RADIATION SAFETY & CONTROL SERVICES, INC.

RSCS
Radiation Safety & Control Services, Inc.

Technical Support Document

REVIEW OF THE GROUND WATER PROTECTION PROGRAM AT THE FORT CALHOUN NUCLEAR POWER STATION

TSD #08-015

Revision 01

Originator: [signature] Date: 5/24/08
David Scott, LEP

Reviewer: [signature] Date: 5/30/08
Matthew Darois

Approval: [signature] Date: 5/30/08
Eric Darois, CHP

Table of Contents

I. Evaluation of FCS' Completion of "Action 1" Items of the NEI Ground Water Protection Program 4
Objective 1.1 of the NEI Ground Water Protection Program: Site Hydrology and Geology 4
Objective 1.2 of the NEI Ground Water Protection Program: Site Risk Assessment . 5
Objective 1.3 of the NEI Ground Water Protection Program: On-Site Ground Water Monitoring 6
Objective 1.4 of the NEI Ground Water Protection Program: Remediation Process 6
Objective 1.5 of the NEI Ground Water Protection Program: Record Keeping........ 7
II. Evaluation of FCS' Completion of Tasks Prescribed in Section 5.0 of the EPRI Ground Water Protection Guidelines for Nuclear Power Plants ("Locating, Installing and Testing Ground Water Monitoring Wells") 7
Section 5.1 of the EPRI Ground Water Protection Guidelines: Data Quality Objectives for Well Drilling 7
Section 5.2 of the EPRI Ground Water Protection Guidelines: Well Installation Considerations........ 7
Section 5.3 of the EPRI Ground Water Protection Guidelines: Monitoring Well Construction........ 8
Section 5.4 of the EPRI Ground Water Protection Guidelines: Maintenance Program for Monitoring Wells 8
III. Update of the FCS Site Conceptual Model........ 9
IV. Review of Construction Photos 12
V. Review and Evaluation of Reports Containing Pre-Operational Ground Water and Geologic Data 13
Design Basis Document PLDBD-CS-51: Seismic Criteria 13
Design Basis Document PLDBD-CS-54: Geotechnical........ 14
Final Safety Analysis Report, Section 2: Site and Environs........ 15
Section 2.2 of the FSAR – General Description of Site and Environs 15
Section 2.3 of the FSAR – Topography........ 15
Section 2.5 of the FSAR – Meteorology........ 15
Section 2.6 of the FSAR – Geology........ 15
Section 2.7 of the FSAR – Hydrology 16
Section 2.7.2 of the FSAR – Ground Water 16
Section 2.10 of the FSAR – Environmental Radiation Monitoring........ 17
Final Safety Analysis Report, Appendix B: Site Environmental Studies........ 17
Updated Safety Analysis Report, Appendix C: Foundation Studies, Dames and Moore 18
Updated Safety Analysis Report, Section 2.6: Site and Environs – Geology........ 18
Updated Safety Analysis Report, Section 2.7: Site and Environs – Hydrology 18
VI. Review and Evaluation of Hydrogeologic Reports for the Characterization of Site Geology and Ground Water Since FCS Became Operational 18

- Hydrogeologic Investigations Report, Fort Calhoun Power Station, Water Treatment Sludge Disposal Area, SCS Engineers, June, 1995 18
- Hydrogeologic Assessment Report, OPPD Nuclear Power Generating Station, Fort Calhoun, Nebraska, Terracon Consultants, Inc., December 14, 2007 19
  - Ground Water Gradients 19
  - Strontium-90 21
  - Hydraulic Conductivity Testing 22

VII. Evaluation of Regional Hydrogeological Characteristics in Reports Published by the U.S. Geological Survey and the Nebraska Department of Natural Resources 22

- Geology of the Omaha-Council Bluffs Area, Nebraska-Iowa, USGS Professional Paper 472, Robert D. Miller, 1964 22
- Reconnaissance of Ground Water Quality in the Papio-Missouri River Natural Resources District, Eastern Nebraska, USGS Water-Resources Investigations 94-4197, I.M. Verstraeten and M.J. Ellis, 1995 23
- 2006 Annual Report of the Missouri Tributaries Basin, LB962, Nebraska Department of Natural Resources 24
- Nebraska Data Bank Interactive Maps, Nebraska Department of Natural Resources 24

VIII. Evaluation of the Priority Index for Selected SSCs Containing Radiological Material 25

IX. Summary of Recommendations 29

X. Referenced Reports 30

List of Tables

Table 1: Recommended Revisions to Priority Factor Scores 25

List of Figures

Figure 1: Existing and Proposed Monitoring Wells 32

Review of the Ground Water Protection Program
Fort Calhoun Nuclear Power Station
Fort Calhoun, Nebraska

This report evaluates several elements of the ground water protection program for Fort Calhoun Station (FCS). The elements reviewed include those outlined in Radiation Safety and Control Services' (RSCS) proposal to FCS dated October 31, 2007, in which the scope of the proposed consulting services was described.

I. Evaluation of FCS' Completion of "Action 1" Items of the NEI Ground Water Protection Program

Objective 1.1 of the NEI Ground Water Protection Program: Site Hydrology and Geology

a) With the completion of construction of an array of monitoring wells within the industrial area in August 2007 (Terracon Consultants, Inc., 2007) and measurement of ground water levels in September, October and November, FCS has characterized the stratigraphy of the area and begun the process of determining ground water flow gradients. Those gradients can be expected to vary seasonally, and several more quarters of monitoring data will be required to understand the range in ground water flow characteristics. Hydraulic conductivity testing was completed in each of the new monitoring wells (except MW-8).

b) This report documents a review of the 2007 Terracon Consultants report and earlier reports of environmental studies of FCS, including sections of the Final Safety Analysis Report (FSAR) and Updated Safety Analysis Report (USAR) (see Section V).

c) One possible pathway for ground water to migrate from on-site to off-site locations has been identified: discharge of ground water from the site to the Missouri River and subsequent flow downstream. Site ground water within the radius of influence of the production well supplying water to the reverse osmosis treatment plant ("RO well") is captured by that well and used for on-site process water. Much of that water ultimately leaves the site in the form of steam or water vapor.

d) The Fort Calhoun Ground Water Protection Plan (GWPP) has been reviewed to evaluate its conformance with the acceptance criteria prescribed by the Nuclear Energy Institute Ground Water Protection Program. The NEI document stipulates that each ground water protection program should establish the frequency at which the site conceptual model is reviewed. Periodic review is required to assure that new information that may be developed pertinent to the occurrence and monitoring of ground water contamination is incorporated into the conceptual site model and the

ground water protection plan. The FCS GWPP specifies the frequency of review of the Site Conceptual Model in Section 6.7 of SO-G-118.

e) The FCS FSAR should be updated to reflect the hydraulic gradients, hydraulic conductivities and ground water flow velocities determined during the August 2007 hydrogeologic investigation of the site. The FSAR should also be revised to indicate the apparent seasonal reversal of ground water gradients near the Missouri River. This phenomenon was documented both by Terracon Consultants (2007) and by SCS Engineers (1995) in their report of closure of the water treatment sludge disposal area.

Objective 1.2 of the NEI Ground Water Protection Program: Site Risk Assessment

a) FCS has evaluated each structure, system or component (SSC) and work practice that could reasonably be expected to contain licensed material and for which there is a credible mechanism for release of the material to ground water (see the evaluation of Priority Indices for each SSC in Section VIII).

b) Leak detection methods for each SSC and work practice that contain licensed material for which there is a credible mechanism for release of the material to ground water are considered in determining the “Priority Index” for each SSC or work practice. In the section “Current FCS Groundwater Protection Status”, the FCS GWPP mentions the existence of leakage monitoring plans for the spent fuel pool, transfer canal and the reactor cavity. In addition, Item 4 of Phase III Initiatives in the GWPP discusses identification of leak detection methods. Specific leak detection methods appropriate for each SSC or work practice, such as operator rounds, engineering inspections, radiation monitoring systems, integrity tests, NDE methods and ground water monitoring, should also be included in the GWPP.

c) Potential enhancements to leak detection systems or programs are discussed in the FCS GWPP (Phase III Initiatives, Item 5).

d) Potential enhancements to prevent spills or leaks from reaching ground water are discussed in the FCS GWPP (Phase III Initiatives, Item 6).

e) The site process for tracking corrective actions is presumably the Condition Report process, but it is not specifically discussed in the FCS GWPP. The process for tracking corrective actions at FCS should be clearly defined in the GWPP.

f) Long-term programs to perform preventative maintenance and surveillance to minimize the potential for inadvertent release of licensed materials to ground water due to equipment failure are discussed in the FCS GWPP, Phase I Initiatives, Items A11 and A12 and Phase III Initiatives, Item C2.

g) The frequency for periodic reviews of SSCs and work practices is discussed in the FCS GWPP (Phase III Initiatives, Item 8).

Objective 1.3 of the NEI Ground Water Protection Program: On-Site Ground Water Monitoring

a) Monitoring wells have been constructed down-gradient of some portions of the plant. The wells were drilled in accordance with the FCS document: "Data Quality Objectives for Well Drilling". Evaluation of the ground water gradients measured during the 2007 investigation reveals ground water flow directions not formerly anticipated in some areas of the plant industrial area. Additional monitoring wells are recommended in locations now revealed to be down-gradient of potential sources of release of radiological material to the environment (see Section VI).

b) Monitoring wells have been placed near SSCs that have the highest potential for inadvertent releases to ground water. However, because of unanticipated ground water gradients in some areas of the plant, additional wells are recommended, as noted above.

c) Sampling and analysis protocols, including analytical sensitivity requirements, are discussed in Item 9 of Phase III Initiatives of the GWPP.

d) The FCS GWPP establishes a formal, written program for long-term ground water monitoring. Details as to the specific wells to be monitored, analytes, sampling frequency, minimum detectable concentrations, data-quality objectives and data management process should be provided.

e) The FCS GWPP discusses review of station or contract laboratory analytical capabilities (Item 9 of Phase III Initiatives).

f) The FCS GWPP discusses establishment of a long-term program for preventative maintenance of ground water monitoring wells (Item 9 of Phase III Initiatives).

g) The FCS GWPP discusses establishing the frequency for periodic review of the ground water monitoring program (Item 9 of Phase III Initiatives).

Objective 1.4 of the NEI Ground Water Protection Program: Remediation Process

a) Item D2 of Phase IV Activities in the FCS GWPP requires that a determination be made as to when ground water clean-up activities are needed. Item 11 of Phase III Initiatives of the GWPP requires establishment of written procedures outlining the

decision making process for remediation of leaks, spills or other instances of inadvertent releases to ground water. The GWPP could stipulate that no investigation of impacts to ground water is needed for leaks or spills that occur inside and are contained within structures, where there is no credible mechanism for release of radionuclides to the environment.

b) The FCS GWPP discusses evaluation of the potential for detectible levels of licensed material resulting from planned releases of liquids and airborne materials being identified by the ground water monitoring program (Items 23 and 24 of Phase III Initiatives).

c) The FCS GWPP discusses the need to evaluate decommissioning impacts resulting from remediation activities during the operating life of the plant, or the absence thereof (Item12 of Phase III Initiatives).

Objective 1.5 of the NEI Ground Water Protection Program: Record Keeping

a) The FCS Ground Water Protection Plan establishes a record keeping program to meet the requirements of 10 CFR 50.75(g). Aspects of this program are discussed in Items A6, A14 and A15 of the Phase I Initiatives and Items 19, 20 and 21 of Phase III Initiatives of the GWPP.

II. Evaluation of FCS' Completion of Tasks Prescribed in Section 5.0 of the EPRI Ground Water Protection Guidelines for Nuclear Power Plants ("Locating, Installing and Testing Ground Water Monitoring Wells")

Section 5.1 of the EPRI Ground Water Protection Guidelines: Data Quality Objectives for Well Drilling

FCS has prepared a document titled: "Data Quality Objectives for Well Drilling". That document adequately describes the data quality objectives for drilling monitoring wells and should be incorporated into the GWPP for FCS.

Section 5.2 of the EPRI Ground Water Protection Guidelines: Well Installation Considerations

5.2.1 Configuration Management for Well Drilling

The construction details for monitoring wells drilled in 2007 are documented in well logs provided by Terracon Consultants (2007). Those drilled in 1995 are documented in well logs provided by SCS Engineers (1995). FCS may find it useful to summarize in a database the pertinent details of each well including total depth, diameter, screened interval, elevation of top of casing and water level. These parameters should be summarized for all site wells.

5.2.2 Permitting Requirements for Well Drilling
Terracon Consultants (2007) notes that the monitoring wells drilled in 2007 were constructed in accordance with Title 178, Chapter 12 of the Nebraska Administrative Code.

5.2.3 Well Location
Well locations were determined based upon the site conceptual model and the FCS document: "Data Quality Objectives for Well Drilling".

5.2.4 Sampling Accessibility
FCS Monitoring wells drilled in 2007 and 1995 are two inches in diameter. This is a common well diameter and is large enough to accommodate a submersible pump for sampling.

Section 5.3 of the EPRI Ground Water Protection Guidelines: Monitoring Well Construction

Drilling and construction of monitoring wells in 2007 and 1995 were completed under the supervision of qualified geoscientists. The geologic materials penetrated during drilling were sampled and logged to allow determination of local stratigraphy. All wells drilled during both of these campaigns conform with recognized standards such as ASTM D5092-02. The wells drilled in 1995 were noted by SCS Engineers to have been drilled by a State of Nebraska Licensed Drilling Contractor.

Both Terracon Consultants (2007) and SCS Engineers (1995) estimated linear ground water flow velocities at the site. SCS Engineers based their estimates on hydraulic conductivities determined by Dames and Moore (1968). Terracon Consultants based their estimates on hydraulic conductivities they determined from slug tests completed in the monitoring wells drilled in 2007.

Section 5.4 of the EPRI Ground Water Protection Guidelines: Maintenance Program for Monitoring Wells

Monitoring wells constructed in 2007 and 1995 have proper surface completions that provide security from vandalism and protection from infiltration of surface water. The

FCS GWPP includes a requirement to establish a maintenance program to insure the continued integrity of monitoring wells (Item 9 of Phase III Initiatives).

III. Update of the FCS Site Conceptual Model

The Missouri River is a large perennial stream that is the primary surface drainage feature in the vicinity of FCS. The river is also the site of regional ground water discharge. Because of its location on the flood plain of the river, the topography in the area of the power plant is flat. The resulting hydraulic gradient within the unconsolidated sediments in the flood plain is also relatively flat. This low hydraulic gradient, combined with moderate hydraulic conductivity of the generally fine-grained alluvial aquifer material, results in relatively slow ground water flow velocity beneath the site.

Land use within the flood plain adjacent to FCS is agricultural. A bluff located approximately 2,500 feet southwest of the river rises a few hundred feet and is up-gradient from the plant. A few residences are located on the bluff. No large withdrawals of ground water that would divert flow off-site exist near the plant. A surface-water municipal supply drawing from the Missouri River is located upstream of FCS in the nearby town of Blair, Nebraska. This municipal supply system is the source of potable water for FCS. The water supply for the City of Omaha is also drawn from the Missouri River, about 20 miles downstream from FCS.

Process water for FCS is purified in a reverse osmosis (RO) treatment plant. The source of water to the treatment plant is a production well located at the northwest corner of the old warehouse. Testing during construction of the well determined that it is capable of producing approximately 500 gallons per minute (gpm). The production well was in service as of August 2007, continuously pumping about 200 gpm.

The radius of influence of the “RO well” has not been determined quantitatively, but can be assumed to be several hundred feet. Water levels measured during the fall of 2007 in some of the newly constructed monitoring wells within the restricted area indicate a direction of ground water flow toward the RO well. Water levels in September and early October showed the flow direction to be to the southwest (toward the RO well) throughout all of the restricted area. In late October and November the ground water flow direction within approximately 600 feet of the RO well continued to be toward the southwest, but at distances greater than about 600 feet from the well, the direction reversed to flow to the northeast (toward the Missouri River).

Section 2.5 of the Final Safety Analysis Report for FCS notes that 70 to 75 percent of the local annual precipitation falls in showers and thunderstorms that occur during the period April through September. This pattern of rainfall is reflected in ground water levels measured at FCS. Water levels measured in site wells on September 10 and 11, 2007 were approximately three feet higher than those measured in the same wells on November 30, 2007 (Terracon Consultants, 2007).

The observed ground water gradients in the restricted area suggest that during the spring, summer and early fall, when most precipitation occurs and river flow is relatively high, bank storage is recharged by river flow and the direction of ground water flow near the river is away from the channel (toward the southwest on the south side of the river). As river flow recedes during the late fall and winter, bank storage is reduced and ground water near the river reverses to flow toward the river. A reversal of ground water gradients near the river was also documented by SCS Engineers in 1995.

The effect on ground water flow of pumping the RO well is superimposed on the effect of river flow. At distances from the well less than about 600 feet, the RO well continually induces ground water flow toward it. At greater distances from the well within the industrial area of the plant, the effects of low river stage during the late fall and winter predominate to cause a reversal of ground water flow toward the river. The hinge line along which the reversal in ground water flow direction occurs appears to be approximately 600 feet from the RO well. This distance is the presumed radius of influence of the well within the restricted area.

Contaminants that may be released to the ground water at FCS would be transported in the direction of ground water flow. The apparent seasonal reversal of flow directions under the northeastern portion of the restricted area, between the location of approximately monitoring wells MW-2A and 2B and the river, will complicate the transport of contaminants in this area. MW-2A and 2B are also located within the area where plant pre-construction photos show a swale formerly existed. The hydraulic properties of the sediments filling this former drainage feature may contrast significantly with those of the adjacent sediments and may affect ground water flow in the area.

No potential receptors of ground water contamination exist within the restricted area. Contaminants may be captured by the pumping RO well southwest of the restricted area. The well produces approximately 200 gpm from an area of aquifer whose shape is approximately circular. Contaminants in ground water drawn into the well would be diluted with water from some sectors within its zone of influence that are not impacted, and the net concentration of contaminants in the well discharge would likely be lower than the level in the intercepted contaminant plume.

The unconsolidated sediments that underlie the plant can be grouped generally into two units: an upper fine-grained sandy clay with silt approximately 20 to 50 feet thick, and an underlying fine to coarse sand with some gravel. This lower unit extends to the relatively flat-lying carbonate bedrock surface at a depth of approximately 70 to 75 feet below grade. Both unconsolidated units are water bearing, but the deeper unit has higher hydraulic conductivity. The depth to ground water ranges from about 15 to 20 feet below ground surface. Solution cavities have been identified within the upper portion of the carbonate bedrock, but the water-bearing characteristics of this unit have not been investigated at FCS.

Tritium is the most likely plant-related radionuclide to be detected in ground water at FCS because of its relatively high inventory within primary cooling water and its lack of retardation by sorption to soil. Other plant-related radionuclides that are less mobile within the environment, but are also present in primary cooling water and have been detected in ground water at other nuclear power stations of similar design, include Sr-90, Cs-137, Co-60, Fe-55, and Ni-63.

Virtually no tritium has been detected in ground water samples collected in September and November 2007. Strontium-90 was detected in the shallow wells of both the MW-3 and MW-4 monitoring well clusters in November. However, Sr-90 was not detected in these wells during the next sampling round in March 2008. No plant-related radionuclides have been detected in the deeper monitoring wells. The source of Sr-90 in MW-3S and MW-4S in November 2007 is not clear. Continued quarterly sampling of these wells and analysis for Sr-90 may suggest that the November results were false positive or may provide an indication of the source of this radionuclide. The ground water flow gradients and related contaminant flow paths in the area where strontium was detected in November 2007 have been shown to vary seasonally. The seasonal reversal of flow gradients in the area of wells MW-3S and MW-4S may influence the local ground water quality.

Potential sources of ground water contamination at FCS include the spent fuel pool (SFP), the safety injection refueling water tank (SIRWT), unlined concrete sumps (including those in rooms 21, 22 and 23 at the lowest elevation of the primary auxiliary building (PAB)), and the radioactive effluent (radwaste) pipeline from where it exits the turbine building underground to its point of discharge underground in the cooling water discharge tunnel.

Releases of radioactive liquids from any of these potential sources would occur at or near the ground surface. Accordingly, the first water-bearing unit to be impacted would be the fine sandy silt layer. Because pumping of the RO well induces a ground water flow gradient that is opposite to the inferred natural gradient toward the Missouri River and because flow gradients near the river apparently reverse seasonally, the existing array of monitoring wells does not allow sampling the flow paths down-gradient from these potential contaminant sources in all flow conditions. FCS may consider adding a few shallow monitoring wells to the array to eliminate these apparent data gaps.

The vertical ground water flow potential in the area of the SFP, SIRWT, and PAB was determined in October 2007 and was generally downward across most of the restricted area. Because of its location within the floodplain of a large river and proximity to the river bank where ground water typically discharges, the vertical flow potential for ground water in the vicinity of the radwaste pipeline is likely upward much of the time. However, during periods of high river stage this vertical flow potential is likely reversed.

Several hundred gallons of primary water overflowed the SIRWT and were released to the ground during one event in the mid-1980s. Although remediation of surface soil was completed, the clean up was based upon surveys for gamma-emitting radionuclides. A substantial volume of tritium likely impacted the soil and ground water during this event. Some of that tritium may remain suspended by capillary forces in the soil within the vadose zone above the water table in the area of the spill. Seasonal rises in ground water level may remobilize a portion of that suspended tritium and contribute to residual ground water contamination.

The SIRWT is an underground concrete tank with a coated carbon steel liner. Undetected leaks to the adjacent soil may have developed around pipe penetrations and cracks in the concrete walls. Because the concentration of tritium in the water within the tank is on the order of several tens of millions of pCi/L, even very slow leaks could result in a significant impact to ground water.

Leakage between the concrete walls and stainless steel liner of the SFP has been monitored for several years in an installed leak-off collection system. Until February 2005, the rate of leakage was a few quarts per day. From that time until June 2006, the leakage rate increased to a maximum of nearly 300 quarts per day. Since June 2006, the rate has decreased to 3 or 4 quarts per day. Although the water collected in the leak-off collection system has been confirmed to be from the SFP, the cause of this observed condition is not known.

Remote inspection of the SFP liner with a submersible camera did not identify any suspected leaks. Testing of the leak-off system was completed in early 2008 by injecting a measured volume of de-ionized water into four ports located in the liner above the normal water level in the SFP. The injected water was recovered over a 24-hour period and revealed that the leak-off system is comprised of two inter-connected systems. Results of the testing suggest that the SFP leak-off system is intact and capable of identifying and capturing leaks from the SFP.

The mechanisms by which radionuclides might be released to the environment from other potential sources, such as unlined concrete sumps within the PAB or from the radwaste discharge pipeline, are more obvious. The crystalline structure of concrete is approximately 15 percent water, and concrete is known to be semi-permeable to water (and tritium). Cracks in the sump concrete or pipe penetrations within the bottom or walls of the sumps would increase the potential for leakage of radioactive fluids that the sumps accumulate. Stress corrosion cracks in the walls of the stainless steel radwaste pipeline, or failure of welds at joints and fittings, would result in release of concentrated radioactive liquids to the adjacent soil.

IV. Review of Construction Photos

A total of 62 photographs of various phases of plant construction were reviewed to identify features pertinent to ground water conditions at the site. The photos confirm the following:

- Prior to construction of the plant, the site was used for crop cultivation.
- Pre-construction topography was generally flat over the industrial area of the site, with a slight downward gradient to the northeast, toward the Missouri River.
- A photograph dated February 3, 1969 shows virtually continuous ice covering the reach of the Missouri River shown in the photo.
- Soils exposed by construction excavation (to a maximum depth of approximately twenty feet) are fine-grained.
- No cobble or boulder-sized clasts are visible in the exposed sediments.
- Stratification of the exposed sediments appears to be horizontal, indicating the presence of flood-plain alluvial deposits.
- Excavation deeper than approximately fifteen to twenty feet encountered the water table and required dewatering to proceed deeper.
- A dense network of piles was installed to the bedrock surface beneath all Class I structures, including the reactor containment building, primary auxiliary building and cooling water intake structure. Installation of these piles and subsequent treatment of the surrounding soils by vibroflotation increased the density of the soils and likely altered their hydrogeologic characteristics.
- A water-filled swale is visible in the area of the plant on several early construction photographs. The swale is located parallel to and approximately 250 feet southwest (inland) from the current channel of the Missouri River. The swale marks the remains of a former channel of the river which is separated from the current channel by accretionary sediments deposited by the river. The swale on the photos terminates to the east and west of the present industrial area of the plant, but a map by Dames and Moore (Plate 3) in Appendix C of the USAR shows the swale to have been continuous beneath the area now occupied by the reactor containment and primary auxiliary building before plant construction began. The sediments filling this swale may have hydraulic properties that contrast with those of the adjacent sediments. If so, the presence of this feature may affect the periodic reversal of ground water flow gradients measured in this portion of the site and could potentially influence the transport of ground water contaminants released in the area.

V. Review and Evaluation of Reports Containing Pre-Operational Ground Water and Geologic Data

Design Basis Document PLDBD-CS-51: Seismic Criteria

This document contains very little geologic data relevant to ground water. Instead, it is focused on determining seismic criteria such as the history of seismicity of the region surrounding FCS, the magnitude of the largest probable ground movement resulting from

an earthquake and determination of the response acceleration spectra. A study of the possible existence of faults was made during the geologic investigation of the area of the site. No faulting was found in the unconsolidated Pleistocene and recent sediments of the Missouri River low lands, indicating no significant seismic activity since the beginning of the Pleistocene Epoch 2 million years before present.

Design Basis Document PLDBD-CS-54: Geotechnical

This document also contains very little geologic data relevant to ground water. PLDBD-CS-54 primarily discusses requirements for foundation design, which must take into account the physical characteristics of the site, including seismology and geology. The geology is described as "consisting of alluvial deposits 65 to 75 feet thick. Bedrock is mostly limestone and exhibits little relief. A number of solution cavities were found to exist in the upper 15 feet of the bedrock."

"The upper 20 to 50 feet of natural soils are predominantly silty sands and sandy silts. The lower soils consist of sand with interbedded gravel lenses. The relatively loose upper soils were not considered suitable for support of heavily loaded foundations or foundations of settlement-sensitive structures. The denser lower soils and bedrock were considered suitable for support of heavy foundation loads without detrimental settlement." The FCS site conceptual model is consistent with this information.

"The ground water level at the site is typically 10 to 12 feet below ground surface. It is generally near river level and varies with it." These depths to ground water are less than the 15 to 20-foot range that was measured in the fall of 2007. Ground water depths are deeper now presumably because the plant grade was raised by addition of fill during plant construction.

Section 6.1 of PLDBD-CS-54 states that "extensive dewatering can potentially cause consolidation of fine-grained soils like those found at Fort Calhoun Station. This could result in settlement of structures supported on spread footings. This possibility should be examined before significant lowering of the water table beneath any structure". Class I structures such as the reactor containment and primary auxiliary building are founded on piles and would not be subject to potential settlement due to dewatering of soils.

However, the old warehouse is not founded on piles and is likely supported on spread footings. This structure is adjacent to the "RO well", a production well that continuously pumps approximately 200 gallons per minute to the reverse osmosis system providing treated make-up water to the plant. Pumping of the well creates a mass of dewatered soil in the shape of a cone, centered on the well. The RO well registration lists a drawdown of the static water level in the well from 18 to 20 feet, at a pumping rate of 500 gallons per minute. Assuming these data reflect current operating conditions, it seems unlikely that the two feet of induced water-level drawdown would pose a significant risk of soil settlement that would damage the foundation of the nearby old warehouse.

Final Safety Analysis Report, Section 2: Site and Environs

The following sections of the FSAR contain some information pertinent to ground water protection at FCS. Brief descriptions of the relevant content are provided below.

Section 2.2 of the FSAR – General Description of Site and Environs

This section presents an overview of the location, size and land use of the FCS property. The FCS site conceptual model is consistent with the contents of this section.

Section 2.3 of the FSAR – Topography

This section describes the flood plain of the Missouri River in the vicinity of FCS, the bluff at the southwestern extent of the flood plain and the variation of land surface elevations across the site.

Section 2.5 of the FSAR – Meteorology

Description of the meteorology of the site provides some insight into the variability of river flow and ground water levels at FCS. The local climate is characterized by warm summers and cold, dry winters, with marked variation in temperature and rainfall from year to year. Air approaching from the west looses most of its moisture on the windward side of the Rocky Mountains. As a result, no significant amount of rain or snow reaches the state from the Pacific.

The source of moisture for Nebraska is the Gulf of Mexico. The remoteness of this source contributes to the wide variation in rainfall from year to year. The prevailing wind direction from May through December is from the south-southeast. Relatively dry winds from the north-northwest predominate throughout the remainder of the year.

Section 2.6 of the FSAR – Geology

This section describes the regional and local geology, including the geologic history since the early Paleozoic Era and the glacial history of the Missouri valley. During the Pleistocene Epoch, when the interior of the continent was covered by continental glaciers, Nebraska was occupied by only the first two of four major ice sheets. Nebraska and western Iowa were not covered by the later continental glaciers, but during advance and retreat of nearby ice sheets wind-blown deposits of fine sand and silt accumulated to thicknesses of as much as 100 feet. These deposits, known as loess, form the steep-sided hills and bluffs of eastern Nebraska and western Iowa.

Unconsolidated sediments at the site generally range from 65 to 75 feet in thickness. The soils are typically interstratified and cross-bedded. The beds change facies or grade laterally so rapidly that no bed lithologic correlation is possible from boring to boring. The boring data indicate that the upper 20 to 50 feet of soil are predominantly silty sands and the lower beds consist of fine sands with occasional interbedded lenses of gravel. The FCS site conceptual model is consistent with the information in this section.

Section 2.7 of the FSAR – Hydrology

Six dams upstream of FCS control flow in the upper Missouri River. The closest is Gavin Point, approximately 150 miles upstream at the South Dakota – Nebraska border. Because of the large watershed between the Gavin Point Dam and FCS, the dam has relatively little effect on day-to-day river flow at FCS. There are no dams on the river downstream of the plant. The design peak flood stage at the plant is an elevation of 1004.2 feet above mean sea level.

Section 2.7.2 of the FSAR – Ground Water

Movement of ground water under the uplands southwest of FCS is toward and into the Missouri River trench. The FSAR notes that the occurrence of springs along the base of the bluff confirms the movement of ground water away from the hills and toward the river.

Ground water levels measured in borings at the site in July and August 1966 reveal that ground water gradients are nearly flat, with only a gentle slope toward the river. The water table was approximately 10 feet below land surface. Ground water levels were noted to vary with river levels. The rate of ground water flow in the alluvial soils varies with permeability but is very low because of the low hydraulic gradients. The temperature of ground water measured in August 1966 was 54° F, and it was noted that no large seasonal variations in temperature can be expected.

The coefficient of permeability (hydraulic conductivity) was reported to vary from 0.5 to 3 feet per day (1.8 E-4 to 1.1 E-3 centimeters per second) in the upper silty sand. In the lower fine to coarse sand and gravel, the permeability was noted to be as high as 20 ft/day (7.1 E-3 cm/sec). The hydraulic conductivities determined by Terracon Consultants in 2007 are an order of magnitude or more higher than the values noted in the FSAR. These higher values may reflect the vertical and lateral variability in soil texture across the site.

A pumping test was conducted by Dames and Moore in 1966 on a test well at the plant site at a rate of 700 gallons per minute. The maximum drawdown in water level was reported to be 21 feet and the radius of influence was estimated to be 1,300 to 1,800 feet. The soils at the site were noted to be in direct hydraulic connection with the Missouri River. A radius of influence of approximately 600 feet for the RO well pumping at about 200 gpm is consistent with the noted radius of influence of the 1966 test well pumping at 700 gpm.

The FSAR section on ground water concludes by stating that "the hydrologic character of the site and surrounding area and the pattern of ground water flow are such that accidental discharge of radioactive fluids into ground water would have no adverse effect on existing or potential ground water users. Such fluids would percolate slowly in the direction of the Missouri River".

While this statement is valid relative to dose, if significant concentrations of radiological material were to be found in ground water beneath FCS, the finding would damage the credibility of plant management and strain public confidence. The NEI Ground Water Protection Initiative acknowledges this risk and seeks to minimize it by improving the detection, management and communication of incidents of ground water contamination by radiological material at all nuclear power plants.

Section 2.10 of the FSAR – Environmental Radiation Monitoring

The FSAR notes that the average concentration of tritium in 11 well water samples in early 1969, prior to plant operation, was 550 picocuries per liter (pCi/L), and in 6 surface water samples the concentration was 1,000 pCi/L. In those same samples the average concentration of strontium-90 was 0.1 pCi/L in well water and 1.3 pCi/L in surface water.

The higher concentration of Sr-90 in surface water is of interest, in view of the results of ground water sampling in November 2007 which found anomalous levels of Sr-90 in monitoring wells MW-3A and MW-4A. Strontium 90 was not detected in these wells during the subsequent sampling round in March 2008. If surface water from the Missouri River were the source of the elevated levels of Sr-90 detected in ground water from these wells, one should expect that Sr-90 would also be detected in wells close to the river, including MW-5A and MW-6. No Sr-90 was detected in these wells. Additional quarterly sampling and analysis to confirm or refute the presence of Sr-90 in MW-3A and MW-4A is warranted, as discussed below in Section VI.

Final Safety Analysis Report, Appendix B: Site Environmental Studies

Appendix B of the FSAR updates the initial comprehensive site investigation conducted by Dames and Moore in 1967, which included field explorations, laboratory tests, geologic and hydrologic studies, engineering seismology and recommendations for foundation design and installation. Updates to the initial report of site investigations were required because some of the information was superseded due to changes in design criteria and additional information acquired during engineering studies and further site investigations. Appendix B provides a brief description of the principal updates and pertinent references.

- Solution cavities were found in the limestone bedrock. Therefore, a more extensive investigation of the bedrock was performed and a special technique for pile installation was devised.
- The values of the design earthquake and maximum hypothetical earthquake factors were increased to 8 and 17 percent of gravity, respectively, in accordance with recommendations of the U.S. Coast and Geodetic Survey.
- The earthquake response spectra were revised due to the change in earthquake factors.
- Potential liquefaction of the soil was found to require consideration.
- Discussion of the 100-year high water level of the Missouri River of 1008.8 feet at the plant site was clarified and revised.

Updated Safety Analysis Report, Appendix C: Foundation Studies, Dames and Moore

Appendix C of the USAR discusses foundation studies for the Class I structures at the site. Much of the report focuses on investigation of solution cavities identified in the limestone bedrock during initial soil boring work. The FCS site conceptual model is consistent with information pertaining to site geology provided in the USAR, Appendix C.

Updated Safety Analysis Report, Section 2.6: Site and Environs – Geology

This section is identical to Section 2.6 in the FSAR, discussed above.

Updated Safety Analysis Report, Section 2.7: Site and Environs – Hydrology

This section is essentially the same as Section 2.7 in the FSAR, discussed above.

VI. Review and Evaluation of Hydrogeologic Reports for the Characterization of Site Geology and Ground Water Since FCS Became Operational

- ***Hydrogeologic Investigations Report, Fort Calhoun Power Station, Water Treatment Sludge Disposal Area, SCS Engineers, June, 1995***

This investigation was undertaken to close the landfill area containing sludge from the FCS water treatment plant. Three 2-inch diameter monitoring wells were drilled and sampled for the investigation. No analyses for radioactive materials were completed on soil or ground water samples. Background levels of several metals were found in ground water samples from the monitoring wells, but SCS Engineers concluded that ground water at the site was not impacted by disposal of sludge in the landfill.

Ground water flow beneath the site was found to be controlled by the Missouri River. During high river stages the flow was away from the river, and during low river stages the flow was toward the river at calculated velocities of less than 0.08 feet per day.

The local and regional geology described by SCS Engineers is consistent with descriptions in PLDBD-CS-54 and the FSAR. Water level measurements made during the 1995 investigation show that ground water levels at FCS were lowest in March and highest in June. This condition reflects the yearly cycle of precipitation for the region noted in the FSAR.

- ***Hydrogeologic Assessment Report, OPPD Nuclear Power Generating Station, Fort Calhoun, Nebraska, Terracon Consultants, Inc., December 14, 2007***

    - **Ground Water Gradients**

Terracon Consultants, Inc. drilled thirteen monitoring wells in or near the restricted area of FCS in August, 2007. The wells are in locations that were presumed to be within the down-gradient flow path of contaminants that potentially could be released from SSCs containing radioactive fluids. The wells were constructed in accordance with industry best practices. Water table and potentiometric surface contour maps constructed based upon water levels measured in the new wells indicate ground water flow directions different from the directions presumed prior to construction of the wells.

Two conditions at FCS produce ground water flow gradients that are opposite to those originally presumed. Construction of a production well that continuously pumps approximately 200 gallons per minute to the reverse osmosis system providing treated make-up water to the plant was completed in December 2005. Operation of the "RO well" began in 2006. Pumping of the RO well induces drawdown of ground water levels in its vicinity and, in the area between the well and approximately the turbine building, a reversal of the seasonally normal flow gradient toward the Missouri River. The generally southwestern ground water flow direction in this area will likely persist as long as continuous pumping of the RO well is maintained.

The vertical component of the ground water gradient at FCS is slightly downward beneath most of the industrial area of the plant. This condition is also contrary to what might be expected within an alluvial aquifer adjacent to a large river, where ground water

generally flows upward and toward the channel to discharge to the river. The gradients measured by Terracon Consultants to be slightly downward and toward the southwest are induced by pumping of the RO well.

The Missouri River is in hydraulic connection with ground water in the alluvial aquifer within its floodplain. During periods of relatively high river stage, which occur generally from April through September when precipitation is greatest, river water recharges the nearby alluvial aquifer and induces ground water flow gradients outward from the river channel. These gradients reverse seasonally, during periods of lower river stage. These reversals in ground water gradients are documented by Terracon Consultants in the report of their 2007 investigation, and by SCS Engineers in their 1995 investigation report.

The pumping rate from the RO well and the stage of the Missouri River at the plant site should be monitored daily and tracked over time. These data can be compared with ground water levels to further characterize the timing and position of seasonal changes in ground water gradients and flow direction near the river. A more thorough description of these periodic changes will help in understanding the mechanism for transport of contaminants that may be released to the ground water system.

Ground water gradients measured across the industrial area of FCS reveal that with the current array of monitoring wells there are a few unanticipated gaps in the ability to monitor potential releases to ground water in the flow paths down-gradient from some sources of radioactive liquids. Specifically, other than monitoring wells MW-1A and 1B, there are no wells on the down-gradient (southwest) side of the radwaste building, spent fuel pool and safety injection refueling water tank.

While it appears that potential releases from these sources would be captured by pumping of the RO well, dilution may make it difficult to detect those releases in the RO well discharge. Shallow monitoring wells at two locations near the exterior southwest walls of the radwaste building would provide a means to more easily and precisely detect a release from these potential sources. Figure 1 shows the locations of two shallow monitoring wells proposed on the southwest side of the radwaste building for this purpose.

Finally, the legends and notes for Figures 6F and 6H in the Terracon Consultants report should be revised. These figures are contour maps showing the potentiometric surface and ground water gradients based upon water levels measured in deep monitoring wells at FCS on October 31 and November 30, 2007. The legends and notes for these two figures mistakenly identify the elevations plotted on the maps as water table elevations measured in shallow wells. Figures 6F and 6H should be revised to eliminate the inconsistency between what is described in the legends and notes and what is actually portrayed on the maps. In their memo dated May 6, 2008, Terracon concurs with this recommendation and will provide revised figures.

- **Strontium-90**

Analysis of ground water samples collected from fourteen monitoring wells in November, 2007 detected Sr-90 in two shallow wells: MW-3A and MW-4A. No strontium was detected in deep monitoring wells. During the subsequent sampling round in March 2008 Sr-90 was not detected in these or any other monitoring wells. Although the concentrations detected in November 2007 (0.972 and 2.81 pCi/L, respectively) are below the U.S. EPA maximum contaminant level for Sr-90 of 8.0 pCi/L, detection of this plant-related radionuclide suggests that a release to ground water from an SSC containing radioactive liquids may have occurred.

As noted in Section 2.10 of the FSAR, an average concentration of 0.1 pCi/L of Sr-90 was detected in eleven ground water samples at FCS between November 1968 and June 1969, before the plant became operational. During that same period, an average of 1.3 pCi/L of Sr-90 was measured in six surface water samples at the plant site. Because ground water within the alluvial aquifer near the river is recharged by surface water during periods of high river stage, and significantly higher levels of Sr-90 have been measured in surface water relative to ground water at FCS, it seems possible that the source of strontium detected in ground water samples from MW-3A and MW-4A may be the Missouri River.

The source of strontium-90 in the river may be liquid radioactive effluent routinely discharged from FCS. An additional less likely source could be fallout from nuclear weapons testing that has been eroded by streams throughout the drainage basin upstream of the plant. Deposition of fallout effectively ended during the 1970s, when atmospheric testing of weapons was banned internationally. Strontium-90 has undergone more than a half-life of decay since that time.

However, if the source of strontium-90 in MW-3A and MW-4A is the Missouri River, it would be reasonable to presume that strontium would also be detected in other monitoring wells closer to the river. No strontium has been detected in wells MW-5A, MW-5B and MW-6, which are located between MWs 3A and 4A and the river. The source of Sr-90 in these wells is undetermined and is difficult to explain because no Sr-90 was detected in the subsequent sampling round. Strontium 90 should be analyzed for in all ground water samples for several additional sampling rounds to determine if the values reported in November 2007 were false positive analytical results or if they can be reproduced. Determining the source of the strontium is a matter of importance, not only to identify any potentially ongoing leaks in SSCs, but also because resolution of its source (if the analytical results are confirmed) will likely be required at the time of plant decommissioning.

Monitoring Well MW-8
The text of the Terracon Consultants report explains that the soil boring in which monitoring well MW-8 is completed encountered refusal on a concrete slab 17 feet below grade. The geologic log for MW-8 indicates that the total depth of the well is 16.5 feet below grade and the screened zone is completed in lean clay. Tables 1, 3 and 4 of the

report note that MW-8 was dry on September 11, October 31 and November 30, 2007. Hydrogeologic profiles included on Figures 7A and 7B of the Terracon report show that the elevation of the water table in early and late October, 2007 was below the bottom of MW-8.

Table 2 of the report indicates that about one foot of water was measured in MW-8 on October 8, 2007. This water was very likely infiltrated soil moisture that moved from the ground surface downward through the unsaturated zone, became perched on top of the concrete slab and drained laterally very slowly because of the relatively low-permeability lean clay in the formation at that depth. For this reason, the water level measured in MW-8 on October 8 and the small volume of water sampled from the well on that date and on November 1, was not representative of the elevation of the water table or of ground water quality in the shallow aquifer in its vicinity.

Because MW-8 is not deep enough to intersect the water table during most times of the year and because of the mechanism by which perched water can be retained within the well, water levels measured in the well and water samples collected from the well are not representative of conditions in the adjacent shallow aquifer and are misleading. MW-8 should be permanently abandoned by pumping it full of grout. An attempt should be made to drill a replacement shallow monitoring well approximately 25 feet deep adjacent to MW-8.

- **Hydraulic Conductivity Testing**

Interpretation of the slug test data provided in the Terracon Consultants report resulted in values of hydraulic conductivity that appeared to be inconsistent with the work of other investigators (Dames and Moore, 1968; Freeze and Cherry, 1979). In their memo dated May 6, 2008, Terracon Consultants justified their interpretations based upon the fact that the tests were conducted in stratified sediments whose hydraulic properties vary vertically and laterally and that the tests measure those properties within only a small radius surrounding the test well.

VII. Evaluation of Regional Hydrogeological Characteristics in Reports Published by the U.S. Geological Survey and the Nebraska Department of Natural Resources

- ***Geology of the Omaha-Council Bluffs Area, Nebraska-Iowa, USGS Professional Paper 472, Robert D. Miller, 1964***

The FCS plant site is near but not within the study area of this professional paper. The report provides a detailed description of the stratigraphy of the study area and the geologic history of the region. The principal geologic units of the area are the glacial

sediments and alluvium of the Missouri River Valley, deposited during the Pleistocene and Recent Epochs. These units overlie bedrock, which is limestone of Pennsylvanian age in the area of FCS.

This report also discusses the engineering properties of the various sediments deposited in the study area, and gives insight as to why fully penetrating piles founded on the bedrock surface were used for the foundation of Class I structures at FCS. The types and thicknesses of soil found at FCS are not capable of supporting the plant design loads with friction piles. The FCS site conceptual model is consistent with the information provided in this professional paper.

- ***Reconnaissance of Ground Water Quality in the Papio-Missouri River Natural Resources District, Eastern Nebraska, USGS Water-Resources Investigations 94-4197, I.M. Verstraeten and M.J. Ellis, 1995***

This paper reports the results of sampling and analysis of ground water from a total of 62 irrigation, municipal supply, domestic and industrial wells completed in alluvial aquifers and the Dakota sandstone aquifer located in the Elkhorn, Missouri and Platte River Valleys within the study area of the report. The report evaluates the effects of cropland application of fertilizers and herbicides on ground water quality within the study area. Sample results include levels of nitrates, herbicides, metals, major ions and a few radionuclides. Introductory sections provide brief descriptions of the climate, soils, geology and hydrogeology of the region, based upon other reports of state-wide scope. The site conceptual model for FCS is consistent with the information in these sections.

Water from all principal aquifers, except the Dakota aquifer, had detectable levels of herbicides. The report notes that where the hydraulic gradient favors loss of surface water to ground water, the detection of herbicides in water from wells along the banks of the Platte River indicates that the river could act as a line source of herbicides to the local aquifer.

This finding has significant implications for the FCS site. First, it points out that seasonal recharge of ground water by river water (demonstrated by local reversal of ground water flow direction) is observed in the alluvial aquifer of the Platte River Valley. This condition has also been documented in the alluvial aquifer of the Missouri River at the FCS site, and apparently is a common occurrence in alluvial aquifers near the major rivers within the Papio-Missouri River Natural Resources District (NRD).

Second, the finding confirms that contaminants in river water can be transported to nearby ground water in the alluvial aquifers in the NRD. As noted in Section 2.10 of the FSAR, the pre-construction average concentration of strontium-90 in river water at FCS was 1.3 pCi/l and in ground water was 0.1 pCi/L. Therefore, the finding of Verstraeten

and Ellis suggests a mechanism that might explain the detection of anomalous levels of strontium-90 in FCS monitoring wells MW-3A and MW-4A in November, 2007. However, it should be noted that no strontium was detected in other wells near the river (MW-5A, 5B and MW-6) during the same sampling event or in any wells during the subsequent sampling in March 2008. Additional quarterly sampling and analysis for Sr-90 is recommended to further investigate its source in monitoring wells at FCS.

- ***2006 Annual Report of the Missouri Tributaries Basin, LB962, Nebraska Department of Natural Resources***

This report includes text and a series of basin-wide figures showing the distribution of such features as surface water bodies, annual precipitation, till deposits, bedrock geology, saturated thickness of unconsolidated aquifers, transmissivity, specific yield, water table elevation, registered well locations and selected ground water hydrographs. The average annual precipitation at Omaha is listed as 30.3 inches. The hydrogeology of the basin is described as complex due to the glacial origin of the recent sediments.

The report states that transmissivity of the sediments in most areas of the basin have values less than 20,000 gallons per day, per foot of aquifer width. This is a limiting value that most of the sediments in the basin do not exceed. Assuming a saturated thickness of about 60 feet at FCS, this would correspond to an average value of less than 45 feet per day for hydraulic conductivity. Section 2.7.2 of the FSAR states that the hydraulic conductivity of the upper silty sands at FCS ranges from 0.5 to 3 feet per day, and that of the lower fine to coarse sand and gravel is as high as 20 feet per day. Therefore, the two references corroborate one another on this finding and are not contradictory.

This report further states that as of October 1, 2005, there were 3,697 registered water wells in the basin and that irrigation was listed as the largest consumer of ground water, with approximately 1,600 irrigation wells in the basin. A map of high-capacity wells in the Missouri Tributaries Basin shows no wells in the immediate vicinity of FCS.

- ***Nebraska Data Bank Interactive Maps, Nebraska Department of Natural Resources***

The Nebraska DNR maintains a data bank of interactive maps on their website. Various layers of data can be added to a base map of any area of interest in the state. Data layers include: soil type, aerial photos on multiple dates, elevations, water bodies, roads and registered ground water wells.

Aerial photographs clearly show the land use in the vicinity of FCS and its change over time. Wells registered to OPPD and a summary of their registration information can also be accessed on the interactive map of the FCS site.

VIII. Evaluation of the Priority Index for Selected SSCs Containing Radiological Material

The following table summarizes FCS' scoring of the priority factors used to calculate a priority index for SSCs containing radiological material, and suggested revisions for selected priority factors. The revised priority indices range from 15 for the steam generator blowdown system, to 76 for the spent fuel pool leak detection system.

Table 1
Suggested Revisions to Priority Factor Scoring

System	Priority Factor	OLD Score	New Score	Reason for Revised Score
Condensate work practice	History	1	1	
	Condition	0	0	
	Design	2	2	
	Pre-release detection	2	2	
	Inventory	1	**2**	PWR secondary system.
	Hazard	1	1	
	Mobility	3	3	
	Post-release detection	1	1	
	Priority Index	21	**24**	
Radwaste sumps	History	1	1	
	Condition	3	3	
	Design	3	3	
	Pre-release detection	3	3	
	Inventory	3	3	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	69	69	
Fuel transfer canal drain	History	1	1	
	Condition	3	3	
	Design	3	3	
	Pre-release detection	3	3	
	Inventory	3	3	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	69	69	
Steam	History	0	0	

System	Priority Factor	OLD Score	New Score	Reason for Revised Score
generator blowdown	Condition	1	1	
	Design	0	0	
	Pre-release detection	1	**2**	Contained before release to the environment.
	Inventory	1	**2**	PWR secondary system.
	Hazard	1	1	
	Mobility	3	3	
	Post-release detection	1	1	
	Priority Index	8	**15**	
Component cooling water	History	2	2	
	Condition	1	1	
	Design	0	0	
	Pre-release detection	2	2	
	Inventory	1	1	
	Hazard	1	1	
	Mobility	3	3	
	Post-release detection	1	1	
	Priority Index	21	21	
Containment sump piping	History	1	1	
	Condition	3	3	
	Design	2	2	
	Pre-release detection	3	3	
	Inventory	2	2	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	69	69	
Discharge header	History	1	1	
	Condition	3	3	
	Design	2	**3**	Single-walled steel subsurface pipe.
	Pre-release detection	3	3	
	Inventory	2	2	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	56	**63**	
Condensate storage tank	History	0	0	
	Condition	1	1	
	Design	0	**2**	Single-walled steel tank with secondary containment.

System	Priority Factor	OLD Score	New Score	Reason for Revised Score
	Pre-release detection	1	**2**	Contained before release to the environment.
	Inventory	1	**2**	PWR secondary system.
	Hazard	1	1	
	Mobility	3	3	
	Post-release detection	1	1	
	Priority Index	8	**24**	
Raw water piping	History	1	**3**	Known recurring in-leakage.
	Condition	1	1	
	Design	2	2	
	Pre-release detection	3	3	
	Inventory	2	2	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	44	**56**	
Spent fuel pool	History	2	**3**	Known ongoing leak.
	Condition	2	**3**	Unknown condition, probable liner corrosion or failed weld.
	Design	0	0	
	Pre-release detection	2	2	
	Inventory	3	3	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	42	**56**	
SPF leak-off system	History	3	3	
	Condition	2	2	
	Design	2	3	High probability for soil or ground water contamination following initial leak or spill.
	Pre-release detection	3	3	
	Inventory	3	3	
	Hazard	3	3	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	76	84	
Safety injection piping	History	1	1	
	Condition	3	3	
	Design	3	3	
	Pre-release detection	3	3	
	Inventory	3	3	
	Hazard	2	2	

System	Priority Factor	OLD Score	New Score	Reason for Revised Score
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	69	69	
Safety injection refueling water tank	History	2	2	
	Condition	1	1	
	Design	2	2	
	Pre-release detection	3	3	
	Inventory	3	3	
	Hazard	2	2	
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	56	56	
SFP cooling/IX	History	2	2	
	Condition	1	1	
	Design	0	0	
	Pre-release detection	2	2	
	Inventory	3	3	
	Hazard	3	3	
	Mobility	2	**3**	High mobility (H-3).
	Post-release detection	1	1	
	Priority Index	31	35	
Turbine building sump	History	1	1	
	Condition	0	**1**	Good condition, no known leaks.
	Design	1	**3**	Unlined concrete sump.
	Pre-release detection	1	**3**	Undetected until in the environment.
	Inventory	1	1	
	Hazard	1	1	
	Mobility	3	3	
	Post-release detection	1	**2**	First detected at on-site monitoring station.
	Priority Index	13	**39**	
Discharge tunnel piping	History	3	3	
	Condition	3	3	
	Design	2	**3**	Singe-wall steel subsurface pipe.
	Pre-release detection	3	3	
	Inventory	2	2	
	Hazard	2	2	

System	Priority Factor	OLD Score	New Score	Reason for Revised Score
	Mobility	3	3	
	Post-release detection	2	2	
	Priority Index	69	**75**	

IX. Summary of Recommendations

1. Drill an additional two shallow monitoring wells near the southwest exterior wall of the radwaste building, in locations recent testing has shown are down-gradient of the spent fuel pool and safety injection refueling water tank. These SSCs are potential sources of release to the environment of radioactive liquids. Figure 1 shows the locations of the proposed shallow wells.
2. Permanently abandon MW-8 by pumping it full of grout and attempt to drill a deeper replacement well to approximately 25 feet below grade near the location of MW-8.
3. Monitor daily the rate of pumping the RO well and the stage of the Missouri River at the FCS plant site. These data should be tracked over time and compared with ground water levels to further characterize the timing and position of seasonal changes in ground water gradients and flow direction near the river. A more thorough description of these periodic changes will help in understanding the mechanism for transport of contaminants that may be released to the ground water system.
4. Summarize the construction details for all wells at FCS, to provide easy access to this information for on-going use. The details to be summarized should include: total well depth, diameter, screened interval, and elevations of the top of casing and a representative water level.
5. Update the Final Safety Analysis Report for FCS to reflect the hydraulic gradients, hydraulic conductivities, ground water flow velocities and the seasonal reversal of ground water gradients near the river determined by recent testing at the site.
6. Clearly define the process for tracking corrective actions in the FCS GWPP.
7. Provide in the FCS GWPP details regarding which specific wells to monitor, their sampling frequency, analytes, minimum detectable concentrations, data quality objectives and a management scheme for the monitoring data.
8. Incorporate in the FCS GWPP the document “Data Quality Objectives for Well Drilling”.

X. Referenced Reports

A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Bouwer, H. and R.C. Rice, 1976, Water Resources Research, vol. 12, no. 3, pp. 423-428.

2006 Annual Report of the Missouri Tributaries Basin, LB962, Nebraska Department of Natural Resources

Data Quality Objectives for Well Drilling, Fort Calhoun Station

Design Basis Document PLDBD-CS-51, Seismic Criteria, Fort Calhoun Station

Design Basis Document PLDBD-CS-54, Geotechnical, Fort Calhoun Station

EPRI Groundwater Assessment for OPPD Fort Calhoun Site, April, 2007

Final Safety Analysis Report, Section 2, Site and Environs, Fort Calhoun Power Station, December, 1971

Final Safety Analysis Report, Appendix B: Site Environmental Studies, Fort Calhoun Station

Geology of the Omaha-Council Bluffs Area, Nebraska-Iowa, USGS Professional Paper 472, Robert D. Miller, 1964

Groundwater, Freeze, R. Allan, and Cherry, John, A., 1979, Prentice Hall, Inc.

Groundwater Monitoring Well Results for 3rd Quarter 2007, Fort Calhoun Power Station

Groundwater Monitoring Well Results for 4th Quarter 2007, Fort Calhoun Power Station

Groundwater Protection Guidelines for Nuclear Power Plants, Electric Power Research Institute, November, 2007

Groundwater Protection Plan 2006 Through Decommissioning, R3, Omaha Public Power District, Fort Calhoun Station

Hydrogeologic Assessment Report, OPPD Nuclear Power Generating Station, Fort Calhoun, Nebraska, Terracon Consultants, Inc., December 14, 2007

Hydrogeologic Investigations Report, Fort Calhoun Power Station, Water Treatment Sludge Disposal Area, Omaha Public Power District, SCS Engineers, June 29, 1995

Industry Ground Water Protection Initiative – Final Guidance Document, Nuclear Energy Institute, August, 2007

Nebraska Data Bank Interactive Maps, Nebraska Department of Natural Resources

Reconnaissance of Ground Water Quality in the Papio-Missouri River Natural Resources District, Eastern Nebraska, USGS Water-Resources Investigations 94-4197, I.M. Verstraeten and M.J. Ellis, 1995

SO-G-118, Standing Order: Site Groundwater Protection Program, Fort Calhoun Station, Unit No. 1.

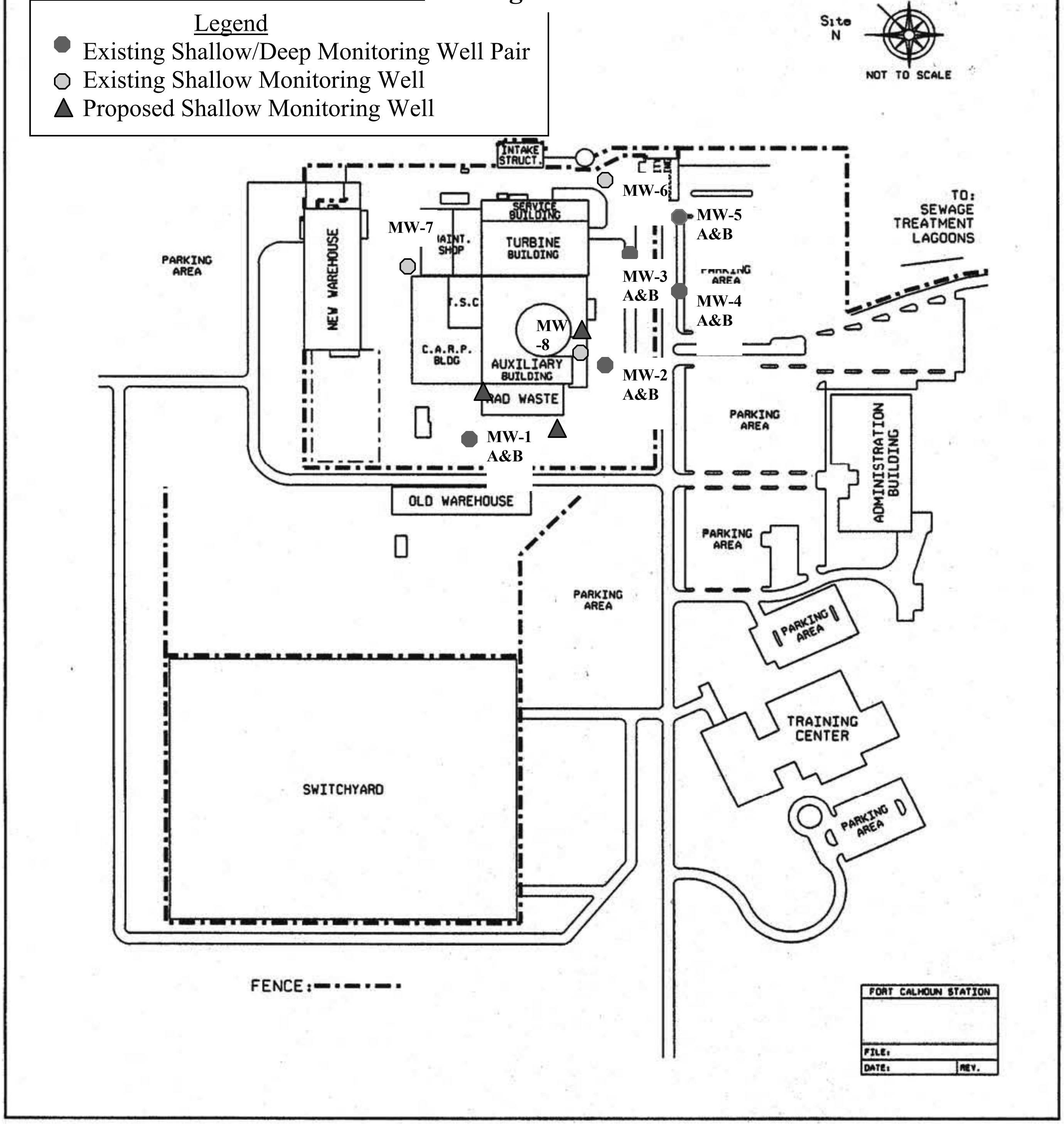
Terracon Memo, May 6, 2008: Radiation Safety & Control Services Response to Terracon's Hydrogeologic Assessment Report, Dated December 14, 2007.

Updated Safety Analysis Report, Appendix C, Foundation Studies, Fort Calhoun Station, Dames and Moore, January 30, 1968

Updated Safety Analysis Report, Section 2.6: Site and Environs – Geology

Updated Safety Analysis Report, Section 2.7: Site and Environs – Hydrology

Figure 1


Legend
Existing Shallow/Deep Monitoring Well Pair
Existing Shallow Monitoring Well
Proposed Shallow Monitoring Well
True N
Site N
NOT TO SCALE
INTAKE STRUCT.
MW-6
MW-5 A&B
MW-7
SERVICE BUILDING
TURBINE BUILDING
MAINT. SHOP
T.S.C
C.A.R.P. BLDG
MW-8
AUXILIARY BUILDING
RAD WASTE
MW-3 A&B
MW-4 A&B
MW-2 A&B
MW-1 A&B
NEW WAREHOUSE
PARKING AREA
TO: SEWAGE TREATMENT LAGOONS
ADMINISTRATION BUILDING
OLD WAREHOUSE
TRAINING CENTER
SWITCHYARD
FENCE:
FORT CALHOUN STATION
FILE:
DATE:
REV.