SMITHGROUP

**BOARDMAN RIVER WALL STABILIZATION**
**MEMORANDUM OF FINDINGS**
City of Traverse City and Traverse City DDA
April 12, 2021

## PROJECT BACKGROUND

Along the frontage of the Lower Boardman River in the 100 and 200 block of Front Street a concrete retaining wall built in the 1930's supports a sanitary sewer main and surface parking and sidewalks. The wall is a cantilevered retaining wall, itself supported by a series of timber piles. In recent years it has become apparent that the river is scouring out the soil underneath the wall footing, which was confirmed by an underwater video inspection of the wall. During the spring of 2020, depressions formed in the landscape areas, paving showed signs of failure, and signposts began falling over, all of which indicated that soil stability issues exist adjacent to the wall.

### Issues

The loss of soils is problematic to the community and the river because the support for the sewer service connections is being lost and/or weakened, which could potentially contribute to the release of raw sewage into the river. In addition, the impact to the sewer system pipes and connections encourages ground water infiltration into the sewer pipes which increases the community costs to treat sewage on typical days and contributes to the failure of the sanitary sewer on larger storm event days as were experienced on three occasions in the spring of 2020. The 24" sewer main resting on the foundation of the wall was lined which aids in preventing ground water infiltration but the numerous sewer service connections are not lined, and ground water can infiltrate the pipes. The 24" sewer main was lined in 2003 and the lining has a life expectancy of 40 years.

The sanitary sewer service lines connecting the commercial businesses along Front Street and the sewer main built on the wall foundation are threatened by the soil subsidence, particularly on the 100 block. Within the past decade the service lines were updated on the 200 block with modern sewer pipes with sealed fittings and fewer joints, making the service lines more ridged. On the 100 block it is assumed that the service lines are predominately clay pipe, many of which likely date back to the construction of the wall and sewer main in the 1930s. These pipes are susceptible to failure at the joints, particularly in the area where soil is settling adjacent to the main to which the service lines connect.

If a sewer service connection were to break, the damage could be detrimental to the Boardman River and the surrounding area. A sewer service connection could leak raw sewage into the Boardman River and into Grand Traverse Bay. While currently ground water may create pressure on the service connection pipe and limit the quantity of effluent escaping the pipe, there remains concern that discharges could negatively impact habitat, wildlife, and water quality. A leak could also cause the ground to become saturated and unstable causing pavement failure to the parking area and unstable soil near building foundations, eventually leading to settlement, if a service connection broke near the buildings. A failure of a service connection can also compound and create a failure in the sanitary main as well. These failures can be dangerous to the infrastructure but also to pedestrians and other users of the public alley.

The soil subsidence has posed risks to the public infrastructure and those who use the sidewalks, parking, and alley. The amount of annual subsidence has increased over the past decade, and this trend is unlikely to slow. In 2020, the loss of soil support caused a parking station to overturn and a hole to open up in the landscape area between the sidewalk and the wall on the 100 block. While the loss of soil is typically incremental over time, the paving in the area can mask over areas of underground soil failure until the issue is made apparent by a sizeable collapse or settlement of pavement. Larger areas of failure can lead to destabilizing events which may threaten the condition of the wall and lead to more significant damage to the sanitary sewer main.

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**Study Process**
In June of 2020, the Traverse City Downtown Development Authority (DDA) authorized an inspection of the wall by SmithGroup to investigate the soil stability issue and sought recommendations on how to stabilize the soils and wall.

Based on the review of the video of the dive inspection of the concrete wall, the review of the wall engineering plans and details (Appendix B), and the observations of the field review, it is apparent that there has been little to no movement of the concrete retaining wall. There is no evidence the wall has settled or canted, and no major cracking of the wall was evident (other than in locations that had been modified by subsequent construction along the wall). The timber piles supporting the wall's foundation are fully submerged and are driven to a bearing capacity of 15 tons. According to the dive inspection, the timber piles appeared to be stable and did not show signs of degradation. Fully submerged timber piles can be expected to maintain structural integrity indefinitely (FHWA).

The inspection also found that the subsidence and settling along the back side of the wall is due to a loss of soil material within the backfill of the wall, specifically within a zone of 10 feet +/- behind (south) of the wall. These soils are being lost due to scouring and undermining of the retaining wall footing. The material loss is exacerbated by high water levels of the Great Lakes and connecting channels which causes soil saturation, loss of consolidation of the backfill soils, and loss of the soils through gaps below the footing and through the walls at penetrations.

The inspection concluded that soils would continue to be lost due to these conditions, and even as water levels recede the soil loss will continue due to the lack of consolidation.

It was agreed that an assessment of options and then the determination of best and most feasible approaches should be determined. The key components of this study include the topographic, bathymetric and utility survey of the area (Appendix C), geotechnical borings (Appendix D) and analysis of the soils on the south side of the river, the development and feasibility assessment of alternative solutions, the refinement of the river's hydraulic model, and testing of alternative solutions to determine the impacts of the alternatives on the river system.

The DDA is in the process of creating a Unified Plan for the Lower Boardman/Ottaway River, and this study is developing recommendations on, among other topics, the restoration and management of the shoreline of the river to create habitat improvements in support of riparian wildlife and fisheries and provide for public access to the waterfront. Extensive public engagement has been conducted as part of this planning effort and the greening of the river's edge and increasing the setback of parking and development along the river have each been significant interests of the community.

## ALTERNATIVES CONSIDERED

SmithGroup explored many options to mitigate the undermining of the existing retaining wall due to scour. The options are detailed below.

### A. Sheet Pile on Land Side of the Wall

This option would require excavation behind the wall to expose the footer of the wall, the sanitary sewer and the sewer service leads. Sewer services could be repaired, and areas of settlement due to scour identified. As needed, a sheet pile wall would be driven into the earth behind the footing of the wall, sealed against the footing with tremie concrete and the excavation backfilled with engineered fill.

Although this option would have no impact on the flood levels of the river, this option was found unsuitable because scour may continue to undermine new areas of the shoreline where sheet pile was not installed, limiting the value of the solution in the long term. Further, the construction logistics of installing sheet pile in and around the sewer, service lines, and other utilities is problematic, and would increase construction costs. The sewer service connections could be repaired within the construction limits which would benefit businesses on the 100 block; however, the sewer connections on the 200 block have already been updated and would add costs to the project without benefit to this infrastructure. Storm sewer and roof drain outfalls would need to be rebuilt on both blocks. On the 100 block, it is desired to recreate a natural shoreline for habitat restoration in the future and the investment in this solution would not further the long-term goals of the DDA and the Unified Plan.

**B. Concrete Filled Geotextile Tube**

This option would place a geotextile tube at the river bottom elevation on a bed of scour stone and filled with sand or concrete to close the gap between the river bottom and bottom of the existing wall footing.

This option was deemed unsuitable because this work would not be a long-term solution and does not address the sanitary sewer main and service connections. Scour could continue to occur at the bottom of the river and could eventually expose and create another gap between the concrete filled geotextile sock and river bottom. Due to the size of the tube and the extent to which the tube would intrude into the river, this option will result in raising to the flood elevation of the river more significantly than the other options. This option would also be abandoned or removed if the 100 block’s shoreline is restored in the future.

**C. Cores in the Footer**

This option would require excavation of a trench behind the existing retaining wall and coring into the existing footer to pump concrete. The concrete would fill the gap due to scour below the concrete footer. A temporary dam would need to be placed in the river to create a dry area for pumping of concrete under the existing footer. Conventional concrete formwork would be used to contain the poured concrete on the river side of the wall foundation.

This option was deemed unsuitable for many reasons. The first being the potential damage to existing utilities and wall. Coring into the footer could create issues in the currently sound footer and existing piles. It could also result in damage to the existing sewer line that is behind the wall.
This option also risks the occurrence of additional scour at the riverbed.

**D. Wall Removal and Sewer Relocation**

This option would remove the wall and leave the wall footing and timber piles in place. The sanitary sewer would need to be relocated to the south (closer to the buildings), sanitary sewer connections can be replaced back to the source, and a slope installed with landscape and erosion and scour protection (likely, stone riprap). As a consequence of this option, the northern 20-30 feet of paving would need to be removed, and the pedestrian bridge would need to be replaced with a single span structure. Depending on the final design of the alley, the pavement demolition may remove approximately (44) parking spaces in the alley. Designed correctly, this option could provide meaningful habitat benefits and align with the Unified Plan.

This option is feasible on the 100 block as adequate space exists to create the landscape slope without impacting the service function of the alley. However, on the 200-block, space is constricted and this approach could not be used without removing the service alley completely.

The study also included an assessment of the potential to lower grades in the parking lot/alley on the 100 block to reduce the restored slope steepness and/or flood elevation. Assuming the pedestrian/vehicular shared use of the alley, the future design needs to consider the need for Universal Access, which may restrict the ability to add slope to the paved area. This investigation also identified two additional key considerations; the need to add steps and walls in the alley to access businesses, and the potential impact to communications and electrical infrastructure in the alley which would be sensitive to changes in grade due to limited burial depths. This idea merits further creative problem solving in future design and engineering efforts.

**E. Sheet Pile Wall Protection**

As described below, this option uses sheet pile along the face of the wall to prevent further scouring and allow for any voids below and next to the wall to be filled. This option is feasible for both the 100 and 200 blocks, although it would not forward the goals of the DDA and the Unified Plan and would cause some change to the flood elevation outside of the project area if completed for both blocks.

## ASSESSMENT OF ALTERNATIVES

The criteria to assess the efficacy and suitability of the solutions includes:

1. Provide long term protection for adjacent properties and sanitary sewer.
2. Maintain the alley and service access on the north side of the commercial buildings facing Front Street to preserve the function and integrity of the historic structures.
3. Limit impact on the flooding elevation of the river; especially upstream of the project area.
4. Preserve opportunities in the future to achieve the developing goals of the Unified Plan, greening the river edge while creating opportunities for pedestrian access to the river.
5. While considering long term goals for the project area, ensure that improvements are prudent and cost effective.

For each alternative we assume the need to replace the sanitary sewer service lines from the sewer main to the building connection on the 100 block.

The table below summarizes the results of our assessment of the alternative approaches. A more detailed description of the cost analysis and hydraulic modelling reflected in the table is provided in Appendix A.

| Alternatives | Long Term Protection – Adjacent Properties and Sanitary Sewer | Maintain Alley and Service Functions | Limit Flood Impacts to Project Area | Achieves goals of the Unified Plan | Cost Effective* | Overall Rating |
|---|---|---|---|---|---|---|
| Sheet Pile – Land Side | 2 | 3 | 3 | 1 | 2 | 2 |
| Concrete Filled Geotextile | 1 | 3 | 1 | 1 | 1 | 1 |
| Cores in Footer | 1 | 3 | 3 | 1 | 1 | 2 |
| Wall Removal & Sewer Relocation | 3 | 2 | 3 | 3 | 3 | 3 |
| Sheet Pile – River Side | 3 | 3 | 2 | 1 | 3 | 2.5 |

Ratings:

1. Does not meet defined criteria, or meets criteria in a minimal way
2. Meets defined criteria satisfactorily or meets a portion of the defined criteria
3. Exceeds defined criteria

* Cost Effectiveness Ratings:

1. Meets less than or equal to 25% of long-term criteria (Unified Plan, scour, sanitary sewer protection, alley service function, constructability)
2. Meets less than or equal to 50% of long-term criteria
3. Meets greater than or equal to 75% of long-term criteria

**RECOMMENDED APPROACH**

Our analysis and assessment determined that the most prudent solution to the issues outline in this report is to treat the two blocks uniquely and respond to the evaluation criteria and the site conditions and constraints of each. Preliminary plans and cross sections are provided (see Appendix E) to illustrate the recommendations described below.

**100 Block**

SmithGroup recommends the removal of the wall on the 100 block. Removing the existing retaining wall allows for a natural shoreline and restoration of habitat along the riverfront. The existing stem of the wall would be removed with the existing footing and timber piles to remain. Riprap would be placed along the river bottom and up the shoreline to protect the shoreline from erosion and scouring while creating habitat for fish and other aquatic and riparian wildlife. Plantings, trees, grasses, and other landscape items will be added to protect the new bank from erosion and promote habitat.

We recommend removing only the vertical stem of the existing concrete wall, leaving the horizontal footing of the old wall in place as a shelter habitat for fish. Methods of creating a stable, scour resistant toe of the slope near the wall foundation will require further consideration during final design.

This approach requires the existing sanitary sewer line behind the wall to be rerouted further south within the alley. The 100 block has many sanitary leads that need to be replaced and this reroute provides the opportunity to fix and stabilize the leads (some of which may be dating back to the wall construction), which will reduce the infiltration of ground water into the sewer system. Replacing the numerous sanitary service connections is also an opportunity to ensure the most effective infrastructure is in place to minimize any opportunity for raw sewage leaks.

In order to do this construction, an easement or purchase of land would be required for a riparian private parcel of land on the 100 Block. This parcel is on the east end of the block and is existing private property. An easement may be agreed upon between the landowner and the City of Traverse City if the owner is willing or the city may be required to purchase the land if the owner is willing. This has potential to delay the construction schedule if not addressed in a timely manner.

**200 Block**
SmithGroup recommends installing a sheet pile wall on the river side of the wall in the 200 block. A sheet pile wall would be driven into the earth on the river side of the retaining wall. The top of the sheet pile would coincide with the top of the wall footing. Once the sheet pile is driven into the river bottom, concrete would be pumped between the sheet pile and the existing retaining wall and fill under the existing footer as well to completely fill the gap. The sheet pile would protect the wall from further scour. Rip rap could be placed into the river bottom to provide some fisheries habitat benefit.

The sanitary leads on this block were replaced about 10 years ago and their condition is likely to be good. As a precaution, we recommend that removing the asphalt alley behind the concrete wall to locate any signs of soil subsidence and backfill with compacted aggregate material, as well as excavate and repair any storm or sanitary sewer service leads that appear compromised.

This option may be constructed with a temporary dam in the river and dewatering between the dam and the existing retaining wall. The concrete that would be pumped between the sheet pile and the wall, and underneath the wall, will create similar conditions long term protection for the timber piles because the concrete and piles will be saturated from the river and ground water. The timber piles should not experience large amounts of degradation and remain structurally sound.

**RECOMMENDATIONS FOR IMMEDIATE ACTION**
There are two intermediate recommendations that could be acted on immediately:

1. Coordinate potential FEMA permitting with the Fish Pass project
2. Enact a monitoring program to track potential infrastructure failures between now and construction

As will be discussed in the modelling portion of this report, we currently anticipate that additional FEMA floodplain permits will be required. The Fish Pass project is also going through the FEMA permitting process for the upstream reach. Coordinating with the Fish Pass project may allow the City to complete the permitting process one time for both projects.

It is also recommended that the following monitoring activities be implemented. The goal of these activities is to check for potential soil loss behind the wall, condition of the existing sanitary sewer and leads, and understand how this soil loss may be impacting the wall's integrity.

- Survey of the existing wall and monitoring the wall's cant
    - Every 6 months, preferably Spring and Fall (after winter freeze and thaw cycles and after spring and summer rain)
- Place benchmark nails in the pavement to the south of the wall and track their elevation fluctuations
    - Monthly and immediately after every larger flow events

- Measure the width of pavement cracks
  - Monthly and immediately after every larger flow events
- Measure point locations of scour depth
  - Monthly and immediately after every larger flow events
- Conduct underwater scour inspections
  - Annually
- Monitor flows in the wastewater line to identify new infiltration resulting from a break in the sewer line
  - Continuous monitoring with weekly evaluation
- Televise the existing 24” sanitary sewer main and sewer service connections in both the 100 and 200 blocks to understand the existing conditions of the pipes and assess the areas in most urgent need of repair
  - Perform this task within the next 2 to 4 months

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# APPENDICES

## APPENDIX A. Technical Analysis

**PROJECT COSTS**
A cost analysis was performed for the above-mentioned recommendations for the 100 and 200 block. The cost analysis includes (8) main components which will be broken down below. The cost estimate does not account for any permitting fees.

1. Construction Mobilization
   a. This cost is estimated to be 5% of the total construction cost, and include temporary utilities, facilities, and management to support construction
2. Site Preparation
   a. All demolition items (tree, pavement, landscape, curb, wall, and utility removals) plus an additional allowance for miscellaneous items found in the field. This section also includes soil erosion control measures.
3. Utility Systems
   a. New storm and sanitary piping, structures, excavation and installation, and storm water quality items (swirl chambers and infiltration landscape beds).
4. Earthwork and Wall Rehab
   a. All materials being hauled off site and all materials brought to site (aggregate, riprap, backfill, tremie concrete, and sheet pile wall).
5. Hardscape Improvements
   a. Concrete for sidewalks, concrete for curbing, HMA, and an allowance for additional base material for HMA (asphalt) pavement to meet final grades.
6. Lighting and Electrical Systems
   a. Conduit and wiring for re-installing the existing pedestrian lighting along the sidewalk and parking lot.
7. Signage and Pavement Markings
   a. This section includes 2 allowances for signage and pavement markings and traffic management devices.
8. Landscaping
   a. All items for restoring any disturbed areas along with all landscaping materials to create a shoreline suitable for habitats (trees, grasses, seeding, etc.) This does not include habitat structures, boardwalks, water access stairs/ramps, special alley paving, or pedestrian amenities, but accounts of the basic restoration of the site.

These components created the cost analysis for both the 100 and 200 block. The cost analysis accounts for a 20% contingency for unforeseen construction related costs. The 100 block estimated construction cost is $1.4 million and the 200 block estimated construction cost is $1.0 million with a total construction cost for the entire project area being approximately $2.4 million.

As noted below, the modelling of the river considered the option of utilizing the sheet pile approach on the 100 Block. This would have some impacts to the flood elevation as noted below. From a cost perspective, this approach is considered "cost neutral" to the recommended approach of removing the wall on the 100 block, since the cost of the sheet pile, removal of the 200 block boardwalk, and other modifications to make this option viable offset the savings from leaving the sewer main in place on the 100 block.

## HYDRAULIC MODELLING OF THE RIVER

**Recommended Option – 100 Block Wall Removal**
Combining the removal of the retaining wall and laying the slope back to create a more natural shoreline on the 100 block and use of the sheet pile on the 200 block does increase the flood elevation in the project area but eliminates the impacts upstream of the site. All other approaches were modeled, and all the other approaches raise the flood water levels upstream to the Boardman dam.

This approach has been modelled in several configurations, with slopes ranging from 3:1 to 4:1, with the installation of fish habitat, and with the preservation of the horizontal footing. While some impacts to the flood elevations occur within the project extents (up to 0.1 ft), none of the configurations tested resulted in upstream flood impacts.

Due to the rise of flood levels, the recommended approach will require a Letter of Map Revision (LOMR) and Conditional Letter of Map Revision (CLOMR) which involves seeking approval of all impacted landowners. LOMRs and CLOMRs are required by the Federal Emergency Management Agency (FEMA) whenever a design project causes a rise in the 100-year flood elevation of more than 0.01 foot within a FEMA designated floodplain. This process should be reasonably expeditious since the City of Traverse City is the predominate riparian landowner.

Additional alternatives were tested in an attempt to mitigate the predicted rise and eliminate the need for a LOMR. These alternatives included modifying the northern shoreline, removing the boardwalk, dredging a portion of the channel, and repairing the existing scour damage; however, none of these alternatives successfully mitigated the predicted rise.

Other considerations for this alternative include:
- Consistent with emerging Unified Plan and community input
- Relocates a segment of the sewer away from the river and allows for upsizing of the sewer in this area
- Facilitates the addition of storm water management best practices to 15 storm leads in this area
- Provides closer access to water
- Adds habitat for fisheries and riparian mammals
- The grades in the alley parking area could be lowered such that the green slope would require less slope
- Easements or property purchase may be required from the single privately held riparian parcel in the project area, as referenced above

**100 Block – Sheet Pile Alternative**
It was found that the addition of a sheet pile wall in the 100 and 200 block will cause a rise in river flood elevations in the project area as well as upstream (to the Union Street Dam/FishPass) of the project area by up to 0.02'. Although the rise is limited, such an impact would require a Letter of Map Revision (LOMR) and Conditional Letter of Map Revision (CLOMR) which involves seeking approval of all impacted landowners between the project site and the Union Street Dam/Fish Pass.

This alternative also requires the removal of the boardwalk on the 200 block. It should be noted that the city believes that the boardwalk was installed with grant money, and such grants often include penalties for removing the improvements. The inclusion of a wetland bench on the north side of the river helped mitigate – but not eliminate – the flood impacts, and the inclusion of a constructed wetland would exceed the cost of a LOMR.

Additional alternatives were tested in an attempt to mitigate the predicted rise and eliminate the need for a LOMR. These alternatives included dredging the channel, repairing scour, replacing the 100-block pedestrian bridge with a single span structure. None of these alternatives yielded a positive effect.

Other considerations for this alternative include:

- Does not preclude future opportunity to green the bank but does add cost to this idea if the community is going to do this at some future date.
- Requires the removal of the boardwalk on the 200 block to eliminate upstream flood level impacts.
- This approach assumes we would still upgrade sewer service leads on the 100 block.
- This approach would preserve public parking on the south side of the river.

**Modelling Process & Discussion**

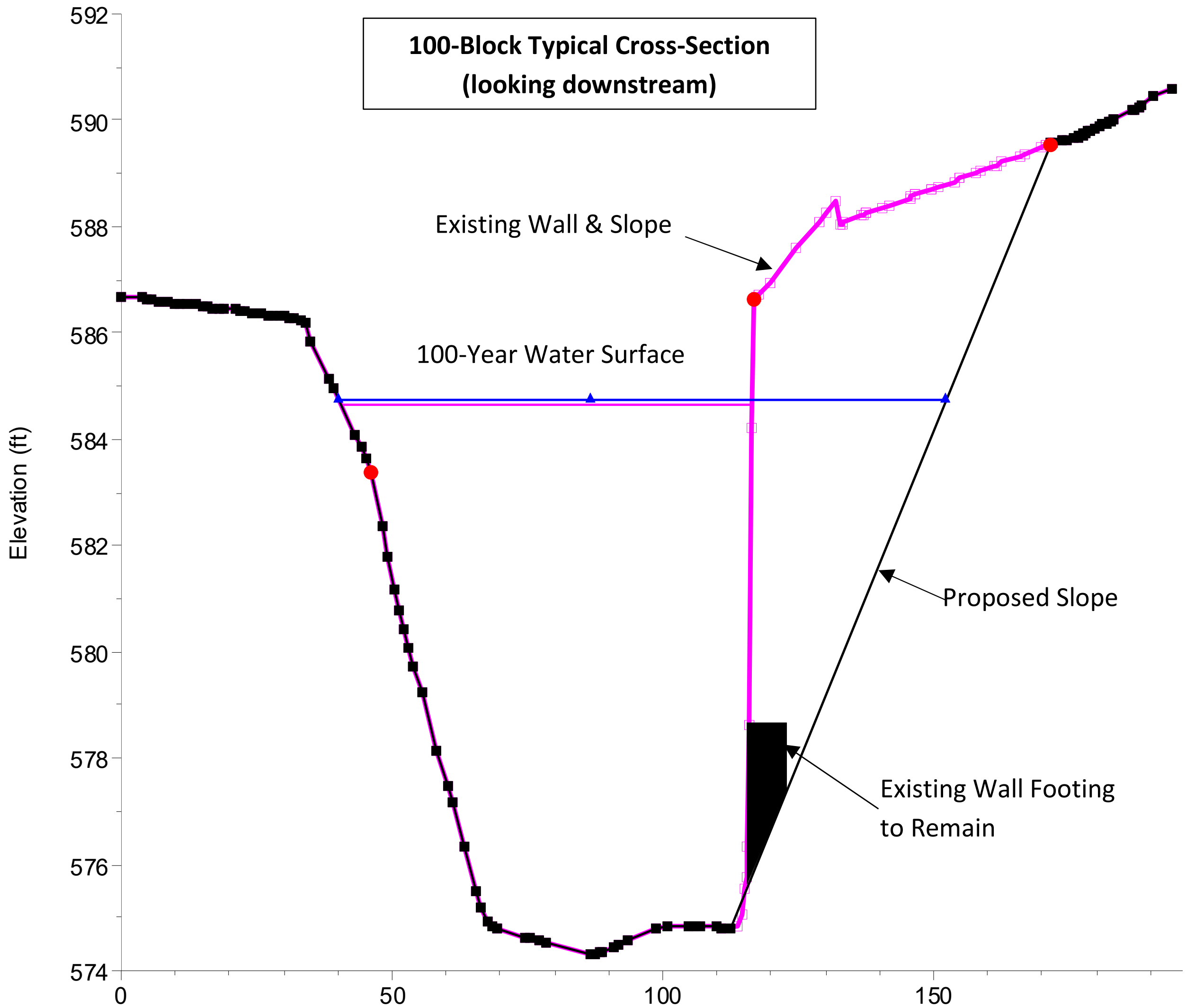
The original source model for this assessment is the FEMA Flood Insurance Study (FIS) model, which was further refined by the Boardman Dam project. A copy of the existing conditions model for the Boardman Dam project was provided by the Great Lakes Fisheries Commission. The model was further updated by the design team using the survey data collected on 11/24/2020. This updated, existing conditions model served as the baseline model upon which all of the design alternatives were evaluated.

The boardwalk was included in the model as ineffective flow areas. Ineffective flow areas exclude any flow conveyance under the boardwalk; consequently, this analysis cannot assess potential impacts/benefits yielded by adjusting the elevation of the boardwalk.

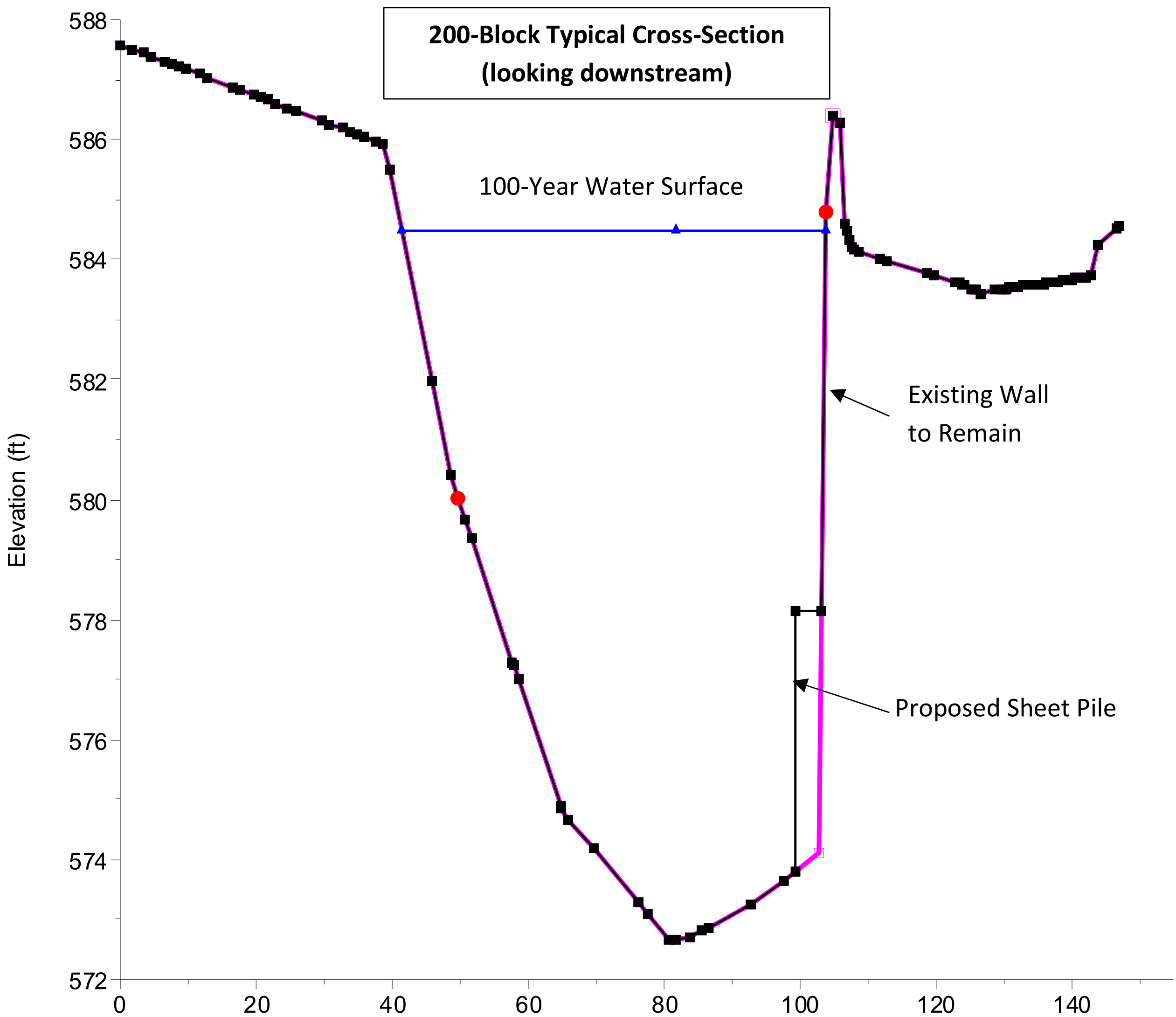
The existing pedestrian bridges were updated in the model based on the survey data. We do not anticipate any additional scour risk around the piers resulting from the proposed project.

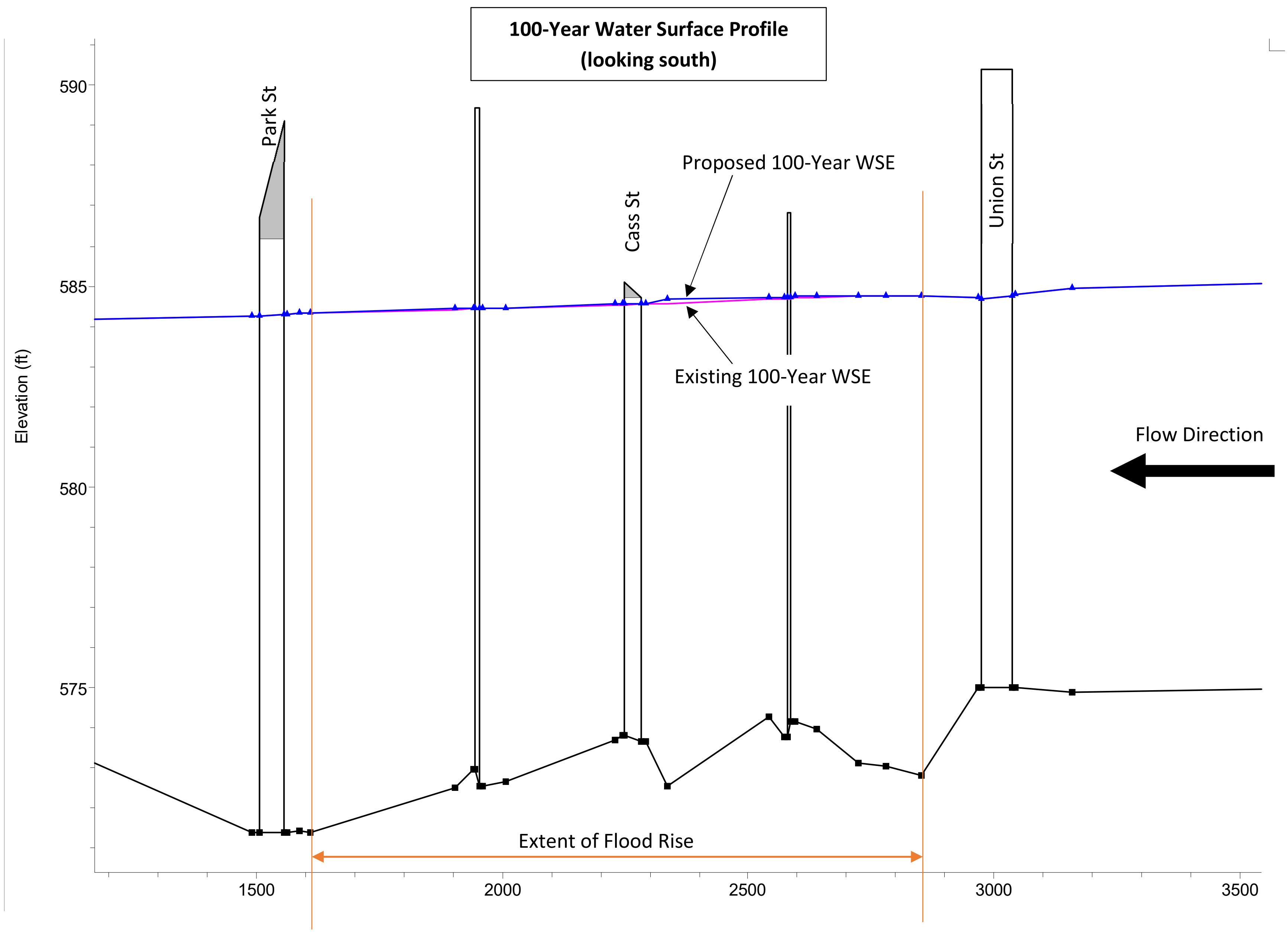
The images below will present typical cross-sections for the proposed design (as represented in HEC-RAS) and a profile plot of the 100-year flood water surfaces (as predicted by HEC-RAS).

A typical cross-section from the 100 Block is presented below. This example utilizes a 4:1 side slope and extends the toe of the slope 3 feet in front of the retaining wall foundation.



A typical cross-section of the 200 Block is presented below. The sheet pile extends up to the base of the wall and slightly constricts the channel.



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**APPENDIX B. Record Drawings of Existing Retaining Wall**

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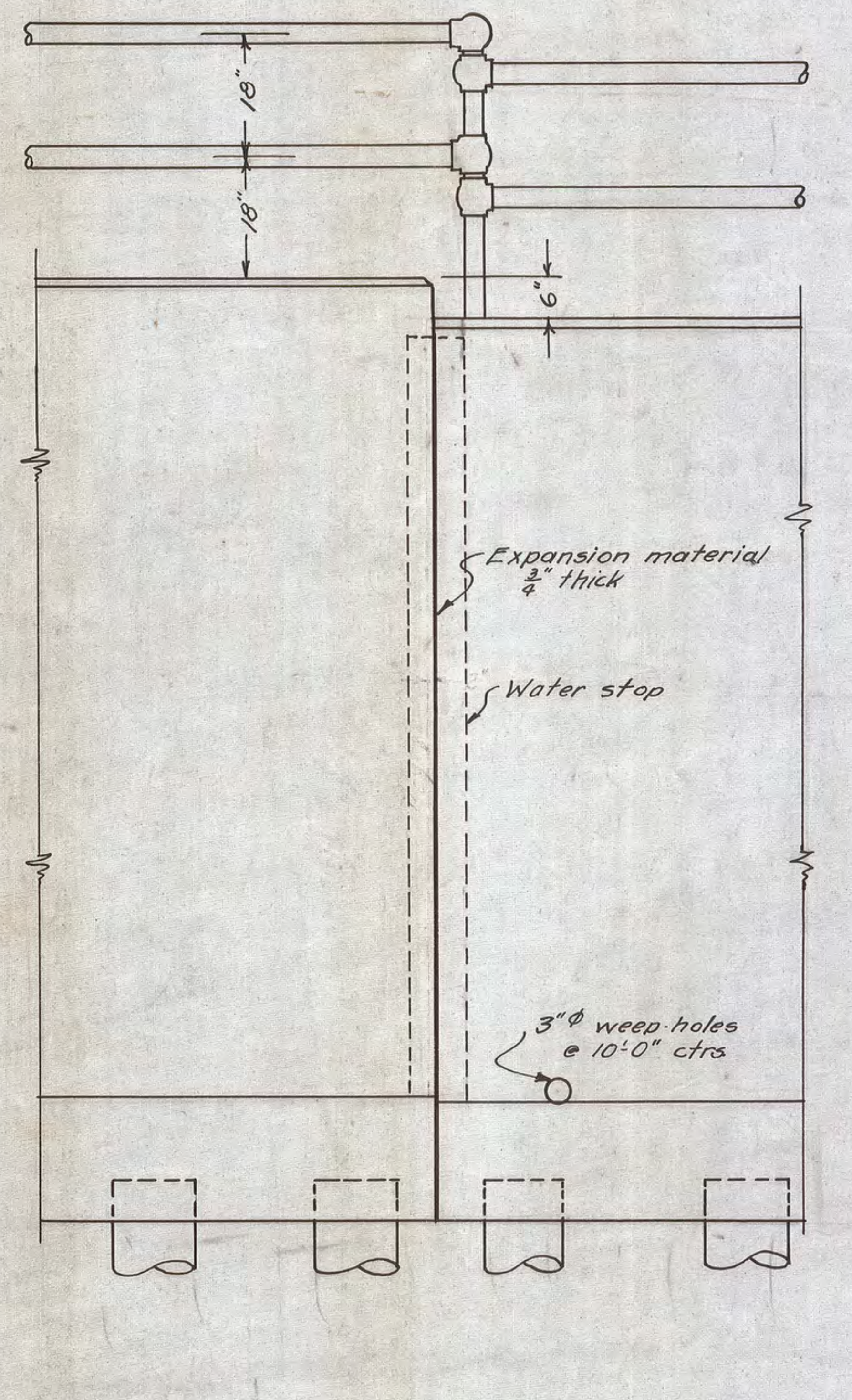
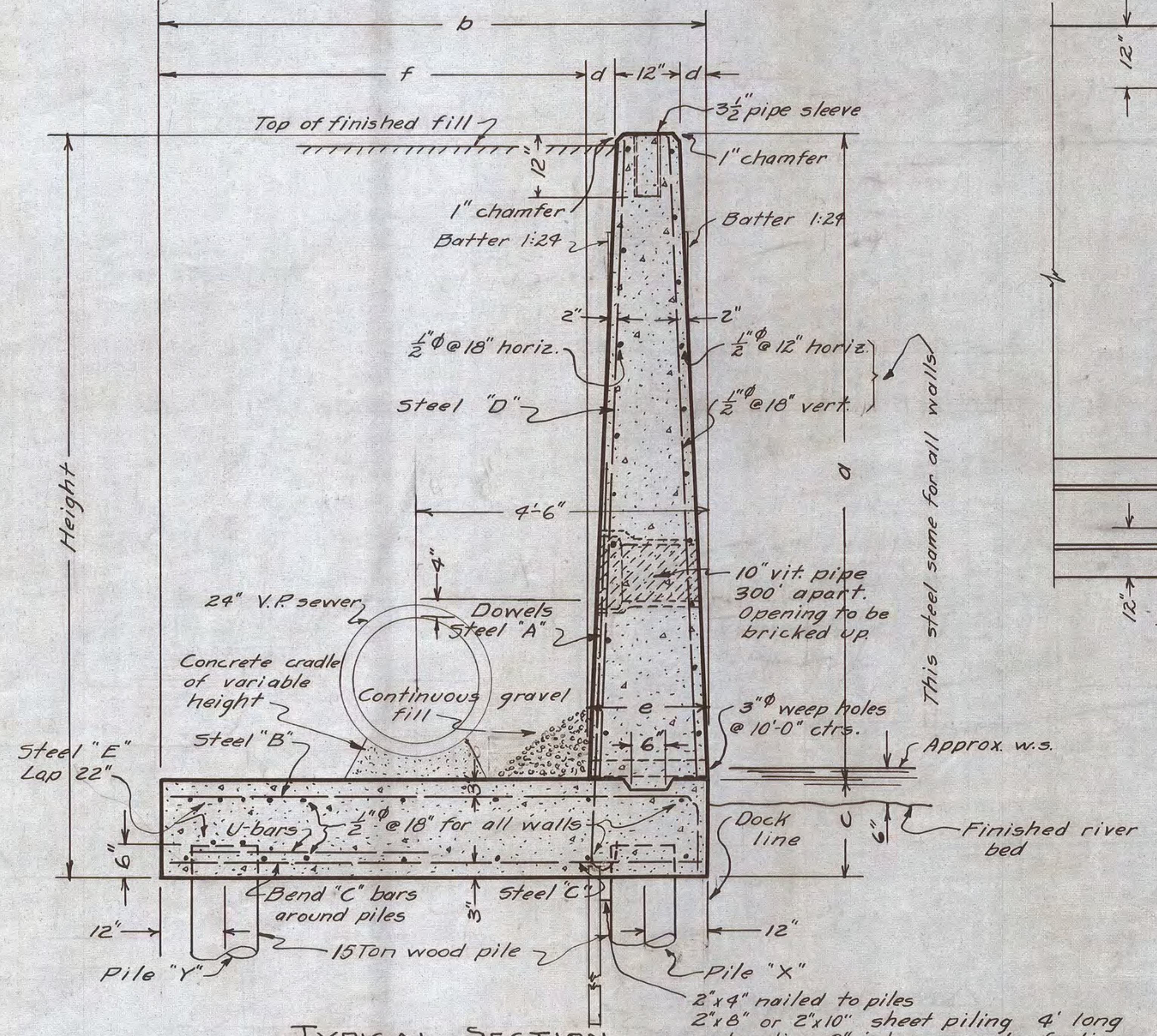
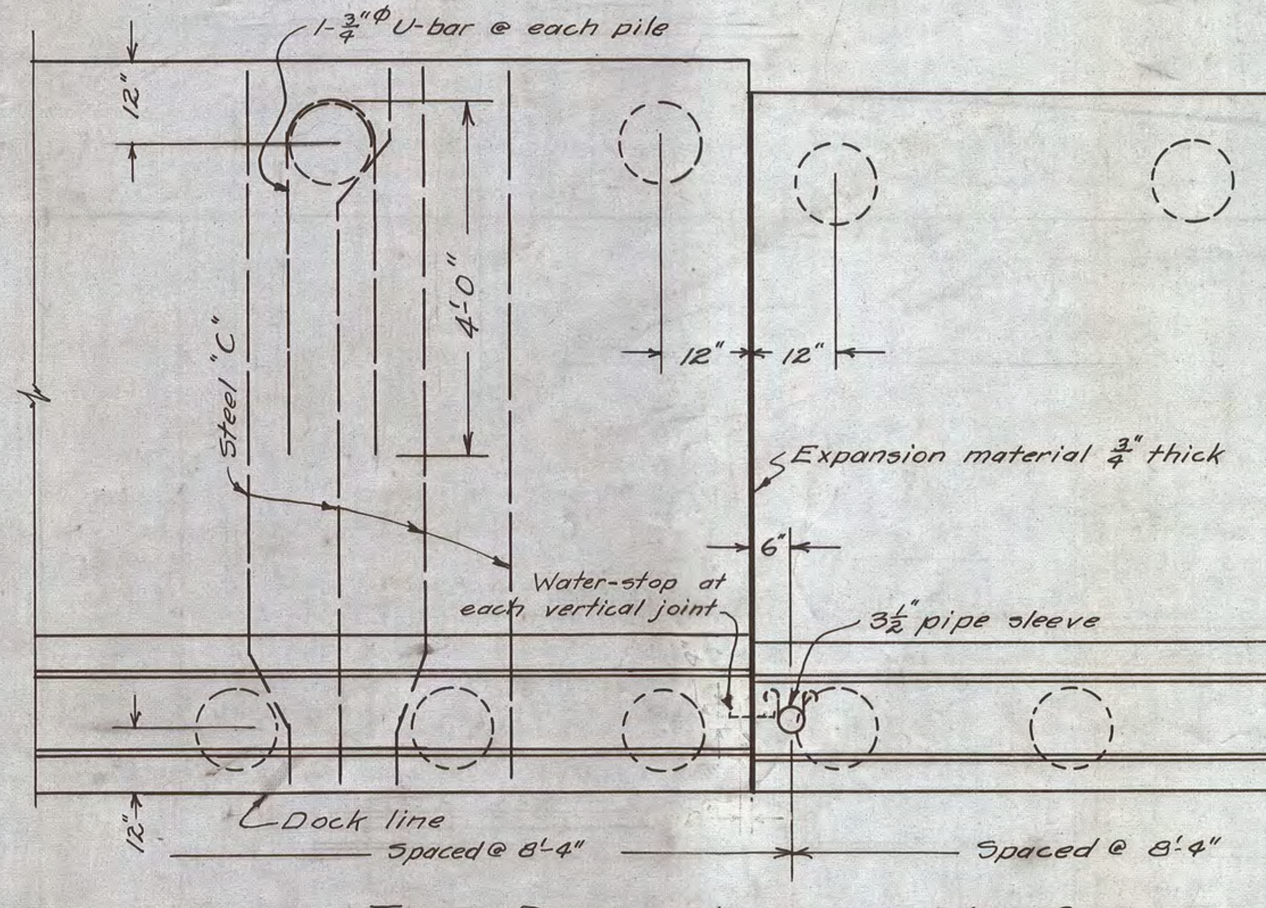



ELEVATION

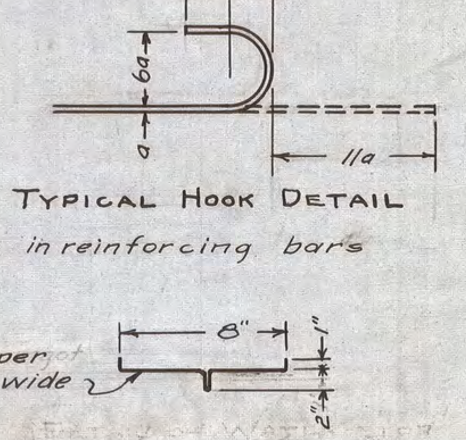


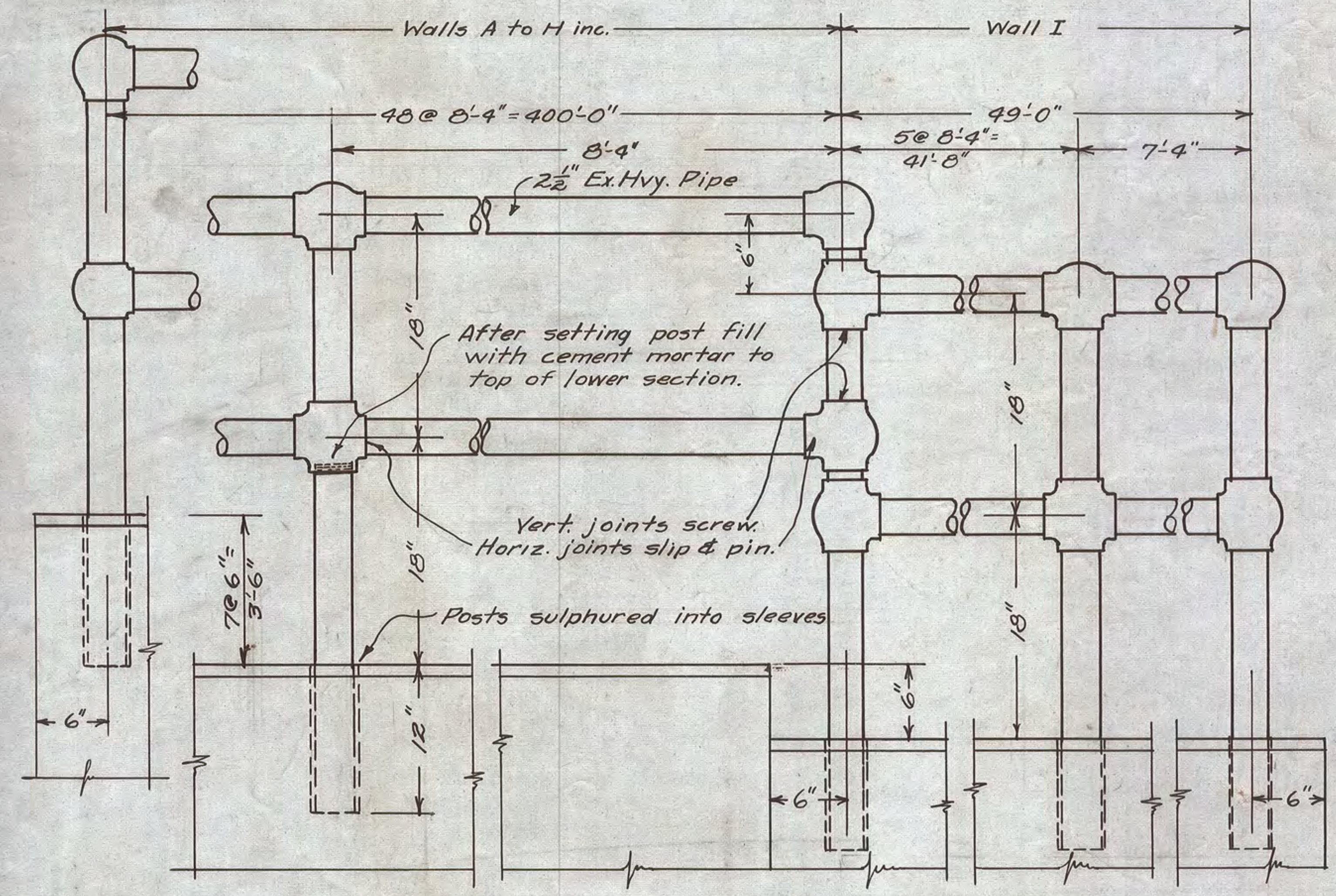

TYPICAL SECTION



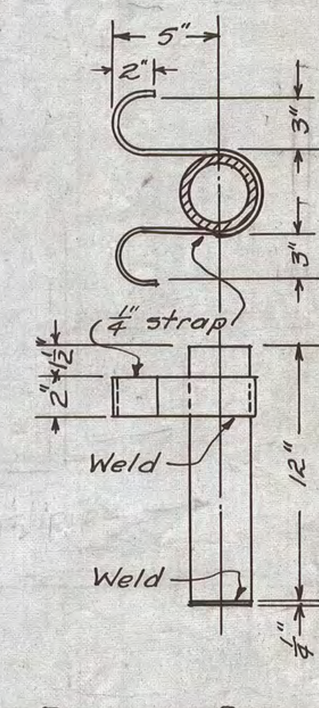

TYPICAL DETAIL AT JUNCTION OF WALL SECTIONS

PLAN




DETAIL OF PIPE RAILING
Scale: 1" = 1'-0"




DETAIL OF PIPE SLEEVE

| | Table of Dimensions | | | | | | | Pile Spacing | | Steel Reinforcing | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | "A" | | | "B" | | | "C" | | | "D" | | | "E" | |
| Wall | Height | a | b | c | d | e | f | "X" | "Y" | Size | Spac. | Length | Size | Spac. | Length | Size | Spac. | Length | Size | Spac. | Length | Size | Number |
| A | 11'-6" | 10'-0" | 8'-6" | 18" | 5" | 22" | 6'-8" | 2'-6" | 3'-9" | ¾"φ | 7½" | 7'-0" | ⅞"φ | 8" | 9'-0" | ¾"φ | 12" | 8'-0" | ¾"φ | 15" | 9'-10" | ½"φ | 4 |
| B | 11'-0" | 9'-6½" | 8'-2¼" | 17½" | 4¾" | 21½" | 6'-4¾" | 2'-9" | 4'-3" | ¾"φ | 8" | 6'-9" | ⅝"φ | 6" | 8'-7" | ¾"φ | 12" | 7'-8" | ¾"φ | 16" | 9'-4" | ½"φ | 4 |
| C | 10'-6" | 9'-1" | 7'-10½" | 17" | 4½" | 21" | 6'-1½" | 3'-0" | 4'-6" | ¾"φ | 9" | 6'-5" | ¾"φ | 7½" | 8'-3" | ¾"φ | 12" | 7'-4" | ¾"φ | 18" | 8'-11" | ½"φ | 4 |
| D | 10'-0" | 8'-7½" | 7'-6¾" | 16½" | 4¼" | 20½" | 5'-10¼" | 3'-3" | 5'-0" | ¾"φ | 10" | 6'-2" | ¾"φ | 8" | 7'-11" | ⅝"φ | 11" | 7'-0" | ¾"φ | 20" | 8'-5" | ½"φ | 4 |
| E | 9'-6" | 8'-2" | 7'-3" | 16" | 4" | 20" | 5'-7" | 3'-6" | 5'-6" | ¾"φ | 12" | 5'-11" | ¾"φ | 9" | 7'-7" | ⅝"φ | 11" | 6'-9" | ¾"φ | 24" | 8'-0" | ½"φ | 5 |
| F | 9'-0" | 7'-8½" | 6'-11¼" | 15½" | 3¾" | 19½" | 5'-3¾" | 3'-9" | 6'-0" | ⅝"φ | 9" | 5'-6" | ⅝"φ | 8" | 7'-3" | ⅝"φ | 12" | 6'-5" | ⅝"φ | 18" | 7'-6" | ½"φ | 5 |
| G | 8'-6" | 7'-3" | 6'-7½" | 15" | 3½" | 19" | 5'-0½" | 4'-3" | 6'-9" | ⅝"φ | 10" | 5'-3" | ¾"φ | 10" | 6'-10" | ⅝"φ | 12" | 6'-1" | ⅝"φ | 20" | 7'-1" | ½"φ | 5 |
| H | 8'-0" | 6'-9½" | 6'-3¾" | 14½" | 3¼" | 18½" | 4'-9¼" | 4'-9" | 7'-3" | ⅝"φ | 12" | 5'-0" | ¾"φ | 9" | 6'-6" | ½"φ | 10" | 5'-9" | ⅝"φ | 24" | 6'-7" | ½"φ | 5 |
| I | 7'-6" | 6'-4" | 6'-0" | 14" | 3" | 18" | 4'-6" | 5'-3" | 8'-3" | ⅝"φ | 12" | 4'-9" | ⅝"φ | 9" | 6'-2" | ½"φ | 12" | 5'-6" | ⅝"φ | 24" | 6'-2" | ½"φ | 6 |

DETAIL OF RIVER WALL
Scale: ½" = 1'-0"


C. E. SAWYER, CITY ENGINEER
HOAD, DECKER, SHOECRAFT AND DRURY
CONSULTING ENGINEERS


TRAVERSE CITY, MICHIGAN
SEWAGE DISPOSAL SYSTEM
# MAIN INTERCEPTING SEWER
# RIVER WALL DETAILS

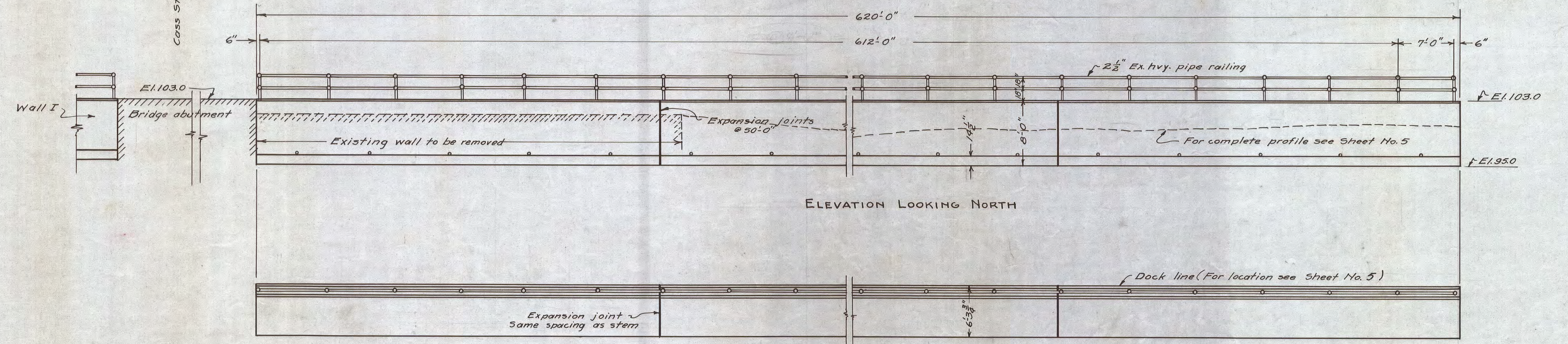
SCALES AS INDICATED
NOVEMBER 1931

11


Plan

River Wall West of Cass Street

Note: For dimensions and structural details see Sheet No.11




Plan

River Wall East of Cass Street

Note: For dimensions and structural details see Wall H, Sheet No.11

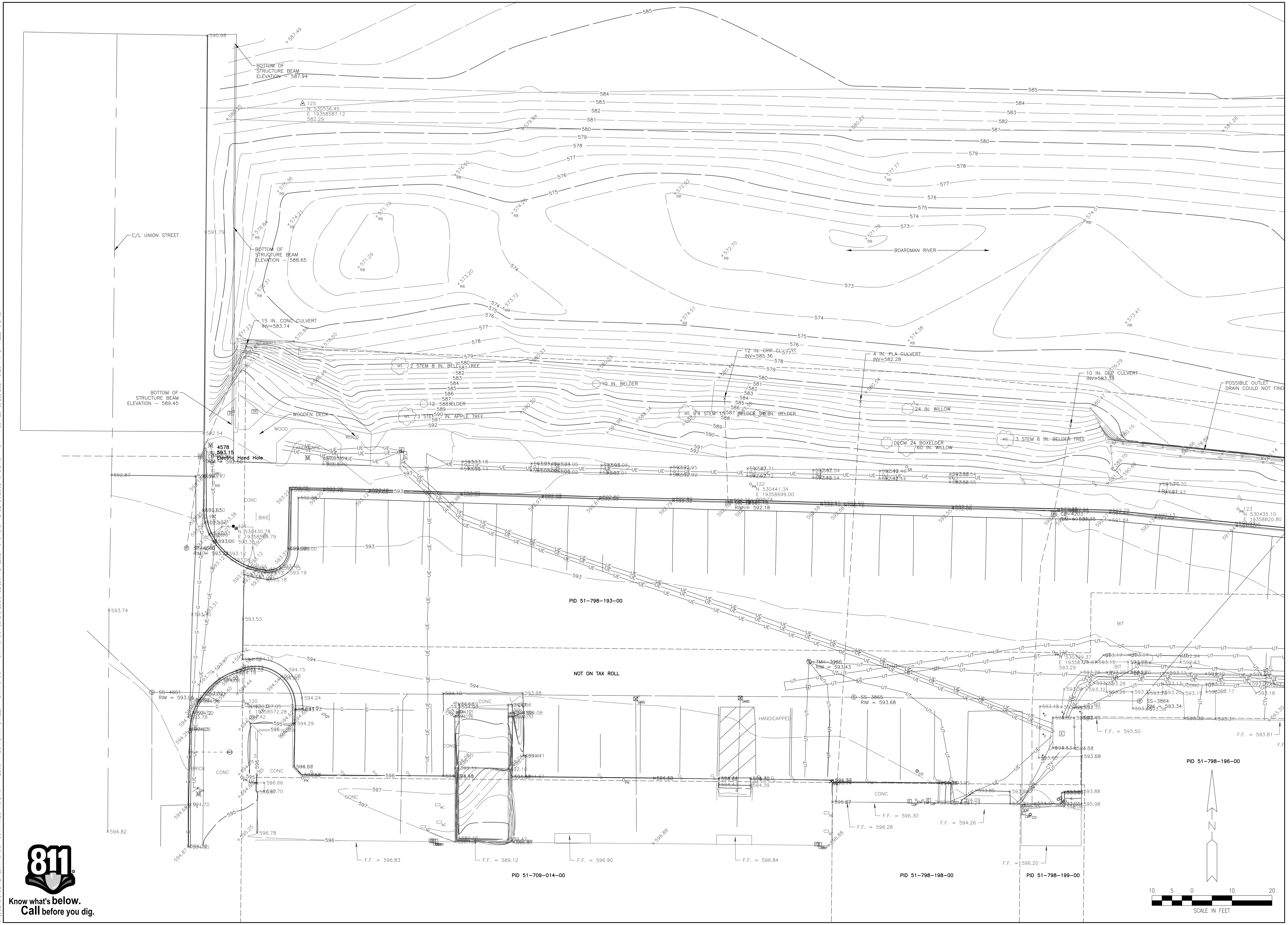
C.E. Sawyer, City Engineer
Hoad, Decker, Shoecraft and Drury
Consulting Engineers

Traverse City, Michigan
Sewage Disposal System
**Main Intercepting Sewer**
**General Layout of River Wall**
Scale: ⅛" = 1'-0"
November 1931

10

SMITHGROUP

# APPENDIX C. Topographic, Bathymetric, and Utility Survey




PROJECT MANAGER:–
FIELD BOOK INFORMATION:–
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811 Know what's below. Call before you dig.

| REV# | DATE | DESCRIPTION | BY |
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WADE TRIM
4241 Old US 27 S., Suite 1
PO Box 618
Gaylord, MI 49734
989.732.3584
www.wadetrim.com

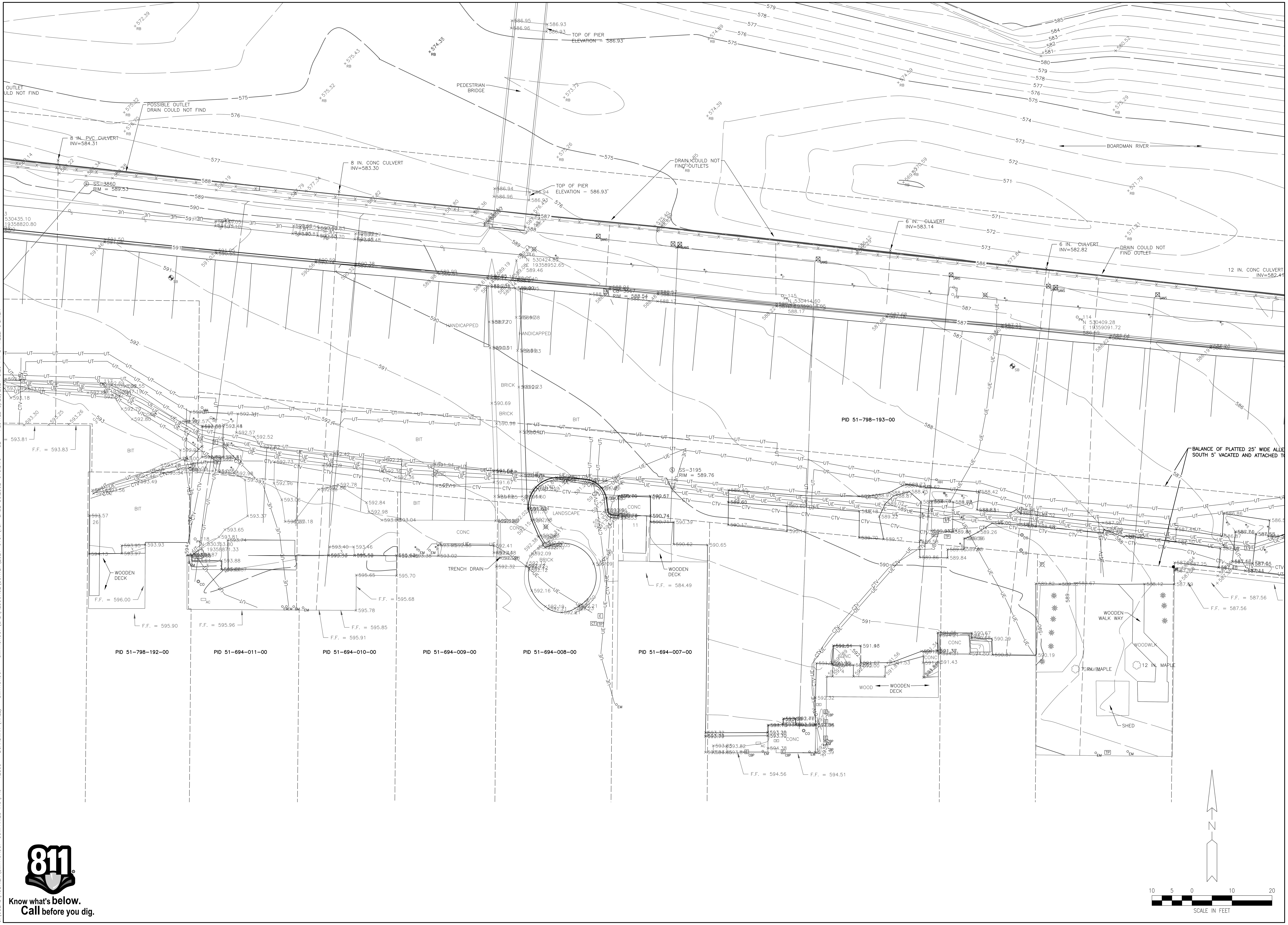
# SMITH GROUP INC

## BOARDMAN RIVER IMPROVEMENT PROJECT
## FROM CASS STREET TO PARK STREET, TRAVERSE CITY, MICHIGAN

ISSUED FOR: DATE: BY:

JOB NO. SGI2002-01G

SHEET 1

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FIELD BOOK INFORMATION: --
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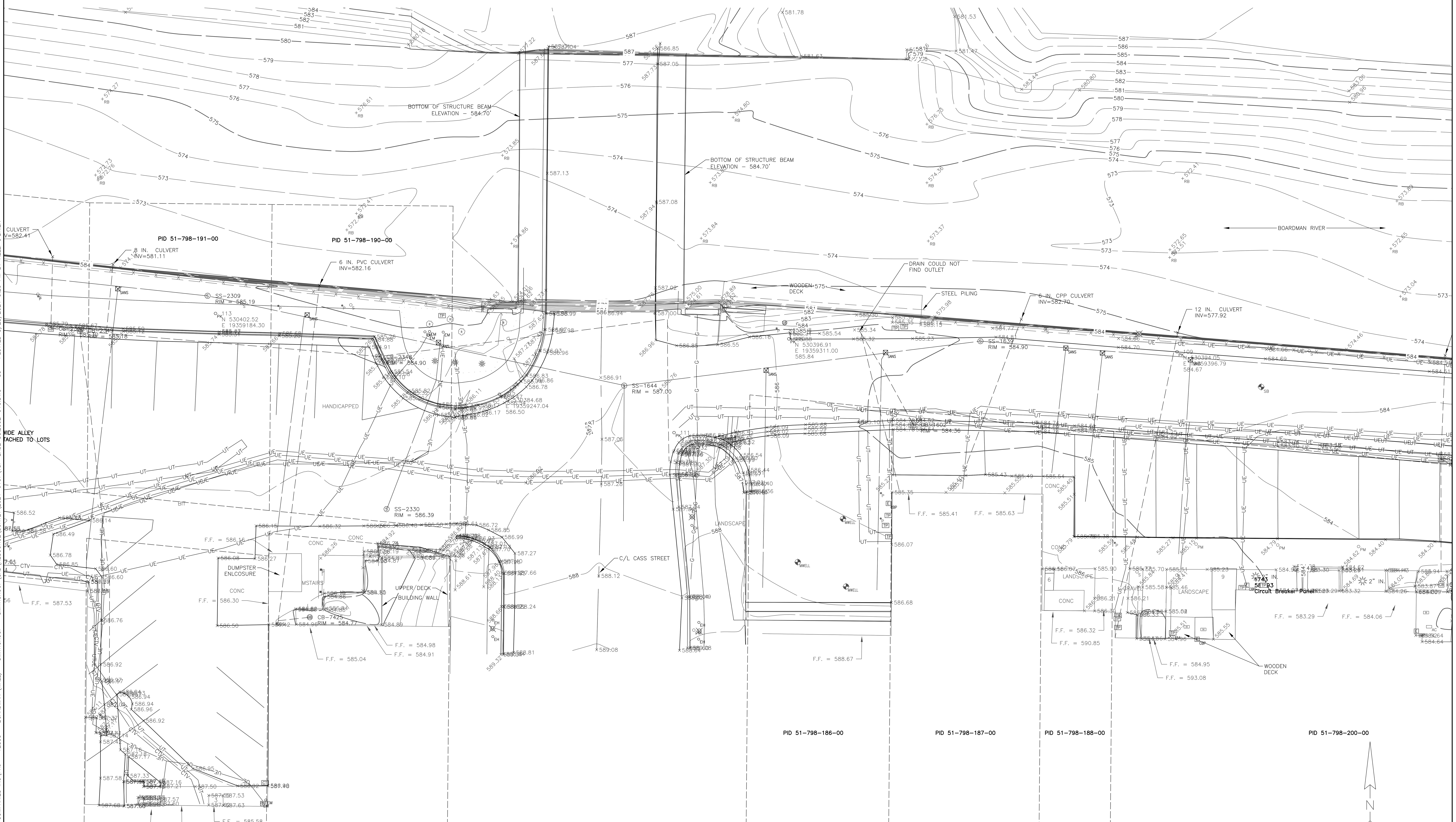
BOARDMAN RIVER IMPROVEMENT PROJECT
FROM CASS STREET TO PARK STREET, TRAVERSE CITY, MICHIGAN

ISSUED FOR: DATE: BY:

JOB NO. SGI2002-01G

SHEET 2

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SCALE IN FEET

PROJECT MANAGER: - FIELD BOOK INFORMATION: -
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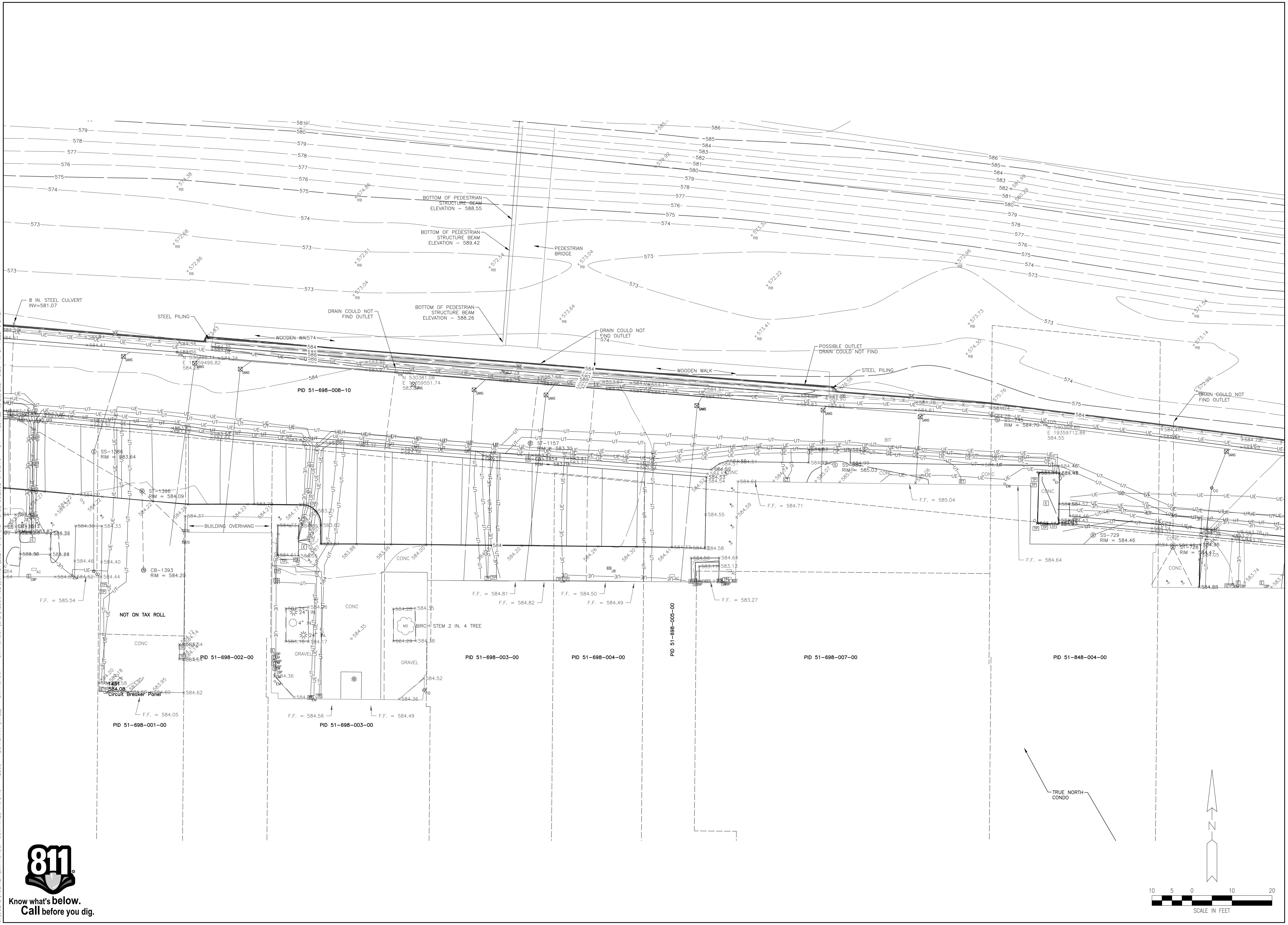
SHEET 3




PROJECT MANAGER: –
FIELD BOOK INFORMATION: –
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Gaylord, MI 49734
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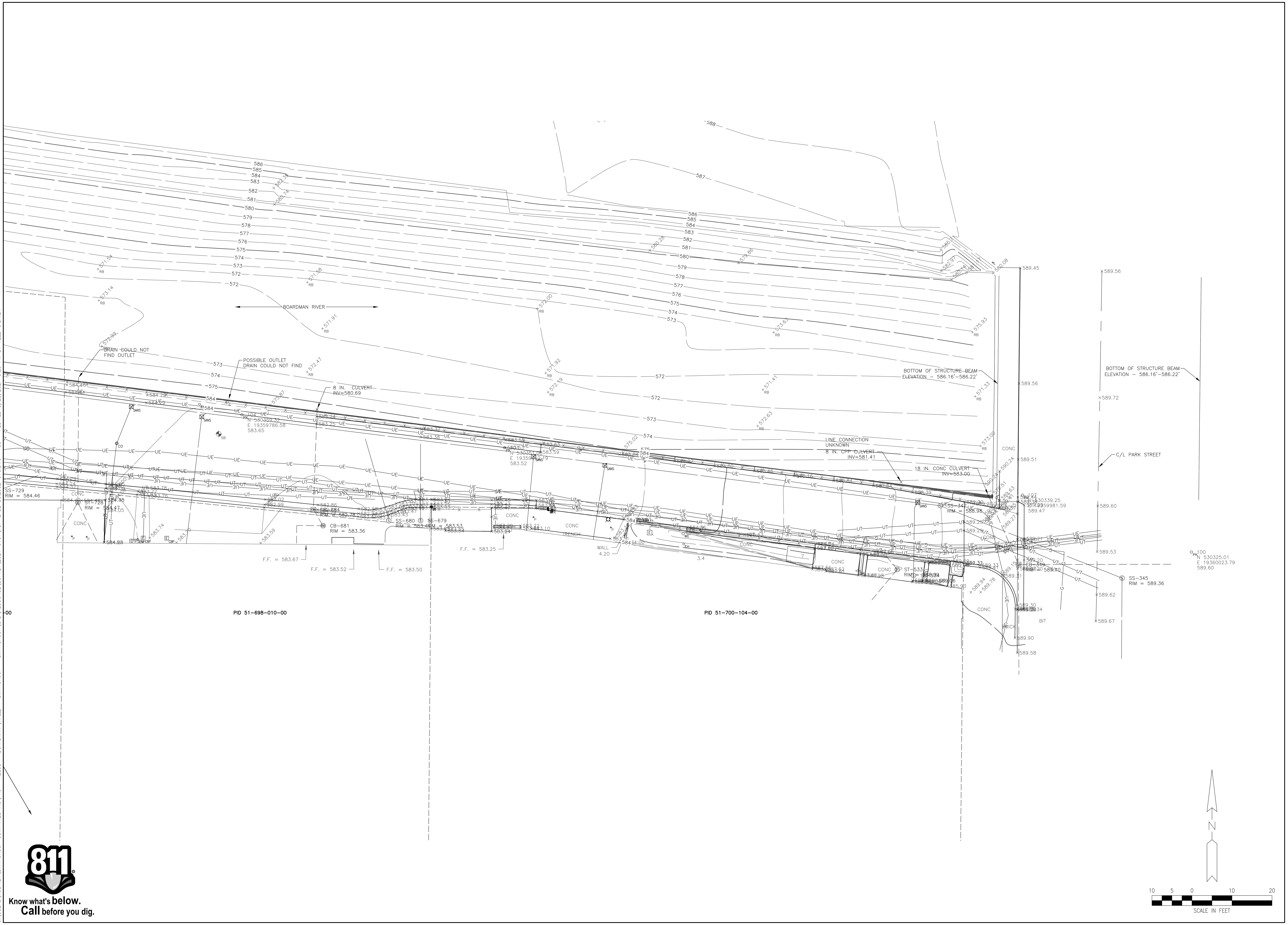
# SMITH GROUP INC

BOARDMAN RIVER IMPROVEMENT PROJECT
FROM CASS STREET TO PARK STREET, TRAVERSE CITY, MICHIGAN

ISSUED FOR: DATE: BY:

JOB NO. SGI2002-01G

SHEET 4




| REV# | DATE | DESCRIPTION | BY |
|---|---|---|---|

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PO Box 618
Gaylord, MI 49734
989.732.3584
www.wadetrim.com

SMITH GROUP INC

BOARDMAN RIVER IMPROVEMENT PROJECT
FROM CASS STREET TO PARK STREET, TRAVERSE CITY, MICHIGAN

ISSUED FOR: DATE: BY:

JOB NO.
SGI2002-01G

SHEET
5



PROJECT MANAGER:– FIELD BOOK INFORMATION:–
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SMITHGROUP

**APPENDIX D. Geotechnical Report**

856 E. Eighth Street, Suite 1
Traverse City, MI 49686-2784

T (231) 941-5200

www.sme-usa.com

January 25, 2021

Mr. Bob Doyle, AIA
Landscape Architect
SmithGroup
201 Depot Street, Second Floor
Ann Abor, Michigan 48104

Via E-mail: *Bob.Doyle@smithgroup.com (PDF file)*

RE: Geotechnical Evaluation
100 and 200 Block Subsidence
Traverse City, Michigan
SME Project No. 085455.00

Dear Mr. Doyle:

We have completed the geotechnical evaluation for the subsidence along the alley of the 100 and 200 blocks of East Front Street in Traverse City, Michigan. This report presents the results of our observations and analyses, our geotechnical recommendations, and general construction considerations based on the information disclosed by the borings.

This evaluation was conducted in general accordance with the scope of services outlined in SME Proposal No. P03228.20 dated October 12, 2020. However, one of the proposed borings was omitted due to access considerations. SmithGroup authorized our services.

## PROJECT DESCRIPTION

The project site is located along the alley of the 100 and 200 blocks of East Front Street, between Union Street and Park Street. The project site location is depicted on the attached Boring Location Diagram (Figure No. 1).

We understand there has been ongoing subsidence of the alley and parking spaces adjacent to the existing retaining wall along the Boardman River. The existing retaining wall extends about 480 feet along the 100 block, and about 580 feet along the 200 block. The retaining wall is about 7.5 to 11.5 feet high and is supported on driven timber piles. We understand the retaining wall has not exhibited discernable movement or distress. Evaluation of the existing retaining wall was not included in our scope of services.

The project consists of stabilizing the soil beneath and behind (retained side of retaining wall) the retaining wall to mitigate future subsidence of the alley and parking spaces adjacent to the existing retaining wall.

Due the limited depth of embedment of the wall below the river bottom, scour is suspected as the primary cause of the subsidence behind the wall. The preliminary plan prepared by SmithGroup to address the potential scour is to drive steel sheet piles along the front (riverside) of the retaining wall, and place toe protection (rip rap) in front of the sheeting. The gap between the new sheeting and the retaining wall will be filled with concrete that will be placed using tremie methods. In addition, flowable fill will be pumped into the void spaces behind the retaining wall and below the pile cap, if feasible.

# EVALUATION PROCEDURES

## FIELD EXPLORATION

SME completed three borings (B1 through B3) on November 10, 2020. Each boring extended 45 feet beneath the existing ground surface. The approximate locations of the borings are shown on Figure No. 1.

The planned number and locations of the borings were determined jointly by SME and SmithGroup. SME determined the depths of the borings and located the borings in the field by referencing existing site features. The existing ground surface elevations at the boring locations were estimated to the nearest 1-foot based on the referenced topographic plans.

The borings were performed with a truck-mounted rotary drill rig and were advanced to the sampling depths using continuous-flight, hollow-stem augers. The borings included soil sampling based upon the Split-barrel Sampling Procedure. Recovered split-barrel samples were sealed in glass jars by the driller.

Groundwater observations were recorded during and upon completion of drilling at each boring. After completion of drilling and collection of groundwater observations, the boreholes were backfilled with auger cuttings.

Soil samples recovered from the field exploration were returned to the SME laboratory for further observation and testing.

## LABORATORY TESTING

The laboratory testing program consisted of performing visual soil classification on recovered samples in general accordance with ASTM D2488. Since cohesive soils were not encountered, SME did not perform additional laboratory testing. The attached Laboratory Testing Procedures provides descriptions of these laboratory tests. Based on the laboratory testing, we assigned a Unified Soil Classification System (USCS) group symbol to each of the various soil strata encountered.

Upon completion of the laboratory testing, boring logs were prepared that include information on materials encountered, penetration resistances, pertinent field observations made during the drilling operations, and the results of the laboratory tests. The boring logs are attached to this report. Explanations of symbols and terms used on the boring logs are provided on the attached Boring Log Terminology sheet.

Soil samples retained over a long time, even sealed in jars, are subject to moisture loss and are no longer representative of the conditions initially encountered in the field. Therefore, we normally retain soil samples in our laboratory for 60 days and then dispose of them, unless instructed otherwise.

# SUBSURFACE CONDITIONS

## SOIL CONDITIONS

The soil conditions encountered at the borings generally consisted of asphalt pavement underlain by very loose to loose existing sand fill overlying loose to very dense natural sands that extended to the explored depth of the borings.

The soil profiles described above, and included on each of the attached boring logs, are a generalized description of the conditions encountered. The stratification depths shown on the boring logs indicate a zone of transition from one soil type to another and do not show exact depths of change from one soil type to another. Soil conditions may vary away from the boring locations from those conditions noted on the logs.

Thickness measurements of surficial pavement should be considered approximate since mixing of the pavement with the underlying subgrade can occur during drilling. If accurate pavement thickness are required, pavement cores should be performed.

## GROUNDWATER CONDITIONS

Groundwater was encountered about 2 to 8 feet beneath the existing surface during drilling, corresponding to approximate elevations 582 to 583 feet. Groundwater was observed in the boreholes about 2 to 10 feet beneath the existing surface upon completion of drilling, corresponding to approximate elevations 577 to 585 feet. The water surface elevation of the Boardman River will approximately match the water surface elevation of West Grand Traverse Bay (Lake Michigan), which is about 581 feet in January 2021.

Hydrostatic groundwater levels, perched groundwater conditions, and the rate of infiltration into excavations should be expected to fluctuate throughout the year, based on variations in precipitation, the water level of the Boardman River, evaporation, run-off, and other factors. The groundwater observations recorded on the boring logs represent conditions at the time the readings were taken. The groundwater depths/elevations at the time of construction may vary from those conditions noted on the logs.

# ANALYSIS AND RECOMMENDATIONS

## SHEET PILING FOR SCOUR PROTECTION

Driving steel sheet piles along the front (riverside) of the retaining wall is a feasible approach to mitigate the loss of soil from beneath and behind the existing retaining wall due to possible scour. Suitable scour protection (such as riprap) should be placed in front of the sheeting to prevent future scour in front of the sheeting.

We understand a hydraulic and scour analysis is being performed. The presence and extent of scour beneath the existing retaining wall should be verified prior to final design. Depending on the anticipated depth of scour, other types of scour protection or mitigation may be considered.

Placing concrete between the new sheeting and the retaining wall is also feasible to fill the gap between those structures. Based on the relatively “clean” sand encountered at the borings, we do not anticipate significant voids are present behind the retaining wall, since the sands will collapse relatively quickly as soil is lost from beneath the retaining wall. Therefore, there will likely not be voids to fill. However, some future subsidence behind the retaining wall should be anticipated since the very loose sands will continue to collapse and densify over time.

However, future subsidence will decrease over time after the scour protection has been installed. The risk of future subsidence could be reduced by excavating a portion of the soil behind the retaining wall, compacting the exposed subgrade, and replacing the excavated soil as engineered fill. Compaction grouting of sands beneath critical structures could also be considered to stabilize the subsoils in these areas. However, grouting the soil along the entire stretch of the retaining wall is likely cost prohibitive.

For sheeting below the water level, an equivalent active fluid pressure of 30 pcf and an equivalent passive fluid pressure of 160 pcf should be used for the design of the flexible sheet pile walls. Rip-rap placed against the base of the sheeting will also provide passive resistance to support the sheeting. The amount of passive resistance from the rip-rap will depend on the size and shape of the rip-rap berm. This earth pressure is based on the walls being flexible enough to permit the active earth pressure condition to be reached. An inward movement equal to approximately 0.001 times the height of the wall is generally required to achieve the active earth pressure condition. We anticipate the sheet piles will deflect enough to achieve the active condition.

Care must be exercised during the sheet pile installation so that excessive vibrations do not cause settlement of nearby existing structures, roadways, and utilities. Some localized settlement should be expected around the sheeting. Installing the sheeting with an impact hammer rather than a vibratory hammer may mitigate some potential for settlement.

Although not encountered at the borings, cobbles and/or boulders are common in the area and could be encountered during sheet pile installation. The engineer preparing the project specifications should carefully outline what constitutes an obstruction and how the contractor will be paid for removal of such obstructions. SME would be pleased to provide additional assistance in developing specifications.

The contractor must provide a safely-sloped excavation or an adequately constructed and braced shoring system in accordance with federal, state, and local safety regulations for individuals working in an excavation that may expose them to the danger of moving ground. If material is stored or heavy equipment is operated near an excavation, use appropriate shoring to resist the extra pressure due to the superimposed loads.

We appreciate the opportunity to be of service. If you have questions regarding this report, or if you require additional information, please contact us.

Very truly yours,

**SME**

Report prepared by:

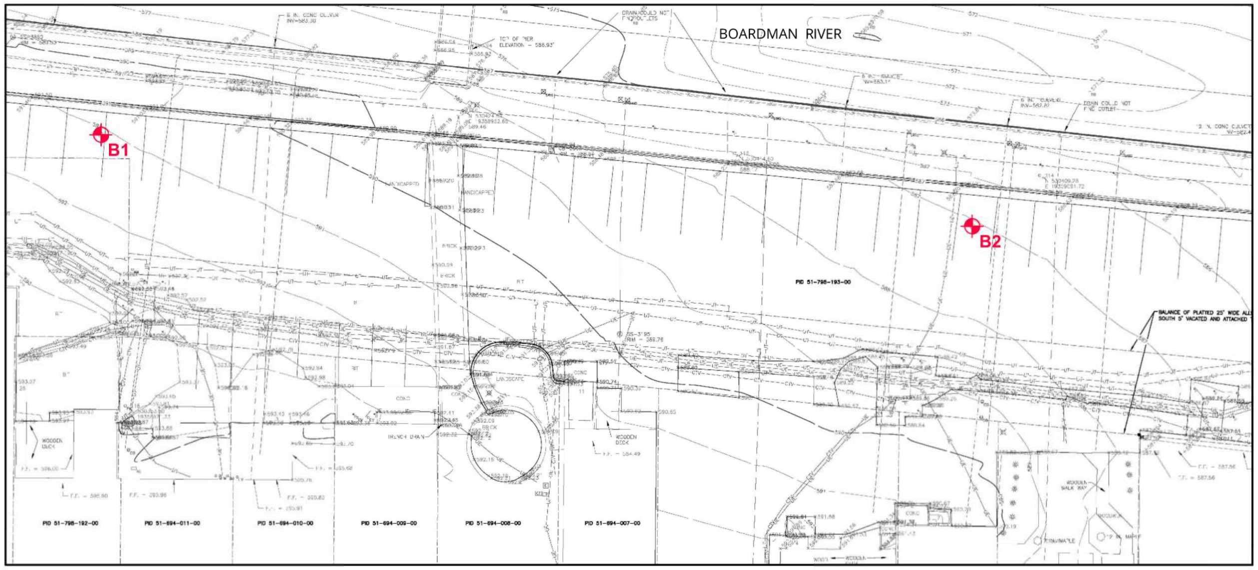
Paul Anderson
Jan 25 2021 3:49 PM

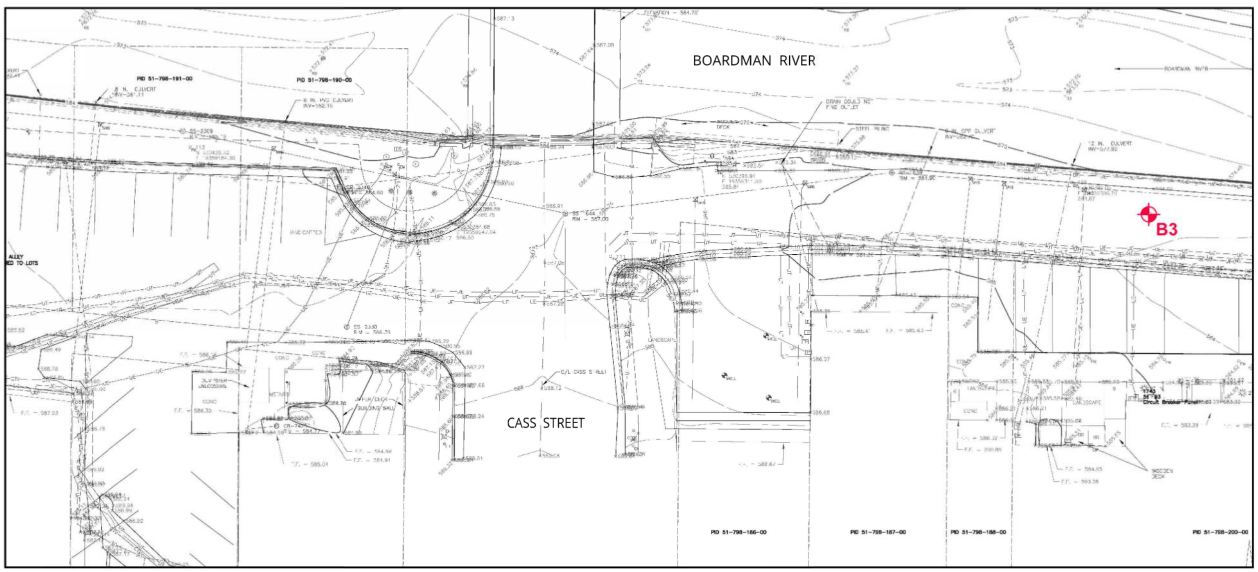
Paul E. Anderson, PE
Senior Project Engineer

Report reviewed by:

Timothy H. Bedenis, PE
Principal Consultant

Attachments: Boring Location Diagram (Figure No. 1)
Boring Log Terminology
Boring Logs (B1 through B3)
Important Information About This Geotechnical-Engineering Report
General Comments
Laboratory Testing Procedures




GRAPHIC SCALE: 1" = 30'

0' 30' 60'

## LEGEND

⌖ APPROXIMATE BORING LOCATION


## LOCATION MAP

NOT TO SCALE

NOTE:
BASE DRAWING INFORMATION TAKEN FROM THE PLAN TITLED "BOARDMAN RIVER IMPROVEMENT PROJECT" (SHEET NOS. 2 AND 3) PREPARED BY WADE TRIM.

SME
www.sme-usa.com

**Project**
100 AND 200 BLOCK SUBSIDENCE

**Project Location**
TRAVERSE CITY, MICHIGAN

**Sheet Name**
BORING LOCATION DIAGRAM

| No. | Revision Date |
|---|---|
| | |
| | |
| | |
| | |

| | |
|---|---|
| Date | 1-15-2021 |
| CADD | JAB |
| Designer | PEA |
| Scale | AS NOTED |
| Project | 085455.00 |
| Figure No. | 1 |

SME

# BORING LOG TERMINOLOGY

## UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

| | | | |
|---|---|---|---|
| COARSE-GRAINED SOIL (more than 50% of material is larger than No. 200 sieve size.) | | | |
| **GRAVEL** More than 50% of coarse fraction larger than No. 4 sieve size | Clean Gravel (Less than 5% fines) | | |
| | | GW | Well-graded gravel; gravel-sand mixtures, little or no fines |
| | | GP | Poorly-graded gravel; gravel-sand mixtures, little or no fines |
| | Gravel with fines (More than 12% fines) | | |
| | | GM | Silty gravel; gravel-sand-silt mixtures |
| | | GC | Clayey gravel; gravel-sand-clay mixtures |
| **SAND** 50% or more of coarse fraction smaller than No. 4 sieve size | Clean Sand (Less than 5% fines) | | |
| | | SW | Well-graded sand; sand-gravel mixtures, little or no fines |
| | | SP | Poorly graded sand; sand-gravel mixtures, little or no fines |
| | Sand with fines (More than 12% fines) | | |
| | | SM | Silty sand; sand-silt-gravel mixtures |
| | | SC | Clayey sand; sand–clay-gravel mixtures |
| FINE-GRAINED SOIL (50% or more of material is smaller than No. 200 sieve size) | | | |
| **SILT AND CLAY** Liquid limit less than 50% | | ML | Inorganic silt; sandy silt or gravelly silt with slight plasticity |
| | | CL | Inorganic clay of low plasticity; lean clay, sandy clay, gravelly clay |
| | | OL | Organic silt and organic clay of low plasticity |
| **SILT AND CLAY** Liquid limit 50% or greater | | MH | Inorganic silt of high plasticity, elastic silt |
| | | CH | Inorganic clay of high plasticity, fat clay |
| | | OH | Organic silt and organic clay of high plasticity |
| **HIGHLY ORGANIC SOIL** | | PT | Peat and other highly organic soil |

## OTHER MATERIAL SYMBOLS

Topsoil, Void, Sandstone, Asphalt Concrete, Glacial Till, Siltstone, Aggregate Base, Coal, Limestone, Portland Cement Concrete, Shale, Fill

## LABORATORY CLASSIFICATION CRITERIA

| | | |
|---|---|---|
| GW | $C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{D_{30}^{2}}{D_{10} \times D_{60}}$ between 1 and 3 | |
| GP | Not meeting all gradation requirements for GW | |
| GM | Atterberg limits below "A" line or PI less than 4 | Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols |
| GC | Atterberg limits above "A" line with PI greater than 7 | |
| SW | $C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{D_{30}^{2}}{D_{10} \times D_{60}}$ between 1 and 3 | |
| SP | Not meeting all gradation requirements for SW | |
| SM | Atterberg limits below "A" line or PI less than 4 | Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols |
| SC | Atterberg limits above "A" line with PI 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 percent……………………..……...GW, GP, SW, SP
More than 12 percent…………………..……..GM, GC, SM, SC
5 to 12 percent……………...……..Cases requiring dual symbols

- SP-SM or SW-SM (SAND with Silt or SAND with Silt and Gravel)
- SP-SC or SW-SC (SAND with Clay or SAND with Clay and Gravel)
- GP-GM or GW-GM (GRAVEL with Silt or GRAVEL with Silt and Sand)
- GP-GC or GW-GC (GRAVEL with Clay or GRAVEL with Clay and Sand)

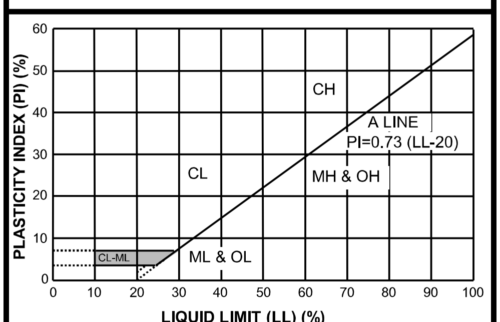
If the fines are CL-ML:

- SC-SM (SILTY CLAYEY SAND or SILTY CLAYEY SAND with Gravel)
- SM-SC (CLAYEY SILTY SAND or CLAYEY SILTY SAND with Gravel)
- GC-GM (SILTY CLAYEY GRAVEL or SILTY CLAYEY GRAVEL with Sand)

## PARTICLE SIZES

| | | |
|---|---|---|
| Boulders | - | Greater than 12 inches |
| Cobbles | - | 3 inches to 12 inches |
| Gravel- Coarse | - | 3/4 inches to 3 inches |
| Fine | - | No. 4 to 3/4 inches |
| Sand- Coarse | - | No. 10 to No. 4 |
| Medium | - | No. 40 to No. 10 |
| Fine | - | No. 200 to No. 40 |
| Silt and Clay | - | Less than (0.074 mm) |

## PLASTICITY CHART




## VISUAL MANUAL PROCEDURE

When laboratory tests are not performed to confirm the classification of soils exhibiting borderline classifications, the two possible classifications would be separated with a slash, as follows:

For soils where it is difficult to distinguish if it is a coarse or fine-grained soil:

- SC/CL (CLAYEY SAND to Sandy LEAN CLAY)
- SM/ML (SILTY SAND to SANDY SILT)
- GC/CL (CLAYEY GRAVEL to Gravelly LEAN CLAY)
- GM/ML (SILTY GRAVEL to Gravelly SILT)

For soils where it is difficult to distinguish if it is sand or gravel, poorly or well-graded sand or gravel; silt or clay; or plastic or non-plastic silt or clay:

- SP/GP or SW/GW (SAND with Gravel to GRAVEL with Sand)
- SC/GC (CLAYEY SAND with Gravel to CLAYEY GRAVEL with Sand)
- SM/GM (SILTY SAND with Gravel to SILTY GRAVEL with Sand)
- SW/SP (SAND or SAND with Gravel)
- GP/GW (GRAVEL or GRAVEL with Sand)
- SC/SM (CLAYEY to SILTY SAND)
- GM/GC (SILTY to CLAYEY GRAVEL)
- CL/ML (SILTY CLAY)
- ML/CL (CLAYEY SILT)
- CH/MH (FAT CLAY to ELASTIC SILT)
- CL/CH (LEAN to FAT CLAY)
- MH/ML (ELASTIC SILT to SILT)

## DRILLING AND SAMPLING ABBREVIATIONS

| | | |
|---|---|---|
| 2ST | – | Shelby Tube – 2" O.D. |
| 3ST | – | Shelby Tube – 3" O.D. |
| AS | – | Auger Sample |
| GS | – | Grab Sample |
| LS | – | Liner Sample |
| NR | – | No Recovery |
| PM | – | Pressuremeter |
| RC | – | Rock Core diamond bit. NX size, except where noted |
| SB | – | Split Barrel Sample 1-3/8" I.D., 2" O.D., except where noted |
| VS | – | Vane Shear |
| WS | – | Wash Sample |

## OTHER ABBREVIATIONS

| | | |
|---|---|---|
| WOH | – | Weight of Hammer |
| WOR | – | Weight of Rods |
| SP | – | Soil Probe |
| PID | – | Photo Ionization Device |
| FID | – | Flame Ionization Device |

## DEPOSITIONAL FEATURES

| | | |
|---|---|---|
| Parting | – | as much as 1/16 inch thick |
| Seam | – | 1/16 inch to 1/2 inch thick |
| Layer | – | 1/2 inch to 12 inches thick |
| Stratum | – | greater than 12 inches thick |
| Pocket | – | deposit of limited lateral extent |
| Lens | – | lenticular deposit |
| Hardpan/Till | – | an unstratified, consolidated or cemented mixture of clay, silt, sand and/or gravel, the size/shape of the constituents vary widely |
| Lacustrine | – | soil deposited by lake water |
| Mottled | – | soil irregularly marked with spots of different colors that vary in number and size |
| Varved | – | alternating partings or seams of silt and/or clay |
| Occasional | – | one or less per foot of thickness |
| Frequent | – | more than one per foot of thickness |
| Interbedded | – | strata of soil or beds of rock lying between or alternating with other strata of a different nature |

## DESCRIPTION OF RELATIVE QUANTITIES

The visual-manual procedure uses the following terms to describe the relative quantities of notable foreign materials, gravel, sand or fines:

| | | |
|---|---|---|
| Trace | – | particles are present but estimated to be less than 5% |
| Few | – | 5 to 10% |
| Little | – | 15 to 25% |
| Some | – | 30 to 45% |
| Mostly | – | 50 to 100% |

## CLASSIFICATION TERMINOLOGY AND CORRELATIONS

**Cohesionless Soils**

| **Relative Density** | **$N_{60}$ (N-Value) (Blows per foot)** |
|---|---|
| Very Loose | 0 to 4 |
| Loose | 5 to 10 |
| Medium Dense | 11 to 30 |
| Dense | 31 to 50 |
| Very Dense | 51 to 80 |
| Extremely Dense | Over 81 |

**Cohesive Soils**

| **Consistency** | **$N_{60}$ (N-Value) (Blows per foot)** | **Undrained Shear Strength (kips/ft$^2$)** |
|---|---|---|
| Very Soft | <2 | 0.25 or less |
| Soft | 2 - 4 | > 0.25 to 0.50 |
| Medium | 5 - 8 | > 0.50 to 1.0 |
| Stiff | 9 - 15 | > 1.0 to 2.0 |
| Very Stiff | 16 - 30 | > 2.0 to 4.0 |
| Hard | > 30 | > 4.0 or greater |

Standard Penetration 'N-Value' = Blows per foot of a 140-pound hammer falling 30 inches on a 2-inch O.D. split barrel sampler, except where noted. N60 values as reported on boring logs represent raw N-values corrected for hammer efficiency only.

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SME

# BORING B1



BORING DEPTH: 45 FEET

**PROJECT NAME:** 100 and 200 Block Subsidence
**PROJECT NUMBER:** 085455.00
**CLIENT:** SmithGroup
**PROJECT LOCATION:** Traverse City, Michigan
**DATE STARTED:** 11/10/20
**COMPLETED:** 11/10/20
**BORING METHOD:** Hollow-stem Augers
**DRILLER:** DB/WN
**RIG NO.:** 552 (CME 55)
**LOGGED BY:** BAB
**CHECKED BY:** JLN

ELEVATION: 591± FT

HAMMER EFFICIENCY: 87%
DATE: 3/10/2020
$N_{60}$ -- O

DRY DENSITY (pcf) -- ■ (90, 100, 110, 120)
MOISTURE & ATTERBERG LIMITS (%) (PL, MC, LL) (10, 20, 30, 40)
HAND PENE.; TORVANE SHEAR; UNC. COMP.; VANE SHEAR (PK); VANE SHEAR (REM); TRIAXIAL (UU)
SHEAR STRENGTH (KSF) (1, 2, 3, 4)
REMARKS

| DEPTH (FT) | PROFILE DESCRIPTION | ELEV. (FT) |
|---|---|---|
| 0.3 | 3 Inches of Asphalt Pavement | 590.8 |
| 8.0 | FILL- Fine to Medium SAND- Brown to Dark Brown- Moist- Loose to Very Loose (SP) | 583.0 |
| 11.0 | FILL- Fine to Coarse SAND with Gravel- Frequent Glass Fragments- Black- Wet- Very Loose (SP) | 580.0 |
| 18.0 | Fine to Medium SAND- Brown to Dark Brown- Wet- Loose to Medium Dense (SP) | 573.0 |
| 28.0 | Fine to Coarse SAND- Brown- Wet- Dense (SP) | 563.0 |
| | Fine to Medium SAND- Brown- Wet- Medium Dense to Very Dense (SP) | |

| SAMPLE TYPE/NO. INTERVAL | RECOVERY LENGTH (INCHES) | SPT BLOWS PER SIX INCHES | $N_{60}$ |
|---|---|---|---|
| SB1 | 18 | 2 3 3 | 9 |
| SB2 | 18 | 2 1 2 | 4 |
| SB3 | 18 | 2 2 2 | 6 |
| SB4 | 18 | 1 1 1 | 3 |
| SB5 | 18 | 2 2 3 | 7 |
| SB6 | 18 | 3 4 5 | 13 |
| SB7 | 18 | 4 6 6 | 17 |
| SB8 | 18 | 9 13 16 | 42 |
| SB9 | 18 | 11 13 21 | 49 |
| SB10 | 18 | 6 7 8 | 22 |

**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) | ELEV (FT) |
|---|---|---|
| ▽ **DURING BORING:** | 8.0 | 583.0 |
| ▼ **AT END OF BORING:** | 6.0 | 585.0 |

**BACKFILL METHOD:** Auger Cuttings & EPCO Hole Plug

NOTES:
1. The indicated stratification lines are approximate. The in-situ transitions between materials may be gradual.
2. The colors depicted on the symbolic profile are solely for visualization purposes and do not necessarily represent the in-situ colors encountered.
3. Borehole was patched with asphalt after backfilling.

*(Continued Next Page)*

SME

# BORING B1



BORING DEPTH: 45 FEET

**PROJECT NAME:** 100 and 200 Block Subsidence
**PROJECT NUMBER:** 085455.00
**CLIENT:** SmithGroup
**PROJECT LOCATION:** Traverse City, Michigan

HAMMER EFFICIENCY: 87%
DATE: 3/10/2020
$N_{60}$ – ○

DRY DENSITY (pcf) – ■ (90, 100, 110, 120)
MOISTURE & ATTERBERG LIMITS (%): PL, MC, LL (10, 20, 30, 40)
SHEAR STRENGTH (KSF) (1, 2, 3, 4): HAND PENE., TORVANE SHEAR, UNC. COMP., VANE SHEAR (PK), VANE SHEAR (REM), TRIAXIAL (UU)

ELEVATION: 591± FT

| DEPTH (FEET) | ELEVATION (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | RECOVERY LENGTH (INCHES) | SPT BLOWS PER SIX INCHES | $N_{60}$ | REMARKS |
|---|---|---|---|---|---|---|---|
| 30–45 | | Fine to Medium SAND- Brown- Wet- Medium Dense to Very Dense (SP) *(continued)* | | | | | |
| 34.5–36 | | | SB11 | 18 | 7 7 9 | 23 | |
| 38.5–40 | | | SB12 | 18 | 13 15 17 | 46 | |
| 43.5–45 | | | SB13 | 18 | 15 18 23 | 59 | |
| 45.0 | 546.0 | END OF BORING AT 45.0 FEET. | | | | | |

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# BORING B2



BORING DEPTH: 45 FEET

**PROJECT NAME:** 100 and 200 Block Subsidence | **PROJECT NUMBER:** 085455.00

**CLIENT:** SmithGroup | **PROJECT LOCATION:** Traverse City, Michigan

**DATE STARTED:** 11/10/20 | **COMPLETED:** 11/10/20 | **BORING METHOD:** Hollow-stem Augers

**DRILLER:** DB/WN | **RIG NO.:** 552 (CME 55) | **LOGGED BY:** BAB | **CHECKED BY:** JLN

HAMMER EFFICIENCY: 87% DATE: 3/10/2020

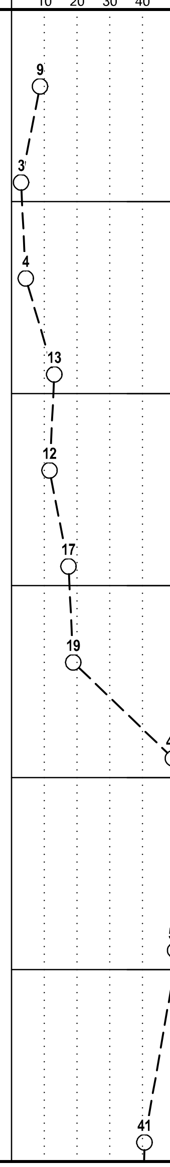
$N_{60}$ -- O

DRY DENSITY (pcf) -- ■ (90, 100, 110, 120); MOISTURE & ATTERBERG LIMITS (%) PL, MC, LL (10, 20, 30, 40)

SHEAR STRENGTH (KSF) (1, 2, 3, 4): HAND PENE.; TORVANE SHEAR; UNC. COMP.; VANE SHEAR (PK); VANE SHEAR (REM); TRIAXIAL (UU)

ELEVATION: 587± FT

| ELEVATION (FEET) | DEPTH (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | RECOVERY LENGTH (INCHES) | SPT BLOWS PER SIX INCHES | $N_{60}$ | REMARKS |
|---|---|---|---|---|---|---|---|
| 586.8 | 0.3 | 3 Inches of Asphalt Pavement | | | | | |
| 584.0 | 3.0 | FILL- Fine to Medium SAND- Dark Brown- Moist- Loose (SP) | SB1 | 18 | 3 3 3 | 9 | |
| 578.5 | 8.5 | FILL- Fine to Medium SAND- Brown- Moist to Wet- Very Loose (SP) | SB2 | 18 | 1 1 1 | 3 | |
| | | | SB3 | 18 | 1 2 1 | 4 | |
| 577.0 | 10.0 | Fine to Coarse SAND- Dark Brown- Wet- Medium Dense (SP) | SB4 | 18 | 3 4 5 | 13 | Foreign odor noted at Sample SB4. |
| 569.0 | 18.0 | Fine to Medium SAND- Brown to Dark Brown- Medium Dense (SP) | SB5 | 18 | 4 4 4 | 12 | Foreign odor noted at Sample SB5. |
| | | | SB6 | 18 | 5 6 6 | 17 | Foreign odor noted at Sample SB6. |
| | | | SB7 | 18 | 4 5 8 | 19 | |
| 559.0 | 28.0 | Fine to Coarse SAND- Brown- Wet- Dense to Very Dense (SP) | SB8 | 18 | 12 16 18 | 49 | |
| | | | SB9 | 18 | 13 15 20 | 51 | |
| | | Fine to Medium SAND- Brown- Wet- Dense to Very Dense (SP) | SB10 | 18 | 12 13 15 | 41 | |




**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) | ELEV (FT) |
|---|---|---|
| ▽ DURING BORING: | 5.0 | 582.0 |
| ▼ AT END OF BORING: | 10.0 | 577.0 |

**BACKFILL METHOD:** Auger Cuttings & EPCO Hole Plug

NOTES:
1. The indicated stratification lines are approximate. The in-situ transitions between materials may be gradual.
2. The colors depicted on the symbolic profile are solely for visualization purposes and do not necessarily represent the in-situ colors encountered.
3. Borehole was patched with asphalt after backfilling.

*(Continued Next Page)*

SME

# BORING B2



BORING DEPTH: 45 FEET

**PROJECT NAME:** 100 and 200 Block Subsidence

**PROJECT NUMBER:** 085455.00

**CLIENT:** SmithGroup

**PROJECT LOCATION:** Traverse City, Michigan

ELEVATION: 587± FT

HAMMER EFFICIENCY: 87%
DATE: 3/10/2020
$N_{60}$ – O

DRY DENSITY (pcf) – ■ (90 100 110 120)

MOISTURE & ATTERBERG LIMITS (%) PL MC LL (10 20 30 40)

HAND PENE. / TORVANE SHEAR / UNC. COMP. / VANE SHEAR (PK) / VANE SHEAR (REM) / TRIAXIAL (UU) — SHEAR STRENGTH (KSF) (1 2 3 4)

| DEPTH (FEET) | ELEVATION (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | RECOVERY LENGTH (INCHES) | SPT BLOWS PER SIX INCHES | $N_{60}$ | REMARKS |
|---|---|---|---|---|---|---|---|
| 30–45 | 557–542 | Fine to Medium SAND- Brown- Wet- Dense to Very Dense (SP) *(continued)* | SB11 | 18 | 9, 11, 16 | 39 | |
| | | | SB12 | 18 | 14, 16, 21 | 54 | |
| 45.0 | 542.0 | | SB13 | 18 | 10, 15, 19 | 49 | |

END OF BORING AT 45.0 FEET.

SME

# BORING B3



BORING DEPTH: 45 FEET

**PROJECT NAME:** 100 and 200 Block Subsidence
**PROJECT NUMBER:** 085455.00
**CLIENT:** SmithGroup
**PROJECT LOCATION:** Traverse City, Michigan
**DATE STARTED:** 11/10/20
**COMPLETED:** 11/10/20
**BORING METHOD:** Hollow-stem Augers
**DRILLER:** DB/WN
**RIG NO.:** 552 (CME 55)
**LOGGED BY:** BAB
**CHECKED BY:** JLN

HAMMER EFFICIENCY: 87%
DATE: 3/10/2020
$N_{60}$ -- O

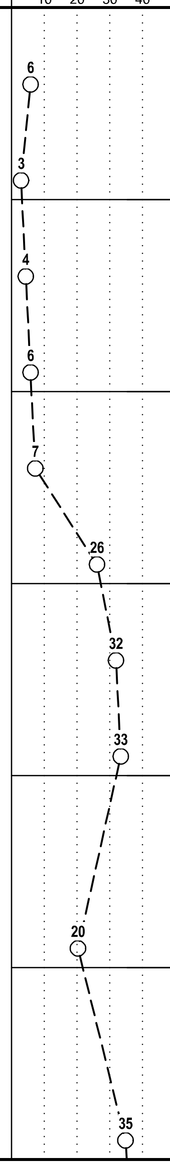
DRY DENSITY (pcf) -- ■ 90 100 110 120
MOISTURE & ATTERBERG LIMITS (%) PL MC LL 10 20 30 40

▼ HAND PENE. ⊠ TORVANE SHEAR ● UNC. COMP. ⊡ VANE SHEAR (PK) × VANE SHEAR (REM) ⊕ TRIAXIAL (UU)
SHEAR STRENGTH (KSF) 1 2 3 4

ELEVATION: 584± FT

| DEPTH (FEET) | ELEVATION (FEET) | PROFILE DESCRIPTION |
|---|---|---|
| 0 – 0.3 | 583.8 | 3 Inches of Asphalt Pavement |
| 0.3 – 8.5 | 575.5 | FILL- Fine to Medium SAND- Few Gravel- Dark Brown- Moist to Wet- Loose to Very Loose (SP) |
| 8.5 – 12.5 | 571.5 | POSSIBLE FILL- Fine to Medium SAND- Dark Brown- Wet- Loose (SP) |
| 12.5 – | | Fine to Medium SAND- Brown - Wet- Medium Dense to Very Dense (SP) |

| SAMPLE TYPE/NO. INTERVAL | RECOVERY LENGTH (INCHES) | SPT BLOWS PER SIX INCHES | $N_{60}$ | REMARKS |
|---|---|---|---|---|
| SB1 | 18 | 2 2 2 | 6 | |
| SB2 | 18 | 1 1 1 | 3 | |
| SB3 | 18 | 2 1 2 | 4 | |
| SB4 | 18 | 1 1 3 | 6 | Foreign odor noted at Sample SB4. |
| SB5 | 18 | 2 2 3 | 7 | Foreign odor noted at Sample SB5. |
| SB6 | 18 | 7 8 10 | 26 | |
| SB7 | 18 | 6 9 13 | 32 | |
| SB8 | 18 | 8 10 13 | 33 | |
| SB9 | 18 | 6 7 7 | 20 | |
| SB10 | 18 | 9 10 14 | 35 | |




**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) | ELEV (FT) |
|---|---|---|
| ▽ DURING BORING: | 2.0 | 582.0 |
| ▼ AT END OF BORING: | 2.0 | 582.0 |

**BACKFILL METHOD:** Auger Cuttings & EPCO Hole Plug

NOTES:
1. The indicated stratification lines are approximate. The in-situ transitions between materials may be gradual.
2. The colors depicted on the symbolic profile are solely for visualization purposes and do not necessarily represent the in-situ colors encountered.
3. Borehole was patched with asphalt after backfilling.

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SME

# BORING B3



BORING DEPTH: 45 FEET

**PROJECT NAME:** 100 and 200 Block Subsidence

**PROJECT NUMBER:** 085455.00

**CLIENT:** SmithGroup

**PROJECT LOCATION:** Traverse City, Michigan

ELEVATION: 584± FT

HAMMER EFFICIENCY: 87%
DATE: 3/10/2020

$N_{60}$ – O

DRY DENSITY (pcf) – ■ (90, 100, 110, 120)

MOISTURE & ATTERBERG LIMITS (%) (PL, MC, LL) (10, 20, 30, 40)

SHEAR STRENGTH (KSF) (1, 2, 3, 4): HAND PENE.; TORVANE SHEAR; UNC. COMP.; VANE SHEAR (PK); VANE SHEAR (REM); TRIAXIAL (UU)

| DEPTH (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | RECOVERY LENGTH (INCHES) | SPT BLOWS PER SIX INCHES | $N_{60}$ | REMARKS |
|---|---|---|---|---|---|---|
| 30–45.0 (Elev. 539.0) | Fine to Medium SAND- Brown - Wet- Medium Dense to Very Dense (SP) *(continued)* | | | | | |
| 33.5–35 | | SB11 | 18 | 7, 10, 17 | 39 | |
| 38.5–40 | | SB12 | 18 | 12, 16, 19 | 51 | |
| 43.5–45 | | SB13 | 18 | 10, 14, 16 | 44 | |

END OF BORING AT 45.0 FEET.

Elevation scale (ft): 550, 545, 540, 535, 530, 525, 520, 515
Depth scale (ft): 30, 35, 40, 45, 50, 55, 60, 65, 70

# Important Information about This

# Geotechnical-Engineering Report

**Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.**

**While you cannot eliminate all such risks, you can manage them. The following information is provided to help.**

**The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.**

## Understand the Geotechnical-Engineering Services Provided for this Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

## Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will not be adequate to develop geotechnical design recommendations for the project.

*Do not rely on this report* if your geotechnical engineer prepared it:
- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

## Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do not rely on an executive summary. Do not read selective elements only. *Read and refer to the report in full.*

## You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:
- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept* *responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

### Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface using various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

### This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are not final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

### This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals' plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

### Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for information purposes only.* To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

### Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

### Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures.* If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

### Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer's services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will not of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration*** by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are not building-envelope or mold specialists.***

GEOPROFESSIONAL BUSINESS ASSOCIATION

Telephone: 301/565-2733
e-mail: info@geoprofessional.org www.geoprofessional.org

# GENERAL COMMENTS

## BASIS OF GEOTECHNICAL REPORT

This report has been prepared in accordance with generally accepted geotechnical engineering practices to assist in the design and/or evaluation of this project. If the project plans, design criteria, and other project information referenced in this report and utilized by SME to prepare our recommendations are changed, the conclusions and recommendations contained in this report are not considered valid unless the changes are reviewed, and the conclusions and recommendations of this report are modified or approved in writing by our office.

The discussions and recommendations submitted in this report are based on the available project information, described in this report, and the geotechnical data obtained from the field exploration at the locations indicated in the report. Variations in the soil and groundwater conditions commonly occur between or away from sampling locations. The nature and extent of the variations may not become evident until the time of construction. If significant variations are observed during construction, SME should be contacted to reevaluate the recommendations of this report. SME should be retained to continue our services through construction to observe and evaluate the actual subsurface conditions relative to the recommendations made in this report.

In the process of obtaining and testing samples and preparing this report, procedures are followed that represent reasonable and accepted practice in the field of soil and foundation engineering. Specifically, field logs are prepared during the field exploration that describe field occurrences, sampling locations, and other information. Samples obtained in the field are frequently subjected to additional testing and reclassification in the laboratory and differences may exist between the field logs and the report logs. The engineer preparing the report reviews the field logs, laboratory classifications, and test data and then prepares the report logs. Our recommendations are based on the contents of the report logs and the information contained therein.

## REVIEW OF DESIGN DETAILS, PLANS, AND SPECIFICATIONS

SME should be retained to review the design details, project plans, and specifications to verify those documents are consistent with the recommendations contained in this report.

## REVIEW OF REPORT INFORMATION WITH PROJECT TEAM

Implementation of our recommendations may affect the design, construction, and performance of the proposed improvements, along with the potential inherent risks involved with the proposed construction. The client and key members of the design team, including SME, should discuss the issues covered in this report so that the issues are understood and applied in a manner consistent with the owner's budget, tolerance of risk, and expectations for performance and maintenance.

## FIELD VERIFICATION OF GEOTECHNICAL CONDITIONS

SME should be retained to verify the recommendations of this report are properly implemented during construction. This may avoid misinterpretation of our recommendations by other parties and will allow us to review and modify our recommendations if variations in the site subsurface conditions are encountered.

## PROJECT INFORMATION FOR CONTRACTOR

This report and any future addenda or other reports regarding this site should be made available to prospective contractors prior to submitting their proposals for their information only and to supply them with facts relative to the subsurface evaluation and laboratory test results. If the selected contractor encounters subsurface conditions during construction, which differ from those presented in this report, the contractor should promptly describe the nature and extent of the differing conditions in writing and SME should be notified so that we can verify those conditions. The construction contract should include provisions for dealing with differing conditions and contingency funds should be reserved for potential problems during earthwork and foundation construction. We would be pleased to assist you in developing the contract provisions based on our experience.

The contractor should be prepared to handle environmental conditions encountered at this site, which may affect the excavation, removal, or disposal of soil; dewatering of excavations; and health and safety of workers. Any Environmental Assessment reports prepared for this site should be made available for review by bidders and the successful contractor.

## THIRD PARTY RELIANCE/REUSE OF THIS REPORT

This report has been prepared solely for the use of our Client for the project specifically described in this report. This report cannot be relied upon by other parties not involved in the project, unless specifically allowed by SME in writing. SME also is not responsible for the interpretation by other parties of the geotechnical data and the recommendations provided herein.

# LABORATORY TESTING PROCEDURES

## VISUAL ENGINEERING CLASSIFICATION

Visual classification was performed on recovered samples. The appended General Notes and Unified Soil Classification System (USCS) sheets include a brief summary of the general method used visually classify the soil and assign an appropriate USCS group symbol. The estimated group symbol, according to the USCS, is shown in parentheses following the textural description of the various strata on the boring logs appended to this report. The soil descriptions developed from visual classifications are sometimes modified to reflect the results of laboratory testing.

## MOISTURE CONTENT

Moisture content tests were performed by weighing samples from the field at their in-situ moisture condition. These samples were then dried at a constant temperature (approximately 110º C) overnight in an oven. After drying, the samples were weighed to determine the dry weight of the sample and the weight of the water that was expelled during drying. The moisture content of the specimen is expressed as a percent and is the weight of the water compared to the dry weight of the specimen.

## HAND PENETROMETER TESTS

In the hand penetrometer test, the unconfined compressive strength of a cohesive soil sample is estimated by measuring the resistance of the sample to the penetration of a small calibrated, spring-loaded cylinder. The maximum capacity of the penetrometer is 4.5 tons per square-foot (tsf). Theoretically, the undrained shear strength of the cohesive sample is one-half the unconfined compressive strength. The undrained shear strength (based on the hand penetrometer test) presented on the boring logs is reported in units of kips per square-foot (ksf).

## TORVANE SHEAR TESTS

In the Torvane test, the shear strength of a low strength, cohesive soil sample is estimated by measuring the resistance of the sample to a torque applied through vanes inserted into the sample. The undrained shear strength of the samples is measured from the maximum torque required to shear the sample and is reported in units of kips per square-foot (ksf).

## LOSS-ON-IGNITION (ORGANIC CONTENT) TESTS

Loss-on-ignition (LOI) tests are conducted by first weighing the sample and then heating the sample to dry the moisture from the sample (in the same manner as determining the moisture content of the soil). The sample is then re-weighed to determine the dry weight and then heated for 4 hours in a muffle furnace at a high temperature (approximately 440º C). After cooling, the sample is re-weighed to calculate the amount of ash remaining, which in turn is used to determine the amount of organic matter burned from the original dry sample. The organic matter content of the specimen is expressed as a percent compared to the dry weight of the sample.

## ATTERBERG LIMITS TESTS

Atterberg limits tests consist of two components. The plastic limit of a cohesive sample is determined by rolling the sample into a thread and the plastic limit is the moisture content where a 1/8-inch thread begins to crumble. The liquid limit is determined by placing a ½-inch thick soil pat into the liquid limits cup and using a grooving tool to divide the soil pat in half. The cup is then tapped on the base of the liquid limits device using a crank handle. The number of drops of the cup to close the gap formed by the grooving tool ½ inch is recorded along with the corresponding moisture content of the sample. This procedure is repeated several times at different moisture contents and a graph of moisture content and the corresponding number of blows is plotted. The liquid limit is defined as the moisture content at a nominal 25 drops of the cup. From this test, the plasticity index can be determined by subtracting the plastic limit from the liquid limit.

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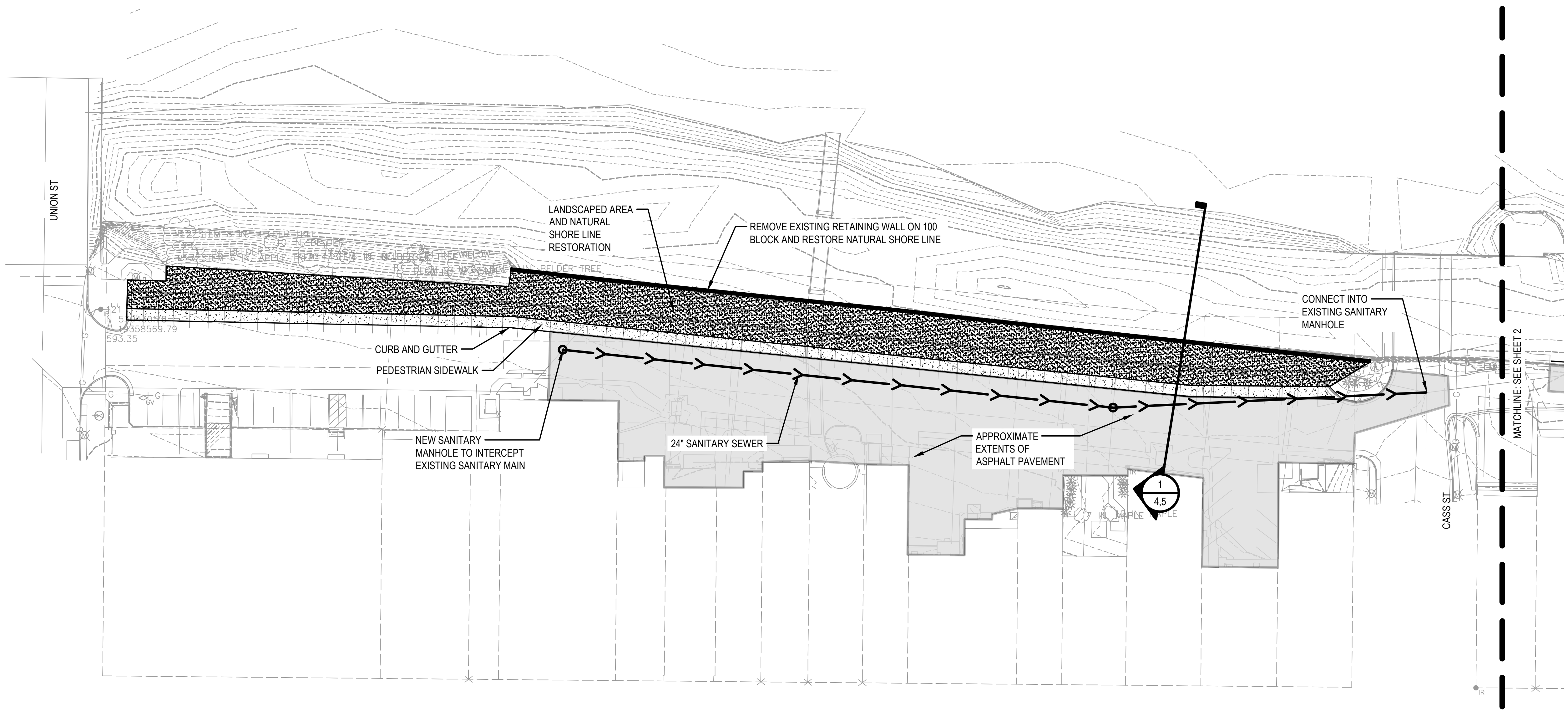
# APPENDIX E. Plans and Cross Sections





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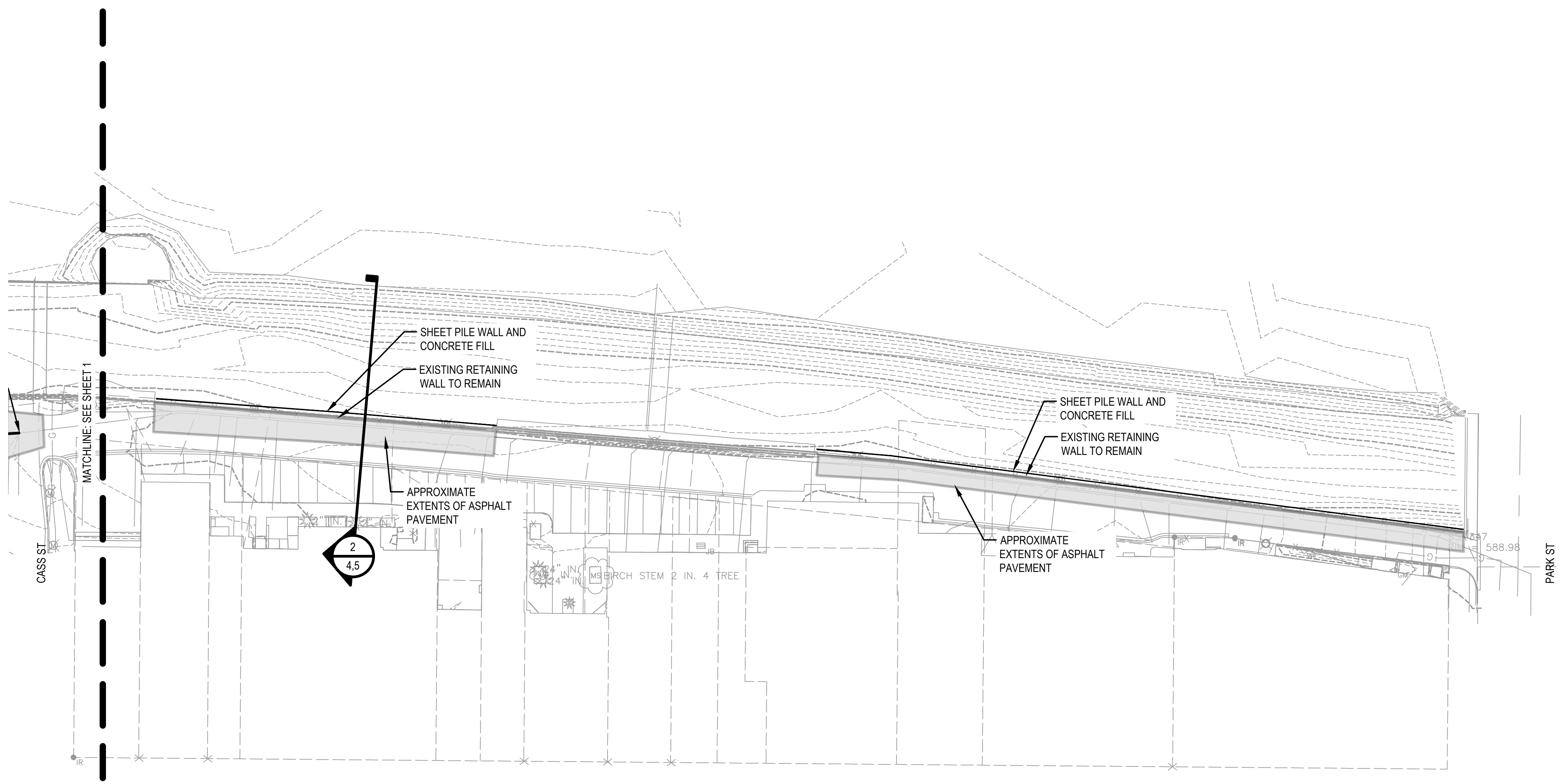
BOARDMAN RIVER
LAYOUT PLAN
DRAWING TITLE

0' 20' 40'
SCALE
DRAWING SCALE

JANUARY 15, 2020
DATE

BOARDMAN RIVER WALL
PROJECT NAME

1
DRAWING NUMBER





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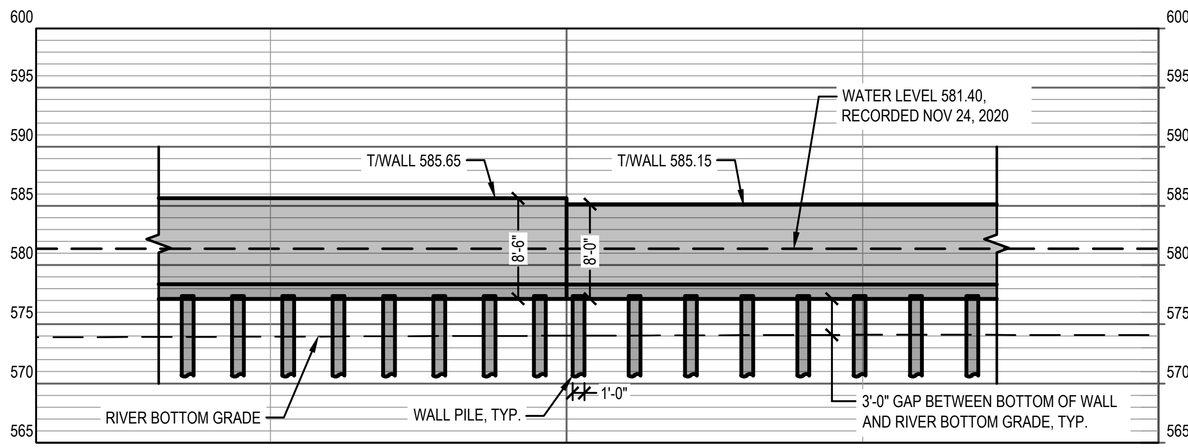
BOARDMAN RIVER
LAYOUT PLAN
DRAWING TITLE

SCALE (0' 20' 40')
DRAWING SCALE

JANUARY 15, 2020
DATE

BOARDMAN RIVER WALL
PROJECT NAME

2
DRAWING NUMBER




1 TYPICAL WALL ELEVATION

SCALE: 1" = 10'

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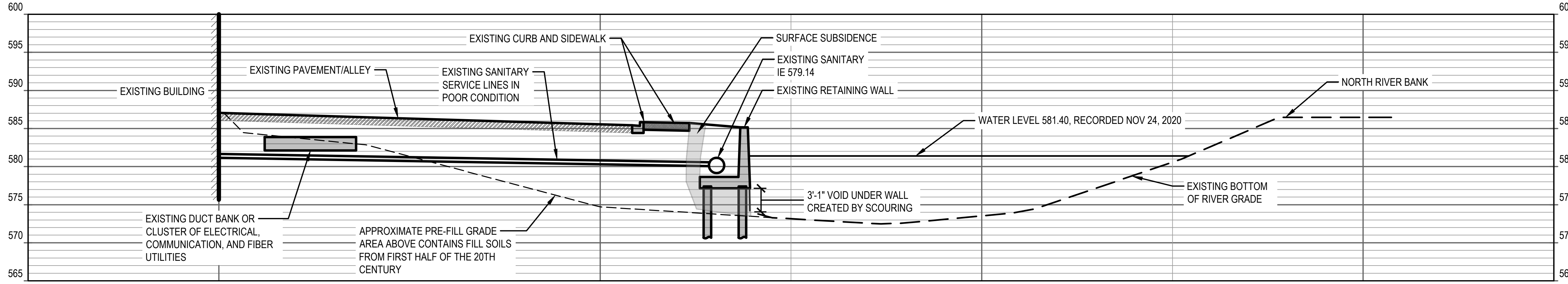
BOARDMAN RIVER
TYPICAL WALL ELEVATION
DRAWING TITLE

SCALE
DRAWING SCALE

JANUARY 15, 2020
DATE

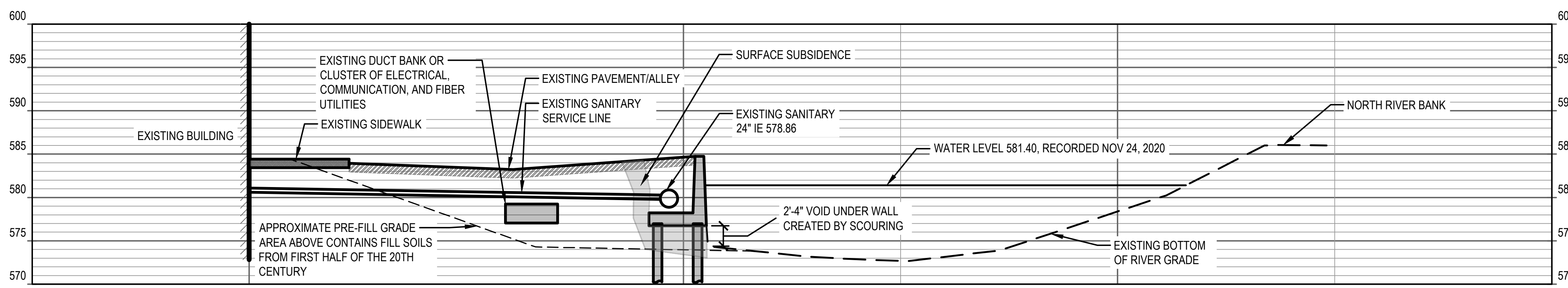
BOARDMAN RIVER WALL
PROJECT NAME

3
DRAWING NUMBER




① EXISTING CROSS SECTION - 100 BLOCK

SCALE: 1" = 10'




② EXISTING CROSS SECTION - 200 BLOCK

SCALE: 1" = 10'

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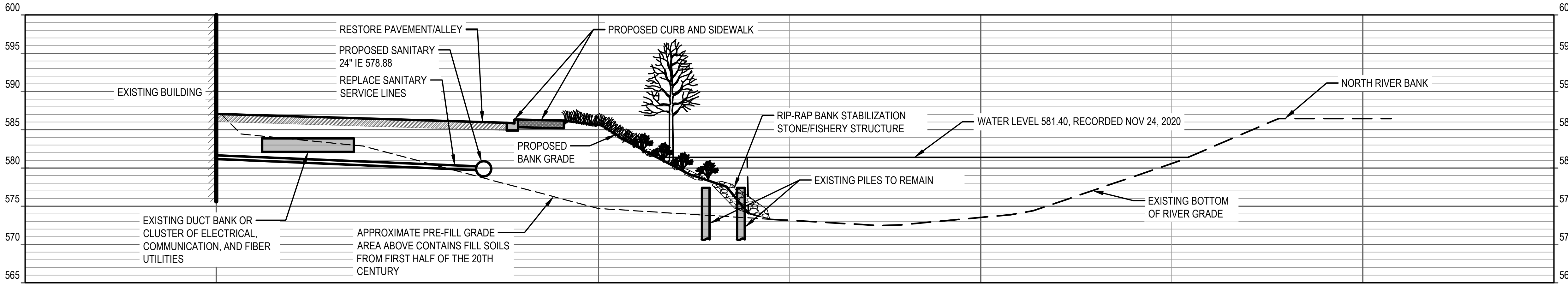
BOARDMAN RIVER
EXISTING CONDITION
SECTIONS
DRAWING TITLE

SCALE 0' 5' 10'
DRAWING SCALE

JANUARY 15, 2020
DATE

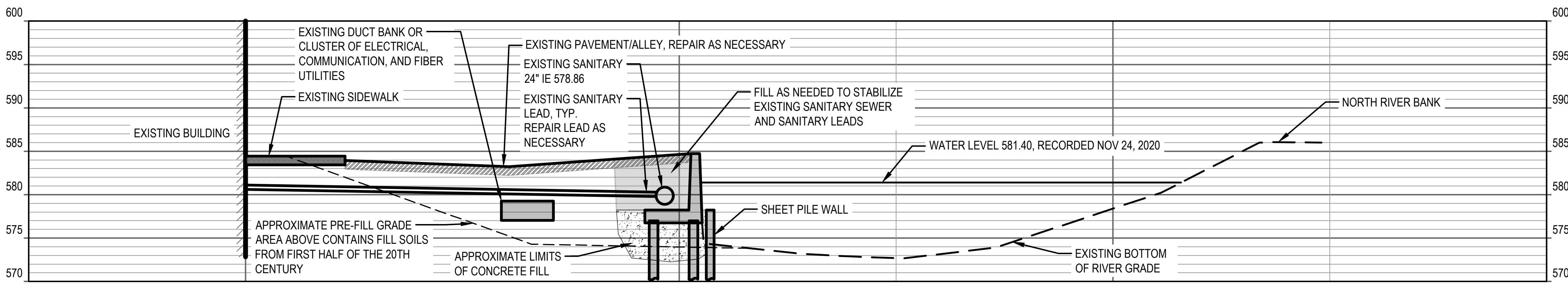
BOARDMAN RIVER WALL
PROJECT NAME

4
DRAWING NUMBER




1 PROPOSED CROSS SECTION - 100 BLOCK

SCALE: 1" = 10'




2 PROPOSED CROSS SECTION - 200 BLOCK

SCALE: 1" = 10'

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BOARDMAN RIVER
PROPOSED CONDITIONS
SECTIONS
DRAWING TITLE

SCALE 0' 5' 10'
DRAWING SCALE

JANUARY 15, 2020
DATE

BOARDMAN RIVER WALL
PROJECT NAME

5
DRAWING NUMBER