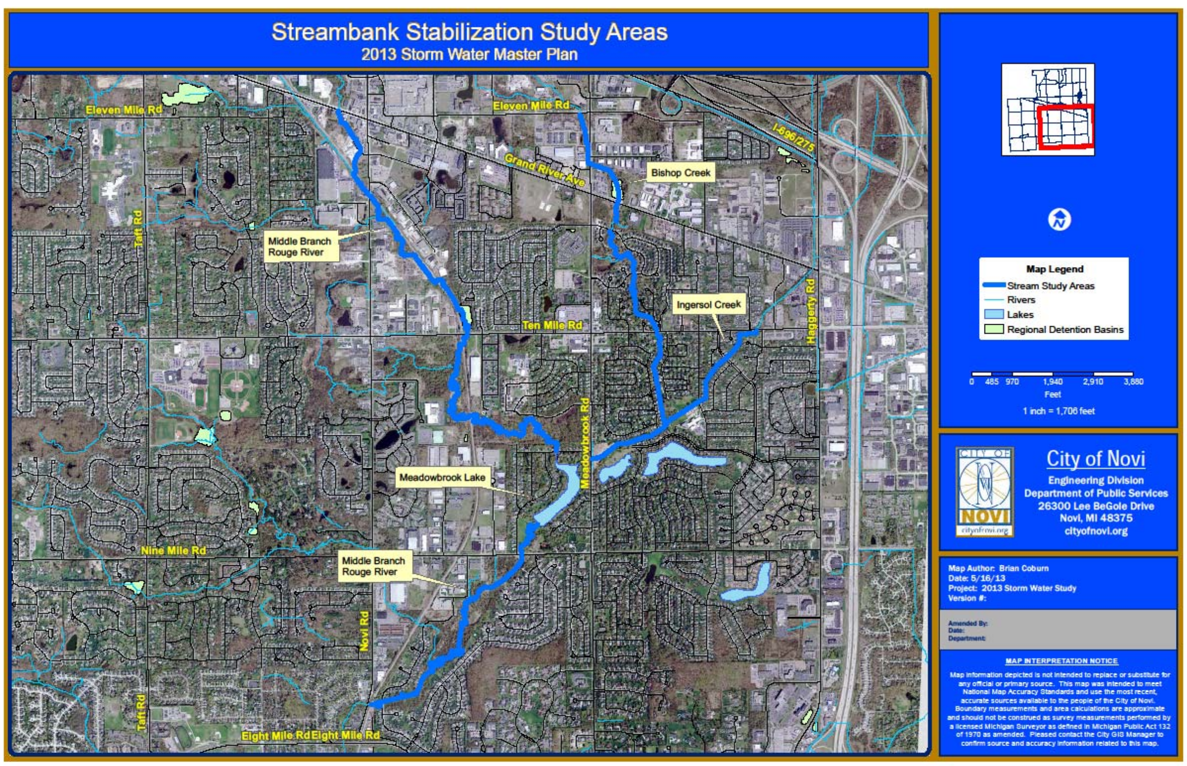
SECTION 6
STREAMBANK STABILIZATION EVALUATION AND RECOMMENDATIONS

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.

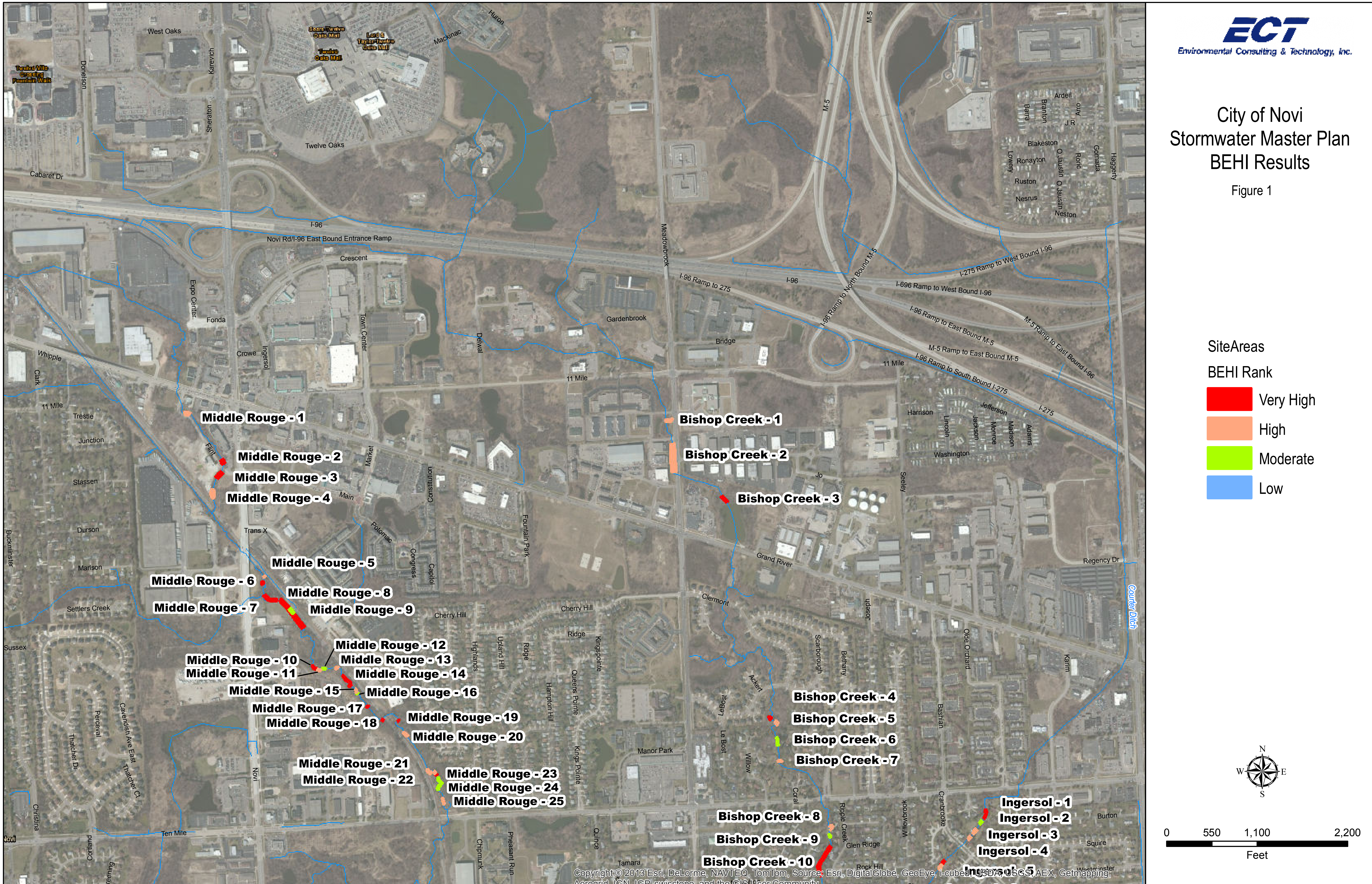
Evan Corbin
Associate Engineer

Marty Boote
Environmental Scientist

APPENDIX A

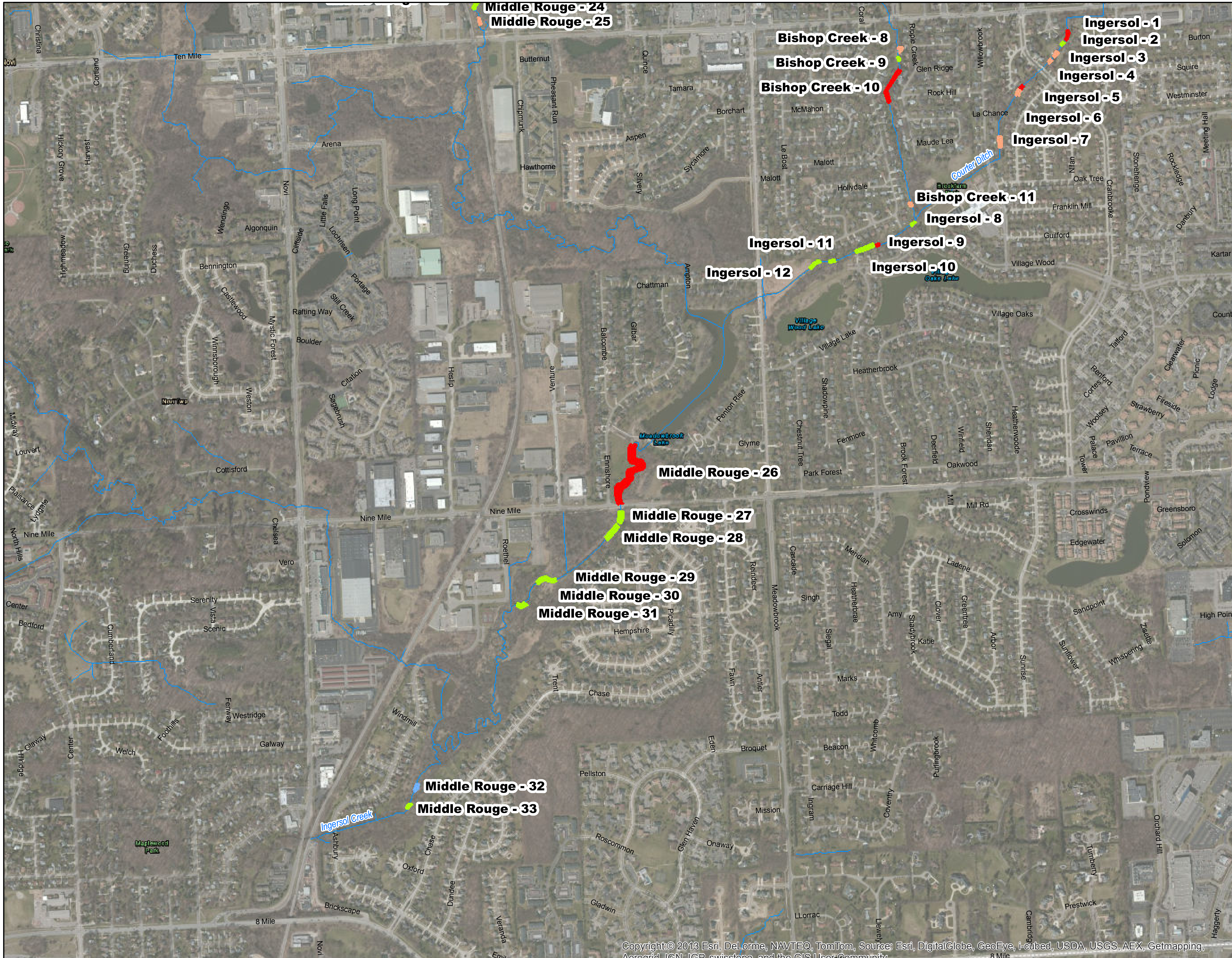
Table 1. BEHI Data

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**



City of Novi
Stormwater Master Plan
BEHI Results

Figure 1



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.

[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.

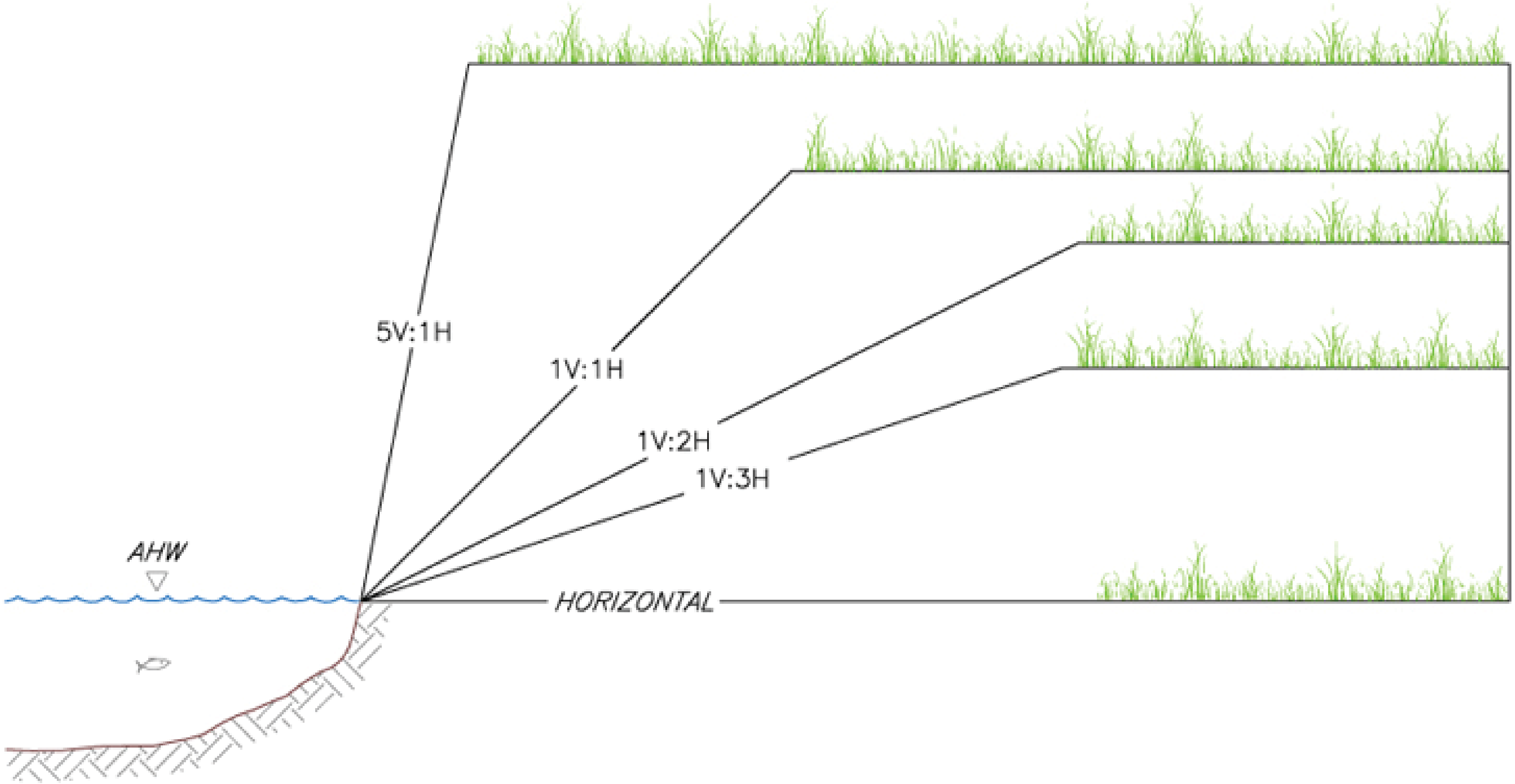
Cribwalls

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.

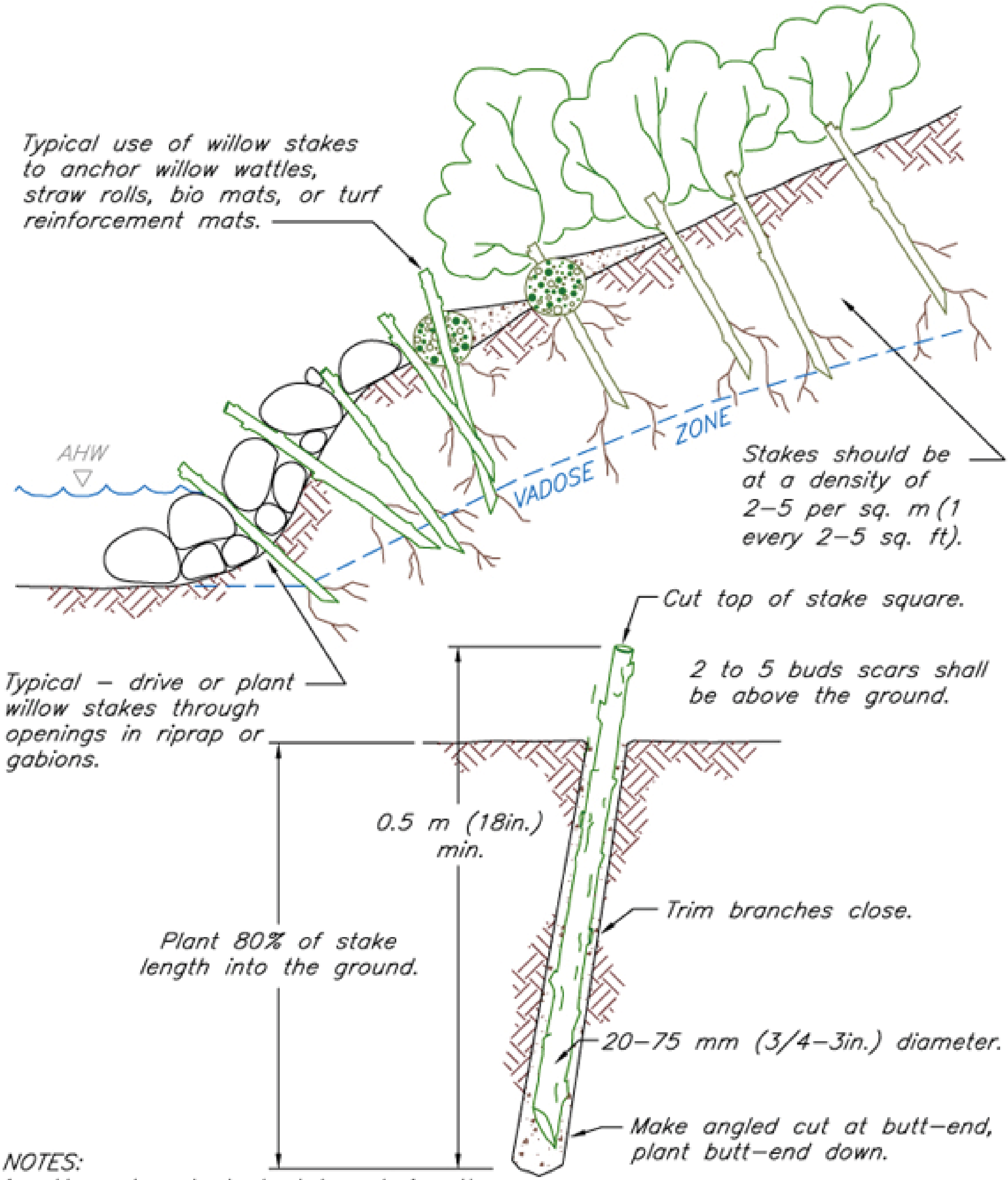


- 1V:3H – Maximum suggested slope angle for establishing plantings or seedlings, when used alone.
- 1V:3H – IV:2H – Optimal slope angle range for soil bioengineering.
- 1V:3H or steeper – Roughen stairstep or terrace slope if planting.
- 1V:2H – Maximum suggested slope angle for unreinforced fills.
- 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)



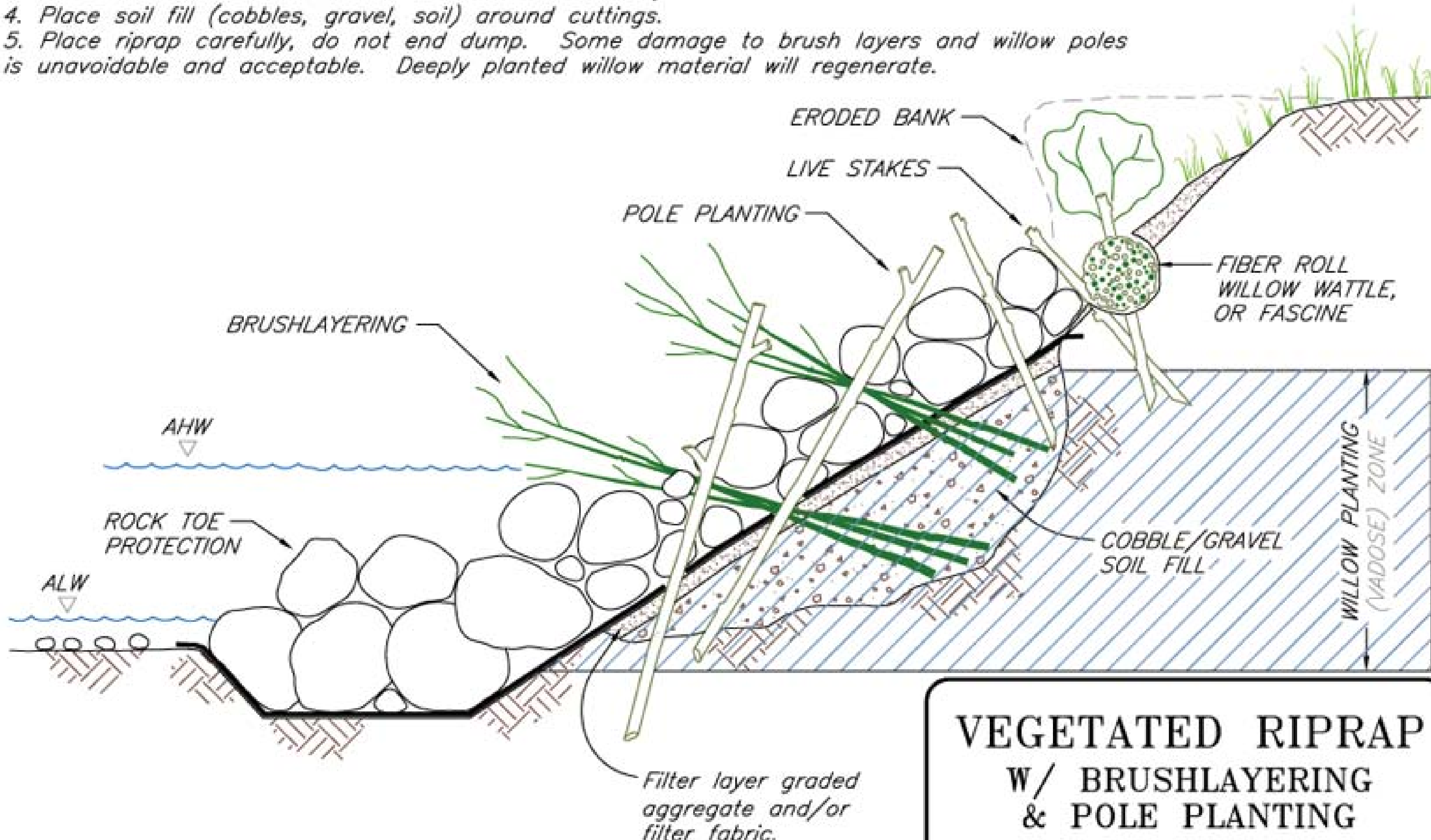
NOTES:

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.

FILE: LVSTK

LIVE STAKING AND JOINT PLANTING

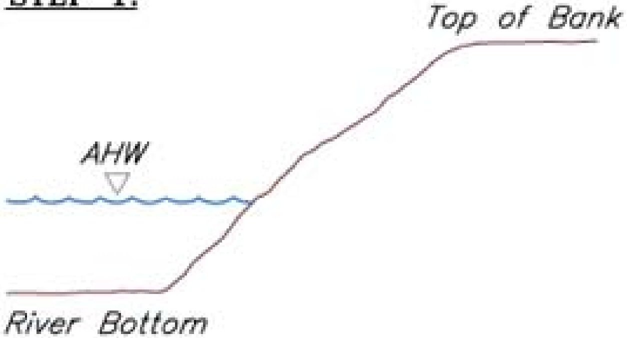
NOTES:
1. Install willow pole planting and brushlayering during bank grading and riprap placement to ensure good contact with 'native ground' and/or soil fill.
2. Willow poles and brush layers should extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in filter fabric 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

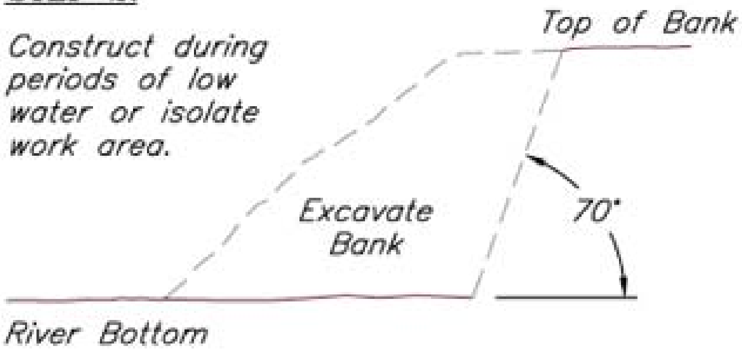
FILE: VRBLPP

STEP 1.



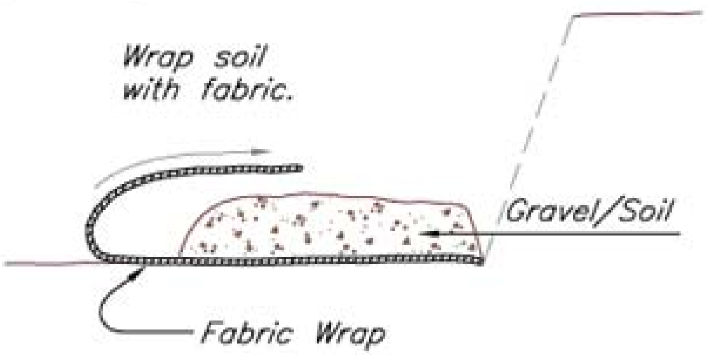
STEP 2.

Construct during periods of low water or isolate work area.



STEP 3.

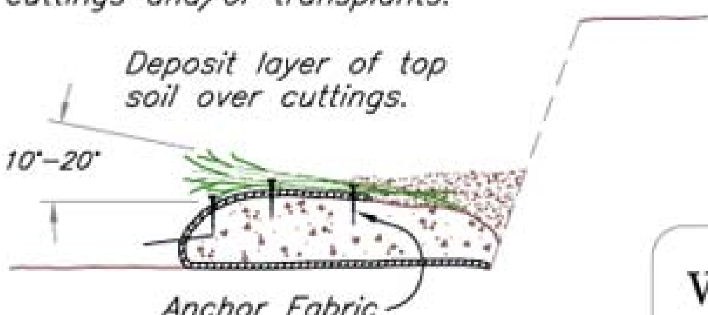
Wrap soil with fabric.



STEP 4.

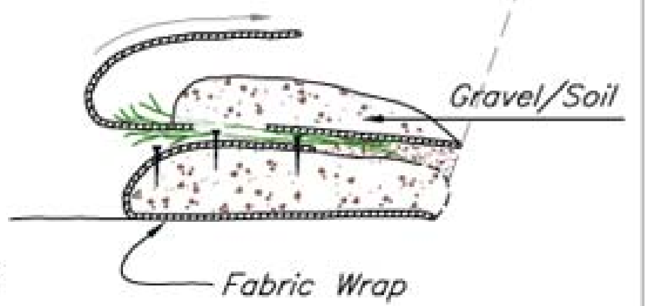
Crisscross layers of dormant cuttings and/or transplants.

Deposit layer of top soil over cuttings.



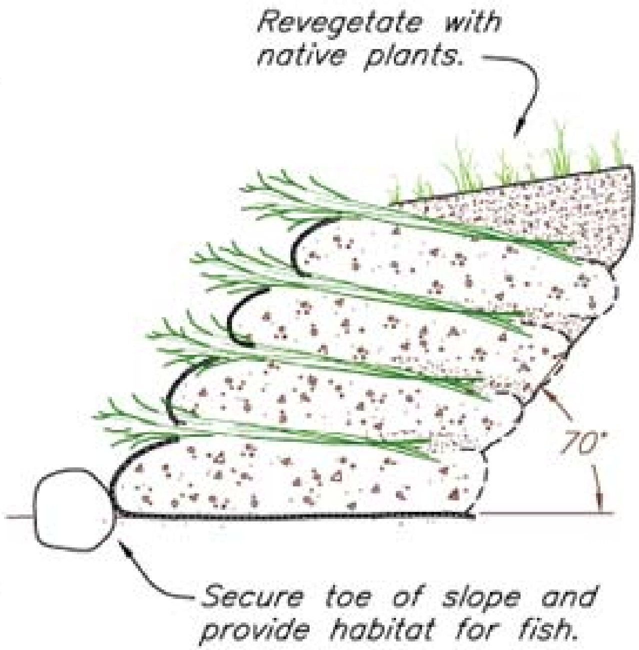
STEP 5.

Wrap second layer of soil/gravel with fabric.



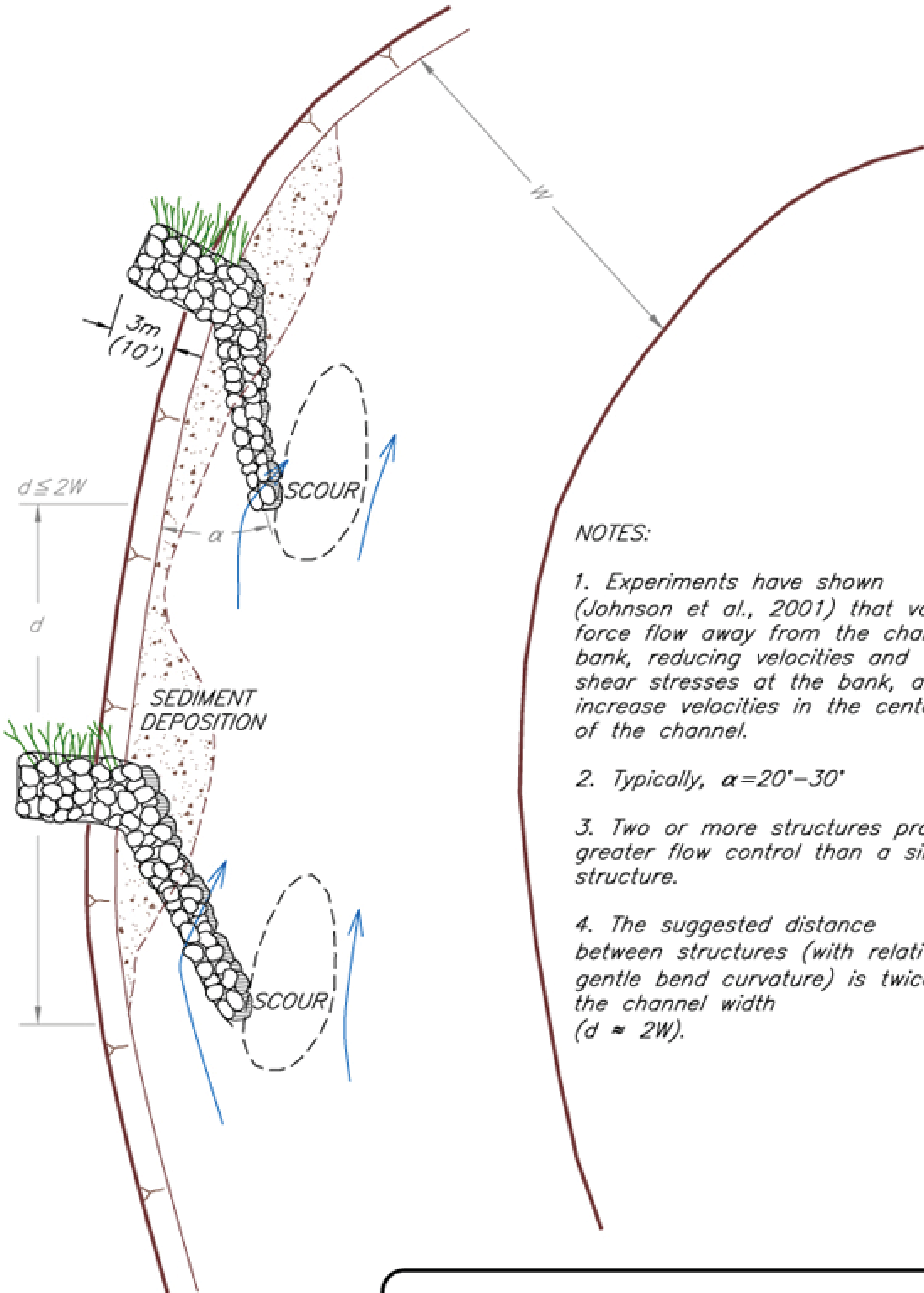
STEP 6.

Repeat steps 3, 4, 5 until desired height of bank is reached.



VEGETATED MECHANICALLY STABILIZED EARTH STEP BY STEP

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.

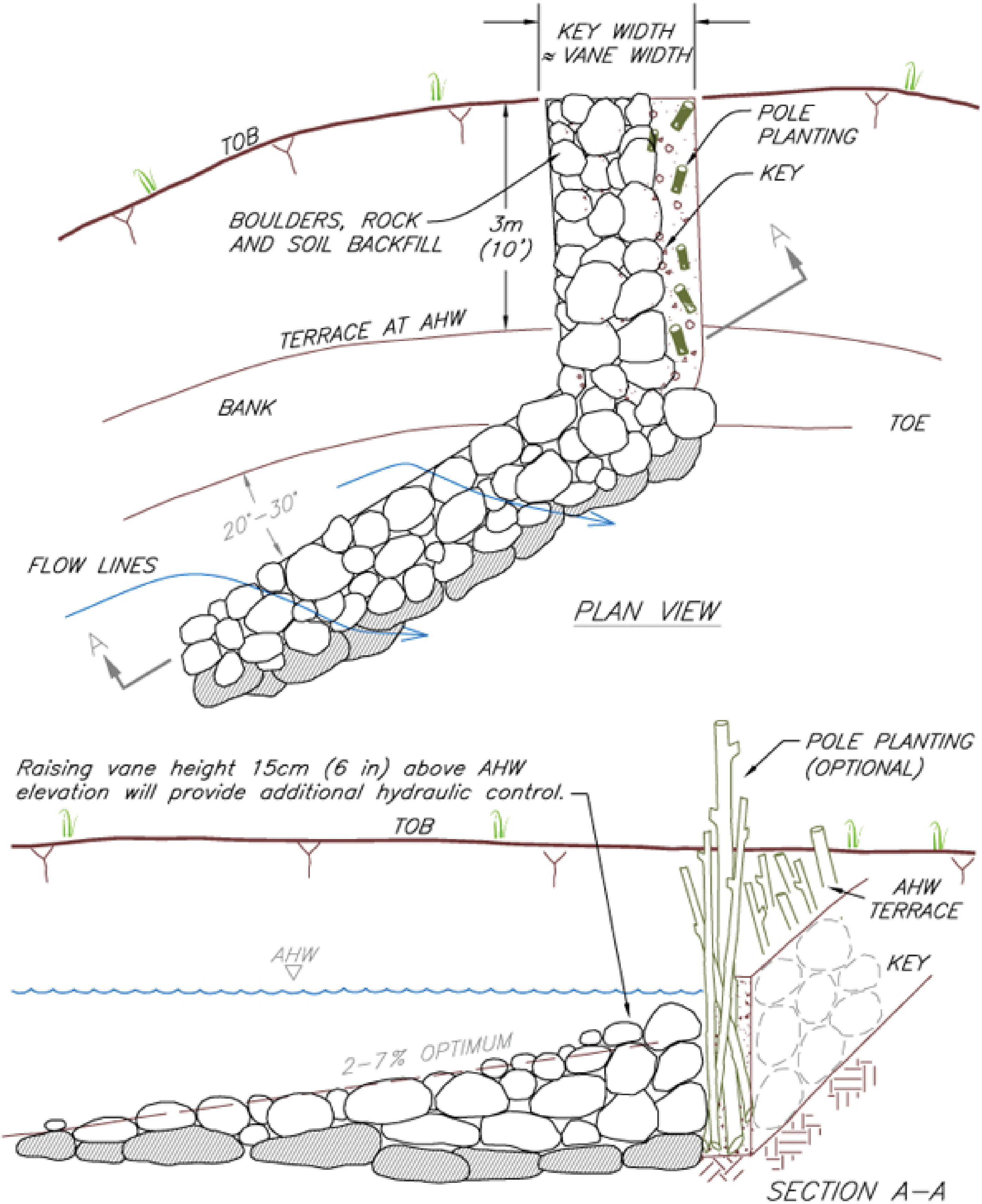
2. Typically, $\alpha = 20^\circ - 30^\circ$

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

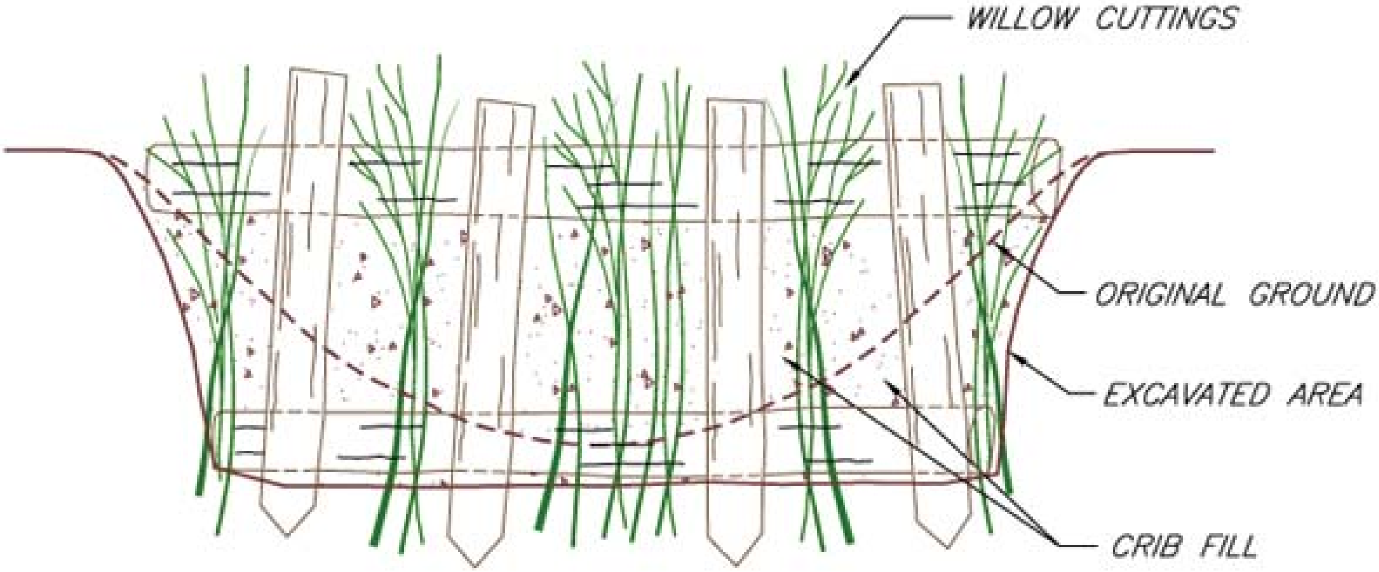
FILE: VANE



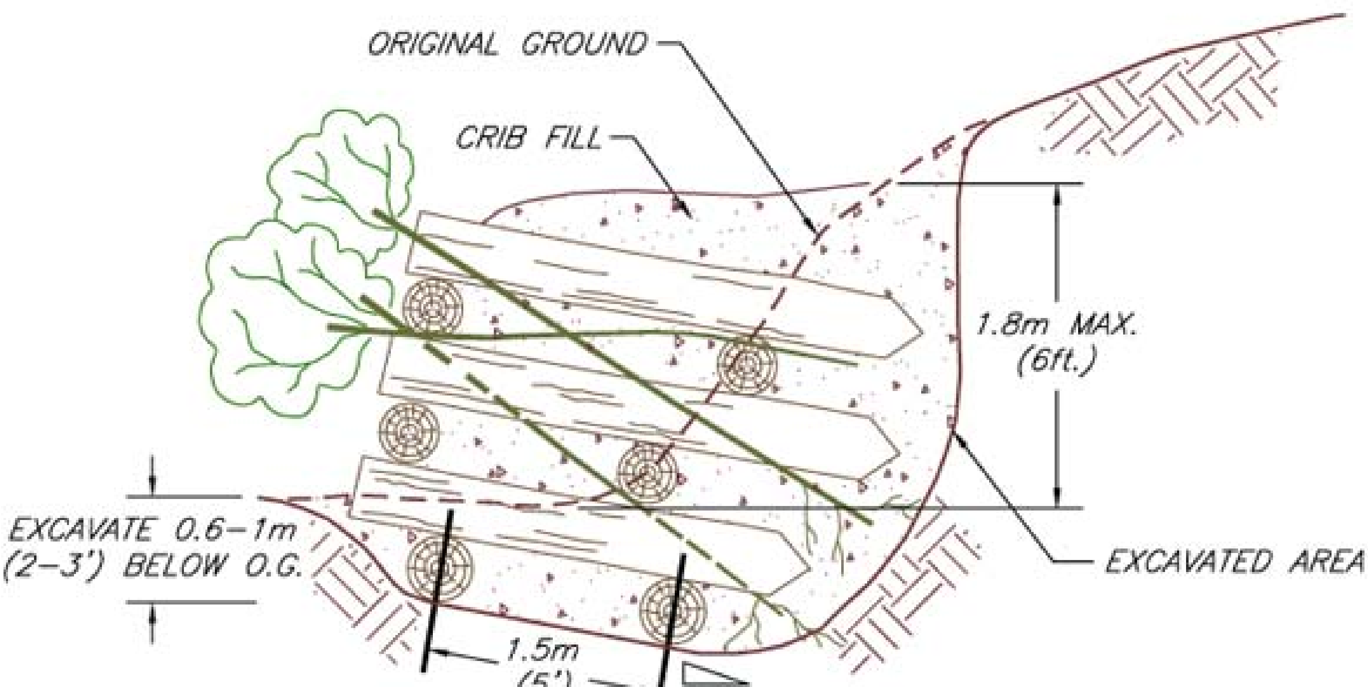
Relatively large, flat footer rocks should be placed as deep as the deepest anticipated scour along the thalweg, or 2 vane rock diameters below the vane rocks, whichever is greater. Inordinate scour can be mitigated by placing a stone or geotextile under layment, or by using self–launching (graded) stone.

TYPICAL VANE BANK KEY DETAIL
(WITH POLE PLANTING)

FILE: VANEKY



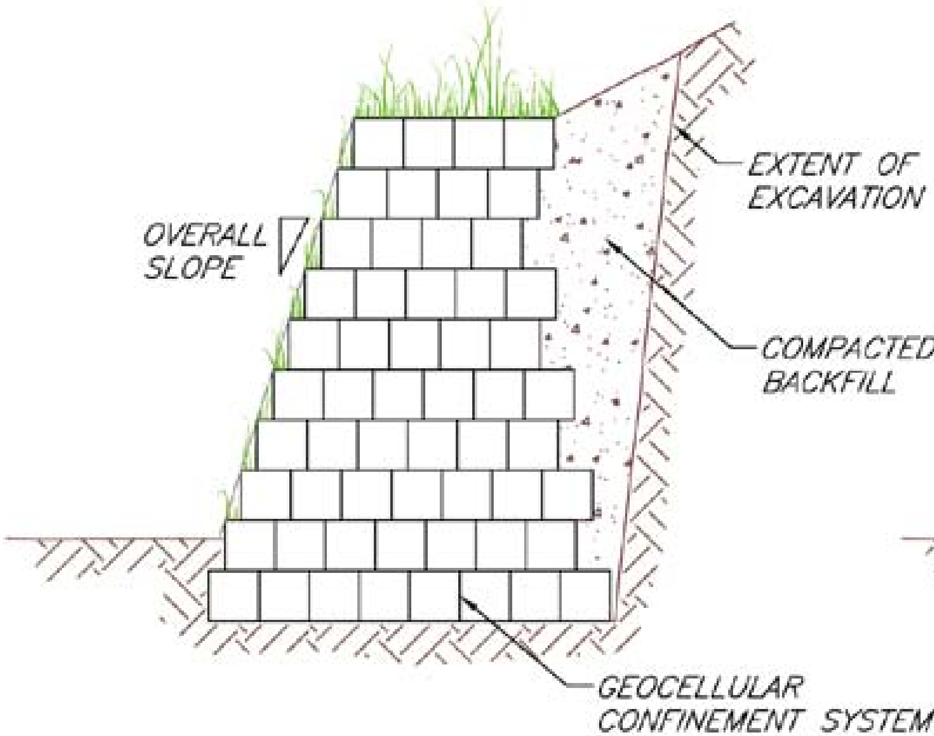
PLAN VIEW AFTER INSTALLATION OF FIRST RANK OF LOGS



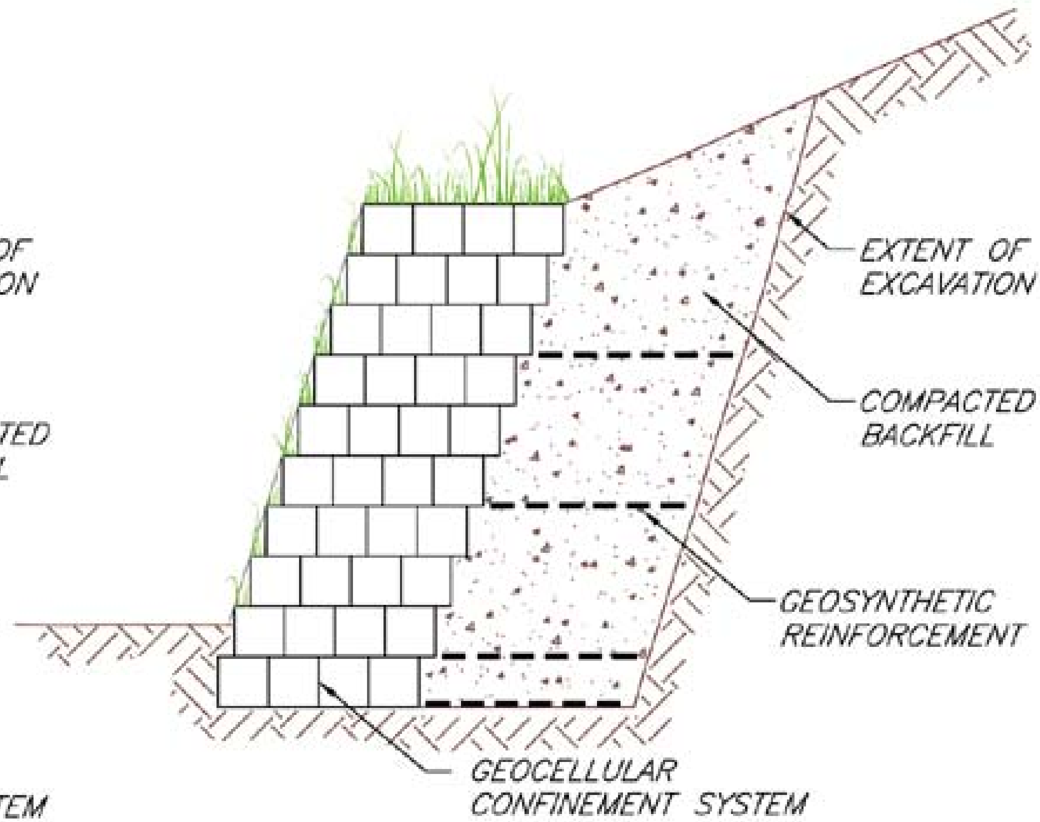
CROSS–SECTION

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