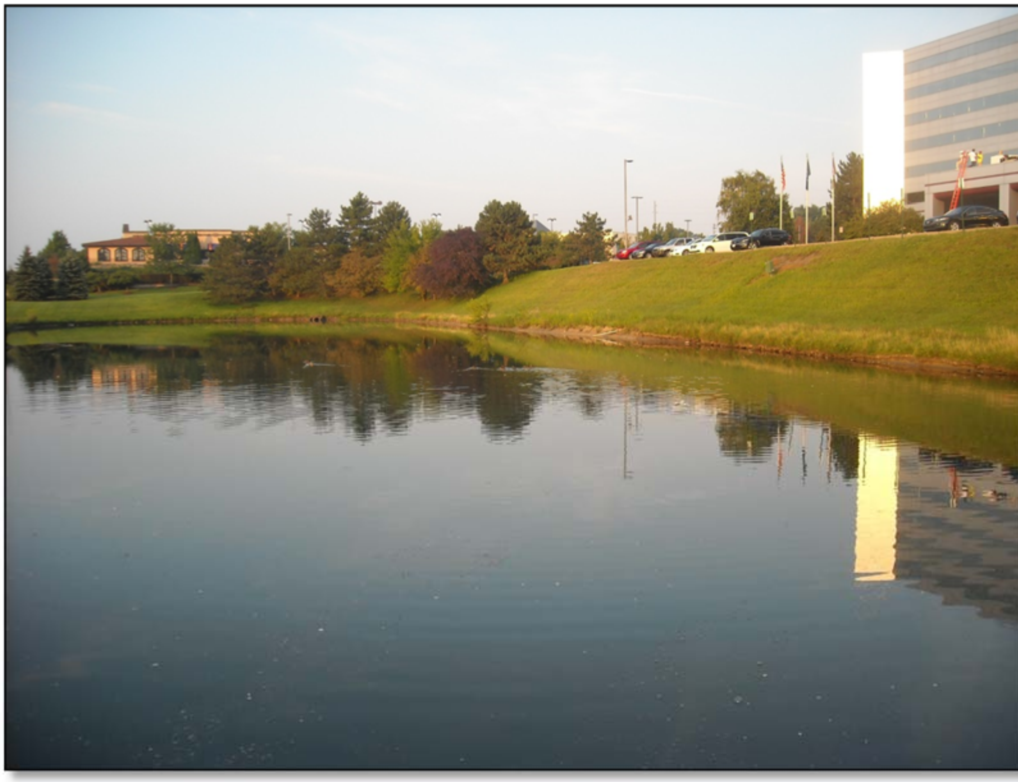
2014 STORM WATER
MASTER PLAN UPDATES



October 20, 2014
SDA Job No.: NV13007

cityofnovi.org

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CITY OF NOVI

2014 STORM WATER MASTER PLAN UPDATES

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SECTION 1 - PROJECT SUMMARY

Purpose and Background

The City of Novi Department of Public Services has identified several areas of storm water conveyance concerns at various locations in the City. The overall intentions of this report are to review these specific areas to develop potential measures to reduce or eliminate the problems and improve storm water quality, and develop cost estimates for future budgeting and planning purposes.

The following areas were evaluated as part of this project:

Subject Area	Evaluated Item / Area of Concern
Lexington Green	• Rear yard flooding • Overland flow between detention ponds
Oakland Glens Mobile Home Park	• Detention pond overflowing into yards and street
Orchard Hill Place Detention	• Damage at inlet and outlet structures • Reduced capacity due to sedimentation
Village Oaks / Village Woods	• Inlet and outlet structure condition • Access to structures for maintenance
Streambank Erosion (various)	• Middle Branch of Rouge River downstream of Grand River to the southerly City Limits (excluding Meadowbrook Lake) • Ingersol Creek downstream of Ten Mile to Meadowbrook Lake • Bishop Creek downstream of 11 Mile to Ingersol Creek

The following paragraphs present a brief summary of each area evaluated, potential measures to improve the situation(s), and cost estimate ranges. Refer to the full sections of this report for detailed discussion of the subject areas and presentation of options for improvements.

Lexington Green

The Lexington Green subdivision is situated south of Nine Mile Road and west of Taft Road. The areas of concern are along Galway Drive from Taft to the west. During heavy and/or long duration rain events, residents report overland flow causing rear-yard flooding between a subdivision detention pond and a wetland in the Pheasant Hills subdivision to the south (which is in the City of Northville). North of the wetland, the water level can rise, leading to rear-yard inundation for homes in the immediate vicinity.

Based on a report prepared by the Oakland County Water Resources Commissioner's (OCWRC) Office in 2012, and field and topographic observations as part of this study, there are several contributing factors which may lead to the flooding. The detention basin is undersized, the outlet from the basin to the wetland lacks capacity, the wetland pond contains significant sediment reducing capacity, and the outlet from the wetland pond to the Randolph Street Drain appears restricted. The study prepared in 2012 presents several potential improvements, all of which require property impacts south of the Lexington Green Subdivision in Northville. This report examined additional options which do not require work outside of the City of Novi.

Evaluated Option	Estimated Construction Cost
Storing storm water upstream of existing basin	$300,000 - $370,000
Construct additional surface detention basin upstream of existing basin	N/A – not viable
Redirecting flow to Regional Basin	$850,000

Refer to Section 2 for a detailed report on the evaluation of the Lexington Green Subdivision.

Oakland Glens Mobile Home Park

The Oakland Glens mobile home park is located north of Thirteen Mile Road and east of Novi Road. The private detention pond in the northerly portion of the site is reported to rise significantly during larger storm events, flooding yards and encroaching on Montmorency Drive (northern loop road) pavement. After it was brought to the City's attention, this drainage issue was reviewed to determine if there were any improvements required upstream and downstream of this area. The condition of the detention pond was reviewed (capacity, inlets, outlets), as well as any potential downstream constraints including the culverts under Novi Road and the ultimate discharge into Walled Lake.

Utilizing existing information, (2 foot GIS data), the volume of the pond cannot be calculated due to lack of information. However, the pond is exhibiting overtopping, which is likely a combination of inflow greater than has been determined, a reduction in stormwater storage capacity due to sedimentation and overgrowth, and the poor condition of the outlet pipe to the adjacent wooded wetland. Potential options to improve the conditions are summarized in the following table.

Evaluated Option	Estimated Construction Cost
Dredge detention pond – increase capacity	$225,000
Clean out ditches between sections of pond	$59,000
Re-route upstream (inflow) drainage	$231,000
Replace and upsize outlet culvert	$32,000

Refer to Section 3 for a detailed report on the current conditions at Oakland Glens, and further discussion on the suggested mitigation measures.

Orchard Hill Place Detention Basins

There are two storm water detention basins north of Eight Mile Road on either side of Haggerty Road which serve the Orchard Hill Place development as well as the businesses on the east side of Haggerty across from the Sheraton hotel. The westerly basin (Orchard Hill Place Basin #1) is on the west side of Haggerty Road in front of the Sheraton hotel. The easterly basin (Orchard Hill Place Basin #2) is on the east side of Haggerty Road north of the Taco Bell restaurant.

Concerns with these basins include deterioration at the inlet and outlet structures, reduced capacity due to sedimentation (particularly basin #2), downstream ditch condition, and maintenance responsibilities due to an unusual ownership arrangement. The following table includes a summary of the potential options to improve the conditions of the Orchard Hill Place Basins.

Evaluated Option	Estimated Construction Cost
Revise ownership and maintenance responsibilities	N/A – potential for $0 transfer
Dredge detention basin #2 – increase capacity	$51,000
Reconstruct outlet of basin #2	$29,000
Remove outlet restriction on basin #1 – increase detention capacity of basin	$19,000
Drainage course stabilization downstream of basin #2	$26,000

Refer to Section 4 for a detailed description of the existing conditions and proposed improvements for the basins.

Village Oaks and Village Wood Lakes

Village Oaks Lake and Village Wood Lake are man-made ponds which receive storm water from subdivisions east of Meadowbrook Road and north of Nine Mile Road. Each pond has several structures at various locations which are the outlet of a storm sewer run and an inlet to the pond. The condition of these inlets is a concern as they have not been maintained appropriately over the years, and are the responsibility of the City. Lack of access to the structures is a primary reason for the lack of maintenance – several of the inlets are located directly behind homes in steep or difficult terrain, and there are no easements in place to allow access. Additionally, the safety of visitors to Village Wood Park and the security of the outlet structure are a concern.

The following table presents the primary options to improve the access and condition problems.

Evaluated Option	Estimated Construction Cost
Acquire easements to have access to structures	$150,000
Repair deteriorated infrastructure	$819,000
Prevent public access to the outlet structure at park	$23,000

Refer to Section 5 for a detailed presentation of the observed deterioration, options for repairs, and cost estimates.

Streambank Stabilization

The City has identified several sections of streambank which have exhibited erosion in the last several years. The erosion is loading the water with sediment which reduces water quality and settles in ponds, causes trees to partially fall blocking flow, and in some cases threatens private and public property.

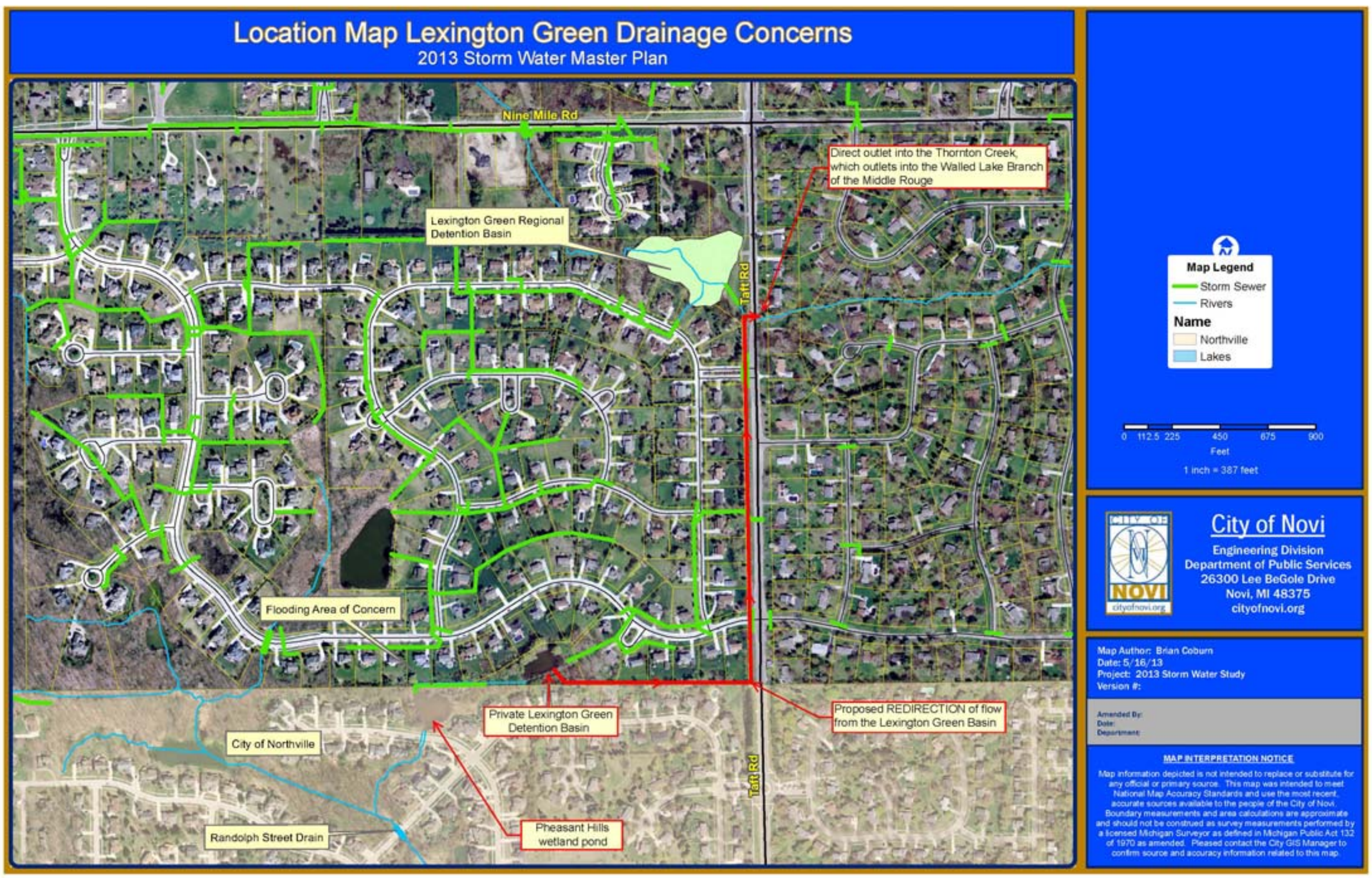
Several stream segments were evaluated, and the majority of the segments were walked to locate and classify the damage, and develop specific remediation and estimates for the most severe locations.

56 specific sites of concern were identified. Of these, thirteen (13) of the sites were further identified as "priority sites of concern" based on the resulting erosion characteristics, length, and potential to damage property. The estimated costs to repair the priority sites range from $20,000 to $832,000, as detailed in Section 6 of this report.

SECTION 2 – LEXINGTON GREEN
Storm Water Drainage and Flooding Concerns

BACKGROUND

Based on concerns and complaints of residents living in the vicinity of the southern-most private Lexington Green detention basin and the Pheasant Hills wetland pond, the Oakland County Water Resources Commissioners (OCWRC) Office conducted a study in 2012 to evaluate the causes of rear-yard flooding and overland flow between the ponds, and potential improvements to alleviate the problems. The report, prepared by Applied Science, Inc. dated May 21, 2012, thoroughly reviewed the contributing factors to the flooding and proposed potential improvement options to reduce flooding in the area.



In the 2012 report, an analysis of the Lexington Green basin, the outlet sewer to the Pheasant Hills wetland pond, and the outlet to the Randolph Street Drain was performed. The conclusions were that the private Lexington Green basin is undersized for the 10-year design storm, the outlet sewer is undersized, the storage volume of the Pheasant Hills wetland is reduced due to sedimentation, and the outlet culvert under Mill Pond Court required cleaning (cleaned in September 2013). Any of these issues individually could cause the overland flow and flooding observed by residents, and in combination, they result in problems with a greater frequency than may otherwise be expected.

The five potential improvements recommended in the 2012 report focus on increasing the capacity of the outlet from the Pheasant Hills wetland to the Randolph Street Drain, increasing the capacity of the outlet from the private Lexington Green basin to the wetland, and grading around the wetland to contain what is currently an overflow condition. All recommended improvements involve impacts adjacent to or within the Pheasant Hills wetland, which is located in the City of Northville, not the City of Novi.

The 2012 report concludes by stating that other potential options not investigated include storing storm water within the storm sewer prior to it reaching the private Lexington Green Basin, as well as redirecting flow from the basin to a different receiving water other than the Pheasant Hills wetland. The focus of this report is to evaluate what would be required to implement the options suggested but not detailed in the 2012 report.

FIELD INVESTIGATION

In October 2013, Spalding DeDecker Associates (SDA) met on-site with the City of Novi Department of Public Services (DPS) staff for a review of the private Lexington Green basin, Pheasant Hills wetland pond, overland flow / flood-prone areas, and outlets from the basin and pond.

Lexington Green Detention Basin Outlet

The basin inlet and outlets were located and appear to be in fair condition, without excessive sedimentation or other restrictions. The route that overland flow water takes when the pond banks are overtopped was walked, and crosses behind several homes along Galway Drive.

The Pheasant Ridge wetland pond and outlet to the Randolph Street Drain were examined, and sediment was observed at the upstream invert.

Pheasant Ridge Wetland Pond – heavy sedimentation

REVIEW OF ADDITIONAL OPTIONS

Additional Detention Upstream of Lexington Green Basin

Two primary options were reviewed for additional detention of storm water prior to it reaching the private basin – storage within existing or proposed underground piping, and construction of an additional basin.

As presented the 2012 report, the capacity of the existing private basin is 15,500 cubic-feet. In order to retain the existing outlet sewer to the Pheasant Hills wetland and contain a 10-year design storm, the basin should have a capacity of 89,000 cubic-feet, 73,500 cubic-feet more than the basin's current capacity. Any storage available or created upstream of the basin could be utilized to increase the effective capacity of the basin and potentially reduce overflow events.

Options for Storing Storm Water Upstream of the Basin

1. Existing storm sewer - The existing storm sewer system upstream of the private detention basin in Lexington Green Subdivision has a storage capacity of approximately 5,100 cubic-feet of in-pipe storage, which could be utilized by restricting the outlet to the basin with a small diameter pipe. This would yield approximately 7% of the deficient storage volume at a relatively small initial cost; however, frequent routine cleaning would be required to prevent the build-up of sediments, and may accelerate the deterioration of subdivision roads if the existing underdrain system is not allowed to drain freely.

2. Replacement storm sewer - This option is similar to the first option, but would involve replacing the existing storm sewer in its current location with larger pipe sizes, and restricting the flow to the basin, providing additional storage within the system. By

upsizing the 1,500 feet of existing storm sewer to 36-inch diameter pipes, the system could store approximately 10,500 cubic-feet upstream of the basin. This option would yield about 14% of the shortfall in storage volume of the existing basin, at an estimated cost of $294,000.

3. <u>Underground Detention</u> – Underground detention provides additional storage utilizing large diameter pipes and structures, specifically designed to accept large flows quickly and release the stored volume over time. A system could theoretically be installed either within the existing storm sewer easements, or within the existing right-of-way and common areas of Lexington Green Subdivision. One area where this may fit is the circle drive, just east of the existing easement to the detention basin access. A detailed system layout was not attempted, but for planning purposes a unit cost of $3/cubic-foot was used which assumes there are no land acquisition costs. The estimated total cost associated with the construction of an underground detention system which could accommodate the full deficient design storm volume of 76,500 cubic-feet is $370,000.

Additional Detention Basin

4. Aerial and property boundary of the Lexington Green Subdivision were reviewed for potential new locations for additional detention basins to make up part or all of the deficiency in the existing basin. Based upon this review, there are no ideal locations for an additional basin within the Lexington Green Subdivision.

Redirecting Basin Outlet Flow Away from Receiving Wetland Pond

5. The potential to redirect flow from the private Lexington Green detention basin to a different receiving water other than the Pheasant Hill wetland pond was also examined. If storm sewer was installed from the private basin at the south edge of the subdivision to the Lexington Green Regional Detention Basin to the north (south of Nine Mile, just west of Taft), a significant amount of flow would be removed from the Pheasant Hill wetland, and overland flows could be reduced. However, to reroute this flow, approximately 3,150 feet of 30-inch storm sewer pipe would be required, of which approximately 500 feet would require easements to cross through six affected parcels. It was also estimated that approximately 500 feet of the storm sewer pipe would have to be directional drilled/bored to avoid disturbing private property along Taft Road. The cost associated with the redirecting of the storm flow to the Lexington Green Regional Detention Basin, including the construction incidentals, is estimated at approximately $705,000, which does not include the costs of permanent easement or right-of-way acquisitions which would be required (estimated at $120,000). However, this scenario is not a viable alternative due to the topographic limitations in that area. Due to the constraints caused by the existing topography and the proximity of the adjacent properties, to maintain an adequate cover depth over the new pipe it would enter the basin approximately one-foot below the bottom of the basin. Therefore, the proposed storm sewer cannot be routed to the regional detention basin. This means the redirected flow from the private Lexington Green Basin would bypass all detention and outlet directly into Thornton Creek, which discharges into the Walled Lake Branch of the Middle Rouge. Since all storm waters must be detained or retained, per the Oakland County Water Resource Commissioner's Office *Design Standards for Storm Water*

Facilities, prior to discharging into the drainage network (including Thornton Creek) as regulated by the U.S. Environmental Protection Agency (EPA) per the National Pollutant Discharge Elimination System (NPDES) Phase II requirements, this would not be a feasible option.

Redirecting Tributary Area 1 Flow Away from Private Basin

5a. An abbreviated version of the above option was also explored to determine if flow from one area identified as “off-site” in the 2012 report could be removed from the area tributary to the private Lexington Green Detention Basin to provide an incremental benefit in terms of reducing flooding. Specifically, Area 1 (which is depicted on Figure 1 of the 2012 report, encompasses Taft Road right-of-way from Bradburn Court in the City of Northville to Byrne Drive in Novi, plus a portion of Connemara Hills subdivision east of Taft Road) contributes flow from 12.1 acres of the basin’s 36-acre total contributing area. According to the 2012 report, for a 10-year, 24-hour storm event, redirecting flow from Area 1 to a different receiving water would remove 8.9 cfs of the total 24.7 cfs that would otherwise discharge to the private basin, or an approximate 36% reduction in flow volume. However, the same topographical limitations would be experienced in this scenario as previously discussed in option 5. Therefore, without the ability to meet the Oakland County Water Resources Commissioner’s requirements and the EPA’s NPDES Phase II regulations, this would not be a feasible option.

PRELIMINARY ESTIMATES

Planning cost estimates for the options are presented in the following tables.

Option 2. *Storing Storm Flow Upstream (Upsize Existing Sewer In-Place)*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$23,500	1	$23,500
36-inch Storm Sewer	Feet	$80	1500	$120,000
36-inch Storm Sewer Directional Bore	Feet	$500	100	$50,000
Restoration	LSum	$18,000	1	$18,000
Traffic Control	LSum	$23,500	1	$23,500
			Contingency (25%)	*$59,000*
			Estimate =	**$294,000**

Option 3. *Storing Storm Flow Upstream (Underground Detention)*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$30,000	1	$30,000
Underground Detention	Cft	$3.00	73,500	$220,500
Restoration (0.5 acres)	LSum	$20,000	1	$20,000
Traffic Control	LSum	$25,000	1	$25,000
			Contingency (25%)	*$74,000*
			Estimate =	**$369,500**

Option 5. *Redirecting Basin Outlet Flow Away from Receiving Wetland Pond*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$50,000	1	$50,000
30-inch Storm Sewer	Feet	$75	2600	$195,000
30-inch Storm Sewer Directional Bore	Feet	$500	550	$275,000
Restoration	LSum	$25,000	1	$25,000
Traffic Control	LSum	$40,000	1	$40,000
Easement Acquisition	Sft	$12	10,000	$120,000
			Contingency (25%)	*$145,000*
			Estimate =	**$850,000**

Option 5a. *Redirecting Tributary Area 1 Flow Away from Private Basin*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$14,000	1	$14,000
30-inch Storm Sewer	Feet	$75	1000	$75,000
30-inch Storm Sewer Directional Bore	Feet	$500	50	$25,000
Storm Catch Basin	Each	$1,750	5	$8,750
Restoration	LSum	$15,000	1	$15,000
Traffic Control	LSum	$20,000	1	$20,000
			Contingency (25%)	*$39,500*
			Estimate =	**$197,250**

Please note that the contingency is each of these estimates includes permitting costs, soil erosion control measures, and miscellaneous work items to complete the improvement. The costs do not include any engineering services.

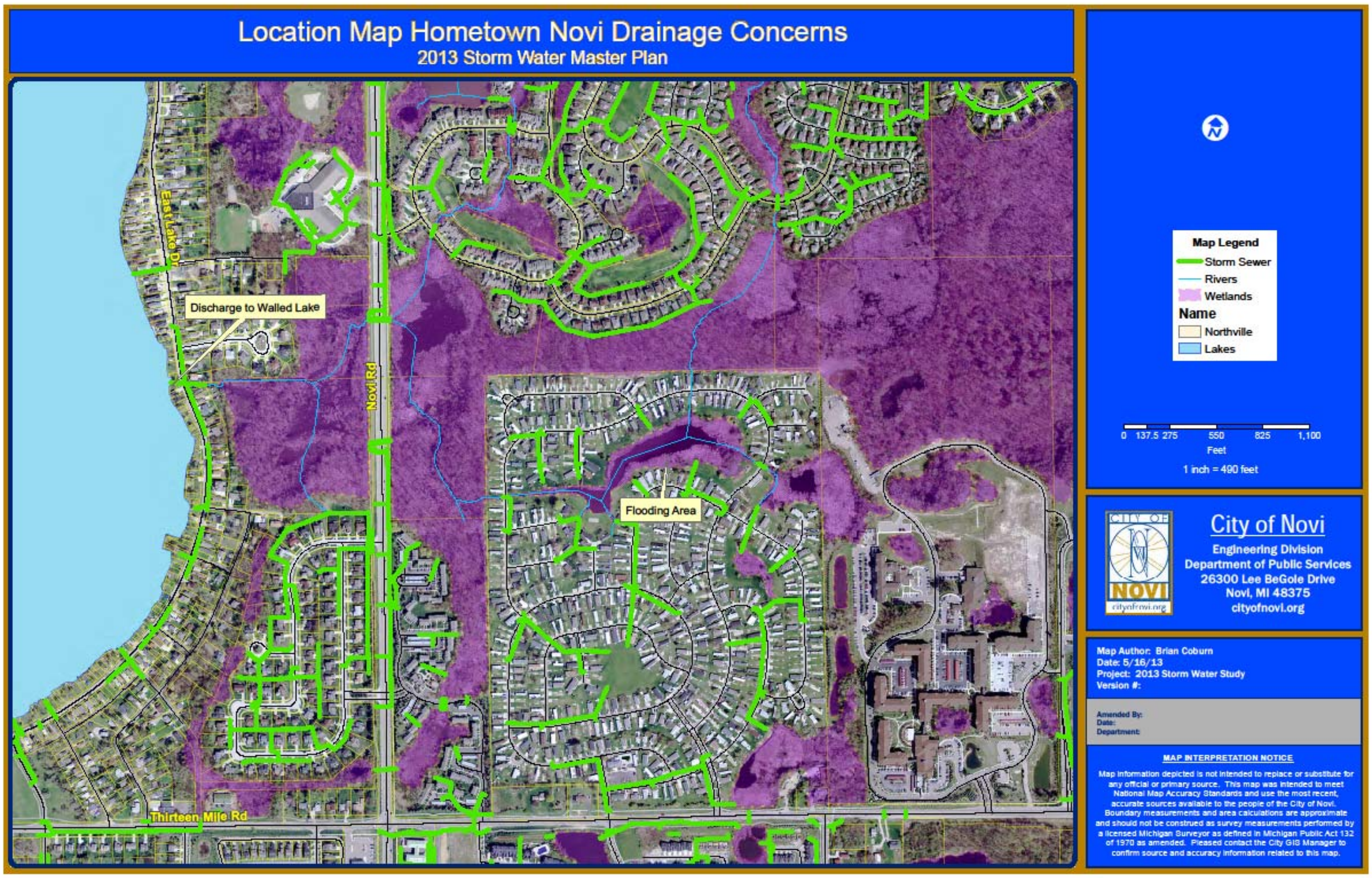
CONCLUSIONS

All of these options involve disturbance within the Lexington Green Subdivision or City of Novi property only, and not in the City of Northville (like those presented in the 2012 report). However, other than the least effective option (Option 1), the feasible options all require significant retrofit of the detention system within the fully developed subdivision at extremely high costs. Therefore, none of the options evaluated are regarded as reasonable given the extent of the disturbance, costs, and limited improvement. The options presented in the 2012 study may be more reasonable when considering cost, relative ease of construction, and benefit.

SECTION 3 – OAKLAND GLENS MOBILE HOME PARK
Storm Water Flooding Concerns

INTRODUCTION

This report examines the Oakland Glens Mobile Home Park (formerly Hometown Novi, formerly Chateau Estates), which is located northeast of the intersection of Thirteen Mile Road and Novi Road. This report describes identified problem areas presented for review and observed in the field, and potential and recommended mitigation measures.



BACKGROUND

During major storm events, the privately owned detention pond in the northern portion of Oakland Glens overflows into adjacent yards and streets. The detention pond receives flow from within the site as well as off-site. The mobile home park is bounded on the west, the north, and partially on the east sides by a wooded wetland area. Refer to the above location map.

Flow from outside sources enters the site from areas to the north and east. The northerly inflow appears to originate in the Maples of Novi subdivision, and also includes water from the wooded wetland area north and east of the site. Water also enters the east end of the detention pond through a 42-inch corrugated metal pipe (CMP) culvert, which includes flows originating within the site as well as from off-site areas to the east. Although this is a private site, the City decided to review this drainage concern to determine if any improvements were necessary upstream or downstream of this site.

The detention pond is generally a continuous body of water with marshy overgrown wet areas, which flows to the west. The outlet of the pond to the wooded wetland to the west is through a 30-inch concrete culvert, which has 4- to 8-inches of sediment within the pipe.

Water leaving the detention pond flows westerly through the wooded wetland, continuing to the west through culverts crossing under Novi Road, which consist of three 43-inch-tall, 68-inch-wide elliptical culverts. There are also two culverts south of this crossing which appear to function as an overflow for the wetland area, and were observed to be dry.

Novi Road Crossing

Flows continue westerly through wetlands and areas of standing water. The ultimate discharge for the drainage system is westerly under East Lake Drive to Walled Lake through a single 43-inch by 68-inch elliptical culvert.

FIELD INVESTIGATIONS

In October 2013, Spalding DeDecker Associates, Inc. (SDA) met onsite with the City of Novi Department of Public Services (DPS) staff for a review of the ponds and outlets. This field review included locating the outlet structure at Walled Lake, the culvert crossing under East Lake Drive, the culverts crossing under Novi Road, and the two culvert crossings in Oakland Glens, which include Montmorency Drive culvert to the west and Montmorency Drive culvert to the east.

These locations were surveyed on November 18, 2013, and it was found that across this drainage area, there was approximately 4 feet of fall from Oakland Glens to Walled Lake, which is a distance of approximately one half-mile. This is a very shallow slope (0.15% average) which likely contributes to the flooding by backing up water into Oakland Glens. Based on this information, there may not be a feasible solution to completely control the flooding. Remediation options are described later in the report.

Outlet under Montmorency Drive

A summary of the pond and culvert drainage from the mobile home park to Walled Lake (direction of flow) is presented below.

Location	Pipe Invert (outlet)	Water Elevation (11/18/2013)
East end of pond – 42” CMP (inlet)	934.21	936.21
West end of pond – 30” Conc (outlet)	932.75	934.44
Novi Road Culvert 43” x 68” Conc (triple culvert)	932.94 (lowest)	933.83
East Lake Drive Culvert (outlet to Walled Lake) 43” x 68” Conc (single culvert)	930.81	932.23

As noted in the table, the invert of the outlet culvert from the mobile home park pond is slightly lower than the invert of the downstream crossing of Novi Road. In general, the mobile home park site is just a few feet above the surrounding wooded wetland and detention pond, and the water flowing through the area moves slowly.

PRELIMINARY DETENTION POND CAPACITY

The volume of the existing detention pond cannot be calculated using the existing GIS 2-foot contour map due to the lack of contour information in the pond area. In order to determine the volume of the pond, a detailed topographic survey of the pond and surrounding area will need to be completed.

Based on field observations and the elevation of the 30” outlet pipe, it appears that excavating accumulated silt and debris would provide additional stormwater storage volume in the pond during a rain event. A complete environmental analysis should be performed on the pond to determine if regulated water courses and/or wetlands would be impacted, which would require a permit from the MDEQ.

Beyond the above preliminary analysis of the existing detention pond, the largest contributing factor to the flooding is likely the off-site drainage areas from the north and east that flow into the detention pond.

CONCEPTUAL REMEDIATION OPTIONS

A hydraulic analysis should be completed to further understand the behavior of the drainage area. However, some conceptual remediation options have been developed for budgeting purposes. It should be noted that one or more of these options could be implemented to reduce the volume of water overflowing the detention pond.

1. Dredge the existing detention pond: Based on the field investigation, there appears to be sediment within the detention pond reducing the available capacity. Additional volume capacity and improved flow can be achieved by dredging the existing pond. Assuming that this is a private detention pond that appears to have sufficient construction access, this would be a fairly simple method to increase storage capacity and reduce the chance of localized flooding. A complete environmental analysis would need to be performed on the pond to determine if regulated water courses and/or wetlands would be impacted, which would require a permit from the MDEQ.

2. Ditch clean out: Based on field investigation, several of the ditches in the mobile home park were overgrown with vegetation, which is likely slowing flow and contributing to sediment deposits. While the plants are providing some uptake of water, the overgrowth is restricting the storm water flow through the site. These ditches should be cleaned out and restored to their original condition (and maintained in this condition) to reduce the chance of localized flooding.

3. Re-route the upstream (inflow) drainage: Due to the minimal elevation change across the site and through the wooded wetland, it will be difficult for the City or Oakland Glens to make any changes that will significantly increase the storm water volume which can

flow through and out of the Oakland Glens site. There are two off-site drainage courses that flow into the existing detention pond, one from the north and one from the east. The northerly watercourse originates from the Maples of Novi and the nearby wooded wetland area, and it appears it could be re-routed to run along the north boundary of the park so it does not enter the site. The easterly watercourse appears to have flows which originate from within the park, as well as from outside sources, and would be more difficult to re-route. If one or both of these drainage courses were rerouted around the mobile home site, thus reducing the flows into the existing detention pond, the chance of localized flooding within the site could be reduced. However, the upstream drainage areas would have to be carefully studied, as well as the new route, to ensure that this would not cause new localized flooding downstream. A complete environmental analysis would need to be performed to determine if regulated water courses and/or wetlands would be impacted, which would require a permit from the MDEQ.

4. Replace and upsize the detention pond outlet culvert: The culvert that inlets into the pond is a 42-inch culvert and the pond outlets through a single 30-inch culvert which flows westerly to a large, flat, wooded wetland area that flows under Novi Road through two sets of 43" x 68" culverts. Since the inlet pipe into the pond is larger than the outlet pipe, the outlet pipe diameter could be increased to pass through larger flows, and if placed at the same invert elevation would not reduce the low water elevation or capacity of the detention pond.

   A complete hydraulic analysis of the area would need to be completed to determine the effects of the current pipe and potentially upsizing the outlet pipe to fully understand the impact this would have on the flooding and to make sure there are no adverse effects downstream of the pond. The downstream culverts draining the wooded wetland and flowing to Walled Lake appear adequate; therefore, increasing the capacity of these culverts would not improve the flooding concerns at Oakland Glens. As mentioned previously, a permit from the MDEQ will be required for improvements which impact regulated water courses and/or wetlands.

PRELIMINARY ESTIMATES

Conceptual estimates for the improvements described above are as follows:

Option 1. *Dredge Existing Pond*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$5,000	1	$ 5,000
Dredge Existing Pond	Cyd	$15	10,000	$150,000
Dewatering	LSum	$20,000	1	$ 20,000
Restoration	Syd	$5	1,000	$ 5,000
			Contingency (25%)	*$ 45,000*
			Estimate =	**$225,000**

Option 2. *Ditch Clean Out*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$5,000	1	$ 5,000
Ditch Cleanout	Feet	$15	2,000	$30,000
Restoration	Syd	$5	2,400	$12,000
			Contingency (25%)	*$11,750*
			Estimate =	**$58,750**

Option 3. *Reroute Upstream Drainage (Northerly Watercourse)*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$5,000	1	$ 5,000

Construct Wetland Channel	Feet	$75	2,000	$150,000
Grading	LSum	$10,000	1	$ 10,000
Restoration	Syd	$20	1,000	$ 20,000
			Contingency (25%)	*$ 46,250*
			Estimate =	**$231,250**

Option 4. *Replace / Upsize Pond Outlet Culvert*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$5,000	1	$ 5,000
42-inch Conc. Culvert	Feet	$160	80	$12,800
Pavement Repair	Syd	$100	55	$ 5,500
Curb & Gutter	Feet	$25	40	$ 1,000
Restoration	Syd	$5	200	$ 1,000
			Contingency (25%)	*$ 6,325*
			Estimate =	**$31,625**

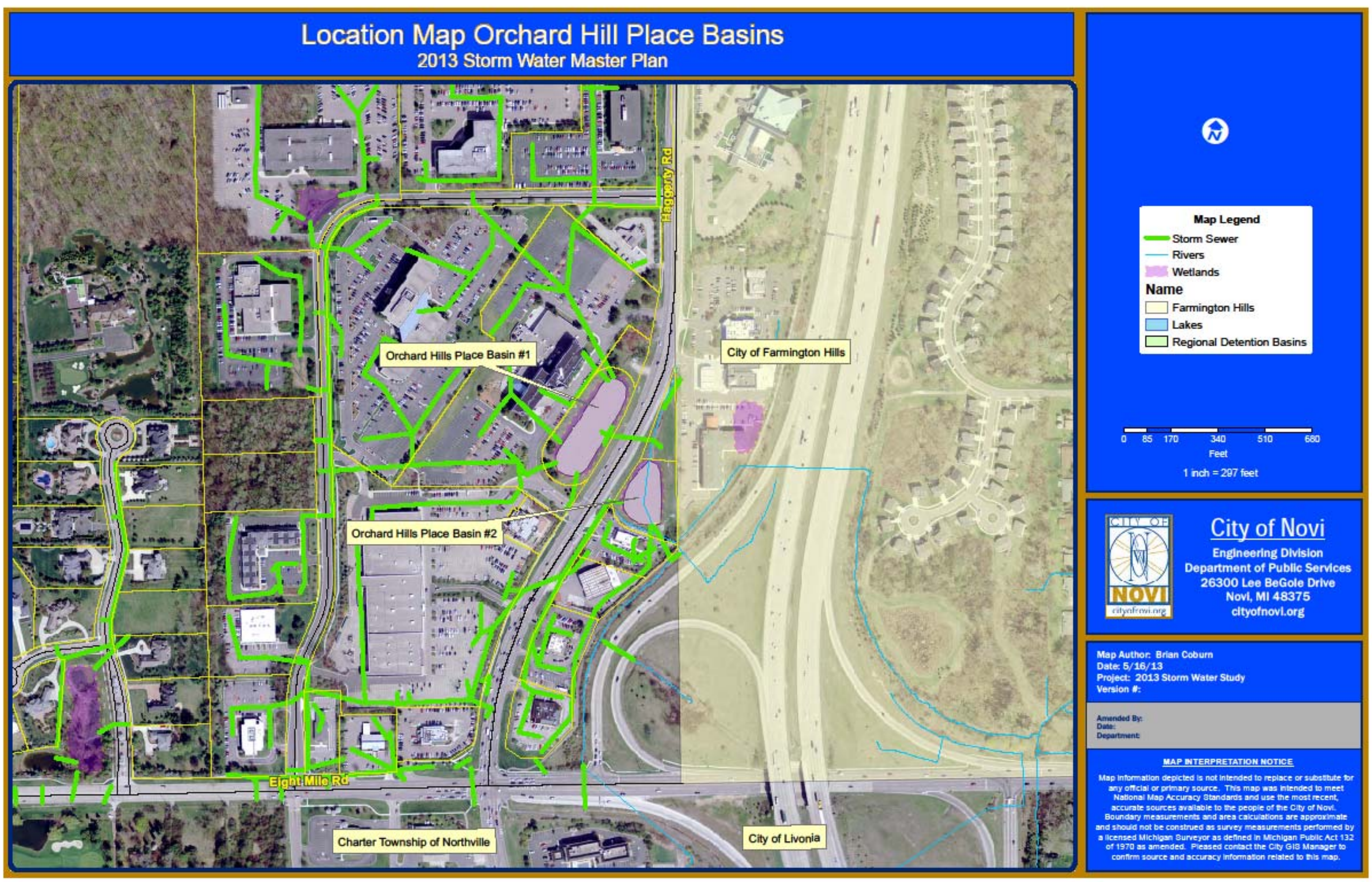
Please note that the contingency is each of these estimates is intended to include permitting costs, soil erosion control measures, and miscellaneous additional work items to complete the improvement. The costs do not include engineering services.

SECTION 4 – Orchard Hill Place Basins Condition and Capacity Concerns

INTRODUCTION AND BACKGROUND

This report focuses on two detention basins within the Orchard Hill Place development located west and east of Haggerty Road, north of Eight Mile Road. This report presents the identified problem areas, and recommends improvements to meet the City's expectations for storm water quality, while also reducing routine maintenance frequency.

These two storm water detention basins serve a commercial area in the southeasterly portion of Section 36. The westerly basin (Basin #1) is owned by the City of Novi, but is maintained by the Orchard Hill Place Association. The easterly basin (Basin #2) is owned by the Orchard Hill



Place Association, but maintained by the City of Novi. City of Novi Engineering staff have reviewed the history of this arrangement, but were unable to determine why the ownership and maintenance has traditionally occurred in this manner.

The on-going concerns with the basins include damage at inlet and outlet structures and pipes, sedimentation, and outlet pipe clogging.

FIELD INVESTIGATION

In August 2013, staff from Spalding DeDecker Associates, Inc. (SDA) and Environmental Consulting & Technology, Inc. (ECT) met on-site with the City of Novi Department of Public Services (DPS) staff, to perform a field review of the detention basins.

Seepage thru South Slope Basin #1

Basin #1 showed no apparent sediment accumulation. Only two small (~10' to 30' long) areas of shoreline erosion were observed, and they did not appear to be contributing significant amounts of sediment to the basin. DPS staff commented that the Sheraton hotel had intentionally plugged the 6-inch outlet, to turn what would otherwise be a low or potentially dry basin into a pond in front of the hotel. Inlet pipes showed separation at the joints in several locations. Along the south slope side of the basin, the bank/slope was soft and there was standing water from seepage through the basin side slope. Long term, this seepage could cause issues with bank erosion.

Basin #2 showed signs of a significant accumulation of sediment. Although flow through the outlet structure was observed, there is significant sediment and plant debris in the pond that adversely affects the storage volume and operation of the basin. DPS staff stated that they could not recall if the basin had ever been dredged.

Sediment Accumulation at Basin #2

The DPS staff also stated that the 6-inch diameter outlet pipe of Basin #2 clogs and requires frequent maintenance. There is also pipe separation at the southwest inlet of this basin.

RECOMMENDATIONS

Some conceptual remedial options have been developed for budgeting purposes. It should be noted that a combination of these options should be implemented to result in the most effective improvement. The conceptual remedial options are as follows:

1. <u>Revise ownership and operations</u>: Although this will not address any flooding issues, it will assist with future maintenance if both basins are owned and operated by a single entity. Alternatively, ownership or maintenance responsibilities of the basins could be corrected so Orchard Hill Place Association owns and maintains Basin #1, and the City owns and maintains Basin #2.

2. Dredge Detention Basin #2: Based on the field investigation, there appears to be a significant amount of sediment within the detention basin, reducing surge capacity and leading to maintenance issues with the outlet. Additional volume capacity can be achieved by dredging the basin. In addition, removing the sediment and debris will lower the chances of the outlet pipe becoming clogged.

3. Repair separated inlet pipes: Some pipe joints near the inlets to the basins have separated, which has likely led to surrounding erosion. These joints can be repaired by removal and replacement of pipe sections, or by lining.

4. Retrofit the outlet of Basin #2: The current outlet pipe has a history of clogging which requires frequent maintenance. The grate of the outlet structure should be retrofitted similar to the way other regional detention basin outlets have been retrofitted in the City. Although this does completely prevent the need for maintenance, this retrofit would reduce the maintenance issues that currently arise with this structure.

5. Retrofit outlet of Basin #1 to permit lower water levels: Remove the existing restriction on the outlet to allow the normal water level to be lower and install a standpipe with stone inlet cone. This would restore Basin #1 back to its original design and functionality as a detention basin, with storm surge capacity and fluctuating water levels. Prior to implementing this, it is recommended that the downstream hydraulics be reviewed to ensure that the increase in discharge will not adversely affect the downstream Basin and surrounding area.

6. Downstream Improvements: The area downstream of Detention Basin #2 is overgrown with vegetation and there are areas of sediment buildup. The ditch in this area should be cleaned out to allow for unobstructed discharge from the Basin. Note that portions of this area cross into the City of Farmington Hills and MDOT right-of-way for I-275.

PRELIMINARY ESTIMATES

Option 2. *Dredge Detention Basin #2*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$5,000	1	$5,000
Dredge Existing Pond	Cyd	$10.00	2,600	$26,000
Dewatering	LSum	$7,500	1	$7,500
Restoration	Syd	$5.00	500	$2,500
			Contingency (25%)	*$10,250*
			Estimate =	**$51,250**

Option 3. *Repair Inlet Pipes with Separation (Cost Included in Above Estimate)*

Item Description	Unit	Unit Price	Quantity	Item Cost
Pipe Repair	Each	$2,000	4	$8,000

Option 4. *Reconstruct Outlet of Basin #2 and Repair Separated Inlet Pipes*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$2,500	1	$2,500
Outlet Structure	LSum	$7,500	1	$7,500
Pipe Separation Repair	Each	$2,000	4	$8,000
Restoration	Syd	$5.00	1,000	$5,000
			Contingency (25%)	*$5,750*
			Estimate =	**$28,750**

Option 5. *Retrofit Outlet of Basin #1*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$2,500	1	$2,500
Dewatering	LSum	$2,500	1	$2,500
Remove restriction, install standpipe	LSum	$8,000	1	$8,000
Restoration	Syd	$5.00	500	$2,500
			Contingency (25%)	*$3,875*
			Estimate =	**$19,375**

Option 6. *Downstream Drainage Course Improvements*
*(**NOTE: partially in City of Farmington Hills**)*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$3,000	1	$3,000
Ditch Cleanout	Feet	$15	500	$7,500
Excavation of sediment	Cyd	$10.00	500	$5,000
Dewatering	LSum	$2,500	1	$2,500
Restoration	Syd	$5.00	500	$2,500
			Contingency (25%)	*$5,125*
			Estimate =	**$25,625**

Please note that the contingency is each of these estimates includes permitting costs, soil erosion control measures, and miscellaneous work items to complete the improvements. The costs do not include design engineering services.

SECTION 5 – VILLAGE OAKS LAKE AND VILLAGE WOOD LAKE
Infrastructure Access and Maintenance Concerns

BACKGROUND

In 1984, the City of Novi passed a resolution taking on the responsibility for the on-going maintenance (including dredging) of Village Oaks Lake and Village Wood Lake. The lakes are located east of Meadowbrook Road, north of Nine Mile. Both were constructed when the subdivisions were built in the early 1970's. The eastern half of Village Oak Lake was hydraulically dredged by the City in 2005. There has been minimal maintenance of the storm water inlet and outlet pipes and structures over the past twenty years, which has primarily been limited to repairing visible damage to structures.

FIELD INVESTIGATION

In August 2013, Environmental Consulting & Technology, Inc. (ECT) and Spalding DeDecker Associates, Inc. (SDA) met onsite with the City of Novi Department of Public Services (DPS) staff, for the inspection of the inlet and outlet structures. Currently, the City has limited easements for accessing the infrastructure around Village Oaks and Village Wood Lakes. For the field investigation, each structure was accessed through private property.

Structure surrounded by Landscaping

Each of the located structures were mapped using GPS and are shown on the included map. One structure (Inlet #1) was not able to be located; however, DPS staff provided us with an approximate location (east end of Village Oaks Lake). The individual structures were difficult to locate due to the landscaping, steep terrain, and improvements installed by the homeowners. Structures were located in difficult to access areas, such as under large pine trees and, in one case, under a deck / overlook. Some inlet pipe end-sections were submerged, and therefore were not visible for observation.

Deck built over Structure

Access hatch in deck


Village Oaks Lake Outlet Structure Hidden by Landscaping

The outlet structure of Village Oaks Lake is located under heavy brush and the pipe is not visible due to a thick layer of stone rip rap. The outlet structure of Village Wood Lake had recently been repaired by the City, and additional rip rap was placed around the structure. The outlet structure and overflow are located in the Village Wood Park. This location is accessible to the public which has lead to safety and maintenance concerns.

CONCEPTUAL IMPROVEMENT OPTIONS

1. Acquire Easements, Repair / Replace Deteriorated Infrastructure: Drainage easements for access and maintenance should be acquired by the City from the individual homeowners and/or the Homeowners Association, as applicable. It is estimated that nine easements will be necessary to provide adequate access for both lakes. These can be negotiated individually or acquired through condemnation. Obtaining these easements would be necessary in order for the City to perform immediate and on-going maintenance. The inlet and outlet structures could then be accessed directly for heavy rehabilitation or full replacement. Significant grading will be needed to develop working areas at some structures. Due to the proximity to private property or impassible slopes, working from the water via boats or a small barge may be required.

2. Repair / Replace Village Oaks Lake Outlet Structure: The outlet structure of Village Oaks Lake is in poor condition. The structure can be replaced with a new structure of the same size in the same location assuming that there are no problems with the current outlet and capacity of the structure (none were reported). If there are known capacity issues, a hydraulic analysis should be completed for the contributing area to the lake and the new outlet structure sized accordingly to improve the hydraulics of the area.

3. Locate Buried Structure: The inlet structure that could not be located is likely buried due to landscaping. It could be located using a variety of methods: Accurate as-built plans could be utilized if they are available, televising to the structure through the pipe at the upstream structure, or advanced surveying equipment and techniques could be used to locate the structure. Once the structure is located, further investigation should be performed to evaluate the integrity of the structure and pipe.

4. Eliminate Public Access to Outlet and Overflow Structures in Village Wood Park: Due to on-going concerns of public access to the outlet structure, security fencing and warning signs can be installed to deter the public from accessing the outlet and overflow structure. This would improve safety and reduce vandalism opportunities.

PRELIMINARY ESTIMATES

Option 1. *Repair Damaged Infrastructure*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$46,000	1	$46,000
Locate Structure	LSum	$2,000	1	$2,000
Clearing (Landscape)	LSum	$34,500	1	$34,500
Tree Removal	Each	$500	16	$8,000
Deck Removal	LSum	$2,500	1	$2,500
Cleaning/Televising Sewer/Structure	LSum	$59,500	1	$59,500
Erosion Control	LSum	$24,000	1	$24,000
Working Platform	LSum	$50,000	1	$50,000
Inlet/Outlet Structure Repairs/Replacement	Each	$9600	12	$115,200
Sewer Pipe Replacement	Feet	$45	1,350	$60,750
Riprap	Syd	$50	60	$3,000
Deck Replacement	LSum	$5,500	1	$5,500
Restoration	LSum	$100,000	1	$100,000
Easement Acquisition	Sft	$12	12,000	$144,000
			Contingency (25%)	*$164,000*
			Estimate =	**$818,950**

NOTE – Access from the water may be the only practical option for several locations.

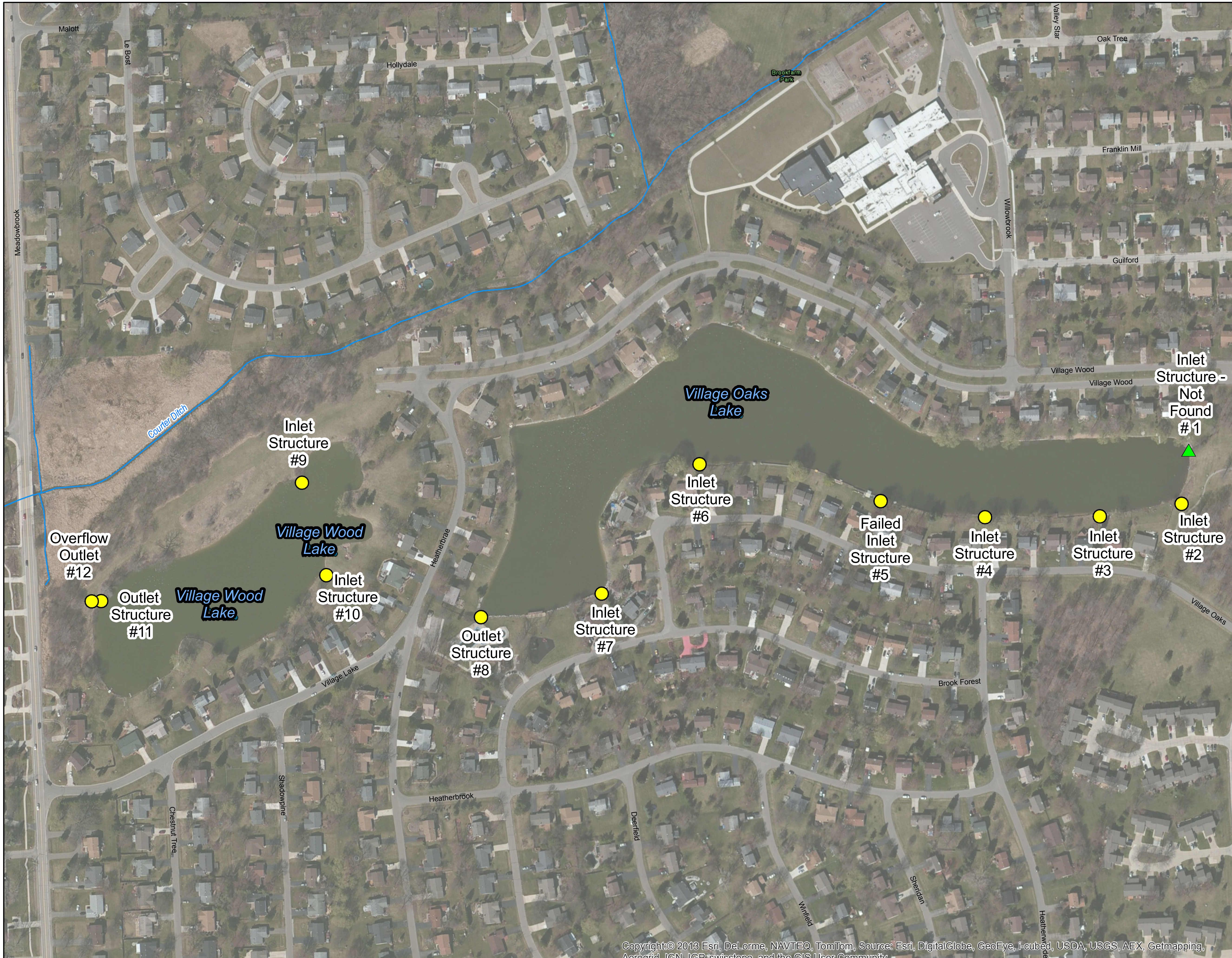
Option 4. *Eliminate Public Access to Outlet and Overflow Structures in Village Wood Park*

Item Description	Unit	Unit Price	Quantity	Item Cost
Mobilization	LSum	$2,500	1	$2,500
Chain Link Fence, 72-inch	Feet	$30	450	$13,500
6' Fence Gate	Each	$750	1	$750
Restoration	LSum	$1,250	1	$1,250
			Contingency (25%)	*$4,500*
			Estimate =	**$22,500**

Please note that the contingency is each of these estimates includes permitting costs, soil erosion control measures, and miscellaneous work items to complete the improvement. The costs do not include engineering services.

Environmental Consulting & Technology, Inc.

City of Novi Stormwater Master Plan Village Oaks Lake & Village Wood Lake



- Structures
- Structures Not Found

N W E S

0 125 250 500
Feet

Access to Structure #2

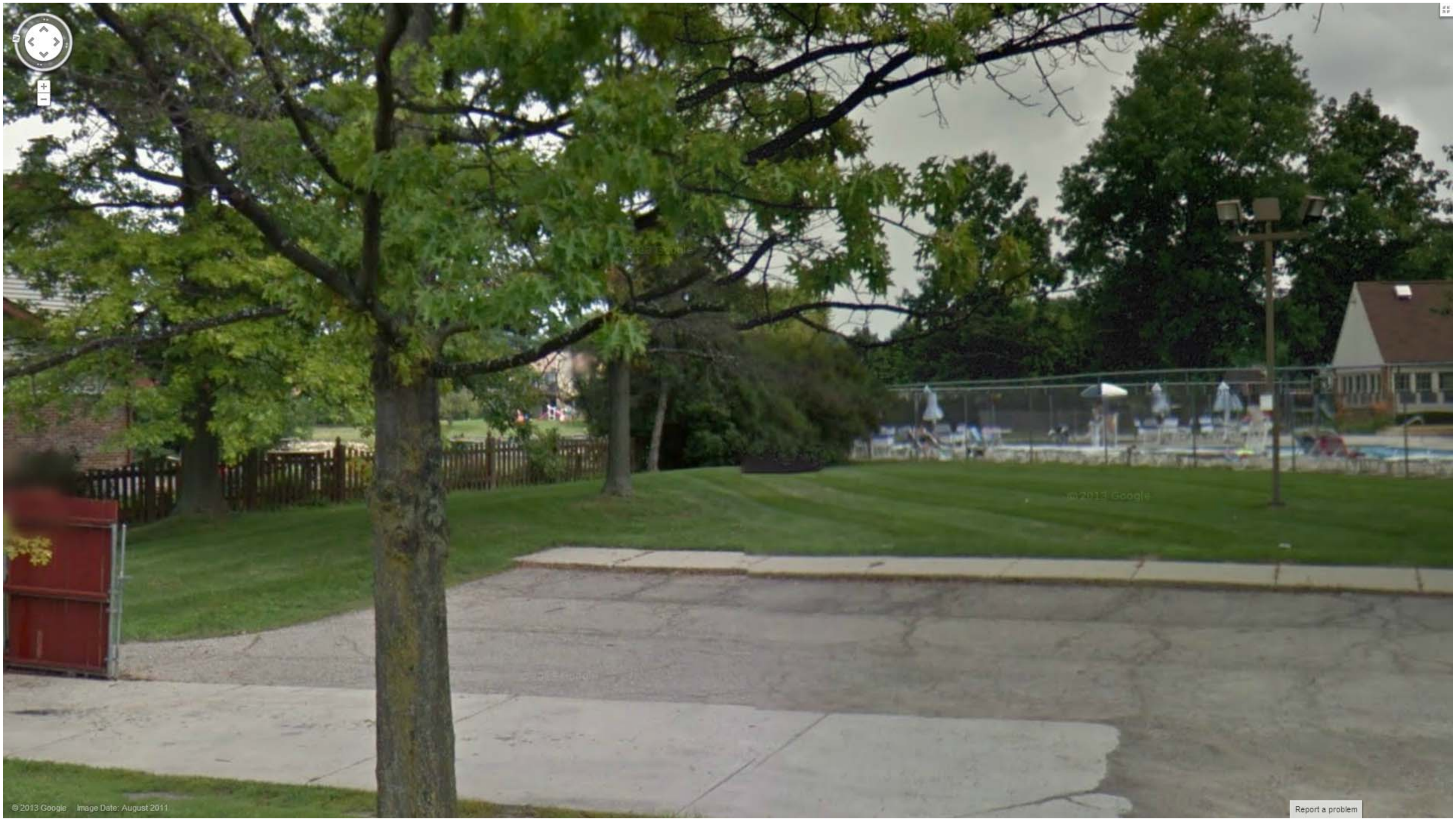
Access to Structure #3

Access to Structure #4

Access to Structure #5

Access to Structure #6

Access to Structure #7



Access to Structure #8

Access to Structure #10

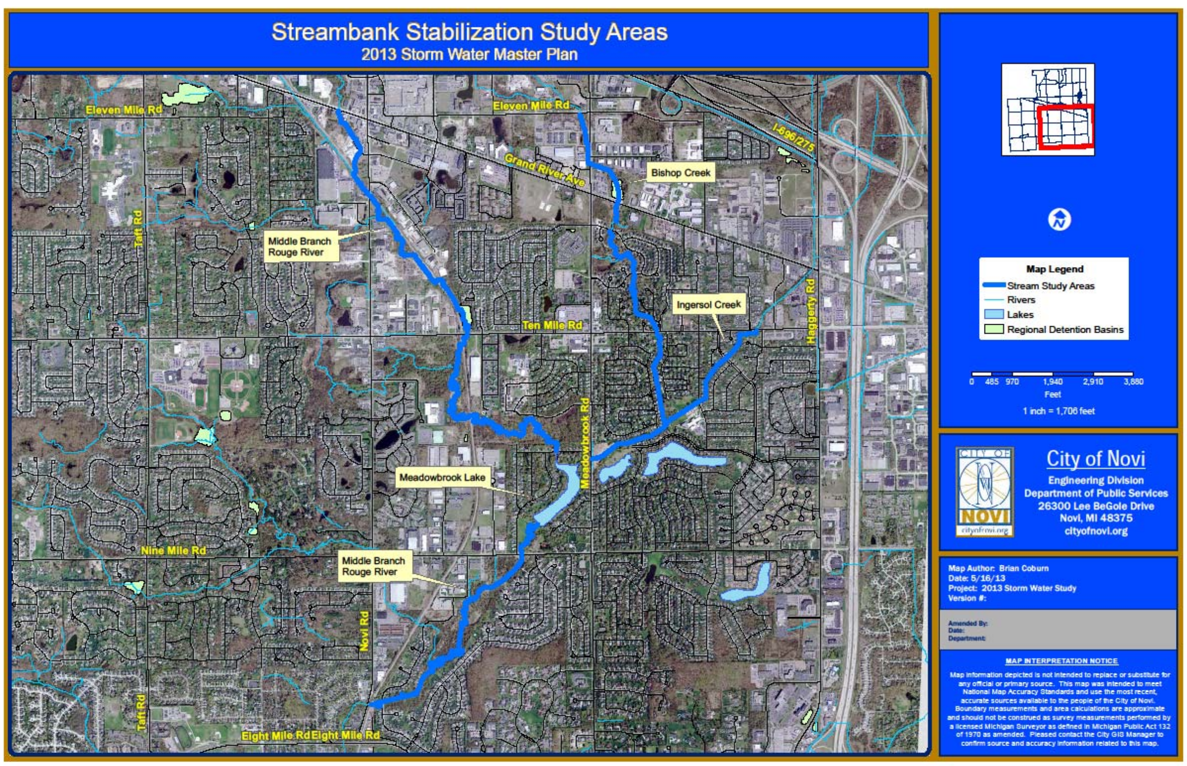
SECTION 6
STREAMBANK STABILIZATION EVALUATION AND RECOMMENDATIONS

INTRODUCTION

This report evaluates on-going concerns with streambank stabilization for specific watercourses within the City. Past studies have focused on the regional detention basin system, and many improvements have been made over the past ten years by the City to address issues related to high frequency storm events. However, there are existing on-going streambank stabilization concerns in the urbanized portions of the City. This report focused on:

- The Middle Branch of Rouge River downstream of Grand River to the southerly City Limits (excluding Meadowbrook Lake)
- Ingersol Creek downstream of Ten Mile to Meadowbrook Lake
- Bishop Creek downstream of 11 Mile to Ingersol Creek

The creek study areas are identified in the vicinity location map below.



Field Investigation

In August 2013, Spalding DeDecker Associates, Inc. (SDA) and Environmental Consulting & Technology, Inc. (ECT) completed a stream walk assessment of the subject creeks. Areas of streambank erosion were located using GPS coordinates, details were noted, and the area was photographed. A Bank Erosion Hazard Index (BEHI) data sheet for each location was completed detailing the specific erosion observed (see summary of each location in Appendix A of the attached report).

During the stream walk, SDA and ECT identified 56 specific sites of concern. Thirteen (13) of the sites were further identified as “priority sites of concern” based on the resulting BEHI value, proximity to infrastructure or private property, and length. Of the 56 sites of concern, 11 were identified in the Bishop Creek reach (2 priority sites), 12 within the Ingersol Creek reach (4 priority sites), and 33 in the Middle Branch of the Rouge River reach (7 priority sites).

The estimated costs to repair the priority sites range from $20,000 to $832,000, as summarized in the attached report prepared by ECT under the direction of SDA. Please refer to the remainder of the report for more detailed descriptions of the erosion observed, and techniques and costs for recommended repairs.

Environmental Consulting & Technology, Inc.

October 16, 2013

Mr. Gerrad Godley, P.E.
Spalding DeDecker Associates, Inc.
905 South Boulevard East
Rochester Hills, MI 48307

RE: Novi Stormwater Master Plan

Mr. Godley,

Environmental Consulting & Technology, Inc. (ECT) has prepared the following summary of the streambank assessments and site investigations of Bishop Creek, Ingersol Creek, and the Middle Branch of the Rouge River for your use.

Streambank Erosion Inventory Data Collection

ECT and Spalding DeDecker completed field work in August 2013. Significant areas of streambank erosion were noted, photographed, and documented with a GPS. A Bank Erosion Hazard Index (BEHI)[1] data sheet was filled out for each erosion reach using the MDEQ Standard Operating Procedure for Modified BEHI assessment[2].

The Modified BEHI procedure ranks streambank erosion potential based on streambank parameters including root depth, root density, bank angle and surface protection. Field measurements are converted to an index for each parameter (1-10) and then summed for an overall score for each site (maximum 40). Overall scores are assigned a risk category of Very Low (<5.8), Low (5.8-11.8), Moderate (11.9-19.8), High (19.9-27.8), Very High (27.9-34.0), or Extreme (34.1-40).

The data for all erosion locations are summarized in Table 1 in Appendix A which includes columns noting the length of the reach, associated photos, and BEHI parameters and scores. Bank erosion areas were noted as Left, Right, or Both. Left and right bank orientations are relative to looking downstream. The location of the sites are shown in Figures 1 and 2 in Appendix A.

Streambank Erosion Site Prioritization

ECT identified 13 of the 56 sites surveyed as priority sites of concern for the surveyed reaches. The 13 sites were selected based on BEHI value, proximity to infrastructure or private property, and length. The selected sites are highlighted in the following table.

---

[1] Rosgen, D.L. 2001. A Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp. II – 9-15, March 25-29, 2001, Reno, NV.
[2] "Assessing Bank Erosion Potential Using Rosgen's Bank Erosion Hazard Index (BEHI)", Michigan Department of Environmental Quality, Version 3, 8/12/08.

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Priority Sites (see Appendix A for all sites)

Site	Bank	Length (ft)	Photos	Concerns	Bank Height (ft)	BEHI Rating	BEHI Category	Stabilization Options[1]	Estimated Cost
Bishop Creek									
4	Right	50	178-189	Residential Property	7.0	29.0	Very High	V + CW/GW	$25,000
10	Both	410	210-241	Residential Property	4.0	29.0	Very High	RR + VMSE	$332,000
Ingersol Creek									
1	Left	110	251-257	Sediment Loading	5.5	31.0	Very High	SF+LS-JP+RR+VMSE	$49,000
3	Right	65	263-267	Residential Property	5.3	23.5	High	RR + VMSE/CW/GW	$32,000
4	Left	40	268-272	Residential Property	5.5	26.0	High	RR + VMSE/CW/GW	$20,000
5	Right	65	273-275	Residential Property	7.0	31.0	Very High	RR + V + VMSE/CW/GW	$42,000
Middle Branch Rouge River									
3	Left	100	334-346	Sediment Loading	10.0	28.0	Very High	RR + V + VMSE/CW/GW	$73,000
4	Both	100	347-354	Sediment Loading	4.5	24.0	High	V + VMSE/CW/GW	$51,000
7	Right	180	364-378	Sediment Loading	10.0	34.0	Very High	SF+LS-JP+RR+VMSE+V	$86,000
8	Left	440	379-382	Sediment Loading	3.5	34.0	Very High	RR + VMSE	$178,000
14	Left	165	408-412	Sediment Loading	7.0	29.0	Very High	RR + CW/GW	$105,000
15	Left	40	413-416	Sediment Loading	13.0	26.0	High	RR + CW/GW	$39,000
26	Both	1000	476-504	Sediment Loading	3.5	31.0	Very High	RR + V + VMSE	$832,000

Stabilization Options[1] • Refer to Appendix B for descriptions of stabilization options • Note: "+" indicates using multiple techniques, "/" indicates optional techniques, dependent on more detailed site data.	Estimated Cost	Quantity
SF = Slope Flattening	$25	LF of bank
LS-JP = Live Staking/Joint Planting	$5	LF of bank
RR = Vegetated Riprap Revetment/Riprap Toe	$175	LF of bank
VMSE = Vegetated Mechanically Stabilized Earth	$125	LF of bank
V = Vanes	$4,000	Each
CW = Cribwalls	$35	SF of front face (bank length x height)
GW = Geocell Walls	$50	SF of front face (bank length x height)

Streambank stabilization typically consists of a combination of techniques that are implemented based on a detailed analysis of site conditions, price and availability of materials. The stabilization options suggested in the above table are based on preliminary site data. The "+" sign indicates that the listed techniques would likely be used in combination and the "/" sign indicates that only one of the listed techniques would likely be used, dependent upon more detailed site information. Typical details and descriptions of the streambank stabilization techniques can be found in Appendix B.

The unit cost estimates provided in the table are based on published unit costs and ECT's construction cost data. These unit costs do not include design, permitting, construction management, and other construction costs (e.g. bonds and mobilization/demobilization). A 35% markup was applied to account for these additional costs in the estimated cost for each site.

If you have any questions regarding the contents of this letter, please contact Evan Corbin at 734-272-0761 or Marty Boote at 734-282-0857.

Respectfully submitted,

ENVIRONMENTAL CONSULTING & TECHNOLOGY, INC.

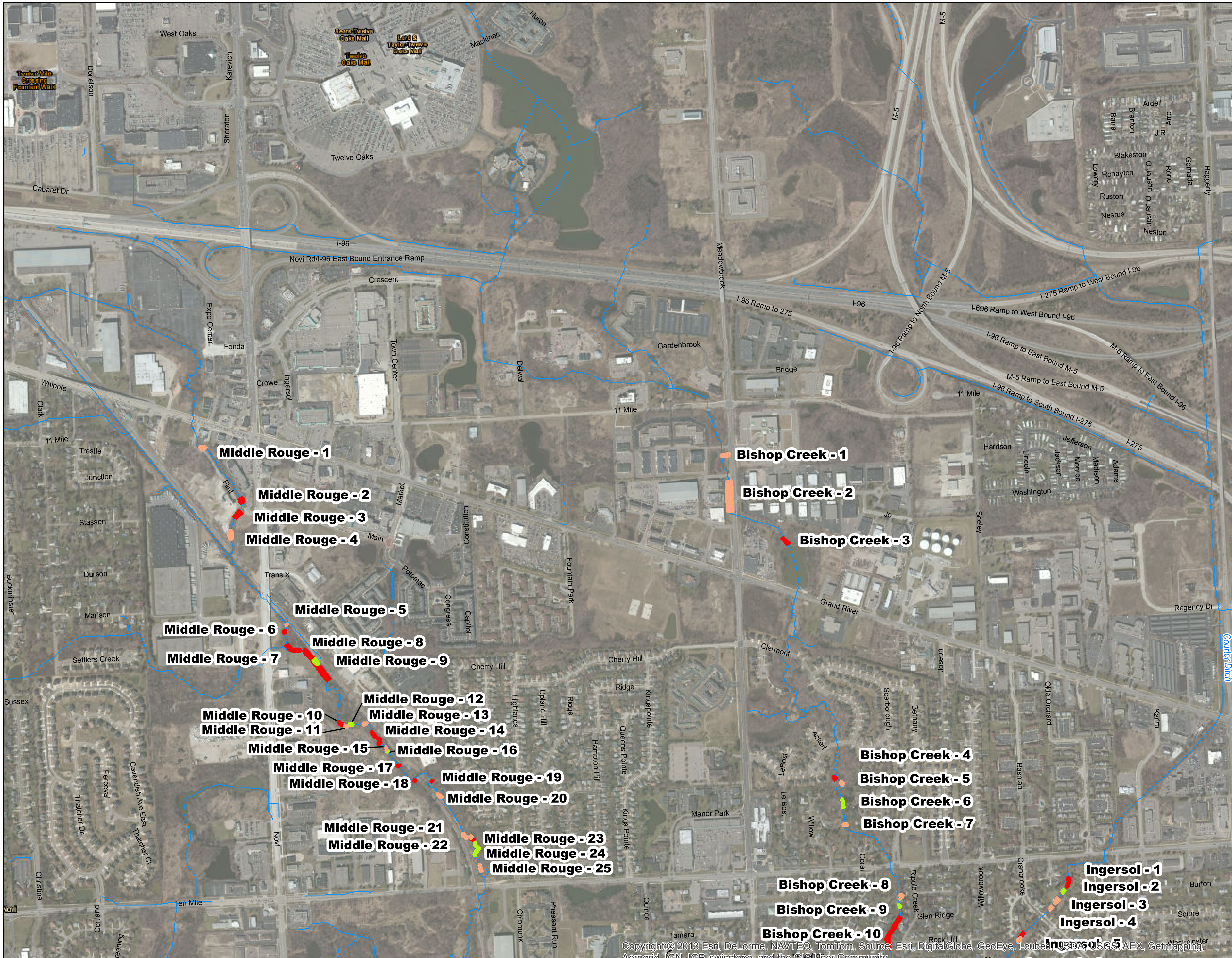
Evan Corbin
Associate Engineer

Marty Boote
Environmental Scientist

APPENDIX A

Table 1. BEHI Data

Site	Bank	Length (ft)	Photos	Bank Height (ft)	Root Depth (ft)	Root Density (%)	Bank Angle (°)	Surface Protection (°)	BEHI Rating	BEHI Category	Stabilization Options[1]	Estimated Cost
Bishop Creek												
1	Left	20	146-153	3.0	2.0	35	100	20	23.5	High	RR+VMSE	$9,000
2	Both	350	157-163	1.3	0.4	60	90	30	23.5	High	SF+RR+VMSE	$307,000
3	Both	85	170-176	3.0	0.8	30	110	30	29.5	Very High	RR+VMSE	$75,000
4	Right	50	178-189	7.0	0.5	10	80	50	29.0	Very High	V + CW/GW	$25,000
5	Both	60	190-193	2.5	1.0	10	90	40	27.0	High	SF+VMSE+V	$30,000
6	Left	100	194-198	4.5	2.5	65	85	70	16.0	Moderate	RR+VMSE	$44,000
7	Left	15	199-200	4.0	2.0	30	95	30	27.5	High	LS/JP+RR	$4,000
8	Left	45	201-204	5.5	0.5	20	85	35	27.5	High	LS/JP+CW/GW	$15,000
9	Right	45	205-209	4.5	2.5	60	95	60	17.5	Moderate	VMSE	$9,000
10	Both	410	210-241	4.0	2.0	15	115	20	29.0	Very High	RR + VMSE	$332,000
11	Right	45	245-250	3.5	1.5	30	90	20	27.5	High	LS/JP+VMSE	$9,000
											Bishop Creek =	**$859,000**
Ingersol Creek												
1	Left	110	251-257	5.5	1.5	30	100	10	31.0	Very High	SF + LS/JP + RR + VMSE	$49,000
2	Right	40	259-262	5.8	1.5	70	70	75	18.0	Moderate	RR+CW/GW	$23,000
3	Right	65	263-267	5.3	2.5	40	90	40	23.5	High	RR + VMSE/CW/GW	$32,000
4	Left	40	268-272	5.5	1.5	25	80	35	26.0	High	RR + VMSE/CW/GW	$20,000
5	Right	65	273-275	7.0	1.0	20	85	10	31.0	Very High	RR + V + VMSE/CW/GW	$42,000
6	Left	60	276-279	6.0	3.0	30	80	60	22.0	High	VMSE/CW/GW	$17,000
7	Right	120	280-284	2.5	1.5	25	90	30	25.5	High	RR+VMSE	$53,000
8	Left	50	287-290	4.5	3.0	80	110	70	17.5	Moderate	LS/JP+RR	$14,000
9	Left	30	291-294	2.5	0.5	10	80	30	29.5	Very High	LS/JP+RR+VMSE	$13,000
10	Right	215	295-302	3.0	1.5	75	90	75	19.5	Moderate	RR+VMSE	$94,000
11	Right	65	303-306	2.5	1.5	70	95	80	17.5	Moderate	RR+VMSE	$29,000
12	Right	140	307-310	3.0	1.0	60	90	70	19.5	Moderate	RR+VMSE	$61,000
											Ingersol Creek =	**$447,000**
Middle Branch Rouge River												
1	Right	65	317-322	8.0	3.0	30	110	30	27.5	High	LS/JP+RR+CW/GW	$46,000
2	Left	50	327-333	3.5	0.5	5	80	10	34.0	Very High	RR+V	$19,000
3	Left	100	334-346	10.0	3.0	20	85	20	28.0	Very High	RR + V + VMSE/CW/GW	$73,000
4	Both	100	347-354	4.5	1.0	40	85	40	24.0	High	V + VMSE/CW/GW	$51,000
5	Left	10	355-357	3.0	1.0	60	90	10	25.0	High	VMSE+V	$7,000
6	Right	35	358-363	10.0	2.0	25	80	25	28.0	Very High	LS/JP+VMSE/CW/GW	$16,000
7	Right	180	364-378	10.0	2.0	10	95	5	34.0	Very High	SF + LS/JP + RR + VMSE + V	$86,000
8	Left	440	379-382	3.5	0.3	15	110	15	34.0	Very High	RR + VMSE	$178,000
9	Right	70	383-387	8.0	6.0	70	65	75	14.0	Moderate	RR+CW/GW	$49,000
10	Right	70	388-392	3.5	1.0	20	80	30	28.0	Very High	RR+VMSE	$31,000
11	Right	40	393-399	6.0	3.0	50	115	50	23.5	High	RR+V+CW/GW	$29,000
12	Left	50	400-403	4.5	3.0	60	100	70	17.5	Moderate	RR+VMSE	$22,000
13	Left	45	404-407	6.0	2.0	20	80	50	24.0	High	VMSE/CW/GW	$13,000
14	Left	165	408-412	7.0	2.0	15	75	15	29.0	Very High	RR + CW/GW	$105,000
15	Left	40	413-416	13.0	3.0	30	80	45	26.0	High	RR + CW/GW	$39,000
16	Right	20	417-420	15.0	10.0	70	75	70	14.0	Moderate	RR+CW/GW	$22,000
17	Both	30	424-427	4.5	1.5	5	80	10	30.5	Very High	LS/JP+RR+VMSE	$27,000
18	Right	20	428-431	5.0	0.5	15	80	25	31.0	Very High	LS/JP+V+CW/GW	$11,000
19	Left	30	432-436	3.0	0.8	15	90	20	31.0	Very High	LS/JP+V	$7,000
20	Right	75	437-440	3.0	1.5	15	85	20	27.5	High	LS/JP+RR	$21,000
21	Right	80	441-444	4.0	2.0	40	75	40	20.0	High	RR+VMSE	$35,000
22	Left	35	445-449	4.0	2.0	20	100	25	27.5	High	RR+VMSE+V	$21,000
23	Right	25	450-454	3.5	1.0	25	80	25	28.0	Very High	RR+VMSE	$11,000
24	Both	150	455-466	4.0	2.0	65	70	70	16.0	Moderate	LS/JP+RR+VMSE+V	$139,000
25	Right	80	467-475	3.0	1.0	30	90	30	27.5	High	RR+VMSE	$35,000
26	Both	1000	476-504	3.5	0.5	20	95	30	31.0	Very High	RR + VMSE + Vx4	$832,000
27	Left	120	672-679	6.0	5.0	60	65	85	13.0	Moderate	RR+CW/GW	$70,000
28	Left	190	680-685	5.0	2.5	15	75	35	18.5	Moderate	LS/JP+VMSE/CW/GW	$48,000
29	Left	140	686-694	4.0	3.5	65	100	65	14.5	Moderate	RR+VMSE/CW	$63,000
30	Right	80	695-698	2.5	1.5	50	80	50	17.0	Moderate	SF+RR+VMSE	$35,000
31	Left	100	699-704	3.0	2.0	70	100	70	16.5	Moderate	RR+VMSE	$44,000
32	Left	80	705-711	3.0	1.5	10	60	25	10.0	Low	LS/JP+VMSE	$17,000
33	Both	70	712-721	2.5	1.5	30	100	40	18.5	Moderate	SF+RR+VMSE	$61,000
											Middle Branch Rouge River =	**$2,263,000**



Environmental Consulting & Technology, Inc.

City of Novi Stormwater Master Plan BEHI Results

Figure 1

SiteAreas

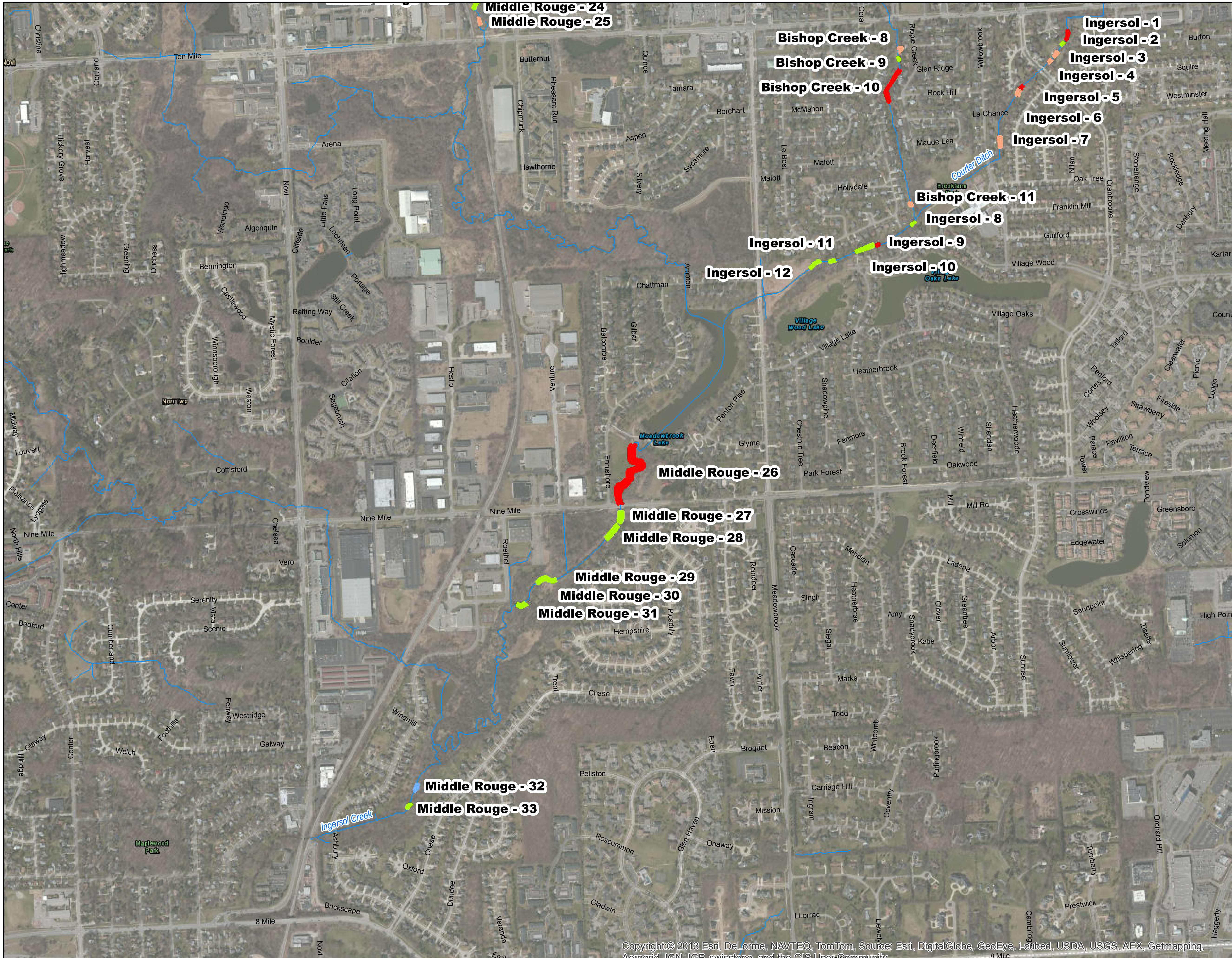
BEHI Rank

- Very High
- High
- Moderate
- Low

N W E S

0 550 1,100 2,200

Feet



ECT
Environmental Consulting & Technology, Inc.

City of Novi Stormwater Master Plan BEHI Results

Figure 2

SiteAreas

BEHI Rank

- Very High
- High
- Moderate
- Low

N W E S

0 550 1,100 2,200

Feet

APPENDIX B

Streambank Stabilization Techniques

The following streambank stabilization technique descriptions represent a compilation of information from a variety of sources, primarily the national Cooperative Highway Research Program Environmentally Sensitive Channel and Bank Protection Measures1, and ECT's professional experience applying the techniques under a variety of site conditions. A basic description of each technique is provided in addition to a statement regarding the general applicability of each technique to the impacted reaches. Typical details are also attached.

Slope Flattening

Flattening or bank reshaping stabilizes an eroding streambank by reducing its slope angle or gradient. Slope flattening is usually done in conjunction with other bank protection treatments, including installation of toe protection, placement of bank armor, re-vegetation or erosion control, and/or installation of drainage measures. Flattening or gradient reduction can be accomplished in several ways: 1) by removal of material near the crest, 2) by adding soil or fill at the bottom, or 3) by placing a toe structure at the bottom and adding a sloping fill behind it. Right-of-way constraints may limit or preclude the first two alternatives because both entail either moving the crest back or extending the toe forward.

Live Staking/Joint Planting

Live stakes are very useful as a revegetation technique, a soil reinforcement technique, and as a way to anchor erosion control materials. They are usually cut from the stem or branches of willow species and the stakes are typically 0.5-1.0 m (1.5 – 3.3 ft) long. The portion of the stem in the soil will grow roots and the exposed portion will develop into a bushy riparian plant. This technique is referred to as Joint Planting when the stakes are inserted into or through riprap. Live staking is a very flexible technique because it can be used to establish vegetation under a variety of conditions, particularly when excavation or the streambank is not desirable.

Live staking is an excellent means of using live plant materials to establish permanent vegetation on streambanks. As noted with other techniques, vegetation alone may not provide sufficient stabilization, but live staking is applicable when combined with other techniques.

Vegetated Riprap Revetment/Riprap Toe

Riprap revetment is a resistive technique of continuous bank protection consisting of riprap or natural weathered stone placed longitudinally along the toe of the streambank only. Riprap toes usually require much less bank disturbance and the bank landward of the toe may be sloped and/or revegetated by planting or through natural succession. A variety of stone sizes can be sued depending on site-specific flow velocities. Natural weathered stone is sometime more desirable due to its natural appearance, but typically requires large rock sizes due to its tendency to tumble and dislodge from the revetment face. Natural stone is often less available and more expensive to obtain as well. Crushed rock such as limestone is readily available in some areas, is less expensive, and tends to "lock" together within the revetment face better than weathered natural stone.

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[1] McCullah, J. and D. Gray. 2005. Environmentally Sensitive Channel and Bank Protection Measures. National Cooperative Highway Research Program Report #544, Transportation Research Board of the National Academies.

Two configurations have been used: (1), an ordinary riprap blanket is covered with a layer of soil 30-60 cm (1-2 ft) thick from the top of the revetment down to base flow elevation, or (2), a crown cap of soil and plant material is placed over a riprap toe running along the base of a steep bank, effectively reducing bank angle. Soils used for fill should not be highly erosive. A variety of methods may be used to establish plant materials including hydroseeding, seeding and mulching, sodding, and incorporation of willow cuttings or root stock in the fill materials.

Riprap toes protect streambanks via armoring where streambank erosion most often occurs and causes total bank failure. This technique requires much less riprap than conventional bank revetments that extend up the bank a considerable distance from the toe or cover the entire bank. This technique also has less ecological impact than other types of hard armoring.

Vegetated Mechanically Stabilized Earth (MSE)

This technique consists of soil wrapped in natural fabric, e.g., coir, or synthetic geotextiles (Turf Reinforcement Mats (TRMs) or Erosion Control Blankets (ECBs)) or geogrids. The fabric wrapping provides the primary soil reinforcement; however, internal geogrid membranes placed at vertical intervals between the layers provide additional lateral soil reinforcement. The durability of this structure varies widely and is dictated by the material used to form the soil encapsulation. Materials vary from light-weight, 100% biodegradable fabrics to rigid synthetic geogrids and facades.

This technique presents a lot of flexibility in terms of construction options and can be designed to meet a range of durability and environmental requirements. MSEs are an effective means of stabilizing streambanks while creating a near vertical face where space constraints require such.

Vanes

Vanes are deflective structures constructed of large woody debris or rock. They differ from transverse structures like spur dikes in that they are angled upstream into the flow at 20 to 30 degrees. Generally, two or three vanes are constructed along the outer bank of a bend in order to redirect flows near the bank to the center of the channel. Typically, vanes project 1/3 of the stream width. The riverward tips are at channel grade, and the crests slope upward to reach bankfull stage elevation at the streambank. Vanes are discontinuous; that is, portions of the bank between the structures are often not treated. Vanes can create habitat by increasing hydraulic diversity and generating streambed scour.

Vanes are not well suited for incised stream channels because high flows contained in the incised channel at flows exceeding bankfull tend to erode streambanks above the elevation of the vanes and cause flanking. However, vanes can be effective in reaches with low bank heights.

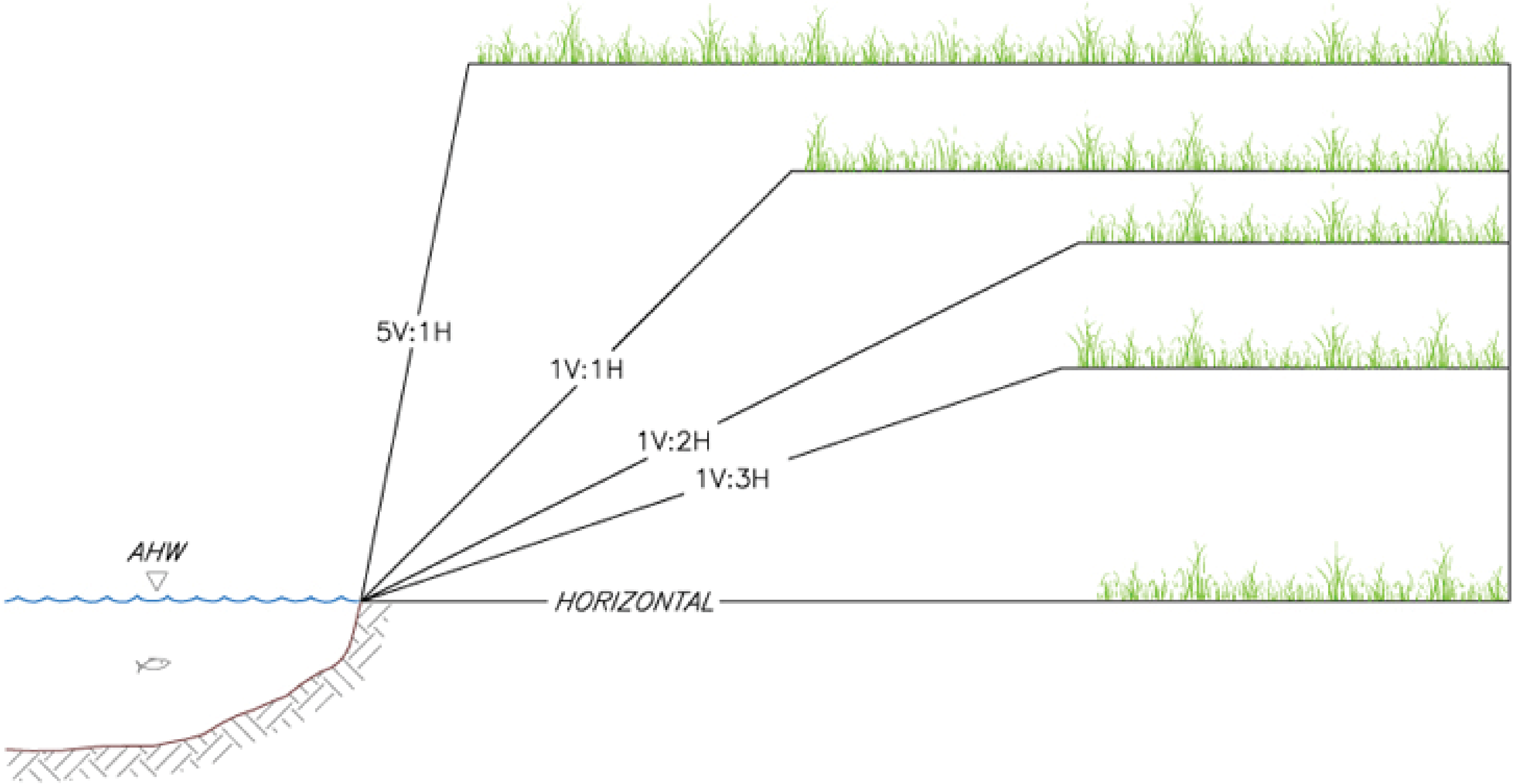
Cribwalls

A cribwall is a gravity retaining structure consisting of a hollow, box-like inter-locking arrangement of structural beams (usually wood). The interior of the cribwall is filled with rock or soil. In conventional cribwalls, the structural members are fabricated from concrete, wood logs, and dimensioned timbers (usually treated wood). In live cribwalls, the structural members are usually untreated log or timber members. The structure is filled with a suitable backfill material and live branch cuttings are inserted through openings between logs at the front of the structure and imbedded in the crib fill. These cuttings eventually root inside the fill and the growing roots gradually permeate and reinforce the fill within the structure.

Cribwalls are an effective means of stabilizing stream banks while creating a vertical or near vertical face where space constraints require such. They do have height limitations, and, if constructed from wood, eventually decompose, leaving vegetation alone to stabilize the streambank.

Geocell Walls

Geocell walls are aggregate or soil filled synthetic cellular containment systems. They can be based solely on gravity or reinforced with geogrid. The leading edge cell can be filled with soil and vegetated. One advantage of geocell walls is that when filled with aggregate and manufactured with perforations, they drain readily after being wetted by high water, lending to their stability.

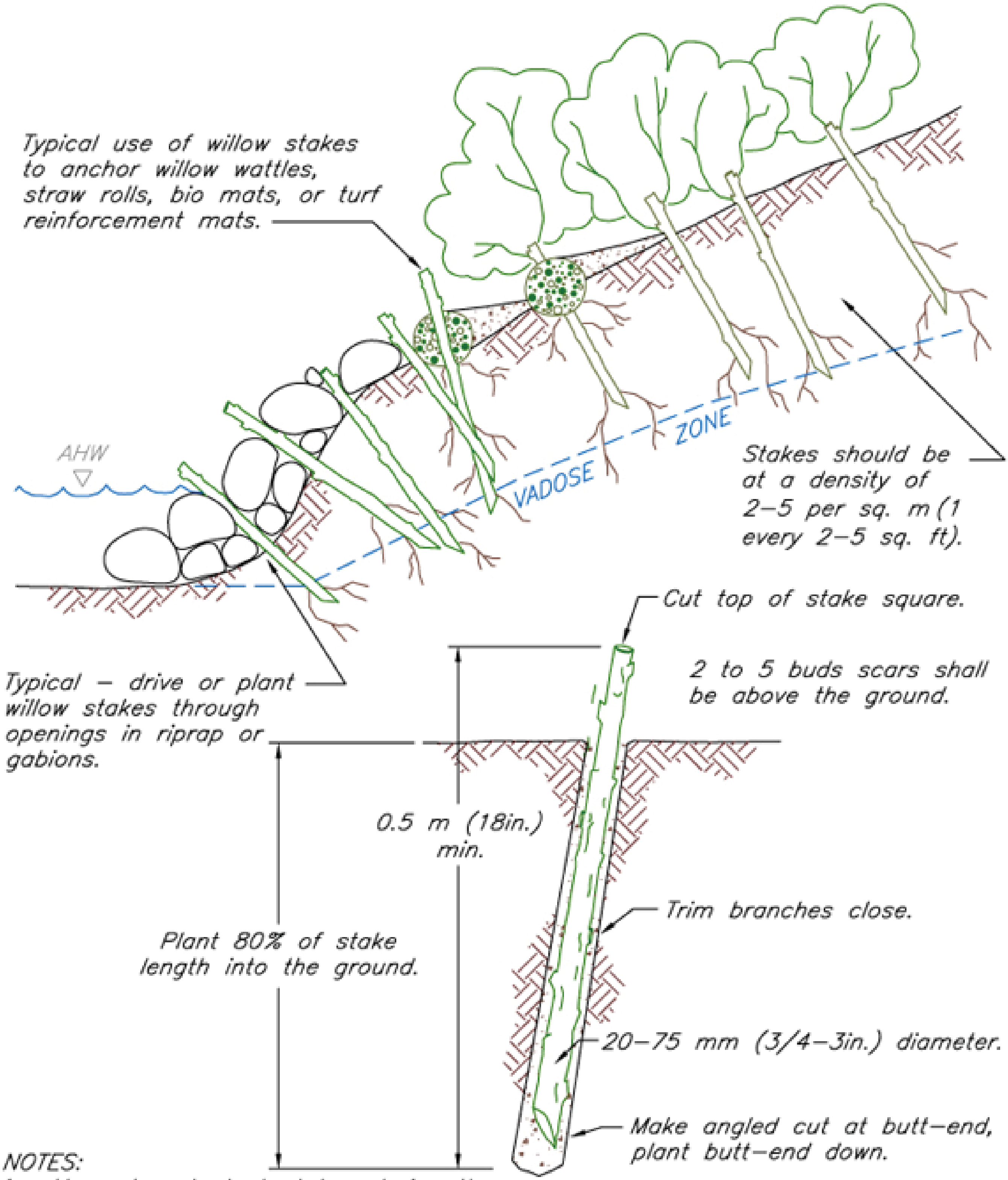


•1V:3H – Maximum suggested slope angle for establishing plantings or seedlings, when used alone.
•1V:3H – IV:2H – Optimal slope angle range for soil bioengineering.
•1V:3H or steeper – Roughen stairstep or terrace slope if planting.
•1V:2H – Maximum suggested slope angle for unreinforced fills.
•1V:2H or steeper – Biotechnical techniques (combination of stabilization structures, soil bioengineering and geotechnical methods) often needed.
•1V:1H – Maximum suggested slope angle for unreinforced cuts in clay soil.
•5V:1H – Typical face angle for rockeries, gabions, crib walls, etc.

FILE: SFLT

SLOPE FLATTENING

(adapted from FISRWG, 1998)

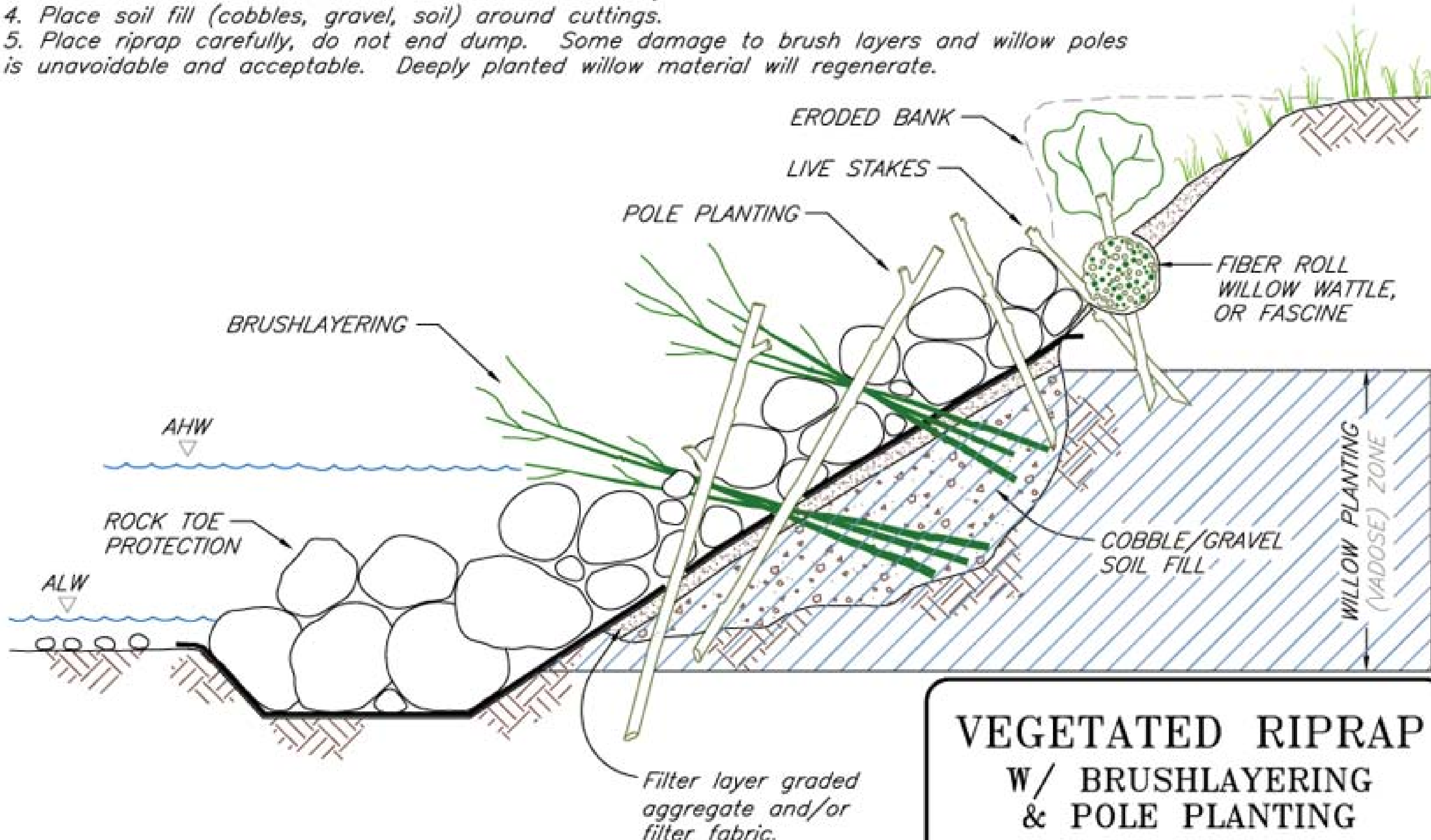


NOTES:
1. Harvest and plant stakes during the dormant season.
2. Use healthy, straight and live wood at least 1 year old.
3. Make clean cuts and do not damage stakes or split ends during installation; use an iron bar and pilot hole in firm soils.
4. Soak cuttings for at least 24 hours prior to installation. Soak for 5–7 days for best results.
5. Tamp the soil around the stake.

LIVE STAKING AND JOINT PLANTING

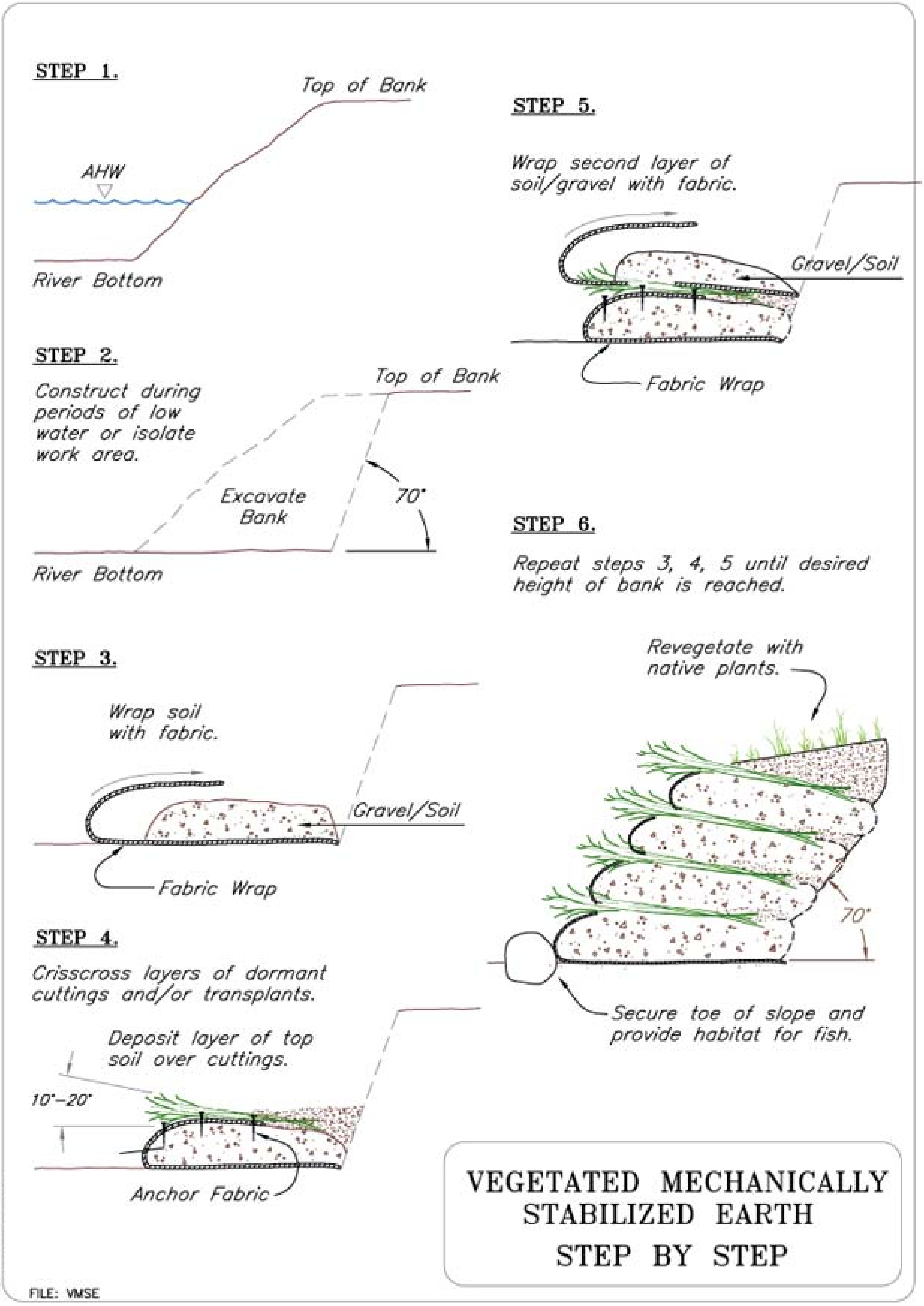
FILE: LVSTK

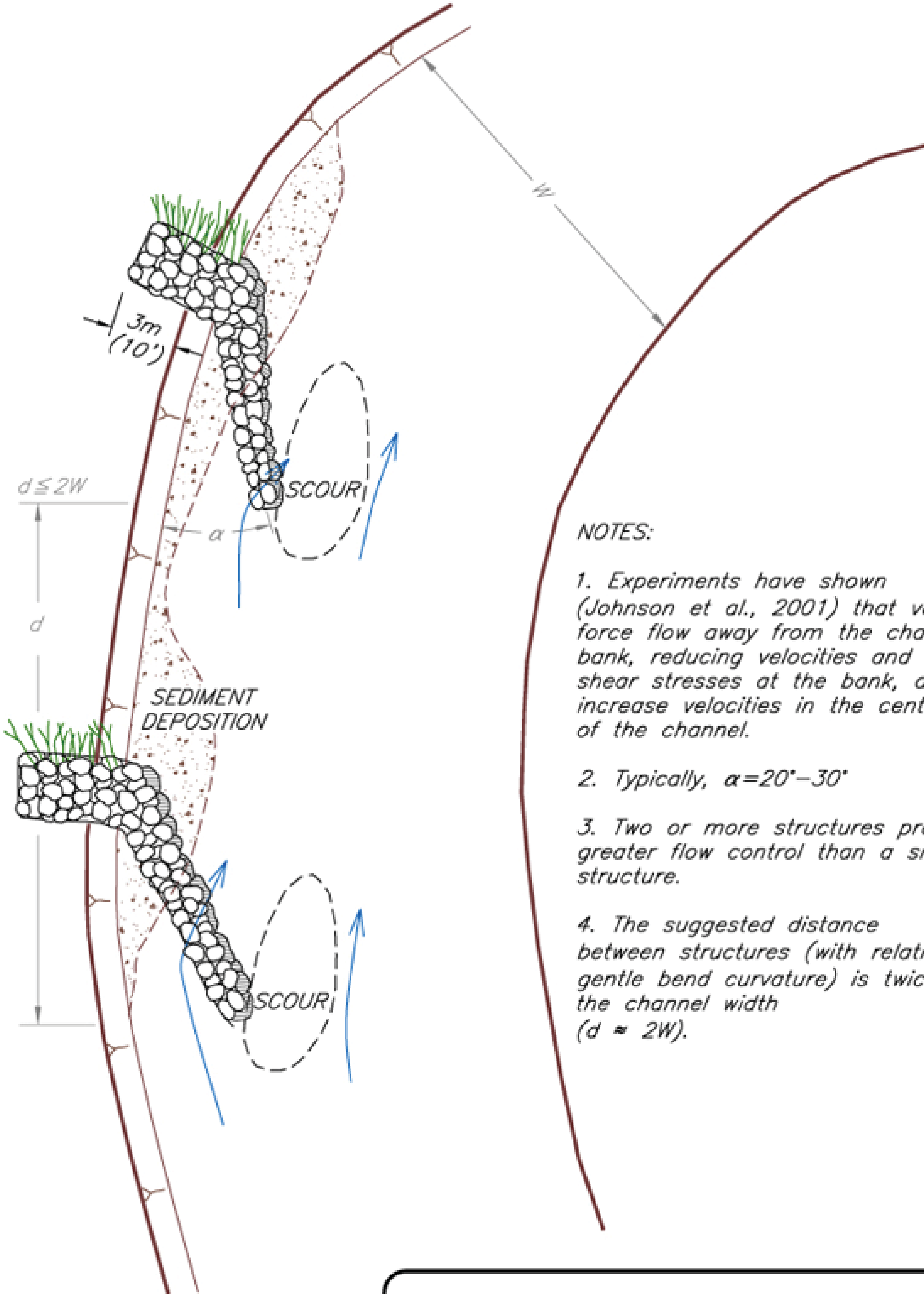
NOTES:
1. Install willow pole planting and brushlayering during bank grading and riprap placement to ensure good contact with 'native ground' and/or soil fill.
2. Willow poles and brush layers should extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in filter fabric as necessary.
4. Place soil fill (cobbles, gravel, soil) around cuttings.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.



VEGETATED RIPRAP W/ BRUSHLAYERING & POLE PLANTING

FILE: VRBLPP


STEP 1.
Top of Bank
AHW
River Bottom
STEP 2.
Construct during periods of low water or isolate work area.
Top of Bank
Excavate Bank
70°
River Bottom
STEP 3.
Wrap soil with fabric.
Gravel/Soil
Fabric Wrap
STEP 4.
Crisscross layers of dormant cuttings and/or transplants.
Deposit layer of top soil over cuttings.
10°–20°
Anchor Fabric
STEP 5.
Wrap second layer of soil/gravel with fabric.
Gravel/Soil
Fabric Wrap
STEP 6.
Repeat steps 3, 4, 5 until desired height of bank is reached.
Revegetate with native plants.
70°
Secure toe of slope and provide habitat for fish.
VEGETATED MECHANICALLY STABILIZED EARTH
STEP BY STEP
© 2004 SALIX
FILE: VMSE



NOTES:

1. Experiments have shown (Johnson et al., 2001) that vanes force flow away from the channel bank, reducing velocities and shear stresses at the bank, and increase velocities in the center of the channel.

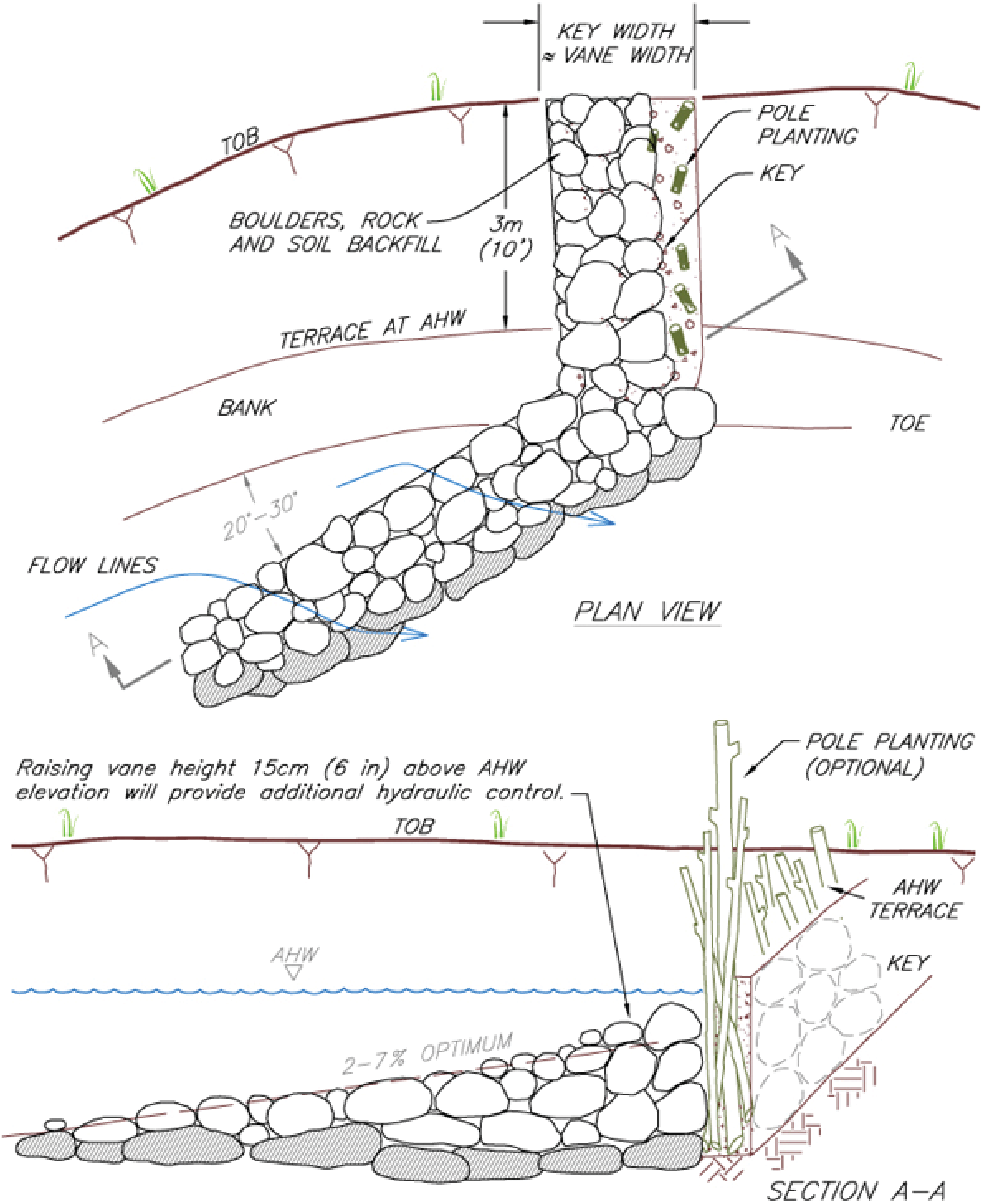
2. Typically, $\alpha = 20° - 30°$

3. Two or more structures provide greater flow control than a single structure.

4. The suggested distance between structures (with relatively gentle bend curvature) is twice the channel width ($d \approx 2W$).

TYPICAL VANE

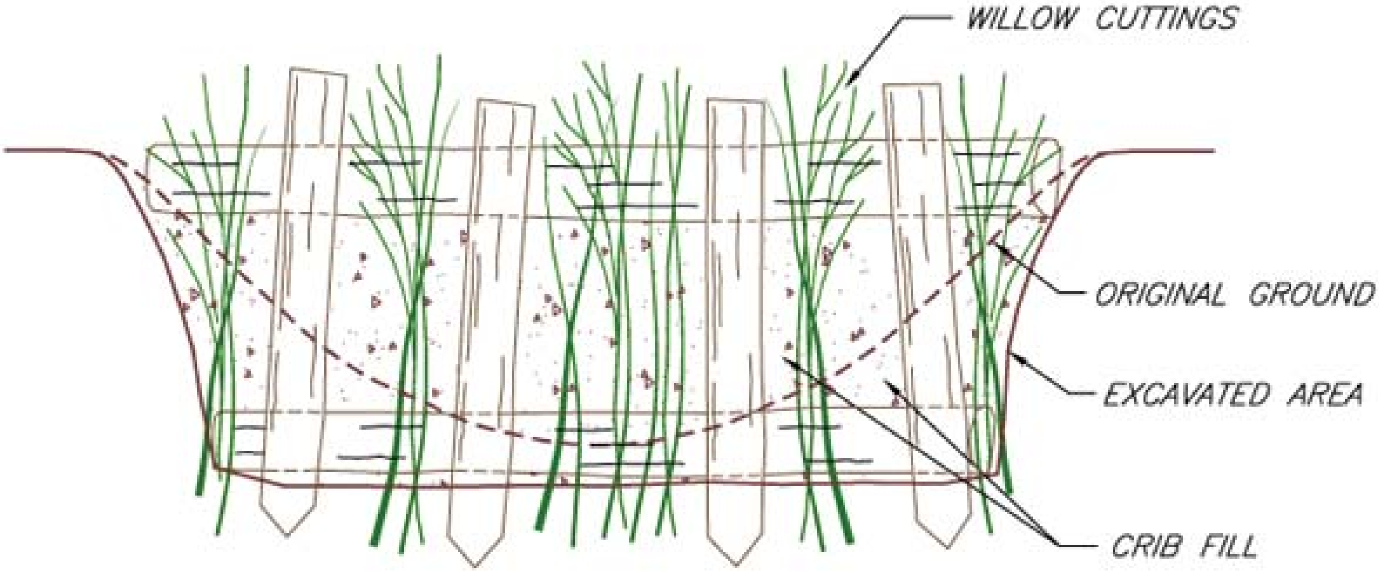
FILE: VANE



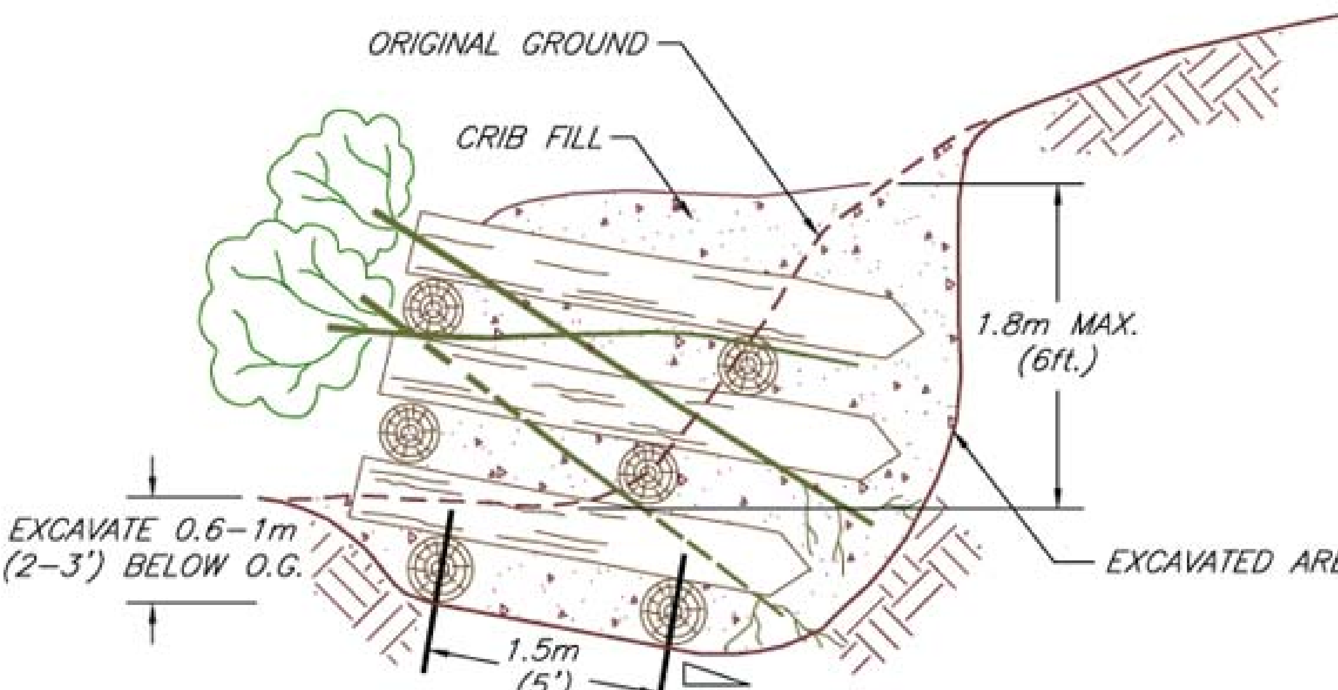
Relatively large, flat footer rocks should be placed as deep as the deepest anticipated scour along the thalweg, or 2 vane rock diameters below the vane rocks, whichever is greater. Inordinate scour can be mitigated by placing a stone or geotextile under layment, or by using self–launching (graded) stone.

TYPICAL VANE BANK KEY DETAIL
(WITH POLE PLANTING)

FILE: VANEKY



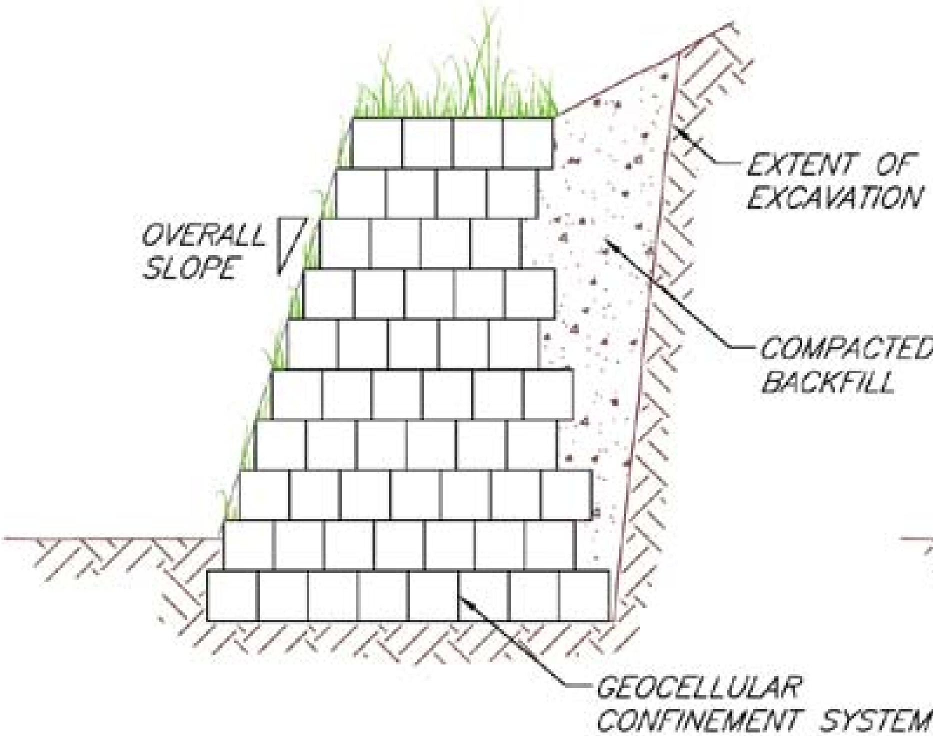
PLAN VIEW AFTER INSTALLATION OF FIRST RANK OF LOGS



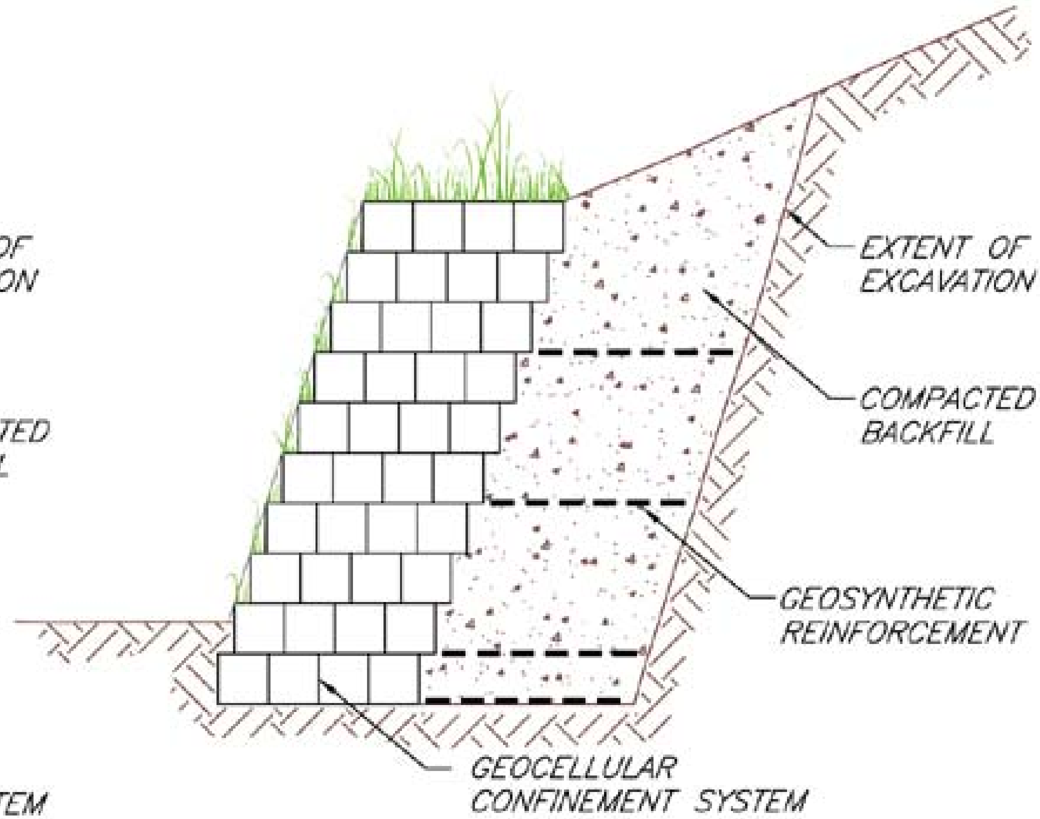
CROSS–SECTION

LIVE CRIB WALL

FILE: LVCRIB



GRAVITY GCS WALL



SOIL REINFORCED GCS WALL

GEOCELLULAR CONFINEMENT SYSTEMS RETAINING WALL DESIGNS

FILE: GCS

Outside meander erosion, residential area, Bank Height = ~ 7', BEHI = 29/Very High

Location: **Bishop Creek** Site: 4 Picture: 187

Toe Erosion, downstream end of Site 4

Location: **Bishop Creek** Site: 4 Picture: 182

Upper Bank Slope Failure, looking downstream, Bank Height = ~ 5.5', BEHI = 31/Very High

Location: **Ingersol Creek** Site: 1 Picture: 251

Undercutting Bank, looking upstream, sediment deposit

Location: **Ingersol Creek** Site: 1 Picture: 256

Toe Scour and Bank Failure, Bank Height = ~ 7', BEHI = 31/Very High

Location: **Ingersol Creek** Site: 5 Picture: 275

Outside Meander Erosion

Location: **Ingersol Creek** Site: 5 Picture: 273

Outside Meander Erosion, looking downstream, Bank Height = ~ 10', BEHI = 34/Very High

Location: **Middle Branch Rouge River** Site: 7 Picture: 365

Gully Erosion along Site 7

Location: **Middle Branch Rouge River** Site: 7 Picture: 369

Active Bank Erosion at downstream end of Site 7

Location: **Middle Branch Rouge River** Site: 7 Picture: 373

Bank Failure, Bank Height = ~ 3.5’, BEHI = 34/Very High

Location: **Middle Branch Rouge River** Site: 8 Picture: 379

Undercutting Bank, looking downstream

Location: **Middle Branch Rouge River** Site: 8 Picture: 381

Undercutting Bank, Bank Height = ~ 7’, BEHI = 29/Very High

Location: **Middle Branch Rouge River** Site: 14 Picture: 408

Mass Wasting at Site 14

Location: **Middle Branch Rouge River** Site: 14 Picture: 411

Outside Meander Erosion & Undercutting Bank, Bank Height = ~ 3.5', BEHI =31/Very High

Location: **Middle Branch Rouge River** Site: 26 Picture: 476

Riprap in channel showing pre-erosion bank location (looking downstream)

Location: **Middle Branch Rouge River** Site: 26 Picture: 481

Active Bank Failure and Slumping

Location: **Middle Branch Rouge River** Site: 26 Picture: 483

Active Bank Failure and Slumping

Location: **Middle Branch Rouge River** Site: 26 Picture: 501