5.11 Condensate Storage Tank

5.11.1 Summary of Condensate Storage Tank

Baseline information for the Condensate Storage Tank is provided in Section 2.0, Site History, Description, and Baseline Condition.

The 150,000-gallon welded steel plate Condensate Storage Tank is located at the riverbank east of the power block and south of the Intake Structure. The tank shell is about 30 ft tall and 30 ft in diameter.

The tank foundation is a 2-ft-minimum-thickness concrete mat supported on 13 10BP42 steel piles driven to bedrock at approximate el. 934 ft. The top-of-concrete elevation is 1005.5 ft. This concrete slab is approximately 41 ft in diameter, resulting in a walkway around the tank. This slab is cast within a steel sheet pile system that is driven into the riverbank to approximately el. 944.8 ft, which is approximately 10 ft above bedrock.

5.11.2 Inputs/References Supporting the Analysis

Table 5.11-1 lists references provided by OPPD and other documents used to support HDR's analysis.

Table 5.11-1 - References for Condensate Storage Tank

Document Title	OPPD Document Number (if applicable)	Date	Page Number(s)
30ft Dia By 30ft High Vertical Field Erected Tank	80087, Rev.1 (#002391)	Unknown	
Tank Foundations	11405-S-418, Rev. 11 (#16588)	Unknown	
Foundation Details – Transformer T1	11405-S-412 (#16583)	1/29/1975	
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 Condensate Storage Tank are provided in Attachment 8.

Observed performance and pertinent background data are as follows:

- The Condensate Storage Tank is a welded steel storage tank designed to the American Water Works Association (AWWA) D100-65 (see 80087, revision 1, file 002391).
- The tank is a flat-bottom storage tank without anchor bolts.
- Construction of the foundation involved a cylindrical sheet pile wall driven through the riverbank. The inside of the sheet pile wall was backfilled to the bottom of the slab elevation. Steel piles were then driven within the contained sheet piles and capped with a structural cast-in-place slab (see tank foundation drawing 11405-S-418).
- The adjacent bank is such that the eastern half of the sheet pile wall is exposed to the river from the bottom-of-concrete slab el. 1003.5 ft to bank grade of approximately 994.4 ft, with the normal river water elevation of 992 ft (see tank foundation drawing 11405-S-418).

- The exposed side of the sheet pile wall was painted with rust-inhibiting paint and constructed with five 3-in.-diameter weep holes at approximately 7 ft on center. These weeps are located at approximate el. 997.5 ft.
- The steel piles are 10BP42 driven to bedrock and capped with a welded steel plate and anchor rods providing positive shear and tension connection to the base slab. This pile size and anchor details are the same as those shown for the transformer foundations in the Turbine Building South Switchyard.
- The driving criteria, tip elevation, and capacities of the 10BP42 piles are unknown. However, the top of the piles are capped with a plate and anchor rods for a positive shear and tension connection (see 11405-S-412).
- The Condensate Storage Tank was not protected by an Aqua Dam and was therefore unprotected from the hydrostatic flood load and hydrodynamic forces from the river flow.
- In accordance with tank levels provided by OPPD, the Condensate Storage Tank was maintained at a minimum of 72 percent full for the duration of the flood event.
- At the time of inspection, the river level had dropped below the surrounding grade. Observations were made around the western half of the Condensate Storage Tank. Access was not available through the security gate onto the walkway on the river side. Observations of the sheet pile wall and the surrounding riverbank were not feasible due to the river level.
- There was a thick layer of river sediment along the concrete foundation and surrounding grade.
- The Trenwa was covered with river sediment with indications that sediment had seeped into the trench via gaps in the removable covers.
- Small localized areas of erosion and scour were observed at the security fence on the north and south sides of the Condensate Storage Tank. No erosion or scour was observed at the tank structure.
- The tank shell, nozzle necks, and flanges below the flood elevation showed signs of surface corrosion through holidays in the coating system. No pitting or significant loss of plate thickness was observed. The bottom plates could not be adequately seen because of the deposit of river sediment.
- The tank shell appears to bulge outward with a point of inflection at about the painted horizontal stripe and another point of inflection just below the rim angle. The magnitude of this deviation from the cylindrical shape cannot be determined from visual observations, and therefore, it is not known if it meets normal AWWA D100 tolerances for tank construction. It is unknown whether this shell deformation is a result of the initial construction or whether it was directly or indirectly caused by the 2011 flood.
- Because of the river level at the time of the field assessment, it was not possible to get a good view of the east (river) side of the east (river) side of the tank. Observations from just north of the Security Building indicate that the out-of-tolerance shape might be limited to all sides of the Condensate Storage Tank except the east side.
- Survey data points were set on the north, south, and west quadrants of the tank. Assessment of current survey data for these points indicates no vertical movement.

5.11.3 Assessment Methods and Procedures

5.11.3.1 Assessment Procedures Accomplished

Assessments of the Condensate Storage Tank included the following:

- Visual inspection of the exterior of the structure, where accessible.
- An assessment of collected survey data to date for indications of trends in the movement of the structure.
- A review of previously referenced documents listed in Table 5.11-1.
- A relative surface soil density test via probing was attempted. However, because of the crushed rock surface below the sediment, it was not possible to push the fiberglass T-probe into the subgrade.

Additional investigations were performed. These included the following non-invasive geophysical and invasive geotechnical investigations:

- Seismic surveys (seismic refraction and refraction micro-tremor) in the PA. (Test reports were not available at the time of Revision 0.)
- GPR in the PA. (Test reports were not available at the time of Revision 0.)
- Geotechnical test borings in the PA. 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.)

5.11.3.2 Assessment Procedures Not Completed

Assessments of the Condensate Storage Tank that were not completed include the following:

- Inspection of the river side of the Condensate Storage Tank was not accomplished due to current river levels. Once the river level drops, the remainder of the structure will need to be inspected.
- Inspection of the riverbank on the north and south sides of the Condensate Storage Tank was not accomplished due to current river levels. Once the river level drops, the remainder of the structure will need to be inspected.
- Inspection of the tank and foundation interface was not accomplished due to the large amount of river sediment deposited adjacent to the tank. Once the sediment is removed, the foundation interface will be inspected.
- Inclinometer readings along the river that will provide an indication of slope movement. Inclinometers have not been installed; therefore, readings were not available at the time of Revision 0.

5.11.4 Analysis

Identified PFMs were initially reviewed as discussed in Section 3.0. The 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 survey data were analyzed, a number of

CPFMs were ruled out as discussed in Section 5.11.4.1. The CPFMs carried forward for detailed assessment are discussed in Section 5.11.4.2.

5.11.4.1 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 2c – Undermined buried utilities

Reasons for ruling out:

- Observed surface erosion in the Condensate Storage Tank area was limited to a few localized areas along the security fence south of the structure. In addition, only localized and limited surface erosion was observed on the ground surface across the facility.

Triggering Mechanism 3 – Subsurface Erosion/Piping
CPFM 3b – Loss of lateral support for pile foundation (due to pumping)

Reason for ruling out:

- The nearby Turbine Building has a documented history of a void below the foundation slab with a potential for increased erosion with greater external water head. For further information see Section 5.8. A more detailed discussion of this KDI is presented in Section 4.1. There is a potential for this previously documented condition to erode larger voids under the Turbine Building and out into the surrounding structures. However, the piles for the Condensate Storage Tank are protected by a sheet pile wall to within approximately 10 ft above bedrock and are therefore not subjected to loss of pile support due to pumping.

Triggering Mechanism 4 – Hydrostatic Lateral Loading (water loading on structures)
CPFM 4a – Overturning
CPFM 4b – Sliding
CPFM 4c – Wall failure in flexure
CPFM 4d – Wall failure in shear
CPFM 4e – Excess deflection

Reasons for ruling out:

- At the 2011 peak flood elevation of approximately 1006.9 ft, the Condensate Storage Tank shell had a maximum of 1.5 ft of external water head on the tank shell.
- Overturning and sliding stability conditions are not credible because the external water force is balanced around the circumference of the tank.
- There were no field observations or indications of tank shell deformations due to flexure or shear.
- OPPD records indicate that the Condensate Storage Tank was maintained at a minimum of 72 percent full during the 2011 flood.

Triggering Mechanism 5 – Hydrodynamic Loading

CPFM 5a – Overturning
CPFM 5b – Sliding
CPFM 5c – Wall failure in flexure
CPFM 5d – Wall failure in shear
CPFM 5e – Damage by debris
CPFM 5f – Excess deflection

Reasons for ruling out:

- At the 2011 peak flood elevation of approximately 1006.9 ft, the Condensate Storage Tank shell had a maximum of 1.5 ft of external water head on the tank shell.
- OPPD records indicate that the tank was maintained at a minimum of 72 percent full during the 2011 flood.
- Overturning and sliding stability conditions are not credible because there was a sufficient internal liquid head resisting structure movement that was much larger than the external hydrodynamic load.
- There were no field observations or indications of tank shell deformations due to flexure or shear.
- There were no field observations of debris around the tank shell, and there was no observed damage to the tank shell and nozzles due to flexure or shear.

Triggering Mechanism 6 – Buoyancy, Uplift Forces on Structures

CPFM 6a – Fail tension piles
CPFM 6b – Cracked slab, loss of structural support
CPFM 6c – Displaced structure/broken connections

Reasons for ruling out:

- At the 2011 peak flood elevation of approximately 1006.9 ft, the Condensate Storage Tank shell had a maximum of 1.5 ft of external water head on the tank shell.
- OPPD records indicate that the Condensate Storage Tank was maintained at a minimum of 72 percent full during the flood event.
- Because of the internal water head, there was no condition where the piling was subjected to net uplift.
- There were no field observations that would indicate uplift on the tank structure.
- There were no field observations of broken structural connections.

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
CPFM 7d – Piles buckling from down drag

Reasons for ruling out:

- The peak flood elevation prior to 2011 was 1003.3 ft, which occurred in 1993. The ground surface outside the tank is about el. 1005 ft. Therefore, the soils had been previously saturated.
- The Condensate Storage Tank structure has a pile-supported foundation, and therefore, loss of structural support for shallow foundations is not credible.
- No broken structural connections or structural displacement was observed.
- No site settlement around the Condensate Storage Tank was observed.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10a – Cracked slab, differential settlement of shallow foundation, loss of structural support

Reasons for ruling out:

- No permanent equipment in the Condensate Storage Tank has the capacity to produce significant dynamic forces due to vibration.
- Liquefaction was not observed.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10b – Displaced structure/broken connections

Reasons for ruling out:

- No permanent equipment in the Condensate Storage Tank area has the capacity to produce significant dynamic forces due to vibration.
- No broken structural connections or structural displacement was observed.
- Liquefaction was not observed.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10d – Pile/pile group instability

Reasons for ruling out:

- No permanent equipment within the Condensate Storage Tank area has the capacity to produce significant dynamic forces due to vibration.
- Liquefaction was not 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
CPFM 11c – Additional lateral force on below-grade walls
CPFM 11d – Pile/pile group instability

Reasons for ruling out:

- Liquefaction was not observed at the Condensate Storage Tank.
- Visual observations and survey measurements indicate no structure movement. Therefore, differential settlement and loss of support (CPFM 11a) did not occur at the surveyed structures.
- No broken structural connections or structural displacement were observed.

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 has dropped and stabilized as of October 4, 2011.
- As of October 11, 2011, groundwater elevations had already had one week to stabilize.
- 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

Reason for ruling out:

- The Condensate Storage Tank and the surrounding utilities have not been subjected to corrosive circumstances that would be considered beyond the normal conditions.

Triggering Mechanism 14 – Frost Effects

CPFM 14a – Heaving, crushing, or displacement

Reason for ruling out:

- The Condensate Storage Tank is on a deep pile foundation system that is not frost susceptible.

5.11.4.2 Detailed Assessment of Credible Potential Failure Modes

The following CPFMs are the only CPFMs carried forward for detailed assessment for the Condensate Storage Tank as a result of the 2011 flood. This detailed assessment is provided below.

Triggering Mechanism 2 – Surface Erosion

CPFM 2b – Loss of lateral support for pile foundation

Observable signs of surface erosion were limited to very small localized areas at the security fence. No large-scale surface erosion was observed around the Condensate Storage Tank or the tank foundation. However, at the time of the inspection, the site was covered with a thick layer of river sediment; therefore, an adequate assessment could not be completed to determine whether areas had experienced erosion. Hand probing of the surrounding soil at the top of the riverbank was not possible due to the presence of a layer of crushed rock at the surface.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Condensate Storage Tank.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
	Observed surface erosion in the Condensate Storage Tank area was limited to a few localized areas along the security fence south of the structure. In addition, only localized and limited surface erosion was observed on the ground surface across the facility.
	The area on the top of the riverbank is covered with revetment to prevent erosion.
Data Gaps: • Observations of the east (river) side of the Condensate Storage Tank foundation including the sheet pile will be performed once the river has receded. • Observation of the ground surface around the tank will be performed once the deposited sediment is removed.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

The Condensate Storage Tank foundation is protected by a sheet pile skirt wall extending from the bottom of the tank to about 10 ft above the bedrock. The skirt wall would protect the tank pile foundations from surface erosion. The surface erosion around the skirt wall was not deep enough to affect skirt wall. Therefore, the potential for degradation is low.

Implication

The occurrence of this CPFM would negatively impact the capacity of the piling supporting the Condensate Storage Tank. This could lead to excessive foundation movement and negatively impact the integrity or intended function of the Condensate Storage Tank. Therefore, the implication of the potential degradation for this CPFM is high.

Confidence

Indicators for this CPFM have not been observed; however, inspection of the east side of the tank and the ground surface around the tank was not possible. Survey data to date have indicated no trends in structure movement. The available data are not sufficient to rule out this CPFM or lead to a conclusion that surface erosion has occurred under the Condensate Storage Tank. Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFM 2b, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. The data currently collected are not sufficient to rule out this CPFM due to the 2011 flood. 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 3c – Undermined buried utilities (due to pumping)

Buried utilities in the area of the Condensate Storage Tank include a 10-in. Auxiliary Feed Water from the Condensate Storage Tank, the Trenwa, the Raw Water Piping, and the ductbank west of the Raw Water Piping with various utilities.

The Triggering Mechanism and CPFM could occur as follows: utility lines can act as possible seepage paths. These seepage paths could connect to several pumping sources such as the Turbine Building (see KDI #1 in Section 4.1), Manhole MH-5, and a number of pumps that were used inside the perimeter of the Aqua Dam that surrounded the PA. The pumps were operated for an extended period (the pump in the Turbine Building sump will continue to operate until the breaks in the drain pipes are sealed), maintaining a head differential on the seepage path networks. Some gradients created by the head differential may have been sufficient to begin erosion of surrounding soil. If seepage is unfiltered and erosion continues unarrested, erosion will extends out intercepting the network of utility trenches, including the 10-in. Auxiliary Feed Water from the Condensate Storage Tank. The potential damage includes settlement of pipe or thrust blocks. Settlement could overstress a pipe that is corroded, could cause a pipe to break, or could cause the displacement of a thrust block, which in turn could cause failure of a pipe operating under pressure.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Condensate Storage Tank.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
A documented void exists under the foundation slab of the Turbine Building with a known hydraulic connection between groundwater elevation and flows into the building sump. A more detailed discussion of this KDI is presented in Section 4.1.	There have been no observed indications of site settlement in the area directly surrounding the Condensate Storage Tank.
MH-5, inside the perimeter of the Aqua Dam, was pumped continually.	
Pumping inside the perimeter of the Aqua Dam.	
Data Gaps: • Observation of the ground surface around the tank will be performed once the deposited sediment is removed. • Additional data will be acquired from GPR, seismic survey, and geotechnical test borings in the Paved Access Area.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

The CPFM has not been observed at the structure. However, voids created due to groundwater pumping at MH-5 might not have been evident at the time of the field assessments. Additionally, the extent of voids due to pumping of groundwater in the Turbine Building sump has not been determined. Indicators for this CPFM have been observed within the paved area between the Service Building and the Condensate Storage Tank. Observations indicate the potential that degradation has occurred due to this CPFM is high. The potential for further degradation will remain until the leaking drain pipes in the Turbine Building are sealed.

Implication

The occurrence of this CPFM on a large scale could cause pipe settlement, thrust block movement, and negatively impact the functionality of the Condensate Water Tank Auxiliary Feed Water. The implication of the potential degradation for this CPFM is judged to be low.

Confidence

Indicators for this CPFM have not been observed; however, inspection of the east side of the tank and the ground surface around the tank was not possible and geotechnical and geophysical information from the Paved Access Area was not complete. Survey data to date have indicated no trends in structure movement. The available data are not sufficient to rule out this CPFM, or lead to a conclusion that subsurface erosion will negatively impact the Condensate Storage Tank Auxiliary Feed Water. Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFM 3c, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. There is Low Confidence that there has been significant degradation to soil beneath the Condensate Storage Tank Auxiliary Feed Water due to the 2011 flood.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3e – Loss of lateral support for pile foundation (due to river drawdown)

The sheet pile wall enclosing the pile foundation has weep holes on the east face to allow water to drain from the inside of the wall back to the river when the river elevation is below el. 997 ft 6 in. As the river level drops, there will be a hydrostatic head pushing water out of the weep holes, which has the potential to erode the soils surrounding the piles from within the wall, if not properly filtered at the weep holes.

The Triggering Mechanism and CPFM could then occur as follows: river water elevation rises to a level that saturates the soil surrounding the piles within the sheet pile wall. As the river level drops below the weep holes, there is a differential head that drains the sheet pile wall. As the water drains, there is a potential for the soil to erode, creating voids around the piling system. If the erosion were to continue, the voids could get large enough to create a loss of lateral support for the piling.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Condensate Storage Tank.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Open weep holes in the sheet pile wall have the potential to allow free movement of soil.	Survey data collected to date indicate no movement of the structure.
	The intent of the weep holes is to drain the sheet pile walls and if designed and constructed properly they should not degrade the soil fill within the sheet pile wall.
Data Gaps: • Observations of the east (river) side of the Condensate Storage Tank foundation including the sheet pile will be performed once the river has receded. • Observation of the ground surface around the tank will be performed once the deposited sediment is removed. • Observations of the weep holes is not considered necessary based on the current collected data.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

The structure has undergone wetting cycles previously. It is reasonable to assume that the foundation system and weep hole drainage system were designed to account for flooding over the top of the weep holes. Therefore, the potential that the 2011 flood caused further degradation for this CPFM is low.

Implication

The occurrence of this CPFM is not expected to negatively impact the capacity of the piling supporting the Condensate Storage Tank, since the distance from the weep holes to the bottom of the tank floor is about 5 ft. A 5 ft void at the top of the piles is not expected to cause the piles to buckle. Therefore, the implication of the potential degradation for this CPFM is low.

Confidence

Indicators for this CPFM have not been observed; however, inspection of the east side of the tank, the ground surface around the tank, and sheet pile wall weep holes was not possible. Survey data to date have indicated no trends in structure movement. The available data are not sufficient to rule out this CPFM or lead to a conclusion that subsurface erosion has occurred under the Condensate Storage Tank support slab. Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFM 3e, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. The data currently collected are not sufficient to rule out this CPFM due to the 2011 flood. 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 3f – Undermined buried utilities (due to river drawdown)

This CPFM is similar to CPFM 3c described above, but the gradient is created by rapidly receding river level instead of pumping.

The Triggering Mechanism and CPFM could then occur as follows: if the river level drops faster than pore water pressure in the foundation soil can dissipate, a gradient could be created that erodes the soil. Depending on the extent of the voids created, impacts could include the following: trench subsidence, unsupported pipe sections, pipe deflections, pipe failure, and possible impacts on adjacent improvements or utilities.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Condensate Storage Tank.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Condensate Storage Tank and utilities are located on the riverbank.	No signs of distress have been observed.
	The river stage level has dropped and stabilized at a level corresponding to the nominal normal river level at 40,000 cfs as of October 4, 2011.
Data Gaps: • Observations of the east (river) side of the Condensate Storage Tank foundation including the sheet pile will be performed once the river has receded. • Observation of the ground surface around the tank will be performed once the deposited sediment is removed. • Additional data will be acquired from GPR, seismic survey, and geotechnical test borings in the Paved Access Area.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

The potential degradation from this CPFM may not have occurred yet, since groundwater levels have likely not dropped to a nominal normal level.

None of the indicators for the CPFM has been observed at the structures. However, voids due to rapid drawdown might not have been evident at the time of the field assessments. Additionally, the extent of voids created by rapid drawdown could be small. The potential that degradation has occurred due to this CPFM is low.

Implication

The occurrence of this CPFM could negatively impact the operation of the structure. This could lead to pipe or thrust block settlement and could negatively impact the integrity or intended functionality of the Condensate Storage Tank piping system. The implication of the potential degradation for this CPFM is considered high.

Confidence

Indicators for this CPFM have not been observed; however, inspection of the east side of the tank and the ground surface around the tank was not possible and geotechnical and geophysical information from the Paved Access Area was not complete. Survey data to date have indicated no trends in structure movement. The available data are not sufficient to rule out this CPFM or lead to a conclusion that subsurface erosion will negatively impact the Condensate Storage Tank piping system. Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFM 3f, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. There is Low Confidence that there will be significant degradation to soil beneath the Condensate Storage Tank piping system due to the 2011 flood.

5.11.5 Results and Conclusions

The CPFMs evaluated for the Condensate Storage Tank 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 2b CPFM 3c CPFM 3e CPFM 3f	

5.11.6 Recommended Actions

The following actions are recommended for the Condensate Storage Tank:

- In-depth tank survey including a shell distortion map with results and recommendations.
- Visual inspection of the east side of the tank and the ground surface around the tank
- Further forensic investigations and physical modifications are recommended to address CPFM 3a (KDI #1). These recommendations are described in detail in Section 4.1.3.

While inspection of the weep holes in the sheet pile wall would be beneficial, it is not deemed necessary at this time.

Continued monitoring is recommended to include a continuation of the elevation surveys of the previously identified targets on this structure and surrounding site. In addition, a review of the ongoing geophysical investigations and monitoring of inclinometer readings is recommended. 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 if an immediate inspection or assessment should be conducted. Observation of new distress indicators might result in a modification of the recommendations for this structure.

5.11.7 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.

5.11.7.1 Additional Data Available

The following additional data were available for the Condensate Storage Tank 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).
- Field assessments of the tank and foundation interface.

Note: OPPD requested information from HDR on firms that specialize in in-depth tank surveys to assist them in a follow-up investigation for possible shell distortion of the tank. HDR has provided this information to OPPD.

5.11.7.2 Additional Analysis

The following analysis of additional data was conducted for the Condensate Storage Tank:

- Groundwater monitoring well and river stage level data from OPPD.

  Data shows 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 were 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.

  All of the SPT and CPT test results 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.

Triggering Mechanism 2 – Surface Erosion
CPFM 2b – Loss of lateral support for pile foundation

Field observations of the Condensate Storage Tank, after OPPD removed the deposited sediment, identified that the surrounding grades were predominately surfaced in gravel. Observations of the grades did not determine that surface erosion had occurred. Observations of the sheet pile skirt wall identified the visible portions of the wall to be in good condition.

Significance

Potential for Degradation/Direct Floodwater Impact

The Condensate Storage Tank foundation is protected by a sheet pile skirt wall extending from the bottom of the tank to about 10 ft above the bedrock. The skirt wall protected the foundations from surface erosion. Therefore, the potential that the 2011 flood caused further degradation for this CPFM is low.

Implication

The occurrence of this CPFM would negatively impact the capacity of the piling supporting the Condensate Storage Tank. This could lead to excessive foundation movement and negatively impact the integrity or intended function of the Condensate Storage Tank. Therefore, the implication of the potential degradation for this CPFM is high.

Confidence

The extent of surface erosion and its potential impact on the tank was not known at the time of Revision 0 due to the river sediment that had been deposited around the tank restricting access and visibility. Subsequent field inspections and a review of surveyed data indicate no structure movement. Since the structure has been monitored and no signs of movement have been detected, the confidence in the assessment of degradation for this CPFM has increased. If further structure monitoring reveals no further issues, the confidence of the assessment for this CPFM becomes high.

Summary

For CPFM 2b, as discussed above, the potential for degradation is low because the tank foundations are protected by a sheet pile skirt wall. It is unlikely this degradation would have occurred to cause impact on the integrity or intended function of the structure. The combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. The data collected since Revision 0 are sufficient to rule out this CPFM assuming the previously recommended monitoring schedule is continued. Therefore, the confidence in the above assessment is high, which means no additional data and inspections are necessary to draw a conclusion.

Triggering Mechanism 3 – Subsurface Erosion/Piping
CPFM 3e – Loss of lateral support for pile foundation (due to river drawdown)

Field observations of the Condensate Storage Tank after OPPD removed the deposited sediment did not identify distress to the tank foundation. Observations of the sheet pile skirt wall identified the visible portions of the wall to be in good condition.

Significance

Potential for Degradation/Direct Floodwater Impact

The structure has undergone wetting cycles previously. It is reasonable to assume that the foundation system and weep hole drainage system were designed to account for flooding over

the top of the weep holes. Therefore, the potential that the 2011 flood caused further degradation for this CPFM is low.

Implication

The occurrence of this CPFM would negatively impact the capacity of the piling supporting the Condensate Storage Tank. This could lead to excessive foundation movement and negatively impact the integrity or intended function of the Condensate Storage Tank. Therefore, the implication of the potential degradation for this CPFM is high.

Confidence

The extent of subsurface erosion and its potential impact on the tank was not known at the time of Revision 0 due to the river sediment that had been deposited around the tank restricting access and visibility and not having inspected the weep holes. The groundwater elevation measured in the monitoring wells closely followed the river level as the floodwater receded and the differential head created by the river drawdown was insufficient to facilitate subsurface erosion. Subsequent field inspections and a review of surveyed data indicate no structure movement; and an observation of the weep holes was not deemed necessary. Since the structure has been monitored and no signs of movement have been detected, the confidence in the assessment of degradation for this CPFM has increased. If further structure monitoring reveals no further issues, the confidence of the assessment for this CPFM becomes high.

Summary

For CPFM 3e, as discussed above, the potential for degradation is low because it is reasonable to assume that the foundation system and weep hole drainage system were designed to account for flooding over the top of the weep holes. It is unlikely this degradation would have occurred to cause impact to the integrity or intended function of the structure. The combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. The data collected since Revision 0 are sufficient to rule out this CPFM assuming the previously recommended monitoring schedule is continued. Therefore, the confidence in the above assessment is high, which means no additional data and inspections are necessary to draw a conclusion.

Triggering Mechanism 3 – Subsurface Erosion/Piping
CPFM 3f – Undermined buried utilities (due to river drawdown)

Significance

Potential for Degradation/Direct Floodwater Impact

The groundwater elevation measured in the monitoring wells closely followed the river level as the floodwater receded. The data indicate that groundwater elevation was about 2 ft above the river level near the beginning of October 2011 and dropped to the river level by about October 14, 2011. Therefore the differential head created by the river drawdown was insufficient to facilitate subsurface erosion. The potential that degradation has occurred due to this CPFM is low.

Implication

The occurrence of this CPFM could negatively impact the operation of the structure. This could lead to pipe or thrust block settlement and could negatively impact the integrity or intended functionality of the Condensate Storage Tank piping system. The implication of the potential degradation for this CPFM is considered high.

Confidence

The extent of subsurface erosion and its potential impact on the piping system was not known at the time of Revision 0 due to the river sediment that had been deposited around the tank restricting access and visibility. Subsequent field inspections and a review of surveyed data indicate no structure movement. Since the structure has been monitored and no signs of movement have been detected, the confidence in the assessment of degradation for this CPFM has increased. If further structure monitoring reveals no further issues, the confidence of the assessment for this CPFM becomes high.

Summary

For CPFM 3f, as discussed above, the potential for degradation is low because the differential head created by the river drawdown was insufficient to facilitate subsurface erosion. It is unlikely this degradation would have occurred to cause impact on the integrity or intended function of the structure. The combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "not significant" category. The data collected since Revision 0 are sufficient to rule out this CPFM assuming the previously recommended monitoring schedule is continued. Therefore, the confidence in the above assessment is high, which means no additional data and inspections are necessary to draw a conclusion.

5.11.7.3 Revised Results

The CPFMs evaluated for the Condensate Storage Tank are presented in the following matrix, which shows the rating for the significance and the level of confidence in the evaluation. CPFMs 2b, 3e, and 3f for the Condensate Storage Tank are not associated with KDIs. 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." CPFM 3c for the Condensate Storage Tank is associated with KDIs #1 and #2. Sections 4.1, 4.2, and 8.3 present the results of additional forensic investigation that was conducted to ascertain whether the CPFM could be ruled out. The results of the additional forensic investigations show that if the recommendations for physical modifications in KDI #1 are implemented that this CPFM is ruled out. Therefore, assuming that the physical modifications recommended for KDI #1 are implemented, the CPFM is moved to the quadrant of the matrix representing "No Further Action Recommended Related to the 2011 Flood.

	Low Confidence (Insufficient Data)	High Confidence (Sufficient Data)
Potential for Failure **Significant**		
Potential for Failure **Not Significant**		CPFM 2b CPFM 3c CPFM 3e CPFM 3f

5.11.7.4 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 Condensate Storage Tank other than CPFMs 2b, 3c, 3e, and 3f had been ruled out prior to Revision 1, because CPFMs 2b, 3e, and 3f have been ruled out as a result of the Revision 1 findings, and because CPFM 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 Condensate Storage Tank. 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.