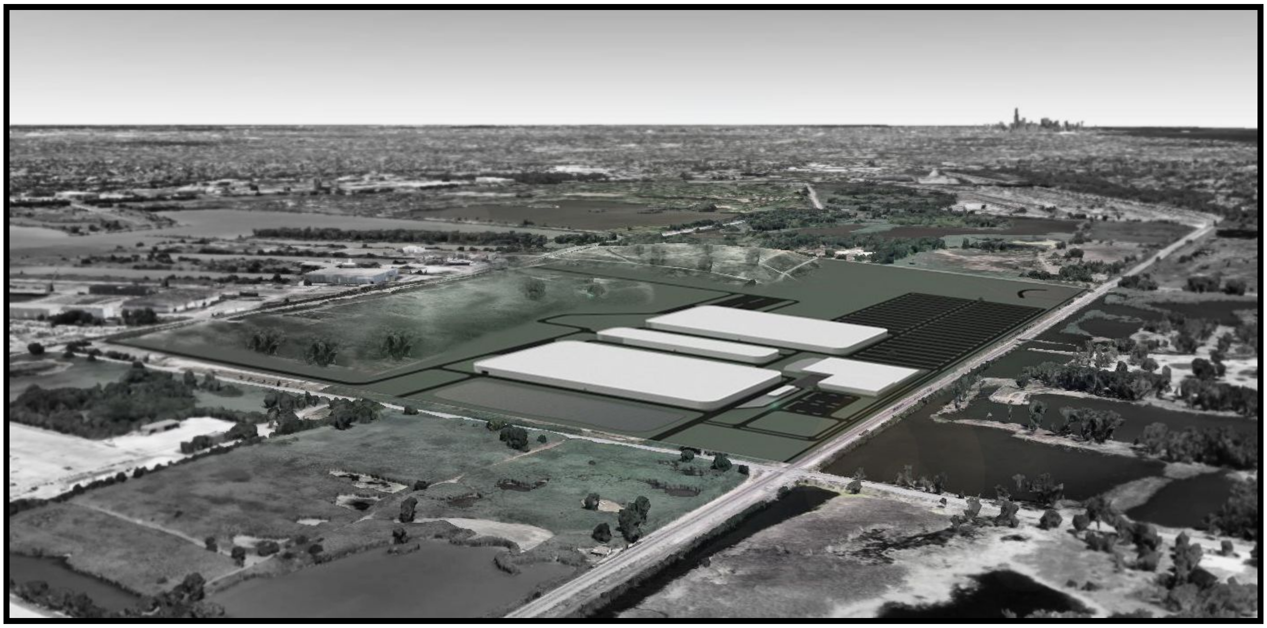
WET ZONE NORTH // 30% Design Study

Ford Automotive Manufacturing Facility Solution

June 6th, 2016



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EXECUTIVE SUMMARY

The Metropolitan Wastewater Reclamation District of Chicago (MWRD) has proposed an investigation into the feasibility of developing industrial facilities that will use MWRD effluent water in their industrial processes, in an initiative to promote the reuse of natural resources. These proposed facilities are to be located in designated Water Enterprise Trade Zones (WET Zone), areas that seek to maximize the use of effluent water in water-intensive industrial and manufacturing processes. This project presents the initial cost and feasibility of designing a proposed Ford Automotive Manufacturing Facility at WET Zone N, located in the Lake Calumet Cluster EPA Superfund Site, North of East 122st Street and just East of Lake Calumet, and will use effluent from the MWRD's Calumet Wastewater Treatment Plant (WWTP).

The Calumet WWTP currently discharges all of its effluent to the Calumet River, and the pursuance of this proposed WET Zone development will allow the MWRD to lessen its impact on the natural surroundings, promote the use of resource recovery and possible resource monetization, and allow for the development of successful industrial businesses that will promote the regional economy.

The Green Team has completed a 30% design study for Ford and MWRD and this report will provide detailed overviews and alternative design decisions of various components of the project.

The northern WET Zone is a brownfield in the Lake Calumet Cluster EPA Superfund Site, and as such requires remediation, site improvement and capping in order to develop the site. Site improvement measures such as soil removal, deep dynamic compaction and impervious capping will all be required in order to move forward with the development of the northern WET Zone.

There are five Ford buildings on the proposed site - one for automotive body assembly (Body), one for Trim-Chassis-Final (TCF) one for paint application (Paint), and a WWTP, in addition to office and cafeteria spaces. The exterior envelope of each building is recycled metal corrugated vertical panels attached to the building's steel frame. Each building's superstructure is supported on a mat foundation. HVAC requirements will be serviced by radiant floor heating in all spaces, chilled beams in the office and cafeteria, air conditioning in the manufacturing buildings, and variable air volume (VAV) units in all buildings.

The on-site WWTP will pump water via pipeline from the MWRD Calumet WWTP and undergo pretreatment, reverse osmosis treatment, and posttreatment. This treated water will be pumped to the Ford manufacturing buildings for use in automotive assembly processes, and effluent from Ford processes will be reused within the facility.

In addition, the site will have a stormwater detention pond at the southeast part of the site. The stormwater from the detention site is later on released into the Calumet River. As per the Green Team's recommendations, the Ford Automotive site will achieve an Envision platinum ranking by implementing various innovative initiatives, such as a Ford Shuttle Service.

The project is expected to be completed in 35 months, beginning in February 27, 2017, including seven construction phases. The estimated construction cost is $476 million, including 1% bond, 8% tax, 1.5% building risk insurance, 0.9% general liability insurance, 10% design contingency, 3% construction contingency and 5% CM fees.

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INTRODUCTION

INTRODUCTION

Project Description

The goal of this project is to develop a WET Zone that will capitalize on MWRD's resources. The proposed development is a new Ford Automotive Manufacturing Facility and will include five facility buildings which will use effluent from the Calumet WWTP and biogas from MWRD. The project encompasses the lifecycle of water and energy while meeting design requirements to minimize cost, maximize energy efficiency and use of MWRD resources and incorporate aesthetics via landscaping and architecture. This site will provide a unique experience for the 4,500+ new employees in the proposed development. The budget for the entire project is set at $464 million.

Site

The site of the project is located east of Lake Calumet in Chicago, Illinois, in WET Zone N and has a total area of approximately 500 acres, 400 of which has been developed for use. An aerial image of the site in context with MWRD and WET Zone S is shown in Figure 0.1 below.

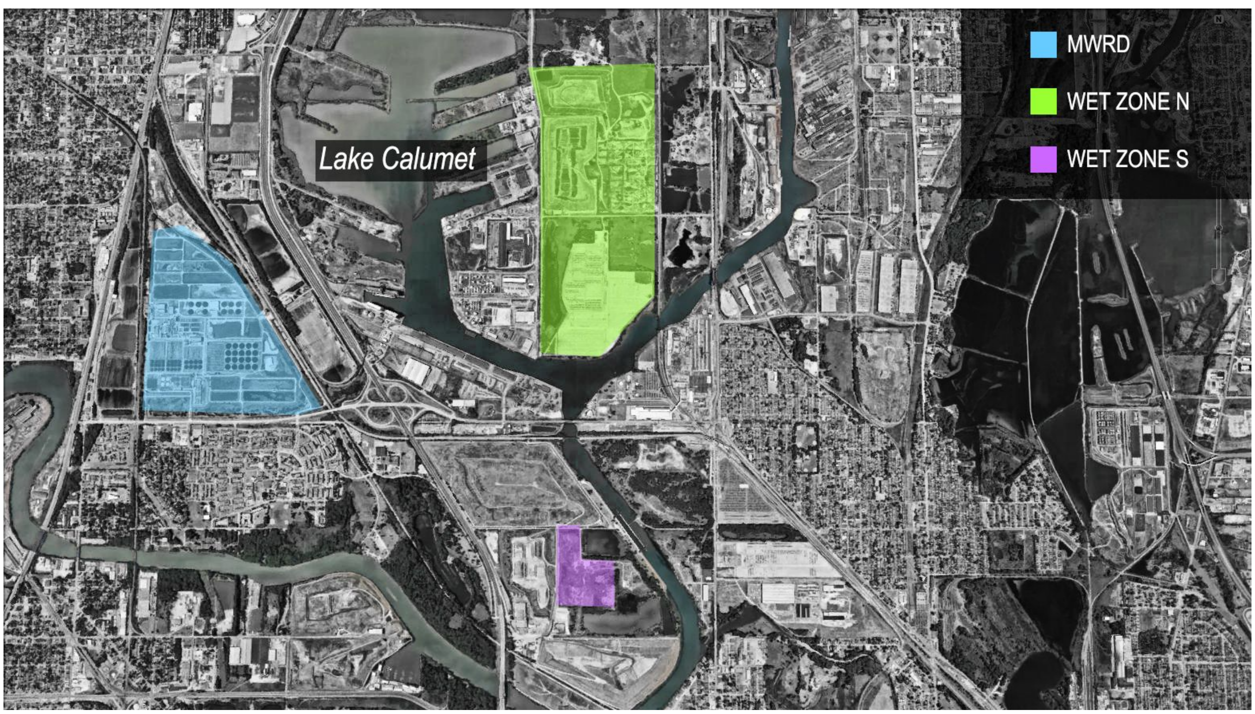


Figure 0.1: WET Zone

A closer view of WET Zone N is show below in Figure 0.2. Some of the main surrounding features of the site are specified in the diagram, including wetlands, parks, and main roads which will ultimately impact the final proposed design.

Figure 0.2: WET Zone N

Section 1

SITE QUALIFICATION

Kai Kasprick

Site Qualification and Permitting

Site – WET Zone N

The area chosen for WET Zone N (shown in Appendix 1A) includes a Superfund site known as the Lake Calumet Cluster[1]. This site, composed of the former Alburn Incinerator parcel, an unnamed parcel, the U.S. Drum parcel, and the Paxton Avenue Lagoons, was used as a mix of industrial facilities and waste disposal areas. The site was originally a wetland. Various excavation, filling, and dumping activities occurred from the 1940's to the 1980's. The site is now covered by as much as 30 feet of fill consisting of various materials, including steel mill slag and industrial, chemical and municipal waste. Environmental concerns include contaminated soil and contaminated surface water runoff from the site into the adjacent wetland areas. In 2007 – 2008, Illinois EPA began construction of a landfill cap, but ran out of resources before completion. Now that the Cluster site is on the National Priorities List, the Illinois EPA can use federal money to complete the cap and investigate the full extent of contaminated groundwater at the site. The landfill cap construction was estimated to begin in late 2015 or early 2016.

The area of contamination includes unregulated and previously regulated disposal sites and saturated contaminated soil, which encompass the entire site. The disposal sites and contaminated soil contain numerous contaminants, including arsenic, barium, cadmium, calcium, chromium, copper, cyanide, lead, manganese, mercury, nickel, zinc, phenanthrene, fluoranthene, acenaphthene, bis(2-ethylhexyl) phthalate, benzene, toluene, polychlorobiphenyls (PCBs), benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene[1]. Most of these contaminants are found across the entire site at the surface, but only in a few specific areas at a depth of 2-3 feet below the surface[2]. At 4-6 feet below the surface, the contamination is almost completely limited to the Alburn Incinerator parcel and the south end of the unnamed parcel.

The plant will make use of the already existing parking area on the south end of the site while preserving the existing wetlands and buffers.

Due Diligence and Permitting

The list of permits and regulations that related to the Ford project and this site can be found in Appendix 1B. As this project is at 30% design, there may be additional permits required as components are updated and finalized. Though the stormwater discharge permits have been included, the current design recommendations will not require them, as the hydrology engineer plans to create a detention pond on the south end of the site.

The US EPA has taken the position that the acquisition of permits is not required for on-site remedial actions, but acceptability criteria must be met. In accordance with this, the operation of treatment or other measures for a period of up to 10 years after the remedy becomes operational and functional is considered part of the remedial action. Activities required to maintain the effectiveness of such treatment or measures following the 10-year period, or after remedial action is complete, whichever is earlier, are considered in the operation and maintenance costs.

Wetland Mitigation

Both WET Zone sites have wetlands that will be not be impacted by the current designs. If the client decided to further establish and/or enhance wetlands on the site, the required construction, maintenance, and monitoring would result in "credits" from wetland mitigation.

The two different reasons for pursuing wetland mitigation are:

- financial gain from mitigation credit sales
- required mitigation from future on-site impact

Currently Chicago has not approved of in-lieu fee mitigation, so the sale of credits would need to be through a wetland bank[2]. The simplest option would be to join an existing wetland bank also located in the Lake Michigan watershed. The closest existing wetland bank is Sauk Trail, over 15 miles away from either WET Zone site. Joining this bank may be possible, but the client would need to contact the Army Corps of Engineers. The other option would be to start a wetland bank on the site. This bank would be subject to approval and regulation by the Army Corps of Engineers, the Illinois DNR, the Environmental Protection Agency, the Fish and Wildlife Service, and the Natural Resources Conservation Service, and the client would need to submit annual monitoring reports for a minimum of 5 years following completion. The financial costs of either option are negligible in comparison to the potential sale price of the credits, but it would burden the client with long-term monitoring and maintenance responsibilities. The mitigation site would also need to pass the review process by the Army Corps of Engineers (outlined in Appendix 1C)[3].

The present project design suggestions do not involve the impact of any wetlands. A future goal of the client is to further develop a WET zone, and if the site reaches a high density of developed area there could potentially be an impact on the surrounding wetlands. This would be subject to Section 404 of the Clean Water Act, and in order to obtain a permit the potential impacts on the wetlands must be minimized. Impacts are only allowed if unavoidable, this would only be an option if no practicable alternative exists. In this case, buying credits from off site would be the simplest option in terms of design, permitting, and maintenance. In terms of cost, going through the process of on site mitigation would likely cost less based on recent credit prices in the area, around $100,000 per credit acre[4]. However, the cost estimate could vary widely depending on many factors, including the level of mitigation, size of the wetland site, amount of available credits, and proximity to the mitigated wetland. Additionally, the potential to further develop the sites as WET Zones is diminished if significant space is dedicated to wetland mitigation, so with proper planning the issue should be avoided.

Section 2

GEOTECHNICAL + SITEWORK

Nathan Zaporski

Geotechnical + Sitework

The bulk of the geotechnical considerations in this analysis consisted of evaluating site conditions in light of the EPA Superfund status of the proposed site, and evaluating alternatives for improving the site for constructability and remediation, as well as evaluating settlement and water retention concerns. Foundation design was completed by the structural lead, Gina Baldea, and can be found in Section 6 and the supporting appendices.

Site Conditions and Subsurface Condition Reconstruction

The lack of comprehensive soil borings on the proposed site required a reconstruction procedure. The main sources of data included borings from ECS, LTD[1] at 13421 S. Vernon, (3 miles SW of the proposed site), borings from the Benesch[2] construction of the existing Ford plant at 130th and Torrence, and contamination evaluation borings on the top 20 feet of the proposed site performed for the EPA by Ecology & Environment (E&E) in 1999[3]. The depth to bedrock at the various locations was checked via the 1996 USGS report on the Calumet/Chicago region[4], and the surface elevations were ascertained from the Cook County LIDAR Database[5], as the available boring logs used differing and often ambiguous terminology to describe the surface elevation.

The site at 130th and Torrence has a similar depth to bedrock as the proposed site (~515 ft), and there was a similar blow count on the clays recovered at about 575' (NAVD088 Datum). Therefore, boring R23 was selected from the Benesch boring logs, and the contents below 575' were transferred to below the fill conditions indicated by the E&E contamination logs. Refer to Appendix 2A for relevant logs, the location of these logs in relation to the proposed site and the reconstructed soil profile, as well as relevant contour maps of the bedrock and groundwater levels.

Site Improvement and Foundation Design Alternatives

The heavily contaminated site conditions (See Section 1) require the evaluation of improvement alternatives. Government regulation requires that the site be capped in order to limit human interaction with the contaminated soil. The proposed built area (building and pavement) will serve as an impervious cap, while any un-built area will require either an EPA-approved impervious cap[6] or sufficient fencing to contain the contaminated and uncapped areas of the site.

In order to build on this site, human interaction with these materials must be limited as much as possible, and this informs the selection of a recommended foundation system. Normally, for a building of this nature on these subsurface conditions, deep caissons would be the recommended foundation design choice. However, the contaminated nature of the proposed site would either require extensive and likely cost-prohibitive permitting to perform the necessary excavation for the construction of caissons, or it would require the removal of contaminated soil and shipment to an off-site specialty waste landfill.

Table 2.1 portrays the cost differences for each alternative. Soil removal alternatives were calculated using a price of $\$100/ft^3$ for hazardous waste removal (provided by discussion with Harish Rao and several domain experts on the project), and considered the removal of the top 3 feet of soil, using areas of 11.8 million ft^2 and 3.7 million ft^2, respectively. Calculations can be found in Appendix 2B.

Table 2.1: Site Remediation Cost Alternatives

Fencing[6.5]	**Hazardous Waste Cap**	**Entire Site Soil Removal**	**Built-area Soil Removal**
$650,000	**$71 million**	$3.5 billion	$369 million

The recommended option is to improve the site conditions through a deep dynamic compaction (DDC) program, and then construct a mat foundation on-grade, using additional fill as needed to coordinate site elevations (Figure 2C.4). This will limit exposure and be significantly cheaper than the soil removal option. The mat foundation will serve as a contamination cap, and the un-built areas would be capped with the impervious cap seen in Figure 2B.1 in Appendix 2B. Fencing is not considered further in this analysis because merely fencing the site would do nothing in terms of remediation, would prohibit the integration of the public into the site, would be aesthetically displeasing and would not allow for an optimum Envision rating for the project (see Section 9: Envision).

Deep Dynamic Compaction: DDC

Figures 2.1-2.2 illustrate the proposed DDC program for the project. Figure 2.2 outlines the area to be compacted, while Figure 2.2 illustrates the spacing pattern. Odd and even passes will be dropped in the pattern shown in Figure 2.2. It is recommended to use a tamper weight of 16 tons, a drop height of 60 feet and a spacing of 15 feet off-center. This program seeks to improve the entire depth of the fill (20 feet), and increase the strength to N = 35-40 (Standard Penetration test). According to Figure 2C.1[7] in Appendix 2C, this corresponds to an applied energy of 400-600 tm/m^2. Two to four passes will likely be needed, and craters shall be filled in and graded between passes.

Figure 2.1: Area for DDC Application

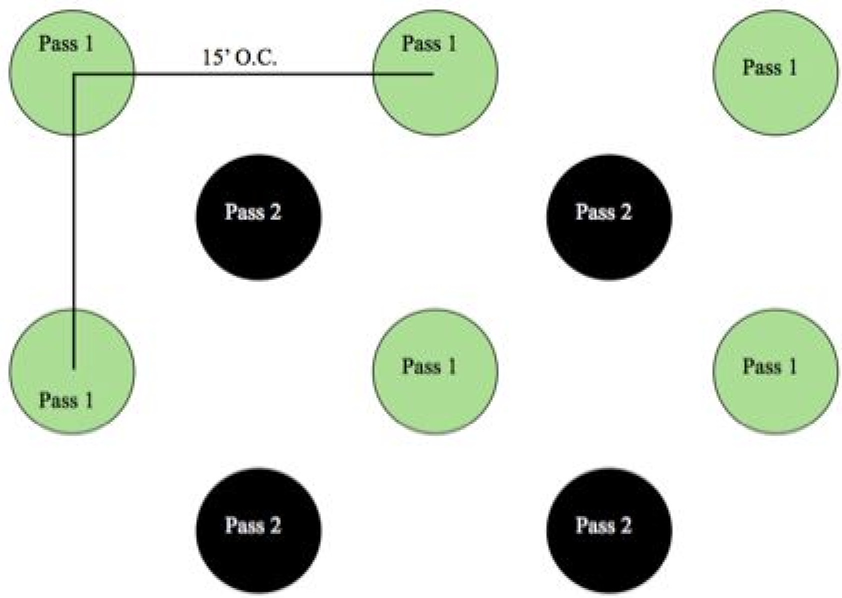


Figure 2.2: Spacing Pattern for DDC

For the protection of workers on site during the DDC process, it is recommended that 1 foot of clean sand fill be placed on the compactable area to serve as a contaminant barrier. This can be seen in the site elevation schematic shown in Figure 2C.2 in Appendix 2C. If the recommended site investigation program indicates a water table shallower than 1-2 m (4-8 feet), additional fill can be added to mitigate cohesion problems with the tamper. Note that this will likely increase the settlement of the subsurface clays.

Additionally, it is recommended that at the edges of the site, west along Stony Island Ave, south along 122nd and east along the existing railway, DDC could cause lateral ground motion and vibrations that will affect these thoroughfares. It is recommended that vibration monitoring be employed along with trench excavation on the site border to monitor and dampen the effects of lateral ground movement.

Figures and supporting calculations can be found in Appendix 2C.

Mat Foundation Design

The design of the mat foundations for the proposed buildings can be found in Section 6: Structure and the relevant supporting appendices.

Settlement

Settlement calculations for the proposed manufacturing buildings can be found in Appendix 2D. Based upon the reconstructed soil logs and provided equations from ECS, it was found that both the soft clay layer and the hard clay layer are each heavily over-consolidated. Each layer was divided up into sub-layers and settlement was predicted using consolidation theory[10]. The soft clay layer was analyzed in three layers, and the hard clay layer was analyzed in four layers. Two loading cases were considered – loading from a 3 ft. concrete mat foundation (for manufacturing buildings) and loading from a 2 ft. concrete slab (office and cafeteria), based on an initial estimate.

The added vertical stress for case 1 (manufacturing) assumed a 3 ft. concrete mat, 100 psf machine load, 100 psf structural steel load and 240 psf for two feet of added fill for site elevation coordination purposes, for a total of 890 psf. Case two assumed a vertical stress increase of 690 psf, from a decrease in machine load and concrete self-weight. However, as discussed in Section 6, consideration of the column loads provided by the steel team creates the need for a 7 ft. concrete mat. This is unrealistic, and a redesign of the structure to minimize the column loads, in tandem with a redesign of the mat to thicken it only beneath the columns, is recommended.

(Note: Newmark adjustments are insignificant for size of buildings considered, therefore settlement is evaluated on basis of mat thickness, floor and machine loadings only.)

Table 2.2 below shows the predicted settlements for each case, including the 7 ft. slab on the office building.

Table 2.2: Clay Settlement from Various Loading Cases

Foundation Thickness/Loading Case	**Predicted Total Settlement**
1. 3’ Mat/890 psf	1.35 in
2. 2’ Mat/690 psf	1.07 in
3. 7’ Mat/1440 psf	2.04 in

Evaluation of differential settlement for mat foundations, after Das (2006)[11] shows a predicted value of $\delta = 0.5$ in. Referring to Figure 2C.4 (site grading), Fill 2 should be compacted upon placement to 98% compaction, eliminating the possibility of Fill 2 contributing to the overall settlement.

Subsidence of the surface fills and soils from the DDC program is assumed to be 1-3 feet, after recommendations from design experts at Hayward-Baker, in addition to recommendations by Slocumb (2004)[9] (See Figure 2C.3) Further settlement of the fill is possible, but there is no way of evaluating further settlement using first principles.

Adding together the differential mat settlement and the settlement from the clays, **over 2 inches of overall settlement is predicted**, which exceeds initial target values of 1 inch. Adding less fill could mitigate this settlement, but it is needed primarily to protect workers and secondarily to assist with grading. Soil removal to offset the added fill would be prohibitively expensive. Indeed, if soil removal were a feasible option, it would allow for the construction of deep foundations. Further design analysis will need to address these potential problems.

Water Retention / Water Table

Groundwater elevations were estimated based upon the available borings, surface elevation LIDAR information (see Appendix 2A). Discerning the true depth of the groundwater was difficult due to inconsistencies in groundwater elevation reporting from previous investigations. Additionally, Figure 2E.3 in Appendix 2E shows an example historical air photo[14] that indicates good buildable conditions and no clear surface water. Analysis of later air photos, and the 1999 E&E report[3] indicate that a significant amount of fill was added over the years. In light of these uncertainties, it was generally assumed that the groundwater elevation is 5-10 feet below the ground surface, which informed the design of the water retention pond (see Section 3: Hydrology and Hydraulics). These relatively shallow groundwater levels could also pose issues for the proposed deep dynamic compaction program. These assumptions will need to be confirmed by a comprehensive subsurface soil investigation program.

The recommended form of water detention will be a detention pond located on the southern end of the proposed site. (See Figure 5.1). Due to the contaminated nature of the site, this pond must have a 3-foot thick impermeable clay liner to prevent the infiltration of groundwater and a path for contaminant transport. See Section 3 for a representative cross-section of the proposed detention pond. Note that the required detention volume is 1,303,377 cubic feet, as determined by the Hydrology team.

Slope stability for the pond was evaluated by a procedure outlined in Peck, et al (1974)[15], and calculations can be found in Appendix 2E. It was found that slope stability should not be a major concern – for a 45^{o} slope, the factor of safety on a 10-foot deep pond is 3.25. (The current design calls for an 18^{o} slope and will therefore not present an issue)

Section 3

HYDROLOGY + HYDRAULICS

Jack Pong

Hydrology + Hydraulics

Site Details

The Ford site has an area of approximately 10.8 million square feet. The area which we are building on is north of East 122nd street. However, everything above this area contains some level of contaminated soil which has heavily influenced our design ideas. Because the soil is contaminated, it is not possible to build any infiltration structure for possible BMP alternatives[1]. Moreover, for the areas that are being dug up to build hydraulic structures, a liner must also be placed to prevent water from infiltrating into the contaminated soil.

Runoff patterns

Runoff patterns was evaluated by analysing the contour map of the site. The elevation of the site heavily varies throughout the site. On the west side of the site, there is a hill with the highest point being 670”. Meanwhile, north of the site the elevation is approximately 610”. However, towards both the south and east end of the site, elevation drops to around 590” before the site meets the road[2]. Therefore, the runoff pattern for the site is towards the south east direction. A detailed contour map of the site is included in Appendix 3A.

Stormwater Release and Detention Analysis

The stormwater release at our site is not regulated as shown in Appendix 3B but according to the industry standard and the standard of sites in Chicago, the maximum release rate can be assumed to be 0.3 cubic feet per second per acre[3] . The site above East 122nd street is 230 acres hence the total allowable release rate is 69 cubic feet per second.

The required site detention volume was calculated using the rational formula: Q=CiA and the 100 year rainfall data. The site’s composite runoff coefficient is affected by the type of landscape and material we have on the site[4]. Further details of these calculation are included in Appendix 3C. These guidelines for detention volume ensures that a certain amount of stormwater is captured, this not only helps prevent sewer overflow but also helps reduce runoff that is sent back to the wastewater treatment plant[5].

The composite C value used for the final calculations was 0.48[6], and the total required storage volume came out to be 1,303,377 cubic feet. Further details of the calculations are shown in Appendix 3C.

Stormwater Storage Location and Type

The stormwater detention pond will hold 1,303,377 cubic feet of water as calculated from the detention volume analysis. The surface area of the pond will be 212,500 square feet and will hold a trapezoidal shape as shown in Appendix 3D. According to the soil boring logs from Ecology and Environment Inc in Appendix 2A and the assumptions presented in the geotechnical section it was assumed that the water table to be 10 feet below the ground surface[1]. After adding a 3-foot layer of clay lining, to prevent water from infiltrating into the soil, a detention pond with a pond depth of 7 feet can be constructed.

The maximum depth of the pond will then be 7 feet with a slope of 1:3 (vertical: horizontal). Further details of the detention pond configuration and cross section can be found in Appendix 3D[7].

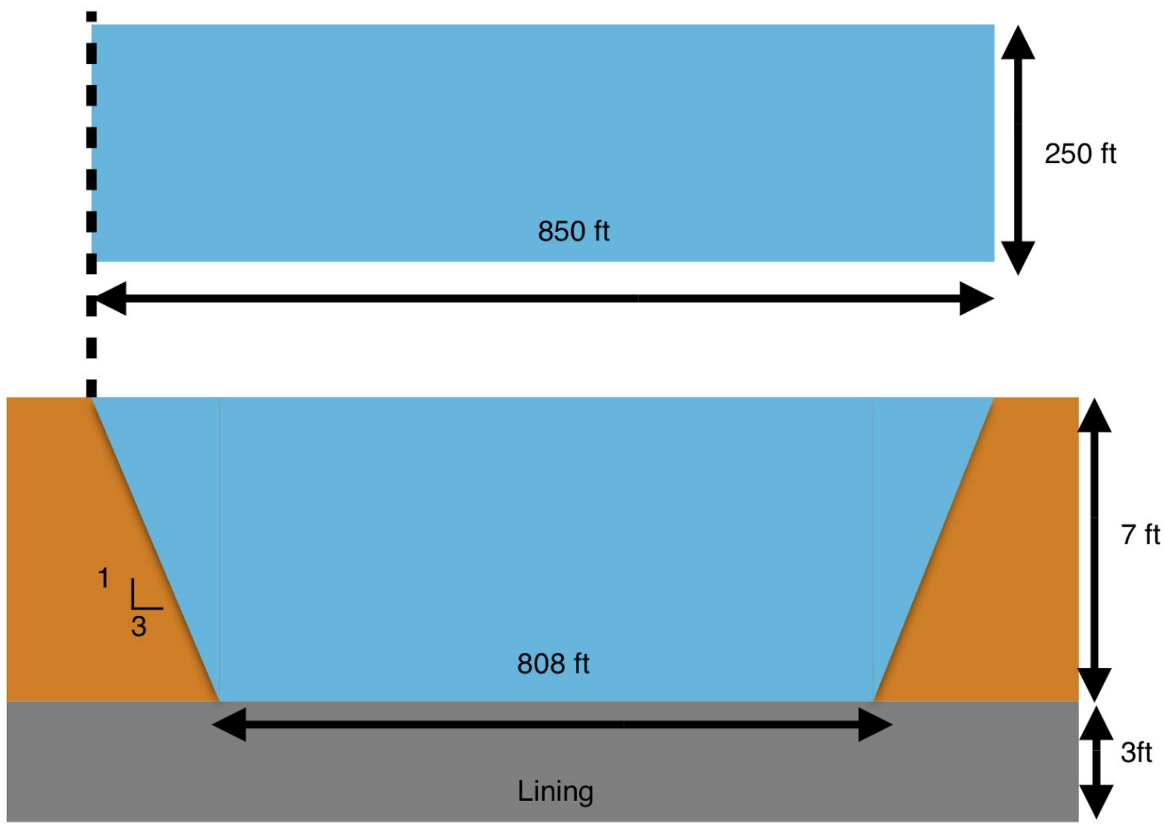


Figure 3.1: Stormwater Detention Pond Cross Section

A stormwater detention pond was chosen as Ford's detention system, but both an underground detention system using oversized pipes of 6 feet in diameter and an above ground detention pond were each considered. Due to to cost factors, it is recommended move forward with the ground level storage system instead of the underground option. As shown in the calculations in Appendix 3E, the ground level storage system would cost approximately $15.3 million, in contrast to an underground detention system, which would cost $39.5 million[8].

Orifice Sizing

This analysis assumed a release rate to be 0.3 cfs per acre. In order to abide by this release rate, a restrictor will be installed on the outflow pipe that moves water from the detention pond to the Calumet river. The orifice diameter is calculated to be 27 inches and is shown in Appendix 3G[4].

Other Design Alternatives

As mentioned previously, the proposed site is filled with contaminated soil, hence infiltration BMPs are not permitted. As a result, many of the potential BMPs brainstormed such as bio-infiltration, infiltration vault and permeable pavement were not possible[4]. Furthermore, due to the limitation from the structure and loads of the proposed buildings, it was not feasible to include green roofs as a part of the design.

After the aboveground detention pond was selected, different alternatives for the use/removal of the excavated soil were evaluated. The first major alternative considered would be to excavate it and transport it to the nearest landfill, the other major alternative alternative would be to excavate the soil and spread it over the north side of the site. Because the proposed site will have to be capped, adding a small layer of soil of less than 0.5 feet would not add much additional cost or drastically affect the elevations. However, in consideration of the contamination outlined in Section 1, the top 3 feet of the soil needing to be excavated is mostly classified as very contaminated and would have to be transported to the nearest hazardous landfill.

Using this information, the cost to excavate and transport all the soil was calculated to be over 40 million dollars, while excavating and transporting only the top 3 feet of soil and capping the rest on the northern part of the project site would only come out to be $15.3 million[8]. A detailed breakdown of this procedure can be found in Appendix 3F.

Stormwater System

The proposed stormwater system, seen in Appendix 3H, will consist of 12 in diameter pipes that flow toward the detention pond above 122nd street. It is mandated that there must be a catch basin for every 10,000 square feet of the developed site and to be 200-300 feet away from each other. Thus, there will be 150 catch basins along the impermeable portions of the site[4].

Section 4

TRANSPORTATION + UTILITIES

Ian Piper

Transportation + Utilities

Objectives

Goals for the transportation design associated with the construction of a Ford Manufacturing Facility in WET Zone N were broken down in the following categories and defined below:

> *Transportation Analysis*
>
> The construction and use of the FORD Manufacturing Facility must not impede on local traffic and must leave the existing roadways and traffic flow in equivalent or improved conditions. Through traffic impact analysis, the impact on surrounding roads and highways will be determined and address if the existing road structure cannot adequately meet the new demand of these facilities. Additionally, site access and circulation must meet the needs of employee traffic and parking, truck and rail deliveries, and emergency vehicle access.
>
> *Utilities, Site Constraints, and Grading*
>
> Connections to standard utilities and MWRD as well as must be determined and meet the demands required by both facilities. Site constraints as they relate to utility and transportation access must be identified and addressed in the design of the manufacturing facilities (i.e. railways, geographic obstacles, protected land, property lines, etc.). Additionally, roadway and parking lot grading must provide adequate ingress and egress for water drainage.
>
> *Pavement Design*
>
> Pavement design of new facility roadways must adequately meet the demands of vehicle use.

To achieve these goals, various requirements, standards, and designs were outlined for the individual transportation components below:

Access and Mobility

Bus routes and train stations[1] have been identified in Figure 4.1. Ford and WET Zone N will be connected to bike trails[2] that will be constructed through the Millennium Reserve environmental and economic renewal plan[3] identified in Figure 4.2. A typical cross section of a two-way bike and pedestrian trail[4] shown in Appendix 4A: Figure 4A.1 was provided to the architect for site planning.

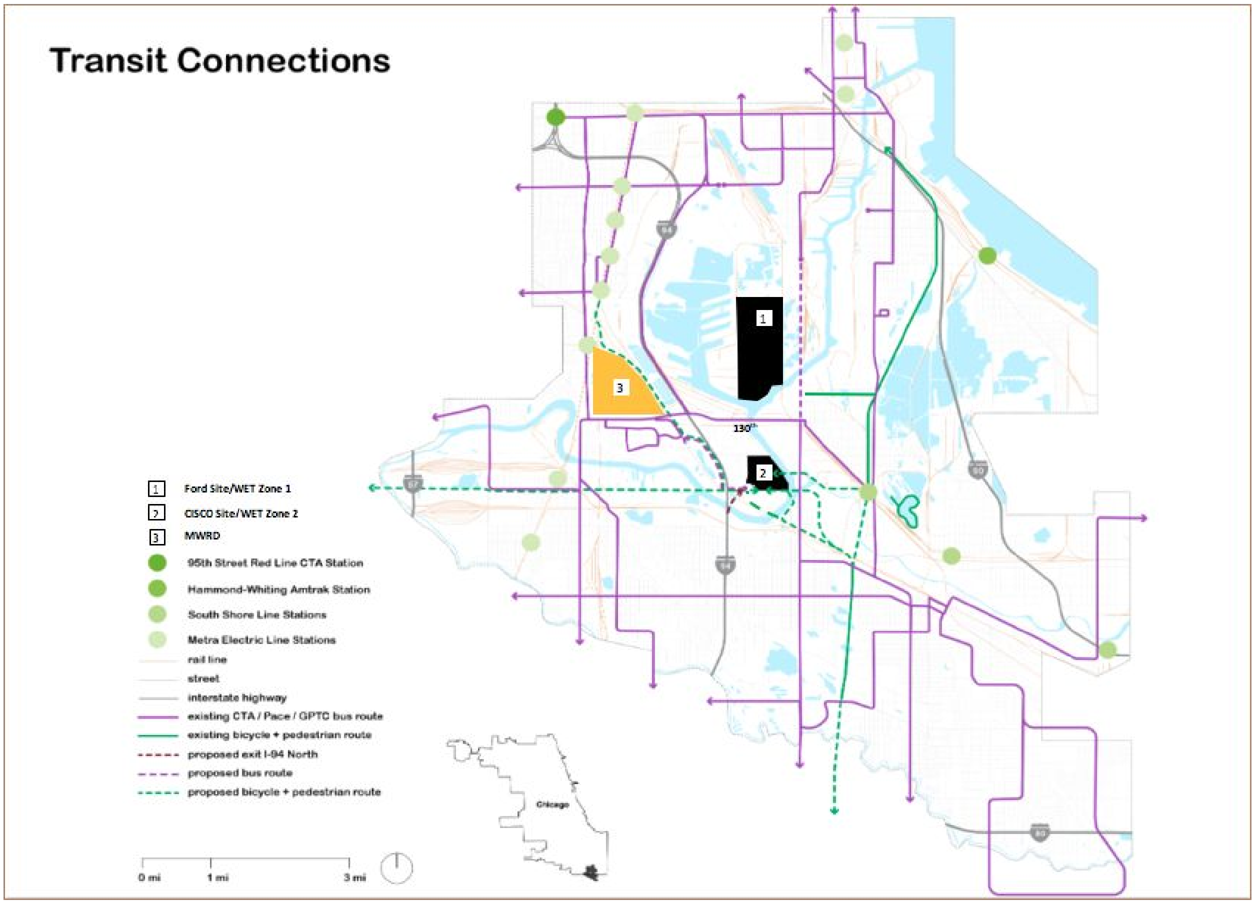


Figure 4.1: Lake Calumet WET Zone Transit Connections

Both sites are located within multiple train stops and have nearby access to existing and proposed bus routes as depicted above.

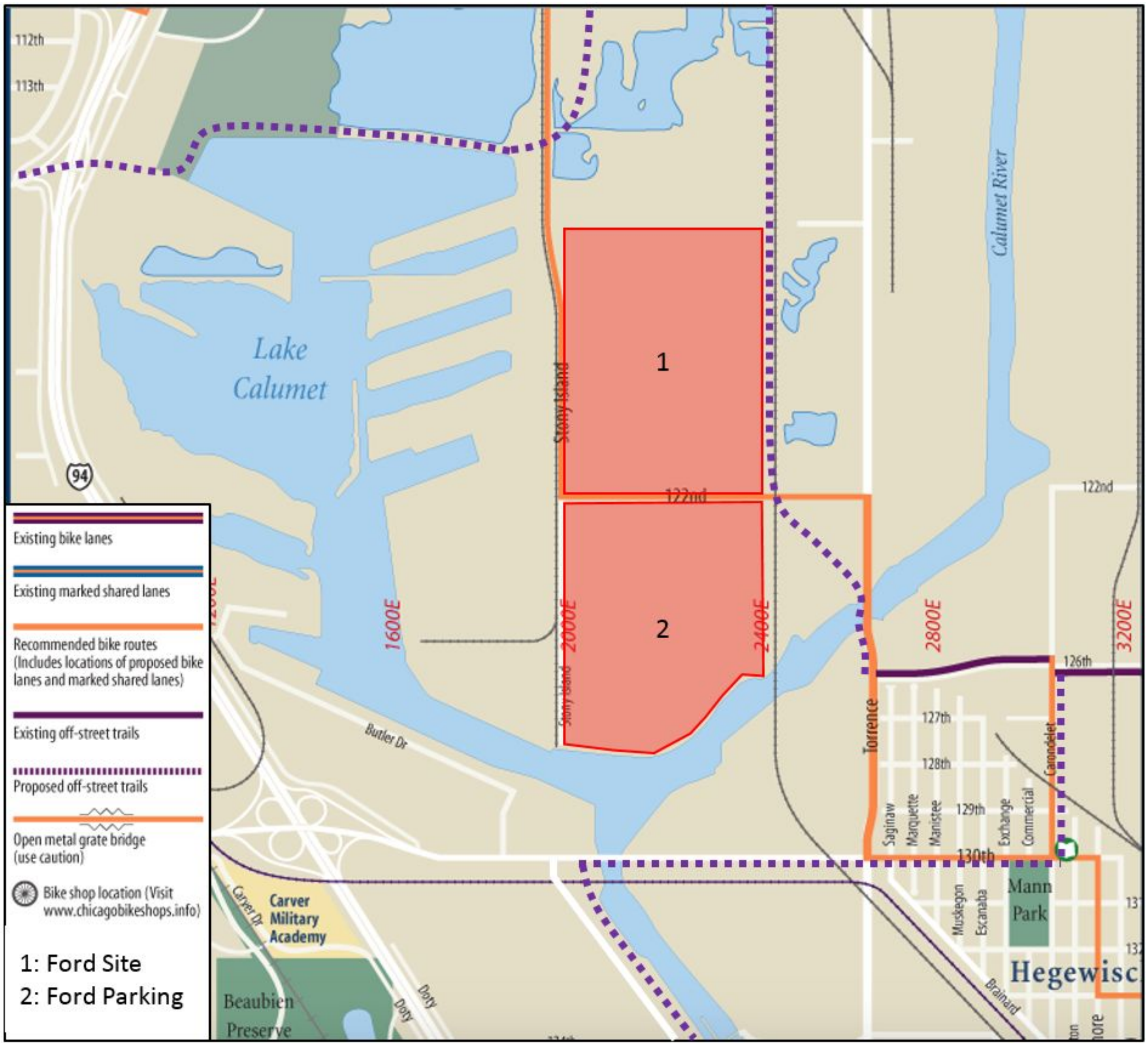


Figure 4.2: Ford and WET Zone N Bike Trails and Roadways

Proposed off-street bike trails running along the eastern edge of the Ford site would provide bike commuter access for Ford employees and promote community engagement with the WET Zone.

Traffic Demand Study

Trip generation for Ford and WET Zone N (Appendix 4B: Table 4B.1) utilized vehicle trips dictated by site specific program of requirements and directional distribution percentages from the Trip Generation Manual, 9th Edition[5]. Vehicle trips were calculated using the employee counts from the program of requirements and assumptions on shift distributions, because they were more conservative and accurate than the Trip Generation Manual vehicle trip estimations. Trip generation was only analyzed during the AM peak hours (7:00-9:00 AM) because it was determined that the Ford morning shift change coincided with the AM peak. Other shift changes did not coincide with other peak traffic hours and were therefore not analyzed as the impact of Ford vehicle traffic would not greatly impact the surrounding roadway system.

Working with transportation domain expert Michael Magnuson, P.E.[6], trip distributions for the Ford site (Appendix 4B: Table 4B. 2) were based on assumed percentages. Traffic analysis was performed for three intersections near the Ford site using Synchro software. Each intersection was analyzed during the AM peak hour for Base Condition, Site + Base (no improvement), and Site + Base (with improvements) and was evaluated through an A through F grading scale and calculated delay time for each of the three scenarios shown in Table 4.1 below.

Intersection	**Control**	**AM Peak Hour**		
		Base Condition LOS (Delay)	**Site + Base (no improvement)**	**Site + Base (w/ improvements**
122nd/Torrence	Side Street Stop Control	A (8.5)	D (53.2 sec)	A (6.4 sec)
130th/Torrence	Signal	C (32.9 sec)	D (42.1 sec)	D (42.1 sec)
130th/ CISCO Access Road	Signal	D (32.7 sec on Access Road)	E (45.8 sec on Access Road)	E (40.7 sec) *
*Improvement doesn't make a difference, therefore improvements not considered				

Table 4.1: Impacted Intersection Results from Synchro Software

Traffic improvements for the Ford site include a site entrance expansion on 122nd St shown in Figures 4.3 and 4.4 below as well as improvements to surrounding intersections as a result of the traffic analysis (Appendix 4C: Figure 4C.1). The cost of these improvements for the Ford Facility will cost an estimated $2.78M (Appendix 4D).

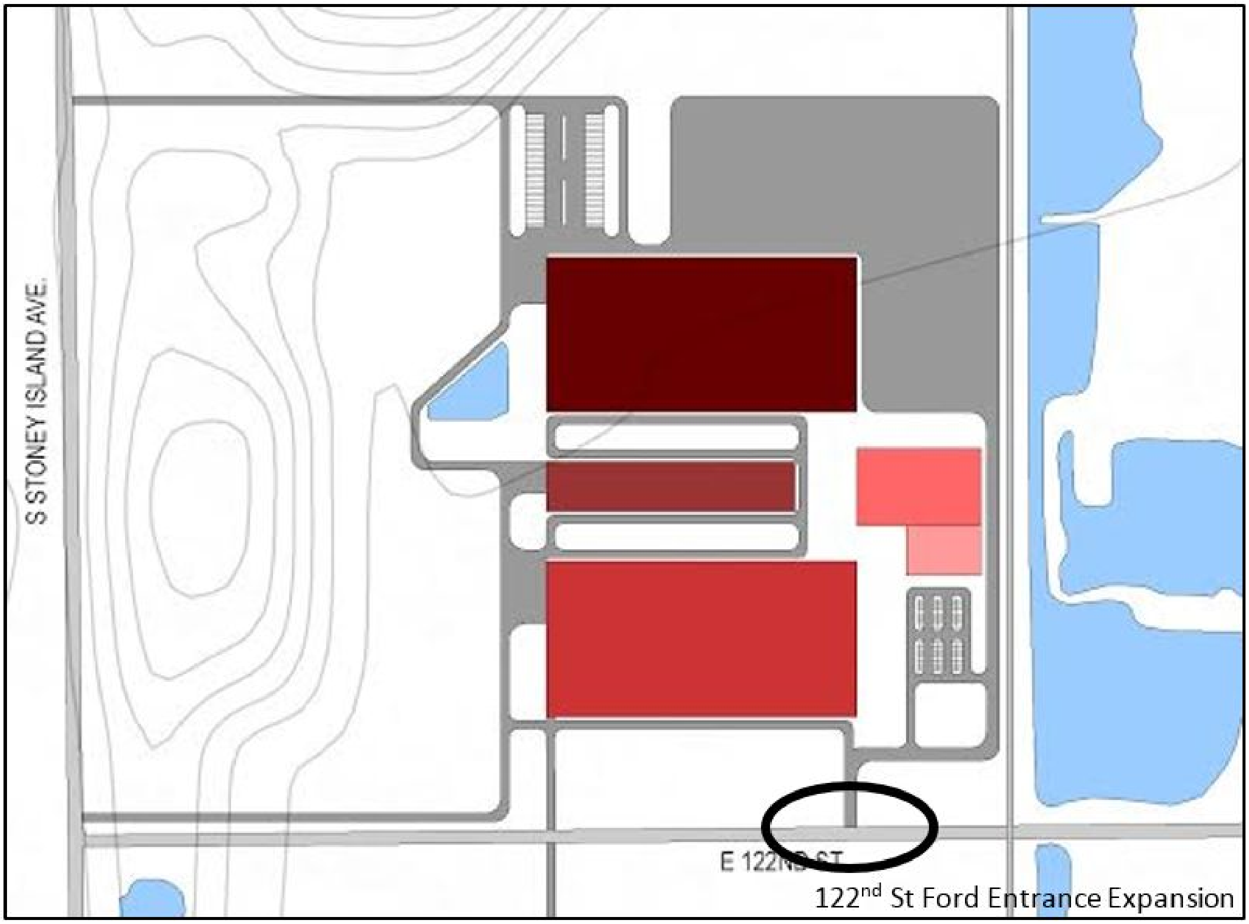


Figure 4.3: 122nd St Ford Entrance Expansion Location

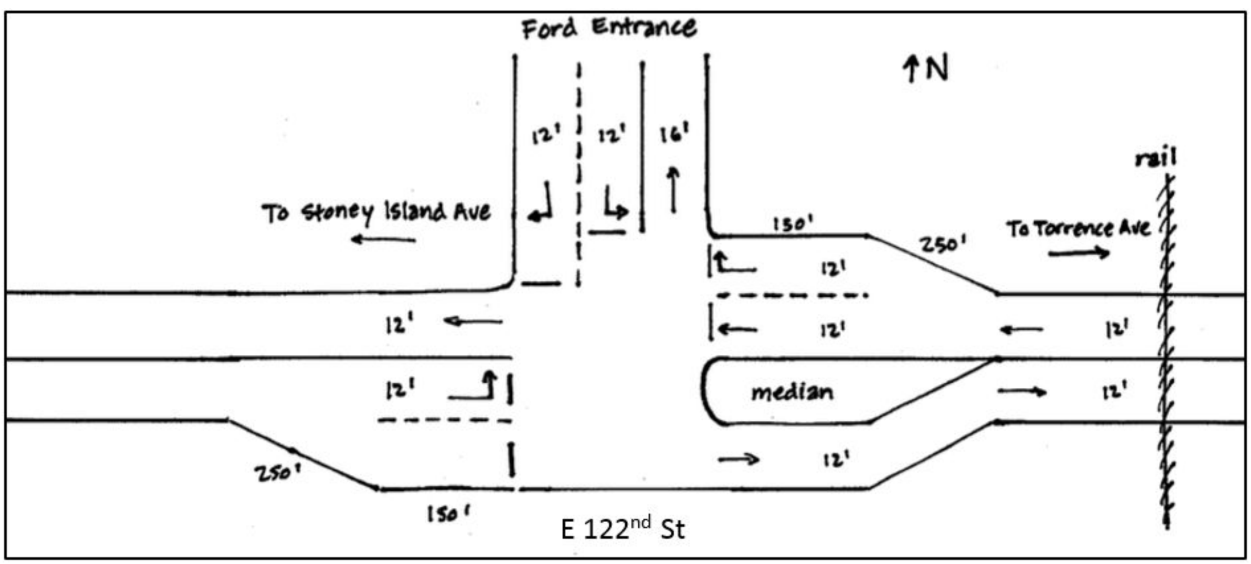


Figure 4.4: Ford Entrance Expansion Intersection Plan

Although these traffic improvements do not account for a significant portion of the total cost to develop WET Zone N and construct the Ford Manufacturing facilities, the development of WET Zone S to include both a CISCO data center and Industrial Park would increase the total cost of traffic improvements to $27.1M shown in Table 4.2 below, It should be noted that this cost does not include traffic analysis that would result in potential improvements and added costs if both WET Zone S and N are fully developed. However, traffic improvements resulting from the development of WET Zone S were designed with the co-development of the Ford and the WET Zone N in mind. Specifically, the new 137th St and I-94 interchange (instead of an upgraded 130th St and I-94 interchange) directs traffic flow away from 130th St which is heavily used by Ford traffic and minimizes the potential need for further improvements to intersections on that road[6].

Site Alternative	Improvements	Cost	Total
FORD (4650 employees)	122nd St Entrance Expansion	$800,000	**$2,700,000**
	122nd St and Torrence Ave Intersection	$1,000,000	
	103rd St and Stoney Island Ave Intersection	$300,000	
	130th St and CISCO Upgraded Road	$600,000	
CISCO ONLY (50 employees)	**Cost Due to CISCO Only Improvements**	$3,640,000.00	**$6,340,000.00**
FULLY DEVELOPED INDUSTRIAL PARK (2025 employees)	**Cost Due to Fully Developed Industrial Park Improvements**	$24,390,000.00	**$27,090,000.00**

Table 4.2: WET Zone Traffic Improvement Cost Totals

Site Circulation

Site Circulation requirements including driveway standards, emergency vehicle access, and general design principles[6,7] are outlined in Appendix 4.E: Table 4E.1 and were given to the Ford architect to use in the design of the site layout.

Rail Connection

Connecting to the Norfolk Southern rail line, 6 loading and unloading industrial track lines measuring 1800ft in length located in the existing Ford parking lot south of 122nd St shown in

Figure 4.5 below. This location was chosen both to provide easy access to the existing rail line and because the existing parking lot is where finished cars will be stored before they are shipped via rail. They were designed based on the track connections in use at the current Ford facility in Lake Calumet and with specifications outlined by a typical industrial track cross section and Norfolk Southern Industrial Track requirements[8] listed in Appendix 4F: Figure 4F.1. The current pavement will have to be removed for the tracks to be installed and then recovered in asphalt shown in Appendix 4G: Figure 4G.1. The cost calculations of the 6 lines are shown in Appendix 4H and total $3.61 million.

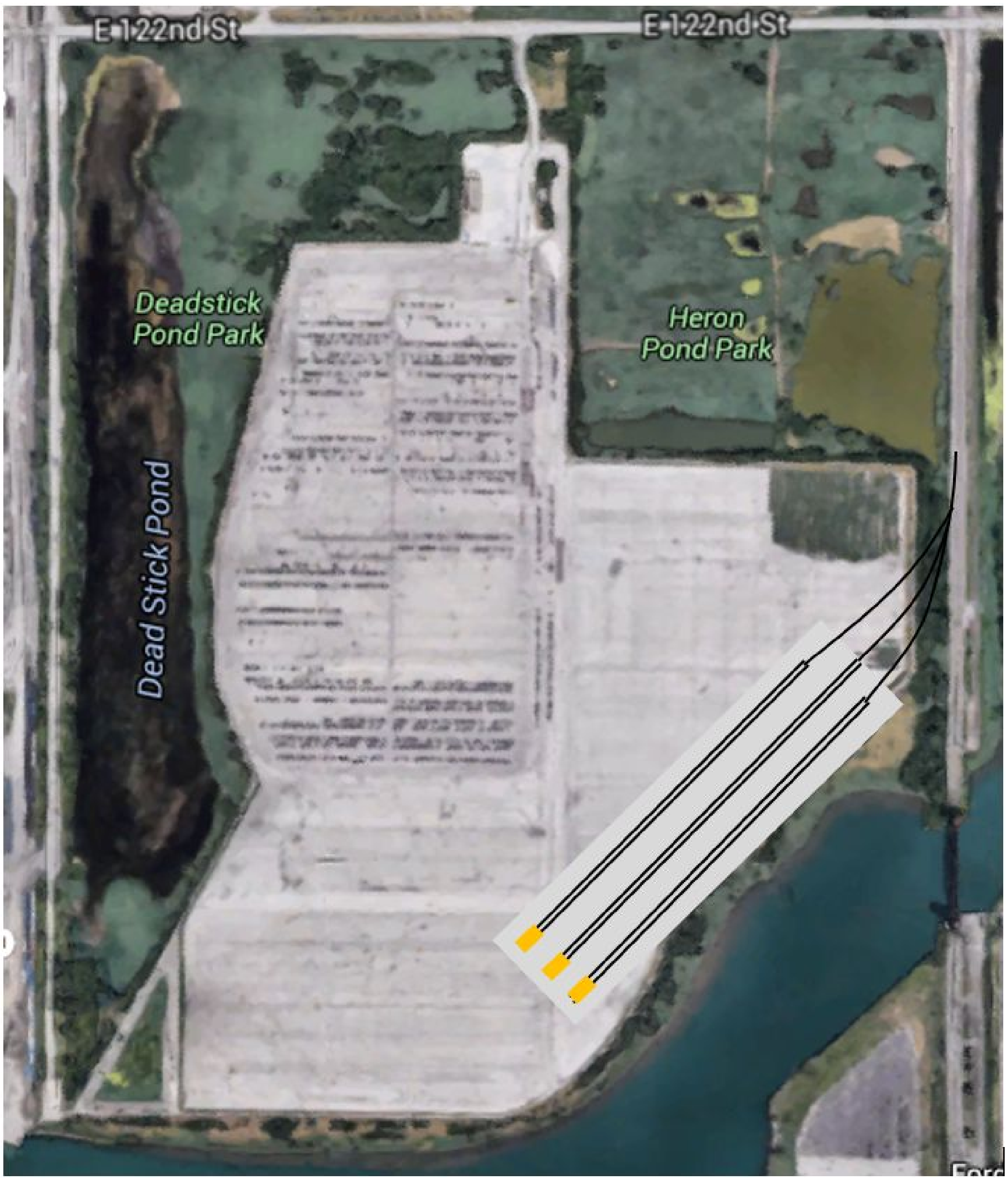


Figure 4.5: Ford Rail Connection

Standard Utility Connections

Working under the assumption that existing roads contain the standard utilities[6] (phone, fiber optic, water, gas, etc.) required by Ford and WET Zone N, the cost of the connections was determined by measuring the 330 ft distance from the Ford Manufacturing Facility to 122nd St shown in Figure 4.6 below. The cost of standard utility connections is $72,600.

Figure 4.6: Ford Standard Utility Connection Distance

Utility Connections to MWRD

Working with the energy estimator, it was determined that horizontal directional drilling of a steel encased 12” outer diameter pipe from MWRD to the Ford and WET Zone N will be utilized in order to pass under I-94, rail line, and the Calumet River. In order to minimize the high cost of horizontal boring, standard 8.625” outer diameter utility pipes will be used to complete the MWRD connection once I-94, rail lines, and the Calumet River have been avoided shown in Figure 4.7 below. The cost of combination of pipes used to provide effluent water to Ford is $4.37 million provided by the cost and energy estimators.

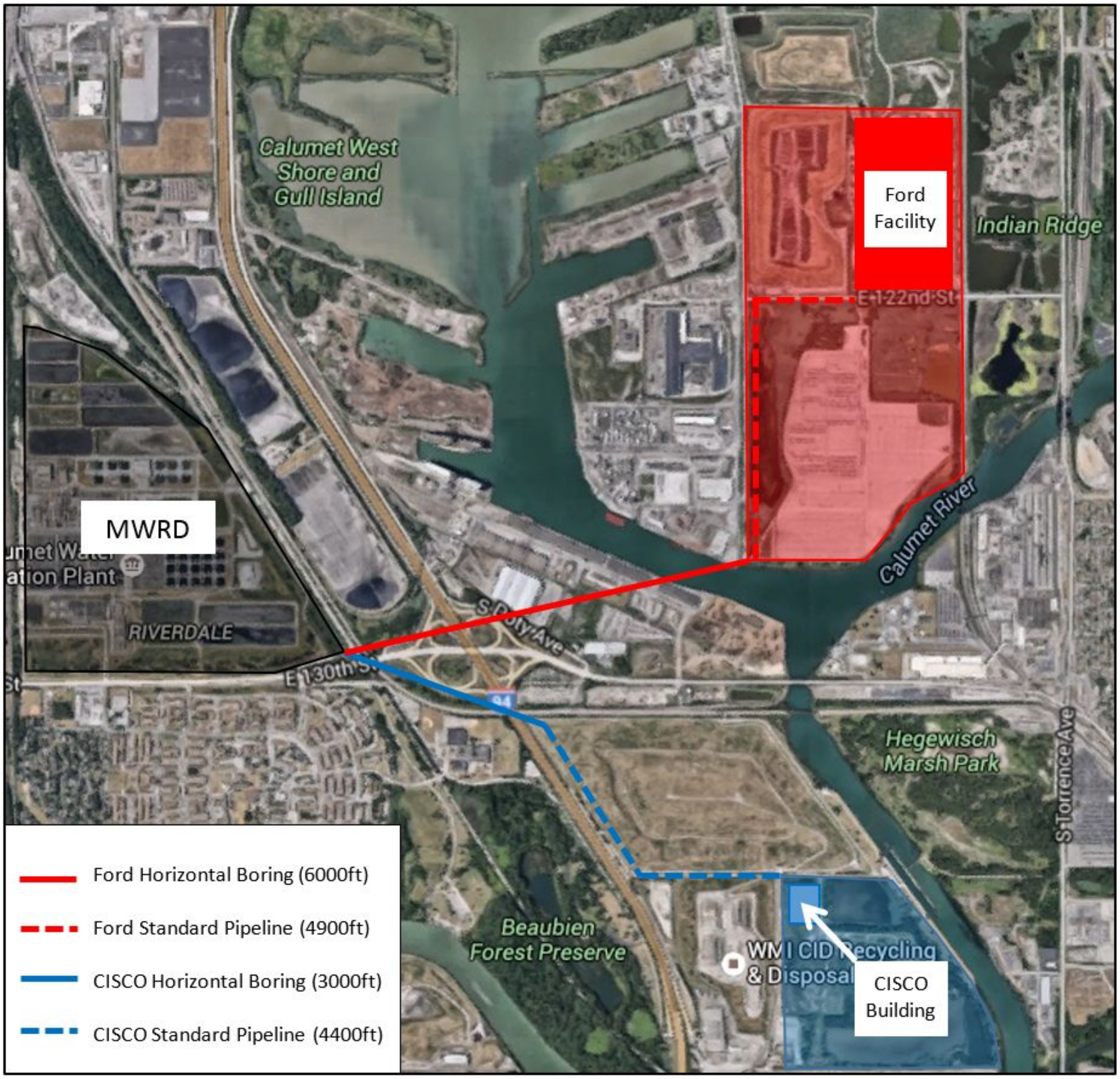


Figure 4.7: Ford and CISCO Utility Connection to MWRD

Parking Demand Study

Parking lot requirements including number of spaces, ADA requirements[9], site layout, dimensions, and grading are all outlined in Appendix 4.I: Table 4I.1 and 4I.2 and were given to the Ford architect to use in the design of the facility parking lots.

Pavement Design

Pavement design for parking lots, driveways, and sidewalks for Ford used standards set by Caltrans: Pervious Pavement Design Guidance[10], 2014 detailed in Appendix 4J. The pavement design for the Ford entrance expansion (Figure 4.4) was set by minimum requirements set by

IDOT Chapter 54: Pavement Design[11] as the calculated widths of the surface, base, and subbase were found to be less than the minimum standard when using the modified AASHTO method (calculations outlined in Appendix 4K: Tables 4K.1-4 and Figure 4K.1). A cross section of the pavement design is shown in Figure 4.8 below.

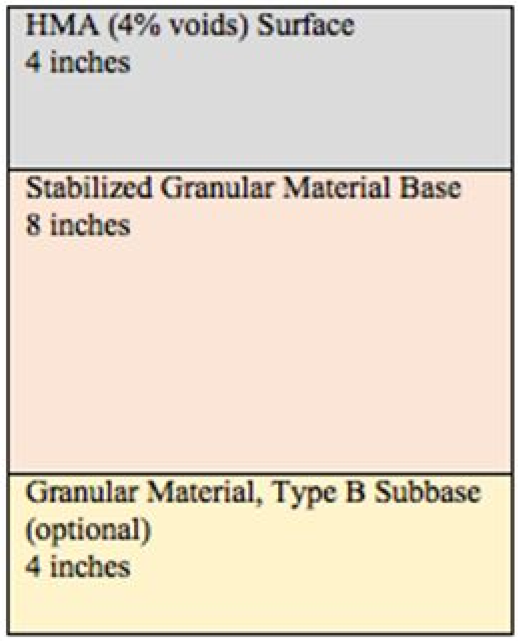


Figure 4.8: Ford Entrance Expansion Pavement Cross Section

Section 5

ARCHITECTURE

Lupe Gómez

Architecture

Program

The northern WET Zone site is the ideal location for the Ford Automotive Assembly Facilities based on its large program requirements. The selected WET Zone N not only provides adequate space for the automotive facilities, but also has enough area for future developments, whether they be manufacturing, recreational, environmental and etc. The main program requirements from Ford are listed below:

1) Ford Manufacturing Facilities
   a. Body Building
   b. Paint Building
   c. Trim – Chassis – Final (TCF) Building
2) Ford Office and Cafeteria
3) Parking Lots (13,000+ Vehicles)
4) Auxiliary Components
   a. Waste Water Treatment Plant
   b. Main Electrical Substation
   c. Cooling Towers

The main requirements of the program are shown with greater detail including square footage and their percentage of the total buildable program in Appendix 5A.

Site Plan

The proposed site plan was finalized after taking into consideration the research and findings of the other design components on the team. The final site plan can be seen in Figure 5.1 below and in greater detail in Appendix 5B.

Figure 5.1: WET Zone N Site Plan

Location and Orientation

The Ford automotive assembly facilities are all located just north of East 122nd Street and nearest the rail line to the east. The site qualification expert determined that the land south of East 122nd Street (where the existing vehicle yard is located) is on a floodplain and thus an area not suitable for construction. Unfortunately, the only area readily available for development is a "brownfield". However, remediating the brownfield, although a costly endeavor, can drastically improve the area for future development and community use.

The orientations of the buildings were decided upon studying the dominant solar paths and discussing research conducted by the energy and LEED experts. The most efficient method of capturing heat and light is the east – west orientation. Additionally, this orientation allows for the easy transfer of assembled cars down each manufacturing facility, which eventually feeds to the vehicle yard in the south. The office/cafeteria building also serves as an anchor to the manufacturing facilities with its central recreational courtyard.

Elevations/Grading

As discussed in the Geotechnical section, due to our implementation of dynamic compaction and various caps, the grading on our site varies throughout. A detailed elevation view of depicting grading, facility heights, and hills is shown in Appendix 5C.

Mobility and Access

In tandem with the transportation expert, it was decided that all heavy truck traffic (shipping/receiving) will have access to the site on the western side vis a vis South Stoney Island Avenue - a road that has been designed for large truck loads. The 60 space trailer lot is located north of the body building nearest the exit. Employees and visitors have access to the site via East 122nd Street from South Torrence Avenue on the eastern side of the site so they do not interfere with heavy truck traffic. The small 100 space visitor lot and large 3000 space employee lot are located south and north of the office/cafeteria building, respectively. The shuttle bus terminal (explained in more detail in the ENVISION section) is located just west of the visitor lot and has direct access to the front of the office/cafeteria building.

There is also a proposed bike path on the eastern side of the site along the rail line with access to the facility building and connection to the larger Millennium Reserve project as discussed in the Transportation section. Additional walking and biking paths are located in the northernmost area of the site and give access to recreational spaces. Interior asphalt roads, including emergency access roads along the perimeter of the facilities, were designed following the Chicago Building Code[1] and the Calumet Design Guidelines[2] published by the City of Chicago.

Landscaping and Other Features

Unbuilt areas on the site are going to be capped, as explained in the Geotechnical section, by a hazardous waste cap. The topmost layer of the cap will be a low-profile prairie mix layer consisting of native grasses and non-native species that will improve water quality and stabilize soil, such as slender wheatgrass and buffalograss. The proposed parking lots and interior roads will also have vegetative 12 foot medians that will also consist of native grasses, overstory trees, and shrubs.

One the major features on the site is the 1.3M cubic foot detention pond just south of the TCF Building. The details of the pond are discussed in greater detail in the Hydrology + Hydraulics section. From an architectural standpoint, the detention pond with its surrounding landscaping and trees beautifully complement the entrance to the facility grounds. There are also proposed boardwalks near the existing northern ponds on the site for recreational activity such as fishing.

The higher elevated western side of the site is reserved for the development of a 30-acre solar panel field to capture energy for our facilities' use. A proposed recreational area for activities such as bird watching and sledding during the winter is located on the hill to the north of the solar panel field.

The Wastewater Treatment Plant, discussed in greater detail in its respective section, and the main substation are located to the north of the Body Building in between the trailer and employee parking lots. This is the ideal location for these infrastructures as they can feed directly to the Body Building.

Renderings of the site entrance, proposed shuttle bus terminal, recreational activity spaces and bike path are shown in Appendix 5D.

Facility Designs

Floor Plan

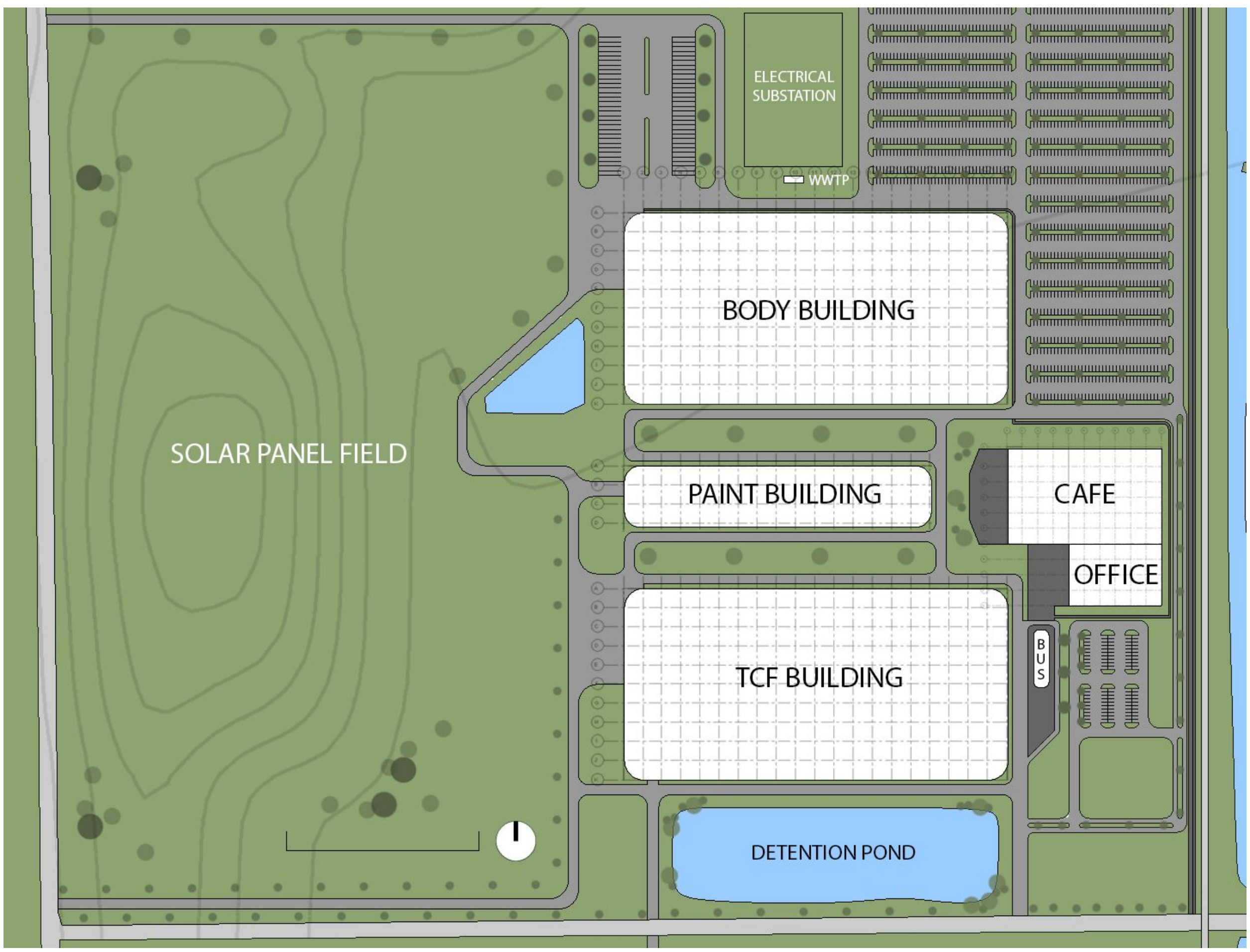


Figure 5.2: Floor Plan

The floor plan, specifying the main facilities, is shown in Figure 5.2 above. Programmatic requirements for the interior of each facility building were not specified by the Ford Motor Company. However, entrances, emergency egress (determined by the building code for the City of Chicago), and loading docks (sizes selected from the "Dock Planning Standards" by Kelly, Inc.)[3] for each building were considered and designed. The floor plan is also shown in greater detail (including construction details) in Appendix 5E.

Wall Sections

The wall sections for the typical manufacturing facility and office/cafeteria building are shown in Appendix 5F. Materials were selected based on various discussions with energy and LEED experts as well with Bill Gains from Ford and Architect Fred Abrams[4]. The materials were chosen based the advantages in recyclability, cost-efficiency, and constructability. The primary exterior material for the facility buildings is the 7.2 Insul-Rib™ insulated wall panels, a traditional corrugated metal panel with a polyurethane foam core, manufactured by Robertson Building Systems. This product is 100% recyclable and is made up of 60% recycled materials. It also offers excellent insulating values and is lightweight and quick to install. The cut-sheet for this product is show in Appendix 5G. Furthermore, as shown in the wall section, the office/cafeteria building has long curtain wall spans in order to illuminate interior working and eating spaces.

The thickness of the mat foundation is 2 feet for the office/cafeteria and 3 feet for the typical manufacturing building. The concrete mat foundation will be left exposed to serve as the interior floor of the facilities and in order to enhance radiation from the radiative heating system inside the slab. The facilities will also have a white insulated corrugated metal roof deck with insulation on top, a lighter and just as efficient alternative to a green roof which would have induced heavier dead loads and the possibility of punching shear onto the mat foundation.

Exterior Aesthetics

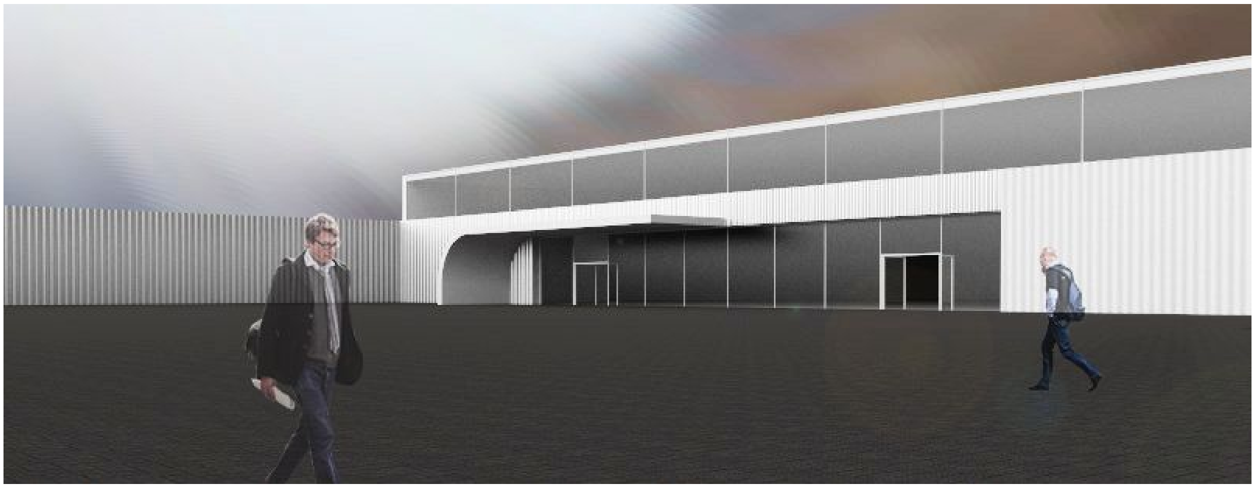


Figure 5.3: Office Main Entrance

All of the manufacturing facilities have Solar White corrugated metal panels that span 10’ along their perimeter. The facilities have their corners filleted to give these massive manufacturing buildings a sleek and modern look. The long spanning curtain wall in the cafeteria also opens up to a courtyard which will blur the line between the interior and exterior giving the Ford employees a unique experience. The office’s main façade has a combination of corrugated metal panels and curtain walls which can be seen in Figure 5.3 above. The main entrance is highlighted by a curving canopy inspired by the F in the official Ford logo.

More renderings of the external aesthetics of the facilities can be seen in Appendix 5H.

Section 6

STRUCTURE

Gina Baldea

Structure

Loads Considered

In order to design a sufficient structural system, the following loads were taken into consideration for each building: Live Load, Dead Load, Roof Load, Snow Load, Wind Load, Seismic Load and Rain Load. Table 6.1 shows the loads for each building, along with maximum column load and column moment, which were found using Visual Analysis. The dead loads for each building were found using the weight of the steel framing system (Appendix 6A)[1]. The wind and seismic loads were found according to ASCE 7-02 (Appendix 6A) [2] .

Type	Body Building & TCF Building	Paint Building	Office/Cafeteria
Live Load	500 psf	500 psf	200 psf
Dead Load	6.39 psf	14.64 psf	9.98 psf
Roof Load	20 psf	20 psf	20 psf
Snow Load	20 psf	20 psf	20 psf
Wind Load	26.7 psf	26.7 psf	26.7 psf
Seismic Load	3.2 psf	5.8 psf	0.34 psf
Rain Load	20 psf	20 psf	20 psf
Maximum Column Load	140 k	154 k	365 k
Maximum Column Moment	315 k-ft	420 k-ft	275 k-ft

Table 6.1: Loads Considered for Each Building

Structural Systems

Roof System

Each building will use a corrugated metal deck with insulation. Corrugated aluminum or steel roofs last up to 100 years and they have high resistance to rotting. They also have noncombustible properties in case of a fire in the factories.[3] Details on the metal decking can be found in the Architectural Appendix 5G.

Framing System

A steel framing system was chosen for each of the Ford Buildings due to its advantages over any other structural system. Steel is fabricated in the shop, as opposed to concrete, which is typically poured on site. This allows for quicker and easier construction. Steel also allows for much longer spans between columns, which is highly important in manufacturing facilities. Lastly, structural steel is currently the least expensive framing system for a majority of construction projects. A structural steel framing system with decking and fire protection is on average 5-7% less expensive than a concrete framing system [4].

Foundation System

A mat foundation was determined to be the most reasonable foundation system for the Ford Buildings. The top layer of soil across the site is extremely contaminated. Therefore, costly permits would be necessary to drill the deep foundations. Another option would be to remove the contaminated soil, but that would cost billions of dollars. Thus, the geotechnical specialist will be using dynamic compaction to strengthen the soil and a mat foundation with impervious caps has been designed.

Material Properties

Table 6.2 shows the strength properties of the materials that were chosen. The wide flange beams will be used throughout the buildings, and the ASTM Tubing will brace certain bays. Appendix 6B discusses the decision to use 6 ksi strength concrete.

Material	Property
Wide Flange Beams	Fy = 50 ksi
ASTM Tubing	Fy = 50 ksi
Plates & Angles	Fy = 36 ksi
Steel Rebar in Mat Foundation	Fy = 60 ksi
Concrete for Mat Foundation	F’c = 6 ksi

Table 6.2: Material Properties of Structural Materials

Body and TCF Buildings

The dimensions and loading conditions are identical for the Body Building and the TCF Building. Therefore, they will have the same structural systems.

Framing

The Body and TCF Buildings are the largest buildings on the Ford Plant, each with an area of 500,000 SF. They will have bays of 50ft x 50ft throughout, as shown in Figure 6.1. W14 x 99 columns and W30 x 99 beams were chosen. The crane rails will run horizontally and include W24 x 62 beams. The corner bays of the building will be braced with HSS 6 x 6 x ½ members for further support. Appendix 6C shows diagrams of the ground level and roof plans, along with an elevation of a typical braced bay.

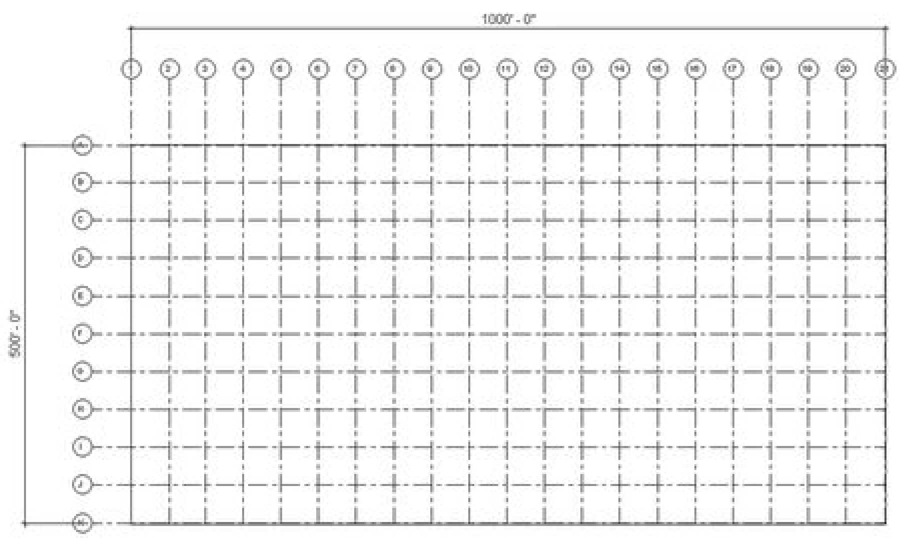


Figure 6.1 Grid System for Body and TCF Buildings

Foundation

All of the Mat Foundations were designed using the Approximate Flexible Method. [5] An initial check for punching shear was completed to determine a preliminary mat thickness. Appendix 6C shows that a foundation of 3 ft is sufficient. The area of steel rebar necessary was found by analyzing 1 square foot of foundation and confirming that it could withstand the ultimate moment. Two No. 9 bars were chosen. A cross section of the foundation is shown in Appendix 6C.

Paint Building

Framing

The grid system for the Paint Building is shown in Figure 6.2. The bays will be 40ft x 40ft throughout. W14 x 99 columns and W30 x 99 beams will be used with HSS 6 x 6 x ½ members for bracing. The paint building will also have a crane rail on the horizontal grids using W24 x 62 beams. Structural plans and an elevation are shown in Appendix 6D.

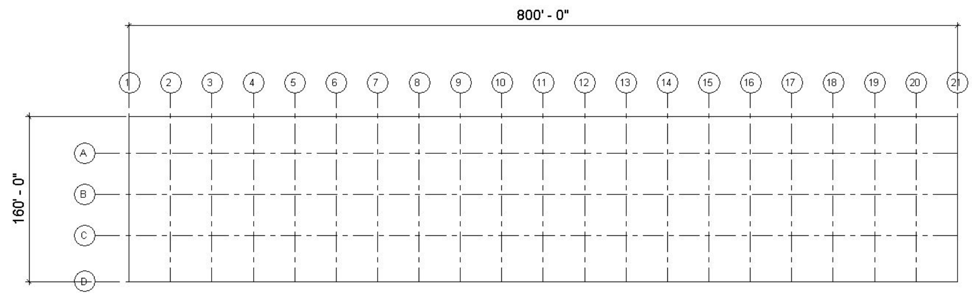


Figure 6.2: Grid System for Paint Building

Foundation

A 3 ft. foundation was chosen for the Paint Building. The area of necessary steel rebar was found to be 2.65 in^2, so 3 No. 9 bars were chosen. Calculations for determining the foundation thickness and rebar are shown in Appendix 6D, along with a cross section of the foundation.

Office/Cafeteria

Framing

The Office and Cafeteria are connected, contributing a combined area of 176,800 SF. The bays will be 40ft x 40ft, except the row of bays at the North end of the building. This row will be 50ft x 40ft (Figure 6.3). W14 x 99 columns and W24 x 146 beams were chosen. There is slightly more bracing in this building because the Office is 2 stories. The second floor of the Office will have W24 x 16 beams at 10ft. O.C. HSS 6 x 6 x ½ members will be used for the bracing. Structural plans of the first floor, second floor, roof and a two-story elevation can be seen in Appendix 6E.

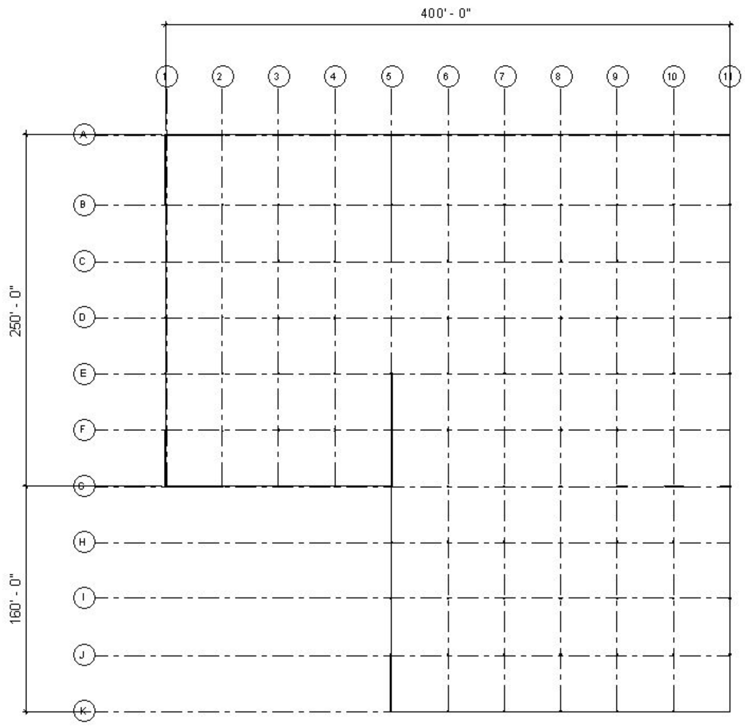


Figure 6.3: Grid System for Office/Cafeteria

Foundation

The maximum column load for the Office/Cafeteria is almost three times larger than the other buildings. It is reasonable to assume that the load will be slightly larger, because the building is two stories. However, when using 365 kips in the punching shear check, the building requires a foundation thickness of almost 7 feet (Appendix 6E). This is much too large of a foundation for the building under consideration. If more time was allotted, the Visual Analysis calculations would be checked for errors. It would also be possible to try larger columns and beams to reduce the column loads. On top of this, 365 kips is the maximum load, so that much force isn't equally distributed at every column. This mat foundation was designed conservatively by assuming the maximum load occurred at each column. If the loading conditions proved to be accurate, a new foundation system would be designed.

Quantities for Construction

If the stated design materials and parameters are chosen, the takeoffs will be according to Table 6.3.

Material	Office/ Cafeteria	Body Building	TCF Building	Paint Building	TOTAL
W14 x 99	1680 LF	5,200 LF	5,200 LF	390 LF	12,470 LF
W24 x 146	10,330 LF				10,330 LF
W30 x 99		20,000 LF	20,000 LF	880 LF	40,880 LF
W24 x 62		10,000 LF	10,000 LF	480 LF	20,480 LF
HSS 6 x 6 x 1/2	2,556 LF	2,272 LF	2,272 LF	906 LF	8,006 LF
6 ksi Concrete	1,237,600 ft^3	1,500,000 ft^3	1,500,000 ft^3	38,400 ft^3	4,267,000 ft^3
No. 9 Rebar	512,400 LF	2,000,000 LF	2,000,000 LF	51,200 LF	4,563,600 LF

Table 6.3: Material Takeoffs for Construction

Further Considerations

Due to time and resource constraints, the entire structural design is missing a few components. Moving forward, the moment connections and base plates must be designed for each building. It has been determined that cross bracing is necessary in each of the buildings, but the exact location of each braced bay must be determined. The beam sizes have been chosen to support the crane rails, but detailed cross sections of the rails should be designed. As mentioned in the design of the Office/Cafeteria, the mat foundation must be checked for errors in calculations, then redesigned in order the reduce the slab thickness. Lastly, a thorough check of the International Building Code 2012 must be completed in order to get all calculations approved.[6]

Section 7

ENERGY + HVAC

Tiffany Kwakwa

Energy + HVAC

Energy Summary

The cost of energy and HVAC (heating, cooling, and air conditioning) equipment comprises one of the largest portions of a building's capital cost as well as operating and maintenance costs. For these reasons, it is important to explore energy efficient alternatives. In doing so, not only are emissions reduced, but the value of the building increases and Envision points (Section 9) can be captured. Using the U.S. Department of Energy's eQUEST software[1], the energy loads of the building can be modeled, with options to change parameters such as building materials, HVAC equipment type, and so on[2]. All models are based off of the 2010 American Society of Heating, Refrigeration, and Air-Conditioning (ASHRAE) Standard 90.1[3], which details common energy standards for buildings. As per the needs of our client, the MWRD, only systems that use water for heating and cooling, rather than air, were considered as one of the primary goals of building the Ford site is to maximize the use of MWRD resources.

Baseline Energy Model

The Ford Automotive site consists of 5 buildings; details on dimensions, ventilation, temperature, and other requirements can be found in Appendix 7A. The shells of the building, as well as the orientation and materials, were determined by discussion with the architect and Envision expert. Below is a figure of the buildings as input into eQUEST. A general manufacturing space was used, which may not accurately capture the energy loads from the automotive manufacturing equipment that will be used. The interior spaces used the default settings for zone divisions – differentiating between office space, reception, bathrooms, and so on. A baseline was established that consists of direct exchange (DX) coils and a furnace with a standard VAV system.

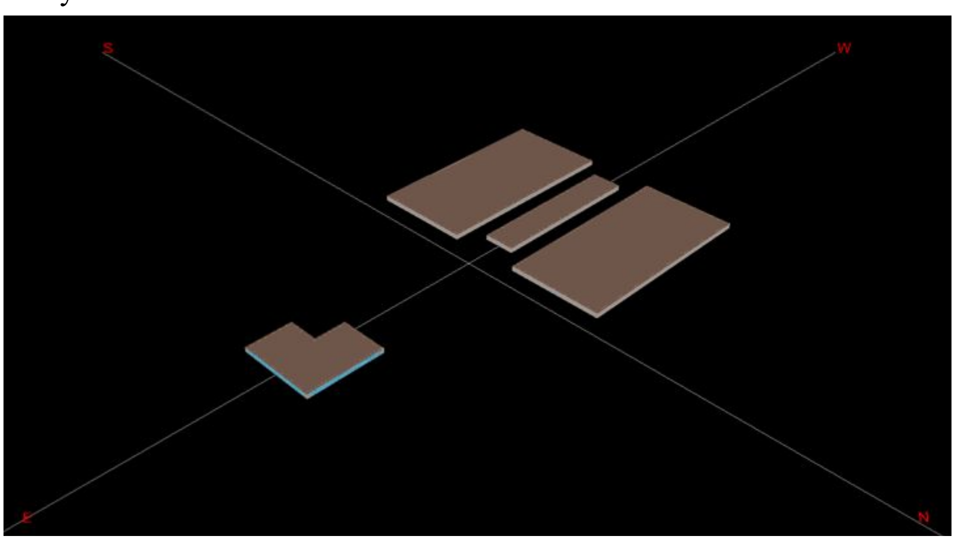


Figure 7.1: Building Schematic in eQUEST

Energy Reduction Techniques

HVAC Alternatives

Two HVAC alternatives were considered: Alternative 1 consists of radiant floor heating using a water-based system for all manufacturing spaces, chilled beams to serve as heating and cooling for the office and cafeteria space, and single zone variable air volume (VAV) for each building, while Alternative 2 consists of a water source heat pump and fan coil to provide both heating and cooling. Radiant floor heating was chosen for its ability to heat spaces close to where employees would be, rather than attempting to heat the air in a space that is 26 feet tall, which would be wasteful[4]. Chilled beams are a convective HVAC technology that can supply heating or cooling to spaces with low ceiling heights. Additionally, the operational costs are lower than conventional systems and these require less ductwork and fans[5]. Some form of air conditioning (AC) is required in areas where the relative humidity and temperature indoors are too high to be comfortable for employees[6]. Fan coils were considered here because their installation cost is simpler than that of central duct VAV units with chilled beams. Yet, VAV units are inexpensive, energy efficient, and some of the most common systems for industrial HVAC[7]. Table 7.1 summarizes the results from the eQUEST runs of each alternative. The red text indicates results that are unfavorable compared to the baseline run. Details of each run can be found in Appendix 7B-7D.

Table 7.1: Energy Demands of HVAC Alternatives

<table>
<tr><th></th><th colspan="2">Baseline</th><th colspan="3">Alternative 1</th><th colspan="3">Alternative 2</th></tr>
<tr><th>**Parameter**</th><th>Technology</th><th>Annual Energy Demand</th><th>Technology</th><th>Annual Energy Demand</th><th>Percent Reduction from Baseline</th><th>Technology</th><th>Annual Energy Demand</th><th>Percent Reduction from Baseline</th></tr>
<tr><td>Heating Component</td><td>Furnace</td><td rowspan="4">3.89x10^6 kWh electricity

12.96x10^9 BTU</td><td>Radiant Floor Heating (water)</td><td rowspan="4">3.29x10^6 kWh electricity

16.09x10^9 BTU</td><td rowspan="4">15.4%

-33.4%</td><td rowspan="2">Water Source Heat Pump</td><td rowspan="4">4.35x10^6 kWh electricity

14.12x10^9 BTU</td><td rowspan="4">-10.6%

-8.8%</td></tr>
<tr><td>Cooling Component</td><td>DX Coils</td><td>Chilled Beams (office and cafeteria)</td></tr>
<tr><td>HVAC (Office, Cafeteria each)</td><td>Standard VAV</td><td>Single Zone VAV</td><td>Fan Coil (can also perform heating and cooling)</td></tr>
<tr><td>Ventilation (Mfg)</td><td>Single Zone DX, Packaged</td><td>Single Zone VAV</td><td>Fan Coil</td></tr>
</table>

Table 7.2 details the cost of each component for each alternative and its purpose. Pricing was found at various wholesaler websites[8,9,10,11,12,13]. In the case for both alternatives, a boiler is required that can supply a maximum of 7.5 MMBTU/hour for a 20 hour workday with peak usage occurring in January. The total cost is $117,800 for thirty-eight 204 MBH boilers at a cost of $3,100 each. Since the boiler at this size is a requirement for both alternatives, its cost is omitted in calculations for annual cost of HVAC equipment. Referencing Appendices 7B-7D show that the January month natural gas usage remains consistent across all alternatives, around 4.5×10^9 BTU/mo.

Table 7.2: Capital Cost for Each Alternative

	Alternative 1		**Alternative 2**	
Purpose	***Technology***	***Cost***	***Technology***	***Cost***
Heating	Radiant Floor Heating	**$1,109,080** ($0.85/sqft)	Fan Coil (for manufacturing space)	**$2,126,280**
Cooling	Chilled Beams (office)	**$816,000** (~$4.60/sqft)	Water Source Heat Pump (office/cafeteria)	**$120,000** ($30,000/ea)
	AC (manufacturing buildings)	**$1,703,150**		
Ventilation	Single Zone VAV (Multizone for paint building)	**$619,000**	Single Zone VAV (Multizone for paint building)	**$624,000**
TOTAL COST	**$4,247,958**		**$2,870,280**	

Building Construction Alternatives

Other options aside from different HVAC equipment were considered for reducing energy consumption for the site. Each alternative was applied to the baseline model, yet there were no significant changes in energy consumption aside from a reduction in natural gas use when better exterior wall insulation (3 inches polystyrene) was used. A new set of shells had to be created due to unresolvable issues in the program from the initial modeling. Because of this, the value of total energy use is different as not all parameters were entered exactly the same. The important part to note is the percentage difference from the various building envelope improvements, which are in Table 7.3 below. Details of the runs can be found in Appendix 7E.

Table 7.3: Changes in Energy Use for Various Runs

	Percent Change From Baseline	
	Electricity	**Natural Gas**
Run 1: Baseline	0%	0%
Run 2: Vent. and Economizer	0%	0%
Run 3: Lower Lighting	-0.17%	+0.82%
Run 4: Exterior Wall Insulation	0%	-13.3%
Run 5: Increase Daylighting	-0.61%	+1.64%

HVAC Cost Analysis

To more accurately compare the long-term costs of the alternatives, engineering economics was employed to compare the proposed designs over a lifetime of 20 years with an effective annual interest rate of 6%[14]. Using 0.0872 for (A/P, 6%, 20), the annual cost of Alternative 1 is $707,738, while Alternative 2 only costs $676,551, which leads to an annual difference of $31,187. Details of the cost and the calculations can be found in Appendix 7F; these calculations draw only upon the capital cost of the HVAC equipment as well as the annual cost of electricity and natural gas at a discounted rate of $2.77/MMBTU from MWRD as operating and maintenance cost would be marginal in comparison.

Proposed Building Recommendations

From these calculations, the Green Team recommends Alternative 1 for its greater use of natural gas, and lower electricity requirement compared to the baseline as well as Alternative 2. While this will cost Ford approximately $31,000 per year more in energy costs, the increased use of the MWRD biogas will benefit the client, proving there is demand for such a resource and that further development in nearby regions of the Calumet MWRD wastewater treatment plant is good for the MWRD. Additionally, Alternative 1 uses less electricity, which will be beneficial, as it will reduce the load on the solar panel array, which will be discussed in Section 8.

Section 8

ENERGY COST

Julia Standley Pradhan

Energy Cost

Several alternative energy systems were considered in order to maximize the use of biogas and treated effluent from MWRD. Solar panels were also considered as a means to offset the electricity requirements of the entire facility. Alternatives were decided upon by comparing the simple payback period, equivalent uniform annual cost (EUAC), and present worth (PW) of the systems assuming an annual interest rate of six percent.

Utility Rates

Illinois Commercial Utility Rates	
Electricity[1]	$0.089/kWh
Natural Gas[3]	$5.35/MMBtu
Drinking Water[4]	$3.81/1,000 Gallons
MWRD Renewable Utility Rates	
Biogas	$2.77/MMBtu
Greywater (Treated Effluent)	$2.86/1,000 Gallons

Table 8.1: Summary of commercial and renewable utility rates available to Ford and Cisco.

Commercial utility rates were obtained from the most recent annual and monthly price averages provided by the U.S. Energy Information Association and City of Chicago. MWRD set the price of biogas as the difference between the wellhead and commercial rates for natural gas. The price of MWRD's treated effluent was determined by conducting a price sensitivity analysis which compared Ford's estimated annual revenue to annual water consumption and its corresponding cost. This analysis also considered the simple payback period for the construction of a water main to connect the two sites. See Appendix 8A for more details on utility rates, and Appendix 8B for calculations related to the price sensitivity analysis.

MWRD Greywater Main

A water main needs to be constructed in order to deliver treated effluent from MWRD to the Ford site. Keeping further development of WET Zone N in mind, the pipeline was designed to facilitate a larger maximum daily flow than the minimum of 0.561 MGD, which does not account for greywater re-use. This will require an HDPE pipe with an inner diameter of 6.963", outer diameter of 8.625", and a DR rating of 11.[6,7,8]

Horizontal directional drilling should be used to construct the pipeline in order to cross I-94 while minimizing obstruction and interruption of interstate activity. A 12" steel casing will surround the HDPE pipe to protect the interstate and surrounding area in case the pipe bursts.[7]

A new pump and control center also needs to be installed at the MWRD site to maintain a water pressure and velocity of 40 psi and 5 fps, respectively.[6,7] Ford will assume half of the pump and control center cost due to the fact that this infrastructure will also serve the water main connected to the WET Zone S site (Cisco).

CapEx for MWRD Greywater Main: $3,414,000
CapEx for Pump and Control Center: $650,000
Total CapEx: $4,064,000

By maximizing greywater use from the MWRD, Ford will save **$194,653.31 annually** without reuse when compared to purchasing potable water. In the event that Ford will utilize a wastewater treatment system that will allow reuse of MWRD effluent, the site will save **$74,380.30 annually**. See Appendix 8C for construction and water consumption cost calculations, as well as a map detailing the site and pipeline layout.

Biogas

Both WET Zone sites have the opportunity to utilize biogas generated by MWRD. The best way to maximize biogas use from MWRD is to purchase the biogas and run it through General Electric's Jenbacher J620 – a 3 MW CHP engine capable of generating heat and electricity.[10] MWRD is investing $8,750,000 in a new waste feeder system to increase the Calumet facility's biogas capacity.[11] This will allow the Calumet Wastewater Reclamation Plant to support a maximum of two Jenbacher engines. The following section describes the benefits associated with two different scenarios. See Appendix 8D and 8E for detailed cost and energy calculations.

Scenario 1 – Each WET Zone site purchases a Jenbacher J620 engine, resulting in significant gas and electric savings for each site. The cost of MWRD's expansion is split evenly between each site.

Annual Energy Savings	
Annual Gas Savings	$474,307.48
Annual Electric Savings	$2,340,714.24
Total	**$2,815,021.72**

Table 8.2: Annual gas and electric savings for one site.

Annual Expenses	
Operating	$894,758.40
Energy Input	$564,039.97
Total	**$1,458,798.37**

Table 8.3: Annual expenses for purchasing a single Jenbacher J620 unit.

Capital Expenses	
Cost of Unit	$1,000,000
Cost of Installation	$3,044,000
Cost of MWRD Expansion	$4,375,000
Total	**$8,419,000**

Table 8.4: Capital expenses for purchasing a single Jenbacher J620 unit, taking into account the required expansion by MWRD.

Simple Payback Period	6.21 years
EUAC (A/P, 6%, 7)	-$1,307,178.82
PW (P/A, 6%, 7)	-$848,018.77

Table 8.5: Summary of economic analyses accounting for a 6% interest rate and 7-year engine lifetime.

While the present worth of the system is negative, the equivalent uniform annual cost indicates that the system would result in a positive earnings of $1,307,178.82 per year. In the case of Ford, the Jenbacher J620 produces much more electricity than is required by the automotive facility. In the event that WET Zone N is further developed, that excess electricity could be used to power other processes on site, or it could be sold back to the grid as an additional source of annual revenue. The simple payback period shows that the engine will essentially pay for itself within its own lifetime.

Scenario 2 – MWRD purchases both generators to offset facility heating and electricity demand. This would require both WET Zone sites to purchase natural gas from the grid, as all biogas from the Calumet facility would be exhausted.

Annual Energy Savings	
Annual Gas Savings	$948,615
Annual Electric Savings	$4,681,428.48
Total	**$5,630,043.45**

Table 8.6: Annual gas and electric savings for MWRD purchasing two Jenbacher engines.

Annual Expenses	
Operating	$1,789,516.80
Energy Input	$0.00
Total	$1,789,516.80

Table 8.7: Annual expenses for purchasing two Jenbacher engines. MWRD will not need to purchase biogas as an energy input since they produce their own.

Capital Expenses	
Cost of Unit	$2,000,000
Cost of Installation	$6,088,000
Cost of MWRD Expansion	$8,750,000
Total	**$16,838,000**

Table 8.8: Capital expenses for purchasing two Jenbacher engines taking into account the cost of expansion.

Simple Payback Period	4.38 years
EUAC (A/P, 6%, 7)	-824,840.85
PW (P/A, 6%, 7)	$4,601,355.96

Table 8.9: Summary of economic analyses accounting for a 6% interest rate and 7-year engine lifetime.

In this scenario, the present worth of the system is highly positive, the equivalent uniform annual cost results in positive earnings, and the simple payback period is less than the engine lifetime. One thing to note is that the EUAC is less positive than that of *Scenario 1*.

The ultimate decision of which party will be purchasing the Jenbacher J620 depends on whether MWRD desires to offset its own heating and electricity costs, or if the facility will allow other WET Zone inhabitants to reap the benefits of this system. From an economic standpoint, MWRD would benefit the most from purchasing two Jenbacher engines. However, companies that are considering moving-in to the WET Zone may not be as interested if they aren't capable of purchasing biogas from MWRD, since the facility can only support two engines. If MWRD chooses to expand its biogas generating capacity even further, there may be the option of all parties being able to purchase a Jenbacher engine.

Solar

Two alternatives were explored to determine the type of solar panel to be used, and the size of the system to be installed.

PV-Thermal hybrid panels from Solimpek were initially considered, but in the end were ruled out due their staggering upfront cost and generation of thermal energy. Typcially, a PV-Thermal panel would be more desirable (higher efficiency, electricity and thermal generation) if the purchaser could afford such a system, which costs 50% more than the standard PV set up.[14] In the case of WET Zone N, utilizing a PV-Thermal panel would decrease the amount of biogas needed from MWRD for heating purposes, so the option was ruled out.

The final decision was to maximize the PV system power capacity by utilizing 30 acres of the available greenspace. Greenspace was chosen over roof space for two reasons. The first being that there is simply a greater abundance of greenspace versus roof space. Second, mounting solar panels on the ground creates a cooling effect on the back of the panel, increasing PV efficiency by reducing stress caused by heat buildup, thereby also increasing the lifetime of the panel. This system will utilize Canada Solar's 320W polycrystalline PV panel.[15] Each panel will be at a fixed 35˚ angle for optimum solar intensity.[17] If the 30 acres of greenspace were dimensioned as a perfect square (1143 ft x 1143 ft), the area could reasonably fit 91 rows of panels, with 575 panels per row. Each panel array requires a spacing factor of 2.5 to eliminate panel losses due to shading.[18] Any excess electricity that is generated can be sold back to the grid at the commercial rate. Results of several economic analyses are described below, see Appendix 8F for system design and the corresponding calculations.

Total # of panels	52,139
Total panel area	1,077,838 sf
System nominal power capacity	16,684,596 W
Avg Sun Hours/Day[19]	4.26

Table 8.10: Summary of PV system specifications and weather conditions.

Capital Expense[16]		
Item	Cost ($/W)	
PV Modules	0.72	
Mounting Hardware	0.31	
Power conditioning unit & inverters	0.22	
Grid Connection	0.26	
Civil & General Work	0.12	
Total	**1.621**	**$27,045,730.86**

Table 8.11: Capital expense of purchasing panels, mounting hardware, and grid-tie inverters for 52,139 Canada Solar panels.

Annual Energy Generation	25,942,879.03 kWh
Commercial Value	$2,308,916.23
Annual Electricity Demand	17,370,000 kWh
Commercial Cost	$1,545,930
Annual Excess Electricity	8,572,879.03 kWh
Annual Revenue from Selling Back to Grid	$762,986.23
Simple Payback Period	11.71

Table 8.12: Summary of electricity cost, value, and revenue, as well as payback period for the entire system.

Given a simple payback period of 11.88 years, this PV system would pay for itself within less than half of the panel lifetime, 25 years. Additionally, since the system generates excess electricity on an annual basis, this excess electricity can be sold back to the grid as a means of generating additional revenue.

Section 9

ENVISION

Emily Northard

Envision

Envision Point System

The Envision point system influenced the recommendation of environmentally responsible alternatives to be used in the design and building of a Ford assembly plant in a “Water Enterprise Trade (WET) zone” in order to achieve an Envision platinum rating.

The critical parameters of the Envision component of this project are the levels of achievement and the verification and award recognition level. The levels of achievement are broken down into five categories; Improved, Enhanced, Superior, Conserving, or Restorative. The levels of achievement are used to score each component in the different categories which are Quality of Life, Leadership, Resource Allocation, Natural World, and Climate.[1] As shown below, these categories are broken into even more subcategories that are given the level of achievement. Appendix 9A shows an example credit with the credit number and title, the intent, the metric, the levels of achievement, a description, evaluation criteria, sources, and a list of related credits.

The verification and award recognition levels are broken down into either Bronze, Silver, Gold, or Platinum which are calculated by the total applicable points starting with 20% for Bronze up to 50% for Platinum. The Institute for Sustainable Infrastructure uses an independent third-party project verification program in order to transparently confirm that a project meets the ENVISION evaluation criteria. This is an important step because it helps those responsible for the cost of the project as well as voters to have confidence that the project has measureable value and it allows the projects to become eligible for ENVISION awards.[2]

The ultimate project goal was to achieve platinum level with 50% of the applicable points. Early on in the design, conservative estimates were made with recommendations that would put the project well over the 50% of required applicable points. Now that the designs have been finalized, extraneous design requirements have been eliminated for cost savings discussed below, bringing the project to 51% of applicable points. This keeps the project at the platinum award level without having to spend extra money for points that don’t contribute heavily to the overall project quality.

The point breakdown is shown below, with the amount of applicable (able to be achieved) points, those submitted (the ones the project meets), and the percentage of points met in each credit category as well as overall. The lowest category for this project is Quality of Life because the site location is in an area that is already very industrialized so it is hard to reverse those effects. The project earns a lot of points in Leadership, Resource Allocation, and Climate and Risk because of its collaboration with the MWRD wastewater treatment plant and reduction of water and energy use resulting from the partnership. The individual category descriptions and the achievements in each are outlined below. Appendix 9B shows the individual points achieved out of the points possible for each component and Appendix 9C has the design implementation required to meet each submitted achievement level.

	Submitted Score Information		
Credit Category	Applicable	Submitted	Percentage
QUALITY OF LIFE	165	55	33%
LEADERSHIP	121	68	56%
RESOURCE ALLOCATION	182	110	60%
NATURAL WORLD	203	99	49%
CLIMATE AND RISK	122	70	57%
Total Points / %	793	402	51%

Table 9.1: Submitted Score Information

Quality of Life

Points under the Quality of Life (QL) category address purpose, community, and wellbeing in regards to the project and location. The purpose subcategory addresses the project's impact on functional aspects of the community, i.e. growth, development, job creation, and the general improvement of quality of life. Wellbeing refers to the safety, mobility, and comfort of both workers and residents throughout the project. Emphasis is given to community in order to preserve the views and natural features or incorporate the local character of the built environment into the design.[1] The project gains the most points in the Quality of Life category through QL2.5: Encourage alternative modes of transportation. It does this by providing a shuttle system and extended bike path from the proposed red line extension to encourage workers not to drive to work. This plan is laid out in Appendix 9D.

Leadership

Points gained under the Leadership (LD) category address collaboration, management, and planning. Collaboration refers to working with a wide variety of stakeholders to fully capture synergies, savings, and opportunities for innovation. Management requires understanding the project as a whole, but can reduce costs, increase sustainability, expand the useful life of the project, and protect against future problems. Planning takes a long-term view in order to prepare for growth-trends, regulatory changes, and any possible future pitfalls.[1] The project gains a lot of leadership points in LD2.1: Pursue byproduct synergy opportunities through its collaboration with MWRD.

Resource Allocation

Resource Allocation (RA) points relate to the materials, energy, and water used in the project. The goal is to minimize the amount of new materials used during the building process. Any recycled or reused content, as well as locally obtained materials, contribute to points earned. Overall energy use should be reduced and any necessary energy should be obtained through renewable sources whenever possible.[1] Likewise, the water use during the project and throughout the lifetime of the product should be reduced as much as possible. Potable water use can be reduced by using greywater for non-potable uses. The project gains a lot of points from the RA category by pairing with MWRD and also using an app called Decon which is further explained in Appendix 9E. Buying local, recycled materials not only reduces life-cycle energy of the project, but also saves money.

Natural World

Points under the Natural World (NW) category address siting, land and water, and biodiversity. Siting involves avoiding impacts on important ecological areas and their natural cycles. The land and water subcategory addresses stormwater and pesticide/fertilizer runoff and any other interruptions on existing hydrologic and nutrient cycles. Biodiversity addresses minimizing impact on native species and their habitats and avoiding introducing new species.[1] Most of the points from this category come from the fact that the project is being built on a brownfield (NW1.7: Preserve greenfields) which awards 23 points. The project has also taken extra care to preserve and protect the wetlands that are so close to the site by following site regulation laws and ensuring any stormwater and runoff is managed.

Climate and Risk

Climate and Risk (CR) applies to the emissions of the project and its resilience to risks both short- and long-term. The emissions subcategory addresses dangerous emissions like greenhouse gases and pollutants that could be released throughout all stages of the project's life cycle. Resilience refers to the ability to withstand short-term risks like fires or floods, but also the ability to adapt to changing long-term conditions such as weather pattern changes, sea-level rise, or climate changes.[1] The project reduces greenhouse gas emissions through our use of renewable energy and energy from the WWTP.

Innovate or Exceed Credit Requirements

Innovation credits are awarded "to reward exceptional performance beyond the expectations of the system as well as the application of innovative methods that advance state-of-the-art sustainable infrastructure."[1] The project is awarded these points under the RA category for its collaboration with the MWRD in order to reduce potable water consumption and recycle water throughout the WET zone. In order to receive the innovation credits, the project must demonstrate achievement in overcoming significant problems, barriers, or limitations or by creating scalable and/or transferable solutions. Using the MWRD effluent water in the project's industrial processes allows both the Ford plant and the MWRD to lessen their impact on the environment, promote the use of resource recovery, and allow for the development of successful industrial businesses that promote the regional economy. By going the extra mile to make use of the MWRD effluent in the assembly plant, the project is worthy of innovation credits in the Resource Allocation category, adding 8 points to the overall score.

Cost

Below is the fee schedule for the cost of Envision verification by the Institute for Sustainable Infrastructure (ISI) based on the size of the project.

FEE SCHEDULE

Project Size ($)	Non-Member Fee	ISI member Fee
Up to 2M	$3,000	$2,400
2-5M	$8,500	$7,000
5-25M	$17,000	$14,000
25-100M	$25,000	$21,000
100-250M	$33,000	$28,000
Over 250M	Contact ISI for large or multi-phase projects	

Table 9.2: ISI Fee Schedule[3]

In addition, an ISI membership costs $500/yr for less than 100 employees (or $1000/yr for more than 100 employees[4]), so it would be economically logical for our team to become an ISI member before certification. There is also a $1000 registration fee to register the project into the system before it can get verified. So our total calculation, not including the cost of paying employees to prepare the documentation and the changes that would need to be made to achieve a platinum level rating, would be the cost of the ISI member fee for our project (P) +$500t +$1000 =P+$1000+500t where t=# of years spent on the project.

The cost for implementing the design changes that result in Envision points is laid out in the estimation summary sheet. As mentioned above, once the design was finalized, extraneous points were eliminated if the cost outweighed the benefit and still allowed the project to stay at platinum Envision award level. An example of this was in the points gained with the installation of monitoring systems. In RA2.3: Commission and monitor energy systems and RA3.3: Monitor water systems, for which the alternative analysis is laid out below.

Parameter	Energy Monitoring System	Water Monitoring System	Do-nothing alternative
Cost	$9170+$240/yr[5]	$3215+$360/yr[6]	$0
Envision Points	11	11	0
Pros	• Gains Envision Points • Could save money if energy drains discovered	• Gains Envision Points • Could save money if water leaks discovered	• No additional cost • Envision points not necessary to maintain platinum
Cons	• High capital cost • Envision points not needed	• High capital cost • Envision points not needed	• No potential for savings if energy/water weaknesses in system

Table 9.3: RA2.3 and RA3.3 Alternatives Analysis

Ultimately, the do-nothing alternative was chosen for the points RA2.3 and RA3.3 because the Envision points were not needed to achieve platinum and both systems required a high capital cost. In addition, the Ford assembly plant will have a pretty good idea of their water and energy usage without additional monitoring systems because much of the water and energy is coming from the MWRD WWTP so they will have access to all of that data. By choosing the do-nothing alternative, money was saved without heavily affecting the quality and environmental impact of the project. A similar decision was made for several other point categories in order to save money while still maintaining the platinum award level.

Section 10

WASTEWATER TREATMENT

Kelly Cai

Wastewater Treatment

Water Treatment Design

The WET Zone North Ford automotive assembly plant will reuse wastewater effluent from the MWRD Calumet wastewater treatment plant. This wastewater will be used in the automotive assembly process.

The Ford automotive assembly processes have required limits for certain water quality parameters including chlorides, TDS, nitrates, and hardness. The full list of water quality parameter limits for Ford are compared to the corresponding MWRD effluent concentrations in **Appendix 10A**. These constituents must be removed by the Ford wastewater treatment plant before use in automotive assembly processes.

Volumetric water requirements for the Ford facility are required for these treatment determinations. Flow schemes for the Ford facility are depicted in **Appendix 10C**. Ford automotive processes require a total flow rate of 1870 m^3/d, with potable water requirements and evaporative losses of 200 and 850 m^3/d respectively, and effluent from Ford processes of 1155 m^3/d. The design flow rate of 1870 m^3/d is 10% higher than the required flow rate for the Ford facility (1700 m^3/d) in order to allow for fluctuation of flow and future increases in water use. A wastewater treatment facility size of about 1000 square feet is estimated for this flow capacity.

The two main alternatives which will be discussed in more detail below are 1) discharge of Ford effluent to sewer (MWRD), 2) reuse of Ford effluent within the Ford facility. These alternatives will influence how much of the total flow will be sourced directly from MWRD. If there is no reuse within the Ford facility, the total flow rate of 1870 m^3/d of would be sourced from MWRD If there is full reuse of the 1155 m^3/d of Ford effluent, much less of the flow (about half) would be sourced from MWRD.

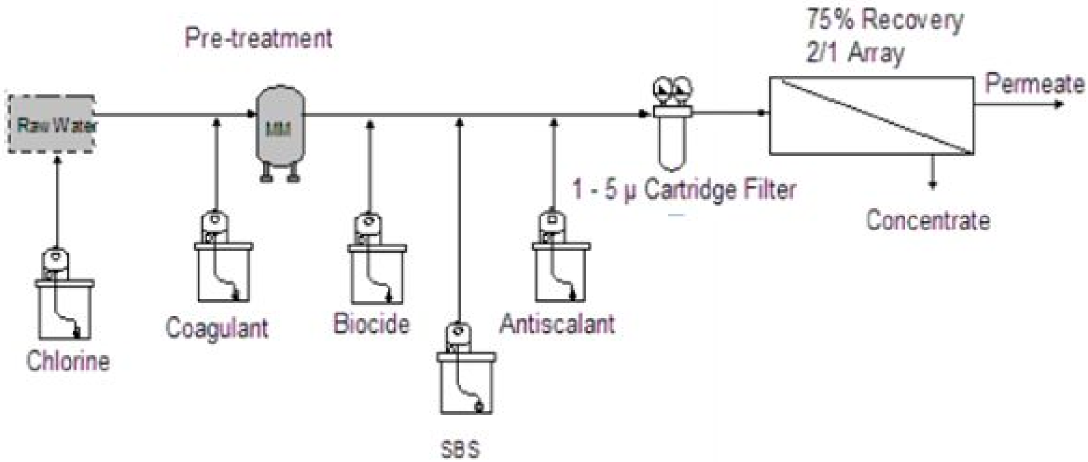
Reverse Osmosis

Reverse osmosis (RO) membrane technology is required for the design of this wastewater reuse treatment plant in order to remove monovalent ions from the water, including chlorides. RO is a physicochemical separation process in which water flows through a semipermeable membrane due to application of an external pressure in excess of osmotic pressure[1]. **Appendix 10D** contains equations used in the design of a reverse osmosis system, and **Appendix 10E** contains a spreadsheet used to compile calculations using membrane properties and operating conditions as inputs and outputting permeate concentration, rejection rate and recovery rate.

Pretreatment and Post-Treatment

Pretreatment is typically employed in order to prevent scaling and fouling of the membrane, which is necessary since reverse osmosis systems do not include backwashing; this can involve addition of disinfectant, antiscalant, acids for pH adjustment, and filtration[1]. Pretreatment would also precipitate out metals present in reused water from Ford effluent, preventing buildup of trace metals in the water over time. Typical dosing order is shown in **Figure 10.1** below.

Figure 10.1: Pretreatment dosing order[2].



Chlorides are added to prevent bacterial growth, however they need to be removed before reaching the membranes[2]. Dechlorination can be achieved by absorption onto activated granular carbon filter media or addition of a chemical reducing agent such as sodium bisulfite (SBS). Carbon filters are more reliable, however there is higher potential of bacterial growth, whereas addition of SBS would require constant monitoring of chlorine levels[3]. The dose rate of SBS is typically 1.5 to 2 times the level of chloride added[2].

Coagulants are added to improve removal efficiency in the 1-5 micron cartridge filters[3]. Acids that are used to lower the pH of the incoming water include hydrochloric acid or sulfuric acid; pH reduction reduces the potential of calcium carbonate scaling in the RO concentrate.

Antiscalants are used to inhibit the formation and precipitation of crystallized mineral salts that form scale; most are typically organic manmade polymers such as polyacrylic acids, carboxylic acids, polymaleic acids, organo-phosphates, polyphosphates, phosphonates, and anionic polymers[3]. The type of antiscalant and dosage used in pretreatment depends on the ion species present in the water and their concentrations (AWC). After pretreatment the feed water is pressurized with feed pump[1].

Post-treatment involves removal of dissolved gases and alkalinity as well as pH adjustment[1]. Caustic soda (NaOH) can be used to increase the pH of the water; this is typically the best choice for pH adjustment due to cost, availability, and solubility in water.

Flow Bending

If all effluent from MWRD were treated in the RO membrane, the permeate concentrations would be far lower than the required concentrations for Ford (see **Table 10.1** below).

Table 10.1: Permeate concentration after MWRD effluent is treated using reverse osmosis compared to Ford requirements for flow rate = 1870 m^3/d

Parameter	C(P) (mg/L)	Ford limit
Cl	4.213	25
NO3	1.185	10
TDS	19.08	300
Hardness	7.286	150

Therefore only a portion of the raw water from MWRD will need to be treated in the RO membrane, and afterwards, blending of raw and permeate water will produce finished water that achieves concentrations 10 to 20% lower than Ford limits[1]. This will reduce the amount of water treated in the RO membrane, which will reduce cost and energy requirements for the treatment plant. This concept is used below to determine flow rates required in the RO feed and raw water required for blending.

Alternative 1: Discharge to MWRD

In the first alternative (**Figure 10.2**), the 1155 m^3/d of effluent from Ford processes would be directly discharged to the sewer. Thus the 1870 m^3/d required in Ford processes would need to be entirely sourced from MWRD effluent wastewater.

Figure 10.2: Alternative 1: Pipeline discharge to MWRD

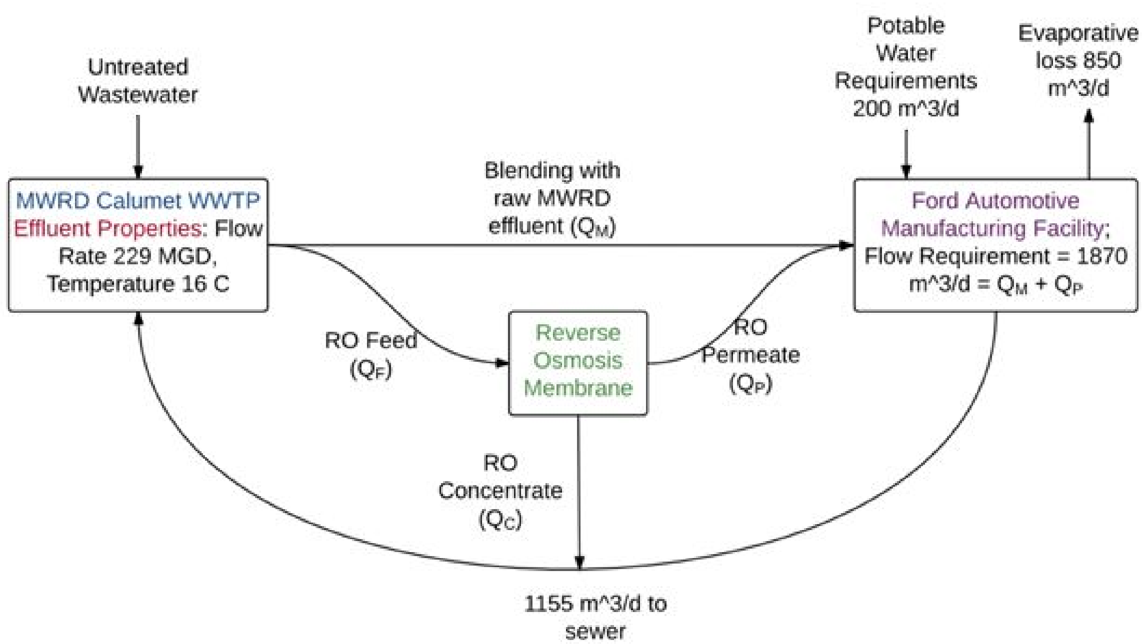


Table 10.2: Flow rates corresponding to Q_F, Q_P, Q_C, and Q_M in **Figure 10.1** above; calculations are presented in **Appendix 10F.**

Flow Rates	**Flow required to achieve concentrations 20% less than Ford requirements (m^3/d)**	**Flow required to achieve concentrations 10% less than Ford requirements (m^3/d)**
RO Feed (Q_F)	2115	2080
RO Permeate (Q_P)	1692	1664
RO Concentrate (Q_C)	423	416
Raw MWRD effluent to be mixed with RO permeate (Q_M)	178	206
Total flow requirement from MWRD ($Q_F + Q_M$)	2293	2286

Table 10.2 shows the flow rates required for RO feed, RO permeate, RO concentrate, and raw MWRD effluent to be mixed with RO permeate in order to achieve concentrations 10-20% less than Ford limits. In order to ensure that all parameters are at least 10-20% less than the Ford limits, calculations were done with the most limiting parameter, chlorides. The concentrations for all key water constituents are listed in **Table 10.4**.

As mentioned before, in this alternative, the effluent water from Ford will be discharged back to MWRD. **Appendix 10B** lists MWRD sewage and waste control ordinance requirements compared to Ford effluent. Ford effluent water quality is adequate for sewer discharge without treatment.

Alternative 2: Re-Use of Ford Effluent

In the second flow scheme (**Figure 10.3**), the 1155 m^3/d of Ford effluent that would have been discharged to the sewer in scheme 1 is instead reused within the facility; in order to fulfill the 1870 m^3/d requirement for ford processes, the remaining flow rate will be taken from MWRD effluent. The Ford reuse effluent and MWRD effluent are first mixed together in the box labeled "MWRD effluent + Ford reuse water," and this mixture is then fed into the RO membrane. This results in slightly lower requirements for RO feed flow, since the influent concentrations of the target water quality parameters are diluted by Ford effluent water.

Water reuse within the plant would be beneficial to Ford in order to reduce pumping costs to and from the Calumet WWTP as well as costs of purchasing the water itself. The total MWRD effluent required in this alternative drops to around 1080 m^3/d, compared to the 2290 m^3/d required in alternative 1.

Figure 10.3: Alternative 2: Water reuse within Ford facility

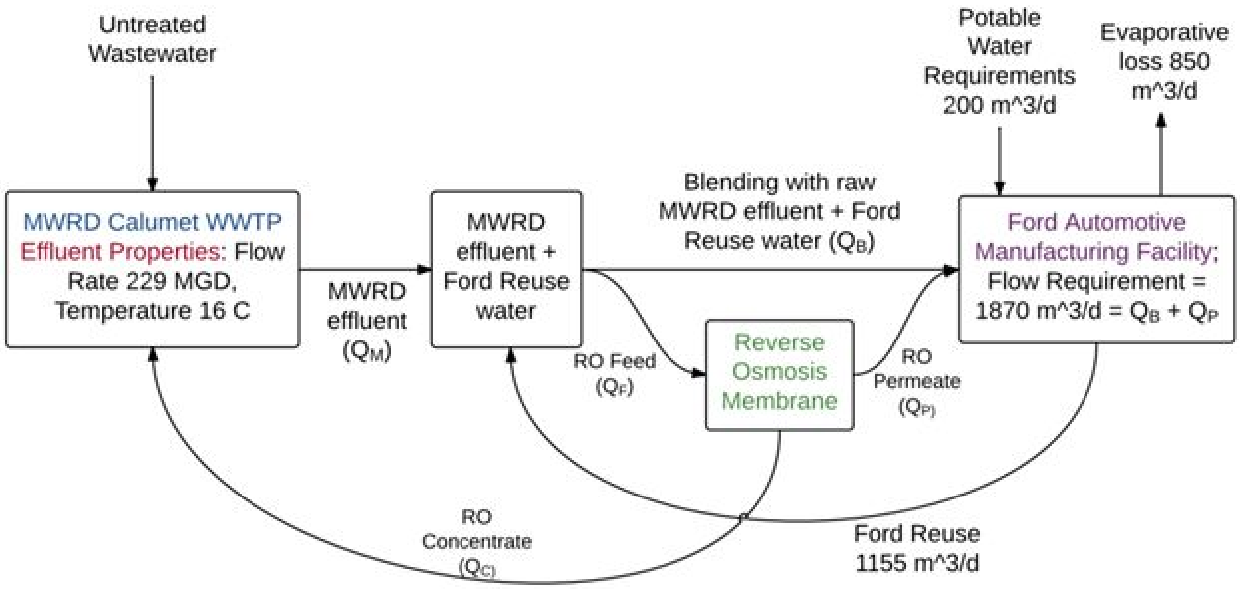


Table 10.3: Flow rates corresponding to Q_F, Q_P, Q_C, Q_M and Q_B in **Figure 10.3** above; calculations are presented in **Appendix 10G**.

Flow Rates	Flow required to achieve concentrations 20% less than Ford requirements (m^3/d)	Flow required to achieve concentrations 10% less than Ford requirements (m^3/d)
RO Feed (Q_F)	1880	1821
RO Permeate (Q_P)	1504	1457
RO Concentrate (Q_C)	376	364
MWRD Effluent required (Q_M)	1090	1077
MWRD Effluent + Ford Reuse water ($Q_M + 1155 = Q_B + Q_F$)	2245	2233
Raw MWRD Effluent + Ford Reuse water to be mixed with RO Permeate (Q_B)	366	413

Table 10.4 below compares flow rates for alternative 1 and alternative 2 in order to achieve the corresponding parameter concentrations 10-20% below Ford limitations. In order to ensure that all parameters are at least 10-20% less than the Ford limits, calculations were done with the most limiting parameter, chlorides.

Table 10.4: Summary of flow rates and concentrations for 10-20% less than Ford limit, with and without reuse

Flow Scheme	Without Reuse		With Reuse	
% Less than Ford Limit	20%	10%	20%	10%
RO permeate flow rate (m^3/d)	1692	1664	1504	1457
Raw flow rate (m^3/d)	178	206	366	413
Parameter	**Mixed concentration of raw and permeate water**			
TDS (mg/L)	90.6	101.8	90.7	102
Chlorides as Cl mg/L	20.0	22.5	20	22.5
Nitrates as NO3 mg/L	5.62	6.3	5.6	6.3
Total Hardness as CaCO3 mg/L	34.6	38.9	34.6	39

Residuals

Reverse osmosis concentrate (retentate) is typically 20-30% of the reverse osmosis influent flow, but this can range from 10-50%[1]. Thus in order to achieve RO permeate flow rates above, the feed flow rate must be higher to account for losses to retentate. **Table 10.5** below shows the feed flow rate required for corresponding permeate flow rates, assuming the residual comprises 20% of the feed flow.

Table 10.5: Permeate flow rate used to calculate feed flow rate required and residuals flow rate, assuming the residual comprises 20% of feed flow.

Flow Scheme	RO Permeate flow rate (m^3/d)	RO Feed flow rate (m^3/d)	RO Concentrate residuals flow rate (m^3/d)
Without reuse, 20%	1692	2115	423
Without reuse, 10%	1664	2080	416
With reuse, 20%	1504	1880	376
With reuse, 10%	1457	1821	364

Options for residual disposal include discharge to brackish surface water, discharge to municipal sewer, or deep-well injection[1]. In this case discharge to municipal sewer is the most likely option due to location of the facility. **Table 10.6** below lists parameter concentrations of the residual streams for alternative 1 and 2 using flows to achieve permeate concentrations 10-20% less than Ford limits. Concentrations were calculated using mass balance equations.

Table 10.6: Residuals concentration assuming the residual comprises 20% of plant flow.

Flow Scheme	**Without Reuse**		**With Reuse**	
% Less than Ford Limit	20%	10%	20%	10%
RO residual flow rate (m^3/d)	423	416	376	364
Parameter	**Residual Concentration**			
TDS (mg/L)	3774	3774	2058	1750
Chlorides as Cl mg/L	833	833	455	387
Nitrates as NO3 mg/L	234	234	128	109
Total Hardness as CaCO3 mg/L	1440	1440	787	669

Section 11

WASTEWATER TREATMENT COST

Breanna Kazmierczak

Wastewater Treatment Cost

Capital Expenses

Using the "Reuse 10%" alternative, the flow rates are designed to be at 90% of the plant's capacity. Therefore, the capacity of the plant will be 2,023 cubic meters per day, or 0.54 MGD (Appendix 11A).

The building size is estimated to be 1,000 square feet, based on research of existing treatment plants and space for treatment equipment. Using unit pricing for WWTP of similar sizing and purpose, the capital cost of building the WWTP will be **$905,340.0**, with overhead, general conditions, insurance, and contingency, the total cost is estimated to be **$1,204,102.20** (Appendix 11B).

Reverse Osmosis was the best treatment option to meet all of the necessary standards in a simple process, but main analysis of alternatives centered around the RO skid configuration within the WWTP. The plant is designed to house two, 200 GPM (gallons per minute) GE E-Series Reverse Osmosis Skids, each costing about **$104,800**. An analysis of alternative machines can be seen in Appendix 11C.

Operational Expenses

The Operational Expenses Estimation of both the "Continuous Use" and "Reuse" systems, as well as a price sensitivity analysis of MWRD effluent rate, can be seen in Appendix 11D. A summary table of annual operational costs can be seen below.

Table 11.1: Operational cost per year. Highlighted in green is the optimal design alternative.

Flow Scheme	Without Reuse		With Reuse	
% Less than Ford Limit	20%	10%	20%	10%
Effluent: $0.00	$911,009.45	$906,961.45	$459,516.76	$452,619.51
Effluent: $0.48	$1,017,136.22	$1,012,764.24	$509,965.16	$502,466.23
Effluent: $0.95	$1,121,052.01	$1,116,362.80	$559,362.55	$551,274.48
Effluent: $1.91	$1,333,305.55	$1,327,968.38	$660,259.34	$650,967.92
Effluent: $2.86	$1,543,348.11	$1,537,369.73	$760,105.13	$749,622.89

The Reuse 10% design has an estimation of **$452,619.51 to $749,622.89** per year in operational expenses depending on the purchase price of effluent from MWRD. This includes chemicals, energy for pumping, parameter testing, sewer discharge expenses (Appendix 11E), labor(Appendix 11F), and all fixed costs such as heating, lighting, and minor equipment replacement.

Section 12

OVERALL COST + SCHEDULE

Huixin Zuo + Peiwen Wu

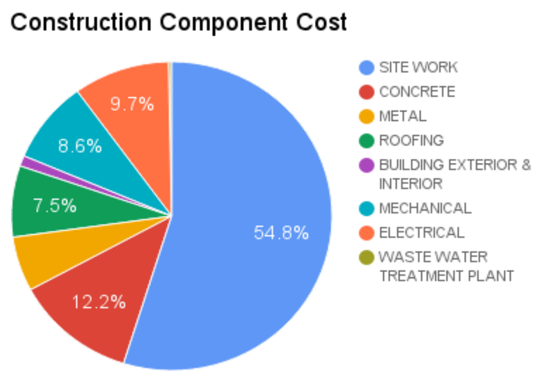
Overall Cost + Schedule

Cost Estimation

Based on the major design alternatives and preliminary estimation, the team has made many major decisions contributing toward a cost-effective and constructible building solution for the specific condition for this project. Due to the variance in the design of the four buildings and site, the overall project cost estimation has been divided into seven different parts, including the Site Work, the Body Building, TCF Building, Paint Building, Office & Cafeteria Building, as well as WWTP and General Condition. Construction Appendix 12A summarizes all the construction cost of this project, directly showing the pricing of the key building systems and site components as well as LEED ENVISION, general conditions and other percentage costs. Appendix 12B,C,D,E contain the detail costs for each building depending on the Architecture, Geotechnical, Structural and Energy designs. Appendix 12G looks at the detailed cost of the Site Work components, while Appendix 12F contains the detailed construction cost of the Waste Water Treatment Plan. Finally, Appendix 12H lists the detailed information of general conditions in this project. The total costs of all the project components are shown below, as well as the total cost of each construction component.

Table 12.1: Full Project Cost Summary

Construction Items	Body Building	TCF Building	Paint Building	Office & Cafeteria Building	WWTP	Site Work
Area(SF)	500000	500000	128000	176800	1000	7000000
Total Cost($)	54,727,769	54,748,697	15,118,251	19,671,068	986,910	179,212,849
Cost per Square Feet($/SF)	109.45	109.50	118.11	111.26	1004.78	25.60



As expected, the Site Work contributes a large part of the project cost. Because the project is developed on a hazardous site, extensive soil treatment and site improvement works have to be conducted before normal construction can commence. As for the building construction, the MEP and concrete are two major cost items. According to the geotechnical and structural designing, there will be a 3" thick mat foundation under each building, which is very costly. Moreover, some soft costs associated with the project are added to the subtotal cost by percentage. The details of those percentage costs are shown below in Table 12.2, the numbers assumed are based on industrial benchmarks and the specific designs of this project.

Table 12.2 Percentage Cost Breakdowns

Project Subtotal	$368,022,987.81
1% Bond	$3,680,229.88
8% Tax	$29,441,839.03
1.5% Builders Risk Insurance	$5,520,344.82
0.9% General Liability Insurance	$3,312,206.89
10% Design Contingency	$36,802,298.78
3% Construction Contingency	$11,040,689.63
5% CM Fees	$18,401,149.39
Project Total	**$476,221,746.23**

All of the unit prices are taken from RSMeans Construction Cost Data 2012, RSMeans Square Foot Costs 2012 and RSMeans Heavy Construction Cost Data 2015, unless otherwise noted. The final cost estimate is adjusted with a 20% markup to account for construction within the city of Chicago.

Construction Schedule

The overall schedule of this project is assumed to be 35 months, which is shown in Appendix 12I, and includes the construction of four buildings, site work and waste water treatment plan. The project will begin on February 27, 2017, with an estimated plan completion date in February, 2020. Construction will be conducted in seven phases, beginning with Site Work in early March, followed by the WWTP, Office & Cafeteria Building, Body Building, TCF Building, Paint Building, and finally, four months of Site Clearing and Move-in preceding completion. Appendices 12J and 12K contain a more detailed schedule of each individual building. The duration of the Body Building and TCF Building is assumed to be 18 months, while the Paint Building and Office & Cafeteria are assumed to be completed within 14 months.

All of the construction phases will have some overlap, depending on the resource allocation and the construction season. All of the concrete work, asphalt paving, and building exterior work can be scheduled successfully to avoid the winter season, thereby reducing the increased costs associated with winter paving and concrete activities.

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12. Overall Cost + Schedule

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2. *RSMeans Square Foot Costs 2012.* Kingston: Robert S. Means Co., 2011. Print.
3. *RSMeans Heavy Construction Cost Data 2015.* Kingston: Robert S. Means Co., 2014. Print.

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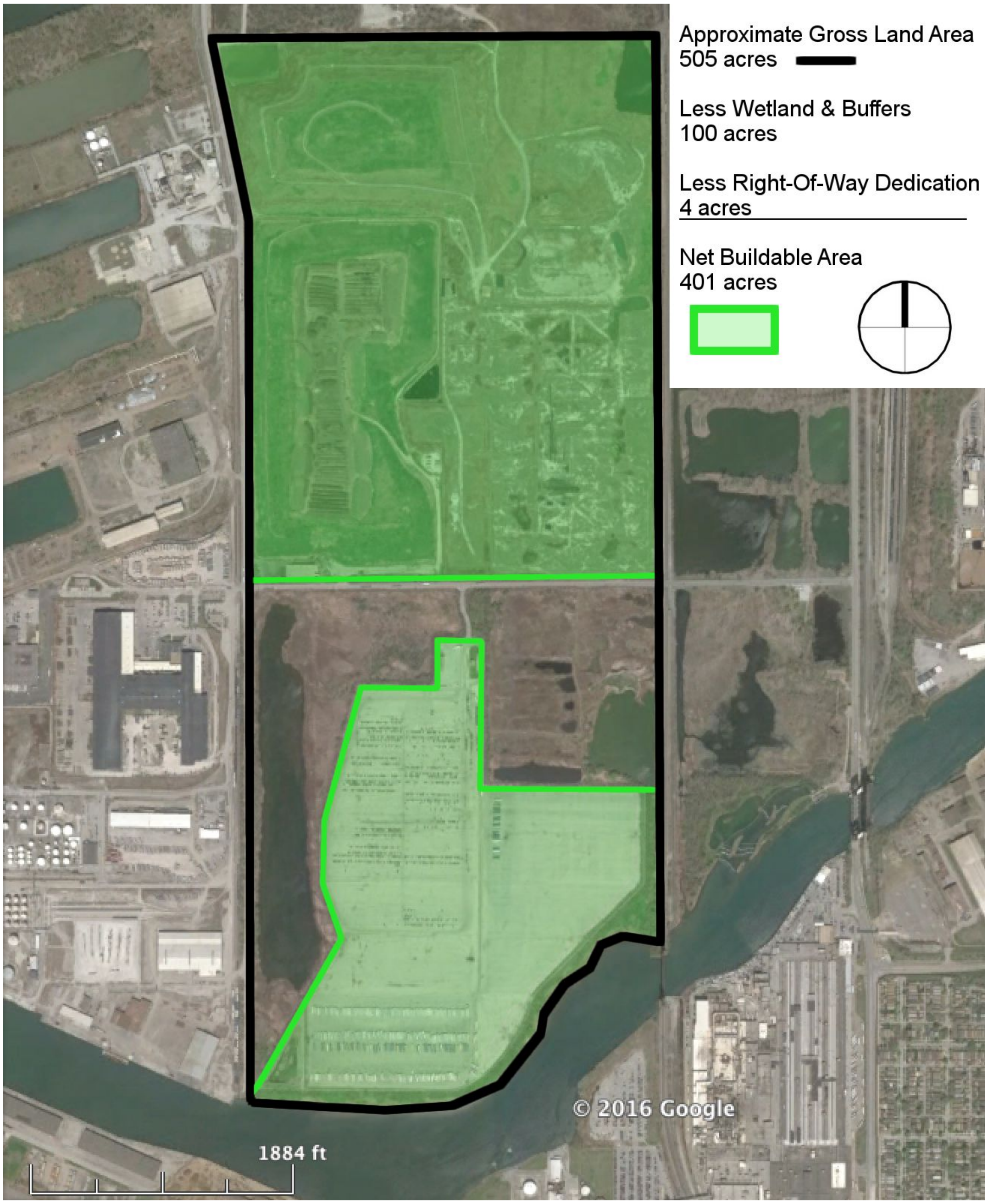
SITE QUALIFICATION

Kai Kasprick

Appendix 1A: WET Zone N



Appendix 1B: Permitting

Regulatory Agency	Permits/Regulations
City of Chicago	Building Permit Electrical Permit CDOT Rules and Regulations
U.S. Environmental Protection Agency	Multi-Sector General Permit for Stormwater Discharges (along with Stormwater Pollution Prevention Plan)
Illinois Environmental Protection Agency	General NPDES Permit for Storm Water Discharges from Construction Site Activities Permit for Industrial Treatment/Pretreatment Works
Illinois Department of Natural Resources	EcoCAT Consultation, Endangered Species Clearance
Illinois Historic Preservation Agency	Project Review
Metropolitan Water Reclamation District	Watershed Management Ordinance Permit
Illinois Department of Transportation	Environmental Survey Request Wetlands Impact Evaluation

Appendix 1C: Wetland Mitigation Requirements

The mitigation site will be reviewed with respect to the following site selection criteria. Failure to meet any of these criteria may be, depending on circumstances, grounds for rejection of a compensatory mitigation site. The site shall:

1. Be owned and/or under the full control of the permittee and/or mitigation sponsor. The sponsor shall provide documentation of this in the form of deed, agreements between sponsor and legal owner of the property regarding use of property and protection in perpetuity;

2. Contain a majority of drained or hydrologically modified hydric soils, recognizing that re-establishment of former wetlands are the preferred form of mitigation;

3. Have no high quality wetlands that would be adversely affected by the construction or restoration work;

4. Contain adequate perimeter upland areas to buffer the wetlands from potentially incompatible land uses on adjacent parcels;

5. Be so situated that adequate hydrology can be ensured (e.g., be located on a floodplain or possess a high groundwater table);

6. Contain no known hazardous waste, which shall be confirmed by an environmental assessment conducted by a qualified person or firm;

7. Be in the position such that the development of the site shall not adversely affect federal or state listed endangered or threatened species, or their habitat, or other high quality habitats or natural areas such as oak groves, prairies, or savannas;

8. Although each site should be selected and managed to utilize the natural water storage functions of wetlands, flood control shall not be the primary purpose. Specifically, mitigation shall not be used to satisfy local or regional stormwater detention requirements;

9. Be proximate or adjacent to public land holdings so as to create contiguous, large-scale habitat areas and;

10. Be inclusive of (but not limited to) an adopted or accepted watershed plan, open space plan, conservancy district, protected riparian corridor, or other local or regional conservation land use plan. This criterion has been established in order to help implement local and regional conservation and watershed plans, and to ensure maximum consistency and compatibility with future surrounding land uses;

The compensatory mitigation project site shall be ecologically suitable for providing the desired aquatic resource functions. In determining the ecological suitability of the compensatory mitigation project site, the Chicago District will consider, to the extent practicable, the following factors:

1. Hydrological conditions, soil characteristics, and other physical and chemical characteristics;

2. Watershed-scale features, such as aquatic habitat diversity, habitat connectivity, and other landscape scale functions;

3. The size and location of the compensatory mitigation site relative to hydrologic sources and other ecological features;

4. Compatibility with adjacent land uses and watershed management plans;

5. Reasonably foreseeable effects the compensatory mitigation project will have on ecologically important aquatic or terrestrial resources (e.g., fens, mature forests), cultural sites, or habitat for federally- or state-listed threatened and endangered species; and

6. Other relevant factors including, but not limited to, development trends, anticipated land use changes, habitat status and trends, the relative locations of the impact and mitigation sites in the stream network, local or regional goals for the restoration or protection of particular habitat types or functions (e.g., re-establishment of habitat corridors or habitat for species of concern), water quality goals, floodplain management goals, and the relative potential for chemical contamination of the aquatic resources.

Appendix Section 2

GEOTECHNICAL + SITEWORK

Nathan Zaporski

Appendix 2A: Subsurface Reconstruction Documents

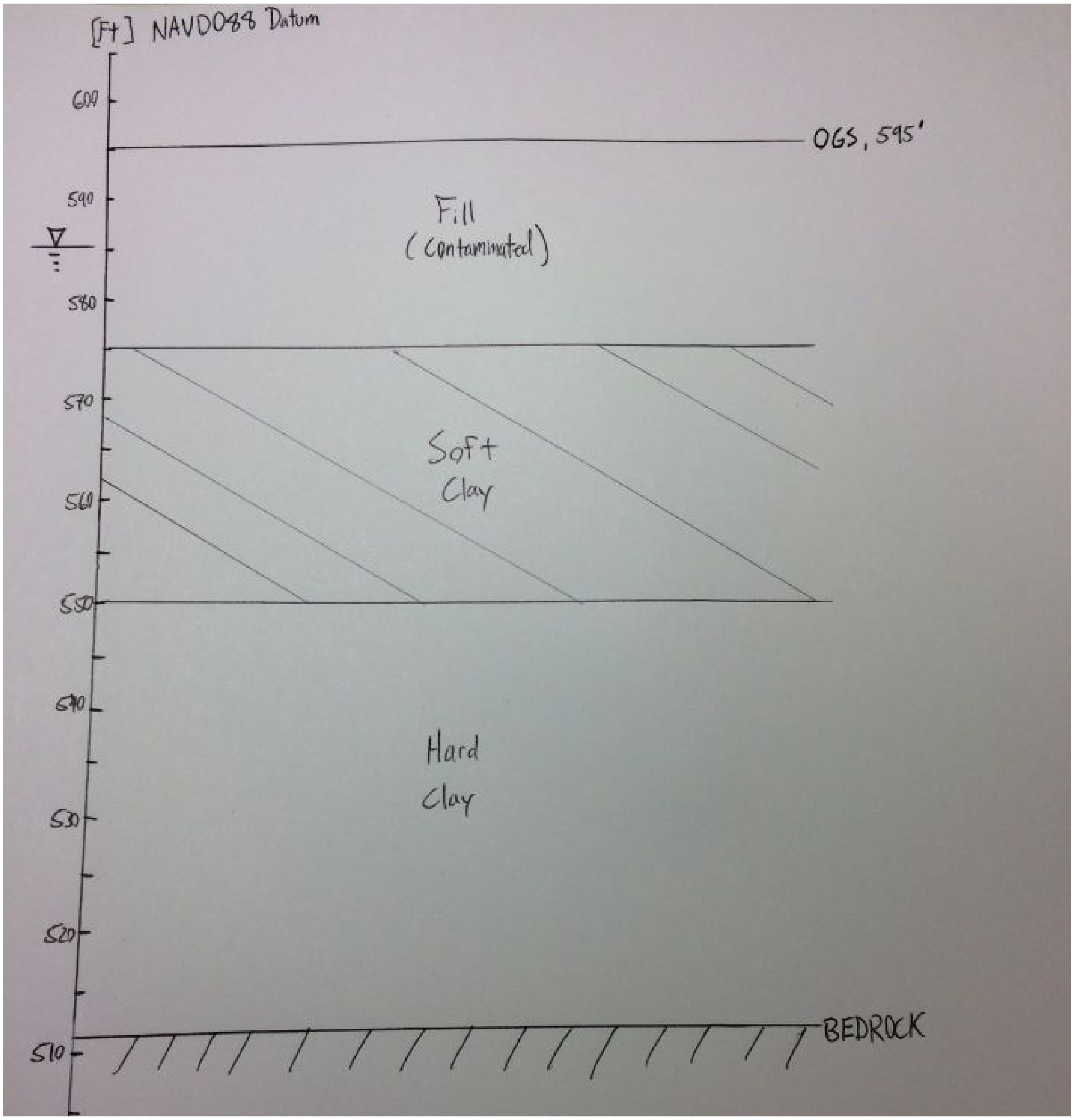


Figure 2A.1: Reconstructed Soil Profile

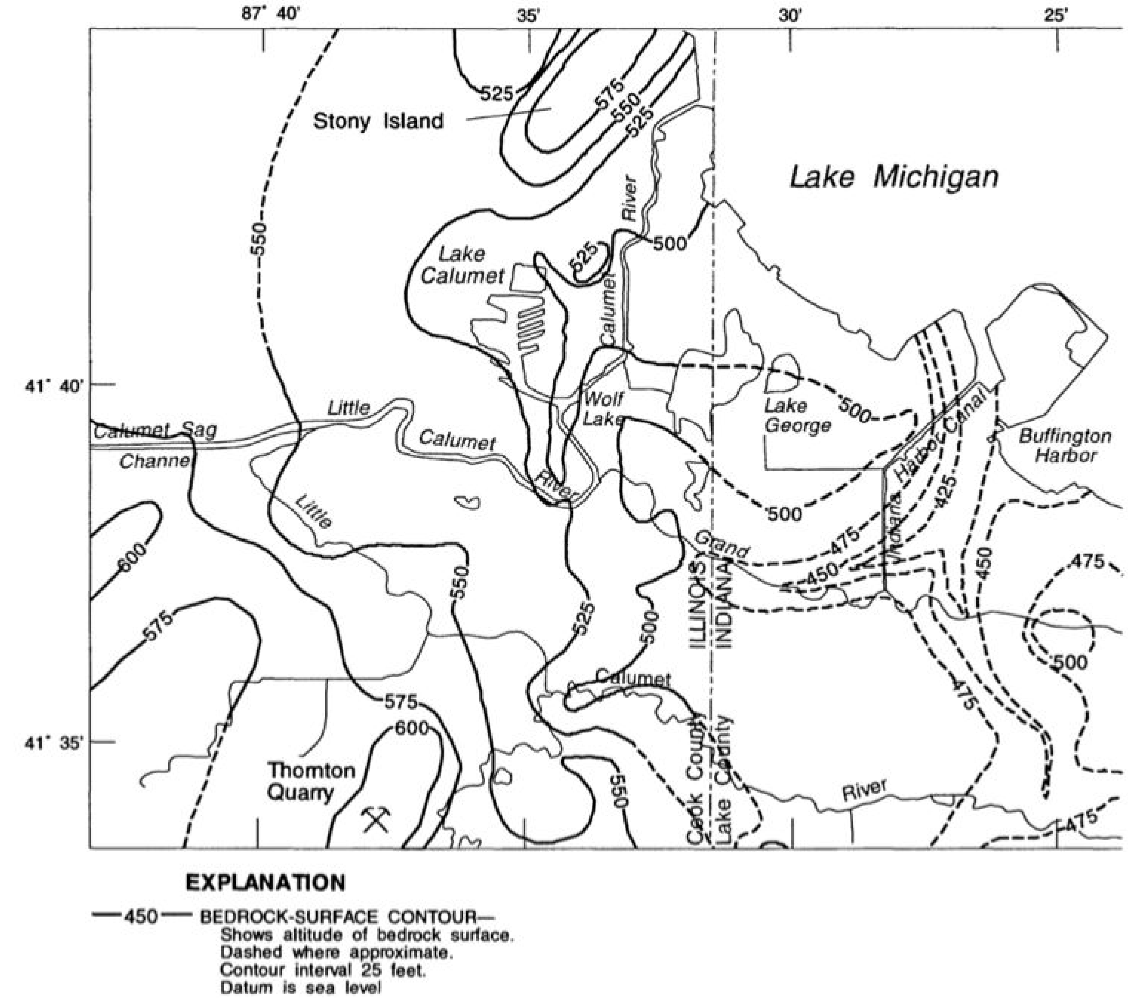


Figure 2A.2: Bedrock Elevations in the Calumet Area, after Kay et al (1996)

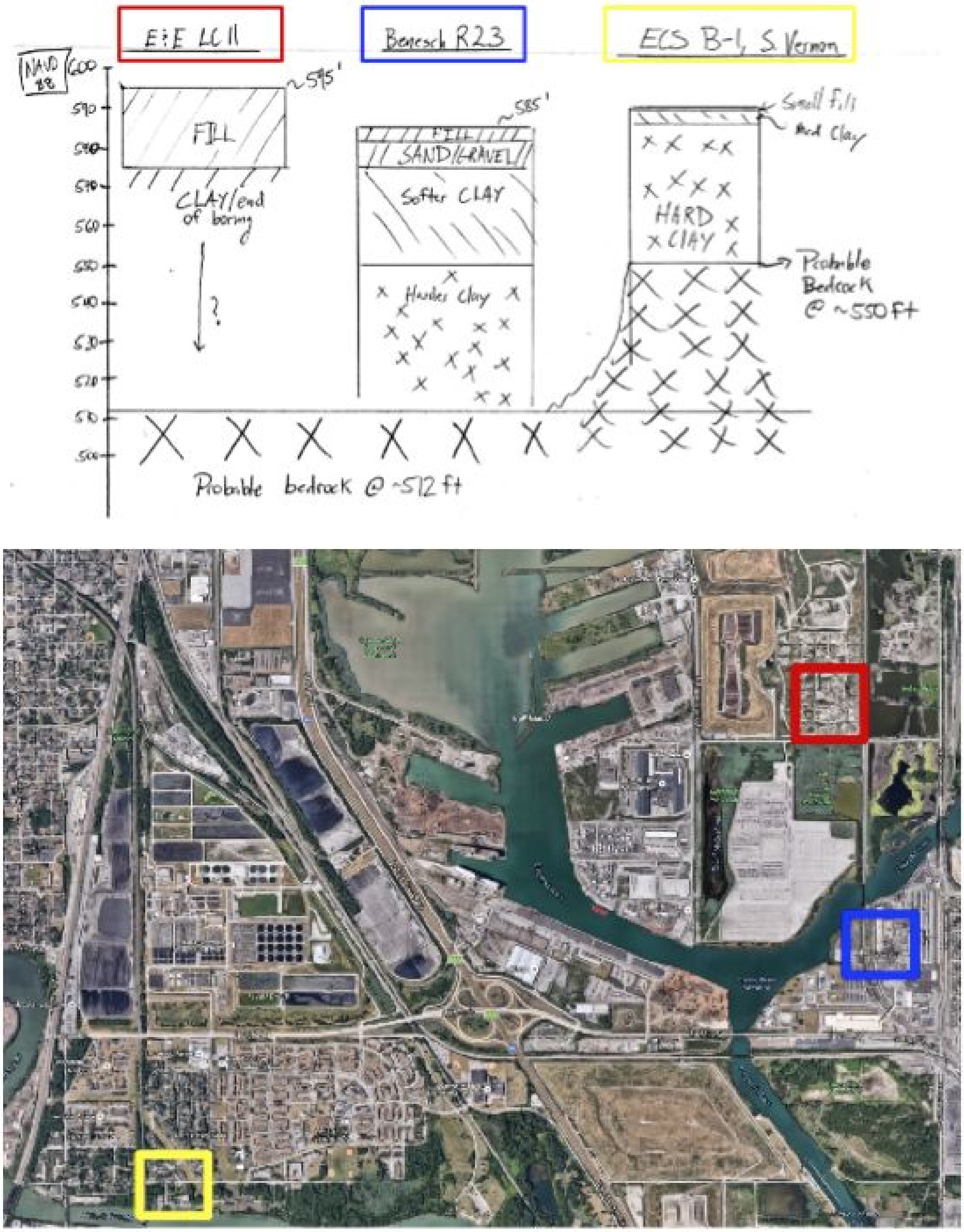


Figure 2A.3: Location of Relevant Boring Logs

Geo Services, Inc.
Geotechnical, Environmental & Civil Engineering
805 Amherst Court, Suite 204
Naperville, Illinois 60565
(630) 355-2838

SOIL BORING LOG

PAGE 1 of 2
DATE 02/18/04
LOGGED BY AT
GSI JOB No. 0304

CLIENT PROJ. NO. 3571
DESCRIPTION Proposed Retaining Wall
CITY Chicago
LOCATION 130th St., Torrence Av., & Brainard Av. Improvements
COUNTY Cook
DRILLING METHOD 3.25" Hollow Stem Auger
HAMMER TYPE Safety Hammer

BORING NO. **R-23**
Station 39+90
Offset 40' Right
Ground Surface Elev. +5.8 CCD

Surface Water Elev. n/a
Stream Bed Elev. n/a

Groundwater Elevation:
First Encounter -3.2 CCD
Upon Completion -8.2 CCD
After ____ Hrs. ____

Description	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Miscellaneous Sand, Gravel, Cinders & Stone-black-loose-moist (FILL)		3		
		4		
		5	NP	14
Fine SAND-brown-trace gravel-medium dense-moist (SP)		2		
		3		
	-5	8	NP	13
Fine SAND-gray-trace gravel-medium dense-saturated (SP)		8		
		11		
		14	NP	23
		4		
		7		
	-10	11	NP	42
Silty CLAY-gray-trace sand & gravel-stiff (CL)		4		
		4		
		8	LOP	17
Clayey SILT-gray-trace fine sand-medium dense-moist (ML)		3		
		4		
	-15	8	NP	14
Silty CLAY-gray-trace sand & gravel-soft to medium stiff (CL)		2		107
		3		
		5	0.9B	21
		3		107
		4		
	-20	5	0.8B	22

Description	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Silty CLAY-gray-trace sand & gravel-soft to medium stiff (CL)		2		105
		2		
		4	0.9B	23
		3		105
		3		
	-25	6	0.3B	23
		2		106
		1		
		1	0.8B	22
Silty CLAY-gray-trace sand & gravel-stiff to very stiff (CL)		2		101
		1		
	-30	3	1.7B	22
		2		106
		6		
		9	2.3B	20
		3		110
		8		
	-35	11	2.5B	18
Silty CLAY to Clayey SILT-gray-medium dense (CL/ML)		3		
		7		
		10	-	20
		5		
		9		
	-40	13	-	24

The Unconfined Compressive Strength (UCS) Failure Mode is indicated by (B-Bulge, S-Shear, P-Penetrometer) ST-Shelby Tube Sample
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206)
The Unit Dry Weight (pcf) is noted in Italics above moist (

Figure 2A.4: Benesch Boring R23 page 1

Geo Services, Inc.
Geotechnical/Environmental & Civil Engineering
805 Amherst Court, Suite 204
Naperville, Illinois 60565
(630) 355-2838

SOIL BORING LOG

PAGE 2 of 2
DATE 02/18/04
LOGGED BY AT
GSI JOB No. 0304

CLIENT PROJ. NO. 3571
DESCRIPTION Proposed Retaining Wall
CITY Chicago
LOCATION 130th St., Torrence Av., & Brainard Av. Improvements
COUNTY Cook
DRILLING METHOD 3.25" Hollow Stem Auger
HAMMER TYPE Safety Hammer

BORING NO. **R-23**
Station 39+90
Offset 40' Right
Ground Surface Elev. -5.8 CCD

Surface Water Elev. n/a
Stream Bed Elev. n/a
Groundwater Elevation:
First Encounter -3.2 CCD
Upon Completion -8.2 CCD
After ____ Hrs. ____

Description	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Silty CLAY to Clayey SILT-gray-medium dense (CL/ML)				
Silty CLAY with Silt Streaks-gray-trace sand & gravel-very stiff to hard (CL)		8 10 12	3.0P	12
	-45	10 12 13	3.0P	11
		19 28 34	4.5+P	10
Silty CLAY to Clayey SILT-gray-trace sand & gravel-hard (CL/ML)	-50	21 33 35	4.5P+	11
Silty CLAY-gray-trace to some sand & gravel-hard (CL)		18 25 28	4.5P	11
	-55	16 29 31	4.5P	9
		20 31 42	4.5P	10
	-60	29 40 45	4.5P	10

Description	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Silty CLAY-gray-trace to some sand & gravel-hard (CL)		16 21 25	11.7B	115 14
	-65	13 18 23	10.9B	115 15
		15 21 33	4.5+P	10
	-70	18 23 41	4.5+P	10
Drillers Observation: Fractured Rock		50/1"		NR
Auger Refusal@ -73.0'				
Apparent Bedrock @ -73.0'				
End Of Boring @ -73.5' Hollow Stem Auger D-120 Automatic Hammer	-75			
	-80			

The Unconfined Compressive Strength (UCS) Failure Mode is Indicated by (B-Bulge, S-Shear, P-Penetrometer) ST-Shelby Tube Sample
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206)
The Unit Dry Weight (pcf) is noted in Italics above moist (

Figure 2A.5: Benesch Boring R23 page 2

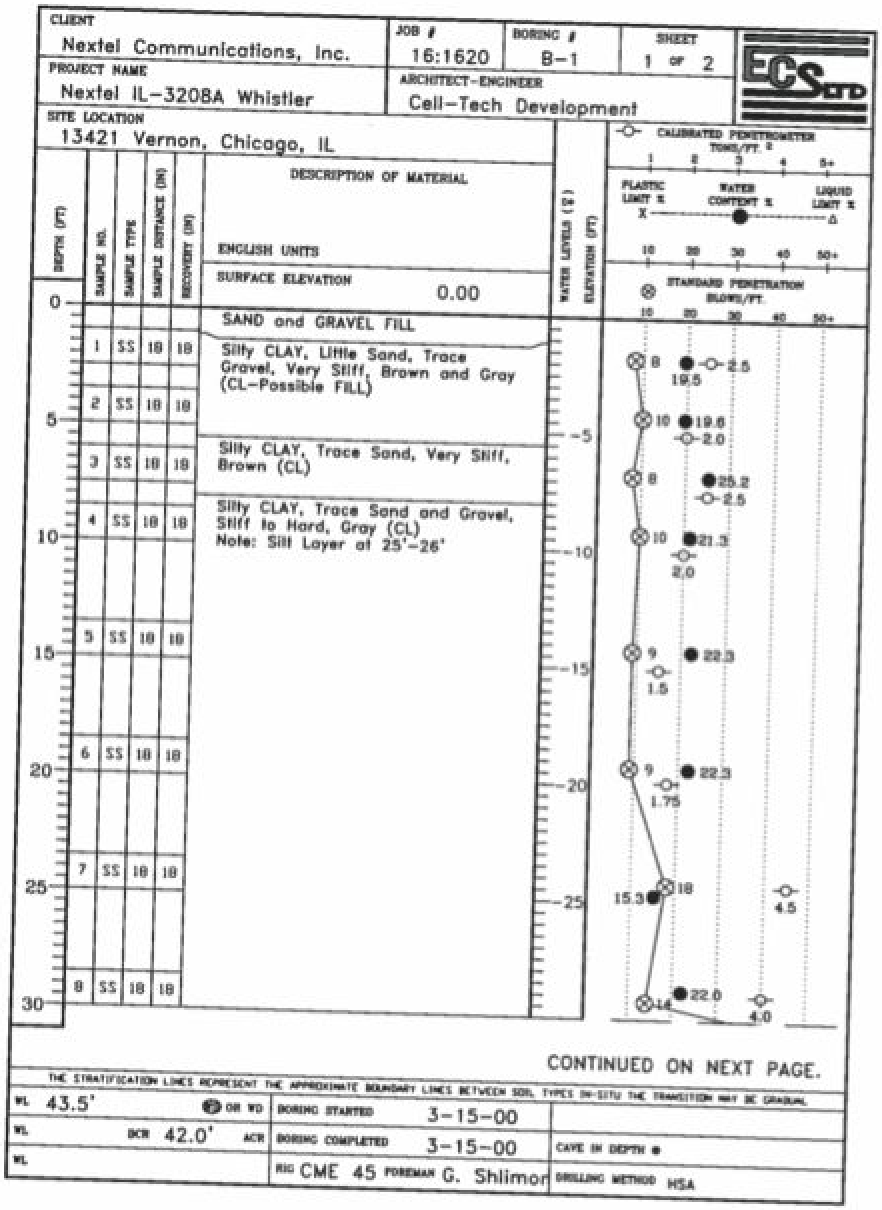


Figure 2A.6: ECS Boring B-1 page 1

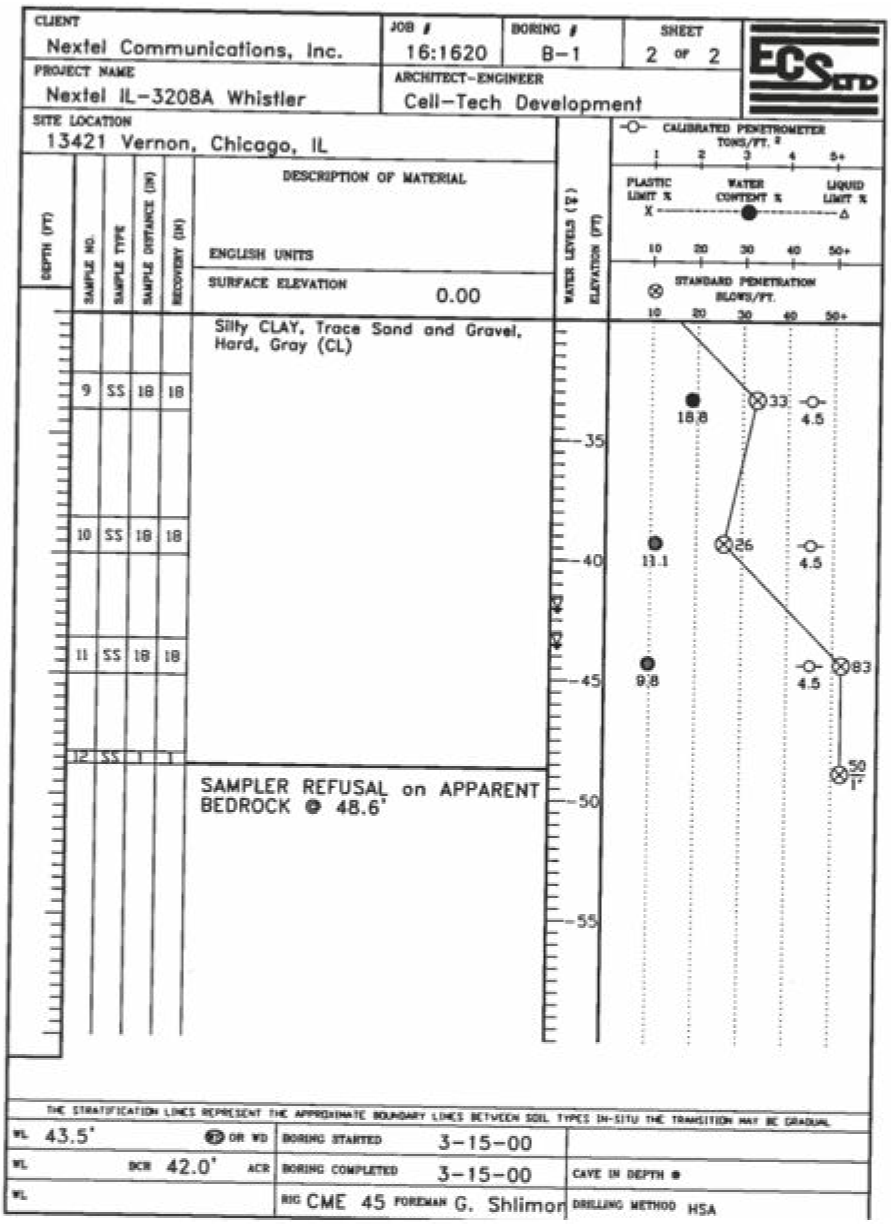


Figure 2A.7: ECS Boring B-1 page 2

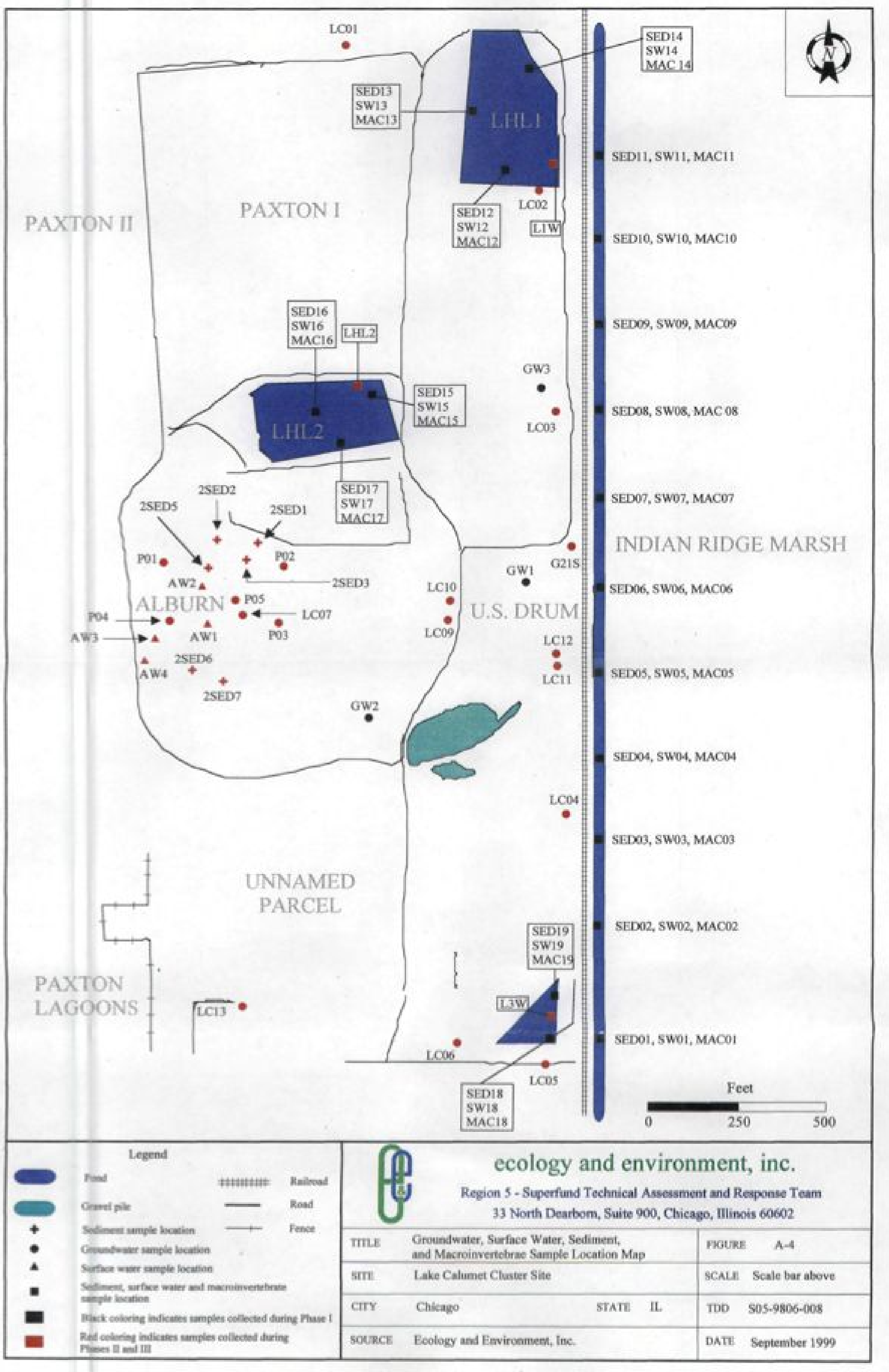


Figure 2A.8: Location of E&E Borings

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size) 2-inch stainless / 10 feet
Annular Material:

Grout- bentonite slurry
Seal- bentonite chips
Filter Pack- sand

Well Development Comments:

Boring Number: LC-03
Start Date: 4/23/99
Completion Date: 4/23/99
Boring Location: Northeast central part of site.

Ground Elevation: 95.85 feet
T.O.I.C. Elevation: 98.34 feet
Depth of Boring: 15.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ hollow stem augers

Depth to Groundwater

While drilling:	5.0 feet	bgs
at completion:	2.9 feet (T.O.I.C)	bgs
after development:	3.1 feet (T.O.I.C.)	bgs

Log	Elev (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0			FILL: Gray silty CLAY, some c-f gravel, trace m-f sand.			
	0.5	2			0	0	
	1.0	2					
	1.5	3					
	2.0	7	6				
	2.5	3		FILL: Gray silty CLAY, trace m-f gravel, trace c-f sand.	0	0	
	3.0	4					
	3.5	6					
	4.0	7	13				
	4.5	2		FILL: Black Gravel (Slag material), wood chips.	0	0	Wet
	5.0	2					
	5.5	3					
	6.0	2	2				
	6.5	5		FILL: Black SAND and GRAVEL, wood noted. (Slag material)			
	7.0	9			0	0	
	7.5	8					
	8.0	40	12				
	8.5	8					
	9.0	50			3	0	Wet
	9.5						
	10.0		8				
	10.5	3					
	11.0	24					
	11.5	49					
	12.0	40		FILL: Brown c-f SAND	0	0	Arkose appearance; Odor noted.

Figure 2A.9: Location of E&E Boring LC-03 page 1

LC-01

ecology & environment, inc.
DRILLING LOG

	Depth (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	12.5	15		FILL: Debris material, paper, wood chips, rubber, glass, plastic.	10	20	
	13.0	7					
	13.5	7					
	14.0	5	6				
	14.5	4					
	15.0	12					Wood is "smoking" at removal from split spoon sampler. (venting methane?)
	15.5	11					
	16.0	7	10		20	100	
	16.5			Boring Terminated at 16.0 feet.			
	17.0						
	17.5						
	18.0						
	18.5						
	19.0						
	19.5						
	20.0						
	20.5						
	21.0						
	21.5						
	22.0						
	22.5						
	23.0						
	23.5						
	24.0						
	24.5						

Additional Comments: Methane noted to be bubbling out of ground surface. OVA readings are above 100 ppm at the ground surface and at 0 ppm in ambient air (over 6-inches above ground). Headspace on the boring hole during drilling reads 70 ppm on OVA.

Figure 2A.10: Location of E&E Boring LC-03 page 2

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite Slurry
Seal- Bentonite Chips
Filter Pack- Sand
Well Development Comments:

Boring Number: LC-04
Start Date: 4/21/99
Completion Date: 4/21/99
Boring Location: South central on east side.

Ground Elevation: 96.36 feet
T.O.I.C. Elevation: 98.47 feet
Depth of Boring: 16.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ Hollow stem augers

Depth to Groundwater
While drilling: 5.0 bgs
at completion: 3.2 (T.O.I.C.) bgs
after development: n/a bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0			Brown silty CLAY, roots and organics noted.			
	0.5	2					
	1.0	2		FILL: Black slag material, some plastic.	2	2	
	1.5	8					
	2.0	23	8				
	2.5	12					
	3.0	11					
	3.5	3			0-5	3	Water in splitspoon gravel size material
	4.0	3	6				
	4.5	5					
	5.0	24					
	5.5	19					
	6.0	13	3		0	0	
	6.5	5					
	7.0	9					
	7.5	7					
	8.0	5	4		0	0	
	8.5	7					
	9.0	2					
	9.5	2					
	10.0	3	1		0	0	
	10.5	4					
	11.0	2					
	11.5	2					
	12.0	2	1				1"recovery of 1" diameter rock (Slag)

Figure 2A.11: Location of E&E Boring LC-04 page 1

ecology & environment, inc.

Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
12.5	5		FILL: Black Plastic, wood chips, other debris.			
13.0	4					PID acting up
13.5	5		Gray m-f SAND	–	0	High humidity.
14.0	10	14				
14.5	4					
15.0	4					
15.5	3					Large stone noted.
16.0	5	16		10	7	1" diameter.
			Boring terminated at 16.0 feet.			
16.5						
17.0						
17.5						
18.0						
18.5						
19.0						
19.5						
20.0						
20.5						
21.0						
21.5						
22.0						
22.5						
23.0						
23.5						
24.0						
24.5						

Additional Comments:

Figure 2A.12: Location of E&E Boring LC-04 page 2

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite Slurry
Seal- Bentonnite chips
Filter Pack- Sand
Well Development Comments: Well goes dry, but recharges quickly.

Boring Number: LC-05
Start Date: 4/26/99
Completion Date: 4/26/99
Boring Location: Southeast corner of site near RR & 122nd St.
Ground Elevation: 98.83 feet
T.O.I.C. Elevation: 100.30 feet
Depth of Boring: 16.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ Hollow stem augers

Depth to Groundwater
While drilling: 10.0 feet bgs
at completion: 7.44 feet (T.O.I.C.) bgs
after development: 9.8 feet (T.O.I.C.) bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0						
	0.5	8		FILL: Gray SAND and GRAVEL	0	0	
	1.0	3					
	1.5	2					
	2.0	2	13				
	2.5	5					
	3.0	2					
	3.5	2		FILL: Brown silty CLAY, some c-f sand, some m-f gravel.	0	0	
	4.0	10	10	FILL: Black SAND and GRAVEL			
	4.5	6					
	5.0	11					
	5.5	11			0	0	
	6.0	13	14	FILL: Brown silty CLAY, some c-f sand, some m-f gravel.			Moist
	6.5	5		FILL: Brown SAND, trace c-f gravel.			
	7.0	14					
	7.5	27			0	0	
	8.0	30	18	FILL: BLACK silty SAND, little c-f gravel.			Wet
	8.5	5		FILL: Gray to Brown SAND and GRAVEL. (Slag and Brick)			
	9.0	12			0	0	
	9.5	9					Wet
	10.0	4	8				
	10.5	7					
	11.0	50					
	11.5						
	12.0		6		0	0	

Figure 2A.13: Location of E&E Boring LC-05 page 1

ecology & environment, inc.

Log	Elev (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	12.5						
?	13.0			(Not Sampled)			
	13.5						
	14.0						
	14.5	11		FILL: Gray to Brown SAND & GRAVEL (Slag & Brick)			
		8					
	15.0				0	0	
	15.5	7		Gray SAND, little m-f gravel.			
		9					
	16.0			Boring terminated at 16.0 feet.			
	16.5						
	17.0						
	17.5						
	18.0						
	18.5						
	19.0						
	19.5						
	20.0						
	20.5						
	21.0						
	21.5						
	22.0						
	22.5						
	23.0						
	23.5						
	24.0						
	24.5						

Additional Comments:

Figure 2A.14: Location of E&E Boring LC-05 page 2

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 feet
Annular Material:
Grout- N/A
Seal- Bentonite chips
Filter Pack- Sand
Well Development Comments:

Boring Number: LC-06
Start Date: 4/26/99
Completion Date: 4/26/99
Boring Location: Southeast central part of site north of fence.
Ground Elevation: 94.64 feet
T.O.I.C. Elevation: 96.51 feet
Depth of Boring: 15.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ Hollow stem augers

Depth to Groundwater		
While drilling:	10 feet	bgs
at completion:	n/a	bgs
after development:	n/a	bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0			FILL: Gray SAND and GRAVEL.			Gravel material appears to be slag
	0.5	4			0	0	
	1.0	50	12				
	1.5						
	2.0						
	2.5						
?	3.0			(No Recovery)			Drilled through slag.
	3.5						
	4.0		0				
	4.5	2		FILL: Black Debris, sand and gravel, little glass, plastic, cloth, wood.	4	100	Moist
	5.0	7					
	5.5	7					
	6.0	6	12				
	6.5	4					
	7.0	4			0	0	Methane noted, OVA reads 100 ppm and drops quickly to zero.
	7.5	2					
	8.0	1	1				
	8.5	2		FILL: SAND & GRAVEL, debris, some plastic, glass.	0	0	Moist
	9.0	3					
	9.5	3		(1" gray silty clay lens notes at 9.5 feet)			
	10.0	15	10				
	10.5	27		FILL: Black SAND and GRAVEL (Slag material), little silt.			
	11.0	16			0	0	
	11.5	15					
	12.0	10	12				

Figure 2A.15: Location of E&E Boring LC-06 page 1

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	Elev./Depth	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	12.5	6		FILL: Black SAND and GRAVEL (Slag material).			
		4			0	0	
	13.0						
	13.5	6					
	14.0	6	4				1" Rock in Splitspoon
	14.5			(No Recovery)			
	15.0						
	15.5			Boring terminated at 15.0 feet.			
	16.0						
	16.5						
	17.0						
	17.5						
	18.0						
	18.5						
	19.0						
	19.5						
	20.0						
	20.5						
	21.0						
	21.5						
	22.0						
	22.5						
	23.0						
	23.5						
	24.0						
	24.5						

Additional Comments: OVA and PID headspace readings are zero at completion of boring.

Figure 2A.16: Location of E&E Boring LC-06 page 2

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite Grout
Seal- Bentonite chips
Filter Pack- Sand
Well Development Comments:

Boring Number: LC-09
Start Date: 4/20/99
Completion Date: 4/20/99
Boring Location: Central part of site.
Ground Elevation: 97.76 feet
T.O.I.C. Elevation: 100.03 feet
Depth of Boring: 20.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ Hollow stem augers.

Depth to Groundwater
While drilling: 7.0 feet bgs
at completion: 4.2 feet (T.O.I.C.) bgs
after development: 3.9 feet (T.O.I.C.) bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	CGI (LEL)	Remarks
	0.0			FILL: Brown to Black silty CLAY, some wood chips, glass, metal shavings.	1.5	0	
	0.5	2					
	1.0	2					
	1.5	3					
	2.0	2	12				
	2.5	5					
	3.0	4					
	3.5	3					
	4.0	3	2				
	4.5	2					
	5.0	2					
	5.5	3					
	6.0	2	6		0.5	0	
	6.5	1		(No Recovery)			
?	7.0	2					
	7.5	1					
	8.0	1	0				
	8.5	4		FILL: Cloth, wood, plastic material, and other debris.	0		100% of LEL Wet
	9.0	6					
	9.5	4					
	10.0	9	6				
	10.5	5		(No Recovery)			
?	11.0	6					
	11.5	3					
	12.0	3	0				

Figure 2A.17: Location of E&E Boring LC-09 page 1

ecology & environment, inc.

Drilling Log

Log	Elev (feet)	Blow Count	Recovery (inches)	Manual Description	PID (ppm)	OVA (ppm)	Remarks
	12.5	5		FILL: Debris; plastic, wood, ceramics.	2	0	
	13.0	3					
	13.5	50					
	14.0		6				
	14.5	9					
	15.0	8					
	15.5	4					
	16.0	3	8				
	16.5	8		FILL: Debris; wood, plastic, paper.			
	17.0	10					
	17.5	9					
	18.0	11	12	Gray m-f SAND			
	18.5	12		FILL: Debris; wood, metal, paper.			
	19.0	7					
	19.5	6					
	20.0	6	16	Gray silty CLAY, trace m-f sand.			
	20.5						
	21.0						
	21.5						
	22.0						
	22.5						
	23.0						
	23.5						
	24.0						
	24.5						

Additional Comments:

Figure 2A.18: Location of E&E Boring LC-09 page 2

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite
Seal- Bentonite Chips
Filter Pack- Sand
Well Development Comments:

Boring Number: LC-10
Start Date: 4/20/99
Completion Date: 4/20/99
Boring Location: Central part of site East of Alburn incinerator area.
Ground Elevation: 100.00 feet
T.O.I.C. Elevation: 97.72 feet
Depth of Boring: 15.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ Hollow stem augers.

Depth to Groundwater		
While drilling:	7.0 feet	bgs
at completion:	n/a	bgs
after development:	3.3 feet (T.O.I.C.)	bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0						
	0.5						
	1.0						
	1.5						
	2.0						
	2.5						
	3.0						
	3.5						
	4.0						
	4.5						
	5.0			Blind drilled to 15.0 feet depth.			
	5.5						
	6.0						
	6.5						
▼	7.0						
	7.5						
	8.0						
	8.5						
	9.0						
	9.5						
	10.0						
	10.5						
	11.0						
	11.5						
	12.0						

Figure 2A.19: Location of E&E Boring LC-10 page 1

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite
Seal- Bentonite chips
Filter Pack- Sand
Well Development Comments: Methane bubbles noted w/ 45% of LEL read on CGI

Boring Number: LC-11
Start Date: 4/19/99
Completion Date: 4/19/99
Boring Location: East central part of site (South of U.S. Drum Pad area)
Ground Elevation: 96.10 feet
T.O.I.C. Elevation: 98.52 feet
Depth of Boring: 20.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ hollow stem augers

Depth to Groundwater		
While drilling:	8 feet	bgs
at completion:	2.8 feet (T.O.I.C.)	bgs
after development:	4.92 feet (T.O.I.C.)	bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0						
	0.5	2		Black Organic silty CLAY, roots noted.	0	0	
	1.0	2					
	1.5	3		FILL: Gray silty CLAY, trace c-f sand, some m-f gravel.			
	2.0	2	18				
	2.5	3					
	3.0	7					
	3.5	11			0	0	
	4.0		18	FILL: White Claylike material.			
	4.5	4			0	0	
?	5.0	8		(No Recovery)			
	5.5	10					
	6.0	12	0				
	6.5	56		FILL: Black Debris; m-f gravel, metal shavings, wood chips.	0	0	
	7.0	14					
	7.5	4					
	8.0	5	6		0	0	
	8.5	4					
	9.0	3					
	9.5	2					
?	10.0	2	0	(No Recovery)			Large Limestone Rock only recovery
	10.5	3					
	11.0	1					
	11.5	1					
	12.0	1	1				

Figure 2A.20: Location of E&E Boring LC-11 page 1

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DRILLING LOG

Log	Elev (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	12.5	5					
	13.0	9			0	0	
	13.5	8		m-f Gray SAND			
	14.0	8	12				
	14.5	3			0	0	
	15.0	4					
	15.5	7					
	16.0	6	18				
	16.5	3		m-f Gray to Black SAND	0	0	
	17.0	2					
	17.5	2					
	18.0	3	10				
	18.5	2			0	0	
	19.0	3					
	19.5	6		Gray silty CLAY, trace c-f sand, trace m-f gravel.			
	20.0	8	14		0	0	
				Boring terminated at 20.0 feet.			
	20.5						
	21.0						
	21.5						
	22.0						
	22.5						
	23.0						
	23.5						
	24.0						
	24.5						

Additional Comments:

Figure 2A.21: Location of E&E Boring LC-11 page 2

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite
Seal- Bentonite chips
Filter Pack- Sand
Well Development Comments:

Boring Number: LC-12
Start Date: 4/20/99
Completion Date: 4/20/99
Boring Location: East central part of site (South of U.S. Drum pad area)
Ground Elevation: 96.05 feet
T.O.I.C. Elevation: 97.74 feet
Depth of Boring: 15.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ hollow stem augers

Depth to Groundwater
While drilling: 10.0 feet bgs
at completion: 3.6 feet (T.O.I.C.) bgs
after development: 3.3 feet(T.O.I.C.) bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0						
	0.5						
	1.0			Blind Drilled to 15.0 feet bgs. (All cuttings are Brown to Gray silty Clay)			
	1.5						
	2.0						
	2.5						
	3.0						
	3.5						
	4.0						
	4.5						
	5.0						
	5.5						
	6.0						
	6.5						
	7.0						
	7.5						
	8.0						
	8.5						
	9.0						
	9.5						
	10.0						
	10.5						
	11.0						
	11.5						
	12.0						

Figure 2A.22: Location of E&E Boring LC-12 page 1

ecology & environment, inc.
DRILLING LOG

Site Name: Lake Calumet Cluster Site
Location: Chicago, Cook County, Illinois
TDD: S05-9806-008
Drilling Firm: Patrick Drilling
Type of Rig: CME-75
Driller/Helper: Kevin Hathaway /
Geologist: Joseph Klemp
Well Casing(type & qty.): 2-inch stainless
Screened interval(type & size): 2-inch stainless / 10 foot
Annular Material:
Grout- Bentonite
Seal- Bentonite Chips
Filter Pack- Sand
Well Development Comments:

Boring Number: LC-13
Start Date: 4/21/99
Completion Date: 4/21/99
Boring Location: Southwest corner of site.
Ground Elevation: 97.14 feet
T.O.I.C. Elevation: 99.16 feet
Depth of Boring: 16.0 feet
Lock Number: n/a
Drilling Method: Rotary w/ Hollow stem augers

Depth to Groundwater		
While drilling:	2.5 feet	bgs
at completion:	2.4 feet (T.O.I.C.)	bgs
after development:	n/a	bgs

Log	Elev. (feet)	Blow Count	Recovery (inches)	Material Description	PID (ppm)	OVA (ppm)	Remarks
	0.0						
	0.5	1		FILL: Black to Brown Debris; Wood, plastic, glass.	0	0	
	1.0	1					
	1.5	1					
	2.0	1	2		0	2	Wet
	2.5						
	3.0	?					
	3.5						
	4.0		4				Wet
	4.5	8			0	0	Piece of rubber noted.
	5.0	4					
	5.5	3					
	6.0	3	5				
	6.5	6			0	2	Mostly paper.
	7.0	4					
	7.5	13					
	8.0	11	11				
	8.5	6					
	9.0	3					
	9.5	3					
	10.0	2	4				
	10.5	3					
	11.0	7		(No Recovery)			
	11.5	5					
	12.0	3	0				

Figure 2A.23: Location of E&E Boring LC-13 page 1

LC-13

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DRILLING LOG

Elev (feet)	Blow Count	Recovery (feet)	Material Description	PID (ppm)	OVA (ppm)	Remarks
12.5	3			0	0	
13.0	1		FILL: Debris; plastic, gravel, glass, wood.			
13.5	1					
14.0	1	1				
14.5	4					
15.0	3					
15.5	1			0	1	Glass, wood, fine gravel.
16.0	1	2				
			Boring terminated at 16.0 feet.			
16.5						
17.0						
17.5						
18.0						
18.5						
19.0						
19.5						
20.0						
20.5						
21.0						
21.5						
22.0						
22.5						
23.0						
23.5						
24.0						
24.5						

Additional Comments:

Figure 2A.24: Location of E&E Boring LC-13 page 2

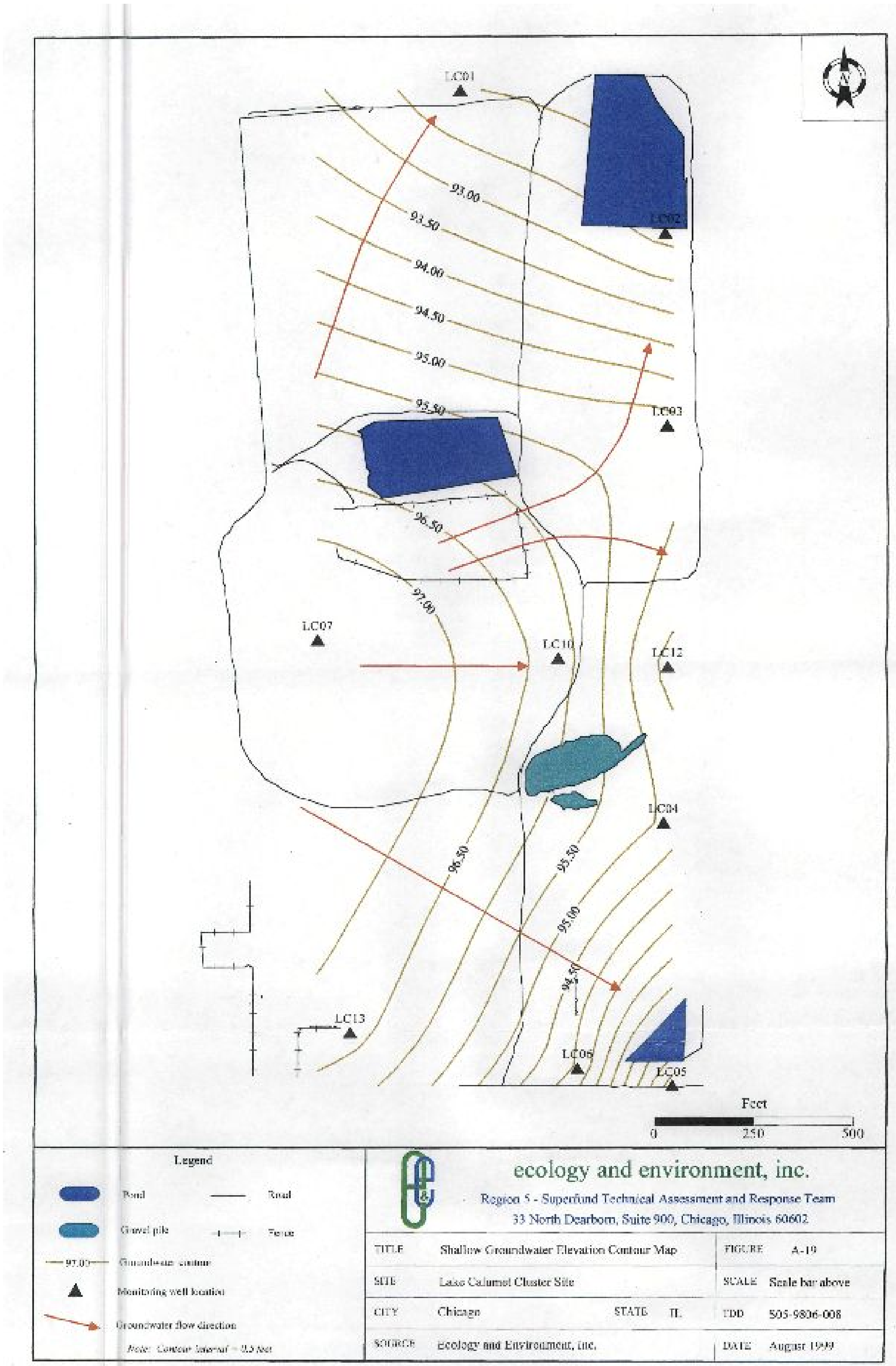


Figure 2A.25: Groundwater Elevation Contour

Appendix 2B: Site Improvement Alternatives

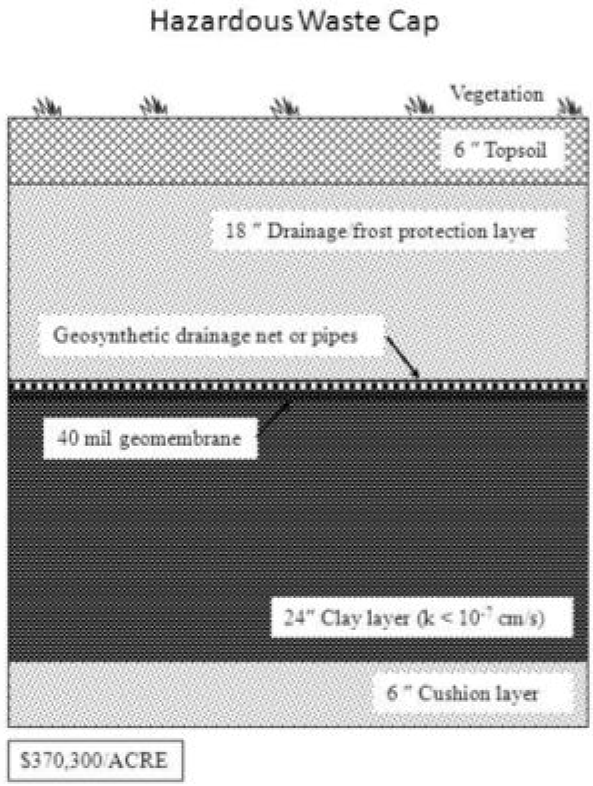


Figure 2B.1: Typical Hazardous Waste Impermeable Cap

Cost Calculations for Capping Alternatives

Fencing:

1) $40/LF (RS MEANS 2012)   2) ~16100 LF perimeter of built area

$40/LF*16100 LF = **$650,000**

Hazardous Waste Cap

1) $370,300/Acre 2) ~191 acres unbuilt land

$370,300/Acre*191 Acres = **$71,000,000**

Soil Removal Option 1 - Entire Site

1) Cost of Contaminated Soil Removal and Transport Estimated at $100/ft^2
2) Total site 271 acres, 3 feet deep

3 ft*271 acres * $100/ft^2 = **$3.5 billion**

Soil Removal Option 2 - Built-Area Soil Removal

1) Cost of Contaminated Soil Removal and Transport Estimated at $100/ft^2
2) Total built area 3.6 million ft^2 , 3 feet deep

3 ft* 3.6 million ft^2* $100/ft^2 = **$369 million**

Appendix 2C: Deep Dynamic Compaction (DDC)

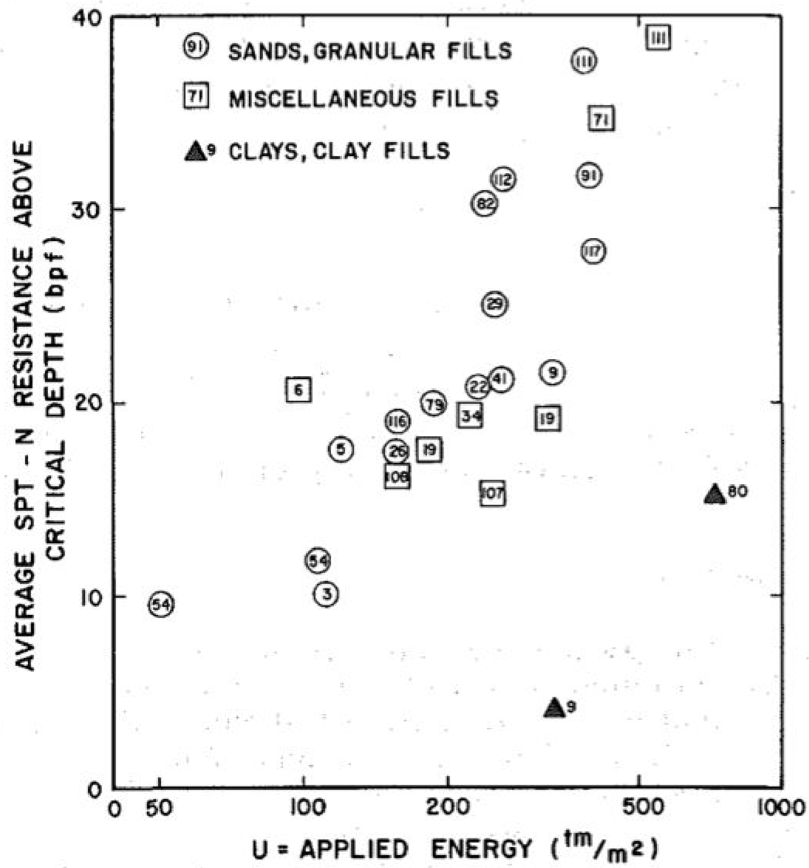


Figure 2C.1: N vs. Applied Energy (Fig. 13 in Mayne et al, 1984)

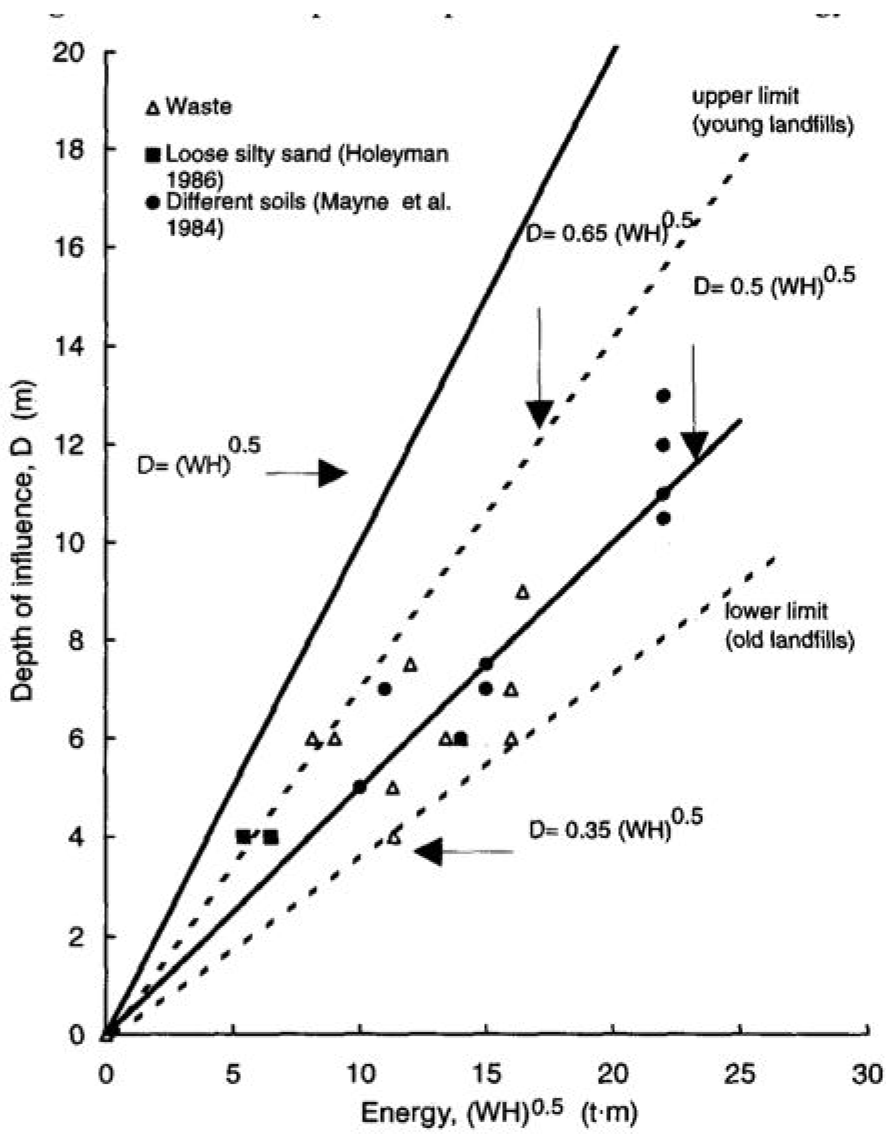


Figure 2C.2: Depth of Influence with Applied Energy (Van Impe et al 1996)

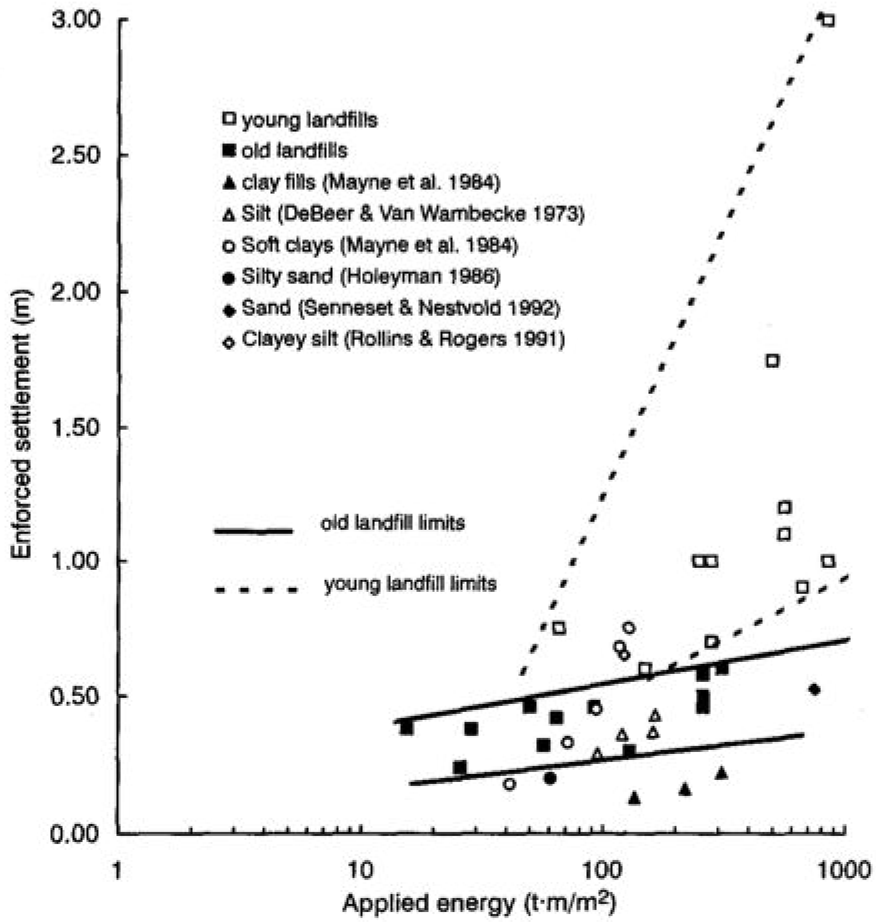


Figure 2C.3: Settlement in Landfill Materials from dynamic compaction (Slocum et al 2004)

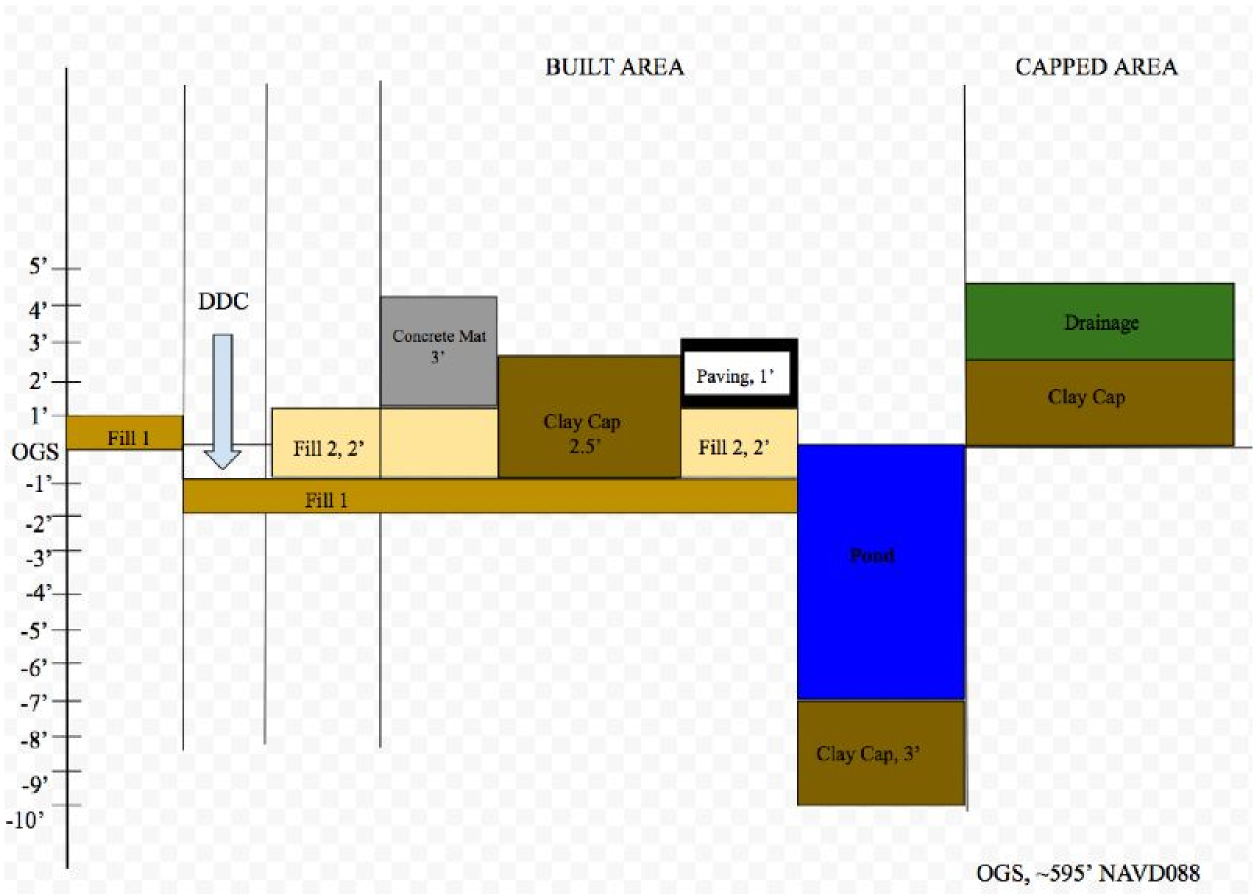


Figure 2C.4: Sample Grading and Site Elevation Plan

Proposed DDC Program Nathan M. Zaporski 6/6/16.

- Add 1 ft clean sand fill for contamination barrier, grade even
- Entire built area 3,691,475.25 ft^2 ~
- Desired improvement depth : 20ft ~ 6m
- Let n = 0.35 for cohesive soils, waste

$$D = n\sqrt{WH}$$

$$WH = \left(\frac{D}{n}\right)^2 = \left(\frac{6}{0.35}\right)^2 = 294$$

$\Rightarrow$ Select: $\underline{\underline{H = 18m = 60\ \text{feet}}}$

$\underline{\underline{W = 16\ \text{ton}}}$

* Goal to improve to N = 35-40bpf. After Mayne, et al (1984), Fig 13 this corresponds to an applied energy of 400-600 tm/m2

$$\text{Passes} = \frac{600}{294} = 2 \text{ passes}$$

$\Rightarrow$ 2-4 passes are recommended

Let spacing be 15 feet o.c.

$\underline{\underline{S = 15\ \text{ft o.c.}}}$

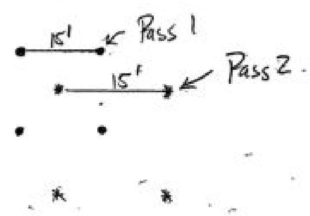


Figure 2C.5: Sample Calculations for DDC Design

Appendix 2D: Settlement

Table 2D.1: Sample Calculations Clay Settlement

Design	Nathan Zaporski	Date	6/6/16						
Task	Compute σ'p and σ'vo for various depths in compressible clay layer								
	Soft Clay			Hard Clay				Equation	Data Source
Elevation [ft]	572.5	565	555	545	535	525	515	-	130th & Torrence Borings, Benesch, #R23
Q [ksf]	2	1.6	2.4	6	4.5	4.5	4.5	-	130th & Torrence Borings, Benesch, #R23
c [psf]	1000	800	1200	3000	2250	2250	2250	c = Q/2	130th & Torrence Borings, Benesch, #R23
w (water content)	0.17	0.22	0.22	0.12	0.11	0.1	0.1	-	130th & Torrence Borings, Benesch, #R23
e0	0.459	0.594	0.594	0.324	0.297	0.27	0.27	e0 = 2.7*SG	Equation from B. Gitskin
LL (Liquid Limit)	25.94	30.04	30.04	21.84	21.02	20.2	20.2	LL = 0.82*w + 12	Equation from B. Gitskin
PI (Plasticity Index	10.419542	13.30717	13.30717	7.531912	6.95439	6.37686	6.37686	PI = 0.7043*LL-7.85	Equation from B. Gitskin
σ'p	6731.635684	5023.973	7535.959	21759.9326	16576.9	16842.02559	16842.02559	σ'p = c/(0.11+0.37PI)	Equation from B. Gitskin
σ'vo	1735	2170	2750	3640	3910	4490	5070	σ'vo = γ_soil*h_soil-γwater*h_water	Equation 6.1 from Holtz & Kovacs
OCR	3.879905293	2.315195	2.740349	5.97800345	4.23961	3.751007926	3.321898538	OCR = σ'p/σ'vo	Equation 8.2 from Holtz & Kovacs

Task	Compute settlement for clays underlying a mat foundation on DDC fill, all manufacturing buildings, assumes 3 foot concrete mat, 100 psf machine load, 100 psf structural steel load and 2*120 psf added sand fill load								
HEAVY LOADING CASE, 3' Mat									
1	2	3	4	5	6	7	8	10	11
Depth below Ground	Mid-layer Depth	Soil Type	σ'vo	σ'p	Δσ	σ'vf = σ'vo+Δσ	Vertical Strain	Hi	Δhi (Column 8*Column 9)
ft	ft	-	psf	psf	psf	psf	(1/1+e0)*Cr*log(σ'vf/σ'vo)	ft	ft
20	27.5	Soft Clay	1735	6731.63568	890	2625	0.002834877	5	0.014174387
25	30		2170	5023.97263	890	3060	0.002153713	10	0.021537133
35	40		2750	7535.95894	890	3640	0.001757014	10	0.017570137
								Total Settlement of Soft Clay: [in]	0.639379878
45	50	Hard Clay	3640	21759.9326	890	4530	0.001650247	10	0.016502468
55	60		3910	16576.8779	890	4800	0.001579401	10	0.01579401
65	70		4490	16842.0256	890	5380	0.001422304	10	0.014223043
75	80		5070	16842.0256	890	5960	0.001272032	10	0.012720322
								Total Settlement of Hard Clay: [in]	0.710878121
								Total Settlement of Clay [in]	1.350257999

OFFICE/CAFETERIA CASE									
Assumes 2' mat, 100 psf structural steel, 50 psf live load, 2*120 psf added fill load									
1	2	3	4	5	6	7	8	10	11
Depth below Ground	Mid-layer Depth	Soil Type	σ'vo	σ'p	Δσ	σ'vf = σ'vo+Δσ	Vertical Strain	Hi	Δhi (Column 8*Column 9)
ft	ft	-	psf	psf	psf	psf	(1/1+e0)*Cr*log(σ'f/σ'vo)	ft	ft
20	27.5	Soft Clay	1735	6731.63568	690	2425	0.002292311	5	0.011461556
25	30		2170	5023.97263	690	2860	0.001730141	10	0.017301411
35	40		2750	7535.95894	690	3440	0.001402881	10	0.014028809
								Total Settlement of Soft Clay: [in]	0.513501316
45	50	Hard Clay	3640	21759.9326	690	4330	0.001309584	10	0.013095844
55	60		3910	16576.8779	690	4600	0.00125163	10	0.012516305
65	70		4490	16842.0256	690	5180	0.001124345	10	0.011243454
75	80		5070	16842.0256	690	5760	0.00100357	10	0.010035701
								Total Settlement of Hard Clay: [in]	0.562695648
								Total Settlement of Clay [in]	1.076196963

OFFICE/CAFETERIA CASE									
Assumes 7' mat, 100 psf structural steel, 50 psf live load, 2*120 psf added fill load									
1	2	3	4	5	6	7	8	10	11
Depth below Ground	Mid-layer Depth	Soil Type	σ'vo	σ'p	Δσ	σ'vf = σ'vo+Δσ	Vertical Strain	Hi	Δhi (Column 8*Column 9)
ft	ft	-	psf	psf	psf	psf	(1/1+e0)*Cr*log(σ'f/σ'vo)	ft	ft
20	27.5	Soft Clay	1735	6731.63568	1440	3175	0.004137229	5	0.020686147
25	30		2170	5023.97263	1440	3610	0.003189518	10	0.03189518
35	40		2750	7535.95894	1440	4190	0.002638815	10	0.026388147
								Total Settlement of Soft Clay: [in]	0.947633692
45	50	Hard Clay	3640	21759.9326	1440	5080	0.002514753	10	0.025147534
55	60		3910	16576.8779	1440	5350	0.002414859	10	0.024148586
65	70		4490	16842.0256	1440	5930	0.002187868	10	0.021878678
75	80		5070	16842.0256	1440	6510	0.001966283	10	0.019662832
								Total Settlement of Hard Clay: [in]	1.090051562
								Total Settlement of Clay [in]	2.037685254

Notes: Newmark adjustments are insignificant for size of buildings considered, therefore settlement is evaluted on basis of mat thickness, floor and machine loadings only

Parameter	Value	Units	Source
Ground Elevatio	595	feet	Boring Reconstruction
γ_soil	120	pcf	Charles Dowding
γ_water	62	pcf	Charles Dowding
Water Table	590	feet	Boring Reconstruction
Cc	0.23	-	B. Gitskin
Cr	0.023	-	B. Gitskin

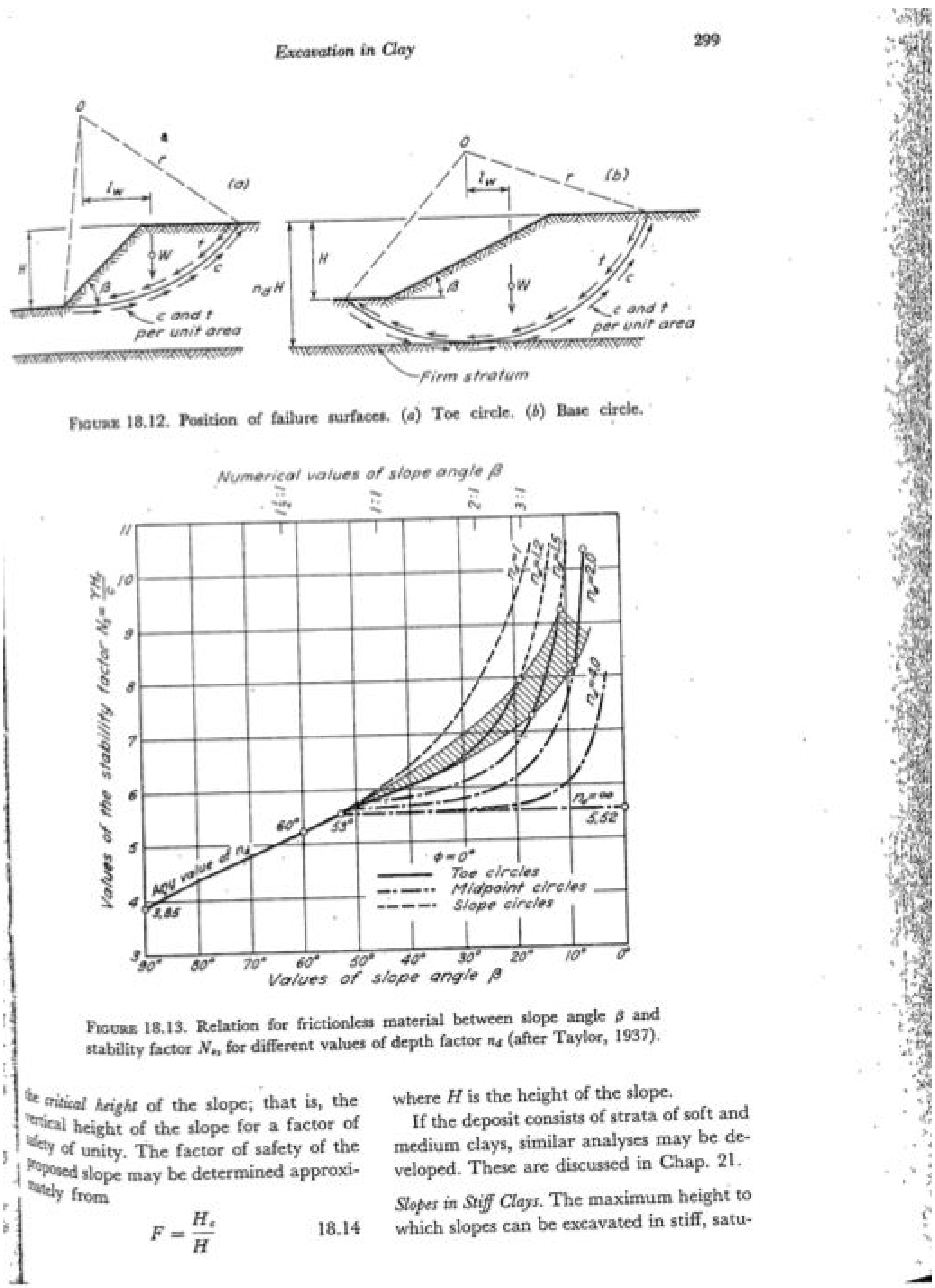
Void Ratio Factor for Consolidation Equation		
Soft Clay		
1	0.68540096	(1/(1+e0) (e0=C9)
2	0.627352572	(1/(1+e0) (e0=D9)
3	0.627352572	(1/(1+e0) (e0=E9)
Hard Clay		
1	0.755287009	(1/(1+e0) (e0=F9)
2	0.771010023	(1/(1+e0) (e0=G9)
3	0.787401575	(1/(1+e0) (e0=H9)
4	0.787401575	(1/(1+e0) (e0=H9)

Table 2D.2: Sample Calculations for Differential Mat Settlement

Design	Nathan Zaporski	**Date**	6/6/16			
Task	Compute Rigidity Factor For Mat Foundations					

Variable	Value	Units	Source
E' (concrete)	57000000	*psi*	Wight & McGregor
Es (AA Limestone)	40000	*psi*	http://www.pavementinteractive.org/article/subgrade/
B	1000	*feet*	Length of Foundation
b	1	*feet*	Width of strip
h	3	*feet*	Slab Thickness
Ib	3888	*in^4*	Moment of Inertia, Ib = 1/12*b*h^3
Kr	3.20625E-06	*Unitless*	Kr = E'Ib/EsB^3, Das Eq. #
δ	**0.5**	*in*	Differential Settlement, Das pg. 281

Appendix 2E: Slope Stability and Site History for Water Retention



Excavation in Clay 299

FIGURE 18.12. Position of failure surfaces. (a) Toe circle. (b) Base circle.

FIGURE 18.13. Relation for frictionless material between slope angle β and stability factor N_s, for different values of depth factor n_d (after Taylor, 1937).

the *critical height* of the slope; that is, the vertical height of the slope for a factor of safety of unity. The factor of safety of the proposed slope may be determined approximately from

$$F = \frac{H_c}{H} \qquad 18.14$$

where H is the height of the slope.

If the deposit consists of strata of soft and medium clays, similar analyses may be developed. These are discussed in Chap. 21.

Slopes in Stiff Clays. The maximum height to which slopes can be excavated in stiff, satu-

Figure 2E.1: Slope Stability Factor, Peck

Stability for Clay Slopes in Detention Pond
CIV-ENV 382, Spring 2016, T1
Nathan M. Zaporski 6/6/16

Assume $\bar{c} = 0.65 \text{ ksf}$, $N_s = 6$, $\gamma = 120 \text{ pcf}$

$$N_s = \frac{\gamma H_c}{c}$$

$$H_c = \frac{N_s c}{\gamma} = \frac{6 \cdot 650 \text{ psf}}{120 \text{ pcf}} = 32.5 \text{ ft}$$

$$F = \frac{H_c}{H} = \frac{32.5 \text{ ft}}{10 \text{ ft}} = \underline{\underline{3.25}}$$

$N_s = 6$ corresponds to a slope of $\beta \approx 45°$. As long as the slope is less than 45°, stability of the clay liner should not be an issue.

Figure 2E.2: Slope Stability Calculation

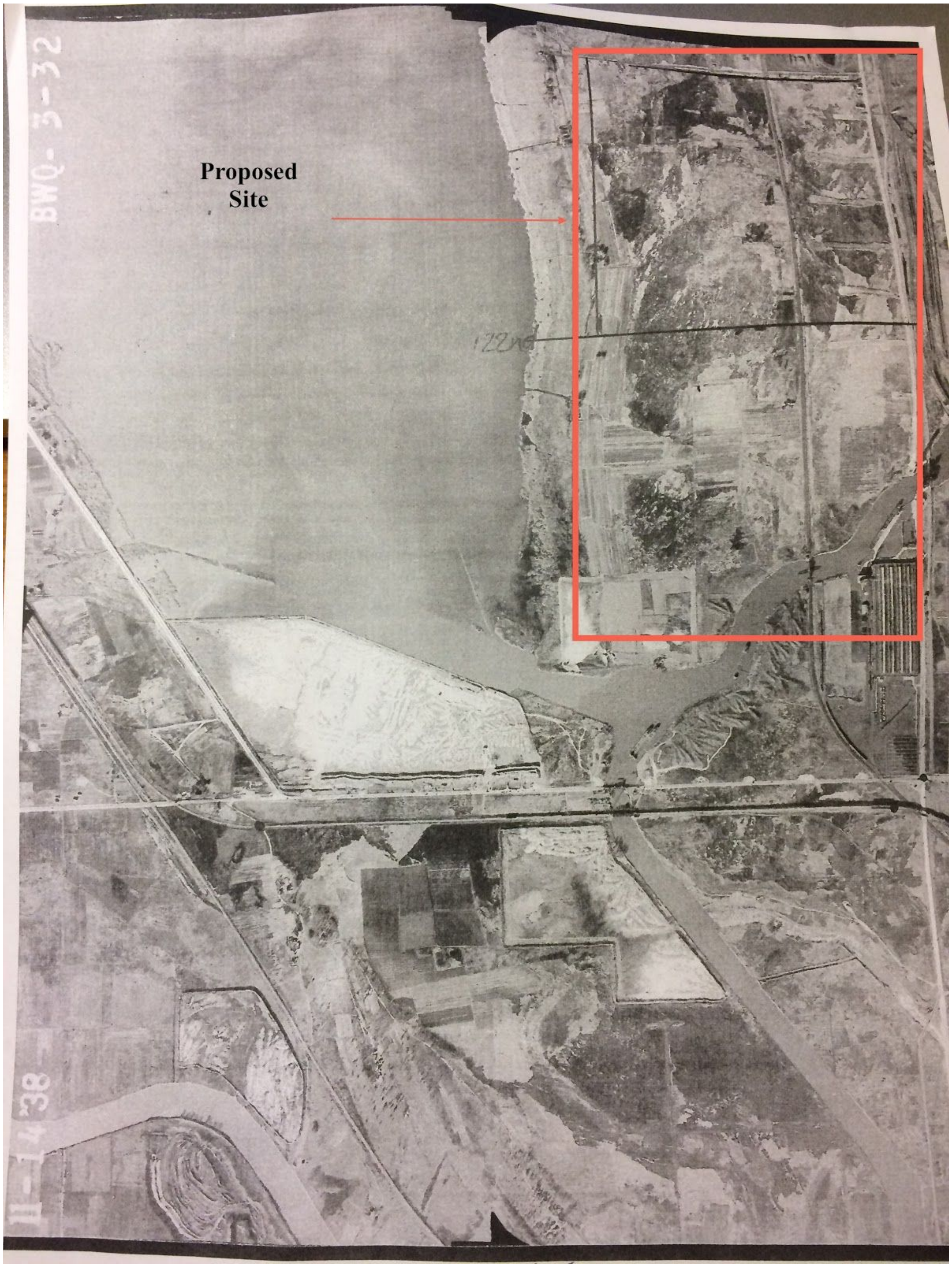


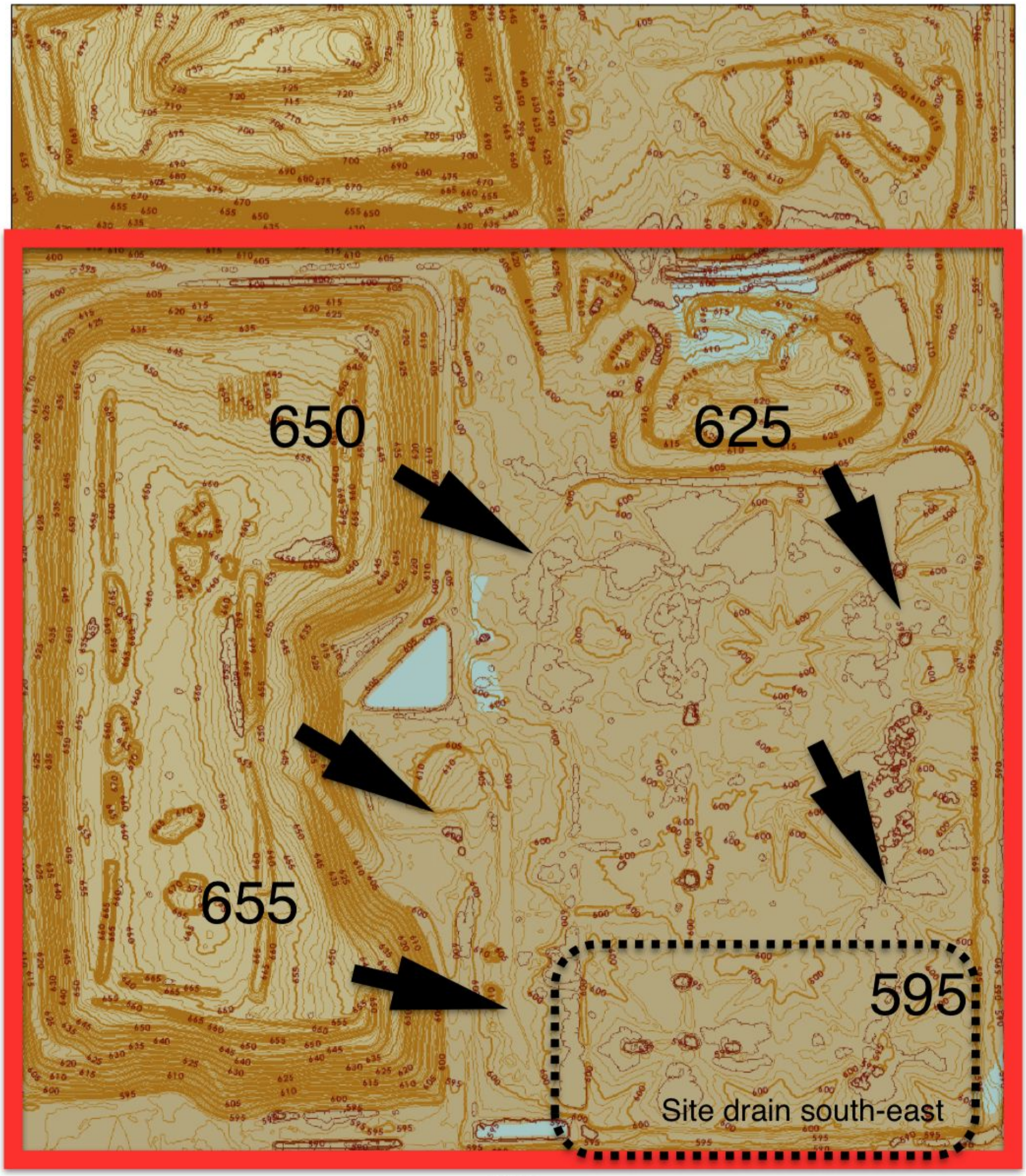
Figure 2E.3: Historical Air Photo, ca. 1937, Illinois Geospatial Data Clearinghouse

HYDROLOGY + HYDRAULICS

Jack Pong

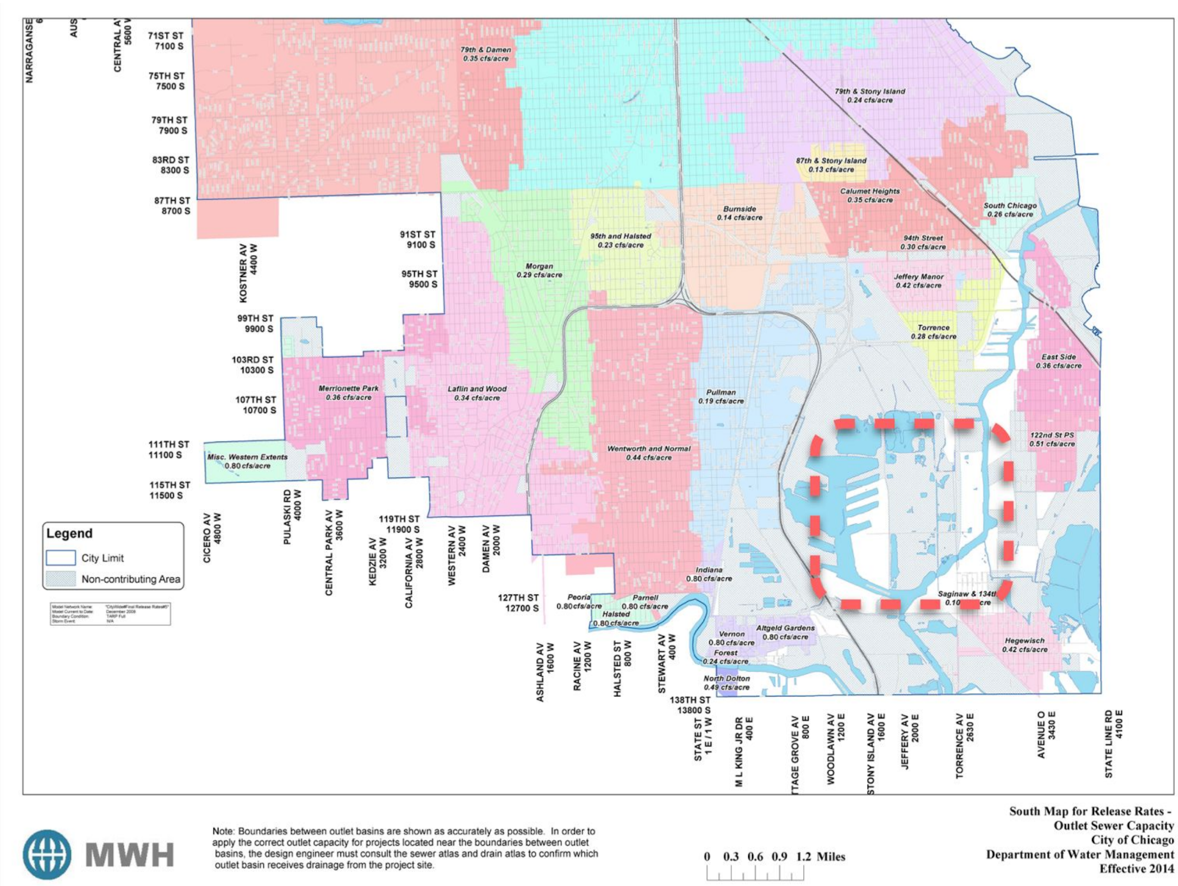
Appendix 3A: Contour Map of Ford Site

Cook County CookViewer Output



1:8000

Appendix 3B: Map Release Rate by Area



Appendix 3C: Runoff and Detention Volume Calculation

Figure 3C.1: C coefficient calculation breakdown

Runoff Calculation

		Proposed Area (sq. ft.)	C-Value 100-Year	Storage Volume (cu. ft.)
Pervious Land	Lawns - Sandy soil, flat, 0% to 2%	1,500,000	0.18	
	Lawns - Sandy soil, avg, 2% to 7%	940,946	0.27	
	Lawns - Sandy soil, steep, >7%		0.36	
	Lawns - Heavy soil, flat, 0% to 2%	3,750,000	0.30	
	Lawns - Heavy soil, avg, 2% to 7%	750,000	0.42	
	Lawns - Heavy soil, steep, >7%		0.47	
	Woodlands, flat, 2%		0.39	
	Native Vegetation with prepared soils		0.10	
	Dry bottom basins to HWL	0	0.75	
	Wetland	493,099	0.80	
	Green Roof		0.50	
Impervious Land	Gravel		0.70	
	Pavement	1,318,355	0.95	
	Roofs (conventional)	1,266,400	0.95	
	Building sidewalls connected by side gutters (enter 25% of the face of the sidewall)	62,010	0.95	
	Wet bottom basins to HWL		1.00	
BMP areas	BMPs providing storage that WILL COUNT toward detention storage (from Worksheet 1.2)	0	1.00	
	BMPs providing volume control storage that WILL NOT BE COUNTED toward detention (from Worksheet 1.2)	0	Storage Provided will be used to factor the adjusted C-value in Cell D38	0

Summary	Total pervious area (sq ft)	7,434,045
	Total impervious area (sq ft)	2,646,765
	Total BMP area (sq ft)	0
	Total site area (sq ft)	10,080,810
	Weighted C- value (non BMP areas)	0.48
	Adjusted C-value (accounts for BMPs)	0.00
	Notes:	*Make note of any adjustments made for purposes of detention calcs here (such as removal of roof area that will discharge directly to Waters)*

Rational Equation: Q=ciA

The Rational equation requires the following units:
Q = Peak discharge, cfs
c = Rational method runoff coefficient
i = Rainfall intensity, inch/hour
A = Drainage area, acre

The composite or area weighted runoff coefficient on a site is calculated by the following:
Cw =(A1C1 +A2C2 +A3C3)/(A1 +A2 +A3)

Figure 3C.2: Detention Storage Calculations

Step 3: **Achieving Rate Control Measures**

Unadjusted Detention Release Rate =	230.000	cfs	230.000	69.300
Dry Weather Flow Rate = (From dry weather flow worksheet)	0.247	cfs	DWF is less than 10% of maximum release rate and will not be included in release rate for storage computation	
Infiltration Facility Release Rate (to be added to eligible release rate when computing required storage)	0.000	cfs	No BMPs with infiltration beds entered on BMP Summary Worksheet or soil's infiltration rate is less than 0.5 in/hr	
Release rate for detention storage computations:	**69.000**	cfs		
Required Storage Volume =	1,303,377	cubic feet	50 acre-ft	162922.0832

Detention Storage Calculations
(Based on Bulletin 70 Rainfall Data)

STORM EVENT (5,10,25,50 or 100) = **100**

Allowable release rate 69.000 cfs

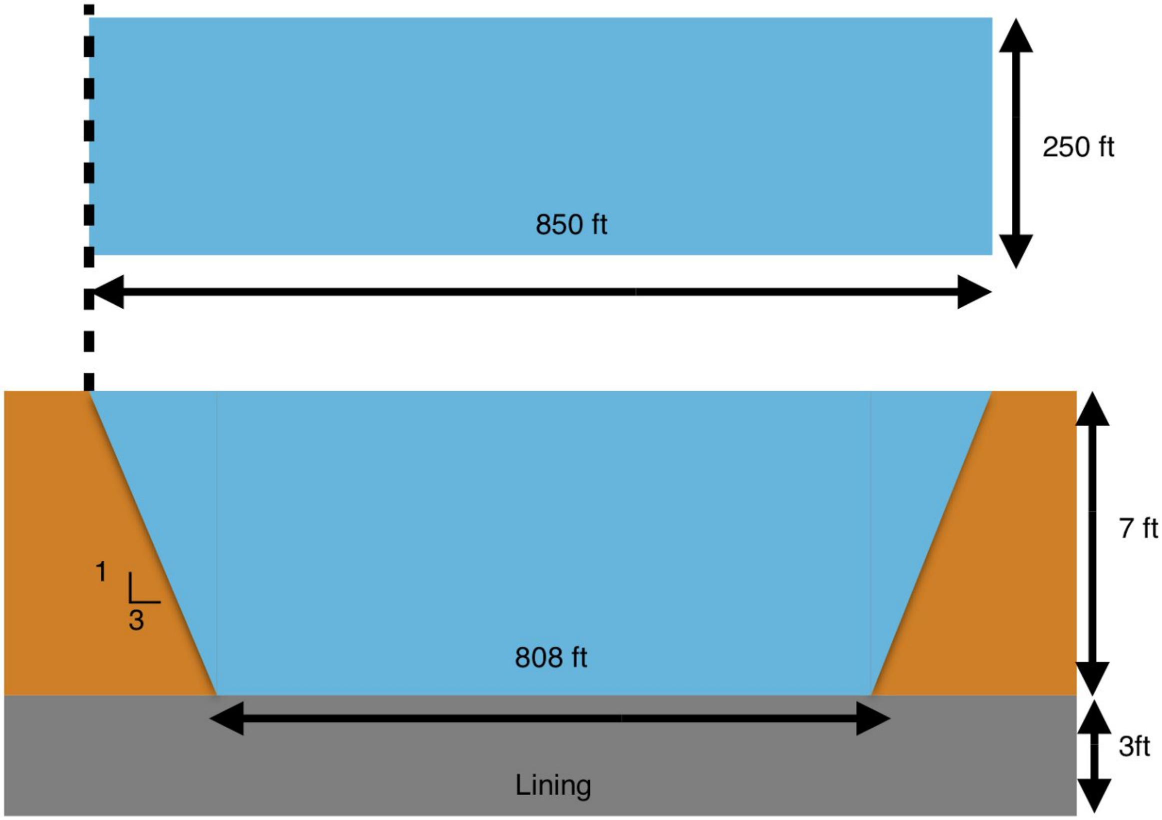
Storm Duration (minute)	Runoff Coefficient C	Rainfall Intensity (in/hr)	Drainage Area A (acres)	Inflow Rate Q=CIA	Total Storm Vol (cf)	Release Rate Qo (cfs)	Storage Rate (Qi-Qo) (cfs)	Storage Volume Rate (Qi-Qo)*t*60 (cf)
5	0.48	10.920	231.42	1221.60	366,479	69.000	1152.60	345,779
10	0.48	10.020	231.42	1120.92	672,549	69.000	1051.92	631,149
15	0.48	8.200	231.42	917.32	825,584	69.000	848.32	763,484
30	0.48	5.600	231.42	626.46	1,127,627	69.000	557.46	1,003,427
60	0.48	3.560	231.42	398.25	1,433,698	69.000	329.25	1,185,298
120	0.48	2.235	231.42	250.02	1,800,177	69.000	181.02	1,303,377
180	0.48	1.617	231.42	180.85	1,953,212	69.000	111.85	1,208,012
360	0.48	0.947	231.42	105.90	2,287,473	69.000	36.90	797,073
720	0.48	0.549	231.42	61.43	2,653,952	69.000	-7.57	-326,848
1080	0.48	0.387	231.42	43.32	2,806,987	69.000	-25.68	-1,664,213
1440	0.48	0.316	231.42	35.33	3,052,649	69.000	-33.67	-2,908,951
2880	0.48	0.170	231.42	19.02	3,286,229	69.000	-49.98	-8,636,971
4320	0.48	0.122	231.42	13.64	3,535,917	69.000	-55.36	-14,348,883
7200	0.48	0.083	231.42	9.29	4,011,132	69.000	-59.71	-25,796,868
14400	0.48	0.046	231.42	5.19	4,486,346	69.000	-63.81	-55,129,654
							Required Detention Volume (cf)	1,303,377

Detention - The City methodology for determining detention or storage volume involves calculating a required storage volume for a series of storm durations and intensities from 5 minutes to 24 hours using the following equation:
$Vs = (Qi - Qo) * t$ where:

Vs = Qi = Qo = Storage volume (cubic feet [ft^3]), Inflow rate (cfs), Release rate (cfs)
t = Storm duration (seconds)
The largest calculated storage volume is then selected as the amount of detention or storage required.

Appendix 3D: Stormwater Detention Pond Details

Figure 3D.1: Detention Pond Cross Section



The volume formula in terms of W, L, a, b, and H is

V = H[ab + 0.5(W-a)b + 0.5(L-b)a + (1/3)(W-a)(L-b)]

= (H/6)[6ab + 3Wb - 3ab + 3La - 3ba + 2WL + 2ab - 2Wb - 2aL]

= (H/6)[2WL + Wb + La + 2ab]

= (H/6)[WL + (W+a)(L+b) + ab]

Volume of detention pond

W= 850 ft

L= 250 ft

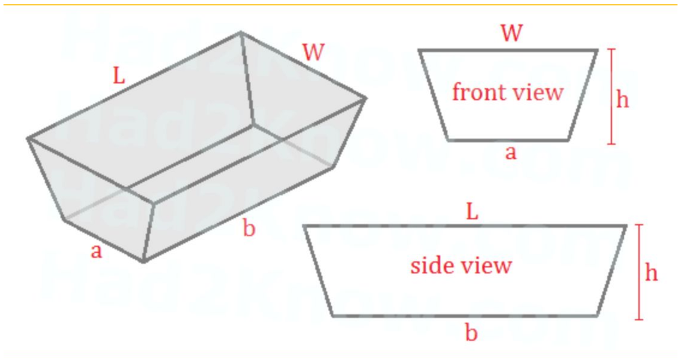
a= 808 ft

b= 208 ft

h= 7ft

Volume= 1,329,916 ft^3

Figure 3D.2: Detention Pond Configuration



Appendix 3E: Alternative Cost Calculations

Underground Detention System

Pipe Cost
6ft diameter pipe: 1,329,916 ft^3 / (pi * 9) = 47,036.16 ft^2 (amount of underground area needed)

47,036.16 ft^2 * $355 = $16,697,780

Excavation and transport cost

Excavate and transport contaminated soil: 48,000 ft^2 * 3 ft * $100/ ft^3= 14,400,000

Excavate non contaminated soil (assuming the cheaper option)= 48,000 ft^2 * 7ft *$25/ft^3 = $8,400,000

Total= 39,497,780

Most cost effective detention pond

Excavate and transport contaminated soil: 642,477 ft^3 * $100/ ft^3 = $6,424,770

Excavate non contaminated soil: 1,385,083 ft^3 * $6.45/ ft^3 = $8,933,785.35

Total= 15,358,555.4

Appendix 3F: Detention Pond Alternatives

Volume of excavated soil

W= 856 ft
L= 256 ft
a= 826 ft
b= 226 ft
h=10ft

Volume= 2,027,560 ft^3

Amount of contaminated soil

W=856 ft
L= 256 ft
a= 847 ft
b= 247 ft
h= 3ft

Volume= 642,477 ft^3

Amount of uncontaminated soil

W= 847 ft
L= 247 ft
a= 826 ft
b= 226 ft
h= 7ft

Volume= 1,385,083

Excavate and transport all soil

Excavate and transport contaminated soil: 642,477 ft^3 * $100/ ft^3 = $6,424,770

Excavate and transport non contaminated soil: 1,385,083 ft^3 * $25/ ft^3 = $34,627,075

Total= $41,051,845

Excavate and only transport contaminated soil

Excavate and transport contaminated soil: 642,477 ft^3 * $100/ ft^3 = $6,424,770

Excavate non contaminated soil: 1,385,083 ft^3 * $6.45/ ft^3 = $8,933,785.35

Total= 15,358,555.4

Appendix 3G: Orifice Restrictor Sizing

Given:

Impervious area on site = 59.34 acres

Curve coefficient (C) = 0.82

Acceleration due to gravity (g) = 32.2 ft/s2

Detention pond volume = 39.92 acre-ft

Detention pond area = 4.878 acres

Detention pond depth = 7 ft

Allowable release rate (Q) = 69 cfs

Required retention volume for one inch of runoff over impervious areas:

VR= 59.34 acre * 1 in * 1 ft/ 12 in = 4.945 acre - ft

Remaining detention volume

VD= 39.92 - 4.878 = 35.042 acre- ft

Depth of retention volume:

HR= 4.945 acre - ft / 4.878 acre = .067 ft

Depth of detention volume and restrictor:

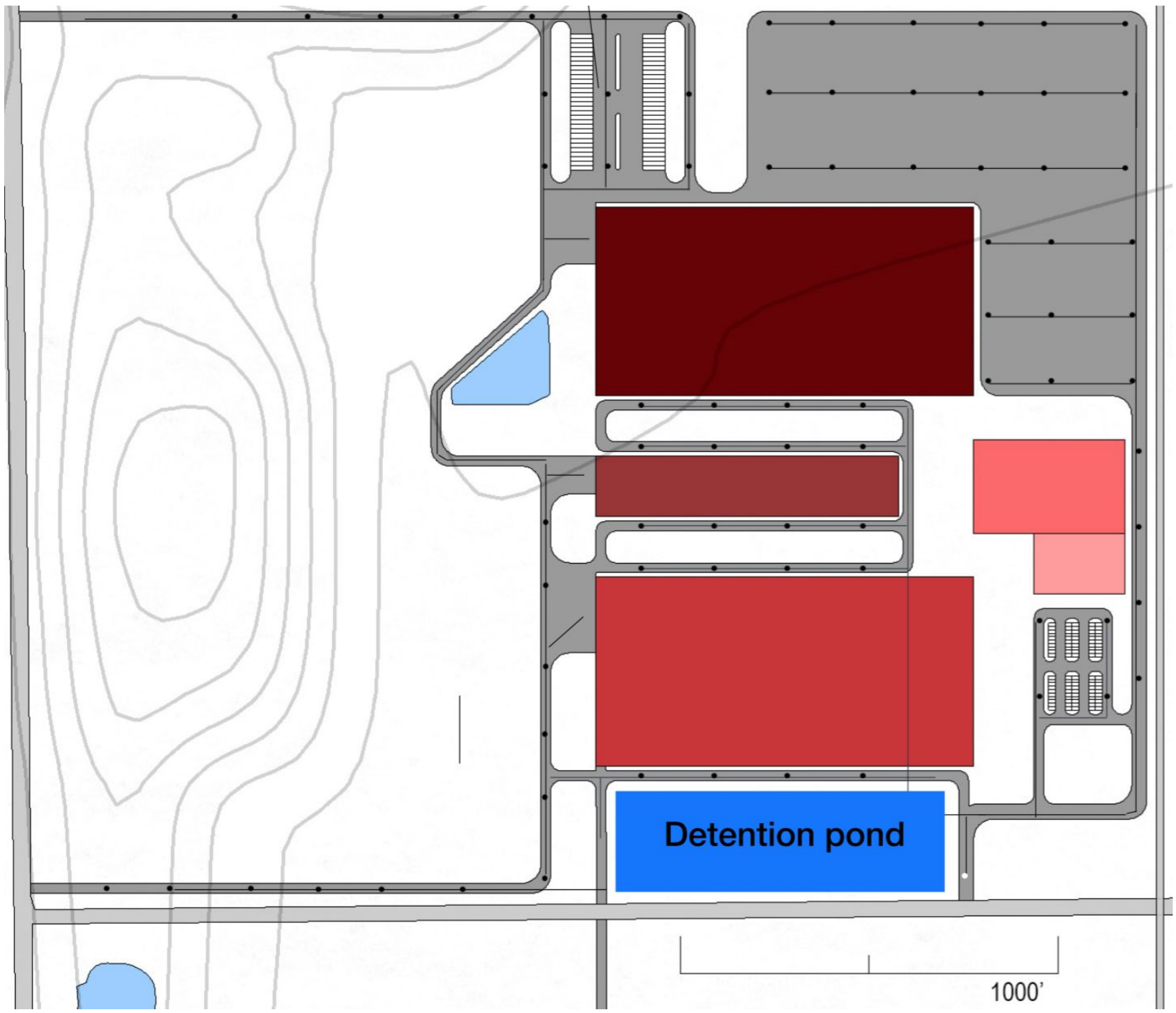
H= 7 ft - 0.067 ft = 6.933 ft

Area of restrictor

69 / (0.82 * sqrt(2*32.2*6.933)) = 3.98 ft^2

sqrt(3.98/pi)= radius*2= 2.251 ft= **27.01 inches**

Appendix 3H: Stormwater System Layout



Appendix Section 4

TRANSPORTATION

Ian Piper

Appendix 4A: Bike Path Cross Section

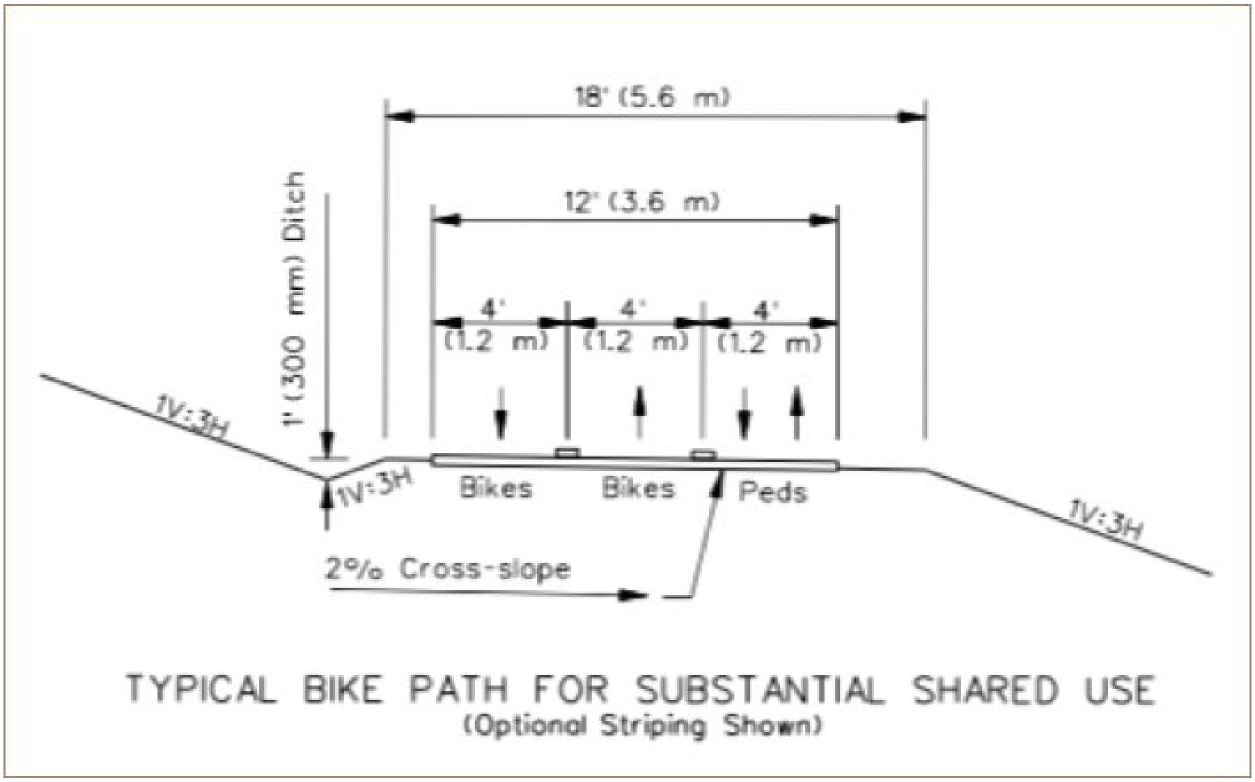


Figure 4A.1: Typical 2-Lane Bike Path

Appendix 4B: Trip Generation and Distribution

Site trip information and assumptions

Ford Manufacturing: 4500 hourly employees/3 shifts (10% carpooling) = 1350 vehicles trips during the AM peak*
(Assume 20 truck trips per hour)
Total vehicles per hour (VPH) during AM peak: 1370

Ford Office: 150 hourly employees/1 shift (10% carpooling) = 135 vehicles during the AM peak*
Total vehicles per hour (VPH) during AM peak: 135
*Shift changes later in the day do not occur during the PM peak hours and therefore were not considered.

Land Use	**AM Peak**		
	In	**Out**	**Total**
Ford Manufacturing	73% = 985	27% =365	1350
Ford Trucks	50% = 10	50% = 10	20
Ford Office	88% = 119	12% = 16	135
TOTAL	1114	391	1505

Table 4B.1: Trip Generation

Direction	**Roadway**	**Percentage of Trips**
North/South (on I-94)	130th St	15%
North (on I-94)	103rd (Stoney Island Ave)	30%
North	Torrence Ave	25%
South	Torrence Ave	15%
South	Brainard Ave	15%

Table 4B.2: Ford Trip Distribution

Appendix 4C: Traffic Improvements

1: 103rd and Stoney Island Ave
- Signal modification and northbound left turn lane

2: 122nd and Torrence
- Northbound left turn lane, southbound right turn lane, eastbound left turn lane

3: 130th and CISCO Access Road
- Northbound left turn lane, westbound left turn lane

Impacted Intersections due to Ford Traffic

Figure 4C.1: Ford Traffic Impacted Intersections

Appendix 4D: Traffic Improvements Cost Calculations

Ford: Road Improvement Cost Estimations: (Provided by Michael Magnuson)

122nd St Entrance: $800,000
122nd and Torrence: $1M
103rd and Stoney Island Ave: $300,000
130th and CISCO Access Road: $600,000*

Total: $2.7M

*Improvements needed as a result on increase in traffic from Ford Site (not CISCO). Necessary for future development of CISCO site and WET Zone S.

Appendix 4E: Site Circulation Requirements

Driveway Requirements: FORD entrance driveways were designed to meet or exceed the standards outlined in the Table 4E.1 below.

	Dimension Reference (See Figure 41-2B)	Non-Commercial Rural	Non-Commercial Urban	Commercial/ Industrial Rural	Commercial/ Industrial Urban	High-Volume Commercial/ Industrial
Throat Width	W	12 ft – 24 ft [1] (3.6 m – 7.2 m)	12 ft – 24 ft [1] (3.6 m – 7.2 m)	24 ft – 35 ft [2] (7.2 m – 10.7 m)	24 ft – 35 ft [3] (7.2 m – 10.7 m)	2@ 24 ft (7.2 m) with median
Return Radii [8]	R	10 ft – 40 ft (3 ft – 12 m)	5 ft – 25 ft (1.5 m – 7.5 m)	10 ft – 50 ft (3 m – 15 m)	10 ft – 40 ft (3 m – 12 m)	25 ft – 60 ft (7.5 m – 18 m)
Angle	A	60° – 90°	45° – 90° [5]	45° – 90° [5]	45° – 90° [5]	45° – 90° [5]
Spacing (minimum)	P (From Property Line to Beginning of Flare)	0 ft (0 m)	0 ft (0 m)	5 ft (1.5 m) [4]	3 ft (1 m)	10 ft (3 m)
	C [9] (From Street Corner)	50 ft (15 m)	30 ft (9 m) [6]	50 ft (15 m)	30 ft (9 m)	100 ft (30 m)
	S (Between Driveways)	0 ft (0 m)	0 ft (0 m)	0 ft (0 m)	0 ft (0 m)	440 ft to 660 ft (135 m to 200 m)
Island Width (minimum		N/A	N/A	10 ft (3 m)	6 ft (1.8 m)	4 ft – 18 ft (1.2 m – 5.4 m)
Island Radius (minimum)		N/A	N/A	5 ft (1.5 m)	5 ft (1.5 m)	N/A
Gradient [7]		15%	10% Des. 15% Max.	6% Des. 10% Max.	5% Des. 10% Max.	5% – 8%

Notes:
(1) Minimum is 16 ft (4.8 m) for field entrances.
(2) Maximum is 60 ft (18 m), located 6 ft (1.8 m) from edge of traveled way (ETW).
(3) Maximum is 85 ft (26 m) at curb.
(4) Located 6 ft (1.8 m) from edge of traveled way (ETW).
(5) Use a minimum of 45° for one-way drives and 60° for two-way drives.
(6) This distance is the undisturbed length of curb between driveway flare and intersecting street flare.
(7) Maximum breakover is 12%.
(8) Straight line flare may be used in place of radius.
(9) Measured from edge of cross-street pavement, not end of radius.

Ford

Table 4E.1: IDOT Driveway Dimension Standards

Emergency Vehicle Access Requirements: 16ft wide access roads that can support emergency vehicles are required around each building. Access roads should be offset from building 10ft and accommodate for emergency vehicle turning radius at the corners (10ft minimum to 40ft maximum). Paving and/or Tuff Track can be utilized, but must support a minimum 70,000lb load.

General Site Circulation Principals: Modes of transportation and vehicle types should remain as separated as possible (use of separate entrances, roadways/sidewalks/bike lanes within the site).

Appendix 4F: Rail Cross Section and Requirements

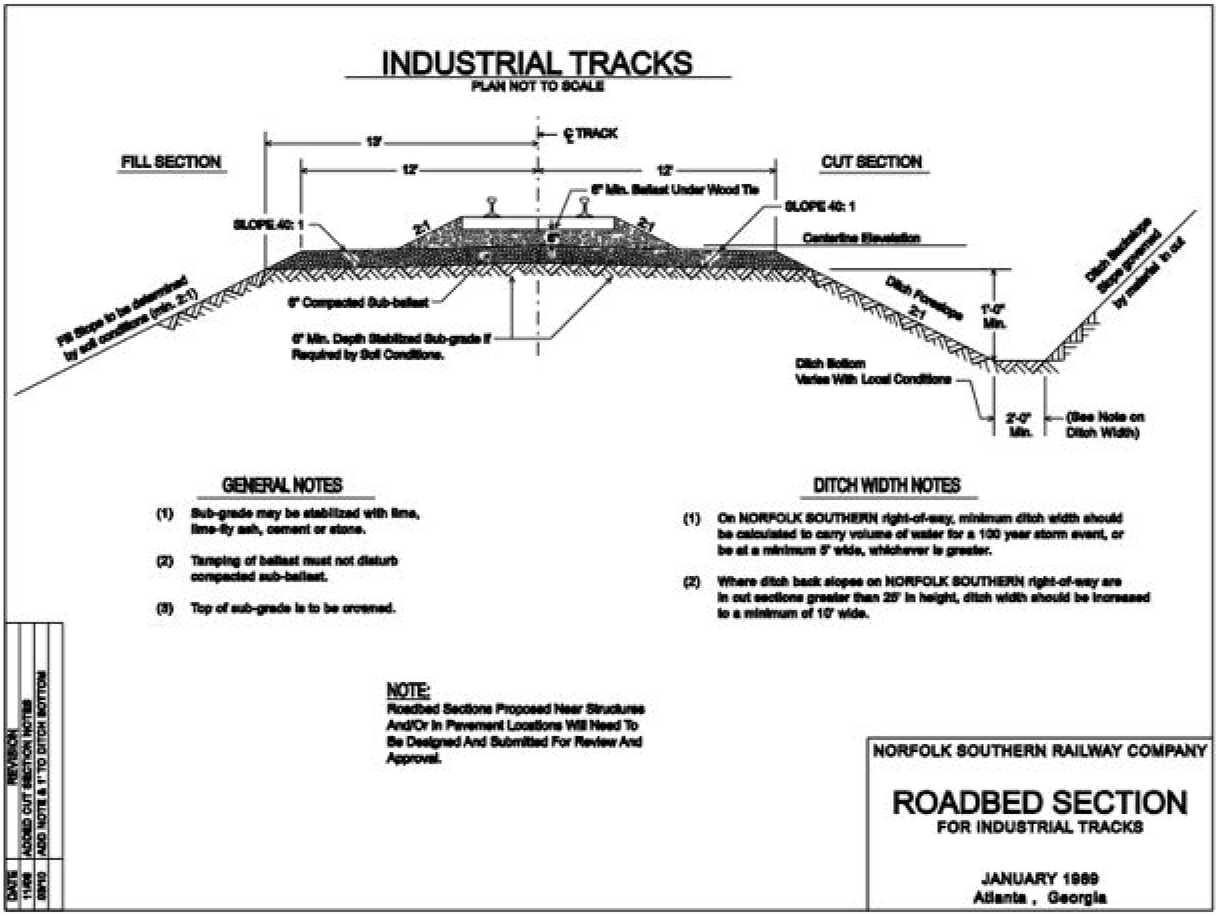


Figure 4F.1: Typical Industrial Track Cross Section

NSCorp Industrial Track Design Requirements:

- Industry tracks where rail cars are loaded and unloaded must be on a 0% (flat) grade
- Industry tracks shall have minimum 30ft, or one half length of a rail car, whichever is greater, of track from the end of the last car spot on the unloading track before an End of Track Device.
- Industry track centers for multiple parallel tracks within the industry facility must be no closer than 14ft, centerline to centerline.
- Turnouts in the main line will not be place within 50ft of a railroad signal or within 100 feet of a railroad track bridge face.
- Tracks should have minimum degree of curvature with a maximum of 12 degrees (radius = 478.34 feet)
- Grading should be designed to Industrial Track roadbed section shown in Figure 5
- Fills and subgrades shall be compacted to a minimum of 90% Modified Procter based on AASHTO Designation T-180, or 95% Standard Procter based on AASHTO Designation T-99

Appendix 4G: Rail Asphalt Paving

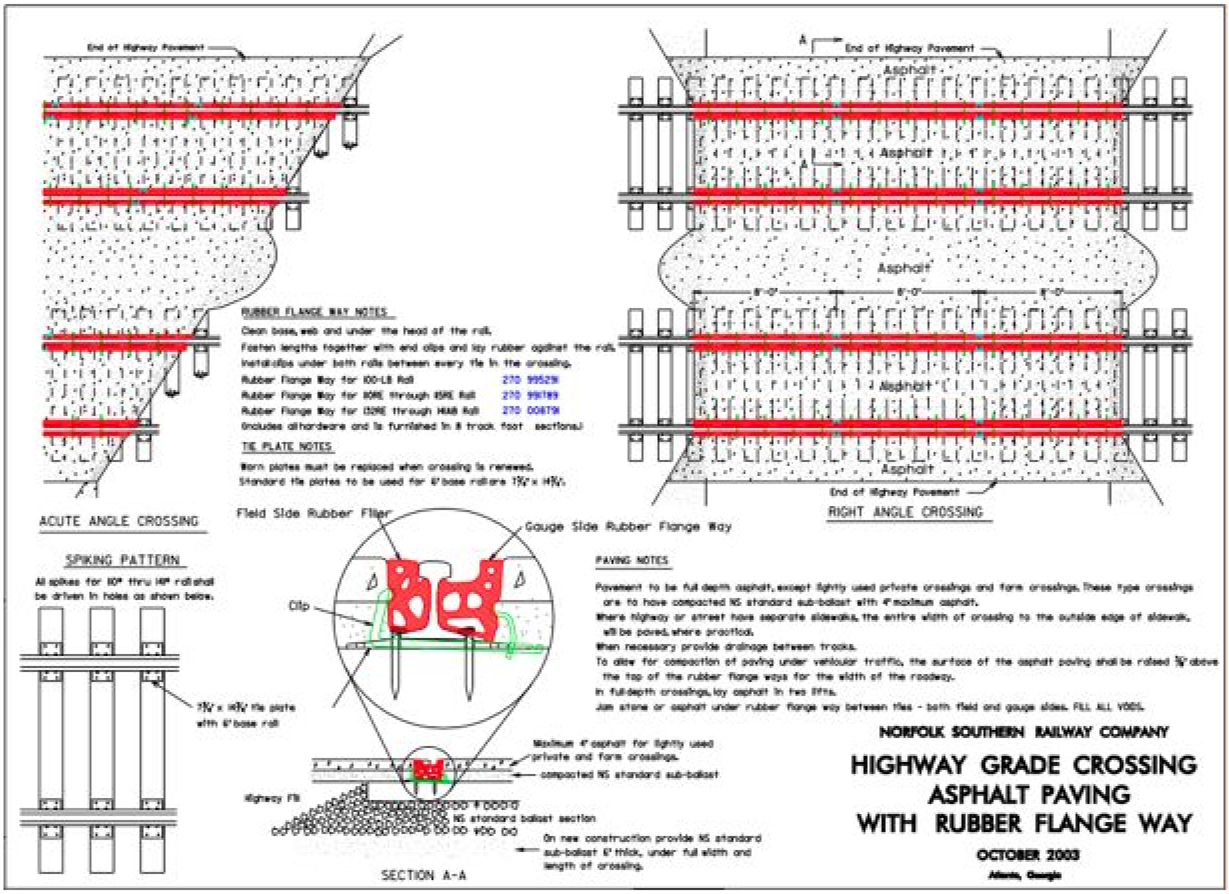


Figure 4G.1: Industrial Track Asphalt Paving

Appendix 4H: Rail Cost Calculations

Rail Connection Cost Calculations: (Cost estimations provided by Michael Magnuson)
Existing Pavement Demolition: $111,780

Rail Connection Area: 230ft x 1800 ft = 414,000 sq.ft
Industry Track Siding (rail, ties, ballast): $160/ft
Total Industry Track length: 6 @ 1800ft = 10800ft
Asphalt (7” on top): $874,000
Mainline Turnout: $250,000
5 Industry Track Turnouts: $130,000

Total rail connection cost:
($111,780) + ($160/ft x 10800ft) + ($874,000) + ($250,000) + (5 x $1300000)
= ~$3.61 million

Appendix 4I: Parking Demand Requirements

Ford Program Requirements:
3100 total parking spaces (3000 hourly employee parking spaces and 100 salaried/visitor spaces)
9200 vehicle yard capacity
1000 batch/hold capacity
60 truck parking

Grading Requirements: Parking lots must be designed with a 1-5% slope to allow for proper ingress and egress for water drainage.

ADA Requirements:

Minimum Number of Accessible Parking Spaces
ADA Standards for Accessible Design 4.1.2 (5)

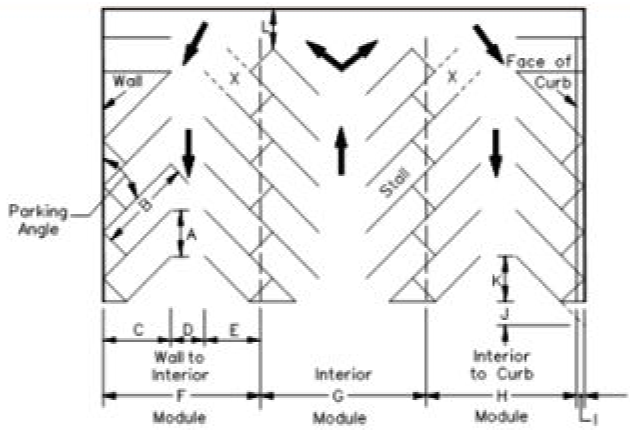
Total Number of Parking spaces Provided (per lot)	Total Minimum Number of Accessible Parking Spaces (60" & 96" aisles)	**Van Accessible Parking Spaces with min. 96" wide access aisle**	**Accessible Parking Spaces with min. 60" wide access aisle**
	Column A		
1 to 25	1	1	0
26 to 50	2	1	1
51 to 75	3	1	2
76 to 100	4	1	3
101 to 150	5	1	4
151 to 200	6	1	5
201 to 300	7	1	6
301 to 400	8	1	7
401 to 500	9	2	7
501 to 1000	2% of total parking provided in each lot	1/8 of Column A*	7/8 of Column A**
1001 and over	20 plus 1 for each 100 over 1000	1/8 of Column A*	7/8 of Column A**

* one out of every 8 accessible spaces ** 7 out of every 8 accessible parking spaces

Table 4I.1: ADA Parking Stall Requirements

Ford:
4 ADA out of 100 total salaried/visitor parking spaces
40 ADA out of 3000 total hourly employee parking spaces

Layout and Dimensions:



X • Stall not accessible in certain layouts

Parking Layout Dimension for 9 ft x 18.5 ft (2.7 m x 5.6 m) Stalls at Various Lengths

Design Feature	Notation	Parking Angle							
		45° (ft)	45° (m)	60°(ft)	60° (m)	75° (ft)	75° (m)	90° (ft)	90° (m)
Stall width, parallel to aisle	A	12.7	3.9	10.4	3.2	9.3	2.8	9.0	2.7
Stall length of line	B	25.0	7.6	22.0	6.7	20.0	6.1	18.5	5.6
Stall depth to wall	C	17.5	5.3	19.0	5.8	19.5	5.9	18.5	5.6
Minimum aisle width between stall lines	D	12.0	3.7	16.0	4.9	23.0	7.0	26.0	7.9
Stall depth, interior	E	15.3	4.7	17.5	5.3	18.8	5.7	18.5	5.6
Module, wall to interior	F	44.8	13.7	52.5	16.0	61.3	18.7	63.0	19.2
Module, interior	G	42.6	13.0	51.0	15.5	61.0	18.6	63.0	19.2
Module, interior to curb face	H	42.8	13.1	50.2	15.3	58.8	17.9	60.5	18.4
Bumper overhang (typical)	I	2.0	0.6	2.3	0.7	2.5	0.8	2.5	0.8
Offset	J	6.3	1.9	2.7	0.8	0.5	0.2	0.0	0.0
Setback	K	11.0	3.4	8.3	2.5	5.0	1.5	0.0	0.0
Cross aisle, one-way	L	14.0	4.3	14.0	4.3	14.0	4.3	14.0	4.3
Cross aisle, two-way	—	24.0	7.3	24.0	7.3	24.0	7.3	24.0	7.3

CIS CO

Notes:
1. *See Section 41-6 for criteria on the number and dimensions of parking spaces for individuals with disabilities.*
2. *If a special section is designated for subcompact vehicles, these stalls can be 8 ft x 15 ft (2.5 m x 4.6 m) for a 90° angle.*
3. *Stalls should be wider for commercial parking.*
4. *The designer should consider bumper overhang when placing lighting, railing, etc. Therefore, these appurtenances should be placed beyond dimension "I" in the figure.*
5. *Two-way traffic in aisles may only be used with a 90° parking angle. Use an aisle width of 26 ft (7.9 m).*

PARKING LOT LAYOUT DIMENSIONS
(9 ft x 18.5 ft (2.7 m x 5.6 m) Stalls)

Figure 41-3A

Table 4I.2: IDOT Parking Lot Dimensions

Appendix 4J: Site Pavement Design

Parking lots and driveways have been designed to Caltrans: Pervious Pavement Design Guidance, 2014 standards.

Ford:

- Driveway or Sidewalk at driveway (Option 2): 0.50 foot pervious concrete on 0.70 foot Class 4 AB
- Parking area for passenger vehicles including trafficked area (Option 2): 0.50 foot pervious concrete on 0.70 foot Class 4 AB
- Parking area for heavy vehicles (Option 2): 0.70 foot pervious concrete on 0.70 foot Class 4 AB (IDOT Bureau of Local Roads and Streets Manual)
- 1% slope for drainage

Appendix 4K: Road Pavement Design

Using the steps outlined by the Modified AASHTO Method for flexible pavement in IDOT Chapter 54: Pavement Design, the pavement surface, base, and subbase thickness were calculated below.

Facility Class: **Class I facility** (4 lanes with ADT <3000)

Type of Vehicle	Number of Vehicles Per Day (estimated from trip generation)	Percent of Total Vehicular Class Volume (ADT) in Design Lane
PV	4500	32%
SU	10	45%
ME	480	45%

Table 4K.1: Type of Vehicles Per Day

Facility Class	Traffic Factor Equation	Equation Number
Class I	$TF=DP\left[\frac{(0.15\bullet P\bullet PV)+(132.50\bullet S\bullet SU)+(482.53\bullet M\bullet MU)}{1x10^6}\right]$	Equation 54-5.1
Class II	$TF=DP\left[\frac{(0.15\bullet P\bullet PV)+(112.06\bullet S\bullet SU)+(385.44\bullet M\bullet MU)}{1x10^6}\right]$	Equation 54-5.2
Class III and Class IV	$TF=DP\left[\frac{(0.15\bullet P\bullet PV)+(109.14\bullet S\bullet SU)+(384.35\bullet M\bullet MU)}{1x10^6}\right]$	Equation 54-5.3

Table 4K.2: Facility Class Traffic Factor Equations

Using the equation for a Class I Facility above: **TF = 2.10**

Soil Classification (from borings taken at 130th and Torrence Ave – confirmed by transportation domain expert, Michael Magnuson): **A-3**

Soil Classification	IBR
A-1	20
A-2-4, A-2-5	15
A-2-6, A-2-7	12
A-3	10
A-4, A-5, A-6	3
A-7-5, A-7-6	2

Table 4K.3: IBR Values for Soil Classification

Corresponding IBR value taken from the table above: **10**

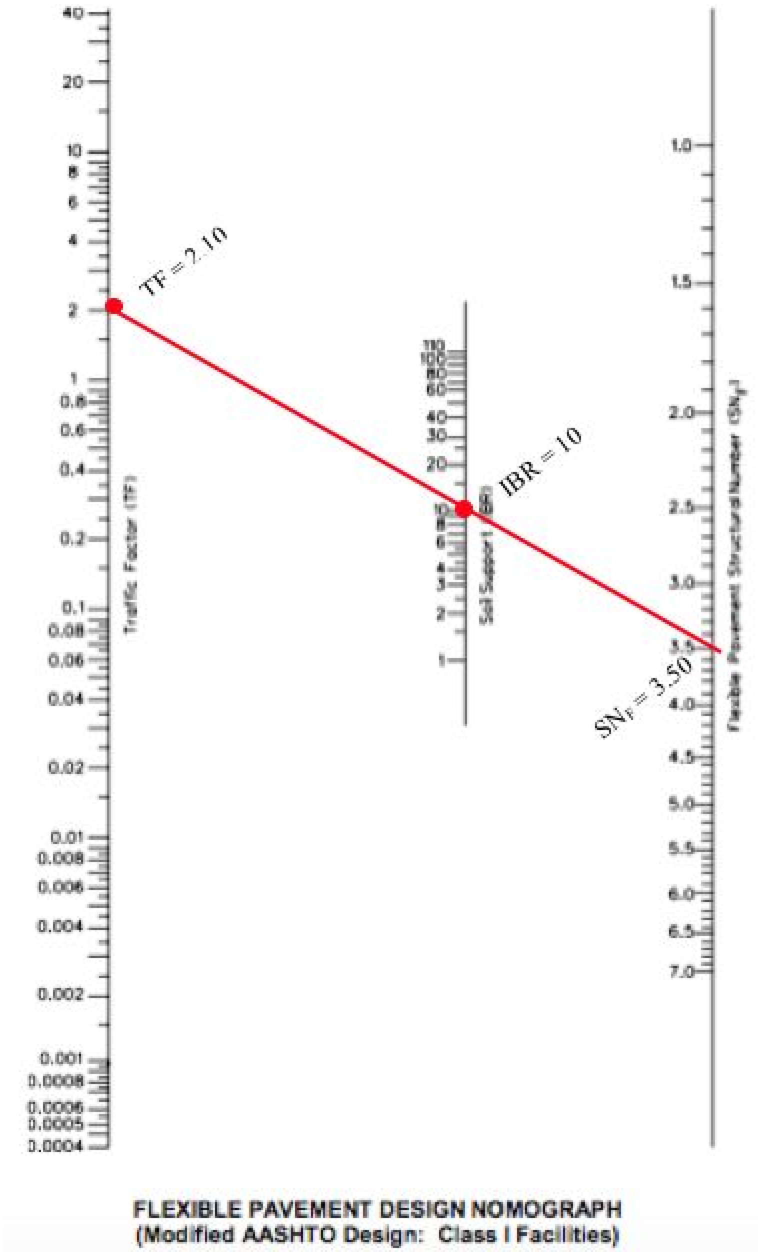


Figure 4K.1: Flexible Pavement Design Nomograph

SN_F: **3.5**

STRUCTURAL NUMBER (D_t) ②		MINIMUM THICKNESS (inches)			MINIMUM MATERIAL ⑤		
From	To	Surface	Base ⑦	Subbase ③ (optional)	Surface	Base ⑥	Subbase ⑧ (optional)
1.00	1.99	2	8	4 ④	Class B Road Mix	Aggregate, Type B ⑦	Granular Material, Type B ④
			6			Stabilized Granular Material (MS_{min} = 300 or CS_{min} = 300)	
2.00	2.49	2	8	4 ④	Class B Plant Mix (asphalt binder)	Aggregate, Type B ⑦	Granular Material, Type B ④
			6			Stabilized Granular Material (MS_{min} = 300 or CS_{min} = 300)	
2.50	2.99	⑨	9	4	Class B Plant Mix (asphalt binder)	Aggregate, Type A	Granular Material, Type B
			7			Stabilized Granular Material (MS_{min} = 300 or CS_{min} = 300)	
3.00	3.49	⑨	11	4	HMA (4% voids)	Aggregate, Type A	Granular Material, Type B
			8			Stabilized Granular Material (MS_{min} = 400 or CS_{min} = 400)	
3.50	3.99	⑨	8	4	HMA (4% voids)	Stabilized Granular Material (MS_{min} = 800 or CS_{min} = 650)	Granular Material, Type B
4.00	4.49	⑨	8	4	HMA (4% voids)	Stabilized Granular Material (MS_{min} = 1,000 or CS_{min} = 750)	Granular Material, Type B
4.50	4.99	⑨	9	4	HMA (4% voids)	Stabilized Granular Material (MS_{min} = 1,200 or CS_{min} = 1,000)	Granular Material, Type B
			9			Pozzolanic, Type A	
5.00	5.99	⑨	10	4	HMA (4% voids)	Stabilized Granular Material (MS_{min} = 1,500)	Granular Material, Type A
≥ 6.00		⑨	12	4	HMA (4% voids)	Stabilized Granular Material (MS_{min} = 1,700)	Granular Material, Type A

Notes:

① *The minimum allowable structural number for Interstates and freeways will be 5.6; for multi-lane State primary highways, 5.0; and for two-lane State primary highways, 4.0.*

② *Where bituminous stabilized granular material with a strength greater than the minimum required above is used, a reduction in the minimum required thickness, up to a maximum of 1 in., will be allowed.*

③ *The minimum thickness of a lime stabilized soil subbase will be 6 in.*

④ *If an uncrushed Aggregate Base Course, Type B is used, a subbase will not be used.*

⑤ *Other approved materials having equal or greater strengths may be substituted for those listed above.*

⑥ *MS = Marshall Stability (lb) or equivalent, CS = 7-day compressive strength (psi) that can be reasonably expected under field conditions.*

⑦ *Lime stabilized soil may be used, provided the minimum thickness is not less than 8 in.*

⑧ *The use of a granular subbase is not mandatory.*

⑨ *Use Policy Resurfacing Thickness (see Chapter 53), unless prior BDE approval is received.*

MINIMUM THICKNESS AND MATERIAL REQUIREMENTS FOR FLEXIBLE PAVEMENTS
(Modified AASHTO Design)

Table 4K.4: Minimum Thickness and Material Requirements for Flexible Pavement

The minimum thickness of the HMA (4% voids) surface was calculated to be 3.5 inches, however, Note 2 in the table above requires a minimum thickness of 4 inches. The base of Stabilized Granular Material will be 8 inches thick on top of an optional subbase of Granular Material, Type B that is 4 inches thick.

ARCHITECTURE

Lupe Gómez

Appendix 5A: Assembly Facility Program

Program Element	Previous Estimate (SF)	Actual (SF)	% of Total Program
Buildings	*1308000*	*1309000*	*13.40*
Building 1: Body Building	500000	500000	5.12
Building 2: Paint Building	128000	128000	1.31
Building 3: TCF Building	500000	500000	5.12
Building 4: Office and Cafeteria	180000	180000	1.84
Waste Water Treatment Plant	-	1000	0.01
Parking Lots	*2205000*	*6454036*	*66.06*
Vehicle Yard (9,200 vehicles)	1490400	4959000	50.76
Batch/Hold (1,000 vehicles)	162000		
Employee Parking Lot (3,000 vehicles)	486000	1226000	12.55
Shipping & Receiving Area (60 trailers)	50400	206000	2.11
Salaried/Visitor Lot (100 vehicles)	16200	63036	0.65
Roads and Paths	-	*362000*	*3.71*
Roads	-	256000	2.62
Bike Path	-	47000	0.48
Sidewalks and Courtyard	-	59000	0.60
Other Components	*103900*	*1644400*	*16.83*
Cooling Towers	3900	3900	0.04
Main Electrical Substation	100000	100000	1.02
Bus Terminal	-	21000	0.21
Detention Pond	-	212500	2.18
Solar Panel Field	-	1307000	13.38
Total	**3616900**	**9769436**	**100.00**

Figure 5A.1: Detailed Program Requirements

Appendix 5B: Site Plan

Figure 5B.1: Northern WET Zone Site Plan

Appendix 5C: Site Elevation

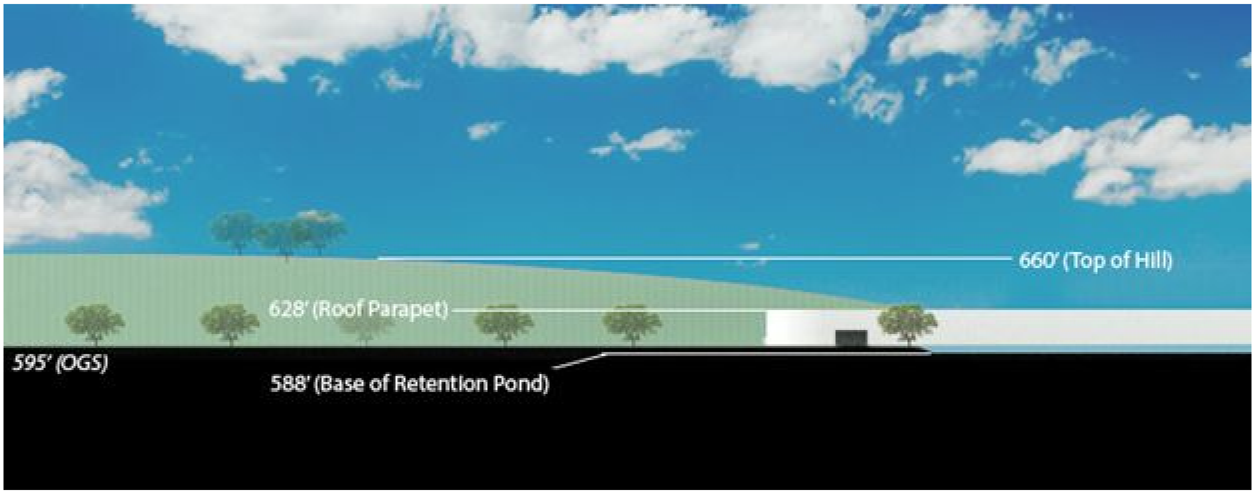


Figure 5C.1: East-West Site Elevation

Appendix 5D: Site Renderings

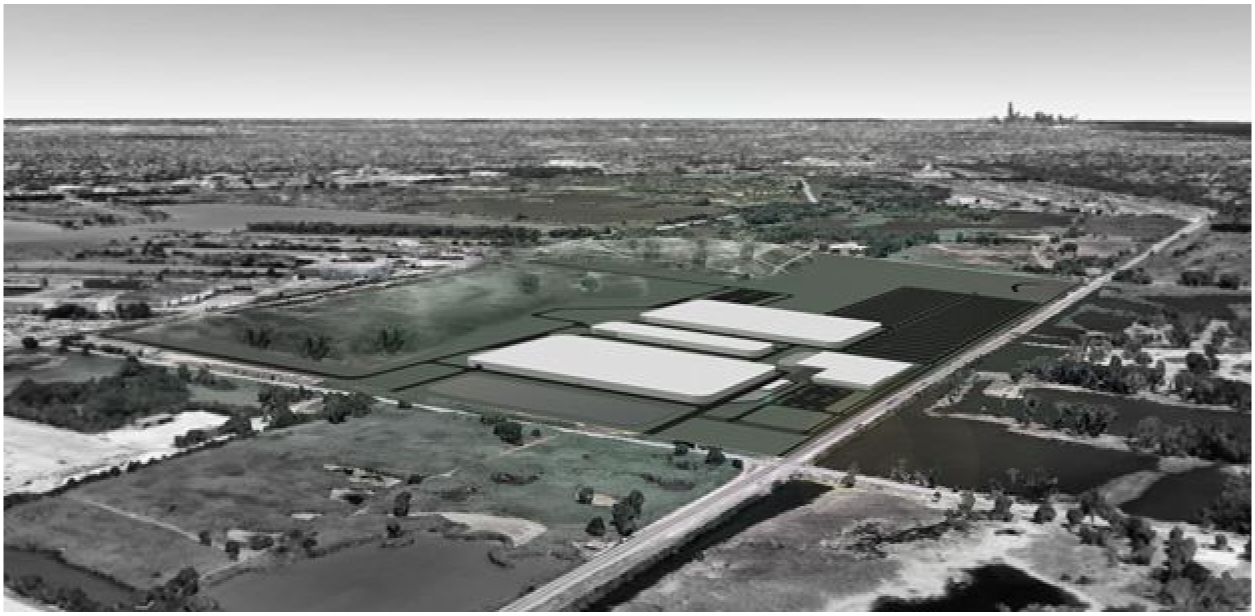


Figure 5D.1: Aerial View of Facilities

Figure 5D.2: Location of Renderings by Figure

Figure 5D.3: Main Employee Entrance near Detention Pond

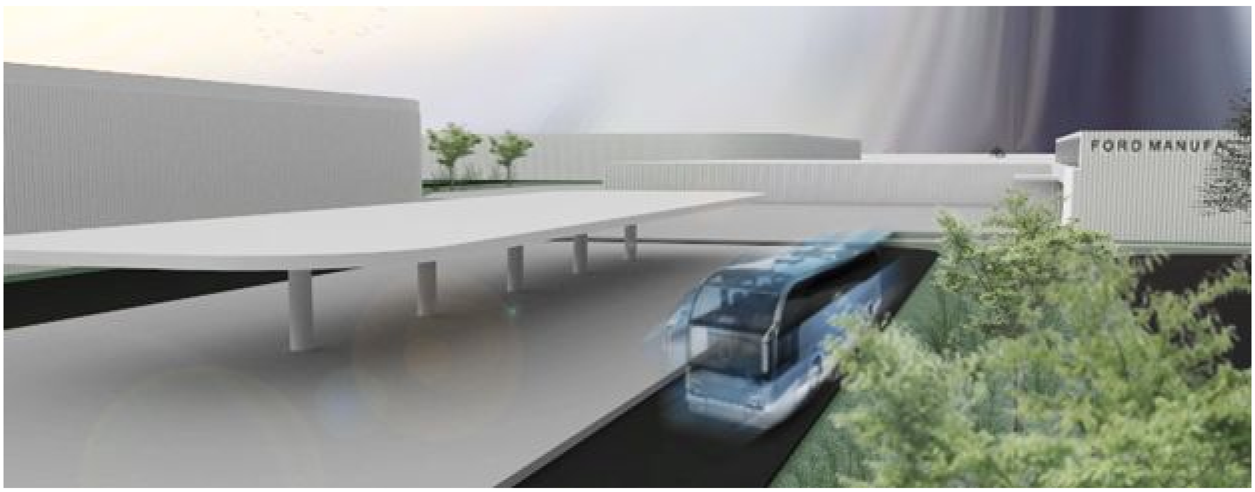


Figure 5D.4: Ford Shuttle Terminal

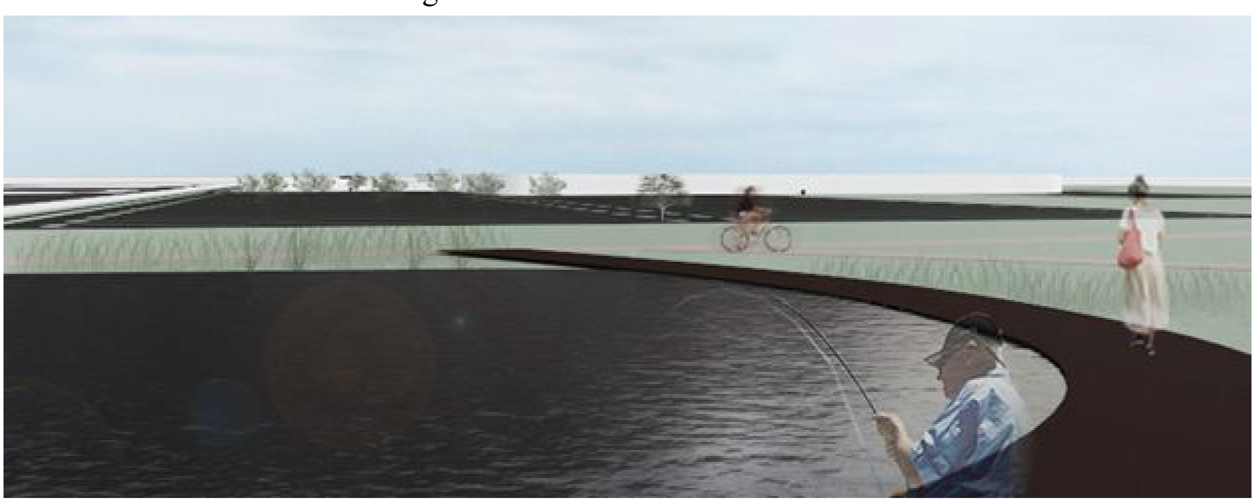


Figure 5D.5: Boardwalk for Recreation

Figure 5D.6: Bike and Walking Path

Appendix 5E: Floor Plan

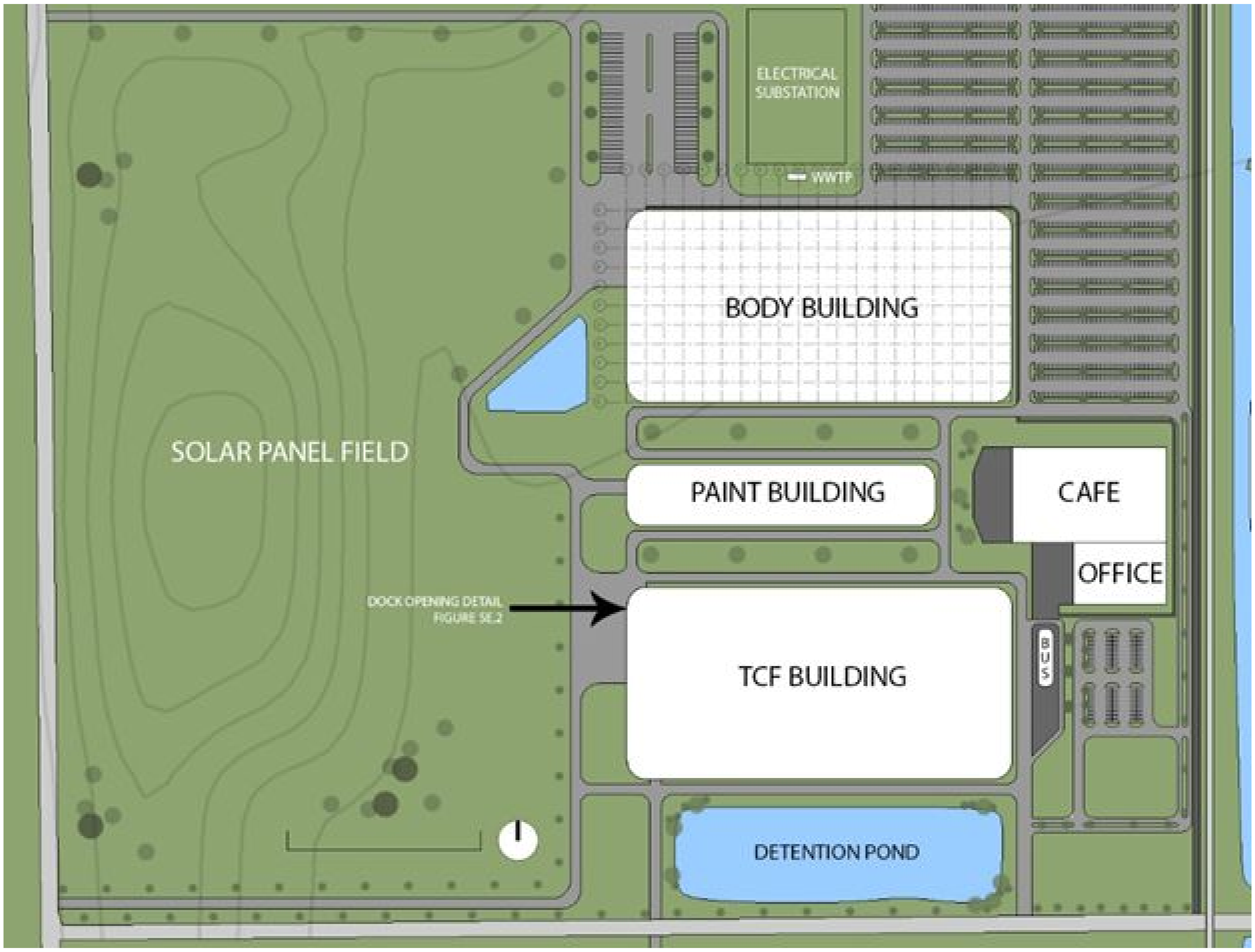


Figure 5E.1: Floor Plan

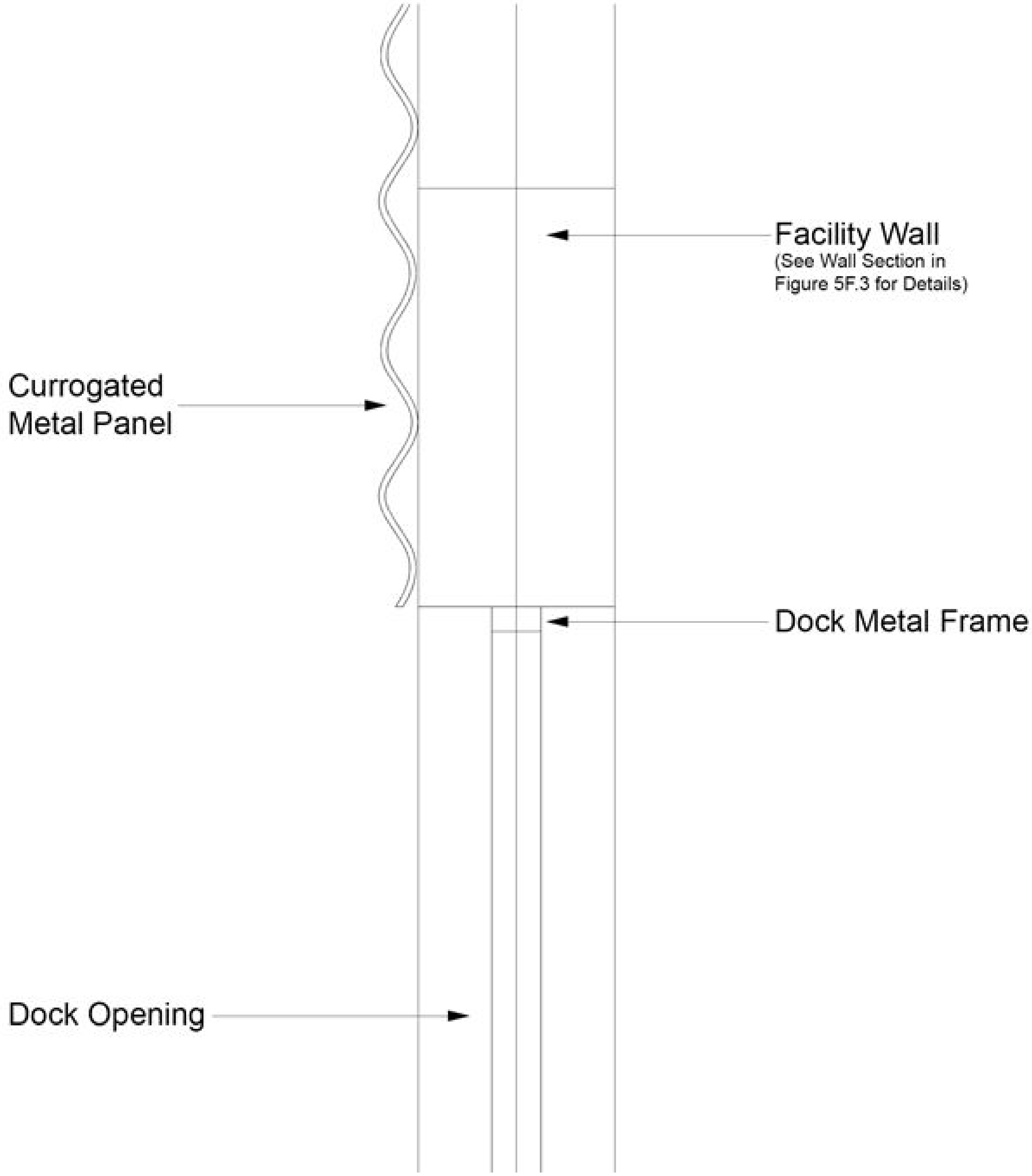


Figure 5E.2: Dock Opening Detail

Appendix 5F: Wall Sections

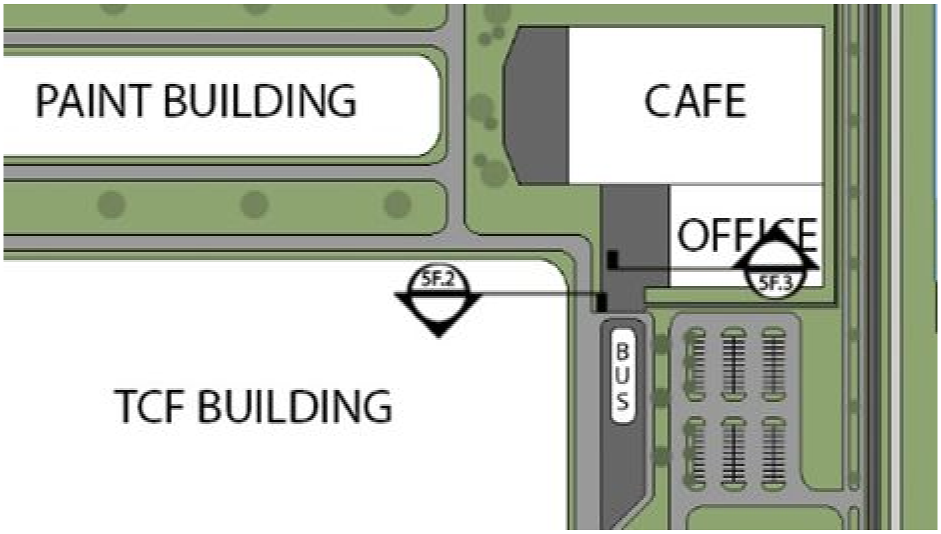


Figure 5F.1: Wall Section Locations

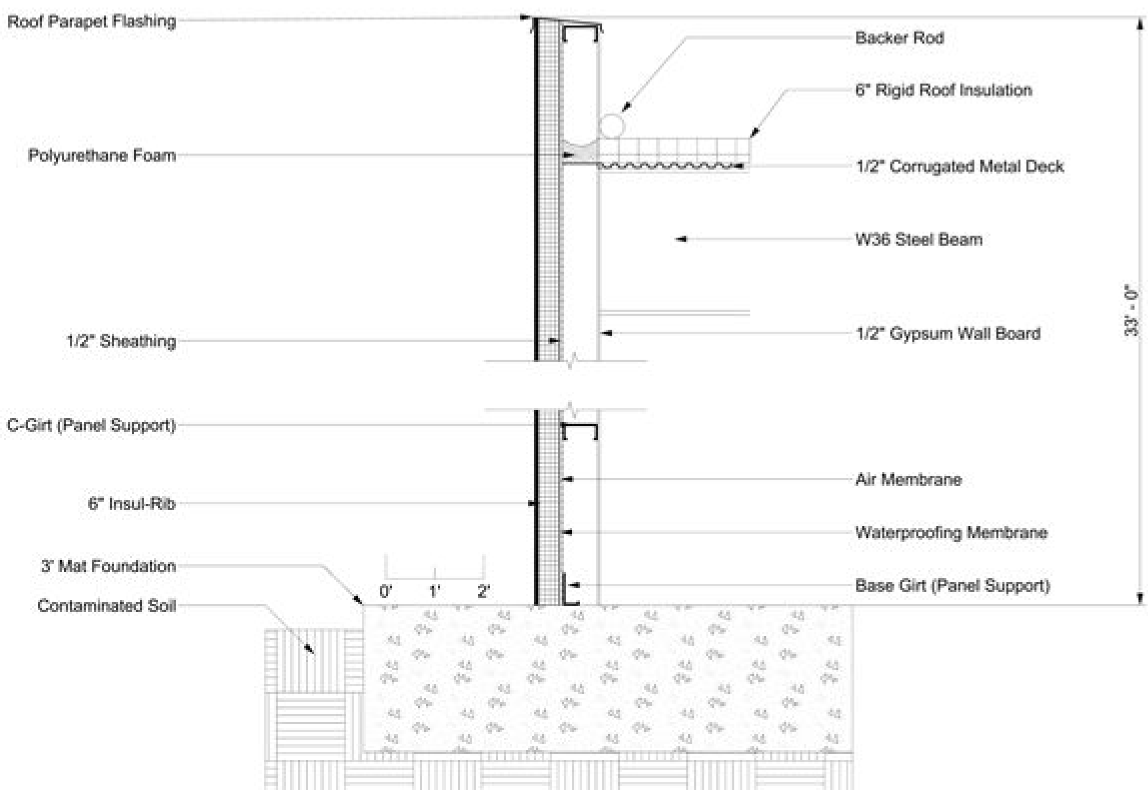


Figure 5F.2: Typical Manufacturing Facility

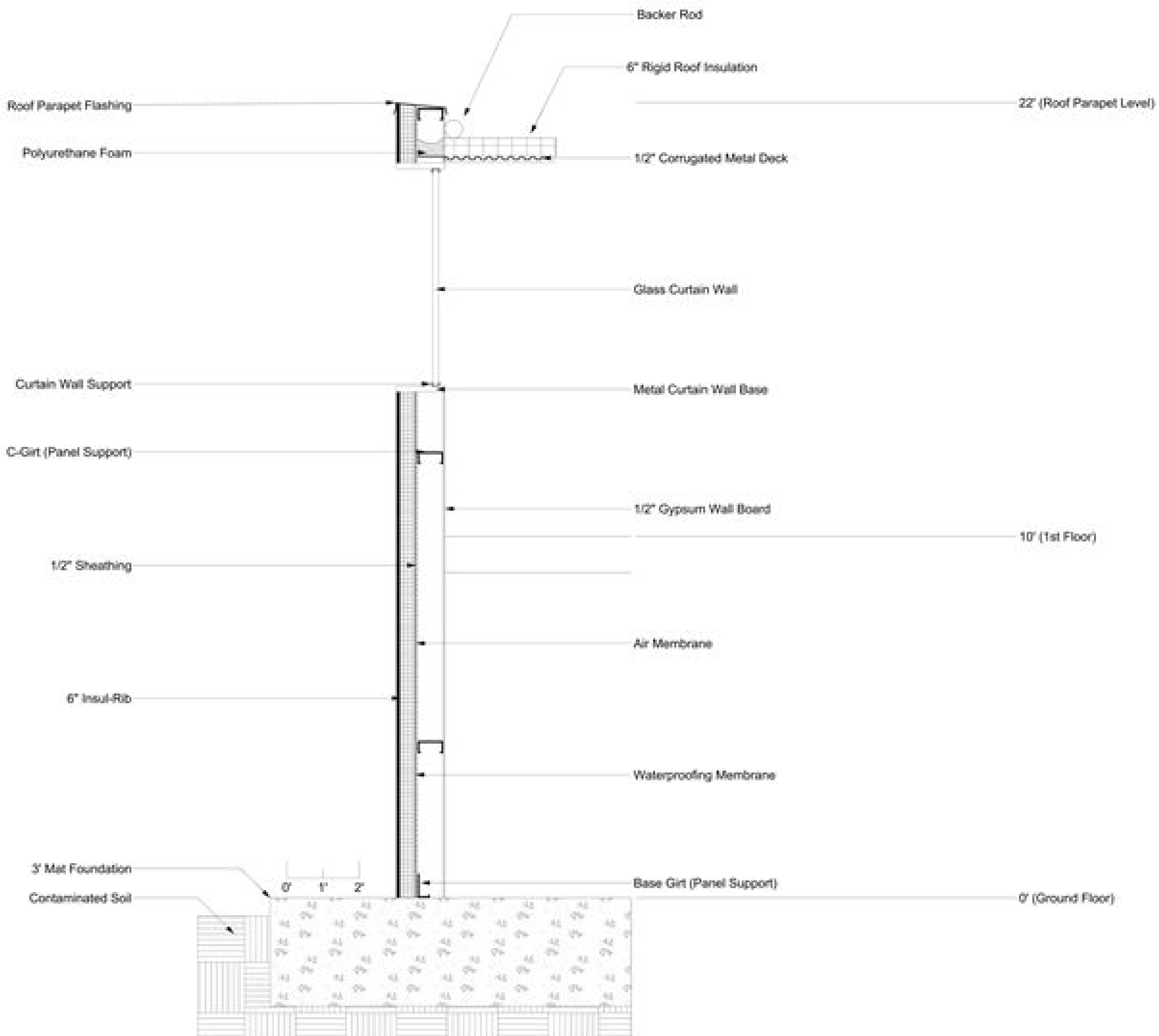


Figure 5F.3: Office Front Façade

Appendix 5G: Insul-Rib™ Cut-Sheet

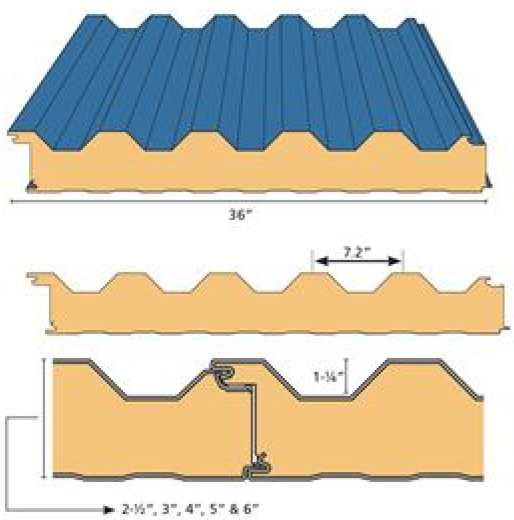
7.2 INSUL-RIB™

The **7.2 Insul-Rib™** insulated metal wall panel combines a traditional 7.2 rib panel design with a polyurethane foam core. This widely used profile is available as an insulated panel in various thicknesses.

The 7.2 Insul-Rib™ panel has a standard FM Approved Class 1 foam core and offers excellent insulating values. The metal and foam composite construction creates a rigid panel far stronger than the individual parts. This increases the span capability of the panel and reduces the need for secondary structural components.

FEATURES AND BENEFITS

- Panels are lightweight and quick to install, significantly reducing construction time.
- A double tongue-and-groove offset side joint permits concealed fastening.
- Consistent insulating values are achieved with built-in thermal breaks, saving energy.



USES AND APPLICATIONS

In new and retrofit construction, 7.2 Insul-Rib™ wall panels are ideally suited for:

ARCHITECTURAL

- Airport Terminal Buildings
- Arenas
- Convention Centers
- Hospitals
- Low and Mid-Rise Offices
- Performing Arts Centers
- Schools & Universities
- Worship Facilities

COMMERCIAL & INDUSTRIAL

- Distribution Centers
- Equipment Maintenance Buildings
- Hangars
- Manufacturing Facilities
- Retail Buildings
- Self-Storage Complexes
- Utility Buildings
- Warehouses
- Utility Buildings

Note: Not intended for exterior walls on cold storage buildings.

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7.2 INSUL-RIB™

MATERIAL SPECIFICATIONS			
EXTERIOR PROFILE	7.2" on-center rib pattern, 1-1/2" deep.		
INTERIOR PROFILE	Mesa nominal 1/8" deep; Light Mesa nominal 1/16" deep		
FOAM CORE	Foamed-in-place, Non-CFC & zero ODP polyurethane, Factory Mutual Class 1 approval.		
THERMAL VALUE			73° MEAN
	R VALUE WITH AIR FILM	2-1/2" PANEL	8.80
		3" PANEL	12.17
		4" PANEL	18.49
		5" PANEL	25.15
		6" PANEL	31.74
	1. R-Values include the air films on each side of the panel. 2. 73° Mean based on ASTM C1363 Thermal Testing.		
MODULE WIDTH	36"		
PANEL THICKNESS	2-½", 3", 4", 5" 6" (Includes rib height)		
PANEL LENGTHS	Standard 8'-0" to 40'-0"		
EXTERIOR FACINGS	Stucco embossed, G-90 galvanized and/or AZ-50 aluminum-zinc coated steel in 26 Ga. 24 Ga. and 22 Ga.		
INTERIOR FACINGS	Stucco embossed, G-90 galvanized and/or AZ-50 aluminum-zinc coated steel in 26 Ga., 24 Ga. and 22 Ga.		
EXTERIOR FINISHES & COLORS	Siliconized Polyester, Fluropon® Full-Strength 70% PVDF Fluoropolymer Coating. Note: Prices may vary by color, gauge and quantity of metal.		
INTERIOR FINISHES & COLORS	USDA-compliant Polyester, Igloo White. USDA-compliant PVC Plastisol White		
PANEL JOINT	Offset double tongue-and-groove with extended metal shelf for positive face fastening.		
FASTENING	Fastener & Clip concealed in the side joint.		
FM Approved Class 1 with no height restrictions.			

TESTS AND CERTIFICATIONS			
		Standard	**Standard / Test Description**
US Certifications	Fire Performance	FM Approval Standard 4880	Class 1 Fire Rating of Insulated Wall, Ceiling and Roof Panels
		NFPA 259	Test Method for Potential Heat of Building Materials
		NFPA 285	Evaluation of Fire Propagation Characteristics of Exterior Non- Load-Bearing Wall Assemblies
		NFPA 286	Fire Tests for Evaluating Contribution of Wall and Ceiling Finish to Roof Fire Growth
		ASTM E84	Surface Burning Characteristics of Building Material
	Structural Performance	FM Approval Standard 4881	Class 1 Exterior Wall Structural Performance
		ASTM E72	Strength Tests of Panels for Building Construction
		ASTM E330	Structural Performance of Exterior Curtain Walls by Uniform Static Air Pressure Differences
	Vapor Barrier Performance	ASTM E283	Rate of Air Leakage Through Curtain Walls Under Specified Pressure Differences
		ASTM E331	Water Penetration of Exterior Walls by Uniform Static Air Pressure Differences
	Thermal Performance	ASTM C518	Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
		ASTM C1363	Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus
	Special Approvals	City of Los Angeles	Product Approval for City/County of Los Angeles
		Miami-Dade Wall	Miami-Dade County Product Control Approved (Note: WACC Vertical Installation Only) NOA No. 13-0212.06, Expiration Date: 03/06/2018
Canadian Certifications	Fire Performance	CAN/ULC S101	Fire Endurance Tests of Building Construction and Materials
		CAN/ULC S102	Surface Burning Characteristics of Building Materials and Assemblies
		CAN/ULC S138	Fire Growth of Insulated Building Panels in a Full-Scale Room Configuration

Load span tables and notes are available at RobertsonBuildings.com

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| 800-387-5335, 905-304-1111, f 905-304-2420

Western Office | 11318-163 St. NW, Edmonton, AB T5M 1Y6
| 780-485-3055, f 780-461-7785

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ROB-7.2-1014

Appendix 5H: Building Renderings

Figure 5H.2: Location of Rendering by Figure

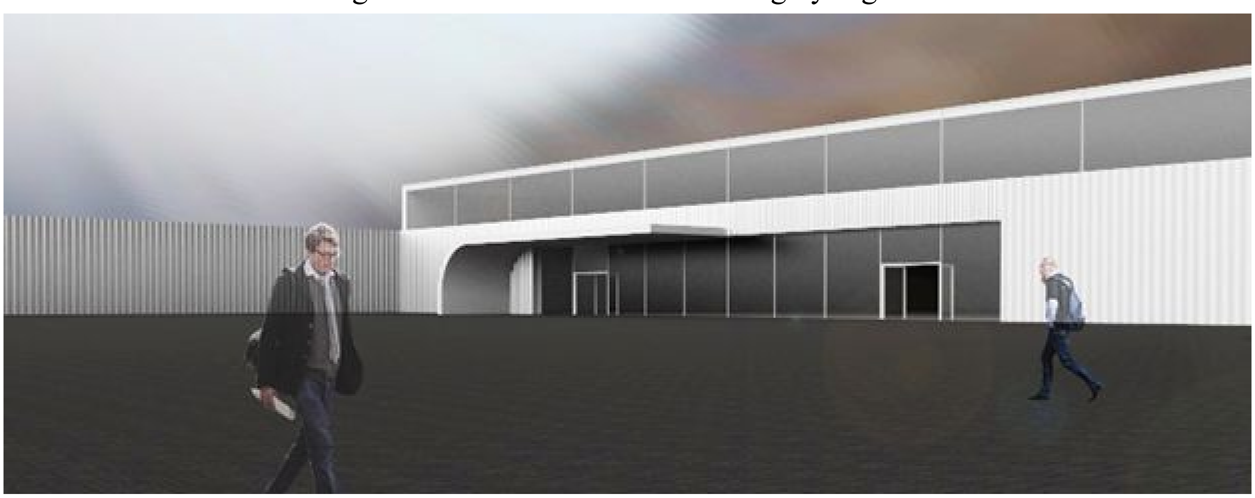


Figure 5H.2: Office Main Entrance

Figure 5H.3: Rear Loading Dock of TCF Building

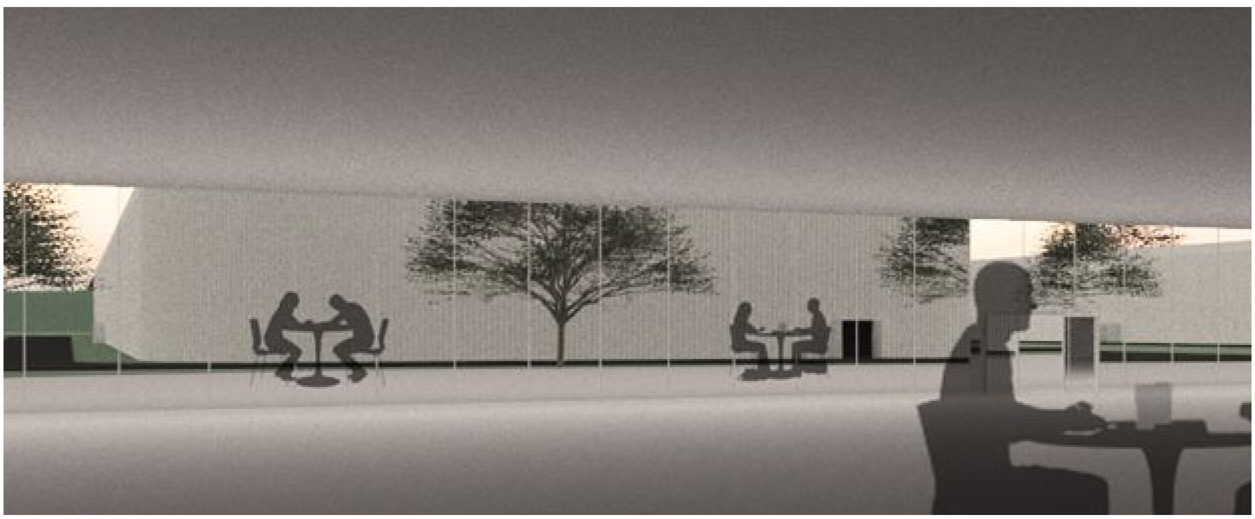


Figure 5H.4: Courtyard View from Cafeteria

Appendix Section 6

STRUCTURE

Gina Baldea

Appendix 6A: Load Calculations

Dead Loads

Design	Gina Baldea			date		5/10/16	
QA	Alex Acosta						
Project	Green Team WET Zone Project; Calculation of Dead Loads						
Determine the Dead Loads for Each Building							
Office Building					*Source: Steel Constuction Manual		
	Member	**Linear feet**		**Weight**		**Total Weight**	
(columns)	W14 x 99	1680	ft	99	lb/ft	166,320	lb
(beams)	W24 x 146	10330	ft	146	lb/ft	1,508,180	lb
(bracing)	HSS 6x6x1/2	2,556	ft	35.24	lb/ft	90,073	lb
						1,764,573	
			Building Area			**Distributed Load**	
			176800	SF		9.98	psf

Figure 6A.1: Dead Load Calculation for Office/Cafeteria Building

Body Building and TCF Building							
	Member	**Linear feet**		**Weight**		**Total Weight**	
(columns)	W14 x 99	5,200	ft	99	lb/ft	514800	lb
(beams)	W30 x 99	20,000	ft	99	lb/ft	1980000	lb
(bracing)	HSS 6x6x1/2	2,272	ft	35.24	lb/ft	80065.28	lb
(crane rail)	W24 x 62	10,000	ft	62	lb/ft	620000	lb
						3194865.28	lb

Figure 6A.2: Dead Load Calculation for Body Building and TCF Building

Paint Building							
	Member	**Linear feet**		**Weight**		**Total Weight**	
(columns)	W14 x 99	390	ft	99	lb/ft	38610	lb
(beams)	W30 x 99	880	ft	99	lb/ft	87120	lb
(bracing)	HSS 6x6x1/2	906	ft	35.24	lb/ft	31927.44	lb
(crane rail)	W24 x 62	480	ft	62	lb/ft	29760	lb
						187417.44	lb
			Building Area			**Distributed Load**	
			12,800	SF		14.64	psf

Figure 6A.3: Dead Load Calculation for Paint Building

Wind Loads

The simplified procedure according to ASCE 7-02 was used to analyze the wind pressure at a height of 30 ft. At a wind speed of 100 mph, taking the architectural overhang into account, the maximum wind pressure will be 26.7 psf (ASCE 7-02 p. 42).

Seismic Loads

Design	Gina Baldea		date	5/10/16		
QA	Alex Acosta					
Project	Green Team WET Zone Project; Calculations for Seismic Loads					
Seismic Load: Office Building						
Use the simplified version in ASCE 7-02 to calculate the seismic load						
	Notation	**Value**	**Units**	**Source**	**Comment**	
	Sds	1.0693	m/s^2	USGS Seismic Design	design elastic response acceleration	
	R	4		ASCE 07-2 Section 9	response modification factor	
	W	1,764,573	lb	CE 323	effective seismic weight of structure	
	V	566057.514	lb	V = (1.2*Sds*W)/R	seismic base shear	
					conversion	
		Building Area		**Distributed load**		
		176800	SF	3.202	psf	

Figure 6A:4: Seismic Load Calculation for Office/Cafeteria Building

Seismic Load: Body & TCF Buildings						
Use the simplified version in ASCE 7-02 to calculate the seismic load						
	Notation	**Value**	**Units**	**Source**	**Comment**	
	Sds	1.0693	m/s^2	USGS Seismic Design	design elastic response acceleration	
	R	4		ASCE 07-2 Section 9	response modification factor	
	W	3,194,865	lb	CE 323	effective seismic weight of structure	
	V	1024880.833	lb	V = (1.2*Sds*W)/R	seismic base shear	
					conversion	
		Building Area		**Distributed load**		
		176800	SF	5.797	psf	

Figure 6A:5: Seismic Load Calculation for Body & TCF Buildings

Seismic Load: Paint Building					
Use the simplified version in ASCE 7-02 to calculate the seismic load					
	Notation	**Value**	**Units**	**Source**	**Comment**
	Sds	1.0693	m/s^2	USGS Seismic Design	design elastic response acceleration
	R	4		ASCE 07-2 Section 9	response modification factor
	W	187,417	lb	CE 323	effective seismic weight of structure
	V	60121.641	lb	V = (1.2*Sds*W)/R	seismic base shear
					conversion
		Building Area		**Distributed load**	
		176800	SF	0.340	psf

Figure 6A.6: Seismic Load Calculation for Paint Building

Appendix 6B: Material Comparison

Originally, 4 ksi strength concrete was chosen to design the mat foundations. However, a brief cost analysis on the larger buildings determined that it was more effective to use a higher strength concrete (Table 6B.1). This also resulted in thinner slabs.

Concrete Strength	Necessary Thickness of Slab	Total Concrete	Price/Unit	Total Cost
4 ksi	3.5 ft	1,750,000 ft^3	$3.96/$ft^3$	$6,930,000
6 ksi	3.0 ft	1,500,000 ft^3	$4.29/$ft^3$	$6,435,000

Table 6B.1: Cost Analysis for Body and TCF Buildings

Appendix 6C: Structural Design of Body & TCF Buildings

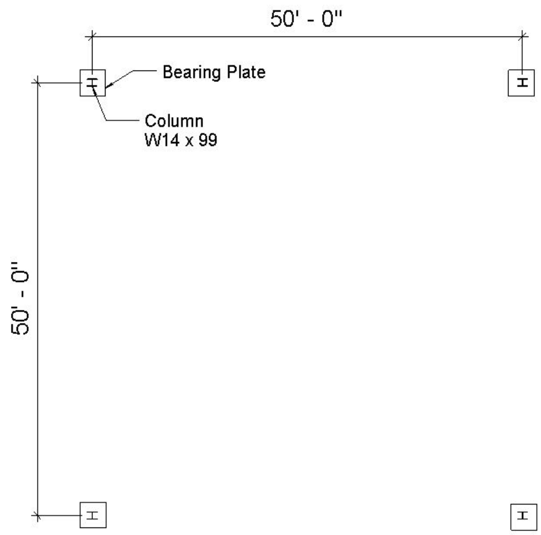


Figure 6C.1: Ground Floor Plan

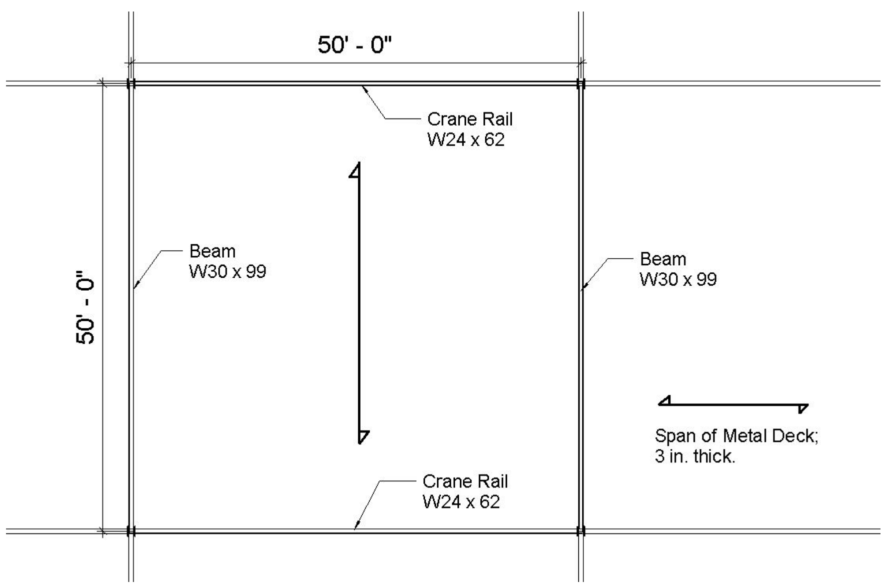


Figure 6C.2: Roof Plan

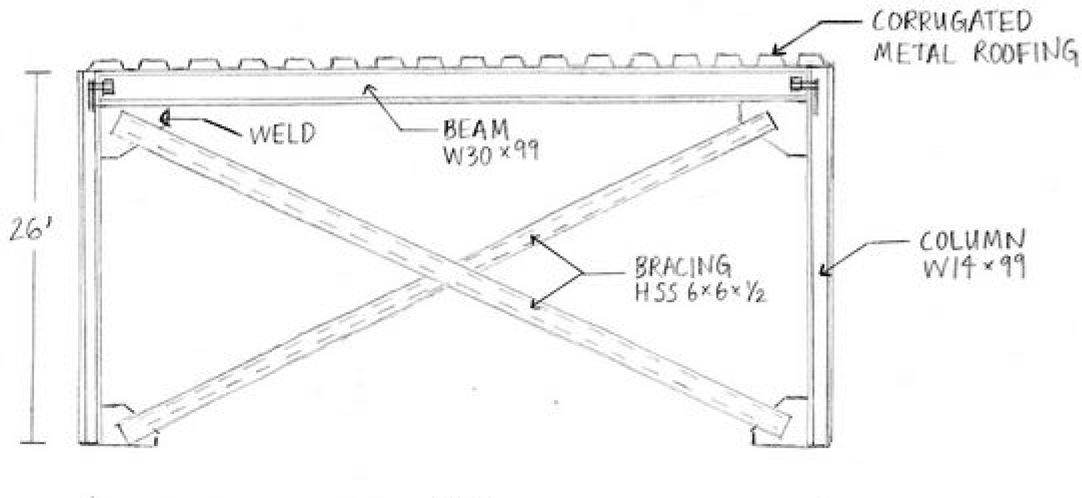


Figure 6C.3: Elevation of Braced Bay

Design	Gina Baldea		date	6/4/16			
QA	Nathan Zaporski						
Project	Green Team WET Zone Project; Structural Design of Mat Foundation						
Body Building and TCF Building							
1.Punching Shear Check		**P < Vc**	The column load must be less than the nominal shear strength				
	Notation	**Value**	**Units**	**Source**	**Comment**		
	P	140,000	lb	CE 323	maximum column load		
	f'c	6000	psi	chosen	concrete compressive strength		
	b	14.565	in	Engineering Tool Box	width of W14x99 column		
	Vc	102,440	lb	Set equal to P	Nominal Shear Strength		
	d	31.023	in	Vc=4*sqrt(f'c)*b*d	preliminary depth of foundation		
		2.585	ft		conversion		
2. Assume thickness of slab							
	d= 3.0 ft						

Figure 6C.4: Calculation for Mat Foundation Thickness

Rebar: Body Building and TCF Building					
Determine the area of steel in a linear foot of foundation					
	Notation	**Value**	**Units**	**Source**	**Comment**
	d	33	in	foundation design	thickness of foundation
	fy	60	ksi		strength of rebar
	b	12	in		1 ft strip of foundation
	f'c	6	ksi		strength of concrete
	As	2	in^2		Trial Area of Steel
	a	1.96	in	a=(As*fy)/(.85*f'c*b)	depth to neutral axis
	Mu	315.00	k-ft	CE 323 Analysis	Ultimate Moment
	As	1.9675444	in^2	As= Mu/(fy*(d-(a/2))	
	a	1.92896509	in		New a value
	As	1.96656727	in^2		Final As
Check ACI Code minimum required area of steel					
	Notation	**Value**	**Units**	**Source**	**Comment**
	b	1	ft		1 ft strip of foundation
	h	3	ft	foundation design	thickness of foundation
	As, min	0.7776	in^2	As, min = 0.0018*b*h	required minimum area of steel

Figure 6C.5: Calculation for Rebar In Both Directions

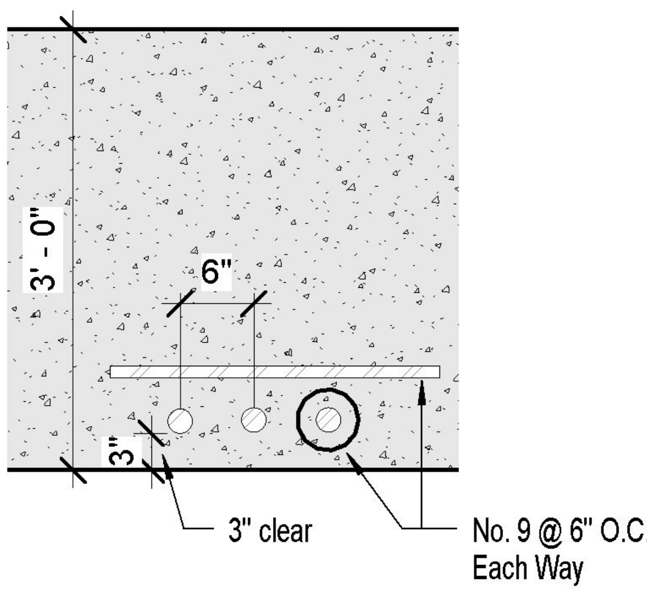


Figure 6C:6 Cross Section of Foundation

Appendix 6D: Structural Design of Paint Building

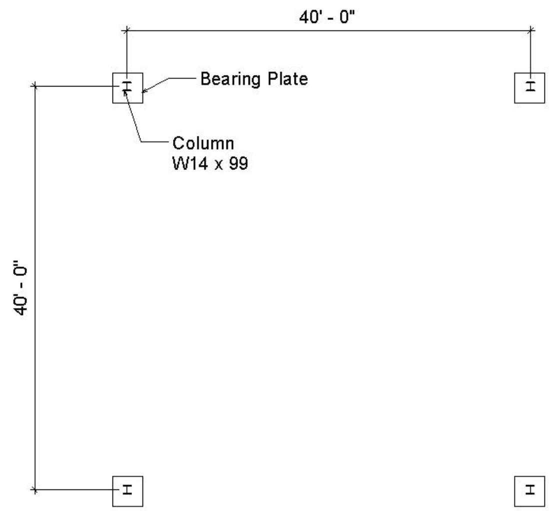


Figure 6D.1: Ground Floor Plan

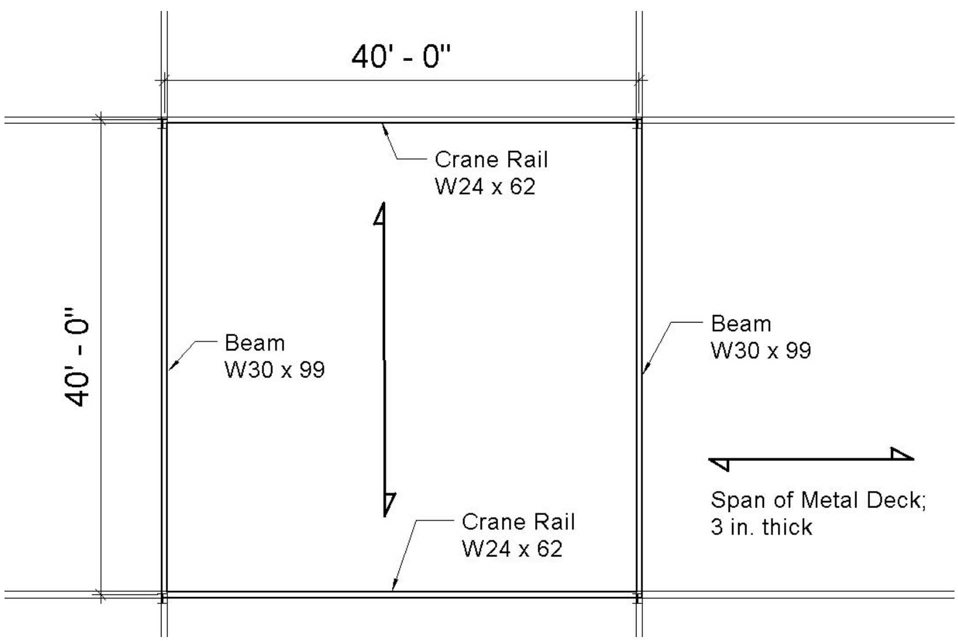


Figure 6D.2: Roof Plan

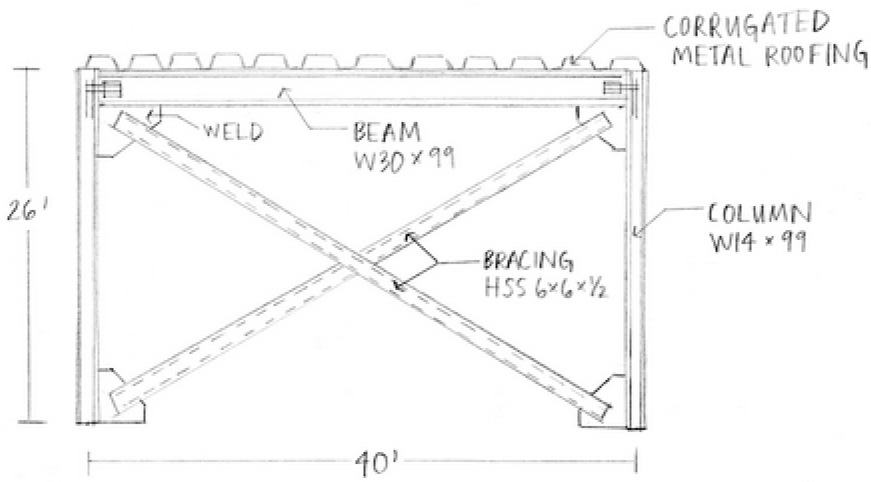


Figure 6D.3: Elevation of Braced Bay

Paint Building					
1.Punching Shear Check		P < Vc	The column load must be less than the nominal shear strength		
	Notation	Value	Units	Source	Comment
	P	154,000	lb	CE 323	maximum column load
	f'c	6000	psi	chosen	concrete compressive strength
	b	14.565	in	Engineering Tool Box	width of W14x99 column
	Vc	102,440	lb	Set equal to P	Nominal Shear Strength
	d	34.125	in	Vc=4*sqrt(f'c)*b*d	preliminary depth of foundation
		2.844	ft		conversion
2. Assume thickness of slab					
	d= 3.0 ft				

Figure 6D.4: Calculation for Mat Foundation Thickness

Rebar: Paint Building

Determine the area of steel in a linear foot of foundation

Notation	Value	Units	Source	Comment
d	33	in	foundation design	thickness of foundation
fy	60	ksi		strength of rebar
b	12	in		1 ft strip of foundation
f'c	6	ksi		strength of concrete
As	2	in^2		Trial Area of Steel
a	1.96	in	a=(As*fy)/(.85*f'c*b)	depth to neutral axis
Mu	420.00	k-ft	CE 323 Analysis	Ultimate Moment
As	2.62339253	in^2	As= Mu/(fy*(d-(a/2))	
a	2.57195346	in		New a value
As	2.64867057	in^2		Final As

Check ACI Code minimum required area of steel

Notation	Value	Units	Source	Comment
b	1	ft		1 ft strip of foundation
h	3	ft	foundation design	thickness of foundation
As, min	0.7776	in^2	As, min = 0.0018*b*h	required minimum area of steel

Figure 6D.5: Calculation for Rebar in Both Directions

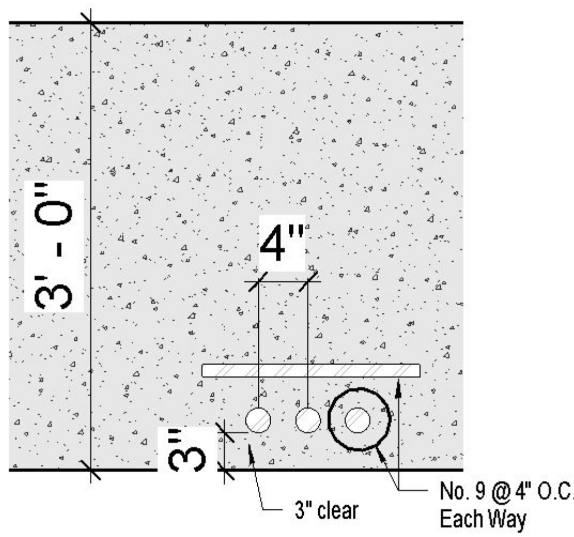


Figure 6D.6: Cross Section of Foundation

Appendix 6E: Structural Design of Office/Cafeteria

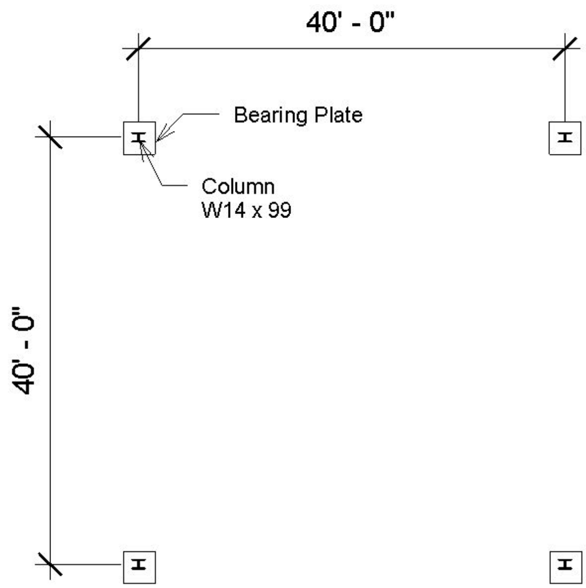


Figure 6E.1: Ground Floor Plan

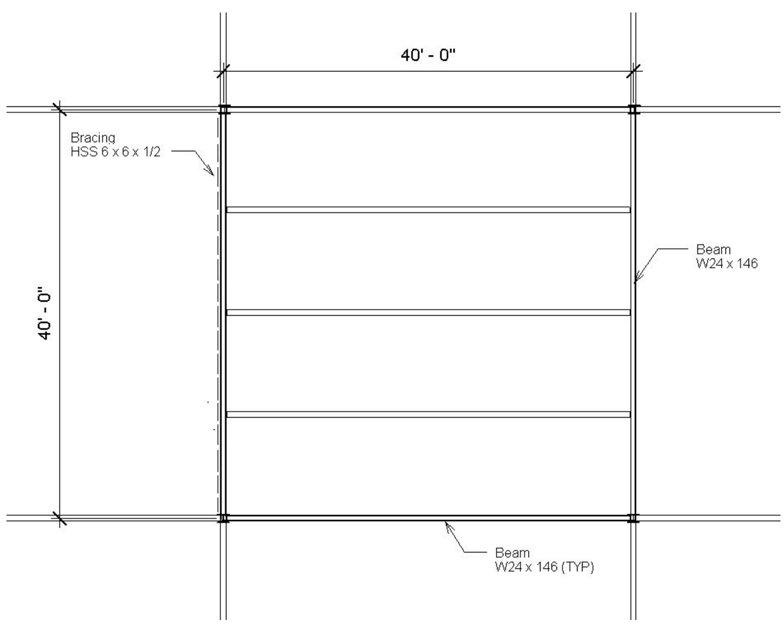


Figure 6E.2: Second Floor Plan

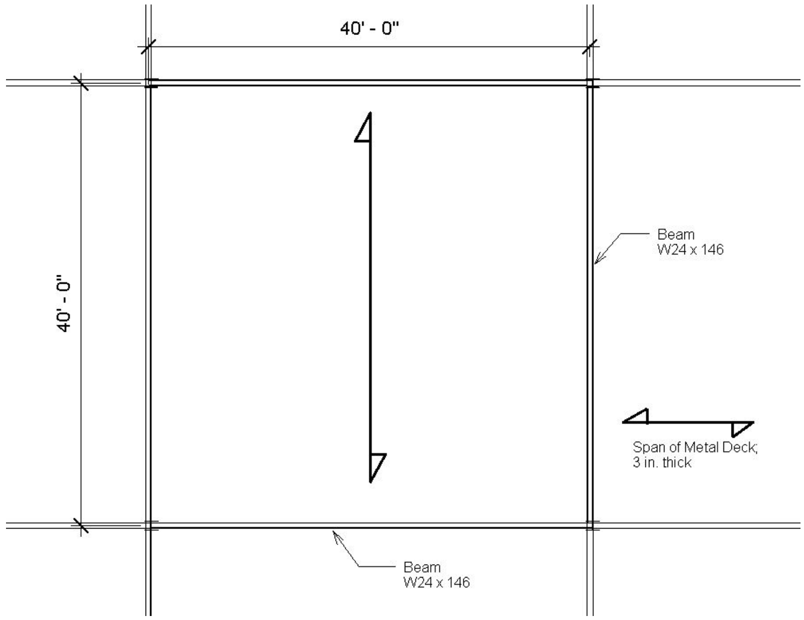


Figure 6E.4: Roof Plan

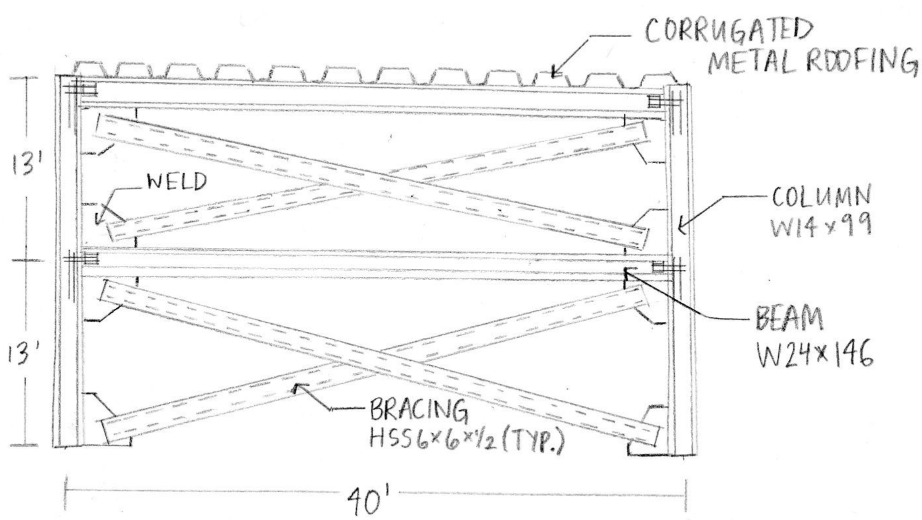


Figure 6E.5: Elevation of Two-Story Braced Bay

Office Building					
1.Punching Shear Check		**P < Vc**	The column load must be less than the nominal shear strength		
	Notation	**Value**	**Units**	**Source**	**Comment**
	P	365,000	lb	CE 323	maximum column load
	f'c	6000	psi	chosen	concrete compressive strength
	b	14.565	in	Engineering Tool Box	width of W14x99 column
	Vc	102,440	lb	Set equal to P	Nominal Shear Strength
	d	80.881	in	Vc=4*sqrt(f'c)*b*d	preliminary depth of foundation
		6.740	ft		conversion
2. Assume thickness of slab					
	d= 7.0 ft				

Figure 6E.6: Calculation for Mat Foundation Thickness

Rebar: Office Building					
Determine the area of steel in a linear foot of foundation					
	Notation	**Value**	**Units**	**Source**	**Comment**
	d	81	in	foundation design	thickness of foundation
	fy	60	ksi		strength of rebar
	b	12	in		1 ft strip of foundation
	f'c	6	ksi		strength of concrete
	As	3	in^2		Trial Area of Steel
	a	2.94	in	a=(As*fy)/(.85*f'c*b)	depth to neutral axis
	Mu	275.00	k-ft	CE 323 Analysis	Ultimate Moment
	As	0.69156805	in^2	As= Mu/(fy*(d-(a/2))	
	a	0.67800789	in		New a value
	As	0.68186611	in^2		Final As
Check ACI Code minimum required area of steel					
	Notation	**Value**	**Units**	**Source**	**Comment**
	b	1	ft		1 ft strip of foundation
	h	7	ft	foundation design	thickness of foundation
	As, min	1.8144	in^2	As, min = 0.0018*b*h	required minimum area of steel

Figure 6E.7: Calculation for Rebar in Both Directions

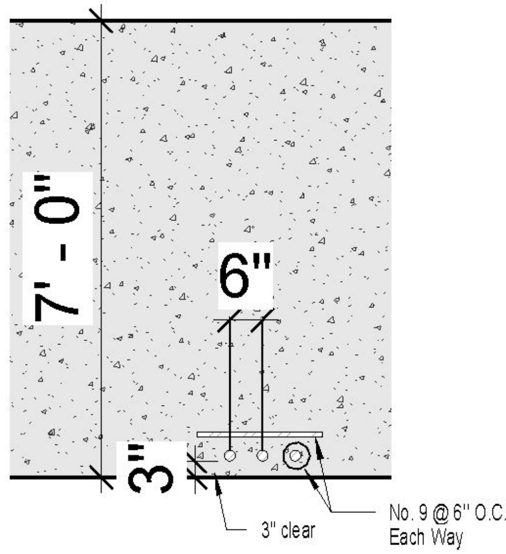


Figure 6E.8: Cross Section of Foundation

Appendix Section 7

ENERGY + HVAC

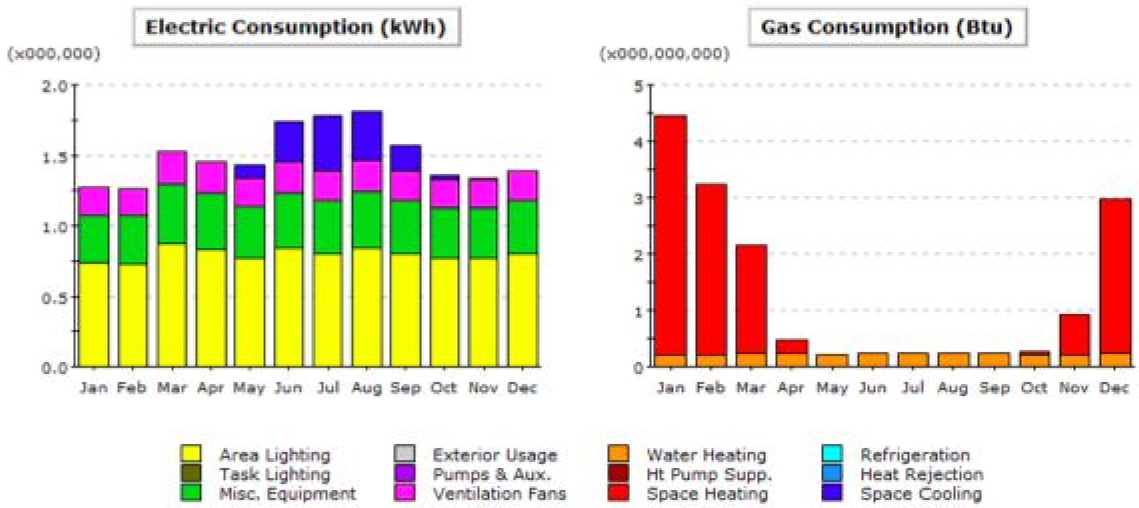
Tiffany Kwakwa

Appendix 7A: Data of Building Parameters

	Parameter	Body Building	Paint Shop	TCF	Office	Cafeteria
Geometry	**Height (ft)**	26	26	26	22	12
	Length (ft)	1000	800	1000	240	400
	Width (ft)	500	160	500	160	250
	Total (ft^3)	13000000	3328000	13000000	844800	1200000
Temperature	**Winter (F)**	65	N/A	N/A	70-74	70-74
	Summer (F)	10 above ambient	N/A	N/A	74-78	74-78
	Max Range (F)	59-104	N/A	N/A	N/A	N/A
	Machining Areas (F)	76+/- 8	76+/- 8	76+/- 8	N/A	N/A
Ventilation	**NT (AC/hr)**	**3.3**	**3.3**	**3.3**	N/A	N/A
	Tempered (AC/hr)	**2.5**	**2.5**	**2.5**	N/A	N/A
	NT (CFM)	**1.25**	**6**	**1.25**	20 cfm/person	9 cfm/person
	Tempered (AC/hr)	**1**	**Unspecified**	**1**	150	4500+150
	CFM needed (NT)	715000	183040	715000	3000	41850
	CFM needed (T)	541666.6667	138666.6667	541666.6667		<Max
	TOTAL CFM Req.	**1256667**	**321707**	**1256667**	**3000**	**44850**
Composition of Air	**Outside**	20-100%	100%	20-100%	N/A	N/A
	Inside	0-80%	0%	0-80%	N/A	N/A
Cooling Tower	**Name**	Weld Water Tower	Paint and E-Coat Tower	Compressor Tower	Same as for cafeteria	Admin Tower
	Type	1-cell	2, 1-cell	2-cell		2-cell
	Size Length (ft)	20	20	35		35
	Size Width (ft)	30	30	30		30

Appendix 7B: Baseline Run (eQUEST)

Data for electricity and natural gas consumption for the 4 buildings using a packaged single zone VAV, DX coils, and furnace.



Electric Consumption (kWh x000,000)

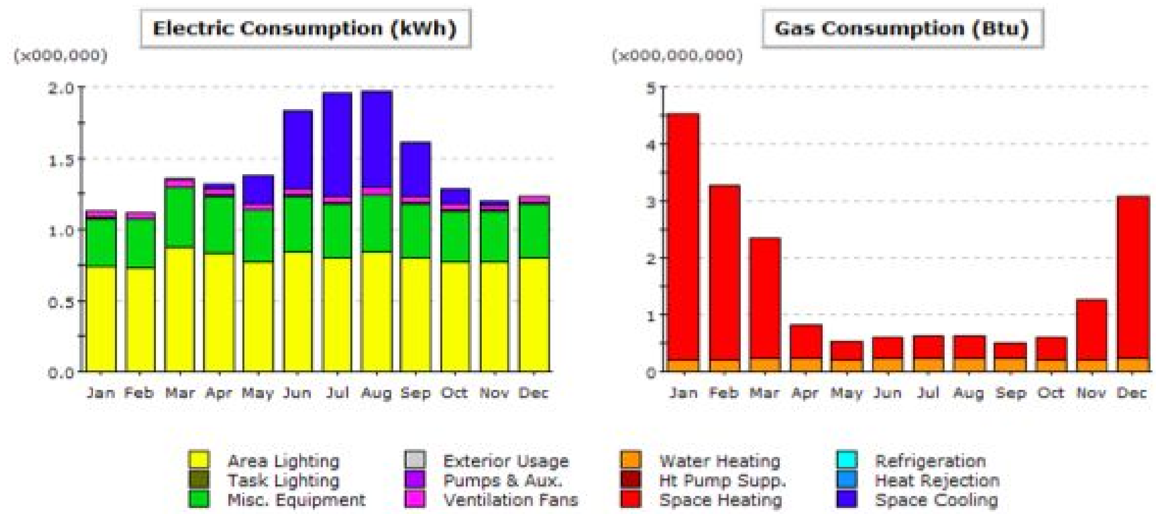
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	0.01	0.10	0.28	0.39	0.35	0.18	0.02	0.01	-	1.33
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.19	0.19	0.23	0.22	0.20	0.22	0.21	0.22	0.21	0.20	0.20	0.21	2.50
Pumps & Aux.	0.00	0.00	0.00	0.00	0.00	0.00	-	-	0.00	0.00	0.00	0.00	0.00
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.35	0.34	0.42	0.40	0.36	0.40	0.38	0.40	0.38	0.36	0.36	0.38	4.52
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.73	0.73	0.88	0.84	0.77	0.84	0.80	0.84	0.80	0.77	0.76	0.80	9.56
Total	1.27	1.26	1.52	1.46	1.43	1.74	1.78	1.81	1.57	1.36	1.34	1.39	17.91

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.24	3.04	1.92	0.23	-	0.00	-	0.00	0.00	0.06	0.72	2.75	12.96
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.21	0.21	0.25	0.24	0.22	0.23	0.22	0.23	0.22	0.22	0.22	0.23	2.69
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	4.45	3.25	2.16	0.47	0.22	0.24	0.22	0.24	0.22	0.27	0.93	2.98	15.65

Appendix 7C: Alternative 1 Run (eQUEST)

From the baseline model, the type of heating equipment was changed to radiant floor heating with a water-based system using a single zone VAV for each shell. Building orientation and geometry remained the same.



Electric Consumption (kWh x000,000)

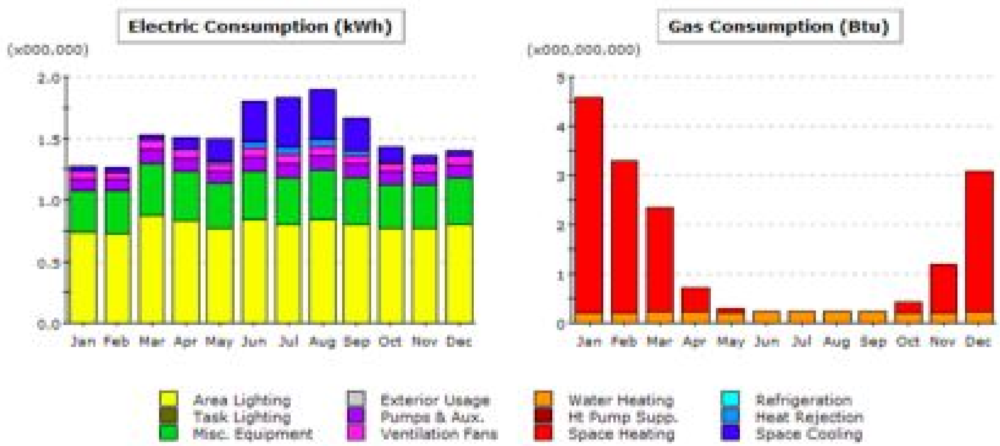
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.01	0.03	0.20	0.55	0.73	0.68	0.38	0.10	0.02	-	2.71
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.50
Pumps & Aux.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.35	0.34	0.42	0.40	0.36	0.40	0.38	0.40	0.38	0.36	0.36	0.38	4.52
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.73	0.73	0.88	0.84	0.77	0.84	0.80	0.84	0.80	0.77	0.76	0.80	9.56
Total	1.12	1.12	1.36	1.31	1.38	1.83	1.96	1.97	1.61	1.28	1.19	1.23	17.37

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.33	3.06	2.10	0.58	0.31	0.37	0.39	0.39	0.29	0.40	1.04	2.85	16.09
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.21	0.21	0.25	0.24	0.22	0.24	0.23	0.24	0.23	0.22	0.22	0.23	2.71
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	4.54	3.26	2.34	0.81	0.53	0.60	0.62	0.63	0.51	0.61	1.26	3.08	18.80

Appendix 7D: Alternative 2 Run (eQUEST)

This run comprises of the same building geometry and orientation, but the HVAC equipment is a water-source heat pump and a 4-pipe fan coil system.



Electric Consumption (kWh x000,000)

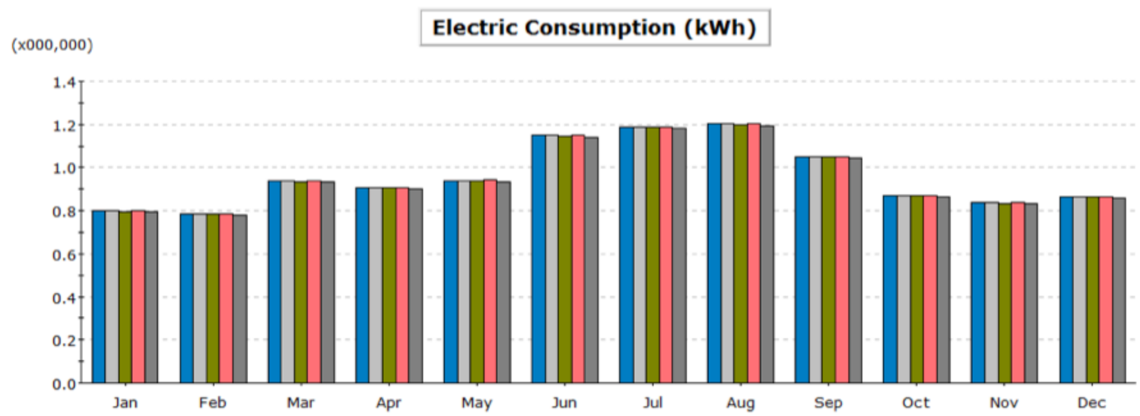
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.04	0.04	0.05	0.09	0.18	0.33	0.41	0.40	0.27	0.12	0.06	0.04	2.03
Heat Reject.	-	-	0.00	0.00	0.02	0.05	0.06	0.06	0.04	0.01	0.00	-	0.24
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.06	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.79
Pumps & Aux.	0.09	0.09	0.12	0.11	0.10	0.12	0.12	0.12	0.11	0.10	0.10	0.10	1.29
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.35	0.34	0.42	0.40	0.36	0.40	0.38	0.40	0.38	0.36	0.36	0.38	4.52
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.73	0.73	0.88	0.84	0.77	0.84	0.80	0.84	0.80	0.77	0.76	0.80	9.56
Total	1.27	1.26	1.53	1.51	1.50	1.80	1.83	1.89	1.66	1.43	1.36	1.40	18.44

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.36	3.08	2.09	0.47	0.06	0.00	-	-	-	0.21	0.98	2.86	14.12
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.21	0.21	0.25	0.24	0.22	0.24	0.23	0.24	0.23	0.22	0.22	0.23	2.70
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	4.57	3.28	2.34	0.71	0.28	0.24	0.23	0.24	0.23	0.43	1.20	3.09	16.82

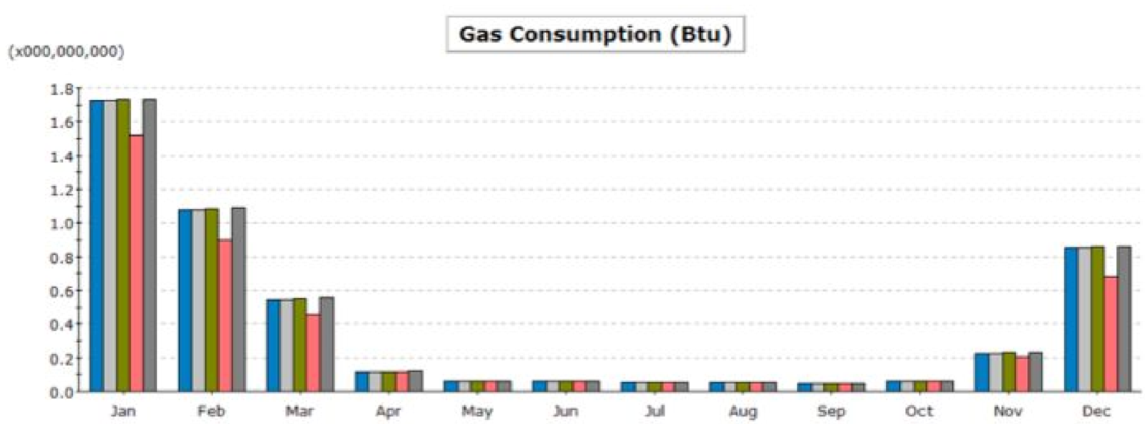
Appendix 7E: Data of Building Parameters

The results of changing building materials or HVAC economizer controls.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Run 1.	0.80	0.78	0.94	0.91	0.94	1.15	1.19	1.20	1.05	0.87	0.84	0.86	11.53
Run 2.	0.80	0.78	0.94	0.91	0.94	1.15	1.19	1.20	1.05	0.87	0.84	0.86	11.53
Run 3.	0.80	0.78	0.94	0.91	0.94	1.15	1.19	1.20	1.05	0.87	0.83	0.86	11.51
Run 4.	0.80	0.78	0.94	0.91	0.94	1.15	1.19	1.20	1.05	0.87	0.84	0.86	11.53
Run 5.	0.80	0.78	0.93	0.90	0.93	1.14	1.18	1.19	1.04	0.86	0.83	0.86	11.46

1. Project F - Baseline Design (06/05/16 @ 14:32)
2. Project F - Vent & Economizer EEM 2 (06/05/16 @ 14:32)
3. Project F - Lighting Power EEM (06/05/16 @ 14:32)
4. Project F - Ext Wall Insul EEM 2 (06/05/16 @ 14:32)
5. Project F - Daylighting EEM (06/05/16 @ 14:32)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Run 1.	1.72	1.08	0.54	0.11	0.06	0.06	0.05	0.05	0.05	0.06	0.22	0.85	4.87
Run 2.	1.72	1.08	0.54	0.11	0.06	0.06	0.05	0.05	0.05	0.06	0.22	0.85	4.87
Run 3.	1.73	1.08	0.55	0.12	0.06	0.06	0.05	0.05	0.05	0.06	0.23	0.86	4.91
Run 4.	1.52	0.90	0.45	0.11	0.06	0.06	0.05	0.05	0.05	0.06	0.21	0.68	4.22
Run 5.	1.74	1.09	0.56	0.12	0.06	0.06	0.05	0.05	0.05	0.06	0.23	0.86	4.95

Appendix 7F: Engineering Economics Analysis

Below details the steps taken in calculating the annual cost of each alternative for a 20 year life-span.

Annual Cost: (capital cost)*(A/P, 6%, 20) + (energy cost/year)
A/P = 0.0872

Sample calculation (Alternative 1):
[($1,109,080 + $816,000 + $1,703,150 + $619,000)*0.0872] + [(3,290,000kWh/yr*$0.089/kWh) + (16,090MMBTU/yr*$2.77/MMBTU)] = **$707,737.76**

Table 7F.1: Alternatives Capital Cost

Equipment	Alternative 1 Equipment Capital Cost	Equipment	Alternative 2 Equipment Capital Cost
Radiant Floor Heating	$1,109,080	**Fan Coil**	$2,126,280
Chilled Beams	$816,000	**Water Source Heat Pump**	$120,000
AC	$1,703,150		
Single Zone VAV	$619,000	**Single Zone VAV**	$624,000
TOTAL	$4,247,230	**TOTAL**	$2,870,280
Total*(A/P)	**$370,358.46**	**Total*(A/P)**	**$250,288.42**

Table 7F.2: Utility and Annual Cost

Alternative 1	Electricity	Natural Gas	Combined Cost
Consumption	3290000 kWh/yr	16090 MMBTU/yr	
Annual Cost Utility	$292,810.00	$44,569.30	$337,379.30
		Annual Total Cost:	**$707,737.76**
Alternative 2	**Electricity**	**Natural Gas**	**Combined Cost**
Consumption	4350000 kWh/yr	14120 MMBTU/yr	
Annual Cost Utility	$387,150.00	$39,112.40	$426,262.40
		Annual Total Cost:	**$676,550.82**

The price of electricity is $0.089/kWh and the price of biogas from MWRD has been priced at $2.77/MMBTU. The annual total cost is the sum of the Total*(A/P) in Table 7F.1 and the combined cost of the two utilities.

ENERGY COST

Julia Standley Pradhan

Appendix 8A: Utility Rates

	$/kWh
Commercial Electricity Price[1]	0.089

Table 8A.1: Average commercial electricity rate for Illinois.

	$/Mcf	$/therm	$/MMBtu
Wellhead Natural Gas Price[2]	2.66	0.26	2.58
Commercial Natural Gas Price[3]	5.52	0.53	5.35
MWRD Biogas Price	-	-	2.77

Table 8A.2: Average natural gas rates for Illinois vs. MWRD biogas rate.

	$/1,000 Gallons
Chicago Water Price[4]	3.81
MWRD Greywater Price	2.86

Table 8A.3: Chicago potable water pricing vs. greywater pricing.

Appendix 8B: Price Sensitivity Analysis - Treated Effluent from MWRD

Treated Effluent Flow WITHOUT Reuse	561,000 GPD
	204,898,000 GPY
Treated Effluent Flow WITH Reuse	215,000 GPD
	78,295,000 GPY

Table 8B.1: Ford flow requirements with and without effluent reuse.

Cars Produced/Year	300,000
Revenue/Car[5]	$36,420
Annual Revenue	$10,926,000,000

Table 8B.2: Approximate annual revenue based on average price of a Ford mid-sized vehicle.

MWRD Greywater Main CapEx	$3,414,000.00
Pump & Control Center CapEx[6]	$650,000.00

Table 8B.3: Capital expense for greywater main construction, pump, and control center.

Since a water main must also be constructed for WET Zone S (Cisco), Ford assumed half of the cost for the installation of the pump and required control center.

Analyzing Ford Facility Only			
Water Rate ($/1000 gal)	Annual Cost W/O Reuse	% of Annual Revenue	Simple Payback Period: MWRD Pipeline + Pump (years)
3.81	$780,662.24	0.007	5.21
2.858	$585,496.68	0.005	6.94
1.905	$390,331.12	0.004	10.41
0.953	$195,165.56	0.002	20.82

Table 8B.4: Price sensitivity analysis based on flow requirements without reuse for Ford only.

Analyzing Ford Facility Only			
Water Rate ($/1000 gal)	Annual Cost WITH Reuse	% of Annual Revenue	Simple Payback Period: MWRD Pipeline + Pump (years)
3.81	$298,304.16	0.003	13.62
2.858	$223,728.12	0.002	18.16
1.905	$149,152.08	0.001	27.25
0.953	$74,576.04	0.001	54.49

Table 8B.5: Price sensitivity analysis based on flow requirements with reuse for Ford only.

Appendix 8C: MWRD Greywater Main

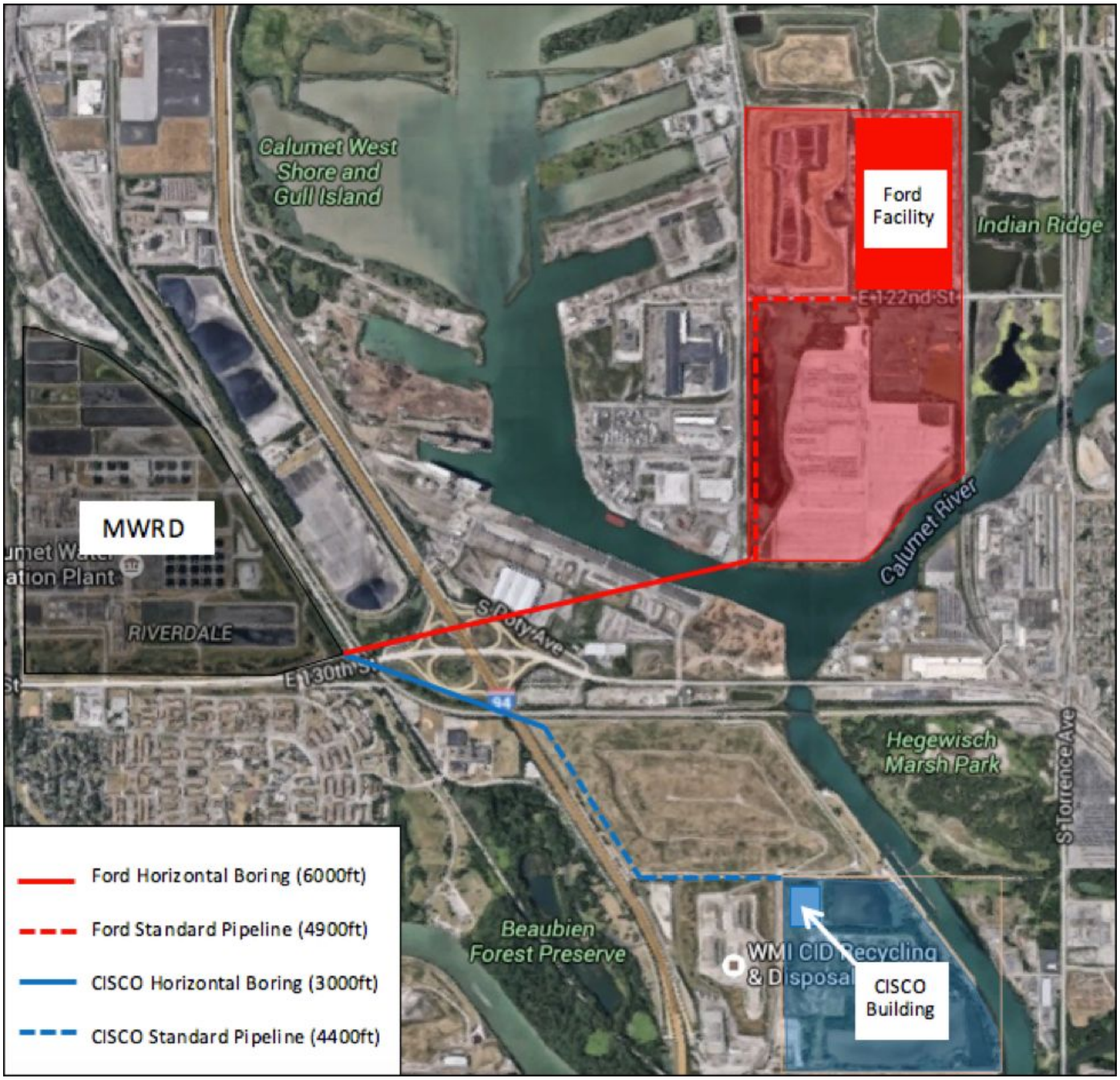


Figure 8C.1: Map of greywater main connecting MWRD to WET Zone N (Ford) and WET Zone S (Cisco).

Image provided by Ian Piper, Transportation Engineer.

Item	Cost	Totals
HDPE (OD 8.625", ID 6.963")[6,7,8]	$139/LF	$834,000
Steel Casing (OD 12")[7]	$250/LF	$1,500,000
Horizontal Directional Drilling Method[9]	$180/LF	$1,080,000
Pump & Control Center[7]	$1,300,000*	$650,000
Total CapEx		**$4,064,000**

Table 8C.1: Summary of costs for greywater pipeline connecting MWRD to WET Zone N (Ford).

*Ford will only assume half of the cost of the pump and control center since this infrastructure is shared with WET Zone S (Cisco).

	Annual water consumption (GPY)	Annual cost based on potable water price	Annual cost based on greywater price from MWRD	**Total savings per year**
Ford WITHOUT Reuse	204,898,000	$586,008.92	$780,662.24	$194,653.31
Ford WITH Reuse	78,295,000	$223,923.86	$298,304.16	$74,380.30

Table 8C.2: Summary of annual savings by utilizing greywater from MWRD. See Appendix 8A for utility rates.

Appendix 8D: Biogas - Jenbacher J620

Required Energy Input	23.556 MMBtu/Hr
Electrical Power Capacity	3,044 kWe
Electrical Efficiency	42.5%
Thermal Power Capacity	10.263 MMBtu/Hr
Thermal Efficiency	42%
Service Life	7 years

Table 8D.1: Summary of Jenbacher J620 technical specifications as provided by Clarke Energy.[10]

Annual Energy Input		
Item	Amount	Cost
Biogas	203,528 MMBtu	$564,039.97
Annual Energy Production		
Item	Amount	Commercial Value
Electricity	26,300,160 kWh	$2,340,714.24
Heating	88,675 kWh	$474,307.48

Table 8D.2: Summary of costs associated with required energy input and value of energy production.

Expense	**Cost**	**Total**
Installation	$1,000/kWe	$3,044,000
Unit	$1,000,000	$1,000,000
Operation	$0.015/kWh	$894,758.40/year

Table 8D.3: Capital and operational expenses associated with J620 obtained from GE sales representatives.[12]

Appendix 8E: Biogas - MWRD Production

Cost of expansion: $8,750,000[11]

Average heat content of biogas: 0.619 MMBtu/Mcf[13]

MWRD Current Biogas Production		
Number of digesters	12	
Max Monthly Biogas Production (March 2015)	35,164 Mcf	21,766.52 MMBtu
MWRD Expanded Biogas Production		
Increased Waste Intake	200,000 gallons	
Resulting Biogas Production	650 Mcf/Day	12,071 MMBtu/Month
Adjusted MWRD Max Biogas Production	33,837.02 MMBtu/Month	406,044.19 MMBtu/Year
Max # of J620 Engines Supported	2	

Table 8E.1: Summary of current and expanded biogas production from MWRD.

Appendix 8F: Solar

Month	Solar Radiation (kWh / m^2 / day)
January	2.48
February	3.09
March	3.65
April	4.30
May	5.15
June	5.57
July	6.01
August	5.56
September	5.15
October	3.70
November	3.71
December	2.79
Annual	4.26

Figure 8F.1: Annual sun hours/day for WET Zone location.[19]

Recommendation: Maximize PV system capacity.

Roof Dimensions	
Length	400 ft
Width	200 ft

Table 8F.1: Dimensions of roof above raised floor area.

Canada Solar 320W Panel Dimensions	
Length	6.41ft
Width	3.225 ft

Table 8F.2: Dimensions of Canada Solar 320W Panel.

Panel Angle	35 degrees
Array Spacing Factor	2.5
Distance between arrays	7.36 ft
Height of ground mount	3.68 ft
Length of ground mount	5.25 ft
# of panels/row	62
# of rows	32

Table 8F.3: Array spacing and mounting hardware specifications.

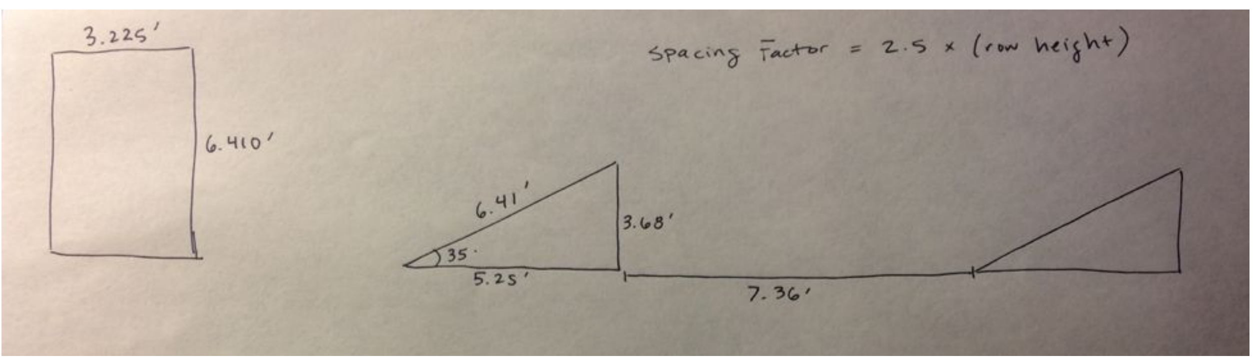


Figure 8F.2: Diagram of solar panel spacing.

ENVISION

Emily Northard

Appendix 9A: Example Credit

Below is an example credit with the credit number and title, the intent, the metric, the levels of achievement, a description, evaluation criteria, sources, and a list of related credits. This is to give an idea of how each point is scored on the Envision point scale, highlighting unique criteria for each individual component.

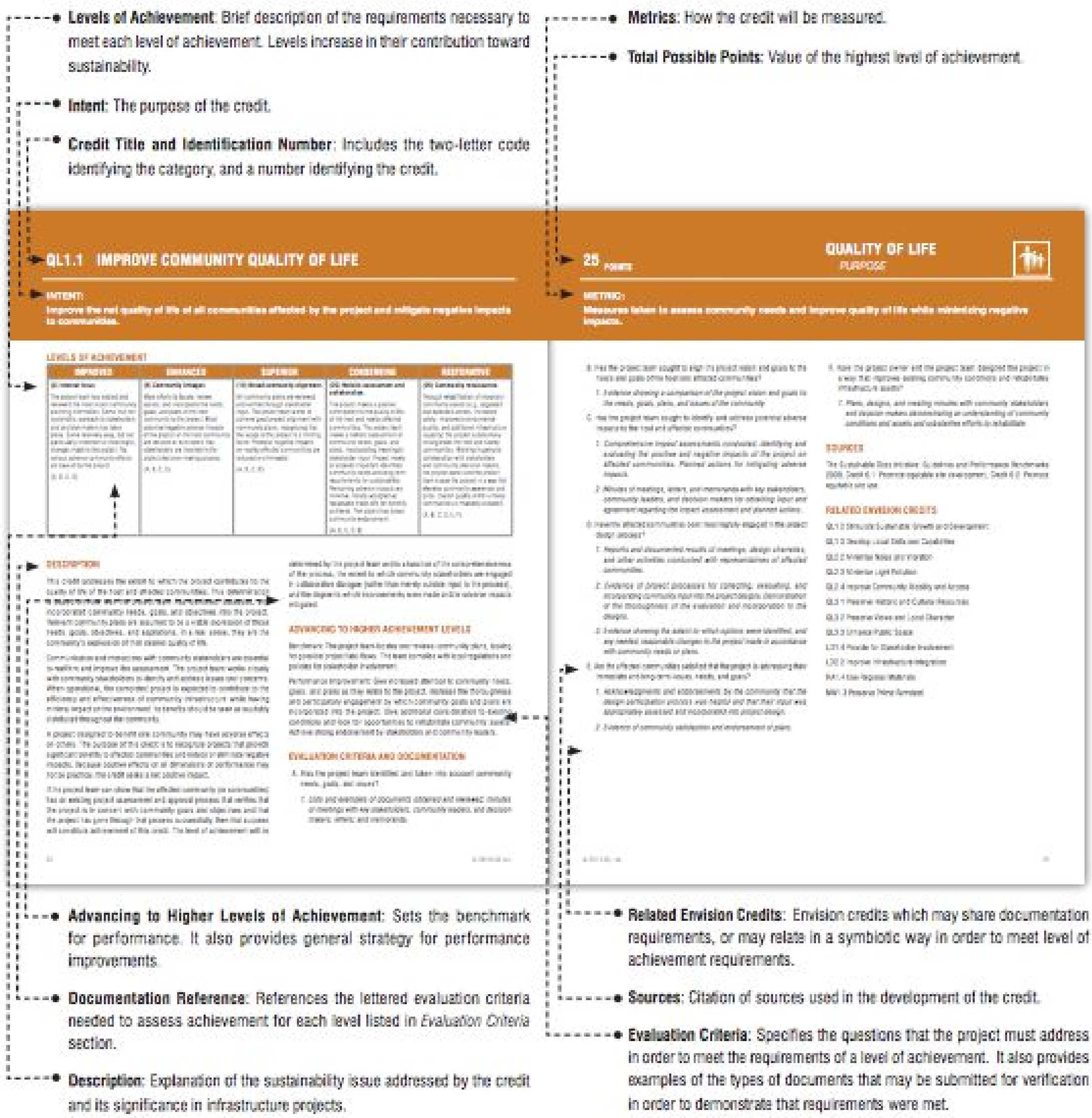


Figure 9A.1: Envision Example Credit[7]

Appendix 9B: Submitted Achievable Envision Points

Presented below is the breakdown for points in each component in the Envision process. The components are shown in the different categories and subcategories described above and the submitted point value is highlighted in the row of possible achievable points. The requirements for each of these points are described in Appendix 9C following.

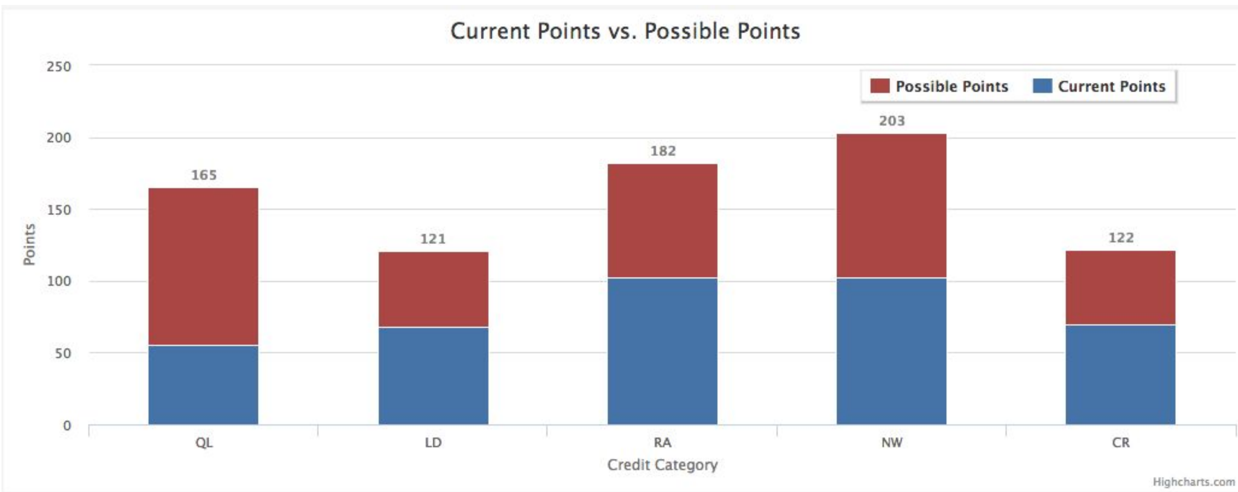


Figure 9B.1: Current Points vs. Possible Points

QUALITY OF LIFE
13 credits

12 credits in progress, 0 credits completed
Last updated 05/24/2016 by Emily Northard

Project progress

55 of 165 Possible points – 33%

Subcategory	Credit			I	E	S	C	R
Purpose	QL1.1 Improve Community Quality of Life	N/A	0	2	**5**	10	20	25
	QL1.2 Stimulate Sustainable Growth and Development	N/A	0	1	**2**	5	13	16
	QL1.3 Develop Local Skills and Capabilities	N/A	0	1	**2**	5	12	15
Wellbeing	QL2.1 Enhance Public Health and Safety	N/A	0	**2**	–	–	16	–
	QL2.2 Minimize Noise and Vibration	N/A	0	1	–	–	**8**	11
	QL2.3 Minimize Light Pollution	N/A	0	1	**2**	4	8	11
	QL2.4 Improve Community Mobility and Access	N/A	0	1	**4**	7	14	–
	QL2.5 Encourage Alternative Modes of Transportation	N/A	0	1	3	6	**12**	15
	QL2.6 Improve Site Accessibility, Safety and Wayfinding	N/A	0	–	3	**6**	12	15
Community	QL3.1 Preserve Historic and Cultural Resources	**N/A**	0	1	–	7	13	16
	QL3.2 Preserve Views and Local Character	N/A	0	1	3	**6**	11	14
	QL3.3 Enhance Public Space	N/A	0	1	3	**6**	11	13
Innovate or Exceed	QL0.0 Innovate or Exceed Credit Requirements	N/A	Maximum Level of 8					8

Submitted 55 Verified

LEADERSHIP
10 credits

9 credits in progress, 0 credits completed
Last updated 05/24/2016 by Emily Northard

Project progress

68 of 121 Possible points — 56%

				I	E	S	C	R
Collaboration	LD1.1 Provide Effective Leadership and Commitment	N/A	0	2	4	9	17	–
	LD1.2 Establish a Sustainability Management System	N/A	0	1	4	7	14	–
	LD1.3 Foster Collaboration and Teamwork	N/A	0	1	4	8	15	–
	LD1.4 Provide for Stakeholder Involvement	N/A	0	1	5	9	14	–
Managment	LD2.1 Pursue Byproduct Synergy Opportunities	N/A	0	1	3	6	12	15
	LD2.2 Improve Infrastructure Integration	N/A	0	1	3	7	13	16
Planning	LD3.1 Plan for Long-term Monitoring and Maintenance	N/A	0	1	3	–	10	–
	LD3.2 Address Conflicting Regulations and Policies	N/A	0	1	2	4	8	–
	LD3.3 Extend Useful Life	N/A	0	1	3	6	12	–
Innovate or Exceed	LD0.0 Innovate or Exceed Credit Requirements	N/A	Maximum Level of 6					6

Submitted 68 Verified

RESOURCE ALLOCATION
14 credits

14 credits in progress, 0 credits completed
Last updated 05/24/2016 by Emily Northard

Project progress

110 of 182 Possible points — 60%

				I	E	S	C	R
Materials	RA1.1 Reduce Net Embodied Energy	N/A	0	2	6	12	18	–
	RA1.2 Support Sustainable Procurement Practices	N/A	0	2	3	6	9	–
	RA1.3 Use Recycled Materials	N/A	0	2	5	11	14	–
	RA1.4 Use Regional Materials	N/A	0	3	6	9	10	–
	RA1.5 Divert Waste From Landfills	N/A	0	3	6	8	11	–
	RA1.6 Reduce Excavated Materials Taken Off Site	N/A	0	2	4	5	6	–
	RA1.7 Provide for Deconstruction and Recycling	N/A	0	1	4	8	12	–
Energy	RA2.1 Reduce Energy Consumption	N/A	0	3	7	12	18	–
	RA2.2 Use Renewable Energy	N/A	0	4	6	13	16	20
	RA2.3 Commission and Monitor Energy Systems	N/A	0	–	3	–	11	–
Water	RA3.1 Protect Fresh Water Availability	N/A	0	2	4	9	17	21
	RA3.2 Reduce Potable Water Consumption	N/A	0	4	9	13	17	21
	RA3.3 Monitor Water Systems	N/A	0	1	3	6	11	–
Innovate or Exceed	RA0.0 Innovate or exceed credit requirements	N/A	Maximum Level of 8					8

Submitted 110 Verified

NATURAL WORLD
15 credits

15 credits in progress, 0 credits completed
Last updated 05/24/2016 by Emily Northard

Project progress

99 of 203 Possible points — 49%

				I	E	S	C	R
Siting	NW1.1 Preserve Prime Habitat	N/A	0	–	–	**9**	14	18
	NW1.2 Protect Wetlands and Surface Water	N/A	0	**1**	4	9	14	18
	NW1.3 Preserve Prime Farmland	N/A	0	–	–	6	**12**	15
	NW1.4 Avoid Adverse Geology	N/A	0	1	2	**3**	5	–
	NW1.5 Preserve Floodplan Functions	N/A	0	2	**5**	8	14	–
	NW1.6 Avoid Unsuitable Development on Steep Slopes	N/A	0	1	–	**4**	6	–
	NW1.7 Preserve Greenfields	N/A	0	3	6	10	15	**23**
Land & Water	NW2.1 Manage Stormwater	N/A	0	–	4	**9**	17	21
	NW2.2 Reduce Pesticide and Fertilizer Impacts	N/A	0	1	2	5	**9**	–
	NW2.3 Prevent Surface and Groundwater Contamination	N/A	0	1	4	**9**	14	18
Biodiversity	NW3.1 Preserve Species Biodiversity	N/A	0	**2**	–	–	13	16
	NW3.2 Control Invasive Species	N/A	0	–	–	**5**	9	11
	NW3.3 Restore Disturbed Soils	N/A	0	–	–	–	**8**	10
	NW3.4 Maintain Wetland and Surface Water Functions	N/A	**0**	3	6	9	15	19
Innovate or Exceed	NW0.0 Innovate or Exceed Credit Requirements	**N/A**	Maximum Level of 9			◀	▶	9
			Submitted		99		Verified	

CLIMATE AND RISK
8 credits

7 credits in progress, 0 credits completed
Last updated 05/24/2016 by Emily Northard

Project progress

70 of 122 Possible points — 57%

				I	E	S	C	R
Emissions	CR1.1 Reduce Greenhouse Gas Emissions	N/A	0	4	7	**13**	18	25
	CR1.2 Reduce Air Pollutant Emissions	N/A	0	2	**6**	–	12	15
Resilience	CR2.1 Assess Climate Threat	N/A	0	–	–	–	**15**	–
	CR2.2 Avoid Traps and Vulnerabilities	N/A	0	2	**6**	12	16	20
	CR2.3 Prepare for Long-Term Adaptability	N/A	0	–	–	–	**16**	20
	CR2.4 Prepare for Short-Term Hazards	N/A	0	3	–	**10**	17	21
	CR2.5 Manage Heat Island Effects	N/A	0	1	2	**4**	6	–
Innovate or Exceed	CR0.0 Innovate or Exceed Credit Requirements	N/A	Maximum Level of 5			◀	▶	5
			Submitted		70		Verified	

Figure 9B.2: Submitted Envision Points

Appendix 9C: Credit Achievement Notes

Below are the necessary design implementations required to achieve each component at the submitted level noted in Appendix 9B above.

QL1.1	Improve community quality of life	Potential negative impacts on the community are reduced or eliminated
QL1.2	Stimulate sustainable growth and development	Creation of jobs in the community
QL1.3	Develop local skills and capabilities	Plan to hire local
QL2.1	Enhance public health and safety	Public health and safety in mind
QL2.2	Minimize noise and vibration	Helps that community is so far away--little impact
QL2.3	Minimize light pollution	non-lighting alternatives
QL2.4	Improve community mobility and access	Satisfactory access
QL2.5	Encourage alternative modes of transportation	pairing red line extension with shuttles
QL2.6	Improve site accessibility, safety and wayfinding	Improve safety and security of its surroundings
QL3.1	Preserve historic and cultural resources	n/a
QL3.2	Preserve views and local character	native plants etc
QL3.3	Enhance public space	Implementation of bike paths
LD1.1	Provide effective leadership and commitment	sustainability is a core value
LD1.2	Establish a sustainability management systems	plan-do-check-act
LD1.3	Foster collaboration and teamwork	whole system design and delivery

LD1.4	Provide for stakeholder involvement	open to a wider community
LD2.1	Pursue by-product synergy opportunities	Successful negotiation with managers of nearby facilities for securing two or more of their unwanted by-product supplies.
LD2.2	Improve infrastructure integration	full infrastructure integration
LD3.1	Plan for long-term monitoring and maintenance	-
LD3.2	Address conflicting regulations and policies	Increased resolve
LD3.3	Extended useful life	Expanded consideration of durability, flexibility, and resilience
RA1.1	Reduce net embodied energy	40% reduction in energy
RA1.2	Support sustainable procurement practices	At least 26% of the purchased materials and supplies meet sustainable procurement policies
RA1.3	Use recycled materials	50% recycled materials
RA1.4	Use regional materials	60% locally sourced [soils (50 mi, 80 km), aggregate (50 mi, 80 km), concrete (100 mi, 160 km), plants (250 mi, 400 km), and all other materials (500 mi, 800 km)]
RA1.5	Divert waste from landfills	50% diverted from landfills
RA1.6	Reduce excavated materials taken off site	50% reused
RA1.7	Provide for deconstruction and recycling	50% of the components or prefabricated units can be easily separated for disassembly or deconstruction.
RA2.1	Reduce energy consumption	30% energy consumption reduction to

		industry norm
RA2.2	Use renewable energy	10% renewable
RA2.3	Commission and monitor energy systems	-
RA3.1	Protect fresh water availability	By using non-potable quality water from WWTP
RA3.2	Reduce potable water consumption	75% reduction- use of MWRD
RA3.3	Monitor water systems	-
RA0.0	Innovation	for WET zone WWTP integration
NW1.1	Preserve prime habitat	Avoid development
NW1.2	Protect wetlands and surface water	At least 50-ft buffer
NW1.3	Preserve prime farmland	don't build on prime farmland-- not a problem
NW1.4	Avoid adverse geology	protection and risk management
NW1.5	Preserve floodplain functions	maintain infiltration and water quality
NW1.6	Avoid unsuitable development on steep slopes	optimal project siting
NW1.7	Preserve Greenfields	brownfield
NW2.1	Manage stormwater	60% improvement for brownfields
NW2.2	Reduce pesticide and fertilizer impacts	plant plants that don't need herbicides/pesticides
NW2.3	Prevent surface and groundwater contamination	design for prevention
NW3.1	Preserve species biodiversity	identify and protect habitat
NW3.2	Control invasive species	plant native plants

NW3.3	Restore disturbed soils	restore soils disturbed during construction
NW3.4	Maintain wetland and surface water functions	-
CR1.1	Reduce greenhouse gas emissions	40% GHG reduction
CR1.2	Reduce air pollutant emissions	Enhanced air quality standards
CR2.1	Assess climate threat	must prepare impact assessment and adaptation plan
CR2.2	Avoid traps and vulnerabilities	Community's resilience plan
CR2.3	Prepare for long-term adaptability	resilient infrastructure-- flood prep, etc
CR2.4	Prepare for short-term hazards	prep for 1-in-50 yr hazards
CR2.5	Manage heat islands effects	60% meet solar reflective standards

Table 9C.1: Design Implementation Requirements

Appendix 9D: QL2.5: Encourage alternative modes of transportation

Currently, the Chicago Transit Authority (CTA) is proposing to make transportation improvements by extending the Red Line from the 95th Street Terminal to the vicinity of 130th Street. This is currently the locally preferred alternative which is important because the QL category places a lot of emphasis on preserving the local character and integrating with the surroundings. A map of the proposed extension is outlined below.

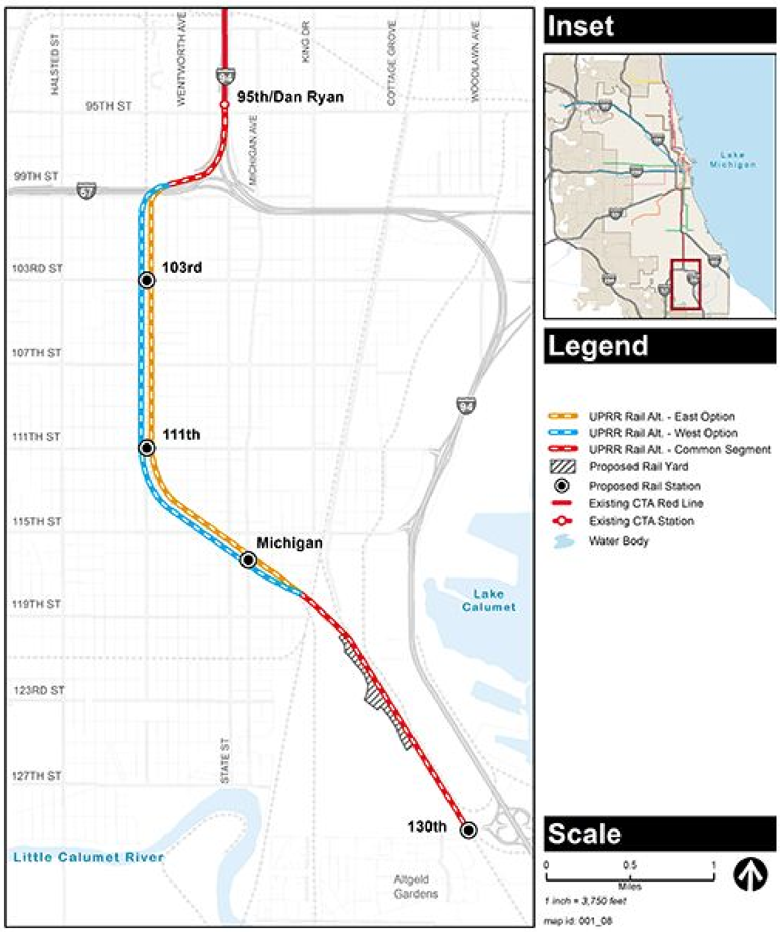


Figure 9D.1: Proposed Red Line Extension[8]

This extension comes to nearly the edge of the project site, providing the perfect location for a shuttle system that could encourage employees to use public transportation for their commute. This shuttle system would consist of a Ford fleet 15-passenger van that would pick up at times in accordance with the trains (5 minutes after every scheduled train at the 130th St. location) and drive to the different buildings to drop the employees off and pick them up again at the end of the work day to bring them to the train.

Figure 9D.2: Ford Fleet Shuttle[9]

Also, in the summer months employees would be encouraged to bike to work or bike from the train. Additional bike paths will be restored and built in order to improve ease of access. Employees could enter via 130th street on existing off-street trails and pick up the proposed off-street trails to get to the site location. The improved access and convenience for nonmotorized transportation would encourage the use of alternative transportation for employees.

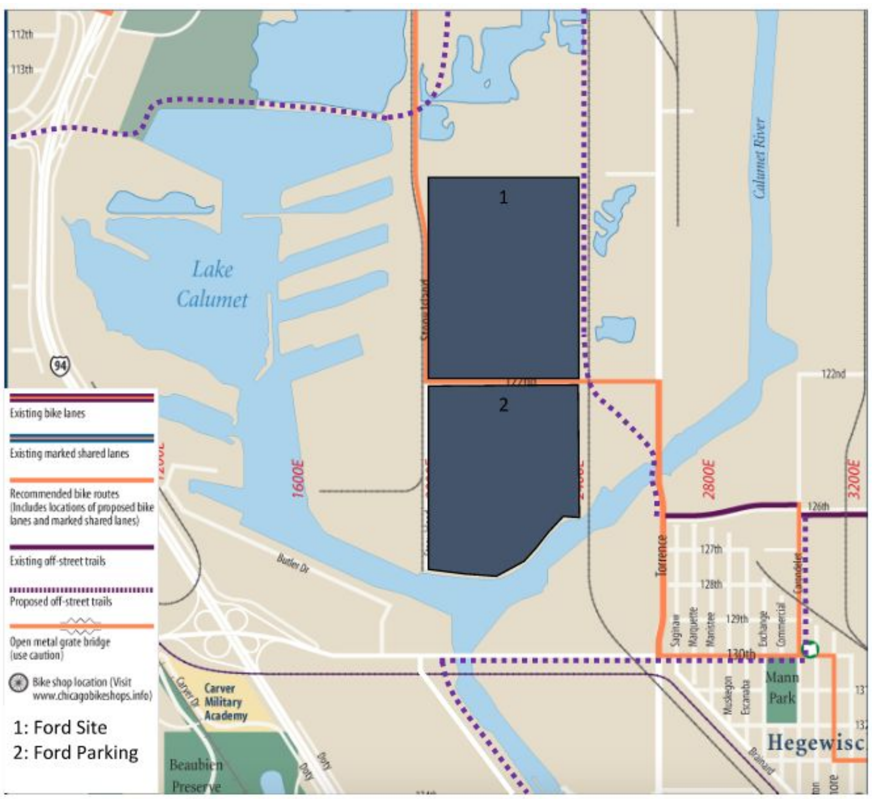


Figure 9D.3: Proposed Bike Path Additions

Appendix 9E: Decon App

For the CivEnv 398 class, Breanna Kazmierczak (WWTP Cost) and I partnered with The Delta Institute to design an application interface that allows data to be efficiently tracked throughout the construction material procurement and recycling process. In theory, Delta Institute would have the app, “Decon,” up and running by the time the Ford project launches and the project could use it to meet the Envision Requirements RA1.2-1.7 (support sustainable procurement practices, use recycled materials, use regional materials, divert waste from landfills, reduce excavated materials taken off site, and provide for deconstruction and recycling). The components of the app are outlined below.

Instructions for Decon

Step 1: Logging Site Address and Materials

- Before the app opens to the Home page, the user creates a profile with a photo, their name, company/organization name, and contact phone number
- From the Home page, the user would first press “Enter new/Edit existing site” to add a new deconstruction site address
- After entering preliminary information about the home type, era, and square footage, the user can then begin adding inventory of materials to the site
- Each material requires a picture, amount, weight, type, and description

Step 2: Sending Requests

- Once all of the materials are logged, the user can go back to the home page and press “View Site List” to move on in the process of sending a donation or selling request
- Once the correct site is selected, an overview of the materials, along with their amounts and weights, are listed. The user can review any logged information by selecting a material
- Once the “Donate” or “Sell” button is pressed, the user can check any of the materials they wish to send in their request
- Next, a location based on a manually entered zip-code is selected for the request. All warehouses and ReUse stores are listed in the map directory
- The user can then review their request, edit it, or add a typed note at the bottom for any additional information they want to pass along
- After sending the request, the user receives confirmation and can return to the home page

Step 3: Sealing the Deal

- The final step in the app is to view incoming and outgoing requests. All incoming requests are in the form of a posting board that is categorized by date. The user can view posts from any warehouses or stores in the directory for special items they are looking for, which could be incentive for the user to log and sell the item

- The outgoing request page pulls up all of the user's requests they have sent. Pending and denied requests can be deleted or sent to a new location. Accepted requests can also be deleted or confirmed by the user-prompting them to contact the warehouse for a specific drop-off or pickup appointment

Decon alleviates several issues that occur with the current flow process of materials to warehouses, and has the potential to grow into a widely used method of communication and transfer of information.

Several advantages to Decon include:

- A standardized method of communication from contractors to warehouses. If many contractors and all warehouses jump on board with the app, there will be one concise way to pass along photos and donation requests.
- A standardized measurement for material bulk. Whether that is weight(lb) or evolves into another unit, the app would allow all contractors to use the same measurement that is most useful for warehouses.
- Photograph transfer from contractors would phase out the need for warehouses to take photos to put on their website.
- Increased interest and necessity as a new wave of young contractors, that are more technologically versed, begin in the business.

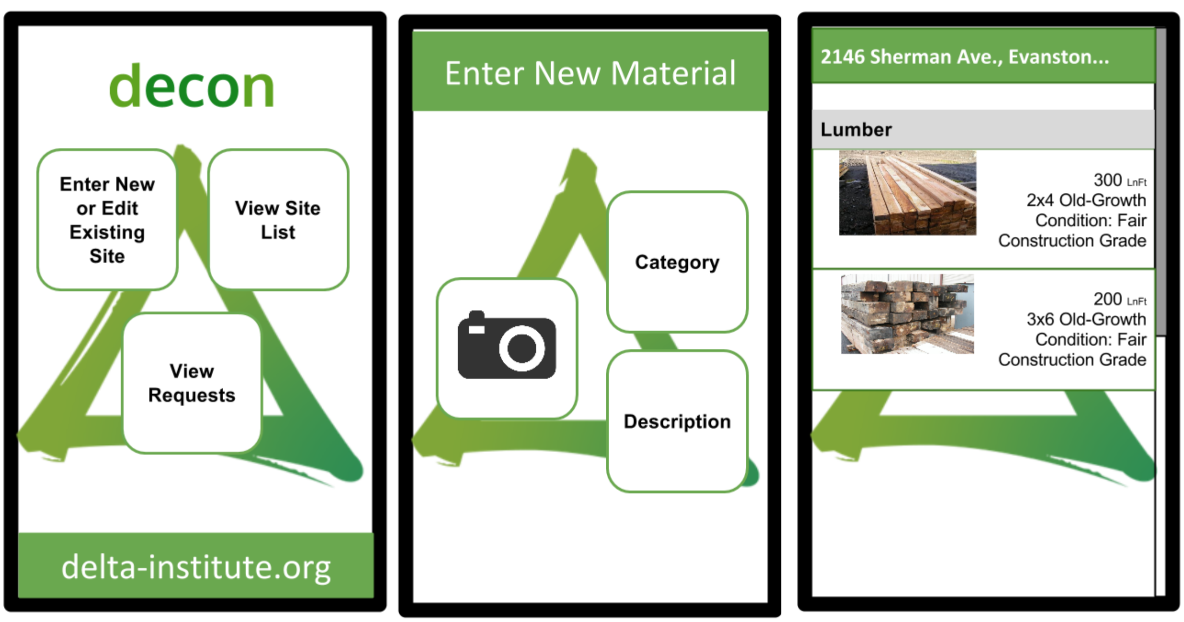


Figure 9E.1: Example screens of Decon app

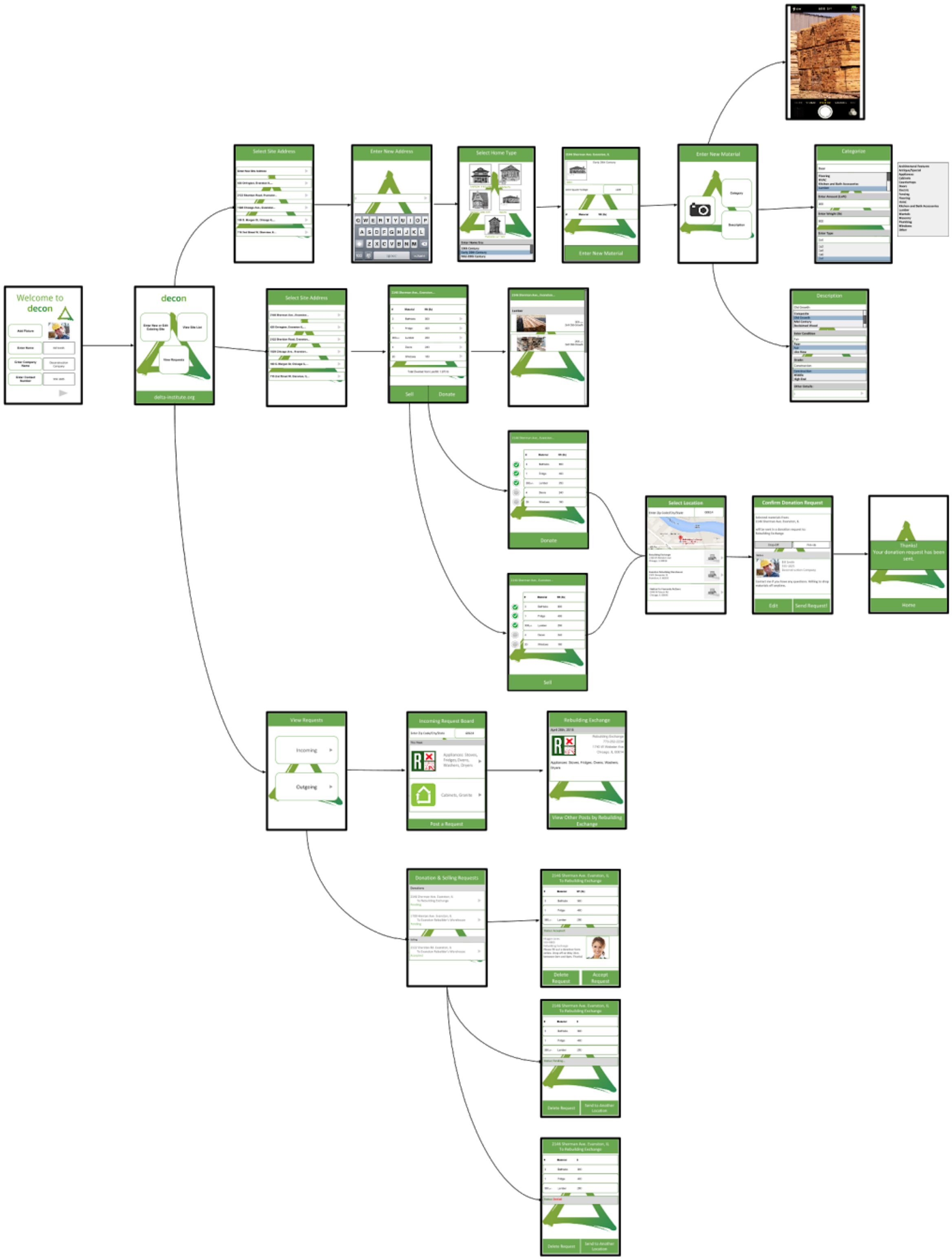


Figure 9E.2: Decon App Flow

Appendix Section 10

WASTEWATER TREATMENT

Kelly Cai

Appendix 10A: Water quality requirements for the Ford automotive assembly plant compared to effluent water quality from Calumet WWTP

Water quality requirements for the Ford automotive assembly plant compared to effluent water quality from Calumet WWTP.

Parameter	Requirements for Ford (Gaines)	Effluent from WWTP[4]
TDS (mg/L)	300	770
Turbidity	2	
pH	6.0-8.0	7.2
Sp Cond	300 uS/cm	1273.4 umhos/com
Chlorides as Cl mg/L	25	170.6
Sulfates as SO4 mg/L	25	80.43
Nitrates as NO3 mg/L	10	47.8 (calculated from 10.8 mg N /L)
Total Hardness as CaCO3 mg/L	150	294
Phosphate as PO4 mg/L	20	11.03 (calculated from 3.6 mg P /L)
Ca+Mg mg/L	30	100
Bacteria		23051 cts/100 mL
Temperature		16 C

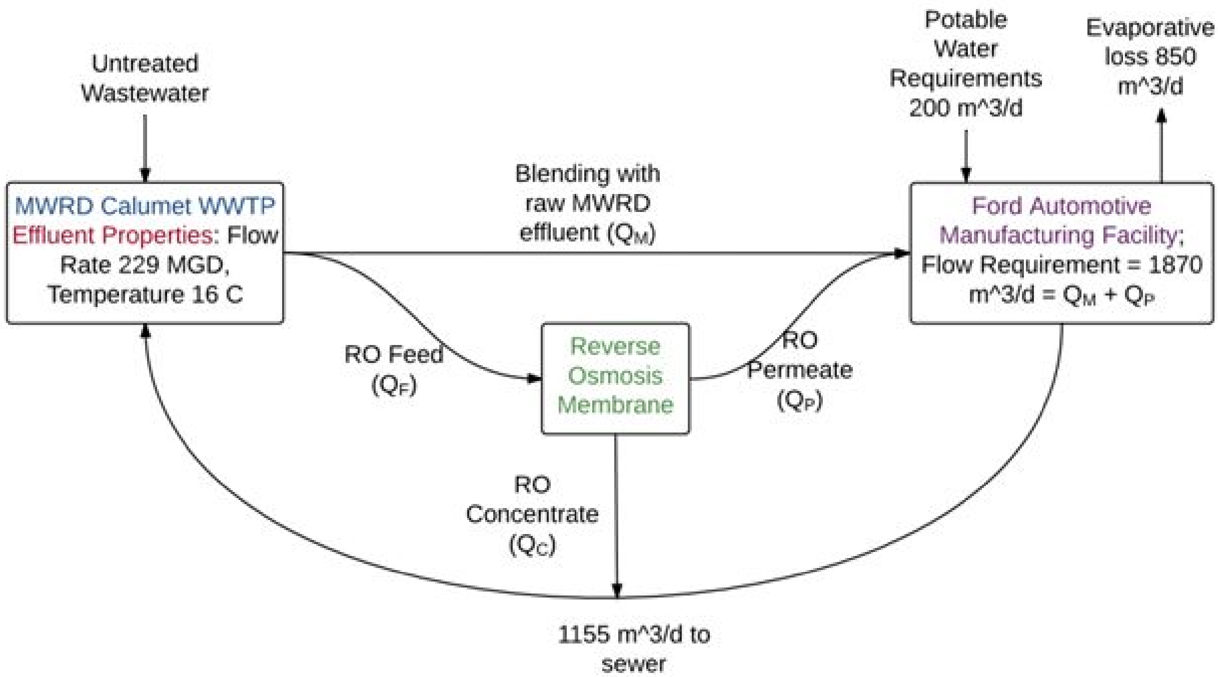
Appendix 10B: Sewage and waste control ordinance requirements for MWRD compared to discharge water quality from Ford processes

Sewage and waste control ordinance requirements for MWRD compared to discharge water quality from Ford processes.

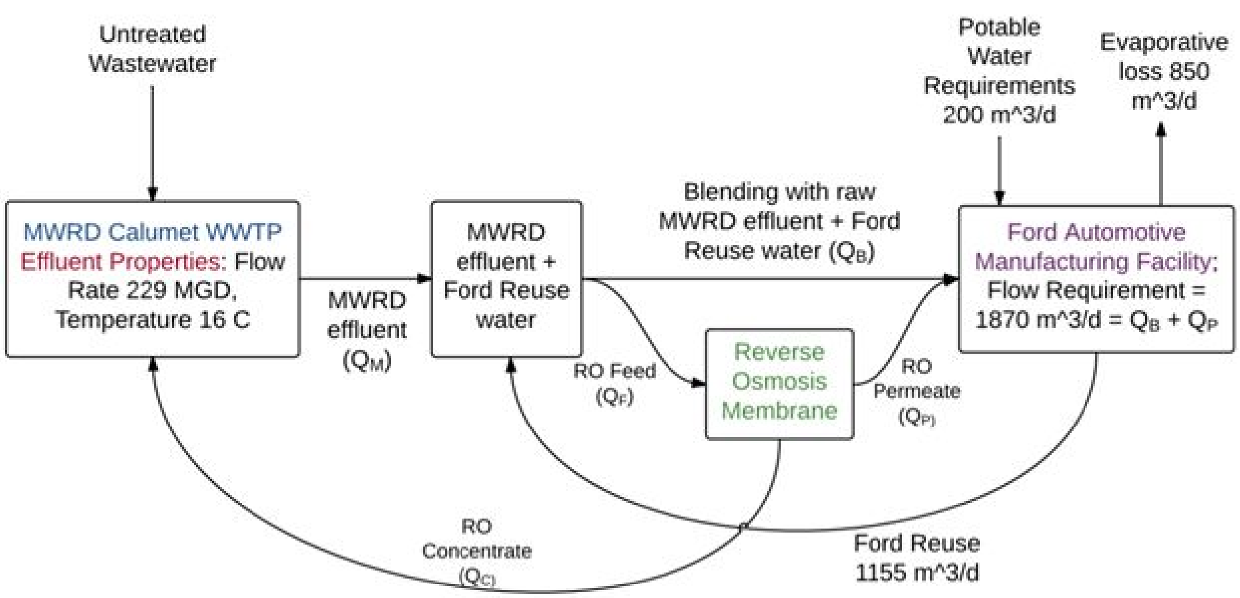
Parameter	Ford Effluent (mg/L) (maximum)	Sewage and waste control ordinance requirement (mg/L)[5]
Cd	<0.002	2
Cr	0.0097	25
Cu	0.023	3
Pb	0.03	0.5
Ni	0.33	10
Zn	0.65	15
pH	9.5	5.0-10.0
Temp (degC)	27	<65.5
Chromium (hexavalent)	<0.005	10
Cyanide (total)	<0.1	5
Fats, oils, and gases (total)	<50	250
Iron	<1	250
Mercury	<0.0005	0.0005

Appendix 10C: Flow schemes between MWRD and Ford Automotive Manufacturing Facility

Flow schemes between MWRD and Ford Automotive Manufacturing Facility
Alternative 1: Pipeline discharge to MWRD



Alternative 2: On-site sanitary wastewater treatment facility



Appendix 10D: Equations and tables to use in water treatment technology design

Equations and tables to use in water treatment technology design

$$\pi = \frac{-RT}{V_b} ln x_w = \frac{n_s}{V} RT = \phi CRT$$

- π = osmotic pressure, bar
- V_b = molar volume of pure water, L/mol
- x_w = mole fraction of water, mol/mol
- n_s = total amount of all solutes in solution, mol
- V = volume of solution, L
- C = concentration of all solutes, mol/L
- Φ = osmotic coefficient, unitless
- **Reference: Crittenden 1354; equations 17-5 to 17-7**

$$\Delta P_{NET} = \Delta P - \Delta\pi = (P_F - P_p) - (\pi_F - \pi_p)$$

$$J_W = k_W(\Delta P - \Delta\pi)$$

- ΔP_{NET} = net transmembrane pressure, bar
- Subscripts F and P refer to feed and permeate
- J_W = volumetric flux of water, L/m^2h
- K_w = mass transfer coefficient for water flux, L/m^2hbar
- **Reference: Crittenden 1361; equations 17-8 and 17-9**
- Equation 17-9 is valid at any point on the membrane surface between the feed water entrance and concentrate discharge but applied and osmotic pressures change continuously along the length of a spiral-bound element due to changing head loss and solute concentration

$$J_S = k_S(\Delta C)$$

- J_S= mass flux of solute, mg/m^2h
- K_S = mass transfer coefficient for solute flux, L/m^2h or m/h
- ΔC = concentration gradient across membrane, mg/L
- **$C_p = J_S/J_W$, solute concentration in permeate**
- **r= Q_p/Q_F, recovery ratio**
- **Reference: Crittenden, 1361, equations 17-10 to 17-12**

$$\text{Flow balance: } Q_F = Q_P + Q_C$$
$$\text{Mass balance: } C_F Q_F = C_P Q_P + C_C Q_C$$
$$C_C = C_F \frac{1-(1-Rej)r}{1-r} = C_F \frac{1}{1-r}$$

- Rejection is frequently close to 100%

- **Reference: Crittenden, 1362, equations 17-13 to 17-16**

$$Re = \frac{\rho V d_H}{\mu}$$

$$Sc = \frac{\mu}{\rho D_L}$$

$$k_{CP} = \frac{0.023 D_L Rd^{0.83} Sc^{0.33}}{2d_H}$$

- **Reference: Crittenden, 1371, equations 17-36 to 17-38**

$$\beta_Z = \exp\left(\frac{J_{W,Z}}{k_{CP}}\right) Rej + (1 - Rej)$$

$$J_{W,Z} = k_W[(P_{FC,Z} - P_{P,Z}) - (\beta_Z \pi_{FC,Z} - \pi_{P,Z})]$$

$$J_{S,Z} = K_s(\beta_Z C_{FC,Z-} C_{P,Z})$$

$$M_{S,Z} = J_{S,Z}(w)(dz)$$

- **Reference: Crittenden, 1391**

$$h_L = \delta_{HL} V_Z^2 dz$$

- **Reference: Crittenden 1393**

Appendix 10E: Spreadsheet for reverse osmosis permeate concentration calculations

Spreadsheet for reverse osmosis permeate concentration calculations

These spreadsheets were developed using example 17-5 in MWH Water Treatment Principles and Design[1]; the three starred values in the parameters table below were the only values changed to reflect Ford/MWRD water quality parameters.

The spreadsheet shown below was used for chloride concentrations; similar spreadsheets were developed for TDS, nitrates, and hardness concentrations by changing molecular weight and feed concentrations. The water flux for the system is around 11 L/m^{2}h, which is within the appropriate range for water of this quality. Calculations for TDS concentrations assumed TDS to be composed of calcium, phosphates, nitrates, sodium, potassium, and chloride, with an average molecular weight of 49 g/mol.

Parameter	Unit	Value	
Membrane Properties			
Element length	m	1	
Element membrane area	m^2	32.5	
Element width	m	32.5	
Effective feed channel height	mm	0.125	
Water mass transfer coefficient (kw)	L/m^2*h*bar	2.87	
Solute mass transfer coefficient (ks)	m/h	6.14E-04	
Element head loss at design velocity of 0.5 m/s	bar	0.2	
Operating Conditions			
Feed flow (Qf)	m^3/d	1312.5	*
Feed pressure (Pf)	bar	14.2	
Feed concentration (Cf)	mg/L NaCl	170	*
Feed temperature (Tf)	degrees C	16	*
Permeate pressure (Pp)	bar	0.3	
Osmotic coefficient (ϕ)		1	
*Assume D(NaCl) = 1.35e-9 m^2/s			

Increment (z)	Equation	Unit	1	2	3	4	10
Q(FC,Z)	Q(F) - Q(P,Z)	m^3/s	0.015191	0.015155	0.015123	0.015093	0.0149735
V(Z)	Q(FC,Z)/hw	m/s	3.739316	3.730543	3.722483	3.715131	3.685778
P(FC,Z)	P(F) - h(L,Z)	bar	14.2	13.0814	11.96804	10.85949	4.2851961
h(L,Z)	δ(HL)*V(Z)^2*dz	bar	1.118599	1.113356	1.10855	1.104176	1.0867968
C(FC,Z)	(Q(F)C(F)-M(Z))/Q(FC,Z)	mg/L	170	170.3933	170.7551	171.0867	172.41133
pi(FC,Z)	ϕ*C(FC,Z)*RT	bar	0.139894	0.140218	0.140516	0.140789	0.1418786
Q(P,Z)	J(W,Z)*w*dz	m^3/s	3.56E-05	3.27E-05	2.99E-05	2.7E-05	9.97E-06
P(P,Z)		bar	0.3	0.3	0.3	0.3	0.3
C(P,Z)	J(S,Z)/J(W,Z)	mg/L	0	2.735515	3.312627	3.1984	7.2978565
pi(P,Z)	ϕ*C(P,Z)*RT	bar	0	0.002251	0.002726	0.002632	0.0060055
k(CP,Z)	(0.023*D*Re^.83*Sc^.33)/2h	m/s	0.000321	0.00032	0.00032	0.000319	0.0003171
β(Z)	see attached	--	1.0346	1.16459	1.02856	1.0258	1.00949
J(W,Z)	see attached	L/m^2*h	39.4776	36.2738	33.0803	29.8988	11.0434
J(S,Z)	ks*(β(Z)*C(FC,Z)-C(P,Z))	mg/m^2*h	107.9915	120.1616	105.804	105.7936	102.38429
M(Z)	J(S,Z)*w*dz	mg/s	0.097492	0.108479	0.095518	0.095508	0.0924303
Reynold's #	ρ*v*d(H)/μ	--	932.9594	930.770588	928.75941	926.925289	919.60161
Schmidt #	μ/ρ*DL	--	742.22519	742.225191	742.22519	742.225191	742.225191
Rej	1-cp/cf			1	0.983946	0.9806	0.9650657

Increment (z)	Equation	Unit	Value
Q(P)	sum Q(P,Z)	m^3/s	0.000227
M(S)	sum M(S,Z)	mg/s	0.961303
C(P)	M(S)/Q(P)	mg/L	4.226086
Rejection	1-(C(P)/C(F))		0.975141
Recovery	Q(P)/Q(F)		0.014974

Appendix 10F: Calculations used to determine flow rates and concentrations for alternative 1

Calculations used to determine flow rates and concentrations for alternative 1, discharge of Ford effluent to MWRD

Flow blending of RO permeate and raw MWRD water will be used to achieve parameter concentrations 10-20% below Ford limits (**Table 10F.1**).

Table 10F.1: Concentrations 10-20% lower than Ford requirements

Parameter	20% less than requirement	10% less than requirement	Requirements for Ford (Gaines)
TDS (mg/L)	240	270	300
Chlorides as Cl mg/L	20	22.5	25
Sulfates as SO4 mg/L	20	22.5	25
Nitrates as NO3 mg/L	8	9	10
Total Hardness as CaCO3 mg/L	120	135	150
Phosphate as PO4 mg/L	16	18	20

Table 10F.2 shows raw MWRD effluent parameter concentrations (C_M) compared to RO permeate concentrations after the water has been treated (C_P); these RO permeate concentrations were calculated using the spreadsheet in **Appendix 10E**. Then in order to calculate the flow rates required for MWRD effluent and RO permeate to achieve concentrations 10-20% less than Ford requirements (**Table 10F.1** above), a mass balance was used. In order to ensure that all parameters are at least 10-20% less than the Ford limits, calculations were done with the most limiting parameter, chlorides.

Sample Calculation: for chloride concentrations 20% lower than Ford limits:

$$Q_M C_M + Q_P C_P = Q_T C_T$$
$$Q_M + Q_P = Q_T$$
$$Q_M * 170 + Q_P * 4.216 = Q_T * 20$$
$$Q_M * 170 + (1870 - Q_M) * 4.216 = 1870 * 20$$

$$\mathbf{Q_M = 178\ m^3/d}$$
$$\mathbf{Q_P = 1692\ m^3/d}$$

Table 10F.2: Concentrations after mixing of raw MWRD effluent and treated RO permeate.

Parameter	**MWRD Effluent (C_M)**	**RO Permeate (C_P)**	**Mixed Concentrations with Q_M = 178 m^3/d and Q_P = 1692 m^3/d**	**Mixed Concentrations with Q_M = 206 m^3/d and Q_P = 1664 m^3/d**
TDS (mg/L)	770	19.1	90.6	101.8
Chlorides as Cl mg/L	170	4.216	20.0	22.5
Nitrates as NO3 mg/L	47.8	1.185	5.62	6.3
Total Hardness as CaCO3 mg/L	294	7.291	34.6	38.9

Mixed concentrations when 178 m^3/d of raw MWRD effluent is mixed with 1692 m^3/d of RO permeate to achieve a chloride concentration 20% less than the Ford requirement with all other parameters more than 20% less than Ford requirements; and mixed concentrations when 206 m^3/d of raw MWRD effluent is mixed with 1664 m^3/d of RO permeate to achieve a chloride concentration 10% less than the Ford requirement with all other parameters more than 10% less than Ford requirements.

Appendix 10G: Calculations used to determine flow rates and concentrations for alternative 2

Calculations used to determine flow rates and concentrations for alternative 2, reuse of Ford effluent

In the second flow scheme (**Figure 10.3**), the 1155 m^3/d of Ford effluent that would have been discharged to the sewer in scheme 1 is instead reused within the facility; in order to fulfill the 1870 m^3/d requirement for ford processes, the remaining flow rate will be taken from MWRD effluent. The Ford reuse effluent and MWRD effluent are first mixed together before being fed into the RO membrane. The resulting concentrations were found using a mass balance equation and are shown below in **Tables 10G.1 and 10G.3,** assuming that the Ford effluent that is being reused was treated to 20% and 10% less than Ford limit respectively.

Table 10G.1: Mixed concentrations of 1090 m^3/d MWRD effluent (Q_M) and 1155 m^3/d Ford Reuse water (combined Q = 2245) assuming Ford reuse water was treated to 20% less than Ford limit

Parameter	**MWRD Effluent (C_M)**	**Ford Effluent (Reuse)**	**MWRD Effluent + Ford Reuse water (C_B)**
TDS (mg/L)	770	90.6	420.5
Chlorides as Cl mg/L	170	20.0	92.83
Nitrates as NO3 mg/L	47.8	5.62	26.1
Total Hardness as CaCO3 mg/L	294	34.6	160.53

In order to ensure that all parameters are at least 20% less than the Ford limits, calculations were done with the most limiting parameter, chlorides. The calculations were done in an iterative process since the RO feed, permeate, and residuals flows are interdependent, and the mixing of MWRD effluent and Ford reuse water also depends on the amount of feed water required. This then affects the mixed concentration C_B, which affects the RO permeate concentrations. The final flow rates after performing the calculation several times are shown below.

Sample Calculation: for chloride concentrations 20% lower than Ford limits:

$$Q_B C_B + Q_P C_P = Q_T C_T$$
$$Q_M + Q_P = Q_T$$
$$Q_B * 92.83 + Q_P * 2.3 = Q_T * 20$$
$$Q_M * 92.83 + (1870 - Q_M) * 2.3 = 1870 * 20$$

$Q_B = 366\ m^3/d$
$Q_P = 1504\ m^3/d$

Table 10G.2: Concentrations after mixing of raw MWRD effluent + Ford Reuse water and treated RO permeate assuming Ford reuse water was treated to 20% less than Ford limit

Parameter	MWRD Effluent + Ford Reuse water (C_B)	RO Permeate (C_P)	Mixed Concentrations with $Q_B = 366\ m^3/d$ and $Q_P = 1504\ m^3/d$
TDS (mg/L)	420.5	10.44	90.7
Chlorides as Cl mg/L	92.83	2.3	20
Nitrates as NO3 mg/L	26.1	0.648	5.6
Total Hardness as CaCO3 mg/L	160.53	3.97	34.6

Table 10G.2 shows mixed concentrations when 448 m^3/d of raw MWRD effluent + Ford Reuse water is mixed with 1422 m^3/d of RO permeate to achieve a chloride concentration 20% less than the Ford requirement with all other parameters more than 20% less than Ford requirements.

The same process was used below to calculate the flows to achieve concentrations 10% less than Ford limits. In order to ensure that all parameters are at least 10% less than the Ford limits, calculations were done with the most limiting parameter, chlorides. **Table 10G.4** shows; and mixed concentrations when 499 m^3/d of raw MWRD effluent + Ford reuse water is mixed with 1371 m^3/d of RO permeate to achieve a chloride concentration 10% less than the Ford requirement with all other parameters more than 10% less than Ford requirements.

Table 10G.3: Mixed concentrations of 1077 m^3/d MWRD effluent and 1155 m^3/d Ford Reuse water (combined Q = 2232 m^3/d) assuming Ford reuse water was treated to 10% less than Ford limit

Parameter	MWRD Effluent	Ford Effluent (Reuse)	MWRD Effluent + Ford Reuse water (C_B)
TDS (mg/L)	770	101.8	357.3
Chlorides as Cl mg/L	170	22.48	78.88
Nitrates as NO3 mg/L	47.8	6.32	22.18
Total Hardness as CaCO3 mg/L	294	38.87	136.42

Table 10G.4: Concentrations after mixing of raw MWRD effluent + Ford Reuse water and treated RO permeate assuming Ford reuse water was treated to 10% less than Ford limit

Parameter	MWRD Effluent + Ford Reuse water (C_B)	RO Permeate (C_P)	Mixed Concentrations with Q_B = 413 m^3/d and Q_P = 1457 m^3/d
TDS (mg/L)	357.3	8.89	102
Chlorides as Cl mg/L	78.88	1.963	22.5
Nitrates as NO3 mg/L	22.18	0.552	6.3
Total Hardness as CaCO3 mg/L	136.42	3.395	39

Appendix Section 11

WASTEWATER TREATMENT COST

Breanna Kazmierczak

Appendix 11A: Plant Capacities based on Alternative

Table 11A.1 : Capacity Requirements for Ford On-Site WWTP based on design Alternatives

Flow Scheme	Capacity of Plant (m^3/day)	Capacity of Plant MGD	Capacity GPM
Without reuse, 20%	2350	0.621	431
Without reuse, 10%	2311	0.611	424
With reuse, 20%	2089	0.552	383
With reuse, 10%	2023	0.535	371

Appendix 11B: Capital Cost Estimation [1,2]

CapEx	Description	Specs	Quantity	Units	Unit Price ($/unit)	Total Price
	Site Work	Should be factored into overall site work costs			50,000.00	
Building	Foundation Formwork	Cast-in-place concrete forming, Mat foundation, Job-built plywood, 1 use	1000	SF	9.65	$9,650.00
	Foundation slab on grade	Curb forms, wood, 6" to 12" high, on grade, one use	1000	SF	8.22	$8,220.00
	WWTP building shell		1000	SF	250.00	$250,000.00
Electrical System	Electrical Service and Distribution	Panel board and feeders	1000	SF	1.39	$1,390.00
	Lighting and Branch Wiring	High intensity discharge fixture, receptacles, switches, A.C. and misc. poower	1000	SF	13.02	$13,020.00
	Telemetry	Chemical monitoring and communication system				$12,500.00
RO System	RO Skid	GE E-Series (E8-288K-DLX-60), 36 membranes, 400 square feet of membrane	2	each	104,800	$209,600.00
	RO Installation	10% of equipment cost				$30,000.00
	RO Pre Filter skid	Pretreatment, 1 micron filter and housing at 450 GPM	1	each	175,000.00	$175,000.00
	Brackish Water storage tank		1	each	30,000.00	$30,000.00
	Pretreatment Chemical Feed System	Sodium Hydroxide, Surfactant, cleaning chemicals, etc	4	each	25,000.00	$100,000.00
	Process Piping	pumps(350 gpm), valves, pipes				$75,000.00
					Subtotal:	**$905,340.00**
Soft Costs	General Conditions and Insurance	0.15				$135,801.00
	Overhead and Profit	0.08				$72,427.20
	Contingency	0.1				$90,534.00
				Total Construction Cost:		**$1,204,102.20**

Appendix 11C: Analysis of RO Machinery Alternatives

Table 11C.1 : Engineering Economic Analysis of GE Reverse Osmosis Skids [1,3]
The GE E-Series 200 GPM shows a lower capital cost than the other alternatives, as well as slightly lower Maintenance and Annual costs of operation.

	GE RO PRO Series (PRO-450-NA,SS,PRE,460,6,AB,TF,SG)	GE E-Series (E8-144K-DLX-60)	GE E-Series (E8-288K-DLX-60-LE)
Quantity of Machines	1	4	2
Flow Rate	450	100	200
Initial Cost	$274,780.00	$278,880.00	$209,600.00
Estimated Life (years)	20	20	20
Salvage Value (10%)	$27,478.00	$27,888.00	$20,960.00
Number of Membranes	108	21	36
Cost per Membrane	$550.00	$550.00	$550.00
Membrane Life (years)	3	3	3
Annual Maitenence Cost	$19,800.00	$15,400.00	$13,200.00
Annual Cost of Operation(energy)	$42,140.59	$38,628.88	$38,628.88
Cost of capital per year at 6%	$23,956.57	$24,314.03	$18,273.88
Cost over Machine Lifespan	**$1,717,943.32**	**$1,566,858.13**	**$1,402,055.20**

Appendix 11D: Operational Expenses Estimation [2,3,4]

Without Reuse

Table 11D.1 : Flow Summary

Flow Scheme	Effluent from MWRD (m^3/day)	Water going through RO (m^3/day)	Water going to Sewer disposal (m^3/day)	Potable Water Used (m^3/day)
Without reuse, 20%	2293	2115	1578	200.00

Table 11D.2 : Itemized Operational Expenses

OpEx - Continuous use		Description		Quantity	Units	Unit Price	Cost/day
	Effluent Cost	from MWRD		605,746.40	gal	$0.000000	$0.00
	Electrical	RO Process Pumps	Process Transfer pump(450 GPM, 60 Hz), operating 10 hours a day, 261 days, @ 2.84 kWh/1000 gal	558,723.78	gal	$0.000250	$139.68
		Building Sump Pump	60 GPM Capacity, 5 HP motor	52,834.40	gal	$0.000007	$0.36
	Chemicals	Sodium Hydroxide	Precipitates heavy metals, neutralizes strong acids, removes silicates		pound	$0.065000	
		Chlorine			pound	$0.061000	
		Sulfuric Acid	Cleaning Membranes		pound	$0.048000	
		Sodium Bisulfite			pound	$0.610000	
		Antiscalant			pound	$4.880000	
		Total Chemical usage	@ 0.528 pounds/1000 gallons	558,723.78	gal	$0.000140	$78.22
	Testing	Laboratory Routing Testing		558,723.78	gal	$0.000040	$22.35
	Disposal	Sewer Discharge Cost		416,863.42	gal	$0.003810	$1,588.25
	Labor	Engineers, maitenence workers, etc	261 business days/year, 8 hours/day, See appendix for shifts	1.00	day	$660.000000	$660.00
	Fixed Costs	Preventative and Corrective of equipment		558,723.78	gal	$0.000003	$1.45
		Membrane Replacement		558,723.78	gal	$0.000004	$1.99
		Lighting and Heating	Midwest Region	1,000.00	ft^2	$0.002877	$2.88
		Safety Equipment & Tools		558,723.78	gal	$0.000001	$0.73

Table 11D.3 : Price Sensitivity Analysis Summary

Effluent Price ($/1000 gallons	0.00	$0.48	$0.95	$1.91	$2.86
Total Cost per Day:	2,495.92	$2,786.67	$3,071.38	$3,652.89	$4,228.35
Total Cost per Year:	911,009.45	$1,017,136.22	$1,121,052.01	$1,333,305.55	$1,543,348.11

Without Reuse 10%

Table 11D.4 : Flow Summary

Flow Scheme	Effluent from MWRD (m^3/day)	Water going through RO (m^3/day)	Water going to Sewer disposal (m^3/day)	Potable Water Used (m^3/day)
Without reuse, 10%	2286	2080	1571	200.00

Table 11D.5 : Itemized Operational Expenses

OpEx - Continuous use		Description		Quantity	Units	Unit Price	Cost/day
	Effluent Cost	from MWRD		603,897.19	gal	$0.000000	$0.00
	Electrical	RO Process Pumps	Process Transfer pump(450 GPM, 60 Hz), operating 10 hours a day, 261 days, @ 2.84 kWh/1000 gal	549,477.76	gal	$0.000250	$137.37
		Building Sump Pump	60 GPM Capacity, 5 HP motor	52,834.40	gal	$0.000007	$0.36
	Chemicals	Sodium Hydroxide	Precipitates heavy metals, neutralizes strong acids, removes silicates		pound	$0.065000	
		Chlorine			pound	$0.061000	
		Sulfuric Acid	Cleaning Membranes		pound	$0.048000	
		Sodium Bisulfite			pound	$0.610000	
		Antiscalant			pound	$4.880000	
		Total Chemical usage	@ 0.528 pounds/1000	549,477.76	gal	$0.000140	$76.93
	Testing	Laboratory Routing Testing		549,477.76	gal	$0.000040	$21.98
	Disposal	Sewer Discharge Cost		415,014.21	gal	$0.003810	$1,581.20
	Labor	Engineers, maitenence workers, etc	261 business days/year, 8 hours/day, See appendix for shifts	1.00	day	$660.000000	$660.00
	Fixed Costs	Preventative and Corrective of equipment		549,477.76	gal	$0.000003	$1.43
		Membrane Replacement		549,477.76	gal	$0.000004	$1.96
		Lighting and Heating	Midwest Region	1,000.00	ft^2	$0.002877	$2.88
		Safety Equipment & Tools		549,477.76	gal	$0.000001	$0.72

Table 11D.6 : Price Sensitivity Analysis Summary

Effluent Price ($/1000 gallons	0.00	$0.48	$0.95	$1.91	$2.86
Total Cost per Day:	2,484.83	$2,774.70	$3,058.53	$3,638.27	$4,211.97
Total Cost per Year:	906,961.45	$1,012,764.24	$1,116,362.80	$1,327,968.38	1,537,369.73

Reuse 20%

Table 11D.7 : Flow Summary

Flow Scheme	Effluent from MWRD (m^3/day)	Water going through RO (m^3/day)	Water going to Sewer disposal (m^3/day)	Potable Water Used (m^3/day)
With reuse, 20%	**1090**	**1880**	**376**	**200.00**

Table 11D.8 : Itemized Operational Expenses

OpEx - Continuous use		Description		Quantity	Units	Unit Price	Cost/day
	Effluent Cost	from MWRD		287,947.48	gal	$0.000000	$0.00
	Electrical	RO Process Pumps	Process Transfer pump(4 x 100 GPM, 60 Hz), operating 10 hours a day, 261 days, at 2.84 kWh/1000 gal	496,643.36	gal	$0.000250	$124.16
		Building Sump Pump	60 GPM Capacity, 5 HP motor	52,834.40	gal	$0.000007	$0.36
	Chemicals	Sodium Hydroxide	Precipitates heavy metals, neutralizes strong acids, removes silicates		pound	$0.065000	
		Chlorine			pound	$0.061000	
		Sulfuric Acid	Cleaning Membranes		pound	$0.048000	
		Sodium Bisulfite			pound	$0.610000	
		Antiscalant			pound	$4.880000	
		Total Chemical usage	@ 0.528 pounds/1000 gallons	496,643.36	gal	$0.000140	$69.53
	Testing	Laboratory Routing Testing		496,643.36	gal	$0.000040	$19.87
	Disposal	Sewer Discharge Cost		99,328.67	gal	$0.003810	$378.44
	Labor	Engineers, maitenence workers, etc	261 business days/year, 8 hours/day, See appendix for shifts	1.00	day	$660.000000	$660.00
	Fixed Costs	Preventative and Corrective of equipment		496,643.36	gal	$0.000003	$1.29
		Membrane Replacement		496,643.36	gal	$0.000004	$1.77
		Lighting and Heating	Midwest Region	1,000.00	ft^2	$0.002877	$2.88
		Safety Equipment & Tools		496,643.36	gal	$0.000001	$0.65

Table 11D.9 : Price Sensitivity Analysis Summary

Effluent Price ($/1000 gallons	0.00	$0.48	$0.95	$1.91	$2.86
Total Cost per Day:	1,258.95	$1,397.16	$1,532.50	$1,808.93	$2,082.48
Total Cost per Year:	459,516.76	$509,965.16	$559,362.55	$660,259.34	$760,105.13

Reuse 10%

Table 11D.10 : Flow Summary

Flow Scheme	Effluent from MWRD (m^3/day)	Water going through RO (m^3/day)	Water going to Sewer disposal (m^3/day)	Potable Water Used (m^3/day)
With reuse, 10%	**1077**	**1821**	**364**	**200.00**

Table 11D.11 : Itemized Operational Expenses

OpEx - Continuous use		Description		Quantity	Units	Unit Price	Cost/day
	Effluent Cost	from MWRD		284,513.24	gal	$0.000000	$0.00
	Electrical	RO Process Pumps	Process Transfer pump(4 x 100 GPM, 60 Hz), operating 10 hours a day, 261 days, at 2.84 kWh/1000 gal	481,057.21	gal	$0.000250	$120.26
		Building Sump Pump	60 GPM Capacity, 5 HP motor	52,834.40	gal	$0.000007	$0.36
	Chemicals	Sodium Hydroxide	Precipitates heavy metals, neutralizes strong acids, removes silicates		pound	$0.065000	
		Chlorine			pound	$0.061000	
		Sulfuric Acid	Cleaning Membranes		pound	$0.048000	
		Sodium Bisulfite			pound	$0.610000	
		Antiscalant			pound	$4.880000	
		Total Chemical usage	at 0.528 pounds/1000 gallo	481,057.21	gal	$0.000140	$67.35
	Testing	Laboratory Routing Testing		481,057.21	gal	$0.000040	$19.24
	Disposal	Sewer Discharge Cost		96,158.61	gal	$0.003810	$366.36
	Labor	Engineers, maitenence workers, etc	261 business days/year, 8 hours/day, See appendix for shifts	1.00	day	$660.000000	$660.00
	Fixed Costs	Preventative and Corrective of equipment		481,057.21	gal	$0.000003	$1.25
		Membrane Replacement		481,057.21	gal	$0.000004	$1.71
		Lighting and Heating	Midwest Region	1,000.00	ft^2	$0.002877	$2.88
		Safety Equipment & Tools		481,057.21	gal	$0.000001	$0.63

Table 11D.12 : Price Sensitivity Analysis Summary

Effluent Price ($/1000 gallons	0.00	$0.48	$0.95	$1.91	$2.86
Total Cost per Day:	1,240.05	$1,376.62	$1,510.34	$1,783.47	$2,053.76
Total Cost per Year:	452,619.51	$502,466.23	$551,274.48	$650,967.92	$749,622.89

Table 11D.13 : Operational cost per year. Highlighted in green is the optimal design alternative.

Flow Scheme	Without Reuse		With Reuse	
% Less than Ford Limit	20%	10%	20%	10%
Effluent: $0.00	$911,009.45	$906,961.45	$459,516.76	$452,619.51
Effluent: $0.48	$1,017,136.22	$1,012,764.24	$509,965.16	$502,466.23
Effluent: $0.95	$1,121,052.01	$1,116,362.80	$559,362.55	$551,274.48
Effluent: $1.91	$1,333,305.55	$1,327,968.38	$660,259.34	$650,967.92
Effluent: $2.86	$1,543,348.11	$1,537,369.73	$760,105.13	$749,622.89

Appendix 11E: Sewer Discharge Flow and Sewer Costs

Table 11E.1 : Water Flow Rate to the MWRD sewer based on design alternative. The current sewer rate in Chicago is 100% of the water intake cost, or $3.81 per 1,000 gallons[4]

Flow Scheme	Effluent from MWRD (m^3/day)	Water going through RO (m^3/day)	Water going to Sewer disposal (m^3/day)	Cost per day
Without reuse, 20%	2293	2115	1578	$1,588.25
Without reuse, 10%	2286	2080	1571	$1,581.20
With reuse, 20%	1090	1880	376	$378.44
With reuse, 10%	1077	1821	364	$366.36

Appendix 11F: Labor Scheduling

Operation will be 261 business days per year, with eight-hour shifts of labor and three shifts per day.[2]

Table 11F.1 : Labor Schedule and Job Details for Ford On-Site WWTP

		Day shift(9:00 AM - 5:00 PM)	Middle Shift(5:00 PM - 1:00 AM)	Night Shift(1:00 AM - 9:00 AM)	Notes
1	Superviser #1	X			Salaried: 35,000/year
2	Superviser #2		X		Salaried: 35,000/year
3	Superviser #3			X	Salaried: 35,000/year
4	Operator #1	X			$15/hour
5	Operator #2		X		$15/hour
6	Operator #3			X	$15/hour
7	Skilled Tradesman/Engineer	X			$20/hour
				Total Cost per year(Salaried)	$105,000.00
				Total Cost per year(hourly labor)	$135,720.00
				Total Cost per year:	**$240,720.00**

OVERALL COST + CONSTRUCTION SCHEDULE

Huixin Zuo + Peiwen Wu

Appendix 12A: Summary Sheet

Area	8,455,812.00 SF		Cost Per SF	$54.83
Item	Description	Total Cost	Comments	Sources
I	SITE WORK	$176449813.6		
II	CONCRETE	$39404244.96		
III	METAL	$18385901.6		
IV	ROOFING	$24008737		
V	BUILDING EXTERIOR & INTERIOR	$3537165.04		
VI	MECHANICAL	$27699562		
VII	ELECTRICAL	$31230176		
IX	WASTE WATER TREATMENT PLANT	$1004780		
X	GENERAL CONDITION	$43,539,572		
	SUBTOTAL	$368,002,987.81		
	Bond	$3,680,229.88	1% of subtotal	Huixin
	Tax	$29,441,839.03	8% of subtotal	Huixin
	Builders Risk Insurance	$5,520,344.82	1.5% of subtotal	Huixin
	General Liability Insurance	$3,312,206.89	0.9% of subtotal	Huixin
	Design Contingency	$36,802,298.78	10% of subtotal	Huixin
	Construction Contingency	$11,040,689.63	3% of subtotal	Huixin
	CM Fees	$18,401,149.39	5% of subtotal	Huixin
	Total Cost	**$476,221,746.23**		

Appendix 12B: Body Building Cost Breakdowns

Area	500,000.00	SF			Total cost/SF=	109.45				
Item	Description	Unit	Quantity Takeoff	Unit Cost	Total Cost	Comments	Sources	Envision Category	Envision Points	Envision Cost
I	CONCRETE				$15,542,076.40					
1	**On Grade Mat Foundation**	CY	55,555	$262.48	$14,582,076.40	3" thick, cast-in-place concrete, including formwork	RSMeans Building Construction Cost Data 2012/Gina	**CR2.3**	16	$14,582,076
2	**Reinforcing rebar**	LF	1,000,000	$0.96	$960,000.00	Beam bolsters, lower, 1-1/2" high, plain steel	RSMeans Building Construction Cost Data 2012/Gina	**N/A**		
II	METAL				$7,404,292.00					
1	**Structural Steel**							**N/A**		
	Structure Steel Beam	Lf	20,000	$206.26	$4,125,200.00	W24*126	RSMeans Building Construction Cost Data 2012/Gina			
	Structure Steel Column	Lf	5,200	$129.67	$674,284.00	W14*99	RSMeans Building Construction Cost Data 2012/Gina			
	Shear stud	EA	500	$2.14	$1,070.00	1/2" diameter, 8-1/8" long	RSMeans Building Construction Cost Data 2012/Gina			
	Bracing Members	Lf	2,272	$110.00	$249,920.00	HSS8x8x1/4	RSMeans Building Construction Cost Data 2012/Gina			
2	**Metal Decking**							**N/A**		
	Corrugated Metal Roof Decking	SF	500,000	$2.45	$1,225,000.00	20 gauge, over 500 squares	RSMeans Building Construction Cost Data 2012/Gina			
3	**Metal Wall**									
4	Metal Corrugated Wall Panels	SF	88,200	$12.75	$1,124,550.00	Aluminum siding panels corrugated, on steel framing, 0.19 thick, natural finish	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Metal joist**	Ton	2	$2,134.00	$4,268.00	Long span joists, span to 96', average	RSMeans Building Construction Cost Data 2012/Gina	**N/A**		
III	Roofing				$9,194,750.00			**CR2.5**	6	$9,194,750
1	**Roof Insulation**	Sf	500,000	$1.14	$570,000.00	1" thick R 2.78	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Roof Waterproofing**	Sf	500,000	$4.20	$2,100,000.00	Cement waterproofing, 1/8" application, sprayed on	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Roof Membrane**	Sf	500,000	$13.00	$6,500,000.00	PVC roofing, heat welded seams, loose-laid & ballasted with stone/gravel	RSMeans Building Construction Cost Data 2012/Lupe			
4	**Drainage Gutter**	LF	3,000	$8.25	$24,750.00	Aluminum, stock units, 5" K type, 0.27 thick, plain	RSMeans Building Construction Cost Data 2012/Lupe			
IV	Exterior & Interior				$1,099,501.06		5	N/A		
1	**Overhead Doors**	EA	6	$10,000.00	$60,000.00	Dock door steel	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Door Frame & Trim**	EA	6	$2,500.00	$15,000.00	Flash tube frame, mil fin, open sill	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Entry/Exit Doors**	Sf	256	$379.76	$97,218.56	4 doors, steel and glass entrance, including hardware, minimum	RSMeans Building Construction Cost Data 2012/Lupe			
5	**Concrete Flooring Finish**	Sf	500,000	$0.25	$125,000.00	Concrete, scarify skin	RSMeans Building Construction Cost Data 2012/Lupe			
6	**Gypsum Wall Board**	Sf	88,650	$6.60	$585,090.00	5/8" fire rated gypsum board	RSMeans Building Construction Cost Data 2012/Lupe			
7	**Sheathing**	Sf	88,650	$0.78	$69,147.00	Pine plywood Reated Sheathing	RSMeans Building Construction Cost Data 2012/Lupe			
8	**Insulation**	Sf	88,650	$0.88	$78,012.00	Thermal or acoustical bat above ceiling, 2" thick	RSMeans Building Construction Cost Data 2012/Lupe			
9	**Interior Paint Finish**	Sf	88,650	$0.79	$70,033.50	Paint 3 Coat, smooth finish, brushwork	RSMeans Building Construction Cost Data 2012/Lupe			
V	MECHANICAL				$7,745,000.00		6			

1	**Domestic Water Distribution**	SF	500,000	$0.56	$280,000.00	Gas fired water heater	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
2	**Rain Water Drainage**	SF	500,000	$0.88	$440,000.00		RSMeans Square Foot Costs 2012/Lupe	**NW2.3**	9	$440,000.00
3	**Fire Protection**	SF	500,000	$4.73	$2,365,000.00	Includes sprinklers-ordinary hazard & standpipe-wet, class III	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
4	**Plumbing fixture and equipment**	EA	500,000	$8.47	$4,235,000.00	Toilet and service fixtures, supply and drainage	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
5	**HVAC**						Tiffany (current #s are old)	**N/A**		
	Cooling tower	EA	1			1-cell, 20x30ft	Ford is sizing this			
	Radiant Floor Heating	SF	500,000	$0.85	$425,000.00	http://www.radiantec.com/pricing/ballpark-estimates.php	Tiffany			
	Single Zone VAV/AHU	EA	1	$619000	$619000		Johnson Air			
	A/C	EA	1	$1703150	$1703150					
VI	**Electrical**				$11,420,000.00		7	**N/A**		
1	**Electrical Service/Distribution**	SF	500,000	$1.39	$695,000.00	Panel board and feeders	RSMeans Square Foot Costs 2012/Lupe			
2	**Lighting & Branch Wiring**	SF	500,000	$20.00	$10,000,000.00	High intensity discharge fixture, receptacles, switches, A.C. and misc. power	RSMeans Square Foot Costs 2012/Lupe			
3	**Communication & Security**	SF	500,000	$1.45	$725,000.00	Addressable alarm systems and emergency lighting	RSMeans Square Foot Costs 2012/Lupe			
	Total Cost				$54,727,769.46			Totals	31	$24,216,826

Appendix 12C: TCF Building Cost Breakdowns

TCF BUILDING						2016/06/06				
Area	500,000.00	SF			Total cost/SF=	109.50				
Item	Description	Unit	Quantity Takeoff	Unit Cost	Total Cost	Comments	Sources	Envision Category	Envision Points	Envision Cost
I	**Concrete**				$15,542,076.40					
1	**On Grade Mat Foundation**	CY	55,555	$262.48	$14,582,076.40	3" thick, cast-in-place concrete, including formwork	RSMeans Building Construction Cost Data 2012/Gina	**CR2.3**	16	$14,582,076.4
2	**Reinforcing rebar**	LF	1,000,000	$0.96	$960,000.00	Beam bolsters, lower, 1-1/2" high, plain steel	RSMeans Building Construction Cost Data 2012/Gina	**N/A**		
II	**Metal**				$7,404,292.00					
1	**Structural Steel**							**N/A**		
	Structure Steel Beam	LF	20,000	$206.26	$4,125,200.00	W24*146	RSMeans Building Construction Cost Data 2012/Gina			
	Structure Steel Column	LF	5,200	$129.67	$674,284.00	W14*99	RSMeans Building Construction Cost Data 2012/Gina			
	Shear stud	EA	500	$2.14	$1,070.00	1/2" diameter, 8-1/8" long	RSMeans Building Construction Cost Data 2012/Gina			
	Bracing Members	LF	2,272	$110.00	$249,920.00	HSS8x8x1/4	RSMeans Building Construction Cost Data 2012/Gina			
2	**Metal Decking**							**N/A**		
	Corrugated Metal Roof Decking	SF	500,000	$2.45	$1,225,000.00	20 gauge, over 500 squares	RSMeans Building Construction Cost Data 2012/Gina			
3	**Metal Wall**									
4	Metal Corrugated Wall Panels	SF	88,200	$12.75	$1,124,550.00	Aluminum siding panels corrugated, on steel framing, 0.19 thick, natural finish	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Metal joist**	Tons	2	$2,134.00	$4,268.00	Long span joists, span to 96', average	RSMeans Building Construction Cost Data 2012/Gina	**N/A**		
III	**Roofing**				$9,194,750.00		4	**CR2.5**	6	$9,194,750.00
1	**Roof Insulation**	SF	500,000	$1.14	$570,000.00	1" thick R 2.78	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Roof Waterproofing**	SF	500,000	$4.20	$2,100,000.00	Cement waterproofing, 1/8" application, sprayed on	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Roof Membrane**	SF	500,000	$13.00	$6,500,000.00	PVC roofing, heat welded seams, loose-laid & ballasted with stone/gravel	RSMeans Building Construction Cost Data 2012/Lupe			
4	**Drainage Gutter**	LF	3,000	$8.25	$24,750.00	Aluminum, stock units, 5" K type, 0.27 thick, plain	RSMeans Building Construction Cost Data 2012/Lupe			
IV	**Exterior & Interior**				$1,120,428.56		5	**N/A**		
1	**Overhead Doors**	EA	8	$10,000.00	$80,000.00	Dock door steel	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Door Frame & Trim**	EA	8	$2,500.00	$20,000.00	Flash tube frame, mil fin, open sill	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Entry/Exit Doors**	Sf	256	$379.76	$97,218.56	4 doors, steel and glass entrance, including hardware, minimum	RSMeans Building Construction Cost Data 2012/Lupe			
5	**Concrete Flooring Finish**	Sf	500,000	$0.25	$125,000.00	Concrete, scarify skin	RSMeans Building Construction Cost Data 2012/Lupe			
6	**Gypsum Wall Board**	Sf	88,200	$6.60	$582,120.00	5/8" fire rated gypsum board	RSMeans Building Construction Cost Data 2012/Lupe			
7	**Sheathing**	Sf	88,200	$0.78	$68,796.00	Pine plywood Reated Sheathing	RSMeans Building Construction Cost Data 2012/Lupe			

8	**Insulation**	Sf	88,200	$0.88	$77,616.00	Thermal or acoustical bat above ceiling, 2" thick	RSMeans Building Construction Cost Data 2012/Lupe			
9	**Interior Paint Finish**	Sf	88,200	$0.79	$69,678.00	Paint 3 Coat, smooth finish, brushwork	RSMeans Building Construction Cost Data 2012/Lupe			
V	**Mechanical**				$7,745,000.00		6			
1	**Domestic Water Distribution**	SF	500,000	$0.56	$280,000.00	Gas fired water heater	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
2	**Rain Water Drainage**	SF	500,000	$0.88	$440,000.00	Roof drainage	RSMeans Square Foot Costs 2012/Lupe	**NW2.3**	9	$440,000.00
3	**Fire Protection**	SF	500,000	$4.73	$2,365,000.00	Includes sprinklers-ordinary hazard & standpipe-wet, class III	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
4	**Plumbing fixture and equipment**	EA	500,000	$8.47	$4,235,000.00	Toilet and service fixtures, supply and drainage	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
5	**HVAC**							**N/A**		
	Cooling tower	EA	1		N/A	See	Tiffany			
	Radiant Floor Heating	SF	500,000	$0.85	$425,000.00	http://www.radiantec.com/pricing/ballpark-estimates.php	Tiffany			
	Single Zone VAV/AHU	EA	1	$619000	$619000		Tiffany			
	AC	EA	1	$1703150	$1703150		Tiffany			
VI	**Electrical**				$11,420,000.00		7	**N/A**		
1	**Electrical Service/Distribution**	SF	500,000	$1.39	$695,000.00	Panel board and feeders	RSMeans Square Foot Costs 2012/Lupe			
2	**Lighting & Branch Wiring**	SF	500,000	$20.00	$10,000,000.00	High intensity discharge fixture, receptacles, switches, A.C. and misc. power	RSMeans Square Foot Costs 2012/Lupe			
3	**Communication & Security**	SF	500,000	$1.45	$725,000.00	Addressable alarm systems and emergency lighting	RSMeans Square Foot Costs 2012/Lupe			
	Total Cost				$54,748,696.96			Totals	31	$24,216,826.40

Appendix 12D: Paint Building Cost Breakdowns

PAINT BUILDING							2016/06/06			
Area	128,000.00	SF			Total cost/SF=	118.11				
Item	Description	Unit	Quantity Takeoff	Unit Cost	Total Cost	Comments	Sources	**Envision Category**	**Envision Points**	**Envision Cost**
I	**Concrete**				$3,757,566.56					
1	**On Grade Mat Foundation**	CY	14,222	$262.48	$3,732,990.56	3" thick, cast-in-place concrete, including formwork	RSMeans Building Construction Cost Data 2012/Gina	**CR2.3**	16	$3,732,990
3	**Reinforcing rebar**	LF	25,600	$0.96	$24,576.00	Beam bolsters, lower, 1-1/2" high, plain steel	RSMeans Building Construction Cost Data 2012/Gina	**N/A**		
II	**Metal**				$1,094,538.60					
1	**Structural Steel**							**N/A**		
	Structure Steel Beam	Lf	880	$206.26	$181,508.80	W24*146	RSMeans Building Construction Cost Data 2012/Gina			
	Structure Steel Column	Lf	390	$129.67	$50,571.30	W14*99	RSMeans Building Construction Cost Data 2012/Gina			
	Shear stud	EA	300	$2.14	$642.00	1/2" diameter, 8-1/8" long	RSMeans Building Construction Cost Data 2012/Gina			
	Bracing Members	Lf	906	$110.00	$99,660.00	HSS8x8x1/4	RSMeans Building Construction Cost Data 2012/Gina			
2	**Metal Decking**							**N/A**		
	Corrugated Metal Roof Decking	SF	12,800	$2.45	$31,360.00	20 gauge, over 500 squares	RSMeans Building Construction Cost Data 2012/Gina			
3	**Metal Wall**									
	Metal Corrugated Wall Panels	SF	57,150	$12.75	$728,662.50	Aluminum siding panels corrugated, on steel framing, 0.19 thick, natural finish	RSMeans Building Construction Cost Data 2012/Lupe			
4	**Metal joist**	Ton	1	$2,134.00	$2,134.00	Long span joists, span to 96', average	RSMeans Building Construction Cost Data 2012/Gina	**N/A**		
III	**Roofing**				$2,363,360.00		4	**CR2.5**	6	$2,363,360
1	**Roof Insulation**	Sf	128,000	$1.14	$145,920.00	1" thick R 2.78	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Roof Waterproofing**	Sf	128,000	$4.20	$537,600.00	Cement waterproofing, 1/8" application, sprayed on	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Roof Membrane**	Sf	128,000	$13.00	$1,664,000.00	PVC roofing, heat welded seams, loose-laid & ballasted with stone/gravel	RSMeans Building Construction Cost Data 2012/Lupe			
4	**Drainage Gutter**	LF	1,920	$8.25	$15,840.00	Aluminum, stock units, 5" K type, 0.27 thick, plain	RSMeans Building Construction Cost Data 2012/Lupe			
IV	**Exterior & Interior**				$674,396.06		5	**N/A**		
1	**Overhead Doors**	EA	2	$10,000.00	$20,000.00	Dock door steel	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Door Frame & Trim**	EA	2	$2,500.00	$5,000.00	Flash tube frame, mil fin, open sill	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Entry/Exit Doors**	SF	256	$379.76	$97,218.56	4 doors, steel and glass entrance, including hardware, minimum	RSMeans Building Construction Cost Data 2012/Lupe			
5	**Concrete Flooring Finish**	SF	128,000	$0.25	$32,000.00	Concrete, scarify skin	RSMeans Building Construction Cost Data 2012/Lupe			
6	**Gypsum Wall Board**	SF	57,600	$6.60	$380,160.00	5/8" fire rated gypsum board	RSMeans Building Construction Cost Data 2012/Lupe			
7	**Sheathing**	SF	57,150	$0.78	$44,577.00	Pine plywood Retared Sheathing	RSMeans Building Construction Cost Data 2012/Lupe			
8	**Insulation**	SF	57,150	$0.88	$50,292.00	Thermal or acoustical bat above ceiling, 2" thick	RSMeans Building Construction Cost Data 2012/Lupe			

9	**Interior Paint Finish**	SF	57,150	$0.79	$45,148.50	Paint 3 Coat, smooth finish, brushwork	RSMeans Building Construction Cost Data 2012/Lupe			
V	**Mechanical**				$1,982,720.00		6			
1	**Domestic Water Distribution**	SF	128,000	$0.56	$71,680.00	Gas fired water heater	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
2	**Rain Water Drainage**	SF	128,000	$0.88	$112,640.00	Roof drainage	RSMeans Square Foot Costs 2012/Lupe	**NW2.1**	17	$112,640
3	**Fire Protection**	SF	128,000	$4.73	$605,440.00	Includes sprinklers-ordinary hazard & standpipe-wet, class III	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
4	**Plumbing fixture and equipment**	SF	128,000	$8.47	$1,084,160.00	Toilet and service fixtures, supply and drainage	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
5	**HVAC**							**N/A**		
	Cooling tower	EA	2			1-cell, 20x30ft	Ford is sizing this			
	Radiant Heating	SF	128,000	$0.85	$108,800.00	http://www.radiantec.com/pricing/ballpark-estimates.php	Tiffany			
	Multi-Zone VAV/AHU	EA	1	$619000	$619000		Tiffany			
	A/C	EA	1	$1703150	$1703150					
VI	**Electrical**				$2,923,520.00		7			
1	**Electrical Service/Distribution**	SF	128,000	$1.39	$177,920.00	Panel board and feeders	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
2	**Lighting & Branch Wiring**	SF	128,000	$20.00	$2,560,000.00	High intensity discharge fixture, receptacles, switches, A.C. and misc. power	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
3	**Communication & Security**	SF	128,000	$1.45	$185,600.00	Addressable alarm systems and emergency lighting	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
	Total Cost				$15,118,251.2			Totals	39	6208990

Appendix 12E: Office & Cafeteria Building Cost Breakdowns

OFFICE AND CAFETERIA BUILDING						2016/06/06				
Area	176,800.00	SF			Total cost/SF=	111.26				
Item	Description	Unit	Quantity Takeoff	Unit Cost	Total Cost	Comments	Sources	Envision Category	Envision Points	Envision Cost
I	**Concrete**				$4,562,525.60					
1	**On Grade Mat Foundation**	CY	16,370	$262.48	$4,296,797.60	3" thick, cast-in-place concrete, including formwork	RSMeans Building Construction Cost Data 2012/Gina	CR2.3	16	$4,296,797
3	**Reinforcing rebar**	LF	276,800	$0.96	$265,728.00	Beam bolsters, lower, 1-1/2" high, plain steel	RSMeans Building Construction Cost Data 2012/Gina	N/A		
II	**Metal**				$2,482,779.00					
1	**Structural Steel**							N/A		
	Structure Steel Beam	Lf	10,330	$117.00	$1,208,610.00	W24*146	RSMeans Building Construction Cost Data 2012/Gina			
	Structure Steel Column	Lf	1,680	$88.50	$148,680.00	W14*99	RSMeans Building Construction Cost Data 2012/Gina			
	Shear stud	EA	400	$2.14	$856.00	1/2" diameter, 8-1/8" long	RSMeans Building Construction Cost Data 2012/Gina			
	Bracing Members	Lf	2,556	$110.00	$281,160.00	HSS8x8x1/4	RSMeans Building Construction Cost Data 2012/Gina			
2	**Metal Decking**							N/A		
	Flooring Decking	SF	38400	$2.58	$99,072.00	3"deep, 20 gauge	RSMeans Building Construction Cost Data 2012/Gina			
	Corrugated Metal Roof Decking	SF	176,800	$2.45	$433,160.00	20 gauge, over 500 squares	RSMeans Building Construction Cost Data 2012/Gina			
3	**Metal Wall**									
	Metal Corrugated Wall Panels	SF	24,160	$12.75	$308,040.00	Aluminum siding panels corrugated, on	RSMeans Building Construction Cost Data 2012/Lupe	N/A		
						steel framing, 0.19 thick, natural finish				
4	**Metal joist**	Ton	1.5	$2,134.00	$3,201.00	Long span joists, span to 96', average	RSMeans Building Construction Cost Data 2012/Gina	N/A		
III	**Roofing**				$3,255,877.00		4	CR2.5	6	$3,255,877.00
1	**Roof Insulation**	Sf	176,800	$1.14	$201,552.00	1" thick R 2.78	RSMeans Building Construction Cost Data 2012/Lupe			
2	**Roof Waterproofing**	Sf	176,800	$4.20	$742,560.00	Cement waterproofing, 1/8" application, sprayed on	RSMeans Building Construction Cost Data 2012/Lupe			
3	**Roof Membrane**	Sf	176,800	$13.00	$2,298,400.00	PVC roofing, heat welded seams, loose-laid & ballasted with stone/gravel	RSMeans Building Construction Cost Data 2012/Lupe			
4	**Drainage Gutter**	LF	1,620	$8.25	$13,365.00	Aluminum, stock units, 5" K type, 0.27 thick, plain	RSMeans Building Construction Cost Data 2012/Lupe			
IV	**Exterior & Interior**				$642,839.36		5			
1	**Curtain Wall**	Sf	6,240	$57.55	$359,112.00	Aluminum stock, including single glazing, average	RSMeans Building Construction Cost Data 2012/Lupe	N/A		
2	**Door Frame & Trim**	Lf	192	$22.00	$4,224.00	Flash tube frame, mil fin, open sill	RSMeans Building Construction Cost Data 2012/Lupe	N/A		
3	**Emergency Exit Doors**	SF	256	$32.53	$8,327.68	Metal fire door, flush, B label, full panel, 20 ga.	RSMeans Building Construction Cost Data 2012/Lupe	N/A		
4	**Curtain Wall Entry Door**	Sf	256	$32.53	$8,327.68	Metal fire door, flush, B label, full panel, 20 ga.	RSMeans Building Construction Cost Data 2012/Lupe	N/A		

6	**Concrete Flooring Finish**	SF	176,800	$0.25	$44,200.00	Concrete, scarify skin	RSMeans Building Construction Cost Data 2012/Lupe	**N/A**		
7	**Gypsum Wall Board**	SF	24,160	$6.60	$159,456.00	5/8" fire rated gypsum board	RSMeans Building Construction Cost Data 2012/Lupe	**N/A**		
8	**Sheathing**	SF	24,160	$0.78	$18,844.80	Pine plywood Reated Sheathing	RSMeans Building Construction Cost Data 2012/Lupe	**N/A**		
9	**Insulation**	SF	24,160	$0.88	$21,260.80	Thermal or acoustical bat above ceiling, 2" thick	RSMeans Building Construction Cost Data 2012/Lupe	**N/A**		
10	**Interior Paint Finish**	SF	24,160	$0.79	$19,086.40	Paint 3 Coat, smooth finish, brushwork	RSMeans Building Construction Cost Data 2012/Lupe	**N/A**		
V	**Mechanical**				$3,260,392.00		6			
1	**Domestic Water Distribution**	SF	176,800	$0.44	$77,792.00	Gas fired water heater	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
2	**Rain Water Drainage**	SF	176,800	$0.62	$109,616.00		RSMeans Square Foot Costs 2012/Lupe	**NW2.3**	9	$109,616.00
3	**Fire Protection**	SF	176,800	$4.73	$836,264.00	Includes sprinklers-ordinary hazard & standpipe-wet, class III	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
4	**Plumbing fixture**	SF	176,800	$3.70	$654,160.00	Toilet and service fixtures, supply and drainage	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
5	**HVAC**						Tiffany	**N/A**		
	Cooling tower	EA	1		N/A	2-cell, 35x30ft	Ford is sizing this			
	Radiant Floor Heating	SF	176,800.00	$0.85	$150,280.00	http://www.radiantec.com/pricing/ballpark-estimates.php	Tiffany			
	Chilled Beams	SF	176,800.00	$4.60	$813,280.00	Space cooling equipment	Tiffany			
	Single Zone VAV/AHU	EA	1	$619,000.00	$619,000.00		Tiffany			
VI	**Electrical**				$5,466,656.00		7			
1	**Electrical Service/Distribution**	SF	176,800	$4.71	$832,728.00	Panel board and feeders	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
2	**Lighting & Branch Wiring**	SF	176,800	$20.00	$3,536,000.00	High intensity discharge fixture, receptacles, switches, A.C. and misc. power	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
3	**Communication & Security**	SF	176,800	$5.97	$1,055,496.00	Addressable alarm systems and emergency lighting	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
4	**Other Electrical Systems**	SF	176,800	$0.24	$42,432.00	Emergency generator, 7.5 kw, uninterruptible power supply	RSMeans Square Foot Costs 2012/Lupe	**N/A**		
	Total Cost				$19,671,068.96			Totals	31	$7,662,290

Appendix 12F: WWTP Cost Breakdowns

WWTP						2016/06/06				
Area	1,000.00	SF			Total cost/SF=	1004.78				
Item	Description	Unit	Quantity Takeoff	Unit Cost	Total Cost	Comments	Sources	Envision Category	Envision Points	Envision Cost
I	WASTE WATER TREATMENT PLANT							RA 0.0, RA3.1, RA3.2	46	$986,910.00
1	Site Work					Factored into total site work	RSMeans Building Construction Cost Data 2012/Gina			
2	Foundation formwork	SF	1000	$9.65	$9,650.00	Cast-in-place concrete forming, Mat foundation, Job-built plywood, 1 use	RSMeans Building Construction Cost Data 2012/Gina			
3	Foundation slab-on-grade	SF	1000	$8.22	$8,220.00	Curb froms, wood, 6" to 12" high, on grade, one use	RSMeans Building Construction Cost Data 2012/Gina			
4	WWTP building shell	SF	1000	$250.00	$250,000.00		*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
5	Electrical Service and Distribution	SF	1000	$1.39	$1,390.00	Panel board and feeders	*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
6	Lighting and Branch Wiring	SF	1000	$13.02	$13,020.00	High intensity discharge fixture, receptacles, switches, A.C. and misc. power	RSMeans Building Construction Cost Data 2012/Gina			
7	Telemetry				$12,500.00		*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
8	RO Skid	EA	4	$75,000.00	$300,000.00	GE E-Series (E8-144K-DLX-50), 100 GPM, 21 membranes, 400 square feet of membrane	*https://engg.gewater.com/d9764fb4-30d6-4c61-bc3e-372b6f671df7*			
9	RO Installation				$30,000.00	10% of equipment cost	*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			

10	**RO pre-filter skid**	EA	1	$175,000.00	$175,000.00	Pretreatment, 1 micron filter and housing at 450 GPM	*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
11	**Brackish Water storage tank**	EA	1	$30,000.00	$30,000.00		*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
12	**Pretreatment Chemical Feed System**	EA	4	$25,000.00	$100,000.00	Sodium Hydroxide, Surfactant, cleaning chemicals, etc	*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
13	**Process Piping**				$75,000.00	pumps(350 gpm), valves, pipes	*Report for Illinois American Water Company. Aubrey Service Area. Value Engineering Report for Water Supply and Treatment Improvements. Rep. no. 184-001273. N.p.: Strand Associates, n.d. Print. March 2015.*			
	Total				$1,004,780.00			Totals	46	$986,910.00

Appendix 12G: Site Work Cost Breakdowns

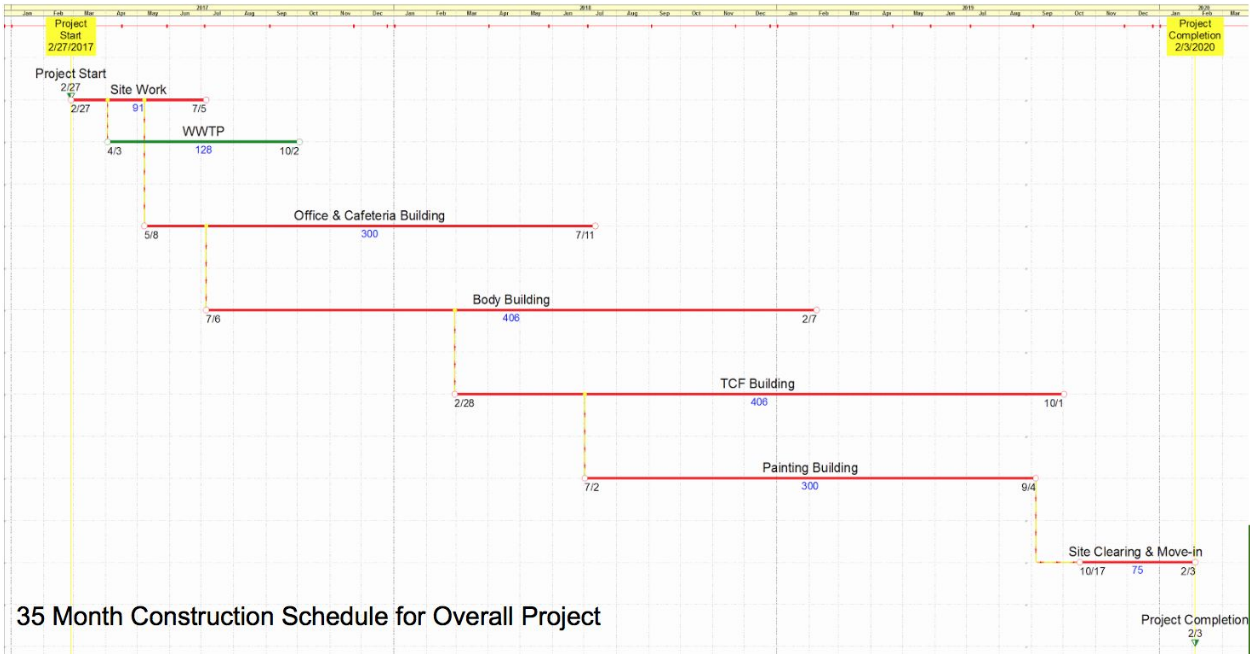
SITE WORK												2016/06/06
Area	7,000,000.00	SF			Total cost/SF=		$25.60					
Item	**Description**	**Unit**	**Quantity takeoff**	**Unit Price**	**Total Cost**	**Comments**	**Source of quantity takeoff data**	**Source of unit price**	**Envision Category**	**Envision Points**	**Envision Cost**	
1	**Mass Excavation**											
1.1	**Erosion Control**	LF	170000	$0.80	$136,000.00		Silt fence, polypropyle ne,3'' high	RSMeans building construction cost data 2012	**NW1.6**	4	$136,000.00	
1.2	**Fence & Stone Entrance**	LF	14144	$7.81	$110,464.64			RSMeans building construction cost data 2012	**QL3.2**	6	$110,464.64	
1.3	**Detention Pond Soil**											
1.3.1	Excavation and transport of contaminated soil	CF	642,477	$100.00	$64,247,700.00		Jack	RSMeans building construction cost data 2012				
1.3.2	Excavation of non-contaminated soil	CF	1,385,08 3	$6.45	$8,933,785.35		Jack					
2	**Fill & Compaction & Capping**								**NW1.7**	23	#REF!	
1.1	**Pre-Compaction Fill**	CF	3000000	$1.80	$5,400,000.00	Gravel fill, under slab, 12"deep after compaction	Nathan	RSMeans building construction cost data 2012				
1.2	**Refill**	CF	300000	$1.80	$540,000.00		Nathan	RSMeans building construction cost data 2012				
1.3	**Compaction**											
1.3.1	DDC Mobilization	LS	1	$30,000.00	$30,000.00			RSMeans building construction cost data 2012				
1.3.2	Deep dynamic compaction	SF	3700000	$1.00	$3,700,000	2 passes	Nathan	RSMeans building construction cost data 2012				
1.4	**Capping**											
	Hazardous Waste Cap	Acre	192	$370,300.00	$71,097,600							
3	**Grading**											
3.1	**Grubbing & Cleaning**	Acre	277	$4,300.00	$1,191,100.00	Cut & chip light trees to 6'' diameter	Lupe	RSMeans building construction cost data 2012	**NW3.3**	8	$1,191,100. 00	
4	**Rail Track**											
4.1	Rail Excavation	CF	414,000	$6.45	$2,670,300							
4.2	Rail Track construction	EA	6	$150,000.00	$900,000.00		Ian	Ian	**N/A**			
4.3	Industry Track Siding	LF	10800	$160.00	$1,728,000		Ian	Ian	**N/A**			
4.4	Asphalt paving	CF	289,800	$0.32	$92,736.00	0.7' thick						
5	**Site Utilities**											
5.1	**Water piping**											
5.1.1	Horizontal boring	LF	6000	$639.00	$3,834,000.00	$139/LF for HDPE pipe with OD 8.625", $500/LF for steel casing.	Ian	Julia/Ian	NW2.1	17	$5,638,470	
5.1.2	Standard Pipeline	LF	4900	$196.00	$960,400.00		Ian	Julia/Ian	^			
5.2	**Other piping**											
5.2.1	Sanitary Sewer	LF	360	$142.00	$51,120.00		Jack	RSMeans Heavy Construction Cost Data 2015				

5.2.2	Storm Water Pipe	LF	24000	$31.50	$756,000.00		Jack	RSMeans Heavy Construction Cost Data 2015			
5.3	**Storm Sewer Inlet**	EA	150	$78.00	$11,700.00		Jack	RSMeans building construction cost data 2012			
5.4	**Sanitary Manhole**	EA	12	$1,200.00	$14,400.00		Assumption	RSMeans building construction cost data 2012			
5.5	**Water-fire hydrant**	EA	10	$665.00	$6,650.00		Assumption	RSMeans building construction cost data 2012			
5.6	**Storm Clean Out**	EA	12	$350.00	$4,200.00		Assumption	RSMeans building construction cost data 2012			
6	Site Concrete										
6.1	**Sidewalk and Courtyard**	CF	19799	$6.80	$134,632.40	including joints, finishing and curing, 4" depth	Lupe		QL2.6	12	$638,593.46
	Aggregate Base Course	CF	29698	$0.80	$23,758.66	6" deep	Lupe	RS Means Building Construction Cost Data 2007			
6.2	**Bus Terminal**	CF	7084								
	Aggregate Base Course	SF	21252			6" deep					
6.3	**Curb & Gutter**	LF	77452	$6.20	$480,202.40	3" High	Lupe	RS Means Building Construction Cost Data 2007			
7	Paving										
7.1	**Parking and Roads**	CF	583891	$8.00	$4,671,126	4" Depth	Lupe/Dan/Ian		N/A		
7.2	**Bike Lanes**	CF	15743	$6.20	$97,607.48	4" Depth	Lupe/Dan/Ian				
7.3	Aggregate Base Course	CF	899451	$4.20	$3,777,693	6" Depth					
8	**Site Improvement**										
8.1	**122nd St Entrance**	EA	1	$800,000.00	$800,000.00		Ian	Ian			
8.2	**122nd and Torrence**	EA	1	$1,000,000	$1,000,000		Ian	Ian			
8.3	**103rd and Stoney Island Ave**	EA	1	$300,000.00	$300,000.00		Ian	Ian			
8.4	**130th and CISCO Access Road**	EA	1	$600,000.00	$600,000.00		Ian	Ian			
9	**Landscaping**								**QL3.2**	Inc above	$0.00
9.1	**Native Grass on Cap**	Acre	192	$4,000.00	$768,000						
9.2	**Building Perimeter Planting**	SF	28620	$5.02	$143,672.40	Including 1" deep hand spread soil preparation and truck dumped, screened, 4" deep landscape grading	Dan/Lupe	RSMeans building construction cost data 2012	Totals	37	7468163.458
9.3	**Green Medians**	Acre	6	$2,000.00	$12,509.03	(2k-4k)	Lupe/Dan/Ian, not include the trees		NW2.2	9	$12,509.03
	Total Site Work Cost				**$179,212,849.62**						

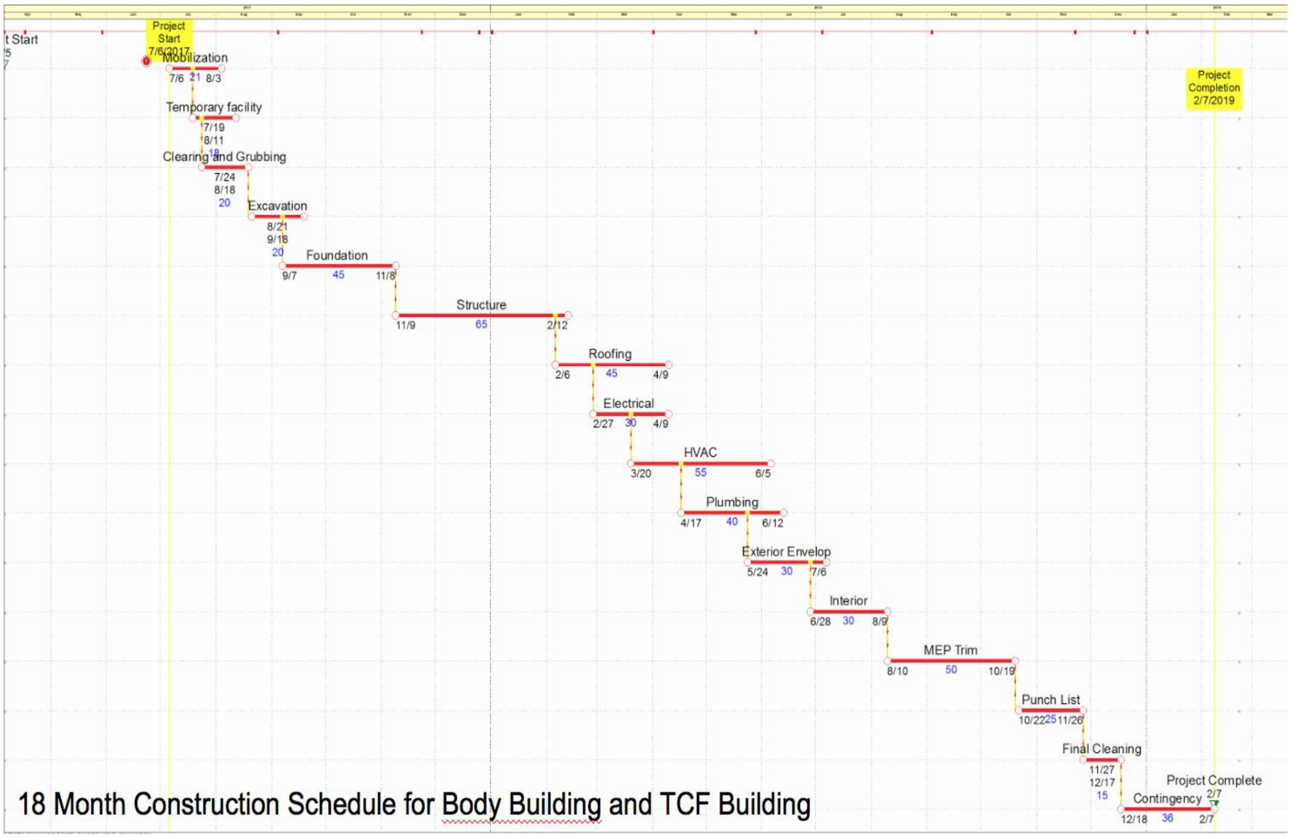
Appendix 12H: General Conditions

GENERAL CONDITION						2016/06/06
Item	**Description**	**UNIT**	**Quantity**	**Unit Price**	**Total**	**Comment**
I	**Project Personnel**					
1	Project Executive	WK	35	$2,500.00	$87,500.00	
2	Project Manager(2)	WK	280	$2,100.00	$588,000.00	Full time
3	General Superintendent	WK	70	$2,200.00	$154,000.00	1/2 time
4	Superintendent	WK	140	$1,975.00	$276,500.00	Full time
5	Assistant Superintendent(3)	WK	210	$1,750.00	$367,500.00	1/2 time
6	Field Engineer(3)	WK	420	$1,650.00	$693,000.00	Full time
7	Surveyor	WK	35	$1,000.00	$35,000.00	1/4 time
8	Safety Supervisor(3)	WK	186	$1,550.00	$288,300.00	Part time
9	Project Accountant	WK	25	$1,150.00	$28,750.00	Part time
10	MEP Coordinator(2)	WK	108	$1,650.00	$178,200.00	Part time
11	Estimator	WK	35	$2,050.00	$71,750.00	1/4 time
	Subtotal				$2,768,500.00	
II	**Temporary Utilities**					
1	Telephone	MO	35	$81.00	$2,835.00	
2	Temporary Power to Building	LS	1	$8,000.00	$8,000.00	
3	Temporary Electricity	MO	35	$70.00	$2,450.00	
4	Water Service and Meter	LS	1	$8,000.00	$8,000.00	
5	Field Office HVAC	Mo	35	$152.00	$5,320.00	
	Subtotal				$26,605.00	
III	**Temporary Construction**					
1	Field Office	LS	2	$3,500.00	$7,000.00	
2	Job Sign	EA	60	$45.00	$2,700.00	
3	Temporary Toilets(5)	MO	35	$110.00	$3,850.00	
4	Silt Fence	LF	14144	$0.85	$12,022.40	
5	Sidewalk Canopy	SF	4950	$0.71	$3,514.50	
6	Waste Dumpster(3)	WK	420	$630.00	$264,600.00	
7	Recycling Dumpster(3)	WK	150	$630.00	$94,500.00	
8	Temporary Road	SY	16219	$7.11	$115,317.09	
9	Scaffolding	SF	258160	$132.00	$34,077,120.00	Building exterior, wall face, 1 to 5 stories, 6'-4"x5' frames
	Subtotal				$34,580,623.99	
IV	**Winter Conditions**					
1	Concrete Slab Enclosure Protection	CY	141,702	$5.30	$751,020.60	
2	Building Heat	MO	10	$137,000.00	$1,370,000.00	
	Subtotal				$2,121,020.60	
V	**Supplies and Service for Equipment**					
1	Small Tools and Consumables	LS	1	$45,000.00	$45,000.00	General tool purchase
2	Temporary Hoist	WK	124	$4,200.00	$520,800.00	
3	Temporary Crane	MO	31	$90,225.00	$2,796,975.00	
4	Load and Haul Equipment	LS	1	$12,500.00	$12,500.00	
	Subtotal				$3,375,275.00	
VI	**Miscellaneous Requirements**					
1	Field Office Supplies	MO	35	$200.00	$7,000.00	
2	Final Clean-up	LS	1	$114,730.00	$114,730.00	
3	Testing	LS	1	$48,200.00	$48,200.00	
4	First Add Attendant and Safety	MO	20	$5,750.00	$115,000.00	
	Subtotal				$284,930.00	
VII	**Permits**	LS	1	$382,617.00	$382,617.00	
	TOTAL				$43,539,571.59	

Appendix 12I: Preliminary Overall Schedule



Appendix 12J: Preliminary Schedule for Body Building and TCF Building



Appendix 12K: Preliminary Schedule for Paint Building and Office & Cafeteria Building