WEST CEMETERY CREEK SEDIMENT MANAGEMENT ALTERNATIVES FEASIBILITY STUDY

Prepared for City of Bellingham Public Works Department
December 10, 2013

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Executive Summary

The West Cemetery Creek watershed is located in Whatcom County, partly within the Bellingham city limits. The watershed drains a portion of the western and northern slopes of Lookout Mountain (known locally as Galbraith Mountain) and flows into Whatcom Creek a short distance after its confluence with Cemetery Creek. West Cemetery Creek has become a maintenance concern for the City of Bellingham at the pedestrian bridge connecting Toledo Court to Wildflower Way. Recent high water events have caused an increase in sedimentation at the bridge. Sediment deposition observed in the recently completed restoration project site located at the confluence of West Cemetery Creek and Cemetery Creek is also of concern. The City of Bellingham is considering management alternatives to reduce flooding and sediment issues and increase project life-span for the bridge, existing levee, and habitat projects. Some sediment and flooding management alternatives are anticipated to have a negative impact on fish habitat and could create unintended upstream and downstream consequences. It is the goal of the City to consider management strategies that avoid or mitigate the potential impacts to habitat.

The evaluation of the watershed conditions revealed that West Cemetery Creek is a dynamic system. Sediment transport and deposition characteristics and rates are extremely variable and event driven. Sediment erosion, transport, and deposition will be an ongoing maintenance and management issue so long as urban development exists in the watershed. Development has altered the morphology of West Cemetery Creek resulting in the lower watershed experiencing increased sediment deposition which is currently driving the management issues. Several site-specific infrastructure maintenance issues were identified in the upper watershed that contribute to point-source sediment inputs, exacerbating the deposition issues downstream.

The analysis of management alternatives integrated several objectives providing multiple benefits to stakeholders. The recommended management strategy consists of a suite of selected project alternatives that were identified as most effective and feasible. This suite of alternatives consists of upper watershed infrastructure and drainage management, eventual bridge replacement, sewer system upgrades, and instream sediment management focusing on erosion reduction and sediment retention. Habitat mitigation strategies can be developed within this project suite. Project development and design costs will be realized once all the opportunities and constraints with respect to private property ownership and environmental permitting are revealed.

In addition to pursuing the active sediment management strategies identified above, strategies that emphasize resiliency and adapting to future conditions are recommended for long-term management consideration. These strategies integrate the existing regulation of land use to avoid or mitigate build-out impacts, but may also eventually include abandoning damaged infrastructure and buy-out of impacted development. Providing technical assistance to help residents who experience flood damage, encouraging conservative upper watershed land use, and consideration of the hazards, risks and watershed impacts of future development is critical for long term decision making. Through the implementation of any management strategy for a dynamic system, adaptations may be needed as changes to the system or the regulatory environment, occur. Therefore, a monitoring program and periodic review of management practices should be included in the management strategy.

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1 INTRODUCTION

The West Cemetery Creek watershed is located in Bellingham, Washington east of Interstate 5 and west of Lake Whatcom (Figure 1-1). Sediment deposition is occurring within West Cemetery Creek in the vicinity of the trail and pedestrian bridge that connects Toledo Court to Wildflower Way and at a recently completed salmon habitat project (Figure 1-2). The sediment deposition is negatively impacting the public trail infrastructure and salmon habitat, and increases the risk to private developments, roads and other infrastructure. The area of sediment deposition is referenced in this study as the "impact area". To assess the sediment deposition and associated impacts, we conducted a watershed-scale desktop evaluation and performed a detailed study and field investigation in the lower and middle portions of the West Cemetery Creek watershed.

1.1 STUDY OBJECTIVES

The objectives of this study are to:

- Gain a comprehensive understanding of management issues from a watershed perspective (fish habitat conditions, land use, stream morphology, flooding, slope stability, sediment transport, public safety, infrastructure management);
- Identify and perform an analysis of management alternatives;
- Identify the most viable and sustainable management alternative to address the problems of West Cemetery Creek at the Toledo Court pedestrian bridge.

1.2 WORK PROGRAM

The work program for this study is summarized in Table 1.

Table 1: Work Program

Task	Description
1. Project Initiation	▪ Obtain existing GIS data and reports, including LiDAR and digital orthophotos, maps and assessments of the watershed basins, existing studies, and land use information
2. Sediment Budget	▪ Identify and map sources of sediment contribution ▪ Estimate sediment stored in the channel, bars and floodplain ▪ GIS mapping of sediment sources and deposition areas
3. Habitat Assessment	▪ Conduct field assessment of the stream for existing fish and wildlife habitat conditions in the "impact area" ▪ Document field findings
4. Alternatives Identification	▪ Inventory a range of alternatives to address the sediment management for the watershed including: o managing point sources o managing instream storage o allowing for natural storage o infrastructure modifications
5. Alternatives Analysis	▪ Estimate approximate planning-level costs for both near-term and long-term

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6. Plan Documentation	▪ Document geomorphic and habitat assessments. ▪ Document alternatives analysis ▪ Develop a plan that incorporates our findings and recommendations for both short and long-term time frames
7. Plan Presentation	▪ Present the West Cemetery Creek Alternatives Feasibility Study to the City upon completion of the project

1.3 PROJECT TEAM

The project team consisted of technical staff from Element Solutions that included a geomorphologist (Paul Pittman), a watershed analyst (Jeff Ninnemann), and a fisheries biologist (Ryan Vasak). The team reviewed existing information, conducted field verification and assessment of data, developed alternatives, and assessed the feasibility of sediment and habitat management alternatives and implementation strategies.

The Element team gratefully acknowledges the assistance of Renee LaCroix for providing project information necessary to complete this analysis.

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1.4 SECTION 1 FIGURES

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Figure 1-1: Vicinity Map

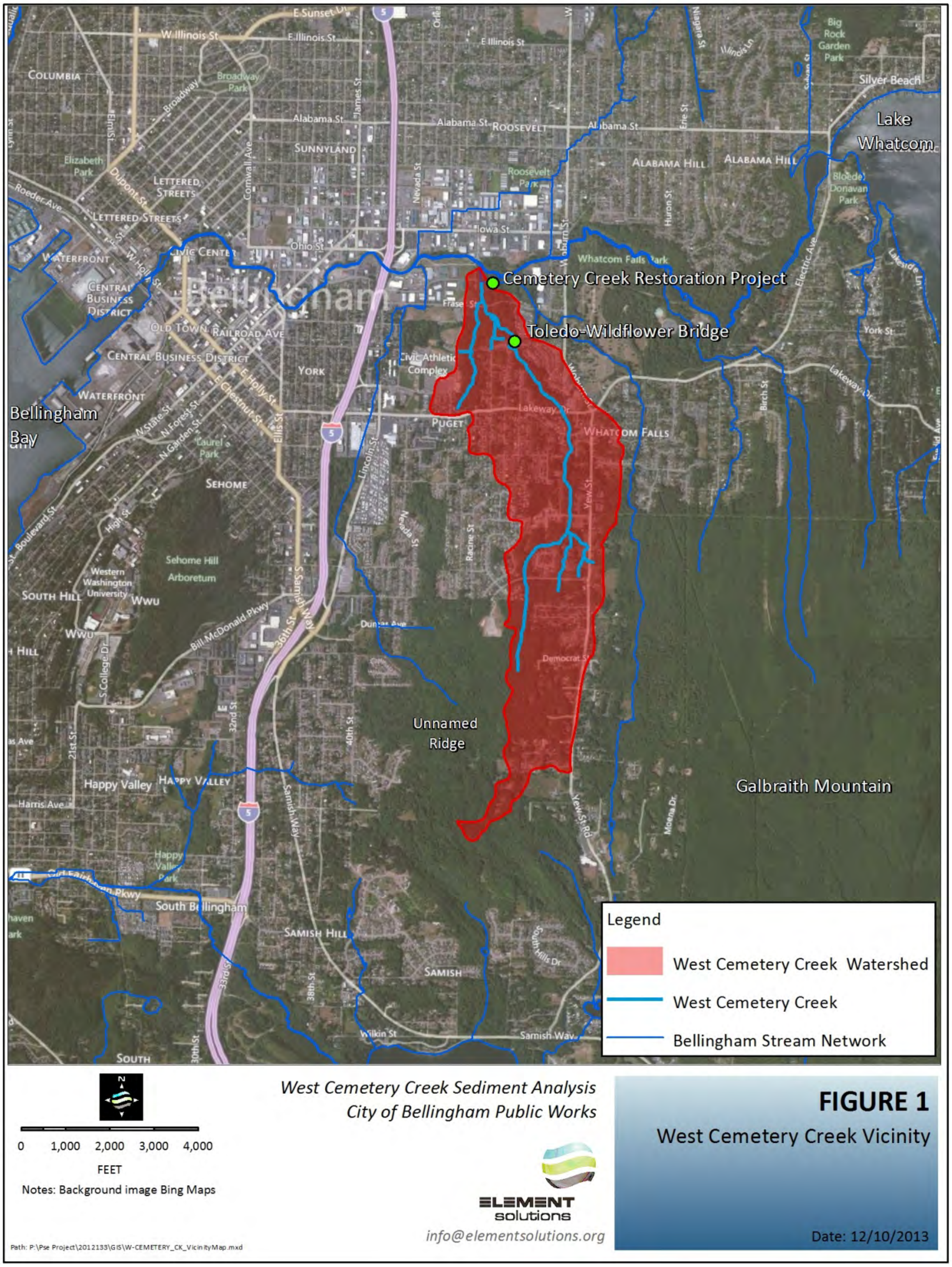

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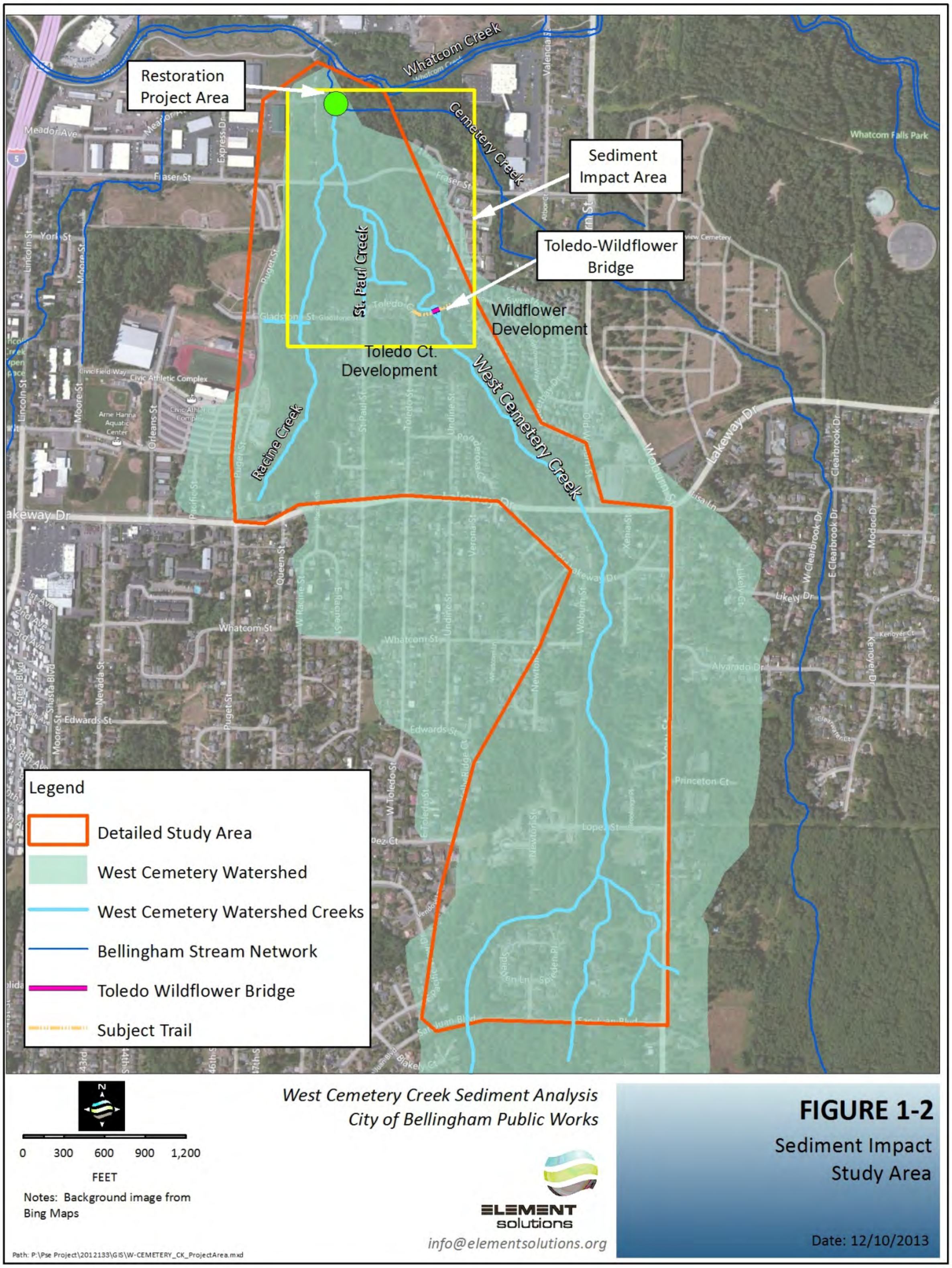
Figure 1-2: Project Area



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2 WEST CEMETERY CREEK WATERSHED ANALYSIS

This section provides a description of the West Cemetery Creek watershed from desktop and field observations, and a summary of relevant background reports and research.

2.1 WATERSHED DESKTOP ANALYSIS

The hydrology, geology and geomorphic investigation and interpretation of the West Cemetery Creek watershed integrated existing research, desktop analysis using existing data, and direct field observations performed by a geologist and fisheries biologist. The following were the data sets used in the GIS desktop analyses (Table 2).

Table 2: Data used for desktop analyses

Data	Format	Date	Source
Aerial photography	SID	1956, 2010, 2011	USDA - NAIP, Whatcom County, Google Earth, Bing
LiDAR	Bare earth grid	2006	USGS
Geology	Shapefile	1998-2000	DNR 1:100,000 Digital Geology
Soils	Shapefile	2009	USDA
Infrastructure Mapping	Shapefile	Unknown	City of Bellingham
Environmental Mapping	Shapefile	2013	City of Bellingham
USGS StreamStats	On-line Map	2013	http://streamstats.usgs.gov/Washington.html

2.1.1 Watershed Physiography

The West Cemetery Creek watershed is located on the western and northern slopes of Lookout Mountain (known locally as Galbraith Mountain) and drains the north and eastern slopes of an unnamed ridge (Figure 2-1). The watershed consists of multiple intermittent, ephemeral, and perennial streams, as well as urban stormwater runoff outfalls. The watershed includes the urbanized areas of portions of Puget, Yew Street, Whatcom Falls, and Magnolia Hills neighborhoods within Bellingham City Limits. Today, major public infrastructure in the watershed includes Lakeway Drive, Fraser Street, underground utilities, and the parks greenway trail and bridge.

2.1.2 Watershed Land Use

Clearing of the land within the watershed began in the late 1800s and early 1900's with the harvesting of trees and the creation of rural residences and infrastructure within the watershed. A second harvesting of timber from portions of the watershed appears to have been done prior to 1950's air photo. The expansion of urban development has slowly expanded into the watershed starting in the 1940's and 1950's. Lakeway Drive realignment was built by 1975, and by 1988 urban development had expanded to include much of the watershed and developed neighborhoods that we see today (Figure 2-2). The area around Toledo Court and Wildflower Way was developed between 1994 and 1996 and the public trail and footbridge was installed during this period (Whatcom County Assessors Records).

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The changes to land use have impacted the hydrology, sediment delivery and stability of the basin. In addition, the development and urbanization of the watershed has created the need to manage the stormwater runoff for flooding or erosion impacts to road networks and private property. Several stormwater outfalls and drainages were observed during our field analyses, and are documented in the City's stormwater overlay map.

Future development and land use activities within the watershed are regulated by the City of Bellingham or Whatcom County land disturbance/development permits. Additional regulations pertaining to the Critical Areas Ordinance, Shorelines Master Program, the National Flood Insurance Program (NFIP) as well as local regulations may apply. Most development potential occurring in the West Cemetery Creek watershed is limited to single-family residences and light industrial build-out. Urban land use potential dominates most of the middle watershed which is mostly built out; however, undeveloped forest land in the upper watershed, and undeveloped wetland complexes in the lower watershed exist.

2.1.3 Existing Reports

One existing report was identified for the vicinity of West Cemetery Creek and is summarized below.

Whatcom Creek Restoration Project Report (City of Bellingham, 2009)

The City of Bellingham conducted creek restoration monitoring analyses in the lower Cemetery Creek in order to evaluate the changes that were occurring in several constructed ponds and enhanced wetlands. The report primarily reviewed the bathymetry of the ponds and showed that the volume of the ponds was fluctuating, but may indicate that the pond nearest the mouth of West Cemetery Creek was filling in with sediment the fastest.

2.1.4 Watershed Description

The historic topographic drainage area of West Cemetery Creek as interpreted from LiDAR is approximately 0.88 square miles with a minimum elevation of 55 feet at Whatcom Creek and a maximum elevation of 850 feet (NAVD 88). The elevation of the Toledo-Wildflower pedestrian bridge is approximately 95 feet (NAVD 88). The historic drainage area has been modified by urban development with some runoff areas being shifted out of the watershed, and others added (Figure 2-3). The current stormwater-influenced drainage basin is approximately 0.92 square miles, approximately 0.036 square miles greater than the historic watershed area. The mean basin elevation is approximately 411 feet as calculated from the LiDAR topography (NAVD 88). The basin topography is generally moderately sloped, with 95% of the watershed area having slopes less than 15%, and approximately 50% of the watershed having slopes less than 7%.

2.1.5 Hydrology

The drainage area of West Cemetery Creek is approximately 0.88 square miles with a relief of approximately 795 feet. The mean average precipitation within the basin is approximately 40.4 inches (USGS 2013, Sumioka et al, 1998). High rainfall in Bellingham generally occurs during the fall and winter when Pacific cyclones cause prolonged, orographically enhanced precipitation.

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These storms can last for several days and are often the cause of flooding in the Pacific Northwest. Flooding can be worsened by rapid rises in freezing level associated with warm marine weather fronts from the central Pacific. The resulting rise in freezing level can rapidly melt lower elevation snow and with the addition of rain (rain-on-snow event), can cause extreme flooding events. The low elevation of this watershed reduces the influence of rain-on snow events, but does not exclude them.

A 2-year return period discharge for West Cemetery Creek (bankfull) is approximately 19.1 cubic feet per second (cfs)(USGS 2013). These events are significant for channel forming processes and sediment transport. A 100-year return period peak discharge is approximately 55.6 cfs for clear-water type floods (USGS 2013). These larger events are important for landscape forming processes. No gauging station exists for West Cemetery Creek or nearby basins; therefore, peak discharges were estimated using published regional regression equations However, the standard error for urban streams using this method is high (Sumioka et al, 1998) and are presented in Table 3. These estimated discharges do not take into account rain-on-snow events or other processes, such as debris flows or dam outburst type flooding, which can greatly increase instantaneous peak discharges beyond the estimated clear-water type floods (Jakob, 1996).

Table 3: Estimated Peak Discharges for West Cemetery Creek

Return Interval	Discharge (cfs)	Standard Error (%)
2-year	19.1	56
10-year	34.2	53
25-year	42.3	53
50-year	49.6	53
100-year	55.6	54
500-year	72.8	--

The West Cemetery Creek watershed is composed of approximately 40% of developed urban area, 10% of developed rural area, and <50% of undeveloped second growth forests (estimated by USGS 2013 & 2010 Aerial). The watershed is heavily influenced by stormwater runoff from streets, houses, parking lots and other impervious surfaces. Stormwater runoff has been shown to drastically affect the stream hydrograph in a number of ways including but not limited to: increased peak flows, quicker storm runoff response, reduced recharge and low flows, and increase siltation and pollutions. A conceptual sketch of pre-disturbance versus urbanization hydrology is shown Figure 2-4.

West Cemetery Creek is expected to exhibit many of the same hydrographic characteristics and geomorphic responses observed in other urban streams. The undeveloped areas in the upper watershed and the large relatively intact riparian zone around the stream help to buffer some of the urban influence on the hydrograph and geomorphic response; however, as build-out continues into the future, these buffer effects will be reduced.

It is our understanding that the residences adjacent to West Cemetery Creek and the Toledo-Wildflower pedestrian bridge have not reported any property flooding issues to the City of

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Bellingham to date. However, we are aware that the City has responded to reports of the trail flooding. Given that the aggradation observed in the impact reach has reduced the effective capacity of the levees by elevating the stream bed and floodplain, and that aggradation is anticipated into the future, the probability that flooding will overtop the levees increases over time.

2.1.6 Geology

Regional Geologic Setting

The primary geologic processes that created and shaped the 36 million year old Cascade Mountains and Bellingham foothills are tectonic (accreted and uplifted terranes) and glacial (erosion and deposition) (Tabor, et al, 2003; Dragovich et. al., 2000; Lapen, 2000). The most recent and prevailing influence on the geomorphology of the Bellingham foothills was the Pleistocene glaciations. Continental glaciers have occupied the Bellingham area at least four times over the past 1.6 million to 10,000 years. These glacial stades and interglacial periods have greatly altered the landscape by eroding bedrock, and depositing large amounts of sediments. The most recent glaciation was the Fraser Glaciation which occurred in the late Pleistocene and transitioned into the Holocene (approximately 21,000 to 10,000 years before present). Glacial deposits from the Fraser Glaciation and previous stades now mantle portions of the Bellingham foothills and locally create thick layers of sediment.

Geology of West Cemetery Creek Watershed

The geology of West Cemetery Creek watershed is underlain by bedrock mapped as the Padden Member of the Chuckanut Formation (Eocene; sandstone, conglomerate, and mudstone) (Lapen 2000) (Figure 2-5). The bedrock has been eroded by glacial advances and is mantled with undifferentiated glacial deposits from the Frasier Glaciation, which have been interpreted by Lapen (2000) as glacial till, advance outwash, marine drift, and terrestrial to glacial marine outwash. These glacial deposits have since been incised through downward cutting by West Cemetery Creek through the basin and in nearby watersheds. Holocene (post-glacial) developments of the West Cemetery Creek include down cutting into the glacial and bedrock geologies in the upper and middle watershed, and deposition and floodplain growth in the lower watershed.

2.2 GEOMORPHIC AND SEDIMENT ASSESSMENTS

Study Reaches

For the purposes of this study, the watershed was subdivided into three watershed reaches based on geomorphic characteristics; the Upper Watershed Reach, Middle Watershed Reach, and the Lower Watershed Reach (Figure 2-6). A watershed-scale desktop assessment was conducted for the whole watershed area and detailed field assessments were conducted for the Middle and Lower Watershed Reaches. Channel slopes were measured from LiDAR and confirmed in the field and are shown in Figure 2-7.

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2.2.1 Geomorphology - Upper and Middle Watershed Reaches

The Upper and Middle Watershed Reaches of West Cemetery Creek include the upper headwaters, development of a single thread stream near San Juan Boulevard and the incised Lakeway Drive gorge area down to approximately 1,000 feet above the Toledo-Wildflower Bridge (Figure 2-8). The upper and middle reaches are differentiated primarily by channel gradient, but also by geomorphology. In addition, the forest cover in the upper watershed is more intact than in the lower watershed and the degree of urbanization is less intense.

Upper Watershed Reach

The upper watershed headwaters coalesce into West Cemetery Creek just upstream of San Juan Boulevard. A geomorphic and stream profile break occur at San Juan Boulevard and the headwater streams transition into a single thread, incised stream cut into the relict glacial landforms and underlain by bedrock of the Chuckanut Formation. The single thread channel generally has a moderate stream gradient of approximately 8% characterized by cascades, riffles and pool morphologies; however, a short reach of the stream system flows across a low gradient 4% topographic feature. This low gradient break in watershed slope may represent a relict glacial landform or geological structure providing grade control. The low gradient sub-reach is shallow enough to encourage sediment deposition and decrease transport potential such that there is a net storage of bedload sediment from the upper watershed in this short reach and a floodplain with over-bank deposits has formed. The Upper Watershed Reach transitions into the Middle Watershed Reach at the downstream end of the low gradient break downstream of San Juan Boulevard.

Middle Watershed Reach

A relatively steep channel gradient (10%), incised channel morphology, increased sediment supply and minimal instream sediment storage generally characterize the Middle Watershed Reach. The geomorphology of the stream channel consists primarily of a straight channel flanked by a moderate to steep walled gorge that is incised into the glacial geologies (Photo 1). Evidence of ongoing incision was observed. The stream-side slopes demonstrated sediment recruitment by slope failures, slumping, and tree-throw process. A narrow alluvial plain with little to no floodplain storage in the upper reach gradually increases in width and some narrow floodplain terraces have developed in the lower portions of the reach. The reach is characterized by cascades, riffle, pool, and logjam-step channel morphology. The Middle Watershed Reach is more urbanized than the Upper Watershed Reach and has increased deforestation, impervious land cover, and modified hydrology influenced by stormwater management infrastructure.

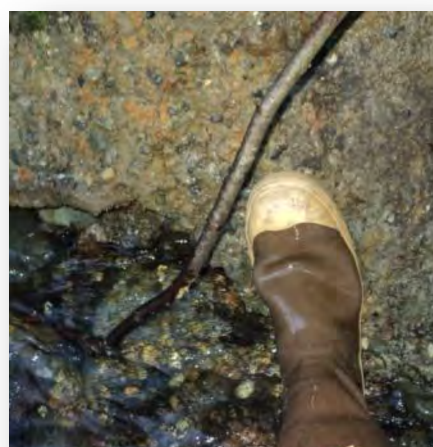

Photo 1: Eroding glacial sediment (till) in base of channel.

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The Middle Watershed Reach is predominately an erosional and transport reach with very little sediment storage available. The Chuckanut Formation is exposed in a few places within the streambed at the base of the gorge and occasionally on the channel banks. The stream has incised into the mantle of glacial deposits ranging between approximately 1 to 40 feet thick overlays the bedrock and this mantle is the primary component of the gorge side walls and locally provides channel bedform and grade control. The glacial soils contribute to a wide range of sediment sizes that are recruited by the stream, but the predominant sediment size fraction is fine grained silt and sand.

2.2.2 Geomorphology - Lower Watershed Reach

Within the Lower Watershed Reach of West Cemetery Creek is the "impact area" that includes the Toledo-Wildflower pedestrian bridge and restoration project at the confluence with Cemetery Creek which are the focus of this study (Figure 2-9). The Lower Watershed Reach begins at the break in slope and widening of the alluvial plain located approximately 1,000 feet upstream of the Toledo-Wildflower pedestrian bridge (Photo 2). The reach is dominated by low stream gradients of 4% decreasing to 1%. The alluvial plain morphology is interpreted as a quasi-alluvial fan in the vicinity of the Toledo-Wildflower pedestrian bridge that transitions into a broad floodplain wetland complex near the confluences with the Cemetery Creek and Whatcom Creek alluvial plains. The floodplain in the reach appears to be inundated during larger storm events based on recent sediment deposition observed in the field. The alluvial fan may be impacted by episodic debris flows, but these are likely very infrequent and likely not a major driver in sediment transport and stream morphology. While we did not find direct evidence that debris flows have occurred in this watershed, the possibility exists that a landslide could initiate a debris flow, or an upstream culvert could become plugged and cause a road wash out that could lead to a debris flow or dam outburst flood.

Photo 2: Alluvial plan development in the transition between middle and lower watershed.

The Lower Watershed Reach floodplain currently is part of a larger floodplain and wetland complex that merges with Cemetery Creek and Whatcom Creek floodplain. Pre-development, the floodplain complex was likely a broad, interconnected wetland complex influenced by the combined hydrology of West Cemetery Creek, Racine Creek, Cemetery Creek, Whatcom Creek, Lincoln Creek, and Fever Creek and the hydrology and sediment transport and deposition were likely modified by beaver activity. The hydrology in the modern floodplain wetland complex has been altered by a road (Fraser Street), historic channelizing, and modified by a change beaver activity.

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Site-Specific Geomorphic Conditions at the Toledo-Wildflower Bridge

The Toledo-Wildflower Bridge is located at a gradient and confinement break where an alluvial fan would be anticipated; however, the alluvial fan morphology is not prominent, perhaps due to the topographic and floodplain alteration resulting from development and West Cemetery Creek alignment modification. Currently, an anastomosing channel form with multiple side channels that interact with Racine Creek and St. Paul Creek exist and West Cemetery Creek returns to a single thread channel at Fraser Street, remaining so until its confluence with Cemetery Creek at the restoration project. The stream consists of pools, riffles, glides, runs, and side channels morphology throughout the bridge sub-reach reach. The bridge sub-reach is presently confined by both a natural bank on the right bank (east of the creek) and an armored levee on the left bank. The creation of this levee has isolated a large portion of the alluvial plain area suspected to be the historic channel and alluvial fan; therefore, deposition of sediment occurs only within the confined area reduced in size from its historic size. The levee protects up to 8 single family residences (depending on flow) located on Toledo Court and Wildflower Way. In addition, there is a sewer main manhole on the eastern bank that is susceptible to flooding (Photo 3). The levee is approximately 2 feet above the floodplain and 2 to 3 feet above the stream bed. Overtopping of the levee during large storm events appears to be a possibility and the Toledo Street homes are topographically lower than the stream bed and may be located in or near the historic stream alignment. The capacity of the channel and levees has been reduced such that we estimated that a 2 to 10-year event could cause flooding of the bridge, sewers, and adjacent properties. The possibility of levee overtopping and flooding can be expected to increase with time.

Photo 3. East end of bridge and sewer man hole within frequent flooding area.

There are currently two primary channels flowing under the bridge. The western channel is incised approximately 1.5 feet into the alluvial deposits and appears to carry the dominant flows. Currently the channel runs close to the western extent of the bridge and along the armored levee (Photos 4 and 5). The western channel appears to be incised into either fill or the native glacial till that is the underlying geology. The eastern channel appears to be aggrading and

Photo 4. Toledo-Wildflower Bridge confluence of west and east channels downstream of bridge

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has a finer-grained substrate than the western channel (Photo 6).

Photo 5. West channel armored levee and gravel bedload.

Photo 6. Eastern channel fine-grained bedload.

It is anticipated that the stream in the bridge sub-reach was relocated and modified during the construction of the Pinewood Hills and Toledo Court housing development in 1994 and 1995. In 1996 the Magnolia Hills housing development was constructed east of the bridge and included the installation of Wildflower Way, residences, and utilities. Additional changes to the reach during the construction of the housing development likely included installation of stream weirs (Photo 7) and a 3 foot high armored levees on the western bank.

Photo 7. Constructed weirs

2.2.3 Sediment Analysis

The stream sediment of interest in this analysis is bedload sediment that is deposited in the study reach of the alluvial fan around the Toledo-Wildflower Bridge at West Cemetery Creek. Both degradation and aggradation are occurring near the area of concern. The bedload size fractions depositing on the eastern side of the study area are dominantly medium to coarse sand through coarse gravels based on the Wentworth Scale (Table 4). Collectively, the size fractions between granule and cobble are termed "gravel". To evaluate the sources, transport nature, and volumes of the sediment in the West Cemetery Creek watershed and to assess the conditions at the bridge, we performed a reconnaissance-level sediment budget.

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Table 4: Sediment Grain Size Fractions (Wentworth Scale)

Inches	Millimeters	Wentworth Grade
> 10	> 256	Boulder
> 2.5	> 64	Cobble
> 0.16	> 4	Pebble
> 0.08	> 2	Granule
> 0.04	> 1	Very coarse sand
> 0.02	>0.05	Coarse sand

Bedload sediment transports by rolling, tumbling, or saltating along the channel bed. Most bedload sediment is transported during higher flows. This study does not consider suspended sediment, debris flows, or the associated impacts.

Upper and Middle Watershed Sediment Processes

The upper watershed is primarily step-cascade morphology and the channel has incised into the glacial geologies and to a lesser extent the bedrock. Channel form is generally straight with little to no floodplain. Long-term storage is limited to instream only and therefore ephemeral in nature. Instream sediment storage results from moderate-sized log jams that create sediment wedges. The upper watershed is, over the long-term, supply limited, and incision is still actively occurring. Sediment delivery occurs when steep inner gorges collapse and erode. Evidence of mass wasting (shallow rapid landslides), incision, and erosion were observed frequently in the middle watershed (Photo 8). Mass wasting events (including small rotation failures), colluvial creep, failing stormwater culverts and unarmored outfalls are the primary forms of sediment delivery to the channel. Tree-throw and bioturbidation also deliver sediment, but at a relatively small level.

Photo 8. Failing outfall, mass wasting, erosion and incision into road fill north of Lakeway Drive.

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Photo 9. Failing outfall below (north) Old Lakeway Drive.

Two failing stormwater outfall culverts were identified as the largest single point-source contributors of sediment within the upper and middle watershed reaches (Figure 2-10). These culvert outfalls are perched creating drops of 3 to 8 feet, and the culvert segments have detached in one instance. During large storm events, the unconsolidated road fill that is supporting the culverts and the adjacent roads is rapidly eroded and sediment is entering the stream. The larger of the two failing outfalls is below Lakeway Drive (Photo 8 – preceding page) and the second one is below Old Lakeway Drive (Photo 9).

Sediment delivery to the system in the middle and upper watershed reaches occurs in two primary modes, episodic and chronic. Episodic delivery results as mass wasting events occur and deposit large volumes of sediment to the stream. This process results in an increase of instream stored sediment as the stream can only remove portions of the input. This sediment is often only stored temporarily until higher stream flows and erosion mobilize the stored sediment and transport it downstream, therefore contributing to sediment "pulses". Chronic sediment delivery occurs from the slow downward incision of the stream, colluvial erosion, and input from tributaries.

We estimated that the quantity of material stored in the channel in the middle reach averages less than 1 cubic yards per 1 lineal yard of channel. Using this estimate, West Cemetery Creek in this reach can have approximately 1,000 – 2,000 cubic yards of sediment stored in the channel. Much of this material is sand, gravel, and cobbles which are transported during a variety of storm events. Eventually this material will be moved downstream and deposited onto the alluvial fan potentially causing increased deposition in the impact area. Over the long term, the middle watershed reach could contribute the largest portion of cumulative bedload sediment to the system.

Lower Watershed Sediment Processes

The lower watershed is predominantly transport-limited, and therefore depositional landforms (alluvial fans, floodplains, and floodplain terraces) develop (Photo 10 – following page). As a result of the net deposition, portions of the stream have developed a limited braided channel form with multiple channels, gravel bars, and inundated floodplain areas. While the net sediment process in the lower reach is transport-limited, periods of supply-limited conditions may occur creating short-term erosion and incision in portions of the impact area sub-reach.

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Historic Sediment Management

Past sediment volume removals have been poorly documented. We understand through discussions with the City of Bellingham Public Works Department that several instream sediment removals have occurred since the reach was confined through the building of residences and their associated levees. The stream reach around the Toledo-Wildflower Bridge was dredged during the construction of Pinewood Hills housing development in 1994 and 1995 and occurred again in the early 2000's (personal communication, City of Bellingham Public Works).

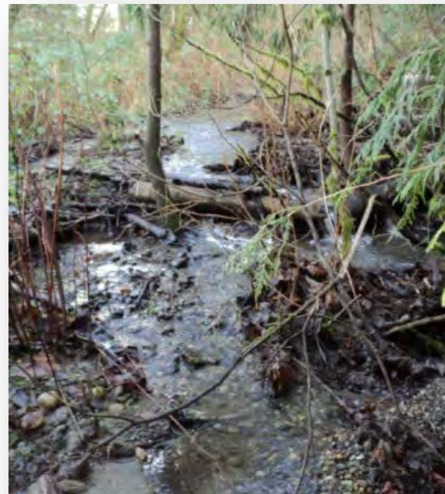

Photo 10. Example of deposition above Toledo-Wildflower Bridge inundating the forest in sediment.

2.3 HABITAT ASSESSMENT

Fish Use

Cemetery Creek is home to at least three species of salmonids and at least three species of native non-game fish (COB 2007, COB 2012, personal obs. 2013). Species identified include Oncorhynchus clarki (cutthroat trout), O. kisutch (coho salmon), O.mykiss (steelhead/rainbow trout), Cottus asper (prickly sculpin), Lampetra spp. (lamprey), and Gasterosteus aculeatus (three-spine stickleback). Smolt traps in Cemetery Creek, operated by the City of Bellingham's Natural Resources Division (COB), have also captured goldfish, red-sider shiners, and largemouth bass. The goldfish, shiners, and bass likely made their way into Cemetery Creek via Lake Whatcom and Whatcom Creek, or through human introduction to the creek.

Photo 11. Juvenile coho salmon captured in the Cemetery Creek smolt trap box on 4/05/2013.

Based on COB smolt trap data from 2006, 2009, and 2012, coho salmon are the most successful salmonid using Cemetery Creek. Over the three sampling years, more than 4,000 coho smolt were caught and identified in the trap box (Photo 11. Cutthroat trout appear to be the next most successful (less than 1,000 individuals caught), while less than 150 steelhead/rainbow trout were captured during the three smolt trap seasons (COB 2007, COB 2012).

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Spawning ground surveys conducted in Cemetery Creek show that coho salmon use portions of the creek for spawning. Based on those observations, coho salmon are probably year around residents, either as adults or juveniles (personal obs. 2012). Both adult and juvenile cutthroat trout have been encountered in the smolt trap box; the juveniles during outmigration/instream migration, and the adults as they move downstream, probably post-spawning (Photo 12). The steelhead/rainbow trout that have been captured in Cemetery Creek have all been juveniles, though there is a chance that adult steelhead spawn in the creek as well (Photo 13).

Photo 12. Adult male cutthroat captured in the 2013 Cemetery Creek smolt trap. Credit- D. Rapozza

Photo 13. Juvenile steelhead smolt caught in the Cemetery Creek smolt trap on 4/05/2013. Note large size of fish, excellent condition, and silvery appearance.

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Stream Habitat Conditions

Stream habitat conditions in the area of concern were evaluated in reference to salmonid habitat requirements. For the purposes of this study, three classifications were used: 1) Spawning habitat, 2) rearing habitat, or 3) migration corridor. Stream habitat was classified based on habitat features (pools, riffles, glides, rapids, cascades, steps) and substrate type (fines, sand, gravel, cobble, boulders, bedrock) as per Bisson et al. (1982), Groot and Margolis (1991) and Kondolff and Wolman (1993).

The instream habitat features and sediment type, in the immediate vicinity of the Toledo-Wildflower Bridge, classify that section of West Cemetery Creek as a migration corridor only. The majority of the substrate in the wetted portions of the channels immediately upstream and downstream of the Toledo-Wildflower Bridge is too fine to be used for salmonid spawning (Photo 7). Unstable stream channel morphology, in concert with active sediment deposition, have eliminated habitat features that would classify the study reach as rearing habitat. Until the stream reaches equilibrium or sediment transport is reduced, West Cemetery Creek immediately upstream and downstream of the bridge will be too unstable to provide either spawning or rearing habitat for salmonids or native non-game fishes.

The upstream and downstream sections of West Cemetery Creek, further away from the bridge, provide both rearing and spawning habitat for salmonids and native non-game fishes. The reach upstream of the bridge flows through a mostly coniferous riparian area, and contains gravels suitable for salmonid spawning. The upper reach consists primarily of riffles and short glides. Instream habitat features in that reach, e.g. pools, are limited. The reach downstream of the bridge appears to be incising downstream of the active alluvial fan, and so instream habitat is variable and ephemeral. Further downstream, as the creek channels continues to lose gradient, habitat forming features exist, and more fish rearing habitat is present.

Potential Restoration Strategies

The size and availability of streambed gravels can have an effect on spawning success of salmonids (Kondolf 2000). In addition, the quantity and quality of available rearing habitat, food sources, competitive interaction, and water quality parameters, affect salmonid survival (Quinn 2005). In this case, channel morphology, streambed substrate motility, and lack of habitat forming features, such as large woody debris, are the critical elements that limit fish habitat quantity and quality in the study area of West Cemetery Creek.

To address fish habitat enhancement, restoration strategies must first address the deposition and aggradation of fine sediment that occurs in the immediate vicinity of the Bridge. Increasing sediment storage potential upstream of the Bridge may mediate the negative impacts on instream habitat. Dredging or other sediment removal actions at the Bridge would likely have a net negative impact on fish habitat, and should be considered as a last alternative. The other habitat issue to address is the active erosion and head-cutting that occurs downstream of the bridge depositional area. A certain degree of erosion and deposition can provide a benefit to salmonids by providing gravel and creating new habitat for fish. However, excessive erosion and deposition is impairs fish habitat and is detrimental to overall ecosystem health.

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To increase instream habitat complexity and diversity, habitat forming features such as logs and rootwads could be added to the study reach. Such structures, when installed properly, tend to form stable pools for holding and refugia, and can facilitate channelbed stability (Rosgen 1996). The middle and upper reaches of West Cemetery Creek flows through a maturing forest, but the quantity and size of recruitable wood is not sufficent to form habitat features and stabilize bedload substrate. In West Cemetery Creek, it is possible to combine both habitat and infrastructure management objectives with install instream large woody debris, thus providing mutual benefits.

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2.4 SECTION 2 FIGURES

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Figure 2-1: Watershed Physiography

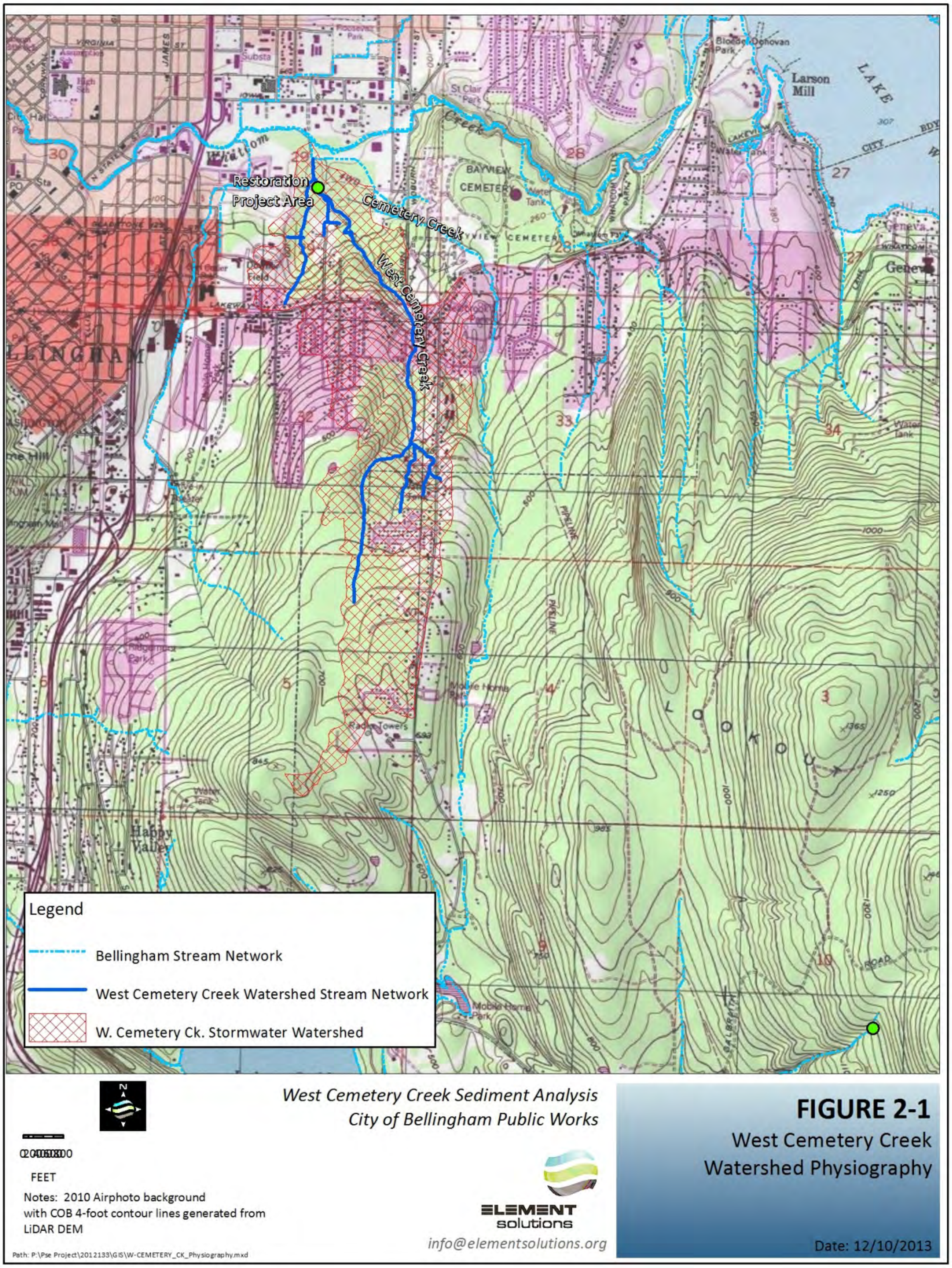

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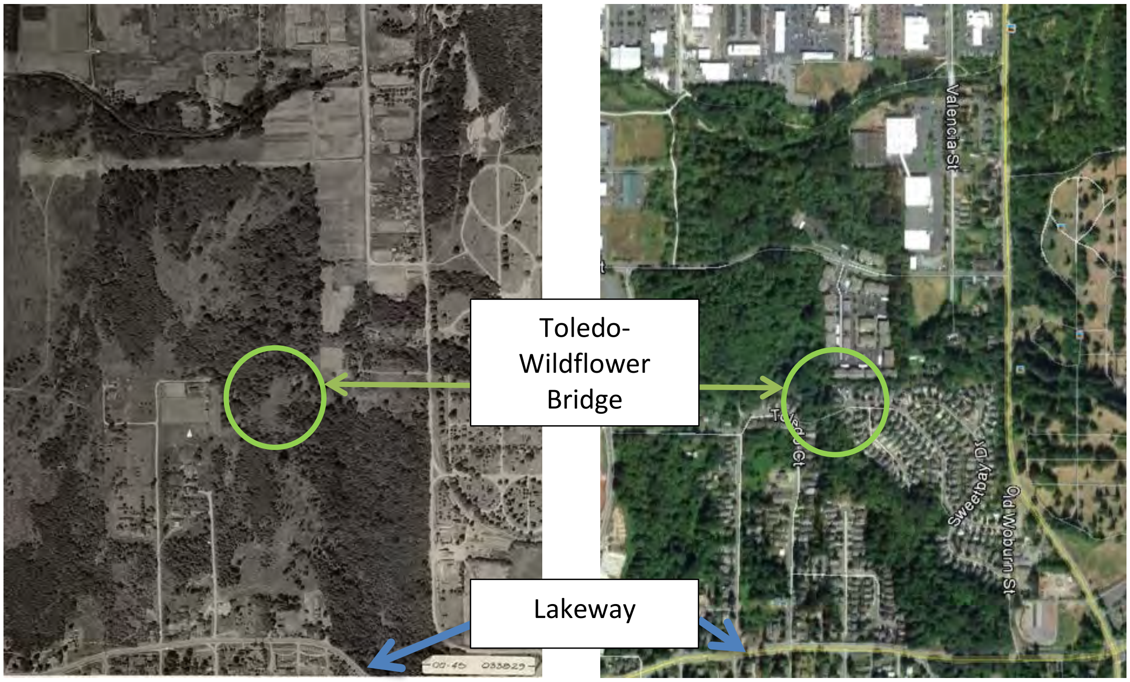
Figure 2-2: Watershed Land Use

1950 to 2011 Watershed Urbanization Relative Comparisons – Lower Watershed



1950 to 2011 Watershed Urbanization Relative Comparisons – Middle Watershed

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Figure 2-3: Stormwater and Historic Watershed Areas

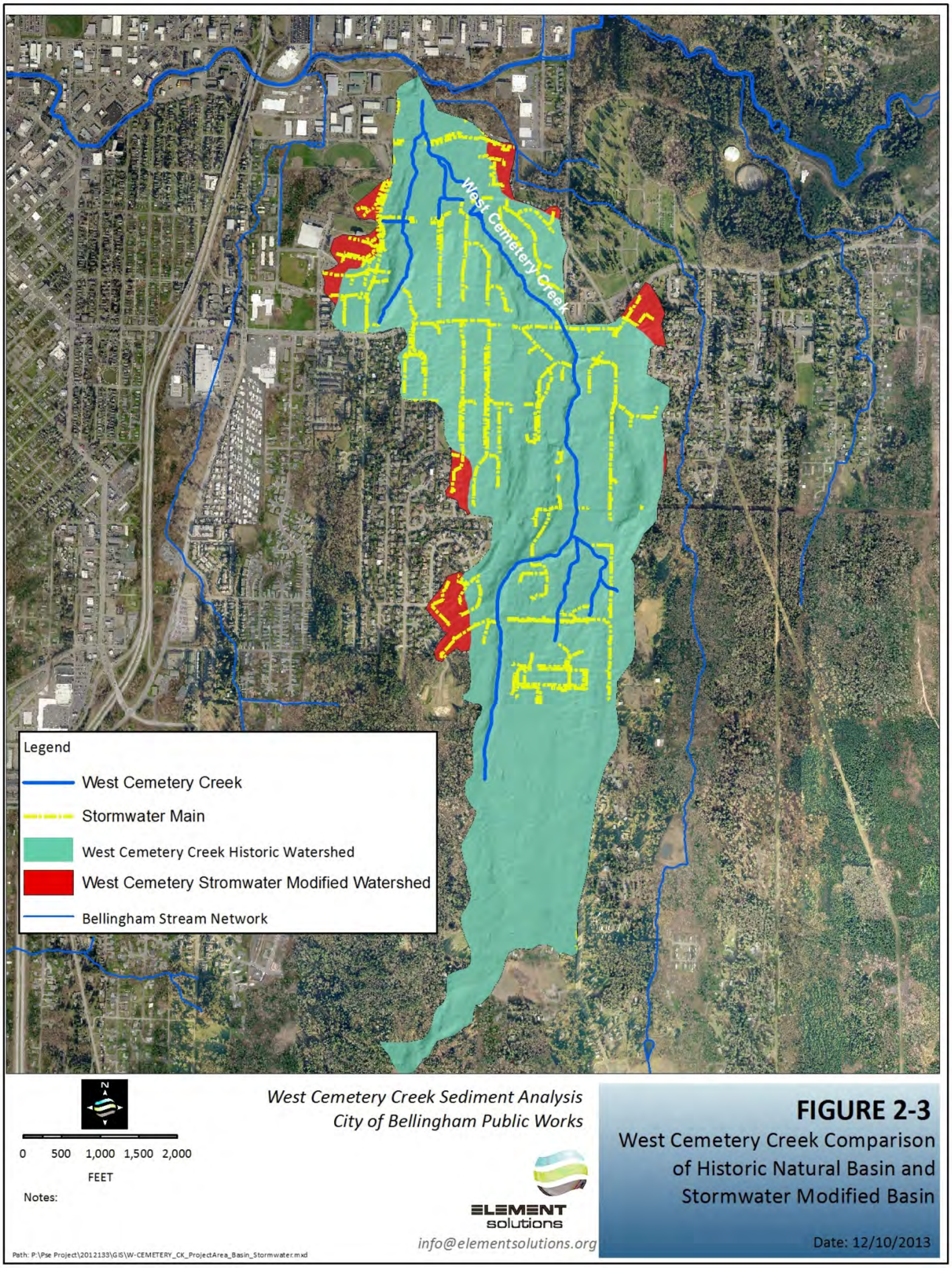

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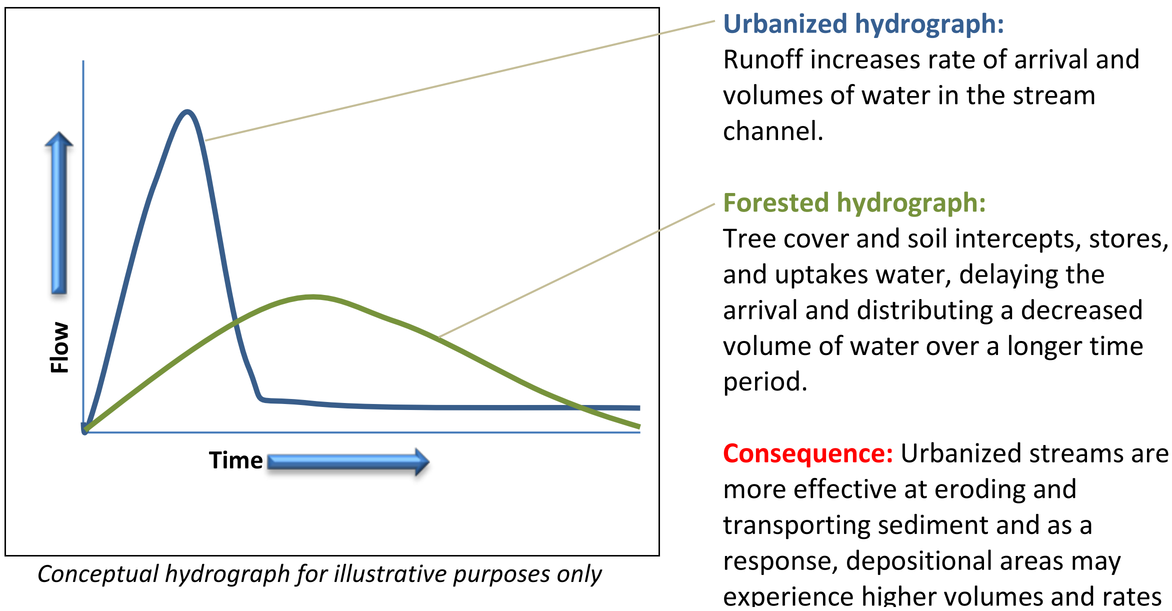
Figure 2-4: Hydrograph Comparisons

Natural versus Management Hydrograph Comparison



Conceptual hydrograph for illustrative purposes only

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Figure 2-5: Watershed Geology

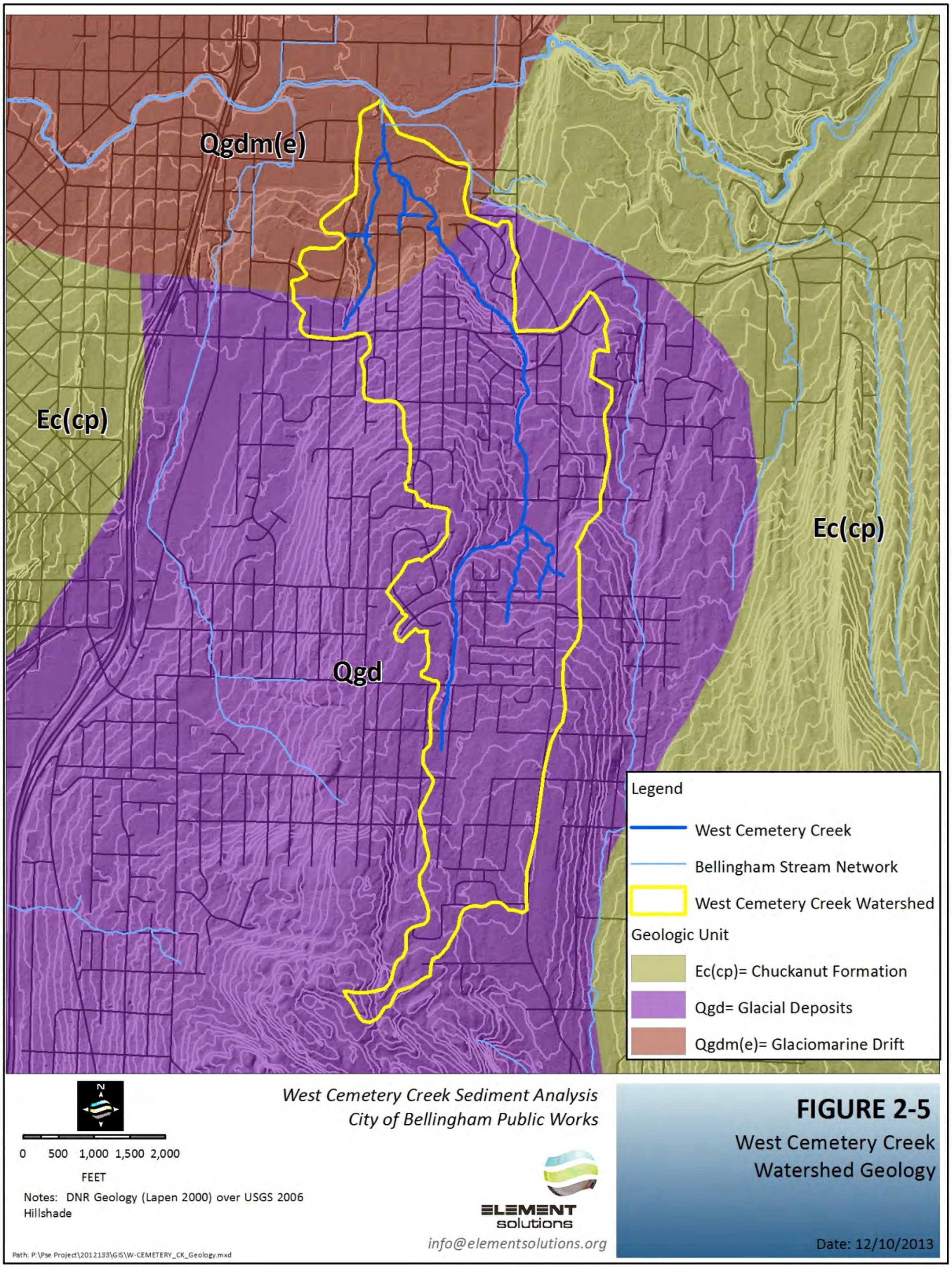

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Figure 2-6: Watershed Reaches

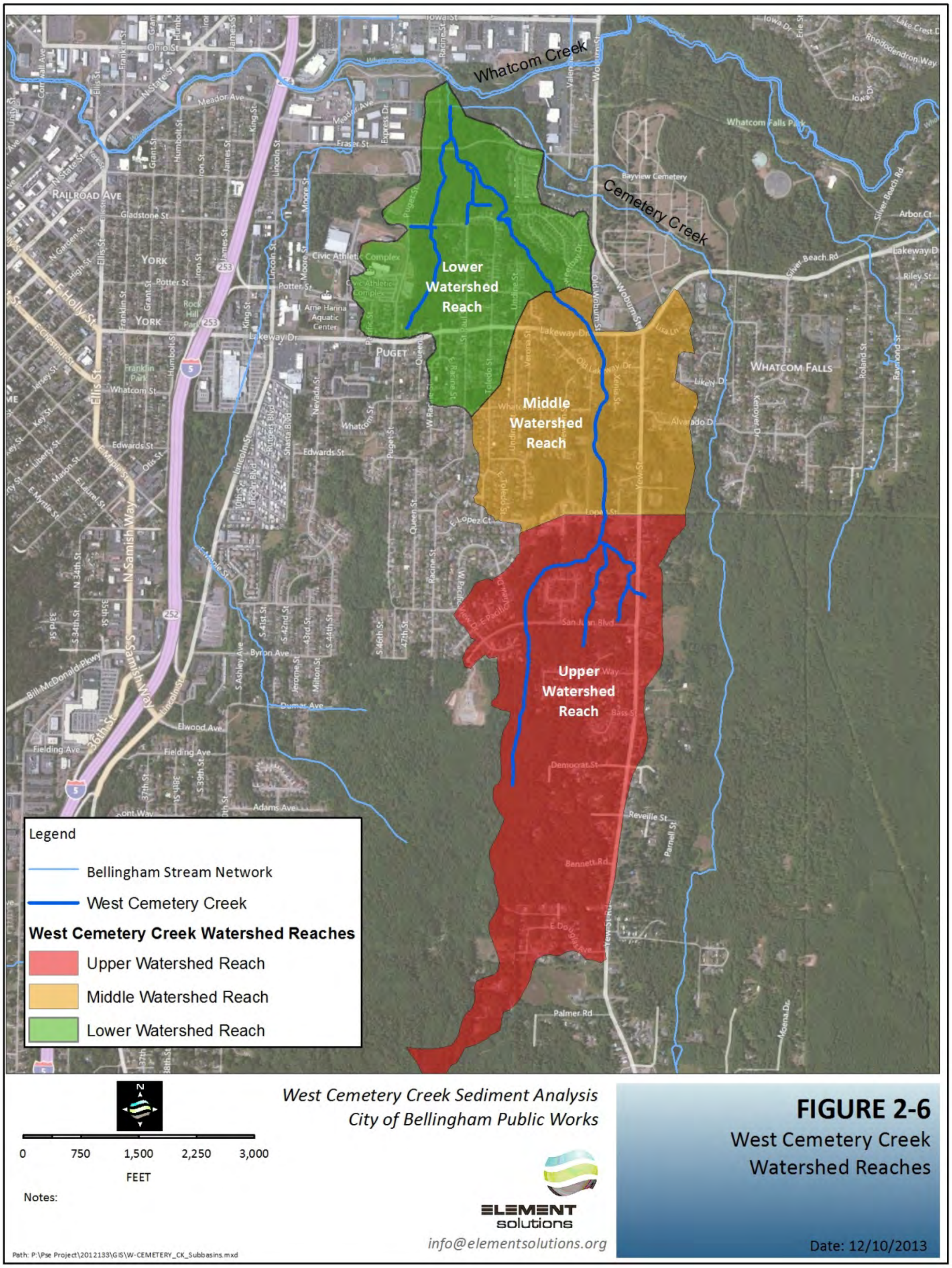

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Figure 2-7: Stream Profile

West Cemetery Creek Channel Gradient (in percent) – San Juan Boulevard to Cemetery Creek Confluence

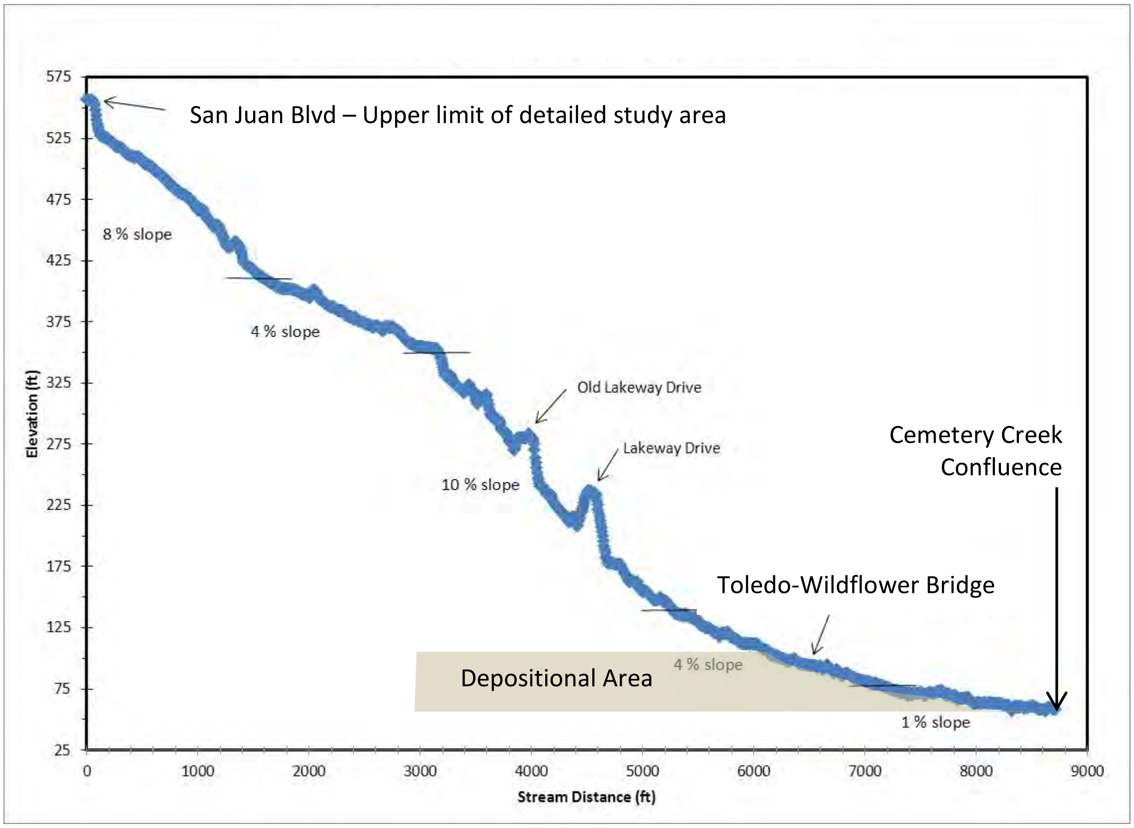

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Figure 2-8: Middle and Upper Watershed Reaches Geomorphology

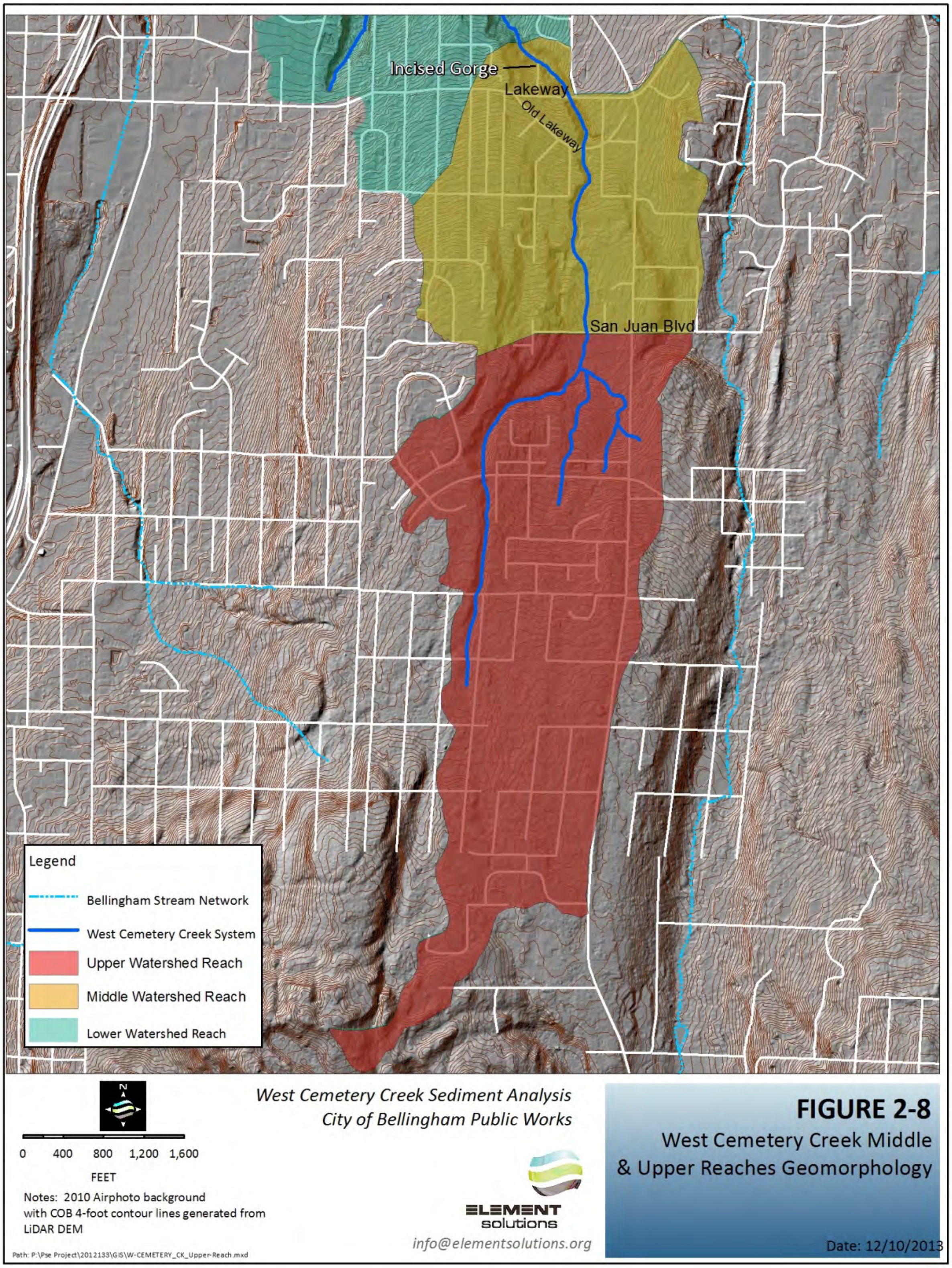

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Figure 2-9: Lower Watershed Reach Geomorphology

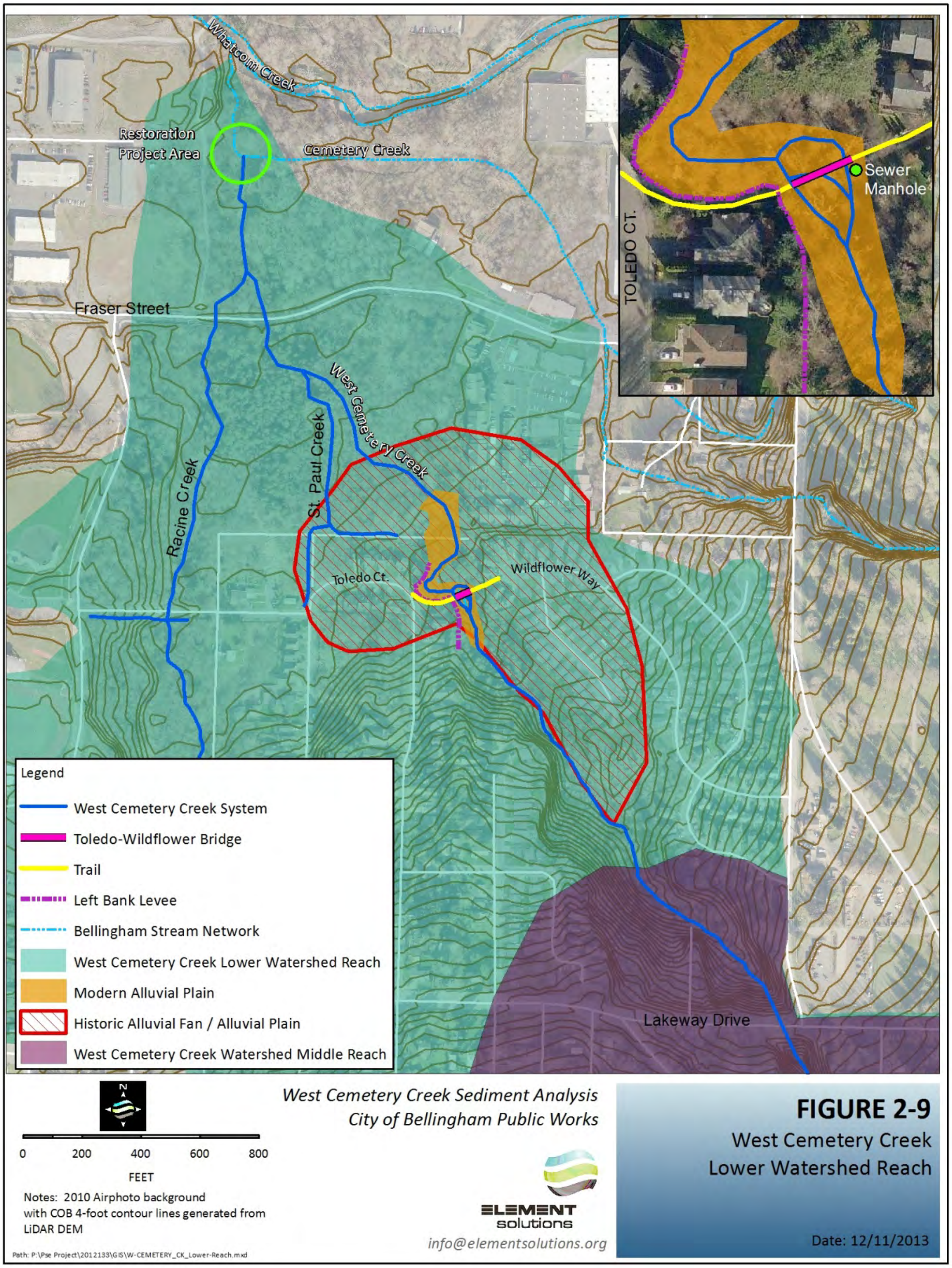

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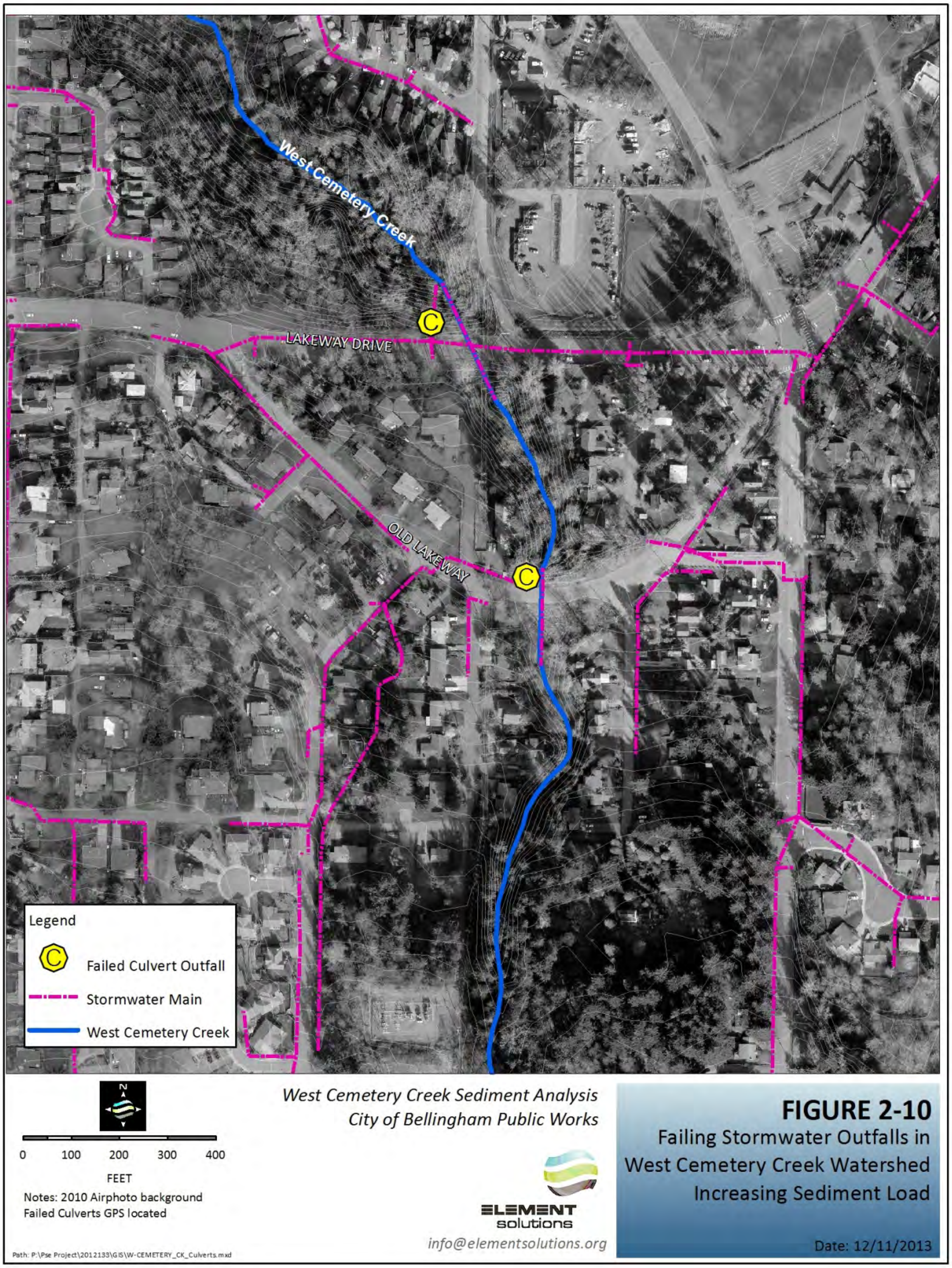
Figure 2-10: Stormwater Systems



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3 ALTERNATIVES IDENTIFICATION AND ANALYSIS

Natural process and hazard management strategies can be categorized into three generalized adaptation approaches:

- Retreat Strategies (removing assets from potential impact area)
- Accommodation Strategies (integrating techniques for "living with" impacts)
- Protection or Buffering Strategies (utilizing natural or artificial barriers to mitigate or reduce impacts)

The "retreat strategy" typically results in the most comprehensive long-term solution; however, because of social, legal, or economic justifications to maintain an established built environment, it is often the most challenging adaptation approach to implement. While the ultimate solution could be to acquire all the properties and remove or relocate all the infrastructure from the area of impact, this alternative was not considered feasible at this time and was not included in the short-term management alternatives identification. However, sediment deposition and flooding in this area are natural processes that will continue indefinitely and if land use continues in the impact area, long-term management alternatives may need to consider the potential future conflicts between natural processes and static land use and integrate these realities. It should be noted that some of the residential development occurs in topographically low areas and none of the identified near-term alternatives will completely eliminate the flooding potential for these properties. Only acquisition and "retreat strategies" can fully mitigate this risk.

The management strategies for the alternatives identified below consider most natural processes associated with West Cemetery Creek with the exception of debris flows that transport large volumes of sediment and debris (for this analysis, greater than 1,000 cubic yards per event). As previously discussed in this analysis, the potential occurrence of a large debris flow is likely infrequent, but not improbable. Because the impacts from large debris flows on the built environment and public safety are much more significant than the management objectives of this analysis, different management approaches would be needed to mitigate these impacts. The following alternatives identified do not address debris flow hazards.

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3.1 ALTERNATIVES IDENTIFICATION

Nine near-term management project alternatives were identified as potentially feasible based on cost, ability to address management goals, and ability to implement within the authority of the City of Bellingham. The nine alternatives are described below and shown on Figure 3-1.

1) No Action

With a no action approach, deposition in particular, will continue in West Cemetery Creek. The impact to infrastructure and private properties will be realized more often in the future. The stream sediment would be expected to eventually aggrade to the point that the bridge would be buried and the stream would seek a new route around or over the trail infrastructure, potentially through private properties. Damage to the bridge and infrastructure is possible. The resulting damage from inundation of the bridge and trail infrastructure would probably be relatively minor, but ongoing and frequent maintenance costs would likely accumulate to a substantial amount. Impacts to the sewer system, levee, roads or private residences are anticipated to be much more costly.

The no action alternative assumes that existing land use management (regulations and planning) would continue and consider impacts from build-out, stormwater runoff, and placing infrastructure in hazardous and critical areas.

2) Stabilization of Middle and Upper Watershed Sediment Sources

Building log-jam/boulder structures in the upper watershed to retain sediment is an option. These structures could be designed to reduce the rate of downstream sediment transport by storing this sediment in-channel. These sorts of features form naturally in West Cemetery Creek and were observed during fieldwork. The structures essentially form a low weir in the channel, which allows material to deposit on the upstream side, leading to the formation of sediment 'wedges' in the channel. The presence of wood in streams additionally has significant habitat benefits.

Although logjam/boulder structures do form naturally in West Cemetery Creek and act to retain sediment in the channel, ultimately the logs will rot and compromise the stability of the structure and are therefore temporary. It is also possible that the structure could fail and release the impounded sediment. Since a failure is more likely to occur under high flow conditions when forces exerted on the structure will be greatest, the sediment that is released may become mobilized and moved down the system to the management area. Although it is not possible to predict such potential failures, the resulting consequences and potential maintenance needs should be acknowledged.

3) Instream Sediment Removals (Dredging)

Removal of accumulated sediment from the channel has been a historic management approach. Sediment removals provide only temporary conveyance increases and require maintenance over time (assumed 10-year maintenance need). Dredging has been found to adversely affect the ecological conditions of the stream, and thus impact fish species valued by the greater community, and potentially species protected under the Endangered Species Act. Instream

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sediment removal causes impacts both upstream and downstream of the removal area and unintended consequences should be identified if this management strategy is to be considered further. Instream sediment removal consists of two strategies; a “less-frequent but large removal (disturbance)” approach, and a “more frequent but smaller removal (disturbance)” approach. The impact on fish habitat for each strategy has not been fully quantified, but the more frequent, smaller disturbance approach would appear to have a greater net habitat impact. From an infrastructure management and flood perspective only, the instream sediment removal strategy utilized historically appeared to be moderately effective at managing the impacts to infrastructure and private properties.

Permitting this alternative may be challenging because of the probable impact to fish habitat.

4) Infrastructure Abandonment

The removal of the topographically low areas of Toledo Court, some adjacent residences, the sewer main opening, and the Toledo-Wildflower Bridge assessed in this evaluation would essentially eliminate the infrastructure maintenance needs and related flooding issues in the impact area. Although this would restore the stream system to a natural depositional environment, we recognize the road, homes, and bridge has a fair amount of social, economic, or public safety value and removal of this infrastructure may not be feasible given the low to moderate impacts currently in the study area. This management strategy may become more appealing as frequency and consequences of impacts increase.

5) Bridge Modification(s)

As of April 2013, the Toledo-Wildflower Bridge currently has impaired conveyance conditions, with vertical clearance of about 1 to 2.5 feet between lowest channel bed elevation and each terminus of the bridge,. Although the bridge could sustain a small ~2 year flooding event, any event larger is likely to cause flooding, possible bridge/trail damage, and possible trail closures. The topography on each of the banks of the creek near the bridge could allow for a bridge to be built that would be higher and wider, which would span the whole stream bed.

This structure would allow for greater storm and sediment conveyance. The bridge would need to be re-designed to the appropriate return period flow and would include an allowance for sedimentation in addition to freeboard. If properly designed, inundation, maintenance, road closures, and upstream flooding impacts should be greatly reduced. For the purpose of this option, a wood boardwalk-style bridge with an approximately 80-foot span is the replacement structure used to develop the cost estimate.

Although this option addresses the trail/bridge flooding issues, it does not address flooding of the sewer system or adjacent homes.

6) Levee Modification(s)

Ideally, setting back the levees would allow for more unimpeded natural processes (flooding, sediment deposit, habitat forming processes). The setback levee concept is to provide a much larger area for storage of sediment and water, as well as dramatically decreasing hydraulic

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forces. Unfortunately for this site, private property constraints and existing development does not allow for a substantial setback of the existing levees. A conceptual compromise would be to realign the levees to reduce the majority of flooding on adjacent homes without significantly impacting the stream habitat. This option, if not designed properly, could restrict high flow between the two bank levees and translate sediment deposition further downstream, potentially increasing the impact to the restoration area.

7) Adding a Riser to the Sewer Manhole

In order to prevent flooding of the sewer system, either a riser extension to the sewer manhole or relocating it outside of the floodplain would address most of the flooding risk. Permitting challenges and costs may affect these alternatives.

8) Realigning Stream Channel

West Cemetery Creek takes a nearly 90 degree bend just below the bridge area. This bend and the associated erosion are increasing the flooding potential of the residence on the adjacent western bank. Currently the residence is approximately 4 feet below the top of the levee and 3 feet below the stream bead. By removing a small hummock that is currently causing the stream to run its present course and establishing a broader floodplain and potential "straighter" stream course, the flooding and erosion risk associated the home at this location would be reduced. The stream realignment would likely increase the conveyance of sediment within the bridge area during flooding events with increased incision and head-cutting an unintended consequence. In addition, this alternative would require removal of large conifer trees and the excavation of a large quantity of soil, potentially negatively impacting fish habitat.

9) Repair Failing Stormwater Outfalls and Culverts

During the West Cemetery Creek field investigation, 2 stormwater outfall culverts were discovered that are contributing large quantities of sediment to the stream system. By repairing these outfalls and culverts, the sediment load of West Cemetery Creek would be expected to reduce, thereby reducing the aggradation rates near the Toledo-Wildflower Bridge and benefiting water quality.

The failing culvert that was found to have contributed the largest amount of sediment to the stream recently is located north of Lakeway Drive and the junction with West Cemetery Creek on the western bank. This culvert drains stormwater runoff from Lakeway Drive. It appears that bypass runoff has undermined the culvert, caused culvert segments to come apart and road-fill to erode, creating a significant waterfall, scour and mass wasting. During large storm events the runoff is rapidly eroding the loose road fill and causing siltation and mobilized sediment to reach the stream. If left unchecked, this problem may undermine the structural integrity of Lakeway Drive.

The second failing culvert that contributes significant sediment to the stream is located north of Old Lakeway Drive on the western bank of West Cemetery Creek. This stormwater outfall drains the residences around Woburn Street and Newton Street. This outfall is smaller than the one on Lakeway Drive, but it still releases stormwater into the ravine through a 3 to 5 foot drop, which

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is eroding the slopes of Old Lakeway Drive and adding sediment to West Cemetery Creek (Photo 10).

Alternatives Planning-Level Costs

Table 5 provides a range of planning-level cost estimates for implementation and maintenance of the conceptual management alternatives identified above. Costs Include estimated design, permitting, mitigation and construction costs.

Table 5: Planning-level Costs of Identified Alternatives

Alternative	Implementation Cost*	Maintenance Costs* (25-year cumulative)	Total Costs 25-Year Life Cycle*
1) No Action	$0	Unknown	Unknown
2) Stabilization of Middle and Upper Watershed Sediment Sources	$50,000	$75,000	$125,000
3) Instream Sediment Removals	$75,000	$150,000	$225,000
4) Infrastructure Abandonment	$75,000	$0	$75,000
5) Bridge Modification	$50,000	$0	$50,000
6) Levee Modification	$200,000	$50,000	$250,000
7) Sewer Manhole Riser	$10,000	$0	$10,000
8) Realigning Stream Channel	$100,000	$50,000	$150,000
9) Repair Failing Stormwater Systems	$25,000	$25,000	$50,000

*Cost Estimates and Assumptions are provided in Appendix A

3.2 ALTERNATIVES ANALYSIS

The nine management alternatives identified as feasible within anticipated fiscal constraints and government authority were evaluated for their ability to meet the City of Bellingham management goals. In general, some alternatives provide benefits to only one management goal. For example, an alternative that focuses exclusively on management of sediment may not address any of the fisheries concerns. Conversely, an alternative that focuses only on habitat may not adequately address the sediment issues. The alternatives that met more than one goal have mutual benefits and were considered more favorable. The outcomes of the analysis resulted in a recommendation of alternative strategies that achieved the greatest relative cost-benefit merits meeting multiple goals.

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3.3 SECTION 3 FIGURES

Figure 3-1: Alternatives Identification

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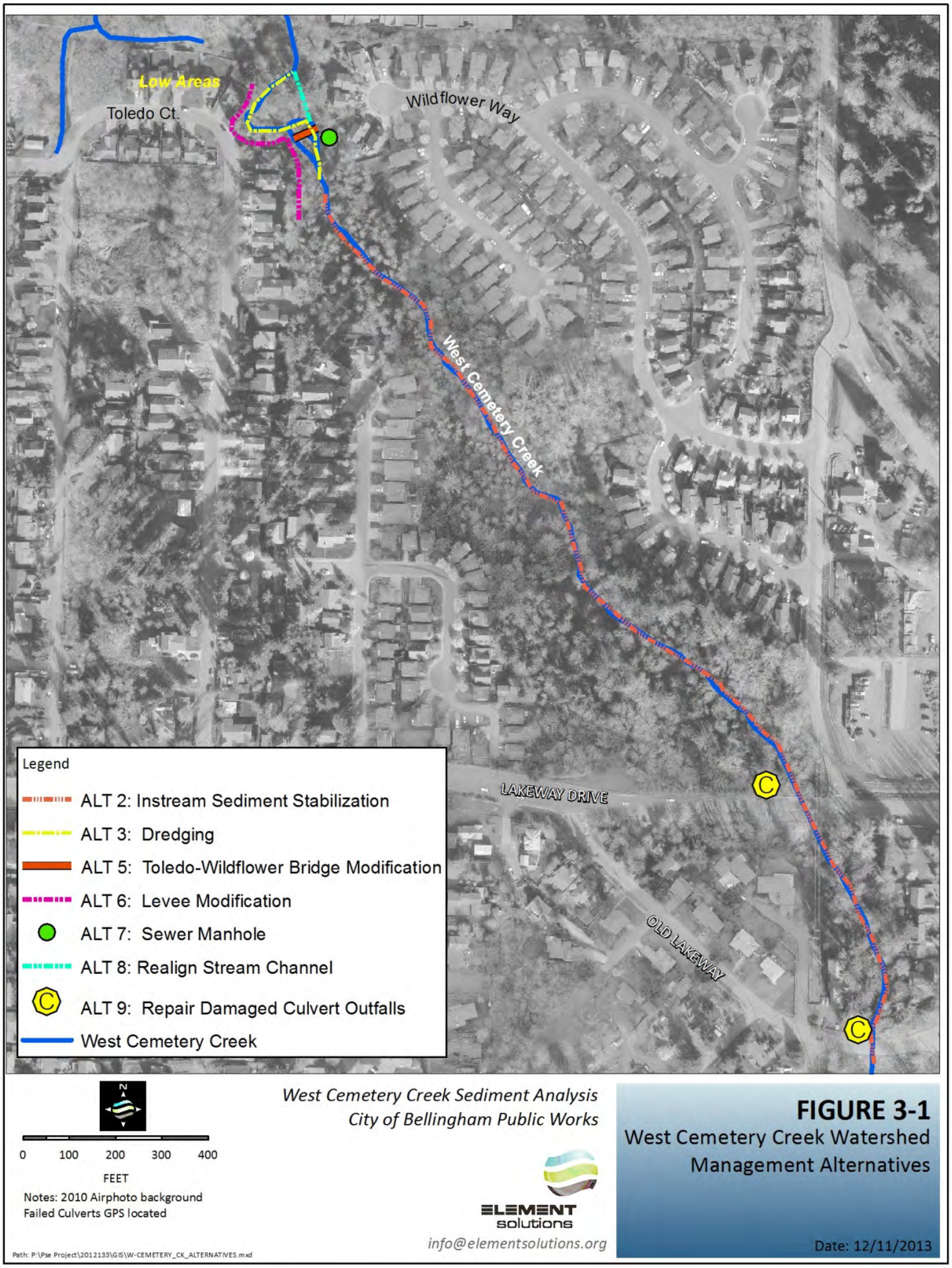
Figure 3-1: Alternatives Identification



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4 Recommendations

Implementation of the following management alternatives are recommended as an overall management strategy that includes a suite of projects to meet the management goals of the West Cemetery Creek impact area. It is anticipated that the City of Bellingham will continue to address future land use and development impacts on stream processes as managed through the planning and regulatory processes, stormwater management in particular. The recommended management strategy includes both immediate or near-term management actions and longer-term management actions. As with implementation of any management actions, establishing a metric to measure and evaluate success or failure should be employed and a monitoring program established to collect this information. At a minimum, establishing surveyed cross sections and detailed habitat mapping is needed to establish base line conditions for which to compare to future conditions.

Recommended Immediate or Near-term Implementation Strategies

The following project alternatives were identified for near-term or immediate implementation and are arranged in order of time-line priority.

Alternative 9: Repairing Damaged Stormwater Outfalls at Lakeway and Old Lake

Repair and maintenance of the existing stormwater systems in the West Cemetery Creek watershed would provide both a near-term and longer-term reduction in sediment delivery to the stream that negatively impacts water quality and fish habitat, and increases maintenance needs and flooding potential. In particular, the damaged outfalls at Lakeway and Old Lakeway are most acute and should be addressed as soon as possible. Potential repair designs include repairing or replacing the broken outfall pipe sections, redirection outlets away from steep slopes, reducing outfall drop height, constructing an outfall energy dissipation structure, and stabilizing the steep and eroded slopes. The costs of maintaining and repairing these damaged outfalls is relatively low and the benefits would be realized over a broad area from the site of the culvert failure, downstream through the impact area and the Cemetery Creek restoration site, as well as into Whatcom Creek, and ultimately Bellingham Bay. Repair of damaged stormwater systems should be given a high priority to avoid prolonged impacts from sedimentation and to avoid the potential damage to roadway fill and slope instability that could impact public infrastructure and exacerbate the problems at Toledo Court.

Alternative 5: Modification of the Toledo-Wildflower Bridge

Develop bridge designs that provide more clearance and allowance for both lateral and vertical channel changes over time to reduce maintenance costs and the impacts to floodplain and channel processes. This alternative is considered fairly low cost to implement and future maintenance costs are anticipated to be very low. The current bridge will need to be replaced in the near-term and therefore implementing of this strategy can

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be sequenced with this maintenance need. Natural channel and floodplain processes would be allowed to occur with decreased impacts and therefore there is a direct habitat improvement by implementing this project.

Alternative 2: Stabilization of Middle Watershed Sediment Sources

Stabilization of instream sediment will reduce downstream transport of bedload, stream incision and colluvial unraveling while increasing floodplain terrace connectivity and instream habitat conditions; therefore provide both reductions in maintenance costs and providing habitat value. Development of designs for instream large woody debris and construction can be done at a low cost and implemented incrementally over time.

Recommended Longer-term Management Strategies

As the implementation of the near-term management strategy is underway, it will be important to monitor the system for changes and to consider longer term management action strategies. A punctuated change in the system that dramatically alters the conditions or causes significant damage and impacts should initiate a reassessment of the site and management alternatives and may expedite the need to implement longer-term management alternatives. The recommended longer-term or changed conditions management strategy is to consider:

Alternative 7: Sewer Manhole Modifications

It is recommended that the sewer manhole riser adjacent to the floodplain be elevated at some point in the future to avoid flooding impacts to the sewer system or a release of sewage into the watershed. A few inches of freeboard currently exist from current flooding levels and this freeboard will diminish over time as the channel bed aggrades. The costs to implement this project are low, but the potential damages could be significant.

Alternative 6: Levee Modifications

It is recommended that long-term management, or response to changed conditions from atypical storms or sediment loads and levee damage, be considered for the existing levee infrastructure and the higher risk homes and infrastructure. At some point in the future, levee maintenance and potential realignment will be needed to address long-term sediment deposition. Ultimately, other more sustainable management decisions than levee maintenance may be more appropriate, such as acquisition of at risk or frequently impacted homes. It is recommended that these alternatives be revisited proactively or as needed prior to commitment of implement a levee modification strategy and integrated into future planning efforts.

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5 Closure

This report was submitted by:

Paul D. Pittman, L.E.G.

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APPENDIX A - WEST CEMETERY CREEK ALTERNATIVES PLANNING-LEVEL COST ESTIMATES

ALTERNATIVE	*Item*	*Unit Cost*	*Units*	*Qty*	*Implementation*	*Assumptions*	*Maintenance - 25 year*	*Assumptions*	*Total Life-Cycle Cost*
2-Stablization of Sediment									
	Instream Wood	$1,000	each	20	$20,000	LWD material	$50,000	Maintenance = full replacement at 25 years	
	Manual labor	$1,500	each	20	$30,000		$25,000	Repair and Monitoring @ $1,000 per year	
	Totals				**$50,000**		**$75,000**		**$125,000**
3-Sediment Dredging	Excavator	$2,000	day	5	$10,000	5 days to excavate	$75,000	Maintenance = redo at 25 years	
	Hauling	$2,000	day	5	$10,000	5 days of haul			
	Mitigation	$20,000	each	1	$20,000	fish exclusion, turbidity			
	Monitoring	$5,000	week	1	$5,000	One staff			
	Permitting	$10,000	each	1	$10,000	all permit submittal			
	Restoration	$20,000	each	1	$20,000	Riparian, instream			
	Totals				**$75,000**		**$75,000**		**$150,000**
4 - Infrastructure Abandonment	Demolition	$10,000	houses	7	$70,000	equipment and dump	$0	No maintenance	
	Labor	$5,000	each	1	$5,000	Project management			
	Totals				**$75,000**				**$75,000**
5 - Bridge Modification (full replacement)	New bridge	$30,000	each	1	$30,000	Materials and Labor	$0	No maintenance	
	Design	$10,000	each	1	$10,000	Staff			
	Permitting	$10,000	each	1	$10,000	Staff			
	Totals				**$50,000**				**$50,000**
6 - Levee Modification	Materials	$250	LF	300	$75,000	engineered soils delivered	$50,000	Repair and Monitoring @ $2,000 per year	
	Equipment	$2,000	day	15	$30,000	place materials			
	Mitigation	$20,000	each	1	$20,000	fish exclusion, turbidity			
	Monitoring	$5,000	week	3	$15,000	One staff			
	Design	$10,000	each	1	$10,000	Engineering drawings			
	Easements	$20,000	total	1	$20,000	Staff and Legal			
	Permitting	$10,000	each	1	$10,000	all permit submittal			
	Restoration	$20,000	each	1	$20,000	Riparian, instream			
	Totals				**$200,000**		**$50,000**		**$250,000**
7 - Manhole Riser	Materials	$2,000	total	1	$2,000		$0	No maintenance	
	Labor & equip.	$8,000	total	1	$8,000	crew and equipment			
	Totals				**$10,000**				**$10,000**
8 - Stream Realignment	Excavator	$2,000	day	10	$20,000	5 days to excavate	$25,000	Monitoring ($1,000/year)	
	Hauling	$2,000	day	10	$20,000	5 days of haul	$25,000	Maintenance (10 instream structures)	
	Mitigation	$25,000	each	1	$25,000	fish exclusion, turbidity			
	Monitoring	$5,000	week	1	$5,000	One staff			
	Permitting	$10,000	each	1	$10,000	all permit submittal			
	Restoration	$20,000	each	1	$20,000	Riparian, instream			
	Totals				**$100,000**		**$50,000**		**$150,000**
9 - Repair Culvert Outfalls	Materials	$5,000	each	2	$10,000	Pipe, energy dissapater	$25,000	Maintenance = full replacement at 25 years	
	Labor & equip.	$7,500	each	2	$15,000	Installation			
	Totals				**$25,000**		**$25,000**		**$50,000**

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