GRAND CANYON RAILWAY BOILER WASTEWATER PRETREATMENT AND STORAGE

30% 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.

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List of Abbreviations

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

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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 of 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 fiscally more responsible than the current disposal methods.

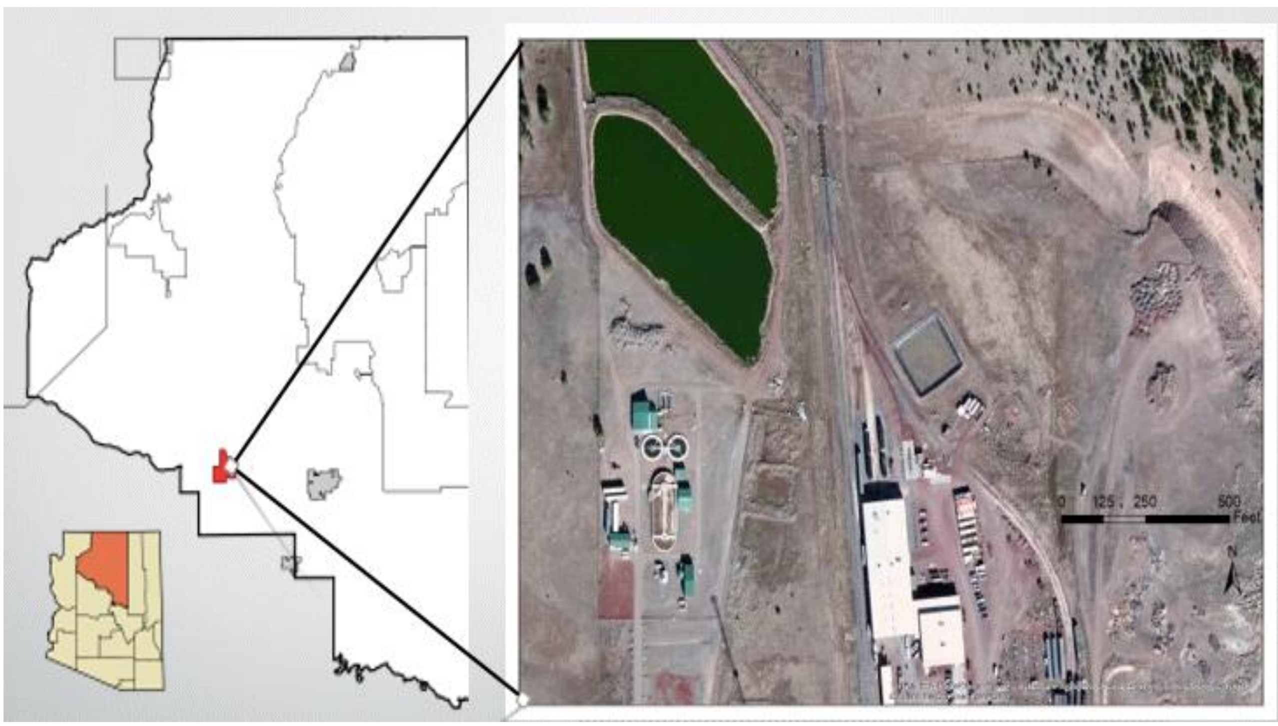

Figure 1: Aerial map showing the region of Coconino County that the team will be designing and retrieving the boiler wastewater from. Site map of the Grand Canyon Railway Station and rainwater catch basin. This map was constructed using ArcGIS.

The site of the Grand Canyon Railway Station is in Williams, Arizona approximately 35 miles west of Flagstaff. The station itself is positioned two miles east of the local Williams Wastewater Treatment Plant (WWWTP). Current conditions of the railway include weekly train operation to and from the

Grand Canyon, cycling approximately 12,000 gallons of water through the boiler per trip, and disposing of the boiler wastewater by shipping it to an industrial wastewater treatment plant in Phoenix. The water that is being used as influent to the boiler is a mixture of tap water and rainwater. The use and ratios of these waters is dependent on the season and the availability of rainwater versus tap water.

1.2. Project Background

The inner mechanics 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.

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. As the trip is completed, the boiler produces steam to move the piston and turn the train wheel. The replacement of the water 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.

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 Name	Main Compound	Use
SS16 [2]	Citric Acid	Cleans resin from the softener and assists in the softening of influent water.
BL197 [3]	Polyalkylene Glycol Monobutyl Ether	Anti-foaming agent added to boiler water to increase efficiency.
BL1240 [4]	Erythorbic Acid	An oxygen scavenger that creates an oxygen free environment and prevents corrosion.
BL7075	Nitrate/Phosphate Compound	Prevents caustic embrittlement of the piping and tank.
BL8182	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 GCR project 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.

Parameter	Concentration
pH	5.5 to 9
TDS	350 ppm or 350 mg/L

Table 2: Influent wastewater standards set by the WWWTP

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. Decision Matrix of Pretreatment Alternatives

One of the two major objectives is a decision matrix rating the four 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.

1.4.2. Decision Matrix of Storage Alternatives

The other major objectives is a decision matrix rating the four storage alternatives. It will be presented to the client for them to make an informed decision on how they would like to store the boiler wastewater.

1.4.3. Source Water and Boiler Water Analysis

A unique deliverable that will be required in the process of determining the source of the total dissolved solids in the boiler blowdown water. Determination of the source will help determine pretreatment alternatives.

10. References

[1] M. Brian, "How Steam Engines Work," 2008. [Online]. Available: https://science.howstuffworks.com/transport/engines-equipment/steam2.htm. [Accessed 25 January 2018].

[2] W. Fengler and D. Ward, "The Development of Modern Steam 4: Advanced Internal Boiler Water Treatment,"2016.[Online].Available:https://static1.squarespace.com/static/55e5ef3fe4b0d3b9ddaa5954/t/56ba2ef160b5e94f4cfe6f75/1455042296931/%23DOMS_4-AIBWT.pdf. [Accessed 25 January 2018].

[3] ChemTreat, “Safety Data Sheet - SS16,” 2017.

[4] ChemTreat, “Safety Data Sheet - BL197,” 2017.

[5] ChemTreat, “Safety Data Sheet - BL1240,” 2017.

Appendices