THE CITY OF MISSION HILLS

MISSION HILLS
STORMWATER MASTERPLAN

UPDATE

Part I – Open Channels
Channel Degradation Assessment
and
Recommended Improvements

FINAL

BLACK & VEATCH
building a **world** of difference™

ENERGY   WATER   INFORMATION   GOVERNMENT

PBA
PATTI BANKS
ASSOCIATES

PROJECT NO. 140200.100

February 13, 2007

Table of Contents

Executive Summary

Existing stream channels within the City of Mission Hills are degrading. This degradation includes exposed sanitary sewer crossings, stagnant pools and failing stream channel walls. Because of this condition, it is in the interest of the City of Mission Hills Kansas to update the Stormwater Masterplan. This update consists of an assessment of channel conditions and a set of proposed improvements aimed to improve the channel conditions and mitigate degradation.

The streams were evaluated using two different approaches. The first approach evaluated the channel stability following fluvial geomorphology principles using the Channel Condition Scoring Matrix (CCSM) as defined in the Kansas City Metropolitan Area Chapter of the American Public Works Association (APWA) Standard Specification and Design Criteria Section 5605 guidelines (Table 5605-2). A qualitative assessment of wall conditions was also included in this first part of the evaluation. The second one evaluated riparian conditions and water quality using the Stream Asset Inventory (SAI) methodology, a protocol developed for the City of Lenexa's Stream Assessment and Natural Resource Inventory Project (Project Report December 2001), and recently revised for Johnson County, Kansas.

According to the assessment, the stream conditions range between poor stability to significant system-wide instability. The lack of sinuosity, pool-riffle structure and steep bank slopes are the main factors that negatively impact the rating based on the CCSM. Lack of vegetative protection also has a negative impact on the stability rating. Despite impending unstable conditions, walls and other bank stabilization mechanisms have prevented bank failures. Walls and concrete channels, however, if not adequately maintained can become unstable overtime due to the abrasive action of high velocity flows. The majority of the streams have narrow main channel widths, compared to stable natural channels.

Wall conditions vary extensively. The channels with newer walls and some with older walls are in good conditions. Other older walls are in poor conditions or show signs of periodic repairs and in a few instances have completely failed. In some cases stream bed degradation has exposed wall foundations, creating a condition that compromises the stability of the walls.

In terms of habitat and water quality conditions the majority of the streams fall in the Type 3 (restorable) category. A few streams have been categorized as Type 2 (high quality) or Type 4 (low quality). As expected on a typical urban setting, Type 1 (highest quality) streams are not present. With the exception of a section where the stream has been piped, no other Type 5 streams were identified (culverts or relatively short pipes under roads were not). Despite the presence of potential aquatic habitat for fish, invertebrates and mollusks, the field work found very little evidence of such aquatic species. It is possible that any of such organisms present in the streams get consistently washed downstream during major storm events due to high flow

velocities in the relatively narrow channels. As expected in typical urban areas, there is, with a few exceptions, little or no vegetation along the stream banks. Where vegetation is present, it is common to find aggressive, non-native exotics such as euonymous (ground cover) and shrub honeysuckle.

Two improvement levels are proposed in this document: (1) optimal restoration: optimal restoration is aimed to maximize stream stability and aquatic and riparian habitat; (2) limited restoration: limited restoration indicates the minimum improvements or minimum maintenance activities (e.g. repair walls) required to stabilize the existing stream. The latter will temporarily fix localized problems to maintain the "status-quo" of the system and does not necessarily addresses systemic and habitat issues.

In general limited restoration includes the repair of existing walls and other infrastructure and/or the reduction of bank slopes. Optimal restoration includes widening the main channel with milder side slopes, removal or relocation of walls, creation of flood benches, creation or modification of meanders, establishment of pool-riffle sequences and creation of a ripparian buffer zone with native vegetation.

Channel Degradation Assessment

A.   Introduction

1. Overview and Purpose

Existing stream channels within the City of Mission Hills are degrading.   This degradation includes exposed sanitary sewer crossings, stagnant pools and failing stream channel walls. Because of this condition, it is in the interest of the City of Mission Hills Kansas to update the Stormwater Masterplan. This update consists of an assessment of channel conditions and a set of proposed improvements aimed to improve the channel conditions and mitigate degradation.

B.   Methodology

1. Evaluation and Conceptual Design Criteria

The evaluation and conceptual design of the recommended improvements are based on hydraulic, fluvial geomorphology principles and water quality and aquatic habitat concerns.

Because flooding is a concern along Brush Creek and its tributaries, the proposed stream stabilization and water quality improvements have been developed such that flooding would not be increased (this condition must be checked during final improvements design).
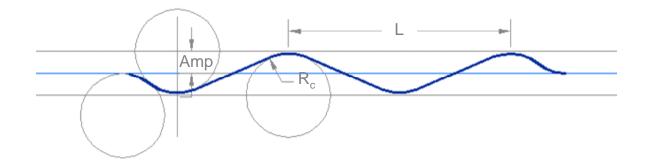
a. Channel Stability and Fluvial Geomorphology

The definition of a stable channel depends on whether the channel boundaries are considered rigid (static) or movable (dynamic). The stability of a rigid channel is achieved when the material forming the channel boundary effectively resists the erosive forces of flow. Stability of a dynamic channel is more difficult to define. In this case, a channel is considered stable if changes are within "acceptable" levels. In general such stability is attained when the sediment supply rate equals the sediment transport rate.

In the urban/suburban context the acceptable levels of change are constrained by rights-of-way and existing or proposed infrastructure. In many cases possible lateral migration and bank instability cannot be tolerated. Therefore, as stated by the Federal Highway Administration (FHA, 1988), development of static equilibrium conditions is preferable in urban/suburban areas. Thus, under static equilibrium conditions a stable channel will have a rigid boundary that effectively resists the erosive forces of flow while avoiding sedimentation of particles that are transported by the flow upstream from the channel of interest.

Recent regulatory trends promote that land use changes and stream modifications do not adversely impact downstream or upstream stability and environmental conditions. To mitigate the impact on the overall stream stability, it has been proposed that channel designs and stream modifications should mimic natural channels. Under this new paradigm, there is a preference for meandering channels that include pools and riffles instead of using constant-slope straight channels. In principle, this new approach would reduce flow velocities and sheer stress in the designed or modified channel, thus making it more stable to erosion. Reduction of flow velocities and sheer stress allows the use of flexible lining (riprap, vegetation, etc.) as opposed to rigid linings (concrete, soil cement, gabions, etc.). Flexible linings are generally less expensive, allow infiltration and have an aesthetic value (natural appearance).

Philip J. Soar and Colin R. Thorne (2001), provide a framework for designing stable channels for river restoration. The underlying assumptions behind this framework are that (1) the dimensions of stable natural channels are proportionally related to the discharge, and (2) the dimensions of the channel are inter-correlated. Based on extensive literature review and research, Soar and Thorne calculated average proportionality relations between discharge and channel dimensions for typical stable natural channels. These average relationships provide a set of guidelines that serve as a basis for dimensioning a stable channel. The following is a summary of guidelines as suggested by Soar and Thorne:

a. Design of main channel is based on bank full discharge (Q_b).
b. Soar and Thorne (2001) indicate that the 2-year flood (Q_2) is an approximate upper boundary to bank full discharge. Preliminary studies in Kansas indicate that, for local urban areas, the 1-yr flood (Q_1) may be a better estimate of bank full discharge.
c. Channel width: $w = a Q_b^{0.5}$ where Q_b = bank full discharge in cfs and a = 2.03 (90% confidence: a = 1.12 to 3.69; lower values of "a" are associated with resistant banks as opposed to erodible banks). For the evaluation and conceptual design for Brush Creek and its tributaries, the lower end of the confidence interval was selected (a = 1.12) assuming stable banks and considering rights-of-way and

2

existing infrastructure constraints. Larger widths, within the 90% confidence range, would also be acceptable.

d. Wave length: $L \cong 12w$ and/or pool riffle spacing $L_{p-r} \cong 6w$

e. Radius of curvature: $R_c = c_{rc}w$ where $c_{rc} \cong 2.4$ (absolute minimum: $c_{rc} = 2$).

f. Amplitude is set to obtain a sinuosity of between 1.2 and 1.4. The amplitude may also be set based on sediment transport requirements and rights-of-way limitations.

b. *Riparian Conditions and Water Quality*

The stream restoration approach by Philip J. Soar and Colin R. Thorne (2001) mimics conditions typically present in natural channels. The meandering pattern, the pool-riffle sequence, wider stream channel and a flexible stream bed structure (rock and gravel) intrinsically have a positive impact to the habitat function of a healthy stream.

A riparian buffer zone consisting of appropriate native vegetation along the banks would enhance the habitat function of the riparian corridor, improve bank stability and improve water quality. Riparian buffer zones help to reduce the amount of excess nutrients (e.g. nitrogen, phosphorus, typically present in lawn fertilizers) and other pollutants.

The Natural Resources Conservation Service (NRCS) recommends a total buffer zone with of 200 ft with a minimum of 25 ft for the streamside buffer zone. The implementation of these recommendations is unrealistic for conditions in the City of Mission Hills due to rights-of-way and existing infrastructure limitations. The City, however, should encourage the creation of riparian buffer zones even if their size is smaller than optimal.

2. *Field Data*

The field data consists of a stream qualitative survey and a set of photographs that illustrate some of the survey findings. The survey is separated in two parts. The first part has an engineering and geomorphic perspective; it includes a channel stability, stream bank condition and wall condition evaluation. The second part has a conservation ecology perspective; it includes a stream stability, aquatic and terrestrial habitat quality and water quality evaluation.

a. *Part 1. Channel stability indicators*

Part 1 of the stream assessment follows the Channel Condition Scoring Matrix (CCSM) as defined in the Kansas City Metropolitan Area Chapter of the American Public Works Association (APWA) Standard Specification and Design Criteria Section 5605 guidelines (Table 5605-2, see Appendix I). The CCSM includes indices that evaluate the channel geometry, bank slope stability, streambed and bank material composition, and evidence of unstable conditions. Channel geometry indicators compare the stream on plan and profile (sinuosity, ratio of

curvature and pool-riffle spacing) to optimal conditions of stable channels based on fluvial geomorphology concepts. Streambed and bed material composition includes soil texture, sediment composition, consolidation, armoring, and vegetative protection. Evidence of unstable conditions includes signs of bank cutting, mass wasting, bar development, scour and sediment deposition.

In addition to the CCSM indicator the walls conditions were evaluated using the following rating criteria: Good (1): no detectable problems, Fair (2): minor and/or isolated problems, Poor (3): severe problems. Wall conditions are reported for left and right walls independently. The overall rating for a channel section is based on the wall that has the worst conditions. A value of zero (0) was given to channel sections that don't have walls.

The field data was collected using a customized form for ArcPad on a handheld PDA device. The form was programmed using ArcPad Studio (a component of the ArcPad Application Builder software). Geographic coordinates were obtained using a GPS connected to the PDA device. The ArcPad form allowed the field entry of a set of parameters associated with each of the stability indicators. These parameters were used as an aid to rate each one of the indicators on the CCSM. In some cases, however, the individual parameters were not measured or recorded and the score for the indicator was selected qualitatively based on observation and professional judgment.

For every channel section, the score for each one of the indicators, the total rating (Σ S*W) and the wall condition indicators were stored in the GIS database. The score range is between 9.8 and 29.4. A score of 12 or less indicates an adequate stream stability condition. Scores between 12 and 18 indicate that stream conditions are poor, that instabilities exist and that special measures may be necessary to address those issues rated as poor in the assessment. A score greater than 18 indicates that the stream has significant system-wide instability issues.

b. Part 2. Riparian conditions and water quality indicators

Part 2 of the stream assessment follows the protocol developed for the City of Lenexa's Stream Assessment and Natural Resource Inventory Project (Project Report December 2001), and recently revised for Johnson County, Kansas. The Stream Asset Inventory (SAI) methodology provides rapid and scientifically defensible indicators of water quality, stream stability, and habitat conditions at a given location that is selected to be representative of a larger stream reach.

The preliminary field investigation consisted of a field reconnaissance, streambank and streambed characterization, erosion characterization, measurement of flow rate, vegetation identification, aquatic identification and classification, site photographs, and general observations of stream conditions. These factors were combined to determine the general health of the stream and future restoration opportunities for the watershed.

The procedure began with a field assessment of:
- Stream Stability - Characterization of Streambanks and Streambeds
- Aquatic Habitat Quality – Stream Flow and Instream Cover
- Terrestrial Habitat Quality – Vegetation Type and Diversity
- Water Quality – Impacts and Aquatic Animals

Field data collected from each sample site was downloaded into a spreadsheet for analysis. Each of the above factors was given a numeric value that was used to determine the stream type (condition) for each segment assessed. Concrete and riprap lined channels, and retaining walls were evaluated as part of this inventory with the understanding that these solutions provide greater bank stability without the other benefits of natural systems. Piped channels are generally given the lowest score as they are strictly for conveyance and do not provide any of the beneficial functions of a natural system.

Stream Stability

Streambank and streambed characterization is used to determine the physical stability of the stream channel. Stability is based upon bank cut, root depth, material composition and erosion potential characterized below:

Composition	Erosion Potential	Stability
Sands and gravel	High	Low
Silts and clays	High	Low
Bedrock	Low	High
Riprap (large rocks)	Low	Moderate to high
Mix of the above	Moderate to high	Moderate to high

The physical form of the stream channel is shaped by the forces of water (direction and velocity of stormwater and surface runoff) acting on these base materials. Channel incision (vertical deepening of channel) occurs when channel stability is low. Bank incision or cutting (horizontal widening of channel) occurs when bank stability is low and bed stability is high. Erosion can also lead to stability problems for structures located too close to the stream channel, cause water quality problems downstream, and be unhealthy to aquatic organisms.

Channels lined with retaining walls, concrete, or riprap, have variable characteristics, typically eroding only during major storm events and/or after several years of exposure. While newer or recently remodeled channels do provide a higher level of bank stability, they do not have natural channel characteristics or functions and thus acts as barriers to the presence of aquatic organisms. Over time, some of the older lined channels have collected rocks, gravel,

5

sediment, or have broken down such that plants have become established in the channel base. These changes are providing some habitat characteristics which could support aquatic organisms.

Several factors are used to evaluate indicators of erosion and deposition within each stream reach. Each of these factors serves as a useful indicator of the cause(s) and extent of erosion and the amount of sediment entering the streams. These factors also assist in identifying restoration opportunities available to each stream reach.

Aquatic Habitat Quality

Aquatic habitat is an important component of stream health and helps to differentiate water quality impacts to aquatic organisms. The factors used to evaluate the quality of aquatic habitats present include stream flow, channel substrate, macrohabitat types (pool, riffle or run), instream fish cover, and instream aquatic invertebrate cover.

Photo 1. Macrohabitats for aquatics

Terrestrial Habitat Quality

The types, diversity, and condition of vegetation present are important factors in determining the condition of the riparian corridor and its ability to protect the stream. Adjoining land uses can also greatly impact the function of the riparian corridor and the stream. The "canopy" or "overstory" layer consists of a variety of tree species, while the "understory layer" consists of shrubs, vines, and/or herbaceous plants, and occasionally small trees. The top three dominant overstory and understory vegetative species are identified for both right and left banks. The presence of undesirable vegetation such as euonymous and honeysuckle negatively impacts the overall health of the riparian corridor as these species generally dominate the understory choking out all other vegetative species including desirable native plants.

Photo 2. Vegetation along stream.

Water Quality

Sediment, pollutants, trash, and other undesirable conditions impact the types and diversity of aquatic life present within streams. The assessment evaluates several direct and indirect water quality indicators. Excessive sediments, trash, and oil and grease are noted. Prominent aquatic invertebrates (damsel fly larvae, dragonfly larvae, snails, crayfish, etc.) are grouped into a general quality category from Group 1 being the best, least pollution tolerant to Group 3 being the worst, most pollution tolerant. The presence of fish, mollusks, and amphibians is another indicator of moderate to good water quality.

Photo 3. Dragonfly.

Stream Scoring

The stream evaluation factors described above are given numeric scores which are totaled, averaged, and then compared to the range for all values within the study area. The relative value for each stream segment is possible by calculating the mean value for the study area and comparing individual scores to the mean. The streams are typed based on the number of standard deviations (SD) from the mean. The stream reaches are then classified according to their score with the higher scores ranking better in stream quality.

Type 1 - Highest Quality (>2 SD from mean). It is generally described as the highest quality naturally occurring stream with little negative impact. Erosion and sedimentation is low, water quality indicators are positive and the surrounding riparian zone is healthy, mature, succession woodland or other high-quality environment.

Photo 4. Type 1, Highest Quality stream.

Type 2 - High Quality (+2 SD from mean). This type of stream may have some down or side-cutting however, bank and bed composition (bedrock) assist in keeping the impact low. Water quality is generally good and the riparian zone is largely intact, although vegetation may be altered from that of a typical native plant association.

Photo 5. Type 2, High Quality stream.

Type 3 – Restorable (±1 SD from mean). Deterioration of the riparian corridor is more noticeable. While some remnant plant associations may be present, overall

vegetative canopy cover is comprised of immature tree species. The potential for restoration exists although erosion and sedimentation can be greater than desirable.

Photo 6. Type 3, Restorable stream.

Type 4 - Low Quality (-2 SD from mean). Impacts are greater on this stream type with significant indicators of bank erosion and sedimentation present. The adjoining riparian corridor may be intact but vegetation is not representative of a native plant association.

Photo 7. Type 4, Low Quality.

Type 5 - Lowest Quality (< -2 SD from mean). The channel in this type is the most changed. The riparian corridor is becoming impaired to the point of providing little protection or benefit, and erosion and sedimentation indicators are significant. Water quality is questionable with noticeable phosphate and nitrate loading (large algae blooms). This category can be used for highly modified and piped channels.

3. GIS Mapping

a. Base GIS Data

The base data consists of aerial photographs and road-centerline and stream shapefiles. The City of Mission Hills provided these data sets. This data was used in the ArcView GIS as a base map to locate and geographically describe the reaches of interest.

b. Field survey GIS Data

Four new shapefiles where generated based on the data collected in the field. The new shapefiles are listed in following table.

Shapefile	Type	Description
Photos	Point	Location and approximate direction of the pictures taken
Sections	Line	Reaches and stream sections surveyed
Improvements	Line	Represents improvement sections
Meanders	Line	Represents proposed meandering pattern under optimal restoration

****

C. Channel and Streambank Assessment Results

1. *Part 1. Channel stability indicators*

The APWA Channel Condition Scoring Matrix (CCSM) ratings range between 15 and 22.2; i.e. the streams condition ranges between poor stability and significant system-wide instability. In general, the CCSM rating is negatively impacted due to steep bank slopes and the lack of sinuosity and pool-riffle structure. Most reaches have a low score on these three indicators. Lack of vegetative protection also has a negative impact on the stability rating. Most of the main channel widths are less than those found in stable natural channels.

Despite impending unstable conditions the extensive use of walls and other bank stabilization mechanisms has prevented excessive bank failures in the form of bank cutting and mass wasting.

The most stable channels include the ones lined with grouted stone walls and concrete bed. These channels, however, do not have a higher rating because the banks are stable as long as the concrete and walls provide the required protection. Concrete lined channels, can become unstable overtime if the concrete is eroded by the abrasive action of high velocity flows. If not maintained, once the concrete lining on the bed is lost, streambed degradation will progress at a rapid pace and the wall foundations will be compromised. Without the concrete and the walls the stream will be extremely unstable, especially if no vegetation protection exists on the banks.
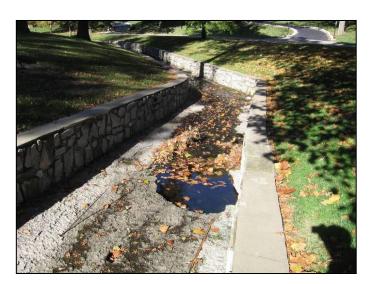

Photo 8. Concrete channel in poor conditions.

Wall conditions vary extensively. The channels with newer walls are in good conditions, some older walls remain in good conditions. Other older walls show signs of periodic repairs. There are locations (e.g. section 219) where the walls are in very bad conditions and parts of the wall have collapsed. In many instances stream bed degradation has allowed exposure of the walls foundations creating conditions that could compromise the stability of such walls. Wall condition ratings are provided in the GIS database.

2. *Part 2. Riparian conditions and water quality indicators*

The stream reaches studied are generally in fair condition even with a mix of manmade (retaining walls) and natural streambank features. There is little to no floodplain or riparian (stream) corridor present throughout most of the Brush Creek Watershed. This is commonly the case along streams in urban areas. All stream reaches show evidence of higher flow rates and volumes from storm events than would generally be encountered in non-urbanized streams.

In general, the stream reaches studied are Type 3 (23 reaches) – restorable, with only a few Type 2 (6 reaches) – high quality and Type 4 (6 reaches) – low quality. The absence of Type 1 streams is not surprising given the urban nature of the stream corridor and adjoining land uses. Only one piped stream reach was observed during the inventory. The general absence of Type 5 streams bodes well for the City in that most of the streams studied have not deteriorated beyond total ecological function. Close attention was paid to surrounding land use when evaluating lined channels, to determine the potential and appropriateness of restoring these to natural stream systems. .

a. *Stability*

It is important to note that much of Brush Creek has been channelized as urbanization has occurred within the watershed. The stream channel is more restricted and relatively straight compared to natural stream channels. In areas where retaining walls have failed or are absent, the stream channel is wider and meanders (stream bending) are reshaping the channel as the stream tries to achieve balance. Steep slopes are abundant throughout Mission Hills. Most of the streamside steep slopes have been armored by retaining walls of varying composition, age, and structural stability.

Stream reaches 271, 201, 220, 56 and 57 are the least stable. The instability appears to be the result of serious bank or retaining wall failure along high stream banks. In the case of reach 220, which is the longest natural channel reach studied, the east streambank has been lined with slabs of concrete, asphalt, and other debris to prevent erosion and collapse of the parking lot located along the top of the bank. This hard surface reinforcement is not stable and is resulting in an increase in water velocity through this reach which in turn results in a higher erosion potential.

Photo 9. Outfall structure in poor conditions.

In areas where there is a mix of retaining walls and natural streambank, there is often considerable erosion of the natural streambank. Erosion of natural banks was also noted at the ends of retaining walls as a result of little to no bank vegetation and increased flows after storm events. Natural bank erosion is less prevalent in areas where the natural bank is quite low, even if the opposite bank is high with or without a retaining wall. In these areas the high water is simply flowing over the low bank and spreading out into yards and potentially flooding streets or other adjoining land uses. Rock faced retaining walls and slab rock banks provide a rougher surface thus actually helping to slow water down compared with the smooth concrete lined channels which increase water velocity.

b. Aquatic Habitat

Aquatic habitat quality varies according to the channel structure and substrate present. Concrete lined channels with little to no substrate (cobbles, gravel, etc.) do not provide habitat structure for fish or aquatic invertebrates. Channel areas that have variable structure in the form of boulders, cobble, gravel, or vegetation generally have a mix of pools, riffles, and runs that are critical to the habitat function of a healthy stream. The movement of large structural materials like boulders indicates high flow volumes and velocities capable of moving such large material. Frequent high flows greatly impact aquatic habitat by constantly moving habitat structure farther downstream. Another factor influencing aquatic habitat structure is the removal of natural debris (tree limbs, rootwads, boulders, and cobble) for aesthetics and to reduce the potential for flooding.

Stream reach 220 has the highest score for aquatic habitat. This is most likely due to the length of the reach having been left relatively natural, and the presence of a mix of macrohabitat types (pools, riffles, and runs) present. The lowest aquatic scores are associated with channels lined with concrete and grouted stone walls and where habitat structure is negligible. Examples of reaches with low aquatic score reaches are: 7, 8, 60 and 270.

Photo 10. Stream with vegetation and in-stream habitat.

Photo 11. Stream with no aquatic habitat.

c. *Terrestrial Habitat*

Stream scores associated with terrestrial habitat are similar throughout the watershed area studied. In urban areas it is quite common to clear existing vegetation along streams (except where steep slopes prohibit access and development). In most sections of Brush Creek there is a roadway adjacent to the stream along with multiple crossings (bridges, culverts, and utilities) of the stream channel itself. As a result, there is generally little to no vegetation present to buffer the stream from the negative impacts associated with changes to adjoining land uses. Removal of trees, shrubs, and herbaceous vegetation (grasses and wildflowers) reduces structural support this vegetation provides with its extensive root systems (1 to15 feet). Replacement with turf grasses offers little stability as these grasses tend to have shallow (3 to12 inch) root systems that cannot hold stream banks during high flow events. In addition, the areas planted with turf grass have often been compacted by building equipment prior to sodding, making this surface almost as impervious as asphalt. An additional problem throughout the Brush Creek corridor is the introduction of euonymous (ground cover) and shrub honeysuckle into landscape plantings. Both of these plant species are aggressive, non-native exotics that can quickly dominate the

14

landscape. By shading out other plant species, these non-native exotics actually expose soil and increase erosion. It was noted during the assessment there is a very large area of euonymous along the stream bank near the intersection of Mission Dr. and W. 63rd St. that is thick enough to be holding the gently sloping stream bank on the west side.

The increase in impervious surfaces (roads and rooftops) and land cover changes from native vegetation to lawns has resulted in an increase in the amount and velocity of stormwater runoff directly entering the stream. Highly manicured landscapes could significantly reduce infiltration producing similar conditions found in impervious surface such as roads and parking lots. In addition, the chemicals used to maintain these landscapes are flushed directly into Brush Creek after storm events, adding to the nutrient and contaminant loads within the creek. The lowest terrestrial scores were noted for reaches 270, 203, 50 and 21.

Vegetation within the golf course is predominantly turf grass with a few small patches of natural vegetation. These patches tend to be in areas with steep slopes that are difficult to maintain. Some larger patches of native vegetation were noted along the north end of the course.

It was interesting to note the presence of cypress knees (Bald cypress roots extending above ground in areas of saturated soils) along reach 202. The presence of these knees indicates that the soils along the stream channel are staying saturated with water for extremely long periods of time. This is a unique feature that is generally not encountered in as dry a climate as that associated with the Kansas City region. Another interesting note is the condition of the tributary flowing into Brush Creek at the northwest end of reach 50. This reach has a road along the east side and a golf course along the west side. Most of the vegetation within the golf course is highly maintained even down some of the streambank slopes. However, the tributary appears to have a relatively healthy mix of vegetation and the stream channel appears to be in better condition than the main channel it is flowing into.

Photo 12. Bald Cypress Knees

d. Water Quality

The initial and final field work for this study was conducted in January, February, and November, which made it impossible to identify the presence of aquatic invertebrates, fish, mollusks, or amphibians. Even the field work in April did not present much evidence of aquatic species, although this may be more indicative of the general stream conditions and the inability of the stream to support a healthy and diverse base of aquatic organisms. Given the high flow rates and volumes, Brush Creek presents a rather harsh environment for the survival of these organisms. Even though the aquatic habitat scores were reasonable for many of the stream reaches indicating that there is habitat present for fish, aquatic invertebrates, and mollusks, it is likely that any present are consistently washed downstream after major storm events.

D. Reach Description and Proposed Improvements

1. Reach BC-R50

The 1-yr flow for this reach is 1593 cfs. The following parameters were determined based on Soar and Thorne criteria for a 1593 cfs flow:

Parameter	Value	
Main channel width (w)	45	ft
Wave length (L)	503	ft
Pool-riffle spacing	252	ft
Radius of curvature (Rc)	107	ft
Range *	89-224	ft
Amplitude (Amp)	81	ft

* Absolute minimum – APWA max

Improvement Reach 1

Stream Section #1
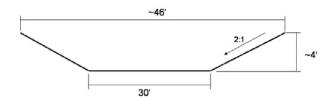
Length: 280 ft

Issues:
- Left wall requires repairs
- Some signs of bank erosion on right bank

Optimal restoration:
- Match proposed cross-section below.
- Increase radius of curvature at confluence.
- Replace wall on left bank with a 2:1 slope (see sketch below).
- Vegetate banks and create buffer zone.
- Replace Indian Ln. bridge with a wider bridge.

Limited restoration:

- Replace wall on left bank.
- Reduce and stabilize slope on right bank.

b. *Improvement Reach 2*

Stream Section #2
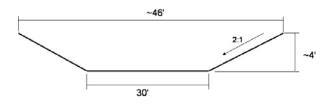
Length: 490 ft
Optimal restoration:

- Match proposed cross-section below and add meandering pattern to channel.
- Vegetate 2:1 banks and create buffer zone (see sketch below).

Limited restoration:

- Modify channel cross-section by matching proposed cross-section below.
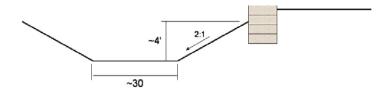- Reduce and stabilize bank slope (see sketch below).

c. *Improvement Reach 3*

Stream Section #3

Length: 150 ft
Optimal restoration:

- Match proposed cross-section below.
- Vegetate banks and create buffer zone.
- Replace wall on right bank with a 2:1 slope.
- The right bank may require building a new wall for slope stability (see sketch below).

Limited restoration:
- Modify channel cross-section as shown and reduce bank slope.
- Replace wall on right bank.

2. *Reach BC-R40*
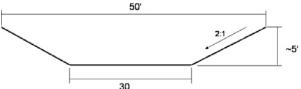
The 1-yr flow for this reach is 1658 cfs. The following parameters were determined based on Soar and Thorne criteria for a 1658 cfs flow:

Parameter	Value	
Main channel width (w)	46	ft
Wave length (L)	514	ft
Pool-riffle spacing	257	ft
Radius of curvature (Rc)	109	ft
Range *	91-228	ft
Amplitude (Amp)	82	ft

* Absolute minimum – APWA max

The following main channel cross section assumes an increase in slope that can be obtained if the Bloch weir is lowered (Improvement Reach 5).

The following figure shows a sketch of the proposed channel geometry through this reach:

19

a. Improvement Reach 4

<u>Stream Section #4</u>

Length: 260 ft

Optimal restoration:

- Replace wall on left bank with a 2:1 slope.
- Match proposed cross-section and add meandering pattern.
- Vegetate banks and create buffer zone.

Limited restoration:

- Replace wall on left bank with a new wall.
- Reduce slope on right bank.

<u>Stream Section #5</u>

Length: 460 ft

Optimal restoration:

- Replace wall on right bank with a 2:1 slope.
- Stabilize left bank with a 2:1 slope.
- Add meandering pattern.
- Vegetate banks and create buffer zone.

Alternative restoration:

- Add wall on left bank to prevent damage to road (Indian Ln.).
- In the short term, flooding problems would not worsen. The channel section, however, may result wider than what it should be. If this is the case, sediment deposition would occur in section potentially increasing flooding in the future as sediment accumulates.

Stream Section #6

Length: 90 ft

Optimal restoration:

- Modify channel to accommodate transition through bridge.
- Vegetate banks and create buffer zone.
- Replace the Merriman Bridge with a wider bridge that accommodates stream restoration modifications.

Limited restoration:

- Do nothing.
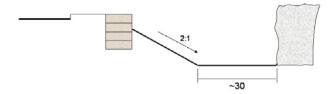
Stream Section #7

Length: 150 ft

Optimal restoration:

- Reduce slope on left bank.
- Vegetate banks and create buffer zone.
- May required extending and lowering encased sewer line.
- A layer of rock is exposed on the right bank. This condition and the closeness to the road (Indian Ln.) on the left may limit restoration efforts. It is possible that a section of wall would have to be built on the left bank (see sketch below).

Limited restoration:

- Do nothing.

b. *Improvement Reach 5*

<u>*Stream Section #8*</u>

Length: 290 ft
Optimal restoration:

- Match proposed cross-section and replace both walls with a 2:1 slope.
- Add meandering pattern.
- Remove Bloch weir.
- Vegetate banks and create buffer zone.

Limited restoration:

- Replace both walls with new walls.
- Lower Bloch weir.

c. *Improvement Reach 6*

<u>*Stream Section #9*</u>

Length: 380 ft
Optimal restoration:

- Replace both walls with a 2:1 slope.
- Add meandering pattern.
- Vegetate banks and create buffer zone.

Limited restoration:

- Replace left wall with new wall.
- Remove section of wall on right bank and change bank slope to 2:1

*d.* *Improvement Reach 7*

<u>*Stream Section #10*</u>

Length: 630 ft
Optimal restoration:

- Match proposed cross-section using 2:1 slopes on both sides.
- Add meandering pattern.
- Existing wall can be used to define the limits of a two-stage channel.
- Vegetate banks and create buffer zone.

22

Limited restoration:
- Match proposed cross-section.
- Increase radius of curvature in the last 370 ft to form a smooth bend upstream from the 63rd St. bridge.

3. **Reach BC-R32**

The 1-yr flow for this reach is 1748 cfs. The following parameters were determined based on Soar and Thorne criteria for a 1748 cfs flow:

Parameter	Value	
Main channel width (w)	47	ft
Wave length (L)	527	ft
Pool-riffle spacing	264	ft
Radius of curvature (Rc)	112	ft
Range *	94-234	ft
Amplitude (Amp)	85	ft

* Absolute minimum – APWA max

a. *Improvement Reach 8*

<u>Stream Section #11</u>

Length: 240 ft
Optimal restoration:
- Replace left wall with a 2:1 slope. Creating a smooth curve between the 63rd St. Bridge and the Indian Ln. low water crossing.
- Vegetate banks and create buffer zone.

Limited restoration:
- Replace left wall with a new wall to create a smooth bend between the 63rd St. Bridge and the Indian Ln. low water crossing.

b. Improvement Reach 9

<u>Stream Section #12and #13</u>

Length: 270 ft

A head-cut on rock is advancing upstream towards the Indian Ln. low water crossing. The right bank is composed of a massive rock formation. This rock formation, however, has been undermined as the head cut advanced upstream. Modification of the right bank is limited by the existing geology. Some aggradation has occurred on the left bank as the stream reaches a stable condition. The section is close to ideal geomorphic conditions.

Optimal restoration:
- Rebuild walls on left bank to protect road and for aesthetic purposes. Existing walls on the left bank combine grouted rock with stacked limestone.
- Vegetate banks and create buffer zone.
- Monitor head cut to determine whether it will progress toward the Indian Ln. low water crossing culverts. A grade control may have to be built to protect the downstream end of the culverts.

Alternative:
- Short term: do nothing.
- Long term: A drop structure may have to be build to protect the downstream end of the culverts.

<u>Stream Section #14</u>

Length: 210 ft
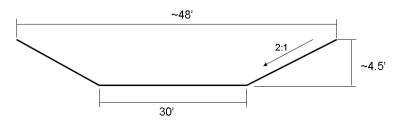
Optimal restoration:
- Match proposed cross-section using 2:1 slopes on both sides.
- Add meandering pattern.
- Vegetate banks and create buffer zone.

Note: Optimal restoration will be difficult to obtain throughout these sections. The proximity of Indian Ln. and geologic conditions on the right bank will limit restoration options. Optimal restoration will required realigning Indian Ln. and potentially building more bridges or culverts.

24

Alternative:

- Do nothing.

c. *Improvement Reach 10*

Stream Section #15 through #18

Length: 640 ft
Optimal restoration:

- Match proposed cross-section (see sketch below).
- Remove walls and add meandering pattern.
- Vegetate banks and create buffer zone.

Limited restoration:

- Match proposed cross-section as necessary.
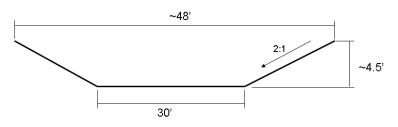- Replace walls with 2:1 slopes on both sides.

d. *Improvement Reach 11*

Stream Sections #19 through #21

Length: 350 ft
Optimal restoration:

- Match proposed cross-section.
- Remove walls and add meandering pattern.
- Vegetate banks and create buffer zone.

25

Note: Optimal restoration will be difficult to obtain throughout these sections. The proximity of Indian Ln. and geologic conditions on the right bank will limit restoration options. Optimal restoration will required realigning Indian Ln. and potentially building more bridges or culverts.

Limited restoration
- Remove walls and stabilize banks. Right bank geologic conditions may allow for slopes steeper than 2:1.
- Left bank is constrained by Indian Ln. To maximize room to allow widening the channel the wall should be replaced and moved as closed as possible to Indian Ln.
- Vegetate banks and create buffer zone where possible.
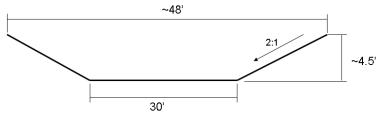
e. *Improvement Reach 12*

Stream Sections #22 through #25

Length: 510 ft
Optimal restoration:
- Match proposed cross-section.
- Remove walls and add meandering pattern.
- Vegetate banks and create buffer zone.

~48'

2:1

~4.5'

30'

Note: Optimal restoration will be difficult to obtain throughout these sections. The proximity of Indian Ln. and geologic conditions on the right bank will limit restoration options. Optimal restoration will require realigning Indian Ln. and potentially building more bridges or culverts.

Limited restoration:
- Left bank is constrained by Indian Ln. To maximize channel width, the wall should be replaced and moved as closed as possible to Indian Ln.

4. Reach BC-R20

The 1-yr flow for this reach is 2136 cfs. The following parameters were determined based on Soar and Thorne criteria for a 2136 cfs flow:

Parameter	Value	
Main channel width (w)	52	ft
Wave length (L)	583	ft
Pool-riffle spacing	291	ft
Radius of curvature (Rc)	124	ft
Range *	104-259	ft
Amplitude (Amp)	93	ft

* Absolute minimum – APWA max

a. Improvement Reach 13

<u>Stream Section #26 and #27</u>
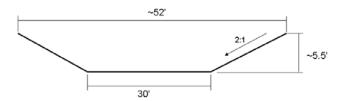
Length: 530 ft
Optimal restoration:
- Match proposed cross-section (see sketch below).
- Add meandering pattern.
- Vegetate banks and create buffer zone.

Limited restoration:
- Do nothing

b. Improvement Reach 14

<u>*Stream Sections #28 through #32*</u>
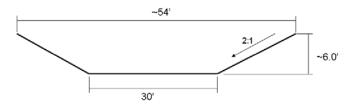
Length: 860 ft

Optimal restoration:
- Remove walls and reduce side slopes to 2:1 (see sketch below).
- Add meandering pattern to channel.
- Vegetate banks and create buffer zone.

Limited restoration:
- Repair and/or replace existing walls

c. Improvement Reach 15

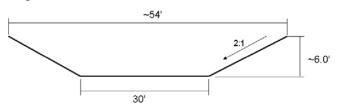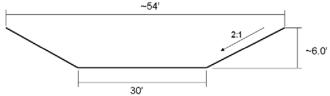<u>*Stream Section #33*</u>

Length: 290 ft

Optimal restoration:
- Match proposed cross-section (see sketch below).
- Vegetate banks and create buffer zone.

Limited restoration:

- Do nothing

d. Improvement Reach 16

<u>*Stream Section #34*</u>

Length: 420 ft

Optimal restoration:

- Remove walls and reduce side slopes to 2:1 (see sketch below).
- Add meandering pattern to channel.
- Vegetate banks and create buffer zone.

Limited restoration:

- Do nothing

5. *Reach BC-R14*

The 1-yr flow for this reach is 3508 cfs. The following parameters were determined based on Soar and Thorne criteria for a 3508 cfs flow:

Parameter	Value	
Main channel width (w)	66	ft
Wave length (L)	747	ft
Pool-riffle spacing	373	ft
Radius of curvature (Rc)	159	ft
Range *	133-332	ft
Amplitude (Amp)	120	ft

* Absolute minimum – APWA max

a. *Improvement Reach 17*

This group of improvements corresponds to the stream segment that includes sections 35 through 43. Water flow through this segment is controlled by the low water crossing located at the downstream end. This feature effectively produces a flat streambed along this stream segment causing backwater effects throughout the stream segment.

To allow water to move slightly faster through the segment, it is recommended to remove the low water crossing. If crossing the stream at this location is necessary, the low water crossing can be moved upstream or upstream of the bend to a point where a riffle would naturally occur. The new water crossing would have to be a culvert or low bridge that would at least allow the channel forming flow to pass without producing a backwater effect. Removing the low water crossing would increase the channel slope.
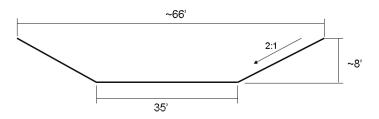
Stream Sections #35 through #37

Length: 750 ft
Optimal restoration:

- Remove walls and reduce side slopes to 2:1 (see sketch below).
- Match proposed cross-section where necessary and modify meandering pattern to obtain smother bends with a larger radius of curvature.
- Vegetate banks and create buffer zone.

Limited restoration:

- Replace or repair walls. Avoid straight wall sections through bends when replacing the walls.

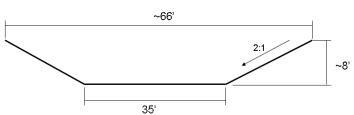### Stream Sections #38 through #40

Length: 450 ft

Optimal restoration:

- Match proposed cross-section (see sketch below).
- Add meandering pattern.
- Vegetate banks and create buffer zone.

Limited restoration:

- Stabilize banks using a 2:1 slope.

Stream Sections #41 and #42

Length: 200 ft

A nick point on rock exists at the downstream end of this stream segment. A weaker layer of rock underneath the limestone has eroded away over time allowing the upper layer to break. A drop structure needs to be built at this location to prevent the nick point from advancing further upstream. This drop structure should direct flow in the direction of the proposed meanders to reduce degradation of the downstream right bank.
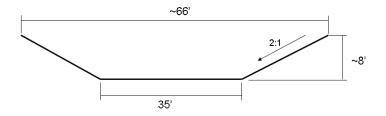

Optimal restoration:
- Remove walls and reduce side slopes to 2:1 (see sketch below).
- Widen the channel.
- Vegetate banks and create buffer zone.
- Stabilize nick point by building a drop structure

Limited restoration:
- Stabilize banks using a 2:1 slope.
- Stabilize nick point by building a drop structure
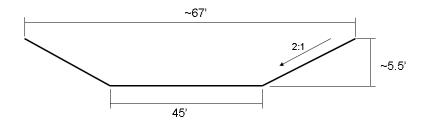

Stream Section #43

Length: 140 ft

Optimal restoration:
- Remove walls and reduce side slopes to 2:1 (see sketch below).
- Match proposed cross-section and modify meandering pattern to obtain smother bend with a larger radius of curvature.

- Vegetate banks and create buffer zone
- Remove bridge and build a replacement on top of drop structure.
- Build energy dissipation structure for drop structure in this section.

Limited restoration:

- Stabilize banks using a 2:1 slope where possible. Repair existing walls as needed.
- Build energy dissipation structure for drop structure in this section.
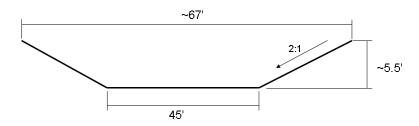

Stream Section #44

Length: 100 ft

Optimal restoration:

- Match proposed cross-section (see sketch below).
- Relocate sewage if necessary to accommodate widened channel.
- Vegetate banks and create buffer zone.

Limited restoration:

- Stabilize banks using a 2:1 slope where possible.
- Bank stabilization on the right bank may be restricted by the existing sanitary.
- Stabilize left bank using a 2:1 slope.
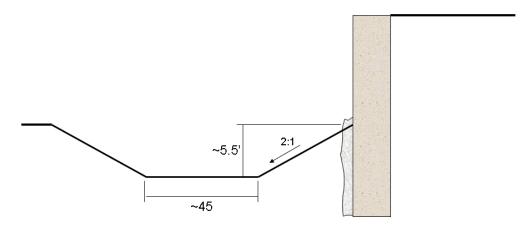
b. Improvement Reach 18

Length: 370 ft

True optimal conditions are not possible to obtain in this stream segment without removing the existing home located on the right bank. Because this segment is located in between bends it is possible to allow the home to remain without significantly altering typical stable stream conditions.

Optimal restoration:
- Match proposed cross-section (see sketch below).
- Repair wall where needed. Use same material for the entire wall for aesthetic reasons. The wall should be keyed into the channel side slope on both the upstream and downstream side to create a smooth transition between the sloped banks and the wall.
- Create a stable riffle through this section by placing large rocks.
- Vegetate left bank and create buffer zone.

Limited restoration:
- Repair wall on the right bank
- Stabilize left bank using a 2:1 side slope.

c. *Improvement Reach 19*

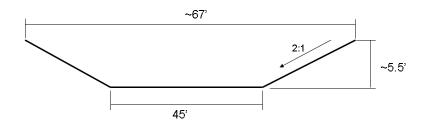*Stream Section #49*

Length: 320 ft

Optimal restoration:
- Remove wall on left bank and match proposed cross-section (see sketch below).
- Modify meandering pattern to obtain smother bend.
- Vegetate banks and create buffer zone.

Limited restoration:
- Repair existing wall

6. Reach BC-R12

The 1-yr flow for this reach is 3410 cfs. The following parameters were determined based on Soar and Thorne criteria for a 3410 cfs flow:

Parameter	Value	
Main channel width (w)	65	ft
Wave length (L)	736	ft
Pool-riffle spacing	368	ft
Radius of curvature (Rc)	157	ft
Range *	131-327	ft
Amplitude (Amp)	118	ft

* Absolute minimum – APWA max
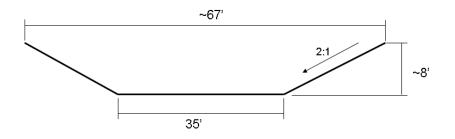
a. *Improvement Reach 20*

Stream Section #50

Length: 730 ft

Optimal restoration:

- Match proposed cross-section.
- Remove wall on right bank and reduce side slopes to 2:1 (see sketch below).
- Replace pedestrian bridge to accommodate wider channel.
- Vegetate banks and create buffer zone.

Limited restoration:

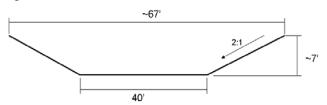- Repair existing walls

b. *Improvement Reach 21*

Stream Section #51

Length: 260 ft

Optimal restoration:

- Widen channel.
- Remove wall on right bank and reduce side slopes to 2:1 (see sketch below).
- Replace bridge to accommodate wider channel.
- Modify meandering pattern to transition into following section.
- Vegetate banks and create buffer zone.

Limited restoration:

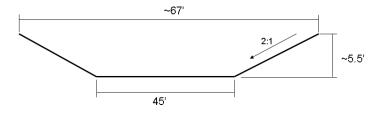- Repair existing walls

~67'

2:1

~7'

40'

Stream Sections #52 and #53

Length: 320 ft

Optimal restoration:

- Widen channel.
- Stabilize banks using 2:1 side slopes (see sketch below).
- Modify meandering pattern to increase sections sinuosity.
- Vegetate banks and create buffer zone.

~67'

2:1

~5.5'

45'

Limited restoration:

- Stabilize banks using 2:1 side slopes.

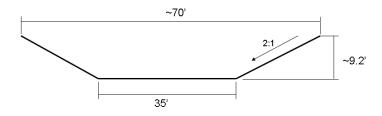c. *Improvement Reach 22*

Stream Section #54

Length: 250 ft

Optimal restoration:

- Match proposed cross-section.
- Remove wall on left bank and reduce side slopes to 2:1 (see sketch below).
- Vegetate banks and create buffer zone.

Limited restoration:

- Stabilize right bank using 2:1 side slopes.
- Repair wall on right bank

7. Reach BC-R10

The 1-yr flow for this reach is 3433 cfs. The following parameters were determined based on Soar and Thorne criteria for a 3433 cfs flow:

Parameter	Value	
Main channel width (w)	66	ft
Wave length (L)	739	ft
Pool-riffle spacing	369	ft
Radius of curvature (Rc)	157	ft
Range *	131-328	ft
Amplitude (Amp)	118	ft

* Absolute minimum – APWA max

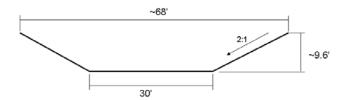### a. Improvement Reach 23

Stream Sections #55 through 59

Length: 820 ft
Optimal restoration:

- Match proposed cross-section (see sketch below).
- Modify meandering pattern to increase sections sinuosity
- Remove gabions (where applicable).
- Replace pedestrian bridge to accommodate wider channel.
- Vegetate banks and create buffer zone.

Limited restoration:
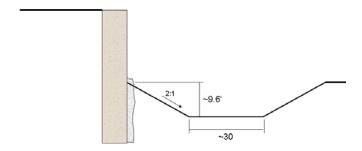- Stabilize banks using 2:1 side slopes.

b. *Improvement Reach 24*

<u>*Stream Section #60*</u>
Length: 340 ft

Optimal restoration:
- Removing the existing wall on the left bank would be ideal. Removing it may compromise the foundations of the adjacent building, thus removing the wall is not advisable and may not be feasible. A stable channel can still be achieved by modifying the meandering pattern, and matching the proposed cross-section (see sketch below).
- Vegetate banks and create buffer zone.

Limited restoration:
- Stabilize right bank using 2:1 side slopes.

8. Reach BC-T30a

The 1-yr flow for this reach is 130 cfs. The following parameters were determined based on Soar and Thorne criteria for a 130 cfs flow:

Parameter	Value	
Main channel width (w)	12.8	ft
Wave length (L)	144	ft
Pool-riffle spacing	72	ft
Radius of curvature (Rc)	31	ft
Range *	26-64	ft
Amplitude (Amp)	23	ft

* Absolute minimum – APWA max
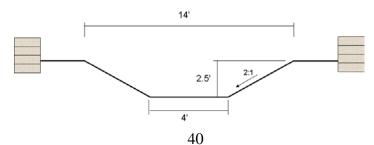
a. Improvement Reach 25

Stream Sections #320 through 326

Length: 1370 ft
Optimal restoration:

- Remove existing walls and build a new wider non-concrete-lined channel.
- The main channel will have 2:1 side slopes. Where possible a flood bench should be created (see sketch below).
- Walls would have to be built for main or secondary bank stability.
- The channel should be built to convey the 100-yr flow since there would be extremely limited space for overflows (that is beyond proposed walls).
- Replace 3 bridges with wider bridges. Alternatively, provide a transition between the bridge opening and the new channel to avoid local scour or bank instability.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended as an alternative to a meandering channel. Preliminary calculations indicate that 19 10-in drops, spaced every 72 ft can be built to produce the stepped channel.
- Vegetate flood benches and banks and create buffer zone where possible.

Alternative:

- Do nothing; existing concrete lined channel should be stable. Repairs and maintenance will be required over time. This alternative does not provide any environmental benefits.

9. *Reach BC-T30b*

The 1-yr flow for this reach is 185 cfs. The following parameters were determined based on Soar and Thorne criteria for a 185 cfs flow:

Parameter	Value	
Main channel width (w)	15	ft
Wave length (L)	172	ft
Pool-riffle spacing	86	ft
Radius of curvature (Rc)	37	ft
Range *	30-76	ft
Amplitude (Amp)	28	ft

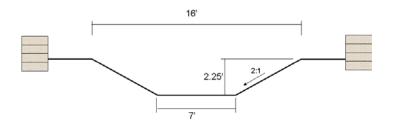* Absolute minimum – APWA max

a. *Improvement Reach 26*

<u>Stream Sections #311 through #319</u>

Length: 980 ft
Optimal restoration:

- Match proposed cross-section and add meandering pattern to main channel. Create flood benches. Remove walls and reduce side slopes to 2:1. Add walls were necessary for bank stability.
- Replace 3 driveway bridges and replace bridge on Seneca Rd as necessary to accommodate new channel.
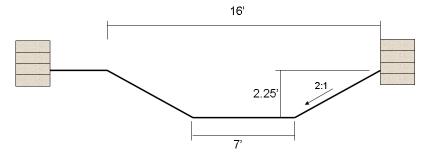- Vegetate banks and create buffer zone.

Alternative:
- Repair existing walls and replace concrete bottom with stable rock.
- The existing channel conveys the 100-yr flow.
- Vegetate banks and create buffer zone if possible on both banks.

b. *Improvement Reach 27*

<u>*Stream Sections #306 through #310*</u>

Length: 550 ft
Optimal restoration:

- Replace bridge on Wenonga Rd. Bridge abutments are in poor condition and may be structurally unstable.
- Match proposed cross-section. Create flood benches (see figure below).
- Repair or replace right bank walls. Add walls on the left bank for slope stability.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended as an alternative to a meandering channel. Preliminary calculations indicate that 7 12-in drops, spaced every 86 ft can be built to produce the stepped channel.
- Replace two driveway bridges to accommodate new channel.
- Vegetate flood benches and banks and create buffer zone.

Limited restoration:

- Repair or replace existing walls as necessary.
- Replace bridge on Wenonga Rd. Bridge abutments are in poor condition and may be structurally unstable.
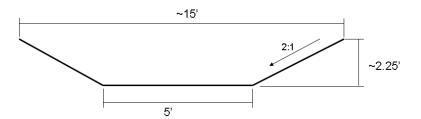
c. *Improvement Reach 28*

Stream Sections #301 through #305

Length: 530 ft

Optimal restoration:

- Remove stacked-stone wall (250 ft)
- Match proposed cross-section and add meandering pattern to main channel. Create flood benches. Remove walls and reduce side slopes to 2:1 (see sketch below).
- Vegetate banks and create buffer zone.

Limited restoration:

- Repair existing walls
- Stabilize right bank on bend at Hiawassee Park

10. Willow Ln

Flows for this reach were assumed to be equivalent to those of Ensley Ln. The assumed 1-yr flow is 100 cfs. The following parameters were determined based on Soar and Thorne criteria for a 100 cfs flow:

Parameter	Value	
Main channel width (w)	11	ft
Wave length (L)	125	ft
Pool-riffle spacing	63	ft
Radius of curvature (Rc)	27	ft
Range *	22-56	ft
Amplitude (Amp)	20	ft

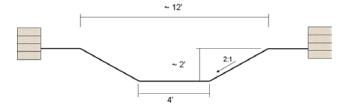* Absolute minimum – APWA max

a. *Improvement Reach 29*

<u>Stream Sections #276 through 284</u>

Length: 750 ft
Optimal restoration:

- Replace 5 driveway bridges with larger bridges.
- Remove existing walls and build a new channel with 2:1 side slopes (see sketch below). Create flood bench if possible.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended as an alternative to a meandering channel. Preliminary calculations indicate that 17 8.5-in drops, spaced every 44 ft can be built to produce the stepped channel. This spacing allows having one drop at every bridge and one in the middle of the segment between bridges.
- Vegetate flood benches and banks and create buffer zone where possible.

Limited restoration:
- Repair walls where needed.

11. Reach Ensley Ln

The 1-yr flow for this reach is 100 cfs. The following parameters were determined based on Soar and Thorne criteria for a 100 cfs flow:

Parameter	Value	
Main channel width (w)	11	ft
Wave length (L)	125	ft
Pool-riffle spacing	63	ft
Radius of curvature (Rc)	27	ft
Range *	22-56	ft
Amplitude (Amp)	20	ft

* Absolute minimum – APWA max

a. *Improvement Reach 30*
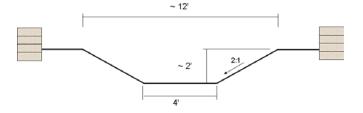
Stream Sections #270 through 275

Length: 720 ft
Optimal restoration:

- Replace 3 driveway bridges with larger bridges.
- Remove existing walls and build a new channel with 2:1 side slopes (see sketch below). Create flood bench if possible.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended as an alternative to a meandering channel. Preliminary calculations indicate that 11 2-ft drops, spaced approximately every 63 ft can be built to produce the stepped channel.
- Vegetate flood benches and banks and create buffer zone where possible.

Alternative restoration:

- Remove existing walls and build new channel that would convey the 10 yr flow

12. Reach BC-T22a

The 1-yr flow for this reach is 373 cfs. The following parameters were determined based on Soar and Thorne criteria for a 373 cfs flow:

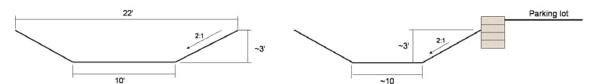| Parameter	Value	
Main channel width (w)	22	ft
Wave length (L)	244	ft
Pool-riffle spacing	122	ft
Radius of curvature (Rc)	52	ft
Range *	43-108	ft
Amplitude (Amp)	39	ft

* Absolute minimum – APWA max

a. *Improvement Reach 31*

Stream Section #220

Length: 540 ft
Optimal restoration:

- Repair pipe outlets that discharge into section.
- Add meandering pattern and reduce slope on right bank to 2:1 (see sketch).
- Provide a smooth transition upstream of Tomahawk bridge (125 ft)
- Vegetate banks and create buffer zone.
- Sections of the parking lot on right bank would have to be removed to accommodate the new left bank slope and buffer zone.

Limited restoration:

- Repair pipe outlets that discharge into section.
- Provide a smooth transition upstream of Tomahawk bridge (125 ft)
- Reduce slope on right bank and add a wall to preserve parking lot area (see sketch).

13. Reach BC-T22b

The 1-yr flow for this reach is 556 cfs. The following parameters were determined based on Soar and Thorne criteria for a 556 cfs flow:

Parameter	Value	
Main channel width (w)	26	ft
Wave length (L)	297	ft
Pool-riffle spacing	149	ft
Radius of curvature (Rc)	63	ft
Range *	53-132	ft
Amplitude (Amp)	48	ft

* Absolute minimum – APWA max

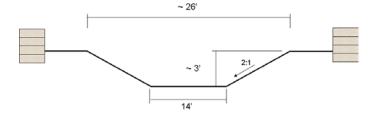*a. Improvement Reach 32*

<u>Stream Section #219</u>

Length: 210 ft
Optimal restoration:

- Widen Tomahawk bridge.
- Add meandering pattern and replace walls with a 2:1 slope (see sketch below).
- Walls may have to be built for main or secondary bank stability.
- Provide a smooth transition downstream from Tomahawk bridge (125 ft)
- Vegetate banks and extend buffer zone if required on both banks.

Limited restoration:

- Replace walls with a 2:1 slope.
- Provide a smooth transition downstream from Tomahawk bridge (125 ft)
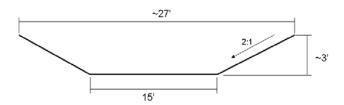
b. Improvement Reach 33

<u>Stream Section #218</u>

Length: 230 ft

Optimal restoration:

- Add meandering pattern and reduce slopes to 2:1 where needed (see sketch below).
- Provide a smooth transition upstream of 63rd Street bridge (80 ft).
- Vegetate banks and extend buffer zone if required on both banks.
- Repair pipe outlets that discharge into section.

Limited restoration:

- Repair pipe outlets that discharge into section.
- Provide a smooth transition upstream of 63rd Street bridge (80 ft).

14. Reach BC-T22c

The 1-yr flow for this reach is 590 cfs. The following parameters were determined based on Soar and Thorne criteria for a 590 cfs flow:

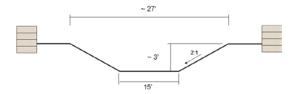| Parameter	Value	
Main channel width (w)	27	ft
Wave length (L)	306	ft
Pool-riffle spacing	153	ft
Radius of curvature (Rc)	65	ft
Range *	53-136	ft
Amplitude (Amp)	49	ft

* Absolute minimum – APWA max

a. Improvement Reach 34

Stream Sections #213 through #217

Length: 600 ft
Optimal restoration:

- Repair or replace existing wall on the right bank.
- Match proposed cross-section (see sketch below). Create flood bench where possible.
- Rebuild the right wall as close as possible to Mission Dr. to allow widening of the channel.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended as an alternative to a meandering channel. Preliminary calculations indicate that 4 2-ft drops, spaced approximately every 150 ft can be built to produce the stepped channel. One of the drop structures can be placed at the location of a sanitary sewer crossing. The sanitary sewer concrete encasement needs replacement.
- Vegetate flood benches and banks and create buffer zone where possible.

Limited restoration:

- Repair walls where needed and protect wall footings. May require rebuilding the walls.
- Repair sanitary sewer concrete encasement and build appropriate energy dissipation structure downstream.
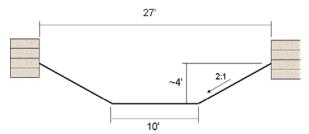
Stream Section #212

Length: 190 ft
Optimal restoration:

- Replace High Dr. Bridge to accommodate wider channel.
- Replace walls and widen channel using 2:1 side slopes (see sketch below). Rebuild the right wall as close as possible to Mission Dr. to allow widening of the channel.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended. The steps can be placed at the downstream end of the High Dr. Bridge and at the downstream end of the reach at the driveway bridge.
- Remove concrete from bottom of the channel, except if needed at drop structures.
- Vegetate flood benches and banks and create buffer zone where possible.

Limited restoration:

- Repair walls where needed. May require rebuilding the walls.
- Build drop structures at High Dr. bridge and at the driveway bridge.
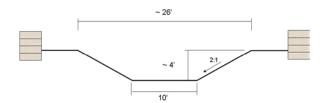
Stream Section #211

Length: 110 ft

Optimal restoration:
- Channel width seems to be appropriate. Actual dimensions need to be checked with survey data. Modify section if needed (see sketch below). Create flood benches if possible.
- Because meandering would be difficult to attain in this reach, a stepped channel is recommended. The proposed improvements for the previous section call for a step at the end of that section. This step will be the first step for the reach. The second step can be placed on the driveway bridge at the downstream end of the section. The separation between the two driveway bridges is relatively close to optimal riffle spacing.
- Check driveway bridges dimensions. Replace bridges or create transitions as necessary for channel stability (the proposed step may be an appropriate transition).
- Vegetate flood benches and banks and create buffer zone where possible.

Limited restoration:
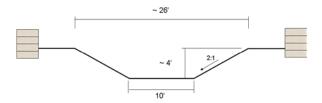- Do nothing.

Stream Sections #208 through #210

Length: 410 ft

Optimal restoration:

- Replace walls and match proposed cross-section (see sketch below). Rebuild the right wall as close as possible to Mission Dr. to allow widening of the channel. Create flood benches if possible.

- Because meandering would be difficult to attain in this reach, a stepped channel is recommended. A step can be placed at about the middle of the reach.
- Remove concrete from bottom of the channel, except if needed at drop structures.
- Vegetate flood benches and banks and create buffer zone where possible.

Limited restoration:

- Some walls may need to be repaired

15. Reach BC-T20

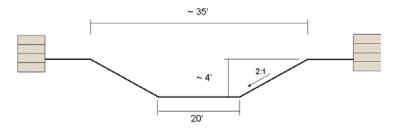The 1-yr flow for this reach is 953 cfs. The following parameters were determined based on Soar and Thorne criteria for a 953 cfs flow:

Parameter	Value	
Main channel width (w)	35	ft
Wave length (L)	389	ft
Pool-riffle spacing	195	ft
Radius of curvature (Rc)	83	ft
Range *	69-173	ft
Amplitude (Amp)	62	ft

* Absolute minimum – APWA max

The following sketch shows the dimensions required for all sections of this reach:

a. *Improvement Reach 35*

Stream Sections #205 through #207

Length: 550 ft
Optimal restoration:

- Remove walls and match proposed cross-section.
- It is possible that a section of wall would have to be built at the top of the 2:1 slope to match the exiting grade. Create flood benches if possible.
- Repair, lower and extend the two weirs and potentially add another weir at downstream end of section #19 (at bridge). Build appropriate energy dissipation structure downstream from weirs to protect the toe of the weir. The weirs will be drop structures. Their separation is adequate, thus meandering in these sections is not necessary.
- Replace two bridges with wider span bridges that accommodate the new channel shape. Bridges seem to be in fair conditions; their size, however, is inadequate. Increasing the span would reduce flooding potential in the area.
- Vegetate banks and extend buffer zone as required on both banks.

Limited restoration:

- Repair walls where needed and protect walls footings (May require rebuilding the walls).
- Repair, lower and widen the two weirs. Build appropriate energy dissipation structure downstream from weirs.

b. Improvement Reach 36

<u>Stream Sections #201 through #204</u>

Length: 660 ft

Optimal restoration:
- Match proposed cross-section and add meandering pattern to channel.
- Vegetate banks and create buffer zone.
- Remove walls on the left bank and reduce side slopes to 2:1.
- Replace bridge with a wider span bridge. Existing bridge is in poor conditions. Visual inspection suggests that there could be serious problems with the structural integrity of the bridge.
- Vegetate banks and extend buffer zone as required on both banks.

Limited restoration:
- Repair or replace bridge.
- Repair and/or replace existing walls.

16. Reach BC-T23

The 1-yr flow for this reach is estimated to be 60 cfs (hydrology needs to be checked for this reach). The following parameters were determined based on Soar and Thorne criteria for a 60 cfs flow:

Parameter	Value	
Main channel width (w)	9	ft
Wave length (L)	98	ft
Pool-riffle spacing	49	ft
Radius of curvature (Rc)	21	ft
Range *	17-43	ft
Amplitude (Amp)	16	ft

* Absolute minimum – APWA max

a. Improvement Reach 37

<u>*Stream Sections #230 through #235*</u>

Length: 770 ft
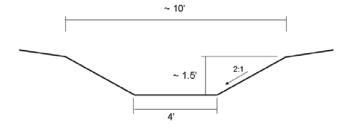
Optimal restoration:
- Replace both walls and stabilize banks with a 2:1 slope. Create flood benches (see sketch below).
- Add meandering pattern.
- Replace pedestrian bridge if necessary to accommodate new proposed geometry.
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Check bridge structural stability, repair or replace bridge if necessary
- Repair and/or replace existing walls as necessary.

55

17. Reach BC-T10

The 1-yr flow for this reach is estimated to be 165 cfs (hydrology needs to be checked for this reach). The following parameters were determined based on Soar and Thorne criteria for a 165 cfs flow:
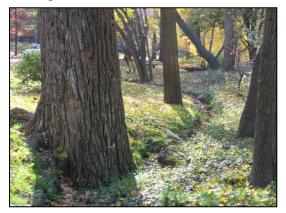
Parameter	Value	
Main channel width (w)	11	ft
Wave length (L)	162	ft
Pool-riffle spacing	81	ft
Radius of curvature (Rc)	35	ft
Range *	29-130	ft
Amplitude (Amp)	26	ft

* Absolute minimum – APWA max

a. *Improvement Reach 38*

<u>*Stream Sections #509 through #510*</u>
Length: 170 ft
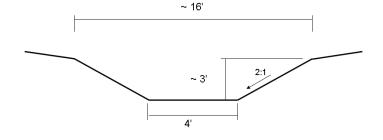
Optimal restoration:
- Remove wall.
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope. Create flood benches (see sketch below).
- Replace bridge if necessary to accommodate new proposed geometry.
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Repair wall next to Pembroke Ln. at the downstream end.

~ 16'

2:1

~ 3'

4'

Stream Sections #506 through #508

Length: 380 ft

Optimal restoration:
- Remove wall.
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope in the main channel. Create flood benches and build walls as needed for bank stability (see sketch below).
- Replace bridge if necessary to accommodate new proposed geometry.
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Repair walls.

Stream Section #505

Length: 130 ft

Optimal restoration:
- Remove wall.
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope in the main channel. Create flood benches and build walls as needed for bank stability (see sketch below).
- Replace bridge if necessary to accommodate new proposed geometry.
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Do nothing

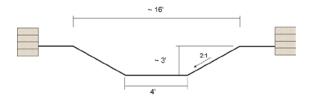

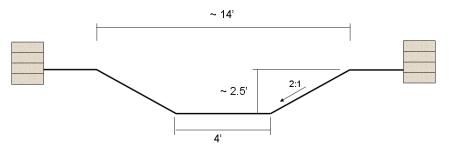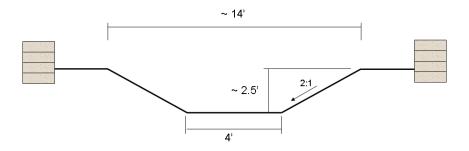*Stream Sections #501 through #504*

Length: 940 ft

Optimal restoration:
- Remove wall.
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope in the main channel. Create flood benches and build walls as needed for bank stability (see sketch below).
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Do nothing

18. Reach RC-R10

The 1-yr flow for this reach is estimated to be 1520 cfs. The following parameters were determined based on Soar and Thorne criteria for a 1520 cfs flow:

Parameter	Value	
Main channel width (w)	44	ft
Wave length (L)	492	ft
Pool-riffle spacing	246	ft
Radius of curvature (Rc)	105	ft
Range *	87-218	ft
Amplitude (Amp)	79	ft

* Absolute minimum – APWA max

a. Improvement Reach 39

<u>Stream Sections #107 through #114</u>

Length: 1620 ft

Optimal restoration:

- Remove walls.
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope. Create flood benches and add walls as necessary (see sketch below).
- Replace two pedestrian bridges to accommodate new proposed geometry.
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Repair walls as needed.
- Stabilize banks using a 2:1 slope.
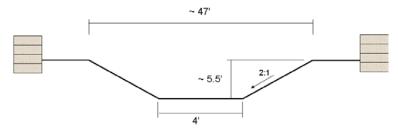

Stream Section #106

Length: 90 ft
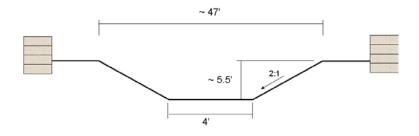
Optimal restoration:
- Remove walls.
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope. Create flood benches and add walls as necessary (see sketch below).
- Move concrete weir upstream. The new weir should be placed in between meanders. This will significantly reduce the impact that the existing weir is having on the right bank located immediately downstream from the weir.
- Vegetate banks and flood benches and create buffer zone.

Limited restoration:
- Repair walls
- Stabilize banks using a 2:1 slope.
- Move concrete weir upstream. The new weir should be placed in between meanders. This will significantly reduce the impact that the existing weir is having on the right bank located immediately downstream from the weir.

b. Improvement Reach 40

<u>*Stream Sections #101 through #105*</u>
Length: 920 ft
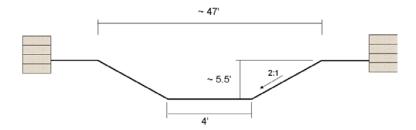
Optimal restoration:
- Relocate the stream following a meandering pattern.
- Stabilize banks using a 2:1 slope. Create flood benches and add walls as necessary (see sketch below).
- Replace pedestrian bridge to accommodate new proposed geometry.
- Remove walls (210 ft, downstream end).
- Vegetate banks and flood benches and create buffer zone.
- Remove low water crossing or rebuild to accommodate new proposed geometry
- Replace sanitary sewer crossing to accommodate new proposed geometry

Limited restoration:
- Stabilize banks using a 2:1 slope.
- Repair sanitary sewer encasement.

E.   Conclusions

Stability indicators showed that the existing steams in the City of Mission Hills have a poor stability rating.   Despite impending unstable conditions, the extensive use of walls and other bank stabilization mechanisms has prevented excessive bank failures in the form of bank cutting and mass wasting. The mix of natural and manmade elements along Brush Creek, are relatively more stable than would have been predicted for an urbanized stream.

Wall conditions vary extensively. Newer walls are in good conditions. Older walls typically are either in poor conditions or show signs of periodic repairs; in a few instances old walls have collapsed. Undermining of the wall foundations due to streambed degradation is a common problem that compromises the stability of many walls that are otherwise in good conditions.

A healthy, vegetated, streamside buffer is critical to the long term health of streams especially in urban environments where stressors are more prevalent. Allowing greater channel width where room permits (channel is not confined by structures like roads and homes) will provide the stream with opportunities to create natural meanders and macrohabitats as it works to provide balance or stability within its own system. In some instances meanders that mimic conditions typically present in natural channels would have to be built to account for space limitations. The meandering pattern, the pool-riffle sequence, wider stream channel and a flexible stream bed structure (rock and gravel) have a positive impact to the habitat function of a healthy stream.

Measures should be taken to revegetate the corridor with more native plant species, especially shrubs, grasses, and wildflowers. Homeowners and the golf courses should be encouraged to remove the exotic non-natives and replant using native riparian species and to allow for a healthier vegetative buffer along the stream channel. This can be accomplished by planting a semi manicured transition zone between the stream and the main yards. There should also be a concerted effort by the City to educate citizens and elected officials on the benefits of streams and stream corridors, the proper use of landscape chemicals, and the need to reduce impervious surfaces adjacent to streams.

F.   References

Intuition & Logic. *Flood Reduction of Brush Creek Geomorphic Analysis.* May, 2002.

Kansas City Metropolitan Chapter, American Public Works Association. *Construction and Material Specifications, Section 5600 Storm Drainage Systems and Facilities, Design Criteria.* 2005.

Soar, Philip J. and Thorne, Colin R. "Channel Restoration Design for Meandering Rivers". Engineer Research and Development Center, US Army Corps of Engineers, 2001.

U.S. Department of Transportation, Federal Highway Administration, "Design of Roadside Channels with Flexible Linings", Hydraulic Engineering Circular No. 15, 1988. This publication will be referred as HEC-15 throughout this document.

Appendix I
Channel Condition Scoring Matrix
(APWA Table 5605-2)

Project: _____

Stream Name and Location: _____

Evaluated by: _____ Firm: _____ Date: _____

	Table 5605-2 CHANNEL CONDITION SCORING MATRIX (adapted from Johnson, et al 1999)			Score (S)	Weight (W)	Rating S*W= (R)
Stability Indicator	Good (1)	Fair (2)	Poor (3)			
Bank soil texture and coherence	cohesive materials, clay (CL), silty clay (CL-ML), massive limestone, continuous concrete, clay loam (ML-CL), silty clay loam (ML-CL), thinly bed limestone	sandy clay (SC), sandy loam (SM), fractured thinly bedded limestone	non-cohesive materials, shale in bank, (SM), (SP), (SW), (GC), (GM), (GP), (GW)		0.6	
Average bank slope angle	slopes ≤ 2:1 on one or occasionally both banks	slopes up to 1.7:1 (60°) common on one or both banks	bank slopes over 60° on one or both banks		0.6	
Average bank height	less than 6 feet	greater than 6 and less than 15 feet	greater than 15 feet		0.8	
Vegetative bank protection	wide to medium band of woody vegetation with 70-90% plant density and cover. Majority are hardwood, deciduous trees with well-developed understory layer, minimal root exposure	narrow bank of woody vegetation, poor species diversity, 50-70% plant density, most vegetation on top of bank and not extending onto bank slope, some trees leaning over bank, root exposure common	thin or no band of woody vegetation, poor health, monoculture, many trees leaning over bank, extensive root exposure, turf grass to edge of bank		0.8	
Bank cutting	little to some evident along channel bends and at prominent constrictions, some raw banks up to 4 foot	Significant and frequent. Cut banks 4 feet high. Root mat overhangs common.	Almost continuous cut banks, some over 4 feet high. Undercut trees with sod-rootmat overhangs common. Bank failures frequent		0.4	

56-65

65

				Score (S)	Weight (W)	Rating S*W= (R)
Table 5605-2 **CHANNEL CONDITION SCORING MATRIX** (adapted from Johnson, et al 1999)						
Stability Indicator	**Good (1)**	**Fair (2)**	**Poor (3)**			
	consolidated with some overlapping. Assorted sizes of particles, tightly packed and overlapped, possibly imbricated. Small % of particles < 4mm		% of material < 4mm			
Sinuosity	$1.2 \leq$ Sinuosity ≤ 1.4	$1.1 <$ Sinuosity < 1.2	Sinuosity < 1.1		0.8	
Ratio of radius of curvature to channel width	$3 \leq R_c/W_b \leq 5$	$2 < R_c/W_b < 3,$ $5 < R_c/W_b < 7$	$2 < R_c/W_b,$ $R_c/Wb > 7$		0.8	
Ratio of pool-riffle spacing to channel width at elevation of 2-year flow	$4 \leq Length/W_b < 8$	$3 \leq Length/W_b < 4,$ $8 < Length/W_b \leq 9$	$3 < Length/W_b,$ $Length/Wb > 9,$ unless long pool or run because of geologic influence		0.8	
Percentage of channel constriction	< 25%	26-50%	> 50%		0.8	
Sediment movement	little to no loose sediment	scour and/or deposition, some loose sediment	near continuous scour and/or deposition and/or loose sediment		0.8	

TOTAL ____

Table 5605-2 CHANNEL CONDITION SCORING MATRIX (adapted from Johnson, et al 1999)						
Stability Indicator	Good (1)	Fair (2)	Poor (3)	Score (S)	Weight (W)	Rating S*W= (R)
Mass wasting	little to some evidence of slight or infrequent mass wasting, past events healed over with vegetation. Channel width relatively uniform with only slight scalloping	Evidence of frequent and significant mass wasting events. Indications that higher flows aggravated undercutting and bank wasting. Channel width irregular with bank scalloping evident	Frequent and extensive mass wasting evident. Tension cracks, massive undercutting and bank slumping are considerable. Highly irregular channel width.		0.8	
Bar development	narrow relative to stream width at low flow, well-consolidated, vegetated and composed of coarse bed material to slight recent growth of bar as indicated by absence of vegetation on part of bar	Bar widths wide relative to stream width with freshly deposited sand to small cobbles with sparse vegetation	Bar widths greater than ½ the stream width at low flow. Bars are composed of extensive deposits of finer bed material with little vegetation		0.6	
Debris jam potential	slight – small amounts of debris in channel. Small jams could form	moderate – noticeable debris of all sizes present	significant – moderate to heavy accumulations of debris apparent		0.2	
Obstructions, flow deflectors (walls, bluffs) and sediment traps	negligible to few or small obstructions present causing secondary currents and minor bank and bottom erosion but no major influence on meander bend	moderately frequent and occasionally unstable obstructions, noticeable erosion of channel. Considerable sediment accumulation behind obstructions	frequent and unstable causing continual shift of sediment and flow		0.2	
Channel bed material consolidation and armoring	massive competent to thinly bed limestone, continuous concrete, hard clay, moderately	shale in bed, soft silty clay, little consolidation of particles, no apparent overlap, moderate % of particles < 4mm	silt, weathered, thinly bedded, fractured shale, high slaking potential, very poorly consolidated, high		0.8	

56-66

67

Appendix II
Stream Assessment and Proposed Improvement Maps