Urban Drainageway Guidance

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1 Background

The Papio-Missouri River Natural Resources District (District) administers an Urban Drainageway Program for matching funding of projects that control erosion, and/or flooding along major drainageways in its jurisdiction. The District currently provides a 60 percent cost-share for selected projects. The District is considering changes to the current policy, to encourage more environmentally sustainable approaches to stream channel projects participating in the Urban Drainageway Grant Program.

It is the goal of the District to encourage implementation of restoration approaches that maximize the natural functions of the stream channel. In order to meet the goals of the District, proposed design strategies need to involve the use of techniques that support their existing Stormwater Management Policies including, but not limited to;

- Floodplain Management
- Landscape Preservation, Restoration and Conservation (habitat enhancement)
- Erosion and Sediment Control (long-term channel stability)
- Pollution Control (natural buffer systems)

This technical memorandum (TM) provides guidance material for the District when ranking Urban Drainageway Program grant applications, while considering the Stormwater Management Policies. Three Levels of Design are identified for the District to use in evaluating and prioritizing funding applications and when determining allocations for each project. This TM also provides an overview of stream channel design practices that can be used to enhance environmental sustainability.

This document offers general guidance and references to publications that provide more detailed information, it is not the intent of this document to serve as a design manual for applicants.

2 Stream Evaluation Approach

This section provides a general approach that can be used to identify the processes impacting the condition of a stream reach within its watershed. In general, the approach is to (1) identify the problems in a stream reach and possible solutions for mitigating these problems based on watershed, site, and stream reach assessments and then (2) recommend a plan for the best alternative considering the costs and benefits. Information and data collected for evaluation using this approach are useful in identifying appropriate stream improvement techniques.

2.1 Watershed Assessment

A watershed assessment of the contributing drainage area should be conducted to begin to evaluate how potential stream improvement techniques for a particular reach may function within the larger watershed. Watershed assessments identify issues on a large scale, examine the history of the watershed, and describe current features of the watershed and stream. This information is useful in defining the hydrologic and hydraulic evaluations to be conducted during the site assessment.

Components of a watershed assessment typically include the following:

- Delineating the watershed boundary
- Determining the drainage area
- Identifying the land uses and land cover within the watershed
- Identifying the drainage network (open channel versus stormwater pipe)
- Identifying the stream order
- Compiling information about the general topography (i.e., typical slopes and whether the watershed has a narrow and long, or broad and short shape)
- Identifying potential future changes to conditions in the watershed

More information about data that are typically gathered as part of a baseline watershed assessment is available in documents listed in the References section.

2.2 Site Assessment

Site assessments are conducted to develop a better understanding of the factors contributing to (and the extent of) impacts to streams that may be addressed during stream improvement efforts. A comprehensive site assessment is imperative for choosing stream improvement techniques that are appropriate to mitigate the factors detrimentally impacting the stream.

Conditions that can be mitigated with stream improvement efforts include;

- Bank and bed erosion (bank failure, bed scouring),
- Avulsion (abandonment of a channel and formation of a new channel),
- Channel slope,
- Sinuosity,
- Threatened infrastructure or structures,
- Degraded habitat, and
- Altered hydrology (low base flow and/or increased frequency and magnitude of peak flow).

As part of the site assessment, a list should be developed indicating the factors contributing to (and the extents of) the impacts to be addressed with stream improvement techniques. For example, factors contributing to scouring can be hydraulic (high velocities and flows of uncontrolled urban runoff) or physical (inadequate vegetative cover or restrictions by bridge crossings, culverts, spillways, or drop structures). Understanding the factors behind the impacts is crucial for choosing appropriate stream improvement techniques to maximize mitigation and restoration efforts.

A typical site assessment includes the following components:

- Site map describing relevant site conditions and constraints
- Hydrologic and hydraulic information (as described in the Omaha Regional Stormwater Design Manual, 2006)
- Existing channel conditions and likelihood of future degradation
- Factors contributing to the existing channel conditions
- Social and economic factors

Social and economic factors associated with the project stream reach should be taken into account because the success of the stream improvement technique often depends on stakeholder input and acceptance, locally available materials, labor supply, markets, accessibility, and type of developed area where the project is located. In addition, the expectations of the local stakeholders should be clearly understood rather than assumed. Additional information on site assessment approaches is available in documents listed in the References section.

2.3 Stream Reach Assessment

A stream reach assessment is typically conducted with the site assessment. A reach assessment establishes the physical characteristics of the stream, which are generally grouped into the channel form and stream classification. Each of these is discussed below. Additional information on reach assessment approaches is available in documents listed in the References section.

2.3.1 Channel Form

Characteristics of the stream channel form, including bed slope, cross section dimensions, longitudinal profile, plan form (pattern), sediment load, substrate, vegetation, debris, discharges, and velocities, should be described for the study reach. Knowledge of these physical characteristics is useful in understanding why the stream is in its current condition. In addition, this information can be used to choose and size appropriate stream improvement techniques. Choosing stream improvement techniques without understanding the mechanisms of the factors creating the impacts and the physical characteristics of the channel can result in the failure of the techniques implemented.

2.3.2 Stream Classification

Stream classification is the process of documenting a channel's physical characteristics and categorizing a particular reach within a standard classification system. Several classification systems exist, and many are related to the stream's current status in an evolutionary process. Schumm et al. (1986) presented the Channel Evolution Model (CEM), which is used to characterize the incision process for streams, describing five stages of channel response (Fischenich and Morrow, 2000). These stages can be viewed as a temporal process (Figure 1), in which the changes occur at a point on a stream over time, or as a spatial process in which the five stages are distributed in a watershed (Figure 2).

Land use changes that affect hydrology and/or sediment yield can cause downcutting or incision as the channel attempts to regain stability. It may take years or decades to achieve a new equilibrium. Degradation can be initiated by base level lowering or grade changes that initiate headcuts that move upstream, leading to rapid channel incision even in the absence of watershed impacts (such as grade changes in the Missouri River that propagate upstream into the Papillion Creek system). Thus, channel incision and evolution can be initiated by a variety of conditions and can be an upstream-down or downstream-up process. There are many streams within the District’s jurisdiction that have impacts from both conditions, and many are incised channels. In most urban settings, the stream channels have been impacted significantly and their CEM status is accelerated by straightening, confinement, reduction in channel length that results in steeper slopes, incised channels due to headcutting, and/or lack of adequate vegetative cover. Understanding the stage of the CEM process will assist in choosing appropriate stream improvement techniques to help the stream reach equilibrium.

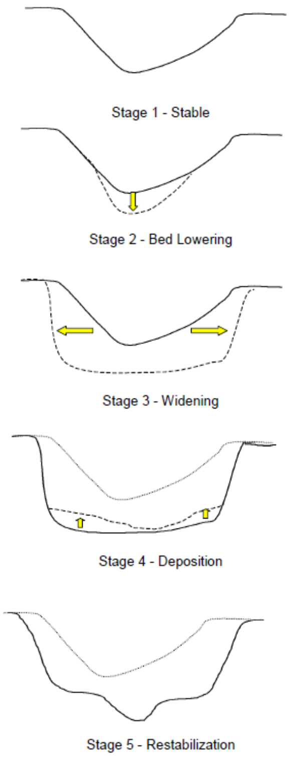

FIGURE 1 - Temporal process - changes occur at a point on a stream over time (Fischenich and Morrow, 2000)

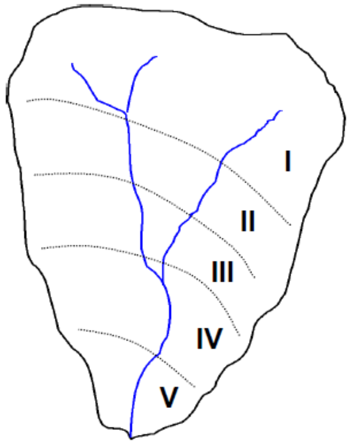

FIGURE 2 -Spatial process - stages of the CEM are distributed in a watershed (Fischenich and Morrow, 2000)

2.4 Stream Improvement Design Approaches

There are a variety of stream improvement design approaches, depending on what is needed to mitigate the impaired condition of the existing channel. In a naturally functioning stream, sediment transport is necessary for the stream’s proper function and health of the aquatic systems it supports. The sediment load and erosion in a stream are balanced between bank stability, sediment available from the watershed, the capacity of the stream to carry the load, and the flow rate (including the associated velocities and shear stresses).

The historical straightening and dredging (deepening) of meandering stream channels in the Papillion Creek and other eastern Nebraska watersheds have reduced the distance that water has to travel from the source (high ground or spring) until it reaches the Missouri River. The reduction in stream length leads to a number of adverse impacts:

- The shorter stream length increases the average slope of the stream, which in turn increases the velocity (and energy) of the flow.
- The incised (deeper) channels restrict the stream's access to its historical floodplain. This in turn decreases the ability of the stream to dissipate the energy of storm flows, resulting in increased erosion on the already unstable and typically under-vegetated banks.
- The straighter channel reduces stream bank diversity for aquatic habitat, and reduces the capacity to assimilate pollutants and storm flows.

Incised or incising channels are typically rehabilitated using one or more of three general approaches:

- Allow the channel to establish a new equilibrium condition on its own (no action) - The endpoint or final channel configuration for this approach is difficult to predict; it entails accepting additional bank and bed erosion, and rehabilitation may require decades to complete.
- Accelerate the process characterized by the CEM and assist the channel in reaching a new equilibrium - This approach is more determinant, and generally consists of developing a stable low-flow channel with adjoining pseudo-floodplains within the existing channel. These provide similar, but diminished functions compared to those of the "natural" floodplains.
- Restore the hydraulic grade of the system to re-establish the hydrologic connection to the historical floodplain – This approach restores at least some of the overbank flooding, but may not be practical if this flooding is intolerable because of adjacent land uses or site constraints.

The first two approaches result in the re-establishment of floodplains, but within the degraded or enlarged channel. These floodplains provide many functions of the historical floodplain (which becomes a terrace), but often at diminished levels because of their smaller relative size. The third approach is an attempt to restore the hydrologic interactions between the stream and floodplain, but often fails to restore the physical or hydraulic conditions within the channel (Fischenich and Morrow 2000).

Implementing any of the above approaches or combinations thereof may involve the use of several techniques, such as modifying the flow or sediment regime, constructing grade control structures, constructing new storage or floodplain area to attenuate high flows, increasing or re-establishing channel sinuosity, and protecting (potentially armoring) stream banks and streambeds. Best results are usually achieved after the factors that initiated the incision have been addressed and the stream has been allowed to adjust toward a new equilibrium and regain some stability. After implementing the second or third approaches, it may be necessary to accelerate the recovery of habitats that were impacted by destabilization of the channel. This may involve the use of structures to create instream habitat such as riffles and pools, planting to re-establish riparian vegetation, modifications to the new floodplain to create functional wetlands within the incised channel, or reconnection of the stream to its original floodplain (Fischenich and Morrow 2000).

3 Evaluating Stream Improvement Techniques

Stream improvement techniques should address the problems identified during the watershed, site, and reach assessments and should be designed and implemented based on site-specific conditions quantified during the stream reach assessment. In addition, each proposed stream improvement technique should minimize undesirable impacts and be assessed based on risk to the existing stream function and site, economic, and/or maintenance constraints. For example, would the proposed stream improvement technique enhance the existing function of the stream reach or could it add to the instability of the channel at higher flows? Would the proposed technique increase the flow’s energy downstream and create the opportunity for downcutting? The risk of implementing each technique should be thoroughly evaluated to ensure that appropriate techniques for that reach are selected. Documents that may be helpful in evaluating proposed streambed techniques to address specific stream reach problems are listed in the References section.

3.1 Overview of Potentially Applicable Stream Improvement Techniques

This section provides an overview of six categories of techniques that may be applicable to stream improvement.

3.1.1 Structural Bank Protection

Structural bank protection is typically used to minimize bank erosion and protect bank alignment. This category of techniques includes the use of rip-rap, toe of bank protection with rocks or logs, and crib walls. Bank stabilization is achieved by armoring, i.e., fortifying the bank composition to withstand the increased bank velocities. Although structural bank protection is effective at reducing bank erosion, it also reduces the stream’s ability to adjust or modify its channel. This rigidity limits the aquatic habitat and water quality functions of the channel and can lead to “sediment starved” flow passing through the stabilized channel, which then may pick up bed and bank materials downstream of the stabilized reach. In addition, rip-rap and toe of bank protection with rocks or logs tend to increase the stream velocity along the bank, which may transfer energy downstream and exacerbate erosion problems in the channel. When evaluating structural bank protection as a stream improvement technique, the results of the watershed and reach assessments must be taken into account. Structural bank protection can be used in concert with bioengineering practices, which are described below.

3.1.2 Bioengineering Bank Protection

Bioengineering techniques include specific techniques used in bank protection, flow retention, flow redirection, and grade control. This section focuses on bank protection with subsequent sections addressing the remaining techniques. Typical bioengineering bank protection techniques include (1) bank reshaping, (2) soil reinforcement with stout biodegradable geotextiles such as coir fabrics protecting soil encapsulated lifts, and (3) plantings trees, shrubs, and herbaceous species. Bioengineering bank stabilization can not only maintain the soil in place, it can support a variety of vegetation that supports wildlife, filters stormwater runoff, and provides shade, all of which improve water quality in the stream.

Bioengineering bank protection usually requires modifications to the channel cross section to provide a floodplain bench and side slopes of 2:1 or shallower for optimum vegetative growth. The effectiveness of this category of techniques may be limited during the first year of plant growth, and is not always applicable in situations with high bank velocities and shear stresses. However, monitoring and basic maintenance (such as making sure geotextiles are in place until there is sufficient vegetative cover and survivorship) can mitigate many issues during this first year. The long-term benefits to habitat and aesthetics are an added bonus to bioengineering bank protection.

3.1.3 Flow Retention

In many urban settings, the stream channels have been impacted significantly by alterations in the alignment, confinement, bed slope, bank slope, vegetative cover, and flow rate. Each of these alterations is impacted by increased impervious area associated with urban development, as well as short-circuiting of drainage paths through the use of pipe networks and/or realigned drainage paths. Stream construction projects are typically initiated to address conditions that threaten damage to infrastructure, loss of property, or hazards to public safety. In most urban cases, stream improvement projects are limited in the restoration approaches that are applicable for bank stabilization and grade control. Typically, the plan form (horizontal alignment) of the stream channel cannot be modified due to site constraints. In addition, the channel cross sectional dimensions may be limited by adjacent property owners or utility infrastructure.

Restoration techniques that reduce the slope of the channel or add roughness to the channel cross section (for example, by modifying a concrete lined channel to a grassed waterway) without compensating for the change elsewhere may increase the peak water surface elevation during runoff events. In most cases, raising the water surface elevation during flooding events (particularly the 100-yr event) is unacceptable due to the potential flooding impacts to private property and Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs). Potential increases in the water surface elevation can be offset by creating storage in tributary areas or providing additional floodplain area along the stream channel. This can be accomplished with off-channel storage ponds or creating wetlands that also act as detention basins. These ponds can also provide water quality benefits through filtering runoff with vegetation and acting as sedimentation basins. This option is viable if sufficient land is available to reduce the impact of flood events.

3.1.4 Flow Redirection

Many stream improvement techniques are available to redirect flow. The main function of these techniques is to direct the flow toward the center of the channel and away from the stream bank. This in turn reduces the velocities near the bank which, when high, can erode the banks. Most of these techniques increase the velocities through a hydraulic jump in the channel center and create some bed scour that must be controlled. Depending on the angle of placement and depositional patterns, the potential for sedimentation along the bank is also created. In naturally functioning streams sedimentation typically occurs on the inside bank of a bend, and scour on the outside bank of the bend creates undercut bank fish and macroinvertebrate habitat. The radius of curvature of the bend and the flow redirection structures must be designed to manage these sedimentation and scour areas. Some flow redirection bioengineering techniques are barbs, log jams, rock drop structures (cross vanes, j-hooks), and porous weirs. Special care should be used when sizing and placing flow redirection techniques in tight radius bends to minimize erosion on the opposite bank or upstream.

3.1.5 Grade Control

Grade control structures are designed to stabilize the stream channel slope while directing flow away from the banks. Their main purpose is to reduce the energy in the system and provide grade stabilization. However, grade control structures may induce sedimentation upstream of the structures. Grade control structures can be integrated with other techniques listed above. Grade control is not an applicable stream improvement technique in aggrading channels.

3.1.6 Flood Control

Flood and stormwater management facilities are also funded by the Urban Drainageway Program. Therefore, this category is incorporated into the Urban Drainageway Program Policy, but is not addressed in this TM at the request of the District.

3.1.7 Habitat Improvement

The foundation for a stream's habitat encompasses channel components such as stream geometry (channel and floodplain) and vegetation and buffer conditions. The benefits of functional habitat along stream corridors are numerous and include, but are not limited to, improved diversity of aquatic life, improved water quality, enhanced erosion control, lower water temperature, increased channel stability, and enhanced flood control through the reconnection to floodplains. The condition of a stream, in terms of its physical habitat, reflects the long-term impacts to the stream channel from a range of watershed factors (hydrologic and hydraulic) and conditions in the channel (such as cross section, meander pattern, and slope). In contrast, other means of determining the condition of a stream such as water quality sampling are not as informative because periodic water quality samples are analyzed at points in time shortly after the samples are collected and thus provide only a "snapshot " compared to physical habitat, which provides a longer-term record of stream conditions.

Habitat can improve through a variety of techniques, including components of the techniques discussed above. For example, a V shaped rock structure called a cross vane can serve as grade control and protect the banks from erosion by redirecting flow to the center of the channel. The riffle-pool sequence created by the cross vane can also enhance the aquatic habitat by creating a deep pool for fish cover and thermal refuge, as well as riffles that aerate the water and provide fish spawning and macroinvertebrate habitat. When a cross vane is coupled with bioengineered bank stabilization, further improve aquatic habitat is possible.

4 Levels of Design

The District is considering adopting a system of three Levels of Design that will be used when evaluating matching funds for applications. The intent of this tiered funding approach is to encourage more holistic approaches to stream stabilization and aquatic habitat enhancement. Matching funds will be distributed according to the three Levels of Design, which consist of the following:

- Level 1 (Restoration) – Restoration of a continuous reach or reaches of the channel through enhancing meanders and stabilizing the bed (possibly elevating incised channels with grade control structures to reconnect to the historical floodplain) and banks, using predominantly bioengineering techniques with some structural techniques if necessary.
- Level 2 (Rehabilitation) – Rehabilitation of a continuous reach or reaches of the channel bed (possibly including grade control structures) and banks along the existing channel alignment, using a combination of bioengineering and structural techniques.
- Level 3 (Stabilization) – Stabilization of a limited, critical area of the channel banks and/or bed that does not have a significant impact on the entire reach with grade control structures along existing channel alignment using bioengineering and/or structural techniques.

Table 1 summarizes the Levels of Design.

TABLE 1
Levels of Design

	Level 1 ***Restoration***	**Level 2** ***Rehabilitation***	**Level 3** ***Stabilization***
Reach Length	Continuous or having a significant impact on the reach	Continuous or having a significant impact on the reach	Repairs in a critical area that does not have a significant impact on the reach
Stream Channel Modification	In a predominately unconfined or historical stream channel	Confined in modified channel pattern	Can be in an unconfined or historical stream or modified/confined channel
Stream Improvement Techniques	Majority are bioengineering techniques, habitat enhancement, flow redirection, and (if possible) flow retention	Bioengineering and/or structural techniques, habitat enhancement, flow redirection, and (if possible) flow retention	Bioengineering and/or structural techniques
Hydraulic Impact	Will restore hydraulic connection to floodplain	May restore hydraulic connection to floodplain	Will not affect hydraulic connection to floodplain

Note: Both Level 1 and Level 2 will accelerate natural stream stabilization processes

4.1 Case Studies

Three stream projects were chosen as case studies to illustrate categorical examples of local projects that would fall into each of the proposed District Levels of Design. The following includes brief descriptions of the projects and their design components. These case studies are not intended to be examples of full watershed, site, or reach assessments as described above.

Level 1 - Cole Creek Restoration

The Cole Creek Project represents 2,700-linear-foot (LF) of stream channel restoration extending from Sorensen Parkway (northern limit) to Hartman Avenue (southern limit). The project was constructed in 2009 and was sponsored by the City of Omaha, the District, Douglas County, Omaha by Design, and the Benson-Ames Alliance, along with other cooperating partners. The purpose of the project was to stabilize degraded and eroding stream banks and bed and implement stormwater best management practices (BMPs) along the stream corridor. See the Cole Creek project website for more information about the project; www.colecreek.org.

Watershed Description

The Cole Creek Project's contributing watershed is near the headwaters of the Cole Creek system, and is located in a mixture of rural (upper end) and urban (lower end) land uses. Cole Creek's headwaters begin north of Sorensen Parkway in the northwest section of Omaha and it flows into Little Papillion Creek near the intersection of Cass and 78th Streets. The project reach is located adjacent to a City park, the football and baseball fields of a local high school, and several private residences. Detailed hydrologic and hydraulic evaluations of flows from the watershed were conducted for this project.

Site and Reach Description

The project reach is bounded on the east by a private high school and a City park, and the west by private residences and the same City park. The site and reach assessments were summarized in the U.S. Army Corps of Engineers (USACE) Section 404 permit mitigation plan (Hayes, 2009). The site investigation included a wetlands delineation, determination of ordinary high water mark, vegetation survey, and soils and hydrologic evaluations. Land use adjacent to the project included recreational/educational, passive recreation, residential, and active recreational.

The study identified the following pre-improvement conditions; an unstable and eroding stream bed, steep and eroding banks, non-native vegetation that did not provide the stabilizing support that the banks needed, and threatened utilities, park facilities, and private facilities. The channel was in CEM Stages 2 and 3 in various parts of the project reach. Cole Creek is a first order stream at the project site, therefore it is a headwater stream.

Stream Design Approach

The project goal was to accelerate the channel evolution process by restoring the stream's physical dimensions to mimic historical (pre-agriculture and development) conditions. Therefore, the stream design approach for Cole Creek was to adjust the cross section dimensions, channel pattern, and longitudinal grade of the channel to re-establish the hydrologic connection to the floodplain. Meanders were constructed in the stream channel, the banks were re-graded, non-native vegetation was removed from banks, and a floodplain bench was created. Native vegetation is preferred because it is well suited to the climatic conditions of the area and will provide bank stabilization through their deep root systems. The floodplain bench allows storm flows to access a wider area stabilized with vegetation to dissipate come of the erosive energy of the flowing water. Several stormwater outfalls were reconstructed and several types of structures were installed (Table 2).

Restoration Techniques and Level of Design

A mixture of structural and bioengineering bank protection, flow retention, flow redirection, and grade control techniques were used on this project (Table 2). The Cole Creek project was a Level 1 (Restoration) project because the channel alignment was modified to include more meander along a continuous reach using primarily bioengineering techniques. Table 2 summarizes the assessment, design approach, and stream improvement techniques that were implemented at Cole Creek.

TABLE 2
Cole Creek Stream Restoration Project Components

Project Component	**Summary of Analysis**
Watershed Assessment	Urban Watershed Channel Form - incised Stream Classification – CEM Stage 2 Hydrologic and hydraulic modeling
Site and Stream Reach Assessments	Factors contributing to the unstable and eroding stream bed and banks – flashy urban hydrology without detention facilities, non-native vegetation, inadequate buffer, confined channel Impacts to reach resulting from contributing factors – channel incision, bank erosion, impaired habitat conditions
Stream Design Approach	Restore entire reach by creating meanders, floodplain benches, grade control, bioretention basins, and stabilizing vegetation to accelerate the stabilization process.
Reach Length	2,700 LF
Stream Improvement Techniques	Structural bank protection: - Stabilized with toe rock Bioengineering bank protection: - Stabilized with native vegetative buffers (filter stormwater) and root wads - Re-graded bank slopes Flow retention: - Created floodplain benches (additional storage area) - Created bioretention basins (infiltrate stormwater) Flow redirection: - Enhanced/created meanders - Installed cross vanes, j-hooks, rock sills - Stabilized stormwater outfalls Grade control: - Created riffle and pool series with cross vanes, j-hooks, riffles rock sills, and low flow crossings

Cole Creek at Sorensen Parkway, Not to Scale (NTS) (April 2010 aerial, courtesy of City of Omaha)

A. Re-graded banks and native vegetation downstream of Sorensen Pkwy

B. Cross vane grade control structure and stormwater outfall

C. Re-graded banks and native vegetation looking toward Sorensen Pkwy

D. Re-graded banks and native vegetation by Sorensen Pkwy

All photos taken spring 2010.

Level 2 - Whitted Creek Rehabilitation

Whitted Creek is in Bellevue, Nebraska and the project site is located southeast of 25th Street and Capehart Road. The 3,500-LF project reach extends from 25th Street downstream to the confluence with Papillion Creek and represents stream channel rehabilitation. The project was constructed in 2009 and was sponsored by the District. The purpose of the project was to stabilize the stream's eroded banks and degraded bed using sustainable bioengineering techniques. For more project information see this website; http://www.papionrd.org/water_quality/urban_water_quality.shtml

Watershed Description

The project reach drains about 2 square miles of urban (predominantly single family residential) watershed area. The watershed was investigated and hydrologic analyses included evaluation of upstream existing detention facilities and their hydraulic impacts on the design channel. Detailed hydrologic and hydraulic modeling of flows from the watershed was conducted for this project. Updates to the 1 percent annual chance floodplain due to the project were incorporated into the ongoing Big Papillion Creek FEMA FIRM remapping project.

Site and Stream Reach Description

The project reach is bounded on the north by a flood control levee and on the south by a hill. A tributary of Whitted Creek flows downstream (east) from 25th Street, is joined with the Whitted Creek mainstem flowing in from the south, and the creek continues to flow east through culverts at Scarborough Drive and under a golf course pedestrian bridge before flowing into Papillion Creek. The site and reach assessments were summarized in a conceptual design report (CH2M HILL, 2008) and the USACE 404 permit application (CH2M HILL, 2009). The site investigation included a wetlands delineation, determination of ordinary high water mark, vegetation survey, and soils and hydrology evaluations.

Due to urban development, historical channelization, and confinement of the stream, the Whitted Creek channel had become severely degraded and incised. This deep incision undermined the bank toe for much of the existing channel, producing steep vertical banks that were eroding, could not sustain vegetative cover, and threatened the integrity of the adjacent flood control levee, private property, and golf cart paths. The channel was in CEM Stages 2 and 3 in various parts of the project reach. Whitted Creek is a first and second order stream at the project site; one segment is a headwater channel that is joined by another headwater segment to form a second order stream for the remainder of the project reach.

Stream Design Approach

The stream design approach for Whitted Creek was to accelerate the channel evolution process characterized by the CEM and assist the channel in reaching a new equilibrium. This was accomplished by stabilizing 3,500 LF of the existing channel bed and banks along the existing alignment, minimizing the potential for future erosion, and improving aquatic habitat conditions in the existing channel. Adjustments to the cross section dimensions and longitudinal grade of the channel were made to stabilize the channel bed and create a hydrologic connection to the floodplain. Several stormwater outfalls were reconstructed and several types of rock structures were installed (Table 3). The existing upstream detention facilities were not modified because, although there was potential for reductions of peak storm flow rates, the facilities were not designated as District flood control structures and could not be relied upon for reducing the 1-percent annual change flow in the creek from a regulatory standpoint.

Restoration Techniques and Level of Design

A mixture of structural and bioengineering bank protection, flow retention, flow redirection, and grade control techniques were used on this project (Table 3). The Whitted Creek project was a Level 2 (Rehabilitation) project because the channel alignment could not be modified to include more curvature due to site constraints imposed by the levee on the north bank and a hill on the south bank. Table 3 summarizes the assessments, design approach, and stream improvement techniques that were implemented at Whitted Creek.

TABLE 3
Whitted Creek Stream Rehabilitation Project Components

Project Component	**Summary of Analysis**
Watershed Assessment	Channel Form – Incised with steep side slopes and increased velocities Stream Classification – CEM Stages 2 & 3 Hydrologic and hydraulic modeling
Site and Stream Reach Assessments	Factors contributing to the unstable and eroding stream bed and banks: flashy urban hydrology; inadequate vegetation and buffer; confined channel; headcutting from Papillion Creek; historical channelization; and confined floodplain Impacts to reach resulting from contributing factors: channel incision; bank erosion; impaired habitat conditions; threatened infrastructure (levee and pedestrian bridge), and private property
Stream Design Approach	Restore entire reach by creating stable bank slopes, floodplain benches, grade control, and stabilizing vegetation to accelerate the stabilization process.
Reach Length	3,500 LF
Stream Improvement Techniques	Structural bank protection: - Stabilized with toe rock Bioengineering bank protection: - Stabilized with native vegetative buffers (filter stormwater) - Re-graded bank slopes Flow retention: - Created floodplain benches (additional storage area) Flow redirection: - Installed cross vanes and rock drop structure - Stabilized stormwater outfalls Grade control: - Created riffle and pool series with cross vanes and rock drop structure

Whitted Creek at 25th Street, NTS (April 2010 aerial, courtesy of Sarpy County)


A. Re-graded banks and native vegetation downstream of 25th St


B. Re-graded banks & native vegetation upstream of Scarborough Dr


C. Series of cross vane grade control structures


D. Re-graded banks and native vegetation upstream of golf cart bridge


E. Re-graded banks, native vegetation, grade control structures


F. Re-graded banks & native vegetation downstream of Scarborough Dr

All photos taken summer 2010.

Level 3 – Settler's Creek at 72nd Street Stabilization

Settler's Creek is in Papillion, Sarpy County, Nebraska and the project consists of an approximately 575-LF reach located along the south side of Centennial Road, upstream of 72nd Street extending to the west (upstream) to Shady Tree Lane. The project was sponsored by the City of Papillion. The Settler's Creek Channel Stabilization project is planned for construction in late 2010.

Watershed Description

The project reach drains less than 1.5 square miles of watershed area. The watershed is urban, and the channel form is incised with steep side slopes and increased velocities. The stream classification was CEM Stages 2 & 3.

Site and Stream Reach Description

Settler's Creek has experienced moderate to severe stream bank erosion and degradation in several locations. Progressive bank failure had the potential to impact the embankment on the south side of Centennial Road and the culvert structure at 72nd Street. The channel has been experiencing general bank and bed scour, and a tributary flowing from a pipe outfall at the southeast end of the reach has been experiencing severe scour. The lack of vegetative cover and the presence of high velocities, bank erosion, and undercutting are factors contributing to the instability of the stream reach. The site is constrained by an overhead power easement on the south and Centennial Road on the north.

Stream Design Approach

The stream design approach for Settler's Creek includes re-grading about 420 LF of the banks (one side or the other) and stabilizing with an erosion control blanket or turf reinforcement mat, installing rip-rap in some locations, and installing a ScourStop™ bed erosion control system at the end of the tributary pipe's flared end section. Stabilization work was not implemented for the entire reach; rather, it was limited to areas where scour problems were the most severe.

Restoration Techniques and Level of Design

A mixture of cross section re-shaping, geotextiles, and rip-rap were proposed for structural and bioengineering bank protection, and sheet pile was incorporated for grade control. The Settler's Creek Stabilization Shady Tree Lane to 72nd Street project was a Level 3 (Stabilization) project. Table 4 summarizes the assessment, design approach, and stream improvement techniques for Settler's Creek.

TABLE 4
Settler's Creek Stream Stabilization Project Components

Project Component	**Summary of Analysis**
Watershed Assessment	Watershed characteristics - mixed use urban Channel Form – Incised with steep side slopes Stream Classification – CEM Stages 2 & 3
Site and Stream Reach Assessment	Factors contributing to the unstable and eroding stream bed and banks – flashy urban hydrology without detention facilities, inadequate vegetation and buffer, confined channel, headcutting, confined floodplain, and high velocities Impacts to reach resulting from contributing factors – channel incision, bank erosion, impaired habitat conditions, and threatened infrastructure (bridges)
Stream Design Approach	Stabilize the existing channel by re-grading and armoring the bank in limited areas where probability and consequences of failure are highest.
Reach Length	420 LF (one side or other) of 575-LF reach
Stream Improvement Techniques	Structural bank protection: - Stabilize with rip-rap Bioengineering bank protection: - Stabilize with erosion control blanket or turf reinforcing mat - Re-grade bank slopes Flow redirection: - Stabilize stormwater outfall with ScourStop^{TM} Grade control: - Sheet pile

Settler's Creek at 72nd Street, NTS (April 2010 aerial, courtesy of Sarpy County)

A. Looking upstream from 72nd Street (July 2010)

B. Looking downstream toward 72nd Street (July 2010)

C. Looking upstream from 72nd Street (mid channel) (July 2010)

D. Looking upstream from 72nd Street (July 2010)

E. Looking upstream from 72nd Street (July 2010)

F. Looking upstream from 72nd Street (July 2010)

4.2 Case Study Cost Evaluation

Construction costs were compiled and evaluated for each case study project. Level 3 costs were estimated for Whitted Creek and Cole Creek by replacing some of the bioengineering techniques with structural techniques and reducing the extents and densities of the vegetation plantings. If Cole Creek were stabilized using structural engineering techniques typical of a Level 3 project, it was assumed that:

- Half of the rock vanes and all of the j-hook vanes would be replaced with rip-rap.
- Half of the rock riffles and all of the root wads would be removed.
- Rip-rap for back stabilization would be increased by 400 percent.
- Live fascines, brush layers, and live stake plantings would be removed.

If Whitted Creek were stabilized using structural engineering techniques typical of a Level 3 project, it was assumed that:

- The use of soil rip-rap (mixture of soil and rock) would increase.
- The 15 small rock structures would be replaced by 3 large drop structures.
- Stabilization riffles would be decreased from 12 to 3.
- The amount of coir erosion control blanket would be increased by 50 percent and permanent plantings would be decreased by 66 percent.

Level 1 construction costs for Settler’s Creek were estimated assuming that:

- The entire 575-LF reach would be stabilized with bank reshaping, geotextiles, and permanent native plantings (grasses, trees, and shrubs).
- Three cross vanes would be installed for flow redirection.
- Stream improvement techniques associated with a design similar to the Cole Creek design would be used.

For the Cole Creek and Whitted Creek projects, the savings in construction cost to reduce the Level of Design from Level 1 or Level 2 to Level 3 was less than 10 percent (Table 5). Elevating the Settler’s Creek project from a Level 3 to a Level 2 project increased the construction cost by more than triple. In general, costs associated with vegetation and geotextiles increase as the Level of Design approaches 1 or 2. Costs associated with structural and earthwork vary between each project and the Level of Design because the reduction in stabilization structures is usually offset by additional earthwork requirements.

TABLE 5
Case Study Construction Cost Evaluation [a]

	Cole Creek	Whitted Creek	Settler's Creek
Level 1 - Construction Cost	$1,168,684 (actual)		
Level 2 - Construction Cost		$1,488,610 (actual)	$91,066 (est.)
Level 3 - Construction Cost	$1,070,372 (est.)	$1,367,655 (est.)	$23,037 (bid)
Percent of Construction Cost Increase from Level 3 to Level 1 or 2 Stream Design	9.2%	8.8%	295%

[a] Easement costs are not included.

In addition to construction costs, design costs were considered; Level 1 and 2 projects typically require a design cost that is about 20-30 percent of construction cost. Design costs are assumed to include survey, conceptual design, hydrologic and hydraulic analysis, detailed design, permitting, and services during bidding and construction management (half time). For the purposes of this TM, it was assumed that Level 3 projects typically require a design cost that is 10 percent of the construction cost. Table 6 is a summary of the design costs associated with each Level of Design. The Whitted Creek and Cole Creek project design costs include conceptual and detailed design, site survey, permitting, and construction observation. Easement costs are not included.

TABLE 6
Case Study Design[a] Cost Evaluation

	Cole Creek	Whitted Creek	Settler's Creek[b]
Level 1 - Design Cost	$403,116 [c] (actual)		
Level 2 - Design Cost		$318,560 [d] (actual)	$18,213 (est.)
Level 3 - Design Cost	$107,037 (est.)	$136,765 (est.)	$2,304 (est.)
Design Cost as a percent of construction cost	Level 1: 34.5%	Level 2: 21.4%	Level 3: 10%

[a] Design costs for Cole Creek and Whitted Creek projects include survey, conceptual design, hydrologic and hydraulic analysis, detailed design, permitting, and services during bidding and construction (half time).
[b] The design cost percent of construction cost was assumed for Settler's Creek.
[c] The Cole Creek project required a USACE 404 Individual permit.
[d] The Whitted Creek project required a USACE 404 Nationwide 27 permit.

The additional design cost required when upgrading a stream project from a Level 3 to a Level 1 or 2 are generally associated with the additional engineering study work necessary during the detailed design phase (i.e., additional hydrologic and hydraulic analysis associated with changes to channel geometry and alignment) and the need for additional construction observation services for contractors that are inexperienced with this type of work.

4.2.1 Level of Design Cost-Share Recommendations

Cost estimates for Level 3 were obtained from Settler's Creek bid tabulations and were estimated for Cole Creek and Whitted Creek to determine the total costs to the Owner assuming the current 60 percent District match. A construction cost was then developed (either from bid tabs or estimates) for a higher Level of Design to estimate how much the District's cost-share match would have to increase to cover the additional expense to the Owner associated with the higher Level of Design. Based on the results shown in Table 7, an increase of 20 to almost 35 percent to the current 60 percent District match would offset the increased construction and design costs to the Owner for implementing a Level of Design 1 or 2 instead of a Level 3 for the Cole Creek and Whitted Creek projects. The percent increase for the Settler's Creek project is significantly higher.

TABLE 7
Case Study Total Cost-Share Evaluation

	Cole Creek	Whitted Creek	Settler's Creek
Level 1 – Total Cost	$1,571,800 (actual)		
Level 2 – Total Cost		$1,807,170 (actual)	$109,280 (est.)
Level 3 – Total Cost	$1,177,409 (est.)	$1,504,420 (est.)	$25,340 (est.)
Total Cost to Owner: 40% of Levels 1 or 2 (60% match by District)	$628,720	$722,868	$43,712
Total Cost to Owner: 40% of Level 3 Cost (60% match by District)	$470,964	$601,768	$10,136
Total Cost to Owner Increase from Level 3 to Levels 1 or 2	$157,756	$121,100	$33,576
Cost to Owner Increase as % of Total Cost to Owner Level 3 to Level 1 or 2	33.5%	20.1%	331%
Cost to Owner Increase as % of Total Cost (Overall Project)	13.4%	8.0%	132.5%

To encourage more environmentally sustainable approaches to stream channel stabilization projects participating in the Urban Drainageway Program, the District will implement a 75 percent match for Level 1 (15 percent increase) and a 60 percent match for Level 2 projects to help offset the additional cost to the Owners for the enhanced Level of Design. Stabilization projects will receive a 40 percent match. Projects with the enhanced Level of Design may provide opportunities for eligibility for additional grant funding from other sources.

In order to be eligible for a Level 1 or Level 2 project, the applicants must apply for Nebraska Environmental Trust grant and Environmental Protection Agency Non-point Source (Section 319) grant funding. The District will reimburse the project sponsor for the local costs, excluding state and federal funding. Although it is not required, Urban Drainageway Program grant applications will be considered more favorably if the project is part of a watershed master plan.

5 Project Review Flow Chart

The District will use the flow chart in Figure 4 to review grant application submittals and determine which Level of Design is applicable. Specific requirements of the submittal are included in the District's Urban Drainageway Program Policy and the recommended components of the design are described in the previous sections. District staff will review grant applications considering the topics discussed in this TM.

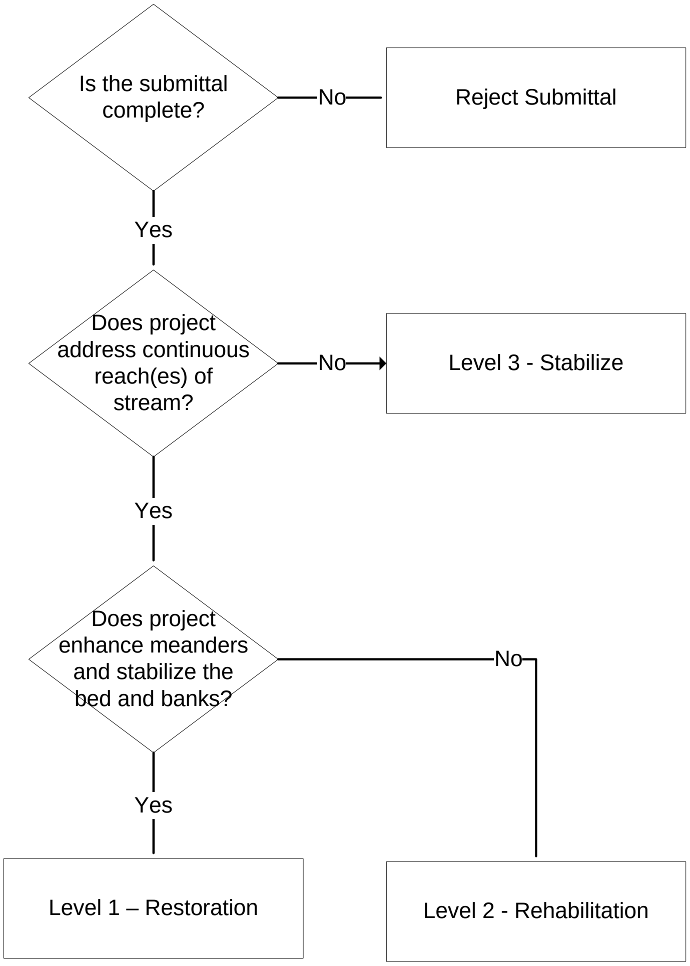

FIGURE 3 –Project Review Flow Chart

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