Tritium Occurrence in Groundwater at Diablo Canyon Power Plant

by S.M. Stoller Corporation

Introduction

This report presents findings from an investigation into the occurrence and migration of tritium in the subsurface at Diablo Canyon Power Plant (DCPP), located adjacent to the Pacific Ocean in San Luis Obispo County, California. Pacific Gas and Electric (PG&E) requested that S.M. Stoller Corporation (Stoller) conduct this independent study as part of a larger effort by the utility to comply with an initiative administered by the Nuclear Energy Institute (NEI) in response to inadvertent releases of tritiated water during the past few years at several nuclear power plants in the United States. PG&E sought to determine the likely source of tritium detected in wells located close to the two nuclear reactors (Units 1 and 2) at DCPP and whether those detections represented a potential threat to human health or local ecosystems.

PG&E has been monitoring aqueous-phase concentrations of tritium and other radionuclides on DCPP property and neighboring areas as part of its Radiological Environmental Monitoring Program (REMP). One of the objectives of the program is to identify potential releases of radionuclides, if any, resulting from plant operations. When this study was requested in summer 2006, tritium had been detected at relatively low concentrations (< 4,000 picocuries per liter [pCi/L]) in two wells located on either side of Units 1 and 2, and at concentrations approaching 17,000 pCi/L in a French drain system located about 100 feet (ft) east of the containment buildings associated with the two reactor units. These concentrations, all of which were less than the maximum contaminant level (MCL) established by the U.S. Environmental Protection Agency (EPA) for tritium (20,000 pCi/L), are the largest observed in the plant area, as measured tritium concentrations in nearby Diablo Creek and a water well on plant property have been consistently less than applicable detection limits of about 300 to 400 pCi/L. Such a distribution of tritium in local surface and subsurface waters indicates that tritium occurrences at wells in the immediate plant area are likely due to "washout," wherein tritiated water vapor released from vents above both containment buildings (AEC 1973) condenses and eventually infiltrates the local subsurface. Because no other radionuclides have been detected in power plant wells at concentrations that are considered significant, the washout of tritium appears to be a normal occurrence that has been taken into account during the licensing of Units 1 and 2.

Stoller used previous studies of the DCPP site and surrounding locales as well as data collected by PG&E though September and early October 2006 to conduct this investigation. In addition to developing conclusions regarding the causes of local tritium detections in the subsurface, we provide a cursory evaluation of REMP results from sampling of surface water bodies located within a few miles to several miles of the plant.

Buildings and other facilities at the DCPP site are referred to in subsequent sections of this report to facilitate spatial descriptions of tritium occurrences. Containment Building 1 is located on north side of the Auxiliary Building and Containment Building 2 is located on the south side (Figures 1 and 2). The Fuel Handling Building, situated immediately east of the Auxiliary Building and the containment buildings, contains two spent fuel pools and the Hot

Machine Shop. The combined footprint of the containment buildings, Auxiliary Building, and the Fuel Handling Building is referred to as the Power Block. The Independent Spent Fuel and Storage Installation (ISFSI), which is currently under construction, is located about 700 ft east-northeast (ENE) of the Power Block (Figure 1).

Local Hydrogeology

Bedrock Flow

Ground water flow in the DCPP area occurs mostly within tuffaceous siltstone and sandstone of the early Miocene Obispo Formation (Hall et al. 1979, PG&E 2006a). Hall et al. (1979) grouped these two types of bedrock into a general category that included interbedded marine sandstone, siltstone, and dolomite and labeled the group with the geological symbol Tof. As part of characterization work for the ISFSI facility, the marine deposits were further divided into three subunits – a, b, and c – on the basis of distinct changes in lithology between them (PG&E 2006a). Combining a geologic map of bedrock units in the power plant area with site topography information indicates that Tof_b is the bedrock subunit controlling water levels and tritium concentrations in Power Block wells. This subunit primarily consists of medium to thickly bedded dolomite (calcium magnesium carbonate), dolomitic siltstone, dolomitic sandstone, and sandstone. The following paragraphs discuss likely subsurface water flow and transport processes in Tof_b rock.

During characterization of the ISFSI site, bedrock subunit Tof_b was further subdivided into Tof_{b-1} and Tof_{b-2}, with the former being more dolomitic and the latter containing mostly sandstone. Two geologic cross sections oriented east-northeastward and passing through the Power Block (Sections 2.6-11 and 2.6-19, PG&E 2006a) indicate the presence of both units below the plant. Figure 3 provides an approximate reproduction of one of those cross sections. The Fuel Handling Building is shown resting on Tof_{b-2} bedrock (at elevations 90 to 115 ft above mean sea level [msl]) and Tof_{b-1} abuts mostly against the containment buildings (at elevations 50 to 85 ft above msl). At this time, insufficient data exist to determine whether specific flow and transport processes in one of these rock types differs from comparable processes in the other. However, enough information is available to describe how water generally migrates within these units.

Both Tof_{b-1} and Tof_{b-2} are characterized as "tight" bedrock units, signifying that water movement through them mostly occurs through fractures in the rock and along bedding planes. Local flow directions and water velocities in the fractures are very difficult to precisely define, let alone accurately predict how they will affect migration of dissolved constituents in the water. However, hydrogeologic principles and groundwater level measurements at various locations as part of ISFSI characterization work indicate that subsurface water will generally flow from higher elevations in nearby hills toward local surface water bodies, in this case the Pacific Ocean and Diablo Creek. Thus, it can be expected that water occurring in Plant Block wells eventually discharges to the ocean or the creek, or possibly both.

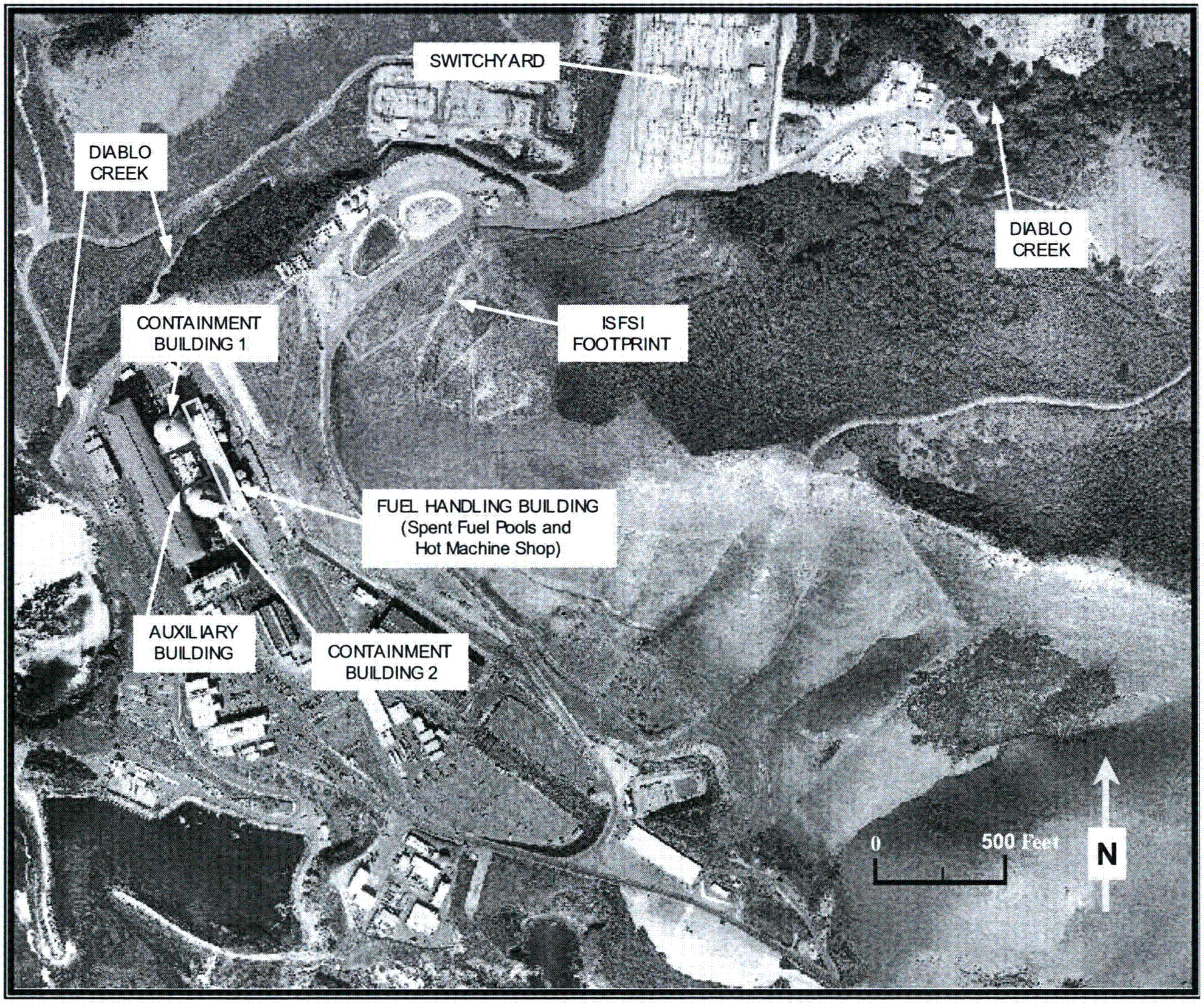

Figure 1. Areal View of Diablo Canyon Power Plant

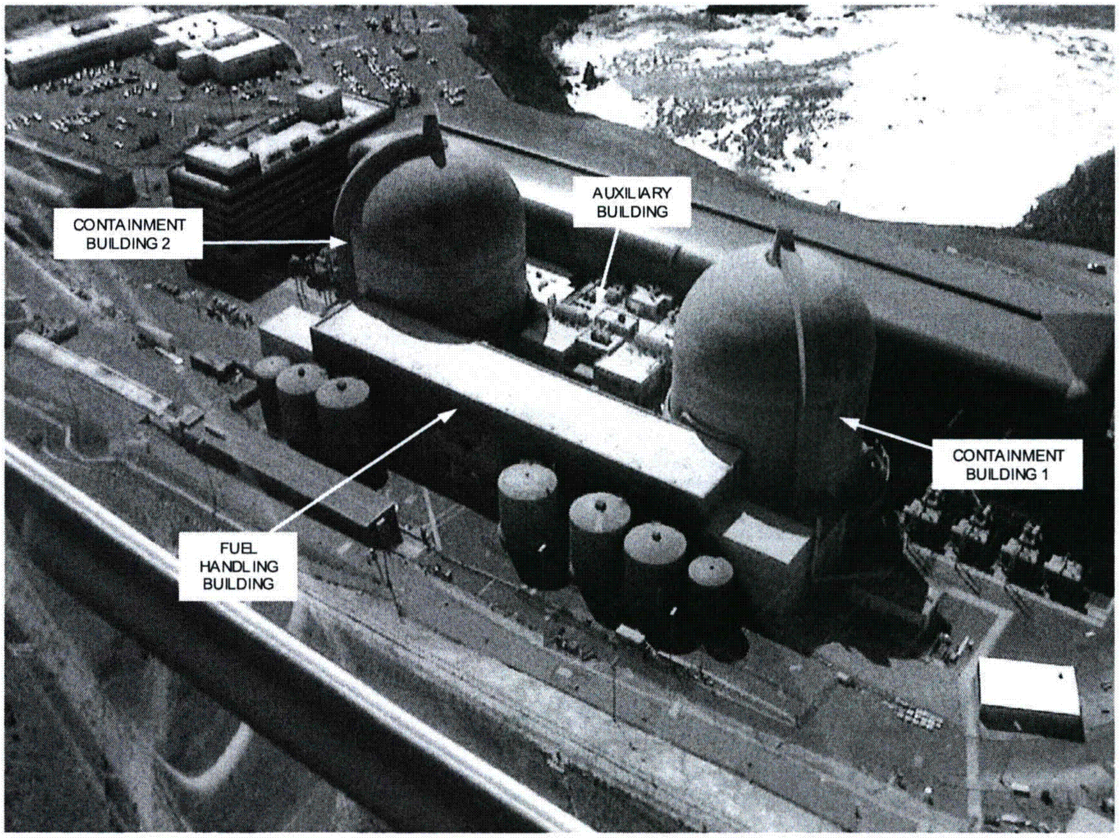

Figure 2. Diablo Canyon Power Plant – Looking to the West-Southwest

Factors that possibly influence local flow directions in the Power Block area include the significant faulting and folding that have occurred in the Obispo Formation over geologic time (Hall et al. 1979, PG&E 2006a). These processes, which are largely responsible for the formation of the Irish Hills that lie to the east of DCPP, have led to observed bedding plane strikes and dips that vary significantly over the area within and surrounding the power plant (PG&E 2006a). As a consequence, few, if any, distinct patterns of groundwater flow direction can be discerned on the basis of geology alone. Pictures of Tof_b bedrock in the vicinity of the containment buildings when the rock was excavated for plant construction show evidence of bedding planes and possibly fractures that are complex and irregularly oriented, thus confirming the difficulty associated with projecting local groundwater flow directions. Short of having more refined data regarding fracture flow in the Obispo Formation, it can only be concluded that groundwater will migrate from higher elevations toward the ocean and Diablo Creek.

An additional factor that appears to affect subsurface migration of water in bedrock is the presence of intermittent clay layers within the Obispo Formation. These lower permeability layers are described in ISFSI characterization work as being as much as few feet thick and laterally continuous over distances of hundreds of feet in some cases (PG&E 2006a). As a result, water infiltrating the subsurface during major storm events is sometimes observed to "perch" above the main body of groundwater flow at a greater depth, leaving an interlying zone of unsaturated fractures. Accordingly, some time must elapse before water in the perched zones gradually finds its way to greater depths and becomes part of a subregional groundwater flow system. It should be noted, however, that the presence of clay layers is not a prerequisite for perched groundwater development, as it is possible that the tortuous flow paths often associated with fracture flow can lead to perched zones forming above an ambient, background groundwater flow domain. That is, recently infiltrated water from precipitation may show a tendency to temporarily flow horizontally within relatively shallow fractures that define "preferential" flow paths, before it eventually finds routes to deeper zones.

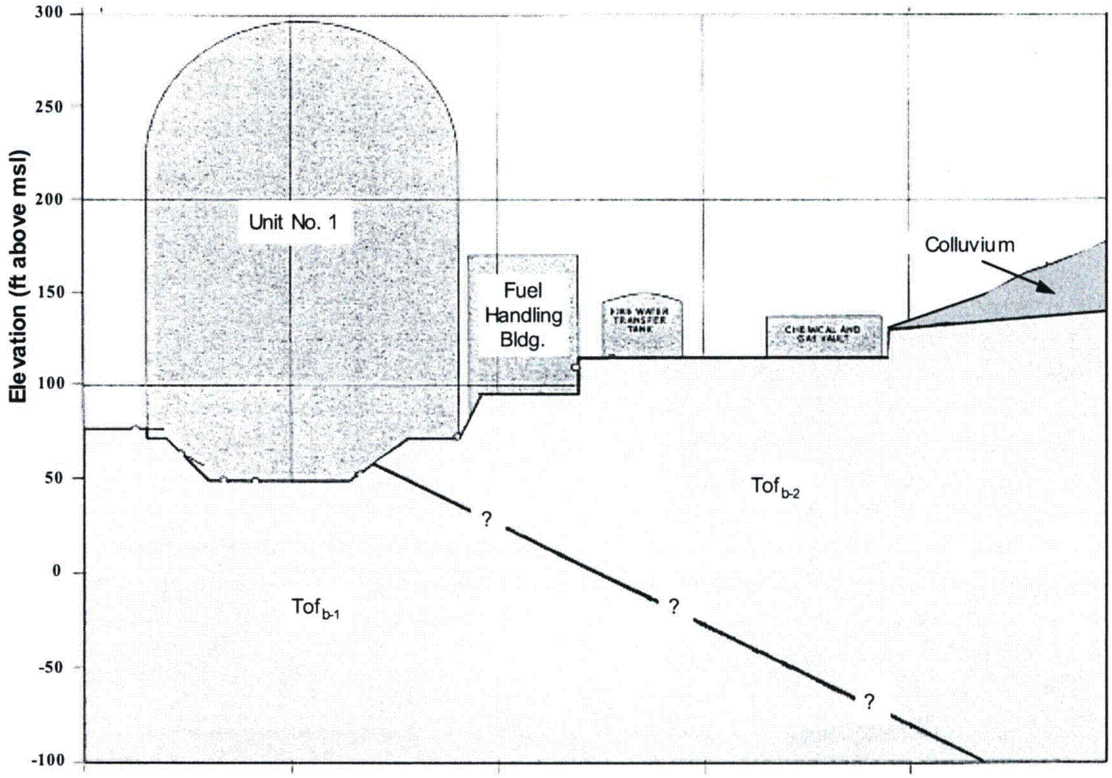

Figure 3. Cross Section Showing Estimated Subsurface Occurrence of Bedrock Units Tof_{b-1} and Tof_{b-2} in the Vicinity of the Power Block

Average annual rainfall at the DCPP site is approximately 16 inches (AEC 1973, PG&E 2006a). Because the majority of each year's precipitation typically occurs during the October-April period, it is likely that most groundwater perching occurs during winter and early spring months, and perched water gradually seeps to the deeper flow system over subsequent summer and early autumn months.

Characterization of the ISFSI site (PG&E 2006a) suggests that groundwater levels in bedrock underlying the Power Block are only slightly higher than the elevation of Diablo Creek, about 400 ft to the northwest. This would place groundwater elevations in the vicinity of the Power

Block at about 40 to 50 ft above msl. However, no groundwater elevation data are presented to support this hypothesis. Further descriptions of the subsurface hydrology beneath and near the ISFSI footprint (Figure 1) indicates that the local top of the subregional groundwater flow system occurs at about 200 ft above msl, and that temporary perched groundwater zones above this elevation during the rainy season are possible.

Given the above-mentioned groundwater levels in the vicinity of the plant and the ISFSI footprint, and topographic information from ISFSI investigations, it is logical to assume that some of the water observed in Power Block wells originates as recharge of rainfall on a ridge located east of the ISFSI footprint. In addition, more flow may stem from recharge on the slopes lying between the ridge and the Power Block, both above and below Reservoir Road. Because the Obispo Formation is overlain by unconsolidated deposits in the form of colluvium over the upper two-thirds of the area between Reservoir Road and the Power Block (PG&E 2006a), it is possible that some of the recharge and flow takes place above the colluvium/bedrock contact. Figure 4 delineates the (1) potential recharge area for groundwater that could migrate toward the Power Block, (2) the approximate area covered by colluvium, and (3) the expected flow direction of groundwater upgradient of the plant (light blue arrow).

Diablo Creek

Diablo Creek drains a 5.2-square mile watershed within the Irish Hills. In the vicinity of DCPP, the creek flows westward and discharges to the Pacific Ocean about 700 feet west-northwest of the Power Block (Figure 1). The creek flows within the base of a ravine that is at about 35 to 45 ft above msl directly northwest of the power block. Flows in the creek under baseflow conditions tend to be low and, with the exception of runoff events during storms, are typically less than one cubic feet per second (cfs).

In the vicinity of DCPP, Diablo Creek flows on a layer of Quaternary alluvium deposited by the creek itself in earlier years. Geologic maps of the area and field observations indicate that the width of the alluvium at ground surface (i.e. from one side of the ravine base to the other) is about 30 to 50 feet. Though information regarding the thickness of the alluvium is not available, width of the alluvial deposits and descriptions of creek hydrology suggest that the distance between the creek bed and underlying bedrock is typically just a few feet, and perhaps 10 ft or more in locales where creek flows had the potential to heavily scour bedrock during major runoff events.

The Quaternary alluvium underlying Diablo Creek, consisting of both fine- and coarse-grained deposits, is expected to contain westward-flowing ground water that is in hydraulic connection with creek water. Some of the ground water occurring in bedrock, both to the north and south of the creek, likely migrates toward and discharges directly to the creek alluvium. However, a significant portion of the bedrock ground water converging on the creek apparently discharges to the atmosphere above the creek bed, as a few areas of healthy vegetation observed in ravine walls just above its base are indicative of seeps discharging from bedrock (PG&E 2006a)..

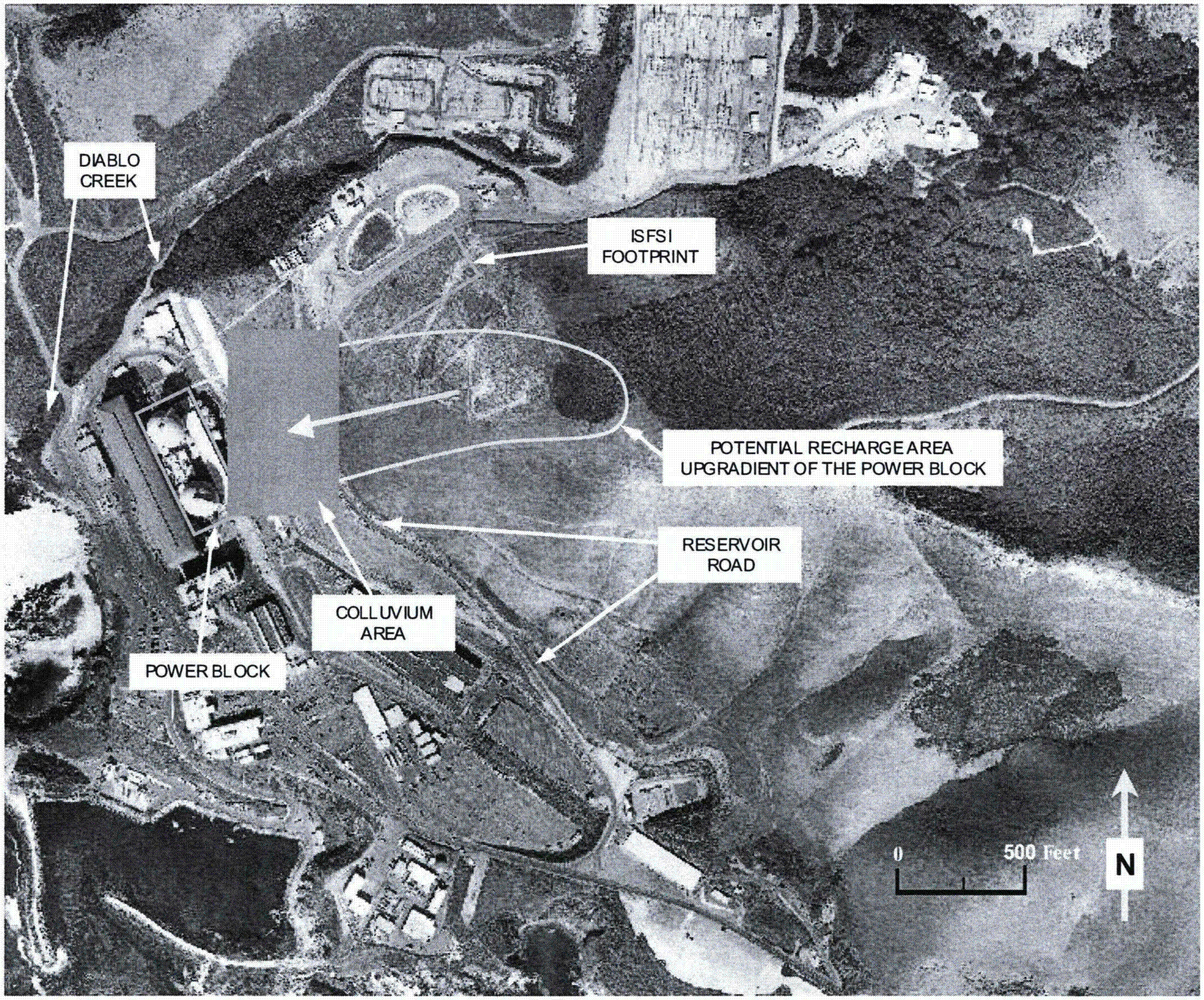

Figure 4. Features Influencing Groundwater Flow Upgradient of the Power Block

Data from REMP Sampling Locations

The REMP at DCPP comprises a network of sampling locations designed to monitor either concentrations or doses associated with several different environmental media, including airborne volatile constituents, airborne particulates, ocean water solutes, drinking water constituents, groundwater constituents, sediments, and a variety flora and fauna. In accordance with this study's emphasis on hydrology, we examined only dissolved concentrations in freshwater media (i.e., non-marine waters). Most of this report section focuses on aqueous-phase concentrations measured at sites around the plant, specifically at four groundwater sampling locations and two surface water locations. The results of sampling at additional freshwater monitoring sites located both north and south of the plant are also mentioned.

Figure 5 contains an aerial photograph showing the locations of eight historical water sampling sites on DCPP property. Of the six wells included in this graphic, two are currently not accessible for groundwater sample collection. Dry Well 01, which is located at the northern end of the previously mentioned French drain system on the east side of the Fuel Handling Building, is covered by a tank structure and is therefore not available for sampling. Similarly, Water Well 01, located adjacent to Diablo Creek about 2,500 ENE of the Power Block, has been abandoned in place due to oil intrusion and a seized well pump (PG&E 2006b).

Table 1 lists the four wells on power plant property that are currently available for groundwater sampling as part of the REMP. The two surface water sampling locations on DCPP property, both on Diablo Creek, are also listed.

Well Features

Detailed information regarding the construction of REMP wells on DCPP property, such as borehole logs and graphical depictions of well components (e.g., casing size, screen lengths, surface seals), was not available at the time of this study. Nonetheless, as shown in Table 1, field observations regarding top-of-casing elevation and well depth made it possible to estimate the bottom elevation of the three wells located in the vicinity of the Power Block (Observation Well 01, Observation Well 02, and Dry Well 115). The combination of this information and measured water levels in the wells helps in assessing flow potentials from one location to another.

As inferred in Table 1, detection of standing water in Observation Well 01 (on the north side of Containment Building 1) requires the presence of a column of water whose surface is located at a minimum elevation of 49.4 ft above msl. Similarly, minimum detectable water elevations at Observation Well 02 (on the south side of Containment Building 2) and Dry Well 115 (on the east side of the Fuel Handling Building) are 43.8 and 42.3 ft above msl, respectively. Such water elevations appear large enough to provide northwestward flow of groundwater to Diablo Creek, which maintains an elevation of about 30 to 45 ft above msl directly northwest of the Power Block.

Table 1. Descriptive Data for REMP Sampling Locations

Well	Approximate Location	Assumed Top of Casing Elevation (ft above msl)	Total Well Depth (ft)	Estimated Well Bottom Elevation (ft above msl)
Groundwater				
Observation Well 01	North side of Containment Building 1	86	36.58	49.4
Observation Well 02	South side of Containment Building 2	86	42.25	43.8
Dry Well 115	Part of the French drain system on the East side of Hot Machine Shop portion of the Fuel Handling Building	115	72.67	42.3
Water Well 02	3800 ft ENE of the Power Block	400	NA	NA
Surface Water				
Site	**Approximate Location**	**Assumed Elevation (ft above msl)**		
5S2	Diablo Creek, 1000 ft upstream of culvert inlet under the Switchyard	200		
WN2	Diablo Creek, near the creek outlet to the ocean	10		

NA = not available

Well Data

Table 2 lists water level data and radionuclide concentrations that have been collected at the four wells currently sampled under the REMP. As discussed in this section, the water elevation data collected from the three wells in the vicinity of the Power Block suggest that flow directions in the bedrock below the Power Block can be complex and are not readily discernible. On the other hand, the concentration data from the REMP wells indicate that there is no leakage from either the spent fuel pools or pipelines. With the exception of tritium, the concentrations of monitored nuclides in the subsurface are either non-detectable or very low in value. Tritium detections are limited to the three wells located in the near-vicinity of the Power Block, and the sources of these detections appear to be atmospheric and associated with normal plant operations, rather than liquid leakage from pipes or the spent fuel pools.

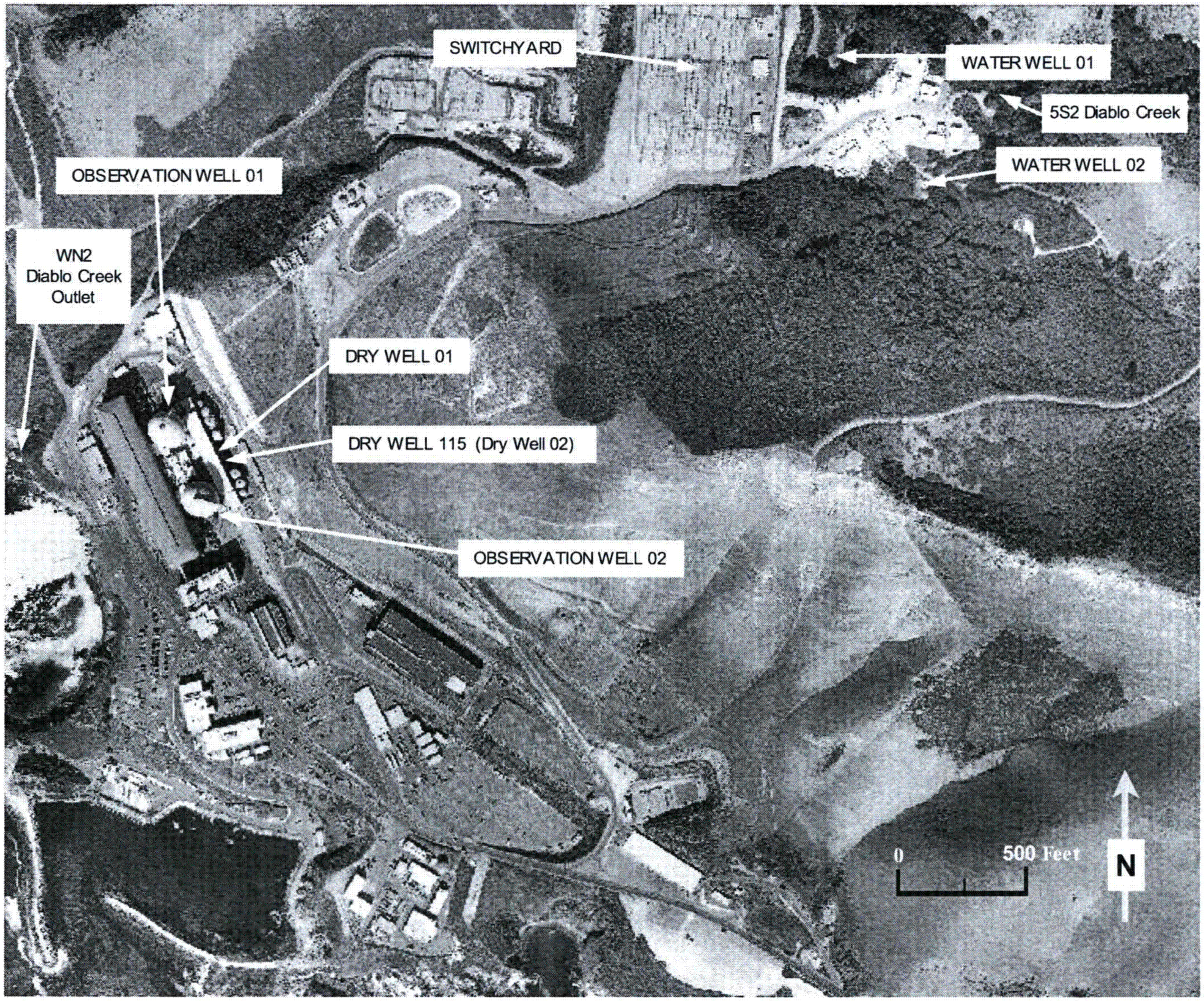

Figure 5. Areal View of REMP Sampling Locations on DCPP Property

Figures 6, 7, and 8 present temporal plots of estimated water elevations and measured tritium concentrations provided in Table 2 for Observation wells 01 and 02, and Dry Well 115, respectively. One of the most notable features of the plots is that the highest water levels are consistently observed at Observation Well 01 (~ 65 to 73 ft above msl), and the lowest water elevations are observed at Observation Well 02. In fact, water elevation data for Observation Well 02 since late June 2006 are essentially reflective of a dry well (Table 2 and Figure 7), which in turn indicate that saturated groundwater occurs at or below a depth of 43.8 ft above msl near this well. Though these respective water levels indicate that groundwater could flow from near Observation Well 01 toward Observation Well 02, other information suggests that there is unlikely to be hydraulic communication between the respective areas of the two wells. For example, the relatively close proximity of Observation Well 01 to Diablo Creek (~ 400 ft) suggests that groundwater near this wells is more likely to discharge to the creek than it is to flow south-southeastward toward Observation Well 02 (~ 550 ft away). In addition, the relatively low tritium concentrations listed in Table 2 at Observation Well 01 (450 – 850 pCi/L) in comparison to those at Observation Well 02 (2,600 – 2,900 pCi/L) infer that the sources of tritium at these two locations are different. Possible reasons for a hydraulic separation between Observation Well 01 and Observation Well 02, if that is indeed the case, are the preferential flow zones commonly observed in fractured bedrock units like those underlying the plant.

Though available information suggests a low probability for subsurface hydraulic communication between areas surrounding Observation wells 01 and 02, it is feasible that groundwater near Dry Well 115 could be part of the same flow system affecting Observation Well 02. The distance separating the two wells (~220 ft) is relatively small and respective water elevations in each are of a similar magnitude (~43 to 51 ft above msl, Figures 7 and 8). In addition, the relatively large distance from either of these two wells to Diablo Creek (~ 650 – 900 ft) appears to limit the potential for groundwater near them to flow toward the creek, and in turn suggests that flow is locally toward the ocean. Moreover, the tritium concentrations observed at these locations suggest that they may be affected by the same tritium source. Though the largest tritium concentrations occur at Dry Well 115 (4,000 – 17,000 pCi/L, Figure 8) and lower concentrations are observed at Observation Well 02 (2600 – 2800 pCi/L), both wells appear to be influenced by a source of tritium that is larger in magnitude than that affecting groundwater near Observation Well 01. It is possible that the different tritium concentrations observed in Observation wells 01 and 02 are attributable to transport phenomena (e.g., dispersion, radioactive decay) occurring in the vicinity of the two wells.

While this explanation for different tritium concentrations in the three wells in the vicinity of the Power Block, as presented in the previous paragraph, is reasonable, it should be mentioned that tritium concentrations measured at Observation Well 02 since late June 2006 may not be representative of actual groundwater at this location. As shown in Table 2, samples collected from this well during the summer and fall of 2006 were limited to 250 milliliters (mL) because the well was virtually dry during this period. In addition, PG&E personnel have reported smells emanating from Observation Well 02 during sampling events that are signs of chemically reducing conditions, which in turn could be the result of microbially driven degradation of organic carbon. Whether these conditions signify an influence on tritium concentrations in samples collected from the bottom of Observation Well 02 cannot be determined at this time.

Table 2. Water Elevation Data and Radionuclide Concentrations at Wells on DCPP Property

Date	Depth of Water Column (ft and inches)	Estimated Water Elevation (ft above msl)	Nuclide	Concentration (pCi/L)	Detection Limit (pCi/L)
	Observation Well 01				
2/23/06	20'2"	69.57	Tritium (H-3)	835.00	449
2/23/06			Strontium-89	< Detection Limit	0.557
2/23/06			Strontium-90	0.65	0.414
2/23/06			Gross Beta	11.70	11.3
6/23/06	24'	73.40	Tritium (H-3)	699.00	296
6/23/06			Stronitum-89	< Detection Limit	0.311
6/23/06			Strontium-90	< Detection Limit	0.415
6/23/06			Gross Beta	4.56	3.99
7/19/06	20'4"	69.73	Tritium (H-3)	464.00	271
7/19/06			Stronitum-89	< Detection Limit	1.03
7/19/06			Strontium-90	< Detection Limit	0.33
7/19/06			Gross Beta	7.90	2.46
8/22/06	17'	66.40	Tritium (H-3)	657.00	273
8/22/06			Stronitum-89	< Detection Limit	0.358
8/22/06			Strontium-90	< Detection Limit	0.377
8/22/06			Gross Beta	6.30	3.62
8/22/06			Nickel-63	40.90	40.5
9/19/06	15' 5"	64.82	Tritium (H-3)	548.00	253
9/19/06			Stronitum-89	< Detection Limit	0.359
9/19/06			Strontium-90	< Detection Limit	0.266
9/19/06			Gross Beta	3.19	2.29
9/19/06			Nickel-63	< Detection Limit	29.9
9/19/06			Iron-55	< Detection Limit	78.1
	Observation Well 02				
2/23/06	3'	46.8	Tritium (H-3)	2600.00	450
2/23/06			Strontium-89	< Detection Limit	0.634
2/23/06			Strontium-90	1.09	0.389
2/23/06			Gross Beta	619.00	5.74
6/23/06	250 milliliters	43.9	Tritium (H-3)	2780.00	304
6/23/06	dry		Strontium-89	Not Analyzed	Not Analyzed
6/23/06	dry		Strontium-90	Not Analyzed	Not Analyzed
6/23/06	dry		Gross Beta	Not Analyzed	Not Analyzed
7/19/06	dry		Tritium (H-3)	Not Analyzed	Not Analyzed
7/19/06	dry		Strontium-89	Not Analyzed	Not Analyzed
7/19/06	dry		Strontium-90	Not Analyzed	Not Analyzed
7/19/06	dry		Gross Beta	Not Analyzed	Not Analyzed
8/22/06	250 milliliters		Tritium (H-3)	2570.00	272
8/22/06	dry		Strontium-89	Not Analyzed	Not Analyzed
8/22/06	dry		Strontium-90	Not Analyzed	Not Analyzed
8/22/06	dry		Gross Beta	Not Analyzed	Not Analyzed
9/19/06	250 milliliters	43.8	Tritium (H-3)	2830.00	251
9/19/06	dry		Strontium-89	Not Analyzed	Not Analyzed
9/19/06	dry		Strontium-90	Not Analyzed	Not Analyzed
9/19/06	dry		Gross Beta	Not Analyzed	Not Analyzed

Table 2. Water Elevation Data and Radionuclide Concentrations at Wells on DCPP Property (continued)

Date	Depth of Water Column (ft and inches)	Estimated Water Elevation (ft above msl)	Nuclide	Concentration (pCi/L)	Detection Limit (pCi/L)
			French Drain - Dry Well 115		
2/24/2006	5'4"	47.63	Tritium (H-3)	3860.00	474
2/24/2006			Strontium-89	< Detection Limit	0.494
2/24/2006			Strontium-90	< Detection Limit	0.398
2/24/2006			Gross Beta	Not Analyzed	Not Analyzed
6/22/2006	Not Analyzed	Not Analyzed	Tritium (H-3)	13510.00	304
6/22/2006			Strontium-89	< Detection Limit	0.318
6/22/2006			Strontium-90	< Detection Limit	0.357
6/22/2006			Gross Beta	11.70	2.11
7/19/2006	9'1"	51.38	Tritium (H-3)	15580.00	276
7/19/2006			Strontium-89	< Detection Limit	1.08
7/19/2006			Strontium-90	< Detection Limit	0.416
7/19/2006			Gross Beta	19.90	2.25
8/22/2006	9' 2"	51.47	Tritium (H-3)	15600.00	264
8/22/2006			Strontium-89	< Detection Limit	0.463
8/22/2006			Strontium-90	< Detection Limit	0.434
8/22/2006			Gross Beta	24.90	2.65
8/22/2006			Cobalt-60	4.54	0.76
9/19/2006	9' 1"	51.38	Tritium (H-3)	16800.00	250
9/19/2006			Strontium-89	< Detection Limit	0.308
9/19/2006			Strontium-90	< Detection Limit	0.281
9/19/2006			Gross Beta	24.10	1.7
9/19/2006			Nickel-63	< Detection Limit	33.6
9/19/2006			Iron-55	< Detection Limit	70.8
			Water Well 02		
02/23/06	Not Analyzed	Not Analyzed	Tritium (H-3)	< Detection Limit	450
02/23/06			Strontium-89	Not Analyzed	Not Analyzed
02/23/06			Strontium-90	Not Analyzed	Not Analyzed
02/23/06			Gross Beta	10.1	5.43
03/29/06	Not Analyzed	Not Analyzed	Tritium (H-3)	< Detection Limit	331
03/29/06			Strontium-89	< Detection Limit	0.298
03/29/06			Strontium-90	< Detection Limit	0.371
03/29/06			Gross Beta	Not Analyzed	Not Analyzed
06/21/06	Not Analyzed	Not Analyzed	Tritium (H-3)	< Detection Limit	289
06/21/06			Strontium-89	< Detection Limit	0.507
06/21/06			Strontium-90	< Detection Limit	0.544
06/21/06			Gross Beta	2.87	2.16
07/19/06	Not Analyzed	Not Analyzed	Tritium (H-3)	< Detection Limit	268
07/19/06			Strontium-89	< Detection Limit	0.931
07/19/06			Strontium-90	< Detection Limit	0.277
07/19/06			Gross Beta	12.2	2.82
08/22/06	Not Analyzed	Not Analyzed	Tritium (H-3)	< Detection Limit	272
08/22/06			Strontium-89	< Detection Limit	0.422
08/22/06			Strontium-90	< Detection Limit	0.351
08/22/06			Gross Beta	7.83	3.3
08/22/06			Nickel-63 (Ni-63)	42.5	37.8
08/22/06			Ni-63 Reanalysis	< Detection Limit	33.3

Table 2. Water Elevation Data and Radionuclide Concentrations at Wells on DCPP Property (continued)

Date	Depth of Water Column (ft and inches)	Estimated Water Elevation (ft above msl)	Nuclide	Concentration (pCi/L)	Detection Limit (pCi/L)
Water Well 02 (continued)					
09/19/06	Not Analyzed	Not Analyzed	Tritium (H-3)	< Detection Limit	252
09/19/06			Strontium-89	< Detection Limit	0.337
09/19/06			Strontium-90	< Detection Limit	0.269
09/19/06			Gross Beta	6.42	1.76
09/19/06			Nickel-63	< Detection Limit	30.4
09/19/06			Iron-55	< Detection Limit	96.4

Regardless of the flow and transport phenomena leading to respective water elevation observations and measured tritium concentrations at Observation Well 01, Observation Well 02, and Dry Well 115, none of the tritium concentrations at these wells exceed the EPA MCL for this constituent (20,000 pCi/L). In addition, the concentrations of other nuclides monitored at these three wells (Table 2) are low and show no indication of inadvertent releases of radionuclides from plant facilities. As discussed in the following sections, it is nevertheless useful to examine possible reasons for the occurrence of detectable tritium in groundwater beneath and near the Power Block, which can occur at relatively high concentrations in Dry Well 115.

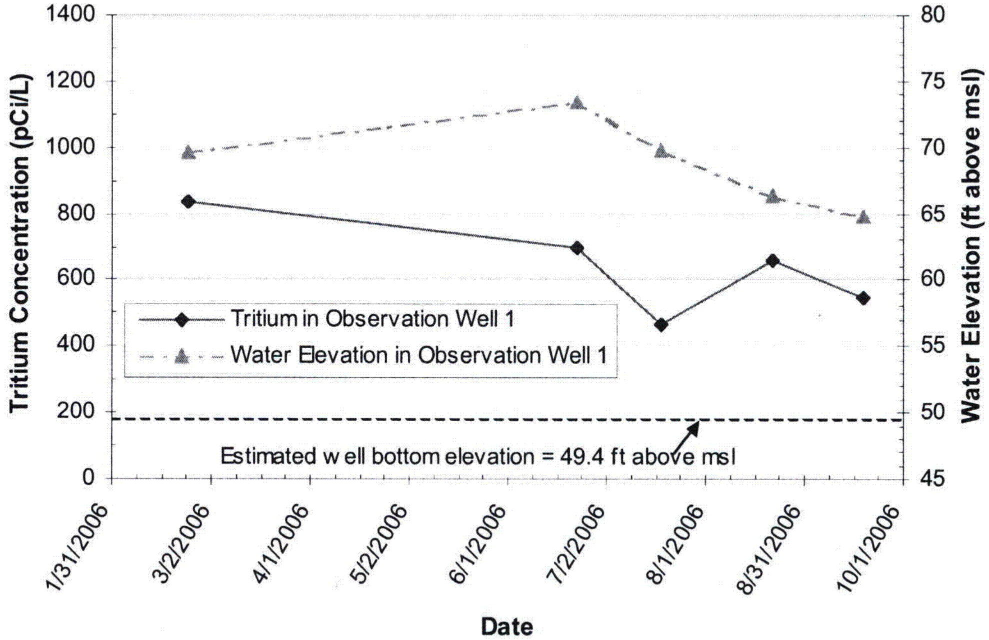

Figure 6. Observed Water Elevations and Tritium Concentrations at Observation Well 01

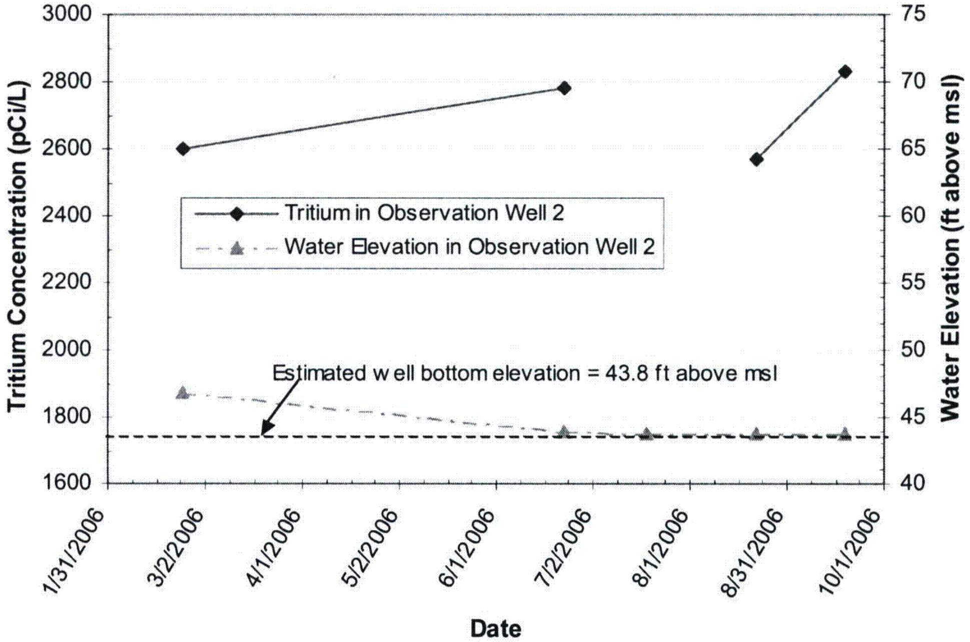

Figure 7. Observed Water Elevations and Tritium Concentrations at Observation Well 02

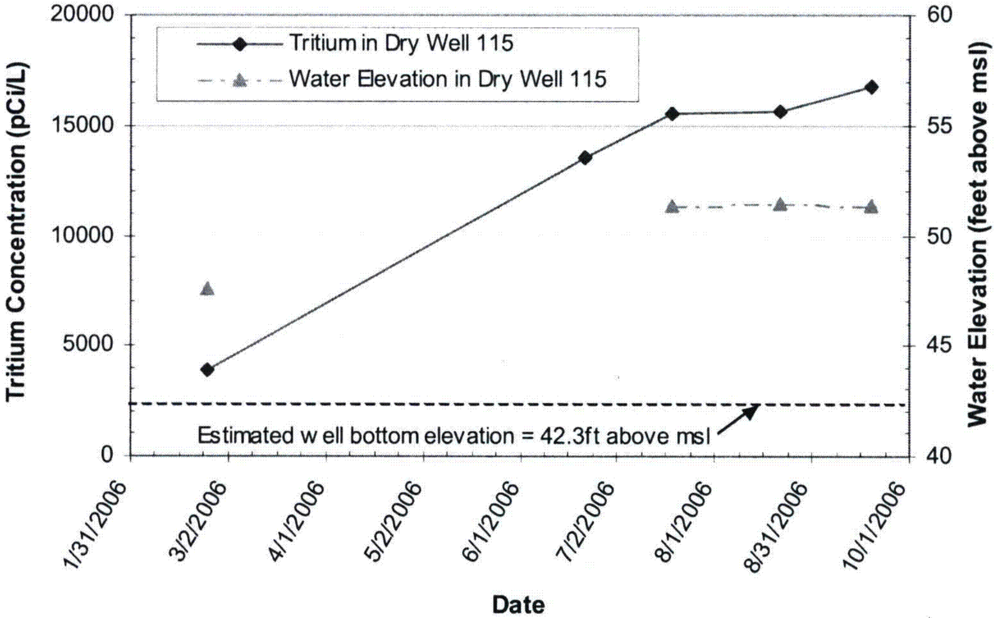

Figure 8. Observed Water Elevations and Tritium Concentrations at Dry Well 115

Tritium concentrations data for Water Well 02 (Table 1) indicate that this constituent is unlikely to be detected at locales some distance away from the Power Block. Similarly, other isotopes monitored at this well are either non-detectable or occur at low, non-threatening concentrations. These results suggest that the presence of detectable tritium at wells in the vicinity of the Power Block is likely to be a localized phenomenon.

Tritium from Rooftop Drains

As previously mentioned, "washout" of tritiated water vapor released from vents above both containment buildings is considered by PG&E to a possible source of the tritium detected in wells used to monitor groundwater beneath and near the Power Block. Though the exact phenomena associated with this process are not precisely known, it does appear to involve the entrainment of vented water vapor in rainfall at the site. Some of the resulting tritiated rainwater falls directly on the ground surface and the remainder falls on the rooftops of plant buildings, from where it is carried to rooftop drains and discharged to grounds surrounding the buildings. This rainwater is expected to either flow toward the ocean or Diablo Creek as runoff or infiltrate the ground surface.

It is also likely that, between rainfall events, cooling of vented water vapor causes it to condense in the atmosphere above the Power Block and subsequently deposit on the rooftops of plant buildings. Though subsequent evaporation probably causes much of this tritiated water to reenter the vapor phase and move downwind of the site in the atmosphere, it is possible that solid materials comprising the rooftops absorb some of the water, perhaps as water of hydration. If this liquid form of tritium accumulates in roofing materials during the dry-season months of April through October, subsequent rainfall-driven sheet flow on the rooftops during the wet-season months that follow could deliver the tritium to building drains.

Regardless of whether tritiated water becomes temporarily stored in rooftop materials, tritium concentrations in water samples collected at the outlets of rooftop drains are expected to be somewhat elevated in comparison to background tritium levels in surface water near the site. Support for this hypothesis is presented in Figure 9, which shows measured tritium concentrations in rainwater apparently collected from a rooftop drain for the Auxiliary Building between early 2000 and late 2005. Though the exact location of this drain is unclear, the data associated with it show tritium concentrations that typically range between 8,000 and 15,000 pCi/L and occasionally exceed the tritium MCL. These concentrations suggest that rooftop drainage could be the source of tritium detected in Dry Well 115 at concentrations that can exceed 15,000 pCi/L.

PG&E has surmised that the relatively high concentrations of tritium in Dry Well 115 between February and September 2006 (Figure 8) are at least partly caused by direct discharge of rainwater from a rooftop drain for the Fuel Handling Building to openings in a manhole cover over the well (Figure 10). To help assess whether this is the case, a waterproof cap was recently placed on the well. If direct discharge of drain water has historically influenced tritium concentrations at Dry Well 115, sampling conducted subsequent to capping of the well will probably result in tritium concentrations that gradually decrease with time. However, it is also possible that some rainwater moving as sheet flow on the paving surrounding the well (Figure

10) could infiltrate underlying bedrock via cracks in the paving. Until such time that several months of new data become available for Dry Well 115, the overall influence of washout on tritium concentrations in groundwater beneath the east side of the Fuel Handling Building cannot be fully determined.

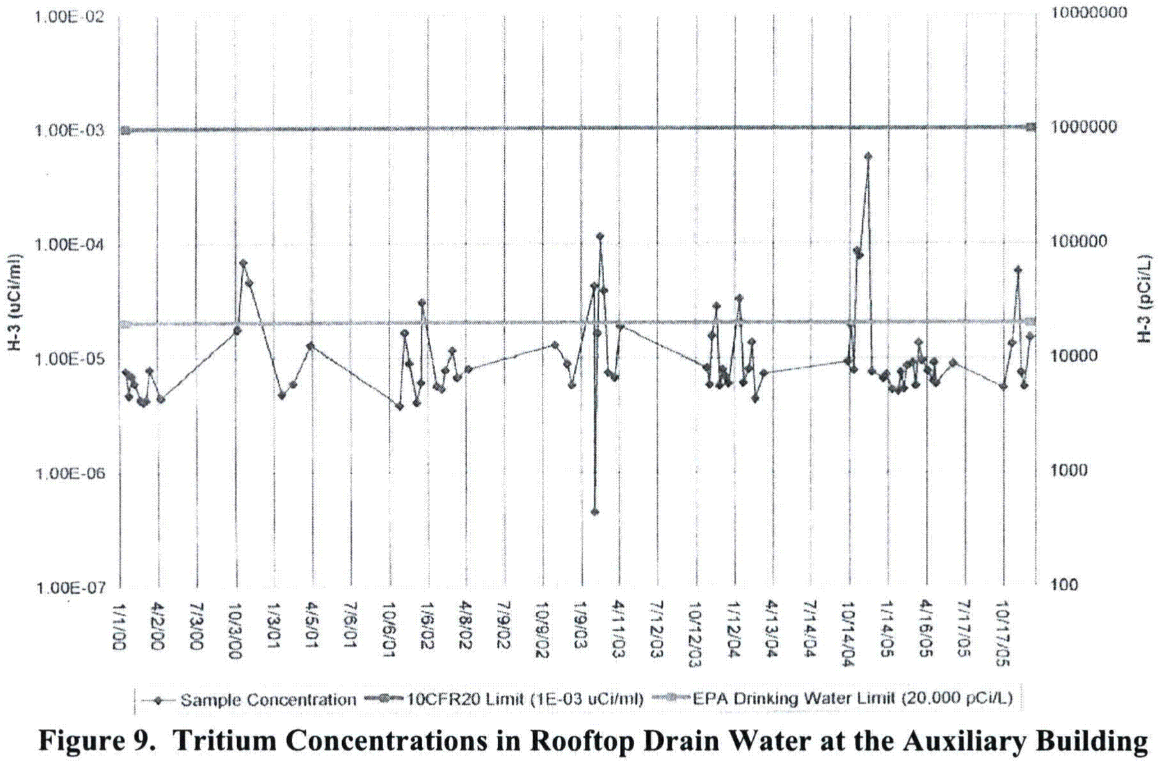

Figure 9. Tritium Concentrations in Rooftop Drain Water at the Auxiliary Building

Rooftop drainage is probably the largest source of the moderately elevated tritium concentrations observed in groundwater in the vicinity of the power plant, with direct rainfall on paved and unpaved areas surrounding the plant representing a smaller source. Deposition of tritiated rainwater on the colluvium located between the paved area east of the Fuel Handling Facility and Reservoir Road (Figure 4) and subsequent recharge of the underlying groundwater system is a potential source of tritium observed in Power Block wells. However, radioactive decay during the travel time between the infiltration area and the Power Block wells could reduce the tritium concentrations substantially before they reach the French drain on the east side of the Fuel Handling Building.

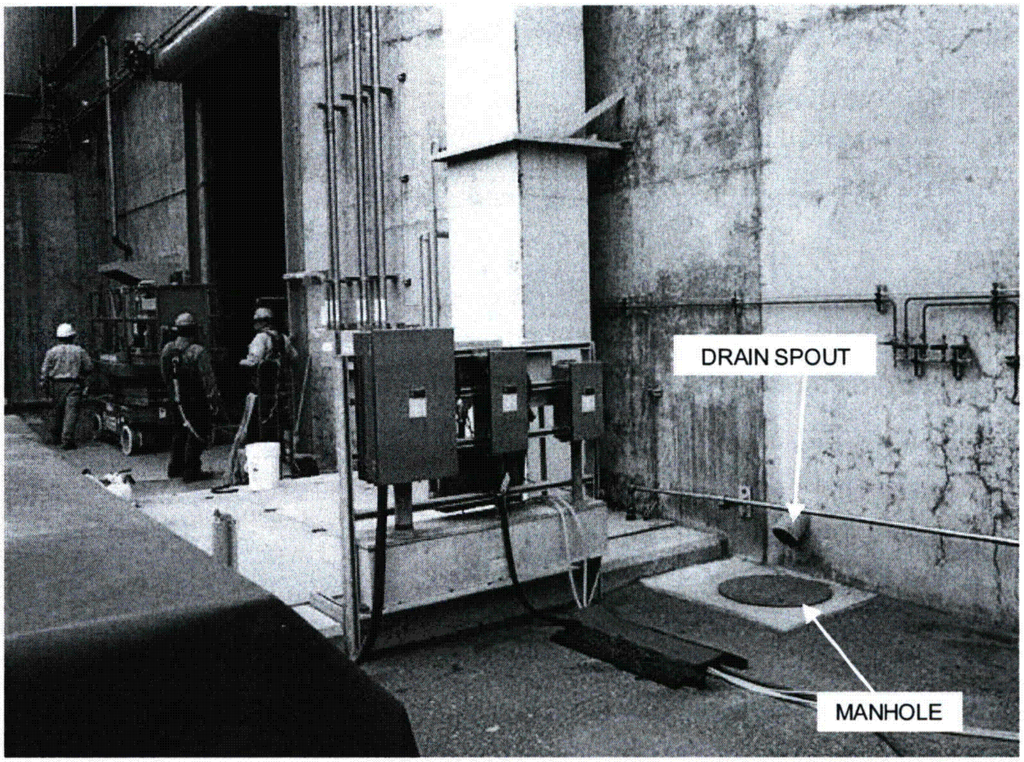

Figure 10. Manhole Cover Over Dry Well 115

Surface Water Data

Nuclide concentration data for the two sampling locations on Diablo Creek (Table 3) provide further evidence that noticeably elevated tritium concentrations are likely limited to subsurface water in the immediate vicinity of the Power Block. Tritium levels at upstream location 5S2 since January 2006 have all been non-detectable. The same is also true for the Diablo Creek outlet (WN2) despite the possibility that ground water in the vicinity of the Power Block has the potential to discharge to the creek just upstream of the outlet. The concentrations of other nuclides at these two locations (Table 3) are also typically below detection limits or are quite low.

Concentration data for several isotopes at surface water sampling locations outside of DCPP property boundaries are presented in Table 4. Again, a preponderance of concentrations that are either non-detectable or quite low indicates that the power plant is not releasing radionuclides at levels that might affect surface water in surrounding areas.

Table 3. Radionuclide Concentrations at Sampling Locations on Diablo Creek

Date	Nuclide	Concentration (pCi/L)	Detection Limit (pCi/L)	Date	Nuclide	Concentration (pCi/L)	Detection Limit (pCi/L)
		5S2				WN2	
1/17/2006	Tritium	< Detection Limit	767	5/19/2006	Tritium	< Detection Limit	308
1/17/2006	Strontium-89	< Detection Limit	0.626	5/19/2006	Strontium-89	< Detection Limit	0.357
1/17/2006	Strontium-90	< Detection Limit	0.987	5/19/2006	Strontium-90	0.887	0.703
1/17/2006	Gross Beta	< Detection Limit	3.43	5/19/2006	Gross Beta	< Detection Limit	3.18
2/21/2006	Tritium	< Detection Limit	445	6/21/2006	Tritium	< Detection Limit	305
2/21/2006	Strontium-89	Not Analyzed	Not Analyzed	6/21/2006	Strontium-89	< Detection Limit	0.407
2/21/2006	Strontium-90	Not Analyzed	Not Analyzed	6/21/2006	Strontium-90	< Detection Limit	0.539
2/21/2006	Gross Beta	4.32	2.65	6/21/2006	Gross Beta	< Detection Limit	2.39
3/7/2006	Tritium	< Detection Limit	457	7/19/2006	Tritium	< Detection Limit	276
3/7/2006	Strontium-89	Not Analyzed	Not Analyzed	7/19/2006	Strontium-89	< Detection Limit	0.686
3/7/2006	Strontium-90	Not Analyzed	Not Analyzed	7/19/2006	Strontium-90	< Detection Limit	0.371
3/7/2006	Gross Beta	3.16	2.62	7/19/2006	Gross Beta	7.35	4.19
4/5/2006	Tritium	< Detection Limit	301	8/23/2006	Tritium	< Detection Limit	272
4/5/2006	Strontium-89	Not Analyzed	Not Analyzed	8/23/2006	Strontium-89	< Detection Limit	0.336
4/5/2006	Strontium-90	Not Analyzed	Not Analyzed	8/23/2006	Strontium-90	< Detection Limit	0.354
4/5/2006	Gross Beta	6.02	2.75	8/23/2006	Gross Beta	< Detection Limit	2.71
5/16/2006	Tritium	< Detection Limit	305	9/19/2006	Tritium	< Detection Limit	255
5/16/2006	Strontium-89	Not Analyzed	Not Analyzed	9/19/2006	Strontium-89	< Detection Limit	0.399
5/16/2006	Strontium-90	Not Analyzed	Not Analyzed	9/19/2006	Strontium-90	< Detection Limit	0.304
5/16/2006	Gross Beta	< Detection Limit	3.5	9/19/2006	Gross Beta	2.92	2.61
				9/19/2006	Nickel-63	< Detection Limit	71.8
6/13/2006	Tritium	< Detection Limit	312	9/19/2006	Iron-55	< Detection Limit	32.1
6/13/2006	Strontium-89	Not Analyzed	Not Analyzed				
6/13/2006	Strontium-90	Not Analyzed	Not Analyzed				
6/13/2006	Gross Beta	< Detection Limit	3.11				
6/21/2006	Tritium	< Detection Limit	295				
6/21/2006	Strontium-89	< Detection Limit	0.511				
6/21/2006	Strontium-90	< Detection Limit	0.569				
6/21/2006	Gross Beta	< Detection Limit	2.32				
7/19/2006	Tritium	< Detection Limit	275				
7/19/2006	Strontium-89	< Detection Limit	0.648				
7/19/2006	Strontium-90	< Detection Limit	0.332				
7/19/2006	Gross Beta	< Detection Limit	3.09				
8/23/2006	Tritium	< Detection Limit	273				
8/23/2006	Strontium-89	< Detection Limit	0.447				
8/23/2006	Strontium-90	< Detection Limit	0.465				
8/23/2006	Gross Beta	4.18	2.93				

Table 4. Radionuclide Concentrations at Surface Water Sampling Locations Outside of DCPP Property Boundaries

Date	Nuclide	Concentration (pCi/L)	Detection Limit (pCi/L)	Comments
Coon Creek				
6/30/2006	Tritium	< Detection Limit	309	flowing
6/30/2006	Strontium-89	< Detection Limit	1.49	flowing
6/30/2006	Strontium-90	< Detection Limit	0.74	flowing
6/30/2006	Gross Beta	< Detection Limit	2.87	flowing
7/12/2006	Tritium	< Detection Limit	321	flowing
7/12/2006	Strontium-89	< Detection Limit	1.25	flowing
7/12/2006	Strontium-90	< Detection Limit	0.54	flowing
7/12/2006	Gross Beta	5.902	2.98	flowing
Morro Creek				
6/30/2006	Tritium	< Detection Limit	311	flowing
6/30/2006	Strontium-89	< Detection Limit	1.25	flowing
6/30/2006	Strontium-90	< Detection Limit	0.561	flowing
6/30/2006	Gross Beta	< Detection Limit	2.96	flowing
7/12/2006	Tritium	< Detection Limit	320	stagnant
7/12/2006	Strontium-89	< Detection Limit	1.12	stagnant
7/12/2006	Strontium-90	< Detection Limit	0.541	stagnant
7/12/2006	Gross Beta	< Detection Limit	2.97	stagnant
Spring Water				
7/12/2006	Tritium	< Detection Limit	315	
7/12/2006	Strontium-89	< Detection Limit	1.09	
7/12/2006	Strontium-90	< Detection Limit	0.64	
7/12/2006	Gross Beta	< Detection Limit	3.17	
Mello (Livestock) Pond				
8/31/2006	Tritium	< Detection Limit	267	
8/31/2006	Strontium-89	< Detection Limit	0.298	
8/31/2006	Strontium-90	< Detection Limit	0.373	
8/31/2006	Iron-55	< Detection Limit	84.4	
8/31/2006	Nickel-63	< Detection Limit	37.8	
8/31/2006	Gross Beta	< Detection Limit	3.84	
NW (Livestock) Pond				
8/31/2006	Tritium	< Detection Limit	266	
8/31/2006	Strontium-89	< Detection Limit	0.394	
8/31/2006	Strontium-90	< Detection Limit	0.547	
8/31/2006	Iron-55	< Detection Limit	90.4	
8/31/2006	Nickel-63	< Detection Limit	38	
8/31/2006	Gross Beta	4.83	2.99	

Conclusions

The following conclusions are drawn from this evaluation of hydrogeologic conditions and measured concentrations of tritium and other radionuclides at DCPP:

- Groundwater beneath and near the Power Block flows within fractures and bedding planes of the Obispo Formation, a bedrock unit consisting of tuffaceous siltstone and sandstone.
- Though groundwater flow directions beneath and near the power plant cannot be directly discerned using existing water elevation data from three wells in the area, studies of the ISFSI site and a general assessment of subregional hydrogeologic conditions indicates that flow is toward the Pacific Ocean and Diablo Creek, the latter of which discharges to the ocean near the plant.
- Measured concentrations of radionuclides at sampling locations on DCPP property indicate that tritium is the only nuclide released as result of plant operations that noticeably affects local water resource chemistry, and tritium is discernible only in groundwater near the power plant itself.
- Tritium concentrations measured at three wells in the near-vicinity of the power plant are less than the MCL established for this nuclide by the EPA (20,000 pCi/L).
- The apparent source of the tritium is water vapor released from vents located above Containment buildings 1 and 2 under normal plant operations. The tritiated water vapor appears to either be entrained in rainfall or condense in the atmosphere, and much of the resulting liquid water appears to deposit on building rooftops where it is subsequently transported to the ground surface via rooftop drains.
- The largest tritium concentrations, as high as 17,000 pCi/L, are observed in a well (Dry Well 115) that comprises part of a French drain system on the east side of the Fuel Handling Building. Direct discharge of rooftop drain water to holes in a manhole covering the well are suspected of causing such concentrations.
- Deposition of liquid water containing plant-derived tritium on other areas in the immediate vicinity of the plant is also possible, which may subsequently become part of groundwater flowing toward wells near the plant. Tritium concentrations in groundwater resulting from this latter process, if feasible, are expected to be lower than those occurring in water draining from building rooftops.
- Radionuclides that are released from DCPP as part of normal operations and end up being dissolved in local groundwater are unlikely to affect human health because (1) the groundwater is not used drinking water or food production purposes; (2) the plant is located on the edge of the Pacific Ocean and several miles away from residences or population centers, and (3) all of the local groundwater eventually discharges to the ocean near the plant.
- The concentrations of monitored radionuclides, including tritium, at two surface water sampling locations on Diablo Creek are either non-detectable or very low in value, indicating that surface water near the power plant remains largely unaffected by normal plant operations. The same finding applies to monitored surface waters at locations outside of DCPP property.

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