2019-2021

Prospective Residential Development of a 17-Acre Parcel and Site Utilities for a 34-Acre Parcel in Adams County, WI

Civil & Environmental Engineering 578: Senior Capstone Design
University of Wisconsin-Madison

UniverCity Alliance
UNIVERSITY OF WISCONSIN–MADISON

Adams County Wisconsin

SAAWM Consulting Engineering

SAAWM Consulting Engineering
324 Wendt Commons
215 N Randall Ave
Madison, WI 53715

April 6th, 2021

To: Jan Kucher, PE
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

RE: Preliminary Design Report

Adams County Residential Development in the City of Adams

Dear Mr. Kucher,

Enclosed in this document is the preliminary design alternatives proposed by SAAWM Consulting Engineering for the utilities design and development of a residential neighborhood located in Adams County, WI. SAAWM is grateful for the opportunity to work on this project and we look forward to finalizing the designs in collaboration with Adams County.

SAAWM Consulting Engineering has focused on continuing the scope of work outlined in the proposal. We have had many discussions involving the site with all the stakeholders involved and have analyzed demographic trends of the area to best suit the needs of the community. The design alternatives discussed in this report are based on in depth analysis of the existing site conditions and are compliant with the applicable regulations and standards of the area.

Each alternative is thoroughly analyzed through four disciplines in Civil Engineering. They include transportation, water resources, construction, and geotechnical analysis. In addition to these four areas, we will consider the social, economic, and environmental sustainability of each alternative. A final design will be recommended from the enclosed decision matrix.

SAAWM Consulting Engineering would like to emphasize its commitment and dedication to provide a thoughtfully planned project for Adams County. We believe our final recommendation for the utilities and residential neighborhood will be an attractive addition to the area. For any additional questions or concerns, please contact Will Claridge at wclaridge@wisc.edu.

Sincerely,

UW-Madison Student
Project Manager
wclaridge@wisc.edu
SAAWM Consulting Engineering

Preliminary Design Report:

Prospective Residential Development of a 17-Acre Parcel and Site Utilities for a 34-Acre Parcel in Adams County, WI

Prepared For:

Adams County Wisconsin

Prepared By:

SAAW Consulting Engineering

SAAWM Consulting Engineering
Team 15
April 6th, 2021

Department of Civil and Environmental Engineering
UNIVERSITY OF WISCONSIN–MADISON

Disclaimer

The concepts, drawings and written materials provided here were prepared by students in the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison as an activity in the course Civ Engr 578 – Senior Capstone Design/GLE 479 – Geological Engineering Design. These do not represent the work products of licensed Professional Engineers. These are not for construction purposes.

SAAW Consulting Engineering

1. Executive Summary

1.1. Project Description

As seen in Figure A, the area proposed for residential development is bounded W. North St., N. Cedar St., W. Park St., and N. Juneau St. in the City of Adams. The development of this area will include placement of housing lots, roadway placement and grading, storm sewer design, and public utilities. In regard to public utilities, the design of sanitary sewer and water were requested for the following three areas: the proposed residential development on the south side of W. North St. in the City of Adams, the proposed County Facilities Building on the south side of the 34-acre parcel to the north of W. North St., and the future residential development on the north side of the 34-acre parcel. The City Engineer, MSA, provided the existing utility plans necessary for design.

Figure A. Aerial view of northern parcel requiring design of public utilities, outlined in red, and southern parcel requiring residential development and public utilities design, outlined in blue (Google Earth). Note: Scale in top left of figure

The purpose of this project is to provide utility and roadway design for future residential lots that meet the City's demand for starter home housing units and provide public utilities to service future developments. After meeting with the client, a layout of the residential development was desired and will be provided in addition to the initial project purpose. When creating design alternatives, the main areas of focus for engineering analysis will include geotechnical, transportation, hydraulic, and construction design.

To address concerns with the 90% Preliminary Design, an infiltration basin has been added to the design to remediate surface water contamination, improve the quality of water discharged into the stream, and allow for groundwater recharge. The infiltration basin has been sized in accordance with WDNR standards to retain the runoff of surrounding impermeable area during a significant storm event. It is placed between the extension of Lincoln St., Vincennes St., and the ditch.

1.2. Design Constraints

Based upon initial review of the project's location and preliminary design work, several constraints were identified. The most concerning factor is perhaps the economic aspect of the project in terms of the marketability of the developed lots. Given the size of the project budget, the finished product value will be significantly higher than current lot prices. While the main concern is delivering a project that is designed and constructed properly, there may be concerns about affordability when purchasing the finished lots. In addition, the fact that some land is owned by the City another portion is owned by the County has caused political challenges in terms of communication with the proper entity. Furthermore, spatial limitations have been encountered with the drainage swale that crosses through the southern parcel. For social concerns, community members may be opposed to the clearing of more trees in the area for aesthetic purposes with existing developments nearby. Other constraints such as constructability and ethical practices have not posed major concerns to the project yet, but they should be considered throughout the duration of the project. Matters over sustainability will be covered later in further detail in the report, in which significant changes have been made to the environmental approach.

1.3. Proposed Design Alternatives

Three design alternatives have been developed for the residential neighborhood in the southern parcel. These alternatives were formed with input from Adams County and the City of Adams and seek to meet the needs of the community.

Utility Design

For each of the three designs, roadways and public utilities will be designed to meet the needs of storm sewer, sanitary sewer, and water. Since these utilities are intended to meet the needs of the development and to follow regulatory codes, the utility design will have little variation between design except for any spatial differences.

Alternative 1: Single Family Lots

The first alternative breaks the existing land into 36 lots sized at 100’ by 135’ that are to be bought and developed into single family housing lots. There are an additional 4 units of varying size near the stream. This style of residential housing is standard throughout the City of Adams. The houses that would be developed on this land would meet median income housing and would help fill the need of affordable housing in the community. A sketch of the proposed layout is shown in Figure B.

Figure B. Design Option 1: Single Family Lots

The pink hatch represents single family lots, the green hatch represents shared green space, and the red hatch is privately owned land.

Alternative 2: Multi & Single-Family Lots

The second alternative has 18 traditional single family lots in the southern half of the parcel and will have 15 multi-family lots sized at 135' by 150' in the northern half of the parcel. Multifamily development is planned to include attached housing units such a condominium or duplex. This combination of multi and single family lots would increase the housing density of the neighborhood and allow for more families to live in the same area of developed land, while helping to reduce lot costs. A sketch of the proposed layout is shown in Figure C.

Figure C. Design Option 2: Multi & Single-Family Lots

The pink hatch represents single family lots, the green hatch represents shared green space, the orange hatch represents multi family lots, and the red hatch is privately owned land.

Alternative 3: Pocket Housing & Single-Family Lots

The third alternative utilizes a pocket housing style in the northern half of the parcel and includes 18 single family lots in the southern portion. Pocket style neighborhoods incorporate shared green spaces and are designed to increase a sense of community. This design is especially appealing for older living communities. A sketch of the proposed layout is shown in Figure D.

Figure D. Design Option 3: Pocket & Single-Family Lots

The pink hatch represents single family lots, the green hatch represents shared green space, the purple hatch represents pocket style housing, and the red hatch is privately owned land.

1.4. Opinion of Probable Cost

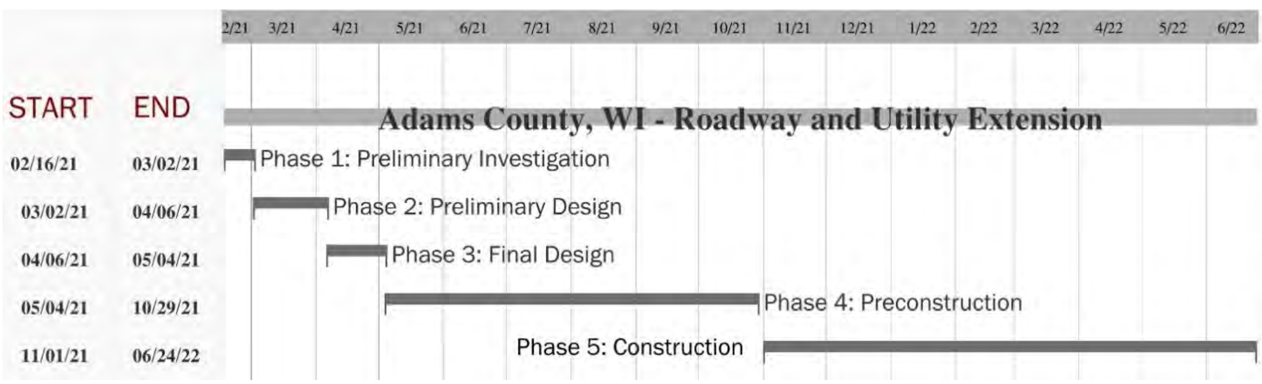
A preliminary opinion of probable cost (OPC) summary has been prepared, and it consists of an opinion of probable construction cost and net present value estimate. Due to current knowledge-based and data-based uncertainties, this OPC will evolve during the final design phase. A contingency of 20% was added to the construction component of the capital cost estimate to account for these uncertainties. Based on construction/utilities costs and the project fee, the calculated probable construction cost was $3,061,300 for Alternative 1, $3,047,000 for Alternative 2, and $3,565,100 for Alternative 3. Note that each project cost estimate exceeds the $2,000,000 budget provided by the client in the Request for Proposal.

Table A. Summary of Probable Construction Costs

Summary of Probable Construction Costs			
Component	All Single Family	Multi & Single	Pocket Style & Single
	Alternative 1	Alternative 2	Alternative 3
Utilities	$ 1,249,100	$ 1,237,700	$ 1,386,950
Construction	$ 1,070,000	$ 1,070,000	$ 1,314,450
Subtotal	$ 2,319,000	$ 2,308,000	$ 2,701,000
Contigency (20%)	$ 464,000	$ 462,000	$ 540,000
CONSTRUCTION TOTALS:	$ 2,783,000	$ 2,770,000	$ 3,241,000
PROJECT FEE (10%):	$ 278,300	$ 277,000	$ 324,100
PROBABLE CONSTRUCTION COST TOTALS:	$ 3,061,300	$ 3,047,000	$ 3,565,100

1.5. Project Schedule

The project schedule consists of a design section (Phases 1 – 3) and construction section (Phases 4 – 5). After the bid is awarded, construction is planned to begin on November 1, 2021 and end on June 24, 2022—this is a tentative construction schedule because groundbreaking will likely be delayed until Spring 2022. These dates are subject to change during the final design phase.



1.6. Design Evaluation

The three design alternatives were evaluated using the decision matrix shown in Table 1 below. Factors used to assess the options were grouped into four areas of emphasis: economic, social, construction, and environmental effects. The factors are listed on the left side of the table with decreasing significance from top to bottom within each group. The emphasis of each factor was quantified into weight magnitudes. For each design alternative, the factors were scored in the value column on a scale of 1-10 based on how well the factor was fulfilled by the design option, with 10 being the best possible score. The maximum score achieved was 7.50 for All Single-Family Design, and the minimum score attained was 6.40 for Pocket Style and Single-Family Design

Table B. Design Alternative Decision Matrix

Decision Matrix							
Factor	Weight	All Single Family		Multi & Single		Pocket Style & Single	
		Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
Economic	45%						
Net Present Value	25.0%	6	1.50	5	1.25	3	0.75
Marketability	20.0%	8	1.60	7	1.40	8	1.60
Social	25%						
Community Appeal	15.0%	9	1.35	5	0.75	7	1.05
Aesthetics	5.0%	8	0.40	6	0.30	7	0.35
Traffic Flow	5.0%	8	0.40	8	0.40	6	0.30
Construction	15%						
Utility Function	10.0%	9	0.90	9	0.90	8	0.80
Constructability	5.0%	8	0.40	8	0.40	7	0.35
Environmental	15%						
Environmental Impact	10.0%	6	0.60	6	0.60	8	0.80
Green Space	5.0%	7	0.35	5	0.25	8	0.40
TOTALS:	100%	Total:	7.50	Total:	6.25	Total:	6.40

1.7. Final Recommendation

Based on the findings of decision matrix and engineering expertise, it is recommended that All Single-Family Design Option be pursued. Most notably, this design alternative scored the highest in social and economic factors. The evaluation has determined that the structure of single family lots will enhance constructability, the amount of green space, and traffic flow. Additionally, the individual units will be of highest appeal to the community. This design appeal will generate increased demand for this style of housing and ultimately produce a favorable rate of return for the project.

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2. Project Overview

2.1. Introduction

Adams County seeks examination and civil engineering services for the area roughly bounded by Godwin Circle (north), Quincy St. and N. Cedar St. (east), W. Park St. (south), and N. Juneau St. and Park St (west). As outlined in red in Figure 1, water and sanitary sewer utilities will be designed for both the new County Facilities Building located at the northeast corner of Juneau and West North St, and the northern area of this parcel to service future development. Additionally, three alternatives have been evaluated for the area south of West North St, as outlined in blue in Figure 1, which include residential development options, roadway design, stormwater management, and public utilities.

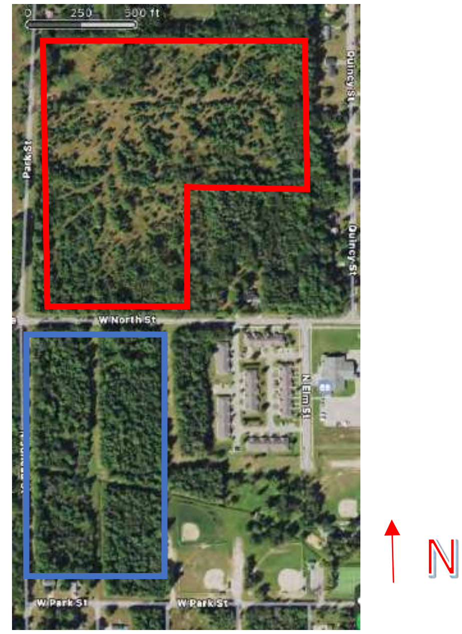

Figure 1. Aerial view of northern parcel requiring design of public utilities, outlined in red, and southern parcel requiring residential development and public utilities design, outlined in blue (Google Earth). Note: Scale in top left of figure

2.2. Project Background & Needs

With the need to extend water and sanitary sewer mains for the planned construction of the County Facilities Building in the Village of Friendship, Adams County is interested in leveraging the investment in those utilities to support residential development to the south. As displayed in Figure 2, The County is working with the architectural firm, Potter-Lawson, on site layout options for a proposed County Facilities Building on a 34-acre site to the north of West North St. and is in need of civil engineering services for design of public utilities to serve that development and future development in the north. The 17- acre wooded area to the east of N. Juneau St, between West North St and West Park St has been examined for utilities and roadways suitable for residential development.

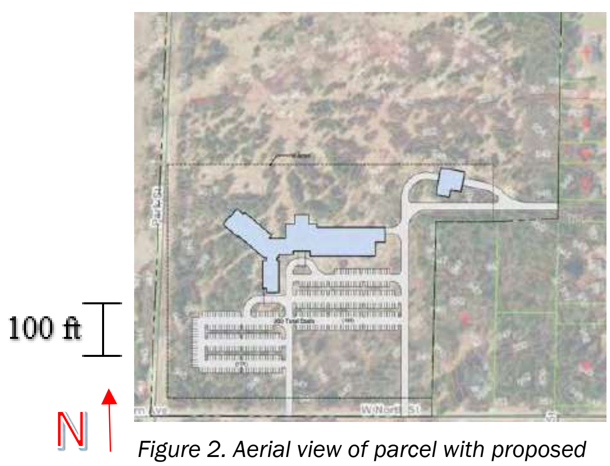

Figure 2. Aerial view of parcel with proposed County Facilities Building north of W North St (Potter Lawson).

County staff, City staff, and Potter Lawson have provided necessary information on the City's housing needs and utility demands for the County Facilities Building. Site visits and conversations have emphasized the City's need for the development of affordable, residential units to provide housing for a mix of their older population and individuals moving to the area, such as newly hired teachers. Each alternative includes the design of sanitary sewer, water, stormwater, grading, and roadways.

2.3. Project Scope

During the initial investigation stage, intended purpose of the project was confirmed with both County and City officials. The scope evolved from what was first stated in the request for proposal to include water and sanitary sewer utilities design for the County Facilities Building and area north of West North St in addition to the originally requested residential development of the parcel south of West North St. Then, geotechnical subsurface conditions were investigated at the site to determine ground water levels and soil conditions for design. This investigation was conducted through both review of previous studies completed by the City of Adams and on-site classification. The findings of this investigation were applied to four areas of engineering expertise for preliminary design: Geotechnical, Hydraulic and Stormwater, Transportation, and Construction.

In the preliminary design stage, housing lots, water, sanitary sewer lines, and roadway extensions were laid out in accordance with the existing land structure, and preliminary roadway grades were determined. After roadway grades were assigned, the runoff volume during significant rainfall events was calculated to design for appropriate stormwater runoff management. Last, an opinion of probable construction costs was compiled to estimate project costs of each design alternative. In evaluating each design option, a decision matrix was created to weigh the relative importance of environmental, social, and economic factors, to assist in providing a final recommendation.

Moving forward with the final design of the preferred alternative, final drawings, contract front end documents, technical specifications, a final geotechnical report, a final opinion of probable construction costs, project schedule, and documented sustainability targets will be produced. Upon completion of the engineering services, applications for required regulatory agency permits (permit fees to be paid directly by Client) will be submitted and routine bidding assistance, construction administration and observation, and completed project documentation services will be provided.

2.4. Project Constraints

Economic: After researching real estate values in Adams County, the typical lot size of ¼-acre (similar to the size of nearby residential lots), is currently valued at $10,000 to $15,000. This conflicts with the given project budget of $2,000,000, which would result in about a $50,000 value per lot after completion. Preliminary net present value calculations, with cash inflows of what individuals are willing to pay for lots, property taxes, and recreation, and cash outflows of engineering costs, construction costs, and materials indicate that this project would result in a short-term financial loss of $35,000 to $40,000 per lot. While the main objective is delivering a project that is designed and constructed properly, there may be concerns about affordability when purchasing the finished lots. However, once the lifecycle and positive externalities of investment are factored in, it is possible that this residential development would pay future economic dividends. In addition, the development of lots could be done in phases to help mitigate economic risk. This would mean avoiding a large lump sum payment for all the lots and instead, smaller payments for a certain number of lots at different times.

Spatial: As outlined in blue in Figure 3, an intermittent stream crosses through the southern parcel of the development and reduces the possible number of residential lots. Although the stream hinders the ability to maximize the number of housing units, it provides a unique opportunity for shared community green space along the sides of the embankment. Additionally, an extension of Vincennes St. has been proposed for all alternatives to offer access to the residential area from the south, which is shown in Figure 3. The stream's positioning conflicts with this potential roadway. Accordingly, two 36" culverts would be constructed to convey the flow under the road.

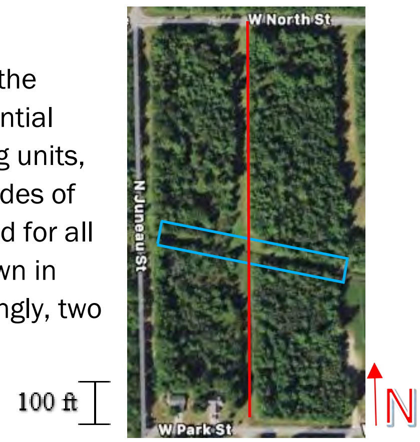

Figure 3. Aerial view of 17-acre southern parcel with the stream outlined in blue and Vincennes St. extension delineated in red.

Social: There are existing developments, such as Adams County Library and Burt Morris Park, near the wooded area proposed for residential development. Community members who used the existing facilities may be in opposition to the clearing of more trees for residential expansion of the area. Additionally, there is a privately owned, undeveloped lot in the area northeast of the stream. Throughout the design process, community engagement will play a key role in provided for an informed and smooth process for all involved parties.

Political: A portion of the project area is owned by the City, and the other portion is owned by the County. During the initial stages of the project, the multiple municipal entities expressed differing views of the area's desired land use. Diligent work was performed to effectively communicate with both entities so that the end design is valuable to both the City and the County.

Ethical: Given the budget constraint for this project, it is important that no abrupt changes or shortcuts are made to save money. For instance, all households should receive the same sized sanitary and water lines to help ensure safety while also meeting users' basic needs.

Constructability: The underground utilities and roadways must effectively transition into existing structures while also meeting the codes and standards of the City, County, and state. Invert, rim, and roadway elevations must be determined to help ensure this smooth transition. This also must coordinate with site grading to establish proper drainage away from households into storm sewer facilities.

Sustainability: A typical residential development should be feasible for 70-100 years, so a similar target lifetime could be expected for this project. Aside from durability, economic, environmental, and social sustainability will be other ultimate goals of the project.

2.5. Regulatory Codes & Design Guides

The following regulatory standards and design guides will be abided by when applicable:

- Wisconsin Department of Natural Resources (WDNR) –NR 216.30
- Sanitary Sewer Design Criteria – Wisconsin Department of Natural Resources (WDNR) –NR 110.13
- Storm Sewer Design – Wisconsin Department of Transportation – Facilities Development Manual 13-25
- Storm Sewer Design Criteria – Department of Natural Resources (WDNR) – NR 216
- Requirements for the Operation and Design of Community Water Systems – Department of Natural Resources (WDNR) – NR 811
- Occupational Safety and Health Administration (OSHA)
- Environmental Protection Agency (EPA)
- County of Adams Design Commission

2.6. Decision Matrix

When evaluating the three alternatives, a decision matrix was implemented to weigh the importance of several design considerations and ultimately provide the final recommendation. The description of the nine factors in consideration are as follows:

Net Present Value: The net present value considers the time value of money when bringing the total benefits and costs of the project to a single, present sum. This metric was utilized to compare the construction and engineering costs, lot value, and property tax inflow between the three alternatives.

Marketability: Marketability considers how sellable the proposed lots will be to the community. City officials stressed the need for the development of affordable, residential units to provide housing for a mix of their older population and individuals moving to the area. This metric also measures how conducive the design is to these needs.

Community Appeal: The residential development will require the clearing of trees that surround existing developments, such as the Adam's County Library and Burt Morris Park. Appeal measures how community members who use these existing developments view the design alternatives in light of the need to prepare the area for construction.

Aesthetics: This metric is concerned with the visual perception and layout of each design alternative.

Traffic Flow: This factor measures the functionality of the proposed transportation engineering plans with its interactions between travelers such as drivers, pedestrians, and cyclists.

Utility Function: The storm sewer, sanitary sewer, and water main design is relatively consistent among the three alternatives. Accordingly, each has a similar utility function score, which measures how well the proposed utility locations and sizes meet the needs of the residential development.

Constructability: This metric was included to measure how efficiently and easily the proposed structures can be built.

Environmental Impact: This factor defines the beneficial and adverse impacts that the respective design has on the environment. A higher score represents more beneficial factors contributing to the impact.

Green Space: This metric measures the amount of grass, trees, or other vegetation set apart for recreational and aesthetic purposes in the development.

2.7. Historical Example

A case study about the 2018 Sun Prairie explosion was performed to help emphasize the importance of locating existing underground utilities. The incident occurred on Main Street in Sun Prairie in July of 2018—a contractor was directional drilling for fiber optic cable, and the drill struck a 4" natural gas main. The gas main exploded soon after, leaving one first responder dead and two others injured.

Figure 4. Aftermath of explosion in Sun Prairie

Contractors are required by law to have underground utilities located before excavating. In Sun Prairie, the utilities in the area were partially located for a similar project before the drilling occurred, but the drilling contractor failed to request a location. The communications company also failed to inform the drilling contractor that the underground utilities were only partially located. This miscommunication led to the gas explosion and one fatality. In the end, the drilling contractor and the communications company were fined a total of $25,000.

Although no high-pressure gas mains are expected to be encountered during the Adams County project, existing underground utilities will be implemented into design—damaging those utilities would prove costly. There are three key takeaways from the case study to be applied during design of the project: (1) design using current utility plans and verify and update those plans with field marking locations (2) locate underground facilities prior to survey for design and immediately prior to construction (3) communicate effectively with other utility companies and contractors who will be working in conjunction with the project contractor.

3. Existing Conditions

The 17-acre southern parcel is a relatively flat, wooded area with a small stream running southeast-northwest, almost dividing the site in half. Two long, narrow areas running north/south on the parcel have been cleared of trees, aligned with existing roads to the south. The 34-acre northern parcel is also mainly composed of trees on relatively flat land aside from two hills in the northern portion of the site. A site map displaying the immediate surrounding area with project site boundaries and existing underground and above ground utilities is shown in Figure 5.

Immediately surrounding the sites are residential and forested areas on flat land. The ground surface elevation varies from about 943 ft to 951 ft MSL for the 17-acre site, while it varies from 945 ft to 952 ft MSL for the 34-acre site, except for the hills on the north parcel that reach 964 ft and 974 ft MSL in maximum elevation. There are no existing structures or buildings within site boundaries.

A geotechnical report with analysis was completed for the proposed project area and is attached in Appendix G. A typical soil profile shown in Figure 4. The subsurface exploration was performed by Soils and Engineering Services, Inc with hollow stem auger Standard Penetration Test (SPT) soil borings, which were used for analysis. The water table was consistent across the boring logs, ranging from 22-23 ft below the surface. While groundwater levels are subject to fluctuating seasonally, it is not expected to affect construction given the scope of the project. The presence of the small stream on the 17-acre site may indicate a higher water table, but that is mainly serving as a swale to route stormwater drainage. In addition, the frost depth is approximately 5 ft in this region, which must be considered when constructing foundations and frost walls for basements.

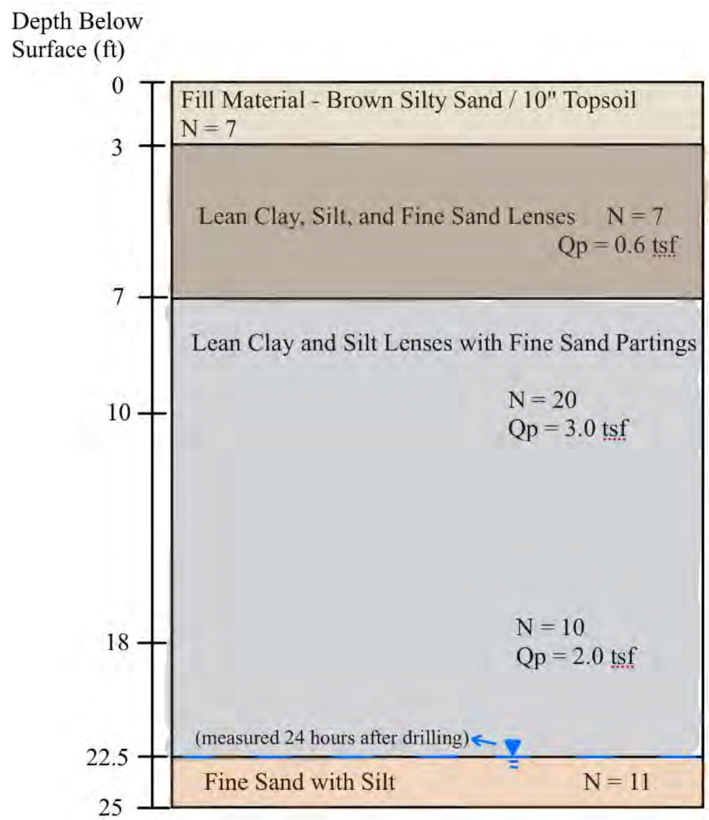

Figure 5. Typical Site Soil Profile

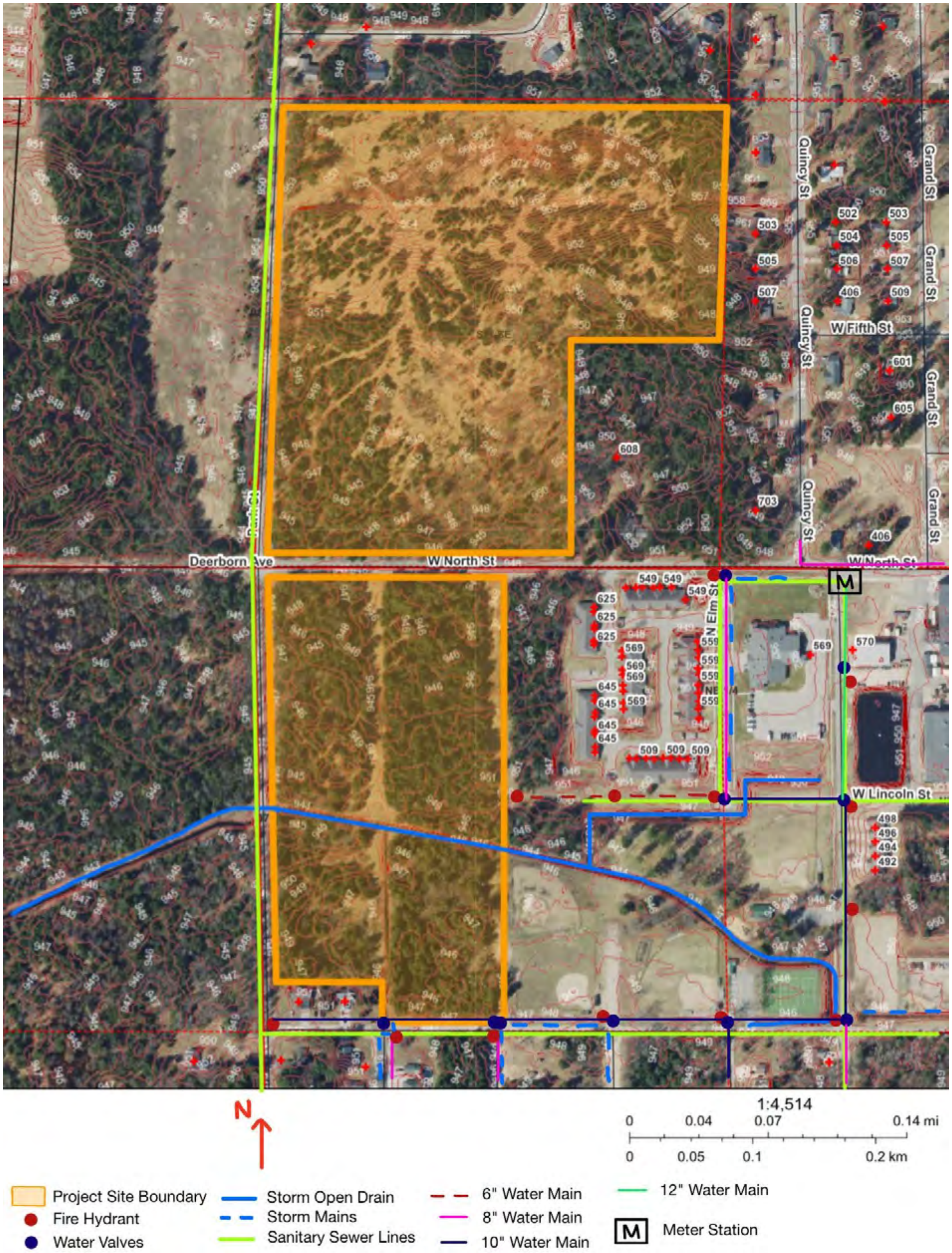

Figure 6. Project Site Map with Existing Utilities

SAAW Consulting Engineering

4. Utility Design

Sanitary and water utility services will be designed for the residential development south of W. North St., the County Facilities Building north of W. North Street, and for future development north of the County Facilities Building. Additionally, storm sewer will be designed for the residential development south of W. North St. Since these utilities are designed to meet the needs of the residential development and to follow regulatory codes, the utility design will have little variation between designs except for any spatial layout differences.

4.1. Hydraulic Design of Storm Sewer

Proposed Design: Storm sewer design will be provided to service the proposed N-E roadway extensions of Vincennes St and Kenwood St between W. Park St. and W. North St., and the proposed residential lots (refer to Sheets 1-3 in Appendix A). The roadway and lot grading are designed to direct surface water runoff to the ditch flowing westward through the site, which will serve as an open storm drain. At the intersection of the extension of Vincennes St. and the ditch, two closed channel, circular culverts will be used to convey flow from the ditch under the roadway. The same design will be used to convey flow from the ditch under the extension of N. Kenwood St. These culverts were chosen to be uniform with the existing small structures at the intersection of the ditch and N. Juneau St. The inverts will be placed at the flowline of the ditch, and the road grade will be set to maintain a minimum 18 inches of cover over the culvert. The effectiveness of the design is described in the following sections.

Roadway Grading Analysis: The roadway grades of the extensions of Vincennes St and Kenwood St are designed to have a single high point. This single high point allows for a continuous grade which directs surface water runoff towards the ditch. Roadways slope down, away from the highpoint at a longitudinal grade (S_L) of 1.5%. The new roads will be constructed to have a 2% crown to ensure that surface water moves toward the inlets. Additionally, all gutter transverse slopes (S_T) are designed to be 0.0625 ft/ft.

Design Discharge: The Rational Method was used to determine the peak flow potential at the site. WisDOT standards specify that storm sewer should be designed to provide capacity for a 10-year frequency, 24-hour rain event (FDM 13-25-20.1). Calculation 1 in Appendix B outlines the assumptions, parameters, and references used to estimate the peak flow during this 10-year frequency, 24-hour rainfall event. As highlighted in Table B1 in Appendix B, the impervious area tributary to the proposed storm sewer generates a peak flow of 13.06 cfs. This result is consistent with other urban areas of similar size and rainfall intensity.

Flow Capacity of the Ditch: Manning's Equation was used to determine the open channel flow capacity of the ditch and the resulting outflow velocity of the culverts. Calculation 1 in Appendix B outlines the assumptions, parameters, and references used to determine the flow in the ditch during a significant event. As displayed in Table B2 in Appendix B, the open channel has a flow capacity of 164 fps. Accordingly, the open storm drain will provide adequate capacity for a 10-year, 24-hour rain event, for the proposed residential development. Taking into consideration the ditch flow in relation to the area of the proposed culverts operating under inlet control, the culverts will have an outflow velocity of 11.5 fps. With a moderately fast outlet velocity, rip rap shall be placed at the culvert outflow areas to prevent erosion.

Inlet and Manhole Locations: Inlet spacing was determined using the specifications of WisDOT FDM 13-25-15. Calculation 2 in Appendix B outlines the assumptions, parameters, and references used to determine the inlet design capacities and spacing on a continuous grade. Combination inlets are used to ensure lack of debris build up. Conclusively, the first inlet should be placed 145 feet from the high point of the grade, and all subsequent inlets should be placed at 50-foot intervals (Sheet 4 in Appendix A). In some cases, these spaces are overridden by the required inlet descriptions described by FDM 13-25-15, such as requiring inlets at intersections. To provide access to the storm sewer, manholes were placed at the end of future stormwater lines and at all intersections. If these intervals were spaced farther than 350 feet apart, an additional manhole was placed to make up the difference and be in accordance with WisDOT standards.

Full Flow Conduit Design: Storm sewer drainpipe was designed to be compliant with WisDOT standards operating under full flow conditions. The conduit will be constructed using a concrete pipe. In order to maintain a self—cleaning velocity of 3.0 fps at full flow, a 12-inch diameter pipe must have a minimum slope of 0.0044 ft/ft (FDM-12-25—35.6). Accordingly, 12-inch diameter, concrete pipes at a 0.50% slope will extend from each side of the two sets of 36—inch culverts located at the intersections of the ditch and proposed roadway extensions.

4.2. Sanitary Sewer Design

Sanitary sewer has been designed to be compliant with DNR standards according to code NR 110.13. As a result, an 8" pipe run at a 0.4% slope will be used. Sanitary sewer will be run down the middle of the roadways and will be tying into manholes 167, 206, and 208 (refer to Appendix F). These sewer lines will maintain a minimum distance of 8' from any water utilities being run in the area. Additionally, sanitary sewer will be run to the lot line on the north side of W. North St. for the future development of the county facilities building and for the northern half of the northern parcel along Juneau St.

4.3. Water Utility Design

Water Utility has been designed to run down the side of the roadways. Hydrants will be added every 300 feet along Juneau, Vincennes, and Kenwood streets. This is in accordance with DNR code NR 811.71. A 10" main and tie will be implemented into existing utilities along W. Park St. and W. North St. Similar to sanitary sewer, water will be supplied to the lot line for the future facilities building north of North St. and to the northern half of the north parcel (refer to Appendix F).

5. Design Alternatives

Three residential development layouts have been produced along with the design of the required utilities to fulfill the needs of the project site. To formulate these alternatives, research was conducted on the historical demographic trends of Adams County and the different layouts of residential neighborhoods. A site visit and client meeting was organized to discuss the needs of the area and the goal of the project. The design alternatives were then narrowed to three options, breaking the parcel into single family lots, a combination of multi-family and single-family lots, and a combination of pocket style hosing with single family lots.

5.1. Alternative 1: Single Family Lots

The first alternative consists of breaking the parcel into 36, ¼ acre lots at 100' by 135' that are to be bought and developed into single family housing lots. There are an additional four units of varying sizes located near the stream with the largest being half an acre and the smallest being a fifth of an acre. This design includes half an acre of green space located north of the stream on the eastern side of the development. This style of neighborhood design is standard through the city of Adams and would be consistent with the surrounding residential developments. A sketch of the proposed layout is shown in Figure 6.

Figure 7. Design Option 1: Single Family Lots

The pink hatch represents single family lots, the green hatch represents shared green space, and the red hatch is privately owned land.

5.2. Alternative 2: Multi & Single-Family Lots

The second alternative includes 18 of the 100' by 135' single family lots in the southern half of the parcel and then has the northern parcel consists of 15 multifamily lots sized at 135' by 150'. Multifamily development is planned to include attached housing units such as duplexes. The combination of multi and single family lots would increase the housing density of the neighborhood and allow for more families to live in the same area of developed land. By increasing the housing density, the land can be more efficiently used to meet housing demands and would also help reduce the costs of the lots. A sketch of the proposed layout is shown in Figure 7.

Figure 8. Design Option 2: Multi & Single-Family Lots

The pink hatch represents single family lots, the green hatch represents shared green space, the orange hatch represents multi family lots, and the red hatch is privately owned land.

5.3. Alternative 3: Pocket & Single-Family Lots

The third alternative includes pocket housing in the northern half of the parcel and 18 single family lots in the southern portion. The pocket housing development includes 27 lots between 0.15 and 0.20 acres. The lots are arranged in a square with 4 lots being in the center along with parking and communal spaces implemented into the neighborhood. In the center of the neighborhood, a 0.75-acre green space is included along with a communal building designed to benefit the entirety of the neighborhood. The shared spaces in the community are designed to increase a sense of community and would be especially appealing for seniors and young families. A sketch of the proposed layout is shown in Figure 8.

Figure 9. Design Option 3: Pocket & Single-Family Lots

The pink hatch represents single family lots, the green hatch represents shared green space, the purple hatch represents pocket style housing, and the red hatch is privately owned land.

6. Alternatives Analysis

6.1. Single Family Lots

Hydraulic Design: The hydraulic design considerations are similar between the three design options. In each of alternatives, adequate road width provides space for the storm sewer, sanitary sewer, and water main to be located at least 8 feet apart, in accordance with DNR regulations. The identical roadway design results in the same impervious area tributary to the storm sewer. As a result, the inlet spacing, conduit size, culvert dimensions, and outflow location will be the same for all three alternatives. To address concerns with the 90% Preliminary Design, an infiltration basin has been added to the design to remediate surface water contamination, improve the quality of water discharged into the stream, and allow for groundwater recharge. It has been sized in accordance with WDNR standards to retain the runoff of surrounding impermeable area during a significant storm event. It is placed between the extension of Lincoln St., Vincennes St., and the ditch.

Transportation Design: The transportation design considerations are almost identical between the single-family lots and multi/single family lots with two 32-foot-wide road extensions running north-south (from Vincennes St and Kenwood St) and a 36-foot-wide road extension running east-west (from Lincoln St). The only difference to consider would be the volume of traffic as the multi-family lots will have a higher population and thus more vehicles will be associated. However, the increase should not be significant enough to alter any of the traffic control options between the two designs.

Construction Considerations: The construction considerations are similar for each of the three alternatives. Roadway construction and utilities construction are required as part of this design. The underground utilities extension will be installed using the open trench construction. Construction will be coordinated with other utilities companies who will be installing utilities in conjunction with the project. Also, Utility Line Openings (ULO's) will be required in contract documents to obtain precise depths of existing utilities.

Geotechnical Design: The geotechnical design considerations are essentially identical across each of the three alternatives. The main geotechnical concern is removing the upper 3 ft of topsoil/fill and replacing it with a control engineered fill to a sufficient dry density (~95% Modified Proctor Density) at specified grades throughout the entire site. If existing grades are sufficient for drainage purposes in certain locations, the topsoil/fill does not have to be stripped and resulting trees can be preserved for aesthetic purposes. Given that wood frame buildings with basements are the heaviest structures within the project scope, their foundation system analysis will serve as the basis for evaluating the soil's behavior under applied pressures. Shallow foundation systems are recommended for the housing portion of the project. The wood framed buildings can be supported on shallow strip footings sized for an allowable bearing capacity of 5000 psf. A minimum 5 ft of cover soils should be provided over the footings with a typical depth around 8-9 ft throughout the site. The foundation wall should be a minimum thickness of 10 inches with a footing minimum width of 18 inches and minimum thickness of 12 inches. These footing sizes should provide for a differential settlement of ¼ to ½ inch and a maximum total settlement of 1 inch. For designated roadway areas, the subgrade should be thoroughly proof rolled to detect unstable, yielding, or unsuitable soils, which must be removed or improved by appropriate preparation and compaction techniques.

6.2. Multi & Single-Family Lots

Hydraulic Design: Refer to Single Family Lot description.

Transportation Design: Refer to Single Family Lot description.

Construction Considerations: Refer to Single Family Lot description.

Geotechnical Design: The geotechnical design should not vary much between the three alternatives. Footing sizes are subject to change based on architectural decisions, such as adding additional stories to housing units. However, that is outside the scope of this design, so recommendations listed in the Single-Family Lot description should be used for this option.

6.3. Pocket & Single-Family Lots

Hydraulic Design: As mentioned previously, the hydraulic storm sewer design will be identical for all three alternatives. However, the additional green space incorporated into the pocket style housing has the potential to provide alternative methods for draining surface water runoff. For instance, the green space could be occupied by green infrastructure technology, such as communal rain gardens. This green technology would potentially decrease the stress put on the storm sewer during significant rainfall events.

Transportation Design: For this design option, there will be a significant difference between the other two options. This is caused by the different roadway design in the pocket housing section. First, the roadway splits into a square shape to allow for more access to the lots and to provide a central communal area. This will alter traffic flows by adding more corners. Furthermore, the pocket style housing has separate parking from individual lots to allow for more housing space on the reduced size lots. Therefore, the parking areas will have higher traffic density. Overall, these differences will not require different styles of traffic control, only the number of stop signs may change.

Construction Considerations: The construction considerations are similar for each of the three alternatives. Roadway construction and utilities construction are required as part of this design. Additional roadway construction is required for the pocket and single-family design, and more clearing and grubbing of the wooded area is required for the roadway construction. The underground utilities extension will be installed using the open trench construction. Construction will be coordinated with other utilities companies who will be installing utilities in conjunction with this project. Also, Utility Line Openings (ULO's) will be required in contract documents to obtain precise depths of existing utilities.

Geotechnical Design: The geotechnical design should not vary much between the three alternatives. Footing sizes are subject to change based on architectural decisions, such as adding additional stories to housing units. However, that is outside the scope of this design, so recommendations listed in the Single-Family Lot description should be used for this option.

7. Opinion of Probable Costs

The opinion of probable costs (OPC) includes an opinion of probable construction costs and an estimate of net present value for each design alternative. Because of knowledge-based and data-based uncertainties, assumptions were made when completing the OPC. This OPC will evolve during the final design phase as additional site condition information is obtained.

7.1. Opinion of Probable Construction Costs

The opinion of probable project cost estimate for each alternative has been calculated as the sum of construction/utilities costs and the project fee. For construction/utilities costs, the estimate has been divided into the following items: Sanitary Sewer, Water Distribution, Storm Sewer, Street Construction, Erosion Control, Mass Earthwork, and General Conditions. The General Conditions estimate item includes mobilization, field supervision, construction staking, and bonding as lump sums. A contingency of 20% as added to the construction estimate to account for uncertainties. In addition, the contractor project fee was determined to be 10% of the total construction cost. Refer to Table 1 for a summary of the probable construction costs.

Table 1. Summary of Probable Construction Costs

Summary of Probable Construction Costs			
Estimate Item:	**All Single Family**	**Multi & Single**	**Pocket Style & Single**
	Alternative 1	Alternative 2	Alternative 3
Sanitary Sewer	$ 444,200	$ 438,500	$ 511,300
Water Utilities	$ 521,700	$ 516,000	$ 592,450
Storm Sewer	$ 283,200	$ 283,200	$ 283,200
Street Construction	$ 699,000	$ 699,000	$ 890,500
Erosion Control/Site Stabilization	$ 63,850	$ 63,850	$ 63,850
Mass Earthwork	$ 234,150	$ 234,150	$ 283,100
General Conditions	$ 73,000	$ 73,000	$ 77,000
Subtotal	$ 2,319,000	$ 2,308,000	$ 2,701,000
Contigency (20%)	$ 464,000	$ 462,000	$ 540,000
CONSTRUCTION TOTALS:	$ 2,783,000	$ 2,770,000	$ 3,241,000
PROJECT FEE (10%):	$ 278,300	$ 277,000	$ 324,100
PROBABLE CONSTRUCTION COST TOTALS:	$ 3,061,300	$ 3,047,000	$ 3,565,100

As shown in Table 1, the calculated opinion of probable construction cost is $3,061,300 for Alternative 1, $3,047,000 for Alternative 2, and $3,565,100 for Alternative 3. Note that each cost estimate exceeds the $2,000,000 budget provided by the client in the Request for Proposal. In order to meet budget requirements, additional funding or a request for reduction in project scope should be considered.

7.2. Net Present Value

For each of the proposed alternatives, net present value was calculated using Capital Cost Totals from Table 1, Adams County land value data, and Adams County property tax data. This estimate does not consider additional sources of revenue as cash flows. The following assumptions were made in order to calculate the net present value: 2.5% discount rate; 30-year time period, all lots will be sold after three years; all lots will be completely developed after 5 years.

The estimated net present value is -$613,400 for Alternative 1, -$826,900 for Alternative 2, and -$1,495,000 for Alternative 3. These values, along with the individual cash flows can be seen in Table 2. Based on this estimate, the All Single-Family Alternative has been identified as the most economically feasible. Further economic analysis using additional factors outside the scope of this project is recommended.

Table 2. Summary of Net Present Value

Summary of Net Present Value (30-Year Time Period)			
Present Value of Cash Flow	All Single Family	Multi & Single	Pocket Style & Single
	Alternative 1	Alternative 2	Alternative 3
Probable Construction Costs	-$3,061,300	-$3,047,000	-$3,565,100
Lot Sale Revenue (Year 3)	$526,500	$601,700	$601,700
Tax Revenue Before Development (Year 3 - 5)	$12,800	$14,600	$9,700
Tax Revenue After Development (Year 5 - 30)	$1,908,600	$1,603,800	$1,458,700
Net Present Value	-$613,400	-$826,900	-$1,495,000

8. Sustainability Analysis

8.1. Economic Sustainability

The initial findings of the project indicated that this project is not economically sustainable in the short term, but by considering overall economic benefits over a longer time period, this project has the potential to become economically sustainable.

As discussed in the Opinion of Probable Costs section, each design alternative has a negative net present value for a 30-year time period. However, this calculation only considered the revenue from lot sales and property taxes. With the increased population of median-income residents, additional revenue will be generated in the form of income tax, sales tax, licenses, and fees. It would take time, but the new development could be worth the large initial investment. This is true particularly for Alternatives 1 and 2, which are the less expensive designs.

By expanding utilities and roads for the area, it paves the way for future development. Additionally, the development of residential units will attract people to the area and positively impact the local economy. Currently, there is a demand for affordable housing and there are people who work in the community that commute from outside of Adams County. By providing attractive and affordable housing, families can move into the area and boost the local economy. The state economy can also be positively impacted by a growth in the local economies. Successful local economies are better able to attract out-of-state people to move to the area.

With Alternatives 2 and 3, a housing community geared towards elderly living positively impacts the community by providing elderly people a more suitable place to live. The houses where many of the aging population live now will be up for sale as they age and move out, causing the selling of housing for younger families.

Based on the initial economic analysis of the designs, it indicates that they would result in economic loss. However, once considering the overall economic benefits that the project would provide to the area, it is possible that this project would be economically sustainable over a long period of time. Further economic analysis using additional factors outside the scope of this project is necessary.

8.2. Environmental Sustainability

The construction process oftentimes has adverse impacts on the surrounding environment. During the construction of this project, measures will be taken to mitigate these impacts. To limit the carbon footprint, local suppliers will be prioritized to reduce transportation emissions. In addition, maximum idle time of large equipment and machinery will be specified in the contract documents to reduce emissions.

Several methods will be implemented to reduce erosion runoff, thereby reducing impacts to local streams and waterways. This is especially important for this project due to the designated wetland located to the west of the site. Erosion control blankets will be placed on areas of steeper slopes and silt fences will be used where rainfall runs off the construction site. Rock entrances to the site will be used to reduce compaction of soil by vehicles and increase infiltration. Additionally, an infiltration basin has been added to the design to remediate surface water contamination, improve the quality of water discharged into the stream, and allow for groundwater recharge.

To promote sustainability within the project, local waterways and green spaces will be preserved when possible. To limit disruption of local waterways, construction will be avoided near the existing seasonal stream. Also, the proposed lots have been drafted to avoid encroaching on the stream. Alternatives 1 & 2 include a 0.4-acre green space north of the stream in the east half of the parcel. Alternative 3 includes this 0.4-acre green space near the stream and an additional 0.75-acre green space in the center of the neighborhood. These green spaces will help with drainage, provide habitat for wildlife, and provide natural beauty to the neighborhood.

To improve walkability and bike-ability of the residential development, a paved path has been included along the stream running east/west through the site to connect to Burt Morris Park. In addition, the bike path will reduce increased vehicle traffic associated with an increase in population. This bike path could also be extended west in a future project to follow the existing greenway corridor west of Juneau Street.

In an effort to promote environmental sustainability, several environmentally friendly options have been factored into design and plan to implement low-impact construction practices. This will benefit both the community and the surrounding environment.

8.3. Social Sustainability

The project is located in Adams County on the outskirts of the City of Adams and adjacent to the Village of Friendship—the needs of the local community must be considered during the construction phase of this project. There is an elderly housing community to the northeast of the site and housing developments to the south. To minimize the disturbance to these communities during the construction phase, the contract documents specify that construction will occur during normal work hours and construction traffic will avoid non-peak roadway hours. Additionally, informational flyers alerting the community to the timeline of the construction phase along with any potential impacts will be distributed prior to construction.

Measures have been taken throughout the design process to ensure long-term social sustainability. Communication with members of both the City of Adams staff and Adams County staff has been crucial in developing the project design. The demographic trends and goals as outlined in the City of Adams Comprehensive Plan from 2017 have provided key insight into the development of the preliminary design. The alternatives have been planned with the knowledge that there is an aging population in the area and that there is demand for median-income housing. Other projects in the area have been researched, such as the addition of a YMCA nearby and the inclusion of walking paths through the area. Future expansion of the area has been considered, and all utilities have been designed to accommodate for growth in the area.

Alternative 1 is the development of single-family housing, and it is consistent with the design of existing neighborhoods in the City of Adams. This design provides the needed median-income housing while also blending into the existing area. Alternative 2 includes single family housing with the addition of multi-family housing. This alternative offers a more community feel to living while also being affordable. The Third alternative includes a single-family housing with a pocket-style neighborhood. This style of neighborhood would encourage community living and would be a good fit for an elderly development.

It has been determined this project will be socially sustainable, and it will benefit the joint needs of Adams County and the City of Adams. Given input from both parties, the social sustainability of each has been considered when designing the alternatives.

9. Impacts

This project will have a significant impact the neighborhood level. The proposed development site is heavily forested and borders several existing housing units and a local park. By developing this site, the necessary forest clearing has the potential to upset existing residents. Also, development of the site would bring new residents and cause increased traffic and day-to-day activities.

At the city and county level, an increase in median-income residents has the potential to boost the economy. An increase in business, along with tax revenue such as property tax, income tax, and sales tax will benefit the surrounding community. The county would benefit because median income housing is in high demand across the area, and by providing units, it will attract people to live in Adams County. Currently, about 30 district teachers commute to Adams county school districts from out of the County, and this project could provide housing for these teachers and others who currently commute in for work.

At the State of Wisconsin level, this project has the potential to retain in-state residents to Adams County or attract out-of-state families to Adams County. Overall, minimal impact is expected to be experienced at the state level.

10. Project Schedule

The project schedule is shown in Appendix E with a complete Gantt chart for the design and construction of the project. The Gantt chart shows past and future events that has been or will be completed. The design process is scheduled to be completed on May 4th, 2021 which then the regulatory agencies will review for about 4 months. The bidding process will then begin and last for about one month. After the awarding of the bid, construction is projected to commence on November 1st, 2021 and last until August 24th, 2022. These dates are flexible to change based on feasibility of construction during winter months. It is possible the start date could be delayed until the spring for this matter. See Figure 10 below for the simplified version of the project schedule.

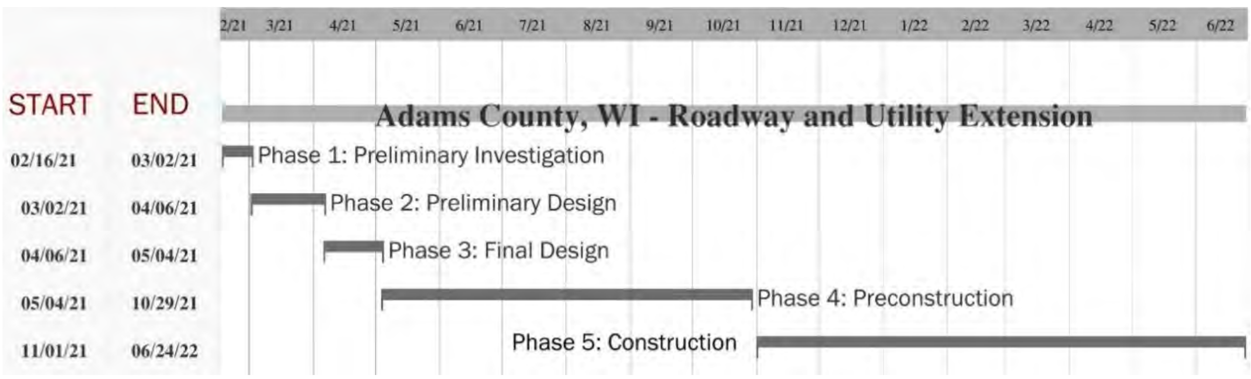

Figure 10. Simplified Project Schedule

11. Uncertainties in Designs

Data Based Uncertainty

Data based uncertainties involve any inaccuracies or assumptions used when formulating and using data. A significant data-based assumption was the soil borings used for analysis of subsurface conditions. There was no history of soil borings on the site, so nearby soil borings were used from the water treatment plant located about ¾ of a mile to the north. These soil borings cannot account for all geological features of the site, but they can be indicative of the site's soil conditions. Additionally, some of the information obtained from outside sources such as the 1 ft topography from public GIS Data or the utility map locations from MSA are assumed to be correct. Without measuring the topography with a survey crew or undergoing a utility discovery, the standard level of accuracy cannot be maintained. Another source of data-based uncertainty arose during the storm sewer design calculations. Approved methods were used to find the flow volumes such as watershed area and values described in the Appendix B.

Knowledge Based Uncertainty

Knowledge based uncertainties involve making assumptions from a lack of information in a design. These assumptions do not involve data and are often made based on collective judgement. A significant knowledge-based uncertainty surfaced while preparing the opinion of probable costs. The probable costs are estimated based on quantities from the different site designs and typical cots from previous projects. To cover the costs of this uncertainty a 20% contingency was applied, but this is not a guarantee as unforeseen circumstances may arise. Another knowledge-based uncertainty that has been made for this project is the community needs. The need for median-income housing and elderly housing has been expressed to us by community members, but there is no way to know the exact number of people looking to move into the area. This could have significant impact to the success of this project if there is less of a demand than initially assumed.

Significance of Uncertainty in Design

Documenting and managing uncertainties is important in any engineering design. Assumptions are valuable for preparing cost estimates or bases of design but relying on these uncertainties can lead to design failure. By documenting these uncertainties, the issues can be addressed as more information becomes available—often, mitigating uncertainties is critical to the safety and viability of the project. Recognized uncertainties are evaluated for potential cost, delay, and liability exposure. The design is adjusted to compensate for the known uncertainties. Compensating for uncertainties is then, as much as possible, included as part of the design and bidding package.

12. Final Design Recommendation

To assist with the final design recommendation, a decision matrix has been assembled as seen in Table 3. The matrix considers four key factors relevant to the project with weighting based on significance. The factors are listed on the left side of the table with decreasing significance from top to bottom within each group. The emphasis of each factor was quantified into weight magnitudes. For each design alternative, the factors were scored in the value column on a scale of 1-10 based on how well the factor was fulfilled by the design option, with 10 being the best possible score.

Table 3: Decision Matrix for Design Recommendation

Decision Matrix							
Factor	Weight	All Single Family		Multi & Single		Pocket Style & Single	
		Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
Economic	45%						
Net Present Value	25.0%	6	1.50	5	1.25	3	0.75
Marketability	20.0%	8	1.60	7	1.40	8	1.60
Social	25%						
Community Appeal	15.0%	9	1.35	5	0.75	7	1.05
Aesthetics	5.0%	8	0.40	6	0.30	7	0.35
Traffic Flow	5.0%	8	0.40	8	0.40	6	0.30
Construction	15%						
Utility Function	10.0%	9	0.90	9	0.90	8	0.80
Constructability	5.0%	8	0.40	8	0.40	7	0.35
Environmental	15%						
Environmental Impact	10.0%	6	0.60	6	0.60	8	0.80
Green Space	5.0%	7	0.35	5	0.25	8	0.40
TOTALS:	**100%**	Total:	**7.50**	Total:	**6.25**	Total:	**6.40**

Because economic factors are the main concern for Adams County, considerable weight has been given to Net Present Value (NPV) and Marketability—25% weight and 20% weight respectively. For the NPV calculations, it was assumed that lots will be sold within three years and fully developed within 5 years. With this assumption, it was calculated that the Single Family Lots have the highest net present value for the 30-year time period (refer to Table D4 in Appendix D). Although net present values for each alternative are negative, the Single-Family option is the least negative. The other economic factor in consideration is the marketability of the lots. As mentioned previously, marketability considers the number of lots, the cost and size of lots, and the demand for lots in this area. Based on the demographic information collected, there is a demand in Adams County for both starter housing and senior housing. Because each of the three alternatives are comparable in number of lots and cost, they have a similar marketability value.

Social factors consisting of community appeal, aesthetics and traffic flow make up 25% of the total weight. This section received the second highest weighting because community impact and opinion are important when considering the difficulty in selling the lots. The first sub-category is community appeal. For this section, single lots were given the highest score as they are commonplace and accepted throughout the area. The Multi-Family option received a low score because there could be resistance to duplexes due to higher family density. Lastly, the Pocket Style option received a moderate score because they can be aesthetically pleasing, yet people may not enjoy the closely packed lots. The aesthetics sub-category has similar scores for single and pocket options because the firm's evaluation has determined that each alternative has admirable outward appearance. The Multi-Family option received a lower score because this type of lot has the potential to include duplexes, which some individuals may find visually displeasing. For the traffic flow, Single and Multi-Family options received he same score as the roadway system will be identical. The Pocket Style housing received a lower score due to a roadway design requiring more corners.

Construction factors have been given a weight of 15%. The first factor considered is utility function. Although utilities will be functional for all options, Alternative 3 received a slightly lower score due to the unconventional roadway design. Regarding constructability, the roadway geometry has caused Alternative 3 to receive a lower score in constructability.

Environmental factors contribute 15% to the total weight. For this project, the positive environmental impacts that were taken into consideration include surface water flow and water retention. The pocket style received the highest score because there will be more shared greenspace with the potential to be occupied with green water drainage structures. Single family scored second highest, as each lot will have a reasonably sized individual yard. Multifamily scored lowest because there will be the least available green space per family.

Based on the design matrix values, Alternative 1 – All Single-Family is recommended. Most emphatically, the single units of Design Alternative 1 result in the option being the most economically feasible and marketable to the surrounding area. In terms of construction and social considerations, Alternative 1 also outperformed the other two options. Ultimately, the All Single-Family design will provide the least initial loss and greatest potential value to the Adam's County community.

Appendices

Appendix A – AutoCAD Drawings

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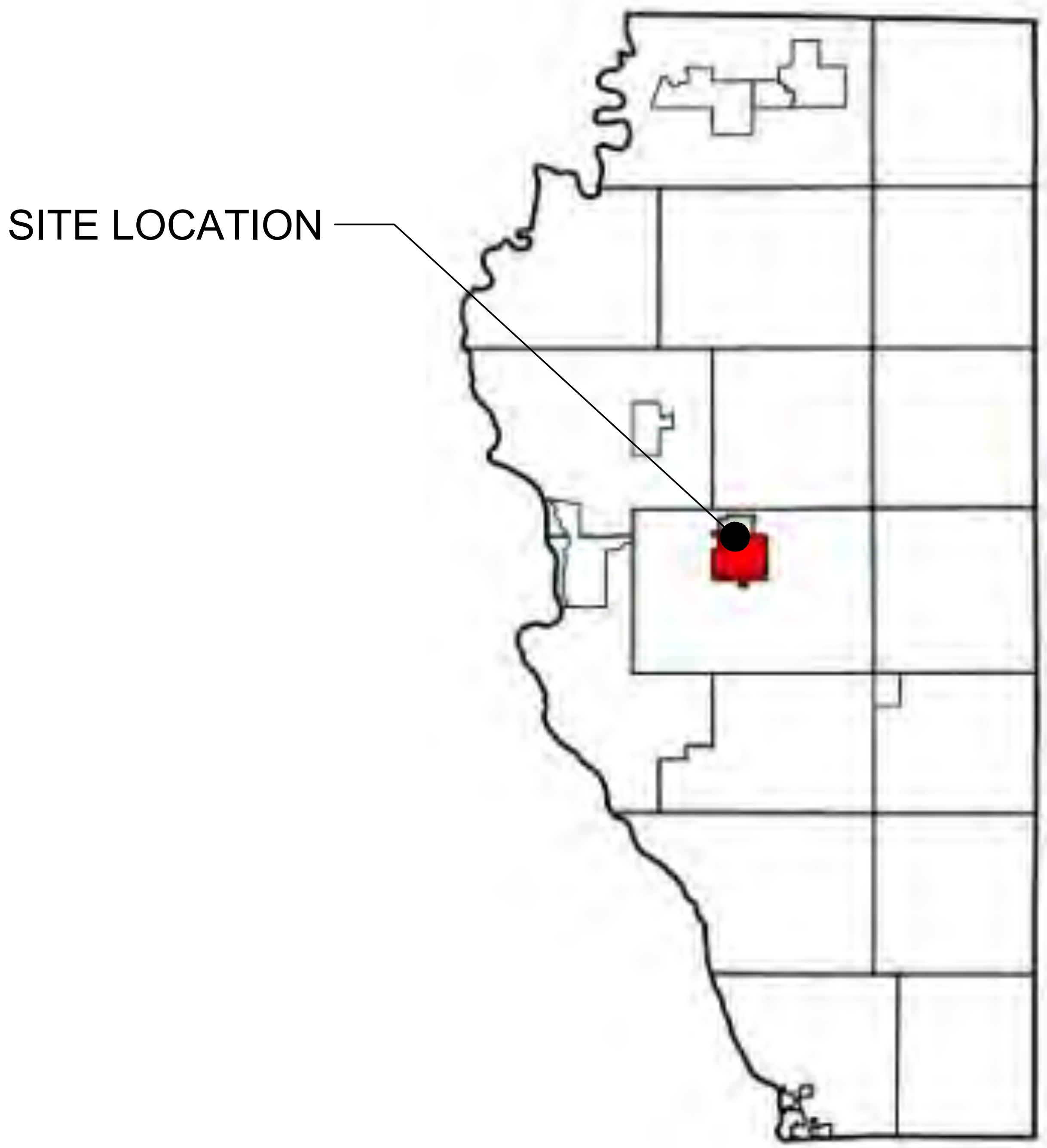
PRELIMINARY DESIGN:

ADAMS COUNTY, WI
MARCH 18, 2021

PROPOSED ADAMS COUNTY UTILITIES AND RESIDENTIAL DEVELOPMENT

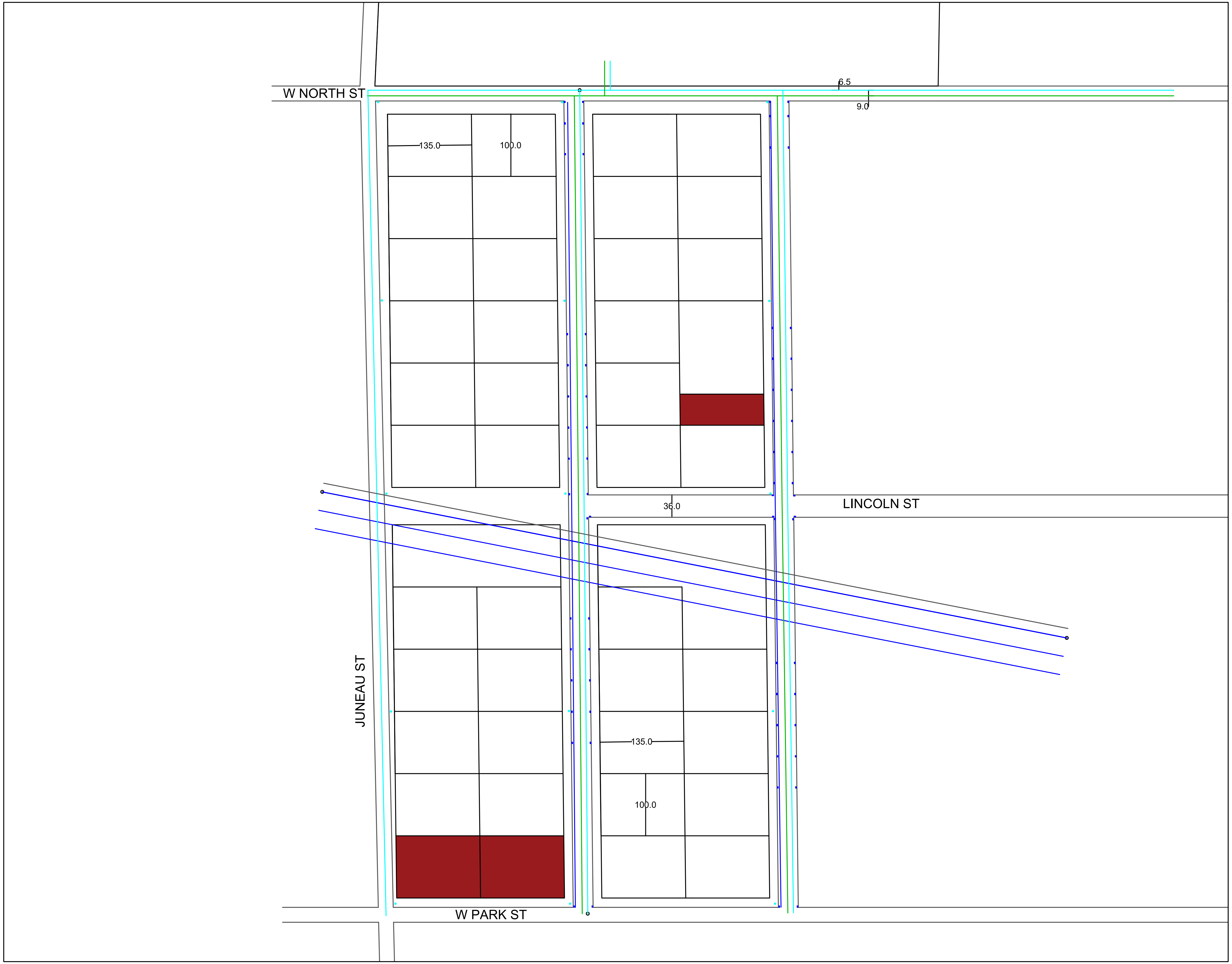


PREPARED FOR:

Adams County Wisconsin

PREPARED BY:

SAAW Consulting Engineering



ADAMS COUNTY UTILITY AND RESIDENTIAL DEVELOPMENT

Sheet 1

Design Option 1

Adams County Wisconsin

PREPARED FOR:

SAAW Consulting Engineering

PREPARED BY:

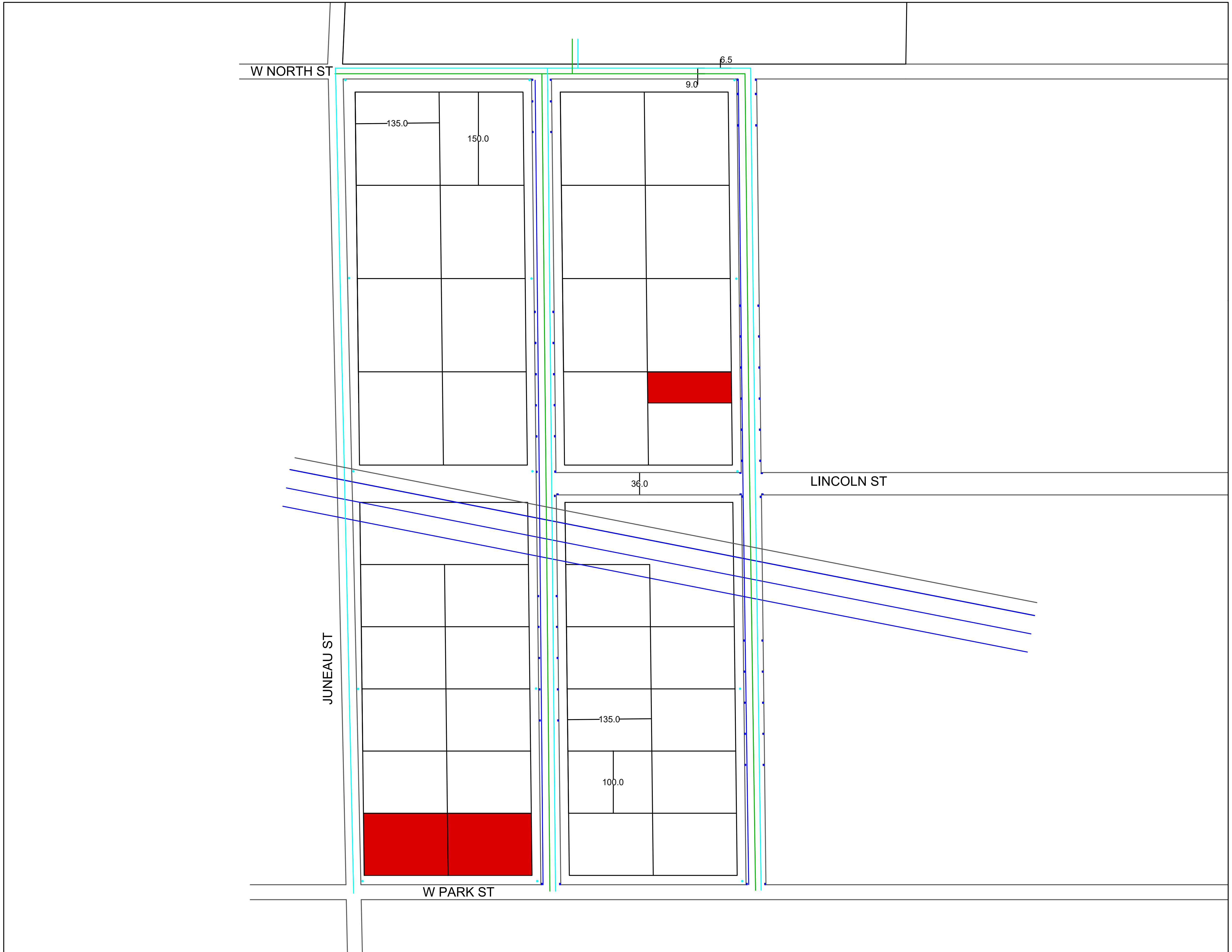
SCALE
1":150'

NORTH

37' 150' 300'

LEGEND

- Single Lot
- Roadway
- Water
- Sanitary Sewer
- Storm Sewer
- Bike Path
- Drainage Creek
- Private Land
- Fire Hydrant
- Storm Gutter



ADAMS COUNTY UTILITY AND RESIDENTIAL DEVELOPMENT

Sheet 2

Design Option 2

PREPARED FOR:

PREPARED BY:

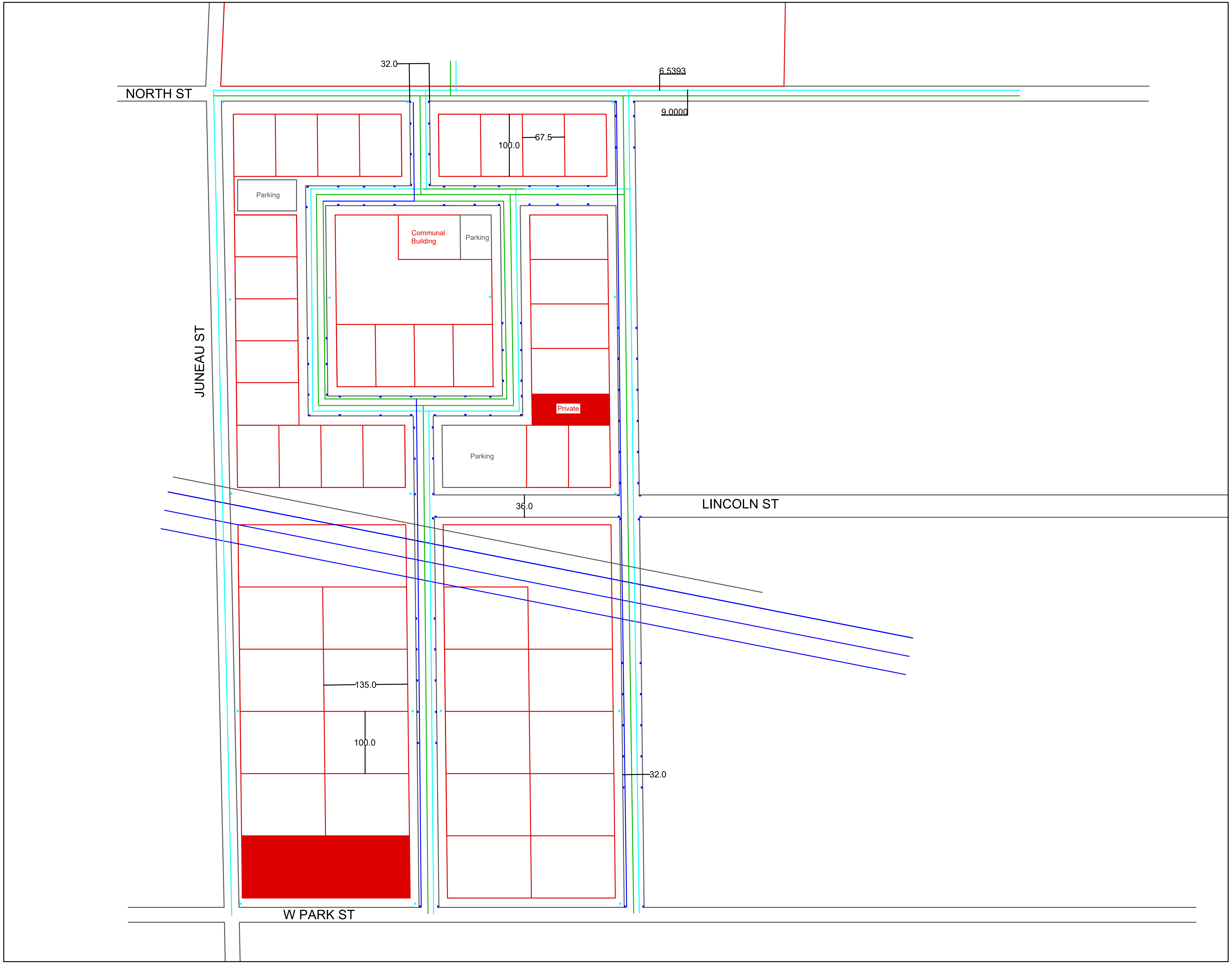
SCALE
1":150'

NORTH

38' 150' 300'

LEGEND

- Single Lot
- Roadway
- Water
- Sanitary Sewer
- Storm Sewer
- Bike Path
- Drainage Creek
- Private Land
- Fire Hydrant
- Storm Gutter



ADAMS COUNTY UTILITY AND RESIDENTIAL DEVELOPMENT

Sheet 3

Design Option 3

PREPARED FOR:

PREPARED BY:

SCALE
1":150'

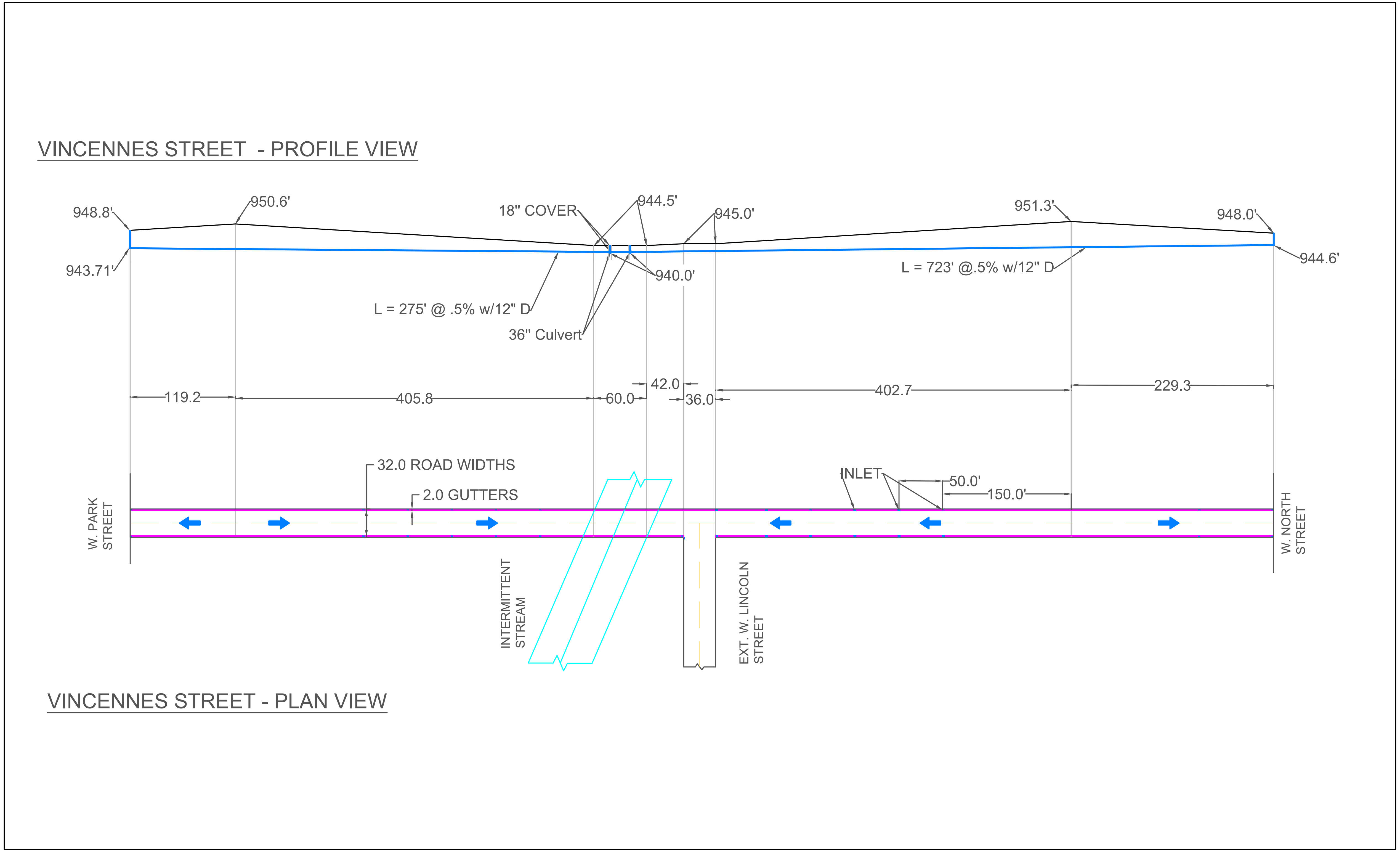
NORTH

37' 150' 300'

LEGEND

- Residential Lot
- Roadway
- Water
- Sanitary Sewer
- Storm Sewer
- Bike Path
- Drainage Creek
- Private Land
- Fire Hydrant
- Storm Gutter

VINCENNES STREET



ADAMS COUNTY UTILITY AND RESIDENTIAL DEVELOPMENT

Sheet 4

PROFILE AND PLAN VIEW OF VINCENNES STREET

PREPARED FOR:

PREPARED BY:

SCALE
1":120'

NORTH

30' 120' 240'

LEGEND

- ROAD LINE
- GUTTER BORDER
- ROAD CENTERLINE
- INTERMITTENT STREAM BORDER
- STORMWATER SEWER
- STORMWATER SEWER FLOW
- STORMWATER INLET

*NOTE: PROFILE HEIGHTS ARE 1:4 FOR CONCEPTUAL VISUALIZATION

Appendix B – Calculations

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Calculation 1

PROJECT / PROPOSAL NAME / LOCATION: ADAMS COUNTY RESIDENTIAL DEVELOPMENT		PROJECT / PROPOSAL NO. 1
SUBJECT: STORM SEWER CALCULATIONS		
PREPARED BY: ALEX MCDONALD, B.S. CIVIL ENGINEERING	DATE: 03/10/2020	FINAL ✓
CHECKED BY: Will Claridge	DATE: 03/11/2020	REVISION ❐

Purpose

The purpose of these storm sewer calculations is to ensure that the existing ditch and proposed culverts at the potential residential development adequately handle the surface water runoff from a 10-year, 24-hour storm, with limited erosion potential.

Methodologies:

The storm sewers are designed to direct the surface water runoff from drainage areas to the receiving ditch and through circular culverts. The adequacy of the stormwater sewers in handling the surface water runoff and in limiting the amount of erosion is based on the system's flow and velocity capacity in relation to the flow and velocity expected from a 10-year storm for this particular catchment.

A spreadsheet incorporating the Rational Method is used in order to determine the surface water runoff potential. The rational formula is Q = CIA where Q is the peak runoff rate (cfs), C is the runoff coefficient, which is the ratio of the peak runoff rate to the average rainfall rate for a duration equal to the time of concentration (t_c), which is the time required for water to travel from the hydraulically most remote point of the basin to the point of interest. I is the intensity of rainfall for a duration equal to the time of concentration (in/hr), and A is the adjacent impervious drainage area (acres). The spreadsheet allows the user to input the runoff coefficient, rainfall intensity, and impervious area adjacent to the proposed storm sewer to determine the peak runoff rate.

A spreadsheet incorporating Manning's equation is used to quantify the capacity of the open channel flow of the ditch, and the closed channel flow of the two sets of two 36-inch circular culverts at the proposed extensions of Vincennes St and Kenwood St. Manning's Equation is
$Q = A*(1.49/n)*(R^{2/3})*(S^{1/2})$ where A (ft^2) is the area of the channel, n is the vegetative retardance factor, R (ft) is the hydraulic radius, and S is the bottom slope of the channel. This spreadsheet allows the user to input the ditch geometry and the vegetative retardance factor (Chow, 1959) to determine the peak flow capacity and resultant velocity of the storm sewer drainage points. These results are compared to the flow rate obtained from the rational equation to ensure that the ditch and proposed culverts can manage the area's surface water runoff at peak flow conditions.

Rational Method Assumptions

The following assumptions were used to estimate the peak surface water flow:

- Peak flow occurs when the entire watershed is contributing to the flow.
- Rainfall intensity is uniform over the t_c.
- Rainfall intensity is the same over the entire drainage area. The intensity is determined for a 10-year frequency storm in order to be compliant with WisDOT standards. Intensity data is gathered from IDF curve for Adams County from WisDOT Facilities Development Manual for 10- year frequency storm at 5-minute t_c (FDM 13-10).
- Frequency of the computed peak flow is the same as that of the rainfall intensity, i.e., the 10-year rainfall intensity is assumed to produce the 10-year peak flow.
- Coefficient of runoff is the same for all storms of all recurrence probabilities. C is chosen to represent conservative estimate of asphalt peak runoff rate to the average rainfall during t_c.
- Used minimum t_c due to small tributary areas and short pipe runs.
- The immediate drainage area being considered for the storm sewer is the impervious adjacent area. This area is determined by adding the N-S distance between West Park St and North St, and the E-W distance of the proposed road extending from West Lincoln St, then multiplying by the road widths.
- Road width used to calculate adjacent impervious area is 32 feet face to face.
- Road lengths used to calculate the tributary impervious area are 1300 feet for the two proposed roads between W. Park and North St, and 350 feet for each of the three auxiliary roads intersecting with the Kenwood St. extension.
- Area to each of the sub-drainage areas is measured to include both lot drainage tributary to each inlet and road area tributary to each inlet

Manning's Equation Assumptions

The following assumptions were used to determine storm sewer capacity:

- Culverts are designed as circular culverts with a diameter of 36 inches.
- Ditch perimeter is assumed to have a 6-foot-wide flat bottom, bottom slope of .17%, and 3:1 side slope.
- Assume non-bank full depth of 3.5 feet during significant rainfall event.
- A natural channel with stones and weeds has a Manning's coefficient, n = 0.035, as given by the U.S. Soil and Conservation Service.
- Culverts operating under inlet control with large outflow velocity should consider rip rap.
- Circular culverts and ditch are designed to handle the runoff from the 10-year, 24-hour storm event.

Results

The circular culverts and ditch are adequately sized to handle the surface water runoff from a 10-year, 24-hour storm event with limited erosion.

The peak flow potential is 9.31 cfs. Since the ditch possess a flow capacity of 163.71 cfs, it will be able to manage peak flows during a 10—year 24-hour storm event. In order to convey the water under the proposed roadway extensions of Vincennes St and Kenwood St, two sets of two 36-inch diameter culverts will be constructed to match the existing culvert design at North Juneau St. Utilizing the ditch flow and culvert area, the culvert outflow velocity is determined to be 11.58 fps. In order to prevent against erosion, SAAWM suggests placing rip rap at the outflow area of the culverts.

References

Chow, V.T. 1959. Open Channel Hydraulics, McGraw Hill, New York.

Wisconsin Department of Transportation. 1997. Facilities Development Manual (FDM). August 1997.

U.S. Department of Agriculture, Soil Conservation Service. 1986. Engineering Field Manual for Conservation Practices. November 1986.

Wisconsin DNR, Bureau of Water Resources Management. 2017. NR 110, Chapter 13.

Calculations

Table B1. Spreadsheet summarizing runoff potential calculation.

Runoff Potential Using Rational Method					
	C	Tc [min]	I [in/hr]	A [acres]	Q [cfs]
Impervious Area Adjacent to Drainage System	0.7	5	6.96	2.68	13.06

Table B2. Spreadsheet summarizing flow capacity calculation.

Flow Capacity Using Manning's Equation											
T [ft]	y [ft]	z	n	Bottom Slope [ft/ft]	R [ft]	V [ft/s]	A [ft^2]	Q, Ditch [cfs]	Q, Single Culvert [cfs]	Culvert Area [ft^2]	Culvert Outflow Velocity [ft/s]
27	3.5	3	0.035	0.0017	2.05	2.83	57.75	163.71	81.86	7.07	11.58

Calculation 2

PROJECT / PROPOSAL NAME / LOCATION: ADAMS COUNTY RESIDENTIAL DEVELOPMENT		PROJECT / PROPOSAL NO. 1
SUBJECT: INLET SPACING ON CONTINUOUS GRADE		
PREPARED BY: ALEX MCDONALD, B.S. CIVIL ENGINEERING	DATE: 03/10/2020	FINAL ✓
CHECKED BY: Will Claridge	DATE: 03/11/2020	REVISION ❐

Purpose

The purpose of these calculations is to determine the spacing of inlets on a continuous grade and ensure that surface water runoff on the site is being intercepted at sufficient intervals.

Methodologies:

A spreadsheet incorporating the design capacity of an inlet (Q), the allowable gutter flow (Q_p), the design discharge of an inlet (Q_D), and the distance between inlets and specific roadway elevations (L) is used to calculate the spacing between inlets. The design capacity of an inlet is represented as $Q = KD^{5/3}$ where Q is the grate inlet capacity in cfs, K is an empirical coefficient for a specific grate with the appropriate design longitudinal and transverse slopes, and D is the curb line flow depth (in feet) upstream from the grate. Combination inlets on a continuous grade have a reduction factor (R.F.) of 1.10 x 0.50 = 0.55; thus, the total allowable inlet capacity, Q_i, is represented as Q_i = R.F. x Q. At the first inlet, the flow capacity is equal to the allowable gutter flow, Q_p. $Q_p=Q_{(b+c)} + Q_{(a+c)} - Q_{(c)}$, where $Q_{(b+c)}$ is the maximum allowable flow in combined areas b and c, $Q_{(a+c)}$ is the maximum allowable flow in combined areas a and c, and $Q_{(c)}$ is the maximum allowable flow in area c (Diagram 2, Appendix C). A gutter design nomograph (Diagram 1, Appendix C) is used to determine these flows. At the first inlet, $Q_{D1} = Q_p$. The distance from the high point of the road to the first inlet is represented as $L_1 = 43560Q_{D1}/IWC$ where I is the rainfall intensity from a five-minute duration, 10-year frequency rain event (in inches/hour), W is the tributary width (in feet) contributing runoff to the subject inlet represented as $W = W_{lane} + W_{house\_lot}$, and C is the composite runoff coefficient. The spacing between the first inlet and subsequent inlets also relies on the equation, $L_2 = 43560Q_{D2}/IWC$; however, now Q_D is the lesser of $Q_p – Q_B$ or $Q_p – Q_i$, where Q_B is the amount of bypass flow for the first inlet and is represented as $Q_B = Q_{D1} – Q_i$. Upon entering the appropriate values outline above, the spreadsheet calculates the spacing between inlets.

Parameters

Table B3. Known parameters used to determine the inlet spacing.

Knowns	
Curb Type	A
Inlet Type	H
Length of Gutter	30 in
Longitudinal Slope of Road	1.50%
Crown	2.00%
Transverse Slope of Gutter	0.063 ft/ft
Street Width	32 ft
K	12.50
D	0.245 ft
R.F.	0.55
I	6.96 in/ft
W	116 ft
C	0.70

Results

The first inlets will be spaced 145 feet from each road's highpoint elevation. Subsequent inlets will be spaced 50 feet from the previous inlet. Inlets will also be placed at intersections in order to intercept surface water runoff before it reaches cross walks (refer to Sheet 4, Appendix A).

References

Wisconsin Department of Transportation. 1997. Facilities Development Manual (FDM). August 1997.

Neenah Foundry Company Inlet Grade Capacities

Calculations

Table B4. Spreadsheet summarizing inlet spacing calculations.

Inlet Spacing Calculations						
Q_P [cfs]	Q_I [cfs]	Q_B [cfs]	Q_{D1} [cfs]	Q_{D2} [cfs]	L_1 [ft]	L_2 [ft]
1.9	0.66	1.24	1.9	0.66	146	51

Appendix C – Diagrams

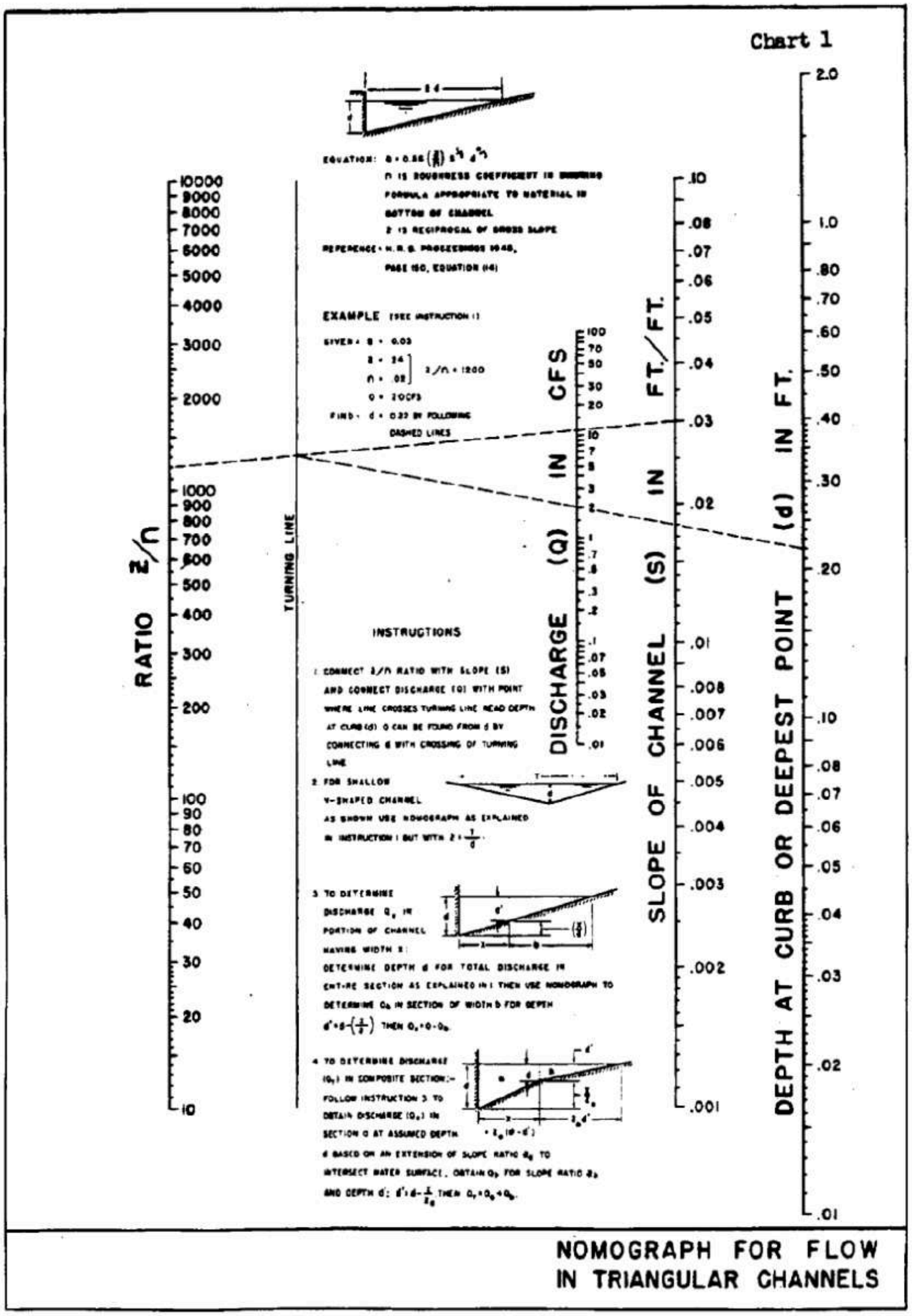


Diagram 1. Nomograph used to determine allowable gutter flow.

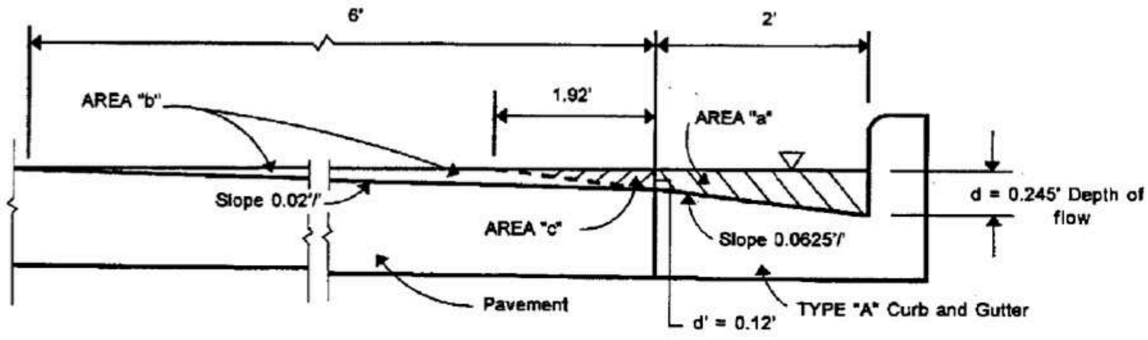


Diagram 2. Image identifies areas a, b, and c which are used to determine allowable gutter flow for a type "A" curb and gutter.

Appendix D– Cost Calculations

Table D1. Fees for SAAWM design services.

SAAWM Fees per Project Phase		
Phase	Expected Duration	Fees
Preliminary Investigation	Feb 16 – Mar 2	$19,800
Preliminary Design	Mar 2 – April 6	$49,500
Final Design	April 6 – May 4	$40,700
Contingency	-	$20,000
Total	-	$130,000

Table D2. SAAWM billing rates and fees.

SAAWM Billing Rates and Expected Fees			
Project Role	Hourly Rate	Hours	Requested Amount
Project Manager	$150.00	200	$30,000
Construction Engineer	$100.00	200	$20,000
Geotechnical Engineer	$100.00	200	$20,000
Transportation Engineer	$100.00	200	$20,000
Hydraulic Engineer	$100.00	200	$20,000
Contingency	-	-	$20,000
Total	-	1000	$130,000

Table D3. Summary of project capital costs.

Summary of Project Capital Costs			
Estimate Item:	**All Single Family**	**Multi & Single**	**Pocket Style & Single**
	Alternative 1	Alternative 2	Alternative 3
Sanitary Sewer	$ 444,200	$ 438,500	$ 511,300
Water Utilities	$ 521,700	$ 516,000	$ 592,450
Storm Sewer	$ 283,200	$ 283,200	$ 283,200
Street Construction	$ 699,000	$ 699,000	$ 890,500
Erosion Control/Site Stabilization	$ 63,850	$ 63,850	$ 63,850
Mass Earthwork	$ 234,150	$ 234,150	$ 283,100
General Conditions	$ 73,000	$ 73,000	$ 77,000
Subtotal	$ 2,319,000	$ 2,308,000	$ 2,701,000
Contigency (20%)	$ 464,000	$ 462,000	$ 540,000
CONSTRUCTION TOTALS:	$ 2,783,000	$ 2,770,000	$ 3,241,000
DESIGN AND ENGINEERING TOTALS:	$ 130,000	$ 130,000	$ 130,000
CAPITAL COST TOTALS:	$ 2,913,000	$ 2,900,000	$ 3,371,000

Table D4. Summary of net present values of annuity cashflows.

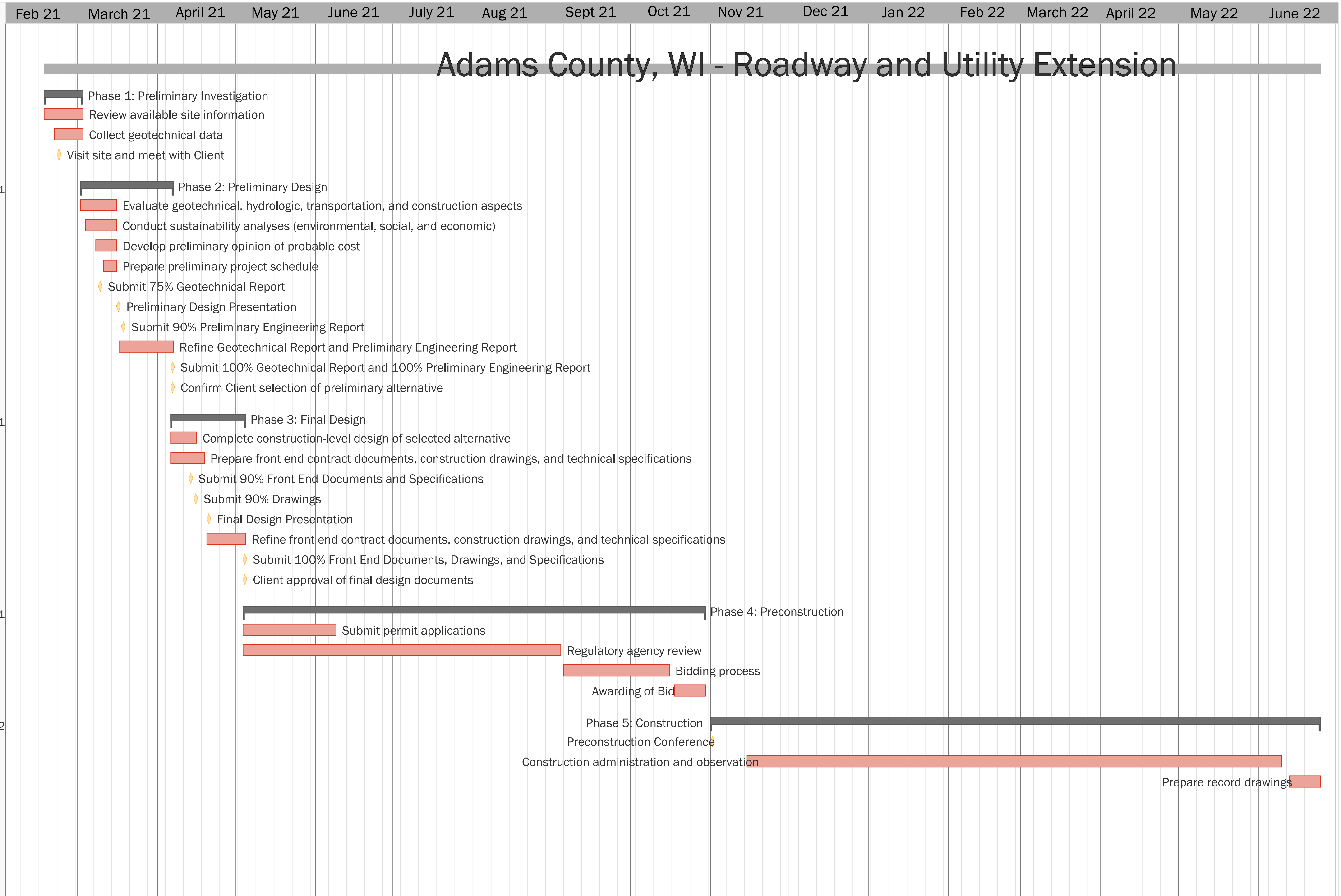
Summary of Net Present Value (30-year time period)			
Present Value of Cash Flow	**All Single Family**	**Multi & Single**	**Pocket Style & Single**
	Alternative 1	Alternative 2	Alternative 3
Capital Costs	-$2,913,000	-$2,900,000	-$3,371,000
Lot Sales (After 3 years)	$526,500	$601,700	$601,700
Tax Revenue (After Development)	$1,908,600	$1,603,800	$1,458,700
Tax Revenue (Before Development)	$12,800	$14,600	$9,700
Net Present Value	-$477,900	-$694,500	-$1,310,600

The individual present values were determined using the fundamental equation of finance, $P = 1/(1+r)^t$ where P is the present worth, r is the interest rate, and t is the time period in consideration. The net present value for each alternative was then determined by adding together each individual present value cash flow.

Appendix E – Project Schedule

See next page for project Gantt Chart.

Adams County, WI - Roadway and Utility Extension



02/16/21	03/02/21	Phase 1: Preliminary Investigation
02/16	03/02	Review available site information
02/20	03/02	Collect geotechnical data
02/21	02/21	Visit site and meet with Client
03/02/21	04/06/21	Phase 2: Preliminary Design
03/02	03/15	Evaluate geotechnical, hydrologic, transportation, and construction aspects
03/04	03/15	Conduct sustainability analyses (environmental, social, and economic)
03/08	03/15	Develop preliminary opinion of probable cost
03/11	03/15	Prepare preliminary project schedule
03/09	03/09	Submit 75% Geotechnical Report
03/16	03/16	Preliminary Design Presentation
03/18	03/18	Submit 90% Preliminary Engineering Report
03/17	04/06	Refine Geotechnical Report and Preliminary Engineering Report
04/06	04/06	Submit 100% Geotechnical Report and 100% Preliminary Engineering Report
04/06	04/06	Confirm Client selection of preliminary alternative
04/06/21	05/04/21	Phase 3: Final Design
04/06	04/15	Complete construction-level design of selected alternative
04/06	04/18	Prepare front end contract documents, construction drawings, and technical specifications
04/13	04/13	Submit 90% Front End Documents and Specifications
04/15	04/15	Submit 90% Drawings
04/20	04/20	Final Design Presentation
04/20	05/04	Refine front end contract documents, construction drawings, and technical specifications
05/04	05/04	Submit 100% Front End Documents, Drawings, and Specifications
05/04	05/04	Client approval of final design documents
05/04/21	10/29/21	Phase 4: Preconstruction
05/04	06/08	Submit permit applications
05/04	09/03	Regulatory agency review
09/05	10/15	Bidding process
10/18	10/29	Awarding of Bid
11/01/21	06/24/22	Phase 5: Construction
11/01	11/01	Preconstruction Conference
11/15	06/09	Construction administration and observation
06/13	06/24	Prepare record drawings

Appendix F – MSA Maps

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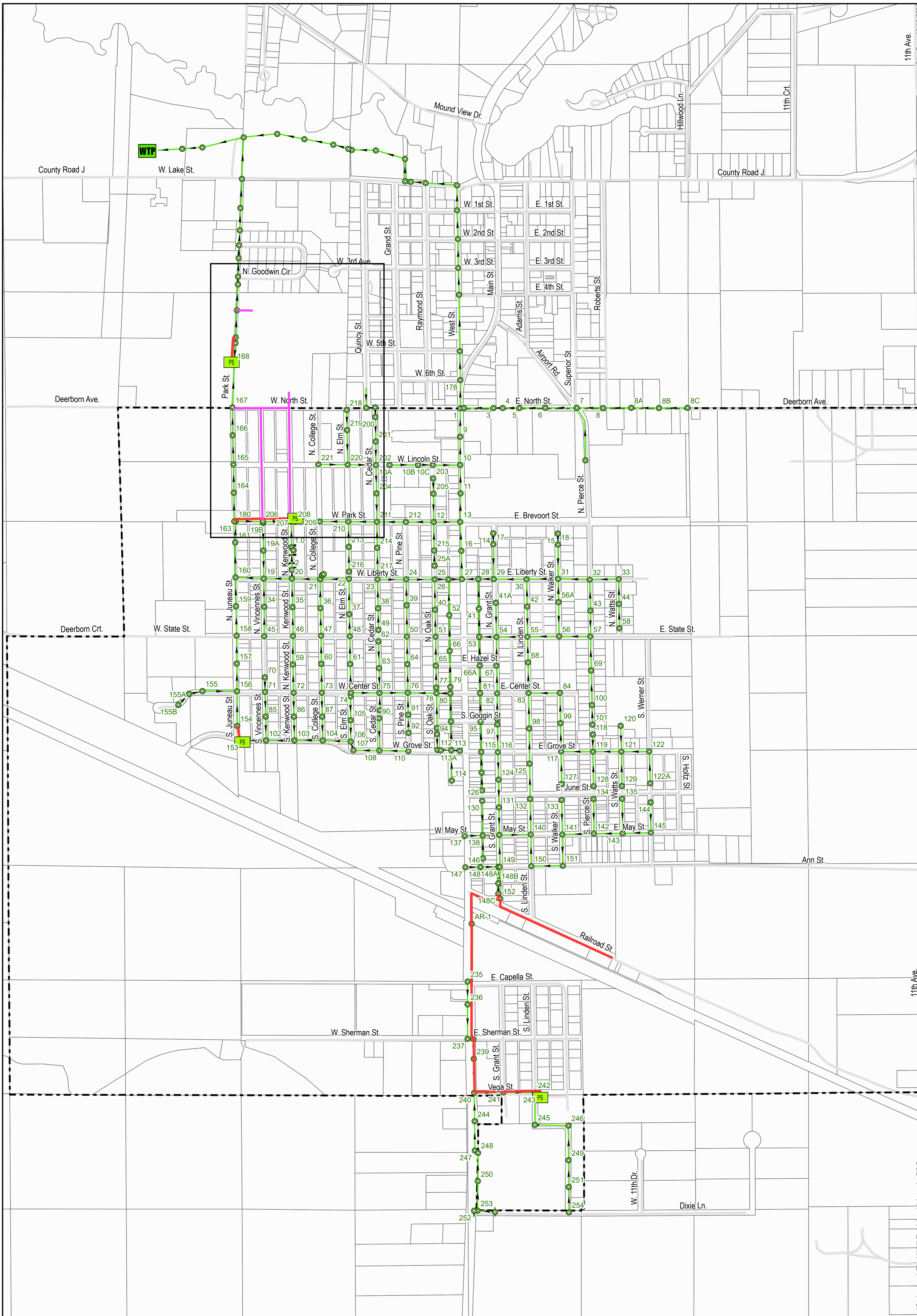


Sanitary Sewer Features

- Sewer Gravity Mains
- Force Mains
- Sewer Manholes

Structure Type

- PS Lift Station
- WTP Treatment Plant

Boundaries

- City of Adams
- Parcels
- Roads
- Proposed Sanitary Sewer

0 500 1,000 2,000 3,000 US Feet

N

Data Sources: Adams Co GIS (Base Map), City Asset GIS, WiDNR Open Data (Roads)

Sanitary Sewer Map

July 2020

MSA

City of Adams
Adams County, WI

0 500 1,000 2,000 3,000 US Feet

Layer5
- Water Tower
- Meter Station
- Production Well
- Storage Basin

Water Mains
- 4"
- 6"
- 8"
- 10"
- 12"
- 14"
- 16"
- 6" Private
- Lateral Lines
- Fire Hydrants
- Proposed Water Main
- Water Valves

Boundaries
- City of Adams
- Parcels
- Roads

Water Distribution Map

July 2020

MSA

City of Adams
Adams County, WI

Data Sources: Adams Co GIS (Base Map), City Asset GIS, WiDNR Open Data (Roads)

Appendix G – Geotechnical Report

See attached report below.

April 6th, 2021

Geotechnical Report

Adams County Residential, Utility, and Roadway Development

Prepared for: **Adams County Building and Grounds Committee**

Prepared by: **SAAWM Consulting Engineering**

SAAWM Consulting Engineering, 324 Wendt Commons, 215 N Randall Ave, Madison, WI 53715

Disclaimer

The concepts, drawings and written materials provided here were prepared by students in the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison as an activity in the course Civ Engr 578 – Senior Capstone Design/GLE 479 – Geological Engineering Design. These do not represent the work products of licensed Professional Engineers. These are not for construction purposes. The soil borings utilized were not taken at the project site, but at another site in the City of Adams and are assumed to be an accurate representation of the proposed site. For class purposes only.

Table of Contents

1. INTRODUCTION

1.1. GENERAL

This report presents the results of the subsurface exploration for the Adams County Residential, Utility, and Roadway development project in the City of Adams, WI. The work was performed for Adams County Building and Grounds Committee at the request of Jan Kucher.

1.2. PURPOSE

The purpose of this study was to evaluate the subsurface conditions at particular boring locations throughout the site and establish parameters for engineers to reference when designing foundation systems, site utilities, stormwater management, and roadway pavement for the proposed project.

1.3. SCOPE

The scope of services for this geotechnical study includes the drafting of the soil boring plan (number, location, and depth), the drilling of soil borings, the evaluation of soil characteristics by field and laboratory testing, evaluation of obtained data, and recommendations for certain construction aspects. The report also contains descriptions of regional geology, groundwater conditions, site preparation, foundation and pavement recommendations, and considerations for construction.

1.4. AUTHORIZATION

The description of services and authorization to perform the subsurface exploration and evaluation were in the form of a signed acceptance copy of SAAWM Consulting Engineers Proposal No. 01 dated February 16, 2021. This report has been prepared exclusively for Adams County Building and Grounds Committee. The information contained in this report may not be relied upon by any other parties without the express written consent of SAAWM Consulting Engineers, and acceptance by such parties of SAAWM's General Conditions.

2. SITE AND PROJECT DESCRIPTION

2.1. SITE FEATURES

The project site is located on a 17-acre parcel of land on the northwest corner of the City of Adams, and it is bounded by Juneau Street to the west, North Street to the north, and Park Street to the south. The project also includes constructing utilities to a 34-acre parcel of land to the north, where Adams County plans for future construction of a new County Facilities Building and further residential development. At the time of exploration, the 17-acre site was a relatively flat, wooded area with a small stream running northwest-southeast, almost dividing the site in half. Two long, narrow areas running north/south on the parcel have been cleared of trees, most likely to serve future roadway areas. The 34-acre site is also mainly composed of trees on relatively flat land aside from two hills in the northern portion of the site.

Immediately surrounding the sites are residential and forested areas on fairly flat land. The ground surface elevation varies from about 943 ft to 951 ft MSL for the 17-acre site, while it varies from 945 ft to 952 ft MSL for the 34-acre site, except for the hills on the north parcel that reach 964 ft and 974 ft MSL in maximum elevation. There are no existing structures or buildings on either site.

2.2. PROPOSED PROJECT DESCRIPTION

Based on the information provided by our client, the 17-acre parcel is being planned for residential development. This could include both single family and multi-unit wood-framed buildings with basement foundations. The project will be designed in order to blend in with the existing surrounding community. If possible, some homes may try to be constructed in a way that allows for a walk-out basement to provide the feeling of a 2-story home to the homeowner. The homes' first floor grade should be at least 2 ft above the street grade with the lower-level floor slab grade 9 ft beneath the first floor. This will put the footing about 8 ft beneath the site grade, which will be deep enough to avoid frost damage since the frost line extends approximately 5 ft beneath the surface. At walk out locations, a 5-foot frost wall will need to be provided beneath the lower-level. The typical exterior wall load will be about 2000 to 3000 plf (pounds per linear foot), and the typical column footing load will be about 10,000 to 15,000 pounds. Site grading, stormwater management, and roadway development will be performed in accordance with the necessary grades for the housing development. Further details are provided in the construction consideration section of the report.

3. SCOPE OF SUBSURFACE EXPLORATION

3.1. SCOPE SUMMARY

The field and laboratory data utilized in the evaluation of the subsurface was obtained by drilling borings into the ground at different locations throughout the site, securing soil samples by the split-spoon sampling method, and performing standard laboratory tests on the collected samples (namely Atterberg limits and grain size distribution).

With respect to the stormwater management area, the field and laboratory work for classification of the subgrade soils was performed to provide information for use by the basin design personnel when considering requirements of Chapter NR151 of the Wisconsin Administrative Code, and of WDNR Technical Standard 1002, "Site Evaluation for Stormwater Infiltration" guidelines.

3.2. FIELD EXPLORATION

Seven borings were drilled with a typical depth explored of 25 ft (between 915 ft and 916 ft MSL) and a typical water table depth of 22-23 ft below the surface (between 918 ft and 919 ft MSL). The borings were drilled between February 17th-18th of 2021 by Soils and Engineering Services, Inc. The borings on the 17-acre site were located along the proposed roadway sections with one near a potential stormwater management facility by the existing drainage swale. These borings were evenly spaced along the roadways to provide the most comprehensive understanding of subsurface conditions throughout the site while covering potential major cut / fill areas. For the 34-acre site, only one boring was performed since the project scope only involves supplying sanitary sewer and water to the parcel. After the selected locations were bored and sampled, the holes were backfilled with bentonite after determining the depth to water. A site map with boring locations and the detailed boring logs are provided in the Appendix.

Subsurface conditions on the site were explored by hollow stem auger Standard Penetration Test (SPT) soil borings in accordance with ASTM 1586. The standard penetration value (N) is defined as the number of blows of a 140-pound hammer, falling thirty (30) inches, required to advance the split-spoon sampler one (1) foot into the soil. The sampler is lowered to the bottom of the drill hole and the number of blows recorded for each of the three (3) successive increments of six (6) inches penetration. The "N" value is obtained by adding the second and third incremental numbers. The SPT provides a means of estimating the relative density of granular soils and comparative consistency of cohesive soils, thereby providing a method of evaluating the relative strength and compressibility characteristics of the subsoils. The soil samples were transferred into clean glass jars immediately after retrieval and returned to the laboratory upon completion of the field operations. Samples will be discarded unless other instructions are received. All soil samples were visually classified in general accordance with the Unified Soil Classification System (ASTM D2487).

3.3. LABORATORY TESTING

Soil samples obtained from the exploration were visually classified in the laboratory and subjected to Atterberg Limits testing (ASTM D4318) and grain size distribution by sieve analysis (ASTM D6913). The granular site soils are a well-graded material with a P200 value that varied from 8.6 to 11.4%. The Selected cohesive soil samples were tested in unconfined compression with an uncontrolled strain loading rate and/or with a calibrated hand penetrometer to aid in evaluating the soil strength characteristics. The values of strength tests performed on soil samples obtained by the Standard Penetration Test Method (SPT) are considered approximate, recognizing that the SPT method provides a representative but somewhat disturbed soil sample. The laboratory testing was performed in general accordance with the respective ASTM methods, and the results are shown on the boring logs in the Appendix.

4. REGIONAL & SUBSURFACE CONDITIONS

4.1. REGIONAL GEOLOGY

The City of Adams, WI consists of relatively flat wooded areas with the project site located on the northwest corner. The major influence of the current regional topography is due to the advancement and receding of nearby glaciers tens of thousands of years ago. While the project site and the rest of the City was not covered by the most recent glaciers, the soils in the area are composed of glacial washout. In addition to the glacial deposits, alluvium deposits also contributed to the regional geomorphology as windblown sand on Pleistocene offshore sediment dominate the area around the city [1]. There are three main types of soil that make up the immediate layers between the two sites on the project as detailed by the Natural Resources Conservation Service soils map in the Appendix. The first and most dominant is a Friendship loamy sand, which is more of a dark brown, fine sand making up about 54% of the area. Next, the Plainfield sand makes up about 36%

and is also a darker brown sand. Finally, the Meehan loamy sand makes up the last 10% of the area.

Cambrian sandstone with some dolomite and shale make up most of the bedrock in Adams County [3]. The depth of the bedrock ranges between 50-100 ft below the surface throughout Adams County [3]. Bedrock was not discovered in any of the borings on the project site, but bedrock outcropping may occur in this area. A more comprehensive geological cross section is provided in the Appendix [2].

4.2. SUBSURFACE CONDITIONS

The soil borings show slightly varying yet consistent soil types throughout the site ranging from fine silty sand (SM & SP/SM) to a mix of lean clay (CL), silt (ML), and fine sand (SP). The first layer extends about 3 ft below the surface and is composed of topsoil and fill material, which is brown sandy topsoil (10 inches) and loose brown silty fine sand (SM). The second layer extends between 3 and 7 ft on average and comprises a medium stiff varved blocky lean clay (CL) mixed with silt (ML) and fine sand (SP). The third layer extends between 7 and 22.5 ft and is composed of blocky lean clay (CL) with silt (ML) lenses and sand (SP) partings. This layer is very stiff from 7 to 13 ft and becomes stiff from a depth of 13 to 22.5 ft. The final layer is a medium dense brown fine sand with silt (SP/SM) that spans from about 22.5 to 25 ft below the surface. Bedrock was not struck in any of the borings as it is projected to be about 50-100 ft beneath the ground. An average depiction of the borings is shown below in Figure 1.

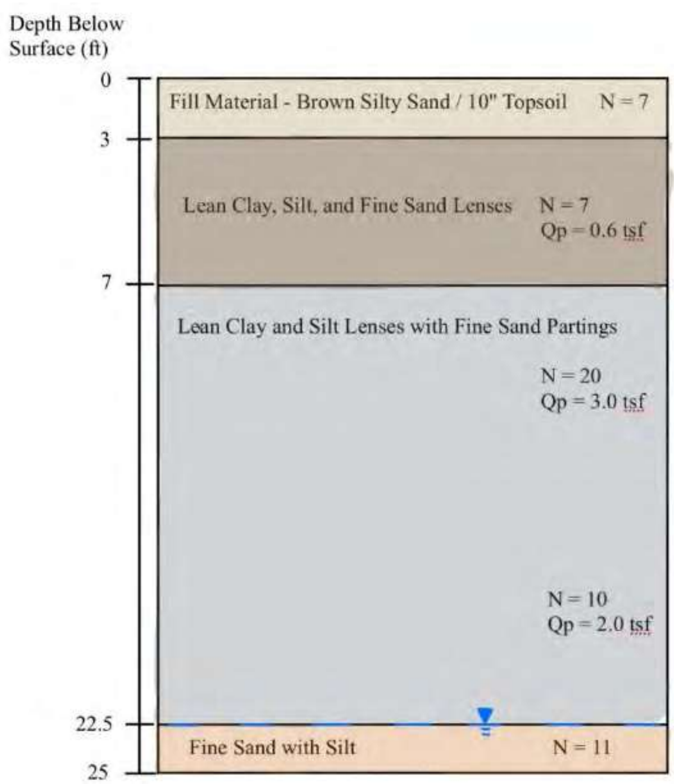


Figure 1. Typical Soil Stratigraphy of the Project Site

The cohesive soils encountered in the borings were generally medium stiff to very stiff, with SPT resistances (N-values) ranging from 7 to 20 blows per foot (bpf) and unconfined compressive strengths between 0.6 and 3 tons per square foot (tsf). The granular soils encountered in the borings were typically loose to medium dense as they experienced blow counts between 7 and 11 on average.

Laboratory Testing Results

Bulk composite SPT soil samples were collected at various depths indicated in the boring logs. A mechanical grain-size analysis (ASTM D6913) was performed for each sample as well as an Atterberg Limit test (ASTM D4318) when applicable. An example laboratory test from Boring 7 between depths of 6 and 7 ft (EL. 937 ft to EL. 932 ft MSL) is provided in the Appendix. This sample was chosen for focused study due to the fact the housing foundations will be in proximity to this layer with a known stronger layer below. The test results indicated a Liquid Limit of 31, a Plastic Limit of about 24, and a Plasticity Index of about 7. Based on these test results, the clayey soil encountered in this layer was classified as CL by the USCS method (ASTM D2487). The same processes were repeated for the other samples.

4.3. GROUNDWATER CONDITIONS

Groundwater observations were made during the drilling operations, and in the open boreholes upon completion. The groundwater table was encountered at depths of 22 to 23 ft below the surface across all borings. The groundwater observations reported herein are considered approximate. It must be recognized that groundwater levels fluctuate with time due to variations in seasonal precipitation, lateral drainage conditions, and soil permeability characteristics. The presence of a small stream on the 17-acre site may indicate a higher water table, but that is mainly serving as a swale to route stormwater drainage. Overall, given the depth and consistency of the water table elevation along with the scope of the project, it should not become a major concern during construction.

Environmental Issues

While not in the scope of this geotechnical report, it should be noted that the ditch running through the middle of the 17-acre site is classified as part of the City of Adams Watershed Preserve. Given this designation, further study on this area should be conducted to address any potential environmental issues.

Potential Sources of Contamination

Given the project area is mainly undeveloped land, not many sources of contamination exist. The greatest potential for contamination would lie with any old gas station locations, dry cleaning services, and nearby farms with agricultural waste. These facilities possess chemicals that can pollute surrounding soil and groundwater if not managed properly. However, there is not a major concern of contamination as the previously mentioned facilities are not in proximity to the project site.

5. DISCUSSION & RECOMMENDATIONS

5.1. FEASIBILITY OVERVIEW

Based on the subsurface evaluation and the scope of the project after the upper 3 ft of topsoil and fill material are excavated and replaced as a control engineered fill, the remaining soils should be sufficient in supporting structures above. Given that wood frame buildings with basements are the heaviest structures within the project scope, their foundation system analysis will serve as the basis for evaluating the soil's behavior under applied pressures. The main geotechnical concern is removing the topsoil and compacting fill to a sufficient dry density (~95% Modified Proctor Density).

5.2. SITE PREPARATION

Before starting construction, all private and public underground utility lines must be located and outlined to prevent issues during excavation and construction. Next, the topsoil on the site, approximately the top 9 to 10 inches of soil, must be stripped and stockpiled for later use in landscape areas. For designated roadway areas, the subgrade should be thoroughly proof rolled to detect unstable, yielding, or unsuitable soils, which must be removed or improved by appropriate preparation and compaction techniques. Scarification and drying of unsuitable soils, or removal and replacement with suitable fill, are two methods, which can be considered. A recommended compacted fill specification is included in the appendix. This should be determined at the time of construction by a qualified soils engineer. Low areas may then be raised to the planned grades with suitable properly compacted fill where necessary. Isolated areas of soft, wet, or otherwise unsuitable soils, requiring undercutting and removal, may be encountered. Erosion control materials, such as silt fences, bio logs, and erosion control blankets will be used to protect exposed soils and prevent sediment movement before proper compacted fill can be put in place.

5.3. FOUNDATION RECOMMENDATIONS

Shallow foundation systems are recommended for the housing portion of the project. The wood framed buildings can be supported on shallow strip footings sized for an allowable bearing capacity of 3000-5000 psf. A minimum 5 ft of cover soils should be provided over the footings. This system requires uniform and stiff subgrade support with crushed rock, gravel, or coarse sand for the base course, select/stabilized soil for the subbase, and suitable native soil which is already present on site. A vapor barrier must be installed between the base course and slab to prevent moisture and gas entering from the soil through the concrete slab. The embedment depth of the foundation should be a minimum of 5 ft below the site grade. If the project proceeds with walkout basement designs for certain houses, a 4 ft frost wall on the same sized footing should be installed beneath the basement floor slab.

The foundation wall should be a minimum thickness of 10 inches with a footing minimum width of 18 inches and minimum thickness of 12 inches. Bearing capacity, settlement, and lateral earth pressure values are provided for what a typical house foundation would experience on this site in Table 2. Calculations of these values are provided in the appendix. These footing sizes should provide for a differential settlement of ¼ to ½ inch and a maximum total settlement of 1 inch. In addition, a summary of the typical soil conditions along with presumptive allowable bearing pressures of each soil type is provided in Table 1 below. These values are based on the NAVFAC Design Manual 7.2 (1982).

Table 1. Summary of Typical Soil Conditions on Site

Typical Depth Range (ft)	Soil Description	USCS	Unit Weight (pcf)	Friction Angle (°)	Cohesion	Bearing Capacity Q_{all} (psf)
0-3	Loose Silty Sand / Topsoil	SM	110	30	0	3000
3-7	Medium Stiff Lean Clay, Silt, and Fine Sand Lenses	CL, ML,& SP	115	25	600	3000
7-22.5	Stiff to Very Stiff Lean Clay and Silt Lenses with Fine Sand Partings	CL, ML, & SP	125	28	2000-3000	5000
25	Medium Dense Fine Sand with Silt	SP/SM	120	32	0	5000

Table 2. Calculated Soil Parameters of Interest

Typical Depth Range (ft)	Soil Description	USCS	Allowable Bearing Capacity, Q_{all} (psf)	Settlement (in)	Lateral Earth Pressure (plf)
3-7	Medium Stiff Lean Clay, Silt, and Fine Sand Lenses	CL, ML,& SP	7000	N/A	750
7-22.5	Stiff to Very Stiff Lean Clay and Silt Lenses with Fine Sand Partings	CL, ML, & SP	27000	0.3	2000

5.4. PAVEMENT DESIGN

Asphalt pavement is recommended for use on the project given its relatively low cost and feasibility. Since the project site lies in the Southern Asphalt Zone of Wisconsin, the recommended asphalt grade is PG 58-28 S [4]. The minimum thickness of the asphalt layer should be 4 inches. Beneath the asphalt, a 12-inch aggregate layer composed of crushed rock or gravel should be placed on top of the subgrade. A minimum of 2% graded cross-slopes to edge of pavement are recommended for design. The subgrade should be thoroughly compacted and then proof rolled to detect unstable, yielding, or unsuitable soils, which must be removed or improved by appropriate preparation and compaction techniques. After a sufficient subgrade has been prepared, the stone base can be placed and compacted. The base material shall be compacted to a minimum of 93% Modified Proctor density. The proposed roadway sections are located in an area that experiences annual freezing cycles, and some of the subgrade soils encountered have been classified as highly susceptible to frost action when free water is present. Therefore, some frost movement may be experienced. However, since the immediate subgrade is silty sand, it should not be a great concern as this layer is more pervious than the clay layer beneath it.

6. CONSTRUCTION CONSIDERATIONS

6.1. REMOVAL OF SOILS AND EROSION CONTROL

Removal and replacement of unsuitable soils and erosion control should follow procedures outlined in the site preparation section (5.2). For site grading of the 17-acre parcel, topsoil must first be removed and stored for later final grading. Given that nearby residences are constructed at an elevation of 951 ft MSL, the grade for the housing locations should be around the same elevation or higher depending on basement design. This elevation will satisfy necessary slope requirements (at least 0.5 in per ft for 50 ft distance between house footprint and street) for drainage away from houses toward the street. Given the relatively lower than recommended elevation throughout the site, fill will most likely be required to meet grade requirements. This fill may be obtained from proposed stormwater management facilities on site, as long as the material meets the fill material specification. Final grading will be performed to adjust the slope of the site in accordance with roadways, driveways, utilities, house footings, and potential stormwater management services to ensure adequate drainage.

6.2. FILL AND COMPACTION RECOMMENDATIONS

Given the boring logs designate the first 3 ft of soil as fill material, the on-site soils may be used and compacted to a minimum of 95% Modified Proctor density. Compaction should be performed with equipment suitable for such purpose, such as a sheepsfoot roller for clayey soils, and a vibratory smooth drum roller for granular material. Proper moisture control is essential to reduce the amount of compactive effort necessary to achieve the desired densities. It is recommended the fill soils be placed at moisture contents within a 3% percent of their optimum moisture content.

6.3. EXCAVATION REQUIREMENTS

All excavations must be performed with caution and utilize methods which will prevent undermining or destabilization of buildings, utilities, pavements, or other structures. The use of a properly designed shoring and bracing, sheet piling, or underpinning system must be utilized as necessary to adequately protect utilities, pavements, and other structures. This must be performed by an experienced specialty contractor. Additionally, extreme care must be used during the installation of any bracing system, especially those using driven or vibratory methods, in order to avoid damaging existing buildings, utilities, and other structures. Consideration should be given to the performance of video and/or photographic documentation of the condition of nearby buildings, utilities, and other structures prior to installation. Earthwork shall be performed in accordance with current Occupational Safety and Health Administration (OSHA) requirements.

6.4. GROUNDWATER ISSUES

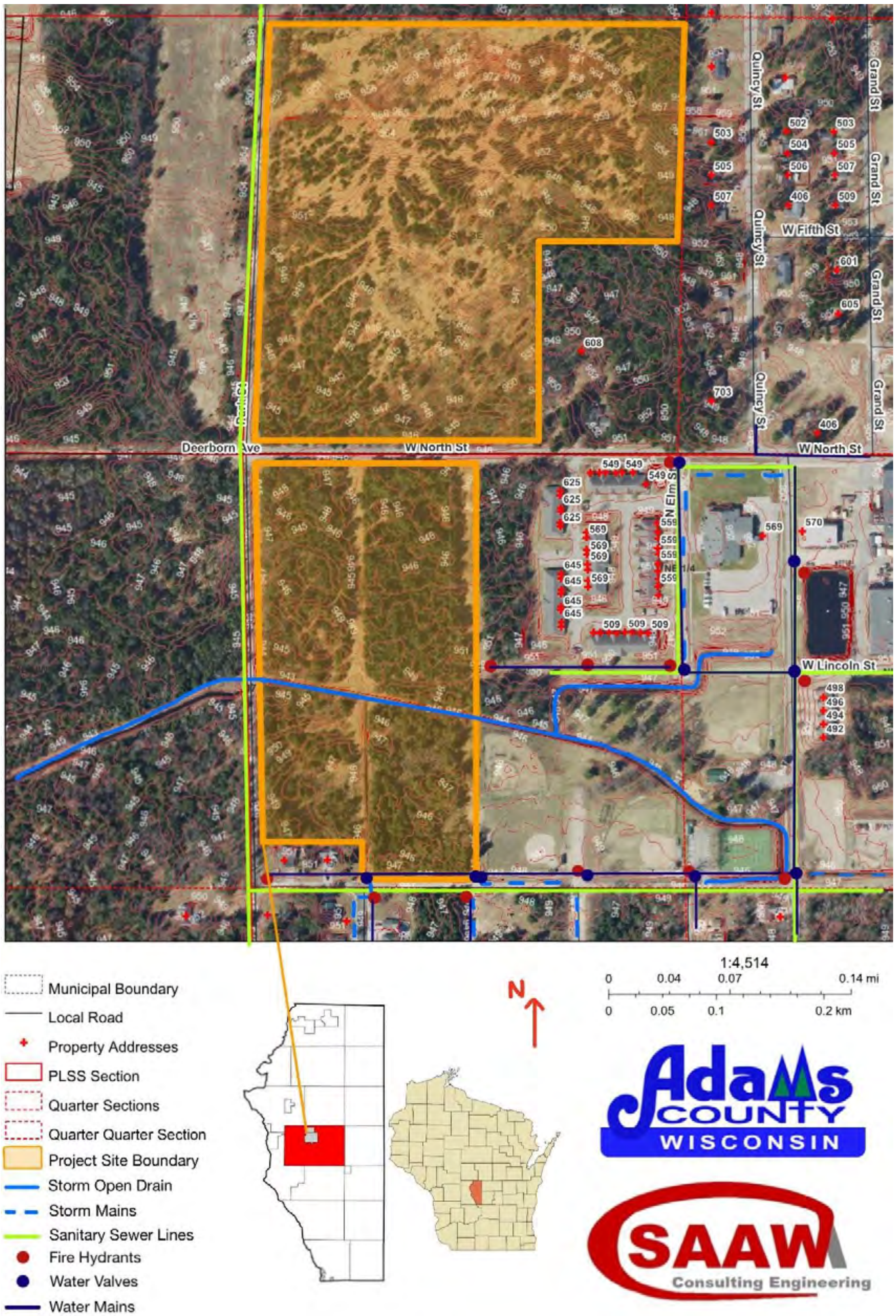
Groundwater considerations are covered in section 4.3 of the report for more detail. With the low elevation and consistency of the water table throughout the site, groundwater should not become a major concern during construction. Dewatering may only be necessary when handling the swale/ditch in the middle of the 17-acre site in order to improve subgrade conditions for potential roadway structures.

6.5. GENERAL COMMENTS

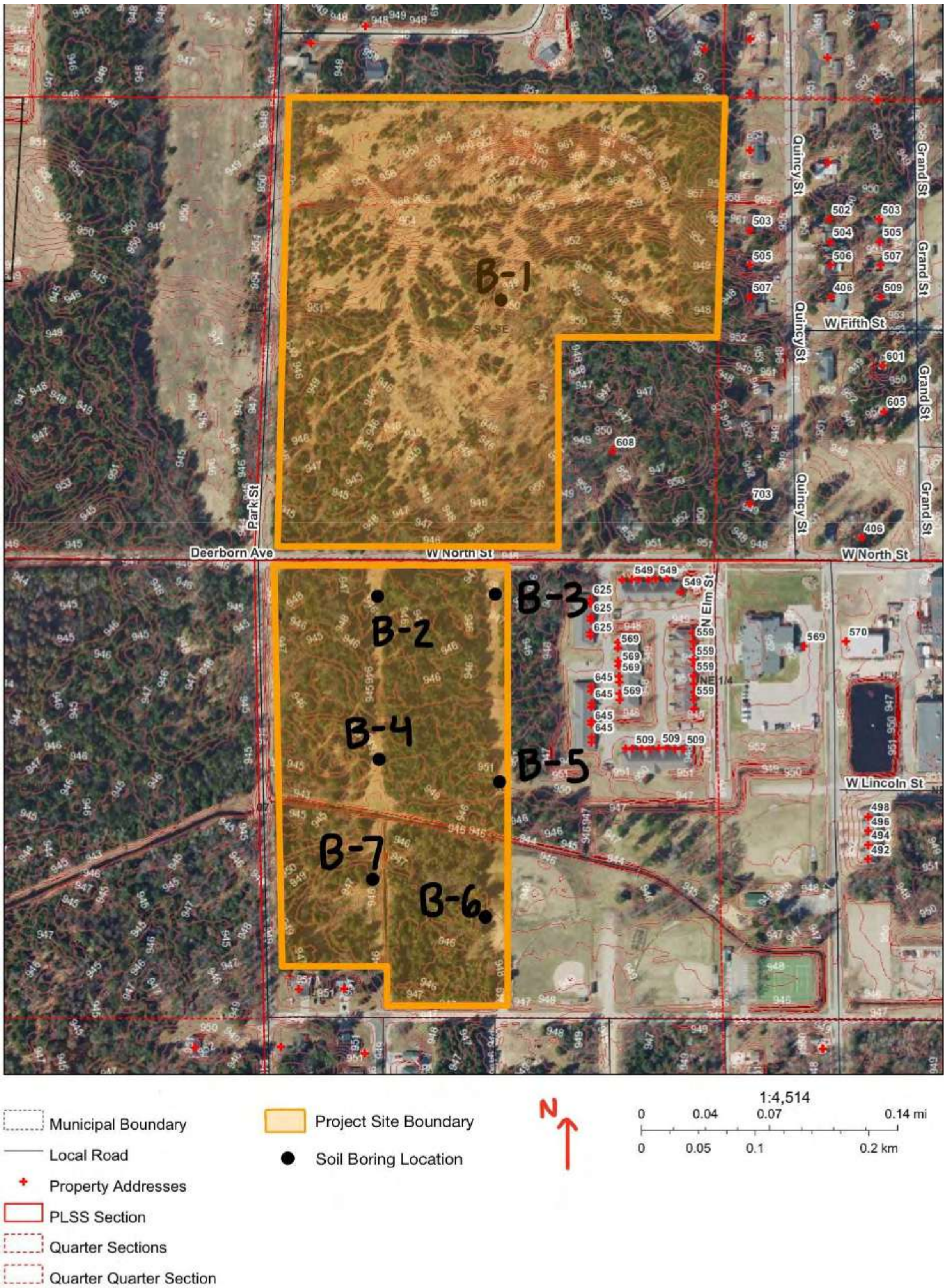
Given the relatively stable and suitable soils found throughout the project site, there should be limited geotechnical issues encountered during construction that would affect sequencing, scheduling, cost, or need for additional exploration.

7. APPENDIX

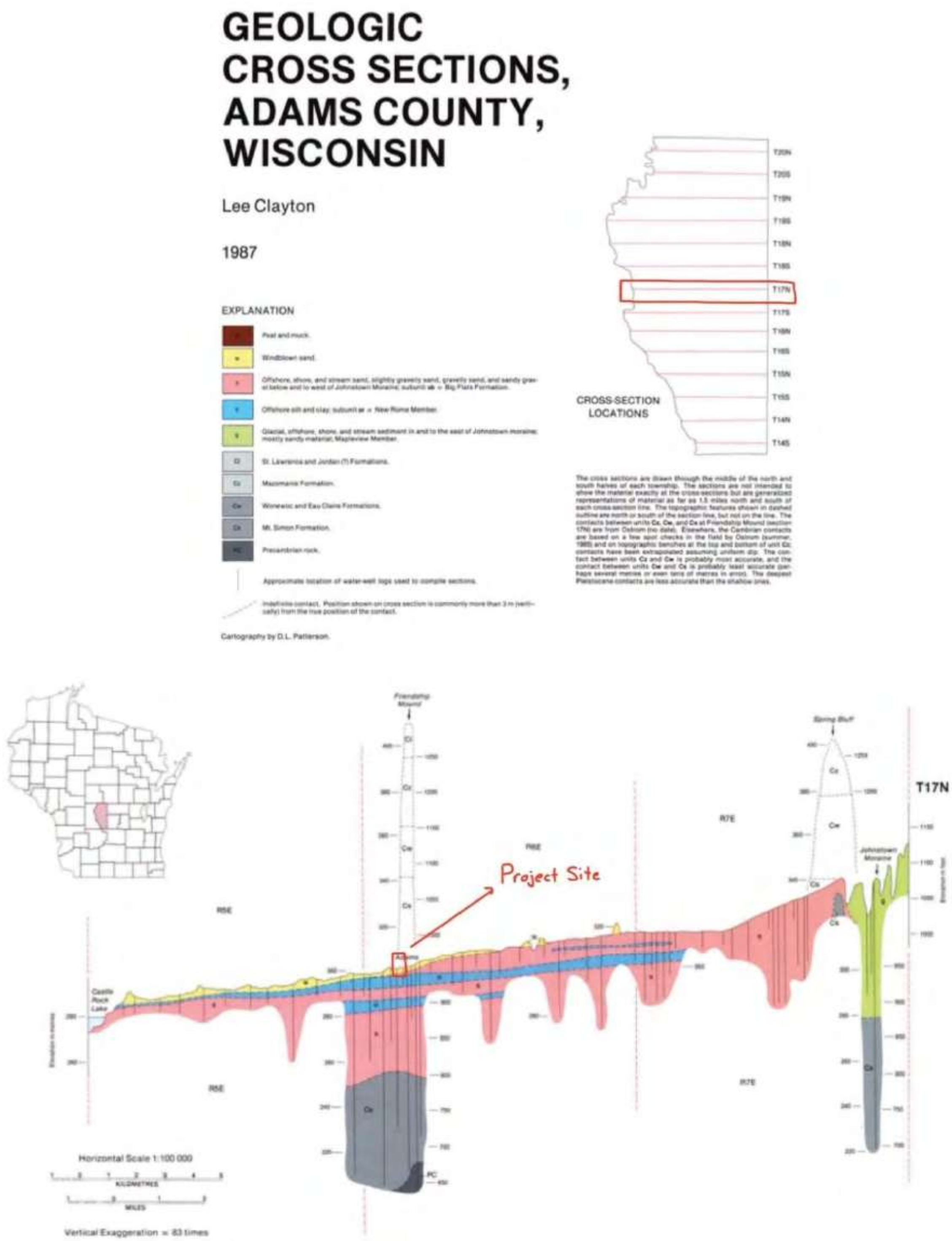
7.1. PROJECT SITE MAP WITH EXISTING UTILITIES



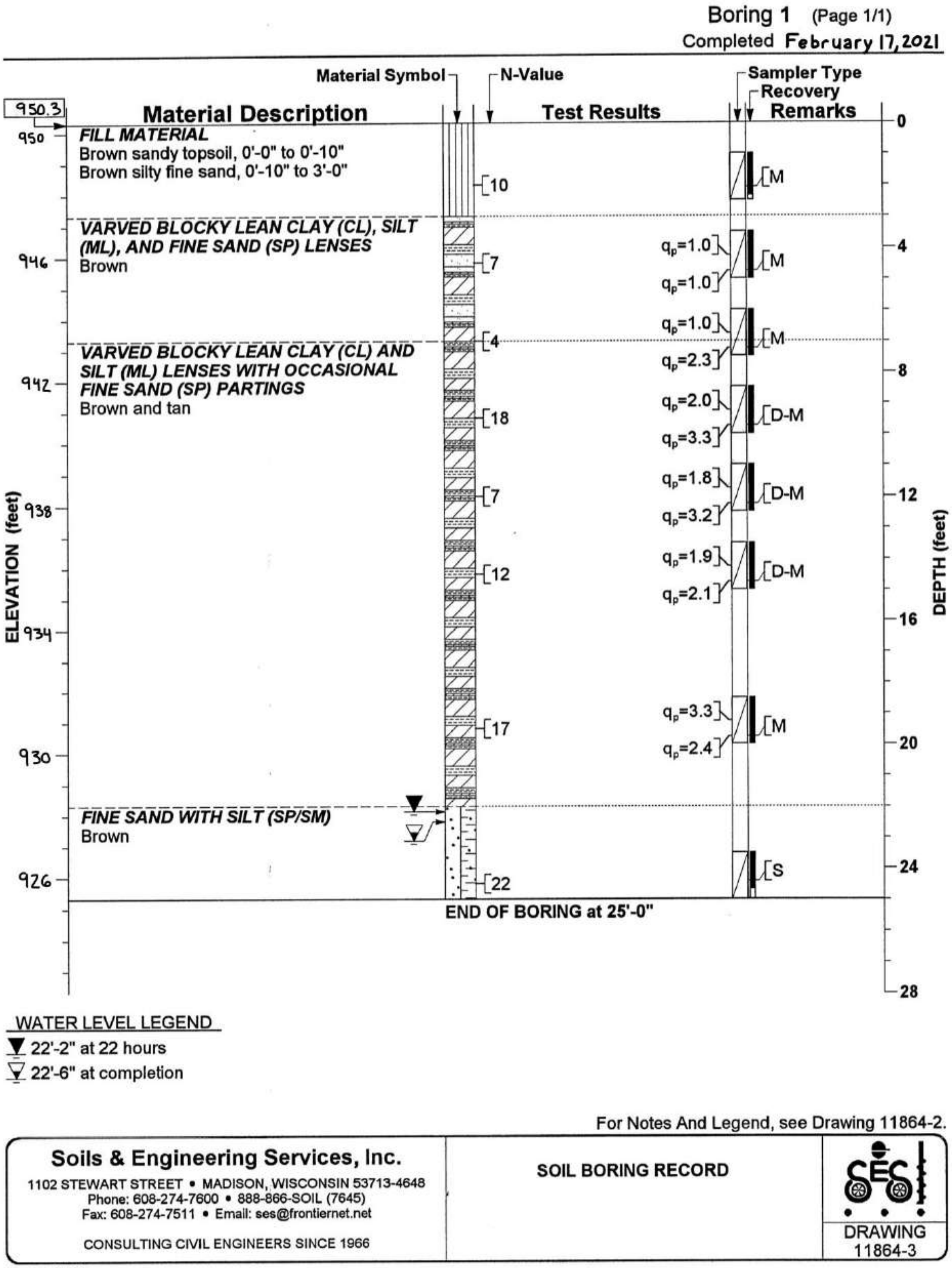
7.2. BORING LOCATION PLAN/SKETCH



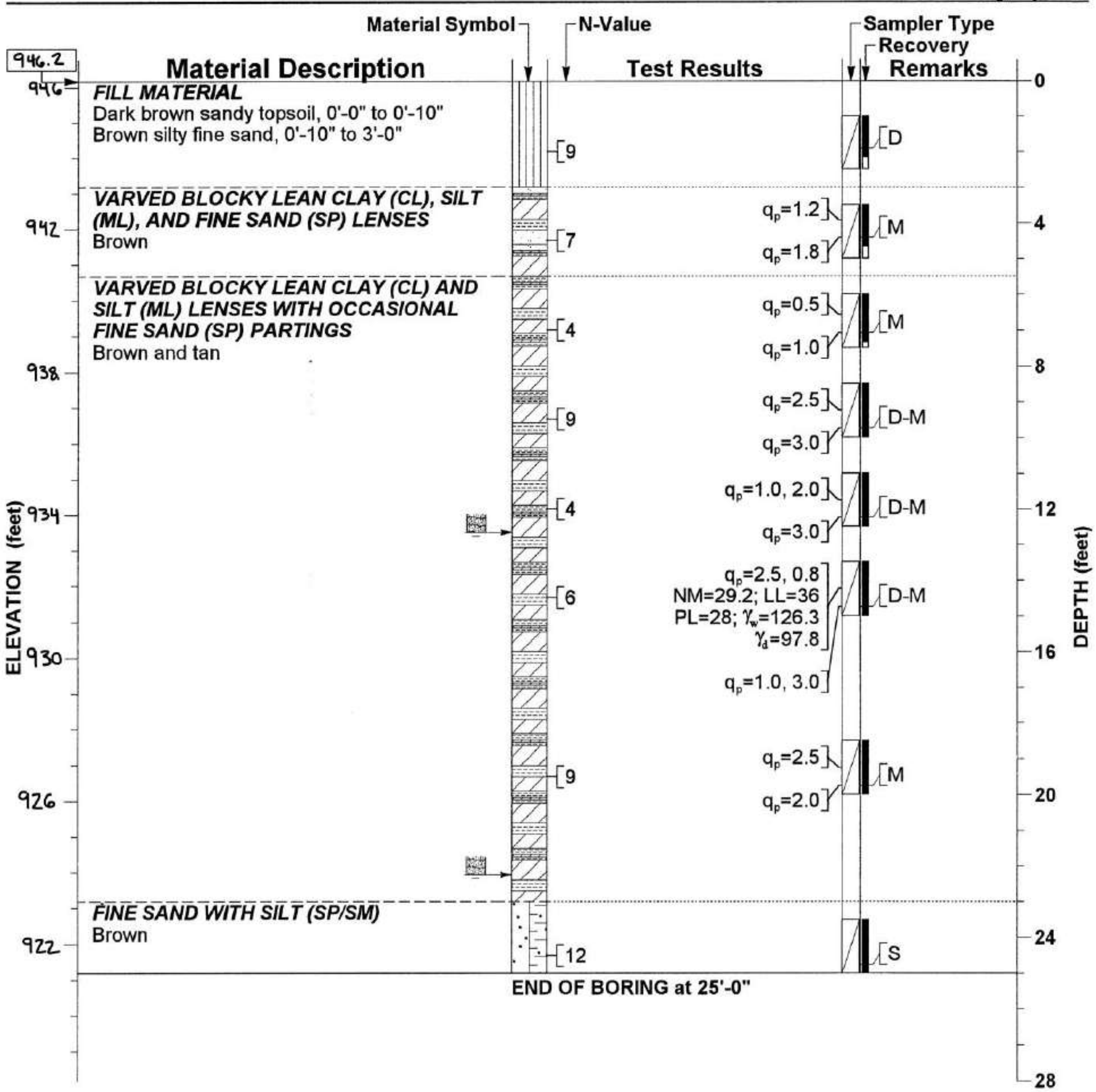
7.3. REGIONAL GEOLOGY DETAILS



7.4. DETIALED BORING LOGS AND NRCS SOILS MAP



Boring 2 (Page 1/1)
Completed February 17, 2021



OTHER LEVEL LEGEND

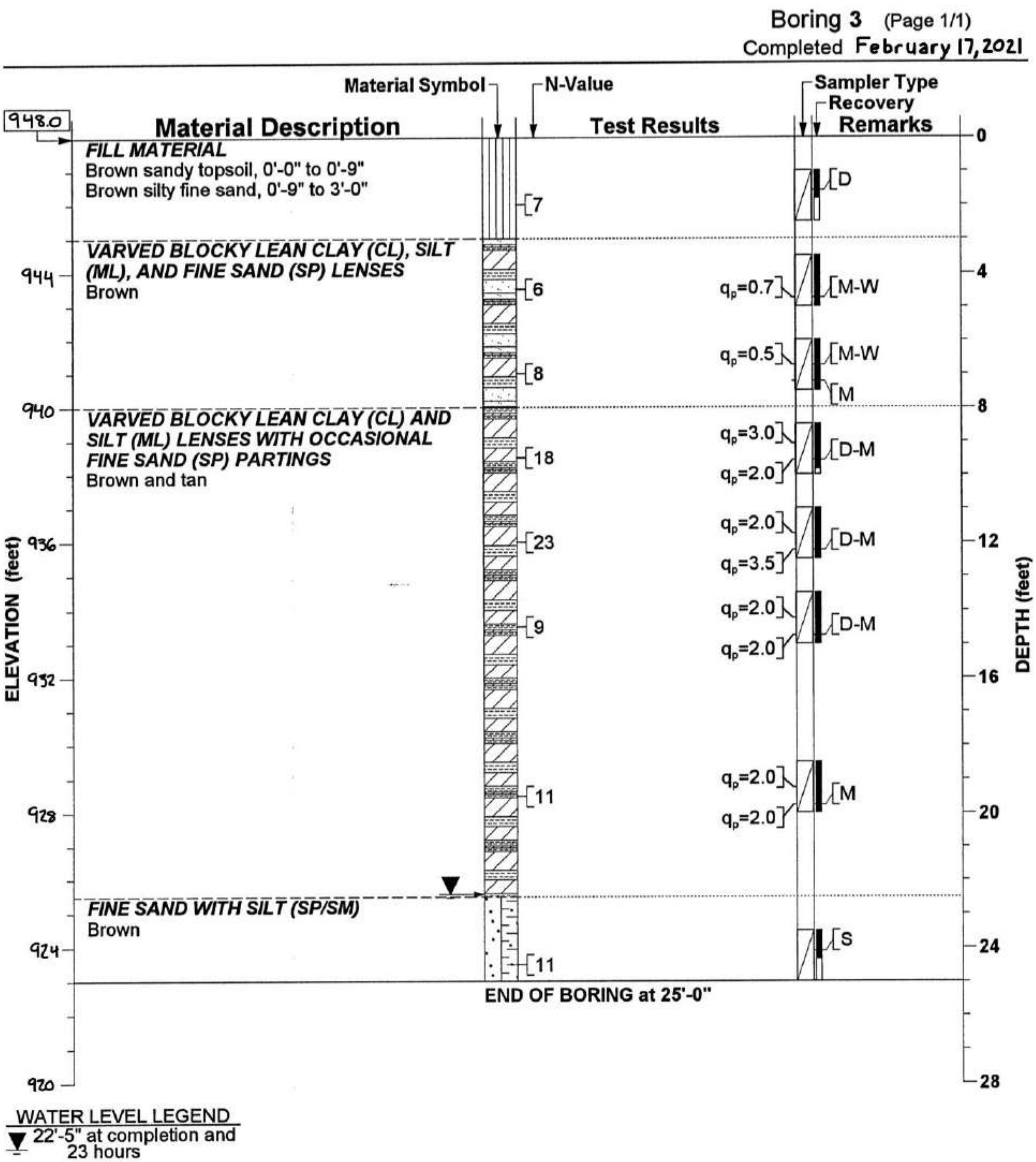
(caved & wet) 12'-8" at at 1 day

(caved & wet) 22'-3" at completion

For Notes And Legend, see Drawing 11864-2.

Soils & Engineering Services, Inc. 1102 STEWART STREET • MADISON, WISCONSIN 53713-4648 Phone: 608-274-7600 • 888-866-SOIL (7645) Fax: 608-274-7511 • Email: ses@frontiernet.net CONSULTING CIVIL ENGINEERS SINCE 1966	SOIL BORING RECORD	DRAWING 11864-4

Printed on 12/9/1999



For Notes And Legend, see Drawing 11864-2.

Soils & Engineering Services, Inc.	SOIL BORING RECORD	DRAWING 11864-5
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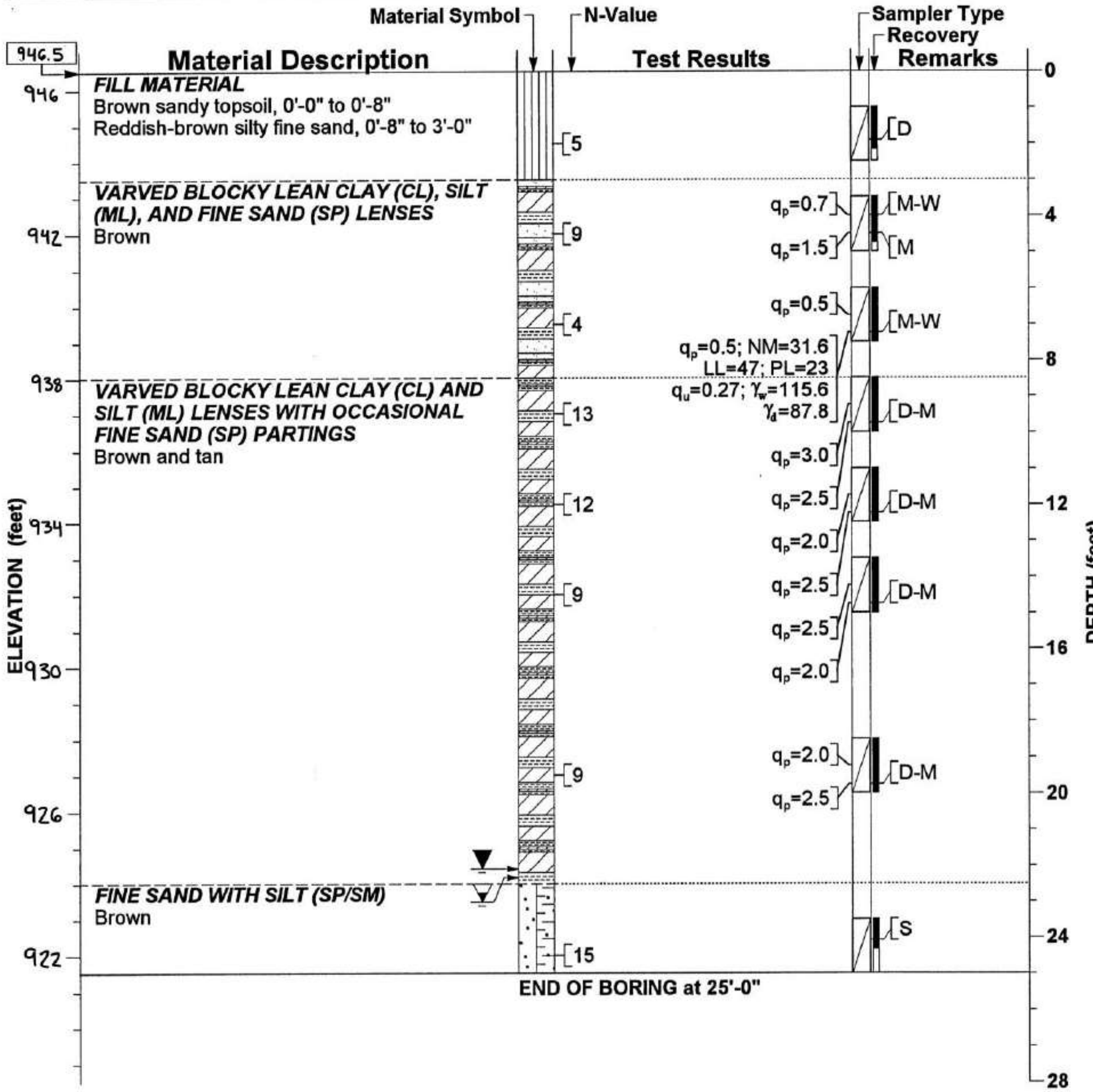
Printed on 12/7/1999

Boring 4 (Page 1/1)
Completed February 17,2021



WATER LEVEL LEGEND

▼ 22'-1" at 1-1/2 hour

▽ 22'-4" at completion

For Notes And Legend, see Drawing 11864-2.

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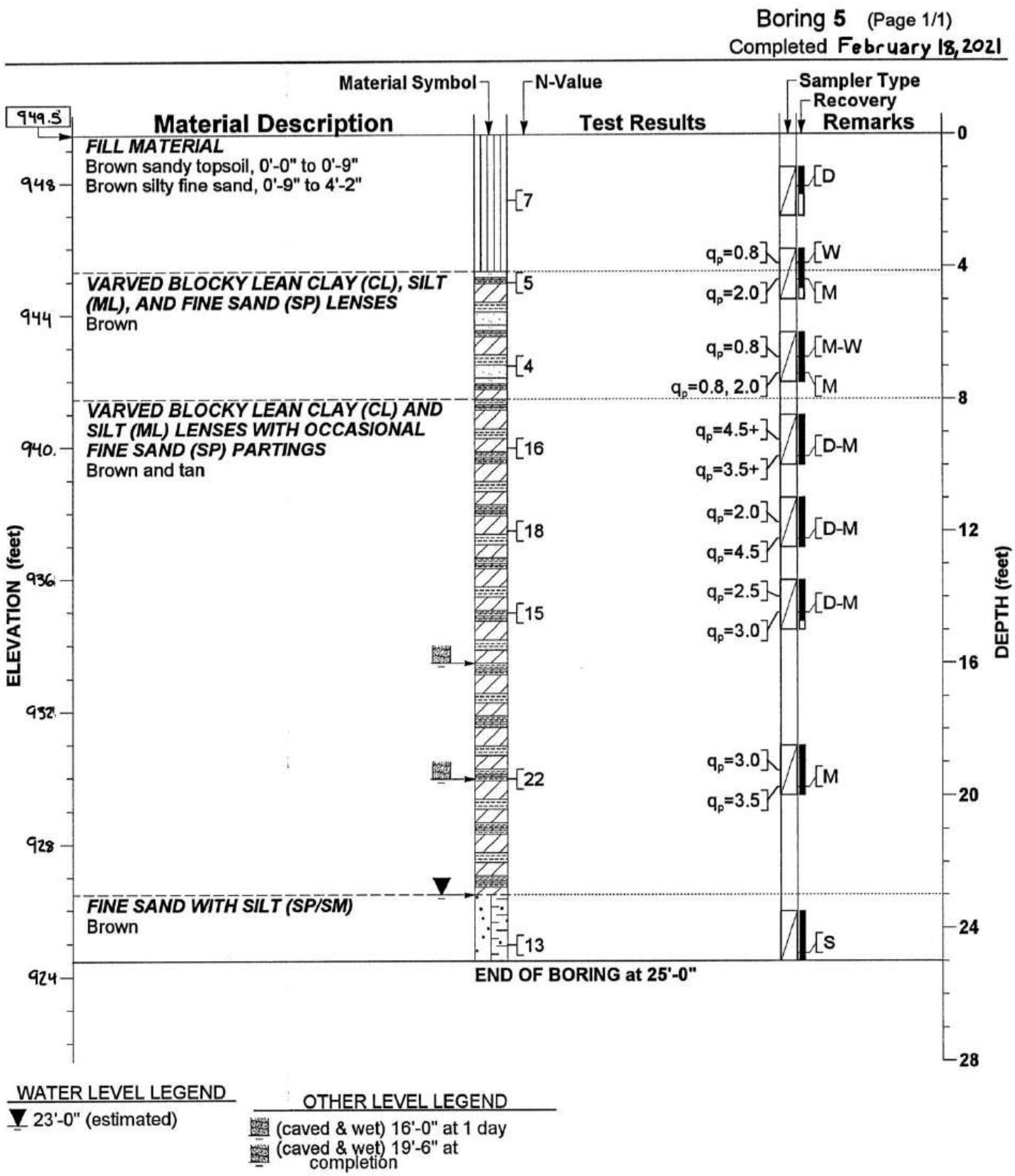
SAAW Consulting Engineering



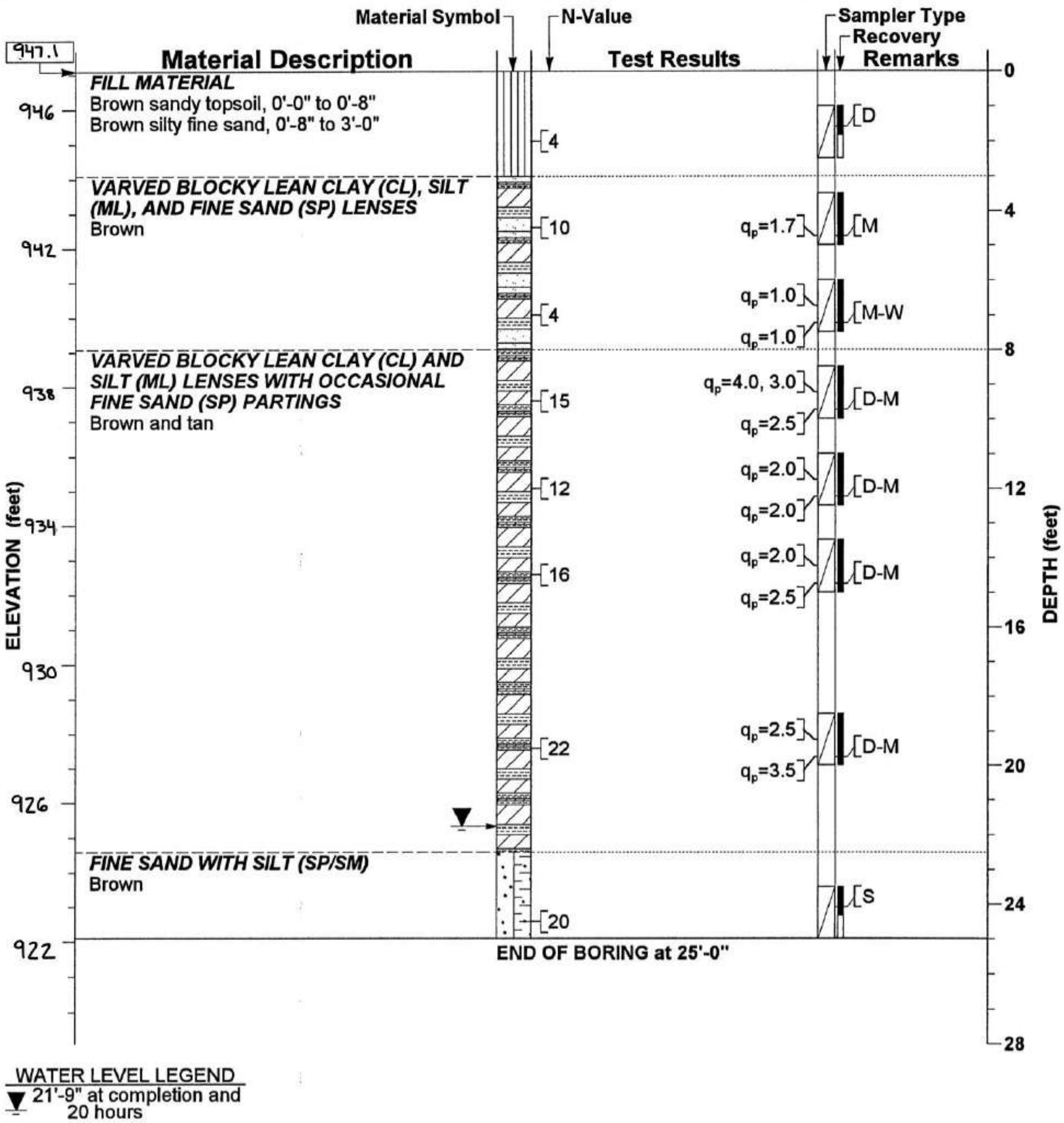
For Notes And Legend, see Drawing 11864-2.

Soils & Engineering Services, Inc. 1102 STEWART STREET • MADISON, WISCONSIN 53713-4648 Phone: 608-274-7600 • 888-866-SOIL (7645) Fax: 608-274-7511 • Email: ses@frontiernet.net CONSULTING CIVIL ENGINEERS SINCE 1966	**SOIL BORING RECORD**	DRAWING 11864-7

Printed on 12/7/1999

SAAW Consulting Engineering

Boring 6 (Page 1/1)
Completed February 18, 2021



For Notes And Legend, see Drawing 11864-2.

Soils & Engineering Services, Inc. 1102 STEWART STREET • MADISON, WISCONSIN 53713-4648 Phone: 608-274-7600 • 888-866-SOIL (7645) Fax: 608-274-7511 • Email: ses@frontiernet.net CONSULTING CIVIL ENGINEERS SINCE 1966	SOIL BORING RECORD	SES DRAWING 11864-8

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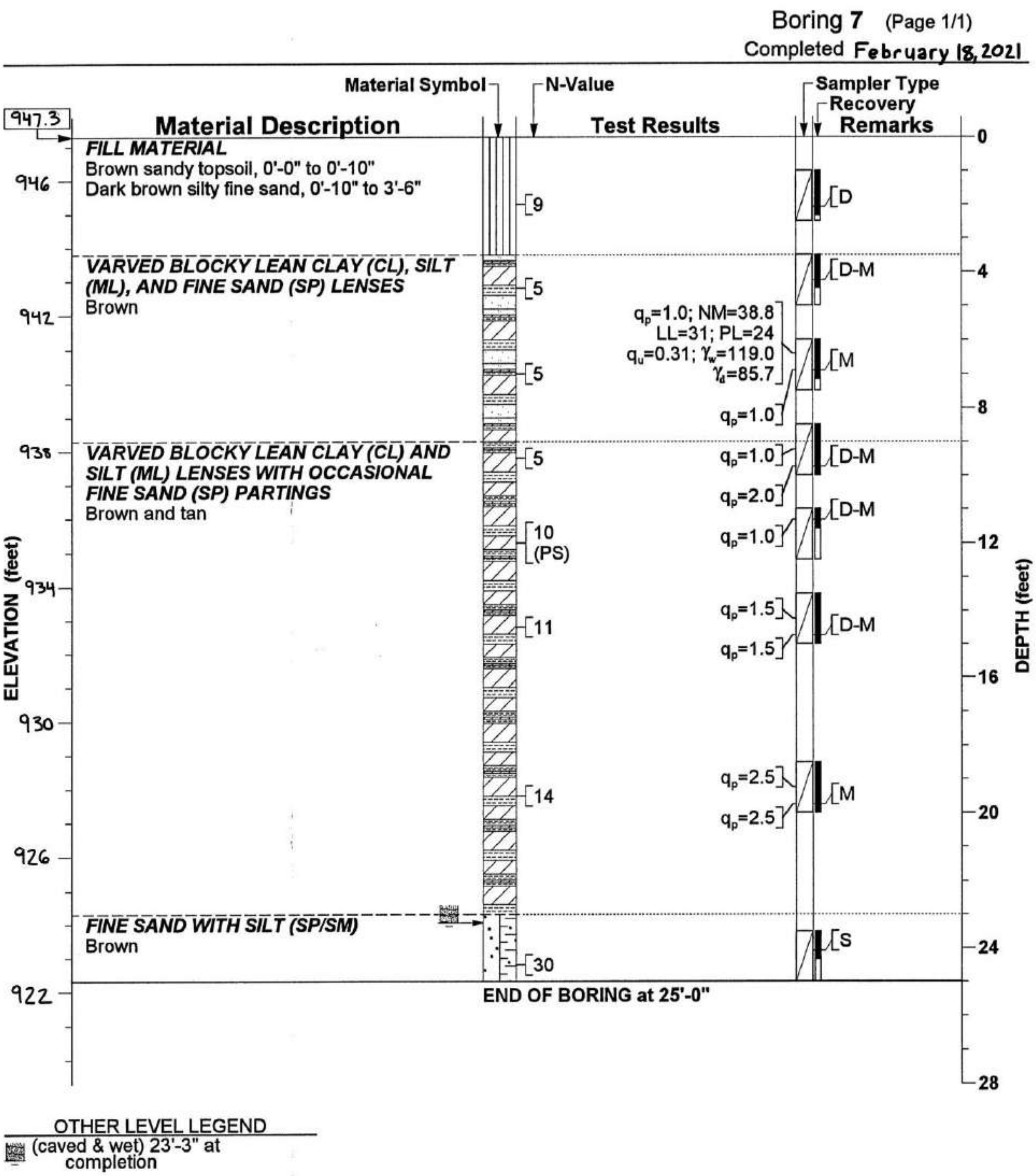

For Notes And Legend, see Drawing 11864-2.

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CONSULTING CIVIL ENGINEERS SINCE 1966

SOIL BORING RECORD

DRAWING 11864-9

Printed on 12/7/1999

LOG OF TEST BORING

General Notes

Descriptive Soil Classification

GRAIN SIZE TERMINOLOGY

Soil Fraction	Particle Size	U.S. Standard Sieve Size
Boulders	Larger than 12"	Larger than 12"
Cobbles	3" to 12"	3" to 12"
Gravel: Coarse	3/4" to 3"	3/4" to 3"
Fine	4.76 mm to 3/4"	#4 to 3/4"
Sand: Coarse	2.00 mm to 4.76 mm	#10 to #4
Medium	0.42 to mm to 2.00 mm	#40 to #10
Fine	0.074 mm to 0.42 mm	#200 to #40
Silt	0.005 mm to 0.074 mm	Smaller than #200
Clay	Smaller than 0.005 mm	Smaller than #200

Plasticity characteristics differentiate between silt and clay.

GENERAL TERMINOLOGY

Physical Characteristics
Color, moisture, grain shape, fineness, etc.
Major Constituents
Clay, silt, sand, gravel
Structure
Laminated, varved, fibrous, stratified, cemented, fissured, etc.
Geologic Origin
Glacial, alluvial, eolian, residual, etc.

RELATIVE DENSITY

Term	"N" Value
Very Loose	0-4
Loose	4-10
Medium Dense	10-30
Dense	30-50
Very Dense	Over 50

RELATIVE PROPORTIONS OF OF COHESIONLESS SOILS

Proportional Term	Defining Range by Percentage of Weight
Trace	0%-5%
Little	5%-12%
Some	12%-35%
And	35%-50%

CONSISTENCY

Term	q_u-tons/sq. ft.
Very Soft	0.0 to 0.25
Soft	0.25 to 0.50
Medium	0.50 to 1.0
Stiff	1.0 to 2.0
Very Stiff	2.0 to 4.0
Hard	Over 4.0

ORGANIC CONTENT BY COMBUSTION METHOD

Soil Description	Loss on Ignition
Non Organic	Less than 4%
Organic Silt/Clay	4-12%
Sedimentary Peat	12-50%
Fibrous and Woody Peat	More than 50%

PLASTICITY

Term	Plastic Index
None to Slight	0-4
Slight	5-7
Medium	8-22
High to Very High	Over 22

The penetration resistance, N, is the summation of the number of blows required to effect two successive 6" penetrations of the 2" split-barrel sampler. The sampler is driven with a 140 lb. weight falling 30" and is seated to a depth of 6" before commencing the standard penetration test.

SYMBOLS

DRILLING AND SAMPLING

CS–Continuous Sampling
RC–Rock Coring: Size AW, BW, NW, 2"W
RQD–Rock Quality Designator
RB–Rock Bit
FT–Fish Tail
DC–Drove Casing
C–Casing: Size 2 1/2", NW, 4", HW
CW–Clear Water
DM–Drilling Mud
HSA–Hollow Stem Auger
FA–Flight Auger
HA–Hand Auger
COA–Clean-Out Auger
SS–2" Diameter Split-Barrel Sample
2ST–2" Diameter Thin-Walled Tube Sample
3ST–3" Diameter Thin-Walled Tube Sample
PT–3" Diameter Piston Tube Sample
AS–Auger Sample
WS–Wash Sample
PTS–Peat Sample
PS–Pitcher Sample
NR–No Recovery
S–Sounding
PMT–Borehole Pressuremeter Test
VS–Vane Shear Test
WPT–Water Pressure Test

LABORATORY TESTS

q_p–Penetrometer Reading, tons/sq. ft.
q_u–Unconfined Strength, tons/sq. ft.
W–Moisture Content, %
LL–Liquid Limit, %
PL–Plastic Limit, %
SL–Shrinkage Limit, %
LI–Loss on Ignition, %
D–Dry Unit Weight, lbs/cu. ft.
pH–Measure of Soil Alkalinity or Acidity
FS–Free Swell, %

WATER LEVEL MEASUREMENT

∇ –Water Level at time shown
NW–No Water Encountered
WD–While Drilling
BCR–Before Casing Removal
ACR–After Casing Removal
CW–Caved and Wet
CM–Caved and Moist

Note: Water level measurements shown on the boring logs represent conditions at the time indicated and may not reflect static levels, especially in cohesive soils.

UNIFIED SOIL CLASSIFICATION SYSTEM

COARSE-GRAINED SOILS

(More than half of material is larger than No. 200 seive size.)

			Laboratory Classification Criteria	
GRAVELS More than half of coarse fraction larger than No. 4 sieve size		**Clean Gravels** (Little or no fines)		
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	Not meeting all gradation requirements for GW	
		Gravels with Fines (Appreciable amount of fines)		
	GM d/u	Silty gravels, gravel-sand-silt mixtures	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
	GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits above "A" line with P.I. greater than 7	
SANDS More than half of coarse fraction smaller than No. 4 sieve size		**Clean Sands** (Little or no fines)		
	SW	Well-graded sands, gravelly sands, little or no fines	$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
	SP	Poorly graded sands, gravelly sands, little or no fines	Not meeting all gradation requirements for SW	
		Sands with Fines (Appreciable amount of fines)		
	SM d/u	Silty sands, sand-silt mixtures	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
	SC	Clayey sands, sand-clay mixtures	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

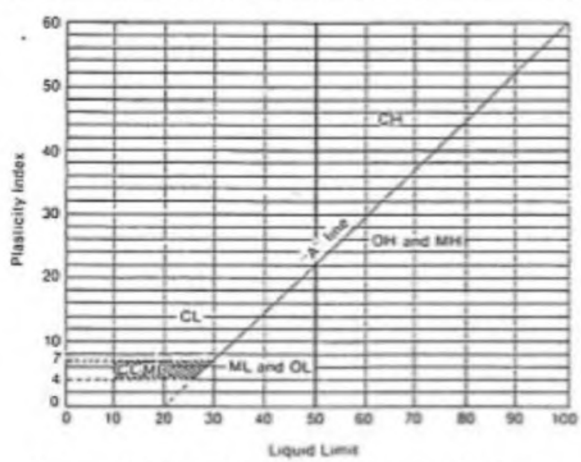
Less than 5 per cent	GW, GP, SW, SP
More than 12 per cent	GM, GC, SM, SC
5 to 12 per cent	Borderline cases requiring dual symbols

FINE-GRAINED SOILS

(More than half of material is smaller than No. 200 sieve.)

SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit greater than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

PLASTICITY CHART



For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg Limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line: PI = 0.73 (LL - 20)

NRCS Soils Map

7.5. LABORATORY TESTING RESULTS

Wis. Dept. of Safety and Professional Services
Division of Safety and Buildings

SOIL EVALUATION - STORM
in accordance with SPS 382.365 and 385, Wis. Adm. Code

Page 1 of 2

Attach complete site plan on paper not less than 8 1/2 x 11 inches in size. Plan must include, but not limited to: vertical and horizontal reference point (BM), direction and percent slope, scale, or dimensions, north arrow, and BM referenced to nearest road.

Please print all information.

Personal information you provide may be used for secondary purposes (Privacy Law, s. 15.04 (1) (m)).

County

Parcel I.D. 59281471035; 59281471031; 59281471051

Reviewed by | Date

Property Owner

Property Location: Govt. Lot NE 1/4 SE 1/4 S 09 T 14 N R 23 E

Property Owner's Mailing Address

Lot # | Block # | Subd. Name or CSM# (New Subdivision)

City | State | Zip Code | Phone Number

[X] City [ ] Village [ ] Town Nearest Road

Drainage area ______ [ ] sq. ft. [ ] acres

Optional:

Test Site Suitable for (check all that apply)

[ ] Irrigation [ ] Bioretention trench [ ] Trench(es)
[ ] Rain Garden [ ] Grassed swale [ ] Reuse
[ ] Infiltration Trench [ ] SDS (> 15' wide) [ ] Other ______

Hydraulic Application Test Method:

[X] Morphological Evaluation
[ ] Double-Ring Infiltrometer
[ ] Other (specify) ______

B-4 Obs. # [X] Boring [ ] Pit Ground surface elev. ______ ft. Depth to limiting factor 6* in.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Sz. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Roots Qu. Sz.	%Rock Frag.	Hydraulic App. Rate Inches/Hr
	0-6	10YR 4/2	TOPSOIL	sil	0,m	mvfr	1,vf	<15	0.13
	6-48	5YR 5/4	c,3,D 10YR 5/6 f,1,P GLEY1 7/10Y	sil	0,m	mvfr	-	<15	0.13
	48-72	10YR 5/3	-	fs	0,sg	mfr	-	<15	0.50
	72-192	2.5Y 5/2	-	s	0,sg	mfi	-	<15	3.60

*Water encountered during drilling at a depth of about 36 inches and upon completion and removal of athe augers at a depth of about 96 inches.

B-5 Obs. # [X] Borng [ ] Pit Ground surface elev. ______ ft. Depth to limiting factor 48* in.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Sz. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Roots Qu. Sz.	%Rock Frag.	Hydraulic App. Rate Inches/Hr
	0-6	10YR 4/2	TOPSOIL	grls	0,m	mvfr	2,vf	15-35	0.50
	6-48	10YR 5/3	-	fs	0,sg	mvfr	-	<15	0.50
	48-120	10YR 5/4	-	fs	0,sg	mvfi	-	<15	0.50
	120-144	2.5Y 5/4	-	fs	0,sg	mfi	-	<15	0.50
	144-192	5YR 4/2	-	si	0,m	mfi	-	<15	0.13

*Water encountered during drilling at a depth of about 48 inches.

CST/PSS Name (Please Print) | Signature | CST/PSS Number SP-111802007

Address | Date Evaluation Conducted 6/23/2020 | Telephone Number

0793 (R11/11)

Consulting Engineering

Property Owner ______ Parcel ID # 59281471035; 59281471031; 59281471051

B-6 Obs. # [x] Boring [ ] Pit Ground surface elev. ______ ft. Depth to limiting factor 6* in.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Sz. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Roots Qu. Sz.	%Rock Frag.	Hydraulic Application Rate Inches/Hr
	0-6	10YR 3/2	TOPSOIL	lfs	0,m	mvfr	1,vf	<15	0.50
	6-48	10YR 4/4	f,3,D 7.5YR 4/6	fs	0,sg	mlo	-	<15	0.50
	48-120	10YR 5/4	-	fs	0,sg	mvfr	-	<15	0.50
	120-144	10YR 5/3	-	fs	0,sg	mvfr	-	<15	0.50
	144-168	5YR 4/2	-	si	0,m	mfi	-	<15	0.13
	168-192	5YR 4/2	-	si	0,m	mvfi	-	<15	0.13

*Water encountered during drilling at a depth of about 48 inches.

Obs. # [ ] Boring [ ] Pit Ground surface elev. ______ ft. Depth to limiting factor ______ in.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Sz. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Roots Qu. Sz.	%Rock Frag.	Hydraulic Application Rate Inches/Hr

Obs. # [ ] Boring [ ] Pit Ground surface elev. ______ ft. Depth to limiting factor ______ in.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Sz. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Roots Qu. Sz.	%Rock Frag.	Hydraulic Application Rate Inches/Hr

Report No: MAT:00941175-2-S1
Issue No: 1

These test results apply only to the specific locations and materials noted and may not represent any other locations or elevations. This report may not be reproduced, except in full, without written permission by Professional Service Industries, Inc. If a non-compliance appears on this report, to the extent that the reported non-compliance impacts the project, the resolution is outside the PSI scope of engagement.

Material Test Report

Client:

CC:

Project

Approved Signatory: Patrick Bray (Branch Manager)
Date of Issue: 7/24/2020

Sample Details

Sample ID:	00941175-2-S1
Client Sample ID:	
Date Sampled:	07/23/20
Sampled By:	Zachary Ashauer
Specification:	Standard Sieve
Supplier:	(none)
Source:	
Material:	Reddish brown CLAY, with silt and sand
Sampling Method:	Split Spoon
Soil Description:	USCS:CL AASHTO:A-4
General Location:	B-1 2.5-9 feet below existing grade

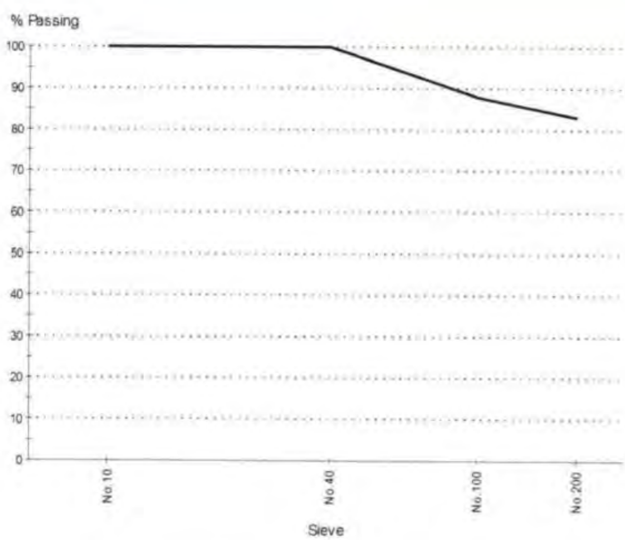
Sample Description:

USCS:CL AASHTO:A-4

Atterberg Limit:

Liquid Limit: 22
Plastic Limit: 12
Plasticity Index: 10

Particle Size Distribution



COBBLES	GRAVEL		SAND			FINES (82.6%)	
	Coarse (0.0%)	Fine (0.0%)	Coarse (0.0%)	Medium (0.2%)	Fine (17.3%)	Silt	Clay
(0.0%)							

Grading: ASTM C 136

Date Tested:
Tested By:

Sieve Size	% Passing	Limits
No.10 (2.0mm)	100	
No.40 (425µm)	100	
No.100 (150µm)	88	
No.200 (75µm)	83	

D85: 0.0990 **D60:** N/A **D50:** N/A
D30: N/A **D15:** N/A **D10:** N/A

Professional Service Industries, Inc.
3009 Vandenbroek Road
Kaukauna, WI 54130

Phone: (920) 735-1200
Fax: (920) 735-1840

Report No: MAT:00941175-2-S1
Issue No: 1

Client: **CC:**

Project

Approved Signatory: Patrick Bray (Branch Manager)
Date of Issue: 7/24/2020

Sample Details

Sample ID:	00941175-2-S1
Client Sample ID:	
Date Sampled:	07/23/20
Sampled By:	Zachary Ashauer
Specification:	Standard Sieve
Supplier:	(none)
Source:	
Material:	Reddish brown CLAY, with silt and sand
Sampling Method:	Split Spoon
Soil Description:	USCS:CL AASHTO:A-4
General Location:	B-1 2.5-9 feet below existing grade

Other Test Results

Description	Method	Result	Limits
Approximate maximum grain size	ASTM D 4318		
Material retained on 425µm (No. 40) (%)		0.2	
Method of Removal			
Grooving Tool Type			
Specimen preparation method			
Drying Method			
Special selection process			
Rolling Method for PL			
As Received Water Content (%)			
Liquid Limit Device Type			
Liquid Limit		22	
Plastic Limit		12	
Plasticity Index		10	
Liquid Limit Procedure		One-point (B)	

Comments

N/A

7.6. RECOMMENDED FILL SPECIFICATIONS

APPENDIX E

RECOMMENDED COMPACTED FILL

SPECIFICATIONS

General Fill Materials

Proposed fill shall contain no vegetation, roots, topsoil, peat, ash, wood or any other non-soil material which by decomposition might cause settlement. Also, fill shall never be placed while frozen or on frozen surfaces. Rock, stone or broken concrete greater than 6 in. in the largest dimension shall not be placed within 10 ft of the building area. Fill used greater than 10 ft beyond the building limits shall not contain rock, boulders or concrete pieces greater than a 2 sq ft area and shall not be placed within the final 2 ft of finish subgrade or in designated utility construction areas. Fill containing rock, boulders or concrete pieces should include sufficient finer material to fill voids among the larger fragments.

Special Fill Materials

In certain cases, special fill materials may be required for specific purposes, such as stabilizing subgrades, backfilling undercut excavations or filling behind retaining walls. For reference, WisDOT gradation specifications for various types of granular fill are attached in Table 1.

Placement Method

The approved fill shall be placed, spread and leveled in layers generally not exceeding 10 in. in thickness before compaction. The fill shall be placed at a moisture content capable of achieving the desired compaction level. For clay soils or granular soils containing an appreciable amount of cohesive fines, moisture conditioning will likely be required.

It is the Contractor's responsibility to provide all necessary compaction equipment and other grading equipment that may be required to attain the specified compaction. Hand-guided vibratory or tamping compactors will be required whenever fill is placed adjacent to walls, footings, columns or in confined areas.

Compaction Specifications

Maximum dry density and optimum moisture content of the fill soil shall be determined in accordance with modified Proctor methods (ASTM D1557). The recommended field compaction as a percentage of the maximum dry density is shown in Table 2. Note that these compaction guidelines would generally not apply to coarse gravel/stone fill. Instead, a method specification would apply (e.g., compact in thin lifts with a vibratory compactor until no further consolidation is evident).

Testing Procedures

Representative samples of proposed fill shall be submitted to CGC, Inc. for optimum moisture-maximum density determination (ASTM D1557) prior to the start of fill placement. The sample size should be approximately 50 lb.

CGC, Inc. shall be retained to perform field density tests to determine the level of compaction being achieved in the fill. The tests shall generally be conducted on each lift at the beginning of fill placement and at a frequency mutually agreed upon by the project team for the remainder of the project.

Table 1
Gradation of Special Fill Materials

Material	WisDOT Section 311	WisDOT Section 312	WisDOT Section 305			WisDOT Section 209		WisDOT Section 210
	Breaker Run	Select Crushed Material	3-in. Dense Graded Base	1 1/4-in. Dense Graded Base	3/4-in. Dense Graded Base	Grade 1 Granular Backfill	Grade 2 Granular Backfill	Structure Backfill
Sieve Size	Percent Passing by Weight							
6 in.	100							
5 in.		90-100						
3 in.			90-100					100
1 1/2 in.		20-50	60-85					
1 1/4 in.				95-100				
1 in.					100			
3/4 in.			40-65	70-93	95-100			
3/8 in.				42-80	50-90			
No. 4			15-40	25-63	35-70	100 (2)	100 (2)	25-100
No. 10		0-10	10-30	16-48	15-55			
No. 40			5-20	8-28	10-35	75 (2)		
No. 100						15 (2)	30 (2)	
No. 200			2-12	2-12	5-15	8 (2)	15 (2)	15 (2)

Notes:

1. Reference: Wisconsin Department of Transportation *Standard Specifications for Highway and Structure Construction.*
2. Percentage applies to the material passing the No. 4 sieve, not the entire sample.
3. Per WisDOT specifications, both breaker run and select crushed material can include concrete that is 'substantially free of steel, building materials and other deleterious material'.

Table 2
Compaction Guidelines

Area	Percent Compaction (1)	
	Clay/Silt	Sand/Gravel
Within 10 ft of building lines		
Footing bearing soils	93 - 95	95
Under floors, steps and walks		
- Lightly loaded floor slab	90	90
- Heavily loaded floor slab and thicker fill zones	92	95
Beyond 10 ft of building lines		
Under walks and pavements		
- Less than 2 ft below subgrade	92	95
- Greater than 2 ft below subgrade	90	90
Landscaping	85	90

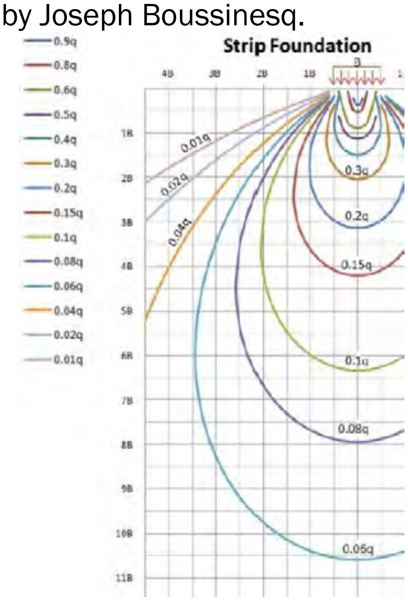
Notes:

1. Based on Modified Proctor Dry Density (ASTM D 1557)

7.7. ANALYSIS CALCULATIONS

7.7.1. ASSUMPTIONS

1. Because of the relatively similar soil stratigraphy throughout the site, the typical soil profile and parameters shown in Figure 1 will be used for analysis.
2. Not all houses will be at the same elevation, but for the purposes of this report, a typical footing elevation will be assumed as follows. Since the bottom floor slab is 7 ft below the surface and the footing thickness is 1 ft, the layer(s) to be used for settlement analysis will be the 3rd layer as shown in Figure 1. For bearing capacity and lateral earth pressure calculations, both the 2nd and 3rd will be used for consideration as the minimum footing depth is 5 ft below the site grade.
3. Assume the typical exterior wall footing is about 2500 plf for a 1-story home with a basement and the footing width is about 18 inches (1.5 ft), the overbearing pressure is approximately 1667 psf (2500 plf / 1.5 ft = 1667 psf).
4. Assume the soil unit weight for each layer is as follows [5]:
    a. Layer 1: Loose Silty Sand – 110 pcf
    b. Layer 2: Medium Stiff Lean Clay – 115 pcf
    c. Layer 3: Very Stiff/Stiff Lean Clay – 125 pcf
    d. Layer 4: Medium Dense Sand with Silt – 120 pcf
5. The compression indices of the clay layer will be calculated using the following equations [6]. The liquid limit of 31 will be used as found from the lab results from Boring 7.
    a. $C_c = 0.009\,(LL-10) = 0.009*(31-10) = 0.189$
    b. $C_r \sim 0.15*C_c = 0.028$
6. The overbearing pressure should dissipate enough throughout the thick clay layer; therefore, elastic settlement on the medium dense sand with silt should be negligible. Only consolidation settlement on the clay layer will be considered.
7. Assume pressure distributions using the following stress contours for strip foundations developed by Joseph Boussinesq.



8. Assume void ratio of 0.6 for clay layers under analysis [7].
9. Assume a friction angle of 28° for the Stiff to Very Stiff Clay layer (3rd layer) and 25° for the Medium Stiff Clay layer (2nd layer) [8].
10. Assume cohesion as half of Q_p as provided in boring logs [6].
11. Assume overconsolidation ratio is 1.5 for the for the Stiff to Very Stiff Clay layer (3rd layer). This would result in a preconsolidation pressure of approximately 2600 psf.

7.7.2. EXAMPLE CALCULATIONS

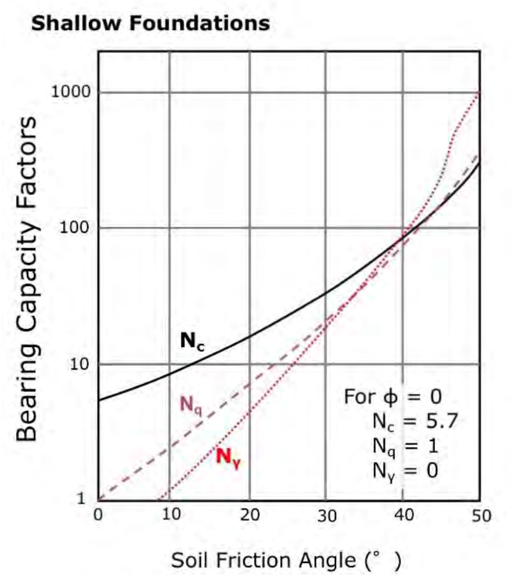
Ultimate Bearing Capacity for Shallow Strip Footings

Terzaghi's General Bearing Capacity Formula:

$Q_u = cN_c + \sigma_D'N_q + 0.5\gamma'(BN_\gamma)$

Where:

Q_u = ultimate bearing capacity (psf)
c = cohesion (psf)
σ_D' = vertical effective stress at footing base
γ' = unit weight of soil below foundation
B = footing width
N_c, N_q, N_γ = bearing capacity factors (refer to chart below)



2nd Layer – Medium Stiff Clay

$Q_u = cN_c + \sigma_D'N_q + 0.5\gamma'(BN_\gamma)$

c = 600 psf
σ_D' = 110 pcf * 3ft + 115 pcf * 2ft = 560 psf
γ' = 115 pcf

B = 1.5 ft
N_c = 22
N_q = 12
N_γ = 10

Q_u = 600 psf*22 + 560 psf*12 + 0.5*115 pcf*1.5 ft*10 = 20782 psf

$Q_a = Q_u$ / F.S. = 20782 psf / 3.0 = 6927 psf ~ 7000 psf

Q_a = 7000 psf

3rd Layer –Stiff to Very Stiff Clay

$Q_u = cN_c + \sigma_D'N_q + 0.5\gamma'(BN_\gamma)$

c = 2500 psf
σ_D' = 110 pcf * 3ft + 115 pcf * 4ft + 125 pcf * 1ft = 915 psf
γ' = 125 pcf
B = 1.5 ft
N_c = 25
N_q = 18
N_γ = 15

Q_u = 2500 psf*25 + 915 psf*18 + 0.5*125 pcf*1.5 ft*15 = 80376 psf

$Q_a = Q_u$ / F.S. = 80376 psf / 3.0 = 26792 psf ~ 27000 psf

Q_a = 27000 psf

Settlement in Stiff to Very Stiff Clay Layer (3rd Layer)

Terzaghi's One-Dimensional Consolidation Equation:

$$S_c = \frac{C_r}{1+e_0} * H * \log\left(\frac{\sigma'_p}{\sigma'_0}\right) + \frac{C_c}{1+e_0} * H * \log\left(\frac{\sigma'_f}{\sigma'_p}\right)$$

Where:

S_c = settlement (ft)
H = height of layer (ft)
C_r = Recompression Index
C_c = Compression Index – will not be used depending on if soil is overconsolidated (OC)
e_o = void ratio
σ'_p = preconsolidation pressure (psf)
σ'_o = initial effective stress (psf)
$\sigma'_f = \sigma'_o + \Delta\sigma'$ = final effective stress after applied pressure (psf)

Break clay layer into three smaller layers and calculate settlement in each to be summed for total settlement.

Layer 1: $S_c = \frac{C_r}{1+e_0} * H * \log\left(\frac{\sigma'_p}{\sigma'_0}\right) + \frac{C_c}{1+e_0} * H * \log\left(\frac{\sigma'_f}{\sigma'_p}\right)$

Depth for analysis: 10.5 ft
Depth below footing = 2.5 ft = 1.67B
H = 5 ft
C_r = 0.028
C_c = 0.189
e_o = 0.6
σ'_p = 2600 psf
σ'_o = 110 pcf * 3 ft + 115 pcf * 4 ft + 125 pcf * 3.5 ft = 1227.5 psf
σ'_f = 1227.5 psf + 0.35*1667 psf = 1810.95 psf

$\sigma'_f < \sigma'_p \rightarrow$ OC

$$S_{c1} = \frac{0.028}{1+0.6} * 5\,ft * \log\left(\frac{1810.95}{1227.5}\right) = 0.015\,ft$$

Layer 2: $S_c = \frac{C_r}{1+e_0} * H * \log\left(\frac{\sigma'_p}{\sigma'_0}\right) + \frac{C_c}{1+e_0} * H * \log\left(\frac{\sigma'_f}{\sigma'_p}\right)$

Depth for analysis: 15.5 ft
Depth below footing = 7.5 ft = 5B
H = 5 ft
C_r = 0.028
C_c = 0.189
e_o = 0.6
σ'_p = 2600 psf
σ'_o = 110 pcf * 3 ft + 115 pcf * 4 ft + 125 pcf * 8.5 ft = 1852.5 psf
σ'_f = 1852.5 psf + 0.13*1667 psf = 2069.2 psf

$\sigma'_f < \sigma'_p \rightarrow$ OC

$$S_{c2} = \frac{0.028}{1+0.6} * 5\,ft * \log\left(\frac{2069.2}{1852.5}\right) = 0.004\,ft$$

Layer 3: $S_c = \frac{C_r}{1+e_0} * H * \log\left(\frac{\sigma'_p}{\sigma'_0}\right) + \frac{C_c}{1+e_0} * H * \log\left(\frac{\sigma'_f}{\sigma'_p}\right)$

Depth for analysis: 20.25 ft
Depth below footing = 12.25 ft = 8.17B
H = 4.5 ft
C_r = 0.028
C_c = 0.189
e_o = 0.6
σ'_p = 2600 psf
σ'_o = 110 pcf * 3 ft + 115 pcf * 4 ft + 125 pcf * 13.25 ft = 2446.25 psf
σ'_f = 2446.5 psf + 0.08*1667 psf = 2579.9 psf

$\sigma'_f < \sigma'_p \rightarrow$ OC

$$S_{c3} = \frac{0.028}{1+0.6} * 4.5\,ft * \log\left(\frac{2579.9}{2446.25}\right) = 0.002\,ft$$

$S_{c,total} = S_{c1} + S_{c2} + S_{c3}$ = 0.015 ft + 0.004 ft + 0.002 ft = 0.021 ft = 0.252 in ~ 0.3 in

$S_{c,total}$ = 0.3 in

Lateral Earth Pressures in Clay Layers

$\sigma'_h = K_o * \sigma'_v$

Coefficient of Lateral Earth Pressure at Rest (K_o):
$K_{o,\text{ sand layer}} = 1 - \sin\varphi = 1 - \sin(30) = 0.5$
$K_{o,\text{ medium clay layer}} = 1 - \sin\varphi = 1 - \sin(25) = 0.58$
$K_{o,\text{ stiff clay layer}} = 1 - \sin\varphi = 1 - \sin(28) = 0.53$

Medium Stiff Clay Layer – Evaluated at depth of 5 ft for minimum depth of basement wall below site grade

$\sigma'_{v,\text{ sand layer}}$ = 110 pcf * 3ft = 330 psf
$\sigma'_{h,\text{ sand layer}} = K_{o,\text{ sand layer}} * \sigma'_{v,\text{ sand layer}}$ = 0.5 * 330 psf = 165 psf

$\sigma'_{v,\text{ medium clay layer}}$ = 110 pcf * 3ft + 115 pcf * 2 ft = 560 psf
$\sigma'_{h,\text{ medium clay layer}} = K_{o,\text{ medium clay layer}} * \sigma'_{v,\text{ medium clay layer}}$ = 0.58 * 560 psf = 324.8 psf

Lateral Earth Pressure = 0.5*165 psf * 3 ft + 0.5*(324.8 psf + 165 psf) * 2 ft = 737.3 plf ~ 750 plf

Lateral Earth Pressure = 750 plf

Stiff/Very Stiff Clay Layer – Evaluated at depth of 8 ft for typical depth of basement wall below site grade

$\sigma'_{v,\text{ sand layer}}$ = 110 pcf * 3ft = 330 psf
$\sigma'_{h,\text{ sand layer}} = K_{o,\text{ sand layer}} * \sigma'_{v,\text{ sand layer}}$ = 0.5 * 330 psf = 165 psf

$\sigma'_{v,\text{ medium clay layer}}$ = 110 pcf * 3ft + 115 pcf * 4 ft = 790 psf
$\sigma'_{h,\text{ medium clay layer}} = K_{o,\text{ medium clay layer}} * \sigma'_{v,\text{ medium clay layer}}$ = 0.58 * 790 psf = 458.2 psf

$\sigma'_{v,\text{ stiff clay layer}}$ = 110 pcf * 3ft + 115 pcf * 4 ft + 125 pcf * 1 ft = 915 psf
$\sigma'_{h,\text{ stiff clay layer}} = K_{o,\text{ stiff clay layer}} * \sigma'_{v,\text{ stiff clay layer}}$ = 0.53 * 915 psf = 484.95 psf

Lateral Earth Pressure = 0.5*165 psf * 3 ft + 0.5*(458.2 psf + 165 psf) * 4 ft + 0.5*(458.2 psf + 484.95 psf) * 1 ft = 1965.5 plf ~ 2000 plf

Lateral Earth Pressure = 2000 plf

7.8. REPORT LIMITATIONS

This report is based on a unique set of project-specific factors. Even seemingly minor changes in the function, location, loading conditions or other factors assumed or provided to us for this report could affect the validity of the recommendations in this report. The geotechnical engineer should be notified of such changes and asked to review their impact on the recommendations.

This report is based on the findings of soil borings at a nearby wastewater treatment plant and do NOT explicitly represent subsurface conditions at the proposed project site but merely a prediction. Similarly, all soil parameters and needed for calculations but not originally are outlined in the assumption section of the analysis calculations.

Subsurface conditions including groundwater and soil conditions can change with time due to construction activities on this site or nearby properties, water table fluctuations, weather conditions and other factors.

Environmental concerns are NOT addressed in this report, as they were not included within the scope of our work. Professional consultation and exploration by a qualified environmental consulting firm is recommended where such concerns may exist.

References

[1] C. Lee, *Pleistocene Geologic Map, Adams County, Wisconsin,* Wisconsin Geological and Natural History Survey, 1987.

[2] C. Lee, *Geologic Cross Sections, Adams County, Wisconsin,* Wisconsin Geological and Natural History Survey, 1987.

[3] M. E. Ostrom, L. C. Trotta and R. D. Cotter, *Depth to Bedrock in Wisconsin,* Wisconsin Geological and Natural History Survey, 1973.

[4] Wisconsin Asphalt Pavement Association, "Wisconsin Asphalt Bid/Mix Specification Tool," 11 November 2019. [Online]. Available: https://www.wispave.org/wisconsin-asphalt-bid-mix-specification-tool/.

[5] Geotechincal Info.com, "Unit Weight of Soil," 2012. [Online]. Available: http://www.geotechnicalinfo.com/soil_unit_weight.html.

[6] K. Terzaghi and R. B. Peck, "Soil Mechanics in Engineering Practice," John Wiley and Sons, New York, 1967.

[7] B. M. Das, Principles of Foundation Engineering, PWS-Kent Publishing, 1984.

[8] Civil Engineering Bible, "Friction Angle of Soils + Typical Values," [Online]. Available: https://civilengineeringbible.com/subtopics.php?i=89.

UniverCity Alliance
UNIVERSITY OF WISCONSIN–MADISON

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UniverCity Year

UniverCity Year is a three-phase partnership between UW-Madison and communities in Wisconsin. The concept is simple. The community partner identifies projects that would benefit from UW-Madison expertise. Faculty from across the university incorporate these projects into their courses, and UniverCity Year staff provide administrative support to ensure the collaboration's success. The results are powerful. Partners receive big ideas and feasible recommendations that spark momentum towards a more sustainable, livable, and resilient future. Join us as we create **better places together**.

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