5.15 Raw Water Piping

5.15.1 Summary of Raw Water Piping

Baseline information for the Raw Water Piping is provided in Section 2.0, Site History, Description, and Baseline Condition.

The Raw Water Piping is a once-through cooling water system that removes heat from the component cooling water system. The Raw Water Piping also provides direct cooling water through the component cooling water piping to selected safety-related components in the event that the component cooling water system is unavailable.

The Raw Water Piping serves as a conduit for discharging water to the river from various sources.

The system is composed of four motor-driven pumps, two strainers and motor sets, valves, piping, instrumentation, and controls.

Two 20-in. raw water pipes are routed between the Intake Structure and the southeast corner of the Auxiliary Building. Alignments of the given pipes are shown on the drawings noted in Table 5.15-1.

Raw water pipes are carbon steel pipe (Attachment 18, OPPD SDBD-AC-RW-101).

The first raw water line is routed out the north side of the Intake Structure to a point where it clears the Discharge Tunnel and other Intake Structure utility lines before it bends 90° and runs about 88.8 ft toward the Service Building. It then makes another 90° bend and is routed to the south, parallel to the Service Building. The alignment in front of the Service Building is routed to avoid Fuel Oil Tank 10 and the Underground Cable Bank. After crossing the Underground Cable Bank north of MH-5, the raw water line is routed west between the Turbine Building and the Turbine Building South Switchyard. After clearing the limits of the Turbine Building, it is routed to the south side of the Auxiliary Building at the southeast corner.

The second 20-in. raw water line exits the south side of the Intake Structure adjacent to and east of other connecting utilities. The raw water line and adjacent utilities are concrete-encased together and routed to the south. Once the utilities clear the Discharge Tunnel (see 11405-M-312 and 314), they make a 45° bend to the southwest and follow a path that passes the southeast corner of MH-5. Once beyond the limits of MH-5, the encased utility lines are routed to the west, and the raw water line continues along an alignment to the southwest. When the raw water line reaches a point south of the Turbine Building South Switchyard, it makes a 45° bend and is routed to the west, parallel to the south face of the Service Building, and outside of the limits of Turbine Building South Switchyard. At a point 18.5 ft west of the location of where the first raw water line enters the Auxiliary Building, it makes a 90° bend to the north and extends to the Auxiliary Building and penetrates into the building at el. 996 ft.

5.15.2 Inputs/References Supporting the Analysis

Table 5.15-1 lists references provided by OPPD and other documents used to support HDR's analysis.

Table 5.15-1 - References for Raw Water Piping

Document Title	OPPD Document Number (if applicable)	Date	Drawing No./ Page Number(s)
Yard Piping Sheet 1	11405-M-312 (#10752)	2/8/2010	
Yard Piping	11405-M-313 (#10753)	7/21/2005	
Yard Piping Sheet 3	11405-M-314 (#10754)	8/3/1973	
Yard Piping	11405-M-315 (#10755)	12/18/2008	
Design Basis Document	SDBD-AC-RW-101	11-10-06	
Naval Facilities Engineering Command, Design Manual 7.01, Soil Mechanics		9/1986	All

Detailed site observations—field reports, field notes, and inspection checklists—for the Raw Water Piping are provided in Attachment 8.

Observed performance and pertinent background data are as follows:

- As early as 1993, excessive flow into a sump in the Turbine Building basement was observed. Subsequently, this flow was attributed to unfiltered groundwater entering breaks in drainage pipes under the Turbine Building basement floor slab.
- In 1997 a void, estimated to be approximately 10 x 8 x 1 ft, was documented below the basement floor slab in the Turbine Building. For further information see Section 5.8. A more detailed discussion of this KDI is presented in Section 4.1.
- Settlement of a column in the Maintenance Shop, north of the Turbine Building, has been documented. The Turbine Building and the Maintenance Shop are west of the corridor and associated utility alignments within the corridor.
- The Aqua Dam that surrounded much of the PA crossed the alignment of the Raw Water Piping.
- The Aqua Dam failed for a short period of time because it was damaged, which allowed floodwater to enter the area inside the perimeter of the Aqua Dam. Surfaces above the Raw Water Piping were inundated with water when the Aqua Dam failed.
- Areas outside the perimeter of the replacement Aqua Dam were inundated for an extended period.
- Concrete areas in the corridor (paved drive and pedestrian areas between the river and the Service Building) have exhibited distress including cracking, slab settlement, and undermining. However, most of the pavement cracking and the other conditions could be pre-existing conditions due the age and use of the facility.
- There is a hole in the pavement and void area beneath the concrete slab north of the Security Building and east-southeast of MH-5. The hole and void area are outside the perimeter of the Aqua Dam that surrounded much of the PA. The pavement failure occurred at the intersection point of pavement jointing. The hole in the pavement is irregular-shaped and is more than 1 ft wide both in

the north–south and east–west directions. The void area beneath the hole was approximated as a 4-ft-diameter-by-0.8-ft-deep void as measured by a tape measure through the hole. The void could be attributed to subsurface erosion.

- The hole in the pavement is near the observed discharge point of a pump operated prior to the removal of the Aqua Dam. The void could be attributed to scour created by the discharge of the pipe operating for an extended period in one place.
- Fire Protection Cabinet FP-3C north of the Security Building and east-southeast of MH-5 is located in proximity to the pavement failure and void area. The fire hydrant was tested September 13, 2011 (reportedly), and failed. According to OPPD operations personnel testing FP-3E during site inspections, the base of FP-3C cracked when the valve was opened. The fire hydrant was shut down, and the access cabinet was tagged out. The cause of failure was unknown at the time field observations were made.
- Pavement slab settling was observed northwest of the Intake Structure and east of the abandoned acid tank.
- A hollow-sounding pavement area was noticed east of the Service Building truck dock.
- The fire hydrant located in FP-3E was being tested on September 13, 2011, during site investigations. No operational problems were observed during the time on site.
- OPPD operations personnel testing the fire hydrant at FP-3E on September 13, 2011, were questioned about other fire hydrant tests. The OPPD employee questioned noted that no problems were observed for the fire hydrant at FP-3D during testing. The information on the problem at FP-3C, noted previously, was gathered at this time.

5.15.3 Assessment Methods and Procedures

5.15.3.1 Assessment Procedures Accomplished

Assessments were made by walking the Raw Water Piping system alignment and observing the ground surface overlying the underground piping system. The surface assessment included using a fiberglass T-probe to hand probe the ground surface along the utility alignments and adjacent areas to determine relative soil strength. The assessment focused on identifying conditions indicative of potential flood-related impacts on or damage to the utility as follows:

- Ground surface conditions overlying and immediately adjacent to the utility and its backfilled trench including scour, subsidence or settlement, lateral spreading, piping, and heave
- Soft ground surface areas (native soil, engineered fill, and/or limestone gravel pavement) as determined by probing
- Water accumulations and flows in subsurface system components (manholes and concrete cable encasement pipes)
- Damage to at-grade or above-grade system features and equipment
- Variance from normal installation conditions including settled, tilted, or heaved system features and equipment
- Operation of the system and appurtenant equipment (i.e., is the system operational?)

Additional investigations were performed to further characterize the subsurface at the facility including areas where conditions indicative of potential flood-related impacts or damage were observed. These included the following non-invasive geophysical and invasive geotechnical investigations.

- GPR. (Test reports were not available at the time of Revision 0.)
- Seismic surveys (seismic refraction and refraction micro-tremor). (Test reports were not available at the time of Revision 0.)
- Geotechnical investigations including test borings with field tests (SPT and CPT) and laboratory tests. Note that OPPD required vacuum excavation for the first 10 ft of proposed test holes to avoid utility conflicts. Therefore, test reports will not show soil conditions in the upper 10 ft of test boring logs. (Test reports were not available at the time of Revision 0.)

5.15.3.2 Assessment Procedures Not Completed

Assessments of the Raw Water Piping that were not completed include the following:

- No excavation to inspect underground systems and conditions was performed.
- No video inspection of the system was completed.
- Inclinometer readings along the river that will provide an indication of slope movement.

5.15.4 Analysis

Identified PFMs were initially reviewed as discussed in Section 3.0. The initial review considered the preliminary information available from OPPD data files and from initial walk-down observations. Eleven PFMs associated with five different Triggering Mechanisms were determined to be "non-credible" for all Priority 1 Structures, as discussed in Section 3.6. The remaining PFMs were carried forward as "credible." After the design review for each structure, the structure observations, and the results of available geotechnical, geophysical, and available survey data were analyzed, a number of CPFMs were ruled out as discussed in Section 5.15.4.1. The CPFMs carried forward for detailed assessment are discussed in Section 5.15.4.2.

5.15.4.1 Potential Failure Modes Ruled Out Prior to the Completion of the Detailed Assessment

The ruled-out CPFMs reside in the Not Significant/High Confidence category and for clarity will not be shown in the Potential for Failure/Confidence matrix.

Triggering Mechanism 2 – Surface Erosion
CPFM 2a – Undermining shallow foundation/slab/surfaces
CPFM 2c – Undermined buried utilities

<u>Reason for ruling out:</u>

- No surface erosion was observed along the surface overlying the raw water alignment. In addition, only localized and limited surface erosion was observed on the ground surface across the facility. The raw water system is constructed below frost depth, and sufficiently below potential scour depths indicated by erosion features observed in other areas.

Triggering Mechanism 7 – Soil Collapse (first time wetting)

CPFM 7a – Cracked slab, differential settlement of shallow foundation, loss of structural support
CPFM 7b – Displaced structure/broken connections
CPFM 7c – General site settlement

Reasons for ruling out:

- Soil supporting and surrounding the raw water lines has been previously wetted. The peak flood elevation prior to 2011 was 1003.3 ft, which occurred in 1993. Ground elevations above the raw water alignments are in the range of 1003 to 1004 ft. The raw water lines were installed as part of the original plant construction in the early 1970s. With the exception of possible trench backfill above repair areas, the trench backfill above the raw water lines has been saturated or wetted over the course of almost 40 years.
- The climate of the region includes times of snow accumulation during the winter and seasonal wet periods (springtime rain events), which can be significant and extended over a period of days. Site soils are subjected to saturation during snow melt periods and during extended rainstorm events. Most trenches with loose backfill exhibit signs of subsidence within 1 or 2 years. After an almost 40-year period, trench backfill over the raw water lines has been wetted and saturated numerous times.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10a – Cracked slab, differential settlement of shallow foundation, loss of structural support
CPFM 10b – Displaced structure/broken connections

Reasons for ruling out:

- Machine vibrations from the facility (turbines in the Turbine Building, pumps in the Intake Structure, or other pieces of equipment) have historically occurred, and no indications of these CPFMs are evident.
- Pumps used on site during the 2011 flood did not cause ground or structure vibrations sufficient to initiate soil liquefaction. Visible indications of liquefaction were not observed around the areas where the pumps were operating, and no occurrences of liquefaction were reported to HDR.
- No structure movements indicative of soil liquefaction and resultant settlement were observed. No structure cracking or lateral movements were observed.

Triggering Mechanism 11 – Loss of Soil Strength due to Static Liquefaction or Upward Seepage

CPFM 11a – Cracked slab, differential settlement of shallow foundation, loss of structural support
CPFM 11b – Displaced structure/broken connections

Reasons for ruling out:

- The structures did not have evident signs of distress identified during the field assessments.
- Liquefaction was not observed at the site.

Triggering Mechanism 12 – Rapid Drawdown
CPFM 12a – River bank slope failure and undermining surrounding structures
CPFM 12b – Lateral spreading

Reasons for ruling out:

- The structures did not have evident signs of distress identified during the field assessments.
- Slope failure was not observed at the site.
- River stage level had dropped and stabilized as of October 4, 2011.
- As of October 11, 2011, groundwater elevations had had one week to stabilize to at least a partial degree.
- The river bank is armored and has historically protected and stabilized the existing river bank.

Triggering Mechanism 13 – Submergence
CPFM 13a – Corrosion of underground utilities
CPFM 13b – Corrosion of structural elements

Reasons for ruling out:

- There are no flood-induced changes to the nature of the buried raw water pipe system.
- The raw water piping system is below the design flood elevation for the facility. Groundwater elevations controlled by Missouri River water elevations, percolation of storm precipitation, and winter snow melt would be expected to contact the piping system and appurtenant improvements. Such buried elements are normally designed and installed to withstand the environment of groundwater and wetted soil.
- Structural elements associated with the raw water pipe system are assumed to include the construction of thrust blocks at pipe bends in the system. Thrust blocks are normally installed in conjunction with water piping where groundwater and wetted soil is expected. Degradation of the thrust blocks is not expected.
- The raw water system is installed in an area of structural backfill, and corrosion due to corrosive soil conditions is not expected.

Triggering Mechanism 14 – Frost Effects
CPFM 14a – Heaving, crushing, or displacement

Reasons for ruling out:

- The Raw Water Piping is installed below the depth of frost penetration.
- Conditions have not changed due to flood conditions.

5.15.4.2 Detailed Assessment of Credible Potential Failure Modes

The following CPFMs are the only CPFMs carried forward for detailed assessment for the Raw Water Piping system as a result of the 2011 flood. This detailed assessment is provided below.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3a – Undermining and settlement of shallow foundation/slab/surfaces (due to pumping)

CPFM 3c – Undermined buried utilities (due to pumping)

This Triggering Mechanism and CPFM could occur as follows: multiple potentially connected seepage paths existed in the soil backfill at the site, including soil backfill in utility trenches, granular trench bedding, building floor drains with open/broken joints, and pre-existing defects/voids under pavement. The paths are exposed at some locations to the river floodwater (e.g., a surficial void north of the Security Building). This network of seepage paths is connected to several pumping sources: the sump pit in the Turbine Building, Manhole MH-5, and a series of surface pumps inside the perimeter of the Aqua Dam. The pumps were operated for an extended period, maintaining a head differential on the seepage path networks. Gradient was sufficient to begin erosion of surrounding soil. Seepage is unfiltered and erosion continues unarrested. Erosion extends out, intercepting the network of utility trenches, including the Raw Water Piping System. Voids are created under the pavement and along the utility trench walls or pipes. The potential damage includes settlement of pipe or thrust blocks. Settlement can overstress a pipe that is corroded, can cause a pipe to break, or can cause the displacement of a thrust block, which, in turn, could cause failure of a pipe operating under pressure.

Below are field observations and data that support the likelihood of this CPFM:

- The raw water piping alignments crossed the Aqua Dam that surrounded much of the PA.
- MH-5, located inside the perimeter of the Aqua Dam that surrounded much of the PA, was pumped for the duration of flooding. This created a head differential. Raw water lines are routed in close proximity to MH-5 and also underground cable banks connected to MH-5.
- The flow of water into MH-5 was observed on multiple field visits. Sources of the water could not be determined.
- The area inside the perimeter of the Aqua Dam was pumped dry, which created a conditional hydrostatic head between the areas inside and outside the perimeter of the Aqua Dam. The area inside the perimeter of the Aqua Dam was pumped from several locations, creating points toward which underground piping and subsurface flows would tend to flow.
- Void areas and potential piping location were observed beneath the concrete slab just north of the Security Building (east-southeast of MH-5) and directly west of the Security Building.
- Based on a conversation with the OPPD operations employee testing FP-3E on September 13, 2011, fire hydrant FP-3C, located northeast of the Security Building, was tested that day and failed. According to the OPPD operations employee, when opening the valve to test the hydrant, the base cracked and leaked, and the valve had to be closed. The access cabinet was tagged out for repair at that time.
- Fire hydrant FP-3D has also been marked with an impairment tag according to October 7, 2011, field observations. The tag states that there was extensive leakage when the isolation valve was opened.
- Concrete areas in the corridor (paved drive and pedestrian areas between the east fence line and the Service Building) have exhibited pavement distress including cracking, slab settlement, and undermining (as evidenced by hollow-sounding pavement areas).
- The Turbine Building sump pit was pumped continually during the 2011 flood. The five pipes connected to this sump pit are floor drain and condensate system flush drain pipes.

Since this is a floor drain system, no infiltration of ground water should occur in the system. The infiltration of groundwater into the system indicates an open flow path of some sort. A record of this drainage issue dates back to 1993.

- An area of apparent pavement settlement, located in the driveway corridor west-northwest of the Intake Structure overhead door, is near the northern raw water alignment.

Below are field observations and data that indicate these CPFMs are unlikely:

- Sediment accumulations and small fish were observed at the bottom of Manhole MH-5 at the time MH-5 was being emptied (on September 14, 2011) and might not be associated with this CPFM. The manhole was uncovered when the Aqua Dam failed and the area was flooded. Sediment and fish could have entered the manhole with floodwater as a result of the Aqua Dam failure. Thus, MH-5 might not be an operational termination point of subsoil piping.
- Alternatively, the observed hole in the pavement north of the Security Building could have been developed by outflow from the surface pumps and is not associated with this CPFM. Temporary surface pumps were pumping water back into the river with hoses placed over the Aqua Dam. One of the discharge points was near the observed hole (see Attachment 5, General Field Reports, FR 118). Concentrated discharge flow might have eroded pavement and created the observed hole.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with these CPFMs for the Raw Water system.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Electrical MH-5 was pumped continually during the flood event and created a point source for underground water to flow toward.	
Pavement distress was noted at multiple locations in the corridor between the Intake Structure and the Service Building. The fire line is located in the same narrow corridor.	
Electrical MH-5 was pumped continually during the flood. Fire protection lines cross the electrical duct banks that connect to the manhole.	
The Turbine Building sump pit has a history of groundwater inflows. Flood conditions increased the hydraulic head of water flowing to the sump.	
Fire Hydrants FP-3C and FP-3D have both failed during testing of the fire protection system subsequent to the subsidence of floodwater from the site. The fire hydrants noted are located to the north and south of the Intake Structure.	

Data Gaps:

- The extent of the subsurface erosion is not well known at this time.
- Geophysical investigation reports to evaluate data related to the raw water system.
- Seismic Survey (refraction/tomography and ReMi).

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

The field observations indicate that the trigger to these CPFMs might have initiated in close proximity to the Raw Water lines. Multiple indications of subsurface distress are located along the corridor between the Service Building and the Intake Structure. Pavement slab settlement, undermining (as evidenced by a hollow-sounding pavement area), and a hole in the pavement with visible undermining were observed in the field. Floodwater inundation and impacts are likely causes for the distress and failures observed in the field.

Fire hydrants to the north and south of the Intake Structure have failed during testing performed subsequent to the subsidence of floodwater from the site. The raw water supply lines connect to the north and south sides of the Intake Structure and are located in proximity to the two fire hydrants.

The raw water line also runs in close proximity to the Service Building and into the Auxiliary Building. Subsurface erosion due to the Turbine Building sump could impact the system. Refer to the discussion of KDI #1 in Section 4.1 for additional information.

With indications of distress throughout the area, the potential for degradation exists.

Implication

The occurrence of these CPFMs on a large scale could cause void areas that would induce pipe settlement, loss of pipe restraint, or failure of the pipe system. Therefore, the implication of the potential degradation for these CPFMs is high.

Confidence

There are multiple elements to these CPFMs, including the inflow of water into MH-5 during the 2011 flood, the hole in the pavement north of the Security Building, the settled pavement section in the corridor, fire hydrant failures, and groundwater drainage to the Turbine Building sump. However, even though the confidence is high that there are multiple distress indicators, the extent and possible impact of these CPFMs on the raw water system is not fully understood.

The data at hand are not sufficient to rule out these CPFMs or to lead to a conclusion that subsurface erosion has undermined the Raw Water Piping system. Additional geophysical data are needed to help determine the possible occurrence of these CPFMs and whether they could impact the Raw Water Piping system.

Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFMs 3a and 3c, as discussed above, the potential for degradation is high because distress indicators exist in close proximity to the system. This degradation in the region could have caused erosion that impacts the integrity or intended function of the structure. The combined consideration of the potential for degradation and the implications of that degradation to the system puts it in the "significant" category. The data currently collected are not sufficient to rule out these CPFMs. Therefore, the confidence in the above assessment is low, which means more data or continued monitoring and inspections might be necessary to draw a conclusion.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3d – Undermining and settlement of shallow foundation/slab (due to river drawdown)

CPFM 3f – Undermined buried utilities (due to river drawdown)

These CPFMs are similar to CPFMs 3b and 3c, but instead of pumping, the gradient is created by rapidly dropping river level.

The Triggering Mechanism and CPFM could then occur as follows: river level drops faster than pore water pressure in the soil can dissipate. A gradient is created that moves soil into existing defects and enlarges voids under or along the utility trench walls or utility pipes. Dependent on the extent of the voids created, impacts might include the following: trench subsidence, unsupported pipe sections, pipe deflections, pipe failure, and even possible impacts on adjacent improvements or utilities.

Below are field observations and data that support the likelihood of these CPFMs:

- The Raw Water Piping is located close to the Missouri River bank.

Below are field observations and data or site conditions that indicate these CPFMs are unlikely:

- The Raw Water Piping system is offset from the river bank. This offset from the river bank reduces the likelihood that rapid drawdown and related bank failure will impact the system.
- Soils in the area of the Raw Water Piping system and to the east are backfill materials that were placed and compacted during construction of site improvements and therefore would be expected to be less susceptible to rapid drawdown impacts. (Structural fill materials are expected to be homogenous and of a structural nature. Compacted in place, they should form a homogenous soil mass with no expected weak planes or layers conducive to the formation of drainage paths through the soil.)
- Indications of this type of CPFM were not observed during the most recent site inspection on October 4 and October 7, 2011.
- The river bank is armored and protected.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with these CPFMs for the Raw Water Piping system.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Floodwater was at a high level for an extended period, which allowed surrounding soils to become saturated.	USACE reduced Missouri River Mainstem System releases to 40,000 cfs on October 2, 2011. River levels corresponding to the 40,000 cfs release rate stabilized at FCS on October 4, 2011.
	The river bank is armored and has been protected in previous floods.
Data Gaps: • Observations of the river bank following drawdown to normal river elevations • Geophysical investigation data to address observed concerns	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

The potential for degradation exists because river levels are still adequate for these CPFMs to occur. However, USACE reduced Missouri River Mainstem System releases to 40,000 cfs on October 2, 2011. River levels corresponding to the 40,000 cfs release rate stabilized at FCS on October 4, 2011. Groundwater levels have thus started to stabilize between the termination of drawdown and the time of Revision 0. The potential for development of subsurface erosion due to river drawdown decreases with time due to stabilization between groundwater elevations and river elevations. The potential for degradation will decrease with time.

Implication

The occurrence of these CPFMs would likely only affect the utility installations near the river. Most of the Raw Water Piping system is located away from the zone of influence of these CPFMs with the exception of the supply lines that connect to the Intake Structure. Thus, the two most important supply components of the system are at the point of greatest risk from these CPFMs.

As groundwater elevations and river elevations stabilize, the potential head differential between them will decrease, and the possibility of subsurface erosion will also decrease. In addition, the stabilized river embankment reduces the likelihood of these CPFMs.

The implication of the CPFMs affecting the Raw Water Piping system is considered low.

Confidence

The data at hand are not sufficient to rule out these CPFMs or to lead to a conclusion that subsurface erosion has undermined the Raw Water Piping system. Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFMs 3d and 3f, as discussed above, the potential for degradation is considered low. The combined consideration of the potential for degradation and the implications of that degradation to the structure puts it in the "not significant" category. The data currently collected are not sufficient to rule out these CPFMs. Therefore, the confidence in the above assessment is low, which means more data or continued monitoring and inspections are necessary to make a final assessment.

5.15.5 Results and Conclusions

The CPFMs evaluated for the Raw Water Piping are presented in the following matrix, which shows the rating for the estimated significance and the level of confidence in the evaluation.

	Low Confidence (Insufficient Data)	High Confidence (Sufficient Data)
Potential for Failure **Significant**	CPFM 3a CPFM 3c	
Potential for Failure **Not Significant**	CPFM 3d CPFM 3f	

5.15.6 Recommended Actions

The following actions are recommended for the Raw Water Piping:

- Further forensic investigations and physical modifications are recommended to address CPFMs 3a, 3c, 3d, and 3f for the Raw Water Piping. CPFMs 3a and 3c are associated with unfiltered flow of groundwater into the Turbine Building basement drain piping system (KDI #1). These recommendations are described in detail in Section 4.1. CPFMs 3a, 3c, 3d, and 3f are associated with the distress in and near the Paved Access Area between the Service Building and the Intake Structure (KDI #2). These recommendations are described in detail in Section 4.2.
- Monitoring of groundwater well data and a review of the geophysical data when available should be done. The results of these reviews will be used to increase the confidence in the assessment results. At the time of Revision 0, groundwater levels had not yet stabilized to nominal normal levels. Therefore, it is possible that new distress indicators could still develop. If new distress indicators are observed before December 31, 2011, appropriate HDR personnel should be notified

immediately to determine whether an immediate inspection or assessment should be conducted. Observation of new distress indicators might result in a modification of the recommendations for this structure.

- Continued monitoring is recommended to include a continuation of the elevation surveys of the previously identified targets on this utility and surrounding site. The purpose is to monitor for signs of structure distress and movement or changes in soil conditions around the structure. The results of this monitoring will be used to increase the confidence in the assessment results. Elevation surveys should be performed weekly for 4 weeks and biweekly until December 31, 2011. At the time of Revision 0, groundwater levels had not yet stabilized to nominal normal levels. Therefore, it is possible that new distress indicators could still develop. If new distress indicators are observed before December 31, 2011, appropriate HDR personnel should be notified immediately to determine whether an immediate inspection or assessment should be conducted. Observation of new distress indicators might result in a modification of the recommendations for this structure.
- Review geophysical and geotechnical reports to evaluate the data as they pertain to the Raw Water System.
- Make additional river bank inspections to evaluate whether signs of CPFMs 3a, 3c, 3d, or 3f exist.
- Install inclinometers to monitor the river bank.
- Perform a detailed analysis of the pavement subgrade and trench alignments if the pavement in the corridor between the Intake Structure and the Service Building is replaced.

5.15.7 Updates Since Revision 0

Revision 0 of this Assessment Report was submitted to OPPD on October 14, 2011. Revision 0 presented the results of preliminary assessments for each Priority 1 Structure. These assessments were incomplete in Revision 0 because the forensic investigation and/or monitoring for most of the Priority 1 Structures was not completed by the submittal date. This revision of this Assessment Report includes the results of additional forensic investigation and monitoring to date for this structure as described below.

5.15.7.1 Additional Data Available

The following additional data were available for the Raw Water Piping System for Revisions 1 and 2 of this Assessment Report:

- Results of KDI #1 forensic investigation (see Section 4.1)
- Results of KDI #2 forensic investigation (see Section 4.2)
- Additional groundwater monitoring well and river stage level data from OPPD.
- Field observations of the river bank (see Section 5.25).
- Results of FWD investigation by AET (see Attachment 6B).
- Results of geophysical investigation by Geotechnology (see Attachment 6C).
- Results of geotechnical investigation by Thiele Geotech (see Attachment 6A).
- Data obtained from inclinometers by Thiele Geotech (see Attachment 6A).
- Results of continued survey by LRA (see Attachment 6E).

5.15.7.2 Additional Analysis

The following analysis of additional data was conducted for the Raw Water Piping System:

- Groundwater monitoring well and river stage level data from OPPD

  Data show that the river and groundwater have returned to nominal normal levels.

- Field observations of river bank

  No significance distress from the 2011 flood was observed.

- Results of FWD investigation by AET.

  FWD and associated GPR testing performed in the Paved Access Area identified anomalies such as soft clay and broken pavement. Additional ground truthing of the investigation results was performed as part of the KDI #2 additional investigations.

- Results of geophysical investigation by Geotechnology.

  Seismic refraction and seismic ReMi tests performed around the outside perimeter of the power block as part of KDI #2 identified deep anomalies that could be gravel, soft clay, loose sand, or possibly voids.

- Results of geotechnical investigation by Thiele Geotech.

  Six test borings were drilled, with continuous sampling of the soil encountered, to ground truth the Geotechnology seismic investigation results as part of the KDI #2 forensic investigation. Test bore holes were located to penetrate the deep anomalies identified in the seismic investigation. The test boring data did not show any piping voids or very soft/very loose conditions that might be indicative of subsurface erosion/piping or related material loss or movement.

  Results of SPT and CPT tests conducted for this Assessment Report were compared to similar data from numerous other geotechnical investigations that have been conducted on the FCS site in previous years. This comparison did not identify substantial changes to the soil strength and stiffness over that time period. SPT and CPT test results were not performed in the top 10 ft to protect existing utilities.

  Data from inclinometers to date, compared to the original baseline measurements, have not exceeded the accuracy range of the inclinometers. Therefore, deformation at the monitored locations since the installation of the instrumentation has not occurred.

- Results of continued survey by LRA.

  Survey data to date, compared to the original baseline surveys, have not exceeded the accuracy range of the surveying equipment. Therefore, deformation at the monitored locations since the survey baseline was shot has not occurred.

Updates to assessment procedures not completed are outlined in Section 5.15.3.2. Excavation to inspect underground systems is included with the KDI #2 investigation. Video inspection of the system was not completed and is not planned due to the expected low value of data produced with respect to addressing these CPFMs.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3a – Undermining and settlement of shallow foundation/slab/surfaces (due to pumping)

CPFM 3c – Undermined buried utilities (due to pumping)

CPFMs 3a and 3c for the Raw Water Piping System are associated with KDI #1. Sections 4.1 and 8.3 presents the results of additional forensic investigation that was conducted to ascertain whether these CPFMs could be ruled out. The results of the additional forensic investigation show that, assuming the implementation of the physical modifications recommended for KDI #1, these CPFMs are ruled out. Therefore, these CPFMs are moved to the quadrant of the matrix representing "No Further Action Recommended Related to the 2011 Flood."

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3d – Undermining and settlement of shallow foundation/slab (due to river drawdown)

CPFM 3f – Undermined buried utilities (due to river drawdown)

CPFMs 3d and 3f for the Raw Water Piping System are associated with KDI #2. Section 4.2 presents the results of additional forensic investigation that was conducted to ascertain whether these CPFMs could be ruled out. The results of the additional forensic investigation show that these CPFMs are ruled out. Therefore, these CPFMs are moved to the quadrant of the matrix representing "No Further Action Recommended Related to the 2011 Flood."

5.15.7.3 Revised Results and Recommendations

The CPFMs evaluated for the Raw Water Piping System are presented in the following matrix, which shows the rating for the estimated significance and the level of confidence in the evaluation.

	Low Confidence (Insufficient Data)	High Confidence (Sufficient Data)
Potential for Failure **Significant**		
Potential for Failure **Not Significant**		CPFM 3a CPFM 3c CPFM 3d CPFM 3f

5.15.7.4 Conclusions

In the assessment of the FCS Structures, the first step was to develop a list of all Triggering Mechanisms and PFMs that could have occurred due to the prolonged inundation of the FCS site during the 2011 Missouri River flood and could have negatively impacted these structures. The next step was to use data from various investigations, including systematic observation of the structures over time, either to eliminate the Triggering Mechanisms and PFMs from the list or to recommend further investigation and/or physical modifications to remove them from the list for any particular structure. Because all CPFMs for the Raw Water Piping System other than CPFMs 3a, 3c, 3d, and 3f had been ruled out prior to Revision 1, because CPFMs 3d and 3f were ruled out using the results of the KDI #2 investigation presented in Section 4.2, and because CPFMs 3a and 3c will be ruled out when the physical modifications recommended for KDI # 1 in Section 4.1 and 8.3 are implemented, no Triggering Mechanisms and their associated PFMs will remain credible for the Raw Water Piping System. HDR has concluded that the geotechnical and structural impacts of the 2011 Missouri River flood will be mitigated by the implementation of the physical modifications recommended in this Assessment Report. Therefore, after the implementation of the recommended physical modifications, the potential for failure of this structure due to the flood will not be significant.