



Revision 1

# **HYDROGEOLOGIC INVESTIGATION REPORT**

**FLEETWIDE ASSESSMENT  
DRESDEN GENERATING STATION  
MORRIS, ILLINOIS**

**Prepared For:  
Exelon Generation Company, LLC**

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## EXECUTIVE SUMMARY

This Hydrogeologic Investigation Report (HIR) documents the results of Conestoga-Rovers & Associates' (CRA's) May to August 2006 hydrogeologic investigation pertaining to the Dresden Generating Station (Station). CRA prepared this HIR for Exelon as part of its Fleetwide Program to determine whether groundwater at and in the vicinity of its nuclear power generating facilities has been adversely impacted by any releases of radionuclides.

CRA collected and analyzed information on any historical releases, the structures, components, and areas of the Station that have the potential to release tritium or other radioactive liquids to the environment and past hydrogeologic investigations at the Station. CRA used this information, combined with its understanding of groundwater flow at the Station to identify Areas for Further Evaluation (AFEs) for the Station.

CRA collected 68 groundwater samples and six surface water samples at the Station. CRA also collected two full rounds of water levels from the newly installed (with the exception of the wells installed in August) and existing wells and measured surface water levels. All groundwater and surface water samples were analyzed for tritium, strontium-89/90, and gamma-emitting radionuclides.

The results of the hydrogeologic investigation are:

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective Lower Limits of Detection (LLDs) in any of the groundwater or surface water samples obtained and analyzed during the course of this investigation;
- Strontium-90 was not detected in groundwater at concentrations greater than the United States Environmental Protection Agency drinking water standard of 8.0 pCi/L;
- Tritium was not detected at concentrations greater than the United States Environmental Protection Agency drinking water standard of 20,000 pCi/L in any of the groundwater or surface water samples obtained and analyzed during the course of this investigation;
- Tritium was detected in the shallow and intermediate groundwater zones at concentrations greater than the LLD of 200 pCi/L, which is considered background, but well below the applicable drinking water standard;
- These tritium concentrations ranged from  $210 \pm 124$  pCi/L, to  $13,200 \pm 319$  pCi/L;

- Strontium-90 was not detected at concentrations greater than the United States Environmental Protection Agency drinking water standard of 8.0 pCi/L in any of the groundwater or surface water samples obtained and analyzed during the course of this investigation;
- Strontium-90 was detected in a single intermediate well (MW-DN-108I) at concentrations greater than the Lower Limit of Detection of 2.0 pCi/L, which is well below the applicable drinking water standard;
- The strontium-90 concentration from MW-DN-108I was  $2.17 \pm 0.783$  pCi/L;
- Based on the results of this investigation, tritium originating from the Station is not migrating off the Station property at detectable concentrations;
- Based on the results of this investigation, there is no current risk of exposure to radionuclides associated with licensed plant operations through any of the identified potential exposure pathways; and
- Based upon the results of this investigation, there are no known active releases into the groundwater at the Station.

Based on the information collected to date, CRA recommends that Exelon conduct periodic monitoring of selected sample locations.

## 1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) prepared this Hydrogeologic Investigation Report (HIR) for Exelon Generation Company, LLC (Exelon) as part of its Fleetwide Program to determine whether groundwater at and near its nuclear power generating facilities has been adversely impacted by any releases of radionuclides. This report documents the results of CRA's May 2006 Hydrogeologic Investigation Work Plan (Work Plan) as well as several other investigative tasks recommended by CRA during the course of the investigation. These investigations pertain to Exelon's Dresden Generating Station in Morris, Illinois (Station) (see Figure 1.1). The Station is defined as all property, structures, systems, and components owned and operated by Exelon LLC located at 6500 North Dresden Road in Morris, Illinois.

Pursuant to the Work Plan, CRA assessed groundwater quality at the Station in locations designated as Areas for Further Evaluation (AFEs). The process by which CRA identified AFEs is discussed in Section 3.0 of this report.

The objectives of the Work Plan were to:

- characterize the geologic and hydrogeologic conditions within the Station, including subsurface soil types, the presence or absence of confining layers, and the direction and rate of groundwater flow;
- characterize the groundwater/surface water interaction at the Station, including a determination of the surface water flow regime;
- evaluate groundwater quality at the Station, including the vertical and horizontal extent, quantity, concentration, and source of tritium and other radionuclides in the groundwater, if any;
- define the probable sources of any radionuclides released at the Station;
- evaluate potential human, ecological, or environmental receptors of any radionuclides that might have been released to the groundwater; and
- evaluate whether interim response activities are warranted.

## 2.0 STATION DESCRIPTION

The following section presents a general summary of the Station location and definition, overview of Station operations, surrounding land use, and an overview of both regional and Station-specific topography, surface water features, geology, hydrogeology, and groundwater flow conditions. This section also presents an overview of groundwater use in the area.

### 2.1 STATION LOCATION

The Station consists of approximately 1,600 acres, of which approximately 400 acres are used for the generating facilities. The other approximately 1,284 acres of property encompass the Industrial Cooling Pond (Pond). The Station is located near the City of Morris, in Grundy County. The Station is located at the junction of the Kankakee and Des Plaines Rivers that merge to form the Illinois River. The Station address is 6500 North Dresden Road, Morris, Illinois. The Station is owned and operated by Exelon. Figure 2.1 presents the Station Boundaries and Features map, which includes key features. The Protected Area (PA) of the Station is the fenced-in area surrounding the Reactor and Turbine Buildings and other critical facilities related to the operation of the Station.

The Pond is located to the south of the Station and serves as the Station's storage and thermal loss point for cooling water used to condense the steam generated during normal operation of the two reactors. Two man-made, unlined canals run between the power generation buildings within the PA and the Pond and are known respectively as the Hot and Cold Canals.

### 2.2 OVERVIEW OF COOLING WATER OPERATION

The Station's generating system consists of a three-unit nuclear generating facility, capable of generating 1,824 gross megawatts of electricity. The generating station consists of one permanently shut down reactor (Unit 1) and two operating reactors (Units 2/3). Historically, Unit 1 began commercial operation in 1960. Unit 1 was subsequently shut down in October 1978 and is being decommissioned under the Nuclear Regulatory Commission's (NRC's) SAFSTOR program. The Station Unit 1 Operating License number is DPR-2. Units 2/3 are boiling water reactors (BWRs) and began commercial operation in 1970 and 1971, respectively. The Station's Unit 2

Operating License number is DPR-19. The Station's Unit 3 Operating License number is DPR-25.

A BWR plant consists of two separate loops of fluids. Each loop is designed to avoid mixing the fluids of one loop with the fluids of another. The loops are called the primary loop and the secondary loop.

The main purpose of the primary loop is to transfer the energy generated from fission in the fuel to the turbine to produce electricity. It is a closed loop system. Nuclear fission creates heat in the fuel. This heat is removed by the flow of reactor coolant water through the reactor vessel to the turbine. Steam is generated as a result and is used to power the turbine, transferring kinetic energy to the generator to produce electricity. The steam is then condensed on one side of the condenser and the water is pumped back to the reactor vessel to be heated by the fuel again.

The main purpose of the secondary loop cooling water is to cool the other side of the condenser, cooling the primary loop steam, and transferring the heat to the environment.

Cooling water for the Station is withdrawn from the Kankakee River by way of the Units 2/3 Intake Canal. Units 2/3 were originally designed to operate in a direct open cycle. Cooling water was routed from the Kankakee River to the Units 2/3 Cribhouse, through the condensers, and discharged directly to a canal routed to the Illinois River.<sup>1</sup>

Just after initial startup of Units 2/3, the Pond was constructed about 2 miles south of the Station. The clay dike encloses 1,284 acres. A 'Hot Canal' was cut from the discharge of Units 2/3 to the Pond Lift Station. Cooling water is lifted 22 feet and routes around the Pond back to weir gates or a Spillway, constructed just south of the Lift Station. The Return Canal ('Cold Canal') routes parallel to the Hot Canal back to the plant. The Cold Canal ends at a Flow Regulating Station with large gates that can divert the cooling water back to the plant (Closed Cycle operation) or discharge it to the Illinois River (Indirect Open Cycle). The Pond and both Hot and Cold Canals reduce thermal impact from dual unit operation.

The cooling water passes through the Units 2/3 Cribhouse and into the condensers. Once it passes through the condensers it exits the Turbine Building and is discharged to the Hot Canal and routes to the Pond. Cooling water is routed through the Pond in such

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<sup>1</sup> The Kankakee River is where the Intake point is located, whereas, the Illinois River is where the Discharge point is located (see Figure 2.1).

a way as to maximize the heat loss. After passing through the Pond, the cooling water is routed back to the Station via the Cold Canal. During the hotter summer months, the cooling water, from either the Hot or Cold Canals, also passes through a series of cooling towers. This allows the Station to increase its efficiency in the summer months. It enables the Station to comply with the thermal limits of its National Pollutant Discharge Elimination System (NPDES) Permit IL0002224. Due to the Station's differing demand for cooling water throughout the day, the water levels in the canals fluctuate markedly on a daily basis. There are two cooling cycles employed at the Station as discussed below.

From October 1 through June 14 of each year, the Station operates in a Closed Cycle mode during which a majority of the cooling water is recirculated, and discharge to the Illinois River is limited. In this mode, the Flow Regulating Gates divert cooling water from the Pond back to the Cribhouse Intake structure. In the Closed Cycle mode, 50,000 gallons per minute (gpm) are discharged (blowdown) to the Illinois River through a permitted outfall.

From June 15 through September 30 of each year, the Dresden NPDES Permit allows the Station to operate in the Indirect Open Cycle mode. In this mode, the Flow Regulating Gates divert all the cooling water flow to the Illinois River through a permitted outfall.

Figure 2.2 provides an overview of the Station's cooling water cycles.

### **2.3 SURROUNDING LAND USE**

Land surrounding the Station is primarily used for residential, agricultural, and limited industrial purposes. The Illinois River lies to the north of the Station, with residences located on the northern banks of a bluff on the river, overlooking the Station. To the east of the Station is the Kankakee River. Residential lots are located immediately south of the Station along the banks of the Kankakee River. To the west of the Station is vacant land owned by Exelon, with a General Electric Fuel Processing Facility further beyond. To the southwest of the Station is Goose Lake Prairie State Park, which is owned and operated by the Illinois Department of Natural Resources (Illinois DNR). The nearest urbanized area is the town of Channahon, which is approximately 3 miles to the northeast of the Station, across the Illinois River. Agricultural land is located further south and west of the Station.

## **2.4        STATION SETTING**

The following section presents a general summary of the topography, surface water features, geology, hydrogeology, and groundwater flow conditions near the Station. The information was primarily gathered from the Dresden Station Updated Final Safety Analysis Report (UFSAR), Revision 6, dated June 2005, and the Final Environmental Statement (FES), dated November 1973. The main references the UFSAR relies upon are listed in Section 10.0 of this HIR. CRA checked and verified all UFSAR references that apply to this HIR.

### **2.4.1      TOPOGRAPHY AND SURFACE WATER FEATURES**

The Station is located within the Kankakee River Basin adjacent to the confluence of the Kankakee River and Des Plaines River forming the Illinois River (Willman and Frye, 1969; Frye et al., 1969). In general, the topography of the area slopes downward toward the Kankakee and Illinois Rivers (see Figure 1.1 and United States Geological Topographic Quadrangle Map – Dresden Mosaic, Illinois dated 1994).

Figure 2.1 presents portions of some of the relevant surface water features at the Station such as the Pond, and Hot and Cold Canals. The topography at the Station is generally flat, with a gentle slope down to the Kankakee and Illinois Rivers. Any surface water flows via storm drains and man-made ditches.

There are four rock (rip-rap) lined storm drain basins at the Station that originate in the vicinity of the Units 2/3 Reactor Building. For the purposes of this report, the storm drain basins are the East Drainage Basin, West Drainage Basin, Southwest Drainage Basin, and Southeast Drainage Basin.

The East Drainage Basin drains the area around the southeastern and northeastern perimeter of the Turbine Building, and a portion of the Station area located between Unit 1 and the Kankakee River. The East Drainage Basin discharges to the Unit 1 Intake Canal.

The West Drainage Basin drains the area around the western perimeter of the Turbine Building, as well as the area to the northwest. The West Drainage Basin discharges to the Units 2/3 Discharge Canal through a point located in the west side of the canal.

The Southwest Drainage Basin is located further to the south and west of the Turbine Building and drains storm water via a drainage ditch located on the south edge of the

PA. The Southwest Drainage Basin, during times of heavy rainfall, discharges to the Hot Canal.

The Southeast Drainage Basin is located further to the south and east of the Turbine Building and drains storm water via a drainage ditch located on the southeast edge of the PA. The Southeast Drainage Basin, during times of heavy rainfall, discharges to the Kankakee River (RETEC, 2005).

The primary surface water features within the area of the Station include the Illinois River to the north, the Des Plaines River to the east, and the Kankakee River to the southeast. The Station is located to the south of the intersection of the Kankakee and Des Plaines River that converge to form the Illinois River. Man-made surface water features include two Intake Canals (Unit 1 and Units 2/3) leading from the Kankakee River, two Discharge Canals (Unit 1 and Units 2/3) leading to the Illinois River, the Pond, and two canals leading to and from the Pond known as the Hot and Cold Canals, respectively. There are also small lakes and wetlands to the south and southwest of the Station.

#### **2.4.2**      **GEOLOGY**

Figure 2.3 presents a stratigraphic section of the Station area geology. The geology near the Station is comprised of these stratigraphic units:

- Overburden and Fill Material;
- Pottsville Sandstone;
- Divine Limestone;
- Maquoketa Shale; and
- Galena Dolomite.

Regionally, the overburden typically consists of a Quaternary Age sand and gravel unit and a glacial till unit with some lenses of coarse-grained glacial drift (Frye, 1969; RETEC, 2005). However, in locations bordering major rivers, overburden deposits of alluvial origin exhibiting variable composition and thickness are expected to be predominant. At the Station, overburden deposits are of limited areal extent and consist of highly organic dark brown to black sandy clay with some gravel (RETEC, 2005). Where present at the Station, the thickness of these deposits is typically less than 5 feet. Fill material, consisting of gravel and sand, is present to depths of up to 30 feet below ground surface (bgs) in certain areas within the PA due to construction of the Station.

At the Station, the overburden deposits, where present, are underlain by the Pennsylvanian-aged Pottsville Sandstone. The Pottsville Sandstone is exposed at ground surface in areas where overburden deposits are absent. Regionally, the Pottsville Sandstone exhibits prominent cross bedding, which was observed in the outcrops along the Hot and Cold Canals at the Station (Harza, 1991, 1995; RETEC, 2005). The sandstone is absent north of the Station, and in areas to the west and southeast of the Station according to residential and State well logs. The thickness of the sandstone, where present, near the Station ranges from 25 to 30 feet.

The Ordovician-aged Divine Limestone unconformably underlies the Pennsylvanian-aged Pottsville Sandstone beneath the Station (i.e., intermediary Silurian- and Devonian-aged units are absent) (Harza, 1991, 1995). Regionally, the Divine Limestone is considered part of the Maquoketa Shale Group and has a regional dip to the southeast of approximately 25 feet per mile (Willman, 1975; Harza, 1991, 1995). The Divine Limestone is widely distributed throughout Illinois; however, in some areas it becomes interbedded with shale and can be inseparable from the shales below (Willman, 1975). This is depicted in many of the intermediate well boring logs (Appendix A) at approximately 35 to 40 feet bgs, where a transitional limestone/shale layer was noted. The thickness of the Divine Limestone varies from 25 to 30 feet thick across the Station (Harza, 1991, 1995).

The Ordovician-aged Maquoketa Shale is also part of the Maquoketa Shale Group and consists of dark gray to dark green dolomitic shale (Willman, 1975). The regional thickness of the Maquoketa Shale consistently ranges between 65 and 70 feet; however, the elevation of the shale surface varies significantly. Based on the three deep wells installed by RETEC in March 2005 (DSP-157D, DSP-158D, and DSP-159D), the thickness of the shale at the Station ranged from 64 to 68 feet. Similar to the Divine Limestone, the Maquoketa Shale has a regional dip to the southeast of approximately 25 feet per mile (Willman, 1975; Harza, 1991, 1995).

Beneath the Maquoketa Shale Group lies the Ordovician-aged Galena Dolomite. Regionally, the Galena Dolomite consists of limestone and dolomite formations (Willman, 1975; Burch, 2002; Buschbach, 1964). At the Station, according to RETEC logs (Appendix A), this unit consists of a light-brownish gray to pinkish-white crystalline dolomite.

### 2.4.3 HYDROGEOLOGY

The hydrogeologic units underlying the Station include the:

- Water table aquifer consisting of the Pottsville Sandstone and Divine Limestone; and
- Deep Aquifer consisting of the Galena Dolomite.

The water table is the uppermost groundwater aquifer. Groundwater in the water table aquifer occurs under unconfined conditions under the Station, and is found within the Pottsville Sandstone and Divine Limestone. The upper flow zone of the water table is defined in the Pottsville Sandstone and the lower flow zone of the water table is defined in the Divine Limestone. The depth to groundwater varies across the Station, ranging from approximately 3 feet bgs to 16 feet bgs (Harza, 1991, 1995; RETEC, 2005). The water table aquifer is monitored by shallow monitoring wells screened within the upper portion of the water table aquifer in the sandstone (20 to 25 feet deep), and intermediate wells (35 and 50 feet deep) screened within the water table aquifer in the limestone.

The Maquoketa Shale is the lower confining unit to the water table aquifer and hydraulically separates the water table aquifer from the lower aquifers at the Station (Harza, 1991, 1995). Regional hydrogeologic reports indicate that vertical migration downward from the water table aquifer is impeded where the Maquoketa Shale is present due to its low permeability acting as an aquitard (Harza, 1991, 1995; RETEC, 2005).

Beneath the impermeable Maquoketa Shale, the Galena Dolomite is the next water-bearing unit and is considered the Deep Aquifer at the Station. The upper portion of the Galena Dolomite is unsaturated as indicated by the apparent dry conditions in the deep wells (RETEC, 2005).

## 2.5 AREA GROUNDWATER USE

CRA conducted an area wide well inventory of all private, institutional, and public wells within approximately 2 miles of the Station and a total of 109 wells were identified (Appendix B). There are 13 domestic (private) wells, one institutional well, four unknown usage wells, and one well owned by the Station that obtain their water from the deeper (i.e., well depth of 600 feet or greater) bedrock aquifers (see Figure B.1). CRA was unable to confirm all well locations using the Illinois State Geologic Survey's online well database. Regional water supplies at towns to the west and northeast obtain their water supplies from deep aquifers at depths over 600 feet below the Maquoketa Shale.

This shale aquitard prevents water from migrating vertically downward to the production wells.

The groundwater beneath the Station is used for potable purposes. The Station obtains water from one 1,500-foot deep well and one 788-foot deep well completed in the deep bedrock below the Maquoketa Shale. The groundwater withdrawn from these wells is stored in a 100,000-gallon domestic water tank, and is used for potable purposes and to produce demineralized water.

### 3.0 AREAS FOR FURTHER EVALUATION

CRA considered all Station operations in assessing groundwater quality at the Station. During this process, CRA identified areas at the Station that warranted further evaluation or "AFEs". This section discusses the process by which AFEs were selected.

CRA's identification of AFEs involved the following components:

- Station inspection on March 22 and 23, 2006;
- interviews with Station personnel;
- evaluation of Station systems;
- investigation of confirmed and unconfirmed releases of radionuclides; and
- review of previous Station investigations.

CRA analyzed the information collected from these components combined with information obtained from CRA's study of hydrogeologic conditions at the Station to identify those areas where groundwater potentially could be impacted from operations at the Station.

CRA then designed an investigation to determine whether any confirmed or potential releases or any other release of radionuclides adversely affected groundwater. This entailed evaluating whether existing Station groundwater monitoring systems were sufficient to assess the groundwater quality at the AFEs. If the systems were not sufficient to adequately investigate groundwater quality associated with any AFE, additional monitoring wells were installed by CRA.

The following sections describe the above considerations and the identification of AFEs. The results of CRA's investigation are discussed in Section 5.0.

### 3.1 SYSTEMS EVALUATIONS

Exelon launched an initiative to systematically assess the structures, systems and components that store, use, or convey potentially radioactively contaminated liquids. Maps depicting each of these systems were developed and provided to CRA for review. The locations of these systems are presented on Figure 3.1. The Station identified a total of 18 systems that contain or could contain potentially radioactively contaminated liquids. The following presents a list of these systems.

<i>System Identification</i>	<i>Description</i>
<b>Unit 1</b>	
13	Emergency Condenser
19	Fuel Pool Cooling
20	Radwaste
33	Condensate
39	Service Water
54	Off Gas
57	Heating Steam
<b>Units 2/3</b>	
13	Isolation Condenser
19	Fuel Pool Cooling
20	Radwaste
23	High Pressure Coolant Injection (HPCI) System
33	Condensate
44	Circulating Water
48	Reactor Building Equipment Drains Sumps
49	Turbine Building Equipment Drains Sumps
54	Off Gas
57	Heating Steam
89	High Radiation Sampling System

After these systems were identified, Exelon developed a list of the various structures, components and areas of the systems (e.g., piping, tanks, process equipment) that handle or could potentially handle any radioactively contaminated liquid. The structures, components, and areas may include:

- aboveground storage tanks;
- condensate vents;
- areas where confirmed or potential historical releases, spills, or accidental discharges may have occurred;
- pipes;
- pools;
- sumps;
- surface water bodies (i.e., basins, pits, ponds, or lagoons);
- trenches;
- underground storage tanks; and
- vaults.

The Station then individually evaluated the various system components to determine the potential for any release of radioactively contaminated liquid to enter the environment. Each structure or identified component was evaluated against the following seven primary criteria:

- location of the component (i.e., basement or second floor of building);
- component construction material (i.e., stainless steel or steel tanks);
- construction methodologies (i.e., welded or mechanical pipe joints);
- concentration of radioactively contaminated liquid stored or conveyed;
- amount of radioactively contaminated liquid stored or conveyed;
- existing controls (i.e., containment and detection); and
- maintenance history.

System components, which were located inside a building or that otherwise had some form of secondary containment, such that a release of radioactively contaminated liquid would not be discharged directly to the environment, were eliminated from further evaluation. System components that are not located within buildings or did not have some other form of secondary containment were retained for further qualitative evaluation of the risk of a release of radioactively contaminated liquid to the environment and potential magnitude of any release.

Exelon's risk evaluation took into consideration factors such as:

- the potential concentration of radionuclides;
- the volume of liquid stored or managed;
- the probabilities of the systems actually containing radioactively contaminated liquid; and
- the potential for a release of radioactively contaminated liquid from the system component.

These factors were then used to rank the systems and system components according to the risk for a potential release of a radioactively contaminated liquid to the environment. The evaluation process resulted in the identification of structures, components, and areas to be considered for further evaluation.

### **3.2 HISTORICAL RELEASES**

CRA also reviewed information concerning confirmed or potential historical releases of radionuclides at the Station, including reports and documentation previously prepared by Exelon and compiled for CRA's review. CRA evaluated this information in identifying AFEs. Any historical releases identified during the course of this assessment, which may have a current impact on Station conditions, are further discussed in Section 3.4.

### **3.3 STATION INVESTIGATIONS**

CRA considered previous Station investigations in the process of selecting the AFEs for the Station. This section presents a summary of the Station's Radiological Environmental Monitoring Program (REMP) and past Station investigations.

#### **3.3.1 POWER PLANT DOCUMENTS-UFSAR REPORT**

During the construction of the Station, a series of comprehensive investigations of regional and local geology, surface water, and groundwater conditions were conducted. These studies were performed for a number of purposes including geotechnical evaluations of the underlying bedrock, engineering designs for the Station around the Pond, present and future sources of groundwater, present and future groundwater use, and other engineering and environmental purposes. These studies are documented in the UFSAR and FES for the Station.

#### **3.3.2 RETEC GROUNDWATER INVESTIGATION STUDY**

In response to tritium detected in July 2004 groundwater samples collected by the Station, RETEC was contracted to characterize the nature of groundwater flow at the facility and to evaluate the extent of the tritium. RETEC reviewed historical data, installed additional monitoring wells, conducted geophysical logging, completed two rounds of water level measurements, performed slug tests, and sampled groundwater for tritium.

RETEC's groundwater investigation report (dated December 7, 2005) concluded that elevated tritium concentrations were detected in groundwater samples from wells located near the Condensate Storage Tank (CST) System, the Unit 1 Spent Fuel Pool,

Unit 1 Reactor Building, and the Radwaste discharge piping location for Units 2/3. RETEC's investigation revealed that the bulk of the tritium discharged to the groundwater from the CST system and flowed toward the east and northwest under the influence of the local hydraulic gradient. The tritium plume was not likely to move in a southeasterly direction, toward residential wells. On November 30, 2005, Exelon submitted this report to Illinois EPA.

### **3.3.3 GROUNDWATER MONITORING PROGRAM**

The Station has a monitoring program that has identified approximately 54 sampling locations (storm drain system catchbasins, groundwater monitoring wells, and surface water sampling locations), some of which are sampled as often as every day.

### **3.3.4 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM**

The REMP at the Station was initiated in 1966. The REMP includes the collection of multi-media samples including air, surface water, groundwater, fish, sediment, vegetation, local cow milk, and residential potable water. The samples are analyzed for beta and gamma-emitting radionuclides, tritium, iodine-131, and/or strontium as established in the procedures developed for the REMP. The samples are collected at established locations, identified as stations, so that trends in the data can be monitored.

Surface water samples and groundwater samples are collected, as part of REMP at a total of five locations. Surface water samples are collected at two locations upstream of the Station on the Kankakee (D-54) and Des Plaines (D-52) Rivers, and at one location downstream of the Station on the Illinois River (D-51). Groundwater samples are collected from a residential well "RW-1" (D-23), and at the Dresden Island Lock and Dam well (D-35).

In 2005, surface water tritium concentrations in the Kankakee River ranged from the Lower Limit of Detection (LLD) of 200 pCi/L to 720 pCi/L and are considered an upstream source.

An annual report is prepared providing a description of the activities performed and the results of the analysis of the samples collected from the various media. The latest report generated was prepared by Station personnel and is entitled "Dresden Nuclear Power Station Units 1, 2, and 3 Annual Radiological Environmental Operating Report, 1 January through 31 December 2005". This report concluded that the operation of the

Station had no adverse radiological impact on the environment. The annual report is submitted to the NRC.

### 3.4 IDENTIFIED AREAS FOR FURTHER EVALUATION

CRA used the information contained herein along with its understanding of the hydrogeology at the Station to identify AFEs, which were a primary consideration in the development of the scope of work in the Work Plan. The establishment of AFEs is a standard planning practice in hydrogeologic investigations to focus the investigation activities at areas where there is the greatest potential for impact to groundwater.

Specifically, AFEs were identified based on these six considerations:

- systems evaluations;
- risk evaluations;
- review of confirmed and/or potential releases;
- review of documents;
- review of the hydrogeologic conditions; and
- Station inspection completed on March 22 and 23, 2006.

Prior to CRA completing its analysis and determination of AFEs, Station personnel completed an exhaustive review of all historic and current management of systems that may contain potentially radioactively contaminated liquids.

CRA reviewed the systems identified by the Station, which have the potential for the release of radioactively contaminated liquids to the environment, and groundwater flow at the Station. This evaluation allowed CRA to become familiar with Station operations and potential systems that may impact groundwater. CRA then evaluated information concerning historic releases as provided by the Station. This information, along with a review of the results from historic investigations, was used to refine CRA's understanding of areas likely to have the highest possibility of impacting groundwater. Where at-risk systems or identified historical releases were located in close proximity or were located in areas, which could not be evaluated separately, the systems and historical releases were combined into a single AFE. At times, during the Station investigation, separate AFEs were combined into one or were otherwise altered based on additional information and consideration.

Finally, CRA used its understanding of known hydrogeologic conditions (prior to this investigation) to identify AFEs. Groundwater flow was an important factor in deciding whether to combine systems or historical releases into a single AFE or create separate AFEs. For example, groundwater flow beneath several systems that contain radioactively contaminated liquid that flows toward a common discharge point were likely combined into a single AFE.

Based upon its review of information concerning confirmed or potential historical releases, historic investigations, and the systems at the Station that have the potential for release of radioactively contaminated liquids to the environment combined with its understanding of groundwater flow at the Station, CRA has identified the following as the only AFEs (see Figure 3.1).

#### AFE-Dresden-1: CST System HPCI Piping for Units 2/3

This AFE was established based on information regarding historical releases of tritiated water in this area. In 1994 there was a leak from the HPCI return piping to the CST. The piping was isolated and repaired. Shallow groundwater monitoring wells were installed at that time. In August of 2004, the wells outside the Units 2/3 Reactor Building identified elevated tritium concentrations resulting from a leak in the HPCI suction piping. The piping was isolated and repaired. In January 2006, the Station personnel identified higher than expected concentrations of tritium in this area as part of its groundwater monitoring program. The HPCI piping in this area was suspect and isolated. The HPCI piping replacement is currently in progress.

#### AFE-Dresden-2: Unit 1 Spent Fuel Pool

This AFE was established based on information regarding the historical releases in this area consisting of a spent fuel pool overflow. Specifically, in 1989, radioactively contaminated water overflowed from the Unit 1 Fuel Pool. Available data showed soil was removed from the area.

#### AFE-Dresden-3: Radwaste Discharge Lines for Units 2/3

This AFE was established based on information regarding historical releases in this area, including those in 1984 and 1986. In October 1984 and July 1986 leaks occurred in the Units 2/3 Radwaste discharge piping. Most notably, in November 1999, a leak occurred on Units 2/3 Radwaste River Discharge Canal pipe. The piping was excavated and subsequently replaced.

AFE-Dresden-4: Piping from CST System and Storm Drain to Unit 1 Intake Canal

This AFE was established based on information regarding a historical release in this area due to a leak in an underground contaminated demineralized water (CDW) pipe. The water flowed into a storm drain that led to the Unit 1 Intake Canal.

## 4.0 FIELD METHODS

The field investigations completed for this HIR were completed in May and June 2006. Supplemental field activities were completed in July and August 2006. CRA supervised the installation of monitoring wells, collected samples from the newly-installed and existing monitoring wells, and collected samples from surface water locations. The field investigations were completed in accordance with the methodologies presented in the Work Plan (CRA, 2006).

### 4.1 SURFACE WATER ELEVATION MONITORING POINTS

Water levels in surface water bodies were measured from four surface water elevation monitoring points (SW-DN-101, SW-DN-102, SW-DN-103, and SW-DN-106) in June 2006 using a portable water level meter from fixed locations on bridges. During the August 2006 supplemental field activities, surface water elevations were measured from seven surface water elevation monitoring points (SW-DN-101, -102, -103, -104, -105, -106, and -107). The surface water elevation monitoring points are presented on Figure 4.1. Staff gauges were not installed at the Station due to safety concerns. Surface water elevations at locations SW-DN-104, -105, and -107 were not collected in May 2006 due to safety concerns at that time.

### 4.2 GROUNDWATER MONITORING WELL INSTALLATION

Sixteen new monitoring wells were installed for the fleetwide hydrogeologic investigation in May 2006. An additional 21 new monitoring wells were installed in July 2006 for the fleetwide hydrogeologic investigation. The additional wells were installed to further characterize the groundwater flow system and to determine the impact of surface water in the canals on groundwater flow directions. Monitoring well construction logs are provided in Appendix A. Figure 4.2 presents the locations of the 37 new monitoring wells and the existing monitoring wells at the Station. These locations were selected based on a review of all data provided, the hydrogeology at the Station, the existing well locations, and current understanding of identified AFEs. Table 4.1 summarizes the well completion details. The shallow boreholes were advanced into the bedrock from approximately 20 feet bgs to 42 feet bgs based upon the depth of the Pottsville Sandstone Formation, with the exception of locations MW-DN-102S (15 feet bgs) and MW-DN-107S (15 feet bgs). MW-DN-102S could not be advanced beyond 15 feet bgs due to complications with drilling and MW-DN-107S was only set on top of the bedrock and screened within the fill material at the Station. The

intermediate boreholes were advanced into the bedrock from approximately 50 feet bgs to 61 feet bgs depending upon the depth to the Maquoketa Shale Formation.

Prior to completing any ground penetration activities, CRA completed subsurface utility clearance procedures to minimize the potential of injury to workers and/or damage to subsurface utility structures. The subsurface clearance procedures consisted of completing an electronic survey within a minimum of 10-foot radius of the proposed location utilizing electromagnetic and ground penetrating radar technology. Additionally, an air knife was utilized to verify utilities were not present at the proposed location to a depth to 10 feet bgs.

Specific installation protocols for the shallow and intermediate monitoring wells are described below:

- the borehole was advanced to the target depth by an air rotary drill equipped with a 6-inch outer diameter drill bit;
- a nominal 2-inch diameter (No. 10 slot) PVC screen, 10 feet in length, attached to a sufficient length of 2-inch diameter schedule 40 PVC riser pipe to extend to the surface, was placed into the borehole through the augers;
- a filter sand pack consisting of silica sand was installed to a minimum height of 2 feet above the top of the screen as the augers were removed;
- a minimum 2-foot thick seal consisting of 3/8-inch diameter bentonite pellets or chips was placed on top of the sand pack and hydrated using potable water;
- the remaining borehole annulus was sealed to within 3 feet of the surface using pure bentonite chips; and
- the remaining portion of the annulus was filled with concrete and a 6-inch diameter protective above-grade casing. The wellhead was fitted with a watertight, lockable cap.

#### **4.3 GROUNDWATER MONITORING WELL DEVELOPMENT**

In order to establish good hydraulic communication with the aquifer and reduce the volume of sediment in the newly installed monitoring wells, monitoring well development was conducted in accordance with the procedure outlined below:

- monitoring wells were surged using a pre-cleaned surge block or bailer for a period of at least 10 minutes;

- water was purged from the monitoring well using an electric submersible or peristaltic pump;
- groundwater was collected at regular intervals and the pH, temperature, and conductivity were measured using field instruments. These instruments were calibrated daily according to the manufacturer's specifications. Additionally, observations such as color, odor, and turbidity of the purged water were recorded; and
- development continued until the turbidity and silt content of the monitoring wells were significantly reduced and three consistent readings of pH, temperature, and conductivity were recorded, or a maximum of ten well volumes were purged.

Thirty-six of 37 newly installed monitoring wells were developed in accordance with this monitoring well development procedure. Monitoring well MW-DN-123S was dry upon installation and was therefore not developed.

A summary of monitoring well development parameters is provided in Table 4.2.

#### **4.4      SURVEY**

The new monitoring wells and surface water sampling locations were surveyed to establish reference elevations relative to mean sea level. The top of each well casing was surveyed to the nearest 0.01 foot relative to the North American Vertical Datum, 1988 (NAVD 88), and the survey point was marked on the well casing. The survey included the ground elevation at each well to the nearest 0.10 foot relative to the NAVD 88, and the well location to the nearest 1.0 foot. A reference point was also marked on the bridge surface or railing.

#### **4.5      GROUNDWATER AND SURFACE WATER ELEVATION MEASUREMENTS**

On May 22, 2006 and again on August 7, 2006, CRA collected a round of water level measurements from the monitoring wells and surface water elevation monitoring points at the Station in accordance with the Work Plan. Based on the measured depth to water from the reference point and the surveyed elevation of the reference point, the groundwater or surface water elevation was calculated. A summary of groundwater elevations for the event is provided in Table 4.3. A summary of surface water elevations for the event is provided in Table 4.4.

Prior to the water level measurements, the wells were identified and located. Once the wells were identified, CRA completed a thorough inspection of each well and noted any deficiencies. Water level measurements were collected using an electronic depth-to-water probe accurate to  $\pm 0.01$  foot. The measurements were made from the designated location on the inner riser or steel casing of each monitoring well, and on the reference point for each surface water elevation monitoring point. The water level measurements were obtained using the following procedures:

- the proper elevation of the meter was checked by inserting the tip into water and noting if the contact was registering correctly;
- the tip was dried, and then slowly lowered into the well until contact with the water was indicated;
- the tip was slowly raised until the light and/or buzzer just began to activate. This indicated the static water level;
- the reading at the reference point was noted to the nearest hundredth of a foot;
- the reading was then re-checked; and
- the water level was then recorded, and the water level meter decontaminated prior to use at the next well location.

#### 4.6 GROUNDWATER AND SURFACE WATER SAMPLE COLLECTION

CRA conducted one round of groundwater sampling during the completion of the Work Plan for these hydrogeologic investigations. A total of 45 monitoring wells were sampled between May 23 and June 2, 2006. Of the 45 monitoring wells sampled, 16 were newly installed. In addition, between August 7, 2006 to August 14, 2006, CRA conducted a supplemental round of groundwater sampling of 21 newly installed wells (installed in July 2006) and one previously installed groundwater well. The sampling for each event was scheduled to allow for 2 weeks to elapse between well development and groundwater sample collection. The existing wells were selected for inclusion in this investigation based on their proximity to AFEs.

At the monitoring well locations, CRA conducted the sampling using pneumatic bladder pumps or peristaltic pumps and dedicated polyethylene tubing to employ low flow purging techniques as described in Puls and Barcelona (1996).

The groundwater in the monitoring wells was sampled by the following low-flow procedures:

- the wells were located and the well identification numbers were verified;
- a water level measurement was taken;
- the well was sounded by carefully lowering the water level tape to the bottom of the well (so as to minimize penetration and disturbance of the well bottom sediment), and comparing the sounded depth to the installed depth to assess the presence of any excess sediment or drill cuttings;
- the pump or tubing was lowered slowly into the well and fixed into place such that the Intake was located at the mid-point of the well screen, or a minimum of 2 feet above the well bottom/sediment level;
- the purging was conducted using a pumping rate between 100 to 500 milliliters per minute. Initial purging began using the lower end of this range. The groundwater level was monitored to ensure that a drawdown of less than 0.3 foot occurred. If this criterion was met, the pumping rate was increased dependent on the behavior of the well. During purging, the pumping rate and groundwater level were measured and recorded approximately every 10 minutes;
- the field parameters [pH, temperature, conductivity, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity] were monitored during the purging to evaluate the stabilization of the purged groundwater. Stabilization was considered to be achieved when three consecutive readings for each parameter, taken at 5-minute intervals, were within the following limits:

pH                                     $\pm 0.1$  pH units of the average value of the three readings,

Temperature                     $\pm 3$  percent of the average value of the three readings,

Conductivity                     $\pm 0.005$  milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity  $<1$  mS/cm and  $\pm 0.01$  mS/cm of the average value of the three readings for conductivity  $>1$  mS/cm,

ORP                                     $\pm 10$  millivolts (mV) of the average value of the three readings,

DO                                         $\pm 10$  percent of the average value of the three readings, and

Turbidity                             $\pm 10$  percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTUs);

- once purging was complete, the groundwater samples were collected directly from the pump/tubing directly into the sample containers; and

- in the event that the groundwater recharge to the monitoring well was insufficient to conduct the low-flow procedure, the well was pumped dry and allowed to sufficiently recharge prior to sampling.

All groundwater samples were labeled with a unique sample number, the date and time, the parameters to be analyzed, the job number, and the sampler's initials. For the May and June 2006 sampling event, the samples were screened by the Station for shipment to Teledyne Brown Engineering Inc. (Teledyne Brown). For the August 2006 sampling event, groundwater samples were shipped to Teledyne Brown based on screening results obtained during well development activities.

Due to the limited volume of water available for collection in monitoring well MW-DN-123S, the monitoring well was not purged and a bailer was used to collect a groundwater sample for tritium only (insufficient volume of groundwater remained to sample for strontium-89/90 or gamma-emitting radionuclides).

Field measurements for the hydrogeologic investigation are presented in Table 4.5 and a sample key is provided in Table 4.6.

CRA containerized the water purged from the monitoring wells during the sampling, as well as the water purged from all of the wells during the hydrogeologic investigation. The water was placed into 55-gallon drums, which will be processed by the Station in accordance with its NPDES permit.

Surface water samples were collected from May 23 to June 2, 2006 at the Units 2/3 Intake Canal (SW-DN-101), Units 2/3 Discharge Canal (SW-DN-102), Recycling Canal (SW-DN-103), Hot Canal (SW-DN-104), Cold Canal (SW-DN-105) and the Pond (SW-DN-106). The surface water sampling locations are presented on Figure 4.1.

The surface water samples were collected by directly filling the sample container from the composite samplers at the determined locations until completely filled. A sample key is presented in Table 4.6.

#### **4.7 DATA QUALITY OBJECTIVES**

CRA has validated the analytical data to establish the accuracy and completeness of the data reported. Teledyne Brown provided the analytical services. The Quality Assurance Program for the laboratory is described in Appendix C. Analytical data for groundwater and surface water samples collected in accordance with the Work Plan are

presented in Appendix D. Data validation reports are presented in Appendix E. The data validation included the following information and evaluations:

- sample preservation;
- sample holding times;
- laboratory method blanks;
- laboratory control samples;
- laboratory duplicates;
- verification of laboratory qualifiers; and
- field quality control (field blanks and duplicates).

Following the completion of field activities, CRA compiled and reviewed the geologic, hydrogeologic, and analytical data.

The data were reviewed using the following techniques:

- data tables and databox figures;
- hydrogeologic cross-sections; and
- hydraulic analyses.

#### 4.8 SAMPLE IDENTIFICATION

Systematic sample identification codes were used to uniquely identify all samples. The identification code format used in the field was: WG - DN - DSP-152 - 052306 - JH - 001. A summary of sample identification numbers is presented in Table 4.6.

WG	-	Sample matrix -groundwater
WS	-	Sample matrix - surface water
RB	-	Sample matrix - rinse blank
DN	-	Station code
DSP-152	-	Well location
052306	-	Date
JH	-	Sampler initial
001	-	Sample number

#### 4.9 CHAIN-OF-CUSTODY RECORD

The samples were delivered to Station personnel under chain-of-custody protocol. Subsequently, the Station shipped the samples under chain-of-custody protocol to Teledyne Brown for analyses.

#### 4.10 QUALITY CONTROL SAMPLES

Quality control samples were collected to evaluate the sampling and analysis process.

##### Field Duplicates

Field duplicates were collected to verify the accuracy of the analytical laboratory by providing two samples collected at the same location and then comparing the analytical results for consistency. Field duplicate samples were collected at a frequency of one duplicate for every ten samples collected. A total of four duplicate samples were collected. The locations of duplicate samples were selected in the field during the performance of sample collection activities. The duplicate samples were collected simultaneously with the actual sample and were analyzed for the same parameters as the actual samples.

##### Split Samples

During the May/June 2006 sampling event, split samples were collected for the NRC for tritium simultaneously with the actual sample at every sample location. Split samples were delivered to the Station personnel and made available to the NRC and Illinois Environmental Protection Agency (EPA).

During the August 2006 sampling event, split samples were collected for the NRC and for the Illinois Emergency Management Agency (IEMA) for tritium simultaneously with the actual sample at every sample location. Split samples were delivered to the Station personnel and made available to the NRC, IEMA, and Illinois EPA.

#### 4.11 ANALYSES

Groundwater and surface water samples were analyzed for tritium and gamma-emitting radionuclides as listed in NUREG-1302 and strontium-89/90 as listed in 40 CFR 141.25.

## 5.0 RESULTS SUMMARY

This section provides a summary of Station-specific geology and hydrogeology, along with a discussion of hydraulic gradients, groundwater elevations, and flow directions in the vicinity of the Station. This section also presents and evaluates the analytical results obtained from activities performed in accordance with the Work Plan.

### 5.1 STATION GEOLOGY

The geology encountered during the monitoring well installation activities is consistent with the geology described in Section 2.4.2 and the geology described by RETEC (RETEC, 2005). The geology beneath the Station consists of a relatively thin overburden deposit that overlies layers of sandstone, limestone, shale, and dolomite. Geologic cross-section locations are shown on Figure 5.1 and the geologic lines of sections are shown on Figures 5.2 and 5.3, respectively. Geological units at the Station consist of the following:

- Thin layer of overburden and fill;
- Pottsville Sandstone Formation;
- Divine Limestone Formation;
- Maquoketa Shale; and
- Galena Dolomite Formation.

Where present, the overburden ranges between 0 and 5 feet thick at the Station and consists of highly organic dark brown to black sandy clay with some gravel. During construction of the Station, fill consisting of gravel and sand was used to replace the overburden within the PA. At monitoring well MW-DN-108I, fill was encountered to a depth of approximately 26 feet bgs. According to Station personnel, MW-DN-108I was drilled over the abandoned intake trough for the Unit 1 cooling water from the Unit 1 Cribhouse. There is approximately 12 feet of fill along the east bank of the Hot Canal near well cluster DSP-159; the fill was placed several years ago during construction. Monitoring well MW-DN-107S was also installed in the fill in the PA.

The Pottsville Sandstone Formation is a hard, gray to yellowish-brown, medium- to coarse-grained sandstone. The Pottsville Sandstone Formation is prevalent beneath the entire area of the Station as shown on Figures 5.2 and 5.3. The thickness of the sandstone near the Station ranges from 25 to 30 feet. Monitoring wells MW-DN-101S to -106S, -109S to -116S, and -118S to -123S are all screened within the Pottsville Sandstone

Formation. According to RETEC, the Pottsville Sandstone Formation was not encountered during drilling activities to the south of the Station at well clusters DSP-158 or DSP-159.

The Divine Limestone Formation is below the Pottsville Sandstone Formation and is a hard, light-gray crystalline limestone. A transitional zone was noted between the Divine Limestone and the underlying Maquoketa Shale at approximately 40 to 55 feet bgs where the Divine Limestone Formation had interbedded layers of shale and traces of chert present. The thickness of the Divine Limestone Formation across the Station is approximately 15 to 30 feet. Monitoring wells MW-DN-101I, -102I, -103I, -108I to -117I, and -119I to -123I are all screened within the Divine Limestone Formation.

The Maquoketa Shale is below the Divine Limestone Formation and is a hard, pale-green to gray shale with some locations having trace amounts of sandstone and limestone. The Maquoketa Shale acts as a confining layer and aquitard at the Station, separating the water table aquifer from the Deep Aquifer below. To identify the bottom of the water table aquifer, the boring was advanced approximately 2 feet into the top of the Maquoketa Shale during installation of intermediate monitoring wells. The depth to the top of the shale ranged from 45 to 55 feet.

Underneath the Maquoketa Shale is the Galena Dolomite Formation; however, it was not encountered during the HIR drilling because none of the newly installed wells penetrated the overlying Maquoketa Shale. The existing monitoring wells at the Station that are set into the upper portion of the Galena Dolomite Formation (DSP-157D, DSP-158D, and DSP-159D) were dry when monitored during the HIR.

Two geologic cross-sections were generated employing the stratigraphic data collected during this investigation. The geologic cross-section locations are shown on Figure 5.1 and the geologic lines-of-sections trending north-south and east-west are shown on Figures 5.2 and 5.3, respectively.

Geologic cross-section A-A' (Figure 5.2) is a north-south section running through the center of the Units 2/3 Reactor and Turbine Building and depicts the approximate depth and location of the buildings with respect to the surrounding wells. This cross-section begins to the north of the PA (DSP-149) and terminates to the south of the PA (DSP-157M). This cross-section transects through the middle of the Radwaste Discharge Piping for Units 2/3 and portions of the CST System HPCI Piping.

Geologic cross-section B-B' (Figure 5.3) is a west-east section through the northern section of the Station. This cross-section begins at the western end of the PA

(MW-DN-110I) at the Station and terminates near the northeastern end of the Station close to the fence line bordering the Unit 1 Intake Canal (MW-DN-101I). This cross-section transects through the Radwaste Discharge Piping for Units 2/3 and the northern portions of the Unit 1 Spent Fuel Pool and the CDW Piping from the CST System.

## **5.2 STATION HYDROGEOLOGY**

The water table aquifer at the Station has been divided into two zones, shallow and intermediate. Groundwater contour maps for shallow and intermediate groundwater zones at the Station are illustrated on Figures 5.4 and 5.5, respectively. These figures are discussed further in the section below.

The shallow groundwater zone at the Station represents the saturated portion of the Pottsville Sandstone Formation and extends to the top of the Divine Limestone Formation.

The intermediate groundwater zone at the Station represents the Divine Limestone Formation and extends to the top of the Maquoketa Shale.

The Maquoketa Shale acts as an aquitard, impeding the vertical movement of groundwater and preventing the migration of groundwater downward to the deeper aquifers.

### **5.2.1 GROUNDWATER FLOW DIRECTIONS**

Generally, groundwater flow in both the shallow and intermediate zones at the Station is radially outward from the Station, and is influenced by the Kankakee River, the Illinois River, and the canal network.

The direction of groundwater flow towards the Kankakee and Illinois Rivers is consistent with the description of regional groundwater flow in Section 2.4.3. Both shallow and intermediate groundwater flow have been influenced by the Station's construction, which includes features such as the Unit 1 and Units 2/3 Buildings and the canal network, as discussed in Section 5.2.2.

As indicated in the preceding discussion, the hydrogeologic framework at the Station is influenced by zones of recharge (i.e., area between the canal network and Kankakee

River) and discharge (i.e., Kankakee River and canal network), fracturing (both natural and man-made during Station construction), building foundations, and the canal network.

#### Shallow Groundwater Zone

The groundwater flow contours on Figure 5.4 were generated using groundwater elevation data from monitoring wells completed in the Pottsville Sandstone Formation and from water levels in the canals. The groundwater flow pattern and water levels in the canal network in the shallow groundwater flow zone are primarily controlled by the location of recharge and discharge zones, and secondarily by man-made structures and fracture distribution and orientation. The shallow groundwater contours parallel the surface water bodies, indicating that the surface water bodies control the groundwater flow patterns in this zone.

A groundwater mound exists to the south of the Units 2/3 Buildings with a high point located at DSP-157S (515.84 feet AMSL) as shown on Figure 5.4.

#### Intermediate Groundwater Zone

The groundwater flow contours shown on Figure 5.5 were generated using groundwater elevation data from monitoring wells completed in the Divine Limestone Formation. The groundwater flow patterns in the Divine Limestone Formation are primarily controlled by fracture distribution and orientation, and the location of recharge and discharge zones. Secondary influences include man-made structures such as the Station's foundations.

As in the shallow groundwater zone, groundwater in the intermediate zone flows radially outward from the center of the Station. A northwest-southeast oriented groundwater divide is evident and is defined by the groundwater elevation in monitoring wells DSP-125 (513.11 feet AMSL) and DSP-152 (513.02 feet AMSL), which are located south of the PA.

### **5.2.2 MAN-MADE INFLUENCE ON GROUNDWATER FLOW**

#### Station Structures

Groundwater flow in the shallow zone is generally radially outward from the center of the Station. The groundwater flow is influenced by the presence of the Unit 1 Sphere,

Units 2/3 Reactor and Turbine Buildings, and associated structures including the Unit 1 and Units 2/3 Radwaste Buildings, the Units 2/3 Off-gas Filter Building, the Unit 1 and Units 2/3 Cribhouses, and the Unit 1 Fuel Pool and Fuel Handling Buildings. Worksheets depicting building depths were provided by Station personnel during the completion of this HIR. These buildings were constructed through bedrock (sandstone and limestone) to a depth of approximately 45 to 50 feet bgs and were cast on top of the confining shale layer (Maquoketa Shale) (see Figure 5.2).

As a result, groundwater flows laterally around these structures. There is little variation in geology around the Unit 1 Sphere; however, the groundwater contours for both shallow and intermediate groundwater zones show a slight deflection to the north on the eastern side of the Unit 1 Sphere. The Unit 1 Turbine Building was also constructed through bedrock, but not cast on top of Maquoketa Shale. The depth of its foundations is approximately 26 feet bgs. Therefore, groundwater in the intermediate zone of the water table aquifer flows beneath the Unit 1 Turbine Building.

### Canal System

The Canal System at the Station also influences groundwater flow. Both the Hot and Cold Canals are unlined flumes, 8 feet deep and 55 feet wide, which were blasted into the bedrock. Therefore, the base of the canals, especially at the northern end, is within the Pottsville Sandstone.

The canal system flow regimes are controlled by Flow Regulating Gates. Water levels within the canals, especially the Hot Canal, may vary as much as 1 to 2 feet during the day based on the Station's need for cooling water. Water levels in the canals are also influenced by the operation of the cooling towers located along their banks and to the southwest of the PA. The pumps and discharge flumes that are associated with these systems are cycled on and off as needed. Monitoring wells located near the canal and the Cooling Tower Pumps and Discharge Flumes include DSP-127, MW-DN-110S/I, MW-DN-103S/I, MW-DN-121S, MW-DN-123S/I, DSP-159S/M, and DSP-126. These wells will be influenced by the varying water levels in the canals and the accompanying surface water discharge to groundwater.

The Units 2/3 Intake Canal also has an effect on the groundwater levels at the Station as shown on Figure 5.5. There is a groundwater low point to the north of the PA in this area. This low point is attributable to the fact that surface water from the Kankakee River is being pumped into the Units 2/3 Cribhouse within the unlined Units 2/3 Intake Canal, and groundwater is being influenced by the pumping of surface water in this area.

### Industrial Cooling Pond

The Hot and Cold Canals run generally north-south to the Industrial Cooling Pond (Pond). The Pond, which covers approximately 1,284 acres, is over 8,700 feet south of the PA (Figure 2.1). The Pond was formed by constructing a clay dike around a low lying area. Approximately 100 drain tiles were installed to drain water from the low lying areas to the Kankakee River. When the pond was constructed these drain tiles were filled with concrete.

The Pond is not lined and is located along the west bank of the Kankakee River. The surface water in the Hot Canal flows south to the Pond and then water from the Pond flows back to the north through the Cold Canal.

### Dresden Island Lock and Dam

The normal pool elevation for the Kankakee and Des Plaines Rivers, which join to form the Illinois River, is 505 feet AMSL. Dresden Island Lock and Dam, located approximately 3,000 feet northwest of the Station, control the pool elevation. This lock and dam (which is controlled by the Army Corps of Engineers) also controls the surface water elevations in the Unit 1 and Units 2/3 Intake Canals and the Unit 1 Discharge Canal.

## **5.2.3 VERTICAL HYDRAULIC GRADIENTS**

Groundwater elevation data from several monitoring well nests installed at the Station have been used to calculate the vertical hydraulic gradient between the shallow and intermediate groundwater zones. The calculated hydraulic gradients for the Station are provided in Table 5.1. A moderate downward vertical gradient (0.062 feet/foot) was calculated to the west of the Units 2/3 Building. A moderate downward vertical gradient (0.0215 feet/foot) was also calculated for the well clusters east of the Unit 1 Turbine Building. At the MW-DN-114 well cluster, which is located south of the turbine buildings in a cove between the Unit 2/3 and Unit 1 Turbine Buildings, a strong upward gradient (-0.332 feet/foot) was calculated. A strong upward gradient was also calculated for well cluster MW-DN-123 (-0.566 feet/foot). The average calculated vertical gradient at the Station is approximately -0.02 feet/foot, which indicates that there is an upward gradient across the Station.

#### 5.2.4 LATERAL GROUNDWATER FLOW AND VELOCITY

##### Shallow Groundwater Zone

Groundwater flow velocity for the shallow zone was calculated using a hydraulic conductivity (slug test methodology) of 34.3 feet per day (RETEC, 2005), a porosity of 30 percent for the Pottsville Sandstone, and a hydraulic gradient of 0.002 to 0.009 foot per foot (based on August 2006 water elevations). The groundwater flow velocity for the shallow zone was calculated to range from 87 to 355 feet per year (ft/yr).

##### Intermediate Groundwater Zone

Groundwater flow velocity for the intermediate zone was calculated using a hydraulic conductivity (slug test methodology) of 0.67 feet per day (RETEC 2005), a porosity of 10 percent for the Divine Limestone, and a hydraulic gradient of 0.007 to 0.09 foot per foot (based on August 2006 water elevations). The groundwater flow velocity for the intermediate zone was calculated to range from 17 to 225 ft/yr.

The horizontal velocities are representative of the area south of the Units 2/3 Turbine Building since the wells used by RETEC to develop the hydraulic conductivities are located in that area.

### 5.3 GROUNDWATER QUALITY

CRA personnel collected groundwater samples from 66 monitoring wells at the Station. The samples were analyzed for tritium and additional radionuclides. Teledyne Brown provided the analytical services. The Quality Assurance Program for the laboratory is described in Appendix C. The analytical data reports are provided in Appendix D.

The analytical data presented herein has been subjected to CRA's data validation process. CRA has used the data with appropriate qualifiers where necessary.

The data reported in the figures and tables does not include the results of recounts that the laboratory completed, except if those results ultimately replaced an initial report. The tables and figures, therefore, include only the first analysis reported by the laboratory. Where multiple samples were collected over time, then the most recent result has been used in the discussion, below.

### 5.3.1 SUMMARY OF BETA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

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A summary of the tritium results for the groundwater samples collected during this investigation is provided in Table 5.2 and shown on Figures 5.6 and 5.7.

All tritium concentrations were less than the United States Environmental Protection Agency (USEPA) drinking water standard of 20,000 pCi/L. Tritium was detected at concentrations greater than the LLD of 200 pCi/L.

All strontium-90 concentrations were less than the USEPA drinking water standard of 8.0 pCi/L.

Tritium was detected in groundwater samples from nine locations in the shallow groundwater zone at concentrations ranging from  $220 \pm 114$  pCi/L to  $4,250 \pm 475$  pCi/L.

Tritium was detected in groundwater samples from twenty-one wells in the intermediate groundwater zone at concentrations ranging from  $210 \pm 124$  pCi/L to  $13,200 \pm 319$  pCi/L. The highest concentration was detected in the groundwater sample collected from DSP-123, which was installed in the intermediate groundwater zone to the north of the Unit 1 Sphere.

A summary of the strontium-89/90 results for the groundwater samples collected as part of the investigation that is the subject of this HIR is provided in Table 5.3 and shown on Figures 5.8 and 5.9. Strontium-89/90 was detected in one monitoring well (MW-DN-108I) at a concentration greater than the LLD of 2.0 pCi/L. In August 2006, a sample was collected from this well, and strontium-89/90 was detected at a concentration of  $2.72 \pm 1.01$  pCi/L. This sample was further analyzed for strontium-90, which was detected at a concentration of  $2.17 \pm 0.783$  pCi/L. Furthermore, a duplicate of this sample was analyzed for total strontium and strontium-90. Since the strontium-90 results exceeded the sum of the total strontium in the duplicate sample, it has been concluded that the results of this sample are invalid.

In May 2006, a sample was collected from this monitoring well (MW-DN-108I). Analyses in July 2006 detected strontium-89/90 at a concentration of  $4.42 \pm 1.23$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $4.37 \pm 0.66$  pCi/L. In July 2006, the sample was re-analyzed and strontium-89/90 was detected at a concentration of  $3.39 \pm 0.774$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $2.72 \pm 1.29$  pCi/L. Because the total strontium from these two samples varied by almost

40 percent and the margin of error was nearly 50 percent, it became necessary to run a third analysis to verify what, if any, detectable concentration existed. This could not be completed for the May 2006 samples due to the samples becoming contaminated at the analytical laboratory. Normal protocol for an anomalous positive result is to perform a confirmatory sampling and analysis of the respective well. Consequently, the well MW-DN-1081 was re-sampled in August 2006, as discussed above.

### **5.3.2 SUMMARY OF GAMMA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS**

Gamma-emitting target radionuclides were not detected at concentrations greater than their respective LLDs. A summary of the gamma-emitting radionuclides results for the groundwater samples collected as part of the investigation that is the subject of this HIR is provided in Table 5.3 and shown on Figures 5.8 and 5.9.

Other non-targeted radionuclides were also included in the tables but excluded from discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

### **5.3.3 SUMMARY OF FIELD MEASUREMENTS**

Table 4.5 presents of a summary of field measurements collected during the well purging and sampling activities. These field measurements included pH, dissolved oxygen, conductivity, turbidity and temperature. The field parameters were typical of a shallow aquifer with carbonate source rock (i.e., the underlying Divine Limestone Formation and Maquoketa Shale). As such, the pH values were found to be above 7.0 and the conductivity was indicative of a shallow water table system subject to surface water recharge.

### **5.4 SURFACE WATER QUALITY**

Six surface water samples were collected from the locations shown on Figure 4.1. The samples were analyzed for tritium, gamma-emitting radionuclides, and strontium-89/90. Teledyne Brown provided the analytical services. The Quality

Assurance Program for the laboratory is described in Appendix C. The analytical data reports are provided in Appendix D.

#### **5.4.1 SUMMARY OF BETA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS**

Tritium was not detected at concentrations greater than the LLD of 200 pCi/L. A summary of the tritium results for the surface water samples collected in this investigation is provided in Table 5.4 and shown on Figure 5.6.

Strontium-89/90 was not detected at concentrations greater than the LLD of 2.0 pCi/L. A summary of the strontium-89/90 analytical results for the surface water samples collected in this investigation is provided in Table 5.5 and shown on Figure 5.8.

#### **5.4.2 SUMMARY OF GAMMA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS**

Gamma-emitting target radionuclides were not detected at concentrations greater than their respective LLDs. A summary of the gamma-emitting radionuclides results for the surface water samples collected in this investigation is provided in Table 5.5 and shown on Figure 5.8.

Other non-targeted radionuclides were also included in the tables but excluded from discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

## 6.0 RADIONUCLIDES OF CONCERN AND SOURCE AREAS

This section discusses radionuclides evaluated in this investigation, potential sources of the radionuclides detected, and their distribution.

### 6.1 GAMMA-EMITTING RADIONUCLIDES

Gamma-emitting target radionuclides were not detected at concentrations greater than their respective LLDs. Other non-targeted radionuclides were also included in the tables but excluded from the discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

### 6.2 BETA-EMITTING RADIONUCLIDES

Strontium-89/90 was detected in one monitoring well (MW-DN-108I) at a concentration greater than the LLD of 2.0 pCi/L. In August 2006, a sample was collected from this well, and strontium-89/90 was detected at a concentration of  $2.72 \pm 1.01$  pCi/L. This sample was further analyzed for strontium-90, which was detected at a concentration of  $2.17 \pm 0.783$  pCi/L. Furthermore, a duplicate of this sample was analyzed for total strontium and strontium-90. Since the strontium-90 results exceeded the sum of the total strontium in the duplicate sample, it has been concluded that the results of this sample are invalid.

In May 2006, a sample was collected from this monitoring well (MW-DN-108I). Analyses in July 2006 detected strontium-89/90 at a concentration of  $4.42 \pm 1.23$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $4.37 \pm 0.66$  pCi/L. In July 2006, the sample was re-analyzed and strontium-89/90 was detected at a concentration of  $3.39 \pm 0.774$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $2.72 \pm 1.29$  pCi/L. Because the total strontium from these two samples varied by almost 40 percent and the margin of error was nearly 50 percent, it became necessary to run a third analysis to verify what, if any, detectable concentration existed. This could not be completed for the May 2006 samples due to the samples becoming contaminated at the analytical laboratory. Normal protocol for an anomalous positive result is to perform a confirmatory sampling and analysis of the respective well. Consequently, the well MW-DN-108I was re-sampled in August 2006, as discussed above.

Tritium was detected at concentrations greater than the LLD of 200 pCi/L. Detectable concentrations of tritium ranged from  $210 \pm 124$  pCi/L to  $13,200 \pm 319$  pCi/L. The following sections focus on tritium and strontium; specifically, providing general characteristics of tritium and strontium, potential sources, distribution in groundwater, and a conceptual model for migration.

## 6.3 TRITIUM

### 6.3.1 GENERAL CHARACTERISTICS

Tritium (chemical symbol H-3) is a radioactive isotope of hydrogen. The most common forms of tritium are tritium gas and tritium oxide, which is also called "tritiated water." The chemical properties of tritium are essentially those of ordinary hydrogen. Tritiated water behaves the same as ordinary water in both the environment and the body. Tritium can be taken into the body by drinking water, breathing air, eating food, or absorption through skin. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the body. Tritium is excreted primarily through urine within a month or so after ingestion. Organically bound tritium (tritium that is incorporated in organic compounds) can remain in the body for a longer period.

Tritium is produced naturally in the upper atmosphere when cosmic rays strike air molecules. Tritium is also produced during nuclear weapons explosions, as a by-product in reactors producing electricity, and in special production reactors, where the isotopes lithium-7 and/or boron-10 are bombarded to produce tritium.

Although tritium can be a gas, its most common form is in water because, like non-radioactive hydrogen, radioactive tritium reacts with oxygen to form water. Tritium replaces one of the stable hydrogen atoms in the water molecule and is called tritiated water. Like normal water, tritiated water is colorless and odorless. Tritiated water behaves chemically and physically like non-tritiated water in the subsurface, and therefore tritiated water will travel at the same velocity as the average groundwater velocity.

Tritium has a half-life of approximately 12.3 years. It decays spontaneously to helium-3 ( $^3\text{He}$ ). This radioactive decay releases a beta particle (low-energy electron). The radioactivity of tritium is the source of the risk of exposure.

Tritium is one of the least dangerous radionuclides because it emits very weak radiation and leaves the body relatively quickly. Since tritium is almost always found as water, it goes directly into soft tissues and organs. The associated dose to these tissues is generally uniform and is dependent on the water content of the specific tissue.

### 6.3.2 DISTRIBUTION IN STATION GROUNDWATER

This section provides an overview of the lateral and vertical distribution of tritium detected in groundwater at the Station. Tritium was detected in groundwater at concentrations greater than the LLD of 200 pCi/L in both the shallow and intermediate groundwater zones.

Hydrogeologic profiles were created across the Station at locations shown on Figure 5.1. Hydrogeologic profiles of the tritium concentrations in groundwater are presented on Figures 6.1, 6.2, and 6.3. The following discussion presents the distribution of tritium concentrations in Station groundwater with respect to the location of a particular AFE.

The distribution of tritium in the shallow groundwater zone is shown on Figure 5.6, and the distribution of tritium in the intermediate groundwater zone is shown on Figure 5.7. As shown in Figures 5.6 and 5.7, there appear to be two primary sources of tritium beneath the Station. One is from the HPCI Piping leaks and the other is from the Unit 1 Fuel Pool overflow. The remainder of this section provides further details on the distribution of the tritium related to the four AFEs.

#### AFE-Dresden-1: CST System HPCI Piping Leak

The most frequent detections of tritium in the shallow and intermediate groundwater zones were identified near the Units 2/3 Turbine Building on its south, east and west sides. As demonstrated in the following paragraphs, the source of the tritium in this area is historical tritium releases from the CST System HPCI Piping.

The highest concentrations of tritium in the shallow groundwater zone were detected within the area surrounding CST System HPCI Piping at monitoring wells MW-DN-102S ( $4,250 \pm 475$  pCi/L), MW-DN-114S ( $2,770 \pm 336$  pCi/L), and MW-DN-107S ( $1,040 \pm 165$  pCi/L). MW-DN-102S is located approximately 600 feet southwest of CST System HPCI Piping. MW-DN-114S is located approximately 450 feet northeast of CST System HPCI Piping. MW-DN-107S is located approximately 300 feet northeast of CST System HPCI Piping.

Groundwater flows radially outward beneath the PA. Near the CST System HPCI Piping, the flow is to the northwest, west and south-southwest with minimal flow also to the northeast. Tritium detected in groundwater follows this flow path as it moves from the HPCI Piping around the buildings to the northwest (Figure 5.4). Tritium was also detected at concentrations greater than the LLD of 200 pCi/L in groundwater samples collected from monitoring wells MW-DN-111S ( $638 \pm 140$  pCi/L) and MW-109S ( $251 \pm 120$  pCi/L), located to the west-northwest, hydraulically downgradient of CST System HPCI Piping. In addition, tritium was also detected greater than the LLD of 200 pCi/L in groundwater samples collected from MW-DN-113S ( $451 \pm 136$  pCi/L), located to the south of the CST System HPCI Piping. Although MW-DN-113S is not presently downgradient of AFE-Dresden-1, seasonal fluctuations in groundwater elevations could result in this well being downgradient to the AFE.

Within the intermediate groundwater zone, tritium was detected in groundwater samples from monitoring wells DSP-125 ( $320 \pm 127$  pCi/L), MW-DN-102I ( $1,380 \pm 195$  pCi/L), DSP-124 ( $10,000 \pm 284$  pCi/L), MW-DN-109I ( $3,620 \pm 413/3,750 \pm 424$  pCi/L), MW-DN-112I ( $1,520 \pm 214$  pCi/L), and MW-DN-110I ( $516 \pm 134$  pCi/L), within the area surrounding CST System HPCI Piping for Units 2/3. DSP-125 is located approximately 100 feet east of the area of the release at the CST System HPCI Piping for Units 2/3. MW-DN-102I is located approximately 600 feet southwest of the CST System HPCI Piping. DSP-124, MW-DN-109I, MW-DN-112I, and MW-DN-110I are all located to the northwest and are located hydraulically downgradient of the release at the CST System HPCI Piping. These tritium levels demonstrate declining ( $10,000 \pm 284$  pCi/L to  $516 \pm 134$  pCi/L) concentrations with increased distance from the CST System Piping.

Groundwater flow in and around the Units 2/3 Turbine Building is radially outward from the center of the PA as depicted for the shallow and intermediate groundwater zones on Figures 5.4 and 5.5. This flow pattern provides a potential explanation for the detection of tritium greater than the LLD of 200 pCi/L in the groundwater samples from monitoring wells MW-DN-102S and MW-DN-102I, which are located southwest of the CST. Groundwater containing tritium that has originated in the area of the HPCI Piping for Units 2/3 also migrates to the northeast underneath the Unit 1 Turbine Building within the intermediate zone of the water table aquifer.

#### AFE-Dresden-2: Unit 1 Spent Fuel Pool

Groundwater flow within the shallow groundwater zone in the area of the Unit 1 Spent Fuel Pool is consistent with the general flow direction across the Station. However, there is a slight deflection of groundwater flow east of the Unit 1 Turbine Building due

to the influence of the structure at that location. The closest shallow monitoring well to the Unit 1 Spent Fuel Pool is MW-DN-118S. The groundwater sample from this well contained tritium at a concentration of  $1,650 \pm 227$  pCi/L while the sample from MW-DN-105S, located upgradient of the Unit 1 Spent Fuel Pool, did not contain tritium at concentrations greater than the LLD of 200 pCi/L. MW-DN-101S is located to the north of the Unit 1 Spent Fuel Pool along the banks of the Unit 1 Intake Canal. The groundwater sample from MW-DN-101S had a tritium concentration of  $220 \pm 114$  pCi/L, only slightly greater than the LLD of 200 pCi/L.

The highest concentration of tritium in the intermediate groundwater zone across the Station was detected in a groundwater sample from DSP-123 ( $13,100 \pm 318/13,200 \pm 319$  pCi/L), which is directly north of the Unit 1 Spent Fuel Pool and also to the north of the Unit 1 Sphere, but along the groundwater flow path originating south of the Turbine Building. MW-DN-119I ( $1,470 \pm 211$  pCi/L) is also located along the flow path originating from the Fuel Pool. DSP-105, DSP-106, DSP-107, and DSP-108 are located to the south and east of the Unit 1 Turbine Building and Sphere. Within the intermediate groundwater zone tritium was detected in groundwater samples from monitoring wells DSP-105 ( $319 \pm 117$  pCi/L), DSP-106 ( $2,370 \pm 289$  pCi/L), DSP-107 ( $9,820 \pm 1,030$  pCi/L), DSP-108 ( $1,930 \pm 244$  pCi/L), DSP-123 ( $13,200 \pm 319$  pCi/L), and MW-DN-101I ( $4,570 \pm 208$  pCi/L).

Tritium detected in the groundwater samples from shallow and intermediate monitoring wells in this area is primarily the result of the Unit 1 Spent Fuel Pool historical release.

#### AFE-Dresden-3: Radwaste Discharge Piping for Units 2/3

There are six wells that are used to evaluate the water quality near this AFE. Groundwater samples from three of these wells contained less than detectable concentrations of tritium. The other three monitoring wells had tritium concentrations ranging from 356 to 1,440 pCi/L.

The groundwater quality downgradient of Radwaste Discharge lines for Units 2/3 is characterized by the analysis of groundwater samples from MW-DN-104S, installed along the Radwaste Discharge Lines for Units 2/3. MW-DN-104S is hydraulically downgradient of the Radwaste Surge Tank and the point at which the discharge piping penetrates the structure. The groundwater sample from this well did not contain tritium at a concentration greater than the LLD of 200 pCi/L. Groundwater flow near the Radwaste Discharge Lines for Units 2/3 is to the north-northeast, consistent with the general groundwater flow direction in the shallow groundwater zone at the Station.

Within the intermediate groundwater zone, tritium was detected in groundwater samples from monitoring wells DSP-122 ( $1,440 \pm 139$  pCi/L), DSP-149R ( $668 \pm 144/694 \pm 143$  pCi/L), and DSP-148 ( $356 \pm 111$  pCi/L). These wells are located near the Radwaste Discharge Piping and downgradient of the 77,000-gallon Radwaste Surge Tank where historical releases have been identified.

The low concentrations of tritium detected in the shallow and intermediate monitoring wells discussed above is likely associated with historical releases from the Radwaste Discharge Piping for Units 2/3, influence from the canal, or both.

#### AFE-Dresden-4: Piping from CST System and Storm Drain to Unit 1 Intake Canal

The footprint of AFE-Dresden-4 includes the area occupied by the CST System piping and the storm drains that discharge to the Unit 1 Intake Canal. The shallow wells, MW-DN-105S, MW-DN-101S, MW-DN-115S, MW-DN-118S, are located in close proximity to the East Drainage Basin storm drain that discharges to the Unit 1 Intake Canal. The groundwater sample from MW-DN-101S contained tritium at a concentration slightly greater than the LLD of 200 pCi/L ( $220 \pm 114$  pCi/L) while the upgradient location of MW-DN-118S had tritium detected at  $1,650 \pm 227$  pCi/L. The groundwater samples from MW-DN-105S and MW-DN-115S were non-detect for tritium at the LLD of 200 pCi/L. In the shallow groundwater zone, two shallow wells, MW-DN-107S and MW-DN-114S, are located near the CST System HPCI Piping leak and had tritium concentrations in groundwater samples of  $1,040 \pm 165$  pCi/L and  $2,770 \pm 336$  pCi/L, respectively. Groundwater flow within the area surrounding the CST System HPCI Piping and Storm Drain to Unit 1 Intake Canal is also locally to the north-northeast, consistent with the general radial flow direction at the Station and with the flow moving around the buildings.

Within the intermediate groundwater zone, tritium was detected in groundwater samples from monitoring wells DSP-125 ( $320 \pm 127$  pCi/L), DSP-105 ( $319 \pm 117$  pCi/L), DSP-106 ( $2,370 \pm 289$  pCi/L), DSP-107 ( $9,820 \pm 1,030$  pCi/L), DSP-108 ( $1,930 \pm 244$  pCi/L), MW-DN-101I ( $4,570 \pm 208$  pCi/L), MW-DN-114I ( $4,190 \pm 473$  pCi/L), and MW-DN-119I ( $1,470 \pm 211$  pCi/L). DSP-105, DSP-106, DSP-107, DSP-108, and MW-DN-119I are all located in close proximity to the storm drain servicing the Unit 1 Intake Canal. The detections of tritium in these wells may be the result of a combination of releases from AFE-Dresden-1 and AFE-Dresden-4.

Most of the storm drainage system adjacent to the Turbine Buildings is constructed below the water table. Portions of the storm drainage system lie below the water table

by as much as 3 feet. As such, infiltration of groundwater into the storm drainage system that extends from AFE-Dresden-1 to AFE-Dresden-4 is contributing to the movement of tritiated water along southern, eastern and western sides of the Turbine Buildings. This is consistent with groundwater movement in this area. Therefore, the majority of the groundwater that enters the storm drains or surrounding fill would eventually discharge into the Canal System.

The Station currently performs weekly monitoring of two manhole locations that are located upstream from the discharge points for the East Drainage Basin and the West Drainage Basin. Manhole DSP-131 is the final manhole on the West Drainage Basin system prior to discharge into the Unit 2&3 Discharge Canal. The August 2006 tritium concentration at DSP-131 was 600 pCi/L. Manhole DSP-132 is the final manhole on the East Drainage Basin system prior to discharge into the Unit 1 Intake Canal. The August 2006 tritium concentration at DSP-132 was 700 pCi/L.

### **6.3.3 DISTRIBUTION IN STATION SURFACE WATER**

Tritium was not detected in the six surface water samples at concentrations greater than the LLD of 200 pCi/L. The surface water sample locations are shown on Figure 4.1.

### **6.3.4 CONCEPTUAL MODEL OF TRITIUM RELEASE AND MIGRATION**

This section presents CRA's conceptual model of groundwater and tritium migration at the Station.

#### Hydrogeologic Framework

Based upon existing Station data from boring logs and water level data, the groundwater flow in the water table aquifer is expected to move under conditions equivalent to porous media flow. The sandstone and the limestone bedrock have characteristics that are equivalent to a porous medium at the scale of this investigation. Therefore, discussions of groundwater flow within the shallow and intermediate zones of the water table aquifer are assumed to be under porous media conditions.

Groundwater flow within the water table aquifer at the Station generally moves from southwest to the northeast to the regional discharge points in the Kankakee and Illinois Rivers. Structures and operations at the Station have modified the flow within the water

table aquifer before it reaches the river systems. The canals act like partially penetrating streams, and may receive water from or discharge water to the groundwater system.

The locations of the canals and the rivers with respect to the Station result in radial groundwater flow from the center of the PA. The potentiometric surface represented on Figures 5.4 and 5.5 demonstrate the multiple groundwater discharge locations and the resultant radial pattern to those locations.

Building foundations and fill also influence groundwater flow by redirecting groundwater flow. For example, as groundwater flows toward the rivers and canals, it encounters the basements and backfill around the Turbine Buildings and other buildings.

The operation of the intake structure near the north side of the Units 2/3 Turbine Building appears to have some localized influence on groundwater flow as is evident by the potentiometric surface shown on Figure 5.4. This figure suggests that the pumping of water into this structure creates a capture zone of groundwater.

Groundwater flow at the Station is limited in the vertical direction by the presence of the Maquoketa Shale. The hydrogeologic profiles presented on Figures 6.1 to 6.3 demonstrate that tritium has not migrated deeper than the base of the Divine Limestone/top of the Maquoketa Shale.

The following presents the tritiated water migration pathways:

- Historic data shows that tritiated water has entered the Station Canal System via the Intake Canal from the Kankakee River.
- Tritiated groundwater flows beneath and around the structures and enters the Canal System via the Intake Canal at the intake structure.
- Surface water in the Canal System can migrate both vertically and laterally into groundwater.
- Tritiated groundwater appears to infiltrate into storm drains, which are submerged below the water table, and enter the Canal System when the storm drains discharge to the Canal System, including the Intake Canal.
- Tritiated Kankakee River water in the canal systems can discharge to groundwater, under certain conditions, and then migrate back toward Kankakee River and some residential wells.

## 6.4 STRONTIUM

### 6.4.1 GENERAL CHARACTERISTICS

Elemental strontium occurs naturally in the earth's mantle as a mixture of four stable isotopes (strontium-88, strontium-86, strontium-87, and strontium-84), and is present everywhere in very dilute concentrations. It is very similar to calcium in its environmental and physiological behavior. All four isotopes behave the same chemically, so any combination of the four would have the same chemical effect on the body.

The radioactive isotopes of strontium do not occur naturally but are produced as a by-product of nuclear fission of uranium-235, uranium-238, or plutonium-239. The most significant isotopes are strontium-90 (half-life of 29 years), strontium-89 (half-life of 51 days), and strontium-85 (half-life of 65 days), which decay by the emission of beta particles. Strontium-90 releases beta particles and decays into yttrium-90. Yttrium-90 decays to the stable isotope zirconium-90.

The Agency for Toxic Substances and Disease Registry (ATSDR) provides a toxicological profile for strontium (ATSDR, 2004). According to this profile, strontium behaves similar to calcium and is absorbed by the body and deposited in bone and blood-forming tissue (bone marrow) when food and water products containing trace amounts are ingested. Strontium-90 has a relatively long half-life of 29 years. The most serious effects of oral exposure to absorbed radioactive strontium are necrotic lesions and cancers of bone and the adjacent tissues. High-level acute exposures can destroy bone marrow, leading to acute radiation syndrome. At lower doses, irradiation of bone marrow may lead to chronic suppression of immune functions.

### 6.4.2 DISTRIBUTION IN STATION GROUNDWATER

This section provides an overview of the lateral and vertical distribution of strontium-90 detected in groundwater at the Station. Strontium-90 was detected in groundwater at concentrations exceeding the LLD of 2 pCi/L in the intermediate groundwater zone.

Since strontium-90 was detected at only one groundwater monitoring location (well MW-DN-108I), the following discussion presents the distribution of strontium-90 concentrations in Station groundwater with respect to monitoring well MW-DN-108I.

Groundwater Monitoring Well MW-DN-108I

Strontium-89/90 was detected in one monitoring well (MW-DN-108I) at a concentration greater than the LLD of 2.0 pCi/L. In August 2006, a sample was collected from this well, and strontium-89/90 was detected at a concentration of  $2.72 \pm 1.01$  pCi/L. This sample was further analyzed for strontium-90, which was detected at a concentration of  $2.17 \pm 0.783$  pCi/L. Furthermore, a duplicate of this sample was analyzed for total strontium and strontium-90. Since the strontium-90 results exceeded the sum of the total strontium in the duplicate sample, it has been concluded that the results of this sample are invalid.

In May 2006, a sample was collected from this monitoring well (MW-DN-108I). Analyses in July 2006 detected strontium-89/90 at a concentration of  $4.42 \pm 1.23$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $4.37 \pm 0.66$  pCi/L. In July 2006, the sample was re-analyzed and strontium-89/90 was detected at a concentration of  $3.39 \pm 0.774$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $2.72 \pm 1.29$  pCi/L. Because the total strontium from these two samples varied by almost 40 percent and the margin of error was nearly 50 percent, it became necessary to run a third analysis to verify what, if any, detectable concentration existed. This could not be completed for the May 2006 samples due to the samples becoming contaminated at the analytical laboratory. Normal protocol for an anomalous positive result is to perform a confirmatory sampling and analysis of the respective well. Consequently, the well MW-DN-108I was re-sampled in August 2006, as discussed above.

This well is located in the vicinity of the Unit 1 Off-Gas Hold-up Piping to the Unit 1 Off-Gas Suppression System. In November 1975, a ditch which had been dug to connect piping between the Unit 1 Off-Gas Hold-up Piping and the newly constructed Unit 1 Off-Gas Suppression System, began to fill with rainwater which flowed along the ditch towards the Unit 1 Circulating Water Intake Canal. The off-gas pipe was breached at the time allowing contaminants from inside the pipe to be flushed out into the ditch (surrounding soil). This release is the likely source of the strontium-89/90 detected in groundwater samples collected from well MW-DN-108I.

Since strontium-89/90 was not detected at concentrations above the LLD of 2.0 pCi/L in groundwater samples from any of the other groundwater monitoring wells throughout the Station property and adjacent to well MW-DN-108I, it is assumed that the detection of strontium-89/90 is localized to this area.

### 6.4.3 DISTRIBUTION IN STATION SURFACE WATER

Strontium was not detected in the six surface water samples at concentrations greater than the LLD of 2.0 pCi/L.

## 7.0 EXPOSURE PATHWAY ASSESSMENT

This section addresses the groundwater impacts from tritium at the Station and potential risks to human health and the environment.

Based upon historical knowledge and data related to the Station operations, and based upon radionuclide analyses of groundwater samples and the isolated detection of strontium-90 in the groundwater sample from MW-DN-108I, the primary constituent of concern (COC) is tritium. The discussions that follow are restricted to the exposure pathways related to tritium.

Teledyne Brown reports all samples to their statistically derived minimum detectable concentrations (MDC) approximately 150 to 170 pCi/L, which is associated with 95 percent confidence interval on their hard-copy reports. However, the laboratory uses a 99 percent confidence range ( $\pm 3$ -sigma) for determining whether to report the sample activity concentration as detected or not. This 3-sigma confidence typically equates to 150 ( $\pm 135.75$ ) pCi/L.

Exelon has specified a LLD of 200 pCi/L for the Fleetwide Assessment. Exelon has also required the laboratory to report related peaks identified at the 95 percent confidence level (2-sigma).

This HIR, therefore, screens and assesses data using Exelon's LLD of 200 pCi/L. As is outlined below, this concentration is also a reasonable approximation of the background concentration of tritium in groundwater at the Station.

### 7.1 HEALTH EFFECTS OF TRITIUM

Tritium is a radionuclide that decays by emitting a low-energy beta particle that cannot penetrate deeply into tissue or travel far in air. A person's exposure to tritium is primarily through the ingestion of water (drinking water) or through ingestion of water bearing food products. Inhalation of tritium requires the water to be in a vapor form (i.e., through evaporation or vaporization due to heating). Inhalation is a minor exposure route when compared to direct ingestion or drinking of tritiated water. Absorption of tritium through skin is possible, but tritium exposure is more limited here versus direct ingestion or drinking of tritiated water.

## 7.2 BACKGROUND CONCENTRATIONS OF TRITIUM

The purpose of the following paragraphs is to establish a background concentration through review of various media.

### 7.2.1 GROUNDWATER

Tritium is created in the environment from naturally occurring processes both cosmic and subterranean, as well as from anthropogenic (i.e., man-made) sources. In the upper atmosphere, "cosmogenic" tritium is produced from the bombardment of stable nuclides and combines with oxygen to form tritiated water, which will then enter the hydrologic cycle. Below ground, "lithogenic" tritium is produced by the bombardment of natural lithium isotopes  ${}^6\text{Li}$  (92.5% abundance) and  ${}^7\text{Li}$  (7.5% abundance) present in crystalline rocks by neutrons produced by the radioactive decay of uranium and thorium. Lithogenic production of tritium is usually negligible compared to other sources due to the limited abundance of lithium in rock. The lithogenic tritium is introduced directly to groundwater.

A major anthropogenic source of tritium comes from the former atmospheric testing of thermonuclear weapons. Levels of tritium in precipitation increased during the 1950s and early 1960s, coinciding with the release of significant amounts of tritium to the atmosphere during nuclear weapons testing prior to the signing of the Limited Test Ban Treaty in 1963, which prohibited atmospheric nuclear tests.

### 7.2.2 PRECIPITATION DATA

Precipitation samples are routinely collected at stations around the world for the analysis of tritium and other radionuclides. Two publicly available databases that provide tritium concentrations in precipitation are Global Network of Isotopes in Precipitation (GNIP) and USEPA's RadNet database. GNIP provides tritium precipitation concentration data for samples collected world wide from 1960 to 2006. RadNet provides tritium precipitation concentration data for samples collected at Stations through the U.S. from 1960 up to and including 2006.

Based on GNIP data for sample stations located in the U.S. Midwest including Chicago, St. Louis and Madison, Wisconsin, as well as Ottawa Ontario, and data from the University of Chicago, tritium concentrations peaked around 1963. This peak, which approached 10,000 pCi/L for some stations, coincided with the atmospheric testing of

thermonuclear weapons. Tritium concentrations showed a sharp decline up until 1975 followed by a gradual decline since that time. Tritium concentrations in Midwest precipitation have typically been below 100 pCi/L since around 1980.

The RadNet database for several stations in the U.S. Midwest (Chicago, Columbus, Indianapolis, Lansing, Madison, Minneapolis, Painesville, Toledo, and Welsch, MN) did not show the same trend, which can be attributed to pre-1995 data handling procedures. The pre-1995 data were rounded to the nearest 100 pCi/L, which dampened out variances in the data. The post-1995 RadNet data, where rounding was not applied, exhibit much more scatter, and similar to the GNIP data, the vast majority of the data were less than 100 pCi/L.

CRA constructed a non-parametric upper tolerance limit with a confidence of 95 percent and a coverage of 95 percent based on RadNet data for USEPA Region 5 from 2004 to 2005. The resulting upper tolerance limit is 133 pCi/L, which indicates that CRA is 95 percent confident that 95 percent of the ambient precipitation concentration results are below 133 pCi/L. The statistical confidence, however, must be compared with the limitations of the underlying RadNet data, which does not include the minimum detectable concentration for a majority of the measurements. Some of the RadNet values below 200 pCi/L may be approximated. Nevertheless, these results show a background contribution for precipitation of up to 133 pCi/L.

### 7.2.3 SURFACE WATER DATA

Tritium concentrations are routinely measured in large surface water bodies, including Lake Michigan and the Mississippi River. Surface water data from the RadNet database for Illinois sampling stations include East Moline (Mississippi River), Moline (Mississippi River), Marseilles (Illinois River), Morris (Illinois River), Oregon (Rock River), and Zion (Lake Michigan). As is the case for the RadNet precipitation data, the pre-September 1995 Illinois surface water data was rounded to the nearest 100 pCi/L, creating a dampening of variances in the data. The post-1995 Illinois surface water data, similar to the post-1995 Midwest precipitation data, were less than 100 pCi/L with the exception of the Moline (Mississippi River) station. Tritium surface water concentrations at this location varied between 100 and 800 pCi/L, which may reflect local natural or anthropogenic inputs.

The USEPA RadNet surface water data typically has a reported 'Combined Standard Uncertainty' of 35 to 50 pCi/L. According to USEPA, this corresponds to a  $\pm 70$  to 100 pCi/L 95 percent confidence bound on each given measurement. Therefore,

the typical background data provided may be subject to measurement uncertainty of approximately  $\pm 70$  to 100 pCi/L.

As part of the REMP, tritium concentrations are measured in the Kankakee, Des Plaines and Illinois Rivers as well as within the canal network at the Station.

Surface water samples are collected as part of REMP at a total of three locations. Samples are collected at two locations upstream of the Station on the Kankakee (D-54) and Des Plaines (D-52) Rivers, and at one location downstream of the Station on the Illinois River (D-51). The concentration of tritium within the Kankakee River (D-54) was not greater than the LLD of 200 pCi/L since 2003 but increased to 720 pCi/L in 2005 and is attributable to an upstream source. The concentration of tritium within the Des Plaines River (D-52) has not been greater than the LLD of 200 pCi/L since 2000 except for one sample at 230 pCi/L in 2003. The concentration of tritium within the Illinois River (D-51) has fluctuated from less than the LLD of 200 pCi/L since 2000 to a maximum concentration of 1,974 pCi/L in 2002.

Since January 2005, the concentration of tritium in the Station intake has ranged from the LLD of 200 pCi/L to greater than 2,500 pCi/L. In addition, available data indicates that upstream background concentrations in the Kankakee River have ranged from LLD of 200 pCi/L to greater than 6,900 pCi/L (RETEC, 2004). The intake canal sample is a direct representation of tritium concentrations in the Kankakee River.

#### **7.2.4 DRINKING WATER DATA**

Tritium concentrations in drinking water from the RadNet database for three Illinois sampling stations (Chicago, Morris, and East Chicago) exhibit similar trends to the precipitation and surface water data. As with the precipitation and surface water data, the pre-1995 data has dampened out variances due to rounding the data to the nearest 100 pCi/L. The post-1995 results show tritium concentrations in samples of drinking water were less than 100 pCi/L and less than the tritium concentrations found in precipitation and surface water.

A residential well, designated RW-1, has been sampled for tritium for over 10 years as part of the Offsite Dose Calculation Manual (ODCM) and is located approximately 0.7 miles south of the plant. Prior to 1995, the groundwater samples from this well consistently contained tritium concentrations less than 300 pCi/L. From 1995 to April 2005, tritium concentrations increased from 232 to 940 pCi/L.

Based on the tritium found in RW-1, in December 2004, Exelon sampled 34 additional residential wells in the same neighborhood. Tritium was detected in groundwater samples from three of the 34 residential wells, designated RW-2, RW-3, and RW-4. These wells are all located beside the Kankakee River to the south of the Station. The locations of these wells are shown on Figure B.1 in Appendix B.

A groundwater sample was collected from the RW-2 well on December 2, 2004, and the sample was split for analysis by two independent laboratories. Due to the discrepancy in the results (366 pCi/L versus 114 pCi/L), another sample was collected on January 13, 2005, and four aliquots were reported ranging in concentration from 360 to 480 pCi/L. Another sample was collected on April 15, 2005, and the reported tritium concentration was 542 pCi/L.

Groundwater samples were collected from the RW-3 well on September 21, 2005 with a concentration of 369 pCi/L and the RW-4 well on August 29, 2005 with a concentration of 468 pCi/L.

A water sample collected from the RW-1 well on April 15, 2005 contained tritium at a concentration of 653 pCi/L. A sample collected from the RW-2 well on the same date contained 542 pCi/L of tritium.

Based on the results of this investigation, the low tritium concentration impact observed in the residential wells to the south of the Station is principally, if not entirely, due to the discharge of tritiated Kankakee River water to groundwater. In addition, the HIR data demonstrate that there is no measurable tritium impact in the canal network from current groundwater migration to the canal network in the vicinity of the PA.

### **7.2.5 EXPECTED TRITIUM BACKGROUND FOR THE STATION**

As reported in the GNIP and RadNet databases, tritium concentrations in U.S. Midwest precipitation has typically been less than 100 pCi/L since 1980. Tritium concentrations reported in the RadNet database for Illinois surface water and groundwater, at least since 1995, has typically been less than 100 pCi/L. Based on the USEPA Region 5 2004 to 2005 RadNet precipitation data, 95 percent of the ambient concentrations of tritiated water in Illinois are expected to be less than 133 pCi/L, based on a 95 percent confidence limit. Tritium concentrations in surface water and drinking water are expected to be comparable or less based on historical data and trends.

Concentrations in groundwater, similar to surface and drinking water, are expected to be less than precipitation values. The lower groundwater concentrations are related to the age of the groundwater as compared to the half-life of tritium. Deep aquifers in proximity to crystalline basement rock, however, can potentially show elevated concentrations of tritium due to lithogenic sources.

As was noted in Section 7.0, the analytical laboratory is reporting tritium results to a LLD of 200 pCi/L. This concentration also provides a reasonable representation of background groundwater quality, given the data for precipitation, surface water, and drinking water.

Based on the evaluation presented above, the background concentration for tritium at the Station is reasonably represented by the LLD of 200 pCi/L.

### **7.3 IDENTIFICATION OF POTENTIAL EXPOSURE PATHWAYS AND POTENTIAL RECEPTORS**

Four potential exposure pathways were identified and considered during the evaluation of tritium in groundwater.

- potential groundwater migration to drinking water users on the Station property;
- potential groundwater migration off the Station property to private and public groundwater users;
- potential groundwater migration off the Station property to a surface water body; and
- potential surface water migration to groundwater off the Station property.

The following section provides an overview these four potential exposure pathways for tritium in groundwater.

#### **7.3.1 POTENTIAL GROUNDWATER MIGRATION TO DRINKING WATER USERS AT THE STATION PROPERTY**

At the Station, the tritium detected in groundwater samples has been isolated to the water table aquifer, which is isolated from the deeper regional groundwater aquifer by the Maquoketa Shale. Groundwater quality data from the Station's potable wells that are completed below this aquitard do not contain concentrations of tritium greater than the LLD of 200 pCi/L. As such, the tritium impact is limited to the water table aquifer.

There are no water supply wells located on the Station property that draw water from the water table aquifer.

There is no complete exposure pathway. Therefore, there is no current risk of exposure associated with groundwater ingestion at the Station.

### **7.3.2      POTENTIAL GROUNDWATER MIGRATION TO DRINKING WATER USERS OFF THE STATION PROPERTY**

The concentrations of tritium in groundwater are less than the USEPA drinking water standard of 20,000 pCi/L. Consequently, there is currently no tritium in the groundwater that could migrate off the Station at concentrations exceeding the USEPA drinking water standard.

There are private water supply wells located on land to the south of the Station. Based on groundwater flow maps, it is unlikely that tritiated groundwater beneath the Station could migrate to the south in the intermediate flow system and onto the private property.

Although there is a potentially complete exposure pathway, there is no current risk of exposure associated with this pathway.

### **7.3.3      POTENTIAL GROUNDWATER MIGRATION TO SURFACE WATER USERS OFF THE STATION PROPERTY**

Groundwater at the Station discharges to Kankakee and Illinois Rivers or through the Discharge Canal. Therefore, there is a potentially complete exposure route to recreational users of surface water including boating, fishing, and swimming.

Tritium results for surface water samples collected as part of this investigation were less than the LLD of 200 pCi/L. In addition, based on the results of this investigation, the Station is not causing any off-Station concentrations of tritium above detectable limits.

Although there is a potentially complete exposure pathway, there is no current risk of exposure associated with groundwater migration to surface water users off the Station property.

#### **7.3.4 POTENTIAL SURFACE WATER MIGRATION TO GROUNDWATER AND SURFACE WATER OFF THE STATION PROPERTY**

Surface water within the Canal System could potentially migrate from the Canal System to groundwater off the Station property. Tritium results for surface water samples collected as part of this investigation were less than the LLD of 200 pCi/L.

As discussed in Section 7.2.4, private wells south of the Station were sampled to evaluate potential impact of the Station's operations on groundwater. The Canal System historically contained elevated tritium concentrations as high as approximately 6,900 pCi/L due to upgradient sources in the Kankakee River. Therefore, as discussed above, the source of these low concentrations in the off-Station wells is principally, if not entirely, due to the discharge of tritiated Kankakee River water to groundwater. In addition, the HIR data demonstrate that there is no measurable tritium impact in the canal network from current groundwater migration to the canal network in the vicinity of the PA.

Although there is a potentially complete exposure pathway, there is no current risk of exposure associated with migration of tritium originating from the Station to the Canal System to groundwater off the Station property.

#### **7.4 SUMMARY OF POTENTIAL TRITIUM EXPOSURE PATHWAYS**

In summary, there are four potential groundwater exposure pathways for tritium originating at the Station:

- potential groundwater migration to drinking water users on the Station property;
- potential groundwater migration off the Station property to private and public groundwater users;
- potential groundwater migration off the Station property to a surface water body; and
- potential surface water migration to groundwater off the Station property.

Based on the groundwater and surface water data provided and referenced in this investigation, none of the potential receptors are at risk of exposure to concentrations of tritium in excess of USEPA drinking water standard (20,000 pCi/L).

## 7.5 OTHER RADIONUCLIDES

Strontium-89/90 was detected in one monitoring well (MW-DN-108I) at a concentration greater than the LLD of 2.0 pCi/L. In August 2006, a sample was collected from this well, and strontium-89/90 was detected at a concentration of  $2.72 \pm 1.01$  pCi/L. This sample was further analyzed for strontium-90, which was detected at a concentration of  $2.17 \pm 0.783$  pCi/L. Furthermore, a duplicate of this sample was analyzed for total strontium and strontium-90. Since the strontium-90 results exceeded the sum of the total strontium in the duplicate sample, it has been concluded that the results of this sample are invalid.

In May 2006, a sample was collected from this monitoring well (MW-DN-108I). Analyses in July 2006 detected strontium-89/90 at a concentration of  $4.42 \pm 1.23$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $4.37 \pm 0.66$  pCi/L. In July 2006, the sample was re-analyzed and strontium-89/90 was detected at a concentration of  $3.39 \pm 0.774$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $2.72 \pm 1.29$  pCi/L. Because the total strontium from these two samples varied by almost 40 percent and the margin of error was nearly 50 percent, it became necessary to run a third analysis to verify what, if any, detectable concentration existed. This could not be completed for the May 2006 samples due to the samples becoming contaminated at the analytical laboratory. Normal protocol for an anomalous positive result is to perform a confirmatory sampling and analysis of the respective well. Consequently, the well MW-DN-108I was re-sampled in August 2006, as discussed above.

It is concluded that this detection is localized to the vicinity of MW-DN-108I. On this basis, there is limited discussion of this result in this report.

No target radionuclides were detected in the groundwater and surface water samples at concentrations greater than their respective LLDs. Other non-target radionuclides were also included in the tables but excluded from the discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

## 8.0 CONCLUSIONS

Based on this hydrogeologic investigation, CRA concludes:

### Groundwater Flow

- There are two significant underlying water-bearing units, Pottsville Sandstone (shallow groundwater zone) and the Divine Limestone (intermediate groundwater zone), beneath the Station. The two formations comprise the water table aquifer.
- The water table aquifer extends through the entire thickness of these two units and is underlain by the Maquoketa Shale, which acts as an aquitard and is continuous across the Station.
- The depth to groundwater beneath the Station ranges between 3 to 23 feet bgs.
- Groundwater flow is influenced by the canal network and the foundations of buildings such that the shallow and intermediate groundwater flows radially outwards from the center of the PA towards the canals and rivers. The canals also influence the flow of groundwater in the intermediate groundwater zone. The shallow groundwater zone discharges to the canal as does the intermediate groundwater zone but to a lesser degree.
- The horizontal groundwater flow velocity for the shallow groundwater zone ranges from 87 to 355 ft/yr while the intermediate groundwater flow velocity ranges from 17 to 225 ft/yr.
- The Station canals act as an interceptor trench for the shallow groundwater zone while the intermediate zone is partially intercepted by the Station canals. Seasonal changes result in differing degrees of hydraulic communication between the groundwater and the canal system.

### Groundwater Quality

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the 68 groundwater samples collected as part of this investigation.
- Strontium-90 was not detected in groundwater at concentrations greater than the USEPA drinking water standard of 8.0 pCi/L.
- Strontium-89/90 was detected in one monitoring well (MW-DN-108I) at a concentration greater than the LLD of 2.0 pCi/L. In August 2006, a sample was collected from this well, and strontium-89/90 was detected at a concentration of  $2.72 \pm 1.01$  pCi/L. This sample was further analyzed for strontium-90, which was

detected at a concentration of  $2.17 \pm 0.783$  pCi/L. Furthermore, a duplicate of this sample was analyzed for total strontium and strontium-90. Since the strontium-90 results exceeded the sum of the total strontium in the duplicate sample, it has been concluded that the results of this sample are invalid.

In May 2006, a sample was collected from this monitoring well (MW-DN-108I). Analyses in July 2006 detected strontium-89/90 at a concentration of  $4.42 \pm 1.23$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $4.37 \pm 0.66$  pCi/L. In July 2006, the sample was re-analyzed and strontium-89/90 was detected at a concentration of  $3.39 \pm 0.774$  pCi/L. In July 2006, this sample was further analyzed for strontium-90, which was detected at a concentration of  $2.72 \pm 1.29$  pCi/L. Because the total strontium from these two samples varied by almost 40 percent and the margin of error was nearly 50 percent, it became necessary to run a third analysis to verify what, if any, detectable concentration existed. This could not be completed for the May 2006 samples due to the samples becoming contaminated at the analytical laboratory. Normal protocol for an anomalous positive result is to perform a confirmatory sampling and analysis of the respective well. Consequently, the well MW-DN-108I was re-sampled in August 2006, as discussed above.

- Tritium was not detected in groundwater at concentrations greater than the USEPA drinking water standard of 20,000 pCi/L.
- Tritium was detected in groundwater samples from nine monitoring wells in the shallow groundwater zone at concentrations ranging from  $220 \pm 114$  pCi/L to  $4,250 \pm 475$  pCi/L.
- Tritium was detected in groundwater samples from twenty-one wells in the intermediate groundwater zone at concentrations ranging from  $210 \pm 124$  pCi/L to  $13,200 \pm 319$  pCi/L.

#### Surface Water Quality

- Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in any of the six surface water samples collected as part of this investigation.
- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the six surface water samples collected as part of this investigation.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the six surface water samples collected as part of this investigation.

AFE-Dresden-1: CST System HPCI Piping for Units 2/3

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples obtained from the monitoring wells located in close proximity to the CST System HPCI Piping.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples obtained from the monitoring wells located in close proximity to the CST System HPCI Piping.
- In the area surrounding the CST System HPCI Piping, tritium was detected in the shallow and intermediate groundwater zones. The groundwater flows with the local hydraulic gradient, to the northwest around the Units 2/3 Turbine Building, and under the Unit 1 Turbine Building.
- There are 12 monitoring wells associated with this AFE. The groundwater samples contained tritium at concentrations ranging from less than the LLD of 200 pCi/L to 10,000 ± 284 pCi/L.
- Tritium in groundwater samples collected in the CST System HPCI Piping area is primarily attributable to the historical releases in this area.

AFE-Dresden-2: Unit 1 Spent Fuel Pool

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples collected from the monitoring wells near the fuel pool.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples obtained from the monitoring wells located in close proximity to this AFE.
- Tritium was detected in the area surrounding the Unit 1 Spent Fuel Pool at concentrations greater than LLD of 200 pCi/L in the groundwater samples from the shallow and intermediate groundwater monitoring wells.
- There are 10 monitoring wells associated with this AFE. The groundwater samples contained tritium at concentrations ranging from less than the LLD of 200 pCi/L to 13,200 ± 319 pCi/L.
- Tritium in groundwater samples collected in the area north of the Unit 1 Spent Fuel Pool is likely attributable to the Unit 1 Spent Fuel Pool historical release.

AFE-Dresden-3: Radwaste Discharge Lines for Units 2/3

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples collected from the monitoring wells located in close proximity to Radwaste Discharge Piping for Units 2/3.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples obtained from the monitoring wells located in close proximity to this AFE.
- Tritium was detected in samples from three of the six monitoring wells near the Radwaste Discharge Piping. The groundwater samples contained tritium at concentrations ranging from less than the LLD of 200 pCi/L to  $1,440 \pm 139$  pCi/L.
- Tritium in groundwater samples collected in the area of the Radwaste Discharge Lines for Units 2/3 is primarily attributable to the historical releases in this area.

AFE-Dresden-4: Piping from CST System and Storm Drain to Unit 1 Intake Canal

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples obtained from the monitoring wells located near the storm drain.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples obtained from the monitoring wells located in close proximity to this AFE.
- Tritium concentrations in samples from monitoring wells near, or hydraulically downgradient, of AFE-Dresden-4 may be impacted by tritium sources from other AFEs.
- There are 12 monitoring wells associated with this AFE. The groundwater samples contained tritium at concentrations ranging in concentration from less than the LLD of 200 pCi/L to  $4,570 \pm 208$  pCi/L.
- Groundwater infiltration into the storm drain system is providing a pathway for tritiated groundwater to the Unit 1 Intake Canal.
- The Storm Drain System acts as a conduit for tritiated water rather than a source of tritium.

### Potential Receptors

- Based on the results of this investigation<sup>2</sup> there is no current risk of exposure to radionuclides associated with licensed plant operations through any of the identified potential exposure pathways.

### General Conclusions

- Based on the results of this investigation, tritium originating from the Station is not migrating off the Station property at detectable concentrations.
- Based on the results of this investigation, there are no known active releases into the groundwater at the Station.

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<sup>2</sup> Using the LLD specified in this HIR.

## 9.0 RECOMMENDATIONS

The following presents CRA's recommendations for proposed activities to be completed at the Station.

### 9.1 FILL DATA GAPS

Based on the results of this hydrogeologic investigation, there are no data gaps remaining to support CRA's conclusions regarding the characterization of the groundwater regime and potential impacts from radionuclides at the Station.

### 9.2 GROUNDWATER MONITORING

Based on the information collected to date, CRA recommends that Exelon conduct periodic monitoring of selected sample locations.

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