GRAND CANYON RAILWAY BOILER WASTEWATER PRETREATMENT AND STORAGE

60% Design Report

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Grand Canyon Railway Capstone Team

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Abstract

The goal of the Grand Canyon Railway project is to design a storage tank and develop pretreatment methods for the effluent boiler wastewater from two biodiesel-fired steam locomotives for subsequent treatment at the Williams Wastewater Treatment Plant. The wastewater to be treated is produced from a process called "Boiler Blowdown" in which water in the boiler is heated and pressurized to blow out the built-up sediment at the bottom of the boiler. The resulting wastewater has a high pH and high concentration of total dissolved solids. These parameters will be treated to meet minimum requirements for discharge into Williams Wastewater Treatment Plant. This proposal looks to outline the engineering work, cost, and staffing required for the completion of alternative solutions to this problem.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ADEQ	Arizona Department of Environmental Quality
BOD	Biochemical Oxygen Demand
CFR	Code of Federal Regulation
EPA	Environmental Protection Agency
GCR	Grand Canyon Railway
GCRP	Grand Canyon Railway Boiler Wastewater Pretreatment and Storage Project
GIS	Geographic Information Systems
NAU	Northern Arizona University
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WWTP	Wastewater Treatment Plant
WWWTP	Williams Wastewater Treatment Plant

List of Equations

Table of Appendices

1. Project Introduction

1.1. Project Understanding

The Grand Canyon Railway Boiler Wastewater Pretreatment and Storage Project (GCRP) has been tasked with designing a storage and pretreatment process for the wastewater from two biodiesel-fired steam locomotives. Over the course of weekly commutes to and from the Grand Canyon, the boiler wastewater becomes highly concentrated with total dissolved solids (TDS) and discharges at a pH of 11.2. At the end of each season, to prevent freeze damage to the piping system, the Grand Canyon Railway (GCR) performs a “blowdown” process which heats and pressurizes the closed boiler system and subsequently blows out all the wastewater and impurities from the boiler. The boiler wastewater had previously been discharged to the local wastewater treatment plant (WWTP) however, due to new influent standards implemented by the United States Environmental Protection Agency (EPA), the wastewater requires pretreatment in order to adhere to these newly implemented standards. The GCR is currently transferring the boiler wastewater to an industrial wastewater treatment plant in Phoenix, a process that is costly and cumbersome. The GCRP will present the client with several different pretreatment alternatives that are both effective and more fiscally responsible than the current disposal methods.

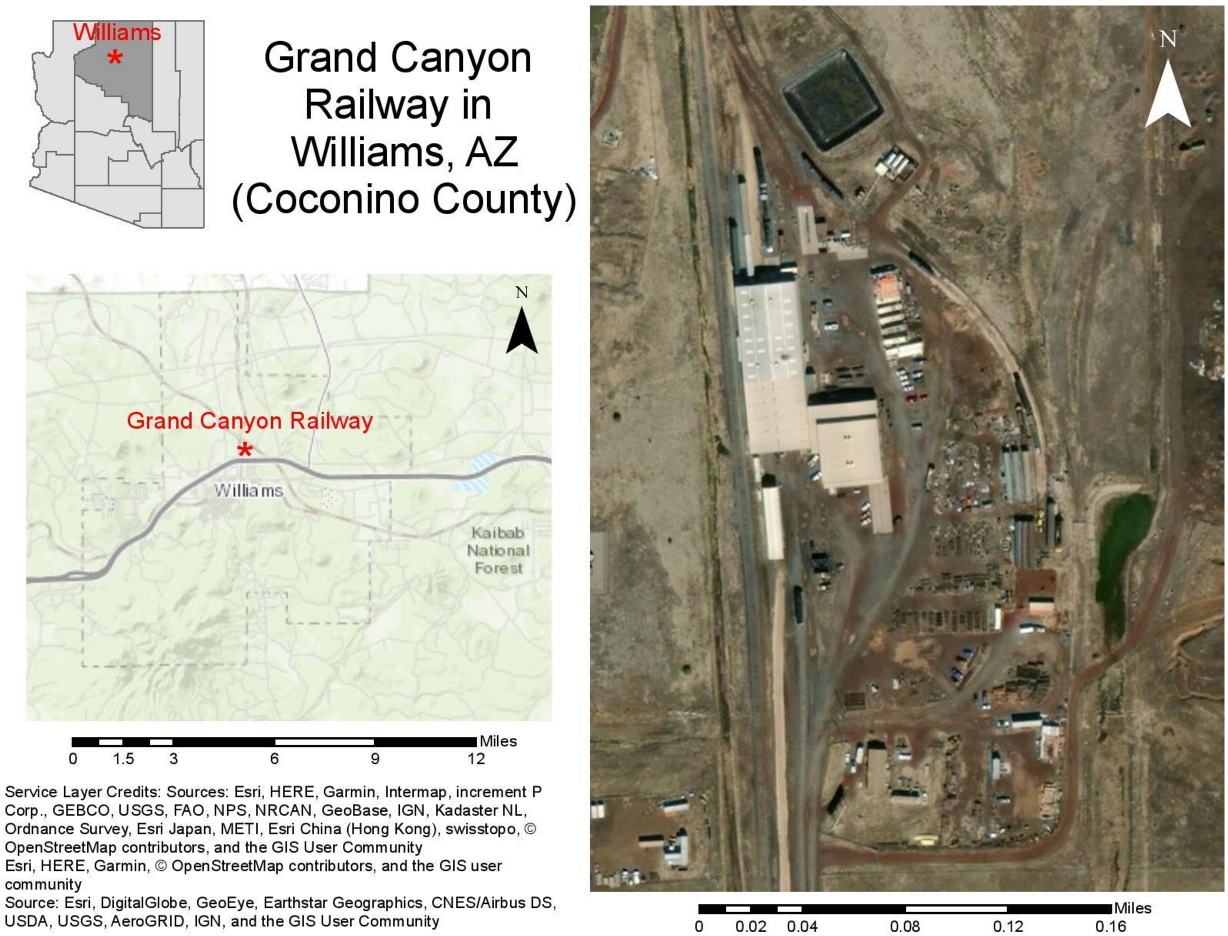

Figure 1. Site map of the Grand Canyon Railway Station (ArcMap).

As shown in Figure 1, above, the site of the Grand Canyon Railway Station is in Williams, Coconino County, Arizona approximately 35 miles west of Flagstaff, Arizona. The station itself is positioned less than a mile east of the local Williams Wastewater Treatment Plant (WWWTP).

1.2. Project Background

The inner mechanics of a steam locomotive involve firing a given fuel within a fire box to heat water in a system of pipes, located in the boiler [1]. This water is superheated and transported from the pipe system to the cylinder of the wheel, pushing the piston and subsequently the wheel forward by one half turn. As the steam exits the system, the negative change in air pressure pulls the piston back and this energy creates one half turn, completing a full wheel turn [1]. The steam that leaves the boiler is pure vapor, because of this when it is superheated and exits the system, sediments and minerals remain behind [1]. Due to this phenomenon, impurities are left in the boiler water and as time goes on, the contaminations become oversaturated within the tank and precipitate [2]. This reaction leaves the wastewater concentrated with inorganics and dissolved solids.

Figure 2, below, displays the entire boiler water cycle, from source to sink. Source water is either rainwater collected in the on-site pond or tap water. Source water is then sent through a sand filter and softener to remove hardness ions, preventing precipitation of the calcium and magnesium out of solution and thus scaling on the heat transfer pipes within the boiler. Treated source water is then sent to the tender, the storage tank on the train itself, to supply water to the boiler. The locomotives leave the Grand Canyon Railway station in Williams, AZ with the boiler and tender tank filled with treated water to complete the trip to and from the Grand Canyon. The replacement of the water in the boiler from the tender occurs throughout the trip to and from the Grand Canyon to maintain boiler temperature and pressure. This process causes constant deposition of solids that precipitate out as the water is turned to steam. This cycle is completed every weekend from mid-summer to late fall and requires about 12,000 gallons to get to and from the Grand Canyon. Since this process occurs throughout the season, the dissolved solids concentration increases until the end of the season when the boiler is blown down with 4000 gallons of water. This blowdown process occurs for both steam engines and thus 8,000 total gallons of wastewater is produced with an approximate TDS concentration of 1500 mg/L and a pH of 11.8. The blowdown wastewater is stored in a holding tanker until it is eventually transported to and treated at a Phoenix WWTP at a cost of approximately $5,000 each year. GCR would like to send boiler wastewater to the Williams WWTP however influent water the plant must have less than 350 mg TDS/L and a pH less than 9. Instead of the boiler wastewater entering the holding tanker, the wastewater will be sent to the chosen on-site pretreatment. From there the wastewater will be sent to the existing on-site grinder pump that is already connected to the Williams WWTP.

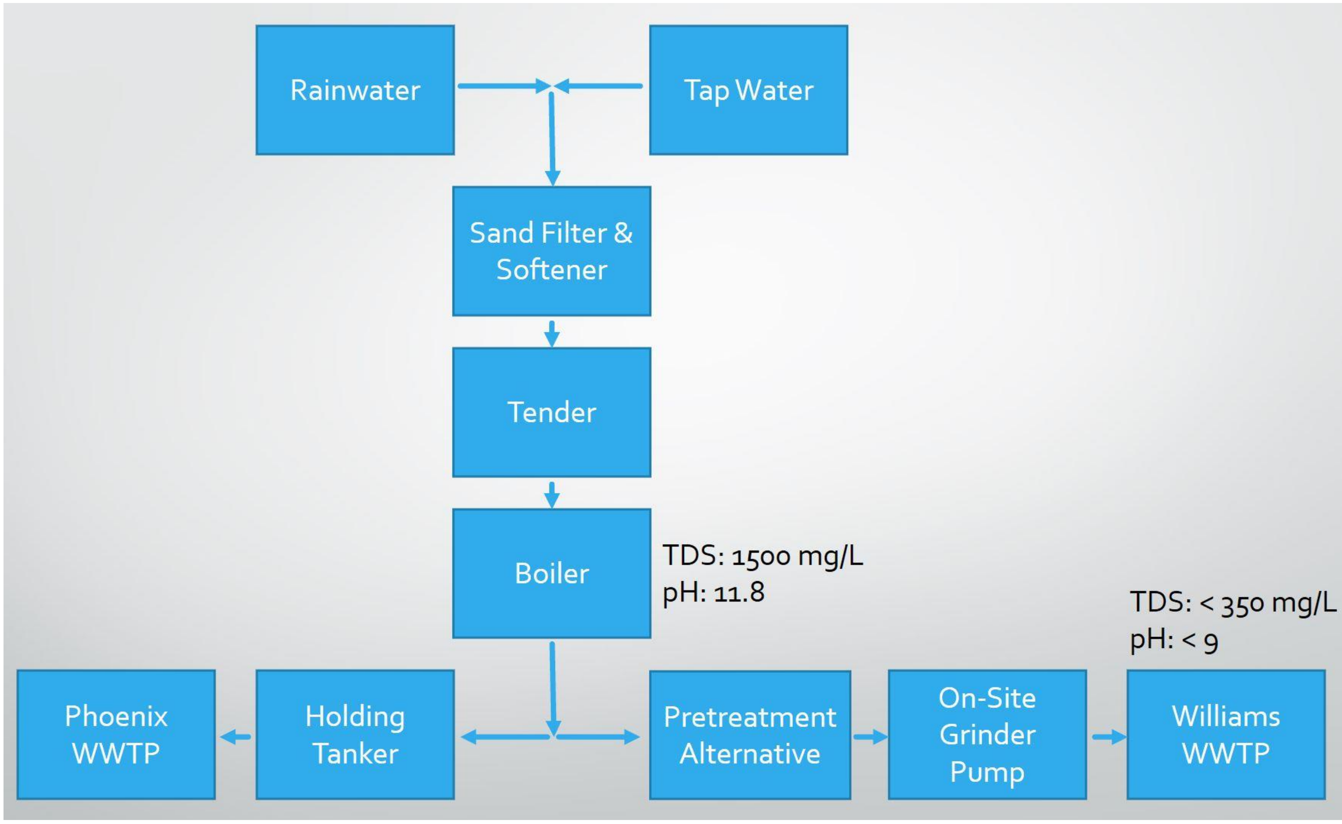

Figure 2. Boiler water source to sink schematic (Microsoft PowerPoint).

There are several chemicals that are added to the influent boiler water to prevent scaling, corrosion, and ionic transformations. The chemicals being added to the boiler are produced by ChemTreat. Due to trademark concerns, it is unclear what the concentration, ratios, and volumes of each compound present in the chemical mixtures added to influent water. These chemicals include the following outlined in Table 1, below.

Table 1: ChemTreat chemicals added to influent boiler water.

ChemTreat Product	Main Compound	Use
SS16 [3]	Citric Acid	Cleans resin from the softener and assists in the softening of influent water.
BL197 [4]	Polyalkylene Glycol Monobutyl Ether	Anti-foaming agent added to boiler water to increase efficiency.
BL1240 [5]	Erythorbic Acid	An oxygen scavenger that creates an oxygen free environment and prevents corrosion.
BL1775 [6]	Nitrate/Phosphate Compound	Prevents caustic embrittlement of the piping and tank.
BL8100 [7]	Filming Amine	A filming amine that creates a monomolecular film that protects the tank from corrosion.

1.3. Constraints and Limitations

This project is limited by several factors that could impact the effectiveness of the pretreatment option and wastewater storage alternatives. The exact chemical make-up of each compound added to the influent boiler water are unknown with respect to their volumes, ratios, concentrations, and frequency. This will remain unknown because the manufacturer has established this as their trademark recipe for boiler maintenance and it is to remain confidential. Additionally, the members of the GCRP team are unauthorized to retrieve a sample of the boiler wastewater due to constraints of occupational safety and health regulations. Because of this, collection methods of the sample may not consistent with proper sampling and storage methods outlined in the proposal.

Influent wastewater must meet be treated to certain standards per the WWWTP. The current state of GCR's wastewater does meet the standards of the WWWTP and therefore must be pre-treated to allow disposal.

Table 2: Influent wastewater standards set by the Williams WWTP

Parameter	Boiler Wastewater	Williams WWTP Influent Requirements
pH	11.8	5.5 < pH < 9
TDS (mg/L)	1500	< 350

The influent standards provided give a constraint of how the wastewater can be treated. The treated water must be treated to a level between the constraints. These constraints effect how the wastewater can be treated and therefore what methods are used during pre-treatment.

1.4. Major Objectives and Unique Deliverables

1.4.1. Cost and Lifecyle Analysis of Pretreatment Alternatives

The major objective of the project is to generate cost and life cycle analyses of the three chosen pretreatment alternatives. It will be presented to the client for them to make an informed decision on how they would like to handle the boiler wastewater. This is a client and CENE 486 deliverable.

1.4.2. Project Status Presentations

Each project member will generate and present a 6 to 8 minute presentation and answer questions for 5 to 7 minutes. The presentation will update CENE 486 students and professors on the progress of the report. This is a CENE 486 deliverable.

1.4.3. Reflection

Each project member will complete a personal reflection of their own experience with the project. Each reflection will include information on the "Triple Bottom Line" and how it relates to the project, project management skills developed during the project, as well as teamwork during the project. This is a CENE 486 deliverable.

1.4.4. Meeting Memo Binder

A meeting memo binder is maintained to organize and archive meeting minutes from team meetings, grading instructor meetings, technical advisor meetings, as well as client meetings. This is a CENE 486 deliverable. This is a CENE 486 deliverable.

1.4.5. Progress Reports

Four progress reports will be generated: a 30% report, a 60% report, a 90% report, and a final report. Progress reports ensure that the team in on schedule to complete the project within the allotted time frame. This is a client and CENE 486 deliverable.

1.4.6. Website

A publicly-accessible website will also be produced that explains the project. It will contain team, client, and project information as well as a document repository of all deliverables. This is a CENE 486 deliverable.

2. Field Work

2.1. Site Investigation

Initial site investigation of the Grand Canyon Railway led to the determination that the chemical additions outlined in Table 1. These chemicals change the chemistry of the water as it passes through the softener and as it interacts with the boiler. This information impacts the treatment process of the water and the potential solutions to the water quality issue presented. Additionally, the site visit allowed for a visual evaluation of the rainwater catchment basin and its capacity in case the team was to utilize the basin for storage. Finally, the site visit allowed for the team to conclude that a small-scale treatment and storage system is required to utilize the space efficiently.

2.2. Sampling

Sampling of the boiler water and rainwater was completed using ASTM 3370-10. However, due to restraints by the occupational safety and health act (OSHA) the team was unable to sample from the boiler water. Employees at GCR obtained the sample at the instruction of the team to maintain QA/QC of the sample to be tested for the parameters outlined in section 3.

3. Testing/Analysis Performed

3.1. NAU Environmental Engineering Lab Testing

3.1.1. pH Testing Methods

The pH of the boiler wastewater, post-softener, tap water, and rainwater were measured using standard method ASTM D1293 [8]. Each pH measurement was performed three times each with two previously calibrated pH meters. The results of the total of six tests for each water type were averaged to ensure quality assurance (QA) and quality control (QC). The averaged results of the pH tests can be found in Table 3.

3.1.2. TDS Testing Methods

Total Dissolved Solids (TDS) in the wastewater was measured using standard method ASTM D5907 [9]. To ensure proper QA/QC, each water type was tested twice. Similar to pH measurement, the average of the results was used as the representative concentration of TDS in the water. The standard deviation of each sample was calculated to allow for possible variation in the results. The results of this test can be found in Table 3.

3.1.3. TSS Testing Methods

Total Suspended Solids (TSS) was measured using standard method ASTM D5907 [8]. This test is a preliminary step to TDS testing thus, two tests for each type of water were performed. The average of these tests was calculated in addition to standard deviation. The results of this test can be found in Table 3.

3.1.4. Iron Testing Methods

Total iron was tested using HACH method 8008 [10].This method requires the reaction of the wastewater with a powder pillow ordered from the certified HACH website and the measurement of total iron concentration with a spectrophotometer. Each sample was measured once, due to powder pillow quantity restraints. The results of the total iron concertation can be found in Table 3.

3.1.5. Results

The boiler wastewater was sampled and tested for pH, TDS, TSS, and total iron at four different stages: source rainwater, source tap water, post-softener source water, and post-use boiler wastewater. Table 3 below, displays the results of the lab analysis. The raw data set is available in appendix A2.

Table 3. TDS, TSS, pH, and Iron Test Results.

Sample Type	Total Iron	TDS	TSS	pH
	mg Fe/L	mg/L	mg/L	
Boiler Wastewater	0.40	2196.90 +/- 26.59	23.40 +/- 8.63	11.70 +/- 0.06
Post-Softener	3.17	397.25 +/- 13.08	16.00 +/- 1.98	6.99 +/- 0.25
Rainwater	5.58	3.00 +/- 1.56	24.60 +/- 3.68	6.61 +/- 0.28
Tap Water	0.00	173.95 +/- 27.08	2.90 +/- 3.11	7.15 +/- 0.22

3.2. GCR Boiler Water Control Report

The GCR completes internal testing of the boiler, tender, and softener water. A copy of the control report thus far was provided by GCR. Interpretation of the control report is currently unclear, preventing analysis of much of the data in the report. Clarification is expected in the immediate future. The complete control report is available in Appendix A1.

Figure 3, below, displays linear regression lines comparing boiler water conductivity with the volumes of four of the five chemical additives. The fifth chemical additive, BL197, was not included, as no volume data is noted in the provided report. No correlation was found between conductivity and BL1240, BL8102, or SS16; all of the regression lines had R^2 values less than 0.04. BL1775 showed positive correlation but it is not a strong correlation with an R^2 value of 0.5194. It is important to note that SS16 is added to a holding tank on the water softener and so the actual volume of SS16 used each time is unknown. Thus, the lack of correlation between SS16 and boiler water conductivity may not be apparent in this analysis.

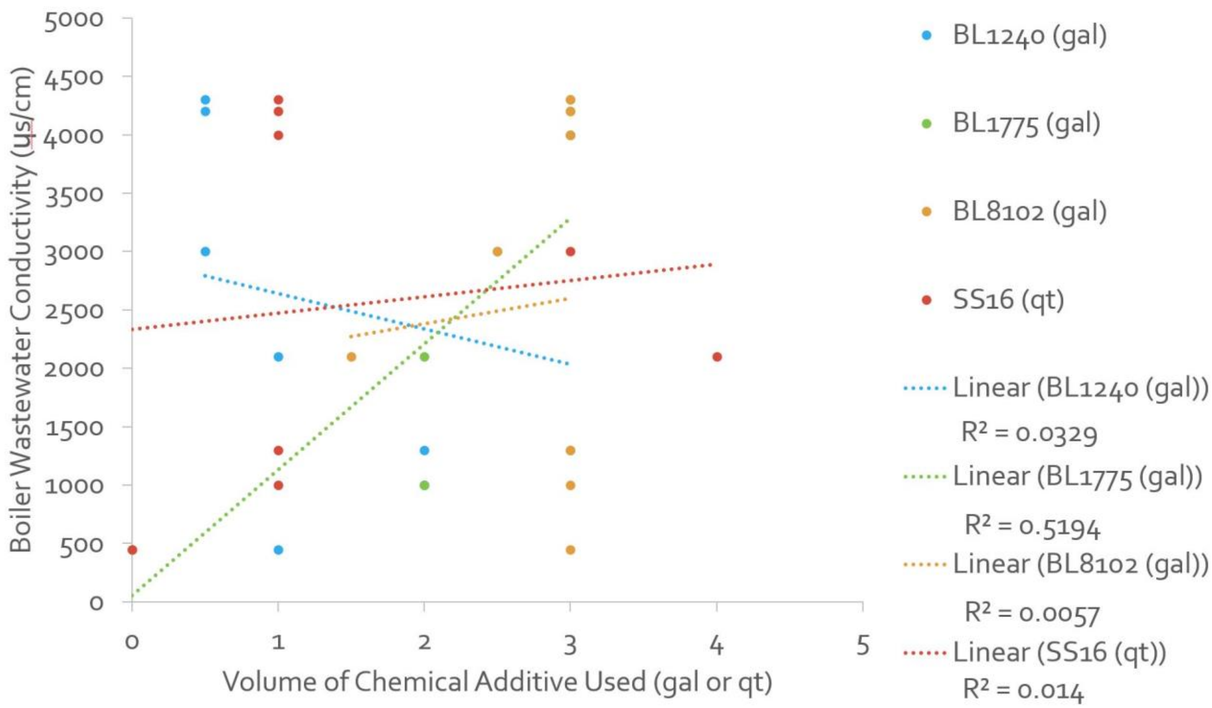

Figure 3. Boiler water conductivity versus volume of chemical additive (Microsoft Excel).

Although speculative at this point, it is believed that the SS16 is not being flushed out of the softener during regular maintenance. In regular zeolite softener maintenance, the softener is first backwashed, then SS16 is run through the softener to replace the hardness ions that have accumulated on the zeolite with sodium ions, and then a final rinse is completed to remove any unwanted traces of the SS16. Boiler water conductivity ranged from 1000-4000 µS/cm for all testing dates except the most recent test where the conductivity was 450 µS/cm. The GCR ran out of SS16 and BL1775 and so they were not used on the last testing date despite standard use for each treatment run. As SS16 is a high conductivity solution, the sudden drop in conductivity when SS16 was not used likely indicates a relationship between the two parameters.

4. Alternatives Pursued

4.1. Rejected Alternatives

4.1.1. Alternative 2: Dilution

This alternative is no longer in consideration. Dilution did not meet the criteria of GCR. Dilution would require excess water to dilute the wastewater into a state that is acceptable by the Williams WWTP. Dilution would bring both the TDS and pH down by amending the wastewater with clean water. Williams, however, does not have a water supply to support the amount of water needed for dilution. Also, this alternative does not treat the water but instead evades the Williams WWTP requirements in an unethical manner.

4.1.2. Alternative 3: Coagulation and Flocculation

This alternative is no longer in consideration. Coagulation and flocculation can reduce the amount of TDS however the use of the coagulation and flocculation system requires a permit per ADEQ. The client, however, requested that there be no permitting involved. Additionally, this alternative has a large demand for maintenance and sludge disposal, which can be unfavorable to daily operation of the station.

4.1.3. Alternative 5: Switch Source Water to Tap Water Only

This alternative is no longer in consideration. Rain water did not appear to impact water quality, so the switch would have no negative effect on boiler wastewater TDS or pH. The rainwater has less TDS than tap water. TDS values for rainwater averaged 3.00 +/- mg/L for rainwater and 173.95 for tap water pH. The complete data set for the water analysis is available in appendix A2.

4.2. Alternatives to be Pursued

4.2.1. Alternative 1: Operation and Maintenance Improvements

The first alternative being pursued is to adjust the existing operation and maintenance aspects of the boiler water process. Below is a table that illustrates each of the operation and maintenance characteristics that require adjustment/improvement:

Table 4: Current and proposed operation and maintenance for the GCR.

Operation & Maintenance	Current O&M of GCRR	Proposed O&M for GCRR
Zeolite Softener Column	• Pressurized fiber glass column. • Influent water flows over a zeolite bed and exits the system through a 10-micron filter. • Currently, no back washing or zeolite bead replacement performed on a regular basis.	• Maintain fiber glass column however, replace the zeolite beads every two to three months [11]. • Backwashing is recommended to be performed at least every six months, depending on the average flow rate of the influent [12].
Increased Blowdown Schedule	• The trains are being blown down once a year, for winterization. • This concentrates contaminants over time, more frequent blowdowns of the trains can keep the boiler from becoming over concentrated and prevent the wastewater from having high concentration of TDS.	• Implementing more frequent blowdowns (every other time the trains run) can keep the boiler from becoming over concentrated with solids. • A concern of this is that blowdowns require chemicals that can strip the inside of the boiler [13].
Sand Filter Maintenance	• There is currently no frequent maintenance of the sand filter. • Pressurized environments can clog the filter with solids not easily removed through backwashing.	• Install a sand filter prior to entering the pressurized column so that influent is not under pressure. • Perform backwashing on the media every two to three months [12].
SS16 Flush	• There is no known action being taken to regenerate the resin in the softener. • This can cause the resin to be filled with hardness (calcium, magnesium, and iron) and let hardness pass through.	• Practice a four-step process of regenerating the resin on a weekly basis: • Backwash the system. • Wash the resin with brine and SS16. • Perform a slow rinse to allow the bed to reclassify and rid of excess brine. • Fast rinse to re-compact bed [14].

4.2.2. Alternative 4: New Zeolite Softener

The second solution being pursued is to replace the existing zeolite softener with a new model. The zeolite softener has been in use for 15 years despite a seven-year lifecycle. As the softener is past the life cycle given by the manufacturer, the softener cannot be expected to perform as expected.

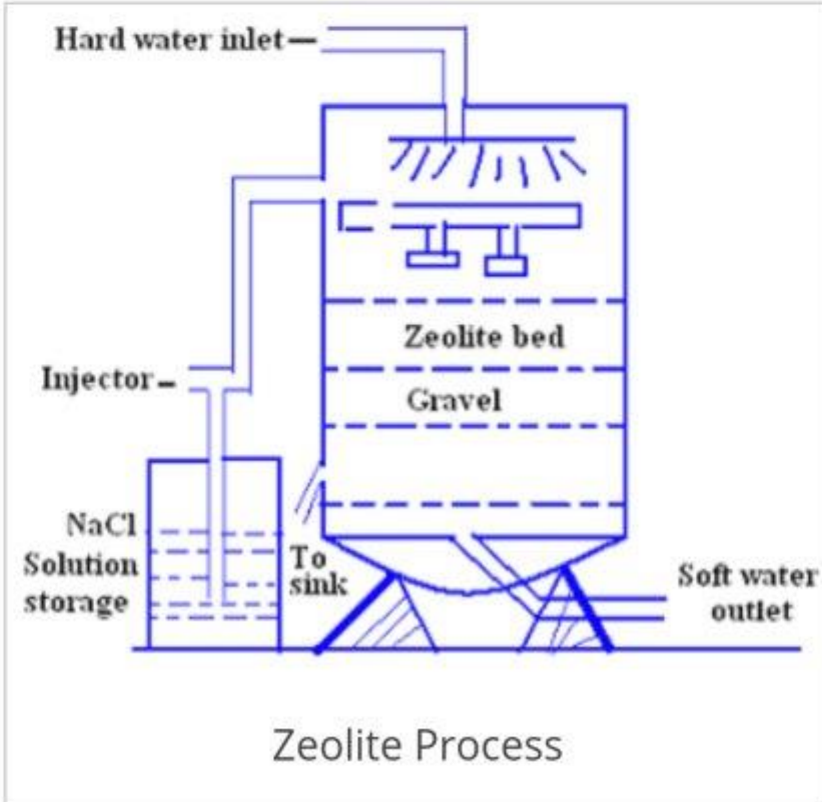

Figure 4. Zeolite softener schematic [15].

The alternative of acquiring a new zeolite softener was further implemented once the conductivity results in appendix A1 was received. The results show a conductivity of 450 uS/cm on October 4th which correlates to a TDS value of about 225 mg/L. The inferred reason that the conductivity dropped so low in this instance is because SS16 was not added to the softener. The SS16 chemical is used to flush the softener, so that excess salts can be removed prior to running feed water through it. The assumption is that there are excess salts on the softener and the SS16 is stripping the zeolite and not flushing the salts. The day SS16 was not added, the salts were not stripped from the zeolite and therefore led to a lower conductivity. With a new softener and proper O&M to maintaining the zeolite bed, the TDS should be able to remain at a low level such as October 4th.

4.2.3. Alternative 6: Reverse Osmosis and Reuse

The third alternative being pursued is a reverse osmosis or RO system. An RO water treatment system is commonly used in desalination. The RO process and consists of a water high in TDS or conductivity being forced through a semipermeable membrane in the direction opposite to that of natural osmosis, this process requires a large amount of pressure and produces concentrated water as a byproduct. This system is the most viable for reuse of the water onsite because the water is treated to an acceptable level to be discharged or reused onsite. Potential issues behind the use of RO is the amount of concentrate water produced. Typical RO systems have a recovery rate of 50-75% [16] which would mean the concentrate water would likely need to be disposed of or shipped to an industrial wastewater treatment plant. However, the recovery rate outlined for RO systems typically assume 10,000 ppm or mg/L of TDS [17]. Because of this, it is likely that the recovery rate on the treatment of the GCR's wastewater would likely be higher than the 50-75%. For the analysis of this project, 50% recovery will be assumed to ensure a factor of safety in the treatment of the wastewater.

(60% only required to be completed up to this point)

5. Final Design Recommendations

5.1. Lifecycle Analysis

5.1.1. Alternative 1: Operation and Maintenance Improvements

5.1.2. Alternative 4: New Zeolite Softener

5.1.3. Alternative 6: Reverse Osmosis and Reuse

5.2. External Impacts

5.2.1. Cultural

5.2.2. Socioeconomic

5.2.3. Environmental

5.2.4. Global

6. Cost of Implementing the Design

7. Summary of Engineering Work

7.1. Scope and Schedule

7.2. Changes to Scope and Schedule

7.3. Original and Modified Gantt Chart

8. Summary of Engineering Costs

8.1. Staffing and Cost

8.1.1. Employee 1

8.1.2. Employee 2

8.1.3. Employee 3

8.1.4. Employee 4

8.2. Changes to Staffing and Cost

8.3. Original and Modified Staffing Chart

8.4. Original and Modified Cost Chart

9. Conclusion

10. References

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[4] ChemTreat, *Safety Data Sheet BL197,* Glen Allen, 2018.

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Appendixes

A1. Grand Canyon Railway Boiler Water Control Report

Grand Canyon Railway
Boiler Water Control Report — Locomotive: 4960 — Year: 2018

GRAND CANYON Railway

Control Tests	Control Limits														
Date		15-Feb	27-Feb	3-Apr	19-Apr	3-May	31-May	9-Aug	13-Sep	4-Oct					
Boiler		Pre	Post	Post	Post	Post	Post	Post	PRE	Post	Post	Post	Post	Post	Post
Conductivity	<3500 uS/cm	1000	1300	2100	4200	4300	3000	4400	4000	450					
pH	Record	10.1	9.6	8.8	11.44	12	11.7	12.04	11.55	10.1					
OH Alkalinity	100-300 ppm	140	90	350	400	900	375	900	820	0					
Orthophosphate	20-40 ppm	3.9	2.4	40.4	11.9	14.9	18.6	21.9	13	9.6					
Iron (Ferrover)	Record	0.56	0.08	0.23	0.34	0.16	0.23	0.21	0.86	over					
Millipore Iron	Record	150	10	10	500	75	50	150	200	250+					
Oxygen Scav	80-320 ppb	7	140	302	OVER	321	308	249	UL	400					
Tender		Pre	Post	Post	Post	Post	Post	Post	Post	Post	Post	Post	Post	Post	Post
Conductivity	Record	200	199	310	300	310	300		400	150					
pH	8.5-10.0	9.2	8.9	10.1	9.28	6.88	6.93		7.25	7.5					
Trace Hardness	<1 ppm	4	0	0	0	0	0		0	0					
Orthophosphate	20-40 ppm	4.7	2.2	2.5	5.5	25	27		8	3.1					
FFA (Titan 360)	0.2-1.0 ppm	0	0.5	0.3	0	0	0		0	0					
Iron (Ferrover)	<0.1 ppm	0.5	OVER	1.55	2.08	5.8	3.8		4.2						
Millipore Iron	Record	100	100	25	75	10	10		50	100					
Oxygen Scav	80-320 ppb	2	165	29	34	239	256		160	77					
Softener		13-Feb	28-Feb	3-Apr	19-Apr	3-May	31-May		12-Sep						
Trace Hardness	<1 ppm	0	0	0	0	0	0	0	0						
Treatment Added		17-Feb	3-Mar	7-Apr	21-Apr	5-May	2-Jun		15-Sep	6-Oct					
Oxygen Scavenger Initial Dosage = 1 Quart	BL1240	2 Gal	2 Gal	1 Gal	.5 Gal	.5 Gal	.5 Gal		3 Gal	1 gal					
Orthophosphate Initial Dosage = 1 gallon	BL1775	2 Gal	3 Gal	2 Gal	3 Gal	3 Gal	2.5 Gal		3 Gal	0 (out c					
Cetamine Initial Dosage = 1 gallon	BL8102	3 Gal	3 Gal	1.5 Gal	3 Gal	3Gal	2.5 Gal		3 Gal	3 gal					
Initial Dosage = 12 ounces	BL197	On Board	On Board	On Board	X1	On Board	On Board		On Board	On Board					
Initial Dosage = 1 Quart pe regeneration	SS16	X1	X1	X4	X1	X1	X3		x1	0					

A2. Water Quality Analysis Data

Table 5. Raw pH lab data.

	Sample Type	Boiler Wastewater			Post-Softener			Rainwater			Tap Water		
pH	Trial	1	2	3	1	2	3	1	2	3	1	2	3
	Oakton pH 700 Meter	11.80	11.71	11.68	6.85	6.71	6.74	6.23	6.28	6.70	7.08	7.39	7.45
	Cole Parmer pH Meter	11.70	11.66	11.64	7.19	7.31	7.12	6.80	6.87	6.76	6.88	7.02	7.07
	Average	11.70			6.99			6.61			7.15		
	Standard Deviation	0.06			0.25			0.28			0.22		

Table 6. Raw TDS lab data (sample volume = 50 mL).

	Sample Type	Boiler Wastewater		Post-Softener		Rainwater		Tap Water	
TDS (g)	Trial	1	2	1	2	1	2	1	2
	Empty Evap. Dish, M0	48.63087	47.33575	47.84139	46.33578	48.3306	49.0526	47.03082	48.54523
	M1	48.74148	47.44417	47.86047	46.35597	48.33072	49.05263	47.03843	48.55482
	M2	48.74183	47.44514	47.86111	46.35624	48.33067	49.05298	47.03869	48.55495
	Difference: M1-M2	-0.00035	-0.00097	-0.00064	-0.00027	5E-05	-0.00035	-0.00026	-0.00013
	Average M, MA	48.74166	47.44467	47.86079	46.35611	48.33070	49.05281	47.03856	48.55489
	Difference: MA-M0	0.11079	0.10891	0.0194	0.02033	9.5E-05	0.000205	0.00774	0.00966
	Average for Sample	0.10985		0.01986		0.00015		0.00870	
	Standard Deviation	0.00133		0.00065		0.00008		0.00135	

Table 7. Raw TSS lab data (sample volume 50 mL).

	Sample Type	Boiler Wastewater		Post-Softener		Rainwater		Tap Water	
TSS (g)	Trial	1	2	1	2	1	2	1	2
	Empty Evap. Dish, M0	1.37144	1.37243	1.37042	1.36918	1.36439	1.367	1.37654	1.3687
	M1	1.3723	1.37388	1.37119	1.37001	1.36546	1.36832	1.37656	1.36895
	M2	1.37231	1.37393	1.37111	1.37009	1.36552	1.3684	1.37659	1.36896
	Difference: M1-M2	-1E-05	-5E-05	8E-05	-8E-05	-6E-05	-8E-05	-3E-05	-1E-05
	Average M, MA	1.37231	1.37391	1.37115	1.37005	1.36549	1.36836	1.37658	1.36896
	Difference: MA-M0	0.00087	0.00148	0.00073	0.00087	0.0011	0.00136	3.5E-05	0.00026
	Average for Sample	0.00117		0.00080		0.00123		0.00014	
	Standard Deviation	0.00043		0.00010		0.00018		0.00016	

Table 8. Raw total iron lab data.

Total Iron	Sample Type	Boiler Wastewater	Post-Softener	Rainwater	Tap Water
	Concentration (mg Fe/L)	0.40	3.17	5.58	0.00