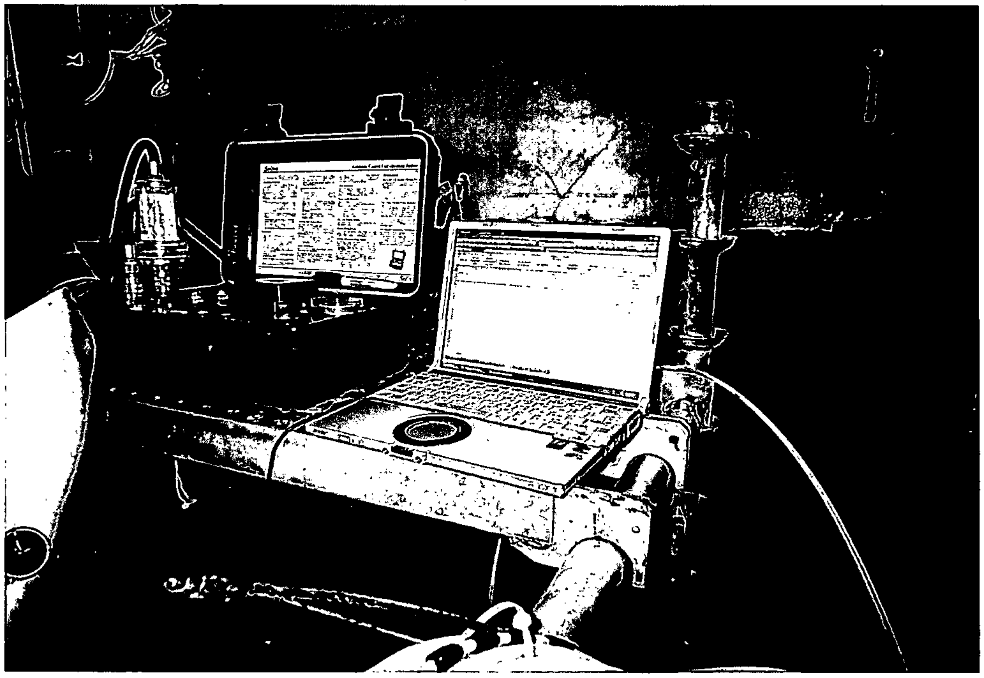
[19] Water quality parameters during well purging were not measured by Entergy personnel as part of their groundwater sampling rounds.

4.5.1.3 Waterloo Low Flow Sampling

Low flow sampling was also conducted in Waterloo installations at MW-30, -31, -32, -39, -40, -51, -52, -54, -60, -62, -63, and -67. Samples were taken from discrete intervals unless the interval was depressurized, in which case 1.5 well volumes were purged prior to sampling.



LOW FLOW SAMPLING OF MW-30

4.5.1.4 Discrete Interval Packer Sampling

During packer testing prior to installation of Waterloo systems, GZA collected groundwater samples representative of several distinct elevations within each borehole. GZA collected water samples for Tritium analysis for each tested interval in all boreholes except MW-40. Water samples were also collected for Strontium analysis in boreholes MW-54, -60, -62, -63, and -66. Sampling procedures were described in **Section 4.4.3.**

4.5.2 On-Site Surface Water Sampling

On January 19, 2007, GZA collected samples from the Discharge Canal and Hudson River to evaluate major cation geochemistry. This sampling was designed to help us assess potential sources of water found within monitoring wells MW-38 and -48. Samples were collected with dedicated high density polyethylene bailers. In addition, Entergy routinely collects composite water samples from the Discharge Canal to evaluate the discharge of radionuclides to the Hudson River. These samples are collected using peristaltic pumps at locations indicated in the Annual Radiological Environmental Operating Report (AREOR).

4.5.3 Off-Site Groundwater Sampling

At the beginning stages of the investigation, prior to a thorough understanding of the hydrogeology of the Site, several off-Site groundwater wells were sampled by Entergy personnel to assess the potential for off-Site contamination. These data are presented in the AREOR and the sampling is conducted under the Radiological Environmental Monitoring Program (REMP). During the course of this study, the normal sampling frequencies were increased to either monthly or quarterly to assess regional background concentrations of contaminants of interest. These sampling points included: four USGS monitoring wells, three LaFarge property wells, and the Fifth Street well in Buchanan. **Figure 4.3** shows the locations of the USGS Wells. **Figure 1.3** portrays the location of the LaFarge wells. Please refer to the AREOR for the location of the Fifth Street well.

USGS Wells - On December 5 and 6, 2006, GZA personnel, accompanied by a New York State Department of Environmental Conservation (NYSDEC) representative, collected groundwater samples from four USGS groundwater monitoring wells to assess background concentrations for Tritium, Strontium and Cesium in the region. The wells were located in Harriman State Park, Rockland County, (RO543); Carmel, New York, Putnam County (P1217); Fort Montgomery, New York, Orange County (local municipal water monitoring well); and Doodletown, New York, Rockland County (RO18). All four monitoring wells were completed in bedrock. The NYSDEC provided GZA with borehole geophysical data. All four wells exhibited upward vertical gradients. GZA selected sample locations based upon the flowmeter data so as to sample the groundwater at a depth just below where it was presumed to be exiting the borehole. The groundwater samples were transported to Entergy under chain of custody procedures. Entergy personnel then shipped the samples to Areva Laboratories in Westboro, Massachusetts for analysis of Tritium, Strontium and Cesium.

LaFarge Wells - GZA personnel supervised the collection of groundwater samples from the Lafarge property immediately South of the Site from groundwater monitoring wells MW-1 through MW-3. Samples were collected by LaFarge's environmental consultant, Groundwater and Environmental Services, Inc., under the oversight of Entergy personnel, GZA and NYSDEC representatives on September 19, 2006. Groundwater samples were collected using a bladder pump following low flow procedures described below. The depths of the wells are shown on **Table 4.1**.

Fifth Street Well - Entergy personnel, accompanied by NRC and NYSDEC personnel, collected samples from the Fifth Street well in Buchanan, New York on November 30, 2005. This well is a former private drinking water well no longer in use.

4.5.4 Off-Site Surface Water Sampling

During the course of this study, off-Site surface water was sampled at the following locations: the Camp Field Reservoir and the New Croton Reservoir, Algonquin Creek, Trap Rock Quarry, the LaFarge property (Gypsum Plant) outfall, and the Hudson River (see **Figure 4.4** for the locations of the Reservoirs). The sampling frequency discussed in the AREOR was increased during the investigation. Detailed sample locations are discussed in the AREOR.

4.6 PIEZOMETRIC LEVELS AND PRESSURE TRANSDUCER DATA

GZA measured piezometric levels at 67 locations at the Site over time (between October 2005 and September 2007) using a system of electronic pressure transducers. These measurements were converted to groundwater elevations (NGVD 29) by referencing the depth of the transducer below the water table at a given time to the elevation of the top of the monitoring well riser. GZA used the resulting data to estimate hydraulic properties of the soil and bedrock, and assess the effects of precipitation, tidal influences, seasonality, and pumping on groundwater flow patterns.

This section describes the methods we used to collect and manage this data. Discussions on the use of the data are presented in **Sections 6.0** and **10.0**.

4.6.1 Transducer Types and Data Retrieval

GZA used two types of transducers, depending on the well type and application. In open wells, GZA installed MiniTroll and LevelTroll transducers, which are vented pneumatic transducers with internal dataloggers. These transducers are manufactured by In-Situ® Inc. In wells equipped with Waterloo systems, GZA installed non-vented vibrating wire transducers manufactured by Geokon® Inc. Each of these transducers was connected to a Geokon datalogger box located within the well vault.

GZA selected and installed pressure transducers within the appropriate operating pressure range required for each well or well interval. **Table 4.5** provides the accuracy of the transducers as reported by In-Situ and Geokon. This table also provides the type of transducer used in each well or well interval.

GZA collected data from In-Situ transducers typically every one to three months, or as needed. We exported data collected from each transducer from data files recognizable only by Win-Situ software into Microsoft® Excel® spreadsheets. Generally, no external data manipulation was required for these data reports. On occasion, adjustments to data were required to correct for daylight savings time, or to correct for measured disturbance of the transducer position within the well.

GZA collected water level data from each Geokon datalogger typically every two weeks to two months, or as needed. After collection, we exported the raw data into Excel spreadsheets and converted reported water levels to water elevations. Because the Geokon transducers are not vented, we adjusted total pressures to account for barometric pressure changes. Into each data report, GZA incorporated: 1) the barometer reading recorded during wellhead zeroing of the respective transducer; and 2) the barometric pressures recorded at or near the Site at the time the total pressures were recorded. Barometric pressures for this project were recorded on an on-going basis on Site using a Geokon transducer exposed to atmosphere. At different times, the barometric pressure transducer was installed several feet above the maximum water table in MW-31, MW-65, and MW-56. For verification, GZA also used barometric pressure data collected by West Point Military Academy, less than ten miles from the Site.

4.6.2 Data Availability and Preservation

A compact disk containing piezometric data collected between October 2005 and September 2007 is provided in **Appendix K**. The data is organized by well number in Excel spreadsheets. Note that piezometric data dated prior to May 2007 reference original well nomenclature.

Graphs of water levels between October 2005 and February 2007 are presented in **Appendix L**. Transducer installation logs are provided in **Appendix M**. As indicated by the legend on the first sheet of this Appendix, colors on these graphs illustrate changes in groundwater temperature. Each graph presents water levels from wells that are grouped together based on proximity to each other and association with selected Site features. Well locations are shown in **Figure 1.3**.

4.7 TRACER TESTING

To further test the Conceptual Site Model and assess groundwater flow paths from the source areas, GZA conducted an organic tracer test consisting of the injection of Fluorescein (a common dye used in anti-freeze) at a tracer introduction point located close to a potential source of Tritium at IP2-FSB. The injection well was installed approximately four feet South of the expansion crack observed in the South wall of the IP2-SFP, adjacent to monitoring well MW-30. The injection well was designed to allow the injection of tracer onto the top of bedrock located at elevation 52 feet. This elevation corresponds to the bottom of the IP2-SFP. Tracer was then gravity fed into the injection well and flushed with water. After injection, routine sampling and monitoring for the presence of tracer in Site wells commenced and continued for 27 weeks[20].

The tracer introduction was made on February 8, 2007. Tap water was introduced into the injection well adjacent to MW-30 beginning at 10:30 hours. By 10:41 hours, 30 gallons of water had been introduced into the injection well to wet the surfaces of the material down gradient from the injection well. The water introduction was then suspended while ten pounds of Fluorescein dye mixture containing approximately 75% dye and 25% diluent, all of which had previously been dissolved in ten gallons of water, was introduced into the injection well. The dye mixture was introduced between 10:42 and 10:50 hours. Tap water introduction was resumed at 10:51 hours and continued until 11:40 hours. A total of 210 gallons of water was used: 30 gallons to wet the surfaces, 10 gallons to dissolve the tracer, and 170 gallons to flush the tracer out of the dry well into the surrounding bedrock fracture system. Water introduction was made at a mean rate of three gallons per minute.

Sampling and monitoring continued through mid-August 2007, which constituted the completion of the test. The well locations monitored during the organic tracer test and the sampling results are presented in **Appendix N**.

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[20] In addition to the routine sampling, specific wells were sampled for a longer period of time as part of short term variability testing (see **Section 9.0**).

The following sections describe the key elements of the test. The results of the tracer test are discussed in **Section 7.0.**

4.7.1 Injection Well Construction

Following excavation of soil and rock along the southern wall of the IP2-SFP for the construction of a new foundation for a heavier crane, the top of rock was exposed along the South wall of the IP2-SFP at elevation 52 feet. Prior to pouring a mud-mat, construction of the crane foundation and backfilling of the excavation, GZA installed one groundwater monitoring well (MW-30) and one dye injection well. The dye injection well was constructed of one-inch Schedule 40 PVC pipe which terminated at elevation 52 feet. In order to provide a reservoir for the dye to accumulate in prior to seeping into bedrock fractures, a one-foot-thick layer of ¾-inch crushed stone was placed on the top of rock over an area approximately 6 feet by 6 feet square. A mud-mat was poured over the crushed stone layer and across the entire floor of the excavation. The excavation was then backfilled. This injection well design allowed for the dye to be injected on the top of rock and infiltrate into the bedrock in a similar manner as water leaking from the South wall of the IP2-SFP.

4.7.2 Background Sampling

Prior to injection of dye, GZA collected background samples to assess the potential of Fluorescein to be present in the subsurface. Almost all sample locations (which included manholes, surface water bodies, nested wells, Waterloo wells) were sampled for approximately one week periods two to five times prior to dye introduction. This set of data helped in the selection of dye type and quantity, and assured that background levels of Fluorescein were not an obstacle to conducting the groundwater tracing investigation.

4.7.3 Sampling Stations

Sampling stations were selected by GZA for their relevance to the project. Some stations were established as control stations. Control stations were established to detect any fluorescent compounds not introduced as part of this investigation which might enter the study area. Most sampling stations were established to detect dyes introduced during this investigation.

Sampling stations included manholes into the Site drainage system, open waters such as the Discharge Canal and the Hudson River, clusters of nested wells, open borehole wells, and wells with Waterloo packer systems installed. Primary reliance for the detection of dye was placed on activated carbon samplers except at Waterloo locations. One carbon sampler was placed in each well and two were placed in open water locations and in manholes. Open water locations may have strong currents that could damage or wash away a sampler. Placing two samplers at these locations helped ensure that data would be collected for any given time interval and provided duplicate samples for quality assurance. At Waterloo wells, water was the only sampling medium.

Carbon samplers are continuous, accumulative samplers that virtually assure that dye migrating with groundwater is not missed at sampling locations. These samplers,

however, provide information on the concentration of dye at a specific time. Because water is an instantaneous sample instead of a continuous sample the Waterloo wells were sampled more frequently.

The sampling schedule was designed to help ensure that the time the tracer arrived was recorded, and that it would be unlikely that a transient event would fail to be detected at any sampling location. The latter point only applies to the Waterloo sampling locations, since carbon packets collect samples continuously. Grab samples of water only represent the conditions at the instant the water is collected.

High frequency (or high intensity) sampling stations were selected based primarily on three criteria:

- The boundaries of the Unit 1 plume. Most wells that are located within the plume were sampled frequently.
- The premise that non-detections of dye could be as important as detections. Therefore, a "halo" of wells expected to have no detectable dye were sampled surrounding the Unit 1 plume so that the boundaries of the tracer plume would be well defined.
- That there was the possibility of poor correspondence between the tracer plume and the Unit 1 plume at some locations, and that the network might have to be adjusted to maintain the halo of non-detection sampling locations. This resulted in frequent review of the sampling network, and sampling stations were moved from the low intensity to high intensity sampling schedule as tracer was detected near the margins of the high intensity sampling network.

4.7.4 Analysis Schedule

Samples were typically shipped from the Site on the sample collection day or the next day to accommodate next day delivery. Primary samples (both carbon and water) were analyzed within five working days after receipt. Water samples analyzed because of tracer detections in the associated carbon samplers were analyzed within five working days following the carbon analyses. Results were communicated to both Ozark Underground Laboratory (OUL) and GZA project management for review of the detections and consideration of whether or not the sampling network should be modified.

4.8 ADDITIONAL GEOPHYSICAL TESTING TO EVALUATE FLOW PATHS

In addition to the downhole geophysical testing described in **Section 4.2.4**, a series of geophysical surveys was conducted to assess the depth to bedrock in certain areas of the Site and to identify the potential presence of preferential groundwater flow paths along utility trenches cut into bedrock. The major findings of the surveys are graphically shown on **Figure 1.3.**

Under the oversight of GZA, AGS conducted surface geophysical surveys to assess depth to bedrock within the IP2-TY, along the North side of IP2-Turbine Generator Building (TB), within the IP3-TY and along the OCA access road on the southern side of the Protected Area. AGS used ground penetrating radar (GPR) and electromagnetic (EM) survey

equipment to complete the surveys. The survey reports are attached in **Appendix O.** The results of the surveys indicate that bedrock is fairly shallow beneath the areas investigated, except for the areas along the Hudson River where the depth to bedrock increases.

Specifically, the following work was completed:

- A GPR survey was conducted to assess depth to bedrock and potential utility trenches cut into bedrock in the IP3-TY.
- A GPR survey was conducted to assess the potential for contaminants to enter groundwater through leaking stormwater pipes (E-Series) and flow with groundwater towards the Hudson River within utility trenches cut into rock along the OCA access road on the South side of the Protected Area, and to identify depth to bedrock and any utility trenches cut into rock along this roadway.
- In order to assess the presence of subsurface utility trenches to provide preferential pathways for contaminated groundwater to flow to the North, thus accounting for the impacts to groundwater observed in monitoring well MW-48 and MW-38, AGS performed a geophysical survey consisting of a seismic refraction survey, GPR survey, and an EM survey to provide information on bedrock topography on the southern side of the Site between the Protected Area and the southern warehouse.
- In addition, several utilities were identified using EM survey techniques. However, no information regarding the nature of the backfill along the utilities could be discerned from the geophysical information.

The findings of the geophysical survey work are discussed in **Section 6.0**.

5.0 LABORATORY TESTING

Entergy and GZA arranged for, and managed, the analyses of groundwater samples. Between October 2005 and the end of September 2007, over 700 samples were analyzed for radiological contaminants, and, as part of the tracer test, nearly 4,400 samples were analyzed for Fluorescein. In addition, a limited number of samples were analyzed for selected water quality parameters. This section describes the respective testing programs as well as some of the Quality Assurance/Quality Control (QA/QC) procedures used to assess the validity of the data.

5.1 RADIOLOGICAL

Entergy and GZA personnel both collected groundwater samples for radiological analysis from existing and newly installed wells between October 2005 and September 2007. Groundwater samples were sent by Entergy personnel via chain of custody to outside laboratories for analysis of select parameters including Tritium, Strontium, gamma emitters (including Cesium, and Cobalt), and Nickel[21]. Samples were analyzed at the following laboratories: IPEC, Teledyne Brown Engineering, Inc., located at 2508 Quality Lane, Knoxville, Tennessee; Areva NP, Inc. located at 29 Research Drive, Westboro, Massachusetts; James A Fitzpatrick, NPP Environmental Laboratory, located at 268 Lake Road, Lycoming, New York; and General Engineering Laboratories located at 2040 Savage Road, Charleston, South Carolina. The results of the groundwater analyses are summarized in **Table 5.1**. Note that the sample nomenclature for groundwater analytical data collected after May 2007 are provided in the figures, however, location nomenclature prior to May 2007 may differ[22] due to subsequent casing reference point upgrades.

5.1.1 Hydrogeologic Site Investigation Analytical Data

Groundwater samples were typically analyzed for the following: Tritium by EPA Method 906; Strontium by EPA Method 905; and gamma emitters (including Cesium and Cobalt). In addition, transuranics and Nickel (as well as other "hard to detect" radionuclides) were also analyzed in specific instances, as appropriate.

Quality control criteria utilized during this investigation included the following as appropriate: laboratory blanks; field duplicates; laboratory duplicates; laboratory control samples; matrix spikes and matrix spike duplicates; initial and continuing calibrations; instrument tuning; internal standards; and regulatory split samples.

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[21] Tritium and Strontium were the primary radionuclides focused on during the current work pursuant to source identification, groundwater flow analysis and contaminant plume delineation. Radionuclides other than Tritium and Strontium also exist to a limited extent and are fully addressed within the context of the Unit 2 Tritium and Unit 1 Strontium discussions.

[22] See **Section 4.3.4.** Note, however: 1) High priority and fast track sampling preceded casing elevation surveys and vault installation in several cases, 2) low flow sampling within a well screen resulted in collection of samples at depths differing from the well nomenclature, and 3) reinstallation of Waterloo multilevel wells to upgrade packer assemblies. In addition, sample intervals are designated by depth from top of casing.

An overall evaluation of the data indicates that the sample handling, shipment and analytical procedures have been complied with, and the analytical results should be useable. However, during one time period (August and September 2006), Strontium analytical results from Teledyne Brown Engineering, Inc. were as much as an order of magnitude different than split samples analyzed by the NRC and the NYSDOH. (Following verification of this information, the laboratory was dropped from the investigation program.) Therefore, that sample set was not utilized as part of the investigation.

Data Collection and Tracking

The data collection and data tracking phase included the following:

- Preparing all sample bottle labels and chain-of-custody forms;
- Documenting all required data in field log books and field logs;
- Performing data entry of the sampling information into Entergy's database system; and
- Quality assurance/quality control reviews of all data entry.

Laboratory Analysis

The laboratory analysis phase included the following:

- Regular communication between the laboratory and the project laboratory data manager;
- Reviewing the laboratory's sample receipt acknowledgement form;
- Documenting the project's progress in Entergy's database system; and
- Laboratory preparation of the Electronic Data Deliverable (EDD).

Data Loading

The data loading phase included the following:

- Loading all EDDs into the database;
- Resolving any data loading issues;
- Creating a post-load report for content review; and
- Notifying the project team when EDDs were available.

Data Visualization and Analysis

The data visualization and analysis phase included the initial data review by the project team and the production of data queries and draft reports to interpret the data. This phase was accomplished through the use of query tools and preformatted reports in the database.

5.2 ORGANIC TRACER

Sampling for the tracer was based on both activated carbon samplers and on grab water samples. All analyses were conducted using a Shimadzu RF5301 fluorescence spectrophotometer operated under a synchronous scan protocol. Details of the analytical approach are presented in the Ozark Underground Laboratory (OUL) procedures and criteria document **(Appendix P)**.

5.3 WATER QUALITY PARAMETERS

Groundwater samples were collected from monitoring wells MW-38, MW-48-23, and MW-48-38 and also from the Discharge Canal and Hudson River. The groundwater was collected as a grab sample using low flow sampling techniques. The surface water samples from the top of the water column were collected using bailers. The samples were collected at high and low tides. Groundwater samples were also collected at mid tide[23]. The samples were sent under chain-of-custody procedures to Life Science Laboratories, Inc., Brittonfield Parkway, Suite 200, East Syracuse, NY 13057. The samples were analyzed for Bicarbonate Alkalinity (as $CaCO_3$) under EPA Method M2320; Iron, Magnesium, Sodium, and Calcium under EPA Method 6010; and Sulfate and Chloride under EPA Method E300.

[23] Sample nomenclature was as follows: Monitoring Location Name-Depth Interval (if applicable), Tide Interval (H=High, M=Mid, L=Low) and replicate number (if applicable).

6.0 HYDROGEOLOGIC SETTING

This section describes the hydrogeologic setting at IPEC. Our description is based on a literature search and the findings of our field investigation program. The hydrogeology is described in reference to the two components of an unconfined aquifer found at IPEC; overburden and bedrock. Both the overburden (in select areas) and bedrock are groundwater-bearing zones which are monitored at the Site. Refer to **Section 4.0** for a summary of the groundwater monitoring system.

6.1 REGIONAL SETTING

The surface topography in the region of the Site slopes downward relatively steeply towards the Hudson River and is characterized by ground surface elevations ranging between approximately 10 and approximately 140 feet above the National Geodetic Vertical Datum of 1929 (NGVD 29). Refer to **Figures 1.3** and **3.2** for Site and regional topographical maps.

The Hudson River is a tidally influenced estuary in the vicinity of the Site, generally experiencing two high tides and two low tides daily. Near high tide, the river experiences a flood current running North. Near low tide, the river experiences an ebb current flowing South. Surface water elevations of the Hudson River as measured at Peekskill, NY, approximately two miles North of the Site, from October 20, 2005 through May 8, 2006 have ranged from -1.31 feet to 3.26 feet NGVD 29. On-Site measurements indicate that the Hudson River elevations vary between -1.1 feet to 3.8 feet NGVD 29.

Other surface water features include the cooling water Discharge Canal with a mean surface water elevation of approximately 1.7 feet above the Hudson River. The Discharge Canal is shown on **Figure 1.3**. The Discharge Canal conveys up to 1.76 million gallons per minute (MGM) from Units 2 and 3, discharging to the Hudson River. As shown on cross-sections A-A' and B-B' on **Figure 1.3**, the walls of the canal are constructed of low structural concrete. However, the current condition and thickness of the canal bottom is variable and appears to range from a 0.5-foot-thick mud slab in the IP2 area (based on construction drawings) to a bedrock bottom in the IP1 area.

Stormwater at developed portions of the region and Site is directed towards and collected in catch basins and discharged to surface water bodies. Stormwater discharges from the Site are routed to the cooling water Discharge Canal[24], the Hudson River, or the groundwater regime through leaks from the storm system.

6.2 GROUNDWATER RECHARGE

Groundwater recharge at and near the Site is limited to precipitation. That is, there is no significant artificial recharge or irrigation in the area. Precipitation in the vicinity of the

[24] There are stormwater outfalls that discharge directly to the Hudson River.

Site is approximately 36 inches per year[25]. Recognizing that a portion of precipitation is lost to evaporation, transpiration, and run-off, direct recharge to an aquifer was estimated. Large scale modeling performed by the USGS for Westchester County, NY[26], suggests that groundwater recharge to glacial till-covered bedrock hills, typical of the conditions near Indian Point, ranges from 3.6 to 7.5 inches per year with an average of 5.5 inches per year. Our experience in a similar hydrogeologic setting[27] found higher natural recharge rates, averaging approximately 10 inches per year. Considering all available information, we believe recharge at the Site is between 1/10 and 1/3 of precipitation. Based on our evaluation, we estimate recharge on and up-gradient of the Site is approximately 10 inches/year[28]. Note that for the purposes of this study (as opposed to water supply evaluations), it is conservative to use high estimates for recharge.

6.3 GROUNDWATER DISCHARGE

Groundwater flows from areas of higher heads to areas of lower heads along the path of least resistance. At the Site, discharge from the groundwater occurs into the Discharge Canal, the Hudson River, and to system underdrains. As evidenced by Site groundwater contours, groundwater discharge is not uniform along the river or to the Discharge Canal. That is, the aquifer in areas of the Site with higher transmissivities (lower resistance to flow) will discharge more water than other areas. Similarly, the water table fluctuates seasonally (due to long term changes in average recharge rates) and locally during rainfall events and periods of snow melt. Consequently, groundwater discharge is not constant in time. Additionally, changes in the river elevation cause additional short term variations in discharge rates.

The Hudson River is the regional sink in the area. As such, groundwater from the upland areas to either side of the river valley flow towards and discharge to the river under ambient conditions, see **Figure 6.10**. Groundwater from IPEC does not flow under the river to the other side (e.g., to Rockland County) under ambient conditions. Further, because of the hydraulic properties of the bedrock, as well as the size of the Hudson River in this area, there is no reason to believe that pumping or injection (non-ambient conditions) could induce such flows.

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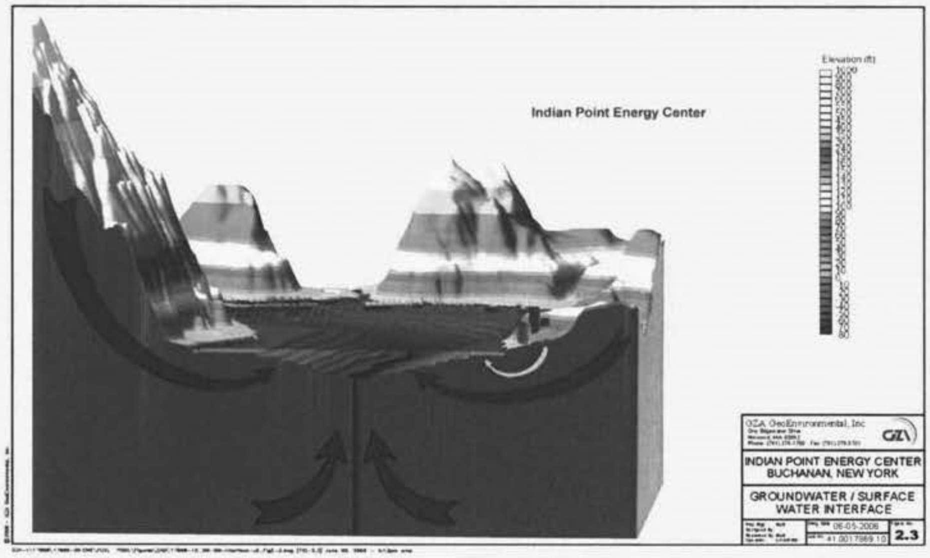
[25] This precipitation value is a 10 year average of data available from the on-Site meteorological station.

[26] USGS. Water Use, Ground-Water Recharge and Availability, and Quality of Water in the Greenwich Area, Fairfield County, Connecticut and Westchester County, New York, 2000-2002.

[27] Calibrated Groundwater Model, Central Landfill Super Fund Site, Johnston Rhode Island, June 2006

[28] Areal Recharge varies temporarily and spatially. The average of 10 inches per year is an estimated watershed-wide, long term average. The development at the Site induces additional runoff. We believe that this potential decrease in areal recharge is offset by recharge from exfiltration of leaky stormwater systems. As discussed in **Section 6.7**, this appears to be the case.



GROUNDWATER FLOW BELOW AND INTO HUDSON RIVER

Foundation drains at three structures (see **Section 6.7**) intercept groundwater (see **Figure 1.3**). This water is conveyed, via gravity flow and/or pumping, to the Discharge Canal, creating local depression in the water table and a flattening of hydraulic gradients downgradient of the structure. With these conditions noted, over a period of months the rate of groundwater discharge to the river at IPEC is continuous and fairly constant. Discussions on the rate of discharge are provided in **Section 6.7**.

6.4 GEOLOGY

This section describes the geology of the Site and region. It is based upon a literature search and the results of our investigations. **Figure 6.2** portrays the regional bedrock geology. The narrative is organized to convey the role of geologic and tectonic processes in creating the mechanisms by which groundwater flows through the Site[29]. Findings support our Conceptual Site Model (CSM) and indicate that the bedrock at the Site is characterized by sufficiently interconnected small bedrock fractures to allow the hydrogeologic system to function and be modeled as a non-homogeneous, anisotropic, porous media.

6.4.1 Overburden Geology

The Lower Hudson Valley has been subjected to repeated glacial advance and retreat, creating a typical glacial morphology of main and tributary valleys and bedrock ledges. The glaciers have controlled the deposition of unconsolidated deposits in the region, although these are absent locally due to erosion and excavation. Glacial till lies directly on the bedrock surface and is generally less than 10 feet thick, although it is locally thicker against steep North-facing bedrock slopes. The till is typically unstratified and

[29] The Inwood Marble, which predominates at the Site, is a crystalline metamorphic rock type. As such, it has a very low primary porosity (i.e., water does not flow through the intact rock itself, but is confined to the fractures in the rock.

poorly sorted. Locally, it consists of a silty, fine- to medium-grained, brown, sandy matrix containing fine gravel to boulder-size bedrock fragments. Fluvial and lacustrine glacial deposits occur in valley bottoms and valley walls. The glacio-fluvial deposits are typically medium to coarse sand and gravel with minor silt. The lacustrine deposits are finely laminated and varved clays fining upwards to fine- to medium-grained sand, and the fluvial/deltaic sediments are mixtures of coarser sands and gravels and finer sands to clays. Recent deposits are essentially flood plain and marsh deposits along the Hudson River, its tributaries, and small enclosed drainage basins.

Overburden geology at the Site is limited to a layer ranging from ground surface to between 3.5 and 59 feet below ground surface (bgs), with thicknesses generally increasing towards the Hudson River. Overburden materials are dominated by anthropogenic fill (borings MW-41, -49, -52, as well as the upper 20 feet of -39, -48, -61, -62, -63, -66 and 67). Soil-based fill materials at the Site consist primarily of silty clay, sand and gravel mixtures (i.e., regraded/transported on-site glacial till) or gravel/cobble/boulder-size blast rock. In areas adjacent to structures excavated into bedrock, the fill occurs as concrete, compacted granular soils, and blast rock fill. Native materials occur as open areas of glacial till overlying bedrock, or silty clays, organic silt and clay, and sandy material overlain by granular fill. A 20- to 50-foot-thick sequence of river sediments (organic silts) is found along the Hudson River above bedrock in borings MW-38, -48, -61, -62, -63, -66 and 67 The approximate location of natural materials is shown on **Figure 6.3**.

6.4.2 Bedrock Geology

The geology of the Site has been investigated and reported by Dames & Moore (1975) prior to this program. **Figures 6.2** and **6.4** show the bedrock geology of the region and the Site, respectively. The current investigations have added substantial detail to this assessment which shows that the bedrock beneath the Site is considerably fractured and contains sufficient interconnectivity to support groundwater flow, at the scale of the Site, as flow through a non-homogeneous, anisotropic, porous media.

The Site is located in a complex of Cambro-Ordovician rocks represented by the Manhattan Formation and Inwood Marble Formation in angular unconformity. The Site lies predominantly upon the Inwood Marble Formation as an angular unconformity with the Manhattan Formation. The oldest rock is the Inwood Formation, which was derived from deposition of carbonate materials in a shallow inland sea during the Cambrian through the early Ordovician period. The Manhattan Formation is interpreted to post-date the Middle Ordovician regional unconformity with the Inwood Marble and represents sediments derived from continental or volcanic island materials in deeper waters.

During the Ordovician period, an island arc system consisting of a series of volcanic islands appeared off the coast of what is currently North America as a subduction zone developed in response to oceanic crust colliding with continental crust. The presence of the volcanic island arc system resulted in interlayering of volcanic material with the sedimentary rocks of the Inwood Marble and Manhattan Formations. As continued subduction occurred and continental land mass began to collide with continental North America during the Taconic and Acadian Orogenies, the rocks of the Inwood Marble

Formation and the Manhattan Formation underwent substantial metamorphism and deformation.

The Inwood Marble is a relatively pure carbonate rock of dolomitic and/or calcic mineralogy with silica rich zones. The rock tends to be coarsely sacherroidal with remnant foliation and intercalated mica schist. The color and crystalline texture vary from place to place due to the various levels of metamorphism; the color is typically white to blue grey. The metamorphic grade is locally elevated due to minor intrusions. The common minerals are calcite, dolomite, muscovite, quartz, pyrite and microcline. The Manhattan Formation is represented on the Site by two distinct members. The lower member is an assemblage of schist, schistose gneiss and amphibolites intercalated with marble, white quartzite and fine-grained metapelite. The marble bearing lower member of the Manhattan Formation likely represents transition from a shallow carbonate sea to deeper water sedimentation and maybe the equivalent to the Balmville Limestone which occurs in Dutchess County[30]. The middle member is garnet rich mica schist. The upper member consists of biotite-muscovite mica schist with quartz-feldspar laminae.

The original sediments have undergone repeated intense phases of burial, metamorphism, uplift, folding and faulting due to: three phases of continental collision (the Taconic, Acadian, and Alleghanian); continental rifting as the present Atlantic Ocean began to form in the Mesozoic; erosion/uplift; and recent glacial rebound. All of these processes have resulted in the presence of fractures that affect the hydraulic properties of the material. The main deformational events are represented by multiple superimposed textures and structures including faults, healed breccias, crenulations, foliation slips, micro-faults, and continuous/truncated joints/fractures. The first phase of fold deformation (F_1) was essentially ductile and produced isoclinal folds contemporaneous with the most intense metamorphism. It was at this time that the dominant foliation likely developed along original bedding planes. The cooling period following this phase marks the onset of regional brittle faulting and development of fractures along the bedding planes. The second phase of folding (F_2) is characterized by flexural slip, indicative of brittle conditions, producing distinct fault and fracture orientations: a conjugate system normal to the foliation; West-Northwest and North-South conjugate strike-slip faults; Northwest faults and fractures parallel to the direction of extension; and thrust and extension fractures parallel to the foliation.

The Cortlandt Complex (a large igneous intrusion located East of the Site) was intruded during the F_2 phase. The post-Cortlandt dislocations were associated with a third phase of folding (F_3) causing a mutual rotation of the structural elements producing a complex of conjugate features with a wide range of orientations as described by Dames & Moore and found during our study. On the Site, the regional features are represented by North-Northeast and North-Northwest trending faults in cross-cutting relationships, representing a conjugate system with a North-South regional compression direction. The final tectonic event was associated with a shear system oriented North-East, reactivating movement along Northeast-trending faults and minor North-Northeast to North-Northwest-trending faults. In addition to these major events, there has been minor

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[30] In Vermont, this unit is equivalent to the Whipple Marble.

normal movement on North-South and Northwest-trending faults associated with continental rifting during the Mesozoic Era.

Finally, post-deformational uplift and glacial rebound have resulted in a series of fractures related to expansion, after the rock mass/ice load was removed during erosion and glacial retreat. These manifest themselves as semi-sinuous or undulating horizontal relief fractures.

6.4.3 Groundwater in Bedrock

In metamorphic bedrock such as the marble present at the Site, groundwater occurs and migrates in open spaces such as fractures. These void spaces are termed secondary porosity. The primary porosity consists of void spaces within the rock matrix itself. The Inwood Marble has a very low primary porosity which does not contribute to the flow or storage of significant volumes of water. Therefore, the presence of fractures and faults ultimately determines the hydraulic conductivity of the bedrock mass. The fracture aperture spacing and the degree of fracture interconnectivity are dominant variables in how groundwater flows through the fractured bedrock environment. Groundwater flows from areas of higher hydraulic head to areas of lower hydraulic head along fractures providing the least resistance. If the structure of the rock is dominated by fractures and foliations of a single orientation, then groundwater flow will be along this orientation towards areas of lower hydraulic head. Also, if fractures are separated by large distances and not interconnected, groundwater will flow in a relatively limited number of fractures and flow will be governed by the orientation of local structures within the rock. This may result in groundwater flow occurring along paths that may not be reflected in topography. However, if there are abundant sets of fractures of differing orientations relatively close together and interconnected, groundwater flow will typically mimic topography.

GZA found no evidences of solution features (i.e., cavities, voids). Such features (if present) can control the direction of groundwater flow. Carbonate rocks have relatively high solubility under certain ambient surface conditions. This can result in solution cavities and caves known as karst systems. In these situations, groundwater can flow predominantly along open cavities and result in preferential pathways. Our assessment of over 3,200 linear feet of rock core and 2,950 linear feet of borehole geophysical logs found no evidence of any large scale solution features. Minor, discontinuous vugs (small unfilled cavities) and voids were observed primarily along partially healed fractures with euhedral calcite crystals growing into fractures. This evidence suggests that prior to denudation, resulting in exposure of the rocks to the current elevations; hydrothermal fluids were percolating through open fractures. Mineralization occurred along the fracture planes resulting in a significant number of healed fractures observed in the rock. In some cases, the fractures were partially healed, resulting in the occurrence of vugs in some of the more brecciated zones. The presence of calcite deposition in fractures supports our observations that solution features are not prevalent at the Site. That is, open fractures are due to tectonic forces, that carbonate is precipitating within the fractures, and no large solution cavity process is occurring.

Since earlier conceptual models for the Site hypothesized that groundwater flow would be to the South-Southeast along the original F1 foliation and fracture sets, we

performed a detailed structural analysis of the bedrock to assess whether groundwater flow would be dominated by discrete fracture flow or would behave more in accordance with flow through porous media. This analysis had implications relative to on-Site contaminant migration and the potential for off-Site migration via dominant fracture sets.

6.4.4 Regional Scale Geostructure

GZA assessed regional fracture patterns presented in the Dames & Moore (1975) report as a photo lineament analysis (**Figure 6.5**). On the regional scale of the lineament analysis, there are three sets of intersecting fracture orientations. The major strike orientations within a 15 mile radius of the Site indicated a Northeast, North, and East-West trend. A review of the major tributaries to the Hudson River indicates the drainage pattern is predominantly aligned with similar orientations and generally structurally controlled.

6.4.5 Site Scale Geostructure

On a Site scale, GZA projected the fracture plane orientations calculated from the borehole geophysical data onto one elevation (elevation 10 feet) to create a Site lineament analysis (**Figure 6.6**). Assessment of the more permeable fractures on this projection showed that fractures were oriented consistent with the regional assessment (Northeast, North and East-West), and that fracture orientations intersect one another. In addition, our Site scale lineament analysis showed a number of Northwest orientated fractures located between Unit 1 and Unit 2 in the area where the Unit 1 and Unit 2 plumes commingle. Evaluation of the preconstruction bedrock topography also indicated that this was a low point in the bedrock surface. Low points in marble bedrock surfaces are usually associated with areas of higher fracture density or faulting as these would be areas more prone to weathering, erosion and glacial gouging. This presents further evidence for a zone of higher transmissivity.

Based upon the regional and Site scale lineament analyses, it was apparent that the multiple fracture orientations result in intersections of fracture planes. However, more detailed analysis was required. Therefore, GZA assessed the individual rock cores and fracture orientations calculated from the borehole geophysical analysis.

6.4.6 Borehole Scale Geostructure

Twenty-three of the forty-seven boreholes were evaluated using acoustical televiewer (ATV) and optical televiewer (OTV) borehole logging techniques by Geophysical Applications, Inc. The ATV data establishes naturally occurring joint/fracture dip angles and planer dip directions for planer features intersecting a borehole.

The apparent joint/fracture orientations and depths were input into a stereographic framework using DIPS software developed by RocScience, Inc. of Toronto, Canada, after correction from magnetic North to true North. The stereographic projections are a southern hemispheric view and are equal-angle based. The program presents the joint/fracture dip and dip direction in a tabular format with customizing options, and allows joint/fracture set selection to establish groups of domains and families of geostructural data.

The 4,623 data points from the 23 boreholes were input into the DIPS program. The polar projections for all the boreholes are presented as **Figure 6.7**. In our opinion, these data show three dominant, apparent, conjugate sets of fractures striking to the Northeast-Southwest, East-West, and North-South. The majority of the dip angles range consistently between 30 and 70 degrees for each major orientation. In addition, there are many horizontal and vertical fractures. The orientations of the fractures, the conjugate sets of fractures, and the presence of vertical and horizontal fractures all support a high degree of interconnectivity.

The database also contains columns showing the depth of the individual joint/fractures and apparent vertical continuous spacing[31]. In each borehole, three average values of apparent vertical joint set spacing for depths between 0-30 feet, 30-100 feet, and depths greater than 100 feet were calculated and summarized in the following table. No significant differences in joint spacing with depth were found.

AVERAGE APPARENT JOINT SPACING, FT							
	Depth Below top of the rock				Depth Below top of the rock		
Borehole	**0~30ft**	**30ft~100ft**	**>100ft**	**Borehole**	**0~30ft**	**30ft~100ft**	**>100ft**
MW-30	0.53	0.64	--	MW-55	0.48	0.47	--
MW-31	1.46	0.63	--	MW-56	--	0.32	--
MW-32	--	0.36	0.39	MW-57	0.55	0.30	--
MW-34	0.72	--	--	MW-58	0.32	0.66	--
MW-35	0.80	--	--	MW-59	0.35	0.41	--
MW-39	--	0.66	0.67	MW-60	1.38	0.83	0.59
MW-40	0.37	1.11	1.69	MW-62	--	0.49	0.64
MW-51	0.37	0.88	0.84	MW-63	--	0.35	0.44
MW-52	0.45	0.58	0.89	MW-65	--	1.26	--
MW-53	--	0.71	--	MW-66	--	0.75	0.59
MW-54	0.47	0.58	0.39	MW-67	0.47	0.59	0.54
				RW-1	--	2.22	1.71

AVERAGE APPARENT JOINT SPACING

Joint spacing is a significant parameter in assessing flow in a fractured rock and assessing the validity of using an equivalent porous media flow model. The spacing of joints was determined by direct measurement from rock core samples or from ATV data in 22 boreholes, and is presented in a database (**Appendix Q**). These data indicate an apparent joint/fracture spacing between 0.3 and 2.2 feet, with an average of 0.7 feet.

Based upon the assessment described above, the data suggest that the bedrock aquifer can be visualized as a series of polygonal blocks separated by interconnected fractures. This geometry is graphically portrayed by a series of seven apparent fracture

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[31]Apparent vertical spacing is the distance between joint/fractures along the vertical line of the borehole.

profiles designated A-A' through G-G' presented on **Figure 6.9**; profile locations are presented in **Figure 6.8**. The profiles show the orientation and potential connectivity of the geostructure if the ATV borehole measured planes extended for 1,000 feet (500 feet on either side of the borehole). The joint/fracture lines represent the trace of the plane projected onto a vertical profile. Additional illustrations of the fracture orientations in three dimensions are presented in **Section 6.4.8**.

6.4.7 Geologic Faults

The groundwater flow pattern and thus contaminant transport can be further influenced by the presence of faults. These faults can either act as barriers or conduits to flow depending on the presence of clay-rich fault gouge. Rock core samples revealed significant clay fault gouge zones that generally ranged between 0.2 and 0.7 vertical feet thick at borehole locations MW-31, -50, -54, -60, and -61. These zones were encountered at depths ranging between 39 and 200 feet below existing grades. The dip angles were measured by the ATV methods and ranged between 49 and 82 degrees at locations MW-31, MW-54, and MW-60, with dip directions toward the East (MW-54) and the Southeast (MW-31 and MW-60). No ATV measurements were conducted at MW-50 or MW-61. At MW-61, no core was recovered between 156 feet bgs and 221 feet bgs. Collection of split spoon samples in this interval verified the presence of a clay-filled fault gouge. This boring likely intersected a steeply dipping North-South trending fault. The presence of this fault is consistent with faults previously mapped by Dames & Moore (1975). The near vertical orientation of the fault is further supported by observations of bedrock core from locations MW-66, advanced within 8 feet of MW-61. No fault gouge was observed in this boring. A fracture zone was noted between 136 and 145 feet bgs and is characterized by low RQDs, however, this fracture zone did not exhibit clay filled fault gouge and was more consistent with tightly spaced fractures.

Because the fault extends to the top of the bedrock, the question arises as to why we did not observe the fault zone above 156 feet bgs at MW-61. This is due to the geometry of the fault. The fault zone is sub-vertical, i.e. less than 90 degrees, but also may vary in orientation with depth. As the boring was advanced deeper into the bedrock, it intersected the fault zone at 156 feet bgs. The boring continued within the fault, in a near vertical portion of the fault, to the termination of the boring.

Furthermore, the rock core samples revealed several fracture zones ranging between approximately 0.5 feet and 110 feet thick. Significant zones of poor to no recovery are evident at MW-50, MW-61 and MW-66: boring MW-50 and MW-54 were aligned along or near the trace of historic faults mapped by Dames & Moore (1975). MW-49 and MW-61, may be aligned along the extension of a historic fault mapped by Dames & Moore (1975). The poor recovery observed at MW-50 and MW-61 is indicative of clay gouge that was washed out during the drilling process (which is consistent with, but not fully verified by, the split spoon samples containing clay, recovered in these borings). We further note the presence of this fault zone does not appear to materially alter groundwater flow directions or contaminant migration towards the Hudson River.

Figure 6.4 portrays faults mapped on the Site by Dames & Moore (1975). There are three major groups of faults with associated fractures identified at and in the vicinity of

the Site. These groups have azimuths of approximately 45, 75, and 290 degrees. The East to N75E faults consist of conjugate faults where the sinistral set strikes West to N70W dipping southward, and the dextral set strikes East to N75E dipping southward. These faults are most often offset or truncated by younger faults. West striking faults in the Inwood Formation are typically characterized by breccias which have been healed by a re-crystallized calcite cement.

An additional fault or fracture zone appears (not shown on **Figure 6.4**) to extend from the Hudson River Southwest between Units 1 and 2, as expressed by fracture orientations and a low in the preconstruction bedrock contours. This appears be a zone of higher transmissivity as indicated by inflections in groundwater contours, tidal response measurements, and the shape of the contaminant plume.

6.4.8 Bedrock Structure Visualization

In order to aid in the visualization of the role bedrock structure plays on groundwater flow as well as show the apparent interconnectivity at the Site, GZA imported data collected throughout the various phases of investigation into a 3-dimensional visualization model. The Environmental Visualization Software (EVS) software suite, created by CTech Development Corporation, was the primary software application used for the development of this model. This software package provides real-time model rendering, animation/flyover capabilities, database and GIS interface utilities, and numerous image output options. EVS also provides the ability to interpolate variably spaced datasets via kriging, an established geostatistical technique. The EVS kriging process selects an optimal semi-variogram model for each kriged dataset in order to estimate unknown values, and provides statistical confidence for estimated values. The results of these analyses can then be rendered across three dimensions (x, y and z) to provide a spatially referenced visualization model.

GZA incorporated the borehole geophysical data provided by GA, the packer testing results, and the USGS evaluation of the HPFM data into the 3-dimensional visualization model. Our goal was to illustrate transmissive fracture locations. For many of the zones identified as transmissive, several fractures likely contribute to the estimated transmissivity. In these cases, a percentage of the estimated zone transmissivity was allocated to each contributing fracture based on the HPFM results and ATV/OTV logs. In addition, multiple fractures in close proximity and exhibiting similar planar characteristics were combined to present a single planar feature to avoid redundancy in the model. The fracture data set was imported into the 3-dimensional visualization model intact.

Figures 6.10 through **6.14** present the locations of transmissive fractures within each boring. Fractures are represented as disks with 50 foot radii. A single disk represents the strike direction and dip angle of a transmissive fracture feature. Fracture disks are also color coded to reflect the assigned transmissivity value. Boring designations and locations highlighted in yellow indicate the borings for which geophysical and transmissivity information was available. Boring designations and locations highlighted in white are lacking geophysical data; therefore, fractures are not presented. The transmissive fracture data set was divided into low transmissive (0.02 - 10 ft^2/day, **Figure 6.10**), moderate

transmissive (10 – 50 ft^2/day, **Figure 6.11**) and high transmissive (50 – 250 ft^2/day, **Figure 6.12**) subsets. While there are limited geophysical data for borings located to the South and East of the Site, the available data do indicate that there appears to be a zone composed of more transmissive fractures within the center of the Site. This observation coincides with a low in the bedrock as elucidated by preconstruction bedrock contours (**Figure 6.4**). This historic depression may be the result of weathered or fractured bedrock being susceptible to glacial advance and retreat, indicating the potential for a fault to be present in this area. This is consistent with the observation of a lineament West of Unit 2 toward the Hudson River discussed above.

Figure 6.13 represents the same fracture data set, but with the fracture disk radius extended to 250 feet. A horizontal cutting plane has been extended across the Site at elevation 10 feet, identifying the strike direction of each fracture as it intersects the plane. For a selected diameter of disk, the width of the strike line has significance. A shallow dipping disk would have more contact with the horizontal cutting plane than a steeply dipping disk. Accordingly, a wider strike line indicates a fracture strike direction with a shallower dip angle. The East-West lineament is clearly visible in this figure, aligned approximately from Unit 2 toward the Hudson River, and comprised of moderate and high transmissive fractures. **Figure 6.14** represents the same horizontal slice concept; however, the slice plane is now placed at elevation -100 feet. There are no high transmissive fractures intersected at this elevation, indicating high transmissive fractures are more predominant at shallow depths. This is consistent with **Figure 6.13**, the Conceptual Site Model, hydraulic conductivity tests and previous reports (Tectonics, 2004). Because we observed no decrease in fracture spacing with depth (see **Section 6.4.6**), this suggests the hydraulic aperture of fractures decreases with depth.

While there are some localized trends in fracture strike direction, there is an abundance of intersecting fractures on a Site-wide scale occurring at all elevations. In addition, the fracture disk component of the 3-dimensional visualization model has been reviewed to identify potential fracture connections on a borehole-to-borehole scale. No significant interconnections were identified. These observations suggest that bedrock is highly fragmented on a Site-wide scale, high transmissive fractures are not continuous across IPEC, and groundwater flow through the Site may be modeled as flow through a non-homogeneous, anisotropic, porous media.

6.4.9 Bedrock Surface Elevations and Preferential Groundwater Flow Pathways

The results of the surface geophysical surveys are portrayed on **Figure 1.3**. The geophysical survey identified apparent bedrock at depths of between 2 and 18 feet below ground surface (bgs) within the IP2-TY. A depression in the bedrock surface exists in the vicinity of monitoring well MW-111. Bedrock in the depression was found at a depth of 16 to 18 feet bgs. Along the North side of the IP2-TB, apparent depth to bedrock was approximately 8 to 12 feet bgs and only intermittent groundwater associated with rainfall events has been encountered. This is likely the depth bedrock was cut in order to accommodate the service water lines. No discrete utility trenches were observed in the bedrock. Based upon the results of the geophysical survey it is more likely that bedrock was cut to a depth to accommodate deep subsurface utilities and potentially dewatering,

rather than install utilities in individual trenches. On the eastern, western and southern sides of the Transformer yard, rock was encountered between 2 feet and 7 feet bgs. No groundwater was encountered in the overburden in these areas. However, groundwater was encountered in the backfill found along the western wall of the Discharge Canal, which forms the eastern boundary of the IP2-TY.

Within the IP3-TY, the approximate depth to bedrock ranged between 7.5 and 10.5 feet bgs. Generally the northern and southern ends of the survey area had the deepest and shallowest depths to bedrock, respectively. Again, the surveys did not exhibit evidence of individual utility trenches cut into bedrock. No groundwater was observed in overburden within borings advanced within the IP3-TY.

To assess the potential for contaminants to enter groundwater through leaking stormwater pipes (E-Series) and flow with groundwater towards the Hudson River within utility trenches cut into rock along the OCA access road on the South side of the Protected Area, the depth to bedrock and utility trenches cut into rock along this roadway was evaluated. The approximate depth to bedrock ranged between 8 and 16 feet bgs. Bedrock reflectors appeared to be less defined in this survey area compared to other areas at the Site. Many potential utilities were observed in the survey area, however it appears that one large bedrock trench was excavated to accommodate the utilities as well as the roadway. The bedrock appeared to be deeper near the "delta gate" along the East side of the survey area, reaching an apparent depth of 16 feet bgs. Further to the West the apparent bedrock surface was observed at a depth of approximately 8 feet bgs.

Seismic data collected around the warehouse on the South side of the Protected Area provided good subsurface information to a depth of approximately 50 feet bgs. In general, the apparent bedrock surface was found at depths of approximately ground surface on the East side of the survey area and sloped down to depths greater than 45 feet to the West. Near MW-48, the bedrock was located at 25 feet bgs. Topography of the bedrock interface ranged from flat to highly variable over relatively short distances and there were a few locations where the bedrock interface "disappeared" or was located greater than 40 to 45 feet bgs. Over most of the area, the bedrock interface was more gradual and slightly undulating along the profile lines. In general, the depth to bedrock was greater then 20 feet across most of the survey area, indicating that subsurface utilities would not be cut into bedrock trenches.

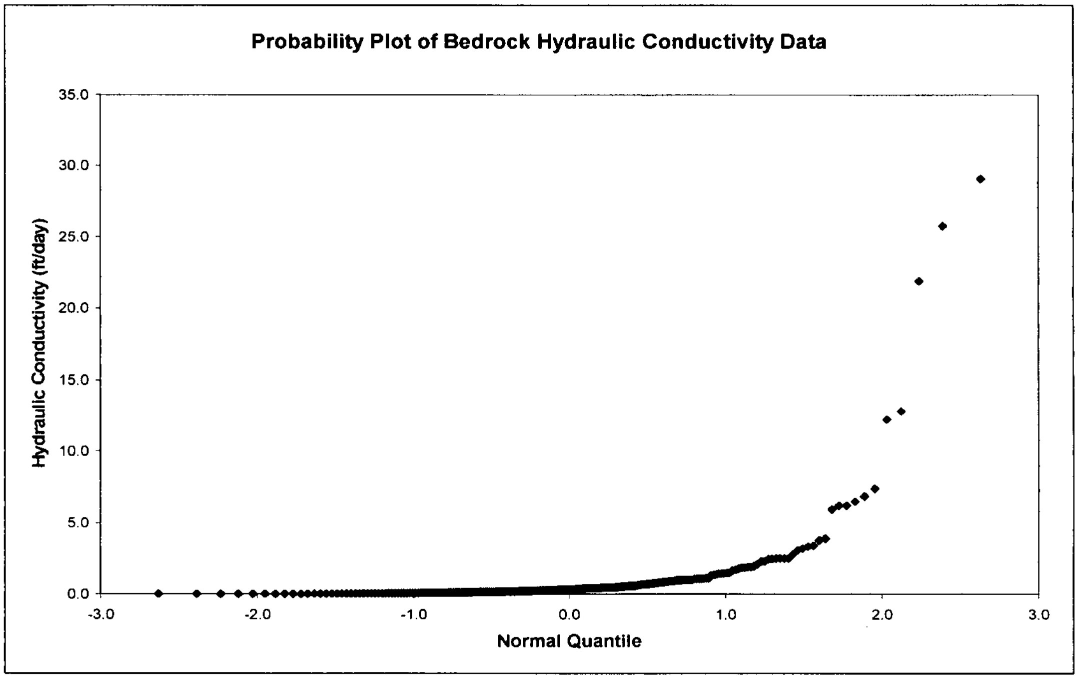
6.5 AQUIFER PROPERTIES

Our investigations demonstrate that, for the purposes of evaluating groundwater flux, bedrock beneath the Site can be modeled as flow in porous media. Following are the hydraulic properties we assigned to our equivalent conceptual porous media model.

6.5.1 Hydraulic Conductivity

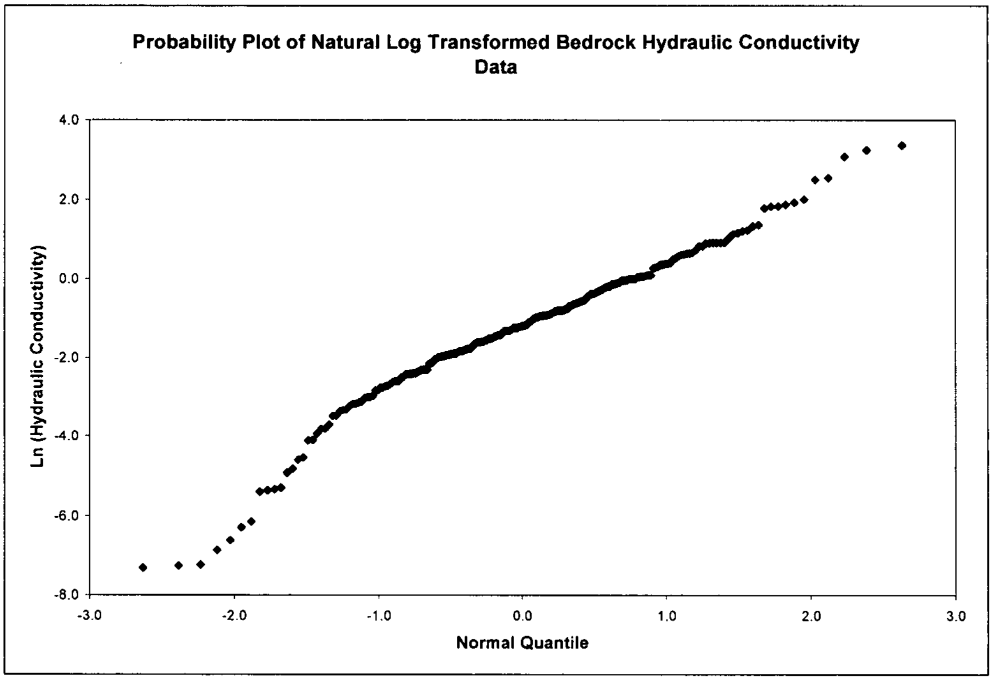
Transmissivity and hydraulic conductivity[32] data were collected as part of the hydrogeologic investigation in both the overburden and bedrock. The geometric mean of hydraulic conductivity in the overburden zone is 12.6 ft/day and the geometric mean in the bedrock is 0.27 ft/day. As indicated below, calculated hydraulic conductivities within the bedrock were found to be log-normally distributed.

GZA used probability graphs to evaluate the statistical distribution of the bedrock hydraulic conductivity data. As shown on the following two graphs, the log-transformed data better approximates a straight line. This indicates the log-transformed hydraulic conductivities are approximately normal and the hydraulic conductivity values are log-normal. This indicates that the geometric mean is a good approximation.



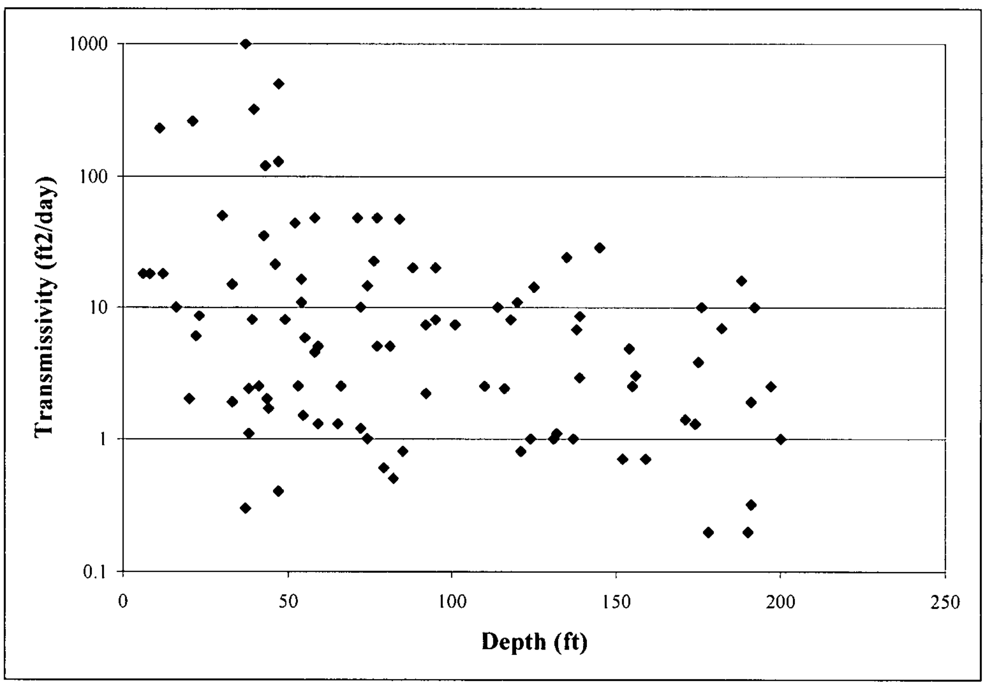
STATISTICAL ANALYSIS OF HYDRAULIC CONDUCTIVITY MAGNITUDE

32 Transmissivity, as used here, is the property measured in the field and is the product of an equivalent hydraulic conductivity (K) and the test interval.



STATISTICAL ANALYSIS OF HYDRAULIC CONDUCTIVITY MAGNITUDE (NATURAL LOG TRANSFORMED)

As shown below, GZA also developed a graph of depth versus transmissivity of bedrock. In viewing that graph, note that all USGS[33] measured transmissivities of greater than 100 ft^2/day were found at depths of less than approximately 50 feet bgs.



TRANSMISSIVITY VS DEPTH

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[33] Transmissivities shown were computed by the USGS from their heat pulse flow meter data which were in agreement with our packer test data.

It should be noted that the hydraulic conductivity values are based on aquifer tests conducted at specific locations and limited hydraulic loading, and are therefore only representative of the aquifer immediately adjacent to the subject borehole.

GZA also conducted a Pumping Test which imposed a larger hydraulic stress over a larger portion of the aquifer. We believe this test provides us with the most reliable estimate of transmissivity of the bedrock in the area of the Pump Test. However, the area of influence of the Pump Test did not encompass the zone of higher hydraulic conductivity within the fracture zone between Units 1 and 2. Depending on the methods used to evaluate the Pumping Test data, we estimate bedrock transmissivity values generally in the range of 30 ft^2/day to 50 ft^2/day[34]. This suggests an average hydraulic conductivity of between 0.2 and 0.4 feet/day.

To further evaluate the vertical distribution of the hydraulic conductivity, we computed the geometric mean of measured values in the upper 40 feet of the aquifer and the geometric mean of all values measured below that depth. This calculation resulted in values of 0.4 feet per day for the upper forty feet and 0.2 feet per day for the deeper aquifer.

6.5.2 Effective Porosity

Evaluation of Pumping Test data also allows calculation of storativity. Our Pumping Test results show the storativity of the bedrock aquifer is 0.0003. (Note: overburden wells were not present within the cone of depression and, therefore, storativity for the overburden could not be evaluated.) Because the bedrock aquifer is unconfined and the primary porosity of the marble is, essentially, zero, the effective porosity of the bedrock can be as small as the storativity. However, due to dead-end fractures, the effective porosity is likely to be higher.

To evaluate the reasonableness of estimated properties, we used the cubic equation, as shown below, to estimate the hydraulic aperture and storativity of the fracture system:

$$Q = \frac{\rho_w g b^2}{12\mu}(bw)\frac{\partial h}{\partial l}$$

Where:

Q = volumetric flow (ft^3)

ρ_w = density of water (62.4 lb/ft^3)

g = gravitational constant (32.2 ft/s^2)

b = aperture opening (ft)

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[34] The Pumping Test indicated the transmissivity of the rock was fairly isotropic, and only limited horizontal anisotropy was observed during the Pump Tests (e.g., in the drawdown observations at monitoring well MW 53-120). At the scale of the, Pumping Test we believe there are sufficient heterogeneities that the aquifer can be considered to be a non-homogeneous isotropic porous media.

μ = dynamic viscosity of water (0.0006733 lb/ft*s)

w = fracture width perpendicular to the flow direction (ft)

$\frac{\partial h}{\partial l}$ = groundwater gradient

From this, the concept of an equivalent hydraulic conductivity has been developed[35]:

$$K = \frac{\rho_w g n b^3}{12\mu}$$

Where:

Variables are as previously defined, and;

n = number of open features per unit distance across the rock face

Using a fracture spacing of one foot and an equivalent bulk hydraulic conductivity of 0.27 feet per day (9 x 10^{-5} cm/sec), this calculation indicates a hydraulic aperture of approximately 75 microns, and a theoretical minimum porosity of 2.4 x 10^{-4}. The calculated porosity is in good agreement with estimates of storativity developed from Pumping Test data (**Section 4.4.4**) and tidal responses (**Section 6.6**).

In summary, the measured effective porosity of the bedrock aquifer is approximately 0.0003.

6.6 TIDAL INFLUENCES

As discussed previously, the Hudson River, adjacent to the Site, rises and falls in response to ocean tides. Based on our measurements, this tidal variation (the numerical difference between low water and subsequent high water elevations) in 2006 ranged from approximately 1.4 feet to 4.3 feet, and averaged approximately 2.7 feet. This variation occurred between approximately elevation -1.5 feet to 3.7 feet NGVD 29 (i.e., the low tide elevations were typically above elevation -1.5 feet and the high tide elevations were typically below elevation 3.7 feet). These data are in good agreement with published information (see **Section 6.1**).

This natural variation produced measured effects that helped us better understand hydrogeologic information obtained at the Site. One such effect is water level changes in monitoring wells at the Site. The observed changes demonstrate that the bedrock aquifer is significantly fractured, and provided additional insight into aquifer properties.

Discharge of heated cooling water, in conjunction with tidal influences, produced a second effect; temporal temperature changes in groundwater in wells located near the Discharge

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[35] Snow, D.T. 1968. Rock Fracture Spacings, Openings, and Porosities. Journal of Soil Mechanics., Found. Div. Proc. Am. Soc. Civil Engrs., v. 94, p. 73-91.

Canal. We used that information to help explain water quality data collected from two specific wells (MW-38 and MW-48, originally proposed as southern boundary monitoring wells), which did not initially conform with our Conceptual Site Model (see **Section 6.6.2** below). These two effects are described in the following sections.

6.6.1 Groundwater Levels

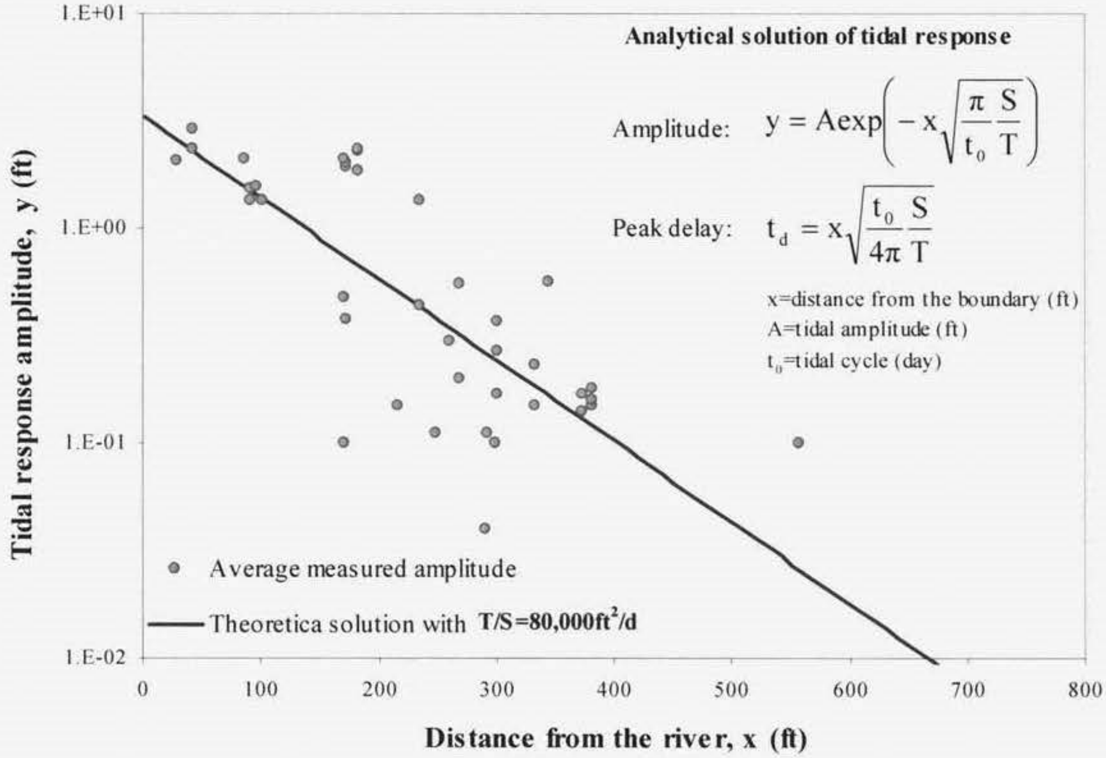
The tidal-induced variations in surface water levels near the edge of the Site's aquifer (in the river and intake structures and Discharge Canal[36]) induced pressure changes in groundwater that were observed in monitoring wells at the IPEC. As a general statement, these responses (as anticipated) varied over time as sinusoidal-like curves that decreased in amplitude and exhibited greater lag time with increased distances from the river/Discharge Canal[37].

At the time of our tidal response study, there were 87 transducers installed in 49 monitoring wells. As shown on the following graph, we observed measurable hydraulic responses to tidal variations at 43 of these transducer locations. In viewing that graph, note distances are measured from the edge of the Hudson River. We chose this as the boundary because data suggests the river has more influence on piezometric levels in the bedrock aquifer than do the intake structures and Discharge Canal. We further note that: 1) 41 of the 44 pressure transducers within 400 feet of the Hudson responded to tidal variations; 2) at greater distances, tidal responses may have occurred but were too small to be recorded because of the accuracy of the transducers; and 3) the tidal response in wells located in the higher hydraulic conductivity area between Units 1 and 2 was more pronounced than in other areas. Cumulatively, these data demonstrate:

- The aquifer is in strong hydraulic communication with the Hudson River; and
- The bedrock aquifer is well-fractured.

[36] The elevation of the water in the Discharge Canal rises and falls with the river elevation, but is maintained approximately 20 inches above the river level.

[37] Observed variations from this trend, in our opinion, are consistent with anticipated heterogeneities in an equivalent porous media model.



TIDAL RESPONSE VS DISTANCE FROM THE HUDSON RIVER

Fetter[38] provides an analytical solution for the theoretical piezometric response of an aquifer adjacent to a tidal boundary (see above graph). The assumptions upon which this solution is based are quite restrictive. In addition to the normal difficulties (aquifer heterogeneities, anisotropic properties, etc.) which limit the practical use of the solution in estimating aquifer properties, [39] it is not clear if water levels at the Site are responding to changes in the river level, changes in the Discharge Canal levels, or perhaps, a combination of both. Further complicating this issue, the concrete canal walls, and at some locations (not all) the concrete canal bottom, should clearly affect propagation of tidal fluctuations in the canal.

With these limitations noted, our review of data indicates that the hydraulic diffusivity[40] (transmissivity, T, divided by storativity, S) of the rock, as estimated by the tidal responses, is on the order of 80,000 ft^2/day. See the above graph and information in **Appendix K**.

As presented in **Section 6.5,** we believe the average transmissivity of the bedrock aquifer is typically in the range of 30 to 50 ft^2/day. Using a transmissivity of 40 ft^2/day and a diffusivity of 80,000 ft^2/day, it follows the storativity of the bedrock aquifer is on the order of $5x10^{-4}$. This value is in good agreement with the values we computed from an evaluation of the Pumping Test data and from the cubic equation (see **Section 6.5.1**).

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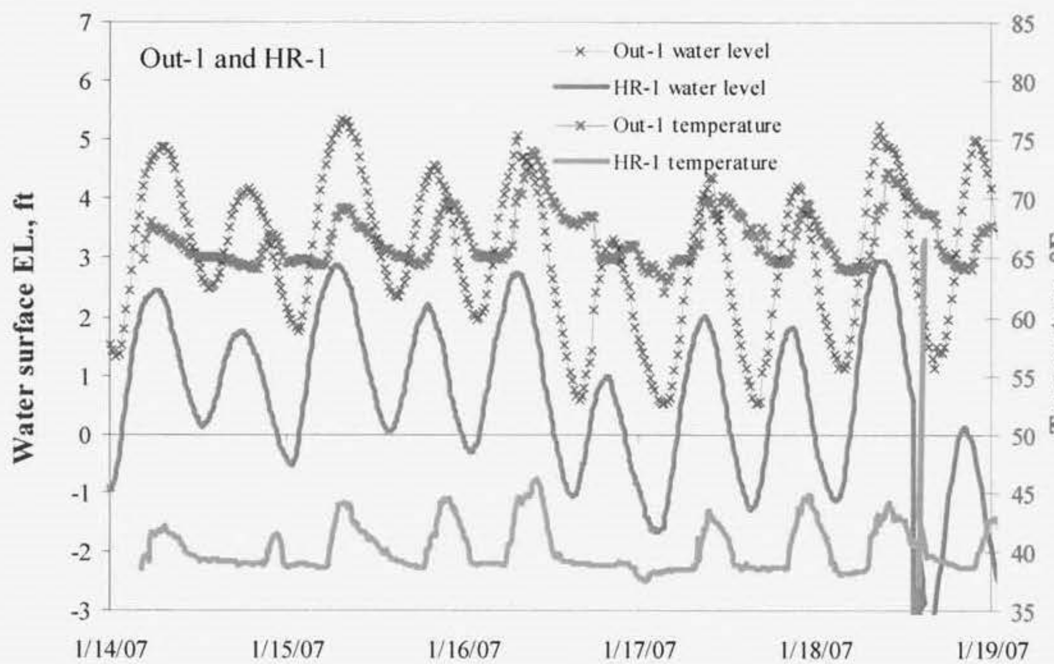
[38] C.W. Fetter, *Applied Hydrology*, Second Edition, Merrill 1988.
[39] Patrick Powers, *Construction Dewatering*, Second Edition.
[40] Freeze & Cherry, *Groundwater* Prentice-Hall 1979.

Another effect of river tidal changes is manifested in monitoring wells in close proximity to the river or Discharge Canal as follows. As the river approaches high tide, the groundwater gradients in proximity to the river become flatter, and at certain locations and tides, are reversed; that is, on a temporary basis, groundwater discharge to the river is generally slowed, and in at least some locations, groundwater flow normally to the river is reversed to then be from the river into the aquifer.

6.6.2 Groundwater Temperature

The cooling water intake structure is located North (upstream) of the cooling water discharge structure (see **Figure 1.3**). When the river is near high tide, the cooling water intake draws river water that contains discharge water[41] (i.e., river flow reverses and water begins to flow away from the ocean). At periods near low tide, the current in the river reduces or eliminates this circulation (within the river) of cooling water. A consequence of this tidal influence is that the temperature of water in the Discharge Canal, in addition to always being warmer than the river water, varies with tidal cycles. This is illustrated on **Figure 6.15** as well as the graph below, a double-axis graph to show the water level and temperature data collected in January 2007 from two stilling wells: Out-1, located at the southern end of the Discharge Canal, and HR-1, located in the cooling water intake structure of Unit 1[42].



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND HUDSON RIVER (JAN. 07)

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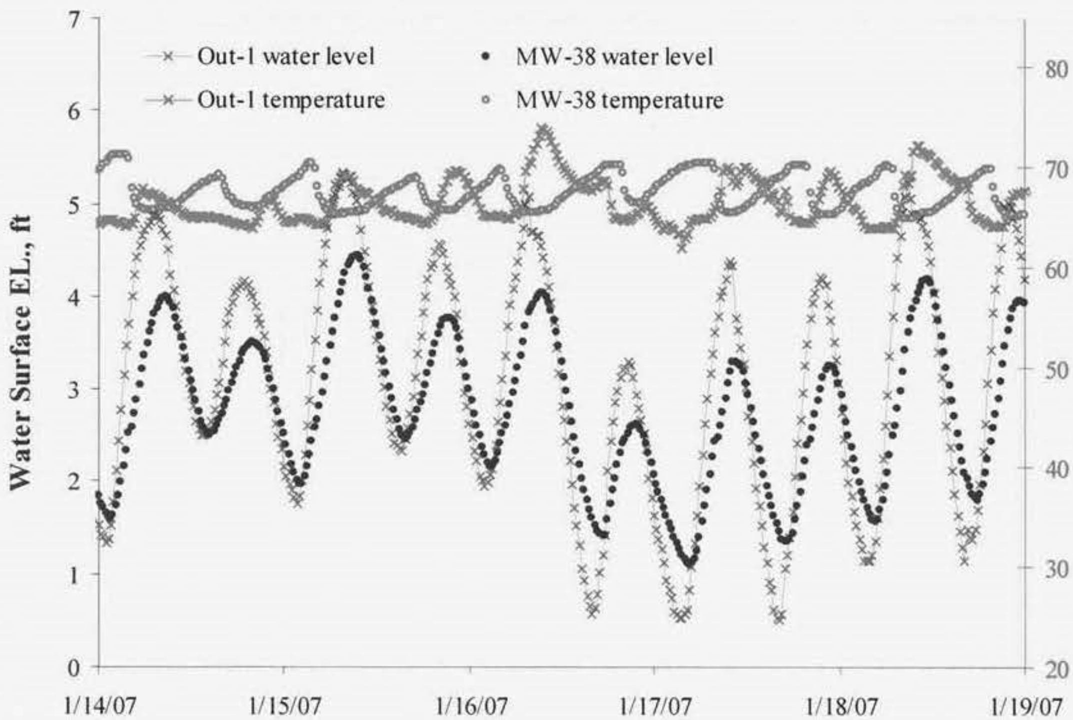
[41] The direction of the flow in the river is tidally influenced, which at periods near high tide, is to the North, away from the ocean.

[42] Unit 1 is inactive and this stilling well should provide a good measure of the river elevations with time.

Based on this information and water quality variations (see **Section 6.6.3**), we evaluated the potential for the Discharge Canal water to influence water quality at two locations originally proposed for southern property boundary monitoring[43], MW-38 and MW-48 (located adjacent to the canal and river respectively; see **Figure 1.3**).

6.6.2.1 Monitoring Well MW-38

Groundwater response to tidal influence of the cooling water Discharge Canal (at this location) is strong and appears to vary between tidal cycles. We note, however, that we observed responses from approximately 60% to at least 86% with an average of approximately 70%.



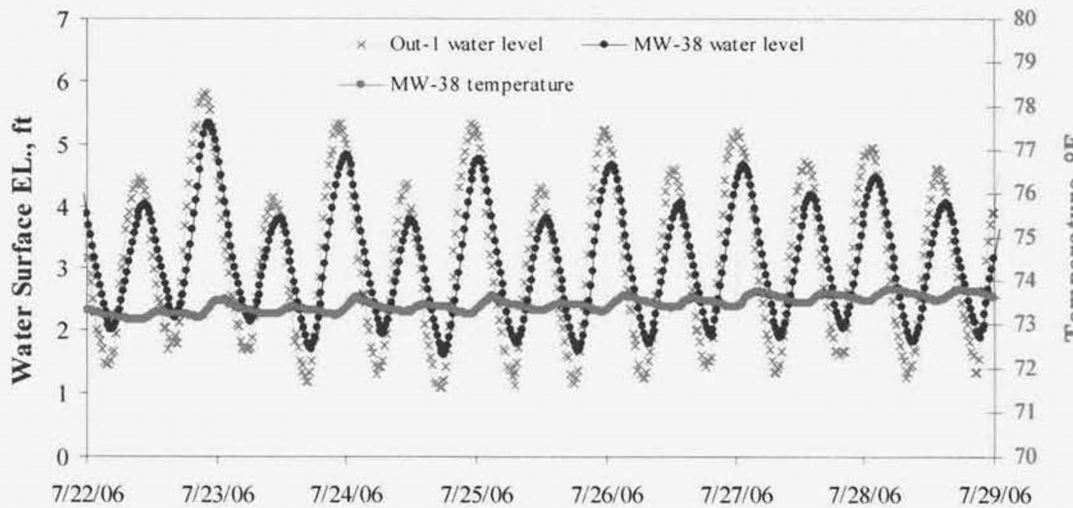
WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND MW-38 (JAN. 07)

Additionally, at high tide the canal level is above the water level in MW-38 and at low tide the water level in MW-38 is above the level of the canal (see above graph). These data demonstrate the potential for water in the canal to migrate to the proximity of MW-38 during periods of high tide.

Groundwater temperature data collected from MW-38 indicate that canal water does in fact, at times, migrate to well MW-38. This is shown on the above graph

[43] The results of our analyses demonstrate that monitoring wells MW-38 and MW-48 are impacted by Discharge Canal water at various times. Therefore, these wells are not suitable for measuring southern boundary groundwater radiological conditions.

which shows water levels and temperatures collected in January 2007. In reviewing this graph, note that the temperature of groundwater in MW-38 is: 1) warmed significantly above ambient ground water temperatures (averaging approximately 70° F as compared to an ambient temperature of approximately 55° F); 2) on average, during this period, warmer than the canal water; 3) at its lowest temperature near high tide; and 4) increases in temperature while water levels in the well decline. These observations are consistent with groundwater discharge to the canal at low tide and canal water flow to the vicinity of well MW-38 during high tide.

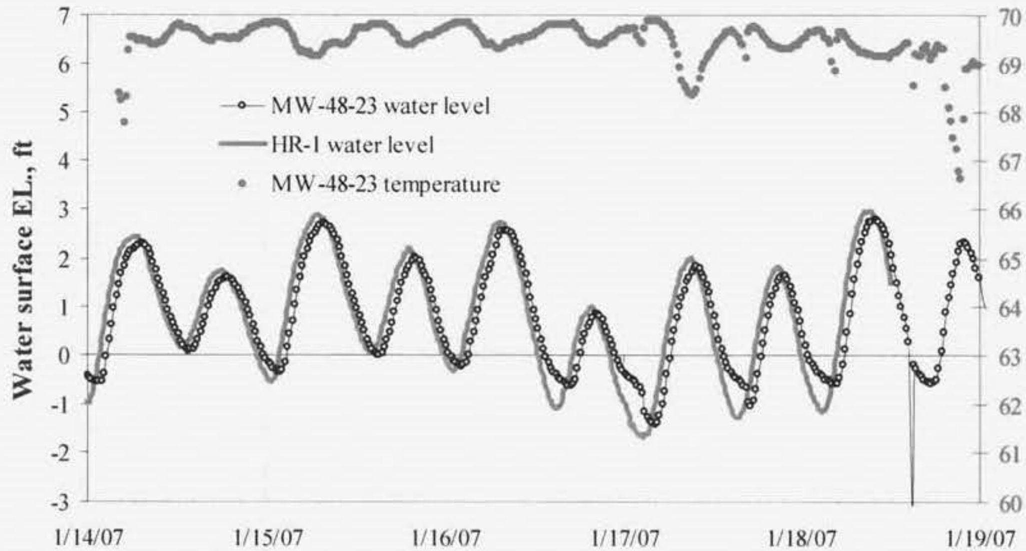


WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND MW-38 (JULY 06)

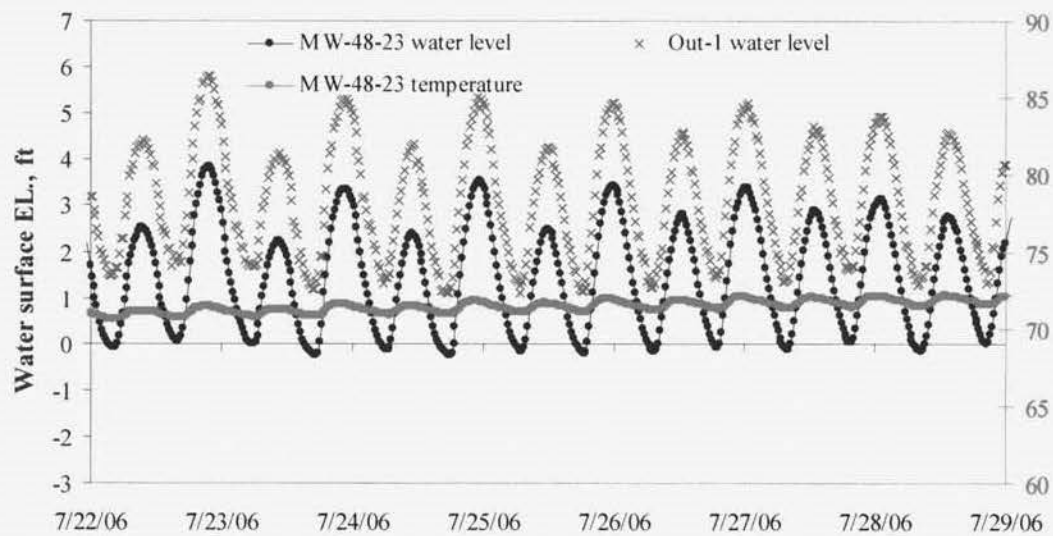
Data presented above, which is for MW-38 in the summer of 2006, while not as dramatic, supports our conclusion that groundwater in MW-38 is mixed, at times, with canal water. In reviewing this graph, note the canal water is significantly warmer than the groundwater, and that water temperature in the well water increases while the canal water level is above the level of water in the well.

6.6.2.2 Monitoring Well MW-48

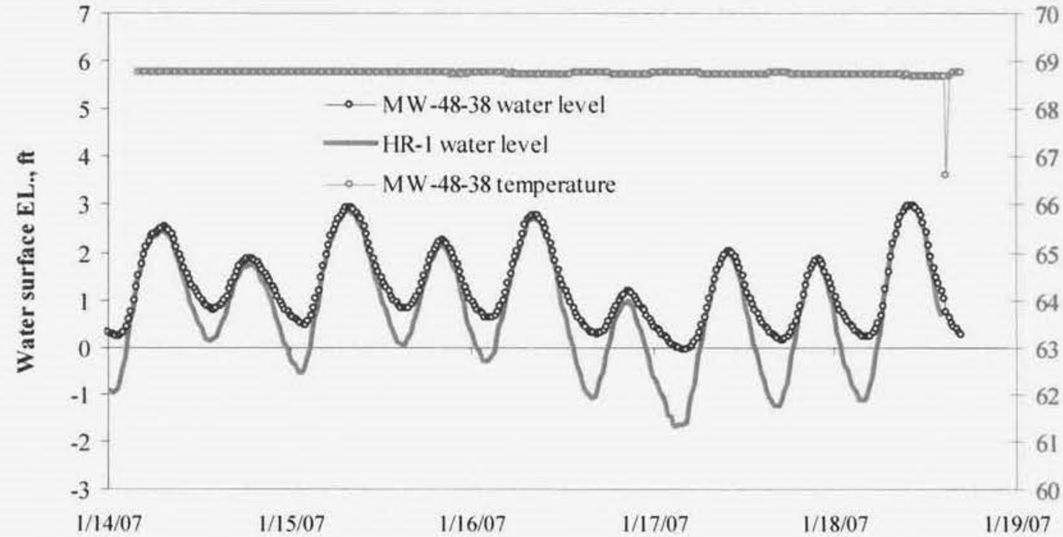
Water levels respond to tidal changes in both wells (MW-48-23 and MW-48-38) at the MW-48 location. The water levels and temperature variations in these two wells are presented and described below.



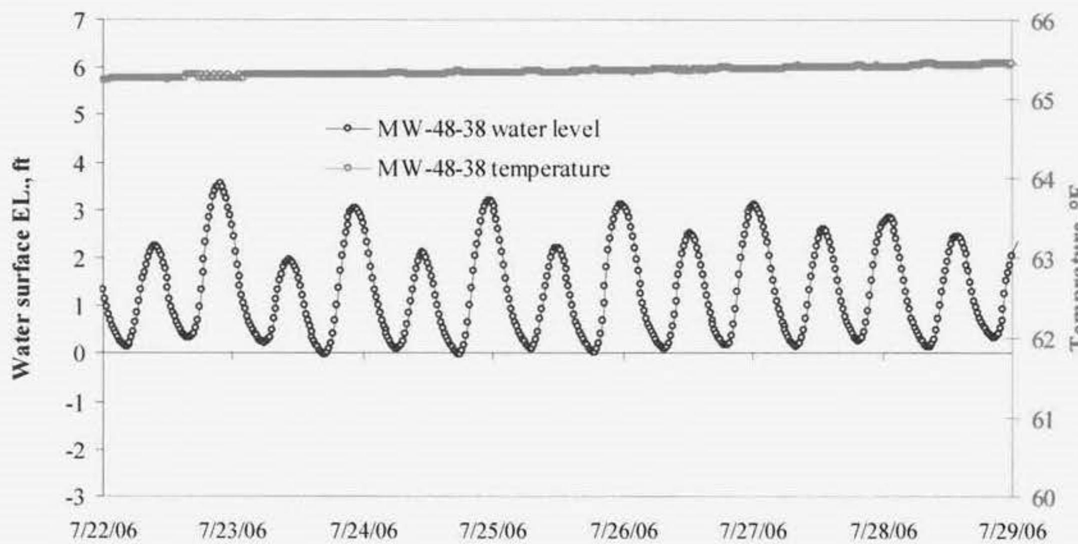
WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR HUDSON RIVER AND MW-48-23 (JAN. 07)



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND MW-48-23 (JULY 06)



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR HUDSON RIVER AND MW-48-38 (JAN. 07)



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR MW-48-38 (JULY 06)

At high tide, the level of water in both of these wells is very close to the river level, while at low tide, it is slightly above the river level and approximately 2 feet below the level of the Discharge Canal. The vertical gradient at this location is upward, with a stronger gradient at low tide. These data are consistent with anticipated trends, indicating groundwater discharge to the river occurs predominantly at low tide.

Note that the river water temperatures shown on graphs in this report are not representative of the temperature of the water in the river adjacent to monitoring wells MW-48. This is due to the location of river transducer HR-1, and tidal induced flows in the river. However, the elevated (above ambient) temperature of the groundwater at these locations (65 to 69° F) indicates it has been warmed by the Site's cooling water discharge.

The temperature of water in monitoring well MW-48-23 varies with some tide cycles, with the coolest temperature being near high tide in the winter, and the warmest temperature being near high tide in the summer. This pattern of temperature change is consistent with this monitoring well receiving river water at times of high tide.

The temperature of water in monitoring well MW-48-38 does not appear to vary with tidal cycles. We interpret these data to mean that physical water quality in monitoring well MW-48-38 is not typically influenced by large exchanges of river water[44]. The elevated groundwater temperature at this location, and the piezometric data, suggest, however, that flows created by purging of the well prior to sampling, at times of high tide, could induce river water flow to this location.

6.6.3 Aqueous Geochemistry

Routine groundwater monitoring indicated the presence of Tritium in a limited number of samples collected from monitoring wells MW-38 and MW-48. MW-38 was originally installed under the first phase of investigation to bound the southern extent of Tritium contamination at the Site along the cooling water Discharge Canal. However, subsequent sampling events indicated the presence of Tritium in groundwater at this location. The presence of Tritium in this well did not fit our CSM or what we knew of groundwater flow at the Site. A second well, MW-48, was installed at the southern Site boundary along the Hudson River to establish if any Tritium would potentially migrate off-Site. Tritium was detected intermittently in groundwater samples collected at this location as well. As neither of these locations was hydraulically downgradient of identified release areas, another mechanism other than groundwater migration from the release area was postulated. This mechanism involved releases from the legacy piping that conveyed contaminated water from the IP1-SFDS to the "E"-series stormwater piping that runs beneath the access road on the South side of the Protected Area and discharges stormwater to the cooling water Discharge Canal. While evaluating this hypothesis, we found evidence, as discussed in **Section 6.62**, that at certain tidal cycles, water from the Discharge Canal and the Hudson River may back flow into these groundwater monitoring wells. To help identify the source of Tritium in these two wells, we developed a focused water quality program specific to these wells. Generally, the water quality program involved analyzing select aqueous geochemical parameters in groundwater and surface water samples. Evaluation of these data can allow conclusions to be drawn regarding the source of the sampled water.

Both data sets (elevation and water chemistry) indicate that water collected from these wells may contain river or cooling water from the Discharge Canal. Based on these findings, we recommend that groundwater sample laboratory results from these well locations not be used to evaluate the extent of groundwater contamination or contaminant

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[44] Relatively large exchanges of water are required to overcome the thermal mass of the subsurface deposits surrounding the well bore. Therefore, while smaller exchanges of groundwater/river water may go undetected via temperature change, they may still be large enough to adversely impact radiological water quality, particularly in consideration of the data from the proximate well screens. Also see discussion in **Section 6.6.3**.

flux to the Hudson River and that these wells not be incorporated into the Long Term Monitoring Plan as Boundary Wells.

6.6.3.1 Sampling

Groundwater samples were collected from monitoring wells MW-38, MW-48-23, and MW-48-38 and from the Discharge Canal and Hudson River on January 19, 2007. These samples were analyzed for bicarbonate alkalinity (as $CaCO_3$), magnesium, sodium, calcium, sulfate, and chloride. The data was graphed on Stiff diagrams and is shown on **Figure 6.16**.

6.6.3.2 Water Quality Evaluation

GZA used the six water quality indicators (bicarbonate alkalinity [as $CaCO_3$], magnesium, sodium, calcium, sulfate, and chloride) to assess whether or not Discharge Canal and/or river water was present or mixed with groundwater at the two locations of interest (note that the MW-48 monitoring well location contains a shallow and a deep well). A summary of our findings follows.

- The river and canal samples are chemically similar and are dominated by sodium and chloride. The sodium and chloride contents are highest at the mid tide sampling event. These data indicate that at mid tide there was a greater vertical mixing of river water which caused the water to contain more sodium and chloride[45].
- The MW-48-23 samples collected at low, mid and high tide are all geochemically similar and are dominated by the sodium and chloride ions. However, the electrolyte concentration of these two ions is approximately half of that measured in the river or canal samples. Additionally, at low tide, there is slightly less sodium chloride and slightly more bicarbonate anion than at mid or high tide. We believe this indicates that at low tide, this location receives relatively more groundwater.
- Samples collected from MW-48-38 at low, mid, and high tide were generally all dominated by calcium and magnesium cations and chloride and bicarbonate anions. These samples also contained similar sodium, chloride, calcium, bicarbonate, magnesium, and sulfate electrolyte concentrations. However, at mid and high tide, there was somewhat more calcium, magnesium, and bicarbonate measured in these samples. It is further noted that the cation/anion imbalance for the MW-48-38 samples (except MW-48-38-L1) was greater than 5%. This indicates a lack of accuracy or the presence of unanalyzed ions in the groundwater samples. While samples from MW-48-38 currently appear more representative of groundwater than those from wells MW-38 and MW-48-23, it is not certain that they are always fully representative of groundwater only[46].

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[45] We believe the river and canal samples are similar (in part) because the river sample location was situated immediately down-river of the Discharge Canal outfall. In addition, the river sampling location visibly appears to remain within the discharge water heat plume. Therefore, the river samples are likely Discharge Canal water or at least mixed with what is being discharged from the canal.

[46] For example, 573 pCi/L of Tritium was detected in this interval on September 5, 2006. Tritium had never previously been detected and has since not been detected in this interval. It may be that this sample was misidentified in the field and the sample was actually obtained from the upper interval of this well where Tritium is routinely detected. However,

- The samples collected from MW-38 at low, mid and high tide are all geochemically similar and are dominated by the sodium and chloride ions. However, the electrolyte concentration of these two ions is less than half of that measured in the river or canal samples. Additionally, at low tide, there is slightly less sodium and chloride than at mid or high tide. We believe this likely indicates that at low tide, this location sees relatively more groundwater.

These data indicate that water samples collected from MW-38 and MW-48-23 are largely representative of the proximate surface water bodies at the Site. Recognizing the source of water in these wells, the other *chemistry data* (e.g., Tritium and Strontium) are suspect and should not be used for evaluation of groundwater contaminant migration or flux. Based on the available data, MW-48-38 may provide samples *more* representative of Site groundwater than MW-38 and MW-48-23. However, further analysis would be necessary to allow this well to be recommended as a southern boundary monitoring location, particularly in light of the above analysis pursuant to the proximate well screens and the potential for false positives. Given the demonstrated groundwater flow directions in this area[47], it is GZA's opinion that an additional southern boundary monitoring location (in addition to MW-51 and MW-40) is not required proximate to MW-48-38.

6.7 GROUNDWATER FLOW PATTERNS

A major purpose of this groundwater investigation was to identify the fate and level of groundwater contaminant migration. The contaminants of potential concern are soluble in groundwater, and at somewhat varying rates, move with it. This section provides a description of identified groundwater flow patterns in and downgradient of identified contaminant release areas. The piezometric data, shown in **Table 6.1**, which form the basis of this evaluation are independent of chemical data collected at the same monitoring locations. Consequently, our evaluation of piezometric data provides an assessment of where contaminants are expected to migrate in various time frames. Refer to **Section 9.0** for information on the observed distribution of contaminants and a discussion on discrepancies between anticipated and observed conditions.

Testing has indicated that the bedrock is sufficiently fractured to, on the scale of the Site, behave as a non-homogeneous, anisotropic, vertically porous media. This finding indicates that groundwater flow is perpendicular to lines of equal heads. This assessment appears particularly valid in horizontal (East-West & North-South) directions.

The nature of bedrock fracturing suggests the hydraulic conductivity is higher in the horizontal than in the vertical direction. Furthermore it appears the upper portions of the rock are more conductive than the deep rock except within the zone of higher hydraulic conductivity between Units 1 and 2. These findings suggest that the bulk of the

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it also is possible that this sample is reflective of river water induced into the well through sampling and/or the specific conditions existing at the time the sample was taken.

[47] While the representativeness of the chemistry data in these wells (MW-38, MW-48-23 and MW-48-38) is not certain, the groundwater elevation data is reliable for establishing flow direction.

groundwater moves at shallower depth, with small masses being reflected deeper into the rock mass than would be seen in anisotropic aquifer.

6.7.1 Groundwater Flow Direction

Groundwater elevations from pressure transducers at a representative low tide have been used to construct a potentiometric surface map of the aquifer beneath the Site (see **Figure 6.17**). We chose this data set after evaluating a number of piezometric data sets. More specifically we have mapped six groundwater conditions:

- Low tide during the drier portion of the year (2/12/07)
- High tide during the wetter portion of the year (3/28/07)
- Low tide during the wetter portion of the year (3/28/07)
- High tide during the drier portion of the year (2/12/07)
- Groundwater elevations at sample locations with the greatest Tritium impact during wet season
- Groundwater elevations at sample locations with the greatest Tritium impact during the dry season

Based on this evaluation, it appears that there is not a great deal of change in groundwater flow patterns over time (see **Appendix S**). However, as groundwater elevations have a smaller tidal response (amplitude) than the fluctuations of the river, low tide is a time with a relatively high degree of groundwater flux from the Site. Furthermore, low tide during the drier portion of the year likely represents a period of highest groundwater flux.

Groundwater flow is in three dimensions. A representative set of groundwater elevations was used to construct a cross-sectional groundwater contour map as shown on **Figure 6.18**. This figure is based on a 1:1 horizontal to vertical hydraulic conductivity. Because horizontal fractures transmit flow in only a horizontal direction, and vertical fractures transmit flow in both a horizontal and vertical direction, the aquifer is vertically anisotropic with a preference for horizontal flow. Conversely, if the vertical hydraulic conductivity decreases with depth, the groundwater flow should be driven deeper than shown on the figure, but would still ultimately discharge to the Hudson River. Based on the observed vertical distribution of piezometric heads, the deepest flow paths of potential interest for this investigation originate near Unit 2. Based on the observed vertical distribution of contaminants (see **Section 9.2**), these flow paths are limited to depths of between 200 and 300 feet below ground surface.

As discussed previously, groundwater flow patterns are also influenced by anthropogenic sources and sinks. The groundwater sources/sinks are shown on **Figure 1.3** and are summarized below:

- Unit 1 Chemical Systems Building (IP1-CSB) Foundation Drain: This drain discharges into the Sphere Foundation Drain Sump (SFDS) and is designed to maintain groundwater elevations beneath IP-1-CSB subbasement to an elevation of approximately 12 feet NGVD 29. The reported groundwater extraction rate from this drain is approximately 10 gallons per minute (gpm).

- IP1-NCD: This drain is designed to maintain groundwater elevations beneath the Unit 1 containment building (IP1-CB) and the Unit 1 Fuel Handling Building (IP1-FHB) at an elevation ranging from 33 to 42 feet NGVD 29. The reported groundwater extraction rate from this drain is approximately 5 gpm.
- Unit 2 Footing Drain: This drain is designed to maintain groundwater elevations beneath the Unit 2 Vapor Containment (IP2-VC) at an elevation ranging from approximately 13 to 42 feet NGVD 29. The long term flow rate from this drain is not known, but short term measurements made prior to and during the Pumping Test indicate it is likely on the order of 5 gpm.
- Unit 3 Footing Drain: IP3-VC is known to have a Curtain Drain. However, specifics of its construction were not available. It is known that a pipe that connects to the Unit 3 Curtain Drain is currently under water in a manhole Northeast of Unit 3. Due to this condition, it is unknown how much or whether or not this drain is removing groundwater.
- Unit 1, 2, and 3 storm drains: The storm drains surrounding Units 1, 2, and 3 were constructed of corrugated metal piping. These pipes and associated utility trenches have been shown to allow at least some infiltration/exfiltration. That is, depending on rainfall and location, these structures may either receive groundwater or recharge the aquifer.

6.7.2 Groundwater Flow Rates

In the interest of evaluating conditions when a relatively large amount of groundwater (and associated constituents) flux to the Hudson River occurs, our discussion of lateral groundwater flow direction focuses on the low tide potentiometric surface contours as shown on **Figures 6.19** and **6.20**. These groundwater contours show that groundwater generally flows toward the Site from the North, East and South, with a generally westerly flow direction across the Site with a gradient averaging about 0.06 feet per feet.

6.7.2.1 Seepage Velocities

We used Darcy's Law to estimate the average groundwater seepage velocity across the Site:

$$V = K * \frac{dh}{dl} * \frac{1}{n_e}$$

Where:

V = average linear groundwater velocity

K = hydraulic conductivity (0.27 feet/day [see **Section 6.50**])

$\frac{dh}{dl}$ = groundwater gradient (0.06)

n_e = effective porosity (assumed to be 0.0003 based on specific yield measured during Pumping Test)

Based on this equation and Site data, we computed the average groundwater seepage velocity to be on the order of 55 ft/day. This is an upper end estimate in that it does not account for the effect of dead-end fractures and irregularities in fracture apertures. That is, we believe the effective porosity is larger than that indicated by hydraulic testing. Also note that this is an average velocity with flow rate in individual fractures being controlled by the local gradient and hydraulic aperture of the fracture. Based on the tracer test (see **Section 7.3.2**), actual measured average seepage rates were substantially less than 55 ft/day.

6.7.2.2 Groundwater Flux

To estimate groundwater flows (i.e., groundwater mass flux) beneath the IPEC, a calibrated analytical groundwater flow model was constructed. This model was based on two independent equations, both of which provide groundwater flow estimates. The first of these equations is based on a mass balance. That is, on a long term average, the groundwater discharging from the aquifer is equal to the aquifer recharge. The second equation is "Darcy's Law", which states the flow per unit width of aquifer is equal to the transmissivity of the aquifer multiplied by the hydraulic gradient.

As discussed in the following subsections using Site-specific data for the governing parameters, both of these independent methods provided similar results. Because we were conservative (that is, we chose values for both equations that we believe may somewhat overestimate flows), we believe the model is appropriate for its intended use for estimating the mass of groundwater discharging to the Hudson River as part of dose impact computations[48]. Please note, this model is not, therefore, conservative for all purposes. For example, we believe it would likely overestimate the yield of extraction wells should they be developed at the facility.

While the calculated groundwater flux from the Site directly to the river (approximately 13 gpm) may intuitively seem small, it is consistent with our Conceptual Site Model and the identified hydrogeological setting.

<u>Mass Balance</u>

The mass balance approach recognizes that the only substantial source of recharge to aquifer is areal recharge derived from precipitation. Precipitation in the area reportedly varies from 49 inches per year (30-year average) to 36 inches per year (10-year average) at the IPEC Meteorological Station. Areal recharge is that portion of precipitation that reaches the water table (total precipitation minus run-off, evaporation and transpiration). The average areal recharge is dependent on total precipitation, the nature and timing of individual storm events, soil types, topography, plant cover, the percentage of impervious cover (roads, buildings, etc.) and precipitation recharge through exfiltrating

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[48] It is noted that the dose impact computations reported for 2006 were based on the mass balance model only. These analyses were completed prior to obtaining sufficient data to implement the Darcy's Law model. It is recommended that future dose impact computations also be based on the mass balance model, but with upgrades based on Darcy's Law analyses.

stormwater management systems. Based on our review of available information, we believe that the areal recharge at the IPEC is greater than 6 inches per year and less than 12 inches per year. For the purposes of this study, an average of 10 inches per year was used (see **Appendix S** for information on how we arrived at this average).

Topographic divides were used to defined the recharge area (see **Figure 3.1**). This provides a recharge area of approximately 4,000,000 square feet (92 acres) and a calculated recharge rate of 38 gpm. From this value, the 20 gpm extracted by pumping from foundation drains was subtracted (see **Section 8.0**). This approach, therefore, indicates that the groundwater discharge to the cooling water Discharge Canal and the Hudson River is approximately 18 gpm.

Darcy's Law

Darcy's Law is presented below:

$$Q = K * A * \frac{dh}{dl} = T * W * \frac{dh}{dl}$$

Where:

Q = volumetric flow (ft^3)
T = transmissivity (ft^2/day)
W = width of the streamtube

To estimate transmissivities, the aquifer was divided into two layers or zones: the upper forty feet; and between depths of 40 feet and 185 feet, the identified bottom of the significant groundwater flow field. In each of the zones, transmissivities were calculated using the geometric mean of hydraulic conductivity testing. The facility was further divided into 6 flow zones representing areas beneath pertinent Site features; and data East (upgradient) of the Discharge Canal was reviewed independently of that West (downgradient) of the Discharge Canal. This process, shown on the following four tables, provides an estimate of the groundwater flux passing beneath structures of interest that discharge to the cooling water Discharge Canal and the Hudson River. In reviewing these calculations, note the resulting total groundwater flow East of the canal is approximately 18 gpm, which indicates that the long term areal recharge to the aquifer is 10 inches per year, or 28% of the 10-year average precipitation recorded at the IPEC.

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	0.36	209	0.600	0.23
Unit 2 North	1.59	294	0.014	0.03
Unit 1/2	31.97	215	0.007	0.26
Unit 3 North	29.87	324	0.054	2.74
Unit 3 South	16.02	338	0.038	1.07
Southern Clean Zone	24.34	879	0.037	4.12
			Total➔	8.45

SHALLOW ZONE <u>BEFORE</u> CANAL (OVERBURDEN AND TOP 40 FEET OF BEDROCK)

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	0.36	209	0.600	0.23
Unit 2 North	1.59	221	0.038	0.07
Unit 1/2	31.97	146	0.022	0.52
Unit 3 North	29.87	316	0.013	0.61
Unit 3 South	16.02	248	0.011	0.24
Southern Clean Zone	24.34	879	0.037	4.12
			Total➔	5.79

SHALLOW ZONE <u>AFTER</u> CANAL (OVERBURDEN AND TOP 40 FEET OF BEDROCK)

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	10.77	209	0.068	0.80
Unit 2 North	10.77	294	0.030	0.49
Unit 1/2	62.15	215	0.023	1.61
Unit 3 North	37.65	324	0.022	1.41
Unit 3 South	22.02	338	0.040	1.55
Southern Clean Zone	19.66	879	0.043	3.83
			Total➔	**9.69**

DEEP ZONE <u>BEFORE</u> CANAL (FROM 40 TO 185 FEET BELOW TOP OF BEDROCK)

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	10.77	209	0.068	0.80
Unit 2 North	10.77	294	0.023	0.29
Unit 1/2	62.15	215	0.018	0.83
Unit 3 North	37.65	324	0.018	1.09
Unit 3 South	22.02	338	0.016	0.45
Southern Clean Zone	19.66	879	0.043	3.83
			Total→	7.25

DEEP ZONE AFTER CANAL (FROM 40 TO 185 FEET BELOW TOP OF BEDROCK)

GZA's groundwater flux calculations are used by Entergy to calculate radiological dose impact. Entergy currently estimates this dose based upon the precipitation mass balance approach alone. Refinements to this dose model are feasible utilizing the hydrogeologic data presented above. These refinements will improve the overall data fit of the flow model in concert with the long term monitoring program being implemented by Entergy.

The resultant dose assessments are expected to remain close to, or be somewhat lower than, what has already been estimated. It is recommended that Entergy evaluate the refinements to the existing model for inclusion in the next annual effluent assessment report.

7.0 GROUNDWATER TRACER TEST RESULTS

A tracer test was conducted to help assess groundwater migration pathways from IP2-SFP. As discussed in the following sections, the test also helped to confirm migration pathways from Unit 1. The test was designed to simulate a leak from IP2-SFP, in that the tracer (Fluorescein) was released directly to the bedrock at the base of the structure, immediately below the shrinkage cracks associated with the 2005 release. The bedrock surface at this location is approximately elevation 51 feet, and thus approximately 40 feet above the water table (as measured in the immediately adjacent MW-30 - see **Figure 7.1**). This approach was taken (recognizing it would complicate tracer flow paths relative to injection directly into the groundwater) to provide better understanding of the role of unsaturated bedrock in storing and transporting Tritium.

A major difference in the test, as compared to possible releases at IP2-SFP, is the rate of the injection. The 2005 Tritium release was measured at a peak rate of approximately 2 liters per day (0.005 gpm), as opposed to the tracer injection that occurred relatively instantaneously (as compared to the Tritium release) at a rate of approximately 3.5 gpm over approximately an hour. This higher injection rate was used to insure that a sufficient mass of Fluorescein was released at a known time. As anticipated, and discussed in subsequent sections, this practice appears to have enhanced the lateral spreading of the tracer in the unsaturated zone.

7.1 TRACER INJECTION

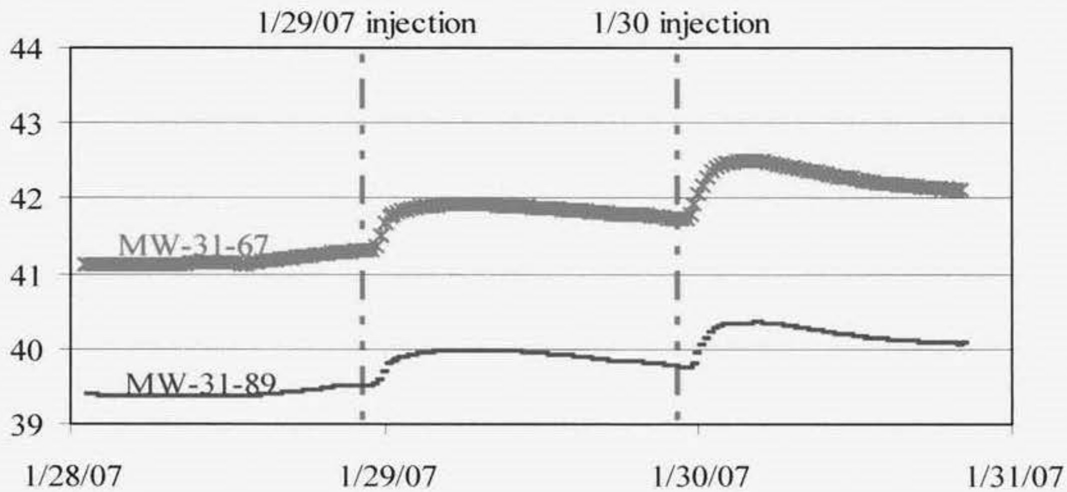
Preparation for the injection began on January 29, 2007 with the injection of potable water to test the ability of the injection point[49], T1-U2-1, to accept water and to pre-wet fractures. The first potable water injection was conducted on January 29, 2007. Five hundred gallons of water (measured using an inline totaling water meter) was introduced as fast as the water source would permit (approximately 8.5 gpm). The water level in the well did not rise significantly. The second potable water injection was conducted on January 30, 2007. A total of 1,012 gallons of tap water was introduced at a mean rate of approximately 8.3 gpm.

The piezometric data collected during that period from wells MW-30, MW-31, MW-33, MW-34 and MW-35 were reviewed for evidence of groundwater mounding. (Note: transducers were not installed in RW-1 and MW-32 on that date.) Mounding, on the order of 0.5 to 1 foot, was recorded at MW-31. No response was noted at the other four nearby monitored locations. Note that MW-31 is located upgradient of the injection point from a *saturated* zone groundwater flow perspective, and unsaturated zone flow in this direction is

[49] The injection point as shown on **Figure 7.2** is constructed from two-inch steel pipe that ends in a tee and perforated piping running directly on the bedrock surface, well above the water table. This perforated piping was covered with approximately 0.5 feet of crushed stone extending from the bedrock excavation face to the South face of the SFP, over a length of approximately 8 feet. The crushed stone was covered with filter fabric prior to placing the concrete mud-mat for gantry crane foundation construction; the mud-mat covers the entire bedrock excavation "floor" adjacent to the South side of the SFP.

consistent with the bedrock strike/dip directions. Based on the shape of the time response curve at MW-31, GZA believes that:

1. The center of the release to the water table was at some distance from MW-31 (see time lag), and;
2. Injected water was released to the water table over a longer duration than the two hour injection test. This opinion is based on the relatively slow decay of the mound at MW-31. This response is shown on the figure below:



PIEZOMETRIC GROUNDWATER RESPONSE TO WATER INJECTION

We have insufficient information to render an opinion on the shape or height of the tracer injection-induced groundwater mound. We note, however, because of the lower rate of the tracer injection, the short duration of the injection (see below), and the groundwater flow velocities, as derived from the tracer test, GZA believes mounding had relatively little effect (compared to unsaturated flow) on the lateral spreading of the tracer. That is, the life of the mound was not of sufficient duration to cause long term, widespread lateral migration in the groundwater.

The tracer injection was performed on February 8, 2007. It consisted of the release of 7.5 pounds of Fluorescein with 210 gallons of water. More specifically, prior to Fluorescein injection, 30 gallons of potable water was released to the well, this was followed by 10 gallons of a Fluorescein-water mixture, followed by 170 gallons of potable water (to flush the Fluorescein out of the well). This procedure resulted in a minimum initial average tracer concentration of 4,300,000 ppb.

7.2 TRACER CONCENTRATION MEASUREMENTS

The concentrations of Fluorescein in groundwater were routinely measured between February 8, 2007 and August 21, 2007[50] at 63 locations. This resulted in the collection analysis of 4,488 samples, including background samples, charcoal samplers and water samples. These data are tabulated and presented on time-concentration graphs in **Appendix N**.

Measurements of Fluorescein concentrations were made by two methods. The first is through aqueous sample analysis (1,969 individual samples). These water sample analyses provide direct concentration measurements, at the time of sampling, with a detection limit of less than 1 ppb.

A second method entailed desorbtion of Fluorescein from packets of activated carbon (carbon samplers) suspended in the groundwater flow path at multi-level sampling locations. This method provides a measure of the mass of Fluorescein moving through a monitoring well screen over the period the activated carbon is in the well. However, the actual concentration of Fluorescein in the groundwater is not determinable from this test. Among other things, carbon sample analyses are useful in establishing that the Fluorescein mass being transported by groundwater did not pass sampling locations between discrete sampling events. This was important for this study because of the potential for high transport rates (see **Section 6.0**).

7.3 SPATIAL DISTRIBUTION AND EXTENT OF FLUORESCEIN IN GROUNDWATER

The groundwater tracer test was developed primarily to identify groundwater migration pathways. We have divided our discussion on observed pathways into three subsections: unsaturated zone migration, the lateral distribution of Fluorescein, and the vertical distribution of Fluorescein.

Unsaturated Zone Transport

By design, Fluorescein was released atop the bedrock, in the unsaturated zone. The bedrock structure (strike and dip direction of bedrock fractures) therefore played a dominant role in controlling tracer migration to the water table. This is witnessed by the significant Fluorescein concentrations observed in the upgradient monitoring well MW-31 and MW-32 (see below) and at lower concentrations in the more distant and upgradient Unit 1 monitoring well MW-42.

The observed unsaturated zone migration to the South and East is consistent with the observed bedrock fracturing (see **Section 6.0**). This mechanism is also evidenced by data showing the highest Fluorescein concentration (49,000 pico-curies per liter - pCi/L)[51]

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[50] In addition to the routine sampling, specific wells were sampled for a longer period of time as part of short term variability testing (see **Section 9.0**).

[51] pCi/L is a standard unit of radiation measurement.

being found in well MW-32, located 60 feet to the South of the injection location, and not in MW-30, located immediately below the injection location.

In reviewing tracer test results, it should be recognized that the Fluorescein released at a single location on the bedrock was not released to the water table at a single location, rather, it reached the water table over an undefined area that likely extends to the East of MW-31, to the South to MW-42, and likely not far to the North of the injection well. As discussed in **Section 7.5**, this limits our ability to evaluate migration rates, but increases our ability to understand likely Tritium migration pathways from IP2-SFP.

The spreading of Fluorescein in the unsaturated zone was likely more pronounced than the spreading of Tritium because of the higher release rate. The tracer test, however, supports data that shows the Unit 2 plume to extend upgradient of the source area and laterally to Unit 1 to the South of IP2-SFB.

Lateral Distribution

Two conditions were selected to show the lateral distribution of Fluorescein in a manner illustrating conditions influencing the migration of groundwater in the vicinity of IP2-SFB. These are:

1. The maximum observed concentrations; and,
2. Conditions just prior to, and including, June 14, 2007.

While the maximum observed concentrations do not illustrate an actual condition, the resulting figure is useful in highlighting migration pathways. We chose June 14th because it represents conditions approximately 4 months after the injection. With estimated Fluorescein transport rates on the order of 4 to 9 feet per day (see **Section 7.4**), conditions proximate to that date clearly illustrate the effects of subsurface storage on both Fluorescein and Tritium[52].

Lateral Distribution – Maximum Observed Concentrations

The distribution of the observed maximum concentrations of Florescein, at any depth, in groundwater is shown on **Figure 7.2**. This figure was developed based on both the observed concentrations and our understanding of groundwater flow directions (inferred from groundwater contours). This figure does not show conditions at any single time; rather it represents our interpretation of the highest tracer concentration, at any time during the test, at a location. In reviewing that figure please note:

- The maximum observed tracer concentration was 49,000 ppb; approximately 1% of the calculated average injection concentration. We interpret these data to mean that there is considerable spreading and mixing of the tracer in the unsaturated and shallow saturated zones.

---

[52] Later dates were not selected because of the associated reduction in the sampling frequency and/or number of sampling locations.

- The 50 ppb contour represents approximately 1/100,000 the concentration of the injected tracer. Because Tritium concentrations in IP2-SFP are approximately 20,000,000 pCi/L this contour (50 ppb Fluorescein) represents the detection limit of a release of Tritium from IP2-SFP (at the injection well).
- The general shape of the resulting plume is strikingly similar to the observed Unit 2 plume, see **Figure 8.1**. This supports our interpretation of contaminant migration from IP2-SFP.
- Because tracer was detected in MW-42 and MW-53, the test can be used to help assess migration pathways from Unit 1. The observed distribution of Fluorescein in the vicinity of Unit 1 supports our interpretation of the migration of Strontium, with a westward migration towards the Hudson River in a fairly narrow zone (see **Figure 7.2**).
- The low concentrations to the West (downgradient) of the cooling water Discharge Canal (as compared to East of the canal) indicate the canal received a significant mass of the tracer, as opposed to direct discharge to the river.
- Concentrations found in Manhole Five (MH-5) indicate the IP-2 Curtain Drain received tracer (see **Section 7.5**).

Lateral Distribution – June 14, 2007

GZA's interpretation of the distribution of Fluorescein in groundwater proximate to June 14, 2007 is shown on **Figure 7.3**. Again, concentrations are the highest measured at any depth. While not ideal for the observed concentrations, the contour interval was selected to match the contour intervals shown on **Figure 7.2**. In reviewing that figure, please note:

- The shape of the plume is more representative of an ongoing release than of a four-month-old instantaneous release in a strong groundwater flow field. This supports other data which indicate water is stored in the unsaturated bedrock (and potentially within the upper water bearing zone) and is released to the groundwater flow field over time.
- The center of the Fluorescien mass in groundwater, in the release area, shifted to the North. (See data for wells MW-30 and MW-32 on **Figures 7.2** and **7.3**). GZA interprets these data to mean:
  - There is more storage in the unsaturated zone in proximity to IP2-FSB, than to the South or West; and
  - The relatively high injection rate resulted in more lateral spreading of the tracer than would have resulted from a slow, long duration release.

Vertical Distribution

The table provided below presents data on the vertical distribution of Fluorescein along the center line of the tracer plume (see **Figure 7.2** for well locations). It presents the maximum observed concentration at each depth and the approximate concentration[53] proximate to June 14, 2007.

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[53] Data estimated for the June 14th date are based on time concentration graphs (see **Appendix N**).

FLUORESCEIN CONCENTRATIONS

MW-31		MW-32		MW-30		MW-33		MW-111		MW-37	
Depth	**Conc.**	**Depth**	**Conc.**	**Depth**	**Conc.**	**Depth**	**Conc.**	**Depth**	**Conc.**	**Depth**	**Conc.**
53	1600 / 0.5	62	49,000 / 2	74	5690 / 2600	18	6.6 / 1	16	2.9 / 2.9	22	47 / 10
67	12,700 / 200	92	24,300 / 500	88	167 / 110					32	1.3 / ND
89	1810 / 3	140	15,300 / 6								
		165	4160 / 16								
		197	621 / 56								

1600 / 0.5 = Max. conc. / conc. proximate to 6/14/07 in µg/L
Depth = Below Ground Surface (Feet)
ND = Not Detected

The available data indicate the bulk of the Fluorescein was migrating at fairly shallow depths, although not always at the water table. As anticipated (consistent with the Conceptual Site Model), it also suggests the pathway becomes somewhat deeper downgradient of the injection point, likely being below the well screens at MW-33 and MW-111. The comparatively low concentrations at MW-111, as compared to Tritium concentrations, likely highlights the importance of unsaturated zone migration in groundwater contaminant distributions.

7.4 TEMPORAL DISTRIBUTION OF FLUORESCEIN IN GROUNDWATER

Groundwater samples were collected at regular intervals between February 8 and August 21, 2007[54]. These data are shown on graphs provided in **Appendix N** with selected information shown below. Interpretation of these graphs is complicated, beyond the normal difficulties associated with interpreting tracer test data in fractured rock. This is because the tracer was *not* injected directly to the water table, as would be more typical. Rather, the tracer was released at the top of the bedrock, in the unsaturated zone, so as to better mimic the behavior of the Tritium release from the cracks in the fuel pool wall; as was the primary objective of the tracer test. Therefore, the tracer then entered the groundwater regime at numerous locations due to unsaturated zone spreading from the release point. In addition, these numerous release points remained active over an extended period of time (months) due to storage in the unsaturated zone; see the previous subsection and **Section 8.1.2** for further discussion.

With these limitations noted, the following observations/interpretations are provided:

- At some locations, the release to the water table was rapid. For example, at monitoring well MW-32-62, located approximately 60 feet to the South of the injection point, the tracer arrival time[55] was approximately one day. Conversely, at MW-30-74, located adjacent to the injection well, the arrival time was approximately 25 days. See the following figures.

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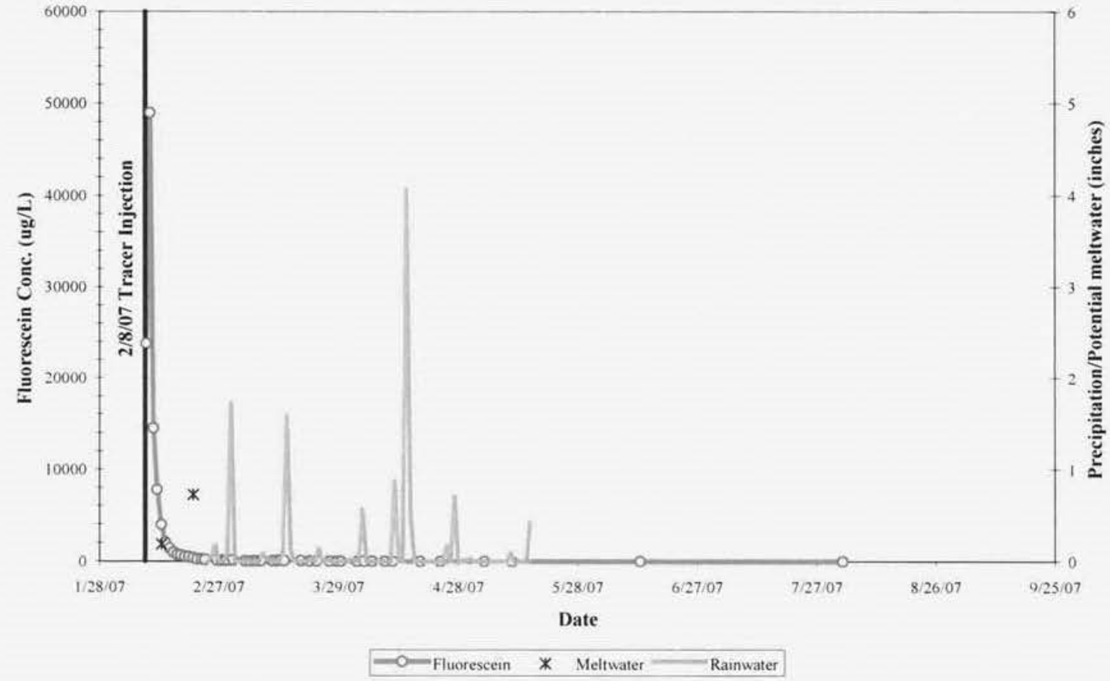
[54] In addition to the routine sampling, specific wells were sampled for a longer period of time as part of short term variability testing (see **Section 9.0**).

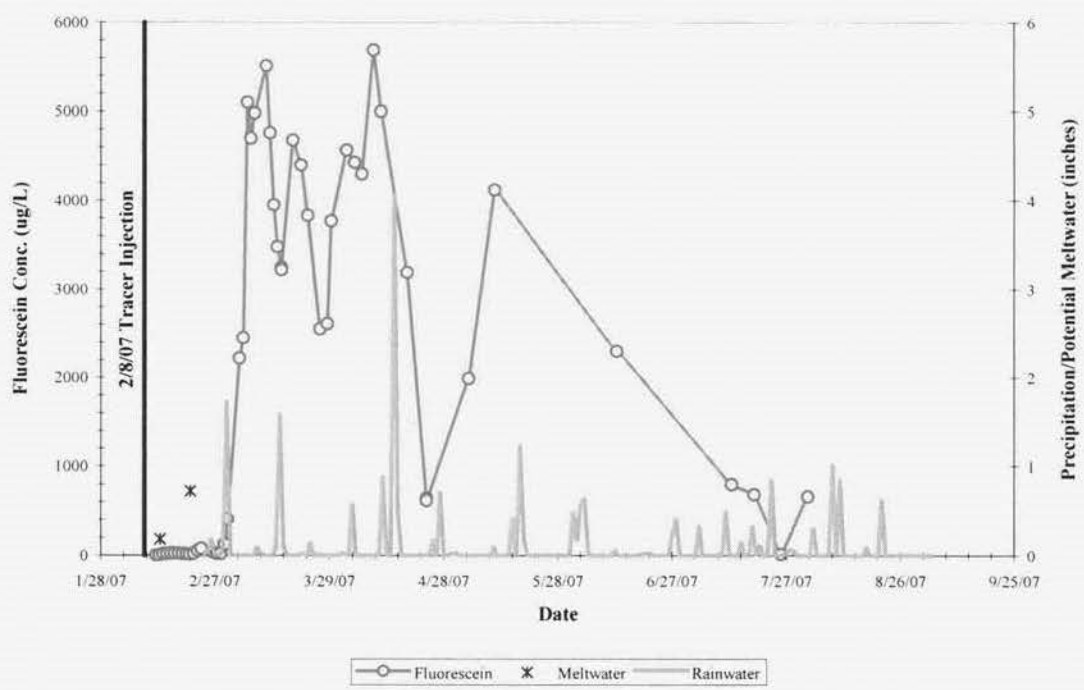
[55] Arrival times are generally established as the center of mass (often the peak) of the concentration vs. time graph.

MW-32-62



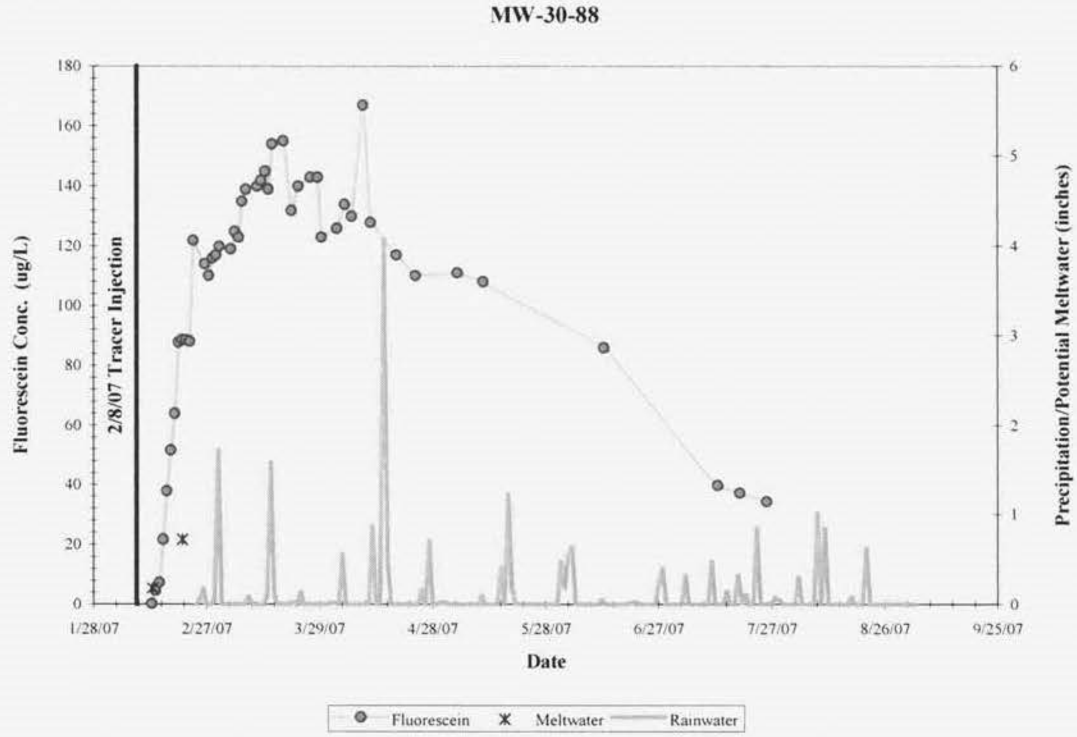
MW-32-62 FLOURESCEIN AND PRECIPITATION VS TIME

MW-30-69



MW-30-69 FLOURESCEIN AND PRECIPITATION VS TIME

- In mid-June 2007, there was still an ongoing source of Fluorescein to the water table in the vicinity of IP2-FSP. This is evidenced by the time-concentration graphs for MW-30 -74 (see previous figure) and MW-30 -88, presented below:



MW-30-88 FLOURESCEIN AND PRECIPITATION VS TIME

- Because the locations and times of releases from the unsaturated zone to the water table are not known, it is difficult, at best, to estimate tracer transport velocities. However, as shown below, the average value appears to be on the order of 4 to 9 feet/day.

Well Location	Time of Arrival Date	Time (Days)	Distance (Feet)	Velocity (Ft/Day)
MW-33	3-5-07	25	110	4.4
MW-111	3-14-07	34	145	4.3
MW-37-22[56]	4-10-07	61	300	4.9
MW-55[57]	3-28-07	48	240	5 to 9

FLOURESCEIN ARRIVAL TIMES AND TRANSPORT VELOCITIES

[56] The source of the Fluorescein observed in MW 37-22 is uncertain. It may be entirely from migration in the bedrock slightly to the North of that location, or may be due, in part or in whole, to transport via storm drains and in the backfill around the Discharge Canal walls. See **Section 4.5**.

[57] The calculated velocity depends on which flow path is selected. Using a flow path from MW-32 (day of release) to MW-55, the calculated velocity is approximately 5 feet/day. Using a flow path between MW-53 and MW-55 (the Strontium flow path) the calculated velocity is 9 feet/day.

Also note, the carbon sampler data supports these estimates to the extent that no evidence of significant Fluorescein migration between aqueous sampling events was found.

The observed tracer migration rates are approximately 1/5 to 1/10 the calculated groundwater velocity of 55 ft/day, see **Section 6.7.2**. GZA attributes the difference between the "observed" and the "computed" transport velocities primarily to the effective porosity of the bedrock. That is, we believe the actual effective porosity is considerably larger (more on the order of 0.003) than that computed from our analyses of the Pumping Test (see **Section 6.5.1**); the aquifer response testing (see **Section 6.6.1**); or the hydraulic aperture of the bedrock (see **Section 6.5.2**). This slower transport velocity helps to explain the observed long term temporal variations in both tracer and Tritium groundwater concentrations, and supports the use of a porous media flow model. As a practical matter, this slower transport velocity encourages the use of conventional groundwater monitoring frequencies (quarterly or longer); and reduces concerns over the possibility of high concentrations of contaminants migrating by a monitoring location between sampling events.

7.5 FLUORESCEIN IN DRAINS, SUMPS AND THE DISCHARGE CANAL

Fluorescein was also detected within storm drain catch basins, foundation drain sumps, and the Discharge Canal. Fluorescein was detected in manholes MH-4, MH-5 and MH-6. In reviewing these data, note:

- MH-5 receives discharge from the IP2-VC Curtain Drain system. The presence of tracer in this manhole indicates that tracer entered the Curtain Drain system due to lateral spreading at the release point during injection. Once in the Curtain Drain system, the tracer migrated to MH-5.
- Water in MH-5 flows towards the cooling water Discharge Canal passing through MH-4, discharging at MH-4A.
- The concentrations detected in MH-4 are very similar to the Fluorescein concentrations detected in samples collected from MH-5, while Fluorescein was not detected in samples collected from the downstream manhole MH-4A. This suggests that either dilution in MH-4A reduced Fluorescein to below method detection limits, and/or the tracer is lost via exfiltration from piping between MH-4 and MH-4A. This loss (if it occurs) in conjunction with flow in the canal backfill, could explain the Fluorescein observed in MW-37. Available data are not adequate to fully address this issue. In any event, the test further demonstrates the need to account for the Tritium being transported in the IP2-VC Curtain Drain (see **Section 7.6**).
- In reviewing data, note that the tracer concentrations in MH-6 are lower than the concentrations observed in MH-5 (peak in MH-6 of 14.4 ppb as opposed to a peak in MH-5 of 43.1 ppb). We attribute the concentrations in MH-6 to groundwater infiltration in the area of the identified tracer plume. Also note the flow from MH-6 is to MH-5.

Fluorescein was also detected in the IP1-NCD, the IP1-SFDS, and the Containment Spray Sump (CSS). We have attributed the presence of tracer at these locations to unsaturated zone migration to the vicinity and West of MW-42. The concentration and arrival times at

these three locations are not easily explained but, taken as a whole, are consistent with the observed migration of Tritium.

Fluorescein was detected at low concentrations, at various times, in carbon samples collected from the cooling water Discharge Canal. Because of the substantial dilution in the canal, the extended release of tracer to the canal and the low concentrations of tracer found in the samples, we believe these data represent background conditions[58], and cannot be used to evaluate the tracer test.

7.6 MAJOR FINDINGS

As an overview, the tracer test, supports our CSM and the observed distribution of contaminated groundwater. GZA also concludes that:

- Unsaturated zone flow is important to the migration of contaminants released above the water table in the vicinity of Unit 2. Bedrock fractures induce this flow to the South and East of the release.
- There is significant storage of contaminated groundwater above the water table or in zones of low hydraulic conductivity (homogeneities) in the saturated zone. These features allow a long-lived release of contaminants to the Site groundwater flow field.
- Observed tracer migration rates are lower than calculated theoretical migration rates. As a practical matter, this "migration" indicates that the use of the estimated average hydraulic conductivity (0.27 ft/day or 1×10^{-4} cm/sec) will overestimate the volume of groundwater migrating through a given area. That is, we attribute the lower transport velocity to be due, in part, to a lower average hydraulic conductivity.
- In our opinion, the tracer test, in conjunction with the Tritium release, indicates that the existing network of monitoring wells can be used to monitor groundwater at IPEC.

[58] It is noted that Fluorescein is the primary colorant in automobile coolant anti-freeze. Therefore, leaks from cars to parking lot/road surfaces can impact surface water bodies via storm drain systems and/or direct runoff. Fluorescein was detected in the Discharge Canal prior to initiation of the tracer injection, further indicating its presence as background.

8.0 CONTAMINANT SOURCES AND RELEASE MECHANISMS

GZA conducted a review of available construction drawings, aerial photographs, prior reports, and documented releases, and interviewed Entergy personnel to assess potential contaminant sources. The primary[59] radiological sources identified were the Unit 2 Spent Fuel Pool (IP2-SFP) located in the Unit 2 Fuel Storage Building (IP2-FSB) and the Unit 1 Fuel Pool Complex (IP1-SFPs)[60] in the Unit 1 Fuel Handling Building (IP1-FHB. These two distinct sources are responsible for the Unit 2 plume and the Unit 1 plume, respectively.

No release was identified in the Unit 3 area. The absence of Unit 3 sources is attributed to the design upgrades incorporated in the more recently constructed IP3-SFP. These upgrades include a stainless steel liner (consistent with Unit 2 but not included in the Unit 1 design) and an additional, secondary leak detection drain system not included in the Unit 2 design.

The identified specific source mechanisms associated with the IP2-SFP and the IP1-SFPs are discussed in the following sections. We have segregated this source discussion based on primary contaminant type; those classified as primarily Tritium sources, as associated with the Unit 2 plume, and those classified as primarily Strontium sources, as associated with the Unit 1 plume. While the groundwater plumes emanating from their respective source areas can clearly be characterized using each plume's primary constituent, radionuclides other than Tritium and Strontium also exist to a limited extent and are fully addressed within the context of the Unit 2 and Unit 1 plume discussions[61].

Discussion of the two primary source types will be parsed further as follows:

- The Unit 2 (Tritium) plume source analyses will be split into: 1) "direct sources" defined as releases to the exterior of Systems Structures and Components (SSCs); and 2) "indirect storage sources" related to natural hydrogeologic mechanisms in the unsaturated zone (such as adsorption and dead-end fractures) and potential anthropogenic contaminant retention mechanisms (such as certain subsurface foundation construction details);
- The Unit 1 (Strontium) plume source analyses will be split into the mechanisms specific to the individual plume flow paths identified.

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[59] In addition to sources that directly impact groundwater, atmospheric deposition from permitted air discharges was also identified as a potential source of diffuse, low level Tritium impact to the groundwater.

[60] All of the pools in the IP1-SFPs contained radionuclides in the past. However, only the West pool currently contains any remaining fuel rods and all of the other IP1 pools have been drained of water. It is also noted that the Unit 1 West pool has been undergoing increased processing to significantly reduce the amount of radioactive material in the pools. Once fuel is removed, the IP1-SFPs will no longer constitute an active source of groundwater contamination.

[61] Contaminants associated with the Unit 2 leak were found to be essentially comprised of Tritium. The Unit 1 plume is comprised primarily of Strontium, but also includes Tritium and sporadic observation of Cesium-137, Nickel-63 and Cobalt-60 at low levels in some wells downgradient of the IP1-SFP (see **Figure 8.3**). Entergy accounts for all radionuclides that can be expected to reach the river in their required regulatory reporting of estimated dose impact.

8.1 UNIT 2 SOURCE AREA

The majority of the Tritium detected in the groundwater at the Site was traced to IP2-SFP. This pool contains water with maximum Tritium concentrations of up to 40,000,000 pCi/L[62].

The highest Tritium levels measured in groundwater (up to 601,000 pCi/L[63]) were detected early in the investigation at MW-30. This location is immediately adjacent to IP2-SFP and directly below the 2005 shrinkage cracks. As shown on **Figure 8.1**, the Tritium contamination ("the plume[64]") then tracks with downgradient groundwater flow[65] through the Unit 2 Transformer Yard, under the Discharge Canal and discharges to the river[66] between the Unit 2 and Unit 1 intake structures. During review of the following sections, it is important to recognize that only small quantities of pool leakage (on the order of liters/day) will result in the Tritium groundwater plume observed on the Site.

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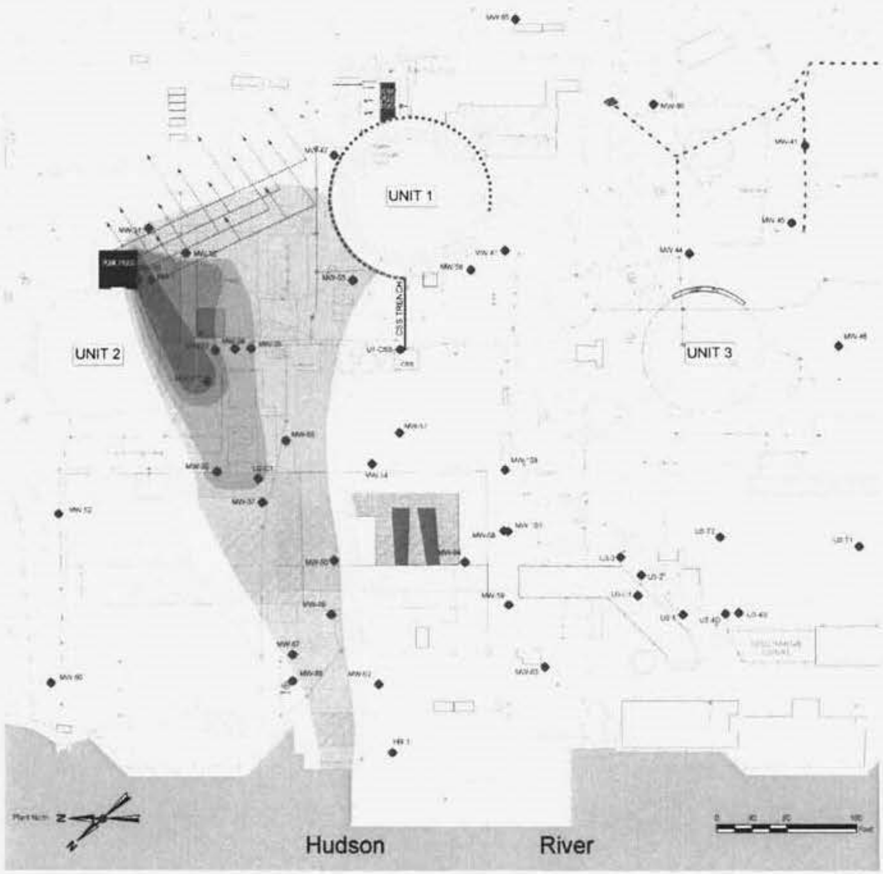
[62] In contrast, the levels of Tritium in the Unit 1 West pool are only on the order of 250,000 pCi/L. Strontium concentrations in IP2-SFP are on the order of 500 pCi/L.

[63] The 601,000 pCi/L Tritium concentration was measured during packer testing of the open borehole prior to multi-level completion. This value is therefore actually a *lower bound* estimate for depth-specific Tritium concentrations at that time. If the multi-level sampling instrumentation could have been completed prior to obtaining these data (not possible because the packer testing was required to design the multi-level installation), samples would have yielded *equal or higher concentrations*. This conclusion reflects the limited standard length and temporary emplacement of the packers used during the packer testing, and thus the greater potential for mixing and dilution between zones, as compared to the numerous packers permanently installed in the multi-level completions.

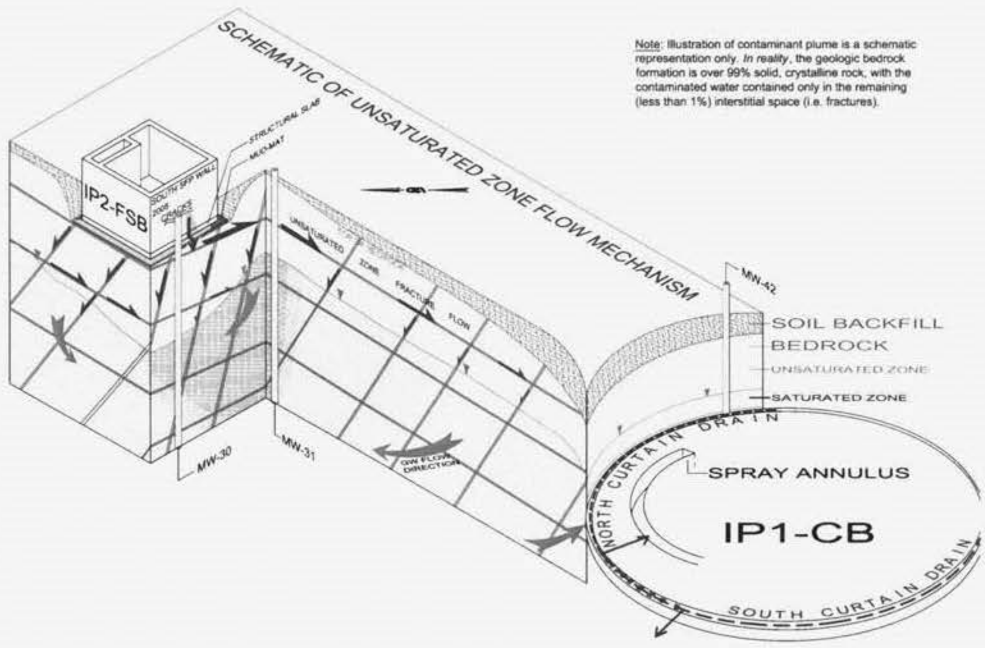
[64] It is noted that **Figure 8.1** does *not* show an actual Tritium plume; the isopleths presented contour upper bound concentrations for samples taken at *any time* and *any depth* at a particular location, rather than a 3-dimensional snapshot of concentrations at a single time. As such, this "plume" is an overstatement of the contaminant levels existing at any time. It should also be noted that the lightest colored contour interval begins at one-quarter the USEPA drinking water standard. While drinking water standards do not apply to the Site (there are no drinking water wells on or proximate to the Site), they do provide a recognized, and highly conservative, benchmark for comparison purposes). Lower, but positive detections outside the colored contours are shown as colored data blocks. See figure for additional notes.

[65] It is recognized that low concentrations of Tritium likely extend to the South, all the way to Unit 1. This conclusion is supported by: 1) the low Tritium concentrations remaining in IP1-SFPs (250,000pCi/L); 2) the data from MW-42 and MW-53; and 3) the Tritium balance between that released by the IP1-SFPs leak and that collected by the NCD. The transport mechanism is through *unsaturated* zone flow which follows bedrock fracture strike/dip directions rather than groundwater flow direction (see schematic of unsaturated zone flow mechanism included below). The levels of Tritium detected *upgradient* of IP2-SFP in monitoring wells MW-31 and MW-32 are also due to unsaturated zone transport from IP2-SFP along the generally southerly striking and easterly dipping bedrock fractures (see structural geology analysis in **Section 6.0** and tracer test discussions in **Section 7.0**).

[66] As the Tritium moves under the Discharge Canal, a significant amount discharges directly to the canal before the plume reaches the Hudson River.



UNIT 2 BOUNDING ACTIVITY ISOPLETHS



IP2-SFP UNSATURATED ZONE FLOW MECHANISM

The IP2-SFP contains both the fuel pool itself as well as its integral Transfer Canal. IP2-SFP is founded directly on bedrock which was excavated to elevation 51.6 feet for construction of this structure. As such, this pool's concrete bottom slab is located approximately 40 feet above the groundwater (as measured directly below the pool in MW-30[67]). During construction, a grid of steel "T-beams" was embedded in the interior surface of the 4-to 6-foot-thick concrete pool walls. These T-beams provided linear weld points for the 6 by 20 foot stainless steel liner plates. Given this construction method, an interstitial space exists between the back of the ¼-inch-thick stainless steel pool liner and the concrete walls. The space is expected to be irregular[68] and its exact width is unknown, but nominal estimates of a $^1/_8$ to ¼ inch are not unreasonable for assessing potential interstitial volume. Using these estimates, the volume of the space behind the liner could be on the order of 1500 gallons. In addition, the degree of interconnection between the spaces behind the individual liner plates is also expected to be highly variable given the likely variability of weld penetration into the "T beams." Therefore, the travel path for pool water that may penetrate through a leak in the liner is likely to be highly circuitous.

8.1.1 Direct Tritium Sources

Two confirmed leaks in the IP2-SFP *liner* have been documented, as well as the 2005 shrinkage crack leak through the IP2-SFP concrete wall[69]. The first liner leak dates back to the 1990 time frame, under prior ownership. This legacy leak was discovered and repaired in 1992. With the more recent discovery of the concrete shrinkage cracks in September 2005, Entergy undertook an extensive investigation of the IP2-SFP liner integrity. Within areas accessible to investigation, no additional leaks were found in the liner of the pool itself. However, after draining of the IP2-SFP Transfer Canal in 2007 for further liner investigations specific to the Transfer Canal, a single small weld imperfection was detected in one of these liner plate welds. This was the only leak identified in the Transfer Canal where the entire surface and all the welds could be and were inspected. This second liner leak is expected to have released tritiated pool water into the interstitial space behind this area of the liner plates whenever the Transfer Canal was filled above the depth of the imperfection (the Transfer Canal is currently drained and this imperfection will be welded leak-tight prior to refilling the Transfer Canal). All identified leaks have therefore been terminated. While additional active leaks can not be completely ruled out, if they exist, the data[70] indicate they must be very small and of little impact to the groundwater[71].

---

[67] While similar and lower groundwater elevations persist downgradient to the West, the shallow groundwater elevations are much higher (up to approximately elev. 45 feet) within only 50 feet to the East (MW-31) and Southeast (MW-32) of the pool.

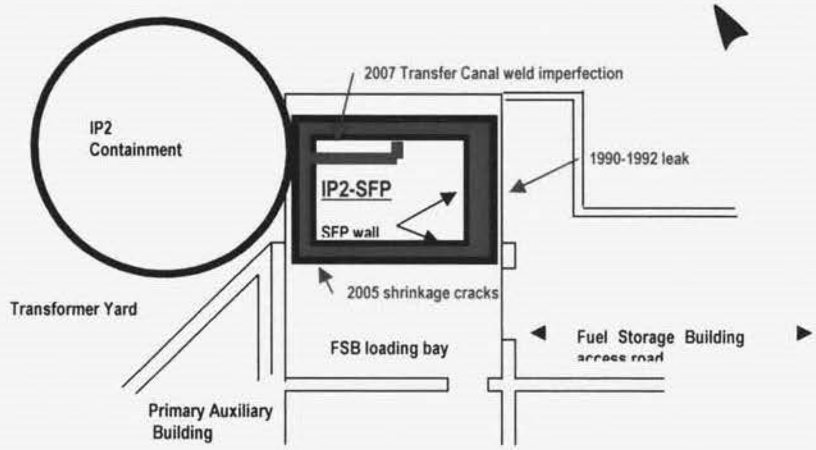
[68] The interstitial space width and uniformity will be related to the degree to which the concrete wall surface falls within a single plane. Because of the practicalities of forming and pouring concrete walls, we believe the surface is unlikely to be planer.

[69] While the 2005 leak from the shrinkage cracks does not appear to be related to a specific leak in the pool liner, it is considered a "direct source" because it still resulted in a release to the exterior of one of the plant's SSCs.

[70] These data include: monitored water levels in the SFP, with variations accounted for based on refilling and evaporation volumes; the mass of Tritium migrating with groundwater is small; and the age of the water in the interstitial space.

[71] For example, the 2005 shrinkage cracks still intermittently release small amounts of water; on the order of 10 to 20 ml/day. This water could represent a transient active leak, or it may just be due to residual water trapped behind the liner plates above the 2005 crack elevation still working its way slowly to the cracks. While this water is contained and prevented from reaching the groundwater, other such small leaks may exist which do reach the groundwater.

The three identified direct sources are discussed individually in the following paragraphs and shown on the figure below.



UNIT 2 FUEL POOL DIRECT SOURCE LOCATIONS

IP2-SFP 1990-1992 Legacy Liner Leak – This leak was first documented on May 7, 1992 when a small area of white radioactive precipitate was discovered above the ground surface on the outside of the IP2-SFP East concrete wall. This boron deposit exhibited radiological characteristics consistent with a potential leak from the pool. A camera survey was then conducted within the IP2-SFP to identify the location of the associated leak(s) in the liner. The survey initially revealed no damage to the liner. However, to further investigatory efforts, divers were utilized to visually inspect accessible portions of the liner. The divers found indications that the liner had been gouged when an internal rack had been removed on October 1, 1990. Two hundred and forty linear feet of the North and West IP2-SFP wall welds were then inspected and vacuum-tested to verify that the identified damage was isolated to this one case. No other leaks were identified, and on June 9, 1992, the leak was repaired.

Subsequent analyses conducted by the previous plant owner indicate that approximately 50 gallons per day could have leaked through the liner. This leak rate and the time scale of the release event would be expected to fill all the accessible interstitial space behind the liner[72]. Once the space behind the liner was filled to elevation 85 feet (the elevation of the 1990 cracks), water then began to leak out of the cracks in the concrete wall, with a maximum total release volume of up to 50,000 gallons. Given the very slow release rate (0.035 gal/min), the porous, hydrophilic nature of concrete, and the location of the leak at approximately five feet above the ground surface, a significant portion of the released water likely evaporated prior to entering the soils. However, given that the soils

[72] While the interstitial space was filling up to elevation 85 feet, any other cracks or joints in the concrete wall below this elevation, such as those identified in 2005, likely released contaminated water to the environment. As discussed below, it is hypothesized that with time, these subsurface cracks/joints may have become sealed due to precipitation of dissolved compounds, either carried with the pool water or derived from the concrete pool wall. This would have been required to allow retention of pool water in the interstitial space below elevation 85 feet after the liner leak was repaired in 1992, and thus subsequent leakage of the 2005 shrinkage cracks.

below the leak were found to be contaminated[73], it is clear that some portion of this release entered the subsurface. While Strontium and Cesium could have largely partitioned out of the pool water to the shallow soils, tritiated water would be expected to have continued to migrate downward to the groundwater.

IP2-SFP 2007 Transfer Canal Liner Weld Imperfection – As part of the recently completed liner inspections initiated by Entergy in 2005, the IP2-SFP Transfer Canal was drained in 2007 to facilitate further leak-detection efforts including vacuum box testing of the welds. These inspections discovered a single small imperfection in one of the liner plate welds on the North wall of the Transfer Canal at a depth of about 25 feet, which is approximately 15 feet above the bottom of the pool. All of the welds and the entire liner surface area of the Transfer Canal have been inspected by one or more techniques and no other leaks were found. Engineering assessments indicate this wall imperfection is likely from the original construction activity since there is no evidence of an ongoing degradation mechanism.

Given that the Transfer Canal is now drained, this weld imperfection is no longer an active leak site. However, the historic practice of maintaining water in the Transfer Canal likely resulted in a generally continuous release of pool water into the interstitial space behind the liner over time, and then potentially through the concrete pool walls and into the groundwater.

IP2-SFP 2005 Concrete Shrinkage Crack Leak - During construction excavation in September 2005 for the dry cask storage project, the South wall of the IP2-SFP was exposed and two horizontal "hairline" shrinkage cracks were discovered (see schematic below). These cracks exhibited signs of moisture, though fluid flow was not observed emanating from the cracks. To promote collection of adequate liquid volumes for sampling and analysis, the cracks were subsequently covered with a plastic membrane to retard moisture evaporation and enhance water vapor condensation. The trapped fluid was drained to a sample collection container. This temporary collection effort not only provided leak rate measurement capability and sufficient water for analysis, it also prevented further release to the groundwater.

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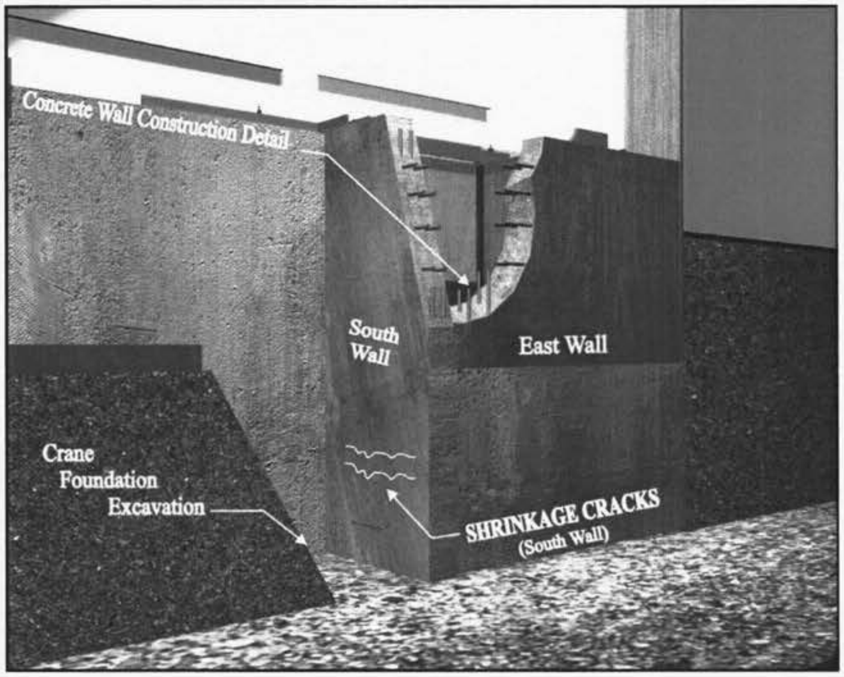
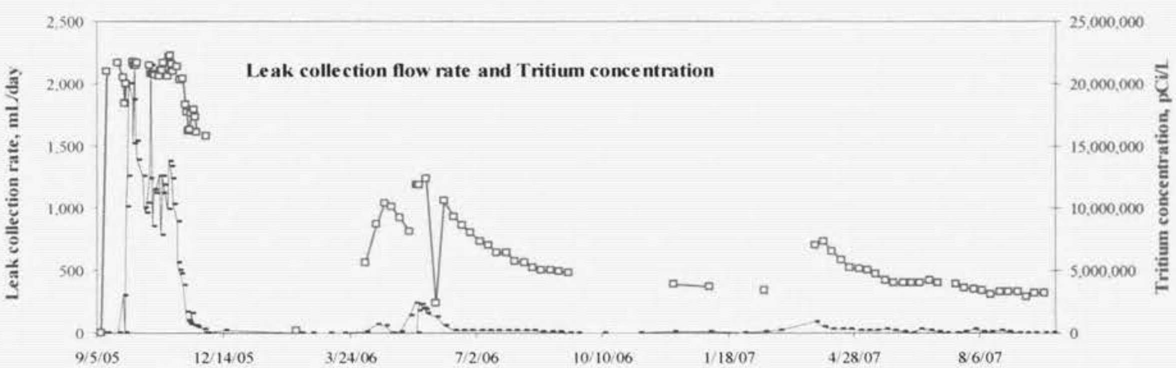
[73] Approximately 30 cubic yards of radionuclide contaminated soils were excavated from the area in 1992.



UNIT 2 SFP 2005 SHRINKAGE CRACKS IDENTIFIED IN SEPTEMBER 2005

Initially, the two cracks were found to be leaking at a combined average rate typically as high as 1.5 l/day (peak of about 2 l/day) from the time of crack discovery/initial containment through the fall of 2005. In early 2006, a permanent stainless steel leak containment and collection device was installed. This containment was also piped to a permanent collection point such that any future leakage from the crack could be monitored and prevented from reaching the groundwater. Subsequent monitoring through 2006 and into 2007 has indicated that the leakage rate had fallen off rapidly and become intermittent with an average flow rate of approximately 0.02 l/day, when flowing (see figure below presenting shrinkage crack flow rate and Tritium concentration over time). This small amount of leakage is permanently being contained and it therefore is not impacting the groundwater.



UNIT 2 2005 SHRINKAGE CRACK LEAK RATE AND TRITIUM LEVELS

Based upon two years of flow and radiological and chemical sample data, it appears that excavation of the backfill from behind the pool wall caused the shrinkage cracks to

begin releasing water trapped in the interstitial space dating back to 1992. This release mechanism is hypothesized to have developed as follows:

- During the original construction, the fuel pool walls developed shrinkage cracks in the concrete upon curing, as is not atypical for concrete.
- When the pool walls were backfilled with soil, they flexed inward slightly in response to the soil pressures developed during backfill placement and compaction[74].
- The pool was then filled with water which exerts an outward pressure against the walls. However, little outward flexure would be expected given the stiffness of the compacted soil backfill, which assists the concrete walls in resisting outward bending motion due to the water pressure.
- The stainless steel pool liner was punctured in 1990 and began leaking. Over time, this leak filled the interstitial space between the liner and the concrete walls. tritiated pool water then likely first leaked out of the lower-most cracks/joints, such as those responsible for the 2005 leak (elevation 62 to 64 feet), and successively leaked out of higher imperfections until it reached the cracks at elevation 85 feet. At this point, leakage was detected and the leak was fixed in 1992.
- At some point during the leakage, the subsurface cracks apparently became plugged with precipitate which stopped the leakage. This allowed pool water to remain trapped behind the liner at an elevation above the 2005 shrinkage cracks, potentially as high as elevation 85 feet. To the extent that the subsurface cracks/joints in the concrete did not all become completely leak-tight, the interstitial space behind the liner was likely recharged by leakage from the Transfer Canal weld imperfection (up until Transfer Canal drainage in July 2007) and/or other small leak sites in the liner.
- With excavation of the soil backfill from behind the southern pool wall, the pressure exerted by the backfill material was sequentially removed from the top to the base of the concrete wall. The elimination of this inwardly focused backfill pressure allowed the outwardly directed water pressure in the pool to flex the wall outward. It is hypothesized that this motion, while limited, was sufficient to initiate leakage from the 2005 shrinkage cracks at a rate of approximately 1.5 l/day during the fall/winter of 2005.
- The released water is believed to be primarily residual water derived from the 1990-1992 liner leak. However, laboratory results for water samples initially collected from the crack in the September 2005 time frame yielded Cesium-137 to Cesium-134 ratios indicating that the age of the water was approximately 4 to 9 years old. This age does not directly correlate with the 1990-1992 release timeframe. Conversely, the water clearly had exited the pool many years ago. A potential explanation for this intermediate age water is the mixing of water from a then-current small leak in the liner with 1992 age water.
- Over time, the shrinkage crack leak reduced the elevation of the residual water trapped behind the liner to the elevation of the cracks. Beginning in 2006 and through 2007, the leak rate was observed to have quickly become intermittent with typical leak rates, when leaking, of only approximately 0.02 l/day. These

[74] While the 4-to 6-foot-thick concrete walls are stiff, some flexure is required for the walls to develop bending stresses.

subsequent water samples did not contain Cesium-134, indicating that this more recent crack water could, in fact, be old enough to be from the 1990-1992 leak[75].

- As a corollary to the above conceptual model, the intermediate-aged crack water may be partially comprised of leakage from the Transfer Canal weld imperfection. This release pathway could potentially explain the measured intermittent and variable leakage collected in the permanent containment system after 2005. The variations in water elevation and temperature in the Transfer Canal are consistent with this hypothesis. While the Transfer Canal leak water would be recent, it is likely that it would take a substantial amount of time to flow from the North wall of the Transfer Canal to the South wall of the IP2-SFP[76]. This hypothesis is therefore consistent with the lack of short-lived isotopes (as associated with SFP water) currently being found in the water from the shrinkage crack. A more significant leak rate with shorter transit times (e.g., the magnitude of the 1990-92 leak) would be expected to, and did previously show, short-lived radionuclide signatures.
- Although several additional theories have also been postulated and investigated, a definitive explanation of the apparent discrepancy in Cesium age ratios could not be definitively determined. This discrepancy from the early sample data when the crack location was first investigated was an important factor in Entergy's decision to perform intensive pool and ongoing Transfer Canal liner inspections.
- It can also be concluded from the above data and analysis that any ongoing active leak in the pool liner, if one exists, must be quite small. Otherwise, the limited volume of the interstitial space between the liner and the concrete wall would transport a more substantial leak to the shrinkage cracks in a short time and the water would thus show a young age[77].

8.1.2 Indirect Storage Sources of Tritium

The extensive testing of the IP2-SFP liners to date by Entergy provides evidence that all direct sources (i.e., releases from SSCs) of Tritium have been identified and are currently no longer contributing radionuclides to the groundwater[78]. However, the Unit 2 plume, while decreased in concentration relative to the samples taken just after

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[75] Cesium-137 was present at sufficient concentrations that if the water was "young", Cesium-134 would have also been present at concentrations above method detection limits. It is further noted that the two isotopes of Cesium should partition to solids at the same ratios. Therefore, preferential removal of the Cesium-134 due to partitioning to the concrete is not an explanation for the lack of this isotope in the more recent crack water samples.

[76] It is noted that the seepage path(s) from the liner leak on the North wall of the Transfer Canal to the shrinkage cracks on the southern pool wall is likely to be particularly circuitous. The interstitial space between these two liners can only be connected (if they are connected at all) at the gate from the Transfer Canal to the fuel pool and/or through imperfections in the concrete wall/floor waterstops or in the concrete itself (given the five-foot-thick concrete wall separating the Transfer Canal from the SFP itself).

[77] As a benchmark, pool water from a one-tenth of a gallon per minute leak would be expected to reach the shrinkage crack in less than two weeks given the estimated volume of the interstitial space.

[78] However, some small amount of leakage could still be ongoing from other potential imperfections in the liner and/or concrete pool wall; large ongoing leaks would result in conditions inconsistent with the measurements of both leak rate and water age collected from the 2005 shrinkage crack. A large leak would also be inconsistent with the reductions observed in the Tritium concentrations in the groundwater.

identification of the 2005 shrinkage crack leak[79], still exhibits elevated concentrations. If all of the releases to the groundwater were terminated, it would be expected that the Unit 2 plume would attenuate more quickly than observed[80]. As such, a subsurface mechanism appears to exist in the unsaturated zone under the IP2-FSP that can retain substantial volumes of pool water for substantial amounts of time. The existence of such a "retention mechanism" is also supported by both the results of the tracer test and the recent evaluation of contaminant concentration variability trends over short timeframes and precipitation events.

The tracer test results, discussed more fully in **Section 7.0**, indicate that:

- Tracer injection directly to the top of bedrock below the IP2-SFP above MW-30 did not result in arrivals at MW-30 in time frames expected for vertical transport through the fractured bedrock vadose (i.e., unsaturated) zone. In fact, the earliest arrivals and maximum tracer concentrations were detected in MW-31 and MW-32 at distances of greater than 50 feet from the injection location;
- Tracer concentrations in MW-30 took longer than expected to reach peak concentrations from the time of first arrival;
- The tracer concentration vs. time curves exhibit a "long tail;" and
- The tracer concentrations exhibit significant variation over short periods of time, which may be related to precipitation events moving tracer out of storage.

It is, therefore, apparent that once tracer, and thus tritiated water, is released from directly below the IP2-SFP, it does not flow directly down to the groundwater but can be "trapped" (held in storage) for substantial periods of time.

The Tritium concentrations in MW-30 were measured on a weekly basis between August 8 and August 30, 2007 (see **Section 9.3.1**). These data show significant variability in concentrations over these short timeframes. This variability appears to far exceed that which can be attributed to variation inherent in groundwater sampling or radionuclide analyses. Aliquots submitted for tracer concentration testing also showed similar trends. It appears that these variations may be the result of the displacement of water, as evidenced by both tracer and Tritium, from this storage mechanism by infiltration such as associated with precipitation events.

Based on the above summarized information, two indirect storage mechanisms are postulated to explain the persistence of the Unit 2 plume. The first is the storage of tritiated water in dead-end fractures in the unsaturated zone. The second is the potential for tritiated water from the SFP to be trapped in the blast-rock backfill above the "mud-mat[81]"

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[79] The earliest samples taken from directly below the SFP in MW-30 (open borehole and packer testing samples) yielded Tritium concentrations over 600,000 pCi/L. More currently, maximum concentrations detected have been below one-half of those initial concentrations.

[80] Rapid attenuation of the Tritium plume would be expected based on 1) Tritium's lack of partitioning to solid materials in the subsurface; and 2) the crystalline nature, low storativity and high groundwater gradients associated with the bedrock on the Site.

[81] Prior to constructing a structural base slab (typically 2 to 5 feet thick) for the fuel pool, a 6-to 8-inch-thick, lean concrete "mud-mat" is typically constructed over blasted bedrock to even out the irregular rock surface and provide a

which was placed prior to construction of the SFP structural base slab. A combination of these two indirect storage mechanisms, as discussed separately below, is a conceptual model that explains the observed Unit 2 plume behavior in the context of the termination of the identified direct release mechanisms[82].

Dead-Ended Bedrock Fracture Storage - Naturally occurring bedrock fractures, as discussed in **Section 6.0,** are seldom long, continuous linear features. Rather, they are more typically networks of interconnected, discontinuous fractures. These networks often contain many dead-ended fractures. While dead-ended fractures are not subject to advective groundwater flow, they still can contain high contaminant concentrations. Contaminants enter these fractures through osmotic pressures set up in the subsurface by concentration gradients (initially high concentrations at the fracture "mouth" and low concentrations within the fracture). Over time, these concentrations equilibrate through liquid-phase diffusion. Therefore, under conditions of high Tritium groundwater concentrations, such as likely occurred during the two year timeframe of the 1990-1992 liner leak, the dead-ended fractures would be expected to end up containing high Tritium concentrations. Once the liner leak was repaired, the input of Tritium to the groundwater would subside and the concentrations in the advective fractures would start to decrease. However, the high Tritium concentrations within the dead-ended fractures would then start to diffuse back out of the dead-ended fractures into the groundwater flowing past them, thus maintaining higher than otherwise expected Tritium concentrations in the groundwater.

Our computation of the volume of the naturally occurring dead-ended fractures in the unsaturated zone below the IP2-SFP yields fracture volumes which are unlikely to support the observed Unit 2 plume for the required time frames (years). However, two additional considerations substantially increase the dead-ended fracture volume: 1) the observed unsaturated flow to the East and Southeast (this migration pathway exposes many more fractures to the Tritium due to the bigger area involved); and 2) construction blasting (which creates more fractures in the bedrock remaining below the structure).

As demonstrated vividly during the tracer test, contaminants released to the bedrock at the bottom of the SFP travel at least 50 to 75 feet to the East and Southeast as evidenced by the high tracer concentrations quickly detected in the upgradient monitoring wells

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hard, flat surface upon which to set the reinforcing rod "chairs" (these chairs elevate the lowest layer of rods to provide sufficient concrete corrosion prevention cover).

[82] It is noted that we originally believed that the groundwater in the Unit 2 Transformer Yard was uncontaminated with Tritium prior to February of 2000. If true, this finding would be inconsistent with the storage mechanisms proposed. Our original conclusion was based on the sampling results at that time from MW-111; this well was sampled as part of the due diligence for property transfer to Entergy and was found not to contain Tritium above detection limits (900 pCi/L). However, interviews with facility personnel revealed that the sample was collected from the upper surface of the water table with a bailer. There was no attempt to purge the well to obtain samples representative of deeper aquifer water because the samples were taken primarily to look for floating oil in the well. Because this sample was collected from the upper groundwater surface (which will be most subject to infiltration by rain water) without adequate well purging, it is likely that this sample result was biased low. As discussed in **Section 9.0**, this well is subject to wide variations in Tritium concentrations due to rainfall events. Therefore, it is entirely plausible that no Tritium was detected above laboratory method detection limits even if Tritium were present at much higher concentrations deeper in the aquifer. As such, this February 2000 groundwater sample result should not be used to assess Tritium groundwater conditions at that time. See supporting data in **Section 9.3.1**.

MW-31 and MW-32[83]; the same behavior would be expected for Tritium. This wide areal distribution would substantially increase the volume of dead-ended fractures available for storage of contaminants.

In addition to naturally occurring fractures, the founding elevation of the SFP was achieved through construction blasting of the bedrock. While the bulk of the blasted rock was removed to allow construction, a zone of much more highly fractured bedrock typically remains after the founding elevation is reached. While these blast-induced fractures may be interconnected, they may not be fully connected to tectonic fractures that intersect the groundwater, and thus would be dead-ended. Therefore, contaminated water may be stored in these fractures and periodically escape in response to precipitation events.

Blast-Rock Backfill Storage - Following blasting of the bedrock to accommodate the IP2-SFP foundation, standard construction practice would have been to pour a mud-mat[84]. Based on construction photographs, it appears that the areal extent of the blasting was not much bigger than the dimensions of the structural slab for the SFP; this would be typical given standard contracting specifications and the cost of blasting. Therefore, it would be expected that the mud-mat was poured directly against the face of the bedrock excavation, without the use of forms. This hypothesis was confirmed visually during the 2005 excavation alongside the IP2-SFP for dry cask gantry crane foundation construction.

The concrete for a mud-mat is typically placed in a relatively fluid state to enhance self-leveling properties. As this fluid concrete is placed, it is typically pushed up against the perimeter forms, or in this case the bedrock face. This placement procedure would be expected to coat and seal off the fractures in the lower portion of the bedrock sidewalls. While the height above the surface of the mud-mat to which this seal would be formed is highly variable and occurrence-specific, it would not be unreasonable to find a 2-to 6-inch high "lip" of concrete against the bedrock. The net effect would have been to create storage volume above the mud-mat, between the sides of the subsequently constructed structural floor slab and the bedrock sidewalls directly at the base of the SFP. While this space was likely filled with blast-rock fill, the pore volume of this material available for pool water storage could easily be over 30 percent of the total volume. This results in a substantial storage volume when compared to that required to "feed" and maintain the Unit 2 plume over time.

During the 1990-1992 liner leak, a large volume of highly tritiated water appears to have been released from the pool, thereafter traveling down the exterior of the SFP concrete wall. This travel path would place the pool water directly into the hypothesized storage containment. Once full, additional pool water would overtop the containment, migrate into fractures that were not sealed off by concrete, and then travel through the unsaturated zone. Once in the unsaturated bedrock, some tritiated water would quickly

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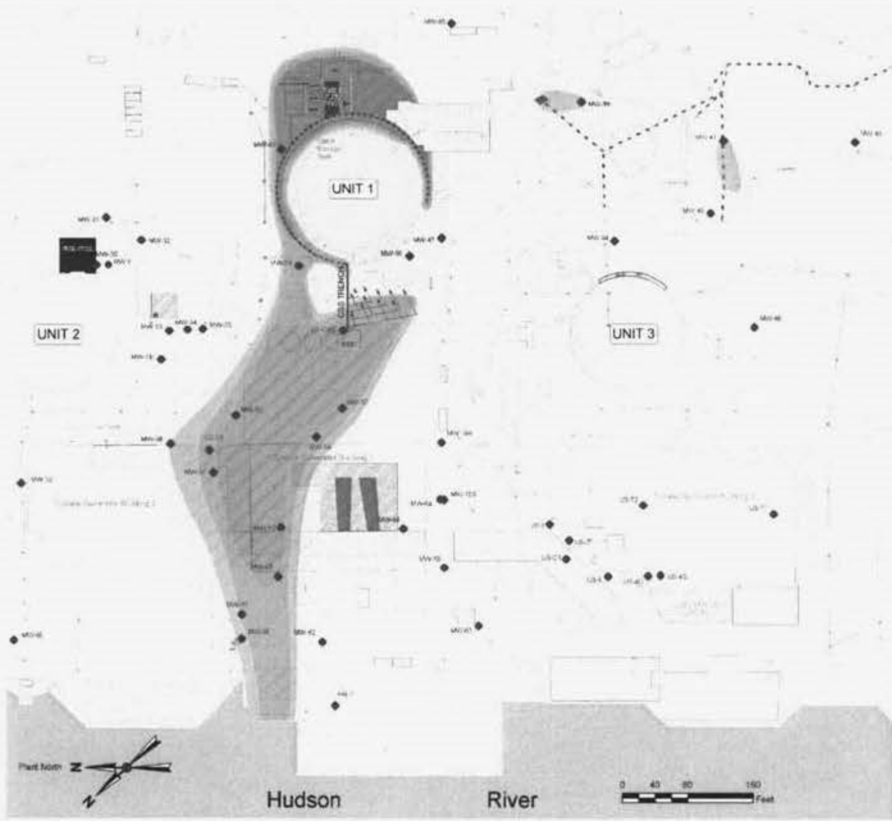
[83] Tracer reached MW-31 and MW-32 in less than four hours (time of first sample), thus supporting the conclusion of unsaturated zone transport to these locations.

[84] A 6-to 8-inch, lean concrete "mud-mat" is typically constructed over blasted bedrock to even out the irregular surface and provide a hard flat surface upon which to set the reinforcing rod "chairs" (these chairs elevate the lowest layer of rods to provide sufficient concrete cover for corrosion prevention).

reach the groundwater and some would be retained in dead-ended fractures, as discussed above. Over time, rainfall events would be expected to repeatedly displace pool water out of the containment and into the bedrock fractures. Contaminated water would therefore continue to impact the groundwater even if all active leaks from the pool were terminated. We believe this process could continue over substantial periods of time[85].

8.2 UNIT 1 SOURCE AREA

The Unit 1 contamination, as shown on **Figure 8.2** and the figure included below, is often referred to as the Strontium "plume"[86]. This is because the other radionuclides detected, including Tritium, Cesium-137, Nickel-63 and Cobalt-60, have a smaller radiological impact when compared to Strontium-90 and the Strontium is found in the entirety of the plume's areal extent, while the other contaminants are found only sporadically and in smaller subsets of the plume's area. The Tritium data for the Unit 1 plume is included on **Figure 8.1** and the Cesium-137, Nickel-63 and Cobalt-60 data are presented on **Figure 8.3**.



UNIT 1 BOUNDING ACTIVITY ISOPLETHS

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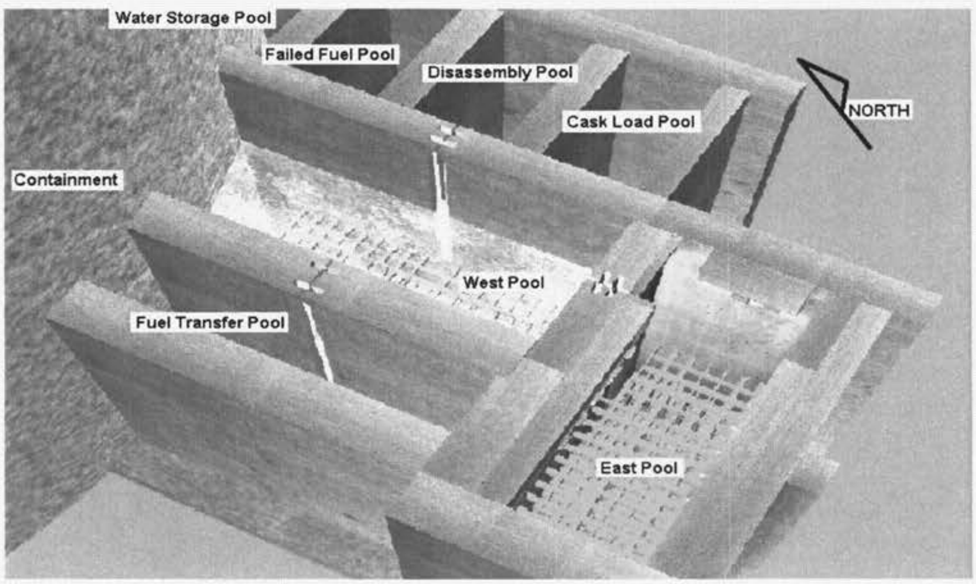
[85] See footnote No. 58 above relative to the reported Tritium results for MW-111 as sampled in May of 2000.

[86] It is noted that **Figure 8.2** does not show an actual Strontium plume; the isopleths presented contour upper bound concentrations for samples taken at *any time* and *any depth* at a particular location, rather than a 3-dimensional snapshot of concentrations at a single time. As such, this "plume" is an overstatement of the contaminant levels existing at any time. It should also be noted that the lightest colored contour interval begins at one-quarter the USEPA drinking water standard. While drinking water standards do not apply to the Site (there are no drinking water wells on or proximate to the Site), they do provide a recognized, and highly conservative benchmark for comparison purposes). Lower, but positive detections outside the colored contours are shown as colored data blocks. See figure for additional notes.

The highest levels of Strontium (up to 110 pCi/L) were originally found adjacent to the North side of IP1-SFPs in MW-42[87]. However, since Entergy began processing the pool water to remove the Strontium, the levels of Strontium (and other radionuclides) in this well have decreased. From MW-42, the Unit 1 "plume" tracks downgradient with the groundwater along the North side of the Unit 1 Superheater and Turbine Buildings[88]. As this plume approaches and moves under the Discharge Canal, it commingles with the Unit 2 plume, and discharges to the river[89] between the Units 1 and 2 intake structures, as does the Unit 2 plume. As discussed in **Section 6.0**, the plume track appears to follow a more fractured, higher conductivity preferential flow path in this area.

The source of all the Strontium contamination detected in groundwater beneath the Site has been established as the IP1-SFPs. The IP1-SFPs were identified by the prior owner as leaking in the mid-1990's, and are estimated to currently be leaking at a rate of up to 70 gallons/day. A schematic of this pool complex is included below.



UNIT 1 FUEL POOL COMPLEX

The IP1-SFPs were constructed of reinforced concrete with an internal low permeability coating[90]; stainless steel liners were not included in the design of these early fuel pools. The pool wall thickness ranges from 3 to 5.5 feet thick. The bottom of the IP1-SFPs is

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[87] The highest concentrations of the other contaminants associated with the Unit 1 plume, including Cesium-137, Nickel-63 and Cobalt-60 were also found in well MW-42. This location is very close to the IP1-SFPs and it is therefore not unexpected to find these higher concentrations of less mobile radionuclides near the source.

[88] This general introductory discussion of the Unit 1 plume is focused specifically on the "primary Unit 1 plume." Further more detailed discussion of the other "secondary Unit 1 plumes," which all originate from the IP1-SFPs, is provided in subsequent subsections.

[89] As is the case with the Tritium from the Unit 2 plume, some Strontium discharges directly to the Discharge Canal before the plume reaches the Hudson River.

[90] The original coating failed and was subsequently removed.

founded directly on bedrock, generally at elevation 30 feet[91]. As such, there is no significant unsaturated zone below the IP1-SFPs. While all of the pools have been drained except the West Pool, the other pools have all contained radionuclide at various times in the past. The West pool, which is approximately 15 feet by 40 feet in area, currently contains the last 160 Unit 1 fuel assemblies remaining from prior plant operations. This plant was retired from service in 1974.

The IP1-SFPs are contained within the IP1-FHB. The foundation system of the FHB and IP1-CB complex contains three levels of subsurface footing drains (see figure included below). The design objective of these drains, with the potential exception of the Sphere Foundation Drain (SFD)[92], appears to be permanent depression of groundwater elevations to below the bottom of the structures[93].

North and South Curtain Drains - The uppermost IP1-FHB drain encircles the Unit 1 FHB and IP1-CB. This footing drain, typically referred to as the Curtain Drain, is divided into two sections, the North Curtain Drain (NCD) and the South Curtain Drain (SCD). Each of these drains starts at a common high point (elevation of 44 feet) located along the center of the eastern wall of the FHB. These drains then run to the North and South, respectively, and wrap around the Unit 1 FHB and CB. The NCD then discharges to the spray annulus in the IP1-CB[94] at an elevation of 33 feet. From the annulus, the water is pumped for treatment and then discharged. The NCD flows at a yearly average of about 5 gpm carrying a Strontium concentration of 50 to 200 pCi/L (concentrations measured prior to reductions in Unit 1 pool water radionuclides via accelerated demineralization). The SCD pipe remains as originally designed with discharge to the Discharge Canal; however, the SCD is typically dry[95].

Chemical Systems Building Drain - The lowest level of the IP1-CSB (contained within the FHB) is also encompassed by a footing drain. The eastern portion of this drain begins at a high point elevation of 22 feet at its northernmost extent, located proximate to the IP1-CB, and then slopes to elevation 11.5 feet at its low point on the southern side of the IP1-CSB. The western portion of this drain begins at a high point elevation of 12.5 feet at its northernmost extent, again located proximate to the IP1-CB, and then slopes to elevation 11.5 feet at its low point on the southern side of the IP1-CSB. Both portions of the drain join at the southern side of the IP1-CSB where the common drain line runs below the floor slab and drains into the IP1-SFDS (bottom elevation of 6.5 feet). This drain typically flows

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[91] The bottom elevation of the individual pools range from a high elevation of 36 feet for the Water Storage Pool to a low of 22 feet for the Transfer Pool.

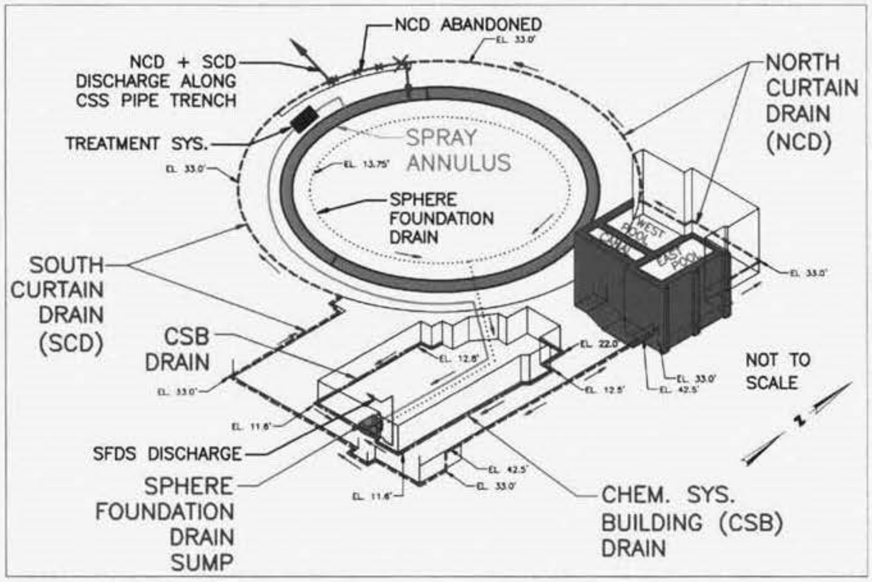
[92] The SFD is constructed at an elevation of 16.5 feet. It is above the bottom of the Sphere (elevation -11 feet) and completely encapsulated in either concrete or grout.

[93] The elimination of hydrostatic uplift pressures allows a "relieved design" to be used for the bottom concrete slabs of the structures. The alternative to a relieved slab design is a "boat slab design." In this case, the slab is heavily reinforced to resist hydrostatic uplift pressures. Boat slabs are more expensive to construct than relieved slabs, and thus are typically only used when it is not feasible to relieve the hydrostatic uplift pressures.

[94] This design modification within the IP1-CB, to allow storage of the footing drain water prior to treatment, was implemented by the former owner once the water was found to contain radionuclides. The initial Unit 1 design connected the two 12-foot perforated footing drain lines into a common 15-inch tee and drain pipe at the entrance to the Nuclear Service Building. This 15-inch footing drain pipe was collocated in the bedrock trench containing the spray annulus to CSS drain line.

[95] The lack of water in the SCD is consistent with the expected impact of the CSB drain given its proximity and lower elevation.

at a yearly average of 10 gpm carrying a Strontium concentration of not detected (ND) to 30 pCi/L.



UNIT 1 FOOTING DRAINS AND DISCHARGE SUMP

Sphere Foundation Drain - The third foundation drain below the IP1-FHB and IP1-CB complex is the SFD. This drain is located directly around the bottom portion of the Sphere and consists of: 1) nine perforated pipe risers spaced around the sphere and tied into a circumferential drain line at elevation 13.75 feet; 2) each vertical riser is surrounded by a graded crushed stone filter; and 3) all of which are within a clean washed sand which encompasses the Sphere from elevation 25 to 16.5 feet (the "sand cushion"). The sand cushion is "sandwiched" between the concrete foundation wall, the Sphere and the grout below the Sphere; it is open at the top, proximate to the annulus. As such, it appears that this drain does not interface with the groundwater, except to the extent that some leakage may occur through imperfections in joint seals. This drain is also connected to the SFDS through a valve.

During the development of the initial Conceptual Site Model, it was understood that the IP1-SFPs were currently leaking, but it was concluded that the footing drainage systems would contain any releases from the IP1-SFPs. This was also the conclusion of a previous analysis performed for the prior owner in 1994[96]. This conclusion was based on:

- The proximity of the drains to IP1-SFPs; in fact, the NCD runs along the North and East walls, and in conjunction with the SCD, completely encompasses the IP1-SFPs;
- The generally downgradient location of the drains relative to the IP1-SFPs;
- The elevation of the drains relative to the bottom of the IP1-SFPs;

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[96] *Assessment of Groundwater Migration Pathways from Unit 1 Spent Fuel Pools at Indian Point Power Plant, Buchanan, NY*; The Whitman Companies, July 1994

- The elevation of the drains relative to the surrounding groundwater elevations[97];
- The continuous flow of the drains, even during dry periods; therefore, the groundwater surface does not drop below, and thus bypass, the drains;
- The reported predominant southerly strike and easterly dip of the bedrock fractures relative to the southerly location of the CSB footing drain; this expected anisotropy should extend the capture zone of this drain preferentially to the North towards the IP1-SFPs; and
- The existence of IP1-SFPs pool water constituents in the drain discharge[98].

In February 2006, Strontium was detected in the downgradient, westerly portion of the IP2-TY (downgradient of IP2-SFP). Given that Strontium could not reasonably be associated with a release from the Unit 2 SFP, the most plausible source remaining was the retired Unit 1 plant where: 1) the SFPs historically contained Strontium at approximately 200,000 pCi/L (prior to enhanced demineralization[99]); and 2) legacy leakage was known to be occurring. Based on this finding, we concluded that either: 1) an unidentified mechanism(s) must be transporting IP1-SFPs leakage beyond the capture zone of the footing drains[100]; or 2) other sources of Strontium existed on the Site. A number of plausible hypotheses potentially explaining each of these two scenarios were therefore developed, and then each was investigated further. During these investigations, additional detections of Strontium were also identified, including some relatively low concentrations in the area of Unit 3. However, with completion of the investigations and associated data analyses, it was concluded that *all of the Strontium detections could be traced back to leakage from the IP1-SFPs.* These Strontium detections can be grouped into five localized flow paths, each associated with a different IP1-SFPs release area. Collectively, these flow paths define the overall Unit 1 "plume[101]" as listed below:

- The primary IP1 flow path;
- The eastern IP1-CB_flow path;
- The southwestern IP1-CB_flow path;
- The IP1-CSS trench flow path; and
- The legacy IP1 storm drain flow path.

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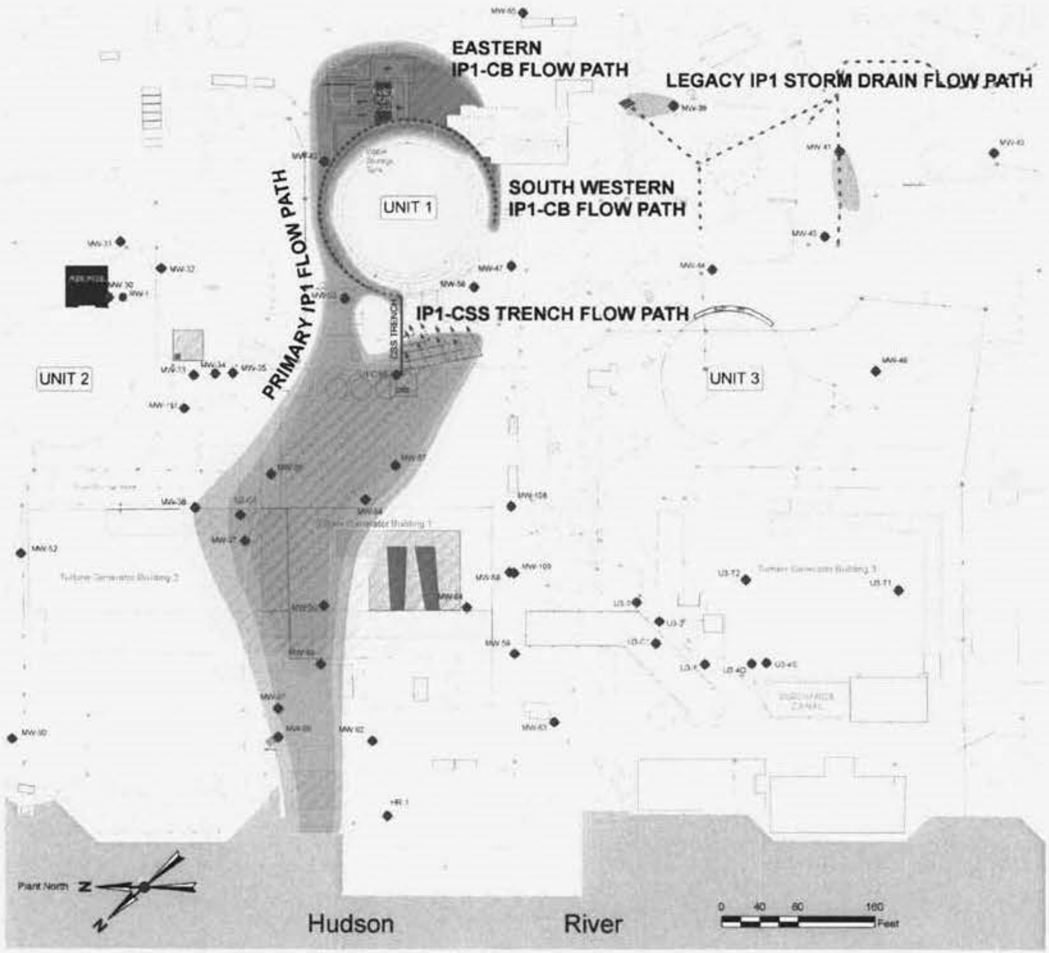
[97] This line of evidence remained supportive of the initial conclusion until the installation of MW-53, which occurred during the third phase of borings (after the discovery of Strontium in the groundwater).

[98] Drain water is treated prior to discharge as permitted monitored effluent.

[99] Strontium levels in IP1-SFPs have been more recently reduced to approximately 3,000 pCi/L under accelerated filtering through demineralization beds. Tritium concentrations in IP1-SFPs are on the order of 250,000 pCi/L.

[100] Once Strontium-contaminated pool leakage enters the groundwater, it is transported in the direction of groundwater flow; Strontium, as well as the other potential radionuclides, do not migrate in directions opposing groundwater flow (with the exception of diffusive flow which is insignificant as compared to advective flow under these hydrological conditions). Therefore leakage entering the groundwater within the capture zone of the footing drains is captured by those drains.

[101] The grouping of Strontium detections into contiguous "plumes" may be an over-simplification, and the detections may, in reality be due to small, isolated individual groundwater entry points and flow paths from the IP1-SFPs. This is likely to be particularly true pursuant to the IP1 Legacy Piping "flow path."



INDIVIDUAL UNIT 1 STRONTIUM FLOW PATH LOCATIONS

The discussions below are focused on the discovery and characterization of these individual flow paths, and the final mechanisms that best explain their existence. Other initially plausible mechanisms were also investigated as part of the Observational Method approach employed[102], but they did not remain plausible in light of the subsequently developed data and analyses, and are therefore not discussed herein. In addition, portions of the discussions below also relate to the concurrent investigation of other potential source areas across the Site. During review of the following sections, it is important to recognize that only small quantities of leakage are required to result in the groundwater plumes observed on the Site.

Primary IP1 Flow Path – Monitoring well MW-42 was initially installed to investigate the premise that contaminants may be leaking into the subsurface from the IP2-Reactor Water Storage Tank (RWST). However, the sample analysis made it clear that IP1-SFPs water was present in the groundwater at MW-42; the radiological profile was consistent with

[102] As indicated above, multiple initially plausible hypotheses potentially explaining the genesis of these flow paths were developed and investigated. These investigations proceeded in a step-wise, iterative manner consistent with the Observational Method, whereby various aspects of the Conceptual Site Model (CSM) were modified to develop an overall CSM that better fit all of the data. Not all mechanisms investigated remained plausible in light of all the data and analyses developed as part of this hypothesis-testing.

Unit 1 fuel pool water (low Tritium, high Strontium and Cesium). While IP1-SFPs leakage was known to be ongoing, this conclusion was *not* consistent with the CSM at the time which was predicated, in part, on containment of IP1-SFPs leakage by the footing drains (North and South curtain Drains, and the Chem. Sys. Building Drain).

An additional monitoring well, MW-53, was subsequently installed downgradient of MW-42 (on the Northwest side of the IP1-CB). Groundwater in this well was also apparently impacted by IP1-SFP water, thus resulting in the initial steps in the identification of the Unit 1 primary Strontium flow path. The groundwater elevations measured in MW-53 proved even more enlightening than the radiological profile. In the case of a *continuously flowing* footing drain such as the NCD, groundwater would generally be expected to be flowing into the drain over the entire length of the drain; the corollary to this conclusion is that the groundwater elevation would be above the drain invert along its entire extent. Otherwise, water flowing into the drain along its eastern, upgradient extent would exfiltrate the drain along its western, downgradient extent and thus, water would no longer discharge out of the end of the drain into the IP1-CB Spray Annulus; it would therefore *not* typically be *continuously flowing.* However, the groundwater elevation in MW-53 was measured at approximately elevation 9 to 10 feet, substantially lower than the water table elevation in MW-42 (35 feet) and the elevation of the NCD invert (33 feet). Therefore, it was found that only a portion of the groundwater which infiltrated the drain to the East was observed as continuous flow at the Spray Annulus collection point. The remainder of the water was exfiltrating along the drain further to the West[103], where groundwater elevations were below the drain invert and thus outside the capture zone of the drain.

Therefore, leakage from the IP1-SFPs was initially being captured by the NCD, but then during transport to the Annulus for collection and treatment, a portion of this leakage was discharging to the groundwater outside the capture zone of the drain. This leakage then migrates downgradient to the West with the groundwater and establishes the Unit 1 primary Strontium flow path.

Eastern IP1-CB Flow Path - A Strontium plume is shown on **Figure 8.2** as existing below the entire IP1-SFPs. With the exception of MW-42, there are no monitoring wells in this area to verify that this plume actually exists. However, it is known that the IP1-SFPs have and continue to leak, and the NCD and CSB footing drains have been shown to contain radionuclides consistent with that expected from IP1-SFPs' leakage. The locations of the specific release points are not known, but could be anywhere along the walls and bottom of the IP1-SFPs.

Once leakage from any of the above postulated points enters the groundwater, it will migrate either to the NCD or the CSB drain, depending on where the specific release point is located relative to these drains. Leakage located along the northeastern portions of the IP1-SFPs is likely to migrate to the NCD (elevation 33 feet), whereas leakage located more to the South and West is more likely to migrate to the lower CSB drain (elevation 22 to

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[103] It is hypothesized that, in the past, the drain likely did not flow continuously. However, over time, the exfiltration rate has been reduced through siltation such that the drain can no longer release water over its western extent as fast as it infiltrates into the drain further to the East.

11.5 feet). These scenarios, when considered for multiple potential release points, should result in Strontium flow paths that are all contained within the plume boundaries shown on the figure.

Southwestern IP1-CB Flow Path - As part of the investigations to identify other potential releases to the groundwater across the Site, low levels of Strontium (less than 3 pCi/L) were detected in monitoring wells MW-47 and MW-56. Groundwater contamination in this area was inconsistent with the known sources and the groundwater flow paths induced by the IP1-CSB footing drains. A summary of the investigations and analyses undertaken to identify the release mechanism responsible for this Strontium flow path follows.

Construction drawings indicate that the IP1-CB and the IP1-FHB were constructed with an inter-building seismic gap and stainless steel plate between the two structures. This construction detail creates a preferential flow path for any pool leakage through the western walls of the IP1-SFPs, as well as leakage from other locations which migrates to the western side of the IP1-SFPs[104]. While this "plate/gap" separates the structures all the way down through the structural foundation slabs, it likely would not have penetrated the mud-mat[105]. In addition, it would not be uncommon for the surface of the mud-mat to *not* be completely cleaned prior to pouring of the structural slab. Even small amounts of soil, mud, dust, etc. between the mud-mat and the structural slab above would result in a preferential flow path along the top of the mud-mat. Therefore, it is expected that pool leakage in this zone (between the structural slab and the mud-mat) could flow laterally and would still be isolated from the fractured bedrock below. It would then, in turn, also be isolated from the influence of the footing drains (both the NCD and the IP1-CSB drain). To the extent that the above hypotheses are correct, this leakage could then build up and flow along the plate and above the top of the mud-mat. With sufficient input of leakage from the pool, the elevation of this flowing water could also rise above the top of the IP1-CB footing[106].

With the above hypothesized conditions, pool leakage may migrate along the plate all the way around the IP1-CB to the South and West until it reaches the end of the plate (at the intersection of the perimeter of the IP1-CB with the IP1-FHB). At that location, the water would follow the top of the mud-mat (and/or top of footing) along the IP1-CB bottom slab further to the West[107]. This leakage flow path is highlighted on **Figure 8.2**. The leakage water would not be constrained to flow into the SCD given that this footing drain is dry. Once past the end of the plate, the pool leakage could enter the bedrock at multiple points, wherever it encounters bedrock fractures. Thereafter, the leakage would enter the groundwater and thus be constrained to migrate in the direction of groundwater flow.

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[104] This hypothesis is further supported by the presence of weeps of contaminated water (SFP leakage) in the eastern wall of the IP1-CB at the footing wall joint.

[105] While not shown on the constructions drawings reviewed "as required", construction photos show that a mud-mat was placed prior to rebar cage construction (also see discussion of rationale under Tritium source areas above). Given the consistent bottom elevations of both the VC and the SFPs structural concrete slabs, a single mud-mat was likely constructed.

[106] Leakage flow above the top of the footing (elevation 33 feet) to the East and Southeast of the VC would not be captured by the SCD given that this drain is dry.

[107] See discussion of likely mud-mat/bedrock excavation wall configuration and the impact of precipitation events in the section above under Tritium source areas.

As shown on the figure, pool leakage entering the groundwater along the South side of the IP1-CB would be expected to mound the groundwater somewhat. This is particularly true in this case given the leakage entry point within the "flat zone" encompassing the groundwater divide between flow to the river to the West and flow to the East to the CSB footing drain[108]. The portion of the pool leakage which flows West would form the southwestern IP1-CB Strontium flow path and thus explain the low levels of Strontium found in MW-47 and MW-56. From this point, the "plume" continues to flow West and joins the primary Strontium flow path.

IP1-CSS Trench Flow Path - During the course of the investigation for potential sources, MW-57 exhibited significant Strontium concentrations. Strontium was also detected in the upgradient IP1-CSS, located in the Unit 1 Superheater Building. This sump was investigated to evaluate the extent to which it may be associated with the contamination identified to the West, near the Discharge Canal. A retired subsurface pipe, designed to drain water from the Unit 1 Spray Annulus to the CSS, was determined to be the input source path for water observed within the sump. During Unit 1 construction, this pipe was installed within a 3-foot-wide trench cut up to 20 feet into bedrock, which slopes downward from the Spray Annulus to the CSS[109]. Construction drawings further indicate that this trench was backfilled with soil. This pipe had been temporarily plugged in the mid-1990's when contaminated water from the NCD was routed to the Spray Annulus. However, the temporary inflatable plug was later found to be leaking and the pipe was then permanently sealed with grout.

As part of our investigations, a monitoring well (U1-CSS) was installed horizontally through the East wall of the CSS at an approximated elevation of 4 feet. This horizontal well is connected to a vertical riser which extends to above the top of the CSS. Water levels in this well typically range from elevation 12 to 18 feet and respond rapidly to precipitation events.

Based upon available data, we believe the IP1-CSS is not a source of contamination to the groundwater. Inspections of the sump indicate the likely entry point for water periodically found in the sump is the pipe from the IP1 Spray Annulus, the joint between the concrete sump wall and the sump ceiling (the floor of the Superheater Building), and/or the joint in the sump wall where the pipe penetrates from the rock trench into the sump. These conclusions are based on:

- The groundwater elevations measured in U1-CSS are above the bottom of the CSS which is generally nearly empty (bottom elevation of 1.0 feet);
- The results of the tracer test confirmed that contaminated groundwater can enter the CSS when it is empty; and
- Visual inspections of the interior of the sump and associated piping.

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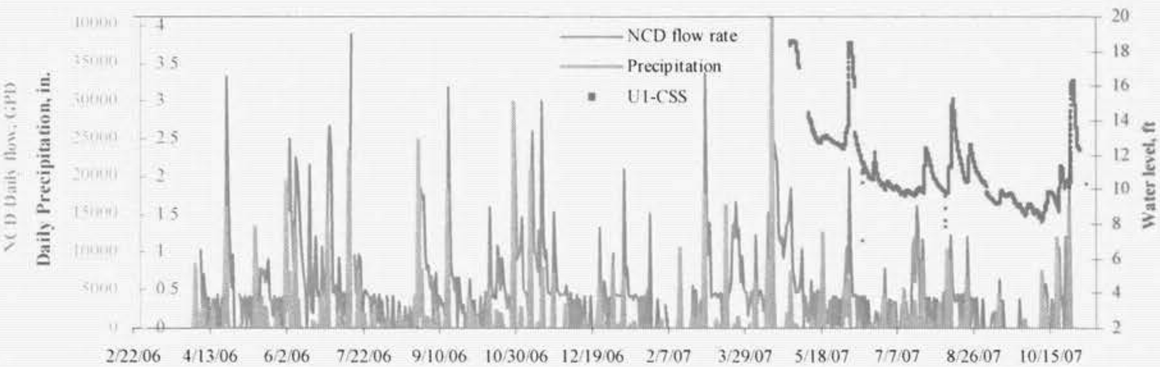
[108] While a groundwater divide must exist between the CSB footing drain and river to the West, the exact location of the divide is unknown.

[109] The trench bottom starts at elevation 22.75 feet at the Spray Annulus and slopes gradually to elevation 21.75 feet at a point 9 feet from the CSS. From this point, the trench slopes steeply to elevation 13 feeet at the CSS.

This sump is no longer in service as the system it supported is retired.

While the CSS itself does not appear to be a release point, we believe the associated bedrock trench between the Spray Annulus and the CSS is a source of contamination to the groundwater. As indicated above, the Spray Annulus is used to store releases collected from the IP1-SFPs by the NCD, which contains contaminants. The Annulus water has been historically documented as leaking into the pipe and surveys indicate that the pipe itself likely leaks into the trench. While the leak into the pipe from the Spray Annulus was sealed, other leakage inputs to the trench also likely exist. One such likely leakage path is for water to flow directly from the NCD through the drain backfill and abandoned piping[110] to the pipe trench. This flow path is supported by the trends in U1-CSS water elevation variation as compared to the NCD discharge rate (see figure included below).



UNIT 1 NCD FLOW, U1-CSS GROUNDWATER ELEVATION AND PRECIPITATION RELATIONSHIPS

These hypothesized leakage paths are highlighted on **Figure 8.2**. Once leakage enters the trench, it should flow along the sloped bottom until it finds bedrock fractures through which to exfiltrate. This leakage will then flow through the unsaturated zone along the strike/dip of the fractures until it encounters the saturated zone, and thereafter will follow groundwater flow.

Because of these hypothesized, but probable conditions, we concluded that leakage has exited the trench and impacted groundwater. Impacts directly to the groundwater below the pipe trench are characterized by Strontium concentrations in monitoring well U1-CSS. In addition, source inputs to the groundwater from the trench are also envisioned to have occurred farther to the South, where the groundwater flow would then carry contamination to MW-57, thus explaining the Strontium concentrations found in that well[111]. While southerly flow in this area is inconsistent with groundwater flow direction, source inputs can migrate from the bedrock trench to the South in the *unsaturated* zone near the

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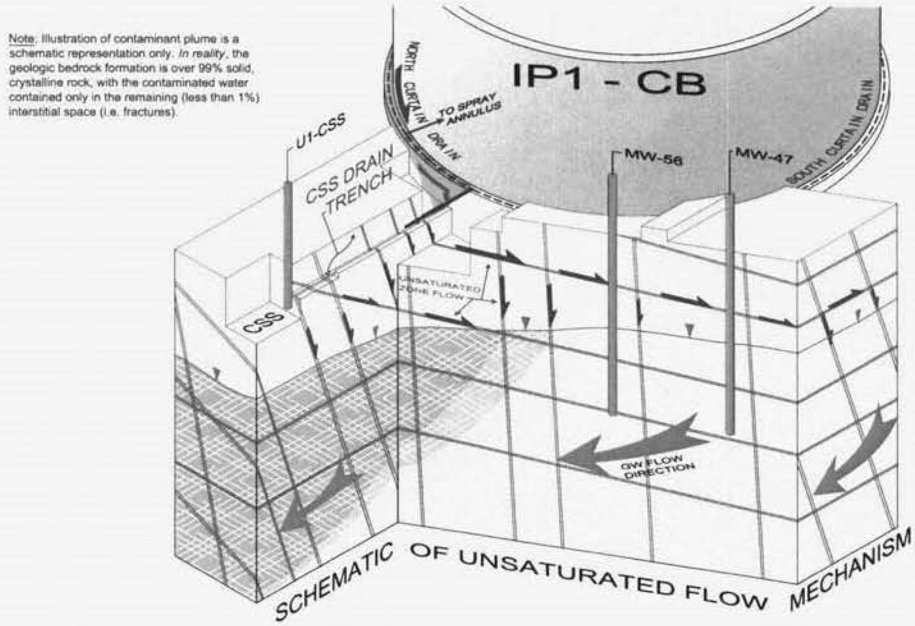
[110] As noted above, the NCD discharge was rerouted into the Spray Annulus when the NCD was found to contain contaminants by the previous owner. Prior to this modification, the footing drain was routed to a 15-inch drain line collocated in the CSS pipe trench. The abandoned piping and permeable backfill still exist and likely act as an anthropogenic preferential flow path.

[111] Monitoring wells U1-CSS and MW-57 do not appear to be in the groundwater flow path of the primary Unit 1 "plume."

CSS, where the unsaturated zone is relatively deep[112]. This hypothesized unsaturated zone flow path is shown on **Figure 8.2,** as well as the schematic included below.



IP1-CSS TRENCH UNSATURATED ZONE FLOW MECHANISM

In addition, the construction details of the Superheater East wall may also channel saturated flow to the South, depending on variation in groundwater elevations. These less direct leakage inputs then establish the southern portion of the source area for the CSS trench flow path such that the groundwater flow carries the "plume" through monitoring well MW-57, thus explaining the Strontium found in samples collected from this well[113].

__**Legacy IP1 Storm Drain Flow Path**__ – As summarized above, the CSB footing drain collects groundwater from the vicinity of the IP1-SFPs; this water has been documented to contain radionuclides. The contaminated water is then conveyed to the SFDS, located at the southern end of the CSB. In addition, historical events, including CSB sump tank overflows in Unit 1, have impacted the SFDS.

Prior to construction of Unit 3, water collected in the SFDS was pumped up to elevation 65 feet and discharged to the stormwater system on the South side of the Unit 1 CSB. The discharge was conveyed by these drains to the South towards catch basin U1-CB-9 (currently under the access ramp to Unit 3), and then West (U1 CB-10) under what is now the IP3-VC toward the Discharge Canal. This pathway was re-routed during construction of Unit 3 in the early 1970s to flow South from catch basin U1-CB-9, then further South towards catch basin U3-CB-A4 and subsequently to the Discharge Canal through the

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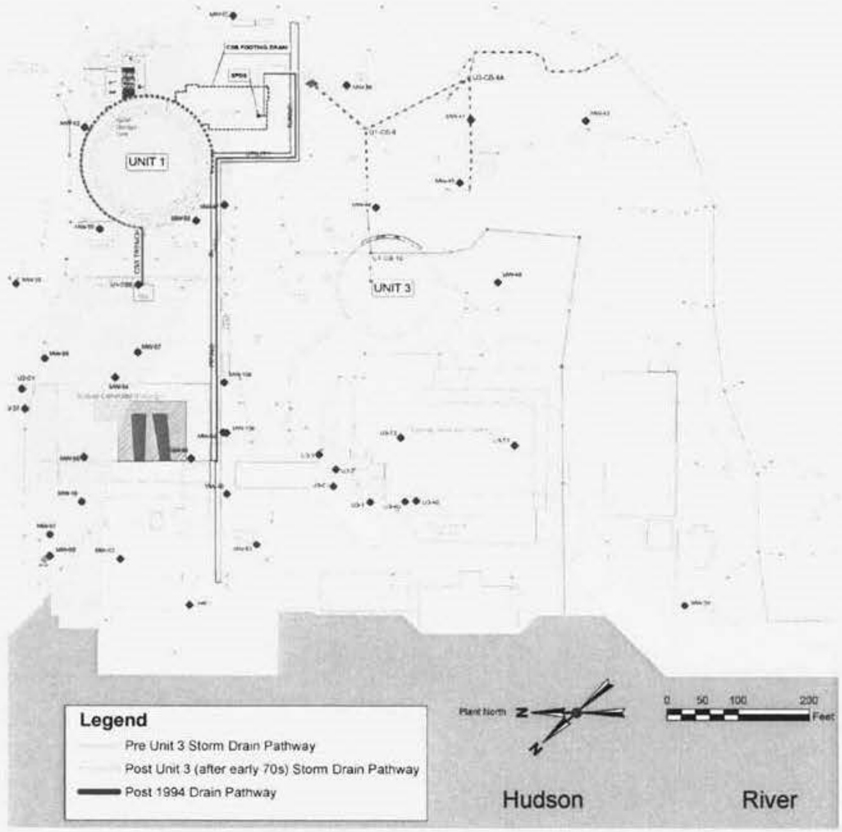
[112] The hypothesized southerly flow of a portion of the trench leakage to the South through the unsaturated zone is consistent with: 1) the strike/dip direction of major joint sets found on Site; and 2) the groundwater flow path from the resulting unsaturated zone input to the wells which identified this Strontium flow path.

[113] This well appears to be located outside, and upgradient of, the primary Unit 1 Strontium flow path to the North.

E-Series storm drains. (See figure included below and **Figure 8.2** where these pathways are also highlighted.)



DIFFERING SPHERE FOUNDATION DRAIN SUMP DISCHARGE PATHWAYS OVER TIME

A recent inspection of the storm drain system, including smoke tests and water flushing, has revealed that a number of pipes along these sections have been compromised and are leaking. Strontium found in groundwater on the South side of the Unit 1 FSB, and upgradient of Unit 3, is coincident with the locations of these stormwater pipes. Therefore, we concluded that some of the contaminated water discharged into these pipes exfiltrated, and then migrated downward through the unsaturated zone and contaminated the groundwater, thus resulting in the "legacy" storm drain flow path[114]shown on **Figure 8.2**.

In 1994, this discharge route was changed again, when contamination was detected in the effluent from the Unit 1 SFDS. The pipe leading from the SFDS towards Unit 3 was capped, and discharges were thereafter routed directly to the Discharge Canal through a series of interior pipes as well as a radiation monitor. As such, the storm drain lines to the

[114] Three discrete isopleths have been drawn around MW-39, MW-41 and MW-43 given the measured concentrations greater than 2 pCi/L. However, it is expected that similar concentrations exist at other locations along the legacy piping alignment in addition to those shown on the figure. During the historic active discharge to the storm drains, it is expected that the individual leak areas would have resulted in commingling of the groundwater contamination into a single "plume" area. This "plume" would have then migrated downgradient across the Unit 3 area. With the cessation of discharge to the storm drains, the "plume" attenuated over time, leaving downgradient remnants which are still detectable as low level Strontium contamination in Unit 3 monitoring wells such as MW-44, 45 & 46, U3-T1 & 2, and U3-2.

South of Unit 1 no longer carry this contaminated water and they are therefore no longer an active source of contamination *to the groundwater*.

However, from a contaminant plume perspective, these historic releases still represent an ongoing legacy source of Strontium *in the groundwater* to the South side of Unit 1. This is because Strontium partitions from the water phase and adsorbs to solid materials, including subsurface soil and bedrock. The Strontium previously adsorbed to these subsurface materials then partitions back to, and continues to contaminate, the groundwater over time, even after the storm drain releases have been terminated.

As shown on **Figure 8.2**, low level residual evidence of this legacy pathway was identified in monitoring wells installed to South of Unit 1 during the course of the investigations proximate to potential sources associated with Unit 3. Strontium, Cesium and Tritium were detected in these wells at levels below the EPA drinking water standard. Three monitoring wells to the South of Unit 1 show "Legacy Storm Drain flow paths" drawn around them. These wells have yielded samples at one time/depth with Strontium concentrations greater than 2 pCi/L, or one-quarter of the Strontium-90 drinking water standard. While the actual extent of these Strontium concentrations is not known given that each has been drawn around a single point, they appear to be limited in extent (based on the data from the surrounding monitoring wells). It is also important to recognize that the specific locations of the historic releases from the storm drain lines are not known. In addition, once water has exfiltrated from the drain line, it moves generally downward in the unsaturated zone as controlled by the strike/dip direction of the specific bedrock fractures encountered. Therefore, legacy groundwater contamination does not have to be located immediately downgradient of the storm drain system (as exemplified by the Strontium found in MW-39 and tracer in MW-42). While three isopleths are shown on **Figure 8.2**, we believe it is possible that other areas in the general vicinity of this piping may exhibit similar groundwater concentrations. We have also concluded that the lower concentrations of Strontium detected in monitoring wells further downgradient, in the Unit 3 area, are also due to these historic, legacy storm drain releases.

9.0 GROUNDWATER CONTAMINATION FATE AND TRANSPORT

Strontium (the Unit 1 plume) and Tritium (the Unit 2 plume) are the radionuclides we used to map the groundwater contamination. The investigation focused on these two contaminants because they describe the relevant plume migration pathways, and the other Site groundwater contaminants are encompassed within these plumes.

While radionuclide contaminants have been detected at various locations on the Site, both the on-Site and off-Site analytical testing, as well as the groundwater elevation data, demonstrate that groundwater contaminants are not flowing off-Site and do not flow to the North, East or South. Groundwater flow and thus contaminant transport is West to the Hudson River via: 1) groundwater discharge directly to the river; 2) groundwater discharge to the cooling water canal, and 3) groundwater infiltration into storm drains, and then to the canal.

The primary source of groundwater Tritium contamination is the IP2-SFP. The resulting Unit 2 plume extends to the West, towards the river, as described in subsequent sections.

The source of the Strontium contamination is the IP1-SFPs. Previous conceptual models, based on information presented in prior reports, indicated that releases from the IP1-SFPs were likely captured through collection of groundwater from the Unit 1 foundation drain systems. However, based upon groundwater sampling and tracer test data, we now know that the Unit 1 foundation drain system, particularly the NCD, is not hydraulically containing *all* groundwater contamination in this area (see **Section 8.0**).

GZA's understanding of the Tritium source and Strontium source are discussed in more detail in **Section 8.0**. The plumes described on the figures in the following subsections are based on: 1) the isopleths bounding the maximum concentrations, as representative of "worst case conditions"[115] (**Figures 8.1** and **8.2**); and 2) the most recent laboratory data collected through August 2007, as representative of current conditions (**Figures 9.1, 9.2, 9.3** and **9.4**). While the figures showing upper bound isopleth concentrations do not show actual conditions, we believe these graphics are useful in developing an understanding of groundwater and radionuclide migration pathways.

In reviewing this section please note the plumes show our current understanding of how anthropogenic features influence groundwater flow patterns, in particular the various footing drains and backfill types used during construction. Also note that flow in the

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[115] It is noted that these figures (**Figures 8.1** and **8.2**) do *not* show actual plumes; the isopleths present contoured upper bound concentrations for samples taken at *any time* and *any depth* at a particular location, rather than a 3-dimensional snapshot of concentrations at a single time. As such, these "plumes" are an overstatement of the contaminant levels existing at any time. It should also be noted that the lightest colored contour interval begins at one-quarter the USEPA drinking water standard. While drinking water standards do not apply to the Site (there are no drinking water wells on or proximate to the Site), they do provide a recognized, and highly conservative benchmark for comparison purposes). Lower, but positive, detections outside the colored contours are shown as colored data blocks. See figure for additional notes.

unsaturated zone plays an important role in both the timing of releases to the water table and in the spreading of contaminants.

Based upon the results of GZA's geostructural analysis, the extent of contaminated groundwater, the 72 hour Pumping Test, the tracer test and tidal response tests, we believe that the bedrock underneath the Site is sufficiently fractured and interconnected to allow the Site to be viewed as a non-homogenous and anisotropic porous media. Based on this finding, and because advection is the controlling transport mechanism, groundwater flow, and consequently contaminant migration in the saturated zone, is nearly perpendicular to groundwater contours on the scale of the Site.

9.1 AREAL EXTENT OF GROUNDWATER CONTAMINATION

Based on measured tracer velocities (4 to 9 feet per day; see **Section 7.4**), the limited distances between release areas and the river (typically less than 400 feet), the age of the plumes (years), and recent interdictions, we believe contaminant plumes have reached their maximum size and are currently decreasing in size. Consequently, our reporting in this section focuses on observed, "current" conditions (the summer of 2007). That is, we saw no need to mathematically predict future conditions.

9.2 DEPTH OF GROUNDWATER CONTAMINATION

Because of the location of Indian Point on the edge of the Hudson River, the width of the river, and the nature of contaminants of potential concern, groundwater flow patterns (and, consequently, contaminant pathways) are relatively shallow. Furthermore, as discussed in **Section 6.0**, the upper portion of the aquifer (typically, the upper 40 feet of the bedrock) has a higher average hydraulic conductivity than the deeper portions of the bedrock. Consequently, the center of mass of the contaminated groundwater is shallow.

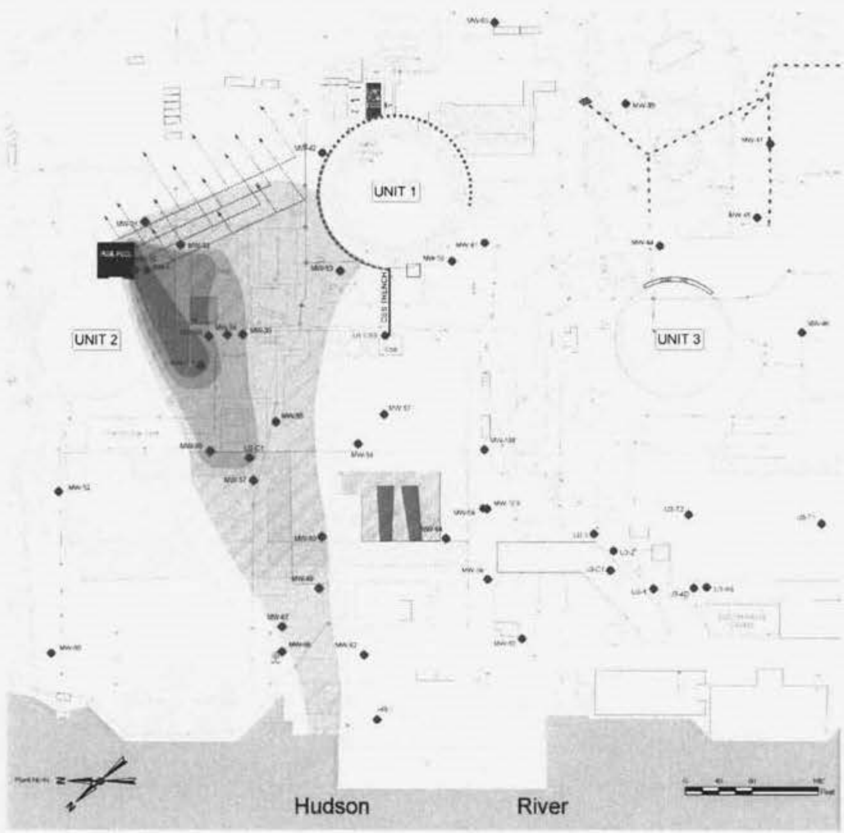
Figures 9.1 and **9.2** are cross sections which show the approximate vertical distribution of Tritium and Strontium, near the center lines of the Unit 1 and Unit 2 plumes, in the summer of 2007 ("current conditions"). In reviewing these figures, note that Strontium was not found below a depth of 105 feet in MW-67. We attribute the low concentrations of Tritium below a depth of 200 feet at this location, at least in part, to the downward migration of Tritium during our investigations. For example, by necessity, well RW-1 was an open wellbore for a period of time[116] which allowed vertical groundwater migration, along an artificial preferred pathway, deeper than would occur along ambient flow paths.

9.3 UNIT 2 TRITIUM PLUME BEHAVIOR

As shown on **Figures 8.1** and **9.3**, the Unit 2 plume exhibits Tritium concentrations originating at the IP2-SFP. The higher concentration isopleths are shown around the entire

[116] RW-1 is located immediately below the 2005 shrinkage crack leak (high Tritium concentrations in shallow groundwater). This well had remained as an open wellbore for periods of time in preparation for and during: 1) the drilling of the wellbore; 2) the packer testing; 3) the geophysical logging; and, 4) the Pumping Test. During these times, vertically downward gradients likely moved some Tritium to levels deeper than it would otherwise exist. When possible, this wellbore has been sealed over its entire length using a Flute Liner System.

pool area so as to include the location of the shrinkage crack leak in the South pool wall, the location of the 1992 leak on the East wall, and the location of the weld imperfection in the North wall of the IP2 Transfer Canal. We believe the core of the plume, as shown, is relatively narrow where Tritium flows downgradient (westerly) to MW-33 and MW-111 in the Transformer yard[117]. This delineation is based on: 1) the degree of connection[118] observed from MW-30 to MW-33 (as compared with that from MW-30 to MW-31 and/or MW-32) as being indicative of a zone of higher hydraulic conductivity limiting lateral dispersion; and 2) the localized increased thickness of the saturated soil in the vicinity of MW-111 (see **Figure 1.3**) which likely behaves as a local groundwater sink/source for westerly bedrock groundwater flow, prior to entering the associated backfill of the Discharge Canal.



BOUNDING UNIT 2 ACTIVITY ISOPLETHS

Tritium has been detected in MW-31 and MW-32, both of which are upgradient of the IP2-SFP. As evidenced by the tracer test (see **Section 7.0**) and hydraulic heads, this

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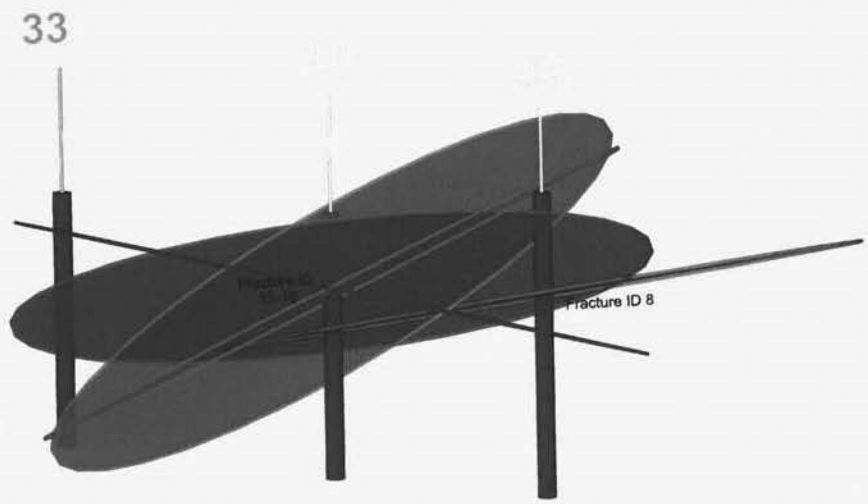
[117] The bedrock in this area was excavated via blasting to allow foundation construction. As such, the upper portions of the bedrock are likely highly fractured in this area. In addition, the pre-construction bedrock contours (see **Figure 1.3**) indicate that the particularly deep depression in the bedrock in the Transformer yard in the vicinity of MW-111 (filled with soil down to elevation 0 feet) was likely excavated to serve as a dewatering sump. The associated deeper blasting-induced fracturing and the saturated soil backfill are also likely to further increase the transmissivity in this area.

[118] The degree of connection is inferred based on both the similar static water levels in MW-30 and -33 (separated by over 100 feet), as contrasted to the much higher water levels in MW-31 and -32 located about 65 feet from MW-30, and the rapid change in water elevation in MW-30 in response to water level perturbations in MW-33 (e.g., during drilling/sampling), with little or no response in MW-31 and -32.

occurrence involves gravity flow along bedrock fractures in the unsaturated portion of the bedrock beneath the IP2-SFP. This unsaturated flow direction is consistent with the dominant foliations (which strike to the Northeast and dip to the Northwest). This behavior is shown on the figure by dashed arrows and the isometric insert (see **Section 8.1**). This mechanism also accounts for some of the Tritium found near Unit 1 and is also supported by the results of the tracer test (see **Section 7.3**). However, once the contaminated water enters the local groundwater flow field, it migrates via advection in a direction generally perpendicular to the groundwater contours (i.e., with the groundwater flow).

In the IP2-TY, the plume is drawn as more dispersive in response to the concentrations measured in MW-34 and -35 as well as the high degree of connection observed between MW-33, -34 and -35 along an orientation transverse to the general groundwater flow direction. See the figure below for a schematic of the three dimensional fracture orientations in this area that account for the observed lateral dispersion. In this general area, the Unit 2 plume is bounded to the South by MW-54 and to the North by MW-52.



Transmissive Fractures in MW-34 and MW-35
at Approximately Elevation 3

3 - DIMENSIONAL BEDROCK FRACTURE ORIENTATIONS

At the western boundary of IP2-TY, Tritium flows into the highly conductive soil backfill found along the eastern wall of the Discharge Canal (see **Figure 1.3**). This conclusion is supported by both the groundwater elevations and Tritium concentrations in MW-36.

The groundwater elevations with depth in MW-36 indicate that once in the Discharge Canal backfill, the groundwater flows downward below the canal wall and, subsequently, into both the Discharge Canal (lower water elevation in the canal) as well as under the canal through the bedrock fractures (see **Section 6.7.2.2** for an estimate of the relative flows to these two discharge locations). Once on the western side of the Discharge Canal, as evidenced by groundwater elevations and Tritium concentrations in MW-37, -49, and

-67, groundwater flow and Tritium migration is to the Hudson River, via both bedrock and unconsolidated material along the riverfront.

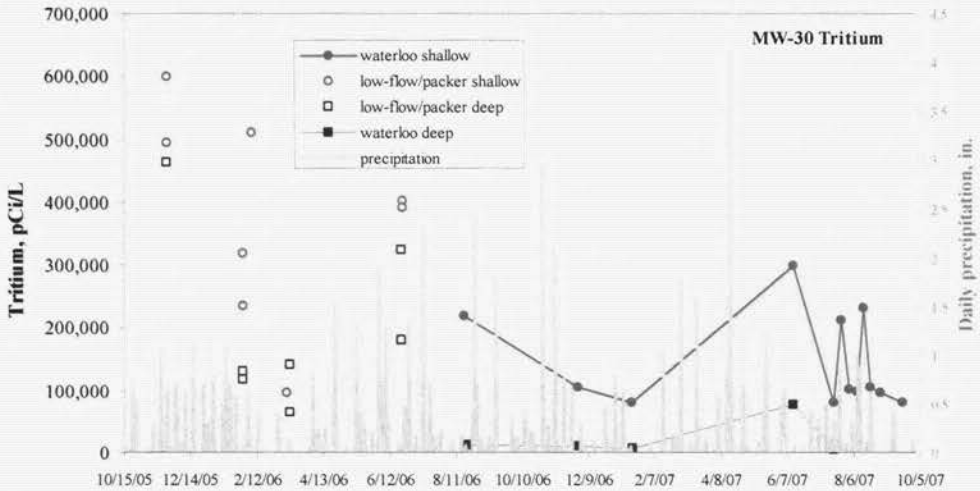
The specific flow path for the Tritium detected in MW-37-22 (located in the fill on the West side of the canal) is not certain. It is however associated with either: 1) upward groundwater flow into the backfill from the bedrock beneath the canal, as supported by the upward vertical hydraulic gradients; 2) groundwater flow into the blast rock fill on the West side of the canal, with northerly flow in the fill to, and around the North end of the canal and then southerly along the East side of the canal to MW-37; and/or 3) exfiltration from the stormwater piping between MH-4 and MH-4A into the fill on the western side of the canal, with a similar flow path as described in 2). See **Section 7.5** for additional information. Regardless of the upstream flow path to MW-37-22, the groundwater flow direction from this location is westerly toward the Hudson River. Also note that the exact pathway to this location does not change the results of the groundwater flux calculations to be used in radiologic dose impact assessments.

Both **Figures 8.1** and **9.3** show a southern component of flow as the Tritium migrates West towards the river. This pathway corresponds with the location of several East-West trending fractures zones and a fault zone. It is likely that this area is characterized by a zone of higher transmissivity that induces the contaminated groundwater to migrate as shown on these figures. We also note that it appears groundwater flow from higher elevations to the North also impedes a more northerly contaminant migration pattern.

9.3.1 Short Term Tritium Fluctuations

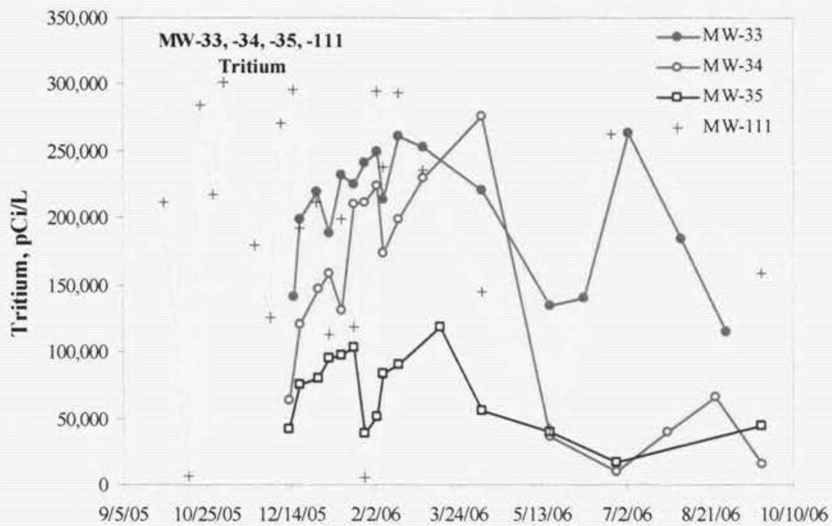
During our investigation, we observed short term fluctuating Tritium concentrations that we cannot reasonably attribute to a continuous release[119] (see **Table 5.1**). These fluctuations make drawing an accurate representation of a plume, on any single date, difficult because any single sample may not be representative of the overall water quality in proximity to the sampling location. In the case of Tritium associated with the IP2-FSB, we believe the fluctuations are associated with temporal variations in the release of Tritium-contaminated groundwater from the unsaturated zone to the water table. That is, we believe the unsaturated zone acts as an intermittent, ongoing source to the groundwater flow regime (see **Section 8.0**). The following graph shows the results of Tritium vs. time in samples collected from MW-30, located adjacent to the IP2-SFP.

[119] In addition, our review of sampling procedures and laboratory methods did not explain the variations observed in samples collected from monitoring well MW-30.



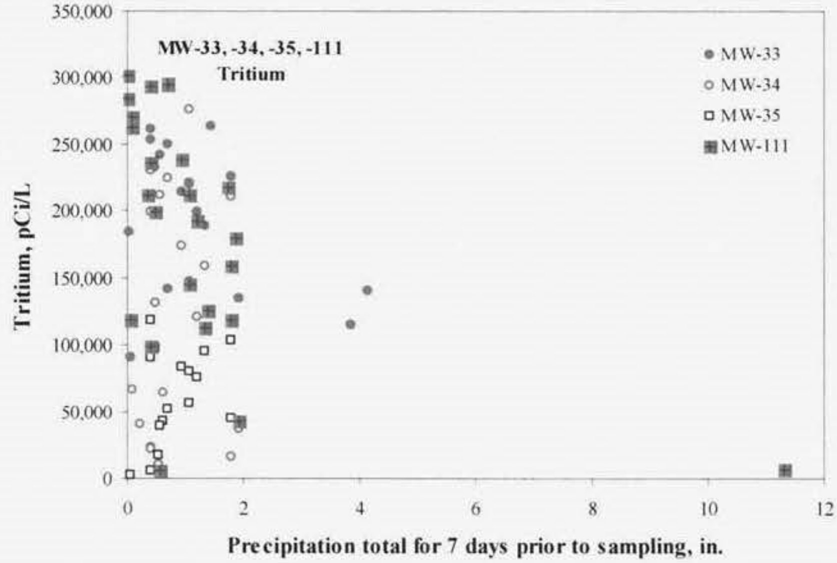
TRITIUM CONCENTRATIONS AND PRECIPITATION VS TIME FOR MW-30

Similar temporal variations in Tritium concentrations are observed in data generated by testing of samples downgradient of IP2-SFP at MW-33-34-35 and -111; see the following figure:



TRITIUM CONCENTRATIONS VS TIME FOR MW-33, -34, -35 AND -111

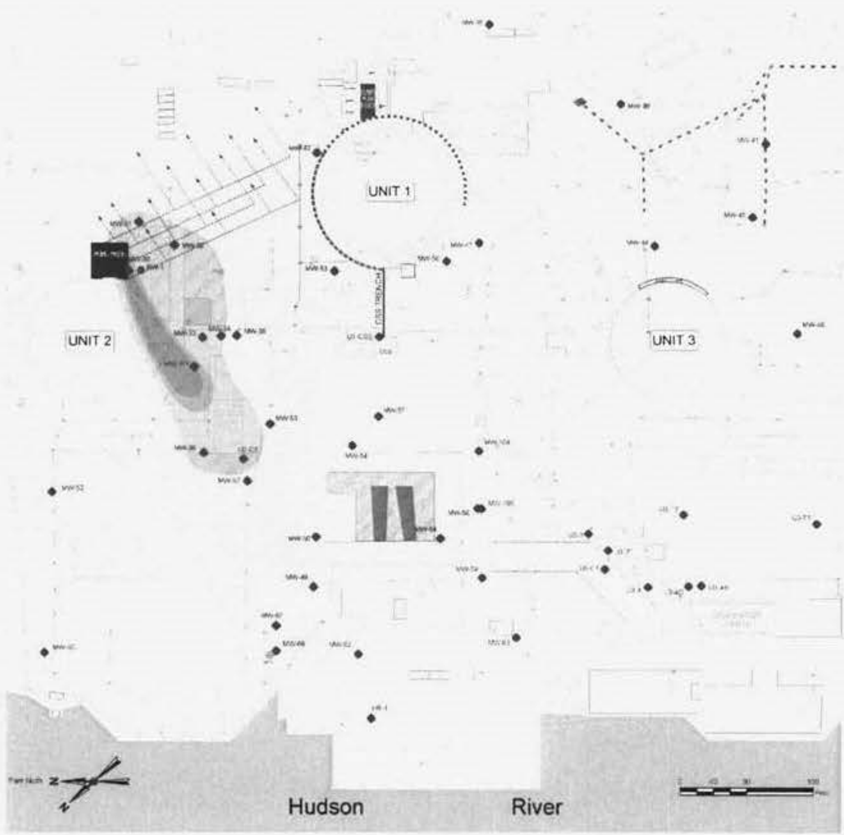
MW-111 is a shallow overburden well completed to a depth of 19 feet below ground surface (bgs). This well is located in a soil-filled bowl-shaped depression within the Transformer yard (see **Figure 1.3**). Consequently, the concentrations of Tritium in samples collected from MW-111 are more sensitive to precipitation (and the likely associated exfiltration from the proximate storm drain) than samples collected from other wells in this area (see above). In particular, note the substantial decrease in Tritium concentration as shown on the following graph, in samples collected after significant precipitation events in October 2005 and May 2006.



TRITIUM CONCENTRATIONS VS PRECIPTIATION

9.3.2 Long Term Variations in Tritium Concentrations

Recognizing the limitations posed by short term fluctuations, we constructed **Figure 9.3**, which shows the lateral extent of Tritium contamination in the late summer of 2007 ("current conditions").



CURRENT UNIT 2 PLUME

Our review of this figure, in conjunction with **Figure 8.1**[120] and **Table 5.1,** reveals the following:

- Despite interdictions, the lateral extent of the two plumes (i.e., the Tritium plume vs. the bounding isopleths) is similar. This indicates storage in the unsaturated zone remains important, and that previous releases did not generate significant groundwater mounding.
- The highest concentrations remain in the area of IP2-SFP. This is consistent with the observed relatively high (4 to 9 feet per day) groundwater transport velocities and an ongoing but smaller release from the unsaturated zone.
- Interdictions made at the IP2-SFP appear to have resulted in measurable reductions in Tritium groundwater concentrations over the entire Unit 2 plume length[121]. The larger reductions in Tritium concentrations are most evident in the source area, closer to the IP2-SFP (see table below).

ANALYSIS OF TRITIUM CONCENTRATIONS OVER TIME

Max. Observe (1) Tritium Concentrations (pCi/L)	Monitoring Well	Current (2) Tritium Concentrations (pCi/L)	Elapsed Time between Max. and Current Concentrations (days)	Current Conc. As Percent of Maximum
601,000	MW-30	92,000	657	15
302,000	MW-111	98,800	629	33
107,000*	RW-1	30,600	3	48
40,600	MW-31	37,700	39	93
44,400	MW-32	14,200	406	32
264,000	MW-33	23,000	390	9
276,000	MW-34	22,200	476	8
119,000	MW-35	5,950	510	5
55,200	MW-36	12,500	494	23
44,800	MW-37	6,680	400	72
3,980	MW-42	1,600	490	40
13,200	MW-53	8,050	346	61
13,100	MW-55	9,910	263	76
10,800	MW-50	4,500	427	42
9,100	MW-66**	9,100	0	100
4,860	MW-67**	4,860	0	100

* Sample obtained during Pumping Test.
** Only one sample analyzed.
(1) Any depth, any date at the indicated location.
(2) Maximum concentration, at any depth, reported during the last project sampling event at the indicated locations.

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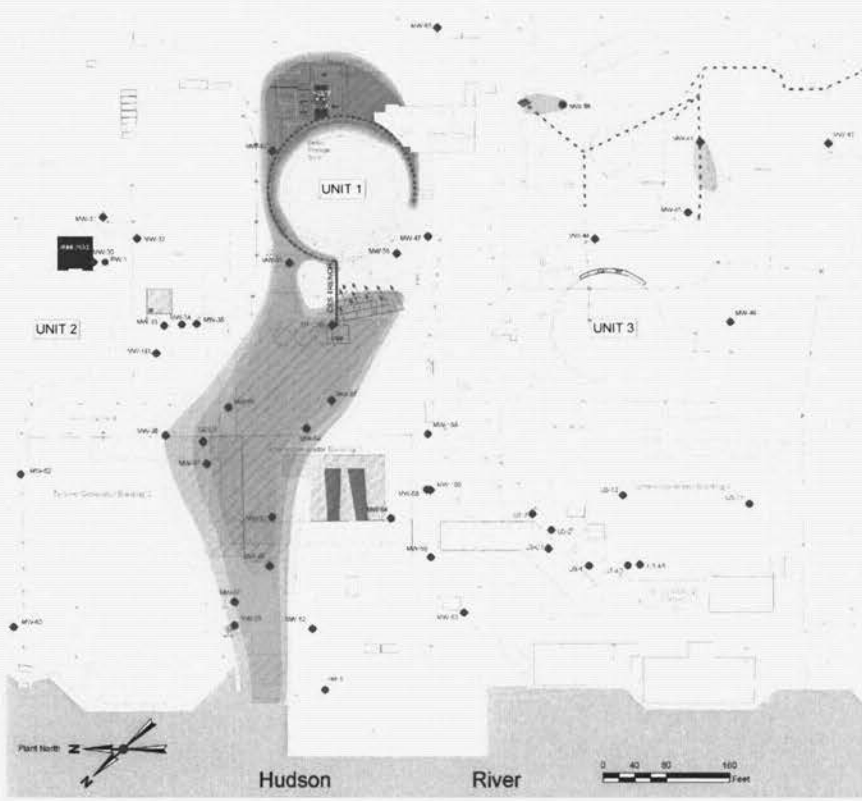
[120] When comparing the Unit 2 (Tritium) plume shown on **Figure 9.3** with the bounding isopleths presented on **Figure 8.1**, the analyses/methods used to develop the bounding isopleths need to be fully considered – please refer to **Section 8.0**.

[121] As based on monitoring well data over the plume length down to and across the Discharge Canal to MW-37, as well as the apparent migration velocity of Tritium in the groundwater observed on-Site. Data from monitoring wells downgradient of MW-37 have not been sampled over a sufficiently long period of time to confirm this conclusion. Further analysis of the plume behavior will be conducted as the Long Term Monitoring Plan data is developed over time.

9.4 UNIT 1 STRONTIUM PLUME BEHAVIOR

Figures 8.2 and **9.4** illustrate the migration paths for Strontium. These flow paths represent Strontium originating from an ongoing legacy leak(s) in the IP1-FHB (see **Section 8.0**). This leak explains the Strontium levels detected in MW-42. This well is located in close proximity to the NCD[122], with the upper screen spanning the elevation of the drain (elevation 33 feet) and the lower screen located approximately 35 feet below the drain elevation. This well exhibits upward vertical gradients from the bedrock into the overburden and the NCD. Therefore, a release through a crack in the Water Storage Pool wall (also forms the wall of the FHB), for example, would flow down through the backfill and into the drain where it would enter groundwater near monitoring well MW-42. However, as described in **Section 8.0**, the NCD is not 100% effective in hydraulically containing leaks from the IP1-SFPs. Contaminated pool water collected along the eastern portion of the NCD is released from the NCD via exfiltration as the groundwater elevations drop below elevation 33 feet towards the West; this is one source mechanism responsible for the Unit 1 Plume.



BOUNDING UNIT 1 ACTIVITY ISOPLETHS

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[122] It is noted that MW-42 is screened in the bedrock slightly North of the drain. As such, it is located hydraulically upgradient of the drain. The drain should therefore form a sink between the potential leaks and the well, thus capturing contaminants from the FHB further South, with the well only encountering groundwater flowing from the North to the South towards the drain (i.e., the well should not sample groundwater in communication with IP1-FHB leaks). However, during rain events, it appears that the groundwater elevations at the drain can increase to a point where the groundwater flow direction is temporarily reversed (flows from the NCD northward past MW-42) due to the high inflows associated with storm drain leaks (storm drains being repaired, and/or taken out of service). This flow reversal can deposit Strontium on fracture surfaces around MW-42, which later enters the well during purging.

The easternmost portion of the overall Unit 1 plume is shown to exist below the entire IP1-SFPs. GZA termed this the eastern Unit 1 CB Flow Path. Strontium-contaminated groundwater in this area will migrate either to the NCD or the CSB drain, depending on where the specific release point is located relative to these drains.

As discussed in **Section 8.0**, the overall Unit 1 plume also extends to the West towards MW-47 and MW-56. GZA termed this the southwestern Unit 1 CB Flow Path. Once the contaminated water enters the groundwater on the South side of Unit 1, it flows either East to the CSB footing drain or to the Northwest towards Hudson River, depending on the hydraulic gradient at the location where the release reaches the water table.

In addition, we believe the bedrock trench that contained the Unit 1 Annulus-to-CSS drain creates a preferential pathway (through the backfill within the bedrock trench), further aiding the transport of Strontium-contaminated groundwater to the West. GZA termed this the Unit 1 CSS Trench Flow Path. Once leakage enters the trench, it should flow along the sloped bottom until it finds bedrock fractures through which it will exfiltrate. This leakage will then flow through the unsaturated zone along the strike/dip of the fractures until it encounters the saturated zone, and thereafter will follow groundwater flow. This pattern is illustrated on **Figure 9.4** by dashed arrows to the West of Unit 1. It results in a spreading of Strontium-contaminated groundwater, which then flows with groundwater to the Hudson River.

Figures 8.2 and **9.4** also show the Strontium contamination related to releases from legacy piping. These historic releases from the drain pipes are currently manifested as sporadic, low level detections of Strontium in groundwater wells (MW-39, -41 and -43) along the legacy piping. Note, as shown, this spatial distribution of contamination is not a result of groundwater contaminant transport to the South; rather it is a result of multiple release points along the piping. In summary, this contamination represents residual contamination which has attenuated and decayed over time, and will not result in further significant migration.

Once outside the drain capture zone, the Strontium migrates West towards the lower groundwater elevations measured in the IP2-TY and along the walls of the Discharge Canal along the southern end of the IP2-TB (MW-36, -55, -37, -49, -50 and -67) (see **Figures 8.2** and **9.4**). A more southerly track is not anticipated because: 1) the higher groundwater elevations measured in MW-58 and -59 just to the South of the IP1 TGB; and 2) the likely existence of low conductivity concrete backfill along the inside of the IP1-TB walls, its subbasement, discharge piping and eastern Discharge Canal wall (as contrasted with the much higher conductivity blast-rock backfill likely used in the IP2-TY and along the outside of the IP1-TGB walls as well as adjacent to the upgradient IP1 structures).

In addition, as discussed in **Section 6.0** and shown on **Figure 6.2**, there are North-South trending faults in the vicinity of MW-49, MW-61, and MW-66, which are characterized by

clay-rich fault gouge[123]. In GZA's opinion (see **Section 6.4.5**), these zones of low hydraulic conductivity limit the southerly extent of contaminated groundwater. In addition, this area is characterized by the two discrete plumes (Tritium and Strontium) commingling and following the same flow path West towards the Hudson River. We attribute this flow pattern to a zone of higher transmissivity located between Units 1 and 2. Also note this area of higher flow is accounted for in our groundwater flux calculations.

The Unit 1 plume in the Transformer yard area is shown as widening due to Strontium concentrations detected in MW-111 and MW-36. This widening may reflect the increased thickness of the saturated zone soil deposits around MW-111, or the presence of high conductivity backfill around the Discharge Canal. This conclusion is supported by the hydraulic heads that indicate groundwater flow to the North along the canal as discussed above pursuant to the Unit 2 plume and the tracer test. West of the Discharge Canal, the Strontium pathways correspond to those described for the Unit 2 plume in **Section 9.3**.

9.4.1 Short Term Strontium Concentrations

As observed with Tritium, it appears that Strontium groundwater concentrations fluctuate, over short durations, more than can be reasonably explained[124] (see **Table 5.1**)by a continuous release at generally constant concentration. We attribute these fluctuations to variations in flows in the IP1-NCD, which are directly influenced by precipitation events (see **Section 8.2**). That is, we postulate that as flows in the drain vary, so do the concentrations and/or volumes of Strontium contaminated water being released.

9.4.2 Long Term Variations in Strontium Groundwater Variations

We used the results of the last sampling event to construct the current Unit 1 plume (see **Figure 9.4** and **Table 5.1**). In reviewing that figure (see below), note the overall configuration is similar to that of the bounded Unit 1 plume (see **Figure 8.2**[125]). The major difference between these plumes is the decrease in concentrations shown in the immediate vicinity of the IP1-SFP[126]. We attribute this decrease in Strontium concentrations to the increased rate of demineralization of the IP1-SFPs water (overall source of the plume).

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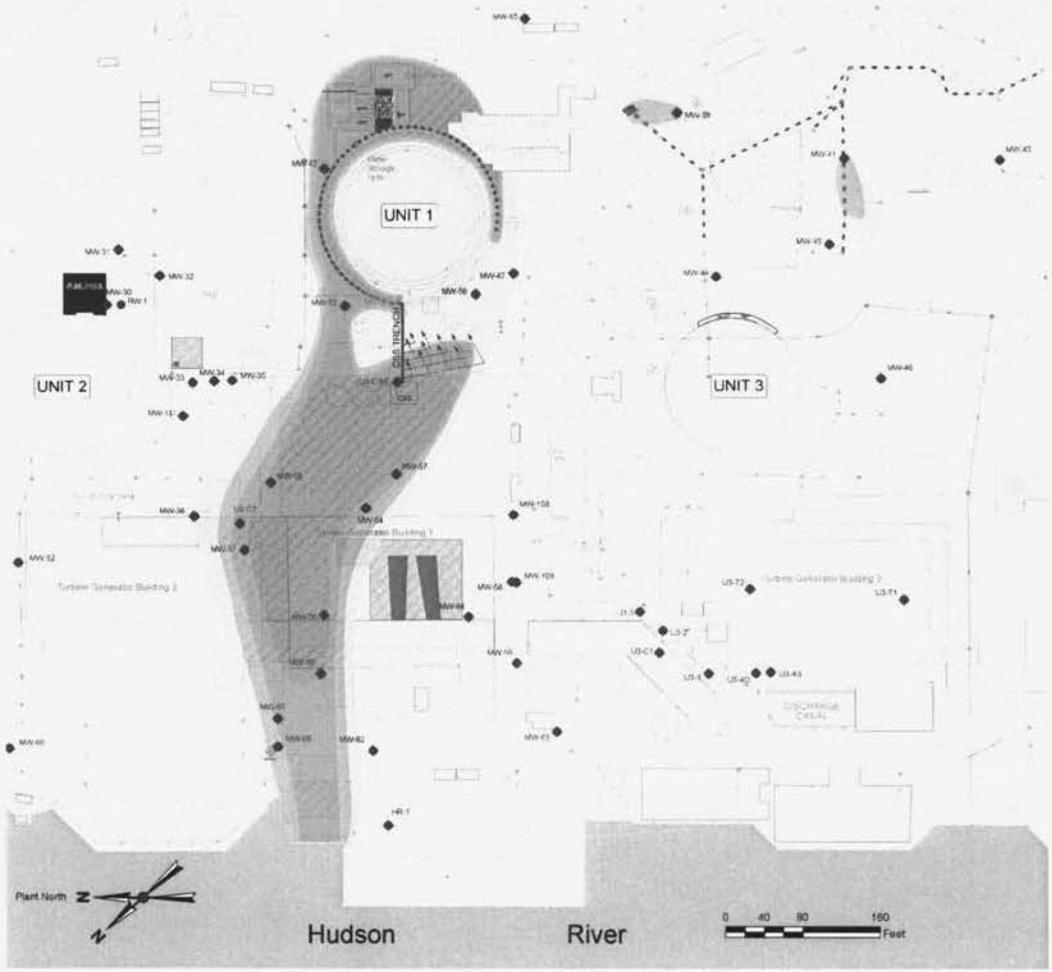
[123] This conclusion has been verified in the areas where the gouge was confirmed with split spoon sampling. See individual boring logs in **Appendix B** for further, more detailed, information.

[124] For example, our review of sampling procedures and laboratory methods did not explain the variations observed in samples collected from monitoring well MW-42.

[125] When comparing the Unit 1 (Strontium) plume shown on **Figure 9.4** with the bounding isopleths presented on **Figure 8.2**, the analyses/methods used to develop the bounding isopleths need to be fully considered – please refer to **Section 8.0**.

[126] It should be noted that the latest data just recently received (well after the report data-cut-off-date of August 31, 2007) for MW-42 shows an increase to 46 pCi/L. This increase, however, still remains within levels consistent with an overall reduction in concentrations in this area, as attributed to accelerated demineralization of the IP1-SFPs.



CURRENT UNIT 1 PLUME

However, because of the timing of the interdictions and, we believe, the slower groundwater transport rates for Strontium, overall the Unit 1 plume has not decayed to the extent the Unit 2 plume has decayed (see **Section 9.4.1**). In fact, due to what we attribute to short term Strontium fluctuations, at six of the well locations within the Unit 1 plume, the highest Strontium groundwater concentrations were observed during the last project sampling event (see the following table for additional detail). In reviewing both figures, note that they show what we believe are conservative estimates of the lateral distribution of the higher (25 pCi/L) Strontium groundwater concentrations.

ANALYSIS OF STRONTIUM CONCENTRATIONS OVER TIME

Max. Observed (1) Strontium Concentration (pCi/L)	Monitoring Well	Current (2) Strontium Concentration (pCi/L)	Elapsed Time between Max. and Current Concentrations (days)	Current Conc. As Percent of Maximum
110	MW-42	20.1	490	18 (3)
37	MW-53*	37	0	100
3.6	MW-47*	3.6	0	100
2.7	MW-56	2.4	332	89
26.8	UI-CSS*	26.8	0	100
21.9	MW-54	19.2	88	88
40.4	MW-55	34.0	263	84
45.5	MW-57	37.9	44	83
5.0	MW-36	2.3	483	46
29.8	MW-37	23.3	40	78
31	MW-50*	31	0	100
25.6	MW-49*	25.6	0	100
19.1	MW-67**	19.1	0	100**
6.2	MW-66**	6.2	0	100

* Current concentration is the maximum concentration of samples analyzed at this monitoring well.

** Only one sample analyzed.

(1) Any depth, any event, at the indicated location.

(2) Any depth, on the date of the last project sampling event, at the indicated location

(3) It should be noted that the latest data just recently received (well after the report data-cut-off-date of August 31, 2007) for MW-42 shows an increase to 46 pCi/L.

10.0 FINDINGS AND CONCLUSIONS

At no time have analyses of existing Site conditions yielded any indication of potential adverse environmental or health risk, as assessed by Entergy as well as the principal regulatory authorities. In fact, radiological assessments have consistently shown that the releases to the environment are a small percentage of regulatory limits, and no threat to public health or safety. In this regard, it is also important to note that the groundwater is not used as a source of drinking water on or near the Site.

Consistent with the purpose of the investigations, we have developed six major supporting conclusions which are described in the following subsections. Based on our findings and conclusions, we are recommending completion of source interdiction measures with Monitored Natural Attenuation as the preferred remedial measure. Refer to **Section 11.0** for more information, including our reasons for making this recommendation.

10.1 NATURE AND EXTENT OF CONTAMINANT MIGRATION

The primary groundwater radiological contaminants of interest are Tritium and Strontium. Other contaminants (Cesium-137, Nickel-63 and Cobalt-60) have been detected, but are limited to areas that have groundwater pathways dominated by Tritium and/or Strontium, and are accounted for in Entergy's dose calculations.

Groundwater contamination is limited to Indian Point's property and is not migrating off-property to the North, East or South. The contamination migrates with the Site groundwater from areas of higher heads to areas of lower heads along paths of least resistance, and ultimately discharges to the Hudson River to the West. This is supported by the bedrock geology, multi-level groundwater elevation data and the radiological results from analytical testing. The nearest drinking water reservoirs are located at distances and elevations which preclude impacts from contaminated groundwater from the Site and there is no nearby use of groundwater.

a. The Site is located over a portion of the aquifer basin where Site-wide ambient groundwater flow patterns, both shallow and deep, have been defined. These flows are towards the Site from higher elevations to the North, East and South. Groundwater flow on Site enters the Hudson River through: footing drains (which discharge to the Discharge Canal); the Discharge Canal; the storm drain system; or direct discharge. The results of over two years of investigations demonstrate that the off-Site groundwater migration to the South, as originally hypothesized by others prior to these investigations, is not occurring.
b. Surface water samples collected from the Algonquin Creek, the Trap Rock Quarry and from the drinking water reservoirs do not exhibit impacts from the Site.
c. The Hudson River is the regional groundwater sink for the area. We found no Site data, published information, or other reasons suggesting that groundwater would migrate beneath the river. To the contrary, based on the area's hydrogeologic setting and all available information, we are confident that groundwater beneath the Site discharges to the river.

d. Because of the hydraulic properties of the bedrock, the bedrock aquifer on-Site will not support large yields, or accept input of large volumes of water.
e. There are no identified off-Site uses of groundwater (extraction or injection) proximate to the Site that influence groundwater flow patterns on the Site. Furthermore, we have no reason to believe that potable or irrigation wells will be installed on or near the Site in the reasonably foreseeable future, in part because municipal water is available in the area.
f. Groundwater flow at the Site occurs in two distinct hydraulic regimes that are vertically connected, bedrock and overburden soils. Most of the groundwater flow and contaminants are found in the bedrock fractures. No evidence of large scale solution features exist in the rock cores obtained from any of the bedrock borings advanced at the Site; i.e., no open voids such as tunnels, caverns, caves, etc., sometimes referred to as "underground rivers," were found. Our on-Site investigatory findings are consistent with that expected for the Inwood Marble. Therefore, this work eliminates from concern solution feature flow associated with karst systems. The second regime is groundwater flow in the unconsolidated soil deposits. This includes groundwater found in native glacial and alluvial deposits, as well as groundwater flow in anthropogenic structures such as blast rock fill and utility trenches. These flow paths, while potentially complicating migration patterns, all terminate at the Hudson River.
g. While groundwater movement in the bedrock is controlled by fracture patterns, the high degree of fracturing allows groundwater flow to be effectively represented and modeled on a Site-wide scale using the well developed techniques derived for porous media[127].

10.2 SOURCES OF CONTAMINATION

The investigations identified two sources of radiological contamination. The IP1-SFPs and the IP2-SFP/Transfer Canal. The IP1-SFPs are the primary source of Strontium groundwater contamination, while the IP2-SFP is the primary source of Tritium groundwater contamination. No evidence of releases from Unit 3 have been identified during this investigation.

During the course of GZA's and Entergy's investigations, we have identified the sources of leakage associated with the IP2-SFP and Transfer Canal. These sources have been eliminated and/or controlled by Entergy. Specifically, Entergy has: 1) confirmed that the damage to the liner associated with the 1992 release was repaired by the prior owner and is no longer leaking; 2) installed a containment system (collection box) at the site of the leakage discovered in 2005, which precludes further release to the groundwater; and 3) identified a weld imperfection in the Transfer Canal liner that, once identified, was prevented from leaking further by draining the Transfer Canal. This weld imperfection was then subsequently repaired by Entergy (completed in mid December 07). Therefore, all identified leaks have been addressed. Water likely remains between the IP2-SFP stainless

[127] While fracture-specific numerical models exist, they are less well developed and less flexible than porous media-based models. The use of a porous media representation requires some level of approximation, particularly on small scales of tens of feet. However, the fracture flow models also require substantial approximations based on fracture statistics and are thus, more problematic at this Site than a porous model.

d. Because of the hydraulic properties of the bedrock, the bedrock aquifer on-Site will not support large yields, or accept input of large volumes of water.
e. There are no identified off-Site uses of groundwater (extraction or injection) proximate to the Site that influence groundwater flow patterns on the Site. Furthermore, we have no reason to believe that potable or irrigation wells will be installed on or near the Site in the reasonably foreseeable future, in part because municipal water is available in the area.
f. Groundwater flow at the Site occurs in two distinct hydraulic regimes that are vertically connected, bedrock and overburden soils. Most of the groundwater flow and contaminants are found in the bedrock fractures. No evidence of large scale solution features exist in the rock cores obtained from any of the bedrock borings advanced at the Site; i.e., no open voids such as tunnels, caverns, caves, etc., sometimes referred to as "underground rivers," were found. Our on-Site investigatory findings are consistent with that expected for the Inwood Marble. Therefore, this work eliminates from concern solution feature flow associated with karst systems. The second regime is groundwater flow in the unconsolidated soil deposits. This includes groundwater found in native glacial and alluvial deposits, as well as groundwater flow in anthropogenic structures such as blast rock fill and utility trenches. These flow paths, while potentially complicating migration patterns, all terminate at the Hudson River.
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[127] While fracture-specific numerical models exist, they are less well developed and less flexible than porous media-based models. The use of a porous media representation requires some level of approximation, particularly on small scales of tens of feet. However, the fracture flow models also require substantial approximations based on fracture statistics and are thus, more problematic at this Site than a porous model.

steel liner and the concrete walls, and thus additional active leaks can not be completely ruled out. However, if they exist at all, the data[128] indicate they must be very small and of little impact to the groundwater.

Our investigations also identified the source of all the Strontium contamination detected in groundwater beneath the Site as coming from the Unit 1 Fuel Pool Complex (IP1-SFPs). The IP1-SFPs were identified by the prior owner as leaking in the mid-1990's. All of the pools have been drained by Entergy except the West Pool, which currently contains the last 160 Unit 1 fuel assemblies remaining from prior plant operations. This plant was retired from service in 1974. Following detection of radionuclides associated with IP1-SFPs in the groundwater, Entergy, as part of their already planned fuel rod removal and complete pool drainage program, accelerated efforts to further reduce activity in the IP1-SFPs through demineralization..

The on-Site tracer test demonstrated that aqueous releases in the vicinity of IP2-SFP are stored *above the water table* in either: 1) unsaturated zone dead-end fractures; and/or 2) anthropogenic foundation details such as blast-rock backfill over a mud-mat (see **Section 8.1.2**). This impacted unsaturated zone water is then periodically released to the groundwater over time as driven, for example, by infiltration of precipitation. Consequently, subsequent releases *to the groundwater* can continue for significant durations after the initial leak has been terminated. In addition, the tracer studies further demonstrate that the migration rates for the Tritium plume *in the groundwater* can be slowed down as compared to the groundwater itself. This reduction in Tritium plume migration velocity occurs when impacted groundwater encounters, and becomes "entrapped" by dead-end fractures, both naturally occurring fractures and those created by excavation blasting during Site construction[129].

The radionuclides identified in the Unit 3 area are related to historic legacy leakage from IP1, and reflect what remains of the plume that has been naturally attenuating since approximately 1994. The pathway to the Unit 3 area was via the IP1-SFDS and then to the storm drain system which transverses along the southeastern portion of the Site; not via groundwater flow to the South (see **Section 8.2**). Exfiltration from this storm drain system had, in turn, resulted in contamination of the groundwater along the storm drain piping. The Sphere Foundation Drain Sump no longer discharges to the storm drain system and this legacy release pathway had therefore been terminated because the associated piping was capped in 1994.

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[128] These data include: monitored water levels in the SFP, with variations accounted for based on refilling and evaporation volumes; the mass of Tritium migrating with groundwater is small; and the age of the water in the interstitial space.

[129] Once contaminants enter dead-end fractures, they no longer migrate with the groundwater flow. However, this "entrapped contamination" does re-enter the flow regime over time due to turbulent flow mixing at the fracture opening as well as diffusion.

10.3 GROUNDWATER CONTAMINANT TRANSPORT

Based on our assessment of the bedrock's hydraulic properties, the area's hydrogeologic setting, the properties of the contaminants, the age of the releases, interdictions made to eliminate or reduce release rates, and the distances between the source areas and the Hudson River, we believe the groundwater contaminant plumes have expanded to their maximum extent and are now decreasing in size. In this regard, the Unit 2 Tritium plume is decreasing faster than the Unit 1 Strontium plume, as anticipated. These conclusions are based on the data available which, given the aggressiveness with which Entergy implemented the investigations, is compressed in duration[130]. Therefore, ultimate confirmation of these conclusions will require monitoring over a number of years to allow ranges in seasonal variation to be adequately reflected in the monitoring data. During long term monitoring, GZA further anticipates that contaminant concentrations in individual monitoring wells will fluctuate over time (increasing at times as well as decreasing, as potentially related to precipitation events), and that a future short term increase in concentrations does *not*, in and of itself, indicate a new leak. In addition, it is also expected that some areas within the plumes will exhibit faster decay rates than others. Both behaviors are commonly observed throughout the industry with groundwater contamination sampling and analyses, and therefore, conclusions pursuant to plume behavior must be evaluated in the context of all of the Site-wide monitoring data. Overall, however, GZA believes that the continuing monitoring will demonstrate decreasing long term trends in groundwater contaminant concentrations over time given the source interdictions completed by Entergy. It is also further emphasized that even the *upper bound* Tritium and Strontium groundwater concentration isopleths presented on **Figures 8.1** and **8.2** result in releases to the river which are only a small percentage of the regulatory limits, which are of no threat to public health.

a. The major groundwater transport mechanism is advection. Sorption retards the migration of radiological contaminants other than Tritium relative to groundwater advection rates, while Tritium, within hydraulically interconnected fractures, can migrate at rates that approach the groundwater seepage velocity.
b. The Unit 2 contaminant plume is characterized by Tritium in the groundwater. Over the last two years, the highest Tritium concentrations in the Unit 2 plume have decreased (see **Table 5.1** and **Figures 8.1** and **9.3**). However, the center of mass of the Unit 2 plume is not rapidly migrating downgradient, and remains in proximity to the IP2-SFP. While a small active leak can not be ruled out completely, this behavior is also consistent with the identified role of unsaturated zone (above the water table) storage of historic releases, with precipitation-induced infusion of this entrapped water into the groundwater regime over time.
c. The Unit 1 contaminant plume is primarily characterized by Strontium concentrations in the groundwater, though near the physical pool area other isotopes are present as expected due to proximity. Over the last two years, the highest Strontium concentrations in the Unit 1 plume have decreased **(Table 5.1)**. These decreases in concentration are consistent with a reduction in Strontium

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[130] It is noted that a number of key monitoring installations have only recently been completed, and monitoring rounds spanning multiple seasons are not yet available.

concentrations in the Unit 1 West Fuel Pool via pool water recirculation through demineralization beds. While the physical leak(s) in this fuel pool still exist, the source term to the groundwater has been reduced through reduction in the contaminant concentrations in the leak water. It is noted, however, the Unit 1 Strontium decreases are more modest and are generally more limited to the immediate source area than that observed for Tritium at Unit 2. The slower rate of plume decay is not unanticipated give the adsorption properties of Strontium. Further planned interdictions include removal of the fuel rods and draining of the pool water, which will permanently eliminate the West Fuel Pool as well as the entire IP1-SFP complex as a source of contamination to the groundwater. With elimination of this source, natural attenuation will reduce Strontium concentrations in the Unit 1 plume over time.

10.4 GROUNDWATER MASS FLUX CALCULATIONS

During the project (over the past two years), as testing progressed and more information became available, we refined methods to calculate the groundwater flux and associated radiological activity to the Hudson River. As described below, we have developed a procedure which is scientifically sound, relatively straight-forward, and appropriately conservative. Groundwater flow rates are provided to Entergy, who computes the radiological dose impact.

a. Migration of radionuclides to the river is computed based on groundwater flow rates, in combination with contaminant concentrations within the flow regime. This information is then used in surface water models to compute radiological contaminant concentrations in the river and thus potential dose to receptors.
b. To assess the validity of the precipitation mass balance method used to date for computing groundwater flux across the Site, GZA also performed groundwater flux computations using an independent method based on Darcy's Law. Thus, the results from two widely accepted groundwater flow calculation methods were compared against each other. The first, the precipitation mass balance method, is a "top-down" procedure based on precipitation-driven water balance analyses. The second, based on Darcy's Law, is a "bottom-up" method using hydraulic conductivity and flow gradient measurements. These two methods resulted in estimated groundwater flow values which were in agreement, providing a high degree of confidence in the values obtained relative to their impact on subsequent dose computations and risk analyses.
c. The original groundwater flux computations were developed for two separate areas of the Site. The northernmost area included both the Unit 2 and Unit 1 plumes. The southernmost area encompassed Unit 3. This bifurcation of the Site was established given: 1) the co-location of the Unit 2 plume and the Unit 1 plume near the western boundary of the Site just upgradient of the river; 2) the much lower contaminant concentrations in the Unit 3 area; and 3) the amount of data available at that time. Current data, derived from a greater number of groundwater elevation and sampling points than reflected in earlier data, show the Site can be divided into six separate areas. The computations were further separated into shallow and deep flow regimes given: 1) the generally higher hydraulic conductivity in the shallow

portion of the bedrock, and 2) the generally more elevated contaminant concentrations in the shallow flow regime.

d. The groundwater contaminant concentrations used for the radiological dose computations were obtained primarily from the analysis of samples taken from the recently completed multi-level wells specifically installed for this purpose. These wells are located downgradient of the Unit 2 and Unit 1 infrastructure[131] and are positioned within the plumes and just upgradient of where the groundwater discharges to the river and Discharge Canal. The multi-level nature of these wells allows the groundwater to be sampled over at least five separate elevations in the bedrock, in addition to the overburden layer above. Sampling zones specifically targeted the most pervious depths within the bedrock boreholes. As such, the groundwater samples encompass the full depth of the contaminant plume, from the upper soil zones to depths where the contaminant concentrations have fallen off to insignificant levels. The high number of samples over the depth of the plume provides a higher degree of confidence that the significant flow zones are accounted for. The high number of vertical sampling zones also provides a higher level of redundancy relative to the longevity and efficacy of the monitoring network over time.

10.5 GROUNDWATER MONITORING

The current groundwater well and footing drain monitoring network is consistent with the objectives of the NEI Groundwater Protection Initiative[132]. Wells have been installed and are currently being monitored to both detect and characterize current and potential future groundwater contaminant migration to the river, as well as, in concert with specific footing drain monitoring, provide earlier detection of potential future leaks associated with the existing infrastructure.

a. The network of 59 monitoring well locations and over 140 sampling intervals/locations, has allowed us to identify groundwater flow patterns. A subset of this network will provide an adequate long term monitoring system.
b. Existing and potential sources have been identified, and monitoring is in place to both evaluate current conditions and identify future releases, should they occur.
c. The nature and extent of contamination is known and reporting requirements are in place.

10.6 COMPLETENESS

Investigations at the Site have been broad, comprehensive, and rigorous. Major components of the field studies include: detailed acquisition of geologic information; automated long duration collection of piezometric data; vigorous source area

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[131] The multi-level sampling network is concentrated in the Unit 2 and Unit 1 areas given that this is where contaminant concentrations are by far the highest. The individual monitoring wells located downgradient of Unit 3 are judged sufficient for computations in this area given the low contaminant concentrations measured, even in the typically more contaminated shallow flow regime.

[132] NEI developed a set of procedures/goals for nuclear plants to assess the potential for releases of radionuclides to potentially migrate off-Site.

identification; comprehensive aquifer property testing, including performance of a full scale Pumping Test; and large-scale confirmatory contaminant transport testing, in the form of an extensive tracer test. The results of this systematic testing program are in agreement with conditions anticipated by our Conceptual Site Model. Based on our review of findings, we have concluded that the field studies conducted at the Site have addressed the study objectives.

a. There is no need to monitor groundwater at off-Site locations. The density and spacing of on-Site monitoring wells is adequate to: 1) demonstrate that contaminated groundwater is migrating to the Hudson River to the West, and not migrating off of the property to the North, East or South; 2) monitor the anticipated attenuation of contaminant concentrations; 3) identify future releases, should they occur; and 4) provide the data required to compute radiological dose impact.
b. Hydraulic conductivity is the most important aquifer property. We have completed more than 245 hydraulic conductivity tests, including a full-scale Pumping Test. Therefore, we believe no future aquifer testing is required. In addition, the contaminant plumes have reached their maximum spatial extent. Therefore, there is no need for contaminant transport modeling.
c. The sources of releases to the groundwater have been identified. In addition to monitoring, actions have been taken to reduce or eliminate these releases. Therefore, we believe no future source characterization is required.
d. All information indicates Monitored Natural Attenuation is the appropriate remedial response and is GZA's recommended approach (see **Section 11.0**). The existing monitoring network will serve this remedial approach. Therefore, no design phase studies are required.

11.0 RECOMMENDATIONS

Based upon the comprehensive groundwater investigation and other work performed by Entergy, GZA recommends the following:

1. Repair the identified Unit 2 Transfer Canal liner weld imperfection (completed mid December 2007);
2. Continue source term reduction in the Unit 1 pool via the installed demineralization system;
3. Remove the remaining Unit 1 fuel and drain the pools; and
4. Implement long term monitoring consistent with monitored natural attenuation, property boundary monitoring, future potential leak identification, and support of ongoing dose assessment.

It is GZA's opinion that our investigations have characterized the hydrogeology and radiochemistry of the groundwater regime at the Site. Therefore, we are not recommending further subsurface investigations (see **Section 10.0**). Based upon the findings and conclusions from these investigations, as well as other salient Site operational information, we recommend the completion of source interdiction measures with Monitored Natural Attenuation (MNA) as the remediation technology at the Site. In no small part, this recommendation is made because of the low potential for risk associated with groundwater plume discharge to the Hudson River.

Monitored Natural Attenuation is defined by the United States Environmental Protection Agency as the reliance on natural attenuation processes (within the context of a carefully controlled and monitored clean up approach) to achieve Site-specific remedial objectives within a time frame that is reasonable compared to other methods. The "natural attenuation processes" that are at work in the remediation approach at this Site include a variety of physical, chemical and radiological processes that act without human intervention to reduce the activity, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater. These primarily include radiological decay, dispersion, and sorption.

MNA is typically used in conjunction with active remediation measures (e.g., source control), or as a follow-up to active remediation measures that have already been implemented. At IPEC, active remedial measures *already implemented* include elimination (e.g., repair of the Unit 2 1990 liner leak and repair of Transfer Canal weld imperfection in mid-December 2007) and/or control (e.g., installation of a collection box to capture moisture from the IP2 shrinkage cracks) of active leaks, and reduction of the source term in the Unit 1 fuel storage pool through demineralization, with subsequent planned removal of the source term (fuel rods) followed by complete draining of the IP1-SFPs.

Remediation

1. Our recommendation of MNA principles includes source term contaminant reduction as an integral part of this remediation strategy. Data demonstrating plume concentration reductions over time, as considered along with other salient

Site information, are consistent with a conclusion that the interdiction efforts to date (both current and in the past) have resulted in: 1) termination of the identified Tritium leaks in the IP2-SFP; 2) identification of an imperfection in a Unit 2 Transfer Canal weld which has been repaired; 3) reduction in IP1-SFP contaminant concentrations; and 4) elimination of Sphere Foundation Drain Sump discharges to the storm drain piping East of Unit 3. As such, these interdictions have resulted in the elimination and/or control of identified sources of contamination to the groundwater, as required:

a. Over the last two years, the highest Tritium concentrations in the Unit 2 plume have decreased. These data are consistent with a conclusion that the leaks responsible for the currently monitored Tritium plume are related primarily to the previously repaired 1992 legacy liner leak and the imperfection in the Transfer Canal weld. With the implemented physical containment of the associated 2005 "concrete wall crack leaks" and the repair of the Transfer Canal liner, the source of contamination to the groundwater has been reduced and controlled.
b. Over the last two years, the highest radionuclide concentrations in the Unit 1 plume have decreased. These decreases are consistent with a reduction in the concentrations in the Unit 1 West Fuel Pool via pool water recirculation through demineralization beds. While the physical leak(s) in this fuel pool still exist, the source term to the groundwater has been reduced due to treatment of the source water. Further planned interdictions include removal of the fuel rods and draining of the pool water, which will permanently eliminate the West Fuel Pool as a source of contamination to the groundwater.
c. The Unit 1 plume in the Unit 3 area has been attributed to a historic legacy discharge from the Sphere Foundation Drain Sump (SFDS) through the storm drain system which traverses along the southeastern portion of the Site. Leaks from this storm drain system have, in turn, resulted in past contamination of the groundwater along the storm drains, with subsequent groundwater migration westward, through Unit 3 toward the river. The SFDS no longer discharges to the storm drain and the Strontium concentrations in the Unit 3 groundwater have decreased to low levels, consistent with natural attenuation processes.

2. GZA selected Monitored Natural Attenuation as the remediation strategy because:

   a. Interdiction measures undertaken and planned to date have, or are expected to, eliminate/control active sources of groundwater contamination.
   b. Groundwater flow at the Site precludes off-Site migration of contaminated groundwater to the North, South or East.
   c. Consistent with the Conceptual Site Model, no contaminants have been detected above regional background in any of the off-Site monitoring locations or drinking water supply systems in the region.
   d. The only on-Site exposure route for the documented contamination is through direct exposure. Because the majority of the Site is capped by

impermeable surfaces, there is no uncontrolled direct contact with contaminants.

e. Our studies indicate that under existing conditions, the spatial extent of the groundwater plume will decrease with time.
f. Groundwater is not used as a source of drinking water on the Site or in the immediate vicinity of the Site, and there is no reason to believe that this practice will change in the foreseeable future.
g. Groundwater associated with the Unit 1 foundation drainage systems is captured and treated to reduce contaminants prior to discharge to the Discharge Canal, consistent with ALARA principles.
h. At the locations where contaminated groundwater discharges to the Hudson River, the concentrations have been, and will continue to be, reduced by sorption, hydrodynamic dispersion and radiological decay. No detections of contaminants associated with plant operations have been found in the Hudson River or biota sampled as part of the required routine environmental sampling.
i. More aggressive technologies would alter groundwater flow patterns and, therefore, in our opinion, offer no clear advantages.

Long Term Monitoring

1. The second primary requirement for implementation of MNA is a demonstration that contaminant migration is consistent with the Conceptual Site Model. In particular, rigorous monitoring is required to demonstrate reductions in source area contamination, reductions in plume contaminant concentrations, and reduction in contaminant discharge to the river over time. The initial implementation stages of this monitoring process were begun nearly two years ago as part of the investigations summarized herein. As outlined above, reductions in maximum groundwater plume contaminant concentrations have already been documented. The elements for long term monitoring, consistent with the objectives of the NEI Groundwater Protection Initiative, are in place. We further note:

   a. Groundwater wells have specifically been installed, and are currently being monitored, to both detect and characterize current and potential future off-Site groundwater contaminant migration to the river. Additional wells have also been installed for monitoring of other Site property boundaries.
   b. Monitoring wells have also been installed just downgradient of identified critical Structures, Systems and Components (SSCs). These wells, in concert with specific footing drain monitoring, provide earlier detection of potential future leaks associated with the power generating units than would be possible with boundary wells alone.
   c. Monitoring wells have been strategically placed to monitor the behavior of the plumes identified on the Site.
   d. MW-38 and MW-48 should be excluded from the monitoring plan as samples from these wells are generally indicative of a mixed groundwater

and Discharge Canal/river water condition and, therefore, are not completely groundwater specific[133].

e. The long term monitoring plan should include action levels, which if exceeded, trigger further analysis and/or investigations, potentially leading to implementation of an interdiction plan, if required.
f. A number of individual vertical sampling zones were included in nearly all the monitoring well installations, particularly within the contaminant plumes and at the location of plume discharge to the river. These individual vertical monitoring zones provide a significant level of vertical resolution and also provide a substantial degree of redundancy relative to the longevity and efficacy of the monitoring network over time[134].
g. While previous and current dose calculations are both reasonable and conservative, we recommend that, with the accumulation of additional Site-specific hydrogeologic information, the calculations be modified to incorporate Site-specific transmissivities and groundwater gradients. Entergy has agreed that Site-specific model information will be utilized in the next NRC required annual assessment of dose from this pathway. Our specific recommendations (which will include additional trend information in early 2008) will be provided under separate cover for Entergy's incorporation to support the annual report.

[133] See **Section 6.6.3** for further discussion pursuant to this conclusion.

[134] The level of redundancy designed into the long term monitoring network anticipates and allows for the loss of a number of monitoring zones without significant impact to the adequacy of the monitoring system.

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-30-69	604885.30	462996.83	77.50	75.66	87.20	51.70	11/11/05	11/19/05	8.4	6.4	4.4
30-71[2]									8.4	4.9	4.4
30-82[2]									-1.6	-6.6	-9.6
30-84									-1.6	-8.1	-9.6
MW-31-49	604924.22	462969.84	77.45	75.64	88.15	75.74	12/20/05	2/14/06	40.8	26.8	26.3
31-63									20.3	12.3	11.8
31-85									5.8	-9.2	-9.7
MW-32-62	604876.03	462953.48	78.90	77.13	200.00	71.40	12/21/05	1/13/06	30.3	15.3	14.8
32-92									-5.2	-15.2	-15.7
32-140									-42.7	-62.7	-63.2
32-165									-69.2	-87.7	-89.2
32-196									-95.2	-119.2	-120.7
MW-33	604767.86	462995.54	18.88	18.62	30.21	12.38	12/12/05	12/14/05		2.9	
MW-34	604755.31	462976.79	18.48	18.07	30.00	14.98	12/8/05	12/13/05		2.0	
MW-35	604744.19	462962.18	18.60	18.44	29.70	10.60	12/6/05	12/20/05		3.6	
MW-36-24	604657.59	463090.60	11.80	11.60	54.00	-12.20	1/24/06	2/1/06	5.2	-4.3	-13.8
36-41				11.75					-20.2	-25.2	-30.2
36-52				11.67					-34.4	-37.9	-41.4
MW-37-22	604604.87	463075.37	15.02	14.85	57.00	-9.98	2/9/06	2/22/06	6.7	-0.8	-8.3
37-32				14.79					-11.8	-14.8	-17.8
37-40				14.96					-22.9	-24.2	-25.4
37-57				14.79					-34.7	-38.2	-41.7
MW-38	603810.21	462505.68	14.34	14.00	40.00	NA	12/1/05		12.0	-6.5	-25.0
MW-39-67	604676.87	462425.51	81.83	79.99	200.00	57.33	2/10/06	2/21/06	15.0	13.0	9.5
39-84									0.5	-3.5	-5.0
39-100[2]									-13.0	-20.0	-23.0
39-102									-13.0	-21.5	-22.0
39-124									-35.0	-44.0	-46.5
39-183									-89.5	-102.5	-106.0
39-195									-113.0	-115.0	-118.5
MW-40-24[2]	603899.35	461950.51	74.95	73.16	200.00	69.95	1/30/06	2/6/06	55.0	49.0	38.0
40-27									55.0	46.5	38.0
40-46									29.0	27.0	19.5
40-81									8.5	-7.5	-11.0
40-100									-20.0	-27.0	-33.5
40-127									-52.0	-54.0	-63.5
40-162									-85.5	-88.5	-117.0
MW-41-13	604531.11	462318.68	54.87	0.00	65.00	40.00	2/23/06	3/2/06	54.7	48.2	41.7
41-40				54.13					35.2	23.2	11.2
41-63				54.13					0.5	-4.5	-9.5
MW-42-49	604857.50	462750.33	69.71	69.42	80.00	44.71	3/16/06	3/22/06	42.7	31.2	19.7
42-78				69.52				3/21/06	2.1	-3.9	-9.9
MW-43-28	604429.78	462192.60	48.76	48.02	65.00	16.30	1/24/06	3/1/06	41.8	29.8	17.8
43-62				47.82				3/1/06	7.4	-5.1	-17.6

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WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-44-67	604516.43	462499.91	93.52	93.02	105.00	62.52	3/10/06	3/15/06	43.5	34.5	25.5
44-102				93.09				3/15/06	18.0	4.0	-10.0
MW-45-42	604471.96	462385.52	53.66	53.20	65.00	38.66	3/22/06	3/29/06	28.3	19.3	10.3
45-61				53.10				3/29/06	2.9	-4.4	-11.6
MW-46	604328.72	462431.26	18.08	16.97	31.50	18.08	2/14/06	2/22/06	0.0	7.6	0.0
MW-47-56	604651.13	462664.08	70.32	69.81	80.00	57.32	3/3/06	2/24/06	39.4	25.9	12.4
47-80				69.74				3/14/06	1.8	-4.2	-10.2
MW-48-23	603473.78	462015.66	15.39	14.76	40.00	-9.60	1/27/06	2/2/06	9.1	-0.4	-9.9
48-37				15.07					-16.4	-20.4	-24.4
MW-49-26	604445.56	463080.21	14.58	14.17	65.00	-8.42	3/16/06	3/17/06	0.4	-5.6	-11.6
49-42	604446.12	463078.45	14.63	14.22				3/20/06	-16.5	-23.5	-30.5
49-65				14.46				3/20/06	-41.0	-46.0	-51.0
MW-50-42	604494.30	463039.18	14.92	14.45	67.00	-7.78	3/13/06	3/13/06	-6.5	-17.5	-28.5
50-66				14.61					-44.1	-47.6	-51.1
MW-51-40	604275.34	461822.43	69.64	67.72	200.00	53.64	3/28/06	3/27/06	38.0	28.0	23.5
51-79									4.5	-11.0	-13.5
51-102[2]									-33.5	-34.5	-43.5
51-104									-33.5	-36.0	-43.5
51-135									-62.5	-67.5	-76.0
51-163									-87.0	-95.0	-98.5
51-189									-116.5	-121.5	-130.0
MW-52-11	604733.05	463253.94	16.77	16.28	12.00	NA[3]	3/21/06	3/21/06	15.3	9.8	4.3
52-18	604733.54	463254.34	16.77	16.37	200.00	3.77			16.3	-2.6	-13.7
52-48									-31.7	-33.1	-39.7
52-64									-42.7	-49.1	-55.2
52-118[2]									-94.2	-102.6	-107.2
52-122									-94.2	-107.1	-107.2
52-162									-138.2	-146.6	-147.7
52-181									-154.7	-166.1	-181.7
MW-53-82	604732.60	462822.15	70.26	69.93	125.00	40.26	6/29/06	6/30/06	10.1	-2.4	-14.9
53-120				70.06					-26.5	-39.5	-52.5
MW-54-35[2]	604554.25	462935.57	14.99	13.09	206.00	-1.81	8/30/06	9/7/06	-15.9	-21.9	-28.9
54-37									-15.9	-23.4	-28.9
54-58									-38.4	-44.4	-50.9
54-123									-102.9	-109.9	-112.9
54-144									-121.9	-130.9	-142.4
54-173									-157.4	-159.4	-168.9
54-190									-171.9	-176.9	-190.4
MW-55-24	604635.96	462996.42	18.25	17.77	77.50	8.75	8/11/06	8/14/06	5.7	-0.8	-7.3
55-35				17.77					-10.2	-14.2	-18.2
55-54				17.77					-24.3	-30.8	-37.3
MW-56-53	604658.09	462708.49	70.26	69.32	88.50	41.26	8/29/06	8/30/06	22.3	17.8	13.3
56-83				69.21					4.0	-5.5	-15.0

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									TOP	CENTER	BOTTOM
MW-57-11	604562.36	462888.55	14.98	14.73	47.00	9.48	7/12/06	7/13/06	11.6	7.1	2.6
57-20				14.75					0.1	-2.9	-5.9
57-45				14.81					-13.8	-22.5	-31.3
MW-58-26	604400.31	462864.26	14.57	14.23	72.00	-0.43	7/12/06	7/13/06	0.0	-7.0	-14.0
58-65				14.14					-33.5	-43.0	-52.5
MW-59-32	604330.15	462912.91	14.52	14.41	77.00	1.52	9/8/06	10/3/06	-5.2	-11.7	-18.2
59-45				13.90					-19.4	-25.9	-32.4
59-68				14.23					-37.1	-46.1	-55.1
MW-60-35	604585.60	463381.26	14.31	12.48	200.00	5.81	10/23/06	10/24/06	-12.4	-22.4	-26.9
60-53									-32.9	-40.9	-46.9
60-55[2]									-32.9	-42.4	-46.9
60-72									-53.9	-59.9	-66.4
60-135									-112.4	-122.4	-128.9
60-154									-134.9	-141.9	-152.4
60-176									-158.4	-163.4	-187.9
MW-62-18			14.69	12.81	38.30	NA	8/17/06	10/5/06	6.7	-1.8	-10.3
62-37									-30.3	-33.5	-36.6
62-52[2]	604350.80	463086.79	14.69	12.82	201.00	-22.31			-36.8	-38.8	-41.3
62-53									-36.8	-40.3	-41.3
62-71									-48.3	-58.3	-69.8
62-92									-75.8	-78.8	-86.3
62-138									-113.3	-125.3	-130.8
62-181[2]									-164.8	-167.8	-185.8
62-182									-164.8	-169.3	-185.8
MW-63-18	604252.14	462968.86	14.18	13.06	35.00	NA	8/17/06	9/22/06	7.1	0.6	-5.9
63-34									-27.1	-30.6	-34.1
63-50	604251.28	462970.42	14.18	12.32	201.00	-17.82			-29.2	-37.2	-45.7
63-91[2]									-69.2	-78.2	-88.2
63-93									-69.2	-80.7	-88.2
63-112									-94.2	-99.2	-99.7
63-121									-105.7	-108.7	-115.2
63-163									-138.2	-150.2	-152.7
63-174									-155.7	-161.7	-178.7
MW-65-48	604851.98	462489.68	69.72	68.86	83.00	34.72	8/21/06	8/23/06	33.9	26.4	18.9
65-80									10.8	-1.7	-14.2
MW-66-21	604408.77	463146.34	14.12	13.41	37.00	-23.48	11/17/06	12/5/06	8.0	0.0	-8.0
66-36									-16.0	-19.5	-23.0
MW-67-39	604426.67	463127.06	14.36	12.51	349.25	-18.64	6/5/07	6/8/07	-15.8	-25.8	-41.3
67-105									-77.3	-92.3	-97.8
67-173									-151.8	-159.8	-175.3
67-219									-196.3	-206.3	-216.8
67-276									-237.8	-262.8	-268.3
67-323									-304.8	-309.8	-317.8
67-340									-322.3	-327.3	-334.8

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-101	Not surveyed		133.86	133.86	15.00	NA	2/7/00	2/7/00	129.9	124.4	118.9
MW-103	Not surveyed		143.44	146.74	26.30	7.00	2/9/00	2/9/00	133.1	125.1	117.1
MW-104	Not surveyed		140.50	140.50	30.00	136.00	2/10/00	2/10/00	131.5	121.0	110.5
MW-105	Not surveyed		135.73	138.51	20.00	NA	2/10/00	2/10/00	131.7	123.7	115.7
MW-107	605014.18	461922.70	140.06	142.76	35.00	NA	2/15/00	2/15/00	126.1	115.6	105.1
MW-108	604454.15	462819.57	14.48	14.23	11.67	NA	2/21/00	2/21/00	12.8	7.8	2.8
MW-109	604396.85	462860.95	14.55	14.25	11.91	NA	2/25/00	2/25/00	12.6	7.6	2.6
MW-110	Not surveyed		134.55	137.72	29.50	126.55	2/25/00	2/25/00	121.1	113.6	106.1
MW-111	604735.19	463023.59	18.93	18.38	16.92	0.90	2/24/00	2/24/00	7.0	4.2	1.5
MW-112	604888.09	461578.48	136.77	36.77	24.00	126.77	2/26/00	2/26/00	128.8	120.8	112.8
RW-1	604879.23	463006.67	77.50	75.82	138.50	51.30	7/28/06	8/1/06			
U3-1	604197.32	462762.55	13.50	13.50	19.00	NA	4/11/96	4/11/96	7.5	1.0	-5.5
U3-2	604262.35	462772.31	14.16	14.11	14.70	NA	Not available [4]		10.5	5.0	-0.5
U3-3	604293.07	462778.30	14.85	14.60	14.70	NA	4/9/96	4/9/96	11.1	5.6	0.1
U3-4D	604167.66	462723.77	14.82	14.52	34.00	-3.78	12/15/97	12/15/97	-10.2	-14.7	-19.2
U3-4S	604158.88	462711.07	14.65	13.94	17.35	-2.65	12/12/97	12/12/97	8.3	2.8	-2.7
U3-T1	604132.98	462555.03	3.27	8.51	1.20	NA	12/12/97	12/12/97	0.0	2.5	0.0
U3-T2	604240.59	462673.84	3.26	8.51	1.60	NA	12/12/97	12/12/97	0.0	2.5	0.0
I-2	605072.45	463218.16	80.92	82.23	40.00	NA	4/8/03	4/8/03	53.8	48.0	42.2
U1-CSS	604631.14	462827.29	15.09	20.07	Not avaialbe [5]						

NOTES:
[shaded box] well screen in unconsolidated deposit {soil backfill/natural soil}
[open box] well screen in consolicated {bedrock}

1. Elevations of sampling ports in waterloo systems or sand packed zone in wells. Low flow sampling locations are given for open rock holes when available.
2. Redundant sampling ports within single sampling zones.
3. Rock surface not encountered.
4. U3-2 is a legacy well installed by Foster Wheeler Env Co. No dates for installation provided.
5. No construction details of U1-CSS were provided to GZA.

TABLE 4.2
WELL NOMENCLATURE
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

ORIGINAL NOMENCLATURE	NEW DESIGNATION
MW-30-74	MW-30-69
MW-30-75	MW-30-71
MW-30-87	MW-30-82
MW-30-88	MW-30-84
MW-31-53	MW-31-49
MW-31-67	MW-31-63
MW-31-89	MW-31-85
MW-36-26	MW-36-24
MW-36-41	MW-36-40
MW-36-53	MW-36-52
MW-37-22	MW-37-22
MW-37-32	MW-37-32
MW-37-40	MW-37-40
MW-37-57	MW-37-57
MW-39-69	MW-39-67
MW-39-85	MW-39-84
MW-39-102	MW-39-100
MW-39-103	MW-39-102
MW-39-126	MW-39-124
MW-39-184	MW-39-183
MW-39-197	MW-39-195
MW-40-26	MW-40-24
MW-40-28	MW-40-27
MW-40-48	MW-40-46
MW-40-82	MW-40-81
MW-40-102	MW-40-100
MW-40-129	MW-40-127
MW-40-163	MW-40-162
MW-41-15	MW-41-13
MW-41-42	MW-41-40
MW-41-64	MW-41-63
MW-42-51	MW-42-49
MW-42-79	MW-42-78
MW-43-28	MW-43-28
MW-43-62	MW-43-62
MW-44-67	MW-44-67
MW-44-104	MW-44-102
MW-45-43	MW-45-42
MW-45-62	MW-45-61

TABLE 4.2
WELL NOMENCLATURE
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

ORIGINAL NOMENCLATURE	NEW DESIGNATION
MW-47-56	MW-47-56
MW-47-80	MW-47-80
MW-48-23	MW-48-23
MW-48-38	MW-48-37
MW-49-25	MW-49-26
MW-49-42	MW-49-42
MW-49-65	MW-49-65
MW-50-42	MW-50-42
MW-50-67	MW-50-66
MW-51-42	MW-51-40
MW-51-81	MW-51-79
MW-51-104	MW-51-102
MW-51-106	MW-51-104
MW-51-137	MW-51-135
MW-51-165	MW-51-163
MW-51-191	MW-51-189
MW-51-42	MW-51-40
MW-51-81	MW-51-79
MW-51-104	MW-51-102
MW-51-106	MW-51-104
MW-51-137	MW-51-135
MW-51-165	MW-51-163
MW-51-191	MW-51-189
MW-52-12	MW-52-11
MW-52-19	MW-52-18
MW-52-50	MW-52-48
MW-52-66	MW-52-64
MW-52-119	MW-52-118
MW-52-124	MW-52-122
MW-52-163	MW-52-162
MW-52-183	MW-52-181
MW-53-80	MW-53-82
MW-53-120	MW-53-120
MW-54-37	MW-54-35
MW-54-38	MW-54-37
MW-54-59	MW-54-58
MW-54-125	MW-54-123
MW-54-146	MW-54-144
MW-54-174	MW-54-173
MW-54-192	MW-54-190

TABLE 4.2
WELL NOMENCLATURE
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

ORIGINAL NOMENCLATURE	NEW DESIGNATION
MW-55-24	MW-55-24
MW-55-35	MW-55-35
MW-55-54	MW-55-54
MW-56-54	MW-56-53
MW-56-85	MW-56-83
MW-57-11	MW-57-11
MW-57-20	MW-57-20
MW-57-45	MW-57-45
MW-58-26	MW-58-26
MW-58-65	MW-58-65
MW-59-31	MW-59-32
MW-59-45	MW-59-45
MW-59-68	MW-59-68
MW-60-37	MW-60-35
MW-60-55	MW-60-53
MW-60-57	MW-60-55
MW-60-74	MW-60-72
MW-60-137	MW-60-135
MW-60-156	MW-60-154
MW-60-178	MW-60-176
MW-62-15	MW-62-18
MW-62-38	MW-62-37
MW-62-54	MW-62-52
MW-62-55	MW-62-53
MW-62-73	MW-62-71
MW-62-94	MW-62-92
MW-62-140	MW-62-138
MW-62-182	MW-62-181
MW-62-184	MW-62-182
MW-63-19	MW-63-18
MW-63-35	MW-63-34
MW-63-51	MW-63-50
MW-63-92	MW-63-91
MW-63-95	MW-63-93
MW-63-113	MW-63-112
MW-63-123	MW-63-121
MW-63-164	MW-63-163
MW-63-176	MW-63-174

NOTES: Names of multi-level wells have been changed to relay approximate (within 1/2 ft) depth to bottom from top of well casing
Names of waterloo sampling intervals have been changed to relay approximate (within 1/2 ft) depth to top of sampling port from top of well casing.
Names of single interval wells have not been changed.

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-30	NS [1]		51.7 [2]			
	Nov 2006	78.470	72.690	5.780	NM [3]	
	Feb 2007	78.057	NS	NS	NM	casing cut (Jan 31, 2007)
	Mar 2007	75.660	NS	NS	NM	2.39' casing cut (Feb 15, 2007)
MW-31	Dec 2005	79.593	NS	NS	NM	
	May 2007	75.641	77.447	-1.806	NM	casing cut for well vault installation (Sept 12, 2006)
MW-32	Dec 2005	78.339	78.939	-0.600	-0.6	
	May 2007	77.126	78.898	-1.772	NM	casing cut for well vault installation (Sept 13, 2006)
MW-33	Dec 2005	18.619	18.879 [4]	-0.260	-0.26	
MW-34	Dec 2005	18.071	18.481 [4]	-0.410	-0.41	
MW-35	Dec 2005	18.444	18.604 [4]	-0.160	-0.16	
MW-36-24	Mar 2006	11.393	NS	NS	-0.33	
	May 2007	11.598	11.799	-0.201	NM	pvc coupling attached for pneumatic slug testing (May 9, 2007)
MW-36-35	Mar 2006	11.604	NS	NS	NM	
	May 2007	11.754	11.799	-0.045	-0.19	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-36-52	Mar 2006	11.492	NS	NS	NM	
	May 2007	11.670	11.799	-0.129	-0.06	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-37-22	Mar 2006	14.784	14.964	NS	-0.18	
	May 2007	14.852	15.021	-0.169	NM	
MW-37-32	Mar 2006	14.725	NS	NS	NM	
	May 2007	14.791	15.021	-0.230	-0.24	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-37-40	Mar 2006	14.790	NS	NS	NM	
	May 2007	14.962	15.021	-0.059	-0.06	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
	June 2007	14.852	15.021	-0.169	NM	pvc coupling removed (June 12, 2007)

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft surveyed	Distance from GS to TOC, ft measured	ALTERATIONS (DATE)
MW-37-57	Mar 2006	14.723	NS	NS	NM	
	May 2007	14.788	15.021	-0.233	-0.25	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-38	Dec 2005	13.990	14.350	NS	-0.36	
	May 2007	13.999	14.342	-0.343	NM	
MW-39	Mar 2006	81.452	81.864	-0.412	NM	
	Jan 2007	79.992	81.827	-1.835	NM	casing cut for well vault installation (Sept 19, 2006)
MW-40	Mar 2006	74.758	74.987	-0.229	NM	
	Jan 2007	73.164	74.948	-1.784	-1.83	casing cut for well vault installation (Nov 8, 2006)
MW-41-13	Apr 2006	NS	54.870	NS	NM	
MW-41-40	Apr 2006	54.130	54.870	-0.740	NM	
MW-41-63	Apr 2006	54.130	54.870	-0.740	NM	
MW-42-49	Apr 2006	69.419	69.714	-0.295	-0.22	
MW-42-78	Apr 2006	69.524	69.714	-0.190	-0.19	
MW-43-28	Mar 2006	48.021	48.761	-0.740	NM	
MW-43-62	Mar 2006	47.821	48.761	-0.940	NM	
MW-44-67	Apr 2006	93.020	93.520	-0.500	NM	
MW-44-102	Apr 2006	92.960	93.520	-0.560	NM	
	NS	93.090	93.520	-0.430	-0.43	pvc coupling attached for pneumatic slug testing (May 7, 2007)
MW-45-42	Apr 2006	53.196	53.662	-0.466	-0.46	
MW-45-61	Apr 2006	53.097	53.662	-0.565	NM	
	NS	53.217	53.662	-0.445	-0.445	pvc coupling attached for pneumatic slug testing (May 7, 2007)
MW-46	Apr 2006	16.970	18.080	-1.110	-1.1	
MW-47-56	Apr 2006	69.805	70.321	-0.516	-0.5	
MW-47-80	Apr 2006	69.742	70.321	-0.579	-0.57	

See Page 6 for Notes

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-48-23	Mar 2006	14.762	15.394	-0.632	-0.63	
	May 2007	14.759	15.387	-0.628	NM	
MW-48-37	Mar 2006	14.765	15.394[5]	-0.629	-0.33	
	May 2007	15.069	15.387	-0.318	NM	
	NS	15.189	15.387	-0.198	-0.198	pvc coupling attached for pneumatic slug testing (May 25, 2007)
MW-49-26	Apr 2006	14.191	14.655	-0.464	-0.42	
	May 2007	14.171	14.582	-0.411	NM	
MW-49-42	Apr 2006	14.133	14.655	-0.522	-0.54	
	May 2007	14.223	14.628	-0.405	NM	pvc coupling attached for pneumatic slug testing (May 9, 2007)
MW-49-65	Apr 2006	14.372	14.655	-0.283	-0.26	
	May 2007	14.457	14.628	-0.171	-0.17	pvc coupling attached for pneumatic slug testing (May 4, 2007)
MW-50-42	Apr 2006	14.432	14.923	-0.491	-0.59	
	May 2007	14.453	14.923	NS	-0.47	pvc coupling attached for pneumatic slug testing (May 7, 2007)
MW-50-66	Apr 2006	14.614	14.923	-0.309	-0.32	
MW-51	Apr 2006	69.340	69.620	-0.280	NM	
	Jan 2007	67.723	69.639	-1.916	-1.83	casing cut for well vault installation (Nov 9, 2006)
MW-52	Apr 2006	16.370	16.766	-0.396	NM	
	NS	14.916	16.766	NS	-1.85	casing cut for well vault installation (Oct 17, 2006)
MW-52-11	Apr 2006	16.283	16.766	-0.483	-1.8	
MW-53-82	Nov 2006	69.930	70.260	-0.330	-0.32	
MW-53-120	Nov 2006	70.060	70.260	-0.200	NM	
	NS	70.190	70.260	NS	-0.13	pvc coupling attached for pneumatic slug testing (Dec 28, 2006)
MW-54	Nov 2006	14.760	14.990	-0.230	NM	
	NS	13.090	14.990	NS	-1.9	casing cut

See Page 6 for Notes

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft surveyed	Distance from GS to TOC, ft measured	ALTERATIONS (DATE)
MW-55-24	Nov 2006	17.670	18.250	-0.580	NM	ground surface measurements taken from top of manhole
	NS	17.770	18.250	NS	-0.48	pvc coupling attached for pneumatic slug testing (Dec 27, 2006)
MW-55-35	Nov 2006	17.670	18.250	-0.580	NM	ground surface measurements taken from top of manhole
	NS	17.770	18.250	NS	-0.48	pvc coupling attached for pneumatic slug testing (Dec 27, 2006)
MW-55-54	Nov 2006	17.680	18.250	-0.570	NM	ground surface measurements taken from top of manhole
	NS	17.770	18.250	NS	-0.48	pvc coupling attached for pneumatic slug testing (Dec 27, 2006)
MW-56	Nov 2006	68.560	70.260	-1.700	-1.76	elevation for 4" well casing prior to pvc riser installation
MW-56-53	Jan 2007	69.322	70.258	-0.936	-0.97	
MW-56-83	Jan 2007	69.207	70.258	-1.051	-1.09	
MW-57-11	Nov 2006	14.630	14.980	-0.350	NM	
	NS	14.730	14.980	NS	-0.25	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-57-20	Nov 2006	14.610	14.980	-0.370	NM	
	NS	14.750	14.980	NS	-0.23	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-57-45	Nov 2006	14.640	14.980	-0.340	NM	
	NS	14.810	14.980	NS	-0.17	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-58-26	Nov 2006	14.230	14.570	-0.340	-0.35	
MW-58-65	Nov 2006	14.140	14.570	-0.430	NM	
	NS	14.250	14.570	NS	-0.32	pvc coupling attached for pneumatic slug testing (Jan 2, 2007)
MW-59-32	Nov 2006	14.310	14.520	-0.210	NM	
	NS	14.410	14.520	NS	-0.11	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-59-45	Nov 2006	13.930	14.520	-0.590	NM	
	NS	13.900	14.520	NS	-0.62	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-59-68	Nov 2006	14.150	14.520	-0.370	NM	
	NS	14.230	14.520	NS	-0.29	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-60	Nov 2006	12.480	14.310	-1.830	-1.85	

See Page 6 for Notes

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-62	Nov 2006	12.820	14.690	-1.870	-1.86	
MW-62-18	NS	12.810	14.690	NS	-1.88	
MW-62-37	NS	12.810	14.690	NS	-1.88	
MW-63	Jan 2007	12.315	14.178	-1.863	-1.85	
MW-63-18	Jan 2007	13.059	14.178	-1.119	-1.16	
MW-63-34	Jan 2007	13.059	14.178	-1.119	-1.16	
MW-65	Nov 2006	69.720	70.260	-0.540	NM	elevation for 4" well casing prior to pvc riser installation
MW-65-48	Jan 2007	68.856	69.723	-0.867	-0.93	
MW-65-80	Jan 2007	68.841	69.723	-0.882	NM	pvc coupling attached for pneumatic slug testing (Dec 28, 2007)
MW-66	Jan 2007	12.155	14.021	-1.866	NM	
MW-66-21	Sept 2007	13.407	14.122	-0.715	NM	
MW-66-36	Sept 2007	13.364	14.122	-0.758	NM	
MW-67	Sept 2007	12.511	14.356	-1.845	NM	
MW-107	Dec 2005	142.757	140.061	2.696	NM	
MW-108	Dec 2005	14.230	NS	NS	-0.25	
MW-109	Dec 2005	14.254	NS	NS	-0.3	
MW-111	Dec 2005	19.385	NS	NS	NM	casing cut approx 1 ft (Mar 20, 2006)
	Nov 2006	18.380	18.930	-0.550	-0.59	casing cut and new manhole installed (Nov 2006)
MW-112	Dec 2005	36.773	NS	NS	NM	
U3-1 [6]	Dec 2005	13.495	NS	NS	NM	
U3-2	Dec 2005	14.114	14.164	NS	-0.05	
U3-3	Dec 2005	14.599	14.849	NS	-0.25	
U3-4D	Dec 2005	14.519	14.819	NS	-0.3	
U3-4S	Dec 2005	13.943	14.653	NS	-0.71	
U3-T1	Mar 2006	8.518	3.267	5.251	5.15	

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TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
U3-T2	Mar 2006	8.512	3.259	5.253	5.15	
I-2	Nov 2006	82.230	80.920	1.310	NM	
HR-1	Apr 2006	18.517	NS	NS	NM	
	May 2007	18.496	14.994	3.502	NM	
OUT-1	Apr 2006	11.910	NS	NS	NM	
	Jan 2007	11.901	8.188	3.713	3.65	
	May 2007	11.891	8.204	3.687	NM	
U3-C1	Jan 2007	18.069	14.981	3.088	NM	
	May 2007	18.060	15.003	3.057	NM	
U2-C1	Apr 2006	15.054	12.054	3.000	3.0	
	May 2007	15.054	12.031	3.023	NM	
RW-1	Nov 2006	81.280	72.690	8.590	NM	
	Feb 2007	76.518	72.738	NS	3.78	casing cut 4.3' (Jan 31, 2007)
	Mar 2007	75.822	NS	NS	NM	casing cut 0.69' (Feb 15, 2007)
U1-CSS	May 2007	20.073	15.088	4.985	5.0	
MH-3	Mar 2006	14.847	NA	NA	NA	
MH-4	Mar 2006	16.949	NA	NA	NA	
MH-4A	Mar 2006	12.707	NA	NA	NA	
MH-5	Nov 2006	18.540	NA	NA	NA	

NOTES: All elevations are above NGVD29.

1. NS: Not Surveyed
2. From Con. Ed. Co. DWG A200002, "Details of excavation"
3. NM: Not Measured
4. Ground surface measurements taken from top of manhole
5. Surveyor error
6. Road box in a sinkhole. Ground surface location is unclear.

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-30	10	5	1.8	8.5	Packered rising slug	Hvorslev[4]
	7	2	1.0	4.8	Packered rising slug	Hvorslev
	3	-1	0.0048	0.02	Packered rising slug	Hvorslev
	-1	-10	0.00071	0.0	Packered rising slug	Hvorslev
MW-31	45	36	0.17	1.4	Packered rising slug	Hvorslev
	37	28	29	250.0	Packered extraction	Unconfined Theis[5]
	29	20	1.7	14.6	Packered rising slug	Hvorslev
	21	12	0.50	4.3	Packered rising slug	Hvorslev
	14	5	0.31	2.7	Packered rising slug	Hvorslev
	6	-3	0.34	2.9	Packered rising slug	Hvorslev
	0	-11	0.20	2.1	Packered rising slug	Hvorslev
MW-32	8	-2	0.016	0.2	Packered rising slug	Hvorslev
	-2	-12	0.31	3.1	Packered rising slug	Hvorslev
	-39	-49	0.30	3.0	Packered rising slug	Hvorslev
	-53	-63	1.0	9.6	Packered rising slug	Hvorslev
	-70	-80	0.41	4.1	Packered rising slug	Hvorslev
	-92	-102	1.1	10.5	Packered rising slug	Hvorslev
	-97	-107	0.15	1.5	Packered rising slug	Hvorslev
	-107	-117	0.36	3.6	Packered rising slug	Hvorslev
MW-33	9	-11	0.55	11.3	Rising slug	Hvorslev
MW-34	9	-12	0.45	9.5	Rising slug	Hvorslev
MW-35	12	-12	0.47	11.0	Rising slug	Hvorslev
MW-36-41	-20	-30	0.24	2.4	Rising slug	Hvorslev
			0.10	1.0	Pneumatic slug	Hvorslev
36-52	-34	-41	0.12	0.8	Rising slug	Hvorslev
			0.095	0.7	Pneumatic slug	Hvorslev
MW-37-32	-12	-18	26	141.7	Rising slug	Hvorslev
37-40	-23	-25	0.0047	0.0	Pneumatic slug	Hvorslev
37-57	-35	-42	2.5	17.4	Rising slug	Hvorslev
			1.1	7.7	Pneumatic slug	Hvorslev
MW-38	12	-25	22	811.0	Specific capacity	Walton[6]
MW-39	23	13	12	122.0	Packered extraction	Unconfined Theis
	12	2	0.6	5.7	Packered rising slug	Hvorslev
	2	-8	1.5	15.0	Packered rising slug	Hvorslev
			2.5	25.0	Packered extraction	Unconfined Theis
	-7	-17	0.51	5.1	Packered rising slug	Hvorslev
	-18	-28	13	128.0	Packered extraction	Unconfined Theis
	-37	-47	2.3	23.0	Packered rising slug	Hvorslev
			2.3	23.0	Packered extraction	Unconfined Theis
	-47	-57	0.016	0.2	Packered rising slug	Hvorslev
	-57	-67	0.067	0.7	Packered rising slug	Hvorslev
	-70	-80	0.019	0.2	Packered rising slug	Hvorslev
	-83	-93	0.0045	0.0	Packered rising slug	Hvorslev
	-93	-103	0.58	5.8	Packered rising slug	Hvorslev
	-103	-113	0.69	6.9	Packered rising slug	Hvorslev

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft²/d	TEST METHOD	METHOD OF ANALYSIS
MW-40	57	47	7.4	74.0	Packered extraction	Unconfined Theis
	47	37	1.1	10.7	Packered rising slug	Hvorslev
	41	31	0.64	6.4	Packered rising slug	Hvorslev
	31	21	0.10	1.0	Packered rising slug	Hvorslev
	23	13	0.088	0.9	Packered rising slug	Hvorslev
	12	2	0.14	1.4	Packered rising slug	Hvorslev
	-5	-15	0.20	2.0	Packered rising slug	Hvorslev
	-20	-30	0.27	2.7	Packered rising slug	Hvorslev
	-52	-62	0.23	2.3	Packered rising slug	Hvorslev
	-71	-81	0.31	3.1	Packered rising slug	Hvorslev
	-85	-95	0.092	0.9	Packered rising slug	Hvorslev
	-103	-113	0.035	0.4	Packered rising slug	Hvorslev
MW-41-40	35	11	0.036	0.9	Rising slug	Hvorslev
41-63	0	-10	22	219.0	Rising slug	Hvorslev
MW-42-49	43	20	0.57	13.0	Extraction	Unconfined Theis
			0.52	12.0	Rising slug	Hvorslev
42-78	2	-10	2.0	23.6	Rising slug	Hvorslev
MW-43-28	42	18	0.45	10.8	Rising slug	Hvorslev
43-62	7	-18	0.16	4.0	Extraction	Unconfined Theis
			0.031	0.8	Rising slug	Hvorslev
MW-44-67	58	25	1.0	10.0	Specific capacity	Walton
44-102	18	-10	0.092	2.6	Pneumatic slug	Hvorslev
MW-45-42	28	10	0.0050	0.1	Extraction	Unconfined Theis
45-61	3	-12	0.20	2.9	Pneumatic slug	Hvorslev
MW-46	12.8	-12.9	0.10	2.6	Rising slug	Hvorslev
MW-47-80	2	-10	1.4	16.4	Rising slug	Hvorslev
MW-48-23	9	-10	4.1	77.0	Specific capacity	Walton
48-37	-16	-24	2.5	20.0	Pneumatic slug	Hvorslev
MW-49-42	-16	-30	6.2	86.8	Pneumatic slug	Hvorslev
49-65	-41	-51	6.2	62.0	Pneumatic slug	Hvorslev
MW-50-42	-6	-28	3.2	70.4	Pneumatic slug	Hvorslev
50-66	-44	-51	0.14	1.0	Specific capacity	Walton
			0.24	1.7	Rising slug	Hvorslev

 See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE[1] EL., ft		K[2] ft/d	T[3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-51	42	-127	0.059	10.0	Specific capacity	Walton
	31	40	0.17	1.6	Packered rising slug	Hvorslev
	20	30	0.39	3.8	Packered rising slug	Hvorslev
	10	19	0.066	0.6	Packered rising slug	Hvorslev
	-5	4	0.073	0.7	Packered rising slug	Hvorslev
	-18	-8	0.075	0.7	Packered rising slug	Hvorslev
	-29	-19	0.22	2.1	Packered rising slug	Hvorslev
	-40	-31	0.16	1.5	Packered rising slug	Hvorslev
	-50	-40	0.38	3.7	Packered rising slug	Hvorslev
	-61	-51	0.036	0.4	Packered rising slug	Hvorslev
	-72	-62	0.082	0.8	Packered rising slug	Hvorslev
	-84	-74	0.052	0.5	Packered rising slug	Hvorslev
	-94	-85	0.075	0.7	Packered rising slug	Hvorslev
	-98	-88	0.15	1.5	Packered rising slug	Hvorslev
	-114	-104	0.14	1.3	Packered rising slug	Hvorslev
	-125	-115	0.19	1.8	Packered rising slug	Hvorslev
MW-52	6	-183	0.011	2.0	Specific capacity	Walton
	4	-5	0.40	3.9	Packered rising slug	Hvorslev
	-2	-11	0.00069	0.0	Packered rising slug	Hvorslev
	-11	-21	0.0010	0.0	Packered rising slug	Hvorslev
	-22	-32	0.0013	0.0	Packered rising slug	Hvorslev
	-33	-43	0.10	1.0	Packered rising slug	Hvorslev
	-43	-53	0.0021	0.0	Packered rising slug	Hvorslev
	-52	-62	0.0018	0.0	Packered rising slug	Hvorslev
	-60	-69	0.025	0.2	Packered rising slug	Hvorslev
	-72	-82	0.15	1.5	Packered rising slug	Hvorslev
	-84	-93	0.16	1.6	Packered rising slug	Hvorslev
	-99	-108	0.13	1.3	Packered rising slug	Hvorslev
	-116	-126	0.084	0.8	Packered rising slug	Hvorslev
	-127	-136	0.13	1.3	Packered rising slug	Hvorslev
	-142	-151	0.14	1.4	Packered rising slug	Hvorslev
	-152	-161	0.064	0.6	Packered rising slug	Hvorslev
	-163	-172	0.031	0.3	Packered rising slug	Hvorslev
MW-53-82	10	-15	0.76	19.0	Extraction	Unconfined Theis
53-120	-30	-50	0.15	3.0	Pneumatic slug	Hvorslev

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-54	-172	-191	1.5	28.1	Packered rising slug	Hvorslev
	-167	-191	1.0	24.0	Packered extraction	Unconfined Theis
	-157	-167	2.5	24.3	Packered rising slug	Hvorslev
			3.1	30.0	Packered extraction	Unconfined Theis
	-142	-152	1.1	10.3	Packered rising slug	Hvorslev
	-131	-141	1.9	18.5	Packered rising slug	Hvorslev
			1.6	16.0	Packered extraction	Unconfined Theis
	-122	-131	2.8	26.3	Packered rising slug	Hvorslev
			1.9	18.0	Packered extraction	Unconfined Theis
	-105	-115	2.5	23.8	Packered rising slug	Hvorslev
			1.3	13.0	Packered extraction	Unconfined Theis
	-96	-105	0.6	5.8	Packered rising slug	Hvorslev
	-86	-96	0.45	4.3	Packered rising slug	Hvorslev
	-69	-78	0.30	2.9	Packered rising slug	Hvorslev
	-59	-69	0.17	1.7	Packered rising slug	Hvorslev
	-49	-59	0.28	2.7	Packered rising slug	Hvorslev
	-40	-49	0.40	3.9	Packered rising slug	Hvorslev
	-30	-40	0.69	6.7	Packered rising slug	Hvorslev
	-20	-30	0.69	6.7	Packered rising slug	Hvorslev
	-9	-19	0.47	4.6	Packered rising slug	Hvorslev
	-6	-9	0.22	0.8	Packered rising slug	Hvorslev
MW-55-24	5.72	-7.28	0.71	9.2	Pneumatic slug	Hvorslev
55-35	-10.18	-18.18	2.5	20.0	Pneumatic slug	Hvorslev
55-54	-24.33	-37.33	3.8	49.1	Pneumatic slug	Hvorslev
MW-56-83	3.987	-15.013	3.9	58.1	Pneumatic slug	Hvorslev
MW-57-11	10	2.6	0.38	2.7	Pneumatic slug	Hvorslev
57-20	0.13	-5.87	3.4	20.5	Pneumatic slug	Hvorslev
57-45	-13.77	-31.27	0.90	15.8	Pneumatic slug	Hvorslev
MW-58-26	0.02	-13.98	0.36	5.0	Extraction	Unconfined Theis
58-65	-33.54	-52.54	1.0	19.0	Pneumatic slug	Hvorslev
MW-59-32	-5.17	-18.17	5.9	77.2	Pneumatic slug	Hvorslev
59-45	-19.35	-32.35	1.9	24.3	Pneumatic slug	Hvorslev
59-68	-37.09	-55.09	0.2	4.2	Pneumatic slug	Hvorslev
MW-60	-174	-188	0.042	0.6	Packered rising slug	Hvorslev
	-158	-168	0.010	0.1	Packered rising slug	Hvorslev
	-147	-157	0.10	0.9	Packered rising slug	Hvorslev
	-137	-147	0.54	5.2	Packered rising slug	Hvorslev
	-121	-130	0.29	2.8	Packered rising slug	Hvorslev
	-101	-111	0.022	0.2	Packered rising slug	Hvorslev
	-85	-95	0.12	1.2	Packered rising slug	Hvorslev
	-74	-84	0.27	2.6	Packered rising slug	Hvorslev
	-55	-64	0.40	3.9	Packered rising slug	Hvorslev
	-36	-46	0.83	8.1	Packered rising slug	Hvorslev
	-20	-30	0.064	0.6	Packered rising slug	Hvorslev
	1	-15	0.00066	0.0	Packered rising slug	Hvorslev

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft²/d	TEST METHOD	METHOD OF ANALYSIS
MW-62	-172	-186	0.37	5.2	Packered rising slug	Hvorslev
	-162	-172	0.72	7.0	Packered rising slug	Hvorslev
	-154	-163	0.34	3.3	Packered rising slug	Hvorslev
	-143	-153	0.042	0.4	Packered rising slug	Hvorslev
	-133	-142	0.091	0.9	Packered rising slug	Hvorslev
	-120	-130	0.24	2.3	Packered rising slug	Hvorslev
	-102	-112	0.22	2.2	Packered rising slug	Hvorslev
	-92	-102	0.076	0.7	Packered rising slug	Hvorslev
	-83	-92	0.060	0.6	Packered rising slug	Hvorslev
	-66	-76	0.050	0.5	Packered rising slug	Hvorslev
	-48	-58	0.0080	0.1	Packered rising slug	Hvorslev
	-37	-47	0.0072	0.1	Packered rising slug	Hvorslev
62-37	-30	-37	3.0	18.0	Pneumatic slug	Hvorslev
MW-63	-172	-187	1.4	21.5	Packered rising slug	Hvorslev
	-151	-161	0.39	3.8	Packered rising slug	Hvorslev
	-141	-151	0.46	4.5	Packered rising slug	Hvorslev
	-131	-141	0.044	0.4	Packered rising slug	Hvorslev
	-109	-119	0.30	2.9	Packered rising slug	Hvorslev
	-96	-106	1.0	9.7	Packered rising slug	Hvorslev
	-86	-96	0.090	0.9	Packered rising slug	Hvorslev
	-74	-84	1.1	10.7	Packered rising slug	Hvorslev
	-64	-74	1.9	17.9	Packered rising slug	Hvorslev
	-57	-67	0.43	4.2	Packered rising slug	Hvorslev
	-47	-56	0.29	2.8	Packered rising slug	Hvorslev
	-36	-46	0.87	8.4	Packered rising slug	Hvorslev
	-22	-36	0.80	11.2	Packered rising slug	Hvorslev
			6.9	96.0	Packered extraction	Unconfined Theis
63-34	-27	-34	48	336.0	Pneumatic slug	Hvorslev
MW-65-48	34	19	0.27	4.0	Extraction	Unconfined Theis
65-80	11	-14	0.39	9.8	Pneumatic slug	Hvorslev
MW-66	-168	-186	0.42	7.6	Packered rising slug	Hvorslev
	-158	-168	0.21	2.0	Packered rising slug	Hvorslev
	-148	-158	0.17	1.6	Packered rising slug	Hvorslev
	-138	-148	0.14	1.4	Packered rising slug	Hvorslev
	-128	-138	0.07	0.7	Packered rising slug	Hvorslev
	-117	-127	1.4	14.0	Packered extraction	Unconfined Theis
	-95	-105	1.5	14.3	Packered rising slug	Hvorslev
	-83	-93	0.050	0.5	Packered rising slug	Hvorslev
	-70	-80	0.18	1.7	Packered rising slug	Hvorslev
	-49	-59	0.040	0.4	Packered rising slug	Hvorslev
	-29	-39	0.090	0.9	Packered rising slug	Hvorslev
	-24	-38	6.5	90.9	Packered extraction	Unconfined Theis

 See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-67	-317	-335	1.1	20.0	Packered rising slug	Hvorslev
			1.3	24.6	Packered extraction recovery	Hvorslev
	-305	-335	1.0	28.9	Packered rising slug	Hvorslev
			0.77	23.2	Packered extraction recovery	Hvorslev
	-301	-316	0.74	11.0	Packered rising slug	Hvorslev
			0.66	9.8	Packered extraction recovery	Hvorslev
	-294	-309	0.25	3.7	Packered extraction recovery	Hvorslev
	-282	-297	0.87	12.9	Packered extraction recovery	Hvorslev
	-270	-285	0.41	6.1	Packered extraction recovery	Hvorslev
	-243	-258	3.4	49.6	Packered extraction recovery	Hvorslev
	-235	-250	2.1	31.1	Packered extraction recovery	Hvorslev
	-219	-234	0.45	6.7	Packered rising slug	Hvorslev
			0.45	6.7	Packered extraction recovery	Hvorslev
	-202	-217	0.91	13.5	Packered rising slug	Hvorslev
			1.0	14.5	Packered extraction recovery	Hvorslev
	-186	-201	0.29	4.3	Packered rising slug	Hvorslev
			0.29	4.3	Packered extraction recovery	Hvorslev
	-156	-171	0.16	2.3	Packered rising slug	Hvorslev
			0.15	2.2	Packered extraction recovery	Hvorslev
	-138	-153	0.14	2.0	Packered rising slug	Hvorslev
			0.12	1.8	Packered extraction recovery	Hvorslev
	-119	-133	0.16	2.4	Packered rising slug	Hvorslev
			0.53	7.8	Packered extraction recovery	Hvorslev
	-115	-130	0.22	3.3	Packered rising slug	Hvorslev
			0.21	3.1	Packered extraction recovery	Hvorslev
	-115	-130	0.34	5.0	Packered extraction recovery	Hvorslev
	-104	-119	0.20	3.0	Packered extraction recovery	Hvorslev
	-86	-100	0.82	12.1	Packered rising slug	Hvorslev
			1.0	14.2	Packered extraction recovery	Hvorslev
	-71	-86	0.27	4.0	Packered rising slug	Hvorslev
			0.27	4.0	Packered extraction recovery	Hvorslev
	-58	-72	0.049	0.7	Packered extraction recovery	Hvorslev
	-42	-56	0.022	0.3	Packered extraction recovery	Hvorslev
	-32	-47	0.045	0.7	Packered extraction recovery	Hvorslev
	-25	-40	0.93	13.8	Packered rising slug	Hvorslev
	-18	-33	1.1	17.0	Packered rising slug	Hvorslev
MW-109	6	2	76	301.0	Specific capacity	Cooper-Jacob[7]
MW-111	5	0	3.5	19.3	Rising slug	Hvorslev
U3-3	6	0	2.5	15.0	Extraction	Unconfined Theis
U3-4D	-10	-19	0.44	4.0	Specific capacity	Walton

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
U3-4S	5	-3	39	333.0	Extraction	Unconfined Theis
I-2	54	42	0.08	0.9	Rising slug	Hvorslev

NOTES: [shaded box] well screen in unconsolidated deposit {soil backfill/natural soil}
[unshaded box] well screen in consolicated {bedrock}

All elevations are above NGVD29.

1. Submerged parts of sand packed zones in wells. Packered or submerged zones for open rock holes.
2. Hydraulic conductivity
3. Transmissivity. Calculated by multiplying K with test zone interval.
4. Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50.
5. Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.
6. Walton, W. C., 1970. Groundwater resource evaluation: New York, McGraw-Hill.
7. Cooper, H.H. and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans.

TABLE 4.5
TRANSDUCER INFORMATION
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	DIAPHRAGM DEPTH ft below toc	DIAPHRAGM EL. ft msl	TRANSDUCER MAKE	PRESSURE RANGE psi	ACCURACY % full scale	ACCURACY ft H_2O[1]
MW-30-69	68.8	6.9	Geokon	10	0.10	0.023
MW-30-71	70.3	5.4	Geokon	10	0.10	0.023
MW-30-82	81.8	-6.1	Geokon	10	0.10	0.023
MW-30-84	83.3	-7.6	Geokon	10	0.10	0.023
MW-31-49	48.3	27.3	Geokon	10	0.10	0.023
MW-31-63	63.0	12.6	Geokon	50	0.10	0.115
MW-31-85	84.5	-8.9	Geokon	50	0.10	0.115
MW-32-62[2]	59.5	17.6	Geokon	10	0.10	0.023
MW-32-92[2]	90.2	-13.1	Geokon	50	0.10	0.115
MW-32-140[2]	137.7	-60.6	Geokon	50	0.10	0.115
MW-32-165[2]	162.7	-85.6	Geokon	50	0.10	0.115
MW-32-196[2]	194.5	-117.4	Geokon	100	0.10	0.231
MW-32-48[3]	48.0	29.1	Geokon	50	0.10	0.115
MW-32-59[3]	58.0	19.1	Geokon	50	0.10	0.115
MW-32-85[3]	85.0	-7.9	Geokon	50	0.10	0.115
MW-32-131[3]	130.5	-53.4	Geokon	50	0.10	0.115
MW-32-149[3]	149.0	-71.9	Geokon	50	0.10	0.115
MW-32-173[3]	172.5	-95.4	Geokon	100	0.10	0.231
MW-32-190[3]	190.0	-112.9	Geokon	100	0.10	0.231
MW-33	variable[4]		In-Situ MiniTroll	30	0.10	0.069
MW-34	variable		In-Situ MiniTroll	30	0.10	0.069
MW-35	variable		In-Situ MiniTroll	30	0.10	0.069
MW-36-24	variable		In-Situ MiniTroll	30	0.10	0.069
MW-36-41	variable		In-Situ MiniTroll	30	0.10	0.069
MW-36-52	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-22	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-32	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-40	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-57	variable		In-Situ MiniTroll	30	0.10	0.069
MW-38	variable		In-Situ MiniTroll	30	0.10	0.069
MW-39-67	66.7	13.3	Geokon	50	0.10	0.115
MW-39-84	83.0	-3.0	Geokon	25	0.10	0.058
MW-39-100	99.5	-19.5	Geokon	25	0.10	0.058
MW-39-102	101.2	-21.2	Geokon	50	0.10	0.115
MW-39-124	123.7	-43.7	Geokon	50	0.10	0.115
MW-39-183	182.2	-102.2	Geokon	50	0.10	0.115
MW-39-195	194.7	-114.7	Geokon	100	0.10	0.231
MW-40-24	23.9	49.3	Geokon	50	0.10	0.115
MW-40-27	26.2	47.0	Geokon	10	0.10	0.023
MW-40-46	45.7	27.5	Geokon	25	0.10	0.058
MW-40-81	80.2	-7.0	Geokon	25	0.10	0.058
MW-40-100	99.9	-26.7	Geokon	50	0.10	0.115
MW-40-127	126.9	-53.7	Geokon	50	0.10	0.115
MW-40-162	161.4	-88.2	Geokon	100	0.10	0.231
MW-41-40	variable		In-Situ MiniTroll	30	0.10	0.069
MW-41-63	variable		In-Situ MiniTroll	30	0.10	0.069
MW-42-49	variable		In-Situ MiniTroll	30	0.10	0.069
MW-42-78	variable		In-Situ MiniTroll	30	0.10	0.069
MW-43-28	variable		In-Situ MiniTroll	30	0.10	0.069
MW-43-62	variable		In-Situ MiniTroll	30	0.10	0.069
MW-44-67	variable		In-Situ MiniTroll	30	0.10	0.069
MW-44-102	variable		In-Situ MiniTroll	30	0.10	0.069

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TABLE 4.5
TRANSDUCER INFORMATION
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	DIAPHRAGM DEPTH ft below toc	DIAPHRAGM EL. ft msl	TRANSDUCER MAKE	PRESSURE RANGE psi	ACCURACY % full scale	ACCURACY ft H_2O[1]
MW-45-42	variable		In-Situ MiniTroll	30	0.10	0.069
MW-45-61	variable		In-Situ MiniTroll	30	0.10	0.069
MW-46	variable		In-Situ MiniTroll	30	0.10	0.069
MW-47-56	variable		In-Situ MiniTroll	30	0.10	0.069
MW-47-80	variable		In-Situ MiniTroll	30	0.10	0.069
MW-48-23	variable		In-Situ MiniTroll	30	0.10	0.069
MW-48-37	variable		In-Situ MiniTroll	30	0.10	0.069
MW-49-26	variable		In-Situ MiniTroll	30	0.10	0.069
MW-49-42	variable		In-Situ MiniTroll	30	0.10	0.069
MW-49-65	variable		In-Situ MiniTroll	30	0.10	0.069
MW-50-42	variable		In-Situ MiniTroll	30	0.10	0.069
MW-50-66	variable		In-Situ MiniTroll	30	0.10	0.069
MW-51-40	39.4	28.3	Geokon	50	0.10	0.115
MW-51-79	78.2	-10.5	Geokon	25	0.10	0.058
MW-51-102	101.9	-34.2	Geokon	50	0.10	0.115
MW-51-104	103.4	-35.7	Geokon	50	0.10	0.115
MW-51-135	134.9	-67.2	Geokon	50	0.10	0.115
MW-51-163	162.4	-94.7	Geokon	100	0.10	0.231
MW-51-189	188.9	-121.2	Geokon	100	0.10	0.231
MW-52-11	variable		In-Situ MiniTroll	30	0.10	0.069
MW-52-18	17.2	-2.3	Geokon	50	0.10	0.115
MW-52-48	47.5	-32.6	Geokon	25	0.10	0.058
MW-52-64	63.7	-48.8	Geokon	50	0.10	0.115
MW-52-118	117.2	-102.3	Geokon	50	0.10	0.115
MW-52-122	121.7	-106.8	Geokon	50	0.10	0.115
MW-52-162	161.2	-146.3	Geokon	100	0.10	0.231
MW-52-181	180.7	-165.8	Geokon	100	0.10	0.231
MW-53-82	variable		In-Situ MiniTroll	30	0.10	0.069
MW-53-120	variable		In-Situ MiniTroll	30	0.10	0.069
MW-54-35	34.7	-21.6	Geokon	50	0.10	0.115
MW-54-37	36.2	-23.1	Geokon	50	0.10	0.115
MW-54-58	57.2	-44.1	Geokon	50	0.10	0.115
MW-54-123	122.7	-109.6	Geokon	50	0.10	0.115
MW-54-144	143.7	-130.6	Geokon	50	0.10	0.115
MW-54-173	172.2	-159.1	Geokon	100	0.10	0.231
MW-54-190	189.7	-176.6	Geokon	100	0.10	0.231
MW-55-24	variable		In-Situ MiniTroll	30	0.10	0.069
MW-55-35	variable		In-Situ MiniTroll	30	0.10	0.069
MW-55-54	variable		In-Situ MiniTroll	30	0.10	0.069
MW-56-53	variable		In-Situ MiniTroll	30	0.10	0.069
MW-56-83	variable		In-Situ MiniTroll	30	0.10	0.069
MW-57-11	variable		In-Situ MiniTroll	30	0.10	0.069
MW-57-20	variable		In-Situ MiniTroll	30	0.10	0.069
MW-57-45	variable		In-Situ MiniTroll	30	0.10	0.069
MW-58-26	variable		In-Situ MiniTroll	30	0.10	0.069
MW-58-65	variable		In-Situ MiniTroll	30	0.10	0.069
MW-59-32	variable		In-Situ MiniTroll	30	0.10	0.069
MW-59-45	variable		In-Situ MiniTroll	30	0.10	0.069
MW-59-68	variable		In-Situ MiniTroll	30	0.10	0.069
MW-60-35	34.6	-22.1	Geokon	50	0.10	0.115
MW-60-53	52.9	-40.4	Geokon	25	0.10	0.058
MW-60-55	54.4	-41.9	Geokon	25	0.10	0.058
MW-60-72	72.1	-59.6	Geokon	50	0.10	0.115
MW-60-135	134.6	-122.1	Geokon	50	0.10	0.115
MW-60-154	154.1	-141.6	Geokon	100	0.10	0.231
MW-60-176	175.6	-163.1	Geokon	100	0.10	0.231

See Page 3 for Notes

TABLE 4.5
TRANSDUCER INFORMATION
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	DIAPHRAGM DEPTH ft below toc	DIAPHRAGM EL. ft msl	TRANSDUCER MAKE	PRESSURE RANGE psi	ACCURACY % full scale	ACCURACY ft H_2O[1]
MW-62-18	variable		In-Situ MiniTroll	30	0.10	0.069
MW-62-37	variable		In-Situ MiniTroll	30	0.10	0.069
MW-62-52	51.3	-38.5	Geokon	50	0.10	0.115
MW-62-53	52.8	-40.0	Geokon	50	0.10	0.115
MW-62-71	70.8	-58.0	Geokon	50	0.10	0.115
MW-62-92	91.3	-78.5	Geokon	50	0.10	0.115
MW-62-138	137.8	-125.0	Geokon	50	0.10	0.115
MW-62-181	180.3	-167.5	Geokon	100	0.10	0.231
MW-62-182	181.8	-169.0	Geokon	100	0.10	0.231
MW-63-18	variable		In-Situ MiniTroll	30	0.10	0.069
MW-63-35	variable		In-Situ MiniTroll	30	0.10	0.069
MW-63-50	49.2	-36.9	Geokon	50	0.10	0.115
MW-63-91	90.2	-77.9	Geokon	50	0.10	0.115
MW-63-93	92.7	-80.4	Geokon	50	0.10	0.115
MW-63-112	111.2	-98.9	Geokon	50	0.10	0.115
MW-63-121	120.7	-108.4	Geokon	50	0.10	0.115
MW-63-163	162.2	-149.9	Geokon	100	0.10	0.231
MW-63-174	173.7	-161.4	Geokon	100	0.10	0.231
MW-65-48	variable		In-Situ MiniTroll	30	0.10	0.069
MW-65-80	variable		In-Situ MiniTroll	30	0.10	0.069
MW-66-21	variable		In-Situ MiniTroll	30	0.10	0.069
MW-66-36	variable		In-Situ MiniTroll	30	0.10	0.069
MW-67-39	38.0	-25.5	Geokon	50	0.10	0.115
MW-67-105	104.5	-92.0	Geokon	50	0.10	0.115
MW-67-173	172.0	-159.5	Geokon	100	0.10	0.231
MW-67-219	218.5	-206.0	Geokon	100	0.10	0.231
MW-67-276	275.0	-262.5	Geokon	100	0.10	0.231
MW-67-323	322.0	-309.5	Geokon	145	0.10	0.334
MW-67-340	339.5	-327.0	Geokon	145	0.10	0.334
MW-107	variable		In-Situ MiniTroll	30	0.10	0.069
MW-108	variable		In-Situ MiniTroll	30	0.10	0.069
MW-109	variable		In-Situ MiniTroll	30	0.10	0.069
MW-111	variable		In-Situ MiniTroll	30	0.10	0.069
U3-1	variable		In-Situ MiniTroll	30	0.10	0.069
U3-2	variable		In-Situ MiniTroll	30	0.10	0.069
U3-3	variable		In-Situ MiniTroll	30	0.10	0.069
U3-4S	variable		In-Situ MiniTroll	30	0.10	0.069
U3-4D	variable		In-Situ MiniTroll	30	0.10	0.069
U3-T1	variable		In-Situ MiniTroll	30	0.10	0.069
U3-T2	variable		In-Situ MiniTroll	30	0.10	0.069
I-2	variable		In-Situ MiniTroll	30	0.10	0.069
U1-CSS	variable		Geokon	10	0.10	0.023

NOTES:
All elevations are above NGVD29.
1. 0.1% of full scale
2. Transducer installation data for MW-32 Waterloo System configuration in place prior to September 2007.
3. Transducer installation data for MW-32 Waterloo System configuration as re-installed in September 2007 (see Appendix D for further information).
4. "Variable" indicates that the transducer has been positioned at different elevations over time (see Appendix M for further information).

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-30-69	6.4	8/18/06	220,000	ND[2]	ND	NA[3]	ND
		11/29/06	106,000	2.5	3,130	ND	ND
		1/16/07	81,700	ND	ND	NA	ND
		6/12/07	297,000	ND	ND	ND	ND
		7/18/07	82,100	NA	NA	NA	NA
		7/25/07	232,000	ND	ND	NA	ND
		8/1/07	103,000	NA	NA	NA	NA
		8/8/07	99,600	NA	NA	NA	NA
		8/15/07	233,000	NA	NA	NA	NA
		8/21/07	107,000	NA	NA	NA	NA
		8/30/07	98,000	NA	NA	NA	NA
		9/7/07	97,900	NA	NA	NA	NA
		9/13/07	93,100	NA	NA	NA	NA
		9/19/07	92,000	NA	NA	NA	NA
30-84	-8.1	8/22/06	12,500	ND	ND	NA	ND
		11/29/06	10,100	ND	294	ND	ND
		1/17/07	7,330	ND	ND	NA	ND
		6/12/07	7,790	ND	ND	ND	ND
		7/18/07	4,800	NA	NA	NA	NA
		7/25/07	5,020	ND	ND	NA	ND
MW-31-49	26.3	11/27/06	298	ND	70	ND	ND
		1/18/07	1,200	ND	ND	NA	ND
		6/12/07	1,480	ND	ND	ND	ND
		8/2/07	11,900	ND	88.3	NA	ND
		9/11/07	6,980	ND	ND	NA	ND
31-63	12.3	11/27/06	6,890	ND	199	ND	ND
		1/18/07	14,100	ND	ND	NA	ND
		6/12/07	5,000	ND	ND	ND	ND
		8/2/07	40,600	ND	ND	NA	ND
		9/11/07	37,700	ND	ND	NA	ND
31-85	-9.2	11/27/06	462	ND	152	ND	ND
		1/18/07	2,660	ND	ND	NA	ND
		6/12/07	317	ND	ND	ND	ND
		8/2/07	2,690	ND	ND	NA	ND
		9/11/07	4,320	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-32-62	15.3	1/19/07	7,670	ND	ND	NA	ND
		6/28/07	24,000	ND	ND	NA	ND
		8/13/07	14,200	ND	ND	NA	ND
32-92	-15.2	1/19/07	11,200	ND	ND	NA	ND
		6/28/07	5,420	ND	ND	NA	ND
		8/13/07	5,700	ND	ND	NA	ND
32-140	-62.7	1/19/07	11,300	ND	ND	NA	ND
		6/28/07	302	ND	ND	NA	ND
		8/13/07	ND	ND	ND	NA	ND
32-160[4]	-82.7	1/19/07	10,500	ND	NA	NA	NA
32-165	-87.7	6/28/07	581	ND	ND	NA	ND
		8/13/07	493	ND	ND	NA	ND
32-196	-118.0	1/19/07	11,300	ND	ND	NA	ND
		6/28/07	2,410	ND	ND	NA	ND
		8/13/07	1,720	ND	ND	NA	ND
MW-33	-0.35	12/15/05	142,000	NA	NA	NA	NA
		12/19/05	199,000	NA	NA	NA	NA
		12/29/05	220,000	NA	NA	NA	NA
		1/6/06	189,000	NA	NA	NA	NA
		1/13/06	232,000	NA	NA	NA	NA
		1/20/06	226,000	NA	NA	NA	NA
		1/27/06	242,000	NA	NA	NA	NA
		2/3/06	250,000	NA	NA	NA	NA
		2/7/06	214,000	ND	NA	NA	NA
		2/16/06	261,000	NA	NA	NA	NA
		3/3/06	253,000	NA	NA	NA	NA
		4/7/06	221,000	NA	NA	NA	NA
		5/17/06	135,000	ND	ND	NA	ND
		6/7/06	141,000	0.7	ND	NA	ND
		7/3/06	264,000	ND	ND	NA	ND
		8/4/06	184,000	NA	ND	NA	ND
		8/30/06	115,000	NA	ND	NA	ND
	2.9[5]	6/15/07	90,600	ND	ND	ND	ND
		8/3/07	23,000	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-34	-0.38	12/13/05	63,900	NA	NA	NA	NA
		12/19/05	121,000	NA	NA	NA	NA
		12/29/05	147,000	NA	NA	NA	NA
		1/6/06	159,000	NA	NA	NA	NA
		1/13/06	131,000	NA	NA	NA	NA
		1/20/06	211,000	NA	NA	NA	NA
		1/27/06	212,000	NA	NA	NA	NA
		2/3/06	224,000	NA	NA	NA	NA
		2/7/06	174,000	ND	NA	NA	NA
		2/16/06	199,000	NA	NA	NA	NA
		3/3/06	230,000	NA	NA	NA	NA
		4/7/06	276,000	NA	NA	NA	NA
		5/17/06	36,400	ND	ND	NA	ND
		6/26/06	10,500	ND	ND	NA	ND
		7/26/06	40,700	ND	ND	NA	ND
		8/24/06	66,900	NA	ND	NA	ND
		9/21/06	16,100	ND	ND	NA	ND
	2.0[5]	8/3/07	22,200	ND	ND	NA	ND
MW-35	-0.4	12/13/05	42,300	NA	NA	NA	NA
		12/19/05	76,000	NA	NA	NA	NA
		12/29/05	80,500	NA	NA	NA	NA
		1/6/06	95,400	NA	NA	NA	NA
		1/13/06	97,800	NA	NA	NA	NA
		1/20/06	104,000	NA	NA	NA	NA
		1/27/06	38,700	NA	NA	NA	NA
		2/3/06	51,400	NA	NA	NA	NA
		2/7/06	84,400	ND	NA	NA	NA
		2/16/06	90,400	NA	NA	NA	NA
		3/3/06	119,000	NA	NA	NA	NA
		4/7/06	56,200	NA	NA	NA	NA
		5/17/06	40,700	ND	ND	NA	ND
		6/26/06	17,400	ND	ND	NA	ND
		9/21/06	45,300	ND	ND	NA	ND
	3.6[5]	6/15/07	2,030	ND	46.6	ND	ND
		8/3/07	5,950	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-36-24	-4.3	2/7/06	NA	1.3	NA	NA	NA
		2/27/06	30,400	NA	NA	NA	NA
		3/23/06	34,200	1.0	ND	64.1	ND
		4/5/06	NA	1.6	NA	NA	NA
		6/5/06	202	ND	ND	NA	ND
		8/28/06	245	NA	ND	NA	ND
		6/27/07	ND	ND	ND	NA	ND
		8/8/07	ND	ND	ND	ND	ND
MW-36-41	-25.2	2/10/06	47,500	NA	NA	NA	NA
		2/27/06	45,800	NA	NA	NA	NA
		3/24/06	55,200	3.5	ND	48.7	ND
		4/5/06	NA	3.5	NA	NA	NA
		6/5/06	20,500	2.3	ND	NA	ND
		8/28/06	20,100	NA	ND	NA	ND
	-25.2[5]	6/27/07	6,110	2.2	ND	NA	ND
MW-36-52	-37.9	2/10/06	22,400	NA	NA	NA	NA
		2/27/06	25,700	NA	NA	NA	NA
		3/24/06	26,800	4.1	ND	ND	ND
		4/5/06	NA	5.0	NA	NA	NA
		6/5/06	24,000	4.4	ND	NA	ND
		8/28/06	14,100	NA	ND	NA	ND
		6/27/07	10,100	2.6	ND	NA	ND
	-38.2[5]	8/8/07	12,500	2.3	ND	ND	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-37-22	-1.5	2/24/06	10,700	NA	NA	NA	NA
		2/28/06	12,800	2.4	ND	42.4	ND
		3/10/06	23,200	4.7	ND	20.8	ND
		3/27/06	34,900	4.1	ND	54.3	ND
		6/27/06	10,500	9.6	ND	NA	ND
		9/29/06	7,370	14.2	ND	NA	ND
	-2.0[5]	6/27/07	4,050	14.9	ND	NA	ND
		8/7/07	2,790	18.3	ND	NA	ND
MW-37-32	-14.8	2/24/06	30,100	NA	NA	NA	NA
		2/28/06	28,600	18.2	ND	34.1	ND
		3/10/06	28,300	15.2	ND	ND	ND
		3/27/06	13,900	19.5	ND	ND	ND
		6/27/06	7,920	29.8	ND	NA	ND
		9/29/06	11,500	15.3	ND	NA	ND
	-14.0[5]	6/27/07	3,130	18.5	ND	NA	ND
		8/7/07	3,810	18.9	ND	NA	ND
MW-37-40	-24.2	2/24/06	16,800	NA	NA	NA	NA
		2/28/06	14,700	4.9	ND	56.5	ND
		3/10/06	17,000	13.5	ND	ND	ND
		3/27/06	15,600	11.1	ND	ND	ND
	-24.0[5]	6/27/07	14,200	24.4	ND	NA	ND
		8/7/07	5,850	9.8	ND	NA	ND
MW-37-57	-38.2	2/24/06	16,000	NA	NA	NA	NA
		2/28/06	13,300	22.7	ND	29.1	ND
		3/10/06	19,100	22.9	ND	ND	ND
		3/27/06	15,900	16.5	ND	ND	ND
		6/27/06	44,800	27.3	ND	NA	ND
		9/29/06	10,500	18.1	ND	NA	ND
	-40.0[5]	6/27/07	5,890	24.2	ND	NA	ND
		8/7/07	6,680	23.3	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-38	-11.1	12/8/05	985	ND	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/10/06	1,010	NA	ND	NA	ND
		1/19/06	758	NA	ND	NA	ND
		1/25/06	1,440	NA	ND	NA	ND
		2/1/06	ND	NA	ND	NA	ND
		2/8/06	ND	ND	ND	NA	ND
		2/16/06	ND	NA	ND	NA	ND
		2/23/06	2,630	NA	ND	NA	ND
		3/3/06	ND	NA	ND	NA	ND
		5/22/06	759	ND	ND	NA	ND
		6/21/06	916	ND	ND	ND	ND
		7/6/06	593	ND	ND	NA	ND
		8/7/06	215	ND	ND	ND	ND
		9/5/06	353	ND	ND	NA	ND
		11/22/06	ND	ND	ND	NA	ND
		2/12/07	2,240	ND	2.7	NA	ND
		8/16/07	604	ND	ND	NA	ND
MW-39-67	12.7	5/22/07	473	2.8	ND	ND	ND
		8/7/07	325	4.8	ND	NA	ND
39-84	-3.8	5/22/07	591	1.7	ND	ND	ND
		8/7/07	252	0.8	ND	NA	ND
39-102	-21.8	5/22/07	805	1.3	ND	ND	ND
		8/7/07	321	ND	ND	NA	ND
39-124	-44.3	5/22/07	261	ND	ND	ND	ND
		8/7/07	192	ND	ND	NA	ND
39-183	-102.8	5/22/07	247	ND	ND	ND	ND
		8/7/07	ND	ND	ND	NA	ND
39-195	-115.3	5/22/07	255	1.3	ND	ND	ND
		8/7/07	200	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-40-27	48.7	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-46	26.7	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-81	-7.8	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-100	-27.3	6/5/07	176	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-127	-54.3	6/5/07	187	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-162	-88.8	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
MW-41-40	20.5	4/12/06	726	2.6	ND	NA	ND
		5/25/06	607	5.2	ND	NA	ND
		6/12/06	676	3.6	ND	NA	ND
		7/14/06	983	7.0	ND	NA	ND
		8/16/06	447	NA	ND	NA	ND
		11/13/06	425	4.6	ND	ND	ND
	18.9[5]	6/19/07	3,910	6.0	ND	ND	ND
		8/14/07	380	6.0	ND	NA	ND
41-63	-4.6	4/12/06	701	5.5	ND	NA	ND
		5/25/06	361	5.2	ND	NA	ND
		6/12/06	268	0.8	ND	NA	ND
		7/18/06	243	2.2	ND	NA	ND
		8/16/06	356	NA	ND	NA	ND
		11/13/06	157	2.1	ND	ND	ND
	-6.1[5]	6/20/07	552	7.1	ND	ND	ND
		8/14/07	547	3.6	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-42-41[6]	28.7	3/31/06	5,400	NA	6,890	NA	NA
		4/7/06	2,880	95.9	48,900	3,190	56.2
		7/21/06	3,580	13	8,290	NA	ND
		9/18/06	1,840	NA	17,700	NA	ND
		11/17/06	2,260	10	6,950	131	ND
42-43[6]	26.7	3/31/06	4,870	NA	6,950	NA	NA
		4/7/06	2,370	93.5	50,000	3,600	40.2
		7/21/06	3,050	12.8	8,890	NA	ND
		9/18/06	1,280	NA	22,600	NA	ND
		11/16/06	2,650	14.9	8,620	228	3.2
42-46[6]	24.2	3/31/06	4,830	NA	8,620	NA	NA
		4/7/06	2,510	110	47,300	4,730	ND
		7/21/06	2,320	10.9	7,860	NA	ND
		9/15/06	1,100	NA	22,600	NA	ND
		11/16/06	2,310	11.4	7,250	249	ND
42-48[6]	21.7	3/31/06	4,600	NA	7,250	NA	NA
		4/7/06	3,980	73.7	53,100	5,120	ND
		7/20/06	2,800	15.2	9,330	NA	ND
		9/15/06	621	NA	38,900	NA	65.3
		11/16/06	1,980	10.6	6,920	207	ND
MW-42-49	27.1	3/23/06	2,630	51.9	102,000	NA	194
		3/31/06	2,490	21.0	6,550	NA	ND
		4/7/06	2,510	109	81,100	2,220	88.1
	23.7[5]	6/18/07	1,340	77.3	19,000	1,030	ND
		8/2/07	1,500	50.2	24,800	805	ND
		8/17/07	1,600	20.1	19,600	526	ND
42-78	-4.3	3/24/06	1,280	ND	4,460	NA	ND
		4/7/06	792	ND	1,980	36.6	ND
	-4.3[5]	6/18/07	378	ND	62.8	ND	ND
		7/27/07	319	ND	ND	ND	ND
		8/17/07	461	ND	45.1	ND	ND
MW-43-28	25.3	4/12/06	346	ND	ND	NA	ND
		5/25/06	ND	2.7	ND	NA	ND
		6/12/06	230	ND	ND	NA	ND
		7/12/06	ND	ND	ND	NA	ND
		8/16/06	260	NA	ND	NA	ND
	25.8[5]	6/18/07	278	1.1	ND	ND	ND
		8/13/07	ND	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
43-62	-2.2	4/12/06	200	ND	ND	NA	ND
		5/25/06	ND	ND	ND	NA	ND
		6/12/06	ND	1.3	ND	NA	ND
		7/12/06	ND	ND	ND	NA	ND
		8/16/06	ND	NA	ND	NA	ND
	-5.2[5]	6/19/07	ND	0.9	ND	ND	ND
		8/13/07	ND	ND	ND	NA	ND
MW-44-67	31.1	3/28/06	338	ND	ND	NA	ND
		5/24/06	237	0.7	ND	NA	ND
		7/20/06	892	ND	35.4	NA	ND
	30.5[5]	6/29/07	268	ND	ND	NA	ND
		8/14/07	417	ND	ND	NA	ND
44-102	2.5	6/13/06	253	ND	ND	NA	ND
		7/20/06	316	ND	ND	NA	ND
		8/4/06	761	NA	ND	NA	ND
		9/13/06	267	NA	ND	NA	ND
	13.5[5]	6/19/07	298	ND	ND	ND	ND
		8/14/07	284	ND	ND	NA	ND
MW-45-42	19.2	4/4/06	518	0.9	ND	NA	ND
		5/25/06	1,820	ND	ND	NA	ND
		6/12/06	2,270	1.0	ND	NA	ND
		7/14/06	419	ND	ND	NA	ND
		8/11/06	3,160	NA	ND	NA	ND
		9/13/06	4,150	NA	ND	NA	ND
		11/13/06	525	ND	ND	ND	ND
	16.7[5]	6/21/07	2,320	ND	ND	ND	ND
		8/15/07	1,160	ND	ND	NA	ND
45-61	-4.1	4/4/06	298	ND	ND	NA	ND
		5/25/06	1,710	ND	ND	NA	ND
		6/12/06	1,020	ND	ND	NA	ND
		7/20/06	372	ND	ND	NA	ND
		8/11/06	1,350	NA	ND	NA	ND
		9/13/06	1,450	NA	ND	NA	ND
		11/13/06	957	1.7	ND	ND	ND
	-4.3[5]	6/21/07	1,470	ND	ND	ND	ND
		8/15/07	1,500	ND	ND	NA	ND
MW-46	0.0	4/12/06	1,380	0.6	ND	NA	ND
		5/24/06	623	ND	ND	NA	ND
		6/13/06	ND	ND	ND	NA	ND
		7/12/06	786	ND	ND	NA	ND
		8/4/06	1,150	NA	ND	NA	ND
		9/13/06	1,470	NA	ND	NA	ND
	7.6[5]	6/14/07	3,430	ND	ND	ND	ND
		8/1/07	662	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-47-56	17.1	4/13/06	760	2.3	ND	NA	ND
		7/18/06	ND	ND	ND	NA	ND
	18.3[5]	6/20/07	529	0.6	ND	ND	ND
		8/10/07	270	ND	ND	NA	ND
47-80	-3.7	4/13/06	2,330	2.7	ND	NA	ND
		7/18/06	1,870	2.9	ND	NA	ND
	-1.7[5]	6/19/07	2,360	3.3	ND	ND	ND
		8/10/07	3,510	3.6	ND	NA	ND
MW-48-23	-5.0	2/8/06	ND	ND	ND	NA	ND
		4/12/06	ND	ND	ND	NA	ND
		4/27/06	238	ND	ND	NA	ND
		5/22/06	755	ND	ND	NA	ND
		6/9/06	737	ND	ND	ND	ND
		7/6/06	ND	ND	ND	NA	ND
		8/8/06	ND	ND	ND	NA	ND
		9/5/06	740	ND	ND	NA	ND
		11/22/06	ND	ND	ND	NA	ND
		2/9/07	272	ND	ND	NA	ND
		8/16/07	393	ND	ND	NA	ND
48-37	-20.6	2/10/06	ND	NA	ND	NA	ND
		4/12/06	ND	ND	ND	NA	ND
		4/27/06	ND	ND	ND	NA	ND
		5/22/06	ND	ND	ND	NA	ND
		6/9/06	ND	2.1	ND	ND	ND
		7/6/06	ND	ND	ND	NA	ND
		8/8/06	ND	ND	ND	NA	ND
		9/5/06	573	ND	ND	NA	ND
		11/22/06	ND	ND	ND	NA	ND
		2/9/07	ND	ND	ND	NA	ND
		8/16/07	ND	ND	ND	NA	ND
MW-49-26	-4.4	3/22/06	15,400	18.4	ND	NA	ND
		5/19/06	14,200	9.0	ND	NA	ND
		6/6/06	14,000	14.1	ND	NA	ND
		7/7/06	10,000	12.6	ND	NA	ND
		8/1/06	13,700	NA	ND	36.7	ND
		8/28/06	11,000	NA	ND	NA	ND
		11/15/06	6,390	15.5	ND	ND	ND
	-5.4[5]	6/26/07	7,760	12.7	ND	ND	ND
		8/9/07	6,720	14.3	ND	ND	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
49-42	-23.4	3/22/06	11,300	19.4	ND	NA	ND
		5/19/06	9,390	12.0	ND	NA	ND
		6/6/06	8,280	16.3	ND	NA	ND
		7/7/06	5,850	19.2	ND	NA	ND
		8/1/06	8,800	NA	ND	ND	ND
		8/28/06	8,690	NA	ND	NA	ND
		11/15/06	6,190	21.1	ND	ND	ND
	-22.4 [5]	6/26/07	4,440	20.8	ND	ND	ND
		8/9/07	4,300	25.6	ND	ND	ND
49-65	-45.4	3/22/06	5,430	18.5	ND	NA	ND
		5/19/06	5,750	11.3	ND	NA	ND
		6/6/06	4,320	17.2	ND	NA	ND
		7/7/06	4,630	15.6	ND	NA	ND
		8/1/06	5,760	NA	ND	ND	ND
		8/28/06	5,540	NA	ND	NA	ND
		11/15/06	3,040	19.2	ND	ND	ND
	-46.4 [5]	6/26/07	2,620	15.8	ND	ND	ND
		8/9/07	2,410	20.8	ND	ND	ND
MW-50-42	-27.1	3/22/06	9,750	19.3	ND	ND	ND
		5/19/06	4,590	19.5	ND	NA	ND
		6/7/06	479	3.9	ND	NA	ND
		7/3/06	398	3.5	ND	NA	ND
		8/1/06	1,410	NA	ND	ND	ND
		8/28/06	311	NA	ND	NA	ND
		11/15/06	1,700	11.3	7.2	ND	ND
	-12.1 [5]	6/26/07	215	11.6	ND	ND	ND
		7/26/07	ND	19.4	ND	ND	ND
50-66	-52.1	3/22/06	6,810	25.5	ND	ND	ND
		5/19/06	10,800	19.5	ND	NA	ND
		6/7/06	10,500	19.8	ND	NA	ND
		7/3/06	8,620	25.3	ND	NA	ND
		8/1/06	7,930	NA	ND	ND	ND
		8/28/06	6,770	NA	ND	NA	ND
		11/15/06	5,050	21.5	ND	ND	ND
	-45.1 [5]	6/26/07	4,210	29.3	ND	ND	ND
		7/26/07	4,500	31.0	ND	ND	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-51-40	27.8	5/30/07	198	ND	ND	NA	ND
		7/24/07	223	ND	ND	NA	ND
51-79	-11.2	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-104	-34.7	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-135	-67.7	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-163	-95.2	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-189	-121.7	5/30/07	187	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
MW-52-11	5.2	6/20/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-18	-1.5	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-48	-32.0	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-64	-48.0	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-122	-106.0	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-162	-145.5	5/24/07	282	ND	ND	ND	ND
		8/6/07	211	ND	ND	NA	ND
52-181	-165.0	5/24/07	248	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
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Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-53-82	-2.4	8/23/06	13,200	6.7	ND	ND	ND
		11/9/06	454	ND	ND	ND	ND
	-4.7[5]	6/22/07	8,680	4.0	ND	ND	ND
		8/9/07	776	ND	ND	ND	ND
53-120	-39.5	8/30/06	4,420	NA	ND	NA	ND
		11/9/06	7,900	24.7	ND	27.1	ND
	-34.7[5]	6/22/07	9,610	35.7	7.9	17.3	ND
		8/9/07	8,050	37.0	ND	ND	ND
MW-54-37	-23.7	5/3/07	801	12.5	ND	ND	ND
		7/31/07	888	5.3	ND	ND	ND
54-58	-44.7	5/3/07	760	2.2	ND	ND	ND
		7/31/07	693	1.8	ND	ND	ND
54-123	-110.2	5/3/07	1,110	21.9	4.21	ND	ND
		7/31/07	963	13.5	ND	ND	ND
54-144	-131.2	5/3/07	1,340	16.1	ND	ND	ND
		7/31/07	1,890	19.2	ND	ND	ND
54-173	-159.7	5/3/07	1,900	20.9	ND	ND	ND
		7/31/07	2,080	14.5	ND	ND	ND
54-190	-177.2	5/3/07	1,870	19.5	ND	ND	ND
		7/31/07	2,250	17.9	ND	ND	ND
MW-55-24	-0.8	11/9/06	2,000	16.6	ND	ND	ND
	2.3[5]	6/28/07	3,080	32.5	ND	NA	ND
		8/2/07	2,710	23.1	ND	ND	ND
55-35	-14.2	11/9/06	9,040	40.4	ND	ND	ND
	-13.8[5]	6/28/07	3,090	32.5	ND	NA	ND
		8/2/07	3,680	34.0	ND	ND	ND
55-54	-30.8	11/9/06	13,100	22.8	ND	ND	ND
	-28.8[5]	6/28/07	10,400	24.7	ND	NA	ND
		8/2/07	9,910	22.2	ND	ND	ND
MW-56-53	17.8	1/4/07	780	ND	13.6	ND	ND
	18.3[5]	6/26/07	289	ND	ND	ND	ND
		8/10/07	216	ND	ND	NA	ND
56-83	-5.5	9/8/06	540	2.7	ND	NA	ND
		11/9/06	165	ND	ND	ND	ND
		1/4/07	1,280	2.3	11.8	ND	ND
	-3.7[5]	6/22/07	1,850	1.9	ND	ND	ND
		8/10/07	1,490	2.4	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-57-11	5.0[5]	6/22/07	4,610	45.5	ND	22.4	ND
		8/6/07	4,090	37.9	ND	ND	ND
57-20	-4.0[5]	6/22/07	1,650	2.0	ND	ND	ND
		8/6/07	966	1.2	ND	ND	ND
57-45	-25.0[5]	8/24/06	4,060	18.8	ND	ND	ND
		6/22/07	955	1.9	ND	ND	ND
		8/6/07	740	2.6	ND	ND	ND
MW-58-26	-7.0	11/16/06	ND	ND	72.7	ND	ND
		1/5/07	260	ND	ND	ND	ND
	-5.4[5]	6/21/07	597	1.0	ND	ND	ND
		7/31/07	856	1.0	ND	NA	ND
58-65	-43.0	11/16/06	ND	ND	ND	ND	ND
		1/5/07	550	ND	ND	ND	ND
	-39.4[5]	6/21/07	315	ND	ND	ND	ND
		7/31/07	342	ND	ND	NA	ND
MW-59-32	-11.7	11/16/06	ND	ND	ND	ND	ND
		1/5/07	ND	ND	ND	ND	ND
	-12.5[5]	6/21/07	467	ND	ND	ND	ND
		7/31/07	169	ND	ND	NA	ND
59-45	-25.9	11/16/06	ND	ND	37.4	ND	ND
		1/5/07	ND	ND	149	ND	ND
	-27.5[5]	6/21/07	754	ND	ND	ND	ND
		7/31/07	249	ND	ND	NA	ND
59-68	-46.1	11/16/06	ND	ND	115	ND	ND
		1/5/07	ND	ND	67.6	ND	ND
	-43.5[5]	6/21/07	590	ND	ND	ND	ND
		7/31/07	819	ND	ND	NA	ND
MW-60-35	-22.7	5/8/07	ND	ND	ND	ND	ND
		7/27/07	761	ND	ND	NA	ND
60-53	-41.7	5/8/07	ND	ND	ND	ND	ND
		7/27/07	ND	ND	ND	NA	ND
60-72	-60.2	5/8/07	ND	ND	ND	ND	ND
		7/27/07	ND	ND	ND	NA	ND
60-135	-122.7	5/8/07	ND	ND	ND	ND	ND
		7/27/07	392	ND	ND	NA	ND
60-154	-142.2	5/8/07	ND	ND	ND	ND	ND
		7/27/07	462	ND	ND	NA	ND
60-176	-163.7	5/8/07	530	ND	ND	ND	ND
		7/27/07	849	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-62-18	-1.8	5/17/07	452	ND	ND	ND	ND
		7/26/07	508	ND	ND	NA	ND
62-37	-33.5	5/17/07	297	ND	ND	ND	ND
		7/26/07	250	ND	ND	NA	ND
62-53	-40.5	5/10/07	393	ND	ND	ND	ND
		7/26/07	345	ND	ND	NA	ND
62-71	-58.5	5/10/07	502	ND	ND	ND	ND
		7/26/07	ND	ND	ND	NA	ND
62-92	-79.0	5/10/07	700	ND	ND	ND	ND
		7/26/07	437	ND	ND	NA	ND
62-138	-125.5	5/10/07	455	0.8	ND	ND	ND
		7/26/07	538	ND	ND	NA	ND
62-182	-169.5	5/10/07	541	ND	ND	ND	ND
		7/26/07	417	ND	ND	NA	ND
MW-63-18	0.6	5/18/07	230	ND	ND	ND	ND
		7/30/07	200	ND	ND	NA	ND
63-34	-30.6	5/18/07	228	ND	ND	ND	ND
		7/30/07	280	ND	ND	NA	ND
63-50	-37.4	5/15/07	326	ND	ND	ND	ND
		7/25/07	225	ND	ND	NA	ND
63-93	-80.9	5/15/07	281	ND	ND	ND	ND
		7/25/07	237	ND	ND	NA	ND
63-112	-99.4	5/15/07	424	ND	ND	ND	ND
		7/25/07	269	ND	ND	NA	ND
63-121	-108.9	5/15/07	311	ND	ND	ND	ND
		7/25/07	296	ND	ND	NA	ND
63-163	-150.4	5/15/07	578	ND	ND	ND	ND
		7/25/07	479	ND	ND	NA	ND
63-174	-161.9	5/15/07	593	ND	ND	ND	ND
		7/25/07	528	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-65-48	26.4	1/4/07	208	ND	ND	ND	ND
65-80	-1.7	9/8/06	ND	ND	ND	NA	ND
		1/4/07	183	ND	ND	ND	ND
MW-66-21	0.0	7/30/07	3,570	1.8	ND	NA	ND
66-36	-19.5	7/30/07	9,100	6.2	ND	NA	ND
MW-67-39	-29.5	8/31/07	4,860	18.6	ND	NA	ND
67-105	-88.5	8/31/07	1,860	1.1	ND	NA	ND
67-173	-164.5	8/31/07	1,050	ND	ND	NA	ND
67-219	-207.5	8/31/07	1,250	ND	ND	NA	ND
67-276	-254.0	8/31/07	679	ND	ND	NA	ND
67-323	-311.0	8/31/07	313	ND	ND	NA	ND
67-340	-329.5	8/31/07	369	ND	ND	NA	ND
MW-101	124.4	12/8/05	ND	ND	ND	NA	ND
		6/8/06	ND	ND	ND	NA	ND
MW-103	125.1	6/8/06	170	ND	ND	NA	ND
MW-105	123.7	12/8/05	ND	ND	ND	NA	ND
		6/8/06	ND	ND	ND	NA	ND
MW-107	111.0	9/28/05	ND	NA	ND	NA	ND
		12/8/05	ND	ND	ND	NA	ND
		4/18/06	ND	ND	ND	NA	ND
		6/6/06	ND	ND	ND	NA	ND
	110.1[5]	7/23/07	ND	ND	ND	NA	ND
MW-108	6.2	9/29/05	ND	NA	ND	NA	ND
		11/3/05	ND	NA	ND	NA	ND
		5/13/06	278	ND	ND	NA	ND
MW-109	6.1	9/29/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		5/13/06	339	ND	ND	NA	ND
MW-110	113.6	6/8/06	225	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-111	4.8	9/29/05	212,000	NA	ND	NA	ND
		10/14/05	6,810	NA	NA	NA	NA
		10/21/05	284,000	NA	NA	NA	NA
		10/28/05	218,000	NA	NA	NA	NA
		11/4/05	302,000	NA	NA	NA	NA
		11/22/05	180,000	NA	NA	NA	NA
		12/2/05	125,000	NA	NA	NA	NA
		12/8/05	271,000	NA	NA	NA	NA
		12/15/05	296,000	NA	NA	NA	NA
		12/19/05	192,000	NA	NA	NA	NA
		12/29/05	212,000	NA	NA	NA	NA
		1/6/06	113,000	NA	NA	NA	NA
		1/13/06	199,000	NA	NA	NA	NA
		1/20/06	119,000	NA	NA	NA	NA
		1/27/06	5,780	NA	NA	NA	NA
		2/3/06	295,000	NA	NA	NA	NA
		2/7/06	238,000	1.2	NA	NA	NA
		2/16/06	294,000	NA	NA	NA	NA
		3/3/06	236,000	NA	NA	NA	NA
		4/7/06	145,000	NA	NA	NA	NA
		5/17/06	43,100	2.5	ND	NA	ND
		6/23/06	262,000	ND	ND	NA	ND
		9/21/06	159,000	ND	ND	NA	ND
	2.4[5]	6/15/07	119,000	1.0	ND	ND	ND
		8/3/07	98,800	1.0	ND	NA	ND
MW-112	120.8	6/8/06	ND	ND	ND	NA	ND
RW-1	-30.0	10/25/06 11:37	64,100	ND	ND	NA	ND
		10/25/06 14:15	29,500	ND	ND	NA	ND
		10/31/06 12:27	107,000	ND	ND	NA	ND
		10/31/06 15:55	26,300	ND	ND	NA	ND
		10/31/06 20:00	18,900	ND	ND	NA	ND
		11/1/06 12:00	18,400	ND	ND	NA	ND
		11/2/06 12:00	24,000	ND	ND	NA	ND
		11/3/06 9:00	30,600	ND	ND	NA	ND
I2	48.0	5/13/06	ND	ND	ND	NA	NA

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
U3-1	-0.7	10/6/05	417	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	ND	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/12/06	744	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	763	ND	ND	NA	ND
		6/22/06	755	ND	ND	NA	ND
U3-2	2.4	10/6/05	960	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	ND	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/28/05	ND	NA	ND	NA	ND
		1/12/06	ND	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	282	ND	ND	NA	ND
		6/22/06	197	1.4	ND	NA	ND
U3-3	4.2	10/6/05	439	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	471	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/13/06	ND	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	263	ND	ND	NA	ND
		6/22/06	179	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
U3-4D	-14.7	10/16/05	ND	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	ND	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		11/22/05	ND	NA	NA	NA	NA
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/12/06	573	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		4/26/06	575	ND	ND	NA	ND
		6/22/06	710	ND	ND	NA	ND
U3-T1	3.2	10/7/05	1,590	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	563	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	498	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	529	NA	ND	NA	ND
		1/12/06	787	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	1,260	ND	ND	NA	ND
		5/26/06	732	1.3	ND	NA	ND
		7/12/06	684	ND	ND	NA	ND
		8/15/06	766	ND	ND	NA	ND
	2.5[5]	6/12/07	506	ND	ND	ND	ND
		8/1/07	490	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
U3-T2	2.9	10/7/05	703	NA	ND	NA	ND
		10/21/05	1,470	NA	ND	NA	ND
		10/28/05	1,280	NA	ND	NA	ND
		11/4/05	1,190	NA	ND	NA	ND
		11/10/05	1,640	NA	ND	NA	ND
		11/18/05	1,130	NA	ND	NA	ND
		12/2/05	1,330	NA	ND	NA	ND
		12/15/05	1,290	NA	ND	NA	ND
		12/30/05	1,690	NA	ND	NA	ND
		1/6/06	2,420	NA	ND	NA	ND
		1/13/06	1,780	NA	ND	NA	ND
		1/20/06	1,750	NA	ND	NA	ND
		1/25/06	2,320	NA	ND	NA	ND
		2/1/06	2,130	NA	ND	NA	ND
		2/17/06	ND	NA	NA	NA	NA
		3/16/06	1,690	ND	ND	NA	ND
		5/26/06	1,900	1.5	ND	NA	ND
		7/12/06	1,830	ND	ND	NA	ND
		8/15/06	1,580	NA	ND	NA	ND
	2.5[5]	6/12/07	1,450	ND	ND	ND	ND
		8/1/07	1,250	ND	ND	NA	ND
U1-CSS	6.1	1/30/07	1,760	19.5	ND	ND	ND
		2/27/07	4,320	13.8	ND	ND	ND
		6/13/07	1,530	14.5	ND	ND	ND
		8/6/07	2,800	26.8	ND	NA	ND
LAF-1	38.3	12/6/05	ND	NA	ND	NA	ND
		6/6/06	ND	ND	ND	ND	ND
		9/19/06	ND	ND	ND	NA	ND
		12/4/06	ND	ND	ND	ND	ND
		3/7/07	ND	ND	ND	ND	ND
		6/7/07	ND	1.1	ND	NA	ND
		9/10/07	ND	ND	ND	NA	ND
LAF-2	-22.3	6/6/06	ND	ND	ND	ND	ND
		9/19/06	ND	ND	ND	NA	ND
		12/4/06	ND	ND	NA	ND	ND
		3/7/07	ND	ND	ND	NA	ND
		6/7/07	ND	ND	ND	NA	ND

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TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
LAF-3	46.5	12/6/05	ND	NA	ND	NA	ND
		6/6/06	ND	ND	ND	ND	ND
		9/19/06	ND	ND	ND	NA	ND
		12/4/06	ND	ND	ND	ND	ND
		3/7/07	ND	ND	ND	NA	ND
		6/7/07	ND	ND	ND	NA	ND
		9/10/07	ND	ND	ND	NA	ND

well screen in unconsolidated deposit {soil backfill/natural soil}
well screen in consolidated {bedrock}

NOTES:

All elevations are above NGVD29.

1. Either the center of the screen/sampling ports (wells) or the midpoint of submerged part (open holes).
2. ND: Not detected above laboratory minimum detection limits
3. NA: Not Analyzed
4. Sampling port location changed since Feb. 07
5. Samples were taken using the low-flow sampling method at given elevations.
6. Suffix of Well ID displayed is representative of sampling depth within the screened well MW42-49.
7. This table contains data for completed well installations only.

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-30-69	11.8	-	-	12.5	-	-	11.8	-	-
MW-30-84	12.8	-	-	13.2	-	-	11.7	-	-
MW-31-49	44.1	-	-	48.0	-	-	39.1	-	-
MW-31-63	41.6	-	-	45.6	-	-	38.1	-	-
MW-31-85	39.6	-	-	43.6	-	-	36.9	-	-
MW-32-62	42.8	-	-	46.6	-	-	38.4	-	-
MW-32-92	10.3	-	-	11.0	-	-	10.3	-	-
MW-32-140	13.1	-	-	13.1	-	-	12.4	-	-
MW-32-165	8.2	-	-	8.3	-	-	7.6	-	-
MW-32-196	6.7	-	-	7.0	-	-	6.3	-	-
MW-33	10.1	-	-	10.7	-	-	9.1	-	-
MW-34	9.9	-	-	10.8	-	-	9.1	-	-
MW-35	10.0	-	-	11.2	-	-	9.4	-	-
MW-36-24	8.9	-	-	7.1	-	-	7.0	-	-
MW-36-41	8.4	8.5	8.2	7.2	7.2	7.2	7.1	7.2	7.1
MW-36-52	7.5	7.4	7.4	6.7	6.7	6.7	6.6	6.7	6.5
MW-37-22	5.4	5.48	5.51	4.9	5.1	4.7	4.1	4.2	3.9
MW-37-32	5.6	5.52	5.51	5.0	5.0	5.0	4.2	4.3	4.1
MW-37-40	5.4	-	-	4.9	-	-	4.1	-	-
MW-37-57	7.2	7.17	7.07	6.2	6.2	6.1	5.4	5.5	5.3
MW-38	4.1	4.13	3.01	3.0	3.8	2.1	1.9	2.5	1.2

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TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-39-67	24.9	-	-	31.1	-	-	24.1	-	-
MW-39-84	24.7	-	-	30.9	-	-	23.9	-	-
MW-39-100	25.0	-	-	31.0	-	-	24.0	-	-
MW-39-124	24.0	-	-	30.1	-	-	23.1	-	-
MW-39-183	18.6	-	-	29.8	-	-	22.8	-	-
MW-39-195	22.7	-	-	28.5	-	-	21.5	-	-
MW-40-24	59.4	-	-	62.9	-	-	58.6	-	-
MW-40-46	58.1	-	-	61.7	-	-	57.4	-	-
MW-40-81	55.0	-	-	58.6	-	-	54.3	-	-
MW-40-100	53.1	-	-	56.8	-	-	52.5	-	-
MW-40-127	52.4	-	-	56.2	-	-	51.9	-	-
MW-40-162	49.4	-	-	53.6	-	-	49.3	-	-
MW-41-13	DRY	-	-	DRY	-	-	DRY	-	-
MW-41-40	29.9	-	-	34.5	-	-	30.0	-	-
MW-41-63	25.9	-	-	31.5	-	-	27.0	-	-
MW-42-49	34.5	-	-	34.9	-	-	34	-	-
MW-42-78	35.6	-	-	36.0	-	-	35	-	-
MW-43-28	32.8			34.1			32.4		
MW-43-62	30.9	-	-	31.8	-	-	31.3	-	-
MW-44-67	33.4	-	-	37.3	-	-	33.1	-	-
MW-44-102	23.1	-	-	24.1	-	-	19.9	-	-
MW-45-42	26.4	-	-	33.1	-	-	26.3	-	-
MW-45-61	25.7	-	-	32.0	-	-	25.2	-	-

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-46	12.8	-	-	14.2	-	-	11.7	-	-
MW-47-56	21.8	-	-	27.2	-	-	21.4	-	-
MW-47-80	22.3	-	-	27.2	-	-	21.4	-	-
MW-48-23	1.5	2.26	-0.08	1.4	2.7	0.1	0.2	1.0	-0.8
MW-48-37	2.0	2.42	0.64	2.1	3.0	1.1	0.7	1.1	0.1
MW-49-26	1.6	1.47	1.04	1.4	2.3	0.4	0.6	1.1	0.1
MW-49-42	1.1	1.34	0.31	1.7	2.3	1.2	0.9	1.7	0.1
MW-49-65	1.5	1.37	0.89	1.8	2.2	1.5	1.0	1.6	0.6
MW-50-42	7.2	7.34	7.24	5.9	6.1	5.7	4.8	5.1	4.8
MW-50-66	4.4	4.46	3.71	3.9	4.3	3.5	2.8	3.3	2.2
MW-51-40	50.6	-	-	53.3	-	-	51.3	-	-
MW-51-79	41.8	-	-	45.6	-	-	43.6	-	-
MW-51-102	37.8	-	-	39.7	-	-	37.7	-	-
MW-51-135	39.1	-	-	41.3	-	-	39.3	-	-
MW-51-163	35.4	-	-	37.0	-	-	35.0	-	-
MW-51-189	30.7	-	-	32.1	-	-	30.1	-	-
MW-52-11	6.0	-	-	6.4	-	-	5.7	-	-
MW-52-18	6.6	-	-	6.7	6.7	6.7	6.0	6.0	6.0
MW-52-48	7.1	7.02	7.08	7.2	7.2	7.2	6.6	6.7	6.5
MW-52-64	6.0	6.0	6.0	6.1	6.1	6.1	5.2	5.2	5.2
MW-52-118	5.4	5.27	5.34	5.5	5.5	5.5	4.9	4.9	4.9
MW-52-122	5.3	5.20	5.25	5.3	5.3	5.3	4.8	4.8	4.8
MW-52-162	1.2	1.04	0.67	0.8	1.0	0.5	0.6	0.9	0.1
MW-52-181	0.9	0.82	0.41	0.6	0.8	0.3	0.3	0.6	-0.3
MW-53-82	9.8	-	-	11.7	-	-	8.7	-	-
MW-53-120	9.9	-	-	10.9	-	-	7.9	-	-

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-54-37	7.7	7.61	7.52	9.7	9.8	9.6	5.3	5.4	5.1
MW-54-58	7.0	6.99	6.86	9.0	9.1	8.9	4.7	4.8	4.5
MW-54-123	6.0	5.96	5.69	7.9	8.1	7.7	3.6	3.8	3.3
MW-54-144	9.1	9.2	8.9	11.1	11.3	10.9	6.7	7.0	6.4
MW-54-173	5.5	5.46	5.17	7.4	7.6	7.3	3.0	3.3	2.7
MW-54-190	5.4	5.36	5.08	7.3	7.5	7.2	3.0	3.2	2.9
MW-55-24	8.6	8.6	8.6	8.2	8.3	8.1	6.7	6.7	6.6
MW-55-35	8.2	8.13	8.10	8.2	8.2	8.1	6.7	6.8	6.6
MW-55-54	8.6	8.52	8.47	7.9	7.9	7.9	6.4	6.5	6.4
MW-56-53	21.0	-	-	26.0	-	-	20.3	-	-
MW-56-83	21.1	-	-	24.4	-	-	18.7	-	-
MW-57-11	9.6	9.59	9.57	11.1	11.1	11.0	7.5	7.6	7.5
MW-57-20	9.4	9.40	9.38	10.8	10.8	10.8	7.2	7.2	7.2
MW-57-45	9.2	9.11	9.08	10.4	10.4	10.4	6.8	6.8	6.8
MW-58-26	8.2	8.04	8.03	8.3	8.4	8.2	4.9	5.0	4.8
MW-58-65	6.3	6.32	6.03	7.5	7.6	7.4	4.1	4.3	3.9
MW-59-32	1.8	1.46	1.06	1.6	2.1	0.9	1.7	2.0	0.9
MW-59-45	2.0	1.9	1.1	1.9	2.9	0.8	2.0	2.7	1.0
MW-59-68	4.2	4.53	2.91	2.3	2.9	1.4	3.4	4.4	2.3

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-60-35	2.6	2.55	2.19	2.9	3.1	2.5	2.2	2.5	1.7
MW-60-53	0.3	0.45	-0.63	0.4	0.9	-0.2	-0.3	1.0	-1.2
MW-60-72	1.5	1.70	0.74	1.7	2.2	0.8	1.0	1.4	0.4
MW-60-135	1.7	1.89	0.94	1.9	2.3	1.4	1.2	1.9	0.4
MW-60-154	0.9	0.94	0.08	1.0	1.4	0.5	0.3	0.7	-0.1
MW-60-176	0.2	0.93	-0.48	0.7	1.4	0.1	0.0	0.7	-0.4
MW-62-18	1.2	2.2	0.3	NA[8]			NA		
MW-62-37	1.4	2.1	0.6	1.4	1.8	0.7	-0.2	0.1	-0.7
MW-62-53	1.5	1.15	0.95	1.6	2.0	0.9	0.9	1.2	0.5
MW-62-71	1.1	1.54	0.89	1.7	2.1	1.2	1.0	1.6	0.2
MW-62-92	1.3	1.84	1.07	2.0	2.3	1.5	1.3	1.9	1.2
MW-62-138	2.1	2.19	1.40	2.3	2.6	1.8	1.6	2.0	1.2
MW-62-181	1.9	2.07	1.33	2.2	2.7	1.6	1.5	1.9	1.1
MW-63-18	1.2	2.00	0.14	NA			NA		
MW-63-34	1.3	2.03	0.51	NA			NA		
MW-63-50	1.6	1.51	0.86	1.7	2.1	1.1	1.0	1.5	0.2
MW-63-91	2.0	1.91	1.16	2.0	2.3	1.5	1.3	1.8	0.4
MW-63-112	0.7	0.80	0.03	0.9	1.4	0.2	0.2	0.6	-0.4
MW-63-121	1.7	2.39	1.41	2.4	3.0	1.4	1.7	2.1	1.1
MW-63-163	1.4	1.47	0.70	1.6	1.9	1.4	0.9	1.4	0.3
MW-63-174	1.5	1.63	0.88	1.8	2.8	2.1	1.1	1.4	0.7

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-65-48	28.2	-	-	31.7	-	-	29.9	-	-
MW-65-80	28.5	-	-	32.0	-	-	30.2	-	-
MW-66-21	1.0	1.6	0.3	NA			NA		
MW-66-36	1.4	1.8	0.8	NA			NA		
MW-67-39[9]	2.0	2.7	1.3	NA			NA		
MW-67-105	2.8	3.5	2.1	NA			NA		
MW-67-173	2.3	3.0	1.7	NA			NA		
MW-67-219	2.4	3.0	1.8	NA			NA		
MW-67-276	3.3	3.9	2.7	NA			NA		
MW-67-323	2.2	2.7	1.6	NA			NA		
MW-67-340	2.6	3.1	2.0	NA			NA		
MW-107	116.8	-	-	120.6	-	-	117.4	-	-
MW-108	9.6	-	-	9.8	-	-	7.2	-	-
MW-109	9.5	-	-	9.1	-	-	4.7	-	-
MW-111	9.6	-	-	10.2	-	-	8.2	-	-
U3-1	4.5	4.54	4.20	4.3	4.5	4.1	3.5	3.5	3.5
U3-2	5.4	5.5	5.3	5.4	5.5	5.4	3.8	3.8	3.8
U3-3	8.4	7.5	7.5	8.0	-	-	4.3	4.3	4.3
U3-4D	4.2	4.23	4.25	3.9	3.9	3.9	3.6	3.6	3.6

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
U3-4S	4.3	4.28	3.91	3.9	4.0	3.7	3.0	3.0	3.0
U3-T1	4.5	4.45	4.51	4.5	4.6	4.3	3.6	3.6	3.6
U3-T2	4.5	4.47	4.33	4.5	4.6	4.3	3.6	3.6	3.6
I-2	50.2	-	-	52.0	-	-	48.7	-	-

NOTES: Approximated levels from adjacent dates at the same lunar phase are given when data from specified date is unavailable.

(shaded)	well screen in unconsolidated deposit (soil backfill/natural soil)
(unshaded)	well screen in consolidated rock (bedrock)

All elevations are above NGVD29.

1. Average piezometric heads of the day.
2. Piezometric heads in tidal wells at first high tide of the day in the Hudson river, at 11:44 am.
3. Piezometric heads in tidal wells at first low tide of the day in the Hudson river, at 6:29 am.
4. Piezometric heads in tidal wells at first high tide of the day in the Hudson river, at 5:26 am.
5. Piezometric heads in tidal wells at first low tide of the day in the Hudson river, at 12:21 am.
6. Piezometric heads in tidal wells at first high tideof the day in the Hudson river, at 7:45 am.
7. Piezometric heads in tidal wells at first low tide of the day in the Hudson river, at 1:55 am.
8. Data not available; transducers installed after the specified dates.
9. MW-67 Waterloo system was installed on 8/27/07. The given piezometric heads are responses to the first low tide (at 5:50 am) and the first high tide (at 11:16am) on 8/28/07.

See Page 7 for Notes

Exhibit F

NRC Inspection Report, May 13, 2008
(ML081340425)

May 13, 2008

EA-08-088

Mr. Joseph Pollock
Site Vice President
Entergy Nuclear Operations, Inc.
Indian Point Energy Center
450 Broadway, GSB
P.O. Box 249
Buchanan, NY 10511-0249

SUBJECT: INDIAN POINT NUCLEAR GENERATING UNITS 1 & 2 - NRC INSPECTION REPORT NOS. 05000003/2007010 and 05000247/2007010

Dear Mr. Pollock:

On May 7, 2008, the U.S. Nuclear Regulatory Commission (NRC) completed an inspection at Indian Point Nuclear Generating Units 1 & 2. The purpose of this inspection, initiated on November 7, 2007, was to assess your site groundwater characterization conclusions and the associated radiological significance relative to Entergy's discovery of a small amount of contaminated water leaking from the Unit 2 spent fuel pool, and the subsequent discovery of additional subsurface groundwater contamination emanating from the Unit 1 spent fuel pool system. This inspection focused on assessing Entergy's groundwater investigation to evaluate the extent of contamination, and the effectiveness of actions, taken or planned, to effect appropriate mitigation and remediation of the condition.

The inspection involved an examination of activities conducted under Entergy's license as they relate to safety and compliance with the Commission's rules and regulations, and with the conditions of the license. Within these areas, the inspection consisted of a selected examination of procedures and representative records, observations of activities, interviews with personnel, and independent analytical and assessment activities. This inspection effort reviewed Entergy's long-term monitoring plan intended for continuing verification and validation of the effectiveness of the licensee's efforts to assess, mitigate and remediate on-site groundwater conditions relative to public health and safety and protection of the environment. Details associated with the long term monitoring program will continue to be the subject of ongoing NRC inspection. The NRC will also continue split sampling for analytical comparison of selected groundwater monitoring wells through 2008. During the course of this inspection, we coordinated activities with representatives of the New York State Department of Environmental Conservation, who observed our inspection and contributed valuable expertise and independent assessment relative to its own focus on public health and safety, and environmental protection.

The enclosed inspection report documents the inspection findings, which were discussed on May 7, 2008, with Mr. Don Mayer and other members of your staff. The team found Entergy's response to identified conditions to be reasonable and technically sound. The existence of on-site groundwater contamination, as well as the circumstances surrounding the causes of leakage and previous opportunities for identification and intervention, have been reviewed in detail. Our inspection determined that public health and safety has not been, nor is likely to be,

adversely affected, and the dose consequence to the public that can be attributed to current on-site conditions associated with groundwater contamination is negligible. No significant findings were identified. However, one minor violation with respect to quality control of groundwater sampling is discussed in this report. This violation is not subject to enforcement action in accordance with Section IV of the NRC Enforcement Policy. The NRC plans no further action with regard to this matter; and no response to this letter is required.

Based on a telephone discussion between Messrs. John McCann, Director of Licensing, and Samuel Collins, NRC Region I Regional Administrator, on April 21, 2008, we understand that Entergy has committed to remove and transfer all spent fuel from the Unit 1 Spent Fuel Pool to Indian Point's Independent Spent Fuel Storage Installation, and drain the spent fuel pool by December 31, 2008, thereby essentially terminating the source of groundwater contamination from that location. Notwithstanding, it is expected that some water will remain on the bottom of the pool to reduce the potential for airborne contamination, provide shielding, and facilitate the removal of the sediment in early 2009. We understand that Entergy will promptly inform the NRC of any condition that could potentially impact or delay this commitment. Additionally, we understand that Entergy will incorporate the implementation requirements of its Long Term Monitoring Program (LTMP) as regulatory specifications in the Indian Point Energy Center's (IPEC) Off-site Dose Calculation Manual, thereby assuring that the LTMP will be regarded as an extension of the Radiological Effluents Technical Specifications and Radiological Environmental Monitoring Program, which are subject to NRC inspection. During the Exit Meeting on May 7, Entergy agreed to document these commitments to the NRC by May 20, 2008. Please inform us if our understanding is not correct.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice," a copy of this letter and its enclosure will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room). Further, in light of ongoing public interest in these matters, the NRC has scheduled a public meeting in Cortland, New York on May 20, 2008, as announced by our Meeting Notice dated May 10, 2008, also available at the NRC web site at http://www.nrc.gov/reactors.plant-specific-items/Indian-point-issues.html, to discuss NRC's assessment of Entergy's performance and actions to address the groundwater conditions at Indian Point, and the associated impact on public health and safety of the environment.

Sincerely,

/RA/

Marsha K. Gamberoni, Director
Division of Reactor Safety

Docket Nos: 50-003, 50-247
License Nos: DPR-5, DPR-26

Enclosure: Inspection Report Nos. 05000003/2007010, 05000247/2007010
w/Attachment: Supplemental Information

adversely affected, and the dose consequence to the public that can be attributed to current on-site conditions associated with groundwater contamination is negligible. No significant findings were identified. However, one minor violation with respect to quality control of groundwater sampling is discussed in this report. This violation is not subject to enforcement action in accordance with Section IV of the NRC Enforcement Policy. The NRC plans no further action with regard to this matter; and no response to this letter is required.

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Sincerely,
/RA/
Marsha K. Gamberoni, Director
Division of Reactor Safety

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DATE	04/29/08		05/02/08		05/13/08		05/12/08		05/1208	

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<u>cc w/encl</u>:
Senior Vice President, Entergy Nuclear Operations
Vice President, Operations, Entergy Nuclear Operations
Vice President, Oversight, Entergy Nuclear Operations
Senior Manager, Nuclear Safety and Licensing, Entergy Nuclear Operations
Senior Vice President and CCO, Entergy Nuclear Operations
Assistant General Counsel, Entergy Nuclear Operations
Manager, Licensing, Entergy Nuclear Operations
P. Tonko, President and CEO, New York State Energy Research and Development Authority
C. Donaldson, Esquire, Assistant Attorney General, New York Department of Law
A. Donahue, Mayor, Village of Buchanan
J. G. Testa, Mayor, City of Peekskill
R. Albanese, Four County Coordinator
S. Lousteau, Treasury Department, Entergy Services, Inc.
Chairman, Standing Committee on Energy, NYS Assembly
Chairman, Standing Committee on Environmental Conservation, NYS Assembly
Chairman, Committee on Corporations, Authorities, and Commissions
M. Slobodien, Director, Emergency Planning
P. Eddy, NYS Department of Public Service
Assemblywoman Sandra Galef, NYS Assembly
T. Seckerson, County Clerk, Westchester County Board of Legislators
A. Spano, Westchester County Executive
R. Bondi, Putnam County Executive
C. Vanderhoef, Rockland County Executive
E. A. Diana, Orange County Executive
T. Judson, Central NY Citizens Awareness Network
M. Elie, Citizens Awareness Network
D. Lochbaum, Nuclear Safety Engineer, Union of Concerned Scientists
Public Citizen's Critical Mass Energy Project
M. Mariotte, Nuclear Information & Resources Service
F. Zalcman, Pace Law School, Energy Project
L. Puglisi, Supervisor, Town of Cortlandt
Congressman John Hall
Congresswoman Nita Lowey
Senator Hillary Rodham Clinton
Senator Charles Schumer
G. Shapiro, Senator Clinton's Staff
J. Riccio, Greenpeace
P. Musegaas, Riverkeeper, Inc.
M. Kaplowitz, Chairman of County Environment & Health Committee
A. Reynolds, Environmental Advocates
D. Katz, Executive Director, Citizens Awareness Network
S. Tanzer, The Nuclear Control Institute
K. Coplan, Pace Environmental Litigation Clinic
M. Jacobs, IPSEC
W. Little, Associate Attorney, NYSDEC
M. J. Greene, Clearwater, Inc.
R. Christman, Manager Training and Development
J. Spath, New York State Energy Research, SLO Designee
A. J. Kremer, New York Affordable Reliable Electricity Alliance (NY AREA)

Docket Nos: 50-003, 50-247
License Nos: DPR-5, DPR-26

Enclosure: Inspection Report Nos. 05000003/2007010, 05000247/2007010
w/Attachment: Supplemental Information

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U.S. NUCLEAR REGULATORY COMMISSION

REGION I

Docket Nos.	50-003, 50-247
License Nos.	DPR-3, DPR-26
Report Nos.	05000003/2007010 and 05000247/2007010
Licensee:	Entergy Nuclear Northeast
Facility:	Indian Point Nuclear Generating Station Units 1 & 2
Location:	295 Broadway Buchanan, NY 10511-0308
Dates:	November 7, 2007 - May 7, 2008
Inspectors:	J. Noggle, Sr. Health Physicist, CHP, team leader T. Nicholson, Sr. Technical Advisor for Radionuclide Transport J. Williams, U.S. Geological Survey, Troy, New York J. Kottan, State Agreements Officer J. Commiskey, Health Physicist
Approved by:	John R. White, Chief Plant Support Branch 2 Division of Reactor Safety

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SUMMARY OF FINDINGS

IR 05000247/2007010 & IR 05000003/2007010; 11/08/2007 - 05/07/2008; Indian Point Nuclear Generating Station Units 1 & 2; Other Activities – associated with ROP deviation memorandum.

The report covers an inspection of a September 1, 2005, licensee-identified Unit 2 spent fuel pool leak investigation final report and long term monitoring plan; and review of historical leakage involving the Unit 1 spent fuel pool by three regional inspectors, one headquarters hydrology specialist, and a U.S. Geological Survey hydrology specialist. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

A. NRC - Identified and Self-Revealing Findings

No findings of significance were identified.

B. Licensee - Identified Violations

None

EXECUTIVE SUMMARY

Background:

On September 1, 2005, the NRC was informed by Entergy that cracks in a Unit 2 spent fuel pool wall had been discovered during excavation work, and that low levels of radioactive contamination were found in water leaking from the cracks having radionuclides similar to Unit 2 spent fuel pool water. Entergy initiated a prompt investigation to determine the extent of the condition and potential impact on health and safety. Initially, Entergy determined that on-site groundwater in the vicinity of the Unit 2 facility was contaminated with tritium as high as 200,000 picocuries per liter of water (about ten times the EPA drinking water standard). Subsequently, Entergy initiated actions to perform a comprehensive groundwater site characterization to investigate the extent of on-site groundwater contamination, identify the sources, and mitigate and remediate the condition. This effort required the establishment of several on-site groundwater monitoring wells to characterize groundwater behavior, flow, direction, and migration pathways.

On September 20, 2005, Region I initiated a special inspection of this matter to examine the licensee's performance and determine if the contaminated groundwater effected, or could effect, public health and safety. On October 31, 2005, NRC's Executive Director of Operations (EDO) authorized continuing NRC inspection to assess licensee performance of on-site groundwater investigation activities, and independently evaluate and analyze data and samples to assure the effectiveness and adequacy of the licensee's efforts. Throughout this effort, the NRC coordinated its inspection activities with the New York State Department of Environmental Conservation (DEC), which initiated its own independent assessment of the groundwater conditions, including observation of NRC's inspection activities.

The NRC issued a special inspection report on March 16, 2006 (ADAMS Accession No. ML060750842). The report assessed Entergy's performance, achievements, and plans relative to radiological and hydrological site characterization; and reported that the on-site groundwater contamination did not, nor was likely to, adversely affect public health and safety. In the report and in subsequent public meetings, NRC indicated that it would continue to inspect licensee performance in this area, including independent evaluation and analysis of data, to assure that Entergy continued to conform to regulatory requirements, and that public health and safety was maintained.

On March 21, 2006, NRC's independent on-site groundwater sample analysis effort first determined that strontium-90 was also a contaminant in the groundwater, a fact that was subsequently confirmed by Entergy and the DEC. This determination resulted in a significant expansion of the on-site groundwater characterization effort since the source of the strontium-90 contaminant was traced to leakage from the Unit 1 Spent Fuel Pool. A full site-wide hydrogeologic investigation was subsequently scoped to include Unit 1 and Unit 3. The NRC inspection charter objectives were similarly revised to provide the necessary oversight. Off-site groundwater samples have also been obtained since the fall of 2005, and have never detected any off-site groundwater contamination.

Since that time, the NRC has continued to inspect and monitor Entergy's activities beyond the limits of normal baseline inspection, as authorized by NRC's Executive Director of Operations (EDO). During this period, NRC inspectors closely monitored Entergy's groundwater characterization efforts, and performed independent inspection of radiological and hydrological conditions affecting on-site groundwater. Additionally, from early 2006 through January 2008, the NRC kept interested Federal, State, and Local government stakeholders informed of current conditions through routine bi-weekly teleconferences.

Status of Current Activities, Plans, and Inspection Results:

On January 11, 2008, Entergy submitted the results of its comprehensive ground water investigation, and included its plan for remediation and long-term monitoring of the on-site groundwater conditions. In its report, Entergy described the sources of the groundwater contamination to be the Unit 1 and Unit 2 spent fuel pools. While both pools contributed to the tritium contamination of groundwater, leakage from the Unit 1 spent fuel pool was determined to be the source of other contaminants such as strontium-90, cesium-137, and nickel-63. Entergy identified its plan to remove all fuel from the Unit 1 spent fuel pool to an on-site storage location and drain the spent fuel pool system by the end of 2008, thereby essentially eliminating the source of the groundwater contamination from that facility. Some water is expected to remain in the bottom of the pool to reduce the potential for airborne contamination and provide shielding until the residual sludge is removed in early 2009. In the January 11, 2008 report, Entergy described its actions to repair or mitigate all identified potential leak locations in the Unit 2 spent fuel pool system that may have contributed to the on-site tritium-contaminated groundwater in the vicinity of that facility.

Notwithstanding, residual radioactivity is expected to continue to impact on-site groundwater for the duration of licensed activities. On-site groundwater is expected to continue to be monitored and reported as an abnormal liquid release in accordance with NRC regulatory requirements. No off-site groundwater has been impacted, since the on-site groundwater flow is to the discharge canal and the Hudson River. Accordingly, the licensee has established a long-term monitoring strategy for the purpose of evaluating the effect and progress of the natural attenuation of residual contamination, informing and confirming groundwater behavior as currently indicated by the existing site conceptual model, and determining changes in conditions that may be indicative of new or additional leakage.

Entergy's performance and effectiveness relative to successfully draining water from the Unit 1 spent fuel pool system by the end of 2008, and the quality and effectiveness of its long-term monitoring program, will be the immediate focus of NRC's continuing inspection of Entergy's performance and conformance with regulatory requirements relative to the existing groundwater conditions. Additionally, NRC will continue to inspect the efficacy of the licensee's long-term monitoring program as part of the Reactor Oversight Process pertaining to radiological environmental and effluents inspection activities.

Notwithstanding, radiological significance from the groundwater conditions at Indian Point is currently, and is expected to remain negligible with respect to impact on public health and safety and the environment. NRC has confirmed with the New York State Department of Health, that drinking water is not derived from groundwater or the Hudson River in the areas surrounding or

influenced by effluent release from Indian Point. Accordingly, the only human exposure pathway of merit is from the possible consumption of aquatic foods from the Hudson River, such as fish and invertebrates. Dose assessment of the potential for exposure from this pathway, continues to indicate that the hypothetical maximally exposed individual would be subject to no more than a very small fraction of the NRC regulatory limit for liquid radiological effluent release.

Status of Current Inspection Results:

1. Upon the initial identification of conditions that provided evidence of an abnormal radiological effluent release affecting ground water, the licensee implemented actions that conformed to the radiological survey requirements of 10 CFR 20.1501 to ensure compliance with dose limits for individual members of the public as specified in 10 CFR 20.1302, including: (1) promptly investigating and evaluating the radiological conditions and potential hazards affecting groundwater conditions, on- and off-site; (2) annually reporting the condition, and determining that the calculated hypothetical dose to the maximally exposed member of the public was well below established NRC regulatory requirements for liquid radiological release; (3) confirming, through off-site environmental sampling and analyses, that plant-related radioactivity was not distinguishable from background; (4) initiating appropriate actions to mitigate and remediate the conditions to assure that NRC regulatory dose limits to members of the public and the environment were not exceeded; and (5) developing the bases for a long-term monitoring program to ensure continuing assessment of groundwater effluent release and reporting of the residual radioactivity affecting the groundwater. Additional refinement of the long term monitoring program is expected to occur as data is collected and evaluated to verify and validate the effectiveness of expected natural attenuation of the existing groundwater plumes, and to ensure the timely detection of new or additional leakage affecting ground water.

2. The determination of contaminated on-site groundwater conditions at Indian Point was the result of the licensee's investigation of potential leakage from the Unit 2 Spent Fuel Pool initiated in September 2005, and subsequent development and application of a series of ground water monitoring wells to determine the extent of that condition. No evidence was found that indicated that the events at Indian Point, that resulted in the on-site groundwater contamination (identified to the NRC on September 1, 2005), were the result of the licensee's failure to meet a regulatory requirement or standard, where the cause of the condition was reasonably within the licensee's ability to foresee and correct, and should have been prevented. This determination is based on: interviews with licensee personnel; comprehensive review of pertinent documentation, including previous condition reports, survey records, radiological liquid effluent and environmental monitoring reports, records of historical spills and leaks documented in accordance with 10 CFR 50.75, "Reporting and Recordkeeping for Decommissioning Planning"; and extensive on-site NRC inspection to confirm licensee conformance with required regulatory requirements.

3. The current contaminated groundwater conditions at Indian Point Energy Center are the result of leakage associated with the Unit 1 and Unit 2 spent fuel pool (SFP) systems. No other systems, structures, or components were identified as contributors to the continuing on-site contamination of ground water.

4. Entergy's hydrogeologic site characterization studies provided sufficiently detailed field observations, monitoring, and test data which supported the development and confirmation of a reasonable conceptual site model of groundwater flow and transport behavior. An independent analysis of groundwater transport through fractured bedrock utilizing geophysical well logging data was conducted by the U.S. Geological Survey (USGS). The USGS assessment corroborated the groundwater transport characteristics that were determined by Entergy's contractor.

5. Entergy's hydrogeologic site characterization and developed conceptual site model provide a reasonable basis to support the determination that the liquid effluent releases from the affected spent fuel pool systems migrate in the subsurface to the west, and partially discharge to the site's discharge canal, with the remainder moving to the Hudson River. Current data and information indicates that contaminated groundwater from the site does not migrate off-site except to the Hudson River. This conceptual site model of groundwater behavior and flow characteristics is supported by the results of independent groundwater sampling and analyses conducted by NRC, which have not detected any radioactivity distinguishable from background in the established on-site boundary monitoring well locations, or in various off-site environmental monitoring locations.

6. Currently, there is no drinking water exposure pathway to humans that is affected by the contaminated groundwater conditions at Indian Point Energy Center. Potable water sources in the area of concern are not presently derived from groundwater sources or the Hudson River, a fact confirmed by the New York State Department of Health. The principal exposure pathway to humans is from the assumed consumption of aquatic foods (i.e., fish or invertebrates) taken from the Hudson River in the vicinity of Indian Point that has the potential to be affected by radiological effluent releases. Notwithstanding, no radioactivity distinguishable from background was detected during the most recent sampling and analysis of fish and crabs taken from the affected portion of the Hudson River and designated control locations.

7. The annual calculated exposure to the maximum exposed hypothetical individual, based on application of Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Release of Reactor Effluents for the Purpose of Evaluation Compliance with 10 CFR Part 50, Appendix I," relative to the liquid effluent aquatic food exposure pathway is currently, and expected to remain, less than 0.1 % of the NRC's "As Low As is Reasonably Achievable (ALARA)" guidelines of Appendix I of Part 50 (3 mrem/yr total body and 10 mrem/yr maximum organ), which is considered to be negligible with respect to public health and safety, and the environment.

8. All identified liner flaws in the Unit 2 spent fuel pool, and the initially identified crack affecting the Unit 2 spent fuel pool system have been repaired or mitigated. However, not all Unit 2 fuel pool surfaces are accessible for examination. No measurable leakage is discernable from evaporative losses based on Unit 2 fuel pool water makeup inventory data. Unit 1 spent fuel pool water is being processed continuously to reduce the radioactive concentration at the source prior to leakage into the groundwater, and actions have been initiated to effect the complete removal of spent fuel and essentially all the water from the Unit 1 Spent Fuel Pool system by the end of 2008, thereby terminating the source of 99.9% of the dose significant strontium-90 and nickel-63 contaminants (the remaining 0.1% is represented by the Unit 2 and Unit 1 hydrogen-3 (tritium) contaminants). Entergy's selected remediation approach for the contaminated groundwater conditions appears reasonable and commensurate with the present radiological risk.

9. The historical duration of leakage from the Unit 1 and Unit 2 spent fuel pool systems that resulted in groundwater contamination is indeterminate. The evidence indicates that the volume of leakage was small compared to the available water inventory, and was much less than the normally expected evaporative losses from spent fuel pools. This conclusion is based on NRC staff review and assessment of spent fuel pool makeup inventory records and applicable leakage collection data, the results of the continuously implemented Radiological Environmental Monitoring Program affecting the Indian Point site, and evaluation of the developed hydrogeologic groundwater transport model. Accordingly, there is no evidence of any significant leak or loss of radioactive water inventory from the site that was discernable in the off-site environment.

10. No releases were observed or detected from Unit 3.

11. The conditions surrounding the leaking Unit 1 spent fuel pool are based on a leakage rate of 10 drops per second (about 25 gallons per day) that was identified in 1992. At that time, the licensee performed a hypothetical bounding dose impact that concluded that there was negligible dose impact to the public caused by this condition. This licensee assessment was inspected and evaluated, at that time, by NRC inspectors. This early bounding hypothetical calculation agrees with the dose impact now confirmed by the recently completed hydrogeologic site investigation, and NRC's independent assessment. Based on extensive review of the circumstances and inspection records from that period, it appears that the licensee was in conformance with the standards, policy, and regulatory requirements that prevailed at that time.

REPORT DETAILS

4.0 OTHER ACTIVITIES (OA)

4OA5 Other Activities

.1 Overview of the Groundwater Contamination Investigation

In September 2005, a crack was discovered leaking on the outside of the Unit 2 spent fuel pool south wall (approximately 30 feet below the top) during excavation of the spent fuel building loading bay. The NRC initiated a special inspection on September 21, 2005, to investigate the implications of the observed Unit 2 spent fuel pool leakage. Based on analysis of the radionuclide concentrations in the Unit 2 spent fuel pool and maximum bounding pool makeup losses, a bounding dose calculation based on direct release to the Hudson River indicated a tiny fraction of 1 mrem (0.00002 mrem/yr) as the estimated dose to the maximally exposed hypothetical individual. Though the radiological significance of the circumstance was negligible, the condition was unexpected. Accordingly, NRC Region I was authorized by the Executive Director of Operations (EDO) to conduct additional oversight inspection of licensee performance and the circumstances surrounding this contamination issue to better understand the condition and examine possible generic implications, since similar conditions had been identified at other facilities.

Due to the complicated nature of the groundwater characterization effort at Indian Point (i.e., a relatively small site containing two operating units and one unit in SAFSTOR, built on a complex fractured bedrock foundation that required sophisticated analysis and modeling to fully understand groundwater behavior), the EDO renewed the increased inspection authorization each year to permit active and frequent inspection oversight. As a result, inspection of the Indian Point contaminated groundwater conditions evolved to include not only radiological environmental and effluent expertise from Region I, but also hydrological assessment expertise from NRC's Office of Research, and later, from the US Geological Survey (USGS). The application of such resources permitted the NRC to conduct several independent reviews and assessments of data, information, and analysis on which the licensee based its conclusions and determinations.

In addition, the NRC and USGS specialists, worked closely with the New York State Department of Environmental Conservations (NYS DEC) by sharing data and assessment information, coordinating independent split sampling of various sample media, and providing a combined oversight of licensee performance.

On November 7, 2005, the licensee began installing a series of monitoring wells on-site, based on an initial understanding of on-site groundwater flow patterns and associated contaminant transport. Thirty-six monitoring wells were installed over the next 2 years, with the final well installed and operational by the end of August 2007. The groundwater monitoring network ultimately developed by Entergy includes these plus a number of previously existing monitoring locations. Various geophysical evaluations and analyses, including groundwater table mapping, ground permeability measurements and groundwater gradient calculations, were performed and two site-wide hydrology tests were

conducted to observe groundwater response in a network of monitoring wells. These tests included a 3-day duration groundwater pump-down test from the Unit 2 spent fuel pool (SFP) leak location, and injection of a tracer dye at the base of the Unit 2 SFP to trace its path across the site.

This body of information was utilized by Entergy to determine the sources of the groundwater contamination, evaluate the potential for leak mitigation through pumping, and confirm the site groundwater transport model through a final tracer test. Throughout the investigation frequent iterations were made to refine the extent of groundwater contamination, the total amount of contaminant released to the environment, and the resulting public dose assessment to ensure that public health and safety were maintained.

As additional wells were drilled and sampled, gradually the full extent of on-site ground water contamination was revealed. A short synopsis providing the significant highlights of the licensee's investigation follows, with a more detailed timeline provided in Attachment 1, "Timeline Synopsis".

On February 27, 2006, hydrogen-3 (tritium) contamination was detected in a monitoring well beyond the discharge canal, providing the first evidence of potentially contaminated groundwater being directly released into the Hudson River. On February 28, 2006, the licensee developed a new groundwater release bounding calculation methodology based on an overall site rainfall recharge into several discrete site drainage areas to the Hudson River. On March 21, 2006, radionuclides other than tritium (strontium-90 and nickel-63) were first discovered in a monitoring well, which was later determined to be associated with the Unit 1 spent fuel pool system.

On April 24, 2006, utilizing a rainfall recharge water mass balance approach to calculate groundwater flow and more recent monitoring well data utilizing the maximum concentrations of hydrogen-3 (tritium), strontium-90, and nickel-63, a new revised public dose estimate (from the hypothetical consumption of fish) indicated a maximum hypothetical public dose of 0.0025 mrem/yr to the total body and a maximum of 0.011 mrem/yr to the highest organ (adult bone). These values represent about 0.1% of the regulatory specification for liquid effluent releases contained in the Offsite Dose Calculation Manual. This specification is derived from 10CFR50, Appendix I, As Low As is Reasonably Achievable (ALARA) design objectives for liquid effluent releases.

The basis for calculating public doses is site specific, and at Indian Point, is based on the hypothetical, assumed consumption of fresh water fish and salt water invertebrates. Due to a higher dose significance of strontium-90 detected in groundwater releases, Entergy revised its Off-site Dose Calculation Manual (ODCM) to include the analysis of strontium-90 in environmental media, such as fish and invertebrates collected from the Hudson River. Consumption of fish was assumed notwithstanding the fact that the New York State Department of Health publishes health advisories for sport and game fish and recommends very limited or no consumption of fish be taken from the lower reaches of the Hudson River due to mercury and Poly-Chlorinated Biphenyls (PCB) contaminants.

Subsequently, during the summer of 2006, Entergy collected and analyzed fish from the Hudson River, and strontium-90 was identified in one fish collected near the plant as well as in several fish caught in a control location 20 miles upstream of the plant at similar concentrations. In order to resolve whether the strontium-90 was plant-related or the result of existing background levels (Sr-90 exists in environment due to weapons-related fallout), an expanded fish sampling program was devised by the New York State DEC. The program included an additional 90 mile upstream sample location, the collection of specific fish species identified by the State's biologist as having limited migratory behavior, and a three-way split of the edible fish portions of the prepared samples between NRC, Entergy, and the NYS DEC. The effort was conducted in June 2007. In the expanded samples, all three independent analytical laboratories reported results that indicated that no plant-related radioactivity was detected or distinguishable from background. To date, no offsite environmental samples (other than water samples from the discharge canal and the tidally influenced intake structure) have indicated any detectable plant-related radionuclides,

The USGS performed an independent fracture flow analysis to determine on-site groundwater flow utilizing different data and methods than Entergy to compare groundwater flow results with the licensee. This provided a comparison of fracture flow dominated groundwater flow with the licensee's groundwater flow results based on an assumption of general porous media flow through dense fracture sets in the ground. No significant differences were observed from these comparisons, which essentially confirmed that either model of groundwater transport flow provided valid results.

On January 11, 2008, Entergy submitted a hydrogeologic site investigation final report to the NRC documenting closure of the groundwater investigation, adoption of selected remediation actions, and a plan for the continued long-term monitoring of the existing contaminant plumes (ADAMS Accession No. ML080320600). On January 25, 2008, Entergy submitted a synopsis of the long term monitoring plan basis to describe a groundwater monitoring network and a sampling schedule to continue monitoring the existing plumes, detect any future Unit 2 spent fuel pool leaks, and detect any future leaks from any other plant systems structures or components at the site (ADAMS Accession No. ML080290204).

This inspection report provides NRC review of the above mentioned licensee activities. Continued NRC inspection will continue through 2008 of the removal of spent fuel and draining of the leaking Unit 1 spent fuel pool, split sampling to verify the basis of licensee's off-site dose assessment, and review of further development and refinements to the licensee's long term monitoring plan. Inspection findings will be documented in future reports.

.2 <u>Final Groundwater Contamination Characterization</u>

By the end of 2007, based on over 900 monitoring well samples, the extent of the on-site subsurface contamination had been mapped and the sources have been determined. Two on-site plumes were discovered emanating from the Unit 2 and Unit 1 spent fuel pool regions, respectively. Due to the influence of the Unit 1 building foundation drain system, some of the Unit 2 plume was drawn into the Unit 1 area, with both plumes intermingling

and following a converging path westward towards the Hudson River. Both plumes were relatively shallow (less than 200 feet below ground surface) following a common groundwater trough between Units 1 and 2, and a groundwater transport velocity of between 4 and 9 feet per day, covering a total distance of about 400 feet to the Hudson River (see Figure 1). Approximately one-half of the combined plumes are being intercepted by the plant discharge canal which allows for substantial dilution of this fraction and is a monitored discharge path. The other portion of the combined plumes flows below the discharge canal and discharges directly into the bottom of the Hudson River.

Due to limited groundwater sampling of the new river front monitoring wells across normal seasonal groundwater flow variations, no trend in plume concentrations is yet discernable. Current contaminant concentrations detected from monitoring wells closest to the Hudson River indicate 9,000 pCi/L of hydrogen-3 (tritium) and 27 pCi/L of strontium-90. A map of monitoring well locations and a table of radionuclide concentration values at each monitoring well are provided in Attachment 2.

These concentrations are slightly below the minimum required effluent release detection sensitivities for these radionuclides (i.e., 10,000 pCi/L for hydrogen-3 (tritium) and 50 pCi/L for strontium-90), and well below the maximum allowable liquid effluent release ALARA guidelines of ten times the effluent concentrations in 10 CFR 20, Appendix B, Table 2, Column 2 (10,000,000 pCi/L for hydrogen-3 (tritium) and 5,000 pCi/L for strontium-90). NRC required calculation of the maximum dose to a hypothetical person consuming fish and invertebrates at the site boundary, indicates less than 0.1% of design objectives for liquid effluents (3 mrem total body and 10 mrem maximum organ). Since the groundwater contamination is considered an abnormal release, the condition is required to be quantified, evaluated and reported in the annual radiological effluent release reports.

.3 Groundwater Sampling

a. Inspection Scope

During the licensee’s groundwater investigation, over 900 groundwater samples were collected and analyzed from the established on-site monitoring well network by the end of 2007. The analytical results provide the basis for assessing the extent of the groundwater plume and for performing calculations of offsite doses to members of the public. In order to assess Entergy’s performance in this area, the NRC implemented an independent split sample collection program with the licensee beginning in September 2005. The monitoring wells selected for independent verification included the southern boundary wells and those bordering the Hudson River that were utilized in effluent release and dose assessment calculations. Sample identity was assured by chain-of-custody procedures that included sample collection observation by the NRC or a representative of the NYS DEC. The NRC samples were analyzed by an independent government laboratory. The NRC samples were sent to the NRC contract laboratory, the Oak Ridge Institute for Science and Education (ORISE), Environmental Site Survey and Assessment Program (ESSAP) radioanalytical laboratory.

By the end of 2007, over 250 split groundwater samples were obtained to provide an independent check of Entergy's analytical results and to independently verify if there was any detectable migration of groundwater contaminants offsite. These split samples represent over 1,000 analyses, primarily for hydrogen-3 (tritium), strontium-90, nickel-63, and gamma-emitting radionuclides that characterized the effluent releases. Analyses for other radionuclides were performed, but none were detected.

Various in-plant contamination sources (the Unit 1 and 2 spent fuel pools and others) were also sampled and analyzed by the NRC for a complete range of radionuclides to evaluate the known and potential leaking sources of radioactivity, and to ensure an adequate scope of radionuclide analysis was conducted by the licensee in their groundwater sampling campaign. In addition, the NRC analyzed miscellaneous environmental samples of interest including offsite water supply sources, Hudson River aquatic vegetation, and fish samples. The New York State DEC also provided confirmation of the licensee's sample analysis results through a parallel split sample program. This provided for a three-way laboratory comparison of many of the offsite release and environment-critical sample results. This three-way data comparison provided for timely identification of any discrepant sample results potentially affecting offsite releases.

b. Findings and Assessment

No findings of significance were identified.

In general, Entergy's groundwater measurements of radioactivity were of good quality and of sufficient sensitivity to assess radiological impact. The quality of Entergy's measurements were confirmed by various split samples analyzed by NRC and the State of New York, (i.e., the Department of Environmental Conservation and the Department of Health). Of the over 1000 results that were reviewed, there were some sample disagreements based on the statistical comparison criteria specified in NRC Inspection Procedure 84750, "Radioactive Waste Treatment, and Effluent and Environmental Monitoring." A discussion of the sample disagreements is provided below.

- Between March and September 18, 2006, Entergy reported some strontium-90 results associated with the Unit 1 plume that were low when compared to NRC results. Entergy's results indicated that the Unit 1 spent fuel pool cleanup system had shown a reduction in the associated groundwater plume concentrations over a relatively short period of time. There was no other consequence due to this disparity. Entergy initiated an investigation into this issue with their offsite contract laboratory. The investigation did not identify a definitive cause. As a result, Entergy terminated its contract with the lab and procured the services of another offsite laboratory. Entergy's reanalysis of the samples confirmed that the original results were low. The reanalysis results were subsequently in agreement with the NRC laboratory results.

- Entergy reported no detectable nickel-63 contamination in four samples from Monitoring Well-42 taken on November 16-17, 2006. Since Monitoring Well-42 is closest to the Unit 1 SFP, and other radionuclides analyzed at the same location remained at expected levels, this indication was not considered reasonable and

was also not in agreement with the New York State or NRC laboratory results. This resulted in an investigation into this issue by the licensee's new off-site contract laboratory. Improper procedure protocol was identified and additional controls were implemented to correct this issue. Reanalysis of the nickel-63 results were in agreement with the NRC laboratory results. No other significant sample anomalies were identified by the NRC through the end of 2007.

The above NRC-identified discrepancies highlighted the need for quality control in the licensee's sample acquisition and laboratory processing and measurement processes. Oversight of offsite laboratory analysis of samples was not originally specified by the licensee for on-site groundwater sampling. NRC radiological environmental monitoring program laboratory quality control requirements, specify radionuclide detection sensitivities, and require blind blank samples and blind radionuclide-spiked samples to be provided by the licensee as a check on the off-site laboratory's analytical performance. These requirements apply to the offsite radiological environmental monitoring program, but no requirements are specified for on-site groundwater sample quality controls.

NRC radiological effluent sampling analyses also require laboratory quality controls as specified above. On February 27, 2006, based on detecting hydrogen-3 (tritium) in a monitoring well near the Hudson River, Entergy revised their bounding dose calculation and began calculating actual effluent releases via the groundwater pathway. At this point in the groundwater investigation, the quality assurance of groundwater sample analyses used in effluent reporting became a requirement. However, the offsite laboratory analyses of groundwater samples were not independently evaluated by Entergy until more than one year later. Technical Specifications Section 5.4.1(a) specifies written procedures shall be established, implemented, and maintained covering Appendix A of Regulatory Guide 1.33, Revision 2, which specifies quality assurance requirements for procedures associated with the control of radioactive effluents released to the environment. The inadequate procedure (O-CY-1420, Rev. 1), constitutes a violation of minor significance that is not subject to enforcement action in accordance with Section IV of the NRC Enforcement Policy. There was no actual or potential consequence of this procedure deficiency, because in function, the NRC and NYS DEC split sampling program provided a very effective verification of Entergy's laboratory sample analysis program during the groundwater investigation by assuring the accuracy of analytical results.

To address this concern, in May 2007, Entergy initiated an on-site groundwater sampling quality control program incorporating a blind blank sample and blind radionuclide-spiked sample program to verify its own offsite laboratory analytical results. In addition, Entergy's corrective action program is still addressing the quality control program requirements relative to groundwater sample analysis, with corrective action responsibilities transferred to the corporate group for resolution (CR-HQN-2007-00894). NRC split sample analysis comparison of the licensee's groundwater sample results are expected to continue until such time as Entergy has addressed all of the concerns associated with laboratory quality assurance issue.

Due to the presence of strontium-90 in groundwater monitoring wells close to the Hudson River, Entergy modified their environmental monitoring analysis of fish samples to include strontium-90 analysis and in September 2006, strontium-90 was detected in one of six fish caught near the plant. Three out of six samples caught 20 miles upstream at the control location also contained similar detectable levels of strontium-90. Entergy concluded that no strontium-90 was detected above background based on similar results obtained from the control location. Strontium-90 is not uniquely generated by nuclear power plants, but was also generated from above ground nuclear testing in the early 1950's and 1960's and now exists ubiquitously in the environment. From a review of applicable scientific literature, comparable levels of strontium-90 that were detected in the September 2006 fish samples were also indicated in background fish testing results in other parts of New York State.

To further clarify the origin of the strontium-90 and confirm the efficacy of utilizing Entergy's control location in monitoring background strontium-90 concentrations in fish, an expanded fish sampling program was conducted in June 2007 led by NYS DEC, in consultation with its fish biologists, to ensure that the control location is sufficiently removed from Indian Point to preclude fish migration and to accurately represent background levels of strontium-90. This expanded fish sampling program collected fish samples from three Hudson River locations: an area influenced by liquid releases from Indian Point, a control location 20 miles upstream, and a special control location 90 miles upstream in the Catskills. Three-way split fish samples were supplied to Entergy, NYS DEC and NRC for inter-laboratory comparison of these results. Neither strontium-90 nor any plant-related radionuclides were detected in any edible fish samples by any of the three participating laboratories at any of the three Hudson River locations. This is considered significant, since public doses from liquid discharges from Indian Point are calculated based on assumed fish and invertebrate consumption. This confirms the results expected from the groundwater effluent and normal plant liquid effluent release calculations, indicating small fractions of one millirem per year to the maximally exposed hypothetical member of the public that consumes fish and invertebrates.

.4 Dose Assessment

a. Inspection Scope

Groundwater effluent discharges and associated hypothetical dose calculations to the public involve a two-step process. First, a groundwater transport model is developed to estimate the amount of radioactive material being discharged and its dilution into the environment. The hydrogeologic site investigation of Indian Point has provided the results for determining this aspect of the dose calculation.

Second, based on methods defined in the Indian Point Energy Center Offsite Dose Calculation Manual (ODCM), calculations are performed to determine the maximally exposed individual (infant, child, teen or adult) and maximum organ (bone, kidney, gastro-intestinal tract, liver, thyroid, lung and total body). NRC has confirmed with the NYS Department of Health that groundwater and Hudson River water is not used for drinking or irrigation purposes in the area surrounding Indian Point Energy Center. Therefore, at Indian Point Energy Center, the liquid effluent dose pathway is through the

ingestion of fish and invertebrates (crab). Both the groundwater effluent discharge and the pathway-to-man methodologies and calculation methods were reviewed throughout the licensee's investigation in order to ensure that the significance of the liquid effluent releases were bounded and the associated dose impact was evaluated to provide an accurate dose assessment of public health and safety.

b. Findings and Assessment

No findings of significance were identified.

The licensee performed an initial conservative bounding dose calculation, dated October 21, 2005, that assumed a worst case condition, i.e., Unit 2 spent fuel pool water being discharged directly into the Hudson River with minimal Hudson River dilution flow (approximately 100,000 gallons per minute). This dose assessment assumed a conservative Unit 2 SFP leak rate of 2.6 gallons per day[1] incorporating all the radionuclides detected. The resultant calculated dose was about 0.0001 millirem/year, well below the ALARA design objectives for liquid effluent releases (3 millirem/year per reactor) and a very small percentage of the public dose limits (100 millirem per year).

The inspectors concluded that the licensee's preliminary offsite dose calculation utilized conservative assumptions regarding the Unit 2 SFP leak rate and groundwater dilution, appropriately applied the methodology of the licensee's Offsite Dose Calculation Manual, provided a timely dose evaluation response to the identified condition.

As more data became available, the licensee performed a revision to the conservative bounding calculation, dated December 13, 2005, using Hudson River dilution based on a six hour half-tidal surge. This resulted in a dilution volume of 1.45E10 gallons. This revised bounding dose calculation was based on the actual radioactivity concentration of the Unit-2 SFP and the resultant annual dose to the hypothetical maximally exposed member of the public was calculated to be about 0.0001millirem/year. This revision was based on conservative and reasonable assumptions and agreed with the result from the original bounding calculation.

As on-site groundwater monitoring wells were installed, groundwater sample results were collected, water table contours were identified, and groundwater transport parameters were determined. Entergy developed a site area drainage model based on annual rainfall groundwater recharge water balance and applied maximum monitoring well groundwater concentrations, which was used in a February 28, 2006 effluent release and off-site dose calculation with a result of 0.000015 mrem/yr to the maximally exposed hypothetical member of the public. This was no longer a bounding calculation, but represented an actual groundwater effluent release determination based on groundwater measurements and groundwater drainage calculations. Radiological and hydrogeologic inspection of this method determined that the basis was reasonable and the calculations were accurate.

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[1]The basis for the assumed value of 2.6 gallons per day is discussed in Section 5 of this report.

Later in the investigation on March 21, 2006, NRC sample results of Monitoring Well-37 (a river front monitoring well) indicated strontium-90 concentration of 26 pCi/L. This was the first indication that strontium-90 was likely being released directly to the Hudson River through the groundwater. Licensee results confirmed both strontium-90 and nickel-63, in addition to hydrogen-3 (tritium), were likely migrating to the Hudson River. The dose significance for these additional radionuclides is over one hundred times that of hydrogen-3 (tritium). On April 24, 2006, Entergy updated their dose assessment in recognition of this new monitoring well data, and applied the maximum concentrations of hydrogen-3 (tritium), strontium-90 and nickel-63. The resulting groundwater effluent discharge and off-site dose assessment indicated a maximum hypothetical public dose of 0.0025 mrem total body and 0.011 mrem maximum organ dose (adult bone) per year. The increase from the previous dose estimates is a direct result of the strontium-90 and nickel-63 radionuclides.

As additional groundwater sample data became available, the licensee's dose assessment model was further refined to rank the monitoring well sample data in each site drainage area from low to high, and apply a 75^{th} percentile of radionuclide concentration to the dose assessment calculations. This approach was determined to be more realistic and yet still conservative. Utilizing this methodology, abnormal groundwater effluent releases were calculated and the following doses for groundwater releases in 2005 and 2006 were officially reported to the NRC in the annual radiological effluent release reports as follows:

2005: 0.00212 mrem total body and 0.0097 mrem maximum organ (adult bone)
2006: 0.00178 mrem total body and 0.0072 mrem maximum organ (adult bone)

Based on discussions with the NRC and USGS hydrologists, Entergy agreed to further evaluate the groundwater flow rate model to utilize groundwater flux calculations based on Darcy's Law, a hydrogeological algorithm that considers actual groundwater gradient and soil permeability rather than inferring groundwater flow based on a rainfall infiltration model. Accordingly, Entergy initiated actions to develop a refined method to calculate local drainage area groundwater flux calculations based on Darcy's Law while retaining an overall rainfall infiltration as input to the local drainage calculations. Entergy intends to use this approach to calculate and report the 2007 groundwater effluent discharges and dose assessments.

.5A Unit 2 SFP Leakage

a. Inspection Scope

The Unit 2 SFP does not have a leak detection system, therefore, the licensee used alternative means of assessing the amount of leakage from the spent fuel pool. Detectable fuel pool inventory loss could not be determined based on fuel pool water makeup records, given the variability in water evaporation loss due to atmospheric temperature, pressure, and humidity variations. A more sensitive indicator of spent fuel

pool water loss utilized the trending of spent fuel pool boric acid concentration over time, since boric acid is not affected by evaporative losses and any reduction in boric acid concentration would likely be due to leakage.

The NRC followed Entergy's progress in examination of the Unit 2 SFP liner and transfer canal for leaks and subsequent repair of a through-wall leak in the transfer canal.

As was reported in the March 16, 2006 special inspection report, NRC investigation into the capture efficiency of the Unit 1 building foundation drain system indicated approximately seven times more hydrogen-3 (tritium) radioactivity was captured by the drain system than was accounted for by Unit 1 SFP leak calculations. Evidence from the hydrogeologic site investigation confirms the source of this additional tritium radioactivity is from the Unit 2 SFP. Based on this understanding, additional NRC analysis used historical Unit 1 building foundation drain system hydrogen-3 (tritium) sample results to attempt to assess the age and variation of the Unit 2 SFP leak since 1999.

b. Findings and Assessment

No findings of significance were identified.

A review of daily boron concentration measurements in the Unit 2 spent fuel pool since the last refueling outage indicated a decrease of 7 parts per million (ppm) (normally 2,300 ppm) over a one year time period. This measurement provided a bounding water loss value of 2.6 gallons per day (gpd), with a large uncertainty of +/- 7.2 gpd. This uncertainty indicates that no definitive loss of spent fuel pool inventory could actually be determined with any certainty.

The licensee has pursued consistent efforts to inspect the Unit 2 spent fuel pool stainless steel liner for evidence of leaks. Approximately 40% of the liner was inspected by underwater video camera. No leakage was determined on the surfaces examined. The remainder of the pool liner surfaces is inaccessible to optical examination due to limitations imposed by the proximity of the fuel racks and other obstructions. Beginning in July 2007, Entergy lowered the water level in the Unit 2 fuel transfer canal, which is immediately adjacent to the spent fuel pool, in order to examine those surfaces for possible leaks. One pinhole leak was discovered and was subsequently repaired on December 15, 2007. An expert review of the material condition of the leak determined that it was due to an original welding construction flaw, and that there were no indications of any active corrosion on the transfer canal surfaces.

Notwithstanding that all identified potential leak locations have been repaired, most of the spent fuel pool surfaces remain unexamined, with the potential for unidentified leaks remaining. Since the Unit 2 spent fuel pool was constructed without a leak collection system, groundwater monitoring remains the only means for assessing leakage from the Unit 2 spent fuel pool.

.5B Unit 1 SFP Leakage

a. Inspection Scope

A review of available licensee records was conducted to search for any possible indications of the beginning or duration of the Unit 1 SFP leak. Records were also reviewed to evaluate the licensee's response to the initial discovery of Unit 1 SFP leakage, and the adequacy of corrective actions to repair or mitigate the effects of the identified leakage based on regulatory requirements and information known at the time.

b. Findings and Assessment

No findings of significance were identified.

A search for historical Unit 1 control room logs and for Unit 1 spent fuel pool inventory makeup records was initiated, but no pre-1994 records were found. Without those records, which are no longer required to be maintained, no data was available to indicate past water inventory makeup trends. The water makeup records and control room log entries represented the only potential data records to evaluate the onset of Unit 1 SFP leakage, which remains indeterminate.

The initial licensee's corrective action program identification and investigation of the leaking Unit 1 SFP (SAO-132 Report 94-06), identified a net fuel pool leak rate (subtracting evaporative losses) of 25 gallons per day, or 10 drops per second, attributed to age-related degradation of the fuel pool epoxy coating, which resulted in pool water penetrating through the fuel pool concrete walls and floors. The corrective actions associated with Report 94-06, included a large scope of investigative activities aimed at identifying potential leakage paths within the Unit 1 plant structures, including groundwater collected in the external Unit 1 building foundation drain system (Figure 2). Bounding dose calculations performed by the licensee in 1994, which assumed four times the identified leak rate released to the Hudson River, indicated that the resulting dose from such a liquid release would be <0.1% of the liquid effluent regulatory specification and ALARA guidelines.

The NRC conducted three separate team inspections in 1994 (specified in Attachment 1) to assess the licensee's identification and resolution of the leaking Unit 1 spent fuel pool condition and based on a comprehensive review concluded that the licensee's investigation was responsive to this concern and the potential impact on the public health and environment. Further, that the licensee's investigation incorporated all reasonable probable pathways of release and had demonstrated no off-site dose impacts would be attributable to pool leakage based on enhanced environmental surveillance.

Entergy's investigative activities did not result in correcting the degraded condition of the Unit 1 spent fuel pools or otherwise eliminate the identified leakage. Unit 1 licensing and procedural requirements were reviewed and no corrective action program violations were identified. NRC requires safety-related functions of plant components to be repaired or corrected in accordance with 10 CFR 50, Appendix B, Criterion XVI. However, the leak rate from the pool did not affect the safety-related function of the Unit 1 spent fuel pool

(associated with spent fuel cooling), and the off-site dose consequence of the leakage was evaluated and determined to have no significant dose impact. Therefore, there was no condition adverse to quality and no violation of NRC requirements identified.

This 1992 investigation was the earliest documentation confirming leakage of the Unit 1 SFP. Since 1992, the leakage rate remained constant until the Fall of 2005, when the Unit 1 West SFP was flooded up to allow fuel inspection as part of the future dry cask storage relocation of the spent fuel. After lowering the water level back down and draining the surrounding pools in November 2005, the Unit 1 West SFP leak rate increased to 70 gallons per day due to a higher water pressure forcing more water to drain through the preexisting cracks to the surrounding now drained Unit 1 spent fuel pools. Based on the tritium concentration measured in the Unit 1 West SFP and the current leakage rate, a comparison of tritium leaking from the Unit 1 West SFP and the total tritium collected by the Unit 1 building foundation drain systems could be compared. Latest calculations indicates that there is approximately three times more tritium collected than can be accounted for from Unit 1 West SFP leakage.[2]

Based on the hydrogeologic site investigation, it is now known that the source of the additional tritium activity is due to migration of tritium contaminated water from the Unit 2 SFP, in the unsaturated zone southward towards Unit 1 and being drawn into the groundwater cone of depression created by the Unit 1 building foundation drain system. Recognizing that the Unit 1 West SFP leak condition was stable at about 25 gpd prior to the Fall of 2005 with a stable radioactive source term, historical review of licensee data was used to evaluate the change in the Unit 2 SFP leakage over time since approximately 75% of the tritium collected in the Unit 1 foundation drainage system was due to the Unit 2 SFP leak.

This evaluation was considered necessary to help investigate the results of a sample taken in the Spring of 2000 from Monitoring Well-111 when Entergy was exploring the possibility of purchasing Unit 2. No tritium was detected in the sample. The monitoring well is located in the current Unit 2 SFP tritium plume. The sensitivity of the sample method should have detected any tritium above 270 pCi/L. This fact would indicate that the Unit 2 SFP tritium plume did not exist in the Spring of 2000, and that the SFP leak may have begun more recently. Entergy's site characterization report indicates the sample was not a reliable groundwater sample as it was taken from the surface of the well without any purging and was, therefore, not considered representative of the groundwater at this location. In order to determine the efficacy of the Spring 2000 Monitoring Well-111 sample and the possibility of a more recent SFP leak, the Unit 1 building foundation drain collection data was accessed to provide an indication of excess tritium infiltration (attributable to Unit 2 SFP leakage) around the time of the Spring 2000 Monitoring Well-111 sample compared to the present time.

If there was no tritium plume emanating from the Unit 2 SFP at that time, then there should be a significant reduction (approximately 75%) in the tritium input to the Unit 1 building foundation drain system. Otherwise, Entergy's site characterization model,

[2] The March 16, 2006 Special Inspection Report indicated a higher unaccounted for tritium balance due to a calibration issue with a flow rate monitor, a condition that has been corrected.

which suggests a long-term tritium leak, would be reasonable. The following table summarizes data extracted by the NRC from licensee data. The two Unit 1 building foundation groundwater drain systems consist of the north curtain drain (NCD) and the sphere foundation drain (SFD). The combination of both of these two french drain type systems represents the total tritium collected annually based on weekly sample collections.

Unit 1 Drain Tritium Collection

Year	SFD uCi	SFD flowrate gpm	NCD uCi	NCD flowrate gpm	Total uCi	Total flowrate gpm	Corrected[3] uCi
1999	8.82E4	18	6.0E5	3	6.9E5	21	4.6E4
2005	2.67E4	24	5.8E4	3.6	8.5E4	28	5.6E4
2006	5.2E4	17	4.7E4	4	9.9E4	22	6.6E4
2007	2.6E4	11	2.7E4	2.8	5.3E4	14	5.3E4

As can be seen, in the final corrected column in the table above, there has been a consistent amount of tritium collection in the Unit 1 drain system that predates the “due diligence” sampling of Monitoring Well-111 in the Spring of 2000. This would indicate that the Unit 2 SFP tritium plume was being captured by the Unit 1 drain system in 1999 as currently characterized, and that the Spring 2000 Monitoring Well-111 sample may not be a valid sample. This confirms the designation as an invalid sample as stated in Entergy’s hydrogeological final report.

Considering factors including the radiological and non-radiological contamination condition at Unit 1, Entergy determined that any immediate remediation (such as groundwater pump down) of the existing contaminated groundwater in the vicinity of the Unit 2 spent fuel pool would be inappropriate at this time. Such remedial action could adversely affect the current groundwater contamination condition, in particular, it would create a situation in which contaminated water that is currently collected, monitored and discharged from the Unit 1 drain systems in accordance with NRC regulatory requirements, to spread elsewhere unnecessarily. Accordingly, the NRC agrees that, in the absence of any over-riding public health and safety concern, pump and treat remediation of the Unit 2 SFP could adversely affect the spread of the Unit 1 groundwater contamination plume and is not advisable.

.6 Hydrogeologic Investigations

a. Inspection Scope

NRC Region I Inspectors, and scientists from the U.S. Geological Survey (USGS) and NRC’s Office of Research made numerous visits to the IPEC site to observe site features, test hole drilling and sampling, rock cores recovered from the test wells, groundwater quality sampling, tracer and pump test procedures, and other site

[3] In 2006, the SFD flowrate monitor was found to be significantly overestimating the flow rate by 50%; therefore assuming relatively constant annual groundwater flow, the total tritium results for the prior years was reduced by 50% to provide a normalized comparison.

characterization and monitoring activities. During these site visits, the inspection team interviewed Entergy staff and contractors, i.e., GZA GeoEnvironmental, Inc. (GZA) geotechnical engineers, geologists, and hydrogeologists, and examined their methods, analytical results and bases for conclusions regarding groundwater contamination transport at Indian Point Energy Center.

b. Findings and Assessment

No findings of significance were identified.

The purpose of the hydrogeological investigation was to identify the on-site, and potential off-site, pathways for the abnormal releases, and to define the conceptual site hydrologic model controlling the subsurface transport of the released radionuclides.

Initially there were significant uncertainties in defining the tritium pathway (the first detected abnormal release radionuclide). In discussions with GZA, it was apparent that the tritium source(s) and pathway(s) were not fully defined. Questions were raised as to the groundwater flow direction, which the IPEC FSAR Section 2.5 references indicated was to the south. Based upon water-level data taken by GZA from a series of installed test wells, the groundwater gradient was initially determined to be west to the Hudson River in the vicinity of the Screen Wall Structure building (near Monitoring Well-67). Upon close examination of the water-level data for the full complement of test wells, the groundwater flow direction was confirmed to be the west and, therefore, the tritium plume was determined to follow the gradient to the Hudson River. Tritium moves at the same rate as the groundwater since it is part of the molecular water composition. Analysis of monitored water levels, temperature and water quality demonstrated tidal effects from the river affecting groundwater flow conditions along the river bank and upgradient to the Discharge Canal.

The question of preferential flow pathways was raised due to the nature of the bedrock underlying the IPEC site, the Inwood Marble, being a metamorphosed carbonate with numerous fractures. These fractures, which can be observed on-site and in the Verplanck Quarry as shown in Figure 3, were inspected for the possibility of solutioning and connectivity. The rock cores collected during the drilling of the test wells were examined for fractures, solutioning and fracture filling. In order to confirm the Entergy/GZA determinations a range of possible conceptual site models were examined to determine the influence of fracturing, solutioning and fracture filling on contaminant transport. In order to fully investigate and independently analyze alternative conceptual site models involving preferential groundwater flow pathways, NRC developed an Interagency Agreement with the USGS - New York Water Science Center located in Troy, New York.

The USGS conducted a detailed flow-log analysis for hydraulic characterization of selected test wells. This analysis examined fracture geometries and hydraulic properties in the bedrock using flow logs, as well as downhole caliper, optical- and acoustic-televiewer, and fluid resistivity and temperature logs, collected in the test wells by Geophysical Applications, Inc. under the direction of GZA. The USGS analysis determined the distribution and character of fracture-flow zones. Hydraulically active

fractures were identified in these zones. Transmissivity and hydraulic heads in these flow zones were estimated using the flow-log analysis method. As reported in USGS Open File Report 2008-1123 "Flow-Log Analysis of Hydraulic Characterization of Selected Test Wells at the Indian Point Energy Center (IPEC), Buchanan, New York" (ADAMS Accession No. ML081120119), the flow-log analysis was corroborated with pump test and tracer test results from GZA's site characterization and analyses.

Figure 4 shows the presence of intersecting (conjugate) fracture sets which provide higher permeability zones and create directional flow properties (anisotropy). These analyses were confirmed by pump test results, and later, tracer test results and observations showing distinct fracture zones and variable permeability in the Inwood Marble between the Unit 1 and 2 SFPs extending west to the Discharge Canal. No solution features affecting radionuclide transport were observed or detected by the field testing and USGS independent analysis. However, fracture connectivity was observed and is a contributor to preferential flow and transport, particularly in partially-saturated bedrock (i.e., above the water table) as demonstrated by the GZA tracer test results. Certain site areas subject to extensive rock backfills, such as the excavated-blast depressions in the transformer yard and along the river, which are porous-flow dominated rather than fracture-flow dominated as indicated in the bedrock.

Early in the investigations, the Discharge Canal was thought to capture the tritium plume. NRC staff questioned this assumption and encouraged its testing. GZA installed Monitoring Well-37 west of the Canal and down gradient of the plume to test the assumption. Sampling in Monitoring Well-37 confirmed that the tritium plume did continue west under the canal toward the Hudson River; however, a significant amount (perhaps up to 50%) of tritium was captured by the canal. Sampling in Monitoring Well-37 also identified strontium-90 which extended the scope of the investigation.

As the conceptual site model (CSM) was developed using observed tritium and strontium-90 monitored data from the numerous monitoring wells, the role of backfill material around buildings and in excavated depressions (e.g., transformer yard and along the river) was investigated by GZA. The role of storm drains, sump pumps and curtain drains on the local hydrology was also investigated and analyzed. The conceptual site model, as reported in the licensee's Hydrogeological Site Investigation Final Report (GZA report), recognized the affect of these features relative to the observed tracer test results and contaminant plume behavior. The conceptual site model incorporated both natural features (e.g., water-levels and flow directions) and human-made features (e.g. building foundations, backfills, curtain drains, storm runoff drains and manholes). The conceptual site model considered percolation to the unsaturated zone, where the Unit 2 tritium source emanates, and flows to the water table. The strontium source was determined to enter the water-table via the north curtain drain surrounding the Unit 1 SFP, and also from the spray foundation sump. Both the tritium and strontium plumes migrate through the connected fractured zones to the Hudson River. Cross-sectional diagrams from the GZA report, shown in Figure 5, depict the flow and transport pathways to the river, including the location of monitoring wells down gradient of the radionuclide sources. Tracer test and radionuclide sampling data from these monitoring wells support the conceptual site model assumptions.

A pump test using Recovery Well-1, with observations in the surrounding monitoring wells, was performed to test the feasibility of a pump, monitor and discharge remediation approach for the tritium plume, and to create a depressed water table (drawdown cone) beneath Unit 2 SFP to capture and provide early detection of abnormal releases. The operation of the Recovery Well-1 caused cesium-137, which had not been previously detected in monitoring wells, to migrate to Monitoring Well-31 and Monitoring Well-32 (west of the Unit 1 and 2 SFP's). This test confirmed the presence of cesium-137 in the fractured rock, and the connectivity of the fractures in the aforementioned fracture zones between the Unit 2 and 1 SFP's. The migration of cesium-137 from Unit 1 to Unit 2 during the test confirmed that the pump test should be conducted at very low pumping rates in the event that other radionuclides were present in the fractured rock and could become mobilized. The fracture filling in the bedrock appears to adsorb the cesium during ambient groundwater flow conditions.

Using insights from this pump test, GZA planned and conducted a tracer test adjacent to Unit 2 SFP at the base of the construction pit where the original abnormal releases of radionuclides were observed. A fluorescein dye tracer was introduced in a shallow borehole above the water table. At the suggestion of NRC staff, the tracer sampling continued for a significantly longer period of time than would be normal to fully detect and analyze the transport pathways. The tracer results confirmed the aforementioned conceptual site model pathways, and identified the role of the fractures in creating preferential transport in the unsaturated zone, and the role of human-made features relative to the observed tritium concentrations in the monitoring wells and Manhole 5 adjacent to Unit 2 SFP. The tracer sampling identified the contaminant pathway direction, transport rate and attenuation for both the tritium and strontium plumes. Since strontium-90 is adsorbed by the fracture filling materials (e.g., clays), the tracer moved at a faster rate than the strontium plume. The residual cesium-137 appears to be relatively immobile due to adsorption and the relatively slow groundwater velocity in the fracture zones until increased by local flow perturbations such as groundwater pumping.

The extensive IPEC site characterization data as reported in the GZA report includes: water levels; tidal effects; upward and downward flow components determined by flow meters and by using the Waterloo packers (i.e. inflatable bladders to vertically isolate fracture zones in a well); tritium and strontium concentrations; and pump and tracer test results. This database provides valuable site-specific information to confirm the conceptual site model (CSM) and dose calculations. This information also provides a valuable two-year baseline for future long-term monitoring and re-evaluation of the conceptual site model since seasonal groundwater flow dynamics, episodic recharge and potential future releases may alter the assumptions in the CSM. This information is also critical in determining the adequacy of the Entergy's chosen remediation approach of monitored natural attenuation for the tritium and strontium-90 plumes.

Monitored natural attenuation refers to the natural groundwater removal of residual contaminants after the source of contamination has been secured, and the radioactive decay acts to diminish the remaining residual radioactivity. Monitored natural attenuation requires the elimination of the contaminant sources, detailed monitoring of the plumes' behavior through a confirmatory groundwater monitoring program and confirmation of the conceptual site model, over time.

The licensee indicated that its long-term groundwater monitoring program will incorporate monitored natural attenuation and have a detection capability for potential future abnormal releases. Future NRC inspection will review the program details to focus on achieving the goals of monitored natural attenuation and detecting future leaks. Specific areas of review include determining which monitoring wells and what monitoring frequencies are needed to demonstrate monitored natural attenuation, early radionuclide leak detection and if the assumptions in the conceptual site model are valid. The long-term groundwater monitoring program will be reviewed in a future NRC inspection to ensure there is sufficient detection sensitivity and monitoring frequency to detect changes in Unit 2 SFP leakage and the capability to detect leaks from other plant components in the presence of existing groundwater contamination.

.7 Prior Indications of On-site Groundwater Tritium Contamination

a. Inspection Scope

The inspectors reviewed NRC required documentation affecting the identification of potential and actual leaks of radioactivity outside of plant systems. The records were reviewed to identify any historical survey data that the licensee possessed that would indicate prior knowledge of any groundwater contamination issue that was not evaluated as required. Title 10 CFR 50.75(g) requires records to be retained of past on-site contamination spills. These records for the Indian Point site were reviewed for relevance to the current site condition.

NRC IE Bulletin No. 80-10, "Contamination of Nonradioactive System and Resulting Potential for Unmonitored, Uncontrolled Release of Radioactivity to Environment", requires licensees to review their facility design and operations to identify nonradioactive systems, that could become radioactive through interfaces with radioactive systems, to include leaks and valve misalignments. The Bulletin required routine sampling and analysis for the identified nonradioactive plant systems be established in order to identify any contaminating events that could lead to unmonitored, uncontrolled releases to the environment. In response to the Bulletin, the licensee developed lists of affected plant systems and sampling periods. The inspectors also reviewed the licensee's program for the sampling of on-site storm drain systems for radioactive liquids and sediments. Also, the inspectors reviewed the results of the "due diligence" sampling that was conducted in early 2000 to identify outside plant areas with residual contamination. These results were also screened for potential evidence of the preexisting groundwater contamination condition.

b. Findings and Assessment

No findings of significance were identified.

The 10 CFR 50.75(g) decommissioning file included records of the prior Unit 2 SFP leak from October 1, 1990 – June 9, 1992 as documented in corrective action report (SAO-132, 92-08). These records indicate an effective cause determination and repair of the condition. In addition all affected soil was excavated to a depth of eight feet and the affected 35 cubic yards of soil was shipped off-site as radioactive waste, with no

residual soil contamination remaining. No evidence of groundwater contamination was determined.

The Unit 1 SFP leak assessment corrective action report (SAO 132 94-06) and hydrology report (Whitman 1994) were included in the decommissioning file, identifying that most of the 25 gpd leak identified in 1992 would be intercepted by the Unit 1 building foundation drain system. Any portion not intercepted by the drain system would likely follow a shallow ground water flow pathway into a small stream discharging into the Hudson River some 1700 feet southwest of Unit 1. Based on this information, the licensee added environmental sampling stations to include the small stream south of Indian Point as well as the Trap Rock Quarry (0.7 miles south of the plant) and an unused groundwater well located off of Fifth Street in the town of Verplanck (1.3 miles south of Indian Point). Environmental records of those sampling activities did not identify any radioactivity in these samples that was plant-related.

Decommissioning file records of the Unit 2 SFP leak that was discovered in September 2005, includes records indicating a 2.6 gpd bounding leak rate was determined in a November 21, 2005, boron-loss mass balance calculation. The current hydrogeologic site investigation report completes the groundwater contamination records in the 10 CFR 50.75(g) decommissioning file.

Other miscellaneous documents were reviewed including some legacy records of low level Cs-137 contamination found in, and associated with, Unit 1 storm drain lines (1-50 picocuries per gram) that predated commercial operation of Units 2 and 3. One area, 10 feet X 70 feet X 3 feet deep, identified in July 1990 on the north side of the Unit 3 fuel storage building, was originally excavated storm drain material with residual levels of Cs-137 (30 pCi/g) from Unit 1 operations; it was later paved over. This action included a dose evaluation which indicated the area would result in much less than 1mrem/yr, which would not require immediate cleanup in accordance with NRC site cleanup screening level of 5 mrem/yr (NUREG/CR-5849).

Review of the "due diligence" site assessment conducted by Canberra Services on February 14 - 22, 2000, identified various areas inside the restricted area with detectable radioactivity. Several monitoring wells were installed and sampled. None of the groundwater samples indicated any detectable plant-related radioactivity.

The IE Bulletin 80-10 program specific to on-site storm drain monitoring was fairly extensive and provided detailed records since 1981. Review of the site wide storm drain system data did not indicate a history of the current extent of elevated tritium contamination. No historical marker was indicated in the storm drain sample data as to when the tritium leaks may have been initiated.

Entergy's IE Bulletin 80-10 program ("IPEC Storm Drain Sampling Procedure", O-CY-151-, Rev. 3) has been recently revised, consolidating two previously separate Unit-specific programs with an updated map of the Unit 1, 2 and 3 storm drain systems, and incorporating a consolidated sampling schedule, with appropriate frequencies, that includes monthly sampling for sensitive storm drain outfalls. The improved program now includes specific sample detection criteria requiring management involvement.

.8 Remediation and Long Term Monitoring Plans

a. Inspection Scope

In addition to providing the hydrogeologic site investigation final report to the NRC on January 14, 2008, a subsequent Memorandum dated January 25, 2008 (ADAMS Accession No. ML, 080290204) provided a synopsis of the Long Term Monitoring Plan Bases. These documents were reviewed along with a number of Entergy and GZA implementing procedures that provide a framework for addressing the current and future groundwater contamination issue. Several meetings were also held between the NRC, USGS and NYS DEC in January and February 2008 to discuss the adequacy of Entergy's plans and procedures.

b. Findings and Assessment

No findings of significance were identified.

Based on the installation of on-site monitoring wells, 36 out of 39 monitoring wells were selected by Entergy for continued sampling at established frequencies. In addition, three storm drain manholes were included in the sampling plan to monitor drainage from the Unit 2 containment footer drain and the Unit 3 foundation and containment footer drains. This initial sampling program consists of 378 annual samples to provide trending information on the current contaminant plumes and provide for early detection of leakage from other potential on-site sources to comply with the requirements of NEI 07-07, "Industry Ground Water Protection Initiative", for early detection and reporting of on-site spills or inadvertent contamination of groundwater.

In addition, the on-site storm drain system for Units 1, 2 and 3 was visually inspected using remote camera technology and large volumes of material (over 100 tons) were removed to complete the inspection and make requisite repairs. During NRC inspection of prior sampling evidence of groundwater contamination, in the March 16, 2006, special inspection report, the storm drain sampling program was assessed as a segregated program (between the operating Units) without proper program administration or data trending review. Since those observations, Entergy has renovated the storm drain systems, validated their connections and flow directions, and consolidated the program into one site-wide program with individual sample detection criteria that initiates management review. The current storm drain sampling program requires over 140 samples per year to detect potentially leaking plant systems as part of the IE Bulletin 80-10 requirement.

Currently, there is no periodic trending review of storm drain sampling data or use of this program with the groundwater monitoring program. Since one of the main functions of storm drains is to remove surface runoff water, many of the storm drains included in the sampling program may not provide any indication of below ground leaking plant systems or components. Since the site groundwater investigation has established the water table and groundwater gradients, the licensee has initiated actions to evaluate the storm drain systems for additional input to the long-term monitoring program.

The long term monitoring plan implementing procedures incorporate periodic sampling from a groundwater monitoring network composed of 36 monitoring wells and numerous other sampling locations. The current groundwater plumes are mapped spatially among this network of monitoring wells to allow future monitoring of the plume's footprint. At the conclusion of this inspection, the licensee was still in the process of defining and establishing the parameters of its long-term monitoring program.

Early in the Unit 2 spent fuel pool leak investigation, Entergy reviewed detailed fuel pool boron sampling data in an effort to determine net leakage losses from the fuel pool, since boron loss would not be affected by pool evaporative losses and any reduction in boron concentration would be due to pool leakage. Transfers of spent fuel and reactor water during refueling outages set a new boron solution level and trends of boron concentration losses after each refueling outage. This trending of boron data provided an initial Unit 2 SFP loss rate of approximately 2.6 gallons per day (approximately 1 drop per second) calculated by Entergy in September 2005. Although there are some complicating factors (e.g., variance in boron data measurement and any unidentified fuel pool cooling system leaks), this approach does provide an early indication of net change in spent fuel pool leakage.

Entergy plans on removing the spent fuel and draining the Unit 1 spent fuel pools by the end of 2008. Some water may remain in the bottom of the pool to reduce the possibility of airborne contamination and provide shielding of remaining sludge. Sludge removal is expected to be completed in early 2009. After completion of these activities, the source of the Unit 1 plume will be eliminated allowing residual radioactivity removal through continued purging from the Unit 1 building foundation drain system and through natural attenuation processes. Relative to Unit 2, the licensee has taken action to repair all identified liner leak imperfections, and has identified a program for monitored natural attenuation on the presumption that leakage has been terminated, based on its current assessment of groundwater tritium concentrations. However, neither the licensee nor the NRC is conclusive at this time, since only 40% of the liner surface was accessible for inspection; and it is too early to detect any significant decline in tritium concentrations (with respect to the natural variability in groundwater flow). Notwithstanding, it is expected that the licensee's implementation of its long-term monitoring program will establish sufficient data to permit a conclusive determination in the near term.

The current dose significance of the Unit 2 SFP tritium leak rate is 1000 times lower than the current Unit 1 plume (approximately 0.000002 mrem/yr versus 0.002 mrem/year), and therefore, additional actions beyond long-term groundwater monitoring of both groundwater plumes by Entergy are not warranted and the current approach is acceptable to the NRC.

Further definition of the long term monitoring plan and licensee commitment to this groundwater surveillance program will be pursued through continuing inspection activities in 2008. These future inspection activities will verify completion of Entergy's planned remediation activities, and to review plume attenuation results to confirm Entergy's site groundwater characterization conclusions.

.9 Regulatory Requirements

a. Inspection Scope

The following regulations were reviewed to identify any areas of noncompliance.

The NRC regulates the radioactive effluent releases from nuclear power plants through guidelines based on instantaneous maximum concentration values specific for each radionuclide as well as regulatory limits on potential doses to the public. The release limits are based on 100 mrem total effective dose equivalent per year. In addition, licensee's are required to meet the ALARA design objective guidelines of 3 mrem to the total body per reactor and 10 mrem to the maximum organ dose receptor per reactor (10CFR50, Appendix I). There are also total site annual exposure limits to actual members of the public from all pathways of 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other organ (40CFR190.10(a)).

Effluent releases are reported by each nuclear power plant licensee to the NRC on an annual basis with calculated maximum doses to the public and comparison to the above indicated NRC limits. In addition, to provide a verification of these calculated releases, a radiological environmental monitoring program is conducted by the licensee providing off-site environmental sample measurement results for biologically sensitive pathways of exposure to man especially in locations directly downstream or downwind of the nuclear power plant. Spills or leaks on the site property are required to be recorded to support future decommissioning activities (10CFR50.75(g)).

Unless drinking water is provided from on-site groundwater wells, the environmental monitoring program does not require on-site groundwater monitoring. This area of the regulations is currently under review. The industry has adopted a Groundwater Protection Initiative (Nuclear Energy Institute; NEI 07-07, August 2007) to initiate on-site groundwater monitoring at all nuclear power plants, and the NRC is proposing additional rulemaking and guidance (10 CFR 20.1406 and Regulatory Guide 4.21) to address the potential for leaks into the groundwater and the need to monitor this potential effluent pathway.

b. Findings and Assessment

No findings of significance were identified.

Instantaneous release rates are limited by procedures that establish gaseous and liquid release radiation monitor system setpoints and automatic discharge valve closures. Based on review of monitoring well sample results from October 2005 through

December 2007, groundwater effluent instantaneous release concentrations were always a small fraction of the regulatory limits.

The annual and quarterly liquid effluent public doses were calculated annually for 2005 and quarterly and annually for 2006 based on a rain precipitation water infiltration drainage model developed by Entergy's hydrogeologists to derive groundwater flux

values to drive the contamination concentrations obtained from monitoring well sample results. In 2005, when few samples were available, the maximum monitoring well sample results were used in the calculations. For the quarterly 2006 groundwater effluent calculations, when multiple sample results were available, the monitoring well sample results were ranked (low to high) and the 75th percentile values were used to derive a best estimate of the groundwater releases to the Hudson River. A half-tidal surge of the Hudson River was used as a final dilution of these releases and dose calculations were performed based on the Indian Point Energy Center Off-site Dose Calculation Manual (ODCM) methodology. The ODCM incorporates exposure pathway dose calculations based on Regulatory Guide 1.109. Doses were calculated based on Hudson River specific bioaccumulation of contaminants in fish flesh and based on infant, child, teen and adult fish consumption rates. Various organs concentrate various radionuclides at differing rates, so doses are calculated for bone, liver, total body, thyroid, kidney, lungs, and gastrointestinal tract, based on applicable dose factors for each critical organ. The maximum age group and organ is reported.

For 2005 and 2006, the following doses were reported for both normal and groundwater liquid effluents.

2005 Liquid Effluents	Units 1 & 2 (mrem)	Unit 3 (mrem)	Limit (mrem)	Max % of Limit
Routine max quarter	2.93E-4 TB[4] 4.68E-4 O[5]	3.29E-4 TB 3.85E-4 O	1.5 5	0.02 0.009
Routine annual	8.11E-4 TB 1.31E-3 O	4.45E-4 TB 5.4E-4 O	3 10	0.098 TB[6] 0.11 O[6]
Groundwater annual	2.12E-3 TB 9.72E-3 O		3 10	0.07 0.1
2006 Liquid Effluents				
Routine max quarter	7.04E-4 TB 1.03E-3 O	6.8E-5 TB 7.6E-5 O	1.5 5	0.05 0.02
Routine annual	8.8E-4 TB 1.26E-3 O	1.27E-4 TB 1.6E-4 O	3 10	0.09 TB[6] 0.085 O[6]
Groundwater annual	1.78E-3 TB 7.21E-3 O		3 10	0.06 0.07

These maximum hypothetical doses represent approximately 0.1% of the ALARA design objectives for liquid effluents (3 mrem and 10 mrem per year per reactor) for Units 1 and 2, combined with the groundwater releases attributed to Units 1 and 2.

In conclusion, based on a review of applicable NRC radiation protection regulations, all effluent and environmental survey and reporting requirements have been met, indicating that the existing groundwater contamination conditions represent a small fraction of regulatory limits and no violation of these requirements have been identified.

[4] TB – Total Body exposure
[5] O – Maximum Organ exposure
[6] Represents total dose from Units 1&2 and groundwater

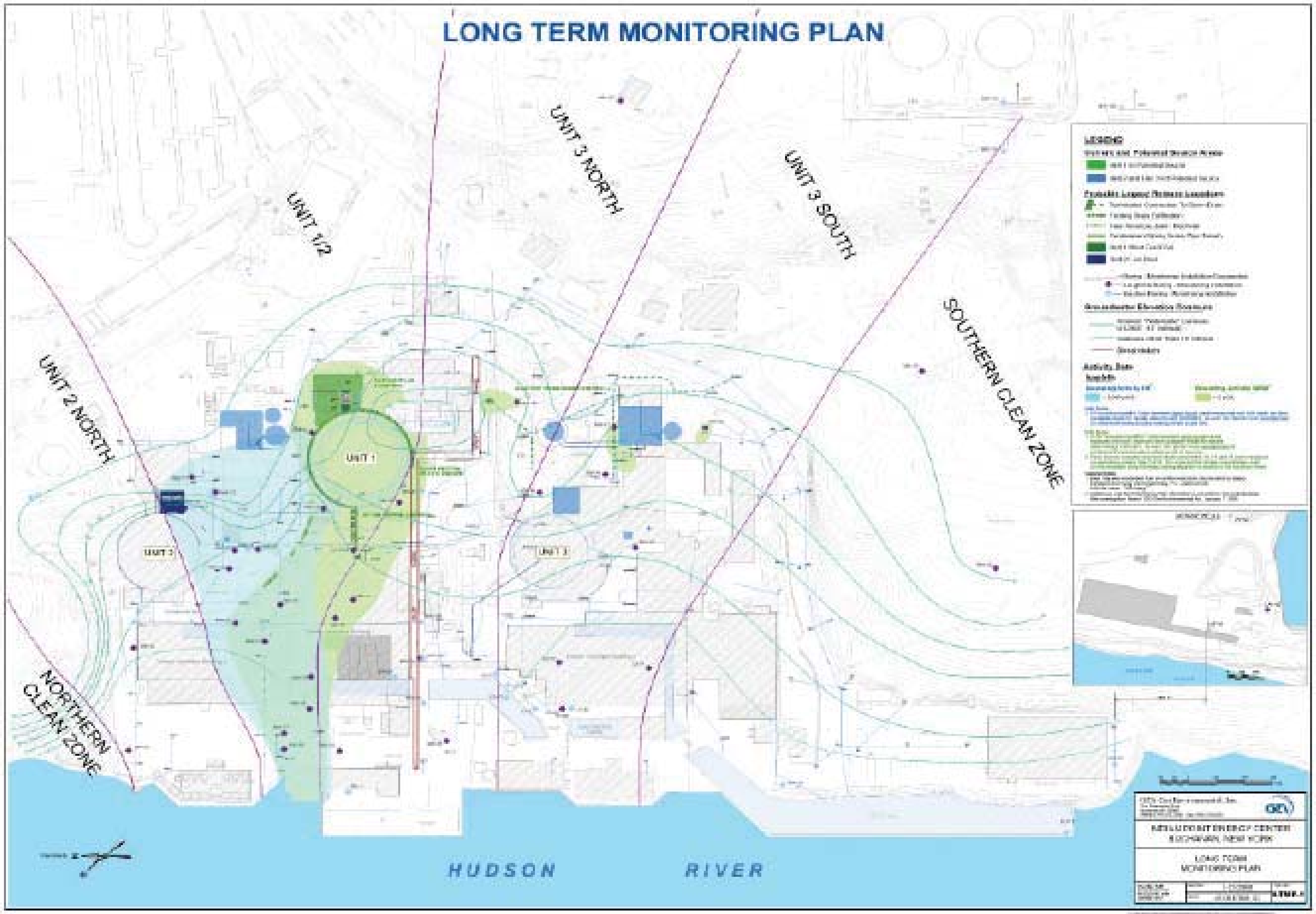
4OA6 Meetings, including Exit

.1 Exit Meeting Summary

The inspectors presented the Inspection results to Mr. D. Mayer and other licensee and New York State representatives on May 7, 2008. The licensee acknowledged the findings presented. Based upon discussions with the licensee, none of the information presented at the exit meeting and included in this report was considered proprietary.

Figure 1

Long Term Monitoring Plan

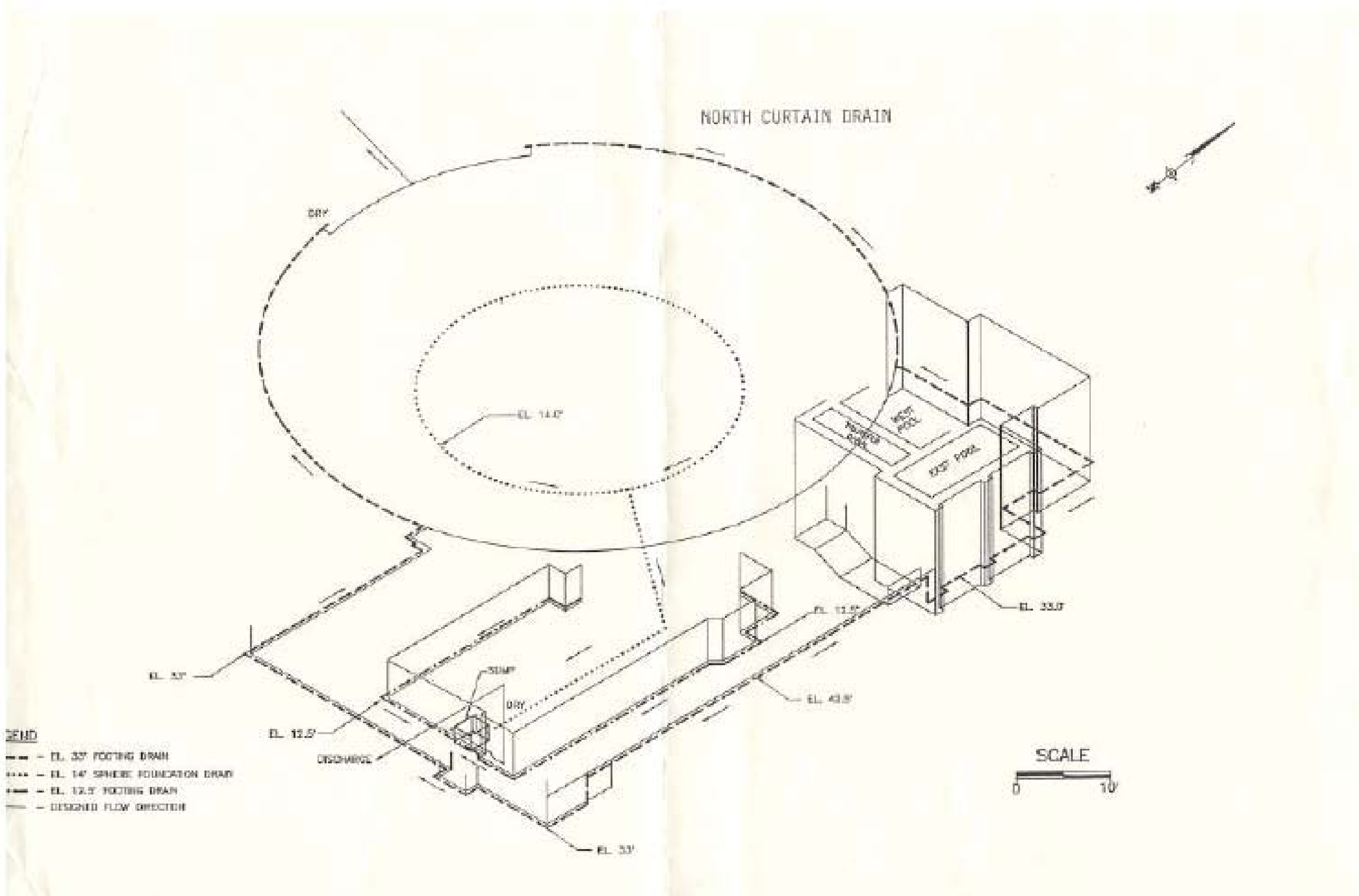


Detailed plume radionuclide concentration values at each monitoring well are provided in Attachment 2.

Enclosure

Figure 2

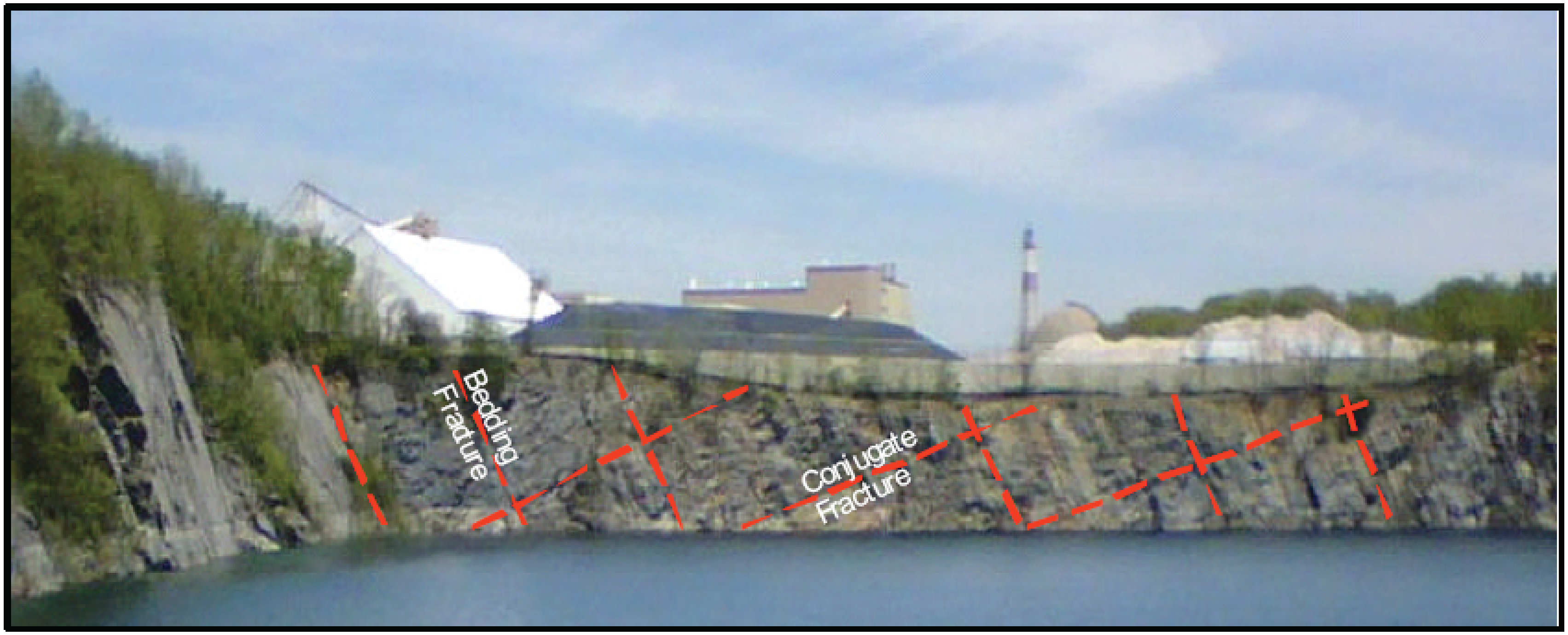
Unit 1 Building Foundation Drain System



Enclosure

Figure 3

Observed bedding and conjugate fractures in Verplanck Quarry (from USGS)



Enclosure

Figure 4

Downhole Flow Meter and Geophysical Survey
Example from Monitoring Well Monitoring Well-58

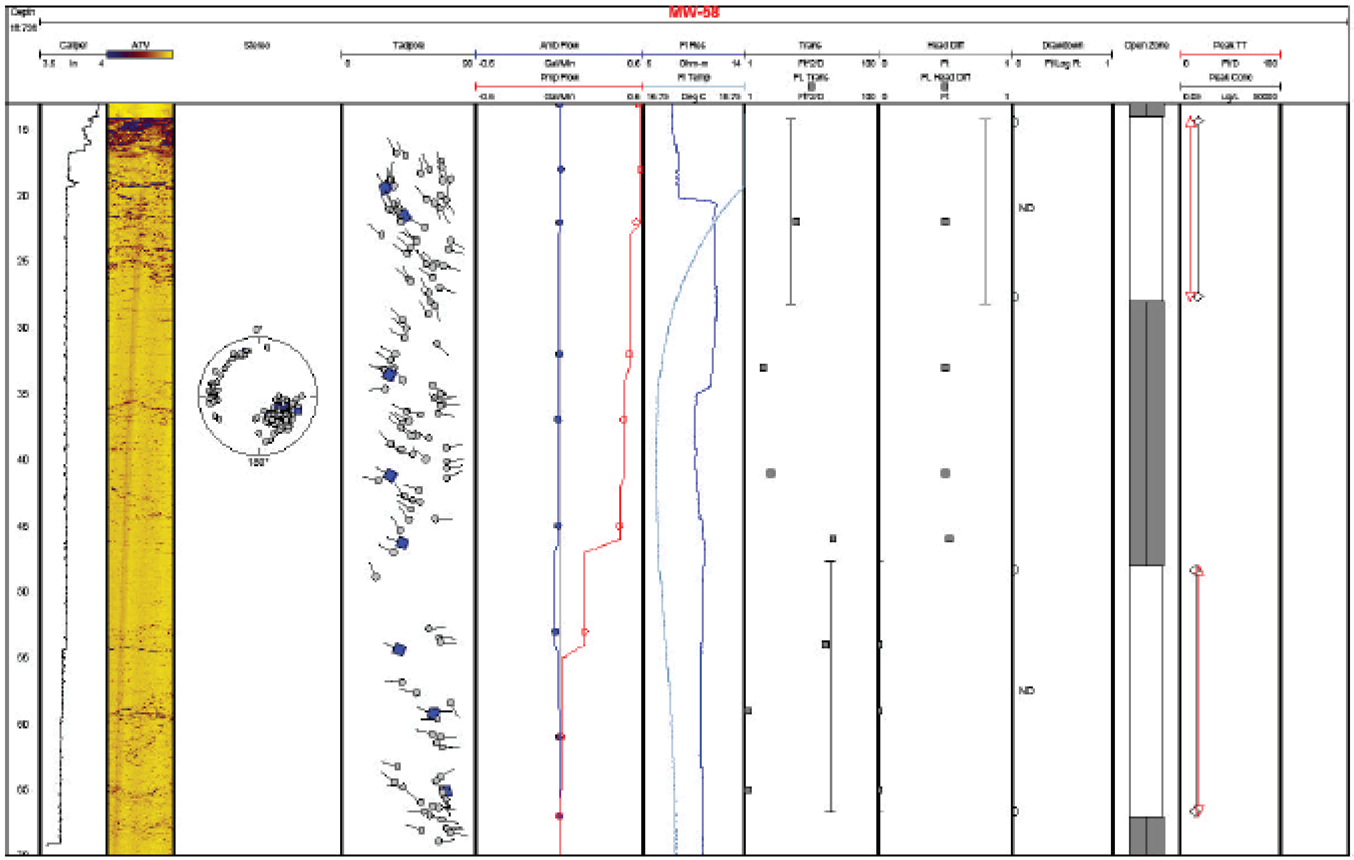
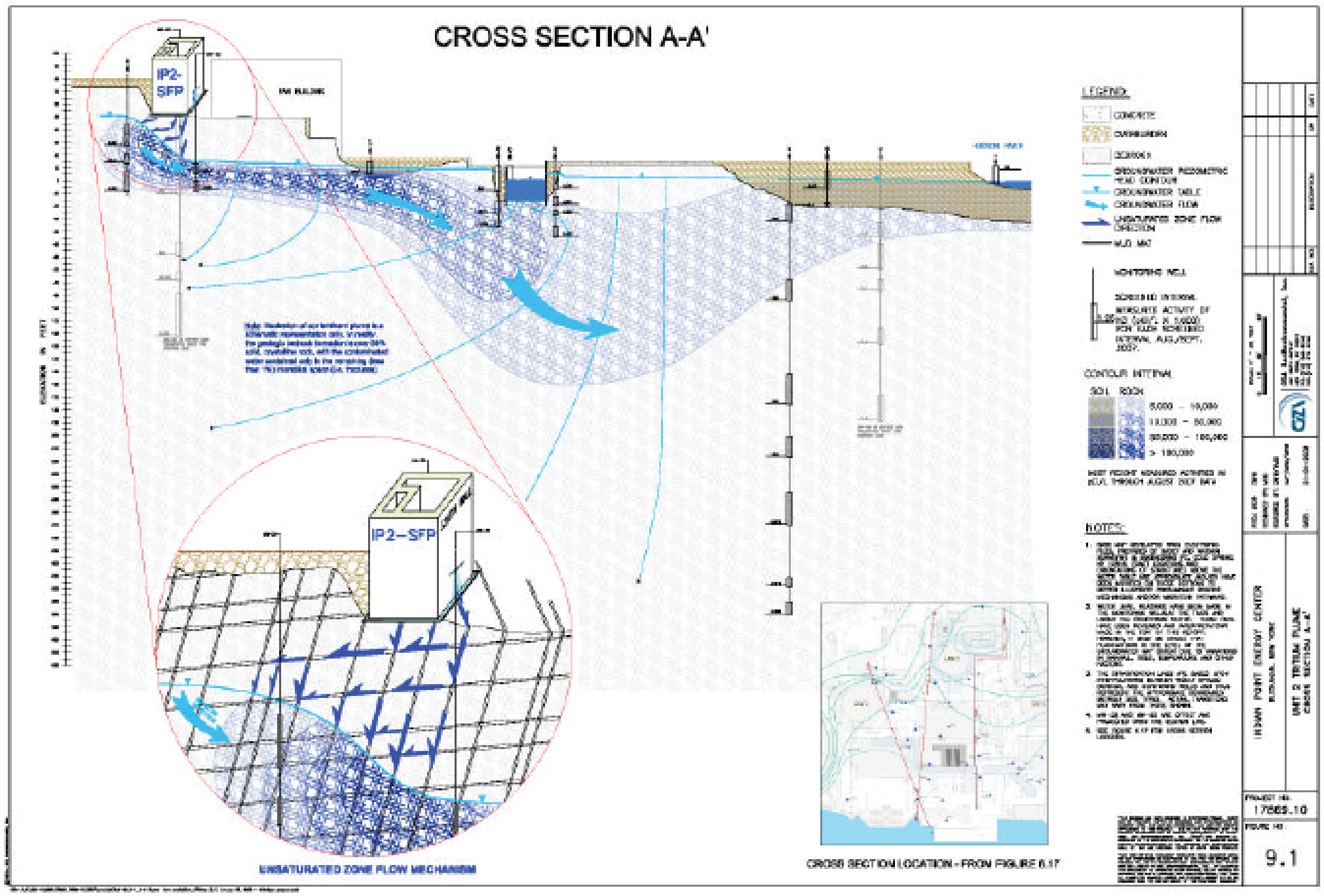


Figure 2. Analysis of geophysical and flow data to identify fracture zones and properties (from USGS)

Enclosure

Figure 5

Unit 2 Spent Fuel Pool Tritium Plume Cross Section



Enclosure

ATTACHMENT 1

Indian Point Contaminated Groundwater Investigation Time Line

Date Event

Unit 1 Spent Fuel Pool Timeline

Unit 1 ceased commercial operations on October 31, 1974

1. April 1990: A nuclear plant operator observed higher than usual frequency of fuel pool makeup than usual, initiated an investigation by Con Edison.

2. 1991: Con Edison began sampling the north curtain drain (NCD) and sphere foundation drain sump (SFDS) for tritium and established separate liquid discharge paths.

3. May 1992: Completed calculations of unaccounted water loss – 25 gpd leakage.

4. May 1994: A task force organization was created with a Unit 1 SFP Project Manager position reporting to the Plant General Manager. Individuals from Chemistry, Operations Maintenance, Health Physics and Engineering were represented.

5. May-June 1994: NRC inspection (Drs. Bores and Jang) to investigate Unit 1 SFP leakage (50-03/94-01) Boron concentration mass balance indicated 91 gpd leak rate to the SFDS and 1.5 gpd to the north curtain drain. Tritium concentration mass balance indicated 73 gpd to the SFDS and 1.2 gpd to the NCD. Hydrogeologist study indicated that the groundwater movement was about 10 ft/day and would flow towards the quarry, not the Hudson River. No violations were identified.

6. July 1994: Whitman hydrogeology report investigation of Unit 1 SFP leak migration concluded that “most” of the leakage would be captured by the Unit 1 building foundation drain system and the rest would migrate to the South in the shallow zone and could be detected in the creek bordering south of the plant and in the Trap Rock Quarry. These sample locations were added to the REMP program.

7. August 1994: NRC inspection (Bores/Jang) to review licensee’s leak investigation (50-03/94-02). Hydrogeologist completed study indicated that groundwater at the site flowed upward and either west or south into the Hudson River. No violations were identified.

8. December 1994: NRC inspection (Bores, Jang, Erikson, Noggle) inspect compliance with Bulletin 94-01 (fuel pool potential siphoning), leak investigation, and SAFSTOR approval (50-3/94-80). Confirmation of tritium in the sphere foundation drain sump that drains groundwater from the bottom of the Chemical Systems Building of Unit 1 in May 1994, provided evidence that the Unit 1 SFP system was leaking beyond the plant structure and resulted in initiating a corrective action SAO-132 report (94-06). 10CFR50.59 evaluations between March 9, 1992 and December 1994 were reviewed and found to be complete and met requirements. In October 1994, boron concentration was increased in the SFP and fluoresce in dye tracer was added to

the water storage pool to detect these sources in the NCD and SFDS. As of mid-December, no increased boron or indications of tracer were detected in either of these Unit 1 drains. Tracer did indicate that the SFDS had been discharging through a Unit 3 storm drain to the discharge canal. Con Edison subsequently rerouted this discharge by hard pipe through the Unit 1 River water system into the discharge canal. NCD was diverted to the Unit 1 sphere sump where this discharge was pumped to the liquid radwaste processing system. The on-site stream was added to REMP monitoring for tritium on a quarterly basis. No violations were identified.

9. January 2, 1996: SECY-96-01, Decommissioning Plan for SAFSTOR and amendment of license for Unit 1 was approved.

10. June-August 1996: NRC inspection (Jang) to review followup actions: modification to north curtain drain for recapture, new RMS detector installed in SFDS (50-3/96-04).

11. February-March 1998: NRC inspection (Jang) to review followup actions: effluent controls and trending of SFP inventory (50-3/98-02).

12. May-June 1998: NRC inspection (Ragland) reviewed schedule for draining and cleanout of pools (50-03/98-04). Con Edison removed all irradiated hardware from both the East and West Unit 1 SFPs.

13. November-December 1998: NRC inspection (Ragland) verified that irradiated hardware had been removed from the East pool and shipped off-site during May-August 1998, with the East pool ready for desludging and draining. PCBs detected in water storage pool sludge. (50-03/98-17).

14. December 1998-February 1999: NRC SAFSTOR inspection (Dimitriadis) (50-03/98-19). Work in progress in draining and desludging various pools. While desludging the water storage pool, PCBs were detected. Due to known leakage of this pool, the NCD was diverted into the Unit 1 sphere annulus for waste processing.

15. April-June 1999: NRC inspection (50-03/99-03) NRR reviewed a Unit 1 safety evaluation for modifications to the SFPs.

16. June-July 1999: NRC inspection (Ragland) reviewed monitoring of pool leakage, north curtain drain water was being treated by mechanical and charcoal filtration. Water storage pool cleanup in progress (50-03/99-06).

17. April 7, 2003: Unit 1 Remediation plan was approved to accomplish several objectives that included pursuing sealing the Unit 1 East SFP, transferring the spent fuel into that pool, and draining the leaking Unit 1 West SFP, thereby stopping the leak.

18. 2004: Insitu dry storage option was proposed by Unit 1 project team to stop the leak. Too many uncertainties surfaced regarding potential airborne radioactivity and future floodup effects on fuel integrity upon final spent fuel removal.

19. September 19-November 17, 2005: The Unit 1 West SFP was flooded up for spent fuel inspection for material condition evaluation. After drain down, Unit 1 SFP leak rate recalculated to be 70 gpd.

20. January 16, 2006: Unit 1 drain system collects seven times more tritium than can be attributed to the current 1 SFP leak rate.

21. March 21, 2006: NRC sample results of Monitoring Well-37 strontium-90 analyses were received indicating 26 pCi/L. This was the first indication that strontium-90 was likely being released in the groundwater to the Hudson River. Initial bounding calculations were revised, indicating less than 0.1% of effluent release limits.

22. April 17, 2006: Due to the 3/21/06 discovery of strontium-90 in Monitoring Well-111, the licensee initiated demineralization of the Unit 1 SFP 40 hrs per week in order to reduce leaking source term. Final assessment of Unit 1 SFP leakage calculations indicated 70 gpd post-drain down since November 2005.

23. April 24, 2006: Updated dose assessment based on 2/28/2006 methodology using more recent monitoring well data and maximum concentrations of hydrogen-3 (tritium), strontium-90 and nickel-63: 2.5E-3 mrem total body and 1.1E-2 mrem maximum organ (adult bone). Strontium-90 analysis was added to REMP fish, Hudson River and sediment samples.

24. August 9, 2006: After completing a temporary system modification, Entergy began continuous cleanup of the Unit 1 West SFP.

25. November 13-17, 2006: NRC on-site team inspection to review Unit 1 SFP leak history and hydrology results of a 3-day pump down test of Recovery Well-1.

26. April 2007: Revised calculation of tritium mass balance for Unit 1 SFP based on total radioactivity per year (based on 65 gpd leak rate) versus total radioactivity collected in the Unit 1 building drains for 2006. The Unit 1 SFP releases accounted for only 30% of the tritium collected in the Unit 1 drain system.

27. June 6-22, 2007: An expanded control zone fish split sampling exercise was conducted to include a second control location in the Catskills to help evaluate background levels of strontium-90 in fish.

<u>Unit 2 Spent Fuel Pool Timeline</u>

Operating license issued September 28, 1973

1. October 1, 1990: Unit 2 SFP stainless steel liner was perforated by a diver during re-rack cutting operation, but was not identified at that time.

2. May 7, 1992: Unit 2 SFP liner was discovered to be leaking (about 50 gpd), due to outside visible boric acid deposits on the wall of the fuel service building. Condition report determined cause and examined all other liner work areas for similar perforations. Entergy excavated 35 cubic yards of soil to a depth of 8 feet leaving no detectable contamination.

3. June 9, 1992: Under water epoxy temporary patch was installed, sealing the leak.

4. June 12, 1992: A steel box was welded over the liner perforation permanently sealing the leak completing corrective actions for this fuel pool leak event.

5. September 1, 2005: Initial discovery of the Unit 2 spent fuel pool leak. Contamination was first detected on a swipe sample of the exposed crack in the SFP south wall excavation area at approximately 65-foot elevation. The NRC resident inspector was informed.

6. September 12-15, 2005: NRC initial radiological scoping inspection and dose assessment, 0.00002 mrem/year based on 2 L/day leak rate.

7. September 20, 2005: NRC Special Inspection Charter was issued, followed by a press release announcing this action.

8. October 5, 2005: Tritium was discovered in the Unit 2 transformer yard Monitoring Well-111. This was the first location removed from the Unit 2 SFP indicating a groundwater contamination concern.

9. October 27, 2005: Unit 2 SFP liner inspection begins with underwater camera inspection to identify any leaks. Visual indications were followed by vacuum box testing.

10. October 31, 2005: NRC Executive Director for Operations issued Reactor Oversight Process deviation memorandum to provide additional NRC resources and continuing NRC inspection of the groundwater contamination investigation through 2006.

11. November 3, 2005: Licensee submitted a non-required 30-day report to the NRC, based on tritium results for Monitoring Well-111 (0.0002 uCi/ml) that were above the radiological environmental monitoring program (REMP) reporting criteria for non-drinking water samples (0.00003 uCi/ml). However, Monitoring Well-111 is an on-site well not representative of an off-site environmental sample therefore, no NRC report was required.

12. November 7, 2005: Drilling of the first new monitoring well was initiated (Monitoring Well-30).

13. January 13, 2006: A permanent leak collection box was installed encompassing the Unit 2 SFP crack.

14. January 31, 2006: A NRC Special Inspection team met on-site to review the Phase 1 monitoring well hydrology results.

15. February 8-10, 2006: A NRC Special Inspection team was on-site to evaluate the licensee's compliance with IE Bulletin 80-10 (radiological monitoring of on-site non-contaminated systems), 10 CFR 50.75(g) (on-site spill documentation for future decommissioning), and chemistry counting quality control requirements. Hudson River waterfront well sample splits were taken for NRC, NYS and IPEC.

16. February 27, 2006: Monitoring Well-37 initial sample result = 30,000 pCi/L, provided the first indication of a tritium groundwater release directly to the Hudson River.

17. February 28, 2006: Licensee provided a revised dose calculation of 0.000015 mrem/yr to the maximally exposed member of the public based on a general site area hydrology water transport and multiple contamination area drainage model. The NRC conducted the SIT exit meeting.

18. March 16, 2006: NRC Special Inspection Report No. 05000247/2005001 was issued describing NRC's initial response and evaluation of the Indian Point groundwater contamination issue.

19. March 21, 2006: NRC sample results of Monitoring Well-37 strontium-90 analyses were received indicating 26 pCi/L. This was the first indication that strontium-90 was likely being released directly to the Hudson River. Initial bounding calculations were revised, indicating less than 0.1% of effluent release limits.

20. April 1, 2006: Due to the 2/21/06 discovery of strontium-90 in Monitoring Well-111, the licensee initiated continuous demineralization of the Unit 1 SFP in order to reduce the leaking source term.

21. April 10, 2006: Entergy groundwater monitoring and commitment letter sent to NRC Region I.

22. April 24, 2006: Updated dose assessment based on 2/28/2006 methodology using more recent monitoring well data and maximum concentrations of hydrogen-3 (tritium), strontium-90 and nickel-63: 0.0025 mrem total body and 0.011 mrem maximum organ (adult bone).

23. June 12-16, 2006: NRC groundwater contamination hydrology inspection team was on-site. U.S. Geological Survey participation was added to the NRC inspection effort.

24. November 7, 2006: NRC split sample results identify licensee strontium-90 results from 8/1 - 9/18/2006 were low and caused licensee resampling and licensee investigation.

25. October 30- November 1, 2006: Entergy conducted a 3-day groundwater draw-down pump test from Recovery Well - 1 (adjacent to Unit 2 SFP).

26. November 13-17, 2006: NRC on-site team inspection to review Unit 1 SFP leak history and hydrology results of a 3-day pump down test of RW-1.

27. February 8, 2007: Fluorescein dye tracer test injected near the base of Unit 2 SFP. Test samples were collected through August 2007.

28. March 21, 2007: NRC inspection team reviewed preliminary tracer test results.

29. May 9-10, 2007: NRC conducted an on-site inspection team review of tracer test results and the evaluation of groundwater transport.

30. June 6-22, 2007: An expanded control zone fish split sampling exercise was conducted to include a second control location in the Catskills to help evaluate background levels of strontium-90 in fish.

31. June 2007: The Unit 2 SFP transfer canal was drained below the pinhole leak, which arrested this leak pathway.

32. July-August 2007: An independent fracture flow analysis using down hole geophysical and flow logs was conducted by the USGS to compare groundwater flow results based on fracture flow with the licensee's groundwater flow rate calculations derived from packer testing data (slug tests) and based on a general porous media groundwater flow model.

33. August 31, 2007: The last monitoring well was installed and became operational (Monitoring Well-67).

34. November 7-9, 2007: NRC inspection team was on-site to compare and review the final site conceptual groundwater model based on all previously derived site data and USGS analyses.

35. December 15, 2007: The pinhole leak in the Unit 2 SFP transfer canal was repaired.

36. January 14, 2008: NRC received Entergy's final site hydrogeological investigation report.

37. January 29, 2008: NRC received Entergy's Synopsis of Long Term Monitoring Plan Bases.

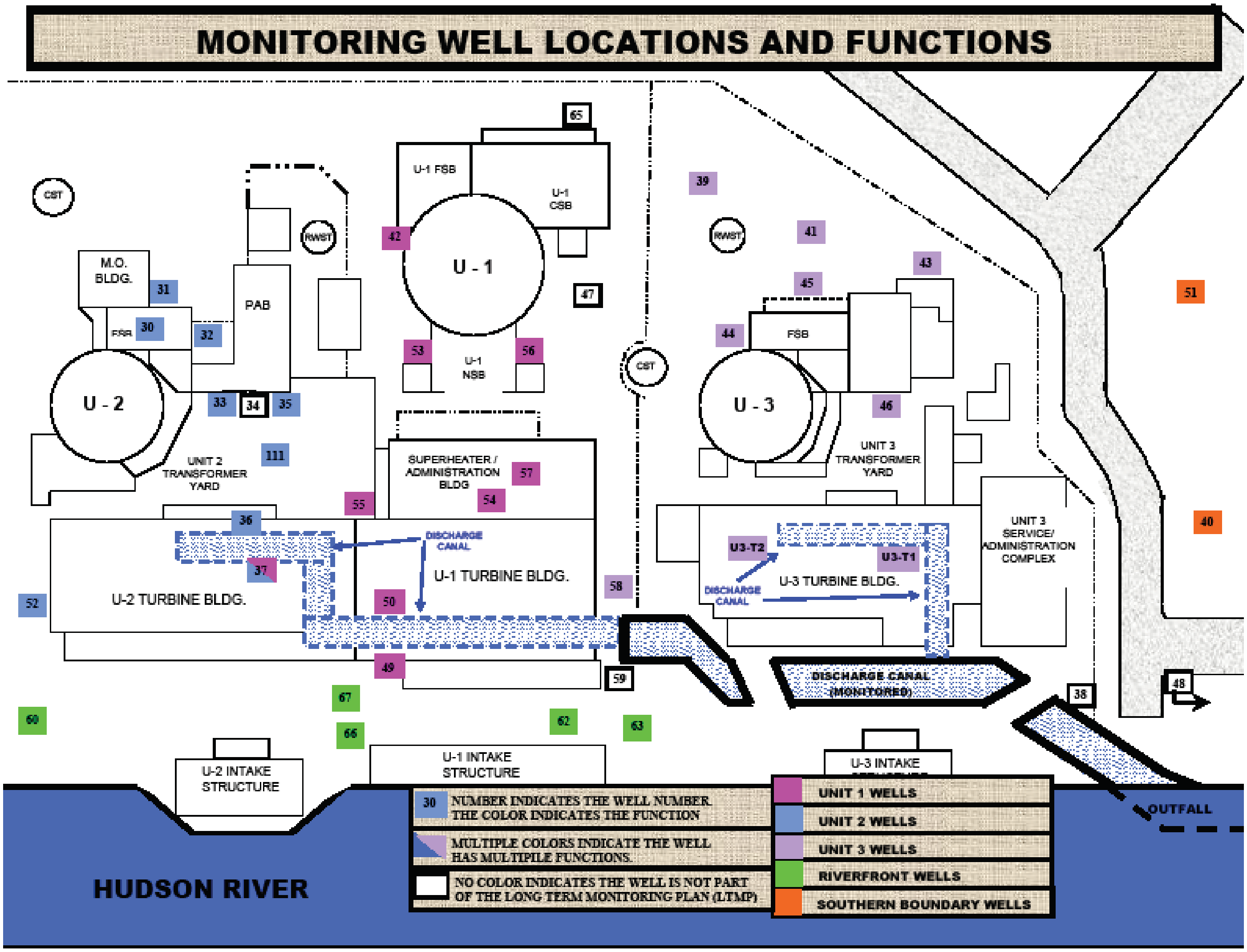
38. February 4, 2008: NRC inspection team conducted a critique of the Long Term Monitoring Plan and associated implementing procedures.

39. February 21, 2008: NRC held a meeting with Entergy and GZA to discuss further development and refinement of the Long Term Monitoring Plan.

40. May 7, 2008: NRC conducted an exit meeting of inspection report 50-003/2007010 & 50-247/2007010.

ATTACHMENT 2

Site Groundwater Contaminant Concentrations



Indian Point Monitoring Well Groundwater Contamination
Results as of 12/31/2007 in units of pCi/L

	H-3	Sr-90	Ni-63	Cs-137
Southern Boundary Wells				
MW-40	ND	ND	ND	ND
MW-51	ND	ND	ND	ND
Northern Boundary Wells				
MW-52	ND	ND	ND	ND
MW60	ND	ND	ND	ND
Eastern Boundary Well				
MW-65	ND	ND	ND	ND
Riverfront Wells				
MW-60	ND	ND	ND	ND
MW-66	9000	11	ND	ND
MW-67	5000	27	ND	ND
MW-62	780	2	ND	ND
MW-63	ND	ND	ND	ND
Unit 2 SFP Wells				
MW-30	130000	ND	ND	3000*
MW-31	36000	ND	ND	200*
MW-32	14000	ND	ND	ND
MW-33	23000	ND	ND	ND
MW-34	22000	ND	ND	ND
MW-35	6000	ND	ND	ND
MW-111	100000	1	ND	ND
MW-36	12000	2.5	ND	ND
MW-37	6000	28	56	ND
MW-55	10000	32	ND	ND
MW-50	4000	47	ND	ND
MW-49	7000	26	ND	ND
Unit 1 SFP Wells				
MW-42	2500	47	200	37000
MW-53	7400	28	ND	ND
MW-55	10000	32	ND	ND
MW-50	4000	47	ND	ND
MW-49	7000	26	ND	ND
MW-47	3500	4	ND	ND
MW-56	1500	2	ND	ND

Attachment

MW-57	4000		38		ND	ND
MW-54	2000		20		ND	ND
MW-58	900		ND		ND	ND
MW-59	800					
Unit 3 Wells						
MW-39	ND		5		ND	ND
MW-41	ND		6		ND	ND
MW-45	2200		ND		ND	ND
MW-44	ND		ND		ND	ND
MW-43	ND		ND		ND	ND
MW-46	1700		ND		ND	ND
U3-T1	530		ND		ND	ND
U3-T2	1200		ND		ND	ND
Off-site Locations						
LaFarge No. 1	ND		ND		ND	ND
LaFarge No. 2	ND		ND		ND	ND
LaFarge No. 3	ND		ND		ND	ND
Trap Rock Quarry	ND		ND		ND	ND
5th Street Well	ND		ND		ND	ND
Camp Field Reservoir	ND		ND		ND	ND
New Croton Reservoir	ND		ND		ND	ND
ND indicates nothing detectable above background						

* Single positive result was obtained immediately after a 3-day pump down test indicating hydraulic connectivity between Monitoring Well-42 and Monitoring Well-30 and 31.

These radionuclide concentrations reflect end of 2007 results. Due to annual cyclic groundwater flow variability, no definite trend of the radionuclide concentrations could be conclusively determined at the present time. Additional sample data over time will clarify whether the Unit 1 and Unit 2 groundwater plumes are shrinking in size or concentration.

ATTACHMENT 3

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel

M. Barvenik	Principal Engineer, GZA Geo Environmental, Inc.
J. Comiotes	Director, Nuclear Safety Assurance
P. Conroy	Manager, Licensing
D. Croulet	Licensing Engineer
P. Donahue	Chemistry Specialist
J. Pollock	Site Vice President
C. English	Unit 1 Project Engineer
G. Hinrichs	Project Engineer
D. Loope	Radiation Protection Superintendent
T. Jones	Licensing Engineer
R. LaVera	Radiological Engineer
D. Mayer	Director, Special Projects
J. Peters	Plant Chemist
S. Sandike	Chemistry ODCM Specialist

New York State Inspection Observers

T. Rice	Environmental Radiation Specialist, New York State, Department of Environmental Conservations (NYS DEC)
L. Rosenmann	Engineering Geologist, NYS DEC
A. Czuhanich	Engineering Geologist, NYS DEC

LIST OF INSPECTIONS PERFORMED

7112203	Radiological Environmental Monitoring Program and Radioactive Material Control

LIST OF DOCUMENTS REVIEWED

Entergy Letter, NL-08-009 to USNRC, “Results of Ground Water Contamination Investigation,” January 11, 2008

GZA Final Report Hydrogeologic Site Investigation Indian Point Energy Center, January 7, 2008

GZA Memorandum to Entergy, “Synopsis of Long Term Monitoring Plan Bases,” January 25, 2008

Consolidated Edison Calculation No. CGX-00006-00, “Seismic Qualification Structural Evaluation of the Unit 2 Fuel Pool Wall Considering Deteriorated Condition of Concrete Due to Pool Leak”

United Engineers and Constructors Technical Report No. 8281,"Evaluation of Spent Fuel Pool Walls - Indian Point 2 Nuclear Power Plant"

ABS Consulting Report 1487203-R-001, "Study of Potential Concrete Reinforcement Corrosion on the Structural integrity of the Spent Fuel Pit", September 2005

Chazen, "Northern Westchester County groundwater conditions summary, data gaps and program recommendations," Contract C-PL-02-71, Dutchess County Office, the Chazen Companies, Poughkeepsie, NY, April 2003

Clark, J.F., P. Schosser, M. Stute, and H.J. Simpson, "SF_6 - ^{3}He tracer release experiment: A new method of determining longitudinal dispersion coefficients in large rivers," *Environmental Science and Technology*, vol 30, pp 1527-1532, 1996

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de Vries, P, and L.A. Weiss, "Salt-front movement in the Hudson River Estuary, New York - simulations by one-dimensional flow and solute-transport models," U.S. Geological Survey, Water Resources Investigations Report 99-4024, 2001

Freeze and Cherry, *Groundwater*, 1979

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ABS Consulting Report 1186959-R-007, April 2004,"Indian Point Unit 1 East Spent Fuel Pool and Rack Fitness for Service Inspection Report"

ENN-DC-114, Rev. 2, "Unit 1 Remediation - Phase 1 Project Plan"

USGS Open File Report 01-385, "Characterization of Fractures and Flow Zones in a Contaminated Shale of the Watervliet Arsenal, Albany County, NY"

Procedures
EN-LI-102, “Corrective Action Process”, Rev. 3
EN-LI-118, “Root Cause Analysis Process”, Rev. 3
EN-LI-119, “Apparent Cause Evaluation (ACE) Process”, Rev. 3
HP-SQ-3.013, Rev. 12, “Routine Surveys Outside the Normal RCA”
2-CY-2625, Rev. 9, “General Plant Systems Specifications and Frequencies”
3-CY-2325, Rev. 6, “Radioactive Sampling Schedule”
IPEC IE Bulletin 30-10 Program
O-CY-1510, Rev. 3, “IPEC Storm Drain Sampling”
O-CY-2740, Rev. 0, “Liquid Radiological Effluents”
O-CY-1420, Rev. 1, “Radiological Quality Assurance Program”
O-RP-NEM-101, Rev. 0, “Nuclear Environmental Monitoring Sampling and Analysis Schedule”
O-RP-NEM-100, Rev. 0, “Notification, Investigation and Reporting of Abnormal Activity in Environmental Samples”
IP-SMM-CY-110, Rev. 0, “Radiological Groundwater Monitoring Program”
GZA-IP-101, Rev. 0, “Radiological Groundwater Monitoring Program Quality Assurance and Procedures IPEC”
IPEC Off-site Dose Calculation Manual

Condition Reports

IP2-2005-03885
IP2-2005-03557
IP2-2005-04151
IP2-2005-03986
IP2-2005-04152
IP2-2005-M-11
IP2-2005-04789
IP2-2005-04799
IP2-2005-04957
IP2-2005-04977
IP2-2005-05145
IP2-2005-05160
IP2-2005-05194
IP2-2006-00137
IP2-2006-00488

Drawings
9321-F-1196-7, Fuel Storage Building Concrete Details No. 1
9321-F-1197-8, Fuel Storage Building Concrete Details No. 2
9321-F-1198-8, Fuel Storage Building Concrete Details No. 3
9321-F-1199-7, Fuel Storage Building Concrete Details No. 4
9321-F-1200-5, Fuel Storage Building Concrete Details No. 5

9321-F-1388-15, Fuel Storage Building Floor Plans, Section & Roof
9321-F-1389-11, Fuel Storage Building - Building Elevations & Section
9321-F-1390-05, Fuel Storage Building - Building Details & Door Schedule
9321-F-2514-16, Fuel Storage General Arrangement Plans & Elevations (U2)
9321-F-2576-24, Fuel Storage Building Auxiliary Coolant System Plans
9321-F-2577-24, Fuel Storage Building Auxiliary Coolant System Sections
9321-F-2715-5, Containment Building Piping & Penetrations - Details of Fuel Transfer Tube
9321-F-2762-15, Fuel Storage Building Piping Supports

Miscellaneous
ENN-LI-101 Att. 9.1, 50.59 Screen Control Form Activity, ID No. DCP-03-2-128
IP2 FSAR, Section 1.2.1.2, "Geology and Hydrology" Rev. 19
IPEC Preliminary Cause Analysis, FSB Concrete Wall/Tritium in the Groundwater, February 10, 2006

NRC Groundwater Sample Result Documentation

ML060720148	ML061880387	ML062720227	ML070110577
ML070110602	ML070110559	ML070110548	ML070110561
ML070940618	ML070940504	ML070940574	ML070940515
ML070940546	ML070940534	ML071900442	ML071900462
ML071900438	ML071900445	ML071900447	ML071900458
ML072840255	ML071900448	ML071900456	ML072840312
ML072840323	ML072840334	ML072840357	ML072840292
ML072840278	ML080080499	ML073180148	ML073180167
ML073620089			

LIST OF ACRONYMS

CFR	Code of Federal Regulations
CR	condition report
CSM	conceptual site model
DEC	State of New York Department of Environmental Conservation
EDO	Executive Director for Operations
EPA	Environmental Protection Agency
ESSAP	Environmental Site Survey and Assessment Program
FSAR	final safety analysis report
FSB	Fuel Storage Building
GPD	gallons per day
GPM	gallons per minute
IN	Information Notice
IP	Inspection Procedure
IP2	Indian Point 2
IPEC	Indian Point Energy Center
IR	Inspection Report
ISFSI	independent spent fuel storage installation
MDC	minimum detectable concentration
MSL	mean sea level
MW	monitoring well
NCD	north curtain drain
NYS DEC	State of New York Department of Environmental Conservation
NYSEMO	State of New York Emergency Management Organization
NYSPSC	State of New York Public Services Commission
ORISE	Oak Ridge Institute for Science and Education
PCB	polychlorinated biphenyls
pCi/L	pico-Curies per Liter
REMP	Radiological Environmental Monitoring Program
SFD	sphere foundation drain
SFP	spent fuel pool
USGS	United States Geological Survey

Note: Explanation of the terms groundwater, ground-water and ground water -- Hydrologists often use the term “ground-water” in adjective form and “ground water” in noun form. This report has not followed that convention, and instead typically uses “groundwater” universally. However, all three forms of the word may be used herein.

Exhibit G

Entergy Ground Water Protection Baseline Information, July 31, 2006
(ML0062220228)

Entergy

Entergy Nuclear Northeast
Indian Point Energy Center
295 Broadway, Suite 1
P.O. Box 249
Buchanan, NY 10511-0249

James Comiotes
Director, Nuclear Safety Assurance
Tel 914 271 7130

July 31, 2006

Re: Indian Point Units 1, 2 and 3
Docket Nos. 50-003, 50-247 and 50-286
NL-06-079

Document Control Desk
U.S. Nuclear Regulatory Commission
Mail Stop O-P1-17
Washington, DC 20555-0001

Subject: **Ground Water Protection Baseline Information**
Indian Point Energy Center – Units 1, 2 and 3

Dear Sir or Madam:

The nuclear industry, in conjunction with the Nuclear Energy Institute (NEI), developed a questionnaire to facilitate compilation of baseline information regarding the current status of site programs for monitoring and protecting ground water. All participating nuclear sites agreed to provide the requested information to both NEI and the Nuclear Regulatory Commission.

Attachment 1 to this letter contains the questionnaire response for Indian Point Energy Center (IPEC). Please contact Mr. Patric W. Conroy at (914) 734-6668 if you have any questions or comments regarding this submittal.

There are no new commitments contained in this submittal.

Sincerely,

Patric W. Conroy for
James Comiotes
Director, Nuclear Safety Assurance
Indian Point Energy Center

Attachment 1 (Ground Water Protection Questionnaire Response)

cc: see next page

IE25

cc: Mr. John P. Boska
U.S. Nuclear Regulatory Commission

Mr. Samuel J. Collins
U.S. Nuclear Regulatory Commission

Resident Inspector's Office
Indian Point Unit 2 Nuclear Power Plant
U.S. Nuclear Regulatory Commission

Mr. Paul Eddy
New York State Dept. of Public Service

Mr. Ralph Anderson
Nuclear Energy Institute

ATTACHMENT 1 TO NL-06-079

GROUND WATER PROTECTION QUESTIONNAIRE RESPONSE

INDIAN POINT UNITS 1, 2 and 3

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 1, 2 AND 3
DOCKET NOS. 50-003, 50-247, AND 50-286

Ground Water Protection Questionnaire Response
Indian Point Energy Center (IPEC)

1. Briefly describe the program and/or methods used for detection of leakage or spills from plant systems, structures, and components that have a potential for an inadvertent release of radioactivity from plant operations into ground water.

   Response: IPEC has identified radioactive contamination in its on-site ground water. This contamination is currently being characterized to determine the sources of this contamination, as well as the nature and extent of the resulting ground water contamination plumes. As such, IPEC's ground water monitoring program is primarily focused on identifying the source of and characterizing after the fact release conditions. However, the program does include provisions for detecting leakage from potential future inadvertent releases to ground water. They include
   - Operator plant rounds include inspection for leaks and spills,
   - Radiation Protection surveys include inspection for leaks and spills,
   - Leaks/spills documented in corrective action program,
   - Inspection of systems, structures and components to identify potential leak points,
   - Radioactive Effluent Monitoring Program (REMP) Sampling,
   - Storm drain periodic sampling program, and
   - Corrective action program reporting/trending.

2. Briefly describe the program and/or methods for monitoring onsite ground water for the presence of radioactivity released from plant operations.

   Response: IPEC is in the process of investigating known Tritium and Sr-90 ground water contamination, resulting from leaks from the Unit 1 and 2 spent fuel pools (SFP). Other potential sources of leakage are also within the scope of this investigation. To accomplish this objective, a program for characterizing the nature and extent of the resulting ground water contamination and the site's hydro-geological characteristics is being conducted. As a part of this program, more than 30 monitoring wells have been installed throughout the site for the purpose of sampling ground water and obtaining hydro-geological data. These monitoring wells are sampled on a periodic basis, with the samples analyzed for Tritium, Sr-90 and gamma emitters. Upon conclusion of this investigation and any warranted remediation, these investigation monitoring wells will be transitioned into a long-term ground water monitoring program.

3. If applicable, briefly summarize any occurrences of inadvertent releases of radioactive liquids that have been documented in accordance with 10 CFR 50.75(g).

   Response: The most significant sources for potential releases to ground water include leakage from the Unit 1 and 2 SFPs, storm drains with contaminated sediment resulting from past spills, and an impoundment containing contaminated soil from a Unit 1 septic leach field that was excavated for construction of Unit 3. Other smaller inadvertent releases and spills have also occurred.

4. If applicable, briefly summarize the circumstances associated with any onsite or offsite ground water monitoring result indicating a concentration in ground water of radioactivity released from plant operations that exceeds the maximum contaminant level (MCL) established by the United States Environmental Protection Agency (USEPA) for drinking water.

   Response: See response to 3 above. IPEC has identified onsite ground water that contains Tritium and Sr-90 in excess of USEPA drinking water criteria. However, no drinking water sources have been impacted by this onsite contamination, and no sources of drinking water are located on or adjacent to the site.

5. Briefly describe any remediation efforts undertaken or planned to reduce or eliminate levels of radioactivity resulting from plant operations in soil or ground water onsite or offsite.

   Response: Some of the current or planned remediation efforts include:

   - Past flaws in the Unit 2 spent fuel pool liner have been repaired as they were discovered. Currently, inspections of the liner are being performed, after which any needed repairs will be affected. Leakage from a crack in the Unit 2 SFP foundation structure, identified during 2005, is being collected to prevent its entry into ground water.
   - The Sr-90 concentration in the leaking Unit 1 SFP water is being reduced by increased demineralization of the pool water.
   - Leakage from the Unit 1 SFP is being collected by a modified curtain drain collection system. Radioactivity in this collected ground water is reduced by a demineralization system. The treated water is then monitored and released through the normal permitted discharge pathway.
   - Removal of spent fuel from the Unit 1 SFP will occur over the next couple of years, after which, the pool will be drained to prevent any further leakage.
   - The lining of certain sumps is planned.
   - The site's storm drains are being cleaned to remove contaminated sediments. After cleaning has been completed, the drain system will be inspected for damage and repaired if required.
   - At the conclusion of the ongoing ground water investigation, a determination will be made if remediation of the ground water plumes is warranted.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of

ENTERGY NUCLEAR OPERATIONS, INC.; ENTERGY NUCLEAR INDIAN POINT 2, LLC; ENTERGY NUCLEAR INDIAN POINT 3, LLC; HOLTEC INTERNATIONAL; and HOLTEC DECOMMISSIONING INTERNATIONAL, LLC; APPLICATION FOR ORDER CONSENTING TO TRANSFERS OF CONTROL OF LICENSES AND APPROVING CONFORMING LICENSE AMENDMENTS	Docket Nos.: 50-3 50-247 50-286 72-051

(Indian Point Nuclear Generating Station)

CERTIFICATION OF SERVICE

Pursuant to 10 C.F.R. § 2.305, I certify that I served the foregoing Declaration of Timothy B. Rice via the NRC's Electronic Information Exchange on this 12th day of February, 2020.

Signed (electronically) by

Joshua M. Tallent
Assistant Attorney General
Environmental Protection Bureau
The Capitol
Albany, NY 12224
(518) 776-2456
Joshua.Tallent@ag.ny.gov