HOUSTON engineering, inc.

DAVEY Resource Group

Maple Grove Office | HEI No. 006104_0027
March 21, 2024

# SYLVAN HILLS PARK

## Stormwater and Habitat Enhancement Feasibility Study

MWMO
Protect it. Pass it on.
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION

# SYLVAN HILLS PARK

## Stormwater and Habitat Enhancement Feasibility Study

Prepared for:

MWMO℠
Protect it. Pass it on.
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION

March 21, 2024
Fridley, MN

HOUSTON engineering, inc.

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of Minnesota.

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# TABLE OF CONTENTS

# TABLES

# FIGURES

# 1 INTRODUCTION

## 1.1 INTRODUCTION

The Mississippi Watershed Management Organization (MWMO) and the City of Fridley (project partners) are collaborating to conduct a feasibility study to investigate opportunities to enhance water quality, habitat, and flood mitigation through park renovations in Sylvan Hills Park.

This study provides concepts of stormwater treatment that also include habitat restoration, enhanced natural features and opportunities for increased public engagement. This project may also serve as a model for other neighborhood parks as an exemplary opportunity to provide a habitat in an urban setting and provide stormwater management that will serve to enrich the park while maintaining the communities' recreational needs.

## 1.2 PROJECT BACKGROUND

Many parks in the City of Fridley were developed 50 to 60 years ago. These parks no longer serve the needs of the surrounding communities and will be updated in the coming years by the City. Collaboration between the City and MWMO prior to re-design of the parks provides an opportunity to meet the goals of both the entities by integrating park design with habitat and stormwater management components.

In the past, Sylvan Hills Park has experienced extended periods of flooding causing sanitary sewer overflows and pipe infrastructure failures. The goal for the park's redesign is to meet the needs of the community and provide effective stormwater treatment.

Sylvan Hills Park is situated in the MWMO. Approximately 78 acres of the watershed are routed through stormsewer near Sylvan Hills Park. The site was identified as a prospective site for capturing and treating stormwater. The contributing catchment consists mainly of medium-density residential areas, primarily privately owned parcels that were developed during the 1950s to 1960s.

1.1 inches of runoff depth was identified as the target for water quality treatment and volume control in the stormwater features. The project partners emphasized the importance of surface features to engage the public, adding natural areas, and keeping the entire park safe and usable. The City took public opinion into consideration and identified open green space and the existing basketball court as two key features to maintain. **Figure 1** shows the existing conditions and features of the park.

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Date
10-25-2023

Checked by
AJS

Scale
AS SHOWN

SYLVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

EXISTING CONDITIONS

PROJECT NO. 6107-0027

FIGURE
1

HEI NO. 6104-0027

## 1.3 GOALS AND OBJECTIVES

Sylvan Hills Park has been recognized as a favorable site for incorporating stormwater treatment, habitat restoration, and flood control measures. Numerous types and configurations of green stormwater infrastructure (GSI) concepts are available for fulfilling these needs. This investigation aims to formulate park reconstruction concepts that seamlessly integrate GSI in a cost-effective, engaging, and efficient manner.

This project aligns with the goals as stated in the Request for Proposal, particularly:

**Water Quantity and Flooding**

*Determining the extent to which adding stormwater storage to the park could reduce flood-risk downstream of the park.*

- **Objective 1** – Explore benefits of additional flood storage.

**Water Quality**

*Improving water quality discharging to the Mississippi River using surface features that engage and educate the public on stormwater management.*

- **Objective 1** – Maximize stormwater treatment volume up to 1.1-inch of runoff volume over the tributary impervious area.
- **Objective 2** – Prioritize volume control and reduction of total phosphorous (TP) and total suspended solids (TSS).

**Habitat**

*Assessing opportunities to create habitats for pollinators, birds and other wildlife.*

- **Objective 1** – Provide engaging and visually appealing stormwater features that will be viewed as an amenity by park visitors.
- **Objective 2** – Add or restore habitat within the park for pollinators, birds, and other wildlife.
- **Objective 3** – Maintain park amenities including:
  - 20,000 square feet of open lawn space
  - Accommodate park space for playground, parking, basketball court, tennis court, and other features.

## 1.4 DATA SOURCES

Data utilized in the analysis were generally from the MWMO, City, and publicly available sources, and are shown in **Table 1.**

**Table 1.** Data sources

| Data | Title | Author |
|---|---|---|
| Sylvan Hills Park Concept | Park Implementation Project | WSB |
| P8 Model | North Model | Barr Engineering |
| XPSWMM Model | July 2019 NCH-F-H Model Updates | Barr Engineering |

| Data | Title | Author |
|---|---|---|
| City GIS Utilities | Various | City of Fridley |
| GIS Web Map | Sylvan Hills Park Study | MWMO |
| City As-Built Plans | Various | City of Fridley |
| Site Survey AutoCAD DWG | 131035_VBASE_E1-Sylvan Hills | Bolton & Menck |
| Community Feedback | Sylvan Hills Community Feedback 08-24-23 | City of Fridley |
| Tree Removal Plan | Sylvan Hills Park - Tree Data | City of Fridley |
| LiDAR DEM | MnTOPO | MN DNR |

# 2 OPPORTUNITY IDENTIFICATION

The key to incorporating stormwater management infrastructure in a developed watershed lies in identifying feasible design options. In alignment with the objectives of the project partners, this study explored green stormwater infrastructure (GSI) methods, specifically focusing on infiltration and detention stormwater treatment. In the park, areas with unsuitable soil for infiltration were acknowledged and factored in when determining the placement of GSI.

## 2.1 CONCEPTUAL STORMWATER DESIGN CONSIDERATIONS

The typical sequencing for selecting GSI opportunities for stormwater treatment first considers volume control/reduction GSI such as infiltration or stormwater capture and reuse. When generating GSI ideas for this study, these were considered priority. If volume reduction GSIs were not feasible, then filtration and other treatment methods were conceptualized. HEI conducted a cursory feasibility screening of potential GSI ideas that would best meet the goals of the project. GSI opportunities were identified based on:

- Anticipated performance of pollutant reduction
- Flood reduction potential
- Site and physical constraints
- Anticipated cost
- Operation and maintenance needs
- Environmental impact or benefit

Each GSI selected for further evaluation was chosen based on site characteristics and constraints, and potential GSI performance. Based on the preferred treatment method and the limited available surface area on site, an underground infiltration system appeared most favorable to meet the project goals.

Soil borings and geotechnical evaluation was conducted by Braun Intertec (see **Appendix A.5**). Soil classification and estimated seasonal high groundwater elevations determined the feasibility of infiltration locations. Groundwater was encountered in the soil borings approximately 14 feet down from the surface of the park. Indicators for seasonal high water were not noted.

The majority of the soils across the site are poorly graded sand (SP), which are excellent for infiltration. However, near the surface, silty and clay materials were documented. In the soil borings near the southern end of the park, an 11-foot layer of silts, clays, and organics were encountered, which are not conducive to infiltration and would require soil correction.

The conceptual designs for all GSI elements were formulated according to the criteria outlined in the Minnesota Stormwater Manual. The capacities of these stormwater treatment features were specifically planned to meet the target volume of 1.1 inches over the contributing impervious area. HEI conducted a cursory analysis of the locations, considering various types and layouts of GSI. This process was guided by the project's goals and objectives, GSI design criteria, available and collected data, and input from both the City and MWMO.

Early in the conceptualization stages, an initial assessment was performed to evaluate the potential to incorporate flood risk reduction. A scenario with 5 acre-feet of storage added to hydrologic model was simulated to approximate the potential downstream flood benefit, see **4.1.1 Initial Evaluation of Flood Reduction .** The results indicated that providing additional storage above the water quality volume did not substantially reduce the flood risk.

## 2.2 PRELIMINARY CONCEPT ALTERNATIVES

Combinations of feasible GSI practices were then drafted as preliminary concept designs. A feasibility review meeting was held with the project partners on September 28th, 2023 to review the preliminary concept GSI for the site. This step ensured the GSI concept alternatives matched the City’s vision. Based on the technical feasibility analysis and meeting discussion, the GSI concepts were selected to be carried forward for assessment. **Table 2** lists the preliminary GSI and their selection status, if they were preferred to carry forward, not preferred, or eliminated from consideration.

**Table 2.** Initial stormwater management concepts that were shared with MWMO and the City.

| Preliminary Concepts | Description | Status |
|---|---|---|
| Alternative 1 | Underground infiltration. | Not Preferred |
| Alternative 2 | Surface infiltration. | Not Preferred |
| Alternative 3 | Surface infiltration with two small infiltration basins and two ephemeral streams. | Not Preferred |
| Alternative 4 | Reuse and infiltration. | Eliminated |
| Alternative 5 | Reuse and infiltration streams. | Eliminated |
| Alternative 6 | Underground infiltration with an ephemeral stream and surface infiltration basin. | Preferred |
| Alternative 7 | Underground infiltration with pumped stream. | Not Preferred |
| Alternative 8 | Underground infiltration with 2 smaller infiltration basins. | Preferred |

## 2.3 SELECTION OF PREFERRED CONCEPT DESIGNS

A meeting on November 1st, 2023, involving the project partners, marked the presentation and discussion of six preliminary concept Green Stormwater Infrastructure (GSI) alternatives. During the deliberations, certain concepts were either excluded from consideration or combined with elements from other alternatives. Following the meeting and subsequent conversations, two alternatives emerged as the preferred GSI for further conceptual design and evaluation. The final selected concept designs represented combinations of earlier alternatives (1 through 5). This approach, incorporating multiple GSI practices and a blend of surface and subsurface elements, not only achieves the desired on-site storage volume but also fosters opportunities for community engagement. **Figures 2** and **3** showcase the Preliminary Concept Designs.

As part of this process, an additional 7.4 acres of runoff southwest of the park were identified and incorporated into the treatment area. This runoff, flowing towards a catch basin south of Rainbow Dr. NE, could be effectively captured by reconstructing the storm sewer across Rainbow Dr. NE. This inclusion augments the drainage area to the Best Management Practices (BMPs) by 12%. By directing the runoff from this additional area, an extra 1.7 lbs of total phosphorus (TP) removal per year is achieved. Recognizing this opportunity presented a strategic means to enhance treatment within the regional system, with an estimated cost-benefit ratio approximating $1,000 per pound of TP.

# 3 CONCEPT DESIGN ALTERNATIVES

The preferred concept designs are described in this section. Further information and considerations for the GSI designs are provided within the narrative of this section.

## 3.1 PARK DESIGN, HABITAT, AND NATURAL AREA CONSIDERATIONS

The approach to natural playground environments is to immerse playground users in the natural world by encouraging exploration of the park space and discovery of natural elements. This approach integrates constructive play and education in an environment that fosters creative solutions and dynamic experiences. This goal will be achieved through strategically placing sensory-specific play features around the playground to capture a child's imagination through native habitats and surrounding stormwater elements.

## 3.2 DESIGN ASSUMPTIONS

The total water quality volume goal for the project is 1.3 acre-feet of storage. Both GSI concept designs meet the treatment goal through a combination of surface and underground treatment, as shown in **Table 3**. Impervious areas were based on the inputs in received P8 model. A drainage map is provided in **Appendix A.2**. Each treatment feature was sized to capture 1.1-inch of volume over the contributing impervious surface to that feature. Preliminary geometry of the features was sized based on available space.

Per the geotechnical report (**Appendix A.5**), the design infiltration rate is 0.8 inches per hour. This rate was used in the clean sand soils (SP) and also where soil corrections are proposed to remove clay, silt, or organic soils. All the features were designed with a shallower depth and drawdown in less than the 48-

hour requirement. This is advantageous because the shallower depth will reduce the loading experienced by the soil by providing a larger relative surface area for infiltration, and will thereby prolong the longevity of the basin. Each infiltration feature is proposed at a minimum elevation of three feet above the water table to provide adequate separation. Where practicable, additional separation from the water table was provided.

**Table 3 -** Designed water quality treatment volumes.

| | Concept A | Concept B |
|---|---|---|
| Drainage Area (acres)* | 71.5 | 71.5 |
| Impervious Area (acres)** | 14.3 | 14.3 |
| Design Storm (inch) | 1.1 | 1.1 |
| Total Storage Volume Goal (acre-feet) | 1.3 | 1.3 |
| Underground Storage Provided (acre-feet)** | 1.06 | 1.20 |
| Surface Storage Provided (acre-feet) | 0.24 | 0.14 |

*Approximately 78 acres drains to Sylvan Hills Park. Approximately 6 of those acres first pass through an offsite BMP and were not included when sizing the BMPs.

** It is unclear whether 4.5 acres of impervious area in the furthest southwest catchment (ID: 1094) drain to the park, so the underground storage was sized to include approximately half of the runoff. This area is included as contributing in the P8 modeling.

## 3.3 CONCEPT A

Concept A has a focal point of a central basin fed by ephemeral streams and includes a regional underground infiltration system, as shown in **Figure 2**.

### Park Design Approach

This approach attempts to draw pedestrians into the park and off the streets by utilizing entrances and pathways connecting Sylvan Lane along the north end of the park and Rainbow Dr. NE on the south. Features include compacted crushed grey trap paths, an ephemeral stream surrounded by narrow bands of selected low growing native plants, and a central basin adjacent to the playground planted with a simple pallet of fox sedge and aspen trees. The central aspen basin can also serve as a nature play area and include elements shown in **Figure 4**. Native species plantings provide a corridor of habitat along the stream along the length of the park and visual separation for nearby homes. These features would be balanced and intertwined with traditional suburban park features of the existing tennis and basketball court.

### Surface Green Stormwater Infrastructure

Runoff from south of the park enters the 12-inch stormsewer along Rainbow Dr. NE. The portion of the stormsewer under Rainbow Dr. NE will be reconstructed to drain towards the park and into the stream and central infiltration basin and will include an additional 7.4 acres of drainage area. The existing southern draining stormsewer will be maintained so conveyance capacity is not diminished. Curb cuts will be utilized at the northern and southern intersections of the park to bring additional runoff into the ephemeral stream via surface drainage. Basins are provided at the North and South of the park primarily for pre-treatment. The central basin near the playground will be designed to function as a green stormwater feature and aspen grove habitat that can also include natural play elements.

**Regional Underground Infiltration System**

Runoff from areas to the north and west of the park drain to separate stormsewer that meets at a manhole at the intersection of Comet Ln NE and Rainbow Dr. NE. A diversion structure will be added at this manhole and 36-inch stormsewer will be installed to divert runoff from this manhole via gravity to the underground infiltration system in the southern half of the park. Stormwater will be detained and infiltrated in a underground storage system. The type of storage system could include concrete chambers, half-dome style chambers, or rock and pipe. The concept design assumes 36-inch diameter round corrugated perforated pipes surrounded by rock. Pretreatment will be provided in a hydrodynamic separator (sedimentation device) prior to the system, or optionally could be designed within the storage system with an isolated pipe/chamber row. Soil borings on the southern half of the site show soil suitable for infiltration. However, there were confining soils not conducive to infiltration observed in approximately half of the system footprint, down to 2 feet below the underground infiltration system bottom. This will require soil correction by removing the confining layer and replacing with sandy soils. Groundwater observed in the borings is approximately 3.6 feet below the proposed bottom of the underground system.

Benefits of Concept A are retaining open surface areas in the park for multi-use space, bringing community awareness to stormwater through surface features and water quality benefits. Maintenance for Concept A will consist of yearly inspections and occasional removal of sediment from the underground infiltration tank. The stream and infiltration basin will require semi-annual inspections and occasional maintenance, cleaning, and repair. Further discussion and comparison of concepts is provided in the Conclusion of this report.

## 3.3 CONCEPT B

Concept B provides the majority of the stormwater management via a regional underground infiltration system and also includes rain gardens to treat local runoff, as shown in **Figure 3**.

**Park Design Approach**

This approach anchors the north and south ends of Sylvan Park with two native rain garden basins. Native plantings or bee lawn could be utilized as visual barriers on the east side of the park, providing separation between the park and homes, while creating pollinator habitat. The central playground has two areas of play; nature play and traditional playground. Nature play would involve the use of earth mounds, log scrambles, hillside slides and natural materials. See images provided in **Figure 4**.

**Surface Green Stormwater Infrastructure**

Curb cuts will be utilized in the northern and southern intersections to bring runoff into two surface basins located at the northern and southern ends of the park. These basins could be planted rain gardens providing habitat and co-benefits to the GSI. Underdrains are proposed in the basins because soil investigation was not conducted in the northern basin and the southern basin likely has confining soil layers observed in nearby borings. The feasibility of infiltration will be assessed in the final design.

**Regional Underground Infiltration System**

The underground infiltration system in Concept B is nearly identical to Concept A, with the difference of increasing the size (volume and footprint) of the underground system to accommodate the additional 7.4-

acre drainage area without the surface storage available in Concept A. This area will be treated underground, rather than at the surface by reconstructing the portion of the 12-inch stormsewer under Rainbow Dr. NE to drain to the underground infiltration system. The existing southern draining stormsewer will be maintained so conveyance capacity is not diminished.

Benefits of Concept B are retaining open and undivided surface areas in the park for multi-use space in addition to water quality benefits. Concept B will have similar maintenance requirements to Concept A. Both concepts include the preferred 20,000 square feet of open green space, an updated playground with natural elements, unaltered basketball and tennis courts and a trail through the park. Both concepts have the capacity to treat the contributing area and meet the 1.1 inch water quality volume goal. Further discussion and comparison of concepts is provided in the Conclusion of this report.

CURB CUT INLET
CREEK TO BASIN

2,400 SQF TOTAL AREA
1,0500 SQF
INFILTRATION BASIN

NATIVE SEED OR BEE LAWN

4:1 SLOPE

11,650 SQF
ASPEN BASIN

PED CROSSING
(CULVERT)

6,060 SQF
TRADITIONAL PLAYGROUND

SHELTER

CRUSHED GREY TRAP
PATHWAYS

EPHEMERAL STREAMS

DIVERSION STRUCTURE
TO UNDERGROUND
INFILTRATION

3,000 SQF TOTAL AREA
1,800 SQF
INFILTRATION BASIN

CATCH BASINS
SCH 40 PIPE TO BASIN

A

# SYLVAN PARK CONCEPT

Scale: 1" = 100'-0"

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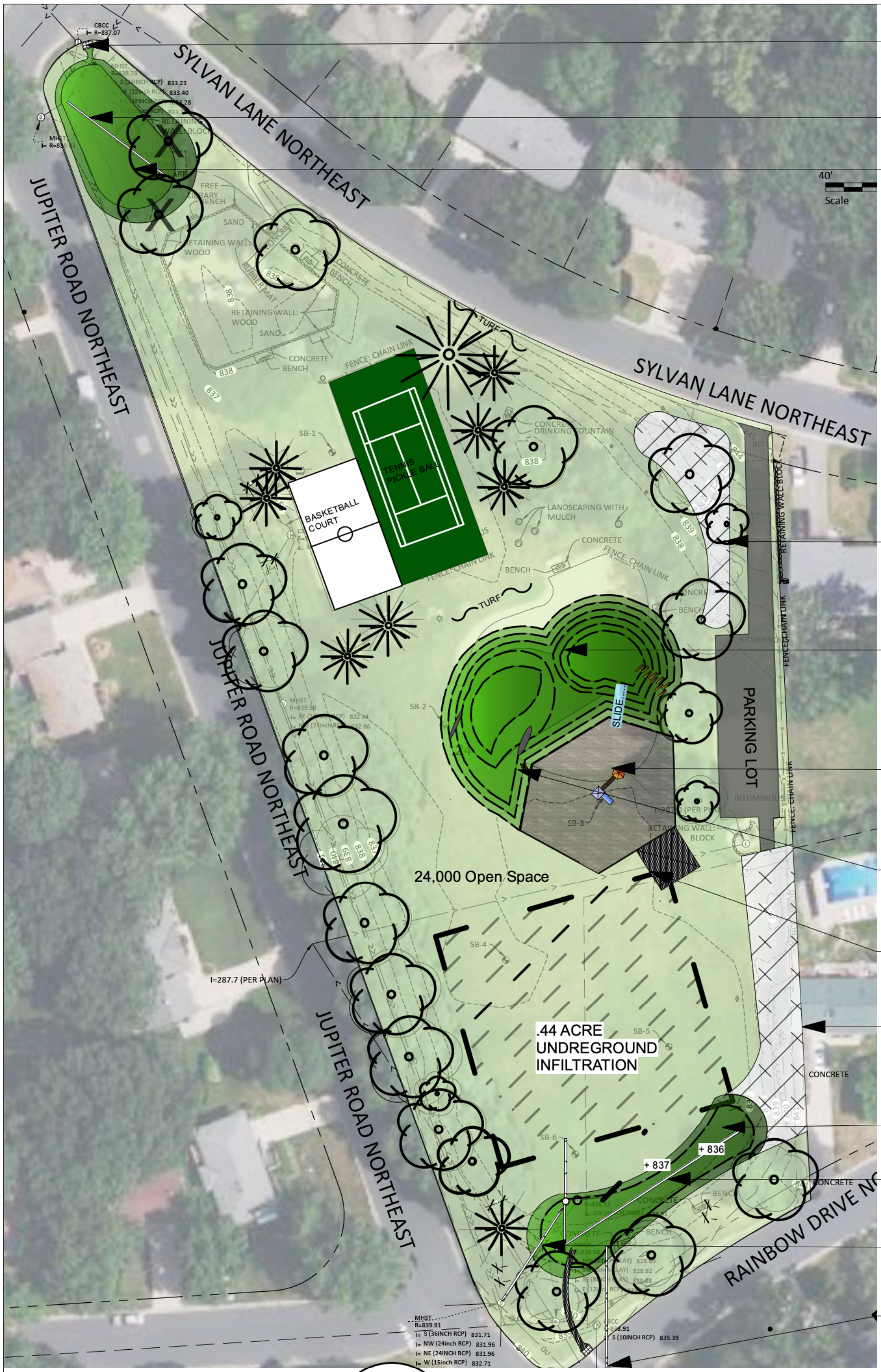
| SIZE | CAGE CODE | DRAWING NUMBER | REV. |
|---|---|---|---|
| | | FIGURE 2 - CONCEPT A | |
| SCALE | 1" = 100'-0" | SHEET Sht-1 OF 1 | |



CURB CUT INLET

UNDERDRAIN

3,000 SQF BASIN

2,700 SQF
NATIVE SEED / BEE LAWN

9,600 SQF
NATURE PLAY AREA
COMBINED TURF/MULCH TBD

5,600 SQF
TRADITIONAL PLAYGROUND
CIP IN CURB, 12" OF CERT
MULCH

MAXIMUM 4:1 SLOPE

SHELTER

4,200 SQF
NATIVE SEED / BEE LAWN

3,000 SQF BASIN

UNDER DRAIN
(PENDING INVESTIGATION)

DIVERSION STRUCTURE

PRETREATMENT CATCH
BASIN SOUTHSIDE OF
STREET

B

## SYLVAN PARK CONCEPT

Scale: 1" = 100'-0"

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**Resource Group**
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| SIZE | CAGE CODE | DRAWING NUMBER<br>FIGURE 3 - CONCEPT B | REV. |
|---|---|---|---|
| SCALE 1" = 100'-0" | | SHEET Sht-1 OF 2 | |

LOG JUNGLE

LOG SCRAMBLE

ASPEN GROVE

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| SIZE | CAGE CODE | DRAWING NUMBER<br>FIGURE 4 - PRECEDENT IMAGES | REV. |
|---|---|---|---|
| SCALE | | SHEET Sht-2 OF 2 | |

# 4 PERFORMANCE ASSESSMENT AND METHODOLOGY

Preferred concepts designs were assessed for their cost performance regarding flood risk reduction, water quality impact to downstream resources, and habitat enhancement as described in the following paragraphs. The assessments are then used to inform a cost-benefit analysis to determine the priority GSI to be selected for implementation.

## 4.1 HYDROLOGIC & HYDRAULIC EVALUATION

An existing XPSWMM model was provided by the MWMO and modified to include and assess the proposed concept GSI. Modeling was performed in XPSWMM version 2016.1 and included the 2-, 10-, 100- and 500-year, 24-hour rainfall with a MSE3 distribution. Rainfall changes that may be available in future conditions were not assessed in this study.

In existing conditions, the model predicts that there is local flooding at the northern and southern intersections bordering the park, see **Appendix A.2**. Further, the depressed park provides a significant amount of flood storage for the regional stormsewer system. The standing water in the park is caused by high flows with the trunk storm sewer along University Avenue. Existing conditions modeling simulates water back-flowing through stormsewer designed to drain the southern intersection, which then surcharges into the park. This occurs in both the 10-year and 100-year synthetic rainfall events that were simulated.

### 4.1.1 INITIAL EVALUATION OF FLOOD REDUCTION POTENTIAL

Flood reduction potential was assessed at the park, the intersections at the northern and southern ends of the park and 3 downstream locations with documented flooding. See **Appendix A.2** for flood assessment locations. A modeling scenario with an underground storage tank with 5 acre-feet (AF) of storage was sized for this site to determine the reasonable maximum flood reduction potential. This scenario was used to determine if further evaluating flood storage alternatives was advisable. 1.1 acre-feet of storage was modeled to represent both Concept A and Concept B (see below for further discussion). Water surface elevations and resulting flood depths for the 10- and 100-year events are presented in **Table 4** and **Table 5**.

**Table 4. Comparison of flood reduction potential for a 10-year event.**

| Location | | Node | Surface Elev. | WSEL* | WSEL | WSEL | Flood Depth | Flood Depth | Flood Depth |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Existing | 5 AF | 1.1 AF | Existing | 5 AF | 1.1 AF |
| 1 | Northern Intersection | IN770952 | 837.69 | 837.99 | 837.82 | 837.70 | 0.3 | 0.1 | 0 |
| 2 | Southern Intersection | IN774198 | 839.25 | 839.61 | 839.27 | 838.72 | 0.4 | 0 | 0 |
| 3 | Park | ST770952 | 836.78 | 837.14 | 834.16 | 833.96 | 0.4 | 0 | 0 |
| 4 | The Cielo Apartments | IN773442 | 841.14 | 841.53 | 841.40 | 841.37 | 0.4 | 0.3[1] | 0.2[1] |
| 5 | University Service Rd and 61st Ave NE | IN774208 | 844.83 | 844.61 | 844.04 | 843.81 | 0.2 | 0 | 0 |

| Location | | Node | Surface Elev. | WSEL* Existing | WSEL 5 AF | WSEL 1.1 AF | Flood Depth Existing | Flood Depth 5 AF | Flood Depth 1.1 AF |
|---|---|---|---|---|---|---|---|---|---|
| 6 | Houses near 61st Ave NE and 2nd St NE | ST771417 | 847.87 | 849.04 | 849.04 | 849.04 | 1.2 | 1.2 | 1.2 |

*Water Surface Elevation

**Table 5.** Comparison of flood reduction potential for a 100-year event.

| Location | | Node | Surface Elev. | WSEL Existing | WSEL 5 AF | WSEL 1.1 AF | Flood Depth Existing | Flood Depth 5 AF | Flood Depth 1.1 AF |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Northern Intersection | IN770952 | 837.69 | 839.28 | 838.33 | 838.60 | 1.6 | 0.6 | 0.9 |
| 2 | Southern Intersection | IN774198 | 839.25 | 840.08 | 839.75 | 839.73 | 0.8 | 0.5 | 0.5 |
| 3 | Park | ST770952 | 836.78 | 839.28 | 838.33 | 838.60 | 2.5 | 1.6 | 1.8 |
| 4 | The Cielo Apartments | IN773442 | 841.14 | 845.11 | 845.08 | 845.07 | 4.0 | 3.9 | 3.9 |
| 5 | University Service Rd and 61st Ave NE | IN774208 | 844.83 | 845.67 | 845.66 | 845.66 | 1.3 | 0.8 | 0.8 |
| 6 | Houses near 61st Ave NE and 2nd St NE | ST771417 | 847.87 | 849.66 | 849.66 | 849.66 | 1.8 | 1.8 | 1.8 |

The 5 acre-foot storage scenario results in minimal additional flood reduction potential at the downstream flood locations (The Cielo Apartments, University Service Rd and 61st Ave NE, Houses near 61st Ave NE and 2nd St NE). The greatest reduction downstream is at University Service Rd and 61st Ave NE in the 10-year event. However, there is minimal existing inundation at this location in the 10-year event and therefore, no substantial reduction in flood risk. About 0.5 feet of flood reduction is also provided in the 100-year event at this location for both storage volumes scenarios.

There is a reduction in local flood elevation and inundation periods in the park and surrounding intersections in the 10-year and 100-year events for both storage volume scenarios. In the 10-year event the northern and southern intersections experience a reduction that reduces the amount of surface inflow the park receives. In the 100-year event there is still reduced overflow reaching the park and a reduced inundation period.

The benefits of the 5 acre-foot storage scenario are comparable to the benefits of the 1.1 acre-foot storage scenario.[1] The 5 acre-feet scenario would cost roughly 4-5 times the amount of the 1.1 acre-foot

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[1] In the 10-year event it was observed that in some locations greater WSEL reductions were predicted in the 1.1 acre-foot scenario than the 5 acre-foot scenario. This may be due to timing of backflows in the stormsewer pipes designed to convey water to the south from the park. Further, the 5 acre-feet storage was not fully utilized in the 10-year event. Generally, both storage volume scenarios predicted similar WSELs in the 10-year evet.

scenario, for only a fraction of increased benefit. Due to the limited benefits of the additional flood storage and site constraints it is not recommended to maximize storage for flood mitigation at this site. Further evaluation could be considered if this site was included in a larger regional assessment to evaluate potential flood risk reduction by providing cumulative storage at multiple sites.

### 4.1.2 FLOOD REDUCTION OF PREFERRED CONCEPT DESIGNS

Given the lack of potential downstream flood reduction, the proposed water storage volume was sized to meet the water quality volume goal of 1.3 acre-feet. An underground infiltration system is proposed to be used to treat the majority of the volume and was modeled as 1.1 acre-feet, which closely represents the underground storage volumes in Concept A and Concept B since a portion of the 1.3 acre-feet of water quality volume is treated on the surface of the park.[2]

The primary goals of storing water on site are to mitigate flooding in the streets in the 10-year and remove structures from the 100-year flood. The Cielo apartments and houses near 61st Ave NE and 2nd St NE experience either minor reduction or no change and will be inundated regardless of the onsite storage volume. The flooding in the local streets will be reduced and the flooding in the southern intersection will be mitigated during the 10-year event. One structure was identified as impacted in the 100-year event near Sylvan Hills Park (approximate elevation of 839.2 however, in proposed conditions, this structure will no longer be impacted.

Overall, the proposed concept designs will provide reduced inundation for local flooding in and around the park in both the 10- and 100-year events. Some inundation may also be reduced downstream in the regional stormsewer system, although to a lesser extent.

## 4.2 WATER QUALITY EVALUATION

The preferred concept GSIs were also modeled for their water quality benefit. The GSI was modeled by using an existing P8 Urban Catchment Model version 3.5 that was provided by MWMO. The site has adequate size to treat the contributing stormwater runoff through infiltration and surface treatment before overflowing downstream through stormsewer that discharges into the Mississippi River. Preliminary P8 modeling simulated the surface and underground treatment features in Concept A and Concept B and the results are shown in **Table 6**.

**Table 6.** TSS and TP reduction for modeled GSI in Concepts A and B.

| Concept A | TSS (tons/year) | TP (lbs/year) |
|---|---|---|
| Existing Load | 4.0 | 24.5 |
| Overflow | 1.5 | 8.5 |
| Removed | 2.5 | 16.1 |
| % Removed | 63% | 66% |
| **Concept B** | **TSS (tons/year)** | **TP (lbs/year)** |
| Existing Load | 4.0 | 24.5 |
| Overflow | 1.5 | 8.4 |
| Removed | 2.5 | 16.1 |

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[2] The size of the underground infiltration basin varies by 0.14 acre-feet in the two preferred concept designs, but flood mitigation is expected to be similar for both concept designs.

| Concept A | TSS (tons/year) | TP (lbs/year) |
|---|---|---|
| % Removed | 62% | 66% |

## 4.3 PRELIMINARY OPINION OF PROBABLE COST

A preliminary Opinion of Probable Cost (POPC) was developed for the construction of each concept design and is included in **Appendix A.3.** Construction costs were estimated by line items of major components and includes contingency for additional minor costs or uncertainty. Total project costs added percentage-based estimates for engineering and construction administration to the construction cost. Due to high inflation and high price volatility for both labor and especially materials in recent years, these POPCs were developed for the current market and are subject to the market's current and future uncertainty.

There are options for some of the concept designs and features to be interchanged between the two concepts. Specific project components can be selected in final design. Reconstruction of several park features are proposed by the city which are not included in this POPC:

- Tree removal and replacement (other than shown removals and proposed Aspen Grove)
- Playground removal, replacement (allocation for site work is included)
- Tennis and Basketball court removal and reconstruction
- Parking removal and reconstruction
- Sanitary lift station flood proofing
- Proposed Shelter

In addition to the POPCs for construction or initial capital costs, life cycle costs were estimated for each design which includes annual and periodic operation, maintenance, monitoring, and other ongoing costs. The estimate includes present value calculations and annual average cost based on a 30-year life cycle of the GSI in each concept. An annual average cost-benefit in terms of dollars per pound of phosphorus removed is given to compare the cost-effectiveness of each concept GSI.

Note that the estimated costs include some park features that do not contribute to realized water quality benefits. Therefore, **Table 7** depicts both the total construction cost and "Stormwater POPC" which consists of the portion of the project cost contributing to the water quality benefits (excludes "Native restoration and other" costs). Both concepts include a playground and pathway through the park which are not included in the estimated costs as they will be funded by the City of Fridley.

**Table 7. Opinion of probable cost and cost benefits.**

| Concept | Total Project POPC | Stormwater POPC | Annualized Cost Benefit ($/lbs TP) |
|---|---|---|---|
| A | $1,493,000 | $1,404,000 | $3,406 |
| B | $1,403,000 | $1,296,000 | $3,170 |

Cost-benefit for TP is found by summing the probable total project cost, the cost of annual operation and maintenance at a 3% interest rate, and the cost of periodic maintenance every 10 years at a 3% interest rate.

# 5 CONCLUSION

## 5.1 SUMMARY AND DISCUSSION OF RESULTS

This study served to integrate reconstruction of Sylvan Hills Park with green stormwater infrastructure and habitat creation to enhance the park while incorporating both citizen amenities and ecological enhancements.

The GSI concepts were evaluated based on water quality benefit, flood reduction, habitat enhancement and cost-benefit, with metrics summarized in **Table 8**. Both concepts have similar storage volume and therefore resulted in similar stormwater benefits. A more detailed cost-benefit of evaluation of each GSI practice and a cost-benefit analysis of reduced sizing of the underground infiltration system is provided in **Appendix A.4**.

**Table 8. Concept benefit evaluations.**

| | Concept A | Concept B |
|---|---|---|
| Total Storage Volume | 1.3 | 1.3 |
| TP Removal (lb/yr) | 16.1 | 16.1 |
| TSS Removal (tons/yr) | 2.5 | 2.5 |
| # of Flooded Structures Mitigated | 1 | 1 |
| Habitat Created (ac) | 0.44 | 0.16 |
| Est. Project Cost | $1,493,000 | $1,403,000 |

Both concepts can remove similar amounts of TSS and TP and achieve the water quality volume goal. Implementing the proposed storage on site will result in the removal of one structure (home) from the 100-year flood event. In the 10-year event, flooding will be reduced in the park and neighboring streets. Providing additional flood storage did not result in sufficient benefit to justify the substantial additional cost.

### 5.1.1 CONCEPT A DISCUSSION

Although Concept A includes more surface treatment, which is generally associated with a lower cost, the expense of the ephemeral stream and additional surface features elevate the stormwater costs slightly higher than Concept B. While providing approximately the same amount of treatment, Concept A is therefore less cost-effective, although not by a large amount. Added value of Concept A includes the habitat corridor provided by the ephemeral stream, the opportunity for public engagement, improved park athletics, and co-benefits of having additional green infrastructure in the park. Further, the addition of the stream restores a more natural ecology to the park, providing surface water during rain events that emulates pre-development conditions.

### 5.1.2 CONCEPT B DISCUSSION

The combination of treatment methods in Concepts B provides similar water quality benefit to Concept A with a lower probable project cost. Without the habitat corridor and ephemeral stream there is more open green space for the community to use and a less segmented park.

There are many factors that will inform the decision on the selection of GSI and park features in addition to those addressed in this study. However, the metrics provided herein show that both concepts can achieve the goals of the MWMO and City. The primary difference between the two concepts is the addition of the stream and central basin in Concept A. The value of the aesthetics, ecology, and engagement must be balanced with the associated cost when compared to Concept B.

## 5.2 RECOMMENDATIONS

Because the park serves as regional flood storage during large rainfall events, it is not recommened for the majority of excavated material to be left in the park. Hauling is a significant portion of the project cost.The flood reduction benefits desribed in this report assumes soil material will be hauled off site. However, construction costs could be reduced by keeping the excavated materail on site, but this would in turn off-set flood reduction benefits. However, it may be advisable to use some of the material on site to raise the parkinglot elevation above flood elevations so that cars are not inundated.

Another budgetary consideration is the type of undergound storage chamber. If dispaced soil is hauled off site, as proposed, it could be adventagious to evaluate storage chambers that reduce excavation. There are various chamber options and materials that are suited for different sites such as, pipe, dome-style, or concrete vaults. Value engineering in final design could provide savings in construction costs.

There is some risk in relation to the uncertainty of the high groundwater table. The soil borings did not indicate characteristics of the seasonal high water table. Monitoring over a wet season (or several years) would be the optimal way to determine a seasonal high-water table, however this is impracticable with the proposed project schedule. Observed groundwater is currently 3.6 feet below the infiltration system, which is 0.6 feet more than the minimum 3 foot freeboard required. It is recommended to evaluate options to maximize the freeboard to the high groundwater table during design, such as: maximize the footprint of the system, consider chambers with higher void ratios, or reducing the treatment volume.

It is recommended that additional soil borings be competed at proposed surface stormwater treatment locations near the north and south end of the park (Concept B), which were outside for the boring locations for this study. This will confirm soil infiltration rates and may dictate the location of those basins before final design is complete.

## 5.3 IMPLEMENTATION AND NEXT STEPS

This study has provided assessments of feasible GSI that can be implemented to achieve project goals at Sylvan Hills Park. The next steps are envisioned as:

1. Determine major design components associated with Concept A or Concept B to be carried forward in final design.
2. Secure funding for implementation of the preferred concept.
3. Conduct final design and development of contruction documents.
4. Plan for operation and maintenance of all features, and consider monitoring GSI performance. [3]

---

[3] Monitoring could include monitoring of water levels for drawdown performance, flow monitoring for mass balance calculations, or sampling of water quality. Monitoring efforts could range from periodic sampling to automated grab

# 6 APPENDICIES

## A.1 PRELIMINARY CONCEPT DESIGNS

## A.2 FLOOD ASSESSMENT FIGURES

## A.3 PRELIMINARY OPINION OF PROBABLE COST

## A.4 DETAILED COST BENEFIT ANALYSIS OF CONCEPT BMPS

## A.5 GEOTECHNICAL REPORT

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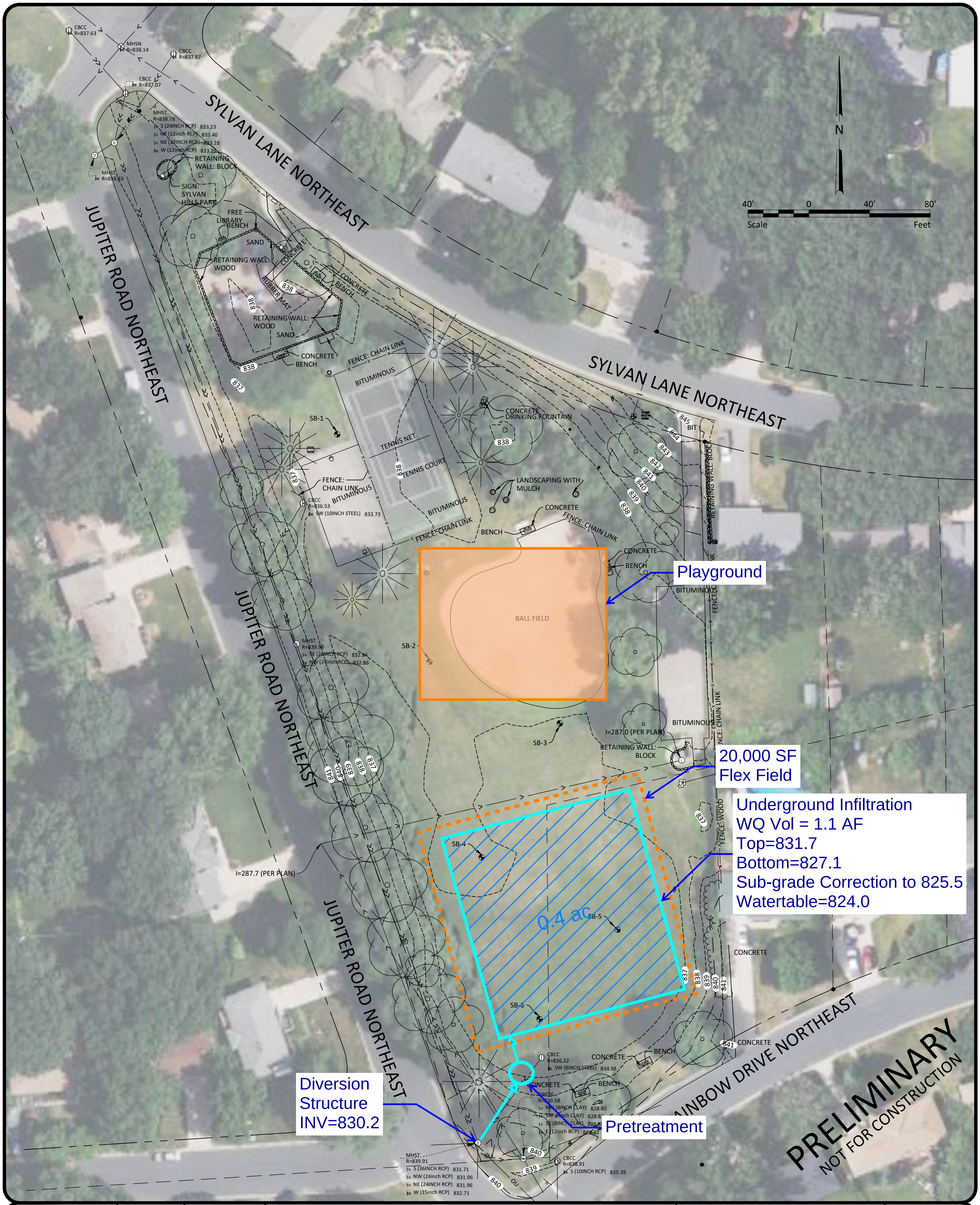
samples and flow monitoring. The level of effort should be determined by level of certainty and risk tollerance for the desired application (model calibration, regulatory reporting, TMDL, etc).



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Date 10-25-2023
Checked by AJS
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SLYVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

Alternative 1
Underground Infiltration
PROJECT NO. 6107-0027

SHEET
1

HEI NO. 6104-0027

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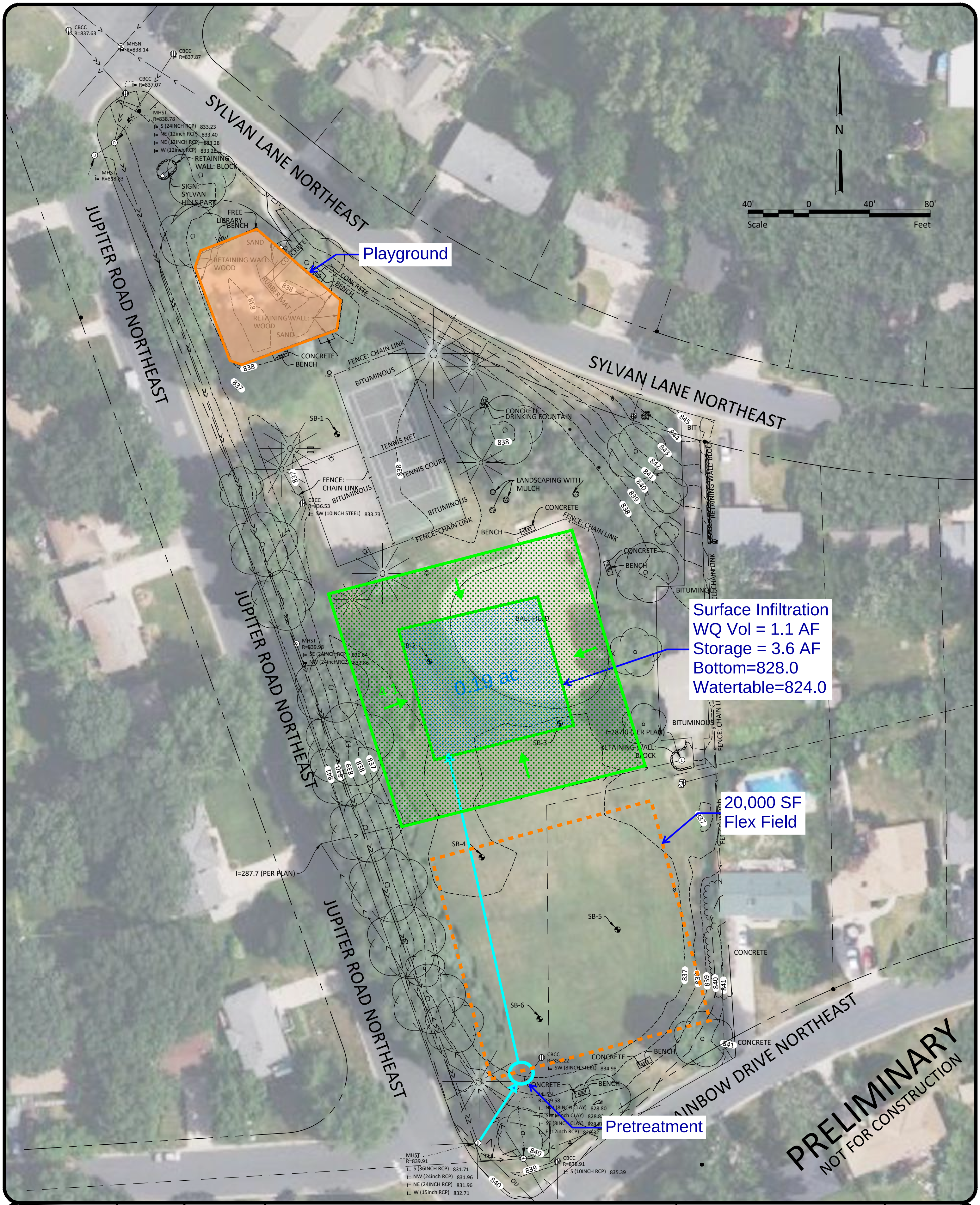

SLYVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

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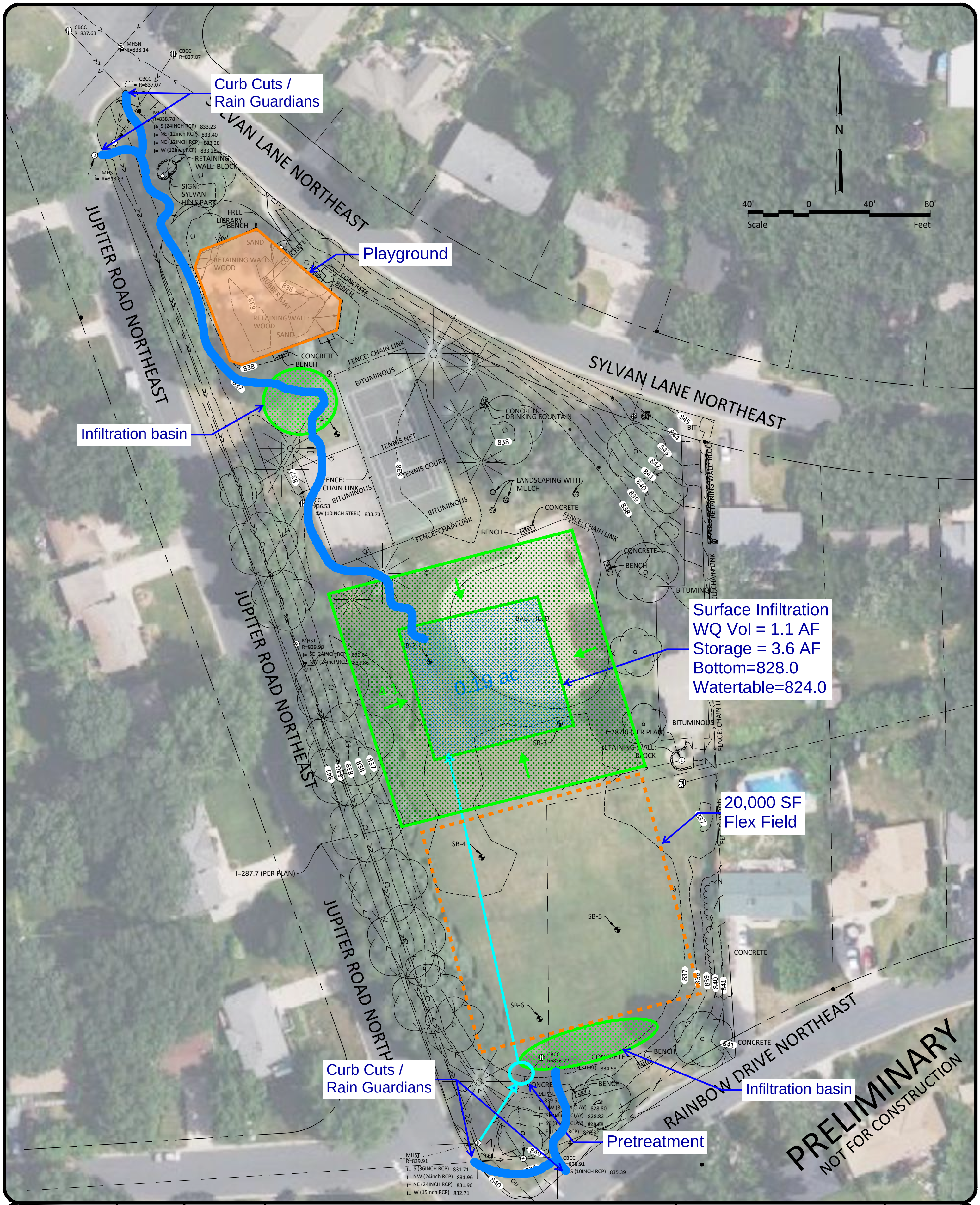
Alternative 2
Surface Infiltration
PROJECT NO. 6107-0027

SHEET
1

HEI NO. 6104-0027



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HEI NO. 6104-0027

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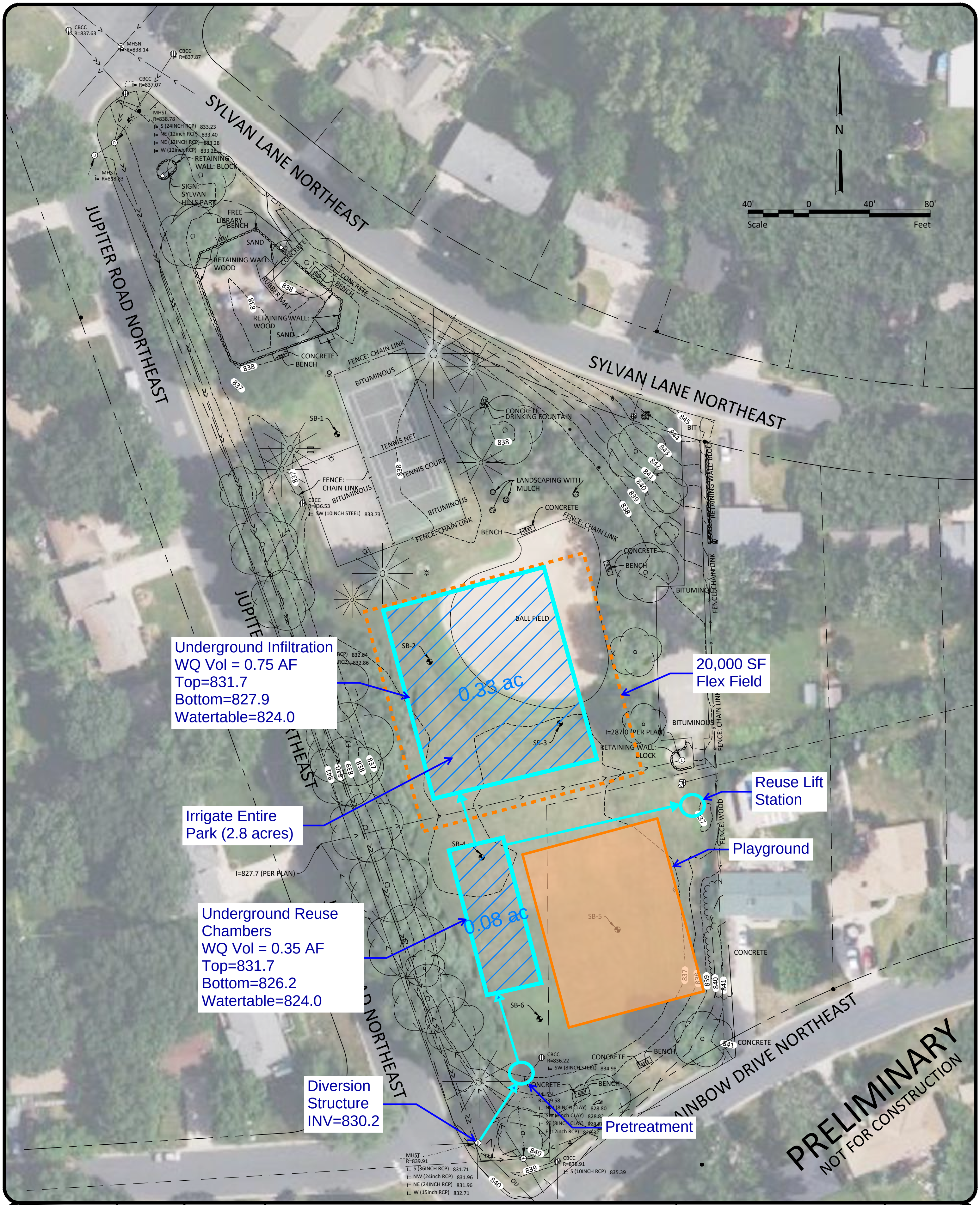

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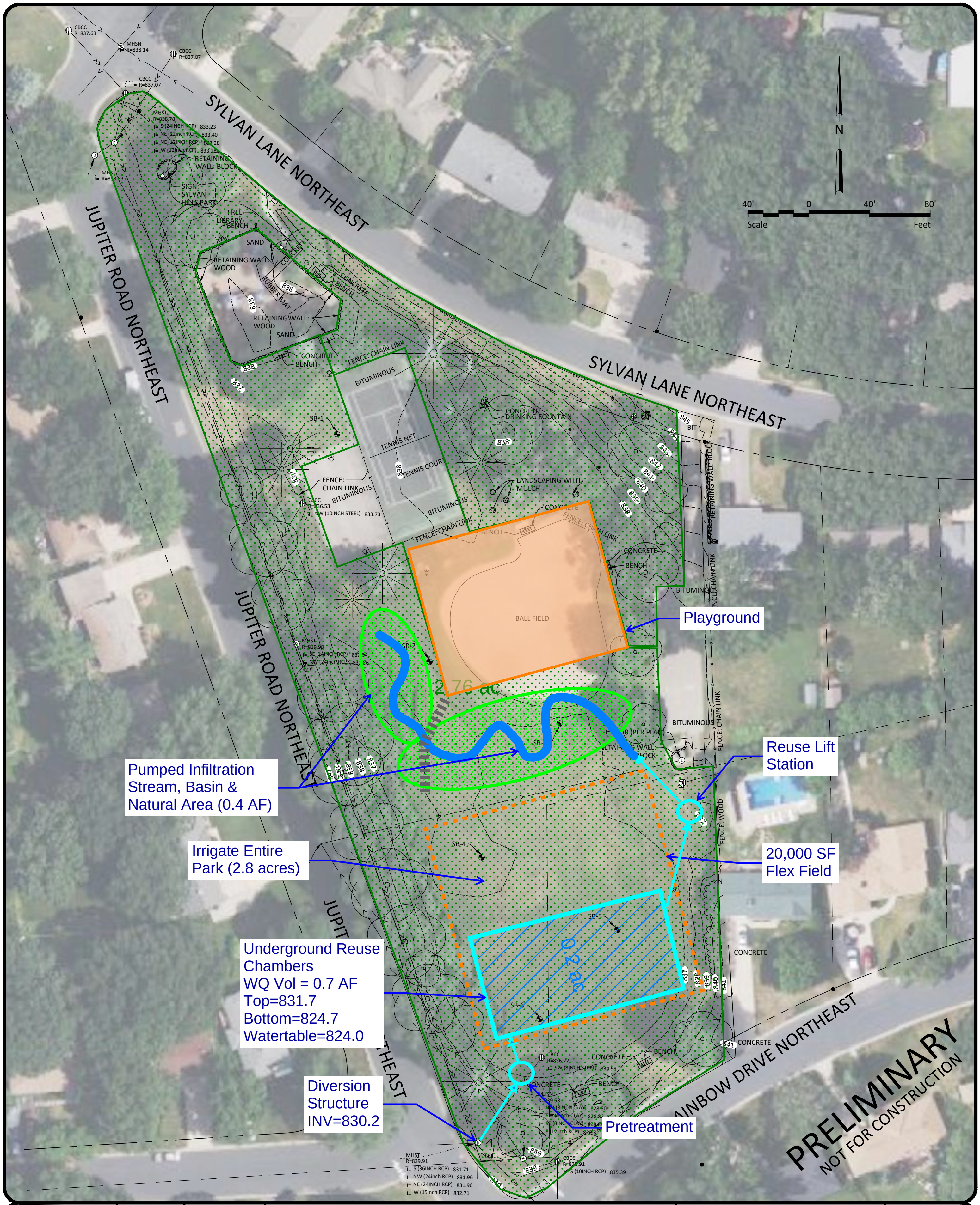
|---|---|
| CKW | 10-25-2023 |
| Checked by | Scale |
| AJS | AS SHOWN |

SLYVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

Alternative 4
Reuse & Infiltration
PROJECT NO. 6107-0027

SHEET
1

HEI NO. 6104-0027



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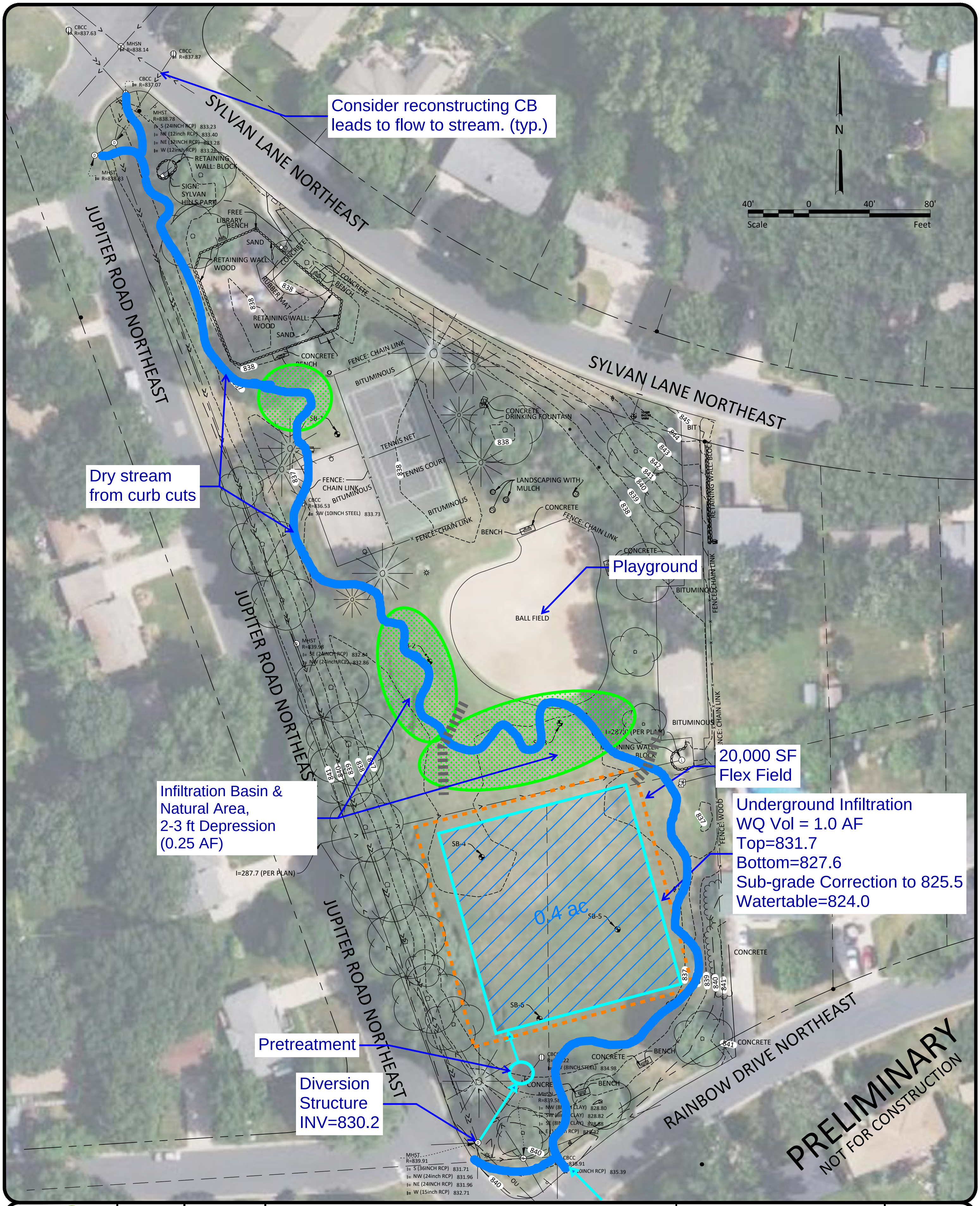
| Checked by<br>AJS | Scale<br>AS SHOWN | | | |

HEI NO. 6104-0027



Consider reconstructing CB leads to flow to stream. (typ.)

Dry stream from curb cuts

Playground

20,000 SF Flex Field

Underground Infiltration
WQ Vol = 1.0 AF
Top=831.7
Bottom=827.6
Sub-grade Correction to 825.5
Watertable=824.0

Infiltration Basin & Natural Area,
2-3 ft Depression
(0.25 AF)

Pretreatment

Diversion Structure
INV=830.2

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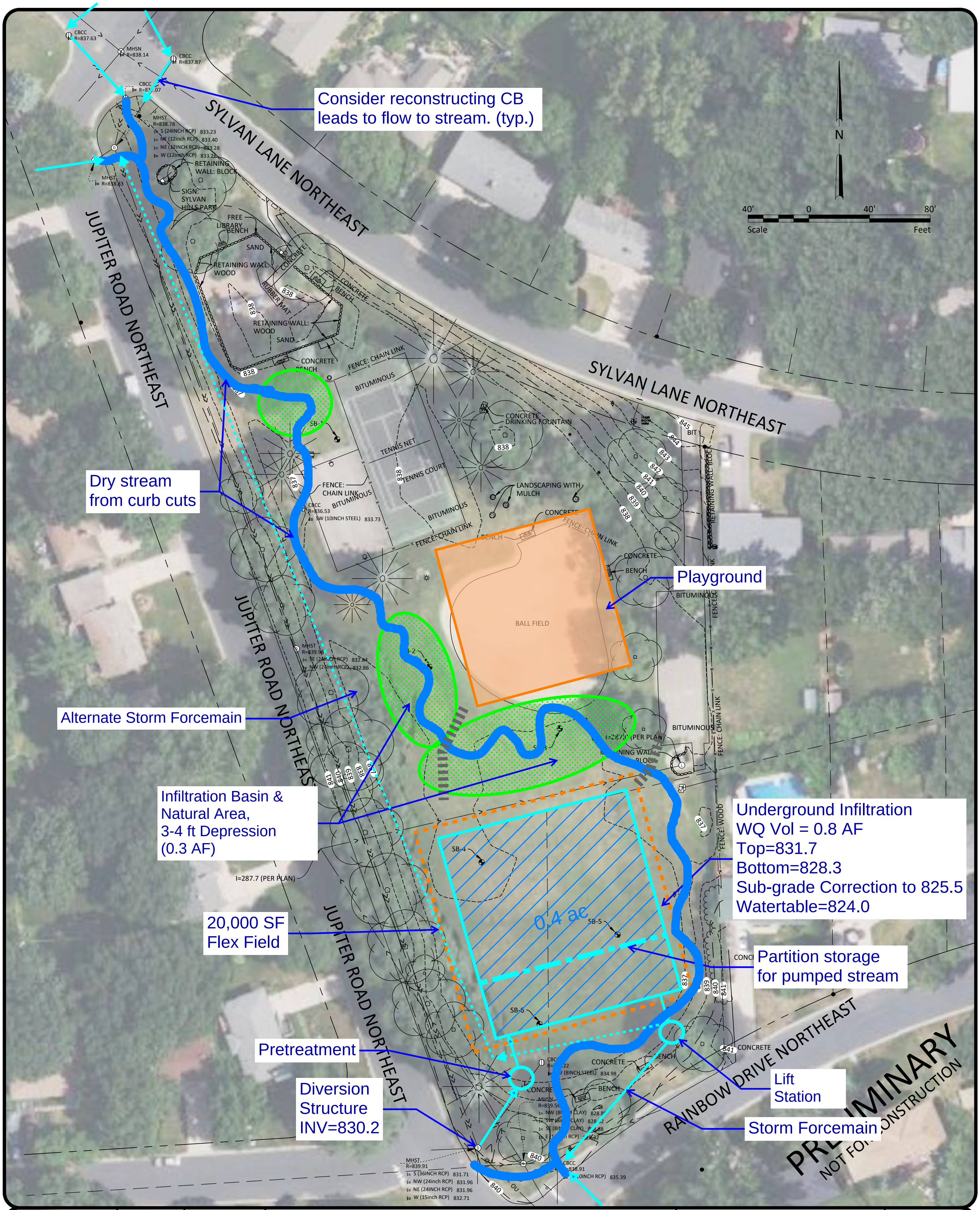
| Checked by | Scale |
| AJS | AS SHOWN |

SYLVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

Alternative 6
UG Infiltration &
Dry Stream

SHEET
1

HEI NO. 6104-0027



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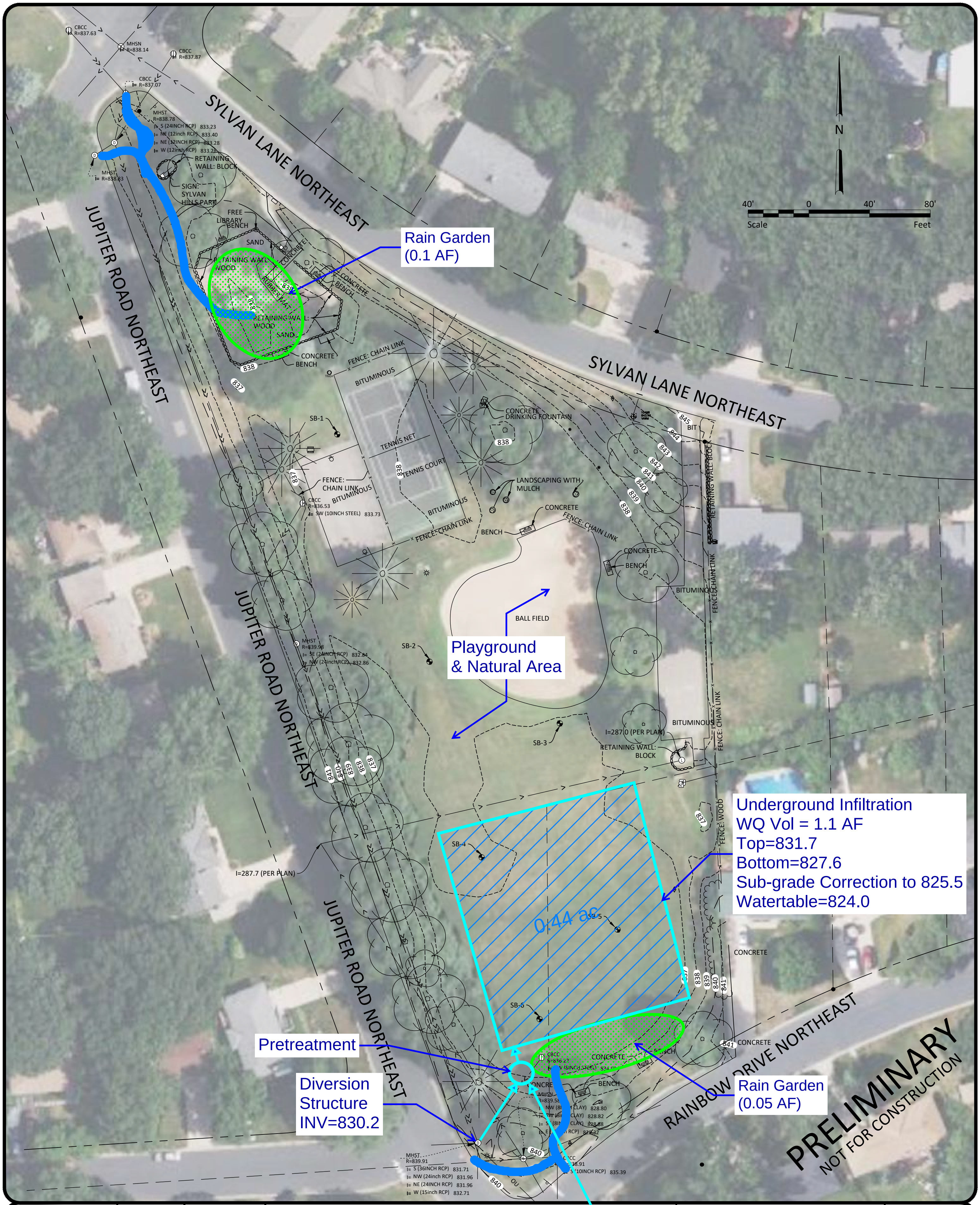
| AJS | AS SHOWN |

SYLVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

Alternative 7
UG Infilt. &
Pumped Stream

SHEET
1

HEI NO. 6104-0027



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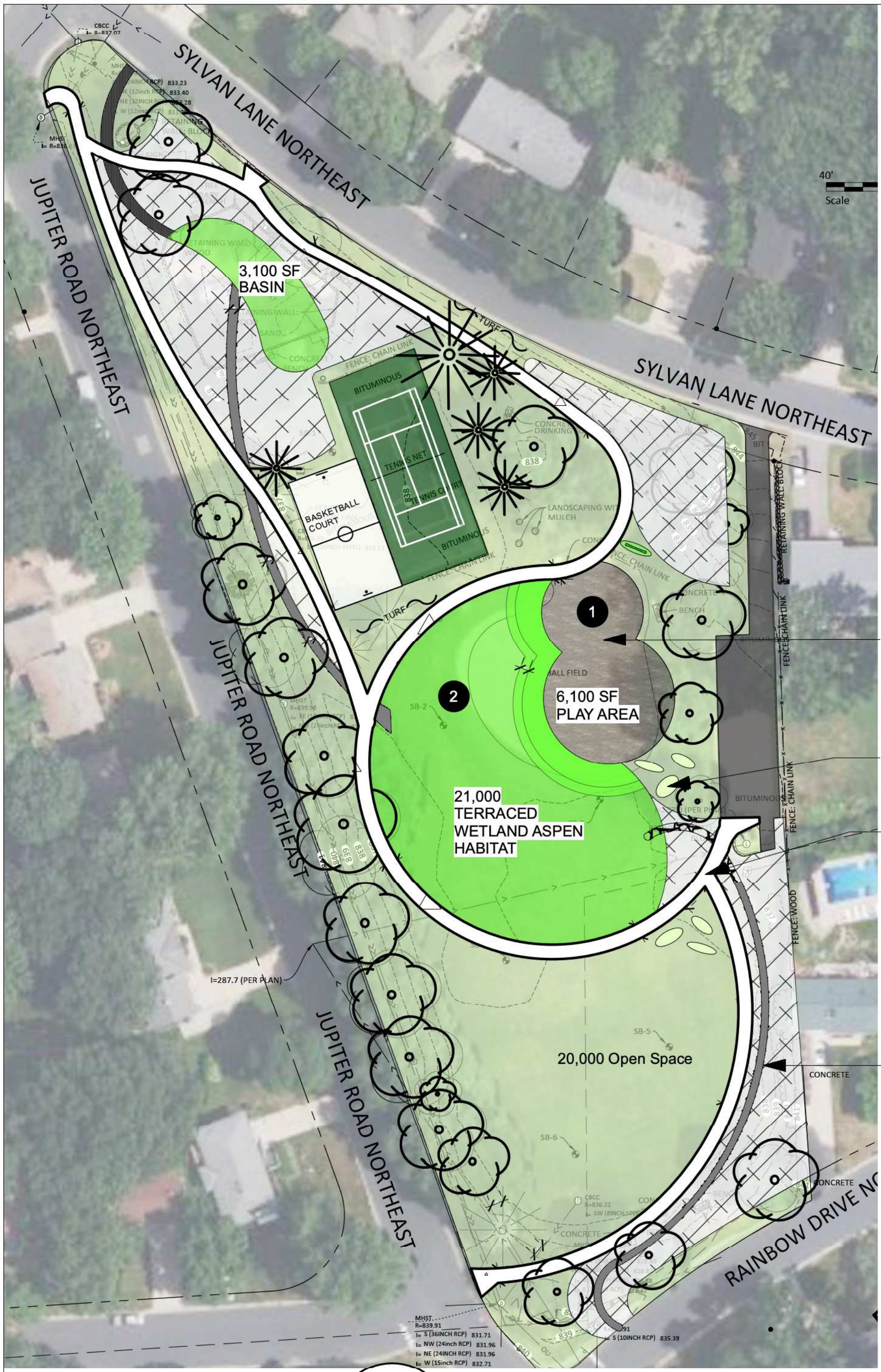
SYLVAN HILLS PARKS STORMWATER AND HABITAT ENHANCEMENT
MISSISSIPPI WATERSHED MANAGEMENT ORGANIZATION
FRIDLEY, MN

Alternative 8
UG Infiltration &
Curb Cut Rain Gardens

SHEET
1

HEI NO. 6104-0027



🟩 TURF

▨ CREEK

▨ NATIVE SOD

🟩 INFILTRATION BASIN

□ ASPHALT PATH

■ PLAY AREA

PLAY AREA: SIMILAR IN SIZE TO CURRENT PLAY AREA

MOUNDS FOR PLAY

1,600 LF OF PATHWAY OR 172 ADDITIONAL STEPS TO WALK THROUGH THE PARK VS THE STREETS

CREEK BEDS OPENS INTO WETLAND AREA

33,000 SQF NATIVE SOD

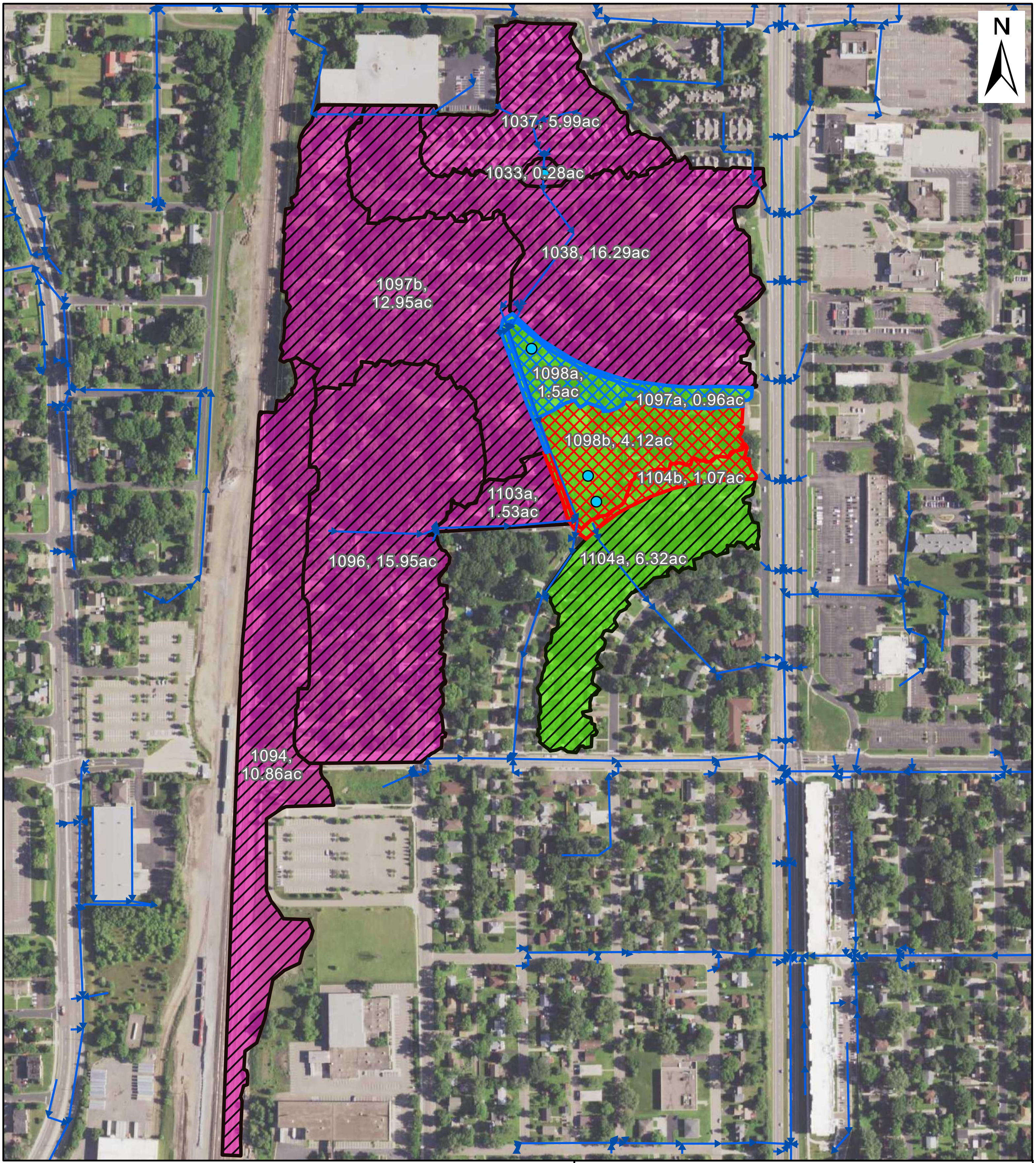
21,000 WETLAND NATIVES

## 1 SYLVAN PARK CONCEPT

Scale: 1" = 100'-0"

**DAVEY**
**Resource Group**
1196 7th St E, St. Paul, MN 55106 ▪ 651-202-3662

| | | | |
|---|---|---|---|
| SIZE | CAGE CODE | DRAWING NUMBER | REV. |
| SCALE 1" = 100'-0" | | SHEET Sht-1 OF 1 | |



- → Stormsewer
- ▭ Drainage Areas
- ● P8 BMPs
- 🟪 Concept A - Underground Infiltration Tank
- 🟩 Concept A - Surface Infiltrtaion Areas
- ▨ Concept B - Underground Infiltration Tank
- ▨ Concept B - Northern Infiltration Basin
- ▨ Concept B Southern Infiltration Basin

0 150 300 600
Feet

## Appendix A.2: Drainage Areas

| Scale: | Drawn by: | Checked by: | Project No.: | Date: | Sheet: |
|---|---|---|---|---|---|
| AS SHOWN | CJC | AS | 6104-0027 | 2/15/2024 | |

HOUSTON
engineering, inc.

Project Area

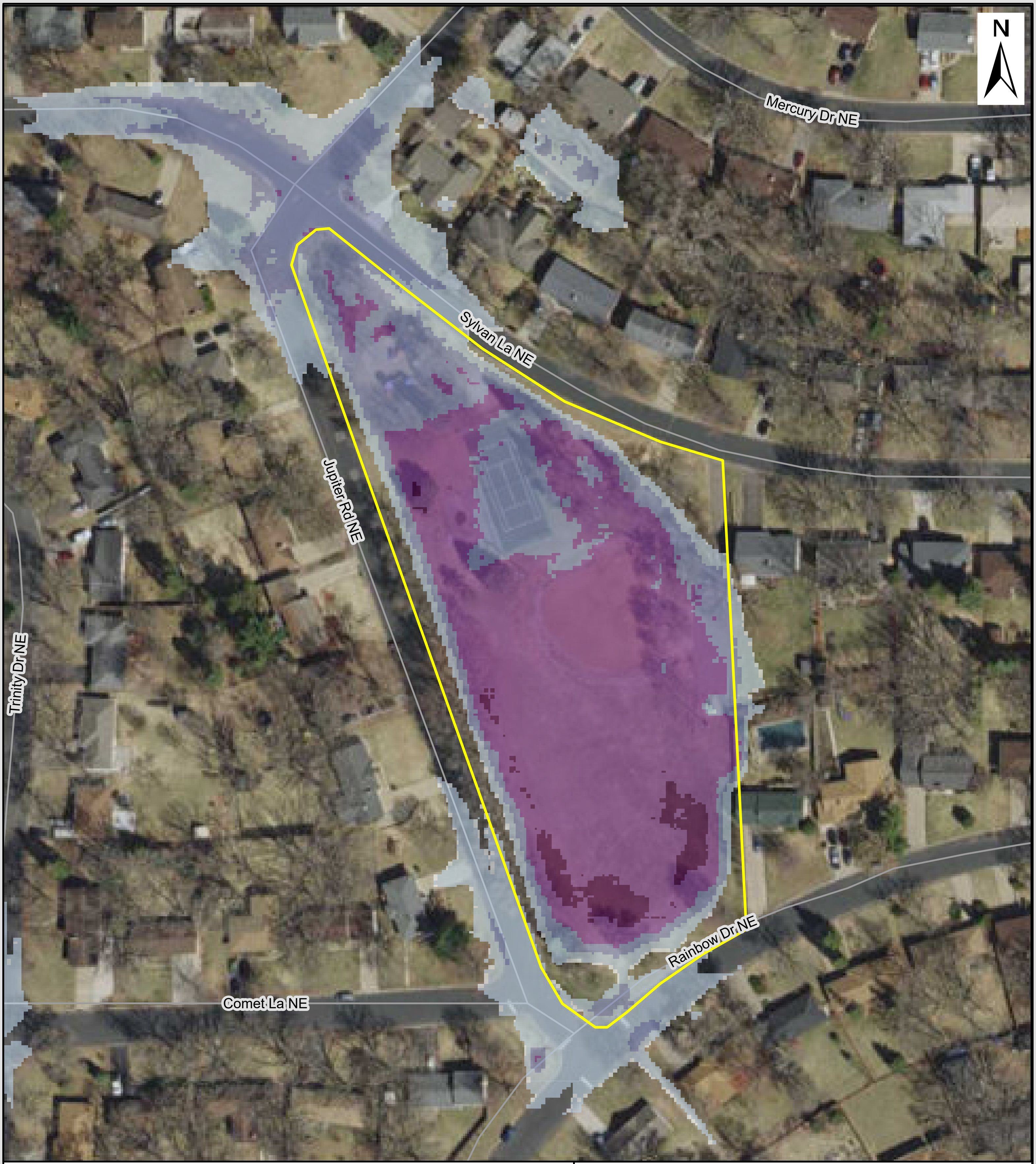
Existing 10yr Depths (Feet)
- 0
- 1
- 2
- 3
- 4

0 40 80 160
Feet

## Appendix A.2: Flood Depth 10 Year Event

| Scale: | Drawn by: | Checked by: | Project No.: | Date: | Sheet: |
|---|---|---|---|---|---|
| AS SHOWN | KRB | AS | 6104-0027 | 1/10/2024 | |

HOUSTON
engineering, inc.



Project Area

Existing 100yr Depths (Feet)

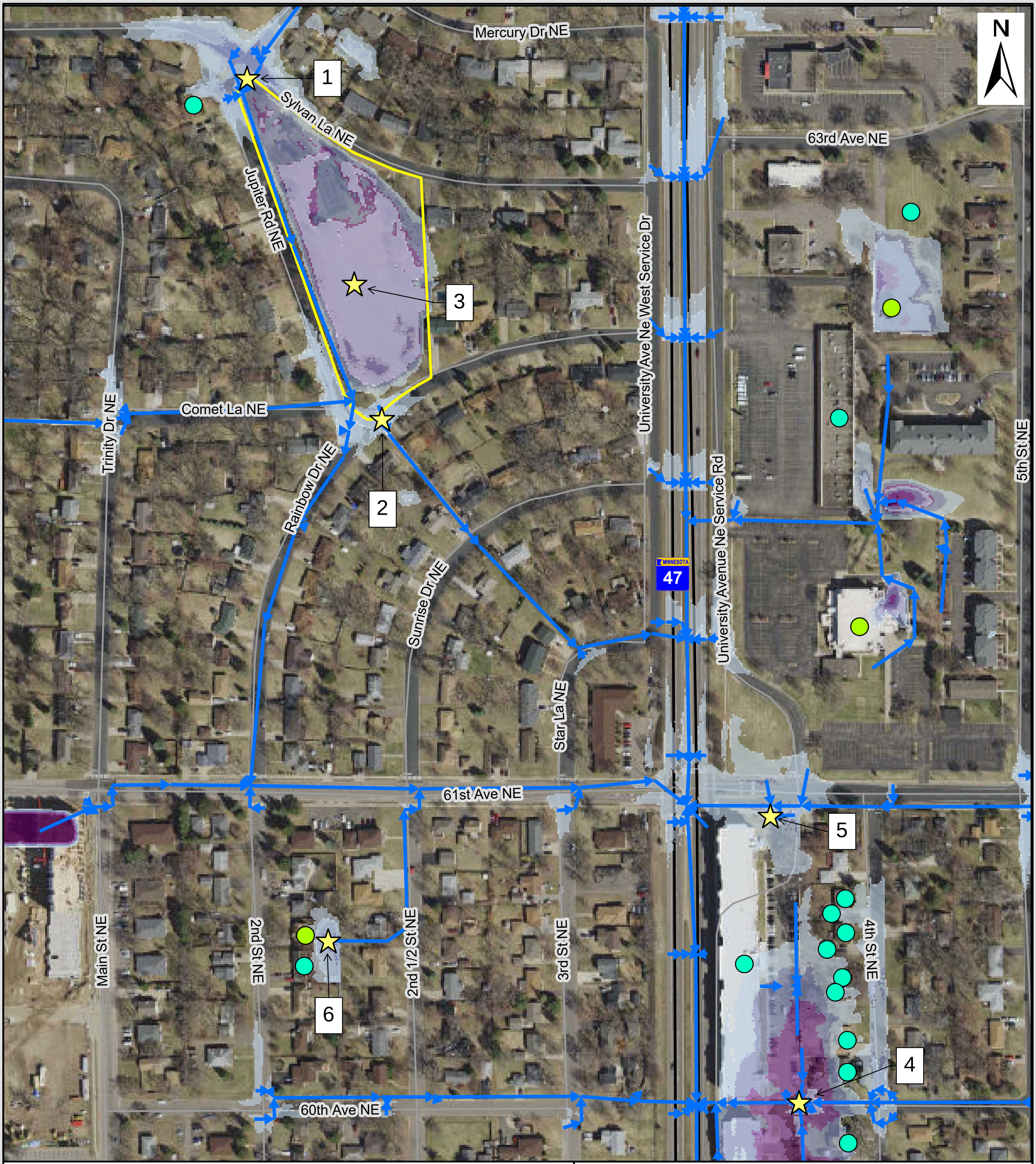
| | |
|---|---|
| ▢ | 0 |
| ▢ | 1 |
| ▢ | 2 |
| ▢ | 3 |
| ▢ | 4 |

0 40 80 160
Feet

## Appendix A.2: Flood Depth 100 Year Event

| Scale: | Drawn by: | Checked by: | Project No.: | Date: | Sheet: |
|---|---|---|---|---|---|
| AS SHOWN | KRB | AS | 6104-0027 | 1/10/2024 | |

HOUSTON
engineering, inc.



- ▭ Project Area
- ☆ Assessment Locations
- → Stormsewer
- ● 10-year Inundated Structures
- ● 100-year Inundated Structures

0 100 200 400
Feet

## Appendix A.2: Flood Mitigation Assessment Locations

| Scale: | Drawn by: | Checked by: | Project No.: | Date: | Sheet: |
|---|---|---|---|---|---|
| AS SHOWN | KRB | AS | 6104-0027 | 1/10/2024 | |

**HOUSTON**
engineering, inc.

# Sylvan Hills Park - Stormwater Concept A

Preliminary Opinion of Probable Cost

3/15/2024

| LINE ITEM | DESCRIPTION | UNIT | EST'D QUANTITY | POPC UNIT PRICE | POPC EXTENSION |
|---|---|---|---|---|---|
| | **North Basin** | | | | |
| 1 | Mobilization | LS | 1 | $2,000 | $2,000 |
| 2 | Curb Cub Inlet (Curb Removal, Replacement and Block Inlet) | LS | 1 | $3,800 | $3,800 |
| 3 | Excavation, Sod Removal and Grading | CY | 78 | $40 | $3,120 |
| 4 | 12" Amended Soils 75/25 | CY | 39 | $50 | $1,950 |
| 5 | Double Shredded Hardwood Mulch | CY | 22 | $100 | $2,200 |
| 6 | Engineered Infiltration Soil Import (CV) | CY | 39 | $60 | $2,333 |
| 7 | Planting Allowance Based on SQF | LS | 1 | $3,500 | $3,500 |
| | | | | Subtotal | $18,903 |
| | **South Basin** | | | | |
| 8 | Mobilization | LS | 1 | $2,000 | $2,000 |
| 9 | Curb and Catch Basin | LS | 1 | $3,800 | $3,800 |
| 10 | Excavation, Sod Removal and Grading | CY | 103 | $40 | $4,120 |
| 11 | 12" amended soils | CY | 103 | $50 | $5,150 |
| 12 | Double Shredded Hardwood Mulch | CY | 43 | $100 | $4,300 |
| 13 | Engineered Infiltration Soil Import (CV) | CY | 67 | $60 | $4,000 |
| 14 | Planting Allowance Based on SQF | LS | 1 | $7,000 | $7,000 |
| | | | | Subtotal | $30,370 |
| | **Stormsewer across Rainbow Dr** | | | | |
| 15 | Mobilization | LS | 1 | $3,000 | $3,000 |
| 16 | 12" RCP Stormsewer | LF | 77 | $90 | $6,930 |
| 17 | CB Manhole Structure Reconstruct | EA | 1 | $6,000 | $6,000 |
| 18 | Road Removal and Reconstruct | SY | 48 | $500 | $24,000 |
| | | | | Subtotal | $39,930 |
| | **Central Basin** | | | | |
| 19 | Mobilization | LS | 1 | $7,000 | $7,000 |
| 20 | Excavation, Sod Removal and Grading | CY | 850 | $40 | $34,000 |
| 21 | 12" amended soils | CY | 103 | $50 | $5,150 |
| 22 | Planting Allowance Based on SQF | LS | 1 | $12,000 | $12,000 |
| 23 | 1.5" Quaking Aspen | Each | 11 | $530 | $5,830 |
| 24 | Engineered Infiltration Soil Import (CV) | CY | 431 | $60 | $25,889 |
| 25 | Double Shredded Hardwood Mulch | CY | 107 | $90 | $9,630 |
| | | | | Subtotal | $99,499 |
| | **Ephemeral Stream** | | | | |
| 26 | Mobilization | LS | 1 | $5,000 | $5,000 |
| 27 | Excavation/Grading | CY | 268 | $40 | $10,720 |
| 28 | Underlaymnet: Nonwoven Geotextile | SQY | 525 | $4.75 | $2,494 |
| 29 | 4"-8" River Rock | Ton | 340 | $135 | $45,900 |
| 30 | Medium Field Stone Boulder | Ton | 38 | $135 | $5,130 |
| 31 | 12" pipe cuvlert | LF | 14 | $38 | $531 |
| | | | | Subtotal | $69,775 |
| | **Underground Infiltration System** | | | | |
| 32 | Mobilization | LS | 1 | $30,000 | $30,000 |
| 33 | Excavation for storage chambers & subgrade correction | CY | 7,800 | $4 | $31,200 |
| 34 | Haul and dispose dispaced material for chambers (CV) | CY | 4,300 | $18 | $77,400 |
| 35 | Rock for Infiltration Storage | CY | 1,751 | $30 | $52,530 |
| 36 | Backfill over storage chambers (CV) | CY | 3,500 | $5 | $17,500 |
| 37 | Subgrade Aggregate Import (LV) | CY | 750 | $18 | $13,500 |
| 38 | CMP Infiltration System | LF | 4,200 | $85 | $357,000 |
| 39 | Pre-treatment hydrodynamic separator | LS | 1 | $100,000 | $100,000 |
| 40 | Sod Repair | SQY | 2,000 | $15.00 | $30,000 |
| 41 | 72" Diversion Structure | LS | 1 | $16,000 | $16,000 |
| 42 | 36" RCP Stormsewer | LF | 76 | $250 | $19,000 |
| | | | | Subtotal | $744,130 |
| | **Restoration and Other** | | | | |
| 43 | Erosion control | LS | 1 | $15,000 | $15,000 |
| 44 | Native Seed: Herbicide, tilling, seeding and blanket | SQF | 13,000 | $0.75 | $9,750 |
| 45 | Bee Lawn: Herbicide, tilling, seeding and hydromulch | SQF | 13,000 | $0.70 | $9,100 |
| | | | | Subtotal | $33,850 |
| | **By Others (not included in total cost)** | | | | |
| 46 | Pathway | SQF | 11,533 | $4.75 | $54,782 |
| 47 | Tradional Playground: surface prep, CIP curb, 12" cert mulch | LS | 1 | $34,000 | $34,000 |
| | | | | Subtotal | $88,782 |
| | **Subtotal** | | | | **$1,036,457** |
| | Contingency | | | 20% | $207,291 |
| | **Construction Total** | | | | **$1,244,000** |
| | Engineering and Construction Administration | | | 20% | $248,800 |
| | **Project Total** | | | | **$1,493,000** |

| **Life Cycle Cost Anaysis** | | | | | |
|---|---|---|---|---|---|
| | Annual BMP Operation & Maintenance | HR | 24 | $250 | $6,000 |
| | Periodic Maintenance (10 yr Vac Sediment Removal) | CY | 41 | $300 | $12,154 |
| | **Total Life-Cycle Cost (30 years, 3% rate)** | | | | **$1,645,000** |
| | Annualized Life-Cycle Cost | | | | $54,833 |
| | Annual TP Removal (lbs/year) | | | | 16.1 |
| | **Cost-Benefit ($/lbs TP)** | | | | **$3,406** |

# Sylvan Hills Park - Stormwater Concept B

## Preliminary Opinion of Probable Cost

3/15/2024

| LINE | | | EST'D | POPC | |
|---|---|---|---|---|---|
| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | EXTENSION |
| | **North Basin** | | | | |
| 1 | Mobilization | LS | 1 | $2,000 | $2,000 |
| 2 | Curb cut or rain guardian | LS | 1 | $3,800 | $3,800 |
| 3 | Excavation, sod removal and grading | CY | 81 | $40 | $3,223 |
| 4 | 12" amended soils | CY | 81 | $50 | $4,050 |
| 5 | Double Shredded Hardwood Mulch | CY | 44 | $100 | $4,400 |
| 6 | Engineered Infiltration Soil Import (CV) | CY | 111 | $60 | $6,660 |
| 7 | Planting Allowance Based on SQF | LS | 1 | $7,000 | $7,000 |
| | | | | Subtotal | $31,133 |
| | **South Basin** | | | | |
| 8 | Mobilization | LS | 1 | $2,000 | $2,000 |
| 9 | Curb and Catch Basin | LS | 1 | $3,800 | $3,800 |
| 10 | Excavation, sod removal and grading | CY | 145 | $40 | $5,802 |
| 11 | 12" amended soils | CY | 145 | $50 | $7,250 |
| 12 | Double Shredded Hardwood Mulch | CY | 43 | $100 | $4,300 |
| 13 | Engineered Infiltration Soil Import (CV) | CY | 111 | $60 | $6,660 |
| 14 | Planting Allowance Based on SQF | LS | 1 | $7,000 | $7,000 |
| | | | | Subtotal | $36,812 |
| | **Stormsewer across Rainbow Dr** | | | | |
| 15 | Mobilization | LS | 1 | $3,000 | $3,000 |
| 16 | 12" RCP Stormsewer | LF | 77 | $90 | $6,930 |
| 17 | CB Manhole Structure Reconstruct | EA | 1 | $6,000 | $6,000 |
| 18 | Road Removal and Reconstruct | SY | 48 | $500 | $24,000 |
| | | | | Subtotal | $39,930 |
| | **Underground Infiltration System** | | | | |
| 19 | Mobilization | LS | 1 | $30,000 | $30,000 |
| 20 | Excavation for storage chambers & subgrade correction | CY | 8,900 | $4 | $35,600 |
| 21 | Haul and dispose dispaced material for chambers (CV) | CY | 4,900 | $18 | $88,200 |
| 22 | Rock for Infiltration Storage | CY | 1,751 | $30 | $52,530 |
| 23 | Backfill over storage chambers (CV) | CY | 4,000 | $5 | $20,000 |
| 24 | Subgrade Aggregate Import (CV) | CY | 850 | $18 | $15,300 |
| 25 | CMP Infiltration System | LF | 4,800 | $85 | $408,000 |
| 26 | Pre-treatment hydrodynamic separator | LS | 1 | $100,000 | $100,000 |
| 27 | Sod Repair | SQY | 2,200 | $15.00 | $33,000 |
| 28 | 72" Diversion Structure | LS | 1 | $16,000 | $16,000 |
| 29 | 36" RCP Stormsewer | LF | 76 | $250 | $19,000 |
| | | | | Subtotal | $817,630 |
| | **Restoration and Other** | | | | |
| 30 | Erosion control | LS | 1 | $15,000 | $15,000 |
| 31 | Bee Lawn: Herbicide, tilling, seeding and hydromulch | SQF | 6,900 | $0.70 | $4,830 |
| 32 | Nature play | LS | 1 | $24,000 | $24,000 |
| 33 | Native Seed: Herbicide, tilling, seeding and blanket | SQF | 6,900 | $0.75 | $5,175 |
| | | | | Subtotal | $49,005 |
| | **By Others (not included in total cost)** | | | | |
| 34 | Pathway | SQF | 11,533 | $4.75 | $54,782 |
| 35 | Tradional Playground: surface prep, CIP curb, 12" cert mulch | LS | 1 | $34,000 | $34,000 |
| | | | | Subtotal | $88,782 |
| | **Subtotal** | | | | **$974,511** |
| | Contingency | | | 20% | $194,902 |
| | **Construction Total** | | | | **$1,169,000** |
| | Engineering and Construction Administration | | | 20% | $233,800 |
| | **Project Total** | | | | **$1,403,000** |

| **Life Cycle Cost Anaysis** | | | | | |
|---|---|---|---|---|---|
| | Annual BMP Operation & Maintenance | HR | 24 | $200 | $4,800 |
| | Periodic Maintenance (10 yr Vac Sediment Removal) | CY | 41 | $300 | $12,154 |
| | **Total Life-Cycle Cost (30 years, 3% rate)** | | | | **$1,531,000** |
| | Annualized Life-Cycle Cost | | | | $51,033 |
| | Annual TP Removal (lbs/year) | | | | 16.1 |
| | **Cost-Benefit ($/lbs TP)** | | | | **$3,170** |

# Geotechnical Evaluation Report

Sylvan Hills Park Stormwater Improvements
Intersection of Sylvan Lane Northeast and Jupiter Road Northeast
Fridley, Minnesota

*Prepared for*

## Houston Engineering

**Professional Certification:**
I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of Minnesota.

Richard S. Jett

Richard S. Jett, PE
Project Engineer
License Number: 58781
March 21, 2024

RICHARD S. JETT
58781

Project B2308886

Braun Intertec Corporation

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The Science You Build On.

**Braun Intertec Corporation**
11001 Hampshire Avenue S
Minneapolis, MN 55438

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Web: braunintertec.com

March 21, 2024 Project B2308886

Alex Schmidt, PE
Houston Engineering
7550 Meridian Circle North, Suite 120
Maple Grove, MN 55369

Re: Geotechnical Evaluation Report
Sylvan Hills Park Stormwater Improvements
Intersection of Sylvan Lane Northeast and Jupiter Road Northeast
Fridley, Minnesota

Dear Mr. Schmidt:

We are pleased to present this Geotechnical Evaluation Report for the above-referenced project. The following report provides the results of our evaluation and should be read in its entirety.

Thank you for making Braun Intertec your geotechnical consultant for this project. If you have questions about this report, or if there are other services that we can provide in support of our work to date, please contact Richard Jett at 815.545.7059 (rjett@braunintertec.com) or Brad McCarter at 612.708.2790 (bmccarter@braunintertec.com).

Sincerely,

BRAUN INTERTEC CORPORATION

Richard S. Jett

Richard S. Jett, PE
Project Engineer

Bradley J. McCarter, PE
Director, Senior Engineer

# Table of Contents

# Table of Contents (continued)

**Description** **Page**

# A. Introduction

## A.1. Project Description

This Geotechnical Evaluation Report addresses the design and construction of the proposed stormwater management improvements at the existing Sylvan Hills Park located in Fridley, Minnesota. The project will include the construction of underground stormwater infiltration system with a top elevation of approximately 831.7 feet and a bottom elevation of approximately 827.6 feet. Figure 1 illustrates the approximate location of the proposed underground stormwater infiltration system.

**Figure 1: Site Layout**

*Figure provided by Houston Engineering (undated).

## A.2. Site Conditions and History

Currently, the site exists as Sylvan Hills Park, which includes a single tennis court, a single bituminous basketball court, a baseball/softball field, and a playground structure. Based on publicly available satellite imagery, it appears that site has been used as a park since at least early 2000's, with the basketball court being constructed in the mid-2000s.

**Photograph 1. Aerial Photograph of Site in 2006**

**Photograph 2. Aerial Photograph of Site in 2005**

The site is generally flat, with less than about 1 foot of surface elevation change across the recently performed soil boring locations.

## A.3. Purpose

The purpose of our geotechnical evaluation was to characterize subsurface geologic conditions at selected exploration locations, evaluate their impact on the project, and provide geotechnical recommendations for use in the design and construction of the proposed stormwater management system.

## A.4. Background Information and Reference Documents

Project information, including stormwater management design overview, was provided by Houston Engineering via email on March 18, 2024.

We have also used publicly available sources of information including topography maps obtained from the Minnesota Department of Natural Resources (MnTOPO website) and Google Earth aerial photographs.

We have described our understanding of the proposed construction and site to the extent others reported it to us. Depending on the extent of available information, we may have made assumptions based on our experience with similar projects. If we have not correctly recorded or interpreted the project details, the project team should notify us. New or changed information could require additional evaluation, analyses and/or recommendations.

## A.5. Scope of Services

We performed our scope of services for the project in accordance with Task Order No. 1020123-21-6104-0027 (associated Braun Intertec Proposal QTB184148, dated September 11, 2023) provided by Houston Engineering and authorized on October 4, 2023. It should be noted that Additional Service #1 (installation of temporary piezometers) was requested via email by Houston Engineering on September 13, 2023. The following list describes the geotechnical tasks completed in accordance with our authorized scope of services.

- Reviewing the background information and reference documents previously cited.

- Staking and clearing the exploration location of underground utilities. Houstin Engineering selected and we staked the exploration locations. We acquired the surface elevations and locations with GPS technology using the State of Minnesota's permanent GPS base station network. The Soil Boring Location Sketch included in the Appendix shows the approximate locations of the borings.

- Performing the requested six standard penetration test (SPT) borings, denoted as ST-1 through ST-6, to nominal depths ranging from 14 to 20 feet below grade across the site.

-

- Install six temporary monitoring wells at each completed soil boring location, take a 24-hour delayed groundwater level reading at each location, and abandon each temporary monitoring well per Minnesota Department of Health requirements.

- Performing laboratory testing on select samples to aid in soil classification and engineering analysis.

- Preparing this report containing a boring location sketch, logs of soil borings, a summary of the soils encountered, results of laboratory tests, and recommendations for the design and construction of the stormwater management improvements.

Our scope of services did not include environmental services or testing and our geotechnical personnel performing this evaluation are not trained to provide environmental services or testing. We can provide environmental services or testing at your request.

# B. Results

## B.1. Geologic Overview

We based the geologic origins used in this report on the soil types, in-situ and laboratory testing, and available common knowledge of the geological history of the site. Because of the complex depositional history, geologic origins can be difficult to ascertain. We did not perform a detailed investigation of the geologic history for the site.

## B.2. Boring Results

Table 1 provides a summary of the soil boring results in the general order we encountered the strata. Please refer to the Log of Boring sheets in the Appendix for additional details. The Descriptive Terminology sheet in the Appendix includes definitions of abbreviations used in Table 1.

**Table 1. Subsurface Profile Summary**

| Strata | Soil Type - ASTM Classification | N values | Commentary and Details |
|---|---|---|---|
| Topsoil / Topsoil Fill | SM | N/A | ▪ Observed at all boring locations with thicknesses ranging from approximately 1 to 3 feet.<br>▪ Predominantly silty sand soils.<br>▪ Generally black to dark brown in color.<br>▪ Moisture conditions were generally moist. |
| Fill | SM, SC, SP | 3 to 8 | ▪ Observed below the surficial layers in Borings ST-1 through ST-3 and ST-5 and extended to depths ranging from about 4 to 6 feet below existing grade.<br>▪ Moisture conditions were generally moist.<br>▪ Highly variable, soils intermixed.<br>▪ Varying amounts of gravel observed.<br>▪ Zones of slightly organic soils encountered throughout the soil profile at varying depths. |

| Strata | Soil Type - ASTM Classification | N values | Commentary and Details |
|---|---|---|---|
| Swamp deposits | MH, OL, Pt, CL | Weight of Hammer to 2 | ▪ Observed in Borings ST-3, ST-5, and ST-6 below the existing surficial soils and fill soils and extended to depths ranging from approximately 6 to 11 feet below existing grade.<br>▪ Generally encountered elastic silt soils and organic clay soils intermixed with layers of peat and lean clay soils.<br>▪ Organic content generally ranged from slightly organic to organic in nature. |
| Terrace deposit | SP | 7 to 15 | ▪ Observed at all six soil boring locations below the surficial soils, fill soils, and swamp deposit soils and extending to the termination depths of the soil borings.<br>▪ Relative densities of the granular soils were generally loose with isolated zones of medium dense soils.<br>▪ Moisture conditions were generally moist to wet.<br>▪ Occasional seams of silty sand soils.<br>▪ Generally light brown to brown in color. |

We did not perform gradation analysis on the topsoil material encountered in accordance with our scope of work. Therefore, we cannot conclusively determine if the encountered material satisfies a particular specification.

For simplicity in this report, we define existing fill to mean existing, uncontrolled, or undocumented fill.

## B.3. Groundwater

During drilling activities, groundwater was observed at four of the completed SPT soil borings at depths ranging from about 12 to 14 feet below existing grade (approximate elevations ranging from 822 to 824 feet). Six temporary piezometers were also installed to depths of approximately 14 feet below existing grade at each of the soil boring locations. Following an initial reading and a 24-hour delayed reading, the temporary piezometers were removed. Table 2 summarizes the depths where we observed groundwater; the attached Log of Boring sheets in the Appendix also include this information and additional details.

**Table 2. Groundwater Summary**

| Location | Surface Elevation (feet) | Measured Depth to Groundwater at Time of Drilling (feet) | Corresponding Groundwater Elevation at Time of Drilling (feet) | Measured Depth to Groundwater 24 hours after Drilling (feet) | Corresponding Groundwater Elevation 24 hours after Drilling (feet) |
|---|---|---|---|---|---|
| ST-1 | 837.3 | 13 1/2 | 824 | 13 1/2 | 824 |
| ST-2 | 836.8 | 13 1/2 | 823 1/2 | 13 | 823 1/2 |
| ST-3 | 837.1 | None Observed | None Observed | None Observed | None Observed |
| ST-4 | 837.1 | None Observed | None Observed | None Observed | None Observed |
| ST-5 | 836.6 | 14 | 823 | 13 | 823 1/2 |
| ST-6 | 836.2 | None Observed | None Observed | 12 1/2 | 824 |

The results of our soil borings and temporary piezometers indicate that groundwater at this site is generally present near, or below, about an elevation of 824 feet. Seasonal and annual fluctuations of groundwater should be expected.

## B.4. Laboratory Test Results

The soil boring logs show the results of the laboratory testing we performed next to the tested sample depth. The Appendix contains these sheets. Laboratory testing was performed in general accordance with ASTM standards.

The moisture content tests performed on select samples indicated moisture contents from about 3 to 39 percent, by weight. Sieve analysis tests (passing the #200 sieve) performed on select samples indicated from about 2 to 35 percent particles, by weight, passing the #200 sieve.

# C. Recommendations

## C.1. Design and Construction Discussion

### C.1.a. Stormwater Infiltration

Based on the results of the completed soil borings, silt and clay laden fill soils and swamp deposit soils were observed in Borings ST-2, ST-3, ST-5, and ST-6 extending to depths ranging from approximately 6 to 11 feet below existing grade. We do not consider these soils to be conducive for infiltration; therefore, infiltration of stormwater within these zones should not be considered by the project team.

Naturally deposited sand soils were observed at the boring locations below the topsoil, fill soils, and swamp deposit soils and extended to the termination depths of the borings. These clean sand soils are generally considered suitable for the infiltration of stormwater. It should be noted, however, that groundwater was generally encountered within the clean sand soils on-site, which may limit the effectiveness of the infiltration through these soil layers.

Groundwater was observed on site generally below an elevation of about 824 feet. We recommend that a minimum 3-foot vertical buffer be provided between the long-term groundwater levels encountered on-site and the bottom of a potential infiltration system to help prevent groundwater mounding and a reduced infiltration capacity of the system.

### C.1.b. Support of Infiltration Structure

Borings ST-4 through ST-6 were performed in the area of the new proposed underground stormwater infiltration system. We do not recommend that the topsoil, fill soils, or swamp deposit soils be considered suitable for support of the proposed underground infiltration system due to the risk of excessive settlement associated with these soils should they be relied upon for support. We recommend that the system is designed to bear on either the naturally deposited sand soils observed on-site or properly compacted and moisture conditioned engineered fill soils following soil corrections to remove the unsuitable topsoil, fill soils, and swamp soils from below the proposed structure. Given a bottom elevation of approximately 827.6 feet, we recommend that a soil correction will be needed below the bottom of the system to remove the existing swamp deposit soils down to the naturally deposited sand soils below. Engineered backfill soils below the system should consist of free draining sand soils as outlined in Section C.3.f.

### C.1.c. Reuse of On-Site Soils

Based on the results of the completed laboratory testing program, the existing fill soils and swamp deposit soils are generally not considered suitable for reuse as engineered fill soils due to their organic content and soil type. The naturally deposited sand soils (SP, SP-SM) observed on-site are considered suitable for reuse, provided they can be moisture conditioned and compacted as outlined in this report. Any materials to be used as engineered fill should be tested and approved by the engineer prior to placement.

## C.2. Stormwater Infiltration

### C.2.a. Soil Infiltration Rates

We understand that the stormwater improvements planned for this site will include the installation of a below-grade stormwater infiltration system with a bottom elevation of approximately 827.6 feet. Granular soils were generally observed within this elevation range in Boring ST-4, while swamp deposit soils were generally observed within this elevation range in Borings ST-5 and ST-6.

The on-site clean sand soils (SP) are generally considered conducive for the rapid infiltration of stormwater in accordance with the Minnesota Stormwater Manual with infiltration value of 0.8 inches per hour for Hydrologic Soil Group A. This infiltration value could also be used in areas where soil corrections are performed to remove and replace the less conducive clay, silt or organic soils.

The existing swamp deposit soils (MH, PT, CL, OL) are generally considered to be in hydrologic groups B and D and therefore are generally not considered conducive to infiltration of stormwater. We recommend that the existing swamp deposit soils are removed down to the naturally deposited granular soils below and replaced with clean sand soils as outlined in section C.3.f.

The provided infiltration rates represents the long-term infiltration capacity of a practice and not the capacity of the soils in their natural state. Field testing, such as with a double-ring infiltrometer (ASTM D3385), may justify the use of higher infiltration rates. However, we recommend adjusting field test rates by the appropriate correction factor, as provided for in the Minnesota Stormwater Manual or as allowed by the local watershed. We recommend consulting the Minnesota Stormwater Manual for stormwater design.

Fine-grained soils (silts and clays), topsoil or organic matter that mixes into or washes onto the soil will lower the permeability. The contractor should maintain and protect infiltration areas during construction. Furthermore, organic matter and silt washed into the system after construction can fill the soil pores and reduce permeability over time. Proper maintenance is important for long-term performance of infiltration systems.

This geotechnical evaluation does not constitute a review of site suitability for stormwater infiltration or evaluate the potential impacts, if any, from infiltration of large amounts of stormwater.

### C.2.b. Impacts of Groundwater

Apparent groundwater was encountered at the soil boring locations at elevations near 824 feet. We recommend that a minimum 3-foot vertical buffer be provided between the long-term groundwater levels encountered on-site and the bottom of a potential infiltration system to help prevent groundwater mounding and a reduced infiltration capacity of the system.

Should an infiltration system be selected for this project, we recommend that a long-term groundwater monitoring program is implemented to further analyze the groundwater levels on-site over a longer period of time. This program should include readings over a period of at least 6 months with this monitoring period taking place over the spring thaw that typically takes place from April to July.

## C.3. Underground Stormwater System

### C.3.a. Overview

It is our understanding that an underground stormwater infiltration system is being planned on site and will include a bottom elevation of approximately 827.6 feet.

### C.3.b. Stormwater System Subgrade Excavations

We recommend removing any organic swamp deposit soils from below the proposed stormwater system and its oversize areas due to the risk of excessive settlement should the organic soils be relied upon for support. Based on the borings and provided information, we anticipate limited soil corrections on the order of 2 to 3 feet below bottom of system will be needed to remove the existing soils to the sandy soils below. We recommend having a geotechnical engineer, or an engineering technician working under the direction of a geotechnical engineer, (geotechnical representative) evaluate the suitability of exposed subgrade soils to support the proposed structure.

Table 3 shows the anticipated soil correction and bottom elevations for each of the completed soil borings.

**Table 3. Stormwater System Soil Corrections Depths**

| Location | Approximate Surface Elevation (feet) | Anticipated Excavation Depth (feet) | Anticipated Bottom Elevation (feet) |
|---|---|---|---|
| ST-4 | 837.1 | 3 | 834 |
| ST-5 | 836.6 | 11 | 825 1/2 |
| ST-6 | 836.2 | 11 | 825 |

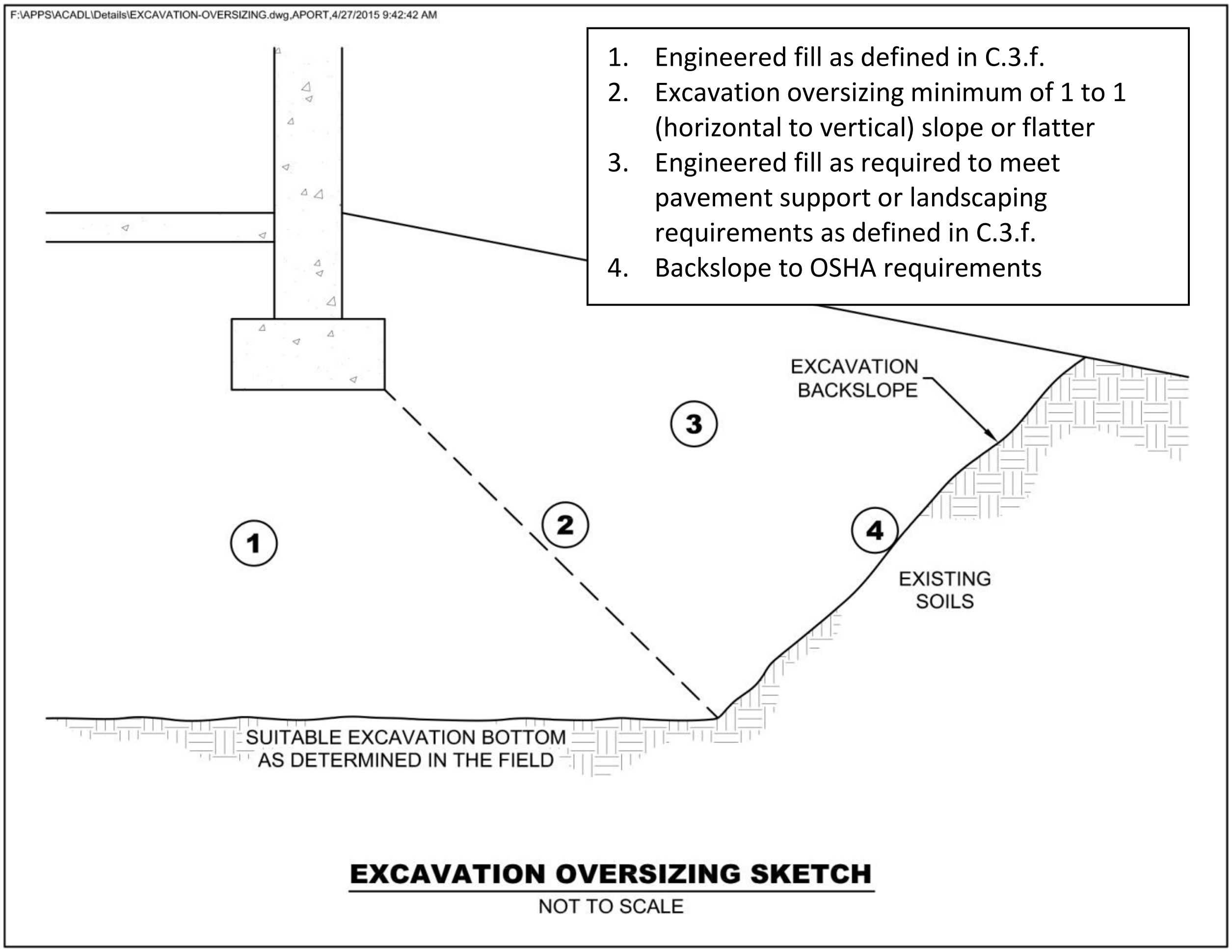
Excavation depths will vary between the borings. Portions of the excavations may also extend deeper than indicated by the borings. A geotechnical representative should observe the excavations to make the necessary field judgments regarding the suitability of the exposed soils.

Care should be taken to limit vibratory action of compaction equipment until the excavation is a minimum of 2 feet above the apparent groundwater surface. This will help provide a more stable platform for construction.

### C.3.c. Excavation Oversizing

When removing unsuitable materials below the proposed stormwater structure, we recommend the excavation extend outward and downward at a slope of 1H:1V (horizontal:vertical) or flatter. See Figure 2 for a generalized illustration of excavation oversizing.

**Figure 2. Generalized Illustration of Oversizing**



### C.3.d. Excavated Slopes

Based on the borings, we anticipate on-site soils in excavations will consist of swamp deposit soils and granular soils. These soils are typically considered Type C Soil under OSHA (Occupational Safety and Health Administration) guidelines. OSHA guidelines indicate unsupported excavations in Type C soils should have a gradient no steeper than 1 1/2H:1V. Slopes constructed in this manner may still exhibit surface sloughing.

It should also be noted that organic soils and water bearing soils were also encountered during our geotechnical exploration. Excavations where these soils are encountered will need to be sloped at a minimum of 4H:1V or shallower to help minimize instabilities in the excavation.

An OSHA-approved qualified person should review the soil classification in the field. Excavations must comply with the requirements of OSHA 29 CFR, Part 1926, Subpart P, “Excavations and Trenches.” This document states excavation safety is the responsibility of the contractor. The project specifications should reference these OSHA requirements.

### C.3.e. Excavation Dewatering

Groundwater is present near an elevation of 824 feet, thus, groundwater should be expected in areas where deeper excavations are planned to extend near this elevation. We recommend removing groundwater from the excavations where encountered. Well point style of dewatering systems are generally more suitable for granular soil types but must take into account and mitigate the potential for lowering the groundwater table below adjacent structures, streets, utilities, etc. Dewatering of high-permeability soils (e.g., sands) from within the excavation with conventional pumps has the potential to loosen the soils, due to upward flow. A well contractor should develop a dewatering plan; the design team should review this plan.

The groundwater surface should be kept a minimum of 2 feet below the bottom of the lowest excavation to help provide a more stable working platform for construction.

### C.3.f. Engineered Fill Materials and Compaction

Table 4 below contains our recommendations for engineered fill materials.

**Table 4. Engineered Fill Materials***

| Locations To Be Used | Engineered Fill Classification | Possible Soil Type Descriptions | Gradation | Additional Requirements |
|---|---|---|---|---|
| ▪ Below stormwater system | ▪ Structural fill | SP, SP-SM | 100% passing 2-inch sieve<br>< 12% passing #200 sieve | < 2% Organic Content (OC) |
| ▪ Storm system backfill | ▪ Retained soils | SP, SP-SM, SM | 100% passing 2-inch sieve<br>< 20% passing #200 sieve | < 2% Organic Content (OC) |

*More select soils comprised of coarse sands with < 5% passing #200 sieve may be needed to accommodate work occurring in periods of wet or freezing weather.

We recommend spreading engineered fill in loose lifts of approximately 12 inches thick. We recommend compacting engineered fill in accordance with the criteria presented below in Table 5. The project documents should specify relative compaction of engineered fill, based on the structure located above the engineered fill, and vertical proximity to that structure.

**Table 5. Compaction Recommendations Summary**

| Reference | Relative Compaction, percent (ASTM D698 – Standard Proctor) | Moisture Content Variance from Optimum, percentage points | |
|---|---|---|---|
| | | Sand Soils (SP, SP-SM) | Silty Sand Soils (SM) |
| Stormwater system backfill | 95 | ±3 | -1 to +3 |

*Increase compaction requirement to meet compaction required for structure supported by this engineered fill.

The project documents should not allow the contractor to use frozen material as engineered fill or to place engineered fill on frozen material. Frost should not penetrate under foundations during construction.

We recommend performing density tests in engineered fill to evaluate if the contractors are effectively compacting the soil and meeting project requirements. However, where sand fill is placed below the stormwater infiltration system, it should not be compacted as this will reduced its infiltration capabilities.

### C.3.g. Groundwater

Given the anticipated close proximity to the apparent groundwater elevation, the proposed stormwater system should be designed to accommodate any hydrostatic forces presented on the stormwater system below an elevation of approximately 824 feet.

### C.3.h. Configuring and Resisting Lateral Loads

We understand that a potential stormwater system may retain soil. We recommend designing the structure walls based on granular soil backfill (SP, SP-SM, SM) as outlined in Section C.3.f. with a wet unit weight of approximately 115 pounds per cubic foot (pcf), a friction angle of 32 degrees, an active lateral coefficient of 0.31, an at-rest lateral coefficient of 0.47, and a passive lateral coefficient of 3.25. Our recommended values also assume the stormwater system wall design provides drainage to prevent water from accumulating. The construction documents should clearly identify the material properties of the soil the contractor should use for wall fill.

## C.4. Utilities

### C.4.a. Subgrade Stabilization

We anticipate that utilities may be installed as a part of the proposed stormwater management system. We anticipate the soils at typical invert elevations will generally be suitable for utility support. However, if construction encounters unfavorable conditions such as swamp deposit soils, organic soils, or water at invert grades, the unsuitable soils may require some additional subcutting and replacement with sand or crushed rock to prepare a proper subgrade for pipe support. Project design and construction should not place utilities within the 1H:1V oversizing of foundations.

### C.4.b. Utility Backfill

We recommend utility trench backfill adhere to the recommendations of Section C.3.f. depending on what overlies the trench.

### C.4.c. Groundwater and Dewatering

Depending on the anticipated invert elevations, temporary dewatering within utility trenches may be needed to facilitate utility installation where excavations extend to depths near or below and elevation of approximately 824 feet. We section C.2.e. for additional information regarding dewatering.

We also anticipate that the groundwater may be near the invert elevations of some utilities. We recommend that the utilities are design to accommodate hydrostatic uplift forces from the potential vertical movement of groundwater should utilities be designed with an invert elevation at or below an elevation of 824 feet.

## C.5. Equipment Support

The recommendations included in the report may not be applicable to equipment used for the construction and maintenance of this project. We recommend evaluating subgrade conditions in areas of shoring, scaffolding, cranes, pumps, lifts and other construction equipment prior to mobilization to determine if the exposed materials are suitable for equipment support, or require some form of subgrade improvement. We also recommend project planning consider the effect that loads applied by such equipment may have on structures they bear on or surcharge – including pavements, buried utilities, below-grade walls, etc. We can assist you in this evaluation.

# D. Procedures

## D.1. Penetration Test Borings

We drilled the penetration test borings with an All-Terrain Vehicle (ATV) mounted core and auger drill equipped with hollow-stem auger. The boring logs show the actual sample intervals and corresponding depths.

We sealed penetration test boreholes in general accordance with MDH procedures.

## D.2. Exploration Logs

### D.2.a. Log of Boring Sheets

The Appendix includes Log of Boring sheets for our penetration test borings. The logs identify and describe the penetrated geologic materials, and present the results of penetration resistance and other in-situ tests performed. The logs also present the results of laboratory tests performed on penetration test samples and groundwater measurements.

We inferred strata boundaries from changes in the penetration test samples and the auger cuttings. Because we did not perform continuous sampling, the strata boundary depths are only approximate. The boundary depths likely vary away from the boring locations, and the boundaries themselves may occur as gradual rather than abrupt transitions.

### D.2.b. Geologic Origins

We assigned geologic origins to the materials shown on the logs and referenced within this report, based on: (1) a review of the background information and reference documents cited above, (2) visual classification of the various geologic material samples retrieved during the course of our subsurface exploration, (3) penetration resistance and other in-situ testing performed for the project, (4) laboratory test results, and (5) available common knowledge of the geologic processes and environments that have impacted the site and surrounding area in the past.

## D.3. Material Classification and Testing

### D.3.a. Visual and Manual Classification

We visually and manually classified the geologic materials encountered based on ASTM D2488. When we performed laboratory classification tests, we used the results to classify the geologic materials in accordance with ASTM D2487. The Appendix includes a chart explaining the classification system we used.

### D.3.b. Laboratory Testing

The exploration logs in the Appendix note the results of the laboratory tests performed on geologic material samples. We performed the tests in general accordance with ASTM procedures.

## D.4. Groundwater Measurements

The drillers checked for groundwater while advancing the penetration test borings, and again after auger withdrawal. We then filled the boreholes as noted on the boring logs.

# E. Qualifications

## E.1. Variations in Subsurface Conditions

### E.1.a. Material Strata

We developed our evaluation, analyses and recommendations from a limited amount of site and subsurface information. It is not standard engineering practice to retrieve material samples from exploration locations continuously with depth. Therefore, we must infer strata boundaries and thicknesses to some extent. Strata boundaries may also be gradual transitions, and project planning should expect the strata to vary in depth, elevation and thickness, away from the exploration locations.

Variations in subsurface conditions present between exploration locations may not be revealed until performing additional exploration work, or starting construction. If future activity for this project reveals any such variations, you should notify us so that we may reevaluate our recommendations. Such variations could increase construction costs, and we recommend including a contingency to accommodate them.

### E.1.b. Groundwater Levels

We made groundwater measurements under the conditions reported herein and shown on the exploration logs, and interpreted in the text of this report. Note that the observation periods were relatively short, and project planning can expect groundwater levels to fluctuate in response to rainfall, flooding, irrigation, seasonal freezing and thawing, surface drainage modifications and other seasonal and annual factors.

## E.2. Continuity of Professional Responsibility

### E.2.a. Plan Review

We based this report on a limited amount of information, and we made a number of assumptions to help us develop our recommendations. We should be retained to review the geotechnical aspects of the designs and specifications. This review will allow us to evaluate whether we anticipated the design correctly, if any design changes affect the validity of our recommendations, and if the design and specifications correctly interpret and implement our recommendations.

### E.2.b. Construction Observations and Testing

We recommend retaining us to perform the required observations and testing during construction as part of the ongoing geotechnical evaluation. This will allow us to correlate the subsurface conditions exposed during construction with those encountered by the borings and provide professional continuity from the design phase to the construction phase. If we do not perform observations and testing during construction, it becomes the responsibility of others to validate the assumption made during the preparation of this report and to accept the construction-related geotechnical engineer-of-record responsibilities.

## E.3. Use of Report

This report is for the exclusive use of the addressed parties. Without written approval, we assume no responsibility to other parties regarding this report. Our evaluation, analyses and recommendations may not be appropriate for other parties or projects.

## E.4. Standard of Care

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

# Appendix

F:\2023\B2308886\CAD\B2308886.dwg,Geotech,10/5/2023 7:13:25 AM

◉ **DENOTES APPROXIMATE LOCATION OF STANDARD PENETRATION TEST BORING**

N

40' 0 80'

SCALE: 1"= 80'

**BRAUN INTERTEC**

The Science You Build On.

11001 Hampshire Avenue S
Minneapolis, MN 55438
952.995.2000
braunintertec.com

Drawing Information

| | |
|---|---|
| Project No: | B2308886 |
| Drawing No: | B2308886 |
| Drawn By: | JAG |
| Date Drawn: | 9/25/23 |
| Checked By: | RSJ |
| Last Modified: | 10/5/23 |

Project Information

Sylvan Hills Park

240 Sylvan Lane NE

Fridley, Minnesota

**Soil Boring Location Sketch**

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# LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

**Project Number B2308886**
**Geotechnical Evaluation**
**Sylvan Hills Park**
**240 Sylvan Ln NE**
**Fridley, Minnesota**

| | | | |
|---|---|---|---|
| BORING: | **ST-1** | | |
| LOCATION: Captured with submeter GPS. | | | |
| DATUM: NAD 1983 HARN Adj MN Anoka (US Feet) | | | |
| NORTHING: | 117239 | EASTING: | 500001 |
| DRILLER: | M. Hoppe | LOGGED BY: | R. Jett |
| START DATE: | 10/02/23 | END DATE: | 10/02/23 |
| SURFACE ELEVATION: | 837.3 ft | RIG: | 7504 |
| METHOD: | 3 1/4" HSA | | |
| SURFACING: | Soil | WEATHER: | Sunny |

| Elev./ Depth ft | Water Level | Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908) | Sample | Blows (N-Value) Recovery | $q_p$ tsf | MC % | Tests or Remarks |
|---|---|---|---|---|---|---|---|
| 836.8<br>0.5 | | SILTY SAND (SM), fine to medium-grained, trace Gravel, black, moist (TOPSOIL FILL) | | | | | |
| 833.3<br>4.0 | | FILL: POORLY GRADED SAND (SP), fine to medium-grained, trace Gravel, contains seams of organic, light brown, moist | ⧗ | 3-2-1-4<br>(3)<br>14" | | | |
| 825.3<br>12.0 | | POORLY GRADED SAND (SP), fine-grained, trace Gravel, contains seams of Silty Sand, light brown, moist, loose (TERRACE DEPOSIT) | ⧗ | 3-4-5-5<br>(9)<br>24" | | | |
| | | | ⧗ | 4-4-4-4<br>(8)<br>24" | | | |
| | | | ⧗ | 3-4-4-15<br>(8)<br>24" | | 3 | P200=2% |
| | | | ⧗ | 3-3-4-4<br>(7)<br>24" | | | |
| 823.3<br>14.0 | ▽ | POORLY GRADED SAND (SP), fine to medium-grained, trace Gravel, light brown, wet, loose (TERRACE DEPOSIT) | ⧗ | 3-3-4-4<br>(7)<br>24" | | 18 | Water observed at 13.7 feet when rechecked 24 hours after drilling.<br>Temporary piezometer was installed to 14 feet and removed after water level rechecked. |
| | | END OF BORING<br>Boring then backfilled with auger cuttings | | | | | |

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# LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

**Project Number B2308886**
**Geotechnical Evaluation**
**Sylvan Hills Park**
**240 Sylvan Ln NE**
**Fridley, Minnesota**

| | | | |
|---|---|---|---|
| BORING: | **ST-2** | | |
| LOCATION: Captured with submeter GPS. | | | |
| DATUM: NAD 1983 HARN Adj MN Anoka (US Feet) | | | |
| NORTHING: | 117089 | EASTING: | 500062 |
| START DATE: | 10/02/23 | END DATE: | 10/02/23 |
| SURFACING: | Soil | WEATHER: | Sunny |

| | | | | | |
|---|---|---|---|---|---|
| DRILLER: | M. Hoppe | LOGGED BY: | R. Jett | | |
| SURFACE ELEVATION: | 836.8 ft | RIG: | 7504 | METHOD: | 3 1/4" HSA |

| Elev./ Depth ft | Water Level | Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908) | Sample | Blows (N-Value) Recovery | qp tsf | MC % | Tests or Remarks |
|---|---|---|---|---|---|---|---|
| | | SILTY SAND (SM), fine to medium-grained, trace Gravel, black, moist (TOPSOIL FILL) | | | | | |
| 836.5<br>0.3 | | FILL: SILTY SAND (SM), fine to medium-grained, trace Gravel, organic, black, moist | | 3-3-5-4<br>(8)<br>18" | | | |
| 832.8<br>4.0 | | FILL: CLAYEY SAND (SC), trace Gravel, slightly organic, brown to black, moist | | 2-2-3-4<br>(5)<br>18" | | 39 | P200=35% |
| 830.8<br>6.0 | | POORLY GRADED SAND (SP), fine to medium-grained, trace Gravel, light brown, moist, loose (TERRACE DEPOSIT) | | 4-4-5-5<br>(9)<br>18"<br>3-3-4-4<br>(7)<br>24"<br>3-3-4-5<br>(7)<br>24" | | 3 | |
| 824.8<br>12.0 | ▽ | POORLY GRADED SAND (SP), fine to coarse-grained, trace Gravel, brown, wet, loose (TERRACE DEPOSIT) | | 4-4-4-6<br>(8)<br>24"<br>3-4-4-5<br>(8)<br>24"<br>3-3-4-3<br>(7)<br>24"<br>3-3-4-4<br>(7)<br>24" | | 15 | |
| 816.8<br>20.0 | | END OF BORING<br>Boring then grouted | | | | | Water observed at 13.4 feet when rechecked 24 hours after drilling.<br>Temporary piezometer was installed to 20 feet and removed after water level rechecked. |

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# LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

**Project Number B2308886**
**Geotechnical Evaluation**
**Sylvan Hills Park**
**240 Sylvan Ln NE**
**Fridley, Minnesota**

| | | | |
|---|---|---|---|
| BORING: | **ST-3** | | |
| LOCATION: Captured with submeter GPS. | | | |
| DATUM: NAD 1983 HARN Adj MN Anoka (US Feet) | | | |
| NORTHING: | 177049 | EASTING: | 500147 |
| DRILLER: | M. Hoppe | LOGGED BY: | R. Jett |
| START DATE: | 10/02/23 | END DATE: | 10/02/23 |
| SURFACE ELEVATION: | 837.1 ft | RIG: | 7504 |
| METHOD: | 3 1/4" HSA | | |
| SURFACING: | Soil | WEATHER: | Sunny |

| Elev./ Depth ft | Water Level | | Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908) | | Sample | Blows (N-Value) Recovery | $q_p$ tsf | MC % | Tests or Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 836.4<br>0.7 | | ▨ | SILTY SAND (SM), fine to medium-grained, trace Gravel, black, moist (TOPSOIL FILL) | | | | | | |
| 833.1<br>4.0 | | ▨ | FILL: SILTY SAND (SM), fine to medium-grained, trace Gravel, organic, black, moist | | ⊠ | 2-2-3-4<br>(5)<br>18" | | | |
| 831.1<br>6.0 | | ▥ | ELASTIC SILT (MH), slightly organic, gray, moist (SWAMP DEPOSIT) | 5 | ⊠ | 1-1-1-2<br>(2)<br>20" | | | |
| 823.1<br>14.0 | | ░ | POORLY GRADED SAND with SILT (SP-SM), fine to medium-grained, trace Gravel, light brown, moist, loose (TERRACE DEPOSIT) | | ⊠ | 2-2-3-4<br>(5)<br>24" | | 9 | P200=5% |
| | | | | | ⊠ | 4-5-4-5<br>(9)<br>20" | | | |
| | | | | 10 | ⊠ | 1-4-4-5<br>(8)<br>20" | | | |
| | | | | | ⊠ | 4-3-4-5<br>(7)<br>20" | | 8 | |
| | | | END OF BORING<br>Boring then backfilled with auger cuttings | 15 | | | | | Water not observed when rechecked 24 hours after drilling.<br>Temporary piezometer was installed to 14 feet and removed after water level rechecked. |
| | | | | 20 | | | | | |
| | | | | 25 | | | | | |
| | | | | 30 | | | | | |

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# LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

| | | | |
|---|---|---|---|
| **Project Number B2308886**<br>**Geotechnical Evaluation**<br>**Sylvan Hills Park**<br>**240 Sylvan Ln NE**<br>**Fridley, Minnesota** | BORING: **ST-4** | | |
| | LOCATION: Captured with submeter GPS. | | |
| | DATUM: NAD 1983 HARN Adj MN Anoka (US Feet) | | |
| | NORTHING: 116960 | EASTING: 500096 | |
| DRILLER: M. Hoppe | LOGGED BY: R. Jett | START DATE: 10/02/23 | END DATE: 10/02/23 |
| SURFACE ELEVATION: 837.1 ft | RIG: 7504 | METHOD: 3 1/4" HSA | |
| | | SURFACING: Soil | WEATHER: Sunny |

| Elev./ Depth ft | Water Level | Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908) | Sample | Blows (N-Value) Recovery | $q_p$ tsf | MC % | Tests or Remarks |
|---|---|---|---|---|---|---|---|
| 834.1 | | SILTY SAND (SM), fine to medium-grained, trace Gravel, dark brown to black (TOPSOIL) | | 3-3-4-5<br>(7)<br>24" | | | |
| 3.0<br>831.1 | | POORLY GRADED SAND (SP), fine to medium-grained, trace Gravel, contains seams of Silt, light brown, moist, loose (TERRACE DEPOSIT) | | 3-3-4-3<br>(7)<br>24" | | | |
| 6.0<br>829.1 | | POORLY GRADED SAND (SP), fine to coarse-grained, trace Gravel, brown, moist, loose (TERRACE DEPOSIT) | | 3-3-4-5<br>(7)<br>18" | | | |
| 8.0<br>823.1 | | POORLY GRADED SAND (SP), fine to coarse-grained, trace Gravel, light brown, moist, loose (TERRACE DEPOSIT) | | 3-4-4-5<br>(8)<br>24"<br>3-4-4-3<br>(8)<br>18"<br>3-4-3-3<br>(7)<br>24" | | 3 | P200=2% |
| 14.0 | | END OF BORING<br><br>Boring then backfilled with auger cuttings | | | | | Water not observed when rechecked 24 hours after drilling.<br><br>Temporary piezometer was installed to 14 feet and removed after water level rechecked. |

# LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

**Project Number B2308886**
**Geotechnical Evaluation**
**Sylvan Hills Park**
**240 Sylvan Ln NE**
**Fridley, Minnesota**

| | | | |
|---|---|---|---|
| BORING: | **ST-5** | | |
| LOCATION: Captured with submeter GPS. | | | |
| DATUM: NAD 1983 HARN Adj MN Anoka (US Feet) | | | |
| NORTHING: | 116913 | EASTING: | 500185 |
| DRILLER: | M. Hoppe | LOGGED BY: | R. Jett |
| START DATE: | 10/02/23 | END DATE: | 10/02/23 |
| SURFACE ELEVATION: | 836.6 ft | RIG: | 7504 |
| METHOD: | 3 1/4" HSA | | |
| SURFACING: | Soil | WEATHER: | Sunny |

| Elev./ Depth ft | Water Level | Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908) | Sample | Blows (N-Value) Recovery | $q_p$ tsf | MC % | Tests or Remarks |
|---|---|---|---|---|---|---|---|
| 836.3<br>0.3 | | SILTY SAND (SM), fine to medium-grained, trace Gravel, dark brown to black, moist (TOPSOIL FILL) | | | | | |
| 832.6<br>4.0 | | FILL: SILTY SAND (SM), fine to medium-grained, trace Gravel, black, moist | ⋈ | 3-4-4-4<br>(8)<br>16" | | | |
| 830.6<br>6.0 | | ELASTIC SILT (MH), contains seams of Peat, organic, gray to black, moist (SWAMP DEPOSIT) | ⋈ | 2-1-1-1<br>(2)<br>18" | | | |
| 828.6<br>8.0 | | ELASTIC SILT (MH), organic, tan to gray, moist (SWAMP DEPOSIT) | ⋈ | 1-1-1-1<br>(2)<br>24" | | | |
| 825.6<br>11.0 | | ORGANIC CLAY (OL), contains seams of Silt, gray, moist (SWAMP DEPOSIT) | ⋈<br>⋈ | 0-0-0-1<br>24"<br>0-0-0-6<br>24" | | | |
| 818.6<br>18.0 | ▽ | POORLY GRADED SAND (SP), fine to medium-grained, trace Gravel, light brown, moist to wet, loose to medium dense (TERRACE DEPOSIT) | ⋈<br>⋈<br>⋈ | 5-7-8-10<br>(15)<br>20"<br>4-5-5-6<br>(10)<br>20"<br>5-5-9-13<br>(14)<br>24" | | 21 | P200=2% |
| 816.6<br>20.0 | | POORLY GRADED SAND (SP), fine to coarse-grained, trace Gravel, light brown, wet, loose (TERRACE DEPOSIT) | ⋈ | 3-5-5-8<br>(10)<br>24" | | 22 | |
| | | END OF BORING<br>Boring then grouted | | | | | Water observed at 13.2 feet when rechecked 24 hours after drilling.<br>Temporary piezometer was installed to 20 feet and removed after water level rechecked. |

# LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

**Project Number B2308886**
**Geotechnical Evaluation**
**Sylvan Hills Park**
**240 Sylvan Ln NE**
**Fridley, Minnesota**

| | | | |
|---|---|---|---|
| BORING: | **ST-6** | | |
| LOCATION: Captured with submeter GPS. | | | |
| DATUM: NAD 1983 HARN Adj MN Anoka (US Feet) | | | |
| NORTHING: | 116853 | EASTING: | 500134 |
| DRILLER: | M. Hoppe | LOGGED BY: | R. Jett |
| START DATE: | 10/02/23 | END DATE: | 10/02/23 |
| SURFACE ELEVATION: | 836.2 ft | RIG: | 7504 |
| METHOD: | 3 1/4" HSA | | |
| SURFACING: | Soil | WEATHER: | Sunny |

| Elev./ Depth ft | Water Level | Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908) | Blows (N-Value) Recovery | qp tsf | MC % | Tests or Remarks |
|---|---|---|---|---|---|---|
| 835.8<br>0.4 | | SILTY SAND (SM), fine to medium-grained, trace Gravel, black, moist (TOPSOIL) | | | | |
| 833.2<br>3.0 | | LEAN CLAY (CL), slightly organic, dark gray, moist (SWAMP DEPOSIT) | 2-1-1-1<br>(2)<br>11" | | | |
| 832.2<br>4.0 | | PEAT (PT), black, moist (SWAMP DEPOSIT) | | | | |
| 830.2<br>6.0 | | ELASTIC SILT (MH), contains seams of Peat, organic, gray to black, moist (SWAMP DEPOSIT) | 0-0-0-0<br>WOH/18"<br>10" | | | |
| 828.2<br>8.0 | | PEAT (PT), contains seams of Elastic Silt, black to dark brown, moist (SWAMP DEPOSIT) | 1-1-1-2<br>(2)<br>24" | | | |
| 825.2<br>11.0 | | ORGANIC CLAY (OL), ELASTIC SILT layers, gray, moist (SWAMP DEPOSIT) | 0-0-1-2<br>(1)<br>24"<br>0-0-2-1<br>(2)<br>24" | | | |
| 822.2<br>14.0 | ▽ | POORLY GRADED SAND (SP), fine to medium-grained, trace Gravel, light brown, moist, medium dense (TERRACE DEPOSIT) | 2-5-6-6<br>(11)<br>24" | | 8 | P200=4% |
| | | END OF BORING<br><br>Boring then backfilled with auger cuttings | | | | Water observed at 12.5 feet when rechecked 24 hours after drilling.<br><br>Temporary piezometer was installed to 14 feet and removed after water level rechecked. |

Depth scale: 5, 10, 15, 20, 25, 30

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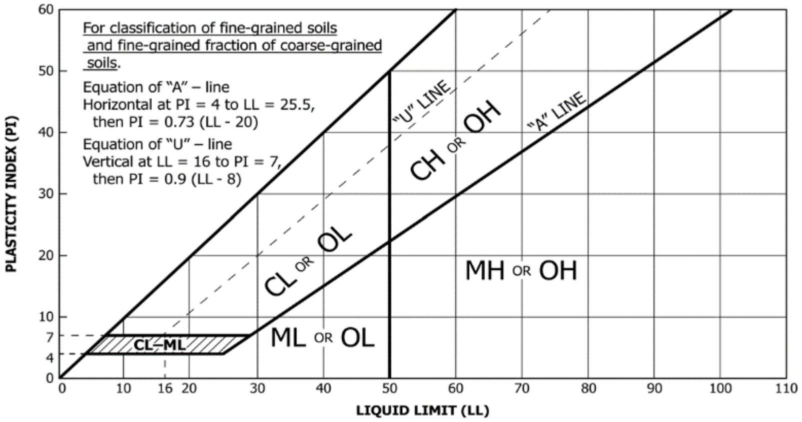
# Descriptive Terminology of Soil

Based on Standards ASTM D2487/2488
(Unified Soil Classification System)

| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests$^A$ | | | | Soil Classification | |
|---|---|---|---|---|---|
| | | | | Group Symbol | Group Name$^B$ |
| **Coarse-grained Soils** (more than 50% retained on No. 200 sieve) | **Gravels** (More than 50% of coarse fraction retained on No. 4 sieve) | **Clean Gravels** (Less than 5% fines$^C$) | $C_u \geq 4$ and $1 \leq C_c \leq 3^D$ | GW | Well-graded gravel$^E$ |
| | | | $C_u < 4$ and/or ($C_c < 1$ or $C_c > 3$)$^D$ | GP | Poorly graded gravel$^E$ |
| | | **Gravels with Fines** (More than 12% fines$^C$) | Fines classify as ML or MH | GM | Silty gravel$^{E\ F\ G}$ |
| | | | Fines Classify as CL or CH | GC | Clayey gravel$^{E\ F\ G}$ |
| | **Sands** (50% or more coarse fraction passes No. 4 sieve) | **Clean Sands** (Less than 5% fines$^H$) | $C_u \geq 6$ and $1 \leq C_c \leq 3^D$ | SW | Well-graded sand$^I$ |
| | | | $C_u < 6$ and/or ($C_c < 1$ or $C_c > 3$)$^D$ | SP | Poorly graded sand$^I$ |
| | | **Sands with Fines** (More than 12% fines$^H$) | Fines classify as ML or MH | SM | Silty sand$^{F\ G\ I}$ |
| | | | Fines classify as CL or CH | SC | Clayey sand$^{F\ G\ I}$ |
| **Fine-grained Soils** (50% or more passes the No. 200 sieve) | **Silts and Clays** (Liquid limit less than 50) | Inorganic | PI > 7 and plots on or above "A" line$^J$ | CL | Lean clay$^{K\ L\ M}$ |
| | | | PI < 4 or plots below "A" line$^J$ | ML | Silt$^{K\ L\ M}$ |
| | | Organic | $\frac{\text{Liquid Limit – oven dried}}{\text{Liquid Limit – not dried}} < 0.75$ | OL | Organic clay $^{K\ L\ M\ N}$<br>Organic silt $^{K\ L\ M\ O}$ |
| | **Silts and Clays** (Liquid limit 50 or more) | Inorganic | PI plots on or above "A" line | CH | Fat clay$^{K\ L\ M}$ |
| | | | PI plots below "A" line | MH | Elastic silt$^{K\ L\ M}$ |
| | | Organic | $\frac{\text{Liquid Limit – oven dried}}{\text{Liquid Limit – not dried}} < 0.75$ | OH | Organic clay $^{K\ L\ M\ P}$<br>Organic silt $^{K\ L\ M\ Q}$ |
| **Highly Organic Soils** | | Primarily organic matter, dark in color, and organic odor | | PT | Peat |

A. Based on the material passing the 3-inch (75-mm) sieve.
B. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
C. Gravels with 5 to 12% fines require dual symbols:
    GW-GM well-graded gravel with silt
    GW-GC well-graded gravel with clay
    GP-GM poorly graded gravel with silt
    GP-GC poorly graded gravel with clay
D. $C_u = D_{60} / D_{10}$ $\qquad C_c = (D_{30})^2 / \ (D_{10}\ x\ D_{60})$
E. If soil contains ≥ 15% sand, add "with sand" to group name.
F. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
G. If fines are organic, add "with organic fines" to group name.
H. Sands with 5 to 12% fines require dual symbols:
    SW-SM well-graded sand with silt
    SW-SC well-graded sand with clay
    SP-SM poorly graded sand with silt
    SP-SC poorly graded sand with clay
I. If soil contains ≥ 15% gravel, add "with gravel" to group name.
J. If Atterberg limits plot in hatched area, soil is CL-ML, silty clay.
K. If soil contains 15 to < 30% plus No. 200, add "with sand" or "with gravel", whichever is predominant.
L. If soil contains ≥ 30% plus No. 200, predominantly sand, add “sandy” to group name.
M. If soil contains ≥ 30% plus No. 200 predominantly gravel, add “gravelly” to group name.
N. PI ≥ 4 and plots on or above “A” line.
O. PI < 4 or plots below “A” line.
P. PI plots on or above “A” line.
Q. PI plots below “A” line.



### Laboratory Tests

| | | | |
|---|---|---|---|
| **DD** | Dry density, pcf | $q_p$ | Pocket penetrometer strength, tsf |
| **WD** | Wet density, pcf | $q_U$ | Unconfined compression test, tsf |
| **P200** | % Passing #200 sieve | **LL** | Liquid limit |
| **MC** | Moisture content, % | **PL** | Plastic limit |
| **OC** | Organic content, % | **PI** | Plasticity index |

### Particle Size Identification

| | |
|---|---|
| Boulders | over 12" |
| Cobbles | 3" to 12" |
| Gravel | |
| Coarse | 3/4" to 3" (19.00 mm to 75.00 mm) |
| Fine | No. 4 to 3/4" (4.75 mm to 19.00 mm) |
| Sand | |
| Coarse | No. 10 to No. 4 (2.00 mm to 4.75 mm) |
| Medium | No. 40 to No. 10 (0.425 mm to 2.00 mm) |
| Fine | No. 200 to No. 40 (0.075 mm to 0.425 mm) |
| Silt | No. 200 (0.075 mm) to .005 mm |
| Clay | < .005 mm |

### Relative Proportions$^{L,\ M}$

| | |
|---|---|
| trace | 0 to 5% |
| little | 6 to 14% |
| with | ≥ 15% |

### Inclusion Thicknesses

| | |
|---|---|
| lens | 0 to 1/8" |
| seam | 1/8" to 1" |
| layer | over 1" |

### Apparent Relative Density of Cohesionless Soils

| | |
|---|---|
| Very loose | 0 to 4 BPF |
| Loose | 5 to 10 BPF |
| Medium dense | 11 to 30 BPF |
| Dense | 31 to 50 BPF |
| Very dense | over 50 BPF |

| Consistency of Cohesive Soils | Blows Per Foot | Approximate Unconfined Compressive Strength |
|---|---|---|
| Very soft | 0 to 1 BPF | < 0.25 tsf |
| Soft | 2 to 4 BPF | 0.25 to 0.5 tsf |
| Medium | 5 to 8 BPF | 0.5 to 1 tsf |
| Stiff | 9 to 15 BPF | 1 to 2 tsf |
| Very Stiff | 16 to 30 BPF | 2 to 4 tsf |
| Hard | over 30 BPF | > 4 tsf |

### Moisture Content:

**Dry:** Absence of moisture, dusty, dry to the touch.
**Moist:** Damp but no visible water.
**Wet:** Visible free water, usually soil is below water table.

### Drilling Notes:

**Blows/N-value:** Blows indicate the driving resistance recorded for each 6-inch interval. The reported N-value is the blows per foot recorded by summing the second and third interval in accordance with the Standard Penetration Test, ASTM D1586.

**Partial Penetration:** If the sampler could not be driven through a full 6-inch interval, the number of blows for that partial penetration is shown as #/x" (i.e. 50/2"). The N-value is reported as "REF" indicating refusal.

**Recovery:** Indicates the inches of sample recovered from the sampled interval. For a standard penetration test, full recovery is 18", and is 24" for a thinwall/shelby tube sample.

**WOH:** Indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

**WOR:** Indicates the sampler penetrated soil under weight of rods alone; hammer weight and driving not required.

**Water Level:** Indicates the water level measured by the drillers either while drilling ( ▽ ), at the end of drilling ( ▼ ), or at some time after drilling ( ▼ ).

**Sample Symbols**

| | | | |
|---|---|---|---|
| ☒ | Standard Penetration Test | ▮ | Rock Core |
| ⧗ | Modified California (MC) | ■ | Thinwall (TW)/Shelby Tube (SH) |
| ◧ | Auger | ▽ | Texas Cone Penetrometer |
| ✋ | Grab Sample | ▽ | Dynamic Cone Penetrometer |

5/2021