EXHIBIT NO. ___(RJR-14)
DOCKETS UE-17____/UG-17____
2017 PSE GENERAL RATE CASE
WITNESS: RONALD J. ROBERTS

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION,

Complainant,

v.

PUGET SOUND ENERGY,

Respondent.

Docket UE-17____
Docket UG-17____

THIRTEENTH EXHIBIT (NONCONFIDENTIAL) TO THE PREFILED DIRECT TESTIMONY OF

RONALD J. ROBERTS

ON BEHALF OF PUGET SOUND ENERGY

JANUARY 13, 2017

WorleyParsons
resources & energy

Talen Montana Colstrip Power Plant

Shutdown Water Management Options Analysis

REV	DATE	DESCRIPTION	ORIG	CHK	APPR
A	6/15/16	Issued for Preliminary Review	DCS		
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Change Log

REV	SECTION	CHANGE DESCRIPTION

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Abbreviations

BC	Brine Concentrator
BFP	Belt Filter Press
BRS	Brine Recovery System
BTU	British Thermal Unit
BXtal	Brine Crystallizer
$CaBr_2$	Calcium bromide
CCR	Coal Combustion Residue
CIP	Clean in Place
CO_2	Carbon Dioxide
COC	Cycles of concentration
CPP	Talen Montana Colstrip Power Plant
CWBRS	Capture Well Brine Recovery System
EDTA	Ethylenediaminetetraacetic Acid
EHP	Effluent Holding Pond
Evap	Evaporation
gpm	Gallons per Minute
HMB	Heat & Material Balance
IBRS	Impoundment Brine Recovery System
KI	Potassium iodide
kWhr	Kilowatt Hours
lb	Pound
mg/l	Milligrams per Liter
mmBTU	Millions of BTUs
mmGal	Millions of Gallons
NA	Not Available
PFD	Process flow diagram
ppm	Parts per million
ppmv	Parts per million by volume
PRST	Pond Return Storage Tank
psig	Pounds per square inch gauge
SO_2	Sulfur Dioxide
STEP	Stage Two Evaporation Pond
TBD	To Be Determined
TDS	Total Dissolved Solids
TH	Total Hardness
TOC	Total Organic Carbon
TSS	Total Suspended Solids
VSEP	Vibratory Shear Enhanced Process
wt%	Percent by Weight

1 EXECUTIVE SUMMARY

Talen's Colstrip Power Plant consists of four wet-cooled coal-fired units (Units 1-4) with air pollution control systems, ground water capture wells, various storage and evaporation ponds, and associated water treatment and purification infrastructure. Air pollution control systems include fly ash removal, flue gas desulfurization and mercury removal equipment. New Coal Combustion Residual (CCR) requirements necessitate the removal of excess water and removal from service of several of the existing plant ponds. The total site water inventory is approximately 1,158 million gallons. An earlier report, 108062-08206-PR-REP-0001 Integrated Water Management Study Report, provided a timeline and management plan that met the CCR requirements assuming that Units 1 through 4 operated at or near their respective historical power production levels.

This report identifies the water management options, equipment, capital cost, and operating cost associated with a shutdown of Units 1 and 2 in the FY2017 to FY2022 time frame. The costs that appear in this document are in addition to any costs associated with the current CCR Rule Master Plan. Information contained in this report can be combined with the current CCR Rule Master Plan to identify the additional cost associated with earlier shutdown of Units 1 and 2. The costs identified in this report are in addition to, and not in lieu of, any CCR management costs.

This document is intended to estimate the costs associated with early shutdown of Units 1 and 2. Calculating costs required the use of assumptions regarding water treatment removal rates and water treatment removal methods. It is important to note that these rates and methods were assumed to facilitate cost calculation. This document is not intended to provide a definitive activity or project plan. Actual activities will be dictated by site conditions and may occur at different times, at different rates, or use different methods than those assumed in this report.

1.1 Key Assumptions

The management plan presented in 108062-08206-PR-REP-0001 assumed that evaporation across the Unit 1 and 2 cooling towers and FGD units would continue. This report assumes that Units 1 and 2 cease operation at various times and provides options for managing and removing water associated with these two units in the years following shutdown without adversely impacting the required CCR Rule Master Plan.

This report assumes that pond inventory from STEP D Cell, STEP E Cell, and STEP Old Clearwell is eliminated in accordance with the current plan using forced evaporation at the 3&4 EHP. The costs associated with forced evaporation of this water are part of the CCR Rule Master Plan and are not associated with an early shutdown of Units 1 and 2. These costs were documented in report 108062-08206-PR-REP-0001 and are not included in the cost calculations contained in this report. The costs that appear in this report only accrue if Units 1 and 2 are shutdown early.

This report also assumes that forced evaporation ceases in 2019 due to the risk associated with the potential for impounding water over a closed CCR unit. Forced evaporation may be used in future years, if available, to process any additional water that must be removed. Weather and plant events present risks that may increase the amount of water which must be removed from the Plantsite area, STEP area, and U1/2 Bottom Ash ponds. The use of forced evaporation after the closure of EHP F Cell would require the construction of a forced evaporation feed pond over the closed and capped F Cell. The cost of a new forced evaporation pond was not included in the cost analysis.

The shutdown of Units 1 and 2 presents two challenges: management of remaining impoundment inventory and management of capture well water. Remaining impoundment inventory includes water stored in Plantsite B Pond, STEP B Cell, and the Unit 1 and 2 Bottom Ash Ponds. The excess inventory, approximately 116 million gallons, is water that does not have to be removed for CCR compliance but that would have to be removed if Units 1 and 2 are shutdown. This analysis assumes that capture well flow continues at its current rate (approximately 374 gpm) for 10 years after emptying of the STEP D Cell, STEP E Cell, and STEP Old Clearwell is complete. In accordance with the CCR Rule Master Plan, these ponds will be empty at the end of 2018. Further, this analysis assumes that capture well flow will continue at 374 gpm for 10 years (2019 through 2028), then continue at 50% of current flow for ten years (2029 through 2038), and then proceed at 25% of current flow for ten years (2039 through 2048).

1.2 Cost Summary

Capital and operating cost vary depending on years after shutdown, the time after shutdown when the capture well brine recovery system begins operation, and the most likely method used to process excess Plantsite B and STEP B Cell inventory (water not part of the CCR Rule Master Plan). Table 1-1 compares the total cost (operating and capital cost in FY 2017 dollars without escalation) for the various shutdown dates assuming the most likely methods used to process water. Since they do not include escalation, the cost estimates in the table below represent FY2017 dollars spent from now through 2048. The detailed cost tables in Section 2 provide a breakdown of expenditures in each fiscal year (in FY2017 dollars) for the various dates. The highest cost-case would be a shutdown of Units 1 and 2 on July 1, 2017.

Table 1-1: Total Cost Comparison (Costs in Addition to those in Current CCR Rule Master Plan)

Shutdown Date	Total Capital Cost ($)	Total Operating Cost ($)	Total Cost (CAPEX + OPEX $)
July 1, 2017 (FY2018)	$32,880,500	$66,631,026	$99,511,526
July 1, 2018 (FY2019)	$23,245,500	$65,922,947	$89,168,447
July 1, 2019 (FY2020)	$17,804,000	$68,032,552	$85,836,552
July 1, 2020 (FY2021)	$14,926,000	$68,032,552	$82,958,552
July 1, 2021 (FY2022)	$14,926,000	$65,273,171	$80,199,171
July 1, 2022 (FY2023)	$14,926,000	$62,513,790	$77,439,790

Capital cost lowers from FY2018 through FY2021 since procurement of required treatment equipment can begin further in advance of the shutdown date. Shutdown dates that occur further in the future require less storage of capture well water and allow for a smaller storage pond and smaller treatment equipment. Capital cost is at its minimum in FY2021, when procurement at least three years in advance of a shutdown date allows for the smallest storage pond and smallest treatment system. Storage pond size and treatment equipment capacity remains the same in the years following FY2021, so capital cost remains the same.

Operating cost lowers from FY2018 to FY2019 as remaining pond inventory is removed via forced evaporation and as CWBRS feed flow lowers (made possible by construction of the CWBRS more than one year in advance of the shutdown date). Operating cost increases if the shutdown occurs in FY2020 since forced evaporation of excess pond water may not be possible. This analysis assumes that more expensive thermal evaporation is used to remove excess pond water for shutdown dates on or after July 1, 2019. The increase in FY2020 operating cost associated with thermal evaporation is off-set somewhat by the lower average CWBRS feed flow, made possible by construction of the CWBRS well in advance of the shutdown date. In the extreme case (a shutdown 30 or more years in the future) a capture well treatment system may not be required. Capture well flow is expected to lower over time and well water quality is expected to improve as a consequence of CCR activities. These improvements would occur even if Units 1 and 2 continue to operate.

The following pages provide the cost basis and detailed cost estimates by shutdown date assuming the most likely shutdown scenarios.

1.3 Need for Separate Capture Well Brine Recovery System (CWBRS)

It is important to understand that capture well water and pond water are two distinct waters with different treatment goals. The chemistry of the water in the existing impoundments is quite different than the chemistry of the water in the capture wells. Simply increasing the capacity of the impoundment brine recovery system (IBRS) would be more expensive (operating and capital cost) than installing a brine recovery system specifically designed to process the capture well water associated with Units 1 and 2 for two basic reasons:

- Capture well flow is much higher and would result in a much larger IBRS
- The basic equipment design would be different

If Units 1 and 2 continued to operate at or near their historical production rates their flow to the IBRS would be approximately 70 gpm. This is the amount of water that must be removed to maintain the Unit 1 and 2 impoundment halogens in balance, segregate the removed halogens, and minimize the potential for corrosion. WorleyParsons created the IBRS performance specification, document 108062-08206-PR-SPC-0002, which recommended a system capable of producing 250 gpm of distillate. Salt and water associated with Units 3 and 4 represent the major load (approximately 85% of the salt and approximately 70% of the water) on the IBRS.

Shutdown of Units 1 and 2 would mean no evaporation of capture well water. That being the case, the water flow from Units 1 and 2 to the IBRS would have to increase from 70 gpm to approximately 350 gpm in the years immediately following shutdown. The flow increase alone would require the IBRS to more than double in size.

Further, the IBRS is required primarily for salt management. Well water chemistry is radically different than that of the impoundments. As stated earlier, impoundment water must be treated to maintain the halogens in balance, segregate the removed halogens, and minimize the potential for corrosion. The IBRS design, therefore, requires larger salt handling systems on a per-gallon-of-recovered-water basis and therefore costs more per per-gallon-of-recovered-water than the CWBRS would cost.

A capture well brine recovery system (CWBRS) would be required primarily for water management and would have a much lower salt load. Its purpose would be to treat the ground capture water, generate a usable water stream for Units 3 and 4, and produce a solid waste that could be disposed of with the waste from IBRS.

The equipment appropriate for one would not be appropriate for the other. Installing separate treatment systems would allow the optimum design for each.

1.4 Need for Preplanning

The costs associated with shutdown depend in large part on the amount of time in advance of shutdown that notification is received and the date by which major equipment procurement and major construction begin. The same general requirements would apply (construction of storage and the construction of the CWBRS) regardless of the shutdown date, but storage and equipment size would increase if shutdown notification time is short.

Shutdown notification must be provided at least nine months in advance to allow construction of a capture well water storage impoundment regardless of the actual shutdown date. Lack of notification at least nine months in advance may require a postponement of the shutdown date. Capture well water storage would be required even if a CWBRS is installed and operational. The season in which the shutdown decision is made may limit the ability to construct the necessary impoundment within nine months. A decision to shutdown made in August, for example, may mean that impoundment construction could not begin until the following April or May. In such a case shutdown of Units 1 and 2 might have to be postponed until the capture well storage pond is completed.

2 CAPITAL AND OPERATING COST CALCULATIONS

2.1.1 Capital Cost Basis

Capital costs include those associated with capture well storage, the CWBRS, and the cost of additional forced evaporation equipment. The capture well storage impoundment and CWBRS must be installed to process capture well water. The additional forced evaporation equipment (additional MineTek units or similar technology) would be required only if Units 1 and 2 are shutdown in FY2017 or early in FY2018 and the excess inventory in Plantsite B, STEP B Cell, and the Unit 1/2 Ash Ponds is removed using forced evaporation.

The size of the CWBRS feed storage pond and the size of the CWBRS itself depend on how far in advance of shutdown work begins on both the storage pond and the CWBRS. It takes approximately three years to procure, construct, and commission a complete brine recovery system. This timeline may be accelerated depending on market conditions, but such acceleration cannot be guaranteed. This report, therefore, assumes the three-year time frame. This report also assumes that construction of the CWBRS feed storage pond begins in the fiscal year before shutdown and that construction is completed and the pond ready to receive capture well water on or before July 1 of the fiscal year in which Units 1 and 2 cease operation.

This report further assumes that CWBRS procurement begins from zero (the year of shutdown) to three fiscal years in advance of the planned shutdown of Units 1 and 2. CWBRS procurement that begins the year of the shutdown would require storage of three years of capture well water and would also require a CWBRS large enough to process any stored water in addition to normal capture well flow. The model assumes that the CWBRS must have capacity sufficient to both process normal capture well flow and remove all stored capture well water within five years of the CWBRS startup.

Table 2-1 summarizes the findings used in the following sections of this report. The capital cost estimates in the table include the cost of the Capture Well Brine Recovery System (CWBRS) and the CWBRS Storage Pond. The estimated cost of the CWBRS Storage Pond is $450,000 per acre if the pond is constructed on short notice (within one year). The estimated cost per acre lowers to $300,000 per acre if the pond construction is planned one or more years in advance.

The capital cost of the additional MineTek units is approximately $427,500. The additional MineTek evaporators are required to provide the necessary additional water removal from the Plantsite B and STEP B Cell, but only if Units 1 and 2 cease operation in FY2017 or early FY2018. The capital cost estimates do not include the cost of installation.

Table 2-1: Capital Cost Estimate (FY2017 Dollars)

BRS Procurement Starts in Advance of Shutdown Date (Years)	0	1	2	3
Capital Cost (FY2017 mm$)	$32.45	$22.82	$17.80	$14.93
CWBRS Storage Pond Capacity (mmGal)	529.51	360.07	185.74	92.87
CWBRS Storage Pond Surface Area (acres)	32.5	22.1	11.4	5.7
CWBRS Brine Concentrator Capacity (gpm)	475	425	370	350
CWBRS Crystallizer Capacity (gpm)	16	16	16	12

2.1.2 Operating Cost Basis

Operating costs include the cost of forced or thermal evaporation of the additional Plantsite B, STEP B Cell, and U1/2 Bottom Ash Pond water and the cost of operating the CWBRS. The current CCR water management plan includes most of the STEP and Plantsite B pond water. The cost associated with disposal of CCR water has already been planned and evaluated. The additional water removal required to empty the Plantsite B, STEP B Cell, and U1/2 Bottom Ash ponds would be specific to the shutdown of Units 1 and 2 and has not previously been calculated or estimated. The excess inventory, approximately 116 million gallons, is water that does not have to be removed for CCR compliance but that would have to be removed if Units 1 and 2 are shutdown. The operating cost associated with forced evaporation of this water assumes the following:

- O&M Cost ($/1000 Gal): $3.30
- Energy Cost ($/1000 Gal): $3.20
- Manpower Cost ($/1000 Gal): $2.60

Based on these estimates, the cost associated with removal of impoundment water via forced evaporation would be approximately $782,600. Shutdown on or after approximately September 1, 2018 (near the end of the 2018 evaporation season) would require removal of excess Plantsite B, STEP B Cell and U1/2 Bottom Ash pond water using thermal evaporation via the Impoundment Brine Recovery System (IBRS). A feedrate of approximately 41 gpm would remove remaining water in approximately four years (one year less than the 5-year requirement explained in later sections). Assume, for example, a shutdown date of 7/1/19 (the start of FY2020). The operating cost of thermal removal would be approximately $2,553 per day ($931,934 per year) and would continue for approximately four years. The total cost of thermal evaporation, therefore, would be approximately $3.73 million over four years, far in excess of the cost of forced evaporation.

The operating cost of the CWBRS includes O&M, energy, chemicals, manpower, cleaning, and sludge disposal. Of these, manpower is independent of system size. The table below summarizes operating cost as a function of BRS system feed flow. All operating dollars are in FY2017 equivalents.

Table 2-2: CWBRS System Operating Cost (FY2017 Dollars)

BRS System Feed Flow (gpm)	475	425	370	350	164	70.5
Operating Cost ($/Day)	$8,530	$8,142	$7,715	$7,560	$6,117	$5,391
Operating Cost (mm$/Year)	3.15	3.00	2.82	2.65	2.23	1.97

2.2 Detailed Cost Estimates

As mentioned earlier, capital and operating cost vary depending on years after shutdown, the time after shutdown when the capture well brine recovery system begins operation, and the most likely method used to process excess impoundment inventory. Table 1-1 compared the total cost (operating and capital cost, excluding escalation) for the various shutdown dates assuming the most likely methods used to process water.

The tables on the following pages provide the detailed cost estimates based on shutdown date, also with assumed values for the most likely scenarios. Cost data from the detailed cost estimate tables on the following pages was used to create the summary provided in Table 1-1.

2.2.1 Shutdown on July 1, 2017

Table 2-3 assumes that the capture well storage pond, CWBRS, and the additional MineTek units required for forced evaporation are procured in FY2017. The CWBRS begins operation in FY2021, so the capture well storage pond and CWBRS must be sized with capacity sufficient to store and process three years of capture well flow. The Plantsite B, STEP B Cells, and Unit 1/2 Ash Ponds empty in FY2018.

Table 2-3: Capital and Operating Cost, Shutdown on July 1, 2017

Fiscal Year	Capital Cost ($)	Operating Cost ($)	Comments
FY2017	$32,880,500	$0	Construct CWBRS storage pond, begin procurement of 475-gpm CWBRS, procure additional MineTek units for forced evaporation.
FY2018	$0	$782,600	Units 1 and 2 shutdown on 7/1/17. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. Plantsite B, STEP B Cell & Ash Pond water removed via forced evaporation, capture well water stored in new pond, no CWBRS system in operation.
FY2019	$0	$0	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. Plantsite, STEP B Cell & Ash Ponds empty. Capture well water stored in new pond, no CWBRS system in operation.
FY2020	$0	$0	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. Plantsite, STEP B Cell & Ash Ponds empty. Capture well water stored in new pond, no CWBRS system in operation.
FY2021 through FY2025	$0	$15,567,102	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system begins operation at 475 gpm, working off inventory in capture well storage pond. Capture well pond nearly empty at end of FY2025.
FY2026 through FY2028	$0	$8,278,142	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system remains in operation at 350 gpm to process capture well water. Storage pond remains nearly empty.
FY2029 through FY2038	$0	$22,325,699	Capture well water flow of 187 gpm, 23 gpm for dust suppression, net of 164 gpm excess. CWBRS system remains in operation at 164 gpm to process capture well water. Storage pond remains nearly empty.
FY2039 through FY2048	$0	$19,677,483	Capture well water flow of 93.5 gpm, 23 gpm for dust suppression, net of 70.5 gpm excess. CWBRS system remains in operation at 70.5 gpm to process capture well water. Storage pond remains nearly empty.
FY2049 Onward	$0	$0	Assumes capture well purity approximately equal to groundwater purity, no further capture well flow processing required.
Total	$32,880,500	$66,631,026	Total Cost (CAPEX + OPEX) = $99,511,526

2.2.2 Shutdown on July 1, 2018

Table 2-4 assumes that the capture well storage pond, CWBRS, and the additional MineTek units required for forced evaporation are procured in FY2017. The CWBRS begins operation in FY2021, so the capture well storage pond and CWBRS must be sized with capacity sufficient to store and process two years of capture well flow. The Plantsite B, STEP B Cells, and Unit 1/2 Ash Ponds empty in FY2018.

Table 2-4: Capital and Operating Cost, Shutdown on July 1, 2018

Fiscal Year	Capital Cost ($)	Operating Cost ($)	Comments
FY2017	$23,245,500	$0	Construct CWBRS storage pond, begin procurement of 425-gpm CWBRS, procure additional MineTek units for forced evaporation.
FY2018	$0	$782,600	Units 1 & 2 remain in operation. Plantsite B, STEP B Cell & Ash Pond water removed via forced evaporation. Capture well water processed normally, no CWBRS system in operation.
FY2019	$0	$0	Units 1 and 2 shutdown on 7/1/18. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. Plantsite, STEP B Cell & Ash Ponds empty. Capture well water stored in new pond, no CWBRS system in operation.
FY2020	$0	$0	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. Plantsite, STEP B Cell & Ash Ponds empty. Capture well water stored in new pond, no CWBRS system in operation.
FY2021 through FY2025	$0	$14,859,023	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system begins operation at 425 gpm, working off inventory in capture well storage pond. Capture well pond nearly empty at end of FY2025.
FY2026 through FY2028	$0	$8,278,142	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system remains in operation at 350 gpm to process capture well water. Storage pond remains nearly empty.
FY2029 through FY2038	$0	$22,325,699	Capture well water flow of 187 gpm, 23 gpm for dust suppression, net of 164 gpm excess. CWBRS system remains in operation at 164 gpm to process capture well water. Storage pond remains nearly empty.
FY2039 through FY2048	$0	$19,677,483	Capture well water flow of 93.5 gpm, 23 gpm for dust suppression, net of 70.5 gpm excess. CWBRS system remains in operation at 70.5 gpm to process capture well water. Storage pond remains nearly empty.
FY2049 Onward	$0	$0	Assumes capture well purity approximately equal to groundwater purity, no further capture well flow processing required.
Total	$23,245,500	$65,922,947	Total Cost (CAPEX + OPEX) = $89,168,447

2.2.3 Shutdown on July 1, 2019

Table 2-5 (following page) assumes that the capture well storage pond and CWBRS are procured in FY2017. Unit 1 and 2 would cease operation after January 1, 2019 (when the forced evaporation window closes). While forced evaporation may be possible in future years, this analysis assumed the worst-case for cost estimating purposes. Assuming that forced evaporation is not available, excess inventory stored in the Plantsite B, STEP B Cell, and Unit 1/2 Ash ponds would have to be processed in the IBRS. The model assumes that this processing occurs over a period of four years at an average rate of 41 gpm. The total volume processed over the time period would approximately equal the current excess inventory in the impoundments (approximately 116 million gallons). The CWBRS begins operation in FY2021, so the capture well storage pond and CWBRS must be sized with capacity sufficient to store and process just one year of capture well flow.

Table 2-5: Capital and Operating Cost, Shutdown on July 1, 2019

Fiscal Year	Capital Cost ($)	Operating Cost ($)	Comments
FY2017	$17,804,000	$0	Construct CWBRS storage pond, begin procurement of 370-gpm CWBRS.
FY2018 through FY2019	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2020	$0	$931,934	Units 1 & 2 shutdown on 7/1/19. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. Capture well water stored in new pond, no CWBRS system in operation. Begin processing pond water in IBRS at rate of 41 gpm.
FY2021 through FY2023	$0	$11,243,885	Continue processing pond water in IBRS at rate of 41 gpm. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system begins operation at 370 gpm, working off inventory in capture well storage pond.
FY2024	$0	$2,816,027	Plantsite B, STEP B Cell, & Ash Ponds empty. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system continues operation at 370 gpm, working off inventory in capture well storage pond. Capture well pond nearly empty at end of FY2024.
FY2025 through FY2028	$0	$11,037,523	Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system remains in operation at 350 gpm to process capture well water. Storage pond remains nearly empty.
FY2029 through FY2038	$0	$22,325,699	Capture well water flow of 187 gpm, 23 gpm for dust suppression, net of 164 gpm excess. CWBRS system remains in operation at 164 gpm to process capture well water. Storage pond remains nearly empty.
FY2039 through FY2048	$0	$19,677,483	Capture well water flow of 93.5 gpm, 23 gpm for dust suppression, net of 70.5 gpm excess. CWBRS system remains in operation at 70.5 gpm to process capture well water. Storage pond remains nearly empty.
FY2049 Onward	$0	$0	Assumes capture well purity approximately equal to groundwater purity, no further capture well flow processing required.
Total	$17,804,000	$68,032,552	Total Cost (CAPEX + OPEX) = $85,836,552

2.2.4 Shutdown on July 1, 2020

Table 2-6 assumes that the capture well storage pond and CWBRS are procured in FY2017. Unit 1 and 2 would cease operation after January 1, 2019 (when the forced evaporation window closes). While forced evaporation may be possible in future years, this analysis assumed the worst-case for cost estimating purposes. Assuming that forced evaporation is not available, excess inventory stored in the Plantsite B, STEP B Cell, and Unit 1/2 Ash ponds would have to be processed in the IBRS. The model assumes that this processing occurs over a period of four years at an average rate of 41 gpm. The total volume processed over the time period would approximately equal the current excess inventory in the impoundments (approximately 116 million gallons). The CWBRS begins operation in FY2021, the same year that Units 1 and 2 cease operation. That being the case, the CWBRS storage pond need only be sized to provide sufficient storage to allow for periodic cleaning (approximately 93 million gallons). The CWBRS system capacity matches that of the capture well flow at plant shutdown. Capital cost is minimized by minimizing the size of the CWBRS storage pond and by minimizing the capacity of the CWBRS itself.

Table 2-6: Capital and Operating Cost, Shutdown on July 1, 2020

Fiscal Year	Capital Cost ($)	Operating Cost ($)	Comments
FY2017	$14,926,000	$0	Construct CWBRS storage pond, begin procurement of 350-gpm CWBRS.
FY2018	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2019	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2020	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2021 through FY2024	$0	$14,991,846	Units 1 & 2 shutdown on 7/1/20. Begin processing pond water in IBRS at rate of 41 gpm (continues for four years). Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system begins operation at 350 gpm. Capture well pond starts nearly empty and remains nearly empty.
FY2025 through FY2028	$0	$11,037,523	Plantsite B, STEP B Cell, & Ash Ponds empty. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system continues operation at 350 gpm. Capture well pond remains empty.
FY2029 through FY2038	$0	$22,325,699	Capture well water flow of 187 gpm, 23 gpm for dust suppression, net of 164 gpm excess. CWBRS system remains in operation at 164 gpm to process capture well water. Storage pond remains nearly empty.
FY2039 through FY2048	$0	$19,677,483	Capture well water flow of 93.5 gpm, 23 gpm for dust suppression, net of 70.5 gpm excess. CWBRS system remains in operation at 70.5 gpm to process capture well water. Storage pond remains nearly empty.
FY2049 Onward	$0	$0	Assumes capture well purity approximately equal to groundwater purity, no further capture flow processing required.
Total	$14,926,000	$68,032,552	Total Cost (CAPEX + OPEX) = $82,958,552

Exhibit No. ___(RJR-14)

2.2.5 Shutdown on July 1, 2021

Table 2-7 (following page) assumes that the capture well storage pond and CWBRS are procured in FY2018 (three years before shutdown). Unit 1 and 2 would cease operation after January 1, 2019 (when the forced evaporation window closes). While forced evaporation may be possible in future years, this analysis assumed the worst-case for cost estimating purposes. Assuming that forced evaporation is not available, excess inventory stored in the Plantsite B, STEP B Cell and Unit 1/2 Ash ponds would have to be processed in the IBRS. The model assumes that this processing occurs over a period of four years at an average rate of 41 gpm. The total volume processed over the time period would approximately equal the current excess inventory in the impoundments (approximately 116 million gallons). The CWBRS begins operation in FY2022, the same year that Units 1 and 2 cease operation. That being the case, the CWBRS storage pond need only be sized to provide sufficient storage to allow for periodic cleaning (approximately 93 million gallons). The CWBRS system capacity matches that of the capture well flow at plant shutdown. Capital cost is minimized by minimizing the size of the CWBRS storage pond and by minimizing the capacity of the CWBRS itself.

Table 2-7: Capital and Operating Cost, Shutdown on July 1, 2021

Fiscal Year	Capital Cost ($)	Operating Cost ($)	Comments
FY2017	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2018	$14,926,000	$0	Construct CWBRS storage pond, begin procurement of 350-gpm CWBRS.
FY2019	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2020	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2021	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2022 through FY2025	$0	$14,991,846	Units 1 & 2 shutdown on 7/1/21. Begin processing pond water in IBRS at rate of 41 gpm (continues for four years). Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system begins operation at 350 gpm. Capture well pond starts nearly empty and remains empty.
FY2026 through FY2028	$0	$8,278,142	Plantsite B, STEP B Cell, & Ash Ponds empty. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system continues operation at 350 gpm. Capture well pond remains empty.
FY2029 through FY2038	$0	$22,325,699	Capture well water flow of 187 gpm, 23 gpm for dust suppression, net of 164 gpm excess. CWBRS system remains in operation at 164 gpm to process capture well water. Storage pond remains nearly empty.
FY2039 through FY2048	$0	$19,677,483	Capture well water flow of 93.5 gpm, 23 gpm for dust suppression, net of 70.5 gpm excess. CWBRS system remains in operation at 70.5 gpm to process capture well water. Storage pond remains nearly empty.
FY2049 Onward	$0	$0	Assumes capture well purity approximately equal to groundwater purity, no further capture well flow processing required.
Total	$14,926,000	$65,273,171	Total Cost (CAPEX + OPEX) = $80,199,171

2.2.6 Shutdown on July 1, 2022

Table 2-8 (following page) assumes that the capture well storage pond and CWBRS are procured in FY2019 (three years before shutdown). Unit 1 and 2 would cease operation after January 1, 2019 (when the forced evaporation window closes). While forced evaporation may be possible in future years, this analysis assumed the worst-case for cost estimating purposes. Assuming that forced evaporation is not available, excess inventory stored in the Plantsite B, STEP B Cell, and Unit 1/2 Ash ponds would have to be processed in the IBRS. The model assumes that this processing occurs over a period of four years at an average rate of 41 gpm. The total volume processed over the time period would approximately equal the current excess inventory in the two impoundments (approximately 116 million gallons). The CWBRS begins operation in FY2023, the same year that Units 1 and 2 cease operation. That being the case, the CWBRS storage pond need only be sized to provide sufficient storage to allow for periodic cleaning (approximately 93 million gallons). The CWBRS system capacity matches that of the capture well flow at plant shutdown. Capital cost is minimized by minimizing the size of the CWBRS storage pond and by minimizing the capacity of the CWBRS itself.

Table 2-8: Capital and Operating Cost, Shutdown on July 1, 2022

Fiscal Year	Capital Cost ($)	Operating Cost ($)	Comments
FY2017	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2018	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2019	$14,926,000	$0	Construct CWBRS storage pond, begin procurement of 350-gpm CWBRS.
FY2020	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2021	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2022	$0	$0	Units 1 & 2 remain in operation. Capture well water processed normally, no CWBRS system in operation.
FY2023 through FY2026	$0	$14,991,846	Units 1 & 2 shutdown on 7/1/22. Begin processing pond water in IBRS at rate of 41 gpm (continues for four years). Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system begins operation at 350 gpm. Capture well pond starts nearly empty and remains nearly empty.
FY2027 through FY2028	$0	$5,518,762	Plantsite B, STEP B Cell, & Ash Ponds empty. Capture well water flow of 374 gpm, 23 gpm for dust suppression, net of 350 gpm excess. CWBRS system continues operation at 350 gpm. Capture well pond remains empty.
FY2029 through FY2038	$0	$22,325,699	Capture well water flow of 187 gpm, 23 gpm for dust suppression, net of 164 gpm excess. CWBRS system remains in operation at 164 gpm to process capture well water. Storage pond remains nearly empty.
FY2039 through FY2048	$0	$19,677,483	Capture well water flow of 93.5 gpm, 23 gpm for dust suppression, net of 70.5 gpm excess. CWBRS system remains in operation at 70.5 gpm to process capture well water. Storage pond remains nearly empty.
FY2049 Onward	$0	$0	Assumes capture well purity approximately equal to groundwater purity, no further capture well flow processing required.
Total	$14,926,000	$62,513,790	Total Cost (CAPEX + OPEX) = $77,439,790

3 WATER MANAGEMENT OPTIONS

This section describes the general options for management of capture well water and management of excess inventory in the Plantsite B and STEP B Cell impoundments.

3.1 Management of Impoundment Inventory

The CCR Rule states that closure of impoundments must begin within 30 days of known final receipt of coal-combustion residue and closure must be completed within 5 years of starting closure activities. An extension of the closure timeframe may be possible with demonstration of factors beyond the facility's control including:

- Climate & weather
- Time to dewater
- Geology & terrain
- Time to get permits

The maximum extension for impoundments less than or equal to 40 acres in size is two years. The extension for impounds greater than 40 acres occurs in 2 year increments cannot exceed 10 years.

The current CCR management plan can accommodate the additional STEP B Cell, Plantsite B Pond, and U1/2 Ash Pond water that was not part of the original removal plan (approximately 116 million gallons of additional water).

Modeling performed for the preparation of this assessment indicates that it would be best to use forced evaporation to reduce all of the STEP and Plantsite B pond levels as low as possible and as quickly as possible regardless of the shutdown date. Any pond inventory remaining after January 1, 2019 would have to be processed in a thermal brine recovery system rather than by processing it using forced evaporation. As mentioned earlier, thermal evaporation is much more expensive than forced evaporation.

The CCR management plan does not require removal of any water in STEP B Cell or the ash ponds and only part of the water in Plantsite B Pond. The impact of this inventory on the management plan does depend on the shutdown date. A shutdown in 2017 would provide the most time to remove this water via forced evaporation. A shutdown in mid-2018 would provide only six months to remove this water and any remaining inventory would have to be processed in the planned IBRS. Similarly, a shutdown after January 1, 2019 would require that all remaining STEP and Plantsite B pond water be processed in the IBRS.

Even if this is the case, there will be available capacity in the IBRS to process the remaining STEP and Plantsite B Pond water over a period of approximately four years, well in advance of the 5-year requirement.

3.1.1 Forced Evaporation

Updated pond level inventories were provided in document "Pond Inventory Rev6 1_1_16.xlsx". The plant has already put into action and received approval for the next three years for the forced evaporation of impoundment water in accordance with the management plan presented in 108062-08206-PR-REP-0001.

This plan anticipates the transfer water from STEP to EHP through the Plantsite B Pond Pump House. It is not possible to use forced evaporation at the STEP ponds as a consequence of their proximity to residential properties. Still, forced evaporation via EHP F Cell can remove all of the necessary impoundment water by 2019, when the use of forced evaporation ceases. This can be accomplished provided that Unit 1 and 2 are shutdown no later than approximately September 1, 2018 (near the end of the 2018 evaporation season). Further, this removal can be achieved without interruption or modification of the current CCR master plan schedules.

Modeling performed in conjunction with this assessment assumed 8 MineTek units and 33 Turbomisters in operation during the evaporation months through June 30, 2017. The model assumes that 2-3 additional MineTek units are installed and operating on or before July 1, 2017 and that 10-11 MineTek units and 33 Turbomisters remain in operation during the evaporation months until December 31, 2018.

There are many potential variations associated with shutdown dates and pond inventories. The July 1, 2017 shutdown date is the most restrictive and would require the largest amount of water removal via forced evaporation. Assuming this date and the additional requirement to remove all water from the Plantsite and STEP impoundments, the specific ponds, required removal amounts, and tentative removal dates would be as follows:

Table 3-1: Target Removal Amounts (mmGal, millions of gallons) and Timeline, 7/1/17 Shutdown

Impoundment	Total Volume to be Removed (mmGal)	7/1/16 to 12/31/16	1/1/17 to 6/30/17	7/1/17 to 6/30/18	7/1/18 to 12/31/18
U1/2 BA Ponds	10.00	0	0	5	5
Plantsite B Pond	54.73	0	0	54.73	0
STEP B Cell	76.29	0	0	76.29	0
STEP E Cell	128.05	-0.49	110.86	17.68	0
STEP D Cell	149.90	81.42	-0.25	68.73	0
STEP Old CW	32.68	1.46	1.55	29.59	0
EHP C Cell	49.26	0	2.63	46.63	0
EHP B Cell	100.00	0	0	0	100.00
EHP H Cell	222.92	19.75	17.86	185.49	0
EHP F Cell	183.13	3.55	0.13	61.06	118.39
Underground	50	6.3	6.2	12.5	25.00
Totals per Year	1056.96	111.99	138.89	557.70	248.39

Capital and operating cost estimates for this approach, as well as for other shutdown dates, appear in Section 2 of this report.

3.1.2 Thermal Evaporation

Shutdown after September 1, 2018 would require processing of remaining Plantsite B, STEP B Cell, and U1/2 Bottom Ash Pond water via the IBRS and would take approximately four years. Removing remaining inventory over this time would require an average feedrate to the IBRS of approximately 41 gpm. The feedrate associated with continued operation of Units 1 and 2 from the STEP and Plantsite B impoundments is approximately 77 gpm. Sufficient margin exists in the IBRS as currently specified to allow removal of excess inventory associated with a shutdown of Units 1 and 2 within four years, one year before the maximum of five years allowed by the CCR regulation. The CCR Rule provides for an extension of the five-year closure requirement if needed. An extension may be required if the ponds cannot be capped and closed within one year. The Rule identifies removal of water as one of the reasons that justifies additional time for closure.

3.2 Management of Capture Well Water

Capture well water from the Plantsite area and STEP area is expected to decrease over time. Seepage calculations have typically demonstrated that once the cap is installed on the impoundment, seepage from the impoundment will be eliminated within two years. This is because the water has been removed and precipitation will be prevented from infiltrating. Capture well flow then becomes a function of the water remaining in the ground. This is difficult to estimate.

This analysis assumes that capture well flow continues at its current rate (approximately 374 gpm) for 10 years after emptying of the STEP D Cell, STEP E Cell, and STEP Old Clearwell is complete. In accordance with the CCR Rule Master Plan, these ponds will be empty at the end of 2018. Further, this analysis assumes that capture well flow will continue at 374 gpm for 10 years (2019 through 2028), then continue at 50% of current flow for ten years (2029 through 2038), and then proceed at 25% of current flow for ten years (2039 through 2048).These assumptions may be conservative. Systems designed to process capture well water in accordance with these assumptions may exceed actual treatment requirements, but installing equipment based on these relatively conservative assumptions would be less expensive than using less conservative assumptions and installing supplementary treatment systems at a later date.

As stated earlier, the major problem is the management of capture well water. This water is completely different than the impoundment water and doesn’t require the same level of treatment. This water should be stored and treated separately. The required storage volume would vary depending on the shutdown date.

3.2.1 Capture Well Brine Recovery System

The CWBRS would require three basic interfaces with the units that remain in operation: steam supply, recovered water return, and solid waste disposal. Steam supply and solid waste disposal would be part of the operating cost. The modeling performed in conjunction with this assessment included assumptions for these costs that can be refined if more accurate data becomes available. Recovered water return would consist of high quality distillate suitable for use as makeup to the Unit 3 and 4 cooling towers. This revenue stream was not included in the financial analysis, but would not appreciably impact operating cost.

If the closing date is before 2019 there would be no need to build the Unit 1&2 bottom ash containment or the new B Pond. A capture well pond would be required to store accumulating well water until it could be processed in a dedicated CWBRS. The CWBRS would need to not only process the normal incoming flow, but also draw down the storage impoundment as well.

As mentioned earlier, the costs associated with shutdown depend in large part on the amount of time in advance of shutdown that notification is received and the date by which major equipment procurement and major construction begin. Table 2-1 provided the capital cost estimates. The same general requirements would apply (construction of storage and the construction of the CWBRS) regardless of the shutdown date, but storage and equipment size would increase if shutdown notification time is short. Thus, work performed now in anticipation of a Unit 1 and 2 shutdown would cost less than work performed at any later date.

It takes approximately three years to procure, construct, and commission a brine recovery system. Beginning procurement on the planned shutdown date would therefore require three years of capture well storage. Similarly, beginning procurement a year in advance of the planned shutdown date would require two years of capture well water storage. Shortfalls in storage volume could be managed using the U1/2 VSEPs if necessary, but would result in higher operating cost. It is important to note that the planned IBRS would not have the capacity to treat U1/2 capture well water.

The cost analysis basis assumes the installation of a single brine concentrator, crystallizer, belt filter press train sized to treat the expected capture well flow at the time of shutdown (350 gpm) with no margin. This approach was taken for three reasons. First, natural evaporation would (in theory) lower the amount of well water flowing to the CWBRS by approximately 37 gpm. Natural evaporation would therefore mean an actual flow to the CWBRS of approximately 313 gpm on a system designed to treat 350 gpm (a margin of about 12%). Second, capture well flow should decrease over time and eventually fall to approximately zero. Though the exact decrease in capture well flow over time cannot be predicted with certainty, it will occur and does provide additional margin. Finally, the large storage volume upstream of the MBRW would provide ample time to clean and maintain the unit.

This basis (350 gpm capacity CWBRS) requires modification if capture well water must be stored prior to CWBRS operation. Treating three years of stored capture water in addition to the normal capture well flow would require a system with a capacity of 475 gpm. Treating two years of stored capture water in addition to the normal capture well flow would require a system with a capacity of 425 gpm. Treating one years of stored capture water in addition to the normal capture well flow would require a system with a capacity of 370 gpm. No capture water need be stored if the CWBRS is operational on or before the shutdown date. If this is the case then the basis can be used, a single train sized to treat 350 gpm of capture water.

3.2.2 Capture Well Storage Pond

The capture well storage pond size will be dictated by both available area and required storage volume. This analysis assumes the construction of a large pond behind the plants and that the new B Pond is not constructed.

Figure 3-1 provides one possible option for the worst-case scenario. The entire hatched area in Figure 3-1 below it is approximately 30 acres. Determining the exact depth of the pond would require further study. Such a study would have to include ground water monitoring due to the ground water separation requirement of the CCR rule and other design criteria to properly determine an accurate depth. Assuming an arbitrary depth value of 50 feet for the CWBRS Storage Pond would yield a total capacity of approximately 490 Million Gallons at max pool. This design would be a slightly smaller pond than EHP J-Cell.

A pond of this size would be full in three years assuming the following:

- Capture well flow continues at approximately 374 gpm
- The plant continues to use approximately 23 gpm for dust suppression
- Pond natural evaporation is approximately 36.6 gpm (predicted value based on historical tray evaporation rate)

These assumptions result in a net flow into the pond of approximately 314 gpm. As discussed earlier, required pond size would decrease if the CWBRS is operational sooner. The size provided in Figure 3-1 includes no margin. The cost analysis conservatively assumed the installation of a slightly larger pond in the worst-case scenario, 530 million gallons and 32.5 acres in size, to provide some margin. If a pond of this size cannot be installed then the U1/2 VSEPs may be required to manage CWBRS storage pond level. The U1/2 VSEPs could be returned to service, process low TDS capture well water, and send reject to the pond along with high TDS well water. Operating cost would increase, but this would allow construction of the smaller 490 million gallon pond. The CWBRS would be about the same size (350 gpm) since the salt loading would be the same – the system would process the same pounds of salt, but it would be in less water.

Figure 3-1: CWBRS Storage Pond

4 MODELING TOOLS AND METHODS

The models used in preparation of this report include a functional block diagram specific to the time period analyzed and specific equipment datasheets showing major process equipment. The equipment worksheets include mass flow, chemistry, operating cost (as appropriate), and capital cost (as appropriate). This section describes the modeling tools used including the modeling methods, model inputs, and model outputs. The plant has already received native files for the general plant. The native files for the specific models used in the preparation of this report will be provided if requested. They have been omitted from the appendices to minimize document length.

4.1 Modeling Tools

4.1.1 WorleyParsons Modeling Tool

WorleyParsons utilizes a proprietary modeling tool for performing plant water balance, chemistry balance, mass balance and cost evaluations. Design inputs can be used to create an infinite variety of scenarios incorporating different treatment options, water sources, or thermal designs. The model consists of several basic components. The basic components can change depending upon specific project data requirements and data availability.

Most water, chemistry, and cost calculations occur internally in the WorleyParsons tool. Some complex processes (precipitation in FGD units and thermal evaporation systems, for example) are too complex for internal modeling. When these situations occur other modeling tools are used to create characteristic curves that are then incorporated into the WorleyParsons Excel-based model. The goal is to provide end-users with a robust and easy-to-use whole-plant water, chemistry and cost model. This model was developed specifically to evaluate options that meet or exceed Talen's site water reduction goals, but the model can be used to evaluate any changes in the plant's water, chemistry, and/or cost in the future. WorleyParsons will provide training to those designated by Talen on the model's use and functionality.

The whole-plant balance accounts for essentially all of the plant flows and all of the total solids (dissolved and suspended) entering and leaving the plant. It is intended as a living document. Updates are expected and will be performed as new data becomes available and as situations change. The model can be revised if plant modifications occur that are not included in the current plant water management plan.

4.1.2 Other Modeling Tools

Other software programs used to create the whole-plant model include:

- OLI Systems Studio 9.2 Stream Analyzer
- French Creek Software WaterCycle Rx
- Vendor-specific Software (Dow ROSA, Dow CADIX, GE Winflows, etc.)

It is important to note that output from these tools was used to calibrate and tune the calculation engine in the WorleyParsons tool, but these programs are not required for the WorleyParsons tool to function. They provided confirmation of calculation methods and results, but are not part of the WorleyParsons calculation engine.

4.1.3 Predictive Modeling

Power plant water losses to atmosphere through evaporation dictate most of the other plant water flows. These losses to atmosphere depend on ambient conditions, plant heat rate, fuel, plant dispatch, and a host of other factors. Accurate modeling of future performance requires a method of relating the varied conditions to atmospheric water loss through evaporation. Plant thermal data was used to determine this relationship for the four units at the site. A multi-dimensional analysis was performed to determine atmospheric water losses. In some cases (FGD evaporation, for example) the water loss is relatively independent of ambient conditions. In other cases (cooling tower evaporation, for example) ambient conditions have a significant impact on atmospheric water loss. Calculations were developed for these general water losses for each unit. The equations were used to predict general water losses for any set of ambient conditions and any whole-plant or individual unit dispatch. Equations were developed for a host of plant water parameters including cooling tower evaporation, boiler steaming rate, FGD evaporation rate, and pond elevations and volumes.

The accuracy of the model can be improved if some values which are currently estimated (seal water flows, for example) can be quantified. The model in its current form is in good agreement with known historical performance and its accuracy has been improved significantly as a consequence of the plant engineering staff’s input. The good agreement between historical performance and the model provides confidence in the ability of the model to predict future performance as processes change to address the new CCR requirements.

4.2 Inputs

In broad terms calculation of the water balance for any power plant requires accurate calculation of the thermodynamic performance of the plant. Thermodynamic calculations determine cooling tower evaporation rates, FGD evaporation rates, boiler energy losses, steam losses to atmosphere, and other unrecoverable water losses. The water balance then determines how water must flow in order to meet the needs dictated by these unrecoverable water losses.

Process-specific constraints and chemistry data dictate how water must be treated and the maximum level to which water can be concentrated as it flows through the plant. These demands include cooling tower and FGD chemistry limits (e.g., chloride concentration), seal water requirements, service water for washdown, and steam cycle sampling losses.

Thermodynamics, process constraints, and chemistry impact overall plant water usage and wastewater production. This information is loaded into the process model as different scenarios are analyzed. The process model automatically calculates the chemistry, flow, and costs associated with each scenario’s unique water usage and treatment requirements.

4.2.1 Power Production, Ambient Conditions, and Elevation

Power production, ambient conditions (dry bulb, wet bulb, precipitation, and tray evaporation rate) and site elevation are used to calculate a variety of parameters including cooling tower evaporation rate, FGD evaporation rate, natural evaporation rates in ponds, steam losses from atmospheric vents, and so on. While not the only parameters required to calculate these various values, ambient conditions are essential.

Power production and ambient conditions were calculated for a variety of time frames including the seasonal evaporation window, winter (no significant forced or natural evaporation) and average annual conditions. Power production, wet bulb, dry bulb, and humidity data was provided by Talen for the period from January 1, 2014 through January 1, 2016. Averages for specific time periods were obtained by averaging data from the two-year data window for the various time periods. The results appear in Table 4-1.

Table 4-1: Average Power Production and Ambient Conditions Used in the Model

Period	Unit 1 Power	Unit 2 Power	Unit 3 Power	Unit 4 Power	Outside Temp	Wet Bulb Temp	Wind Speed	Outside Humidity
Avg Annual	222.44	213.96	595.42	642.24	47.37	40.51	6.11	58.89
Avg 1/1-6/30	203.56	174.24	529.12	581.94	42.24	36.94	6.31	60.27
Avg 7/1-12/31	241.61	251.51	660.26	701.35	52.45	44.07	5.91	57.57

Unit 1 and 2 power production was, of course, assumed to be zero after the respective shutdown dates described earlier.

Tray evaporation rates were obtained from surrounding weather stations with 10 years or more of recorded data. In this case evaporation rates for Bozeman, Dillon, Fort Assinniboine, and Malta were averaged and used to estimate the Colstrip tray evaporation rate of 37.7 inches per year. Data for Huntley station, the closest station to Colstrip, was 40.55 inches per year. October data for Huntley was not available, so the more conservative average from surrounding stations was used in this analysis (37.7 inches per year). Average precipitation was similarly calculated. The difference between the two (average annual evaporation minus annual average precipitation) provided the net average pond evaporation rate of 1.22 gpm per acre used in the analysis.

4.2.2 Coal Data

The coal analysis was provided by Talen and appears in Table 4-2. This information is used in the model to calculate coal consumption, ash flows, FGD load, FGD chemistry, chloride contribution from coal to the plant's water systems, and other plant impacts.

Table 4-2: Coal Data

Energy Content, BTU/lb	8,413.0
C, wt%	49.38%
H, wt%	3.29%
N, wt%	0.77%
S, wt%	0.70%
Cl, wt%	0.00%
O, wt%	9.38%
H_2O, wt%	25.66%
ash, wt%	10.82%
Fly Ash, wt% of Total Ash	60.00%
Total, wt%	100.00%
lb SO_2/MMBtu, lb/mmBTU	1.66
Electricity Generation, Btu/kWhr	3412.14

4.2.3 Energy Balance

The energy balance for each unit begins with the coal data. When coupled with unit heat rate and power production the energy balance calculates fuel flow, capacity factor, and energy losses (total, parasitic, stack, and cooling tower). The results are used within the model to calculate a variety of water and chemistry impacts.

Table 4-3 summarizes the Unit 1, 2, 3, and 4 energy balances for the average annual power production and average annual ambient conditions that appear in Table 4-1.

Table 4-3: Energy Balance (Average Annual Conditions)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
Design Plant Power Production , MW	333.0	333.0	805.0	805.0
Capacity Factor, %	66.80%	64.25%	73.97%	79.78%
Gross Heat Rate, Btu/KWh (net)	10,600	10,600	10,600	10,600
Actual Plant Power Production, kw	222,436	213,955	595,420	642,241
Fuel Flow, lb/Hr	280,259	269,574	750,202	809,194
Parasitic Energy Loss, %	5.00%	5.00%	5.00%	5.00%
Stack Energy Loss, %	10.00%	10.00%	10.00%	10.00%
Cooling Tower Energy Loss, %	52.81%	52.81%	52.81%	52.81%
Total Thermal Energy Input, mmBTU/Hr	2,357.8	2,267.9	6,311.4	6,807.8
Electricity Generation, mmBTU/Hr	759.0	730.0	2,031.7	2,191.4
Total Energy Losses, mmBTU/Hr	1,598.8	1,537.9	4,279.8	4,616.3
Parasitic Energy Loss, mmBTU/Hr	117.9	113.4	315.6	340.4
Stack Energy Loss, mmBTU/Hr	235.8	226.8	631.1	680.8
Cooling Tower Energy Loss, mmBTU/Hr	1,245.2	1,197.7	3,333.1	3,595.2
Total Energy Losses, Btu/kWhr	7,187.9	7,187.9	7,187.9	7,187.9
Parasitic Energy Loss, Btu/kWhr	530.0	530.0	530.0	530.0
Stack Energy Loss, Btu/kWhr	1,060.0	1,060.0	1,060.0	1,060.0
Cooling Tower Heat Loss, Btu/kWhr	5,597.9	5,597.9	5,597.9	5,597.9

4.2.4 Mercury Control

Mercury control in the plant flue gas is facilitated by the addition of activated carbon and either calcium bromide or potassium iodide. The model allows users to select either chemical. The modeled scenarios assume the use of potassium iodide beginning approximately June 1 of 2016. The mercury control calculation adds chemical based on a unit’s coal consumption (which is in turn calculated from the coal data and the unit energy balance). This data is used in the FGD chemistry module, discussed later in this report, to add the appropriate amount of calcium, potassium, chloride, and/or bromide to the FGD water streams.

Table 4-4 (following page) summarizes the mercury control calculations for Units 1, 2, 3, and 4 for the average annual power production and average annual ambient conditions that appear in Table 4-1.

Table 4-4: Mercury Control Chemical Calculations (Average Annual Conditions, Potassium Iodide)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
$CaBr_2$ Feed, lbs per mmlbs Coal	200.00	200.00	200.00	200.00
KI Feed, lbs per mmlbs Coal	12.25	12.25	12.25	12.25
Activated Carbon Feed, lbs per mmlbs Coal	150.00	150.00	150.00	150.00
$CaBr_2$ Feed, lbs/Hr	0.00	0.00	0.00	0.00
KI Feed, lbs/Hr	3.43	3.30	9.19	9.91
Activated Carbon Feed, lbs per hour	42.04	40.44	112.53	121.38
$CaBr_2$, % to Scrubber	80.00%	80.00%	80.00%	80.00%
$CaBr_2$, lbs/Hr to Scrubber	0.00	0.00	0.00	0.00
KI, % to Scrubber	80.00%	80.00%	80.00%	80.00%
KI, lbs/Hr to Scrubber	2.75	2.64	7.35	7.93
Activated Carbon, % to Scrubber	98.00%	98.00%	98.00%	98.00%
Activated Carbon, lbs/Hr to Scrubber	41.20	39.63	110.28	118.95

4.2.5 Fly and Bottom Ash

Ash percentages from the coal data coupled with fuel consumption for each unit were used to calculate fly ash production, bottom ash production, the water content of the bottom ash, wet bottom ash production, bottom ash evaporation, and total bottom ash water loss. This information is used in the FGD and bottom ash modules to model solids and water loading based on power production.

Table 4-5 summarizes the bottom and fly ash calculations for Units 1, 2, 3, and 4 for the average annual power production and average annual ambient conditions that appear in Table 4-1.

Table 4-5: Fly and Bottom Ash (Average Annual Conditions)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
Fly Ash Production, lb/Hr	18,194	17,500	48,703	52,532
Bottom Ash Production, lb/Hr	12,129.63	11,667.17	32,468.74	35,021.93
Bottom Ash Moisture, wt%	20.00%	20.00%	20.00%	20.00%
Water in Bottom Ash, lb/Hr	2,425.93	2,333.43	6,493.75	7,004.39
Wet Bottom Ash Production, lb/Hr	14,555.55	14,000.61	38,962.49	42,026.32
Water Loss in Bottom Ash, GPM	4.85	4.66	12.98	14.00
Bottom Ash Evaporation, GPM/MWh	0.19	0.19	0.07	0.07
Bottom Ash Evaporation, GPM	42.26	40.65	43.47	46.88

4.2.6 SO_2 Removal

Coal data and coal consumption were used to calculate the total SO_2 content in the flue gas. FGD design information was used to determine the removal, on a percentage basis, for the SO_2. This information was then used to calculate the rate of gypsum (calcium sulfate) formation in the FGD units. Table 4-6 summarizes the SO_2 calculations for Units 1, 2, 3, and 4 for the average annual power production and average annual ambient conditions that appear in Table 4-1.

The calculations are used in the model to predict the rate of gypsum formation and the consequent sludge formation in the paste plant, ponds, and other solids handling systems.

Table 4-6: SO_2 Removal (Average Annual Conditions)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
SO_2 Molecular Wt, lb/lbmol	64.07	64.07	64.07	64.07
Sulfur Molecular Wt, lb/lbmol	32.07	32.07	32.07	32.07
Gypsum Molecular Wt, lb/lbmol	172.17	172.17	172.17	172.17
SO_2 in Flue Gas, lb/hr	3,919.72	3,770.27	10,492.35	11,317.42
FGD SO_2 Removal Eff, %	95.50%	95.50%	96.50%	96.50%
SO_2 Removed, lb/Hr	3,743.33	3,600.61	10,125.11	10,921.31
Gypsum Formed, lb/Hr	10,059.76	9,676.23	27,210.08	29,349.75

4.2.7 Lime Feed

Sulfur dioxide (SO_2) is removed by contacting the flue gas with an aqueous solution or slurry containing a sorbent. The most common sorbents are lime ($Ca[OH]_2$) and limestone ($CaCO_3$). After fly ash removal, the flue gas is bubbled through the scrubber, and the slurry is added from above. The lime or limestone reacts with the SO_2 in the flue gas to create insoluble calcium sulfite ($CaSO_3$). The resultant calcium sulfite is further reacted with oxygen to produce gypsum ($CaSO_4$). Lime feed was calculated based on scrubber design data provided by Talen.

No lime is consistently added to the Unit 1 and 2 scrubbers, but the process model does contain lime feed capability for these two units as well as Unit 3 and 4 scrubbers (where lime is consistently added). Table 4-7 provides the results of the lime feed calculations for Units 3 and 4. Results from this calculation are used within the process model to predict solids accumulation and chemistry changes within the FGD.

Table 4-7: Lime Feed (Average Annual Conditions)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
Lime Required, lb/NetMW	0.00	0.00	10.06	10.06
Lime Required, lb/Hr	0.00	0.00	5,989.92	6,460.94
Calcium Hydroxide - $Ca(OH)_2$, lb/Hr	0.00	0.00	7,911.82	8,533.97
Water Req'd for Hydration, lb/Hr	0.00	0.00	1,921.90	2,073.03
Lime Solids in Water, wt%	15.00%	15.00%	9.00%	9.00%
Total Lime Slaking Water, lb/Hr	0.00	0.00	81,919.22	88,360.97
Total Lime Slaking Water, GPM	0.00	0.00	163.71	176.58

4.2.8 FGD Water Losses

General FGD water losses include water contained in solids and water lost to evaporation across the individual FGD units. The FGD evaporation rate has a significant impact on the rate at which salt concentrates in both the STEP and EHP ponds and other FGD-related systems. Design data was provided by the plant. The model uses this design data plus 10% to conservatively estimate the rate at which salt accumulates. Table 4-8 provides the results of the FGD water loss calculations for Units 1, 2, 3, and 4. The results are used within the model to predict changes in FGD chemistry and solids loading.

Table 4-8: FGD Water Losses (Average Annual Conditions)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
Total Solids Formed, lb/Hr	28,295.40	27,216.61	76,023.47	82,001.61
Solids Water Content, wt%	84.40%	84.40%	82.00%	82.00%
Water Loss in Solids, lb/Hr	153,085.37	147,248.86	346,329.15	373,562.88
Total Mass Loss, lb/Hr	181,380.77	174,465.47	422,352.63	455,564.49
Water Loss in Solids, gpm	305.93	294.26	692.10	746.53
FGD Design Evaporation, gpm	350.90	350.90	785.40	785.40
FGD Evaporation, gpm	234.39	225.46	580.92	626.60

4.2.9 Cooling Tower Energy Balance

The energy balance described in Section 4.2.3 calculates the amount of energy that must be removed by the individual cooling towers. This energy calculation is determined by difference in accordance with equation 4.2.9-1.

<u>Equation 4.2.9-1:</u>

Cooling Tower Heat Load = Total Thermal Energy Input – Electrical Energy Generated – Parasitic Energy Losses – Stack Energy Losses

Stack and parasitic energy losses for the plant were not available, but these losses are well-defined in coal-plant designs. These losses vary only slightly from plant to plant. Cooling tower load is very large in comparison to the parasitic and stack energy losses, so small differences in the latter two would not result in significant change to the cooling tower heat load.

This cooling tower heat load determines the heat that must be rejected by the individual unit cooling towers. Cooling tower design information (recirculation rate, drift rate, liquid/gas ratio) coupled with ambient conditions (makeup water temperature, wet bulb, dry bulb) determine the moisture and mass flow of the incoming air as well as the moisture and mass flow of the exit air. The difference in moisture mass in the exit and incoming air dictates the cooling tower evaporation rate. The cooling tower heat load must equal the heat removed by the air in order to maintain the necessary plant energy balance. Cooling tower drift losses are a relatively minor flow and were calculated as a percentage of recirculation rate. The drift percentage was provided by Talen.

Table 4-9 (following page) provides the results of the cooling tower energy balance for Units 1, 2, 3, and 4. These results, coupled with chemistry, are used within the model to determine cooling tower chemical feed requirements, cooling tower blowdown flow, and cooling tower makeup water flow.

Table 4-9: Cooling Tower Energy Balance (Average Annual Conditions)

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
Total Cooling Water Flow, gpm	113,000	113,000	238,000	238,000
Cooling Water Approach Temp, deg F	15.00	15.00	15.00	15.00
Cooling Water Supply Temperature, deg. F	57.51	57.51	57.51	57.51
Cooling Water Temperature Rise, deg F	22.02	21.18	27.99	30.19
Cooling Water Return Temperature, deg. F	79.53	78.69	85.50	87.70
L/G Ratio	0.97	0.97	1.00	1.00
Temperature of Exit Air, deg F	72.78	71.93	79.05	80.94
Drift (as % of Recirc Water Flow)	0.005%	0.005%	0.010%	0.010%
Makeup Water Temperature, deg. F	57.51	57.51	57.51	57.51
Water Content of Entering Air, grains/lb dry air	37.45	37.45	37.45	37.45
Enthalpy of Entering Air, Btu/lb	17.16	17.16	17.16	17.16
Water Content of Leaving Air, grains/lb dry air	137.17	133.21	170.26	181.58
Enthalpy of Leaving Air, Btu/lb	38.89	38.06	45.63	47.88
Humidity Ratio of Leaving Air, lb water/lb dry air	0.01960	0.01903	0.02432	0.02594
Dry Air Flow, lb/min	971,567	971,567	1,984,920	1,984,920
Humidity Ratio of Entering Air, lb water/lb dry air	0.00535	0.00535	0.00535	0.00535
Heat Rejected from CW, MMBtu/hr	1,245	1,198	3,333	3,595
Heat Removed by Air, MMBtu/hr	1,246	1,198	3,333	3,596
Qair/Qcw	100%	100%	100%	100%
Tower Evap, gpm	1,660	1,594	4,516	4,900
Tower Drift, gpm	5.65	5.65	23.80	23.80

4.2.10 Boiler Thermal and Hydraulic Balance

Talen provided boiler design data that included efficiency. Boiler steaming rate is a function of total thermal energy input, boiler efficiency, and drum pressure. Process Flow Diagram (PFD) data entry, described later in this report, allows users to specify individual unit heat rates, boiler efficiencies, drum pressures, unit power production, boiler blowdown (as a percentage of steaming rate), and other data used in the calculation. This information is used to calculate blowdown flows, steam losses to atmosphere, blowdown quench water requirements, boiler makeup requirements, and other water losses.

Table 4-10 (following page) summarizes the results for Units 1, 2, 3, and 4. These results are used within the model to calculate blowdown and quench water chemistries, boiler chemical feed requirements, and other boiler operating data.

Table 4-10: Boiler Thermal and Hydraulic Balance

Parameter	Unit 1	Unit 2	Unit 3	Unit 4
Boiler Efficiency, %	82.50%	82.50%	84.50%	84.50%
Drum Pressure, psia	2,600	2,600	2,520	2,520
Steam Enthalpy, BTU/lb	1,080	1,080	1,089	1,089
Steam Flow, lb/hr	1,801,099	1,732,431	4,896,414	5,281,445
Blowdown, % of steam flow	2.00%	2.00%	1.00%	1.00%
Blowdown Flow, lb/hr	36,022	34,649	48,964	52,814
Blowdown Tank Pressure, psia	13.07	13.07	13.07	13.07
Blowdown Condensate, lb/hr	14,993	14,421	20,886	22,528
Blowdown Vent Steam, lb/hr	21,029	20,227	28,078	30,286
Blowdown Vented to Atmosphere, gpm	42.02	40.42	56.11	60.52
Blowdown to Drain, gpm	29.96	28.82	41.74	45.02
Blowdown Drain Temp, deg F	140.00	140.00	140.00	140.00
Quench Water Temperature, deg F	75.00	75.00	75.00	75.00
Boiler Leaks & Drains, gpm	10.00	10.00	10.00	10.00
Boiler Makeup, gpm	81.99	79.24	107.85	115.54
Blowdown Quench Water, gpm	33.19	31.92	46.23	49.87
Quench Rtn Flow, gpm	63.15	60.74	87.97	94.89
Heat Load of Quenched Blowdown, mmBTU/Hr	1.90	1.82	2.64	2.85

4.2.11 Process Flow Diagram (PFD) Inputs

Many of the inputs described earlier were consolidated and placed on the PFD for ready reference and adjustment. These key inputs on the PFD allow users to quickly change conditions and evaluate the impacts to the whole-plant water and chemistry balance. User-adjustable inputs appear throughout the model, but the inputs located on the PFD define the key parameters that commonly vary and that significantly impact the plant's water and chemistry balance. A complete description of these inputs, their purpose, and their location on the PFD is beyond the scope of this report. Training on use of the process model can be provided on request.

4.2.12 Chemistry Data

Individual treatment processes must be tuned as chemistry dictates. Chemistry is an essential process model input. Simple flow or mass balances cannot determine overall plant water demands.

Accurate modeling of chemistry is perhaps even more important than accurate modeling of flow. No chemistry changes occur in some processes other than direct mixing (dilute brackish water streams in tanks, for example), but many processes result in significant changes in chemistry (FGD units and cooling towers, for example). Mixing streams can dissolve some salts, precipitate others, and change the form of still others. Spreadsheet modeling was used for relatively simple processes where no significant precipitation or dissolution occurred. Specific modeling programs (WaterCycle Rx by French Creek Software, Studio Stream Analyzer by OLI Systems) were used where necessary to calibrate and confirm the results of spreadsheet models.

Water quality for the various sources evaluated appears in their respective calculation sheets. Talen provided chemistry data from several sources for various waters including off-site laboratory results, solids analysis, and on-site logsheet and laboratory data. This data was evaluated, averaged, compared, and reconciled to obtain the water qualities used in the model and in the preparation of this report. Water quality changes constantly, however, and even relatively minor changes in water quality can significantly impact the rate at which salt enters and exits the plant. That being the case, the model can be used to evaluate changes in water chemistry regardless of the process in which they occur.

In broad terms the plant receives makeup water from three sources – raw water, capture well water, and precipitation. Chemistry data was available for both the raw water (Castle Rock Lake) and the capture wells. Plantsite, STEP, and EHP water chemistry was also available. Chemistry from these sources was used as the model starting point. Changes in chemistry are automatically calculated by the model as they occur. Chloride concentration in a pond, for example, changes in the course of an evaluation period. Model iterations carry forward the final chemistry from the iterative calculation over an evaluation period and use it as the starting chemistry for the iteration in the next sequential evaluation period.