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Alcoa Warrick Power Plant Barge Unloading Conveyor

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Acknowledgements

We would like to start by acknowledging Dr. Kerry Hall, Ph.D., P.E. Dr. Hall is a University of Southern Indiana Associate Professor of Engineering, and our senior design project advisor. We would like to thank Dr. Hall for his guidance and expertise throughout this design project. Our team would also like to thank Rachel Meeks, P.E., along with the rest of the team from Alcoa Warrick Power Plant, for presenting us with this design project opportunity. Their help throughout this project is greatly appreciated. We would also like to thank Wade McGrady, P.E., of Manley Brothers Engineering for providing subject matter expertise in areas outside the realm of our knowledge. Our team expresses our sincere gratitude to these individuals for their knowledge and expertise provided to us from the beginning to the end of our senior design project.

Abstract

The purpose of this project was to analyze the current bulk material unloading system of the downriver dock at Alcoa Warrick Power Plant in Newburgh, Indiana. Alcoa is a power-generating station used for aluminum smelting and power generation for the grid. To meet the aluminum smelting and power generation requirements, bulk materials, such as coal, alumina, calcined coke, and limestone, are delivered via barge to the facility. The current system utilizes a process in which material is unloaded from the material barge using a excavator, like an material handler, placed onto an incline conveyor, the material is conveyed to a bag house where the dust is vacuumed and the material is dropped into a heavy-duty Mountain Mac truck, where it is then hauled to the respective stockpile. The project aimed at eliminating the use of trucking to haul material to the stockpiles. This will reduce the manhours needed to meet demands, and it will allow demand to increase extensively in the future if the company needs the ability to do so. The analysis performed by our team has resulted in a proposed design of a new conveyor system to transport material directly to the stockpile from the material barge. The design solution was aimed to solve Alcoa Warrick Power Plant’s problems, but was also designed in consideration with the economic, public health, safety, global, cultural, social, environmental, and economic impacts it may have.

Table of Contents

List of Figures

List of Tables

Alcoa Warrick Power Plant Barge Unloading Conveyor

1. Introduction

This senior design project involved an analysis of the current bulk material unloading operation at Alcoa Warrick Power Plant. The current unloading system contains a few different problems regarding efficiency and production. With the current demands Alcoa is facing, trucks are having to work overtime to unload all the bulk material being brough to the site. Throughout the past semester, an analysis of the project site has been performed, and a few proposed solutions have been designed to fix the problems Alcoa is currently facing. These solutions were developed through a long process involving many different engineering practices including, surveying, 3D laser scanning, soil sampling, CAD design, and construction cost estimating.

1.1. Background on Alcoa

Alcoa Power Generating Inc Warrick Power Plant is a coal-fired electricity generating station located in Newburgh, Indiana. The plant supplies power to the aluminum smelting processes of Alcoa and Kaiser Aluminum, as well as the local grid. Alcoa receives four bulk product shipments from their two terminals along the Ohio river. These four bulk products include alumina, calcine coke, coal, and limestone. The upriver dock, labeled alumina dock in figure 1 is the dock used to unload alumina barges. The downriver dock, labeled down river dock in figure 1 is used to unload coal, calcined coke, and limestone. The alumina unloading dock uses a pneumatic unloading system, which is working efficiently and was not part of the analysis in this senior design project.

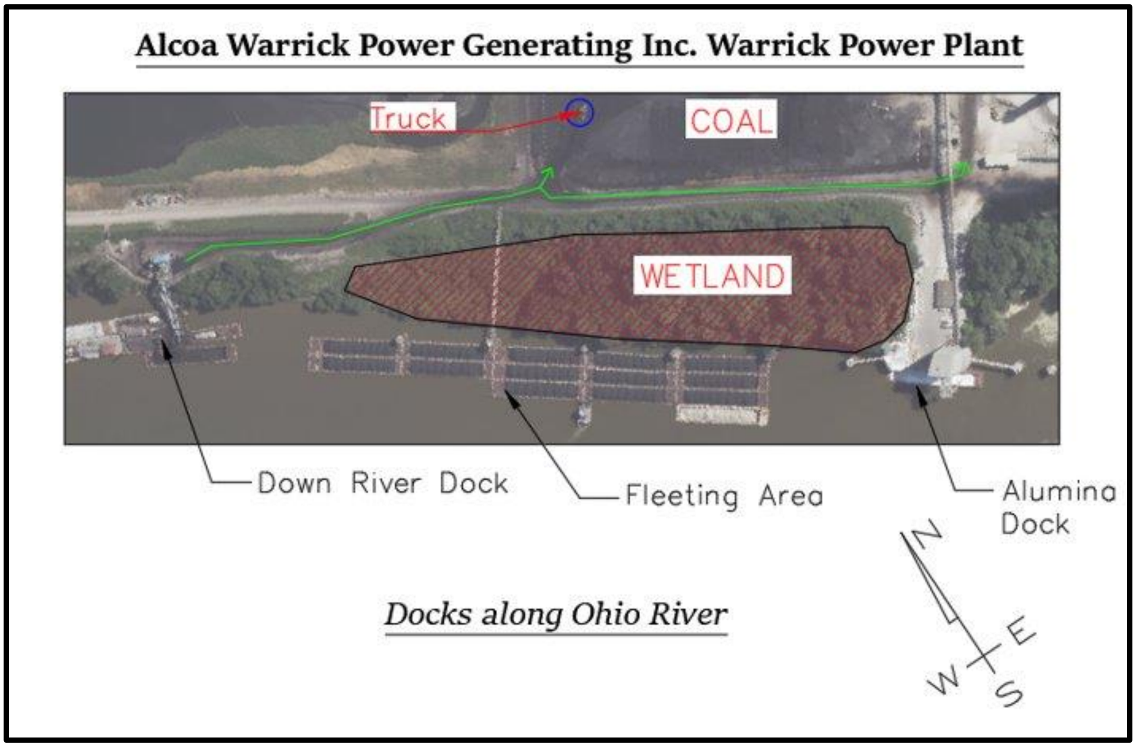


Figure 1: Project Area of Interest

1.2. Project Purpose

After reaching out to Alcoa Warrick Power Plant in January 2023, our team received a response from Rachel Meeks, P.E., the fuels area coordinator at Alcoa. She responded with a project involving the current offloading system used at Alcoa to unload the coal, limestone, and calcined coke. In her response, it was explained to our team that she was looking for a design of a new overland conveyor for the offloading system. Currently, Alcoa offloads the material using a hopper and trucks to take the coal, limestone, and coke to their respective places. The goal for the new overland conveyor would be to offload the coal and limestone straight from the barge to their respective stockpiles. The calcined coke is transported a much further distance than the coal and limestone, so the new conveyor system would need to have the ability to still use trucks to transport the coke. The goal of a new conveyor system is to eliminate the continuous use of trucking to transport material, while developing a system which increases safety, increases system efficiency, decreases emissions, and decreases long-term costs.

1.3. Logistics

There are two terminals on Alcoa's property along the Ohio river used to supply bulk materials to the power generating station and smelting processes of Alcoa and Keyser Aluminum. Bulk materials are transported in hopper barges. Hopper barges are typically 200 ft long, 35 ft wide and vary in depth from 11 to 14ft . A typical "tow", or group of barges is made up of 15 barges and one tugboat. This configuration allows the tugboat and tow to fit through the 1200 ft locks encountered on the Ohio river. One tow of American barges equals approximately 216 rail cars (Peterson). Because of this, it is clear to see the many advantages barge transportation has when comparing to other modes of transportation.

The bulk product received at the terminals includes alumina, calcined petroleum coke, coal, and limestone. Alumina, produced from the refinement of bauxite ore, is used to create aluminum metal. Calcined petroleum coke, commonly referred to as "coke", is used to produce anodes at the facility for the aluminum smelting process. Coal is used as a fuel source to generate power, and limestone is used in the power plant's flue gas desulfurization, (FGD) system. When combustion occurs at a coal-fired power plant, sulfur dioxide is produced. This is a harmful gas, so the FGD system is used to help reduce the amount of sulfur dioxide being released into the atmosphere.

1.4. Current Material Unloading System

Mentioned previously, there are two systems at Alcoa Warrick Power Plant that are in use to unload bulk material. The first is the alumina unloading dock, and the second is the dock used to unload coal, limestone, and calcine coke. The system analyzed in this project was the dock used to unload coal, limestone, and calcined coke.

The process of how the current system works is as follows: the barge containing bulk material is placed next to the dock barge with the material handler sitting on top, next, the material handler will grab the material from the hopper barge and place it into the hopper sitting on top of the incline conveyor, the material will go through the hopper and will be placed on the incline conveyor, the material will go up the incline conveyor to the tuck hopper bag house, last the material will go through the truck hopper and will drop into the back of the heavy duty truck to transport it to the stockpile. The bag house is used to vacuum the dust when the material is being dropped moved from the barge to the hopper, and from the tuck hopper to the trucks. See figure 2 for an ariel view of the unloading system. Alcoa contracts the part of the unloading system to Evansville Marine Services, EMS, a local company that specializes in riverine operations. EMS owns the portion of the process in the river. This includes several flat deck barges and equipment such as the material handler, a crane for removing fiber glass covers from the barges, and the inclined conveyor. Alcoa owns the portion of the process that is on land. This includes the bag house, truck hopper, and four 40-ton Mountain Mack trucks required to offload material. Reference appendix B for more information on the current unloading process.

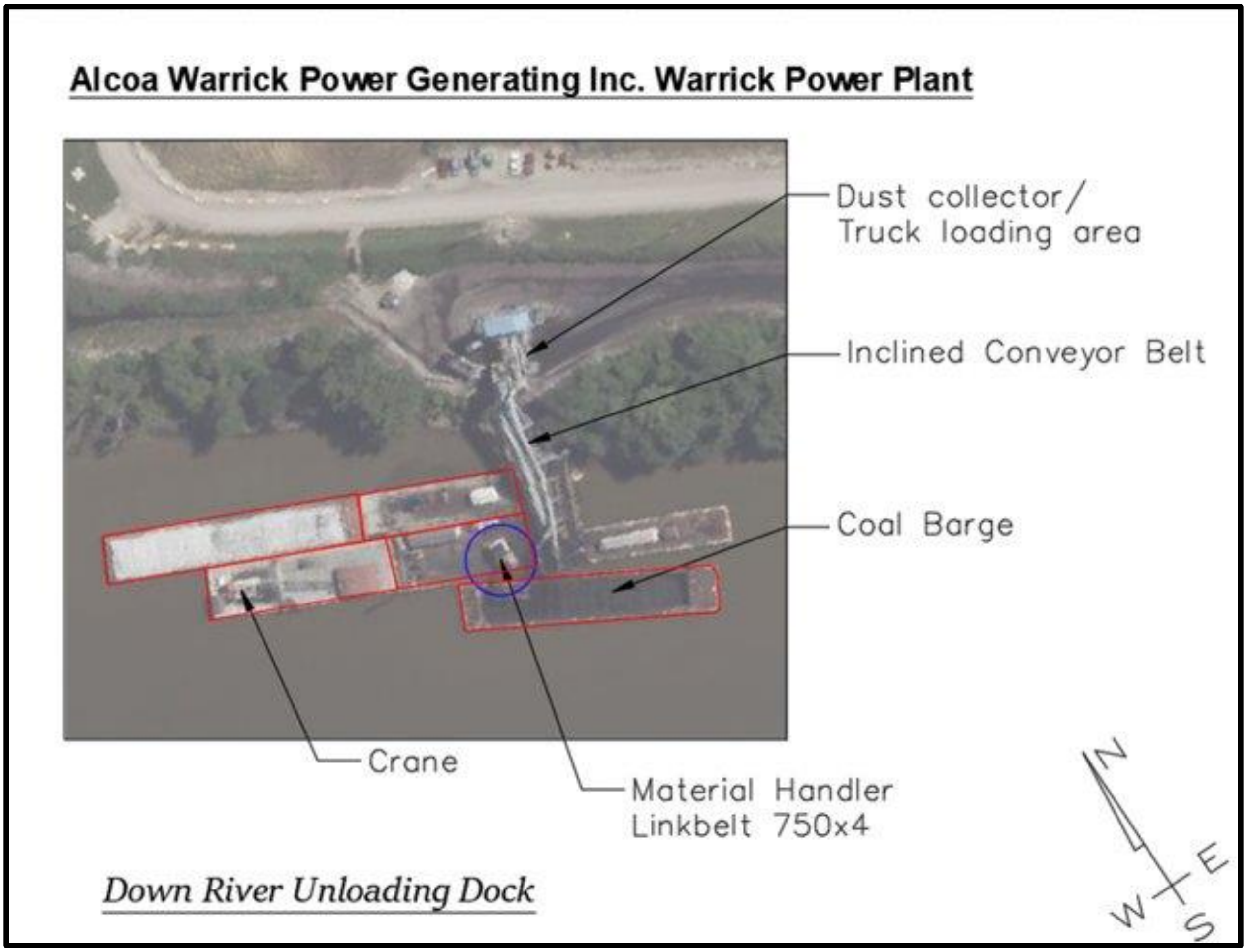


Figure 2: Down River Unloading Dock

1.5. Objective

Alcoa Warrick Power Plant is currently unloading 1.2 million short tons of coal per year, 260,000 short tons of limestone per year, and 70,000 short tons of calcine coke per year from the downriver dock terminal. They are utilizing three to four 40-ton Mountain Mack trucks to deliver the material to each of the respective stockpiles on the project site. Because the current unloading system relies on trucking to deliver bulk material from barge to stockpile, Alcoa needs employees to work longer days and weekends to meet the current demands. Overtime is often necessary in industry, however when it becomes a reoccurring it creates a social strain in the workforce. Overtime pay is passed on to the local consumer by way of higher energy costs.

Our objective in this design project was to eliminate the use of trucking to transport bulk material by designing a new conveyor system to transport the material from the unloading dock to their stockpiles. While doing this, it was important to keep in mind the current demands and future demands and design a system that can meet or exceed those demands. Also, it is important to design a system that will abide by the Code of Ethics for Engineers. From section 1.1 of the Code of Ethics for Engineers, “Engineers, in the fulfillment of their professional duties, shall: Hold paramount the safety, health, and welfare of the public” (Engineers, 2019). Throughout this project, one of our team’s main goals was to design a system that adheres by the code of ethics by designing a system that will increase the safety, health and well-being of the public and surrounding community. Our team also considered the impacts a new conveyor system would have on the safety culture at Alcoa. Eliminating the use of trucking at the plant will increase workplace safety, and workers will feel more secure and confident in their work environment, which will lead to a positive workplace culture. The economic effects of our project will be felt by the local community by reducing the cost of electricity per kilowatt hour.

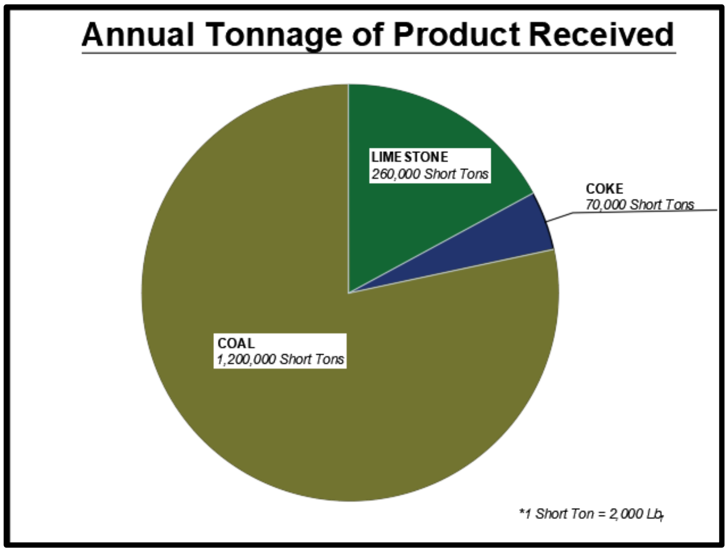


Figure 3: Annual Tonnage of Product Received at Alcoa

2. Data Collection

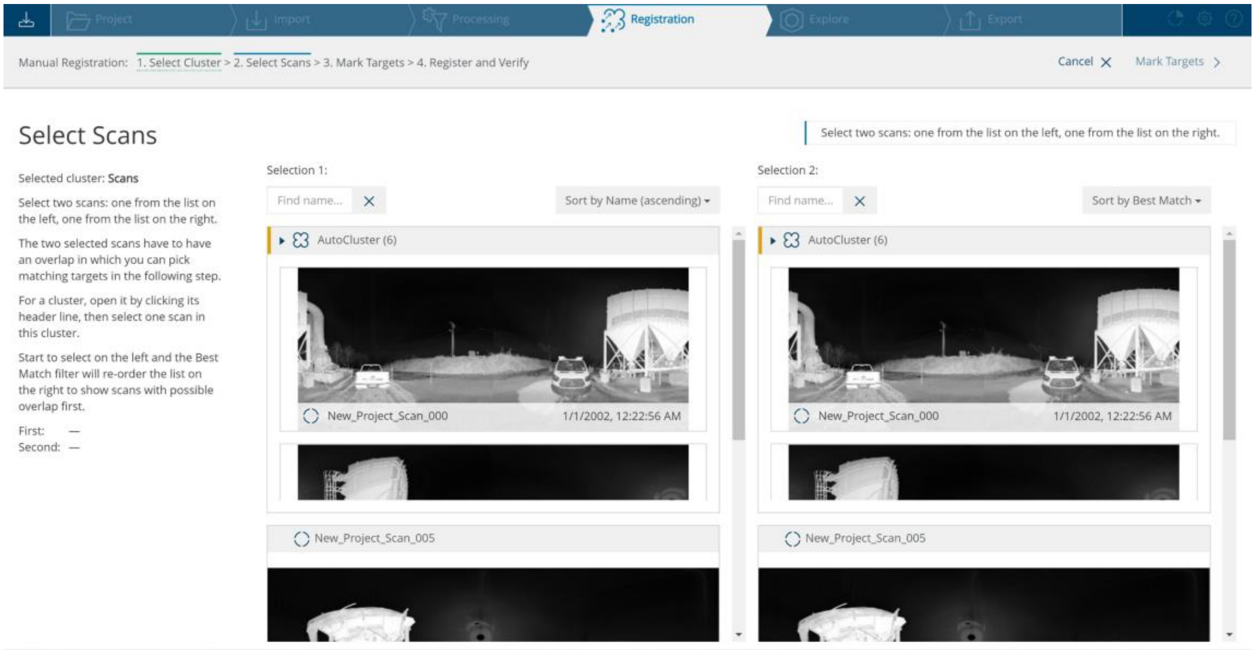
The first step in designing a material handling system is to determine the capacity of the existing system and compare this to the current and projected demand. To achieve the goal, the team began by collecting the required information to calculate this capacity. The team developed a plan to focus efforts on the two key areas, the downriver dock, and the alumina line, which would need to be passed by the proposed conveyor to reach the limestone stockpile. Due to the plant’s safety protocols, a representative from Alcoa’s team had to be present at each site visit. This would become a nuisance to Alcoa if numerous site visits were needed. To reduce repeated site visits technology such as laser scanning was used to gather large quantities of data in a short amount of time.

2.1. Faro 3D Scanning

The Faro Focus 3D laser scanner, owned by the University of Southern Indiana, uses a combination of Lidar and imagery to create 3D models. Our team used the laser scanner to collect data in the area surrounding the incline conveyor and bag house. When the scanner is collecting data, it is generating point clouds. These point clouds are groups of points, each having a cartesian based x, y, and z value relative to the position of the scanner. This information is overlayed with imagery taken by the scanner from the same location. Multiple scans are needed to capture and develop a site in 3D. Targets are used to tie individual scans together by triangulating the scan positions relative to each other. Targets such as cross hair placards or spheres are placed such that each scan location has a clear line-of-sight to three un-moved targets from the previous scan.

Figure 4: Current Conveyor on Dock Barge at Alcoa (Owned by EMS)

The data collected from the Faro scanner was saved to a 32 giga-byte SD card and processed off-site the following day. Processing the data required Faro's proprietary Scene software. This software processes the collected point cloud data into groups called clusters. Once accepted in the registration step the user can then explore or export the data to third-party software. Figure 5 shows a snapshot of the data registration step from the project site scans.



Select Scans

Select two scans: one from the list on the left, one from the list on the right.

Selected cluster: **Scans**

Select two scans: one from the list on the left, one from the list on the right.

The two selected scans have to have an overlap in which you can pick matching targets in the following step.

For a cluster, open it by clicking its header line, then select one scan in this cluster.

Start to select on the left and the Best Match filter will re-order the list on the right to show scans with possible overlap first.

First: —
Second: —

Figure 5:Data Registration Step from Site Scans

The post-processed data set was then imported into Autodesk Recap for further manipulation of the dataset. Within Recap many tools are available for working with laser scans. We used Recap to truncate the data file to prevent overloading other programs with unnecessary data. The Indiana state plane west zone coordinate system was assigned to the file and it was exported as a Recap project file (.rcp), into Autodesk Civil 3D.

The benefit to using a laser scan over 2-dimensional imagery is it prevents lost time due to missed measurements in the field. Many unknowns were present at this stage in the design process and an unforeseen change in the design could put our team behind schedule. Figure 6 displays the post-processed imagery and model space around the incline conveyor and bag house.

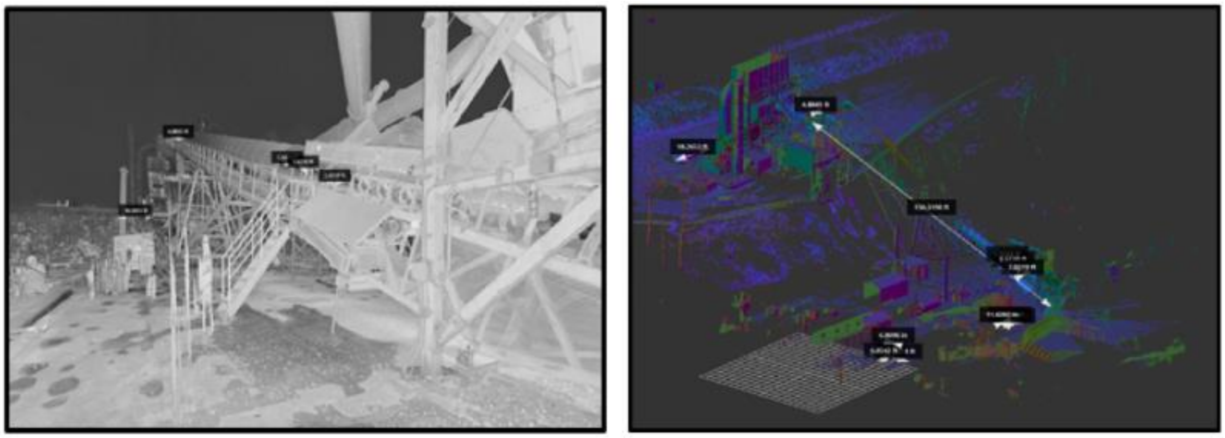


Figure 6: Post Processed FARO Imagery

2.2. GNSS surveying

During the same site visit, the GNSS surveying equipment, also owned by the University of Southern Indiana, was used to obtain surface elevations at the project site. The GNSS surveying equipment uses a local base station to gain connection to satellites. The base station used in this survey is the InCORS base station on Interstate 41 on the north side of Evansville. Due to the project site being at a lower elevation along the river in comparison to where the base station is located, the rover, used to take survey points, had difficulty maintaining connection. Although this did not turn out the way we were hoping, the survey data points we were able to collect helped us later in the project when creating a contour map. See appendix D for photographs from the site visit.

2.3. Online Resources

To aid our team’s design, supplemental data available through the United States Geological Survey (USGS) and United States Department of Agriculture (USDA) websites were used respectively to fill in areas that were beyond the capabilities of our team or not permitted by the project timeline.

2.3.1 USGS Lidar Data

The United States Geological Survey (USGS) website was used to obtain lidar data of the Alcoa project site. This lidar data gave us the ability to create a topographic map of the site. A topographic map is a 2-dimensional interpretation of 3-dimensional space used to communicate changes in elevation. This is achieved by a series of lines called contours. Each contour represents a path of equal elevation. The spacing between the contours is not accurately depicted in 2D imagery thus, the spacing or contour interval is specified. With this information the rate of change in elevation can easily be communicated on a 2-dimensional print or PDF. Figure 7 displays the USGS lidar data within Autodesk Recap. Figure 8 displays the corresponding topographic map overlayed with satellite imagery created with Autodesk Civil 3D.

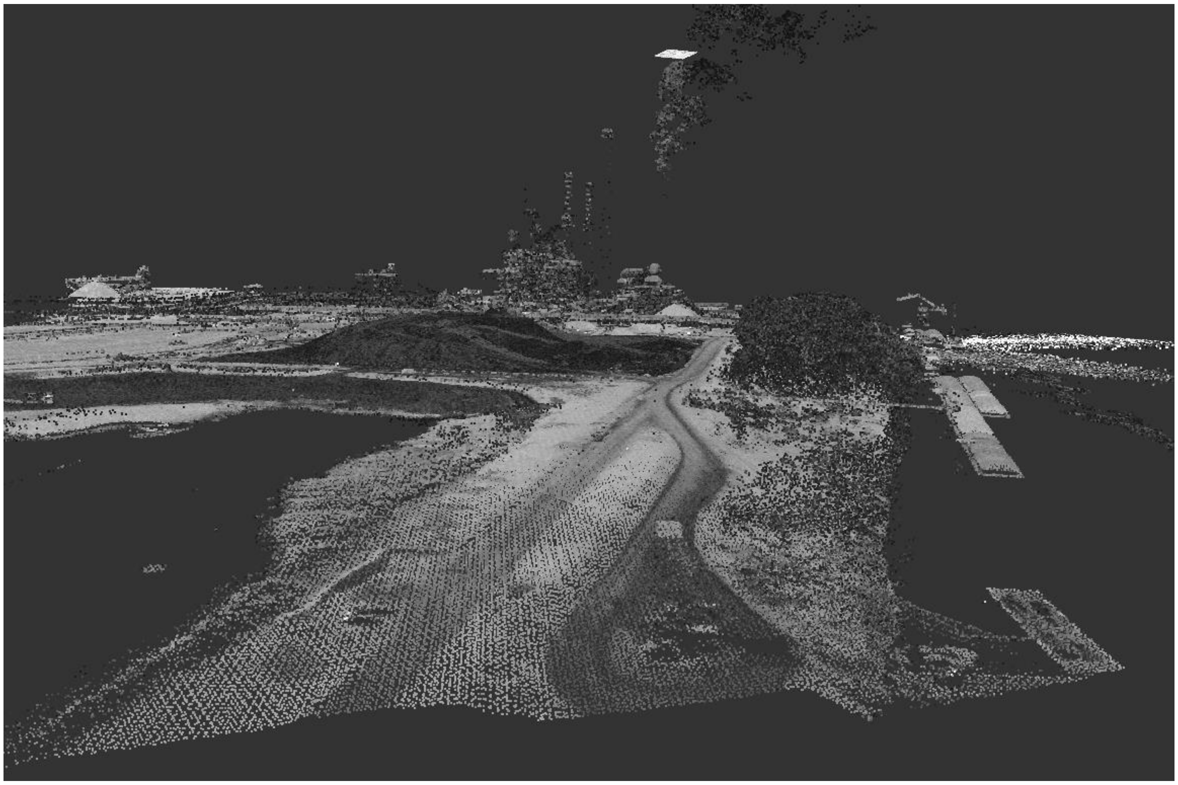


Figure 7: Lidar Data of Alcoa

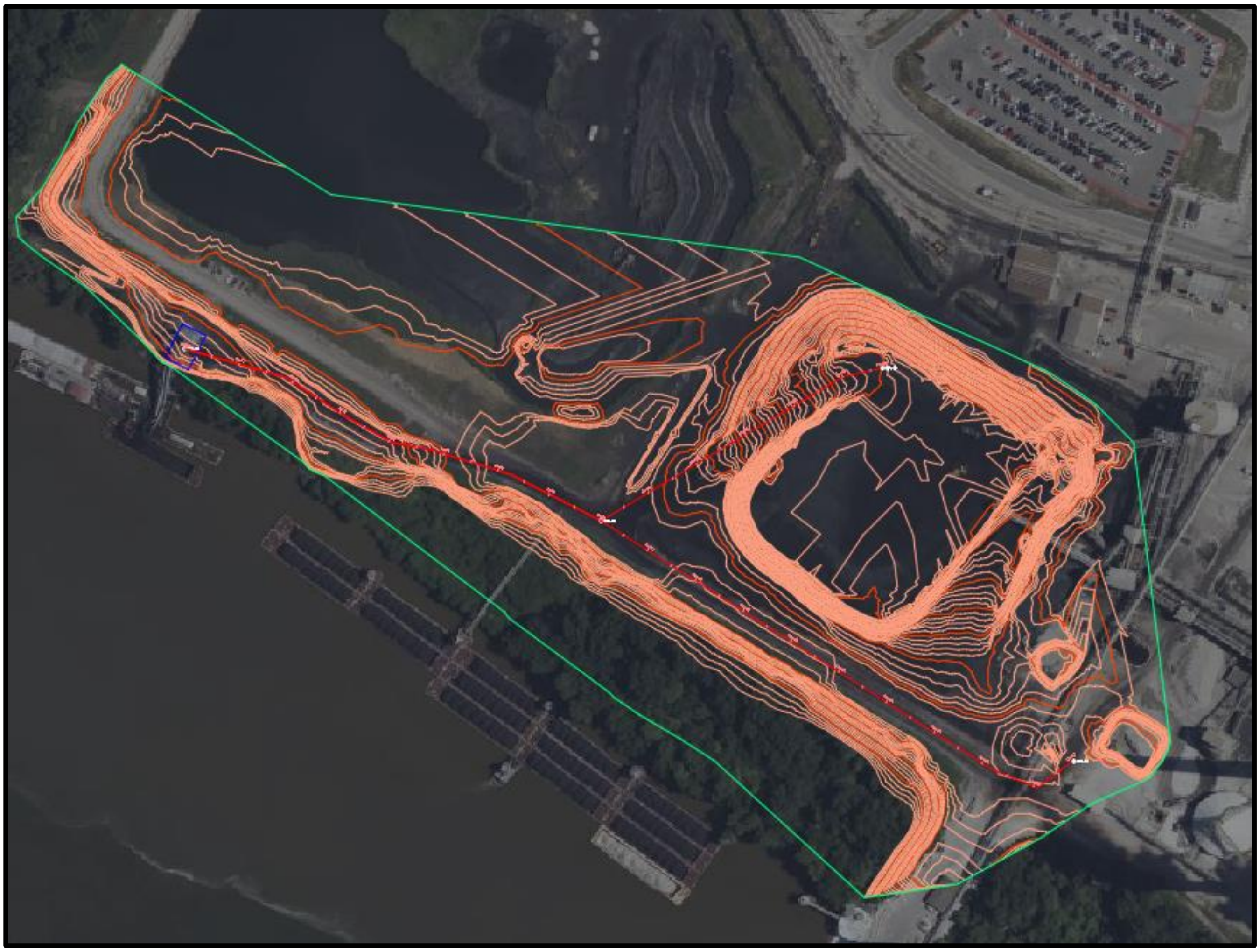


Figure 8: Topographic Map Overlay of Alcoa

2.3.2 USDA Soil Survey

Through the United States Department of Agriculture (USDA) Soil Survey website, a soil survey of the Alcoa project site was performed. The soil survey through the USDA website allows to see the physical properties, chemical properties, and engineering properties. This allows our team to see if the soil where we want to build structures contains soil that is suitable to build on. Figure 9 shows the USDA soil survey map for Alcoa. Table 1 shows the different soil types contained within that property.

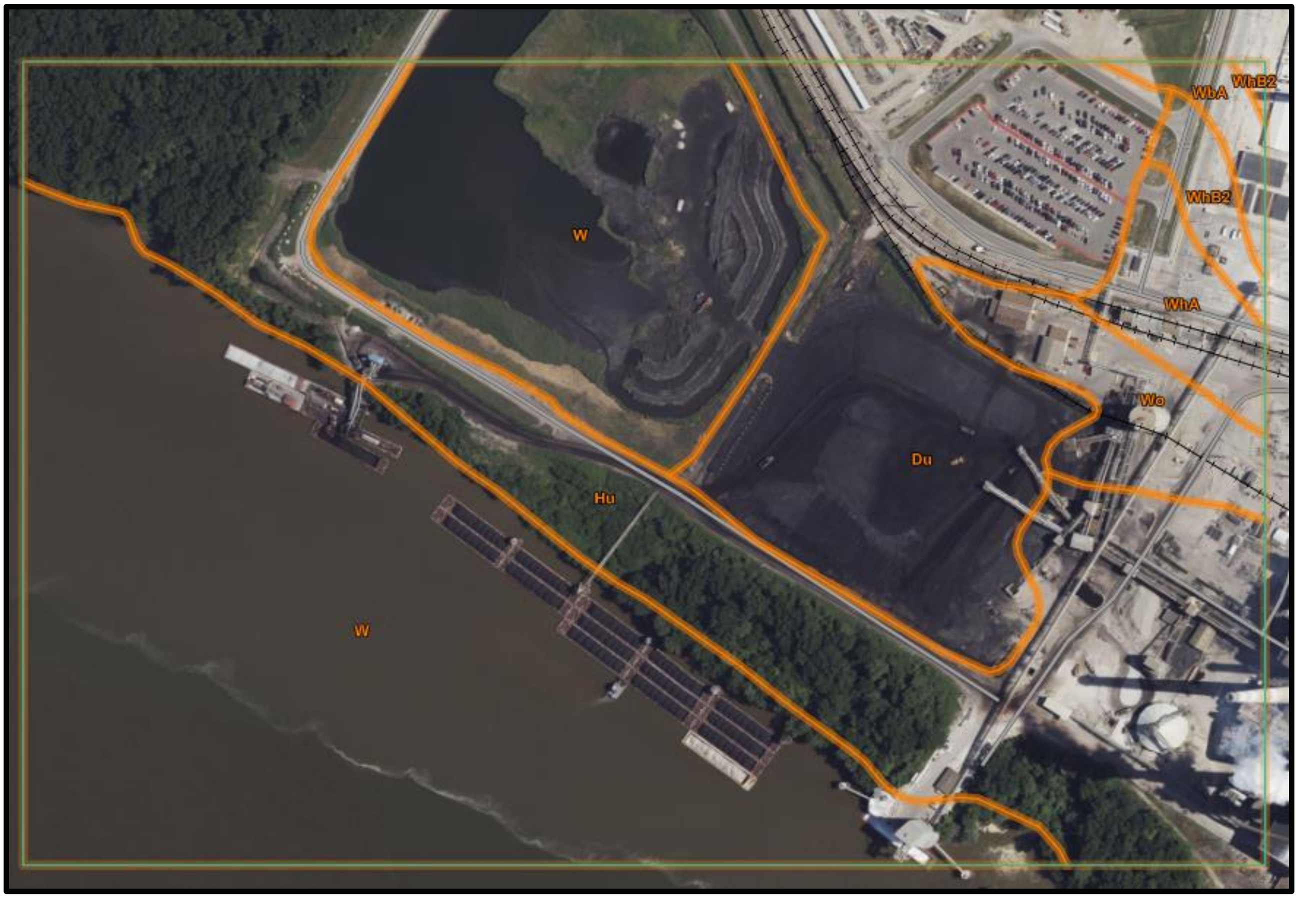
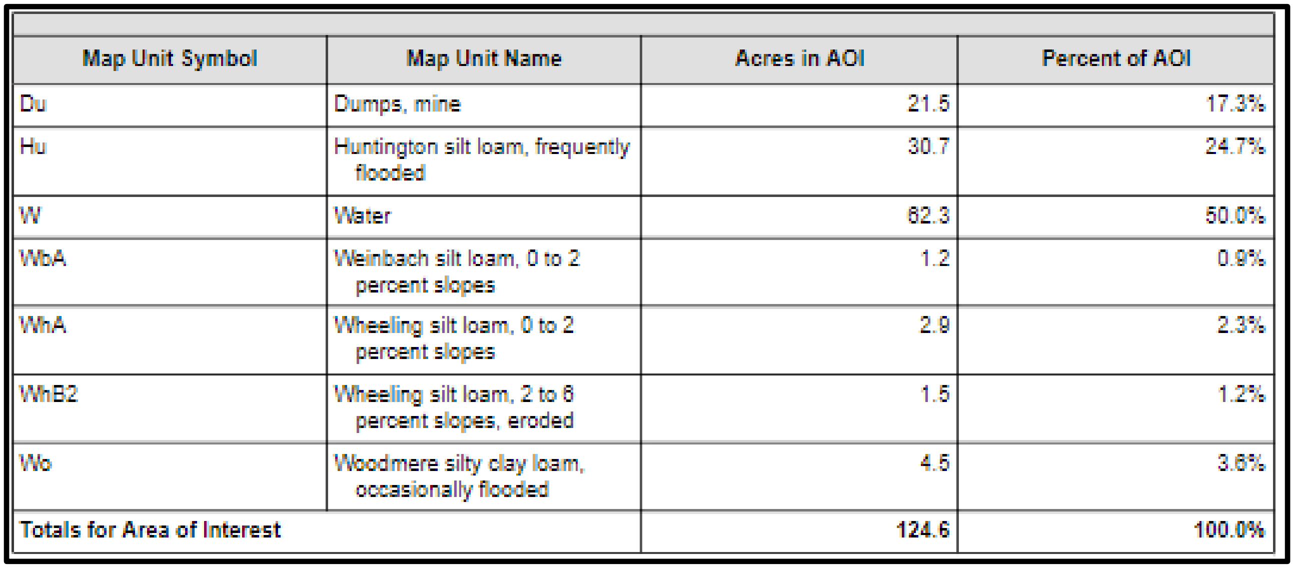


Figure 9: Soil Survey Data

Table 1: Soil Types Contained in Figure 9



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Du	Dumps, mine	21.5	17.3%
Hu	Huntington silt loam, frequently flooded	30.7	24.7%
W	Water	62.3	50.0%
WbA	Weinbach silt loam, 0 to 2 percent slopes	1.2	0.9%
WhA	Wheeling silt loam, 0 to 2 percent slopes	2.9	2.3%
WhB2	Wheeling silt loam, 2 to 6 percent slopes, eroded	1.5	1.2%
Wo	Woodmere silty clay loam, occasionally flooded	4.5	3.6%
Totals for Area of Interest		**124.6**	**100.0%**

3. System Analysis

The information gathered from the field, online resources and the Alcoa team enabled our team to calculate the current system capacity. This analysis is needed to measure the effect a change will have on the system. Our analysis focused on the path the product takes through the system. Sub-components of the system were the material handler, incline conveyor and trucking. These sub-components were analyzed independent of each other. The difference between the largest production rate and smallest is inefficiency in the system, with the smallest being the controlling factor.

3.1. Sub-Component 1: Material Handler

An important piece in the system that affects the amount of bulk material able to be unloaded is the material handler grabbing and moving the material onto the conveyor. During the first site visit, the material handler being used to unload the material was a Link Belt 6000. This material handler had a three cubic year bucket attached and had a capacity of 1,260,000 cubic yards per year. During the second site visit, EMS replaced the material handler with a new piece of equipment. The new material handler was a Link Belt 750 X4. This material handler had a larger bucket on it (4.25 cubic yards), and it has a capacity of 1,785,000 cubic yards per year.

Table 2: Equipment Alcoa Currently Uses

Current Equipment			
Material Handler:	Link Belt 750 x4	Link Belt 6000	
Bucket :	4.25	3	yd^3 Clamshell
Hours/day	10	10	hrs
Cycle time	30	30	Sec/cycle
Cycle rate	2	2	cycles/min
Production Rate	510	360	yd^3/HR
Daily output	5100	3600	yd^3/Day
Annual output	1,785,000	1,260,000	short tons/Year

3.2.Sub-Component 2: Incline Conveyor

Analysis of the existing conveyor consists of both the current conditions, previously discussed, and the capacity. To accomplish this several factors had to be considered. First, the material being transported, its angle of repose and bulk density were considered. The largest demanded material at the site is coal, thus it was used as the material in the analysis as it is assumed to control. The angle of repose of bituminous coal is 35 degrees. Second, the conveyor's speed, cross section, and inclination were needed. The speed of the conveyor was found on the bag house plans, see Appendix E. The belt speed was said to be 584 feet per minute. Next the width and through angle of the trougher rollers were needed. This was obtained by reviewing the faro laser scan seen in figure 10. The angle is measured to be 36.94 degrees, and 1.6330 ft. The nominal dimensions are 35 degrees and 18-inch rollers with a curved belt width of 48 inches.

The angle of incline varies with the river level as the conveyor is mounted to a barge, however it is allowed to raise up with the barge with an expendable chute attached to the truck hopper on the bag house. The average angle maintained is 18 degrees. This and the preceding information allowed us to calculate the output of the incline conveyor to be 2000 short tons per hour when conveying coal. This production rate amounts to more than 5 million short tons per year.

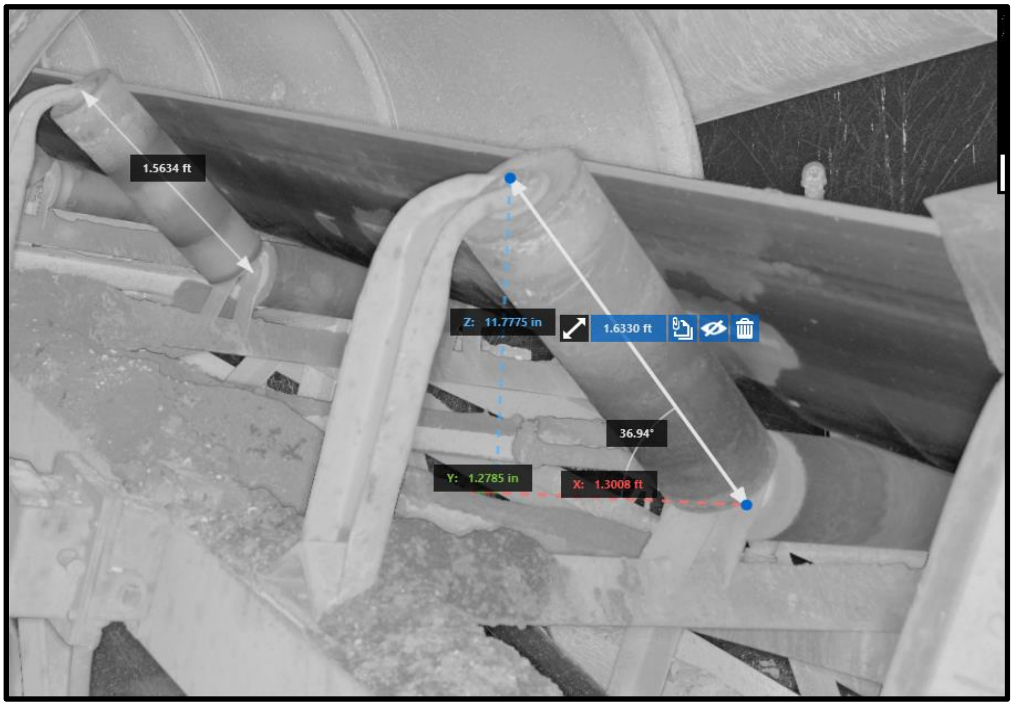


Figure 10: FARO Scan of Conveyor Rollers

Table 3: Conveyor Belt Production Rates

Conveyor Belt Production Rate		
Production Rates	**Coal**	**Limestone**
ft^3/min	876	934
ft^3/hr	52,560	56,064
yd^3/hr	1,947	2,076
m^3/HR	1,488	1,588
lbs/hr	4,204,800	5,606,400
Ton/hr	2,102	2,803
Ton/yr	5,466,240	7,288,320

3.3.Sub-Component 2: Trucking

Analysis of the existing trucking was involved calculating the production rate from the information provided by Alcoa. From the previous calculations we determined that either the material handler or trucking controlled the system. Using the annual demand that was currently met by 4 trucks hauling coal, and 3 hauling limestone, the cycle time was back calculated using goal-seek in excel. The resulting number of trucks for each coal and limestone matched what Alcoa had told us they required with overtime.

Table 4: Existing Trucking Production Rates

Production Rate of Existing Trucking			
Material	Coal	Limestone	
Truck capacity	16	16	yd^3
Cycle time	0.15	0.52	HR
Cycle time	9	31	MIN
Quanity hauled per hour/Truck	107	31	yd^3/HR
Number of trucks required	4.00	2.40	Trucks

4. Results of Analysis

4.1.Problem 1

The primary inefficiency, heavy-duty trucks, used to transport the bulk material from the unloading dock to the stockpiles were first assumed to be inefficient by the owner, Alcoa Power Generating Inc. This assumption is based on information provided by Alcoa. They informed our team that to meet the demand truck drivers were required to work overtime. This was verified through calculations made by the senior-design team summarized in *3.3 System Analysis* (16). The material handler and current conveying system both had production rates exceeding the current demand. The lowest capacity, trucking, was the controlling production rate of the system. The use of trucking degrades the operation by lacking the ability to adapt to increases in demand without considerable cost impacts safety risks. By using trucks, the benefits of a higher performing material handler and conveyor belt are lost.

The environmental impact of choosing an alternative method to diesel powered trucks is a significant factor to be considered as well. The short distance trips and varying elevations are having to travel long distances and large elevation changes to transport and dump the material. This is an issue because the trucks are using large amounts of energy to transport the material from the unloading dock to the stockpiles. To deliver coal, the total flat distance traveled to and from the unloading area is 2,800 feet. The trucks are also traveling through an elevation change of approximately 53 feet. To deliver limestone, the trucks are traveling a total flat distance of 3,600 feet, and they go through an elevation change of approximately 16 feet. Table 5 shows a summary of the previously mentioned numbers.

Table 5: Material & Distance Traveled

Material	Total Flat Distance Traveled (ft)	Elevation Change (ft)
Coal	2,800	53
Limestone	3,600	16

4.2. Problem 2

The condition of the current conveying system does not outweigh the inefficiencies found in trucking, however the impact on the overall performance of the system is still a factor to be considered. Damage and fatigue to the current inclined conveyor is resulting in lost material. As seen in figure 11, the conveyor cover is damaged and has led to an excess of material loss. Also in figure 11, the material has built up along the walkway of the conveyor, which has become a safety hazard for people needing to use the walkway to access the conveyor or baghouse. Last, the dock barge that the conveyor is sitting on is heavily damaged. The dock barge has many dents along the side caused by debris from the river bumping into it (Figure 12). Also, the dock barge is foam-filled, meaning there have been many leaks inside the barge, which means the life span of the barge is getting shorter as time goes on. If a new system is to be implemented, the inevitable downtime that would occur provides time for these issues to be addressed.

Figure 11: Material Build Up on Current System

Figure 12: Build Up of Driftwood Around Dock Barge

5. Proposed Designs

5.1. Design Option 1

The basis for the proposed conveyor system and its alignment to the existing features are presented in this section as *Design Option 1*. The preliminary specifications, geometric constraints, and a summary of the assumptions made are seen below preceding the alignment of the proposed conveyor belt system.

5.1.1 Preliminary Specifications

The minimum required specifications regarding the proposed conveyor system are listed below. Additional specifications may be added following the review of a licensed structural engineer, and consultation with the conveyor product design team.

1. The new conveyor system shall be a tube conveyor system to match the existing limestone conveyor.
2. The system's components such as belts, pulleys and other commonly replaced items shall be interchangeable with the existing ones for maintenance purposes.
3. The existing dust collection unit is to be integrated with the proposed conveyor to maintain compliance with Indiana Dept. of Environmental Management (IDEM) air quality regulations.

4. Industrial Epoxy coatings are to be applied to all structural steel members to protect against corrosion.

5.1.2 Geometric Constraints

Geometric constraints identified during the design process are listed below. These constraints were developed to ensure the conveyor system would be functional, cost effective, and add minimal disruption to Alcoa's on-going operations.

1. The proposed conveyor system shall maintain a minimum of 16-feet ground clearance when intersecting with lanes of travel.
2. The proposed conveyor system shall maintain a minimum elevation of 390-feet (NAVD-88) the elevation of the 100-year flood plain as estimated by NOAA.
3. A maximum of 20 degrees of inclination in the longitudinal plane shall be maintained in either direction of belt travel.
4. The turning radius of the belt shall be designated by the selected manufacturer's specification. As well as the tripper locations and other proprietary design components.

5.1.3 Assumptions

It is assumed that prior to the construction of this design a full geotechnical analysis of the existing fly-ash dam will be conducted. The area of influence regarding the pier locations was not considered in the proposed alignment and may need adjusted pending the geotechnical engineer's report. Compromising the integrity of the earthen dam poses an increased risk of failure. In turn a failure of the dam will impact the environment by releasing the contents of the fly-ash retention pond directly into the Ohio River.

5.1.1 Proposed Alignment

The proposed alignment of the conveyor system is shown in the figures below. Figure 13 is an overview of the entire system. The figures proceeding the site overview are more detailed plan views and their corresponding section views. These drawings were developed using Autodesk Civil 3D, Plant 3D, and Recap Pro.

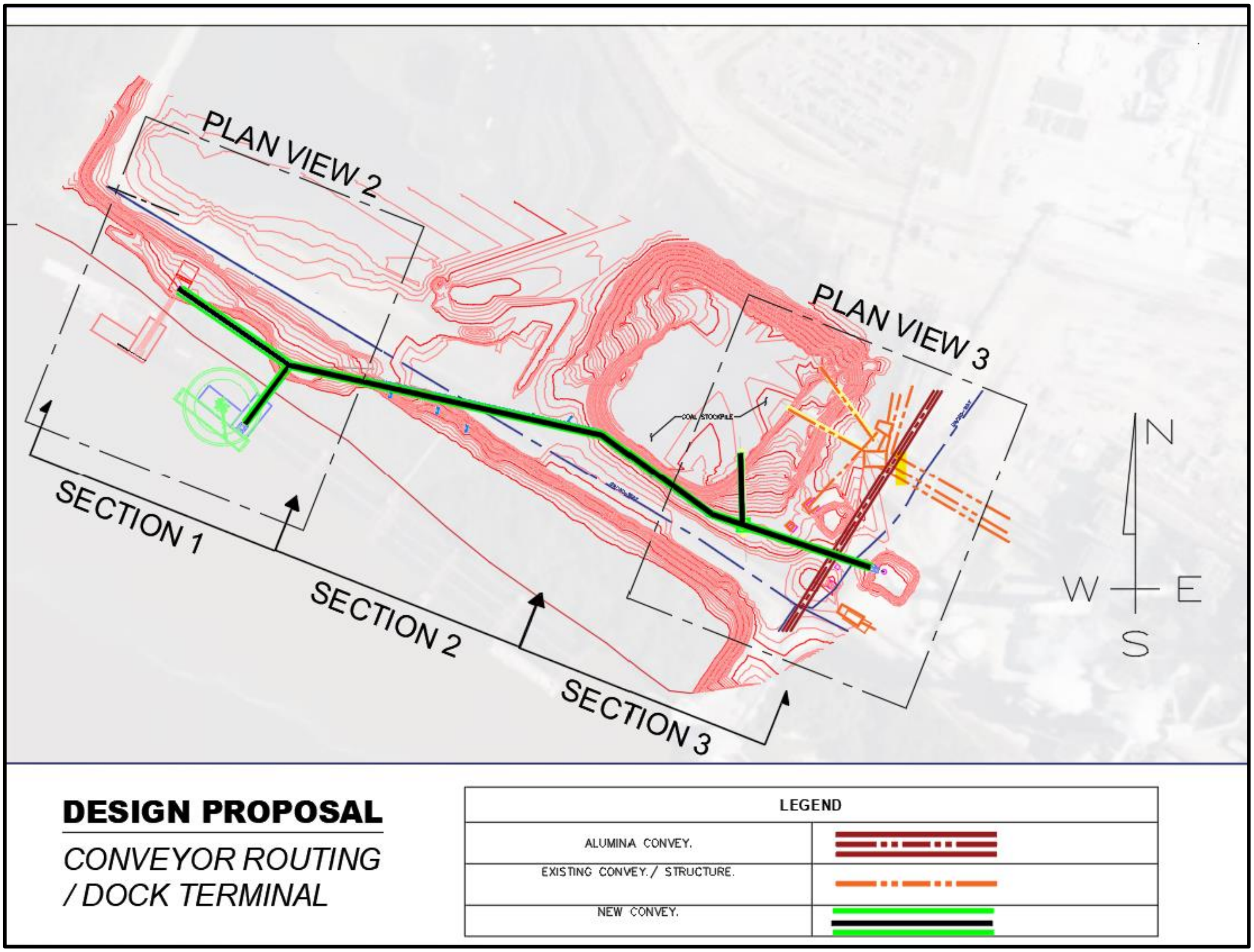


Figure 13: Proposed Conveyor Route

Figure 13, depicts the entire project site with the green and black lines representing the proposed conveyor alignment. The plan view area depicted by the dashed boxes are below in figures 14 and 17. These figures are accompanied by conceptual section views.

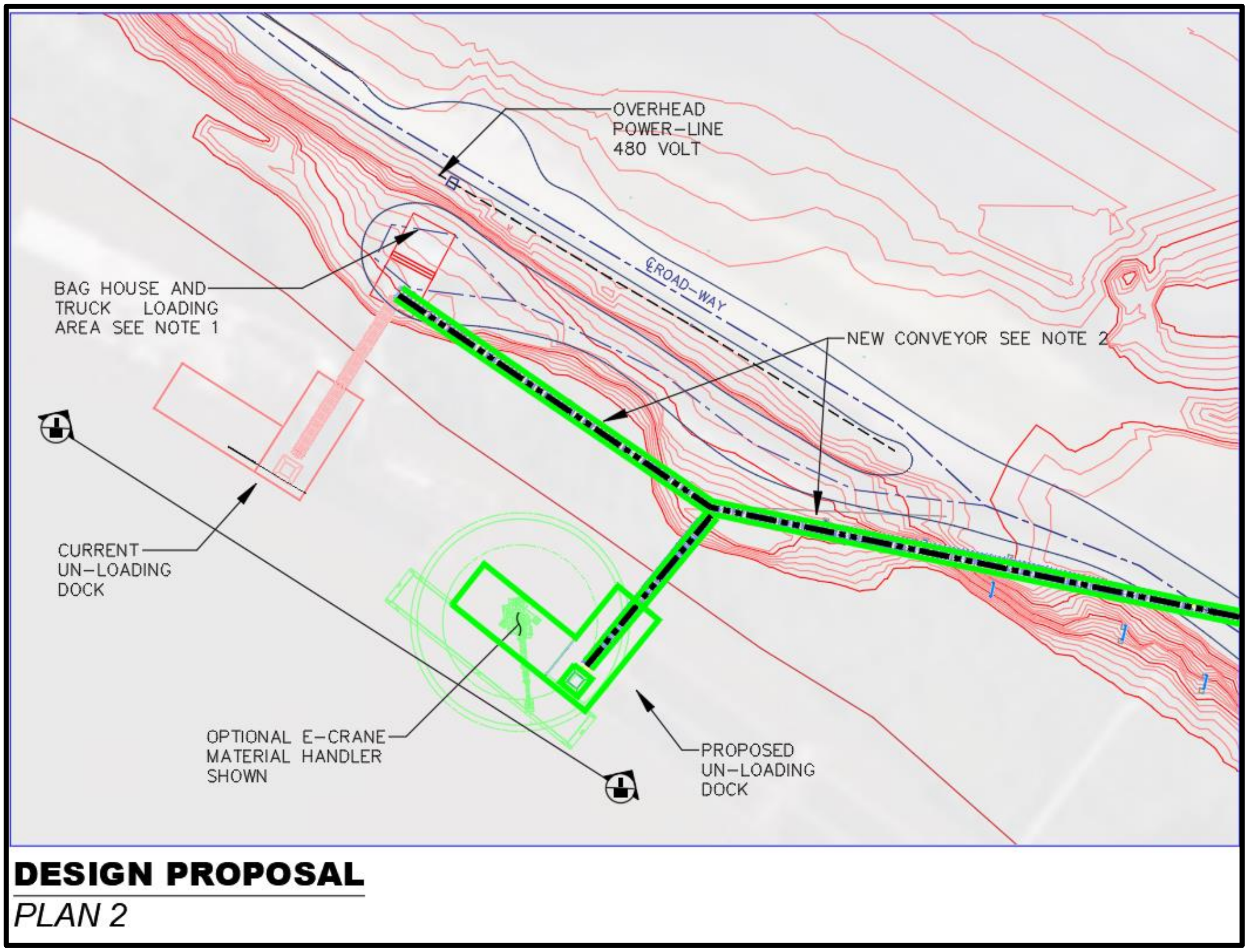


Figure 14: Proposed Conveyor Route of Design 1 and 2

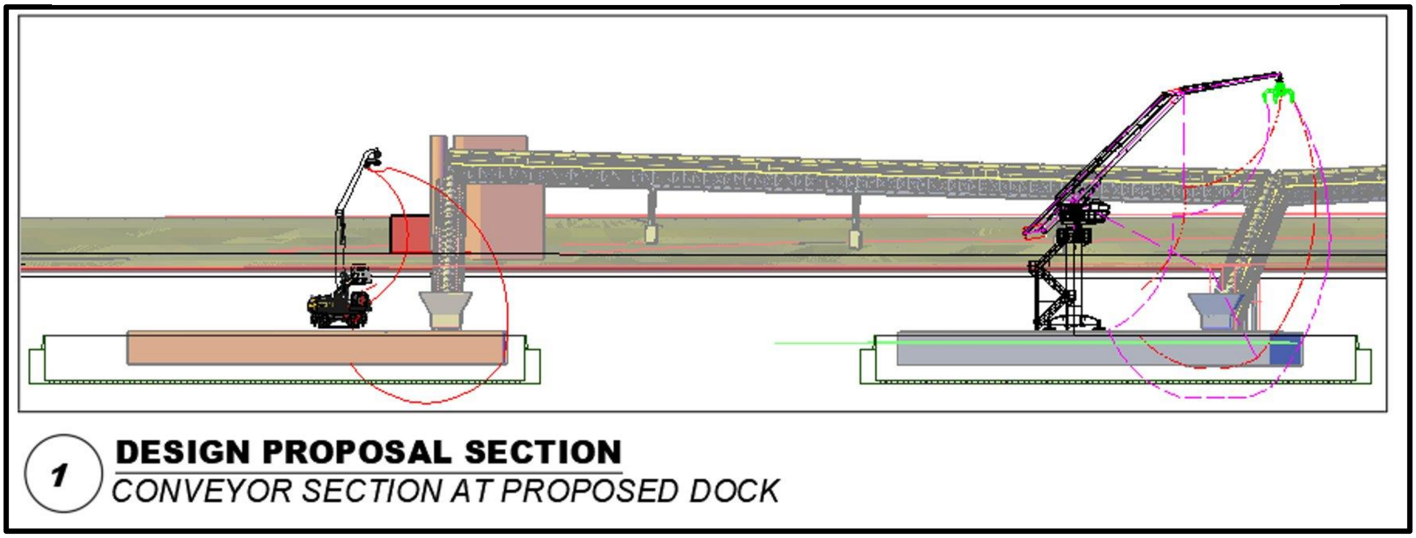


Figure 15: Display of Typical Material Handler VS E-Crane Material Handler

Figures 14 and 15 are of the downriver unloading area called out as Plan 2 and Section 1 respectively in the overview drawing. This proposed plan is to shift EMS upriver to an outcropping the was previously utilized. This area was used to unload barges during the construction of the baghouse in 2008. This choice was made due to unknown conditions beneath the water. Hydrographic data was unavailable in this location, and our team wanted to be certain the coal barges that typically draft at 10 feet could be unloaded year-round.

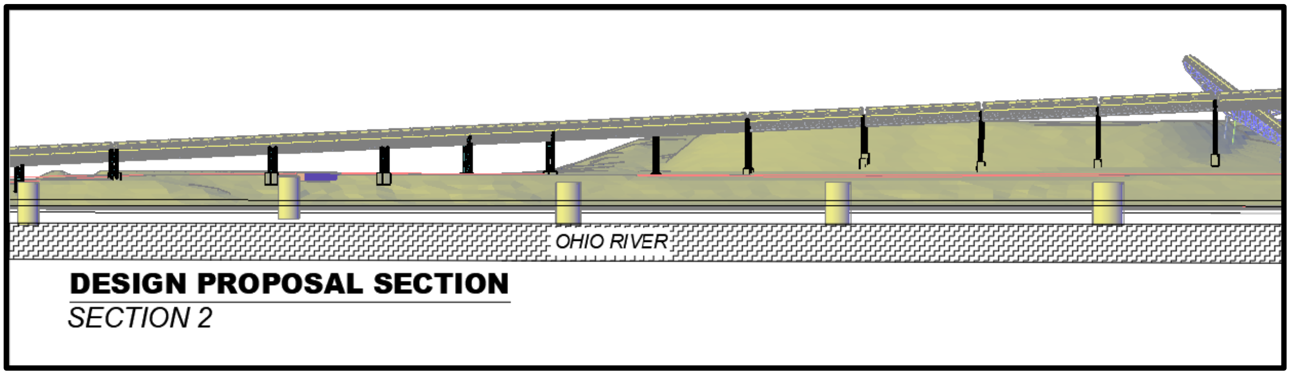


Figure 16: Section 2 of Proposed Conveyor Design

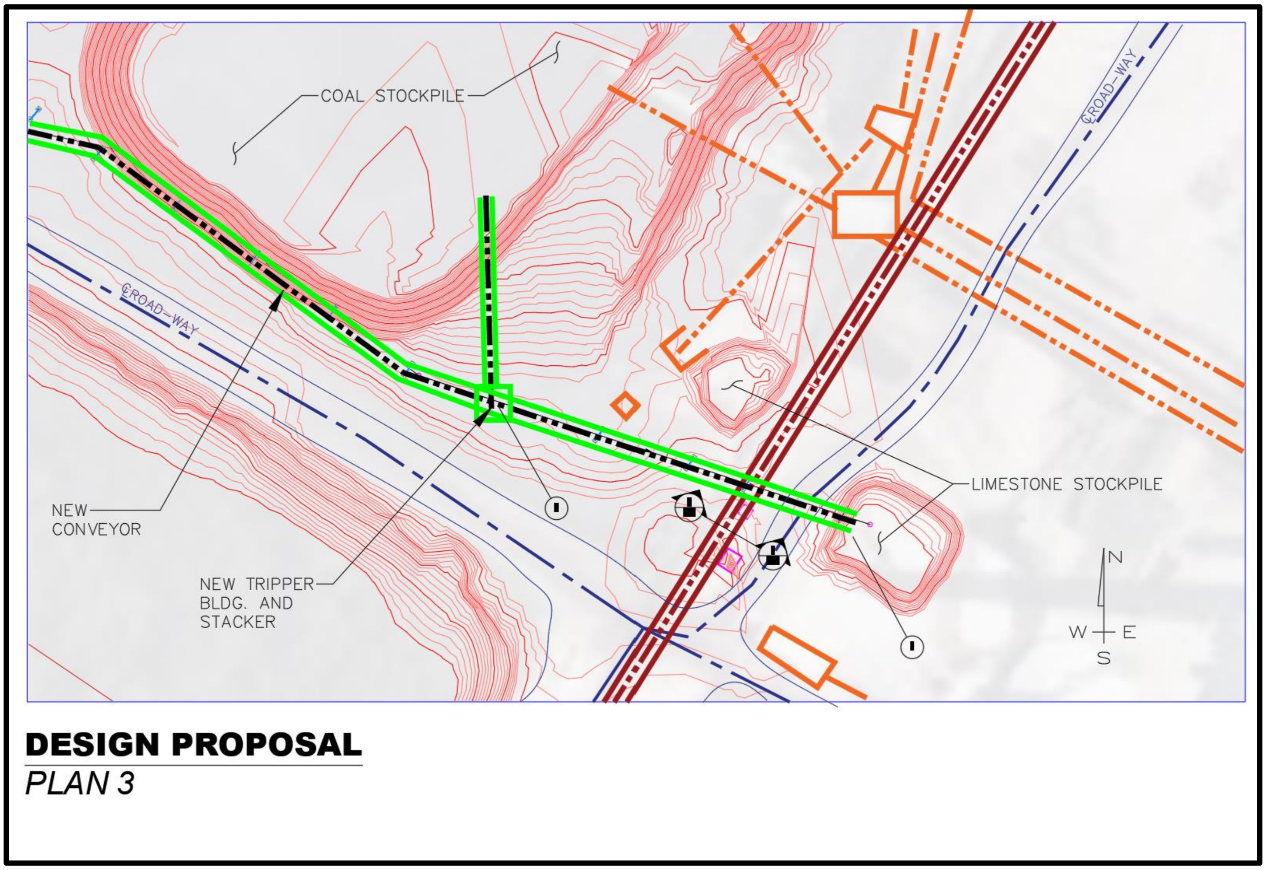


Figure 14: Plan View of Conveyor to Coal & Limestone Stockpiles

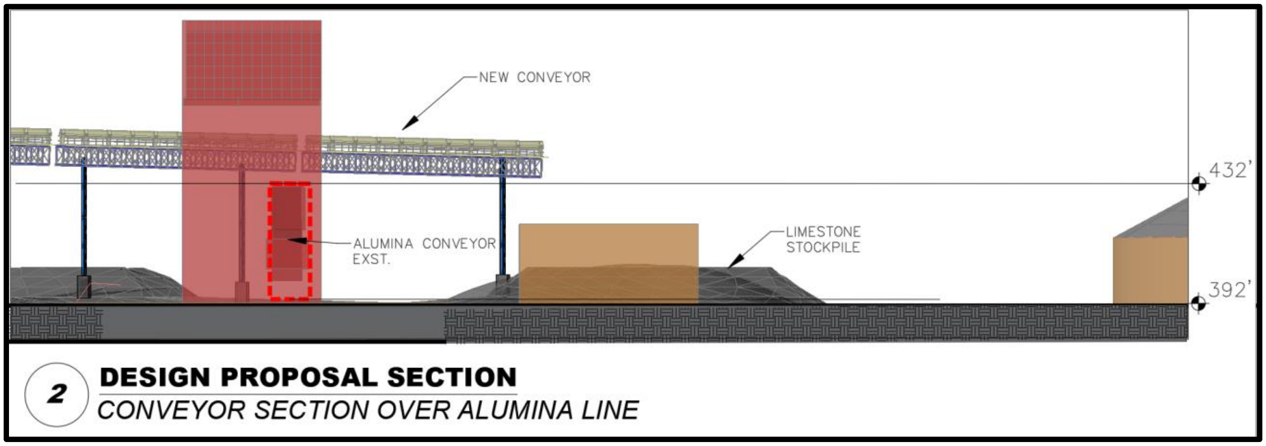


Figure 15: Design Showing Proposed Conveyor Clearing Existing Alumina Conveyor

5.2. Design Option 2

Figure 16: E-crane system at another facility

The second design option has the same conveyor design, but a different material handler is being introduced. If Alcoa wanted the option to increase the capacity of their unloading operation significantly, they would need to introduce a new material handler. In the new proposed conveyor design, the material handler is what controls the capacity of the entire system because the amount of material being unloaded is dependent on the amount of material the material handler can do. The new proposed material handler is called an Equilibrium Crane, or E-Crane.

5.2.1 E-Crane

The proposed material handler is called an Equilibrium Crane, or E-Crane. The proposed E-Crane model is the 700 series. To gain more information on this piece of equipment, our team reached out to E-Crane and got in contact with one of their company's representatives. Their representative gave us a quote of approximately $1,000,000 for the piece of equipment, including delivery and set up. Figure 19 shows a photograph of an E-Crane in use at another project site.

5.2.2 Material Handler Comparison

When analyzing the material handlers, our team performed an analysis comparing the two pieces of equipment. To be able to determine if it is worth purchasing an E-Crane, we have gone through what we believed would be the main reasons as to why an E-Crane would be a suitable option for the proposed unloading operation at Alcoa. Figure 20 shows the comparison between a typical material handler versus the E-crane material handler is shown below.

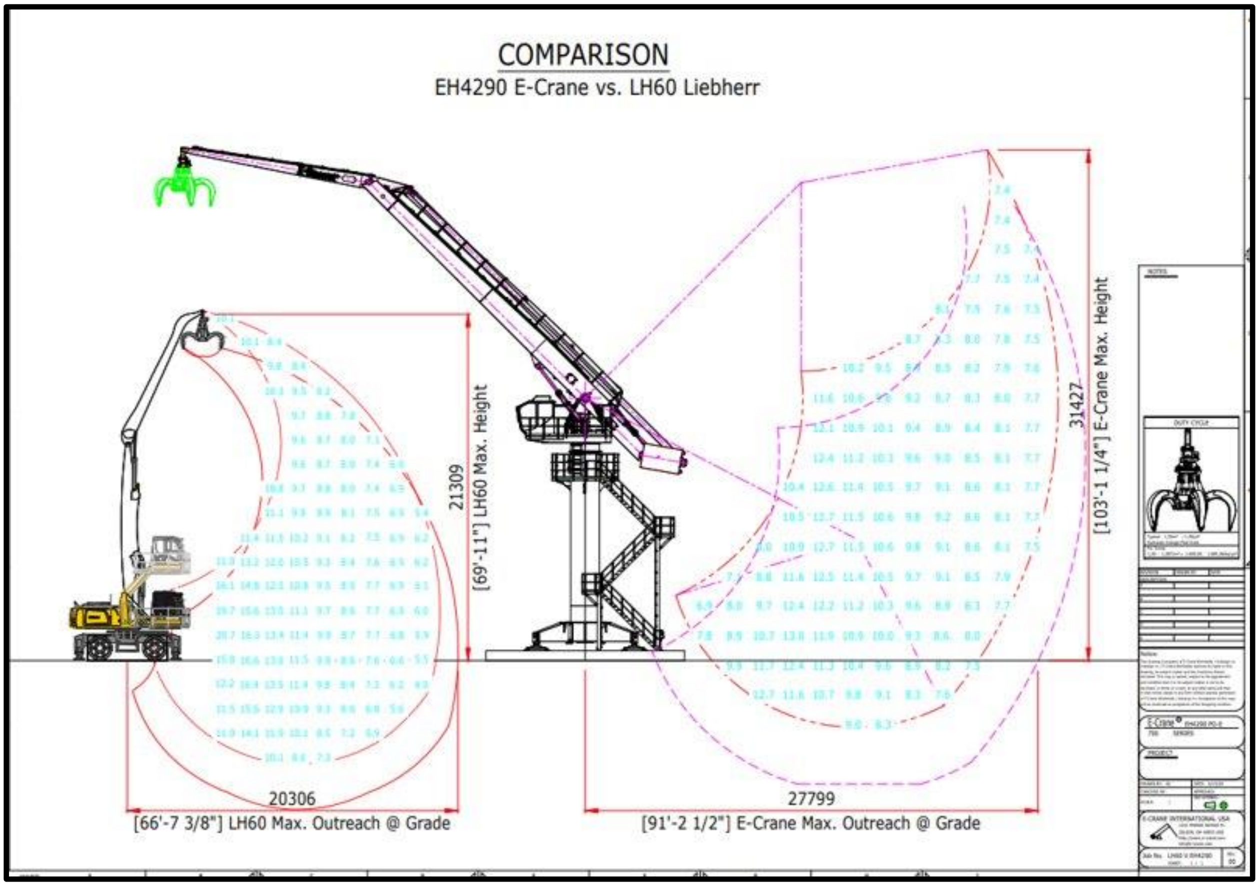


Figure 17: Typical Material Handler Compared to E-Crane Material Handler

5.2.3 Main Benefits of E-Crane

One of the main benefits of purchasing an E-Crane would be energy savings and increased lifespan of the equipment. The E-Crane's production rate is comparable to that of the existing material handler. This information regarding the E-Crane can be found in appendix F. However less energy is wasted due to the counterweight and source of power. The next benefit is reduced emissions. E-Cranes do not emit harmful pollutants like diesel-powered handlers, which makes them a more environmentally friendly option. This is important when considering the environmental, health, and safety impact this design will have on the surrounding community.

Not only does the E-Crane have low emissions and a fast cycle time, the E-Crane also allows for more flexibility. The E-Crane is highly maneuverable and can be used for different uses at Alcoa. For instance, due to its flexibility and much longer reach, the E-Crane can be used to remove debris from the water intake at the power plant. Currently, Alcoa is having to bring in a special land excavator to try and reach the debris built up that is now blocking the water intake. This costs money to pay someone to remove the debris, so if the E-Crane was already at the project site, it could be floated to the water intake and be used to remove the debris. The last main benefit of the E-Crane is the energy cost savings. Because the E-Crane is an electric powered piece of equipment, they are a more energy efficient piece of equipment in comparison to a diesel-powered material handler. See appendix F for more detail on the energy cost savings over a 5-year span.

With all those potential benefits in mind, it is important to realize that this is a very expensive piece of equipment. Upon contacting a representative at E-Crane, a general quote was received for the E-Crane 700. The representative gave a total price of $1,000,000, including shipping and set-up. The shipping cost would be a huge undertaking, and it would have a global impact because it would have to be constructed and shipped from Belgium. If an E-Crane were to be deemed a viable option by Alcoa, a closer look at the costs and benefits would need to be analyzed.

6. Construction Cost Estimate

The construction cost estimate conducted by our team is meant to aid Alcoa in their own feasibility study of the project. Our estimate includes both design options covered previously in section *5 Proposed Designs.* The estimating processes relied on developing unit costs for materials, obtaining quotes from vendors, and seeking insight from our industry liaison's. A summary of the estimate can be found below this section in *Table 6.*

6.1.Estimated Cost of Design Option 1

Design Option 1 involves the routing of a new conveyor belt assembly and supporting structure from the material stockpiles to unloading area. To obtain a unit price for the conveyor system our team assumed a pier to pier spacing of 80 feet based off the existing alumina conveyor. In similar fashion, the material take-off was completed using the design of the alumina conveyor. Cost data was retrieved from RSMeans estimating book (Gordian, 2017) as well as the Construction Cost Estimating book (Robert Peurifoy, 2013). The individual construction activities and required equipment were also needed to complete the unit price estimate.

The equipment needed for this project was assumed to be (1) telescopic handler that extends 48-50 feet, (1) flatbed truck and trailer capable of carrying heavy machinery to and from the job site. (1) excavator to assist in construction and placement of the conveyor truss spans, and (1) 10.5 cubic yard cement mixing truck.

The materials used in the project include 8,000 psi concrete for the foundations of the conveyor supports, piers, and a foundation for a switch building. construction of the conveyor system involved numerous structural steel elements and are listed with detailed below in *Table 6.*

The unit cost for one 80-foot section of the conveyor supporting structure is ($118,000). The proposed design alignment requires 22 spans to complete the system. The total cost for the conveyor supporting structure is ($2.6 million). This includes material, labor, and equipment costs.

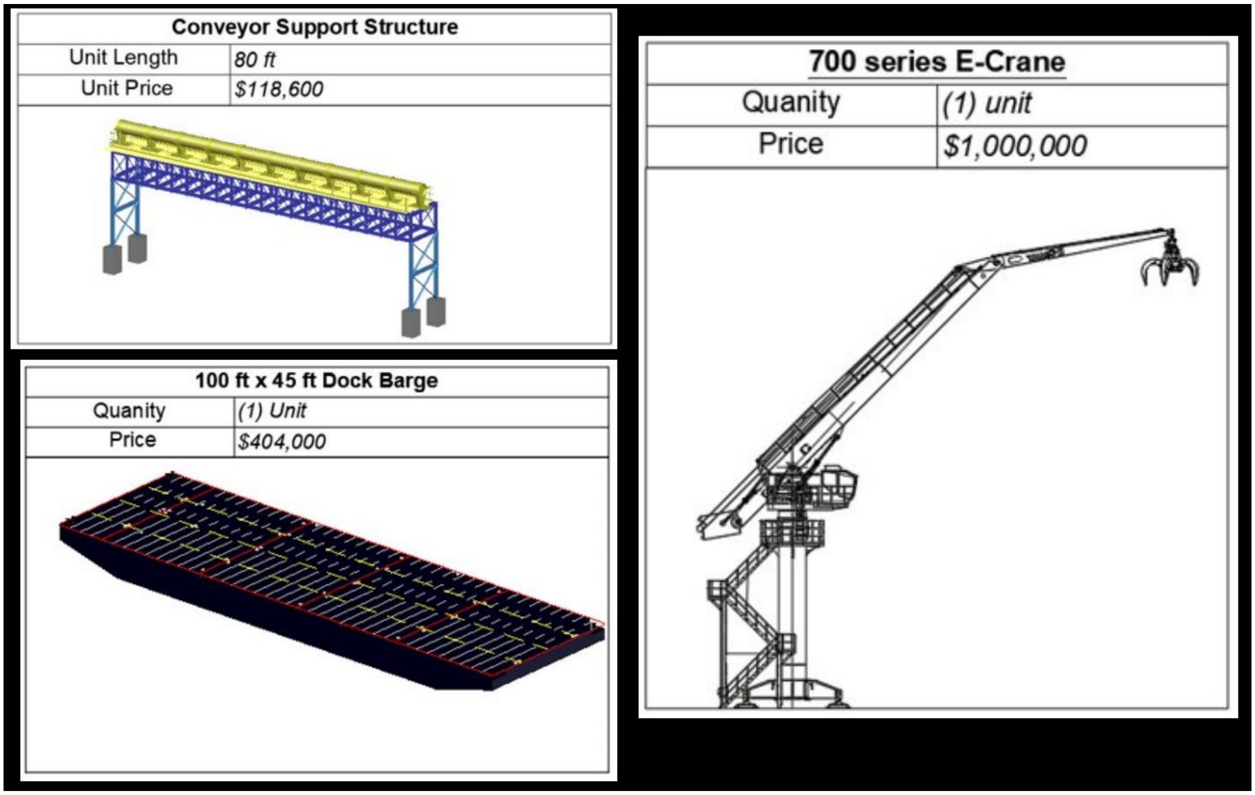
Items not included in this estimate are as follows:

1. The conveyor belt assembly that Alcoa already has cost data for.
2. The steel corrosion protection which will depend on the coating method that will be left to the contractor to decide. However, we strongly urge this to be done in a fabrication shop paint booth to reduce costs.
3. Project safety and supervision, Alcoa will work with the contractor to develop a plan that meets their requirements and is within their budget.

6.2. Estimated Cost of Design Option 2

Design option 2, as previously discussed, is an addition to *Design option 1,* the intent is to increase the system efficiency with respect to energy consumption. The cost savings data located in Appendix F. provided by Kelly Carl of E-crane is meant to supplement this estimate for further economic analysis.

Kelly Carl quoted the E-crane at a price of ($1 million). This estimate was said to include purchase, shipping, and installation. This system also would require 1-2 barges depending on the size of the barge. In our estimate we assume the incline conveyor barge is reused and a separate barge is purchased at a value of ($404,880). This brings the total cost of Design option 2 to approximately ($4 million) excluding the same cost items as mentioned above.



Conveyor Support Structure	
Unit Length	*80 ft*
Unit Price	*$118,600*

100 ft x 45 ft Dock Barge	
Quanity	*(1) Unit*
Price	*$404,000*

700 series E-Crane	
Quanity	*(1) unit*
Price	*$1,000,000*

Figure 21: Unit Price of critical design features

Table 6: Basis of Cost Estimate

Basis of Construction Cost Estimate

Material

Steel

No. of Pieces	Desc.	Length (ft)	Weight (lb/ft)	Total Weight (lb)	Cost
4	W8x48	30	48	5,760	$22,600
14	W8x31	15	31	6,510	$25,500
40	W5x19	10	19	7,600	$29,800
30	W5x19	8	19	4,560	$17,900

Concrete

Material	Volume (ft^3)	Weight (lb)	Cost
8000 psi concrete (Double Pier)	75.40	11,310	$100
8000 psi concrete (Tripper Building)	280	42,000	$200
8000 psi concrete (Single Pier)	384	57,600	$1,000

***Unit cost of Material for (1) 80 -foot span of conveyor :* $97,101**

Labor

Labor	Amount	Rate ($/hr)	Time (hours)	Cost ($)
Iron Worker	4	25	640	$ 70,400.00
Cement Mason	4	28.09	1760	$ 217,528.96
Cement Finisher	3	26.24	1760	$ 152,401.92
Equipment Operator	2	30.84	1760	$ 119,412.48
Laborer	8	21.78	1760	$ 337,328.64
Raising Gang	6	27.93	1760	$ 324,434.88
Welding Crew	3	20.29	1760	$ 117,844.32
Detail Crew	3	30.18	1760	$ 175,285.44
Decking Crew	4	20	1760	$ 154,880.00
Millwright	1	26.23	840	$ 24,236.52

***Total projected cost of labor:* $1,669,517**

Equipment / Other

Other	Amount	Dimensions (ftxft)	Weight (lb)	Cost ($)
barge	1	100x45	506,100.00	$ 404,880.00
Tripper Building	1	(4)*15x30	x	$ 50,400.00
Mobilization	2	x	x	$ 76,720.00
E-crane	1	x	x	$ 1,000,000.00
Telescopic Handler	1	x	x	$ 21,726.00
Excavator	1	x	x	$ 87,360.00
Mixing Truck	1	10.5 cy	x	$ 60,912.00

***Total projected cost of labor:* $1,701,998**

7. Appendix

A. ABET Design Factor Considerations

The table below shows the ABET design considerations.

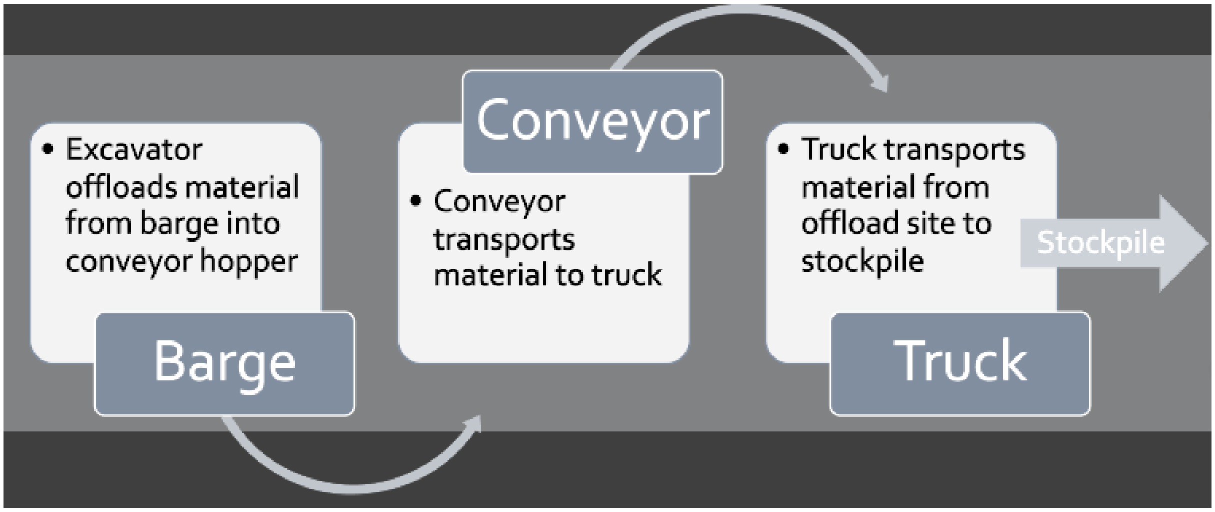
Design Factor	Page number, or reason not applicable
Public health, safety, and welfare	Section 5.2.3
Global	Section 5.2.3
Cultural	Section 1.5
Social	
Environmental	Section 4.1
Economic	Section 1.5
Ethical & Professional	Section 1.5
Reference for Standards	Sections 1.5, 6.1

B. Current Unloading System

The figures below show the current unloading system at Alcoa Warrick Power Plant, as well as a diagram explaining the process of the current system. Figure 22 shows the material handler loading material into the hopper that sits on the conveyor. Figure 23 shows the trucks being loaded with the bulk material at the bag house. Figure 24 displays the current unloading system using a flow-type diagram.

Figure 17: Material Handler Loading Material into Hopper

Figure 18: Trucks Being Loaded from Figure 22 Conveyor



- Excavator offloads material from barge into conveyor hopper

Barge

Conveyor

- Conveyor transports material to truck

- Truck transports material from offload site to stockpile

Truck

Stockpile

Figure 19 Flow Chart of Current Unloading System

C. Bulk materials at Alcoa Warrick Power Plant

The following figures show photographs of the coal stockpile, limestone pile, and alumina barge being unloaded at Alcoa. Figure 25 shows the coal stockpile, and figure 26 shows the limestone stockpile. As mentioned in the report, the unloading dock used to unload alumina at Alcoa was not a concern in this project, but since it is an important aspect of Alcoa's operations, figure 27 shows an alumina barge being unloaded using a pneumatic system.

Figure 22: Coal Stockpile

Figure 21: Limestone Stockpile

Figure 20: Alumina Unloading System

D. Alcoa Site Visit

The following images show our team's site visit to Alcoa. During this site visit, we collected data using the GNSS surveying equipment and the Faro 3D laser scanner. These images reflect our team collecting the data using those pieces of equipment. Figure 28 shows team member, Caleb Hurst, using the GNSS surveying equipment. Figure 29 shows the FARO 3D laser scanner scanning the current conveyor.

Figure 23: GNSS Surveying at Project Site

Figure 24: FARO Scanner in Use at Project Site

E. Conveyor Belt Analysis

As mentioned in section 11 “Conveyor Belt Analysis”, the speed of the current conveyor belt was found from the drawing given to our team from the Alcoa team. Figure 30 shows the drawing of the bag house and current conveyor. Figure 31 shows a zoomed in part of the drawing showing where the conveyor belt speed is located on the drawing.

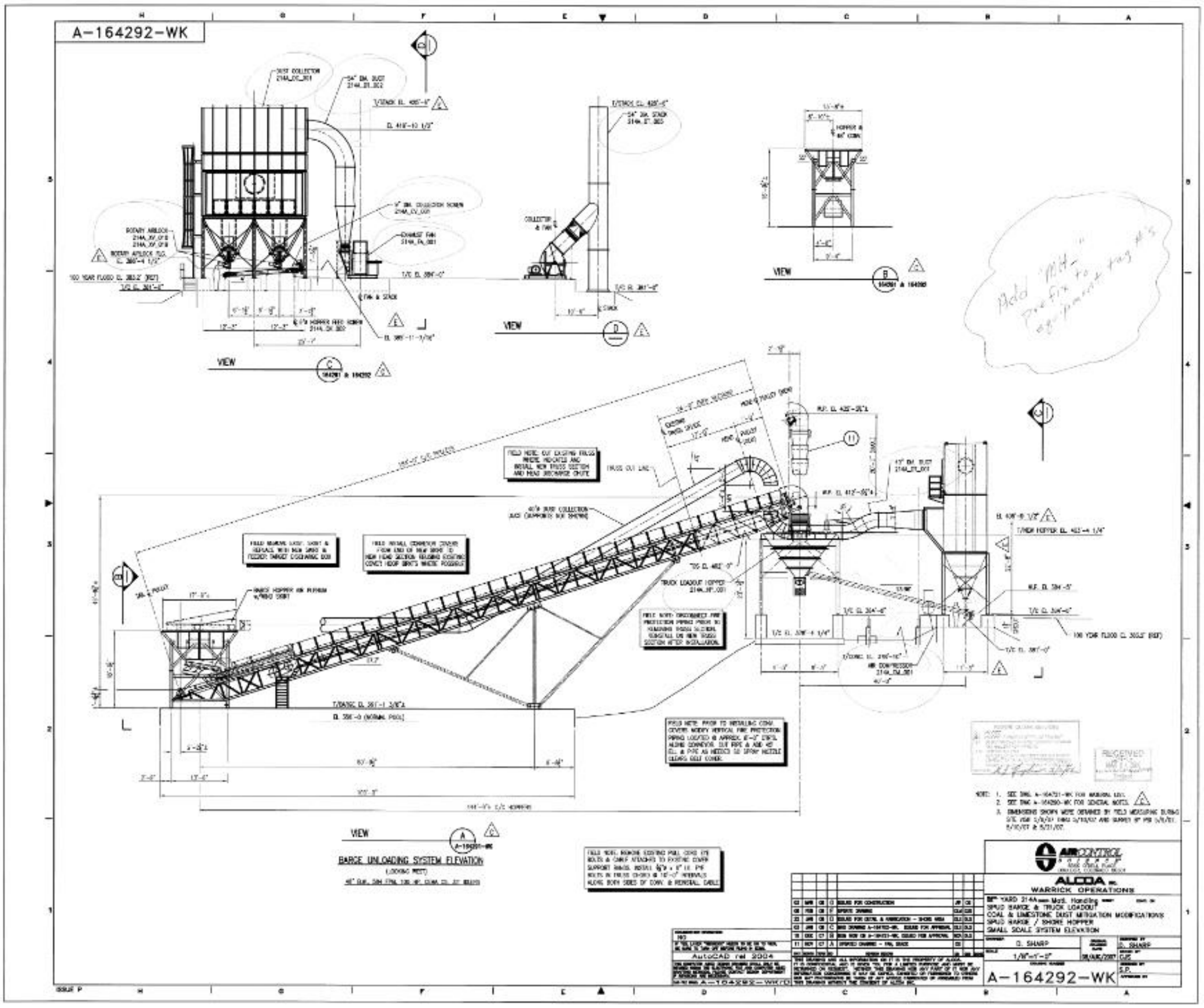
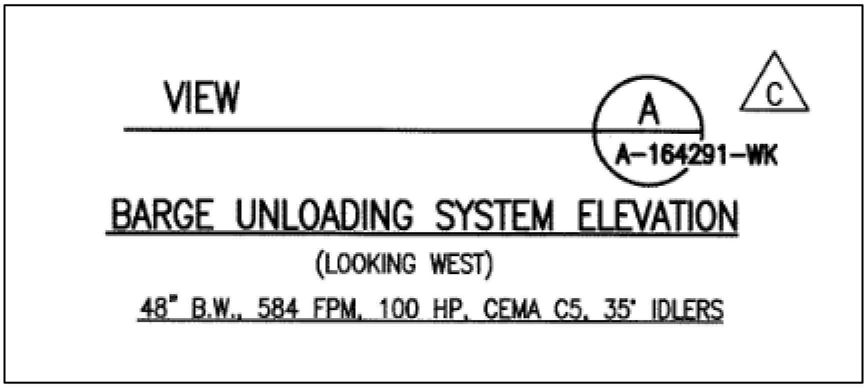


Figure 25: Drawings of Bag House and Conveyor



VIEW A
A-164291-WK
C

BARGE UNLOADING SYSTEM ELEVATION
(LOOKING WEST)
48" B.W., 584 FPM, 100 HP, CEMA C5, 35° IDLERS

Figure 26: Belt Speed

F. Equilibrium-Crane (E-Crane) Information

Figure 32 shows a drawing of an E-Crane provided to us by an E-Crane representative. Table 7 shows the cycle time for an E-Crane, provided by the same E-Crane Representative. Table 8 shows the energy costs of an E-Crane over a 5-year span. Table 9 shows the energy costs of a typical diesel-powered material handler over a 5-year span.

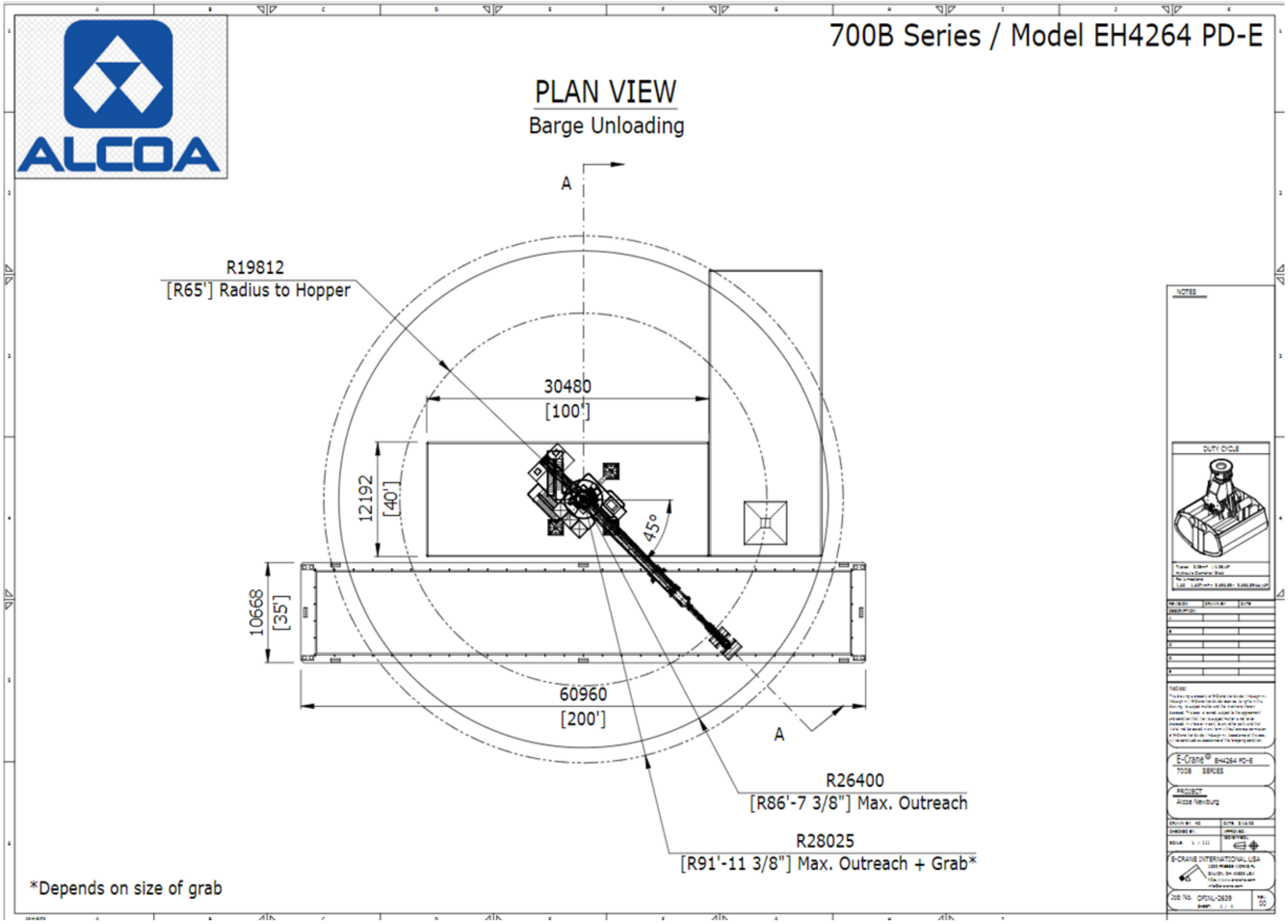
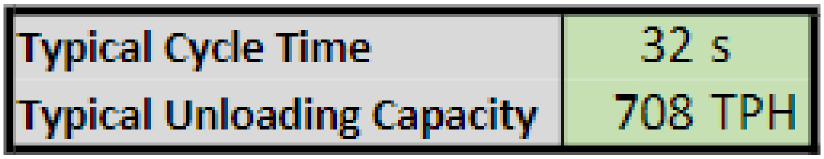


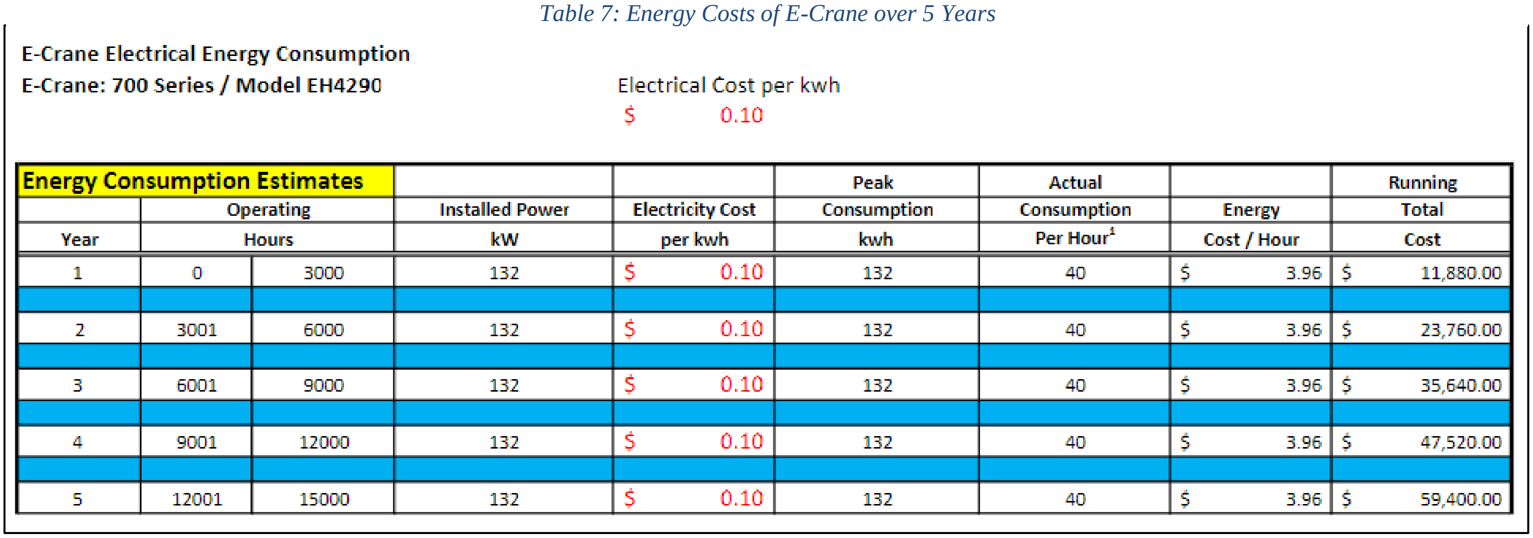
Figure 27: Drawing of E-Crane



Typical Cycle Time	32 s
Typical Unloading Capacity	708 TPH

Figure 28: E-Crane Cycle TIme

Table 7: Energy Costs of E-Crane over 5 Years

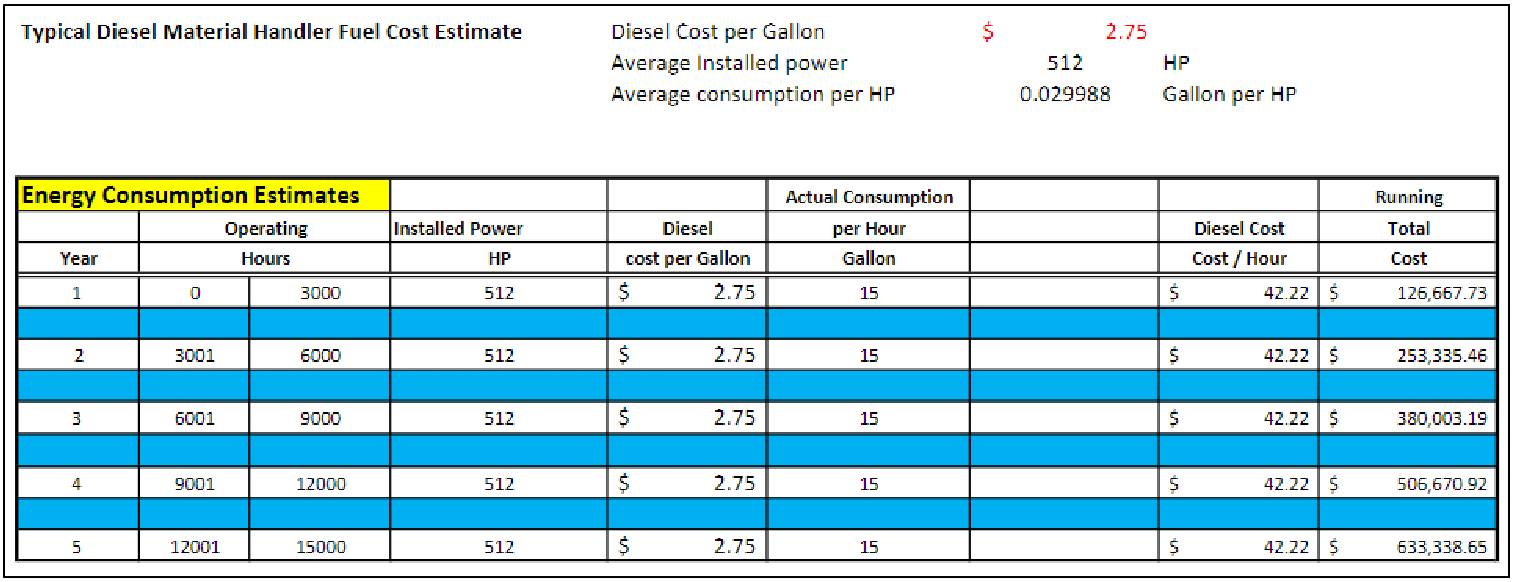


E-Crane Electrical Energy Consumption
E-Crane: 700 Series / Model EH4290

Electrical Cost per kwh
$ 0.10

Energy Consumption Estimates					Peak	Actual		Running
	Operating		Installed Power	Electricity Cost	Consumption	Consumption	Energy	Total
Year	Hours		kW	per kwh	kwh	Per Hour[1]	Cost / Hour	Cost
1	0	3000	132	$ 0.10	132	40	$ 3.96	$ 11,880.00
2	3001	6000	132	$ 0.10	132	40	$ 3.96	$ 23,760.00
3	6001	9000	132	$ 0.10	132	40	$ 3.96	$ 35,640.00
4	9001	12000	132	$ 0.10	132	40	$ 3.96	$ 47,520.00
5	12001	15000	132	$ 0.10	132	40	$ 3.96	$ 59,400.00

Table 8: Typical Diesel Material Handler Fuel Cost Estimate over 5 Years



Typical Diesel Material Handler Fuel Cost Estimate

Diesel Cost per Gallon	$ 2.75	
Average Installed power	512	HP
Average consumption per HP	0.029988	Gallon per HP

Energy Consumption Estimates					Actual Consumption			Running
	Operating		Installed Power	Diesel	per Hour		Diesel Cost	Total
Year	Hours		HP	cost per Gallon	Gallon		Cost / Hour	Cost
1	0	3000	512	$ 2.75	15		$ 42.22	$ 126,667.73
2	3001	6000	512	$ 2.75	15		$ 42.22	$ 253,335.46
3	6001	9000	512	$ 2.75	15		$ 42.22	$ 380,003.19
4	9001	12000	512	$ 2.75	15		$ 42.22	$ 506,670.92
5	12001	15000	512	$ 2.75	15		$ 42.22	$ 633,338.65

8. References

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