

Wastewater Tank

Industrial Design-Bid-Build

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1. Case Study Method

The Project Case Study Method involves an in-depth examination of a single project, the case. It provides a systematic way of looking at events, collecting data, analyzing information, and reporting the results. Case Studies are one of the most effective tools you can use to promote best practices and cost-effective, experiential training. A recent search on Google.com for the term “case study” showed over 15 million hits. Of those hits, almost 750,000 hits included references to Java, which demonstrates a phenomenal uptake in the IT industry. Like its close cousin the White Paper, case studies appear to be growing in popularity every year.

1.1. NORA Goal 10

This Case Study was developed under a Cooperative Agreement with NIOSH in support of the National Occupational Research Agenda (NORA), Goal 10. Goal 10 is concerned with improving understanding of how construction industry factors relate to injury and illness outcomes; and increasing the sharing and use of industry-wide practices, policies, and partnerships that improve safety and health performance (NIOSH, 2013).

More specifically, the aim of NORA Goal 10.1 is to: Analyze how construction industry complexity and fragmentation can affect safety and health performance. Evaluate safety roles, responsibilities, interactions, and oversight among the multiple parties involved with complex construction projects. Address regular and accelerated construction project lifecycles. Identify obstacles and opportunities for improving system performance.

National Institute for Occupational Safety & Health. (2013, April 24). “NORA Construction Sector Strategic Goals.” Retrieved from <http://www.cdc.gov/niosh/programs/const/noragoals/Goal10.0/>

1.2. Case Study Design

The research adopted a comparative case study approach (Yin, 1994). Data were collected from a total of 23 construction projects, 10 in Australia/New Zealand and 13 in the United States of America. For each project, features of work were purposefully identified by project participants in consultation with the research team. Features of work were selected as the unit of analysis because they presented a particular health and safety problem or challenge.

“Features of work were selected as the unit of analysis because they presented a particular health and safety problem or challenge.”

For each feature of work, comprehensive data was collected to capture decisions that were made in relation to the design of the feature of work, the process by which it was to be constructed and the way that health and safety hazards were to be addressed. Data were collected by conducting

in-depth interviews with stakeholders involved in the planning, design and construction of the selected features of work. These interviews explored the timing and sequence of key decisions about each feature of work, and the influences that were at play as these decisions ‘unfolded’ in the project context. During the course of the research 288 interviews were conducted (185 in Australia and 103 in the USA). The average number of interviews per feature of work was 6.7.

Projects chosen for data collection represent four different construction sectors (residential, commercial, industrial, and heavy) as well as four different delivery methods (Design-Bid-Build, Design-Build, accelerated, and collaborative). This was done to help determine the role OSH plays in each type of construction project. The projects were then placed on a matrix. Figure 1 represents the 14 projects studied within the United States with the project featured in this case study highlighted in yellow. Figure 2 shows where American and Australian projects overlap on the matrix.

Figure 1: Matrix of American projects

	Residential	Commercial	Industrial	Heavy
Design-Bid-Build	Roanoke House	Dining Hall	Wastewater Tank	Highway Expansion
Design-Build	Blacksburg House	Psychiatric Hospital	Server Farm	New Highway
Accelerated	Blitz Build	Football Stadium	Chemical Plant	Bridge Project
Collaborative	Mountain House	New Hospital	Coal Plant*	Coal Plant*

**Note: The coal plant project is considered to be both an industrial and a heavy construction project.*

Figure 2: Overlap of American and Australian Projects

	Residential	Commercial	Industrial	Heavy
Design-Bid-Build	US	AUS+US	US	US
Design-Build	AUS+US	US	AUS+US	AUS+US
Accelerated	US	AUS+US	AUS+US	AUS+US
Collaborative	US	US	US	AUS+US

From: Wakefield, R., Lingard, H., Blismas, N., Pirzadeh, P., Kleiner, B., Mills, T., McCoy, A. & Saunders, L. (2014). ‘Construction Hazard Prevention: The Need to Integrate Process Knowledge into Product Design’. Paper presented at the CIB W099 International Conference: Achieving Sustainable Construction Health and Safety, 2-3 June 2014 Lund, Sweden.

1.3. Case Study Analysis

Dependent variable

Data was collected about OSH hazards and the risk control solutions implemented within the case examples. This data was elicited during the interviews and supplemented with site-based observations and examination of project documentation (e.g. plans and drawings). For each feature of work, a score was generated reflecting the quality of implemented risk control solutions. This score was based on the hierarchy of control (HOC).

The Hierarchy of Control classifies ways of dealing with OSH hazards/risks according to the level of effectiveness of the control

The hierarchy of control (HOC) is a well-established framework in OSH (see, for example, Manuele, 2006). The HOC classifies ways of dealing with OSH hazards/risks according to the level of effectiveness of the control. At the top of the HOC is the elimination of a hazard/risk altogether. This is the most effective form of control because the physical removal of the hazard/risk from the work environment means that workers are not exposed to it. The second level of control is substitution. This involves replacing something that produces a hazard with something less hazardous. At the third level in the HOC are engineering controls, which isolate people from hazards. The top three levels of control (i.e., elimination, substitution and engineering) are technological because they act on changing the physical work environment. Beneath the technological controls, level four controls are administrative in nature, such as developing safe work procedures or implementing a job rotation scheme to limit exposure. At the bottom of the hierarchy at level five is personal protective equipment (PPE) – the lowest form of control. Although, much emphasized and visible on a worksite, at best, PPE should be seen as a “last resort,” see, for example Lombardi et al.’s analysis of barriers to the use of eye protection (Lombardi et al. 2009). The bottom two levels in the HOC represent behavioral controls that they seek to change the way people work (for a summary of the limitations of these controls see Hopkins, 2006).

Each level of the HOC was given a rating ranging from one (personal protective equipment) to five (elimination). The risk controls implemented for hazards/risks presented by each feature of work were assigned a score on this five point scale. In the event that no risk controls were implemented, a value of zero was assigned.

Independent variable

Social network analysis (SNA) was used to map the social relations between participants involved in making design decisions about each feature of work. SNA is an analytical tool to study the exchange of resources between participants in a social network. Using social network analysis, patterns of social relations can be represented in the form of visual models (known as sociograms) and described in terms of quantifiable indicators of network attributes. In a sociogram, participants

are represented as nodes. To varying extents, these nodes are connected by links which represent the relationships between participants in the network.

SNA has been recommended as a useful method for understanding and quantifying the roles and relationships between construction project participants (Pryke, 2004; Chinowsky et al. 2008). The technique has been used to analyse knowledge flows between professional contributors to project decision-making (see, for example, Ruan et al. 2012; Zhang et al. 2013). Network characteristics have also been used to explain failures in team-based design tasks (Chinowsky et al. 2008) and identify barriers to collaboration that arise as a result of functional or geographic segregation in construction organizations (Chinowsky et al. 2010). More recently, Alsamadani et al. (2013) used SNA to investigate the relationship between safety communication patterns and OSH performance in construction work crews.

In order to gauge the construction contractor's prominence in a project social network, the contractor's degree centrality was calculated. Degree centrality refers to the extent to which one participant is connected to other participants in a network. Thus, degree centrality is the ratio of the number of relationships the actor has relative to the maximum possible number of relationships that the network participant could have. If a network participant possesses high degree centrality then they are highly involved in communication within the network relative to others. Pryke (2005) argues that degree centrality is a useful indicator of power and influence within a network.

Degree centrality can be measured by combining the number of lines of communication into and out of a node in the network (see, for example, Alsamadani et al., 2013). This presents an aggregate value representing the participant's communication activity. However, the independent variable used in this research was calculated using only the construction contractors' outgoing communication. This was a deliberate choice because the research aim was to investigate whether OSH risk control is of a higher quality when project decisions are made with due consideration of construction process knowledge. Thus, the flow of communication from the construction contractor to other network members was deemed to be of greater relevance than the volume of information they received.

From: Wakefield, R., Lingard, H., Blismas, N., Pirzadeh, P., Kleiner, B., Mills, T., McCoy, A. & Saunders, L. (2014). 'Construction Hazard Prevention: The Need to Integrate Process Knowledge into Product Design'. Paper presented at the CIB W099 International Conference: Achieving Sustainable Construction Health and Safety, 2-3 June 2014 Lund, Sweden.

1.4. Benchmarking and Best Practices

Benchmarking is a powerful management technique that can be used to improve an organization's performance by searching for a partner organization that is the best at a given process and constantly adapting or adopting the partner's practices to increase performance (Kleiner, 1994). The process to be benchmarked is usually determined by analyzing performance figures and other data. A process that has relatively low performance figures and could be improved is often chosen to be benchmarked. Demand for benchmarking comes from several sources, such as increasing enforcement activity, regulations, investor and liability concerns, customer perceptions, and competition with other organizations. The results of effective benchmarking include increased productivity, efficiency, employee morale, and a competitive advantage.

The benchmarking process can be divided into five stages: Planning, analysis, integration, action, and maturity. During the planning stage, the organization identifies the process that needs to be benchmarked. This selection is usually done to fulfill a predetermined need, such as boosting performance figures in an area that needs improvement. Measurable performance variables are also identified. Benchmarking partners are selected based on their best-in-class performance in the targeted process. The partner does not necessarily have to be in the same industry. The organization concludes the planning stage by determining the data collection method and collecting the data. It is important for the organization to be able to distinguish between ethical and unethical means of data collections, especially if it involves handling sensitive information from the partner company.

During analysis, the organization determines the current performance gap for the process that will be benchmarked. The team then predicts future performance levels.

The integration stage involves the organization communicating their benchmark findings. Communication is crucial during this phase of benchmarking, especially when seeking approval from those with more organizational authority. Operational goals and plans are established from the benchmarking findings.

The action stage is characterized by implementing practices, monitoring progress and results, comparing results to stakeholder needs, and adjusting the benchmark goals as necessary. Since benchmarking is a continuous process, the last step will certainly be repeated as industry standards and the needs of stakeholders change over time.

A benchmarking process reaches the maturity stage after the best practices are fully implemented into the targeted process. While benchmarking begins with management, the employees involved in the process are the ones who ultimately integrate the new process.

Kleiner, B. M. (1994). Environmental benchmarking for performance excellence, Federal Facilities Environmental Journal, 5(1), 53-63.

1.5. Learning Objectives

- ✘ *Understand sociotechnical systems complexities of a construction work system*

- ✘ *Understand different sectors, delivery systems, and cultures*

- ✘ *Understand project and industry supply chain and work system complexities*

2. Wastewater Tank

2.1. Overview

The project involved in this case study was the construction of a wastewater tank to help the system manage overflows and allow the utility to comply with EPA requirements. In addition to constructing an overflow tank, a trunk line had to connect the tank to the main line on the other side of a creek.

2.2. Project Profile

2.2.1 Case Background

The federal government placed a consent decree on KUB to improve its aging infrastructure to handle sewer overflows and water quality issues. This led to the creation of the Partners Acting for a Cleaner Environment program. This program, referred to as PACE 10, is a \$530 million, ten year program was launched in 2004 with a mission to maintain and upgrade existing wastewater facilities to handle the demands of a growing city and more stringent federal requirements.

Once the response to the consent decree was accepted, KUB was required to develop an engineering improvement plan with a list of projects to increase capacity and eliminate chronic overflow locations within the system. Nine alternatives were identified for the wastewater treatment plant. Each alternative was first developed to a conceptual level and then screened to rule out any options that would be unfeasible to do operational, site, or treatment constraints. The alternatives were also evaluated in terms of costs and non-monetary factors. The remaining alternatives were then further developed to generate preliminary design and flow diagrams, hydraulic profiles, plant layouts, and preliminary cost estimates. Cost estimates and preliminary design drawings were then developed for each option for further evaluation. The chosen option was biologically enhanced ballasted flocculation/high-rate clarification with 12MG of wastewater storage. The main reasons that this option was chosen were because of cost and the ability to effectively upgrade the treatment plant to meet requirements. A flow analysis showed that two separate tanks (5.5MG and 6.5MG) would be more effective than one 12MG tank.

The wastewater storage tanks were placed as task number three in the improvement plan and given a window from July 2008 until July 2011 to design and construct the 12MG of storage near the treatment plant. The designer wanted to have the tanks submerged for aesthetic reasons and satisfy public opinions, but completely submerging the tanks would be too expensive. The final design called for the tanks to be partially submerged.

The site for one of the tanks was a tract of land adjacent to the utility's wastewater treatment plant. This decision was made because the land was already owned by the utility, the treatment plant was in close proximity, and the property was located at a low point in the sewer line. The property is bordered on four sides by the treatment plant, a railroad, a creek, and a four-lane highway. For OSH reasons, construction tasks were given an extended timeframe due to the proximity of the surrounding hazards.

2.2.2 Case Narrative

Federal and state governments gave a utility consent decree that wastewater system must be upgraded to meet certain capacity requirements due to reported overflows in the wastewater system. The utility responded to the consent decree and the response was accepted by the government. The accepted consent decree requires the utility to improve the wastewater system so that the overflows within the system are reduced to levels that meet regulatory requirements. Once the consent decree was accepted the utility was required to develop an engineering improvement plan with a list of projects to increase capacity and eliminate chronic overflow locations within the system. The utility used a flow model of the system to test different options and determine which list of projects increased capacity in the most effective way versus their respective cost. The projects were broken up into sewer basins, and each project is dependent on others (thus the projects must be evaluated as a whole). Public meetings were held for input, and a public committee was formed to give input into the process.

Another part of the consent decree was a requirement to upgrade sewer treatment plants to meet anticipated peak flow volume based on system improvements and anticipated new connections to the system. The system evaluated the capacity needed at the WW plant based on worst case conditions, and developed a list of options to increase capacity to the required levels from the model. Nine alternatives were identified for the WWTP. Each of these potential improvement alternatives was first developed to a conceptual level. At the conceptual level the alternatives were screened to rule out those that were considered by the utility not to be feasible due to operational, site, or treatment constraints. Also as part of the screening analysis, each alternative was evaluated in terms of costs and non-monetary factors to determine if the alternative should be considered further for analysis. This was done by ranking the options 1-5.

Next, the screened alternatives were developed further to generate preliminary design and flow diagrams, hydraulic profiles, plant layouts, and preliminary cost estimates. Table 4-9 shows the list of improvement projects required for each of the options that were further evaluated after screening. Cost estimates and preliminary design drawings were then developed for each of the options for further evaluation. Option 3 was chosen based on both cost and the ability to effectively upgrade the WWTP to meet requirements (option 1 was found to not meet effluent limits). The WW storage tanks were then placed as task three in the improvement plan and given a window of July 2008 - June 2011 to design and construct 12 million gallons of storage near the treatment plant. The one mention of an OSH related topic in the document was that any projects at the WWTP would have to be given an extended construction time because the site is constrained because it is bordered by a major 4 lane highway, creek, railroad, and WWTP.

Site Layout

The site that was chosen for the tank was an open parcel of land beside the wastewater treatment plant that was already owned by the utility. The main driver for the location was that it was at a low point on the sewer line, was in close proximity to the treatment plant, and was less expensive because it was already owned by the utility. The site ultimately was not large enough for the tank and substation, and the utility was able to secure a long term lease for a parcel of land adjacent to the site.

The site was bordered by the railroad on one side, which required special permitting through the railroad for construction, a creek, the WWTP, and a major 4 lane road. A safety plan was adopted by the constructor for workers due to the proximity of the roadway and railroad.

Site Excavation

The main driver for partially submerging the tank was aesthetics. The utility did not want the tank completely above ground because of how it would look in the surrounding area, and completely submerging the tank was determined to be too expensive. The utility's management was very sensitive to local opinion, which was the background for why aesthetics was such a concern for the tank's placement in the ground. The CM said the key result they got from this stage was the depth of excavation.

The method of excavation was left up to the subcontractor and CM. The owner or designer did not want to dictate means and methods for liability reasons, and thus the design by the A/E just stated how deep the excavation needed to be. The first choice was to bench at a 1½ to 1 slope, but because of the close proximity of the railroad this was not possible for the entire excavation because the railroad had to be supported. The decision was made to pile and lag on the side of the excavation nearest to the railroad. The sub said that the only other option they considered for this part of the excavation was steel sheeting, but that this was more expensive because they wanted to leave the material in the excavation area. The excavation sub then used a structural engineer to produce the stamped excavation construction drawings.

During excavation, the main concern of the sub was with ensuring workers were tied off properly because the excavation was 40-45 feet in depth. They also had to excavate around fuel lines, and thus they monitored the oxygen to ensure safety for workers. Per the contract with the CM, the sub had to submit a site specific safety plan, complete a Job Safety Analysis for every construction task, and attend weekly safety meetings and toolbox talks. The CM also had a site safety engineer dedicated to this project and the other 5.5 MG tank because they felt the size of the site and proximity to other hazards created risks that needed increased monitoring. The sub also stated they had a superintendent and project engineer full-time onsite. They said they would typically not have a project engineer dedicated to a project this size, but that the coordination and scheduling required because of the size of the site made it necessary for this project.

Exterior Wall Construction

The wastewater tank was made of steel-reinforced cast-in-place concrete, which is an industry standard for tanks of this size. The tank subcontractor said that the steel in the concrete is a large safety concern that can cut a person in half if it comes loose and someone is in the way. Therefore they take great care to keep people out of the way and safe while working around the material. They also used engineered scaffolds to work around the tank because they want the workers as protected as possible. There were also some enclosed spaces around the excavation area between the tank and excavation as well as where the tank was built, however having the sides of the excavation benched allowed workers more room to move around and work safely. Safety controls included OSHA mandated air quality tests where appropriate and administrative controls.

Roof Structure

To install the roof of the tank, workers constructed a false work of ribs, shoring, and plywood decking before pouring a thin layer of reinforced concrete. The shape of this concrete shell was spherical with a rise one tenth of the tank's diameter. The design of the roof and false work eliminated the risk of workers being struck, caught in, or crushed by a collapsing structure or material. Worker safety training was also used as an administrative control to help prevent the fall hazard for workers on top of the tank.

Trench Excavation

There were three primary options available for installing the connection line across the creek. One was to use divers to lay the pipe, another was to pump out water from the construction area and trench across the creek, and the other was to divert the creek during construction. The bid documents that were given for the subcontract had drawings that showed the creek being diverted. Pumping out water to trench was deemed unfeasible because according to the schedule in the submitted consent decree engineering plan, the trunk line would have to be installed during high pool for the water to meet deadlines. The construction site is at the mouth of the creek going into a lake, and thus during the winter when the lake is down the depth of the creek is lower.

The subcontractor that was chosen had experience with marine construction, and since they were pre-qualified they met minimum safety requirements specified by the owner. The CM knew the scheduling would preclude pumping, and thus the sub's experience with marine construction was a factor in the decision. The bid submitted by the sub referenced using divers instead of diverting the creek, and this option was approved by the CM and owner when the bid was awarded. The sub stated that diverting the creek was a method that could be used for smaller creeks, but that the size of the creek at the mouth precluded this from being a feasible option both in cost and constructability.

The sub said that they were left to determine the exact method for getting the pipe to a 3 foot depth under the bed of the creek. Using a backhoe from the barge onsite was an option for shallow jobs, but since the depth during construction was 10-12 feet this was not feasible. Thus, they excavated using a clam bucket, and checked the elevation from above both before and after stone was put in the trench.

Utility Installation

The pipe was put on the barge and any connections were made above water, and then was lowered into the creek and put in place by trained divers from a third party construction diving company. This was done by securing the pipe to a backhoe using steel chains and lowering down into the trench. There are special attachments that can be bought for lifting these materials, but these can be expensive and the maneuverability of using steel chains was another important factor in the method because the divers had to be able to easily place the pipe into place and release from the lifting equipment.

The subcontractor company was used to using divers and had all of the certification required, experience working with the CM, and the procedures and experience to install the pipe safely. This included daily checklists to inspect the air tanks and other equipment, and using trained dive tenders on the barge with each diver to monitor air and the safety of the diver. The sub contractor had to abide by all of the CM's safety procedures, which included submitting a site specific safety plan, completing JSA's when starting any new task, and weekly safety meetings and toolbox talks.

2.2.3 Stakeholders

Internal demand for this project came from several sources. The client (owner) was responsible for several tasks during the project's timespan. Such tasks included working with the EPA to determine requirements for the improvement plan, driving the timeline and budget for the improvement plan, approving the plan before submission, and overall oversight of progress within the organization. Groups within the client's organization also managed different aspects of the project. The owner's

safety division audited the site to ensure the workers were meeting OSHA requirements. They also ensured that there were no regulatory or compliance issues with the treatment plant during construction. Another group that was in charge of operating the adjacent treatment plant ensured that the plant could meet capacity demands. A department within the utility worked with outside groups during the development of the overall improvement plan. This included running an analysis and developing options for the projects. A fourth group within the utility developed the RFP for construction once the design was finalized. This group also helped the CM select subs and meet the owner's requirements for the project.

There were several internal suppliers for the tank construction and trunk line installation. The principal contractor served as pre-construction consultant during the design phase and then won the bid to become the construction management firm for this project. As the CM, the principal contractor was responsible for managing the construction process and hiring subs. Engineers were hired by the owner in the planning stage to manage the sewer improvement plan and develop a project plan to meet the EPA requirements. A second group of engineers was brought on to design the wastewater tanks based off of the needs of the owner.

Several trade contractors also served as suppliers. The tank sub helped design the pre-stressed concrete tank based on the design specifications and capacity determined by the engineers. The sub then constructed the tank. The excavation sub determined means and methods with input from the CM before performing the 40-45 foot excavation for the tank. Another sub was responsible for the installation of the trunk line across the creek. This sub was responsible for determining the means and methods of installation, which turned out to be installing the pipe beneath the creek bed.

External private stakeholders for this project included the railroad company, conservationists, local residents, and the utility's (client's) customers. The railroad company owned the tracks and right of way adjacent to the site, so they issued permits allowing excavation to take place near the tracks. They also approved the shoring plan since the tracks were still supported. Conservationists were given representation on the oversight board during the planning stage to give input on the development of the overall sewer improvement plan. Local residents and the customers also gave input into the sewer design and addressed any potential concerns, which were considered in the final design of the improvement plan.

External public stakeholders for this project included the EPA, city, and state governments. The EPA was the party that initially issued the consent decree to the utility mandating the sewer improvement project. The EPA approved the improvement plan and made sure that the final product met the requirements set forth in the consent decree. The city government issued permits allowing the CM to construct the pipeline across the creek. The state government had a presence on the oversight board during the project planning stage.

2.2.4 Project Objective

The objective of this project was to build a wastewater overflow tank and connect it to the main sewer line in order to prevent the system from overloading and contaminating the water supply.

2.2.5 Sector x Delivery System

This project is an example of an industrial design-bid-build (DBB) project.

2.2.6 Features of Work

Features of work in this case study include the site layout, site excavation, exterior wall construction, roof structure, trench excavation, and utility installation.

3. Problem

3.1. Context

The local utilities provider was under an EPA decree to upgrade its infrastructure to handle overflows in the event of heavy rainfall as well as addressing ongoing water quality issues. Chronic overflow areas within the system were identified by the utility. After an exhaustive analysis of peak flows and hydraulic profiles, the utility decided to build two overflow tanks. The site chosen for one of the tanks was located adjacent to an existing treatment plant also owned by the utility. This location was also selected due to its low elevation on the sewer land and because the land was already owned by the utility. The site for the wastewater tank was bordered on four sides by the wastewater treatment plant, a railroad (which required special permitting to work within the right of way), a creek, and a busy road.

Another part of the project was the installation of a trunk line to connect the wastewater tank to the main trunk line across the creek.

3.2. Objectives

For the main excavation, the CM preferred to have the site overexcavated and benched back to give workers more room to work and ensure safety. The side against the railroad could not be benched back so it was instead retained using piling and lagging. Engineered scaffolding was used for the safety of workers working on the tank at height from the bottom of the excavation. The proximity of underground fuel lines warranted the need for constant monitoring of the air quality down in the excavated space.

A clam bucket was used to dig the trench into the creek bed for the trunk line. Welding the pipes together was done on the surface on a barge and lowered into place by the divers. Routine checks of equipment, spotters for each diver, and daily safety talks were put in place to ensure the safety of the divers.

4. Results

4.1. Safety-Critical Decision Making

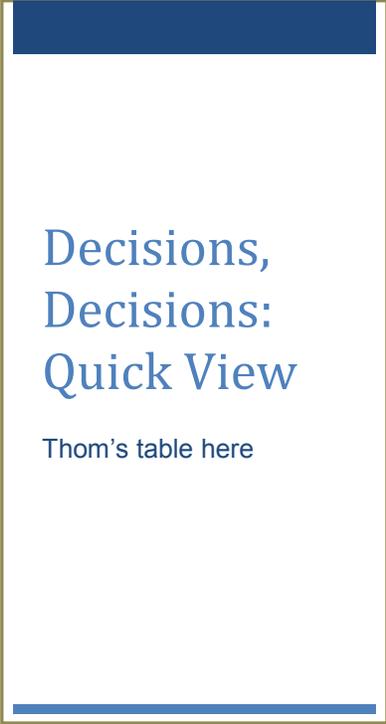
Safety was a key factor in the bidding process. The owner and CM made their selection based off of a list of pre-qualified subs. Submitting data on their safety programs and safety performance was mandatory to be a qualified subcontractor, and any sub who failed to meet minimum requirements were not even considered for the bid.

Due to the large size of the site and the proximity of other hazards, the CM had a full-time safety engineer dedicated to the project. A full-time supervisor and project engineer were also present on the site. As per the contract with the CM, the subs were required to submit a site-specific safety plan and a Job Safety Analysis for each construction task. In addition, subs also were required to attend weekly safety meetings and toolbox talks.

The wastewater tank was designed to be partially submerged. The sides of the excavated area were benched where possible. The proximity of the railroad required the subs to pile and lag that side of the excavation. Because the excavated area was 40-45 feet deep, workers nearby were instructed to tie off. The excavation also took place near underground fuel lines, so air quality was consistently monitored as per OSHA standards. Engineered scaffolding was used around the tank to keep workers as protected as possible.

The installation of a trunk line across a nearby creek was included in the bid for the tank. Several options for installing the pipes were considered, including temporarily diverting the creek, but the sub ultimately decided on installing the pipe underneath the creek bed. The sub had prior experience with marine construction and was pre-qualified by the owner and CM. Means and methods were left up to the sub, and the sub decided on having the trench excavated by a clam bucket and the pipe set in place by divers from a 3rd party company.

The sub had experience with using divers and had current certification. Safety procedures included daily inspections of diving equipment and air tanks, using trained spotters on the barge for each diver to monitor air and the safety of the diver, and abiding by the rest of the agreement with the CM such as attending weekly safety meetings, toolbox talks, and completing JSA's before starting a new task.



Decisions, Decisions: Quick View

Thom's table here

4.2. Hierarchy of Controls

Elimination is seen as the most effective method of hazard control. An example of elimination in this project was benching the sides of the excavation area to prevent the instance of a cave-in and allow workers more room to move.

If elimination is not a possibility to solve a safety problem, the next desirable alternative is substitution, which could mean substituting in a safer material or a safer process. Assembly of the underwater pipe was done on the barge as opposed to in its final location at the bottom of the creek. This decision limited the diving team's exposure in a potentially hazardous underwater environment.

Engineering control is the third most effective form of hazard control. Piling and lagging was done on the side of the excavation that was adjacent to the railroad tracks since there was not enough room to bench outward on that side. This temporary structure helped prevent instances of collapses or cave-ins. Workers used scaffolding while building the waste tank to prevent falls.

Several administrative controls were used during this project. A site safety plan was created before the excavation which outlined some of the hazards associated with the nearby railroad tracks, highway, and treatment plants. The safety plan included several practices to help protect workers from these hazards. Communication was used to warn workers of any approaching trains. Workers down in the excavated area were in close proximity to fuel lines, so oxygen levels were regularly monitored. A spotter was also provided for all divers installing the pipes under the creek bed. The most common administrative control used was worker training, which was used throughout the project for all features of work.

The least effective form of hazard protection is Personal Protective Equipment (PPE), which was a common response for many tasks throughout the project where the above mentioned controls would not have been possible or economically feasible. Other than typical jobsite PPE, such as hardhats and gloves, the only special kind of PPE used by workers was a fall arrest system for workers constructing the tank.

4.3. Social Network Analysis

4.4. Project Performance

The scope of this project was to build a new wastewater tank and connect it to the main trunk line. The purpose of the tank was to handle excess wastewater during peak flows, which would prevent overflows and allow the utility to comply with EPA standards on water quality. The utility was given a window from July 2008 to July 2011 to design and construct the tanks. It is not known if any injuries or deaths were reported during the project.

5. Case Evaluation

5.1. Results & Benefits

Building wastewater storage tanks allowed for the utility to more quickly meet regulatory deadlines on eliminating system overflows (KUB, n.d.). As of 2014, the utility has built four storage tanks with a combined capacity of 20MG. The utility estimates that the tanks could be potentially used up to fifteen times a year, depending on rainfall, for a few days at a time.

KUB. (n.d.) Storage Tanks Help Equalize Flow During Heavy Rains. Retrieved from <https://www.kub.org/wps/portal/Customers/Home/ResidentialCustomers/ServiceInformation/WastewaterPrograms/PACE10Program/WastewaterStorageTanks> on 30 July 2014.

5.2. Lessons Learned

6. References

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