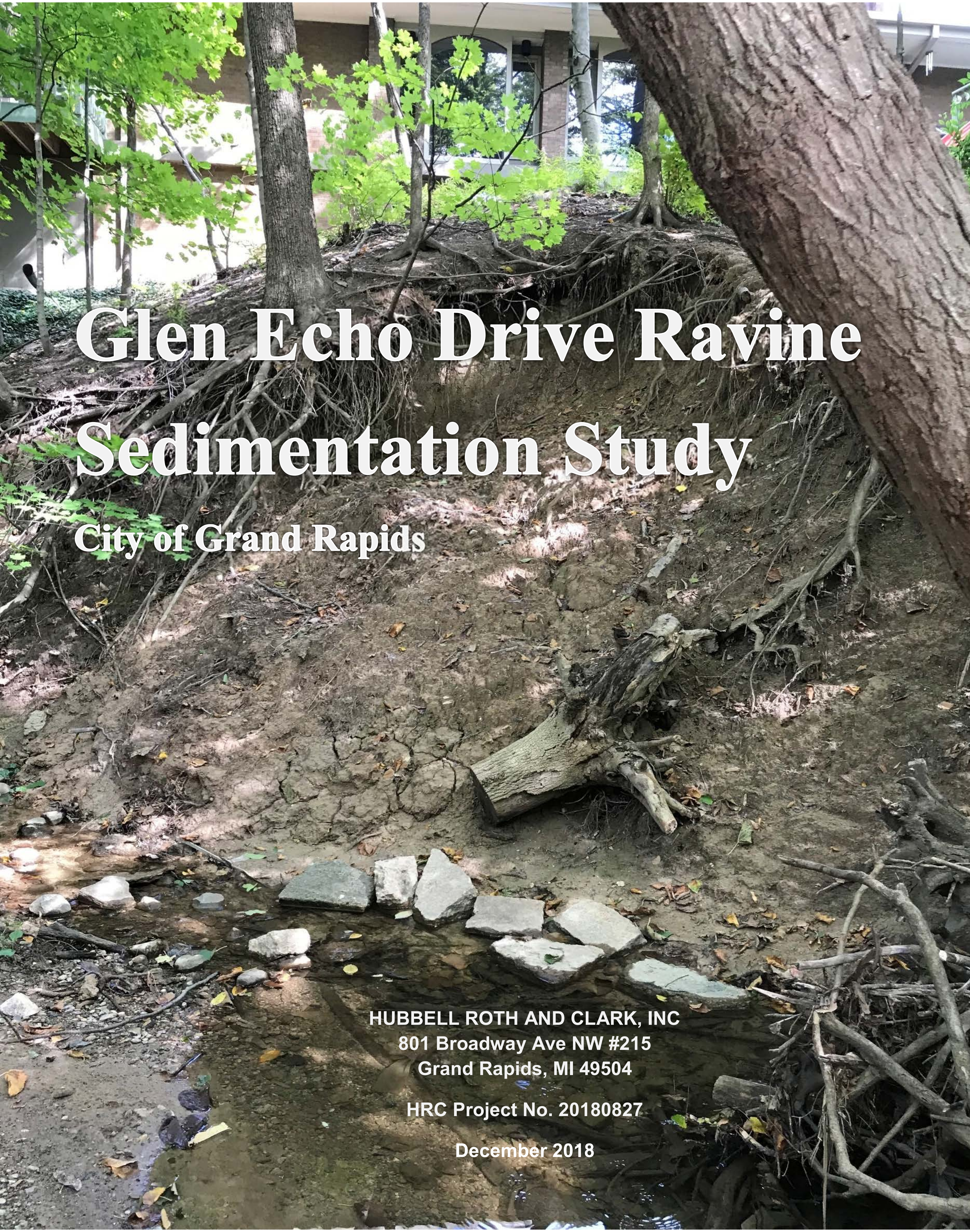

Glen Echo Drive Ravine Sedimentation Study

City of Grand Rapids

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Chapter 1 - Understanding the Project

The Glen Echo sedimentation study was commissioned by the City of Grand Rapids to address the sedimentation that is occurring on the Glen Echo branch of the Breton-Burton Drain (which is a tributary to Plaster Creek) upstream and downstream of Barfield Drive, SE. This sedimentation has resulted in problematic plugging of three 24-inch diameter HDPE culverts that were previously installed to provide cover and isolation between a sanitary sewer and the drain, south of Glen Echo Drive SE and just east of Burning Tree Drive, SE.

The City is experiencing continued excessive sediment buildup that has been occurring at a rate that requires frequent maintenance in order to maintain proper drainage along a reach of this second order natural stream southeast of the homes on Glen Echo Drive SE. The continued deposition of sand and silt completely plugs three culverts, which, when plugged, causes the storm water flows to overtop the channel banks and flow overland jeopardizing properties and structures and depositing dirt and debris along this grassed area. Several residents have stated that they are currently experiencing flooding and erosion on their properties despite the frequent cleaning of the sediments from the culverts. The City is interested in determining what could be done to halt the sediment build up and prevent the further maintenance requirements.

This report and study is to evaluate these concerns and the existing condition of the upstream channel and watershed in order to determine the specific causes of the continued sediment origin and deposition and to identify specific channel improvements, management practices and/or infrastructure improvements that could be implemented to reduce or mitigate the situation.

The open channel project study area is located just south and east of Glen Echo Drive SE and between Burning Tree Drive SE on the south and Meadowbrook Street SE on the north as shown on Figure 1. The watershed that is drained to the downstream point extends up to just south of Burton Street on the north, Ridgewood Ave SE on the east and to Inverness Drive, Whippoorwill Court and Burning Tree Drive on the west. A map of the watershed drainage area is shown on Figure 2.

Approximately 780 feet upstream of Barfield Drive a tributary branch from Mission Hills Drive and Meadowbrook Street enters the main branch drain from the north. Flow to this 30-inch diameter storm sewer includes drainage from the north end of Mission Hills Drive, SE, Meadowbrook Street SE Woodlawn Ave., SE, Ridgewood Ave. SE as well as Britton Ct. SE and a portion of Edgewood Ave. SE near Meadowbrook St. SE plus the Our Savior Lutheran church site at the SW corner of Ridgewood and Burton and the Zaagman Funeral Home at the SW corner of Woodlawn and Burton. There is a total of 35 public catch basins. Only the Funeral Home appears to have a functioning detention basin. Our Savior Lutheran Church at the corner of Ridgemoor and Burton does not appear to have any detention basin and its parking area has 3 catch basins that appear to be connected to the public system. The open channel section of the Main Branch downstream of this 30-inch diameter storm sewer is somewhat steep for the first 280 feet (4.2%) and in then eventually transitions to a flatter slope (1.6%) as it proceeds towards Barfield Drive. The overall drainage area tributary to this storm drain outlet is approximately 49 acres.

Approximately 220 feet upstream of Barfield Drive a tributary branch from Capilano Drive enters the main branch from the east. Flow from this branch originates from an 18-inch diameter storm sewer that takes drainage from Capilano Drive, SE, Capilano Ct., SE Mission Hills Drive, SE as well as areas to the south and east through 8 catch basins. The open channel section of this tributary branch downstream of the 18-inch diameter storm sewer is very steep at its upstream end and in then eventually transitions to a flatter slope as it near the main branch. The overall average slope of this tributary is approximately 8%. The overall drainage area tributary to this storm drain outlet is approximately 13 acres.

Approximately 180 feet upstream of Barfield Drive a tributary branch from Glen Echo Drive enters the main branch from the west. This 12-inch diameter branch sewer enters the main branch of the drain and includes drainage from the area of Glen Echo Drive northeast of Barfield Drive through 6 catch basins as well as the south portion of the Saint Paul the Apostle church site and the east portion of the Ridgemoor Montessori Center site. The Saint Paul site has a functioning detention basin at the SW corner of the site and then discharges into the storm sewer at the north end of Glen Echo Drive. The overall drainage area tributary to this storm drain outlet is approximately 17 acres.

At the point were the Main Branch of Glen Echo Drain crosses under Barfield Drive there is significant additional flow tributary to this drain that comes from storm sewers draining areas to the northwest from 10 catch basins including the westerly portion of the Ridgemoor Montessori Center and also from residential areas to the southeast of Barfield Drive from 6 catch basins. The overall drainage area tributary to the storm drain outlet downstream of Barfield Drive is approximately 96 acres.

Downstream of Barfield Drive SE the drainage channel narrows somewhat but the rate of meander increases thus likely increasing the stresses on the channel sidewalls due to the channel velocities and approach vectors. At the point where the triple 24-inch diameter HDPE culverts begin, the overall drainage area is approximately 102 acres. At the downstream end of the culverts the area along the lower end of Glen Echo Drive and Whippoorwill Court Joins in and the total drainage area at that location is approximately 122 Acres.

At the upstream and of these triple 24-inch diameter culverts, excessive sedimentation deposits and cannot be transported through the culverts since there are three pipes and the velocity is slowed significantly at this point so that sedimentation occurs and the inlet to the culverts becomes blocked. This has not alone led to a blockage of drainage as most of the sediment that is transported down the creek is significantly a very porous sand or granular material and the water from the dry weather flow usually seeps through the sand and into the pipes. However most of the sand is deposited in front of the pipes thus leading to the pipes frequently becoming plugged so that they cannot transport the higher flows that occur during rainfall events thus leading to the flow going overland to the downstream end of the pipes. Since this plugging occurs, the pipes have had to be cleaned frequently so that they can be ready to transport flow.

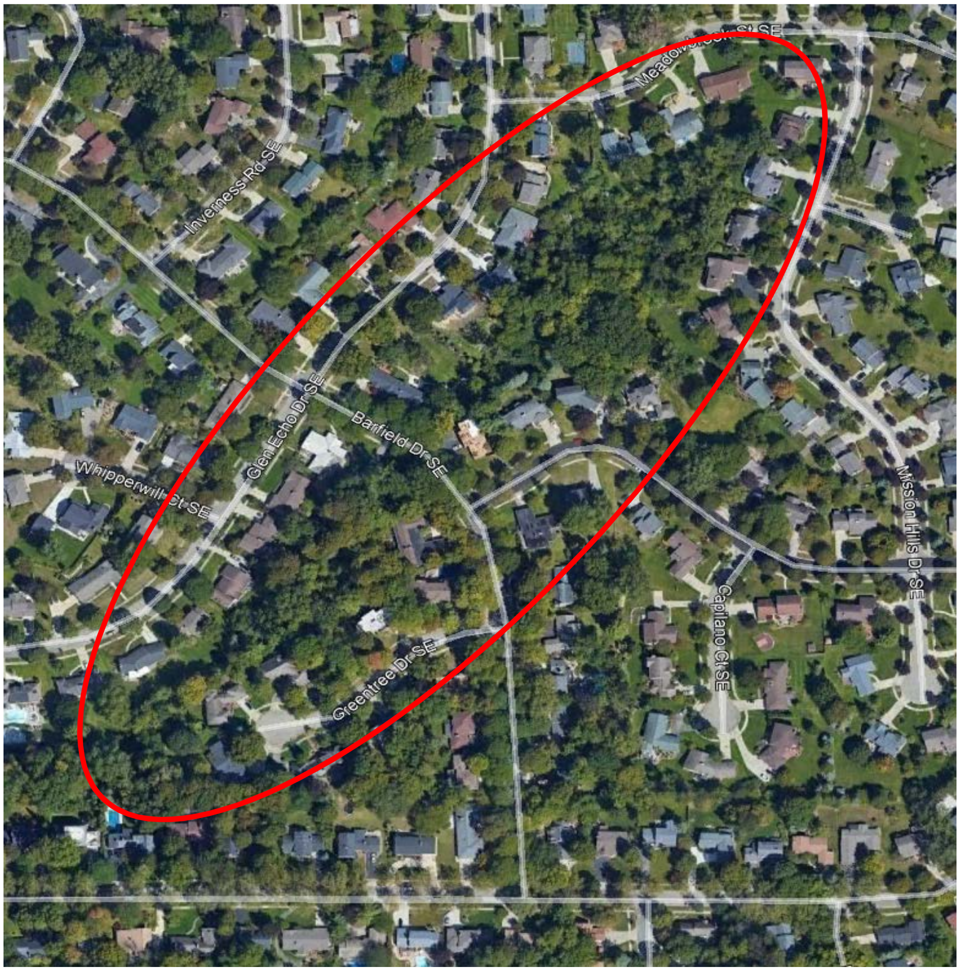


Figure 1 – Open Channel Project Location Map

Figure 2 – Overall Watershed Area

Study Area History

To validate the concerns of excessive sedimentation an understanding of the source of the sediment needs to be undertaken. Once the sources of the sediment are identified the underlying causes for the streambank instability and higher than normal bank erosion, can be conducted. Reviewing topographical and drainage maps it was determined that the study watershed area contains a ephemeral second order tributary stream that drains approximately 102 acres or about 0.16 square miles of watershed that eventually is discharged to the sediment deposition area upstream of the triple culverts. Most of the drainage area contributing to this stream comes from storm runoff from mostly residentially developed area that is fully developed and enclosed within storm sewers and was likely developed between the 1960's and late 1980's with the aforementioned institutional developments along Burton Street. Upon review the drainage characteristics of the watershed area the watershed is well vegetated and stable and does not produce significant sediment with the exception of the open channel ravine areas, which are quite wooded and have exposed erosion areas due to the open channels which are incising the banks quite prolifically due to the steep slopes, increased flows and meanders in the flatter channel sections.

Figure 3 - Typical Upstream Ravine Drainage Channel – looking southwest from Barfield

Figure 3 indicates what was typically observed throughout most of the upstream open channel study reach. The width of the active channel represented in this photo measured out to be approximately 8.5 feet. It was very difficult to determine what the bankfull channel is in this reach due to the variability of geomorphic features that could be measured. This suggests that the water forces and flow rates that created the channel are likely very dynamic and changing and with that sediment loads are significant that a well-defined channel bankfull width and depth is difficult to document

Chapter 2 – Existing Conditions and Watershed Analysis

Understanding the cause of the sediment buildup within the study reach is an important task of this study. It is also important to determine whether improvements to the geomorphology of the stream course can be completed to alleviate the bank erosion (and curtail excessive erosion) that has been observed. By definition, stream stability is defined by:

> "A rivers ability, in the present climate, to transport the flow and sediment from the watershed, over time, such that the channel maintains its dimension, pattern, and profile without aggrading or degrading." *Dave Rosgen, 2000*

On August 27, 2018 and September 26, 2018 site visits were conducted to observe, measure and photograph the sediment deposition area as well as the upper watershed channels in order to determine if and where excessive bank erosion is occurring and to determine if the stream has, and is continuing to, depart from its historical reference condition. On the date of the August visit, there was base flow conditions occurring in the upper watershed. Tentative measurements were made to determine slope and the locations of channel culverts and inverts. The following observations were made:

- A modified Rosgen Level II field evaluation was conducted to develop an understanding of the type stream and current streambank stability issues. Based on our preliminary measurements and observations we have determined that the stream is moderately over widened but severely incised in many locations. There are areas of the study reach where, in the past, large boulders and broken concrete have been placed to slow the flow and reduce the erosive nature of the discharge. Those armored areas appeared as check dams and were, in our opinion, mostly effective in reducing the instability.
- An estimated bankfull width of approximately 8.5 feet and a bankfull depth of approximately 1.1 feet was measured in a few locations and are not consistent with a stream with a contributing watershed of approximately 0.08 square miles. The stream is classified as a Rosgen B 4-5 stream. This means that the stream has significant slope (above 0.5%) and its bed is composed of predominately gravel and sand. Bankfull features were very difficult to determine within the study reaches and there was poor connection with the flood prone flood plain due to the over-widened channel, steep valley slopes, anthropogenic confinements and continuing bed incision.
- The stream has historical sinuosity but the width to depth ratio is excessively high which means that bankfull flows will likely not be effective at forming a new bankfull floodplain elevation. This is one of the causes of the erosion observed.
- Overall the steam is highly entrenched, but is appropriate for this type of single thread channel.
- High or very high bank erosion hazard index (BEHI) locations were noted in many locations. These locations were found where the channel was incised (typically just downstream of the concrete or rock check dams) or where sharp bends have occurred in the channel. The remainder of the study reach exhibits high incision with very active bank and bed erosion.
- Dynamic equilibrium is a condition where what is naturally eroding is then deposited on the next downstream point bar (a very natural and healthy process for a stream). Equilibrium has not been achieved on this stream due to the fact that the flow coming from the various culverts is generally

clean water and thus has little sediment content. This creates an imbalance in the geomorphic stability of the system and is a contributing factor in the rate of upstream bank erosion.

- Overall, the confinement of the stream is not an issue except where heavy boulder was previously installed which creates a threshold streambank (hardened) channel. Most of the residential homes that are riparian to the stream corridor have all been constructed up on the high terrace, well above the flood prone area and eroding channel.
- One home that was downstream of Barfield Road storm sewer outlet on the right bank is affected by bank erosion or failure due to stream bank erosion issues. Figure 3 is a typical picture of an actively eroding area that was observed.
- Generally mature native forest vegetation has established within the valley and there is evidence of surface soil erosion is occurring due to the lack of understory vegetation.

Figure 4 – Eroding Area behind the homes on Greentree Dr. SE.

After evaluating the entire length of the study area, there are areas that can be considered as stable as these bank areas are either reinforced by the existing vegetation or are areas hardened by boulders. The bank sections that were observed to be eroding are generally short in length and the sediment contributions from those reaches are very low. The sediment within the bottom of the channel appears to be relatively mobile and is passed by these stable areas by the flows. Boulders appear to have been placed in at culverts discharge areas to reduce storm discharge velocities as is shown on Figure 4 below.


Figure 5– Stream banks and bed stabilized by heavy boulder installation

Chapter 3 Characterizing the System

Understanding Stream Evolution

It is well documented that urbanization of a watershed has a deleterious effect on the rivers and streams receiving the watershed's storm runoff. As the watershed is urbanized, flows and soil erosion runoff typically increase. Typically, within an urban setting streams and rivers respond to the changing watershed by incising or down cutting and then over-widening. This is followed by the stream utilizing the excessive sediments generated from bank erosion to create a new bank full flood-prone floodplain. Table 1 is a progression chart that documents the typical transformation processes that occurs when streams are affected by a change to their hydrology, sediment supply or both. There is always a degree of down cutting and widening before stability is restored. In this particular case, progression no. 6 is what we believe to be occurring in this study reach. At this time the stream channel is at stage G in that it is in the process of over-widening, eroding the banks and incising is occurring.

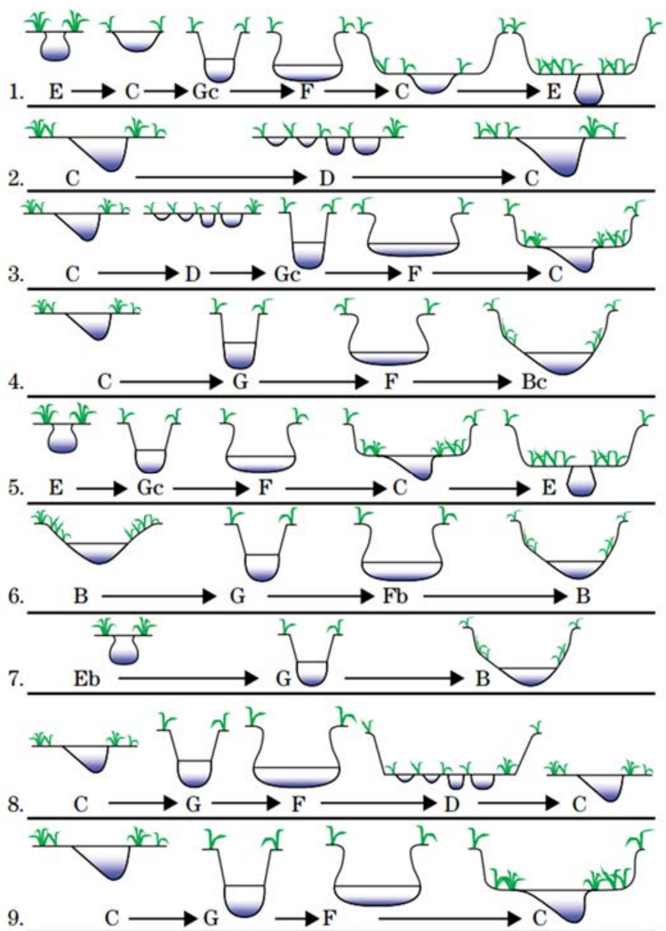


Table 1 Successional stages of channel evolution (Rosgen, 2007)

The study area's urbanized watershed is contributing flows that are significantly altering this reach. The 30-inch storm outlet pipe is discharging flow from the Mission Hills Drive SE and upstream residential/institutional areas northeast of this watercourse, may not have been originally a totally urbanized part of the watershed hydrology that historically created the geomorphology of this watercourse. The additional flow from this urbanization of this drainage area may have caused the watercourse to become unstable. In about 2004, the City had constructed a series of rock or concrete obstructions to reduce the erosive forces of the flow especially at each of the discharge pipes. While reviewing the plan, profile and dimensions of this stream it was observed that the majority of the sand and sediment is generated between these obstructions. In addition, the bed of the stream channel is, in many locations, resting on solid clay. This suggests that the slope of the channel has not been effectively controlled by the placement of these obstructions and that the horizontal movement of the channel is generating the sediment. Additional rip rap may address the horizontal movement of the stream. Since storm generated runoff in developed urban areas is generally clean water, bank stabilization methods must be installed to reduce or stabilize the eroding banks and halt the horizontal bed movement.

Streambank Erosion Control

All stream banks erode. The question is whether the rate of erosion is natural or accelerated by anthropogenic (man-made) influences. It is evident by our observations that a combination of many factors is likely at the root cause of the excessive amount of sediment moving down this channel and causing the blockages. These include:

1. Increased flows and development of the watershed has increased flows well above historical levels that formed this drainage system. This caused stream bed incisions to occur which results in excessive down cutting to occur that generates sediment.
2. Placement of rock and/or concrete revetment to stabilize the storm outlets has resulted in shifting the flows around the revetments causing excessive bank erosion.
3. Dense wooded canopy vegetation that limits the amount of sunlight effects the density of vegetation needed to maintain stream bank stabilization by root support. Add in the fact the recent ash tree decline has resulted in many dead trees being up-rooted has caused upper bank instability which adds additional sediment to the stream bed.

Chapter 4 – Alternatives and Recommendations

In order to rectify these erosion problems, there are a few options for addressing the rate of erosion and resulting sediment transport.

1. Reduce the peak flow rates that these open channel stream branches experience through peak flow reduction by constructing control structures along the streams or within the existing pipes to retard the flow rates and enhance the storage within the pipes.
2. Optimize the use of existing detention storage basins at the commercial/institutional sites along Burton and/or require the private property owners to construct additional detention storage where there currently is none.
3. Construct pipes along the steepest sections of these open channels to enable the flow from dry weather and lower frequency storm events to be transported down the steepest sections exclusively through pipes and thus avoid the scouring velocities that occur during these low frequency events. Flows during extreme events would use both the pipe as well as overflowing into the open channel. The result would be a significant net reduction in annual erosion rates.
4. Construct a control structure at the upstream end of the triple 24-inch diameter pipes to direct the flow from most events thru a single (probably the center one) 24-inch pipe while allowing the excess flow from higher flow events to overflow into the other two. This alone will not reduce the rate of sedimentation upstream but should significantly reduce the rate at which the pipes completely plug and require maintenance cleaning.
5. Improve the conveyance capacity downstream of the triple culverts so that backwater created by the narrowed channel downstream doesn’t enhance settling within the pipes. Currently a series of rock filled gabions exist downstream of the culvert outlets. These gabions are likely increasing the back water levels downstream of the culverts thus slowing the velocities and enhancing sedimentation within the pipes. Removal of these gabions will reduce the rate of sediment buildup within the triple pipes.
6. Install natural stream erosion protection measures in the open channel sections of the watershed upstream of the triple culverts.

There are a few options for constructing control devices within the storm sewers that would be fairly low impact and serve to reduce the peak rate of discharge during low frequency storm events. It is recognized that during high frequency events these control structures would be allowed to overflow and thus allow the peak flows to pass downstream. By constructing control structures within sewer manholes at the following locations in the sewer system, it is estimated that 3275 cubic feet (0.08 acre feet) of storage could be utilized which would be equivalent to a depth of 0.01 inches over this portion of the watershed:

- Ridgewood Avenue and Britton Court (12”)
- Meadowbrook Street between Ridgewood and Edgewood Avenues (12”)
- Woodlawn Avenue and Meadowbrook Street (24”)
- Mission Hills Drive S. of Meadowbrook Street (30”)
- Glen Echo Drive NE of Barfield Drive (12”)
- Inverness Drive NE of Barfield Drive (12”)

The size and specific details of these sewers need to be investigated in order to confirm the size of the orifice restriction but it would typically be no smaller than 6" in size and the overflow would need to be positioned within the manhole so that the capacity of the sewer would not be impaired and that the height of overflow could be maintained within the pipes. Positioning these control orifices at the downstream end of relatively flat sections of sewer would allow for storage within the pipe as well as flow reduction during moderate events. During extreme events the flow rate would not be hindered since it could still overflow and be passed downstream within the structure.

A detention storage basin already exists at the Zaagman Memorial Chapel. It is not known whether this basin works effectively. The orifice control on this basin should be reviewed to determine whether it is still in place and whether the overflow provisions are in place. A review of this basin after several significant rainfall events showed no evidence of ponding or that storage had even occurred.

Our Savior Lutheran Church at the corner of Ridgewood and Burton has three catch basins that capture the drainage from its parking area and roofs but it is not certain where these drain to. If they do drain to the public sewer on Britton Court or Ridgewood, the storm system might benefit from employing some sort of detention storage along with a restricted outlet.

Saint Paul the Apostle Church already has a detention basin in the SW corner of their lot which was designed to restrict peak flows and provide detention storage. There are no details on the LUDS plans files within the REGIS system for the SW basin. The Northerly basin drains the north portion of the lot into the Burton System, which doesn't connect to this system. The details of the connection and control orifice / overflow for the SW basin system should be investigated.

The Ridgemoor Montessori School on Inverness Drive has no catch basins shown on the REGIS Plans but it is likely that the drainage from its parking area and roofs are directed to the storm drains along Glen Echo or Inverness Drive. The storm system might benefit from employing some sort of detention storage along with a restricted outlet near this site's outlet at Inverness Drive or the north end of Glen Echo Drive. This site probably should have had some sort of detention storage and restricted outlet installed when it was constructed, which appears to be in the early to mid-1990's.

Another option would be to construct small diameter pipes along the centerline of the steepest sections of the tributary creeks along the Capilano Branch and the Mission Hills Branch open channels. If a 16-inch diameter pipe were to be installed along the Capilano Branch from the 18-inch diameter outlet to the point where the tributary joins the main stream (approximately 280 feet), over 100 percent of the flow capacity of the 18-inch diameter pipe could be transported down the ravine without eroding its bottom or banks. Flows above 17 CFS, which is slightly above the 10-year flow at this location would need to overflow and thus would be transported down both through the pipes and the existing ravine to the main branch of the open channel ravine.

Similarly, if a 24-inch diameter pipe were to be installed along the ravine bottom from the end of the Mission Hills Branch outlet, down approximately 350 feet, almost 65 percent of the capacity of the existing 30-inch diameter pipe could be transported down the steepest section of this ravine without eroding the bottom or banks. Excess flows would be required to overflow at the top at the current outlet and could then be transported down the ravine both through the pipes and the existing ravine to the main branch of the open channel ravine. The 24-inch pipe would be capable of transporting a flow equivalent to 65% of the 30-inch sewer capacity.

Based on the reduction of time that flow would be traversing down the slope into the main branch, it is estimated that the installation of the Capilano sewer would reduce the sediment load on the main branch of the Glen Echo Ravine by approximately 94% versus current conditions and installing the Mission Hills sewer would reduce the sediment load by 68% below what it is currently transporting. Estimating cubic yards of sediment transport in these ephemeral streams is difficult. However, based on the duration of time that these two streams might be actively flowing and the difference in width of flow trench with and without the pipes, the annual volume of sediment transport is currently estimated to be 6 and 19 CY/ year for the Capilano and Mission Hills Branch respectively whereas once the above relief pipes are installed, those volumes could be lowered down to 0.3 and 6 CY/year respectively for the Capilano and Mission Hills Branches or 94% and 68% reduction respectively.

Constructing a control structure upstream of Barfield Drive would allow for some detention to occur within the low-lying area of the main drain up to and just beyond the so-called Capilano branch. If an 8-foot tall control structure were to be constructed with an 18-inch diameter outlet at the invert of the stream, approximately 220,000 cubic feet (5.1 acre-feet) could be stored upstream of this area without impacting properties. The actual elevation of the overflow room of this control structure would need to be confirmed by a detailed survey prior to implement implementing this option. In addition, the 18-inch diameter outlet structure would need to have a grate installed on the on the inlet in order to prevent large debris from entering the storm sewer. Alternately the existing 36-inch diameter inlet and grate could be reutilized for this purpose. The overflow structure would simply consist of the upper rim of the manhole and this too would need to also be protected with a grate to prevent large debris from being drawn into the structure.

The reduction in flow provided by this structure could be significant during large events since the volume stored would be equivalent to a 0.8 inch depth over the 69.5 acres tributary to this location in the watershed. However constructing this structure would likely require q renegotiation of the drainage easements with almost all of the riparian properties upstream of Barfield Drive.

At the upstream or inlet end of the triple 24-inch pipes, a control structure could be constructed to direct the normal dry weather flow through the center 24-inch diameter culvert. This would help ensure that the center culvert would be kept clean and in a good flowing state during most of the time since cleansing velocities would occur more frequently. Weirs could be installed within the control structure to overflow to the second and then the third pipes at progressively higher floors thus maintaining those two culverts in an available state to transport flow during moderate frequency events. This structure could also restrict flow slightly so as to optimize use of the channel upstream for storage and thus slow/reduce flows using center pipe for outlet thus keeping it clean and then overflow to other two and then over the top during extreme events.

It is recognized that, currently, the flow down the Glen Echo Branch is in excess of the capacity of these triple pipes fairly frequently and flows over land across the grassy area along the three lots to the downstream end of the culverts. Constructing the control structure discussed above would reduce the frequency of cleaning of these triple pipes significantly since cleansing velocity would be maintained in the center culvert and the side culverts would be utilized less frequently and only during higher frequency events thus ensuring that they would experience flow through these side pipes only during high frequency events and thus they would likely be maintained in a cleaner state. A sketch of the upstream control structure is included in Figure 6 at the end of this report.

Removing the gabion check dam structures downstream of the triple pipes that were originally designed to reduce the channel velocity would help to reduce the rate of sediment accumulation within the pipes. Due to their placement, they are probably not significantly reducing the rate of channel erosion within the channel section that they are constructed within since they likely create areas of localized higher velocity around them. It is assumed that reducing channel erosion was likely the original intent of their installation. Removing these obstructions by just cutting and removing the wire baskets and redistributing the stone over the channel bottom in close proximity to the baskets will allow the stone within them to eventually redistribute across and along the channel downstream.

Natural Physical modifications to the stream reach

In addition to the above measures to reduce peak flows or provide hard engineering solutions to slow the rate of erosion within the open channels, geomorphological alternatives to protect the stream banks from the high rate of erosion developed by the flow rates from this urbanized watershed. These measures are elaborated below. Since it has been identified that the source of the sediment is from the upstream banks and stream beds which is occurring due to the heightened flows that have resulted from the urbanization of the watershed, our recommendations include creating and stabilizing the banks and the channel bed by utilizing natural stream channel design protocols, if possible and feasible, as opposed to alternatives that would require significant heavy equipment to be utilized to facilitate their implementation.

Based upon our analysis of the erosion occurring within the stream valley, it appears that the majority of the erosion is occurring all along the stream within the study area but very likely at the upstream steeper sections which are exhibiting excessive erosion. It was further determined that the majority of the erosion noted by the riparian residents is limited generally to the toe of the slope and not on the upper stream valley side slopes.

If the goal of this project is to stabilize the entire stream reach's eroding stream banks, we recommend that a series of riffles, log vane structures, rock and roll log structures, bankfull bench and boulder toe protections be installed at appropriate locations according to the geomorphology present in this system. Creating a bankfull channel and minor flood plain in concert with controlling the flow generated shear stresses causing the horizontal erosion, installing the appropriate bank stability measures and vegetation establishment and woody management will provide the needed stability to control the storm flows in this system.

If the goal is to also address just the erosion instability at specific critical locations, then a limited installation of the techniques outlined below can be installed within the stream channel and a number of physical alterations to the channel banks can be used in order to create a stable stream channel. A stable Stream Channel is illustrated in Figure 7 below in the Lane's Stability Equation.

Natural Streambank and Bed Stabilization Techniques

The specific installation of each of the following natural structures is dependent on further design and geomorphic calculations.

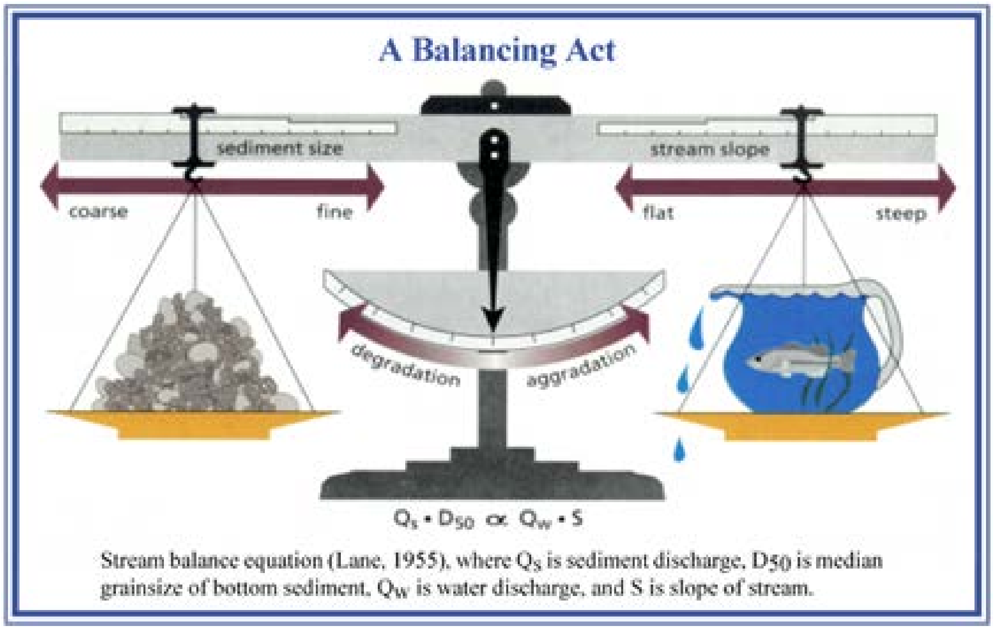


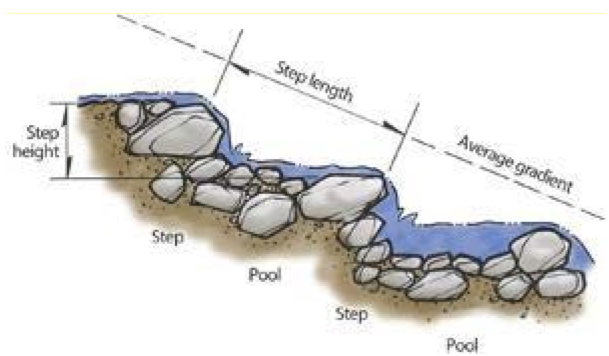
Figure 7 – Lane's Stability Equation

Stone Toe Detail

The Stone Toe Structure is typically used on the outside bends of a stream channel to prevent lateral scour and channel movement. These features use existing boulders placed during past restoration efforts and are found within the specific construction area.

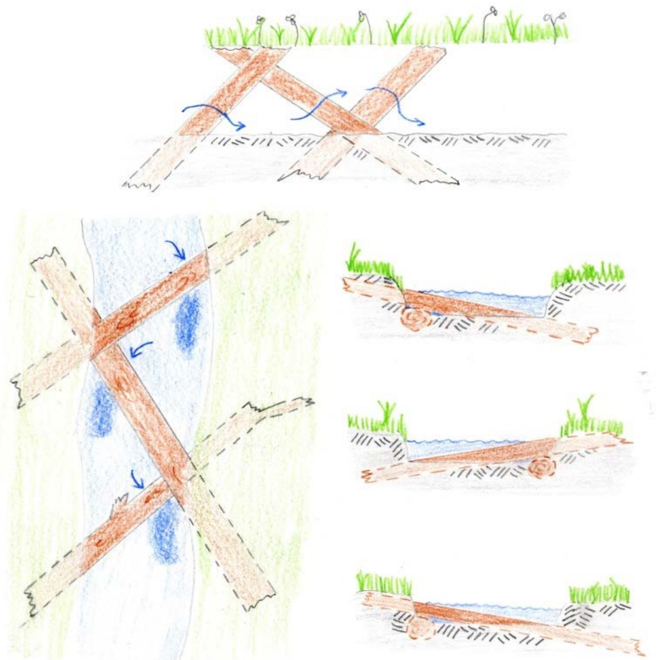
Log Vane Detail

The Log Vane Structure is used to divert flow stresses away from the outside bank of a stream channel. The flow stress is the force that accelerates bank erosion. Log Vane Structures could be constructed using the trees that would be removed to allow for equipment access.



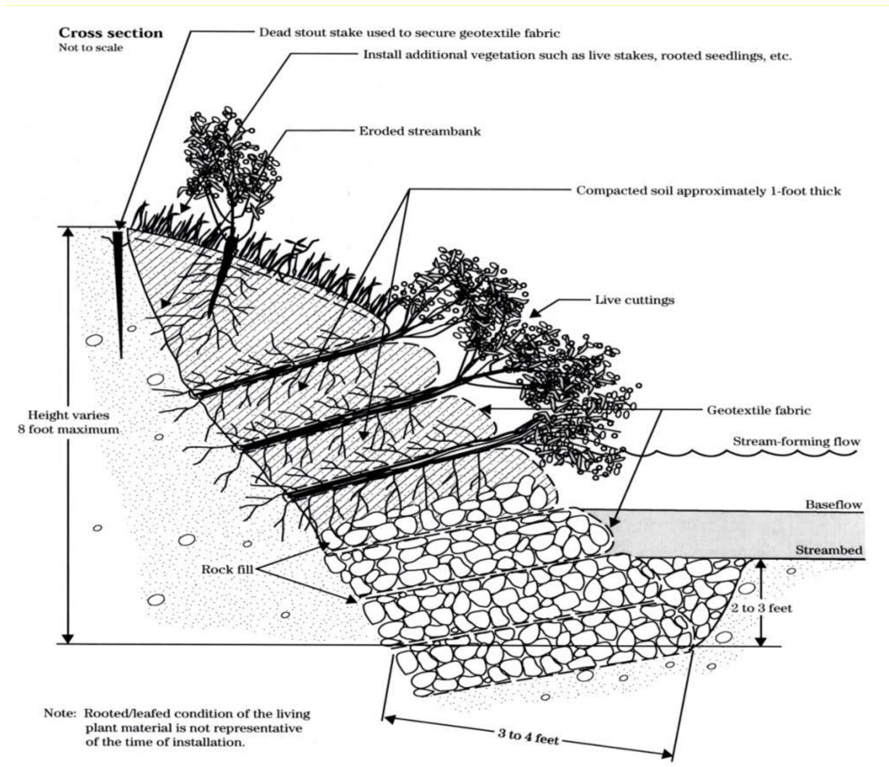
Step Pool Cross Section

Step pools, as shown above, are installed throughout a stream reach to reduce channel slope while providing bed stability in a relatively short distance. Rock materials are sized so that the flows are not able to dislocate the steps. The spacing of the steps would be in accordance with the observed riffle-pool sequence presently occurring in the watercourse.



Typical Sketch of a Rock and Roll Vane Structure

Rock and Roll Structures are constructed to utilize trees found within or obtained from the stream channel valley. These structures also decrease channel slope, provide roughage and reduce the 21-inch erosive forces of the flow.



VRSS Streambank Stabilization Structures.

Typically used on outside channel bends where expected erosive forces are higher.

There are a number of issues that present themselves when contemplating implementing an urban streambank restoration project. The following is a list of issues to be considered:

- Access. There is really no good open access to this valley. Access to this drainage system would have to be provided from Barfield Dr. SE. Significant removal of existing vegetation and grading would likely be required to create this access route. Restoration of the access route would also be significant and expensive. Access easements would be needed to utilize this access route to reach the work areas. In addition, contractors would likely need space to stage their equipment and materials. There is no obvious staging site location except within the existing road right of ways. Significant clearing and erosion protection (both temporary and permanent) will be necessary to allow for even small off-road vehicle access to the eroded areas in the valley.
- Permitting. The Michigan Department of Environmental (MDEQ) Quality is generally supportive of stabilizing stream banks and beds because of the ecologically beneficial effects to downstream reaches. Stability of the tributary streams and rivers throughout the watershed reduces sediment loading which does affect critical habitat downstream. We believe that the State would be in favor for this stream to be restored to a natural channel plan, profile, and dimension that recognizes the alterations that have occurred to the watershed. In order to be as thorough as possible in our assumed position concerning our understanding of the MDEQ's position, we recommend petitioning the MDEQ to review the study reach and the streambank erosion issues so as to gather their support and comments for approval.
- Costs. Due to the fact that the stream study reach is within a confined valley, the logistics of accessing the eroded bed and bank areas will be difficult and costly. The techniques shown below would utilize local wood and boulders in the design. It is somewhat difficult to develop a solid cost estimate for this type of stream restoration, but based on using an assumed number for the bed stabilization techniques for the area described above plus adding in the difficulty of access, our opinion of project cost is approximately $178,000 to accomplish the natural erosion protection as described above for the entire study reach. A breakdown of this opinion is included in the Table 2 below.
- If no action is taken, we believe that the existing rate of streambank erosion in the upper reach will continue its erosive horizontal movement and will continue to create sediment loads that will plug the three culverts downstream. It was also noted that some of the residents have taken effective action to stabilize their specific properties. The placement of bank boulders is providing some stabilization. However, we feel that the placement of these boulders has not properly been done to ensure a long-term solution and some adjustment is likely necessary.

<u>Cost Opinions</u>

An opinion of cost to construct the proposed structural improvements as discussed above are as follows:

1. Construct Control Structures (Control Orifices with Overflows) within the manholes at the following intersections:
    a. Ridgewood Avenue and Britton Court (12”) - $1,200.
    b. Meadowbrook Street between Ridgewood and Edgewood Avenues (12”) - $1,200.
    c. Woodlawn Avenue and Meadowbrook Street (24”) - $1,500.
    d. Mission Hills Drive S. of Meadowbrook Street (30”) - $1,700.
    e. Glen Echo Drive NE of Barfield Drive (12”) - $1,200.

f. Inverness Drive NE of Barfield Drive (12") - $1,200.

2. Construct a 24-inch diameter pipe down the Mission Hills Branch approximately 350 feet - $70,000.
3. Construct a 16-inch diameter pipe down the Capilano Branch approximately 285 feet - $65,000.
4. Re-direct the 12-inch outlet from the Glen Echo Branch so it is oriented downstream - $14,000.
5. Construct an outflow restrictor structure on the downstream side of Barfield Drive with an overflow weir with grate and rip-rap - $20,000.
6. Construct an inlet control structure for the triple 24-inch pipes at the upstream end - $15,000.
7. Remove the Check Dam gabion baskets downstream and allow the stone material to redistribute. $4,000.

The total opinion of cost to construct the above improvements is $196,000. Including an allowance for Engineering and Contingencies results in a project cost of $246,000.

The above structural improvement projects could be prioritized as follows:

1. Construct an inlet control structure for the triple 24-inch pipes at the upstream end.
2. Remove the gabion check dams downstream of the triple pipes.
3. Construct a 16-inch diameter pipe down the Capilano Branch.
4. Construct a 24-inch diameter pipe down the Mission Hills Branch.
5. Re-direct the 12-inch outlet from the Glen Echo Branch so it is oriented downstream.
6. Construct weir structures inside of individual manholes at various locations.
7. Construct the control structure and overflow downstream of Barfield Drive SE.

Given that there are also natural techniques to reduce the rate of erosion and thus scour and sediment transport from the existing upstream channels, they may be incorporated in lieu of some of the above structural improvements or in addition to some of the minor improvements above. With the objective of reducing cleaning frequency of the triple pipes, some combination of reducing the sediment scour on the open channels using natural techniques coupled with the installation of the weir structure on the upstream end of the triple pipes and removal of the downstream gabion baskets would probably result in the most cost-effective approach to this problem. We would suggest that some collaboration on the pros and cons of each of these approaches take place before a final project budget is recommended.

Table 2
Project Cost Opinion Sedimentation Reduction and Streambank Stabilization Techniques
Glen Echo Drive SE Ravine Watercourse

Conventional Engineering Structural Solutions				
Upstream Control Structures within Manholes				$ 8,000
24-inch culvert down Mission Hills Branch				$ 70,000
16-inch culvert down Capilano Branch				$ 65,000
Redirect Glen Echo Branch				$ 14,000
Construct a Drop Structure Downstream of Barfield				$ 20,000
Construct a Weir Structure Upstream of Triple Culverts				$ 15,000
Remove Gabions Downstream of Triple Culverts				$ 4,000
TOTAL CONSTRUCTION COST OPINION				**$ 196,000**
Engineering and Construction Contingencies				$ 50,000
SUBTOTAL PROJECT COST OPINION				**$ 246,000**
Natural Streambank Stabilization Techniques				
Description	**Units**	**Unit Price**	**Quantity**	**Total Price**
Mobilization	LS	Lump Sum		$ 5,500
Remove Tree, over 6 inch to 18 inch	EA	$500	20	$ 10,000
Remove Tree, 19 inch to 36 inch	EA	$1500	10	$ 15,000
Stone Toe Structures	LF	$45	250	$ 11,250
Earth Excavation and Bankfull Bench Creation	CY	$30	870	$ 26,100
Reuse of existing Boulders Check Dams	EA	$550	5	$ 2,750
Log Vane	EA	$2,500	5	$ 12,500
Rock n roll Log structures	EA	$3,000	4	$ 12,000
Erosion Control Blanket (C 250)	SY	$4	300	$ 1,200
Access Restoration (earthwork, planting, etc.)	acres	$15,000	0.5	$ 7,500
Seed Mix – Dense Shade Woodland Streambank Mix	acres	$4,500	0.5	$ 2,250
Shrub Plant Plugs 12” pots	EA	5.5	250	$ 1,375
Estimating Contingencies	LS	5%		$ 7,046
TOTAL CONSTRUCTION COST OPINION				**$ 115,000**
Engineering and Construction Contingencies	LS	25%		$ 29,000
SUBTOTAL PROJECT COST OPINION (Rounded)				**$ 144,000.**
GRAND TOTAL PROJECT COST OPINION				**$ 390,000.**

Summary and Recommendations

The recommended projects as discussed above will be focused on with the enhancements discussed above with the expected construction cost listed below and as prioritized as follows:

1. Weir Structure Upstream of the triple culverts. $15,000.
2. Remove gabions D/S of triple culverts and level out/distribute existing fill material. $4,000.
3. Install a pipe within the steep section of the Capilano Branch Drain however an easement will likely be required on downstream parcel as well as some erosion protection at the downstream outlet of the pipe using outlet divider walls or other natural stream features. The pipe will need to be installed within the existing and proposed easements and a MH drop structure will be constructed at the upstream end. $65,000.
4. Install a pipe within the steep section of the Mission Hills Branch within the existing easement as well as some erosion protection at the downstream outlet of the pipe using outlet divider walls or other natural stream features. This pipe will also need to be installed within the existing and proposed easements and a MH drop structure will be constructed at the upstream end. $70,000.
5. Upstream Structure Flow Restrictors. $8,000.
6. Redirect the Glen Echo Branch Pipe within the existing easement and provide erosion protection downstream of the outlet. $14,000.
7. Construct a Drop Structure downstream of Barfield Drive along with a low flow restrictor and an overflow out of the top of the structure to the creek below including some rip rap at the outlet $20,000.
8. Some additional natural stream bottom erosion protections should be incorporated both upstream and downstream of Barfield Drive as required to reduce erosion in these sections. It is recommended that at least $115,000. of construction cost be included for this purpose.
9. Modifying or installing additional detention on Private Sites should be encouraged but is not included within the conclusions of this this report since this report is focused on publicly financed improvements that can be constructed within public property or drain easements.

The above capital projects include a grand total construction cost of $311,000. If a 25% allowance for Engineering and Contingencies is included, the overall Project Cost would be $390,000.

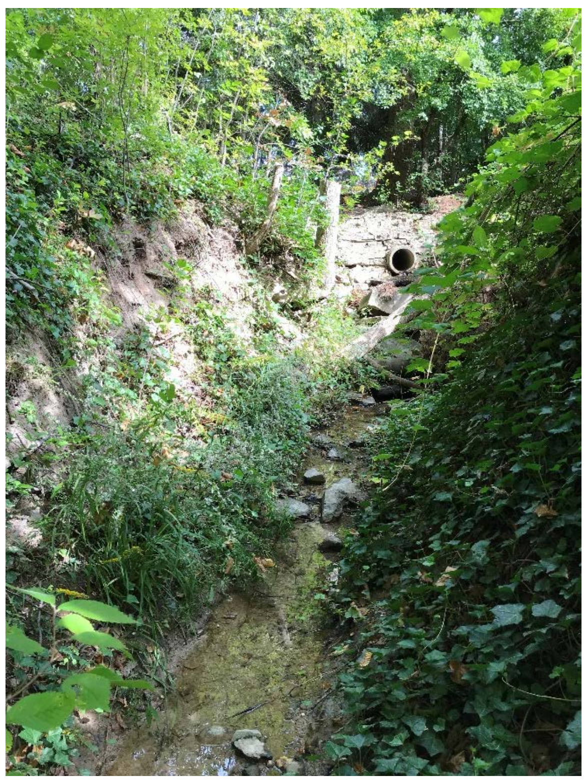
Chapter 5 - Photographs

The following photographs are of selected features taken to convey the appearance of the project area. The progression of the photographs is from upstream, beginning at the 30-inch storm sewer outlet downstream of Mission Hills Drive and progressing downstream to the triple culvert outlet.

30-inch Concrete Culvert Structure Discharging from Mission Hills Drive.

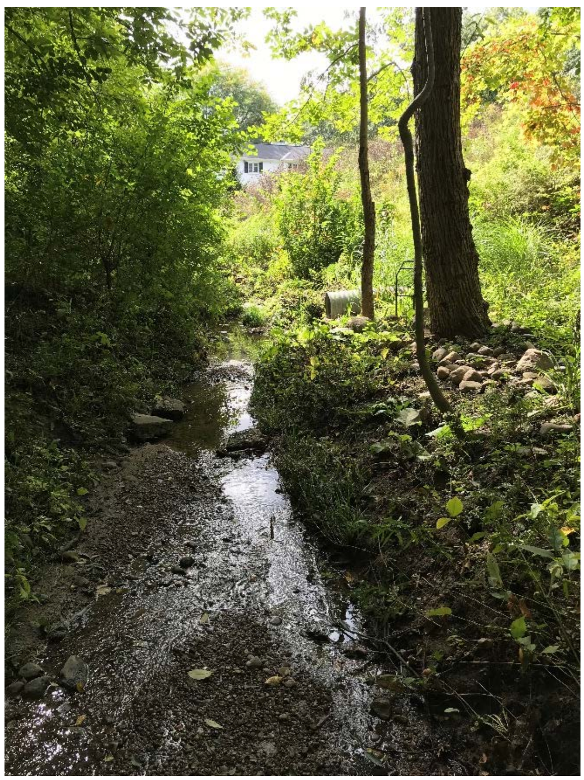
Stream channel immediately downstream of the 30-inch Culvert. The stream bed is extremely eroded at this location due to the steep bed slope. The flow works its way around the placed concrete debris.

Capilano Branch 18-inch diameter outlet



Capilano Branch 18-inch diameter outlet. Note that the stream has dropped several feet below the pipe invert due to historic erosion.


Main Branch just downstream of the Capilano Branch Confluence


Main Branch just downstream of the Capilano Branch Confluence. Note the 12-inch Glen Echo Branch entering from the Right (west)

Glen Echo Branch entering from the west bank. This pipe enters perpendicular to the Main Branch and is eroding the near bank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Looking upstream on the Main Branch from just downstream of the 12-inch Glen Echo Branch

36-inch sewer upstream of Barfield Drive. This bar rack repeatedly plugs up with debris from trees.

36-inch sewer upstream of Barfield Drive

42-inch CMP sewer outlet sewer downstream of Barfield Drive. Note that the 36-inch RCP transitions to a 42-inch CMP about 30 feet upstream of this outlet.

Downstream of Barfield Drive. Note severe bank erosion on bank.
Picture taken looking upstream.

Highly eroded stream banks just downstream of Barfield Drive on the Left (SE)? Bank.
Picture taken looking upstream

12-inch PVC sewer from Greentree Cul-de-sac upstream of triple 24-inch HDPE culverts.
Note that triple 24-inch culverts are buried with sediment just to the right of the 12-inch pipe.
Also note gabions baskets

Looking upstream on the Main Branch from the triple culvert entrance

Looking downstream on the Main Branch from the triple culvert entrance. The grassed area is above the triple 24-inch culverts and experiences overland flow quite frequently.

Looking downstream on the Main Branch about 100 feet downstream from the triple culverts entrance.
This area is above the triple 24-inch culverts and shows evidence of overland flow quite frequently.

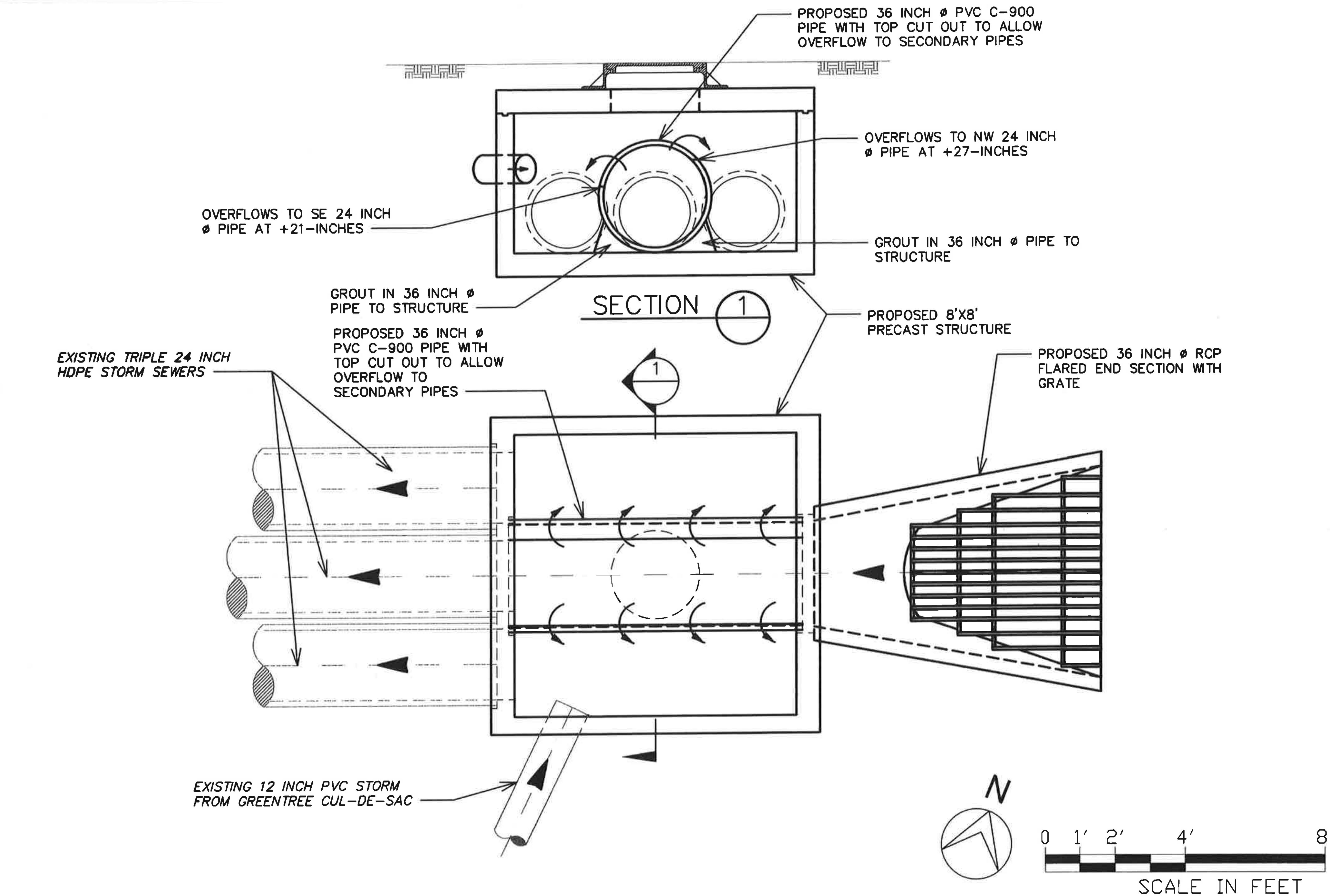
Lawn area above the triple 24-inch culverts just upstream of the triple culvert outlet.

Triple 24-inch culvert outlets in gabion edged channel.
Note Lawn area just upstream of the triple culvert outlet.

Triple 24-inch HDPE culvert outlets in gabion edged channel.

Gabion lined channel just downstream of triple 24-inch culvert outlets looking downstream.

Oversized Figures



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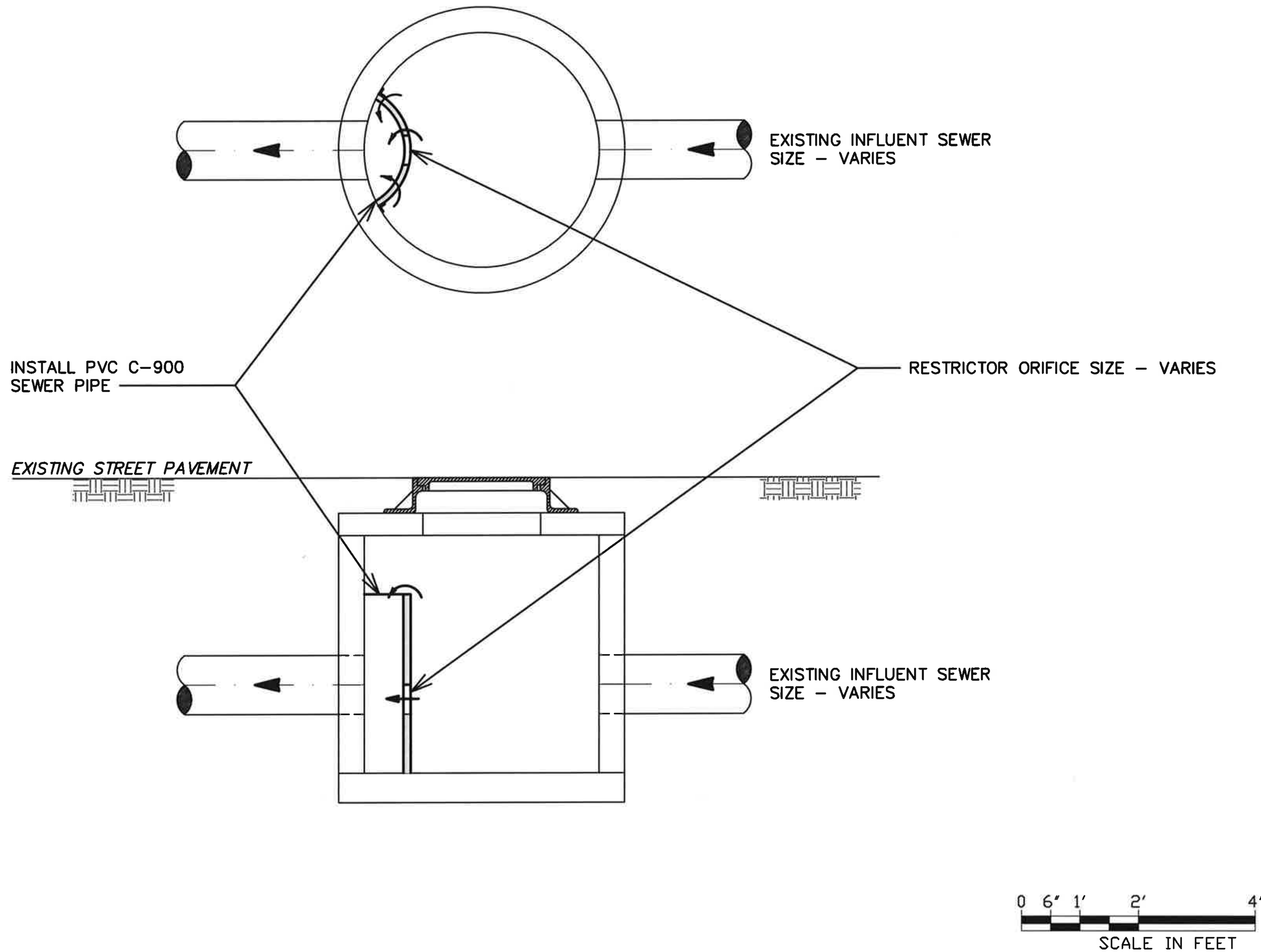
CONSULTING ENGINEERS SINCE 1915
801 BROADWAY NW SUITE 215
GRAND RAPIDS, MICH 49504

GLEN ECHO SEDIMENT STUDY
PROPOSED FLOW SPLIT STRUCTURE AT
UP-STREAM END OF TRIPLE 24 INCH PIPES

JOB NO.	DATE	FIGURE NO.
20180827	10/19/2018	6



GLEN ECHO SEDIMENT STUDY
PROPOSED TYPICAL FLOW
RESTRICTION IN EXISTING PIPE

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DATE 10/19/2018
FIGURE NO. 8

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