SQUALICUM CREEK WATERSHED CHANNEL MIGRATION ZONE MAPPING TECHNICAL REPORT

Prepared for the City of Bellingham Department of Public Works
September 13, 2016

Submitted by:
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Submitted To: Analiese Burns
Habitat and Restoration Manager
City of Bellingham Public Works
2221 Pacific Street
Bellingham, WA 98229

RE: **Squalicum Creek and Associated Tributary Channel Migration Zone Mapping**
Whatcom County, Washington

Dear Ms. Burns,

Element Solutions is pleased to present the following Squalicum Creek and Associated Tributary Channel Migration Zone Mapping report. As a local firm that has served the City of Bellingham and the greater Whatcom County community for over 20 years, we are deeply invested in the continued growth of our community as well as the health and vitality of the rivers and streams that define our landscape.

We hope that the results of our mapping and analysis will provide regulators, planners, and other public service professionals an invaluable tool for addressing some of the challenges associated with balancing the complexities of natural systems and active earth processes with urban development and land management needs. The following report describes the approach, methods, and work plan that were used to comprehensively evaluate, describe, and delineate the Squalicum Channel Migration Zone, and presents the results of our extensive field and desktop mapping.

Thank you for the opportunity to work with you and the City of Bellingham Public Works Department to develop deliverables that will help inform sustainable, responsible, and defensible land use practices now and into the future.

Sincerely,

Paul Pittman, MS, LEG
Earth and Environmental Sciences Manager - Principal

Table of Contents

Appendices

Executive Summary

The Channel Migration Zone (CMZ), or the "area within which a stream channel has historically occupied or may occupy in the future" (Ecology, 2014), is a planning and regulatory tool that allows for a comprehensive approach to stream and watershed management to support responsible development within the city limits of Bellingham. In addition, it can help inform future restoration efforts. The analysis provided in this study utilized Ecology CMZ mapping guidance and integrated both desktop and field analyses to delineate areas of current and future channel migration processes and hazards (erosion, scour, avulsion, fluvial-induced landslides). Our findings indicate that the basin has undergone considerable anthropogenic modifications which have influenced both present day erosion rates and channel locations and that channel migration processes are still underway and are expected to continue into the future. Using the best available science, desktop and field information, combined with professional judgment, we provided a recommended regulatory CMZ. The intent of the mapped CMZ is to notify the City and development proponents when it is applicable to conduct a more detailed, site specific analysis to evaluate potential hazards, risks, or restoration opportunities associated with channel migration processes.

Acknowledgements

Element Solutions would like to thank and acknowledge the City of Bellingham for the opportunity to assess the modern fluvial geomorphology and stream characteristics of the Squalicum Creek basin. The Element team included:

- Paul Pittman, MS, LEG - Project Manager and Fluvial Geomorphologist
- Adam Crispin, BS - Environmental Scientist, Aquatic Ecologist
- Micah Gregory, BS, GIT - Environmental Scientist
- Nick Brown, BS - GIS Analyst
- Lucas Phillips, BA - GIS Analyst

Project management consultation, review annotation, and guidance were provided by:

- Renee LeCroix, City of Bellingham Assistant Public Works Director.
- Analiese Burns, Habitat and Restoration Manager, City of Bellingham Public Works Department, Natural Resources.
- Steve Sundin, Senior Planner, City of Bellingham Planning and Community Development Department

1 Introduction

1.1 Background and Purpose

The Squalicum Creek Watershed, one of the largest sub-watersheds of Bellingham Bay, has experienced substantial natural and anthropogenic modifications throughout recent geologic history. Originating from headwaters in the Cascade foothills and post-glacial uplands, Squalicum Creek flows west and drains approximately 22 square miles (mi^2) of land. Of the approximately 28 stream-miles traversed by Squalicum Creek and associated tributaries within city limits, more than 25% (approximately 7 miles) is confined by culverts, man-made channels, or floodplain retention ponds. Due to urban development, hydromodifications, and other factors, Squalicum Creek was found to exceed Washington State water quality standards for several contaminants and was subsequently listed by the Department of Ecology (Ecology) with Category 5 Impairment (303d list); these findings have prompted large-scale restoration efforts within the basin. The ongoing Squalicum Creek Re-route Project, for example, has relied on historic geologic and hydrologic benchmarks to restore the creek to its original floodplain.

One key tool that has been developed to assist regulatory agencies and resource managers is the delineation of the Channel Migration Zone (CMZ), or the *"area within which a stream channel has historically occupied or may occupy in the future"* (Ecology, 2014). The CMZ determination can inform project planners of physical stream processes to support flood management and ecological restoration efforts, and allows for a comprehensive approach to stream and watershed management. The purpose of this analysis is to utilize the Ecology methods for watershed-scale CMZ delineation and Best Available Science to inform future restoration efforts and provide regulatory guidance for responsible development within the Critical Areas of the CMZ.

1.2 Study Area Overview

The Squalicum Creek CMZ study area includes Squalicum Creek and its primary tributaries (Spring, Baker, and Toad Creeks) within the City of Bellingham city limits and Urban Growth Area (UGA) (Figure 1). For our analysis, the Squalicum Creek basin was divided into five distinct sub-watersheds based on the City GIS layer for watersheds and sub-watersheds (see also Lawson and Clancy et. al, 2015). To organize the approach and sharpen our focus to an appropriate scale, each sub-watershed was then divided into stream reaches (twenty three reaches in total), which correspond to the 8.5x11-inch pages provided in the appendices below (Appendix I, Appendix II).

The sub-watersheds include:

- Lower Squalicum Creek (Reaches A-1, A-2, and D-1 –D-6)
- Lower Spring Creek (Reaches B-1, B-5, B-6 and D-1)
- Lower Baker Creek (Reaches C-1, C-4, and C-6 – C-8)
- Baker Creek Tributaries: Irongate and Telegraph Creeks (Reaches C-2, C-3, and C-5)
- Lower Toad Creek (Reaches D-7 – D-9)

After thorough desktop evaluation of the surficial geology and geomorphic characteristics of each sub-watershed, stream reaches with potential for active hydrology were evaluated in the field. To the extent feasible, additional factors that influence channel migration processes within the CMZ such as hydrology (flow), vegetative cover (bank stability), and erosion potential (erodability) were also evaluated using the methods provided below.

1.3 Assumptions and Limitations

The study included field and desktop mapping of lateral erosion hazard areas and geotechnical hazards, as well as evaluation of avulsion hazard potential within the study area. Subsequent delineation of Erosion Setbacks (ES) and Geotechnical Setbacks (GS), integration of these setbacks into the Erosion Hazard Area, and final delineation of the CMZ and Detached (syn. "Disconnected") Migration Area (DMA) were performed with respect to a 100-year planning period. The study assumes that qualitative erosion rates and processes observed in the past century will continue to occur at similar rates in the future. However, the potential exists for catastrophic or rapid changes to occur due to infrequent, episodic, or unpredictable events, including but not limited to large woody debris jams, catastrophic floods, landslides, earthquakes, tectonic deformation, and changes in land use. Unexpected and catastrophic events can and do occur, and the substantial uncertainty regarding their frequency and magnitude render their occurrence beyond the scope of this evaluation and the accompanying deliverables. All maps should be considered "living" documents and should be regularly updated to accommodate changing natural conditions and urban development.

The following assumptions and/or limitations influenced our mapping of lateral erosion/avulsion susceptibility (or "erosion potential") and geotechnical hazard areas in the study area, and should be considered in all uses and applications of this technical report:

1. Lateral erosion and/or avulsion hazards, geotechnical hazards, and all associated setbacks were mapped without regard to any man-made structures that were not emplaced specifically to protect an actively used public road or existing infrastructure. In some instances, man-made features may increase the risk associated with geologic hazards if they were to fail or direct flow towards unstable banks or slopes. With the exception of the levee break avulsion hazard described later in this document, risk management related to the failure of man-made features (such as culverts, dams, bank armoring, etc.) is beyond the scope of this assessment, and potential hazards related to these types of failures were not specifically mapped or evaluated.

2. The Erosion Hazard Area (EHA) as defined in this analysis includes areas where erosion and associated slope processes are *possible* within a 100-year time frame; no statements herein are intended to express or imply knowledge or opinion regarding the *probability* that they will occur. The specific methodology used in this assessment to delineate the EHA is moderately conservative, meaning that more conservative and less conservative methodologies exist. No site-specific studies or probability analyses were performed for this determination.

3. Many flood hazard assessments, including FEMA base flood elevation (BFE) mapping, have historically focused only on the elevated water levels resulting from traditional overbank flooding. While the potential hazards resulting from this type of flooding can be severe, the additional flood hazards associated with rapid erosion, scour, and high velocity discharge

can be even greater and more destructive. The lateral erosion hazard potential in this assessment was estimated based upon average stream flow conditions, and the risks associated with these additional flood hazards are not specifically addressed. The technical report and accompanying figures should be used in conjunction with other hazard assessments and studies to make comprehensive planning decisions, assess risk, or guide additional studies.

4. The hazards mapped in this analysis were delineated subjectively without respect to any benchmark level of acceptable risk, and the resulting maps and figures should be considered a planning-level assessment tool. The mapping effort for this analysis was completed at a reach and sub-reach scale; therefore, site-specific investigation may still be necessary. Site-specific analyses should be performed for specific projects or wherever more detailed assessment is indicated.

5. No risk evaluation of specific identified hazards or calculation of multiple probabilities was performed for this assessment.

6. It is understood that changes in climate, hydrology, geology, sediment supply, woody debris occurrence and distribution, and human development will inevitably alter the behavior of the fluvial system in the future. The channel and stream response to these changes is difficult to predict over time, and no specific predictions regarding future channel or stream conditions are expressed or implied over the 100-year planning period.

    - Improvements in technology, new information, and evolving geologic interpretations may allow for more accurate mapping or a reinterpretation of mapped hazards in the future. Maps should be updated as new information and technology becomes available.

7. The hazards mapped for this analysis were limited to lateral erosion, avulsion, and/or geotechnical hazards in and adjacent to streams within the Squalicum Creek watershed. Other natural geologic hazards may exist within the study area, including but not limited to flooding, deep seated landslides, seismic and/or liquefaction hazards, tectonic deformation, and tsunamis.

1.3.1 Additional Field Limitations Due to Reach Access

In preparation for conducting this field assessment, we drafted the following letter to City of Bellingham residents living adjacent to the Squalicum Creek channel and associated tributaries:

Dear Resident of the Squalicum Creek Watershed,

We need your help! You are receiving this postcard because your property includes or is adjacent to Squalicum Creek, Baker Creek, Spring Creek, or one of their tributary streams. The City of Bellingham and its consultant (Element Solutions) will be conducting a Channel Migration study of streams in the Squalicum Creek Basin in order to assess regulatory and environmental conditions in one of Bellingham's most valuable aquatic resources. To accomplish this work, City designated representatives will be surveying streams in the Basin over the next few weeks and *may need to temporarily pass through your property via the stream during work hours from 7:00 am to 5:00 pm, Monday through Friday. The field surveyors will wear bright orange safety vests so that they are clearly visible, and will remain within or immediately adjacent to subject streams. We hold landowner privacy in the highest regard.*

If you would like to respond to this notice, have questions, or to declare that you take issue with this study please feel free to contact us at: info@elementsolutions.org or 360.671.9172
If you are not the owner of the property located at this address, please forward this information to the property owner or contact us at your earliest convenience. We appreciate your cooperation!

The letter was distributed to the owners of all properties abutting or adjacent to the subject stream channels in which fieldwork was planned to occur. Few comments were submitted in reply, however. Throughout the course of our work, we received only two responses denying access to the stream channel adjacent to the responder's property. Due to these responses and various other factors limiting access, we were unable to collect field data in some stream segments. In addition to landowner participation issues, other reaches, either in whole or in part, were not evaluated due to one or more of the following factors: limited site access due to prohibitively high water; dense blackberry overgrowth; and artificial urban watercourses comprised of culverts, ditches, and/or extensive underground piping, which essentially prohibited natural geomorphic processes from occurring in the stream segment and negated the purpose of field analysis.

The following reaches were included in the GIS analyses but do not have corresponding field data:

- Reaches B-1 through B-3(Urbanized)
- Reach B-4 (Large wetland preventing access)
- Reach B-6 (Landowner participation)
- Reach C-1 (Urbanized)
- Reaches C-3 and C-5 (Time constraints)
- Reach D-7 (Landowner participation)

2 Regulatory Function and Context

The Shoreline Master Plan (SMP) and Critical Areas Ordinance (CAO) update in 2005 were the catalyst for the development of a regulatory CMZ in the City of Bellingham. However, the concept of a CMZ is rooted in multiple management plans, acts, and regulations, such as:

- Shoreline Management Act (SMA): *"Applicable shoreline master programs should include provisions to limit development and shoreline modifications that would result in interference with the process of channel migration that may cause significant adverse impacts to property or public improvements and or result in a net loss of ecological functions associated with the rivers and streams"* (Chapter 173-26 WAC, 58).

- Growth Management Act (GMA): Critical Areas - RCW. 36.70A.030 (5).

- Endangered Species Act (ESA): Limit 12 of the 4(d) Rule requires the delineation of a CMZ.

- National Flood Insurance Act (NFIA) supports the delineation of a CMZ to manage flood hazards and reduce flood damages. Ecology encourages “meander belt” delineation for Comprehensive Flood Hazard Management Plans.

- WAC 173-26-221(3)(b) Principles. *“Flooding of rivers, streams, and other shorelines is a natural process that is affected by factors and land uses occurring throughout the watershed. Past land use practices have disrupted hydrological processes and increased the rate and volume of runoff, thereby exacerbating flood hazards and reducing ecological functions. Flood hazard reduction measures are most effective when integrated into comprehensive strategies that recognize the natural hydrogeological and biological processes of water bodies. Over the long term, the most effective means of flood hazard reduction is to prevent or remove development in flood-prone areas, to manage storm water within the flood plain, and to maintain or restore river and stream system's natural hydrological and geomorphological processes.”*

2.1 Delineation Guidance

In general terms, the combined historic migration zone, erosion hazard area, and avulsion hazard zone is “the geographic area where a stream or river has been and will be susceptible to channel erosion and/or channel occupation” (*Rapp et al*, 2003). In [WAC 173-26-221(2)(c)(iv)(3)(b)], the State of Washington describes this concept further as: “The dynamic physical processes of rivers, including the movement of water, sediment and wood, cause the river channel in some areas to move laterally, or ‘migrate,’ over time. This is a natural process in response to gravity and topography and allows the river to release energy and distribute its sediment load. The area within which a river channel is likely to move over a period of time is referred to as the CMZ or the ‘meander belt’.”

The State further establishes recommendations on how to delineate the historic migration zone and geologic hazard areas in [WAC 173-26-221(2)(c)(iv)(C)(3)(b)]: “For management purposes, the extent of likely migration along a stream reach can be identified using evidence of active stream channel movement over the past one hundred years. Evidence of active movement can be provided from historic and current aerial photos and maps and may require field analysis of specific channel and valley bottom characteristics in some cases. A time frame of one hundred years was chosen because aerial photos, maps and field evidence can be used to evaluate movement in this time frame.” In addition to the State recommendation of using the 100-year migration potential, FEMA also recommends developing channel migration zones that predict (estimate) 100-year migration potential.

The CMZ can be used to plan for or assess public safety hazards (risk to life/property), economic costs (cost/benefit analysis), and ecological function, particularly with respect to salmon recovery efforts. The CMZ can also be used for regulatory purposes (CAO and SMP) to lessen future risk. The State describes this concept in [WAC 173-26-221(2)(c)(iv)(C)(3)(b)]: “Scientific examination as well as experience has demonstrated that interference with this natural process often has unintended consequences for human users of the river and its valley such as increased or changed flood, sedimentation and erosion patterns. It also has adverse effects on fish and wildlife through loss of critical habitat for river and riparian dependent species. Failing to recognize the process often leads to damage to, or loss of, structures and threats to life safety."

2.2 Definitions

Although the CMZ parameters are repeatedly defined throughout this report, we provide the following commonly used terms as a reference:

The **Channel Migration Zone (CMZ)** is defined by Ecology as the "area within which a stream channel has historically occupied or may occupy in the future". Ecology guidance defines the CMZ as the cumulative areas of the Historic Migration Zone (HMZ), plus the Erosional Hazard Area (EHA), plus the Avulsion Hazard Area (AHZ), minus the Detached Migration Area (DMA), such that:

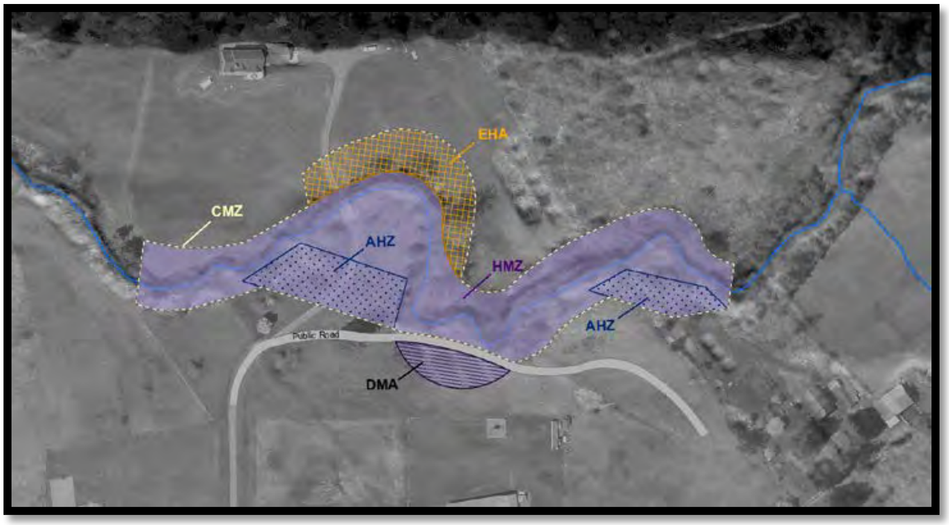
$$\mathbf{CMZ = HMZ + EHA + AHZ - DMA}$$

The **Historic Migration Zone (HMZ)** is a composite of the historic locations of the river over some length of historic record, as determined from historic information and topographic interpretation. The HMZ includes the area(s) in which stream processes could be identified from LiDAR and was used to define the lateral extent of a stream migration or alluvial plain/valley wall in the post glacial fluvial system. Due to the lack of detailed historical information for the study area, LiDAR was relied on for stream reaches where anthropogenic modification and/or urban development has obscured or reworked significant portions of the HMZ.

The term **Erosional Hazard Area (EHA)** refers to the hazards resulting the lateral migration of a channel by bank erosion. Bank erosion can occur from channel expansion, channel meandering, channel course changes, or channel bank slope failures related to fluvial bank undercutting. The term **Erosion Setback (ES)** refers to the mapped setback from the bank of an active stream. In this analysis, it is based upon the estimated rate of lateral stream bank erosion over the 100-year planning period. The EHA also includes the **Geotechnical Setback (GS)** which refers to the mapped setback from the crest of steep slopes whose stability could be influenced by stream erosion and/or channel migration over the 100-year planning period.

The term **Avulsion Hazard Zone (AHZ)** describes hazards associated with rapid changes of a particular stream channel that result in the formation of a new stream alignment and the abandonment of the former channel. This may occur at and around channel bends (meanders) in the form of chute cutoffs.

The **Detached Migration Area (DMA)** or Disconnected Migration Area refers to areas within the historic (unconstrained) CMZ where the potential for channel migration is severely restricted or eliminated by structural development, land use, and/or hydromodifications.



3 Geologic and Hydrogeologic Background

3.1 Quaternary Geology and Geomorphic Setting

Washington State Department of Natural Resources (WDNR) geologic maps indicate that the Squalicum Creek stream corridor predominantly traverses Pleistocene glacial stratigraphy, including Everson glaciomarine drift (see cover photo). Sumas glacial outwash deposits as well as occasional bedrock-controlled channel segments also occur in the northeastern quarter of the study area, where exposures Chuckanut Formation sandstone, siltstone, and/or conglomerate may exist at the surface. The existing surficial geomorphology in the study area has been shaped by a variety of geologic, environmental, and anthropogenic processes, including glacial deposition, extensive post-depositional reworking of glacial deposits and soils by hydrologic processes, regional uplift, and tectonic and volcanic activity. As with any dynamic earth system, some of these processes are ongoing, while others are subject to the cyclical and oscillatory variability associated with climate and geology.

The most recent glaciation in the Puget Lowland, known as the Fraser Glaciation, occurred during the Pleistocene epoch and includes several alternating periods of glacial advance and retreat, referred to respectively as stades and interstades. During the glacial maximum roughly 16,950 years ago, the Puget Lobe of the Cordilleran Ice Sheet occupied nearly the entire Puget Lowland and was greater than 1000 meters thick in many areas (Porter and Swanson, 1998). The study area is mantled with glaciomarine sediment from the Everson Interstade, and also includes small glacial outwash deposits from the Sumas Stade as well as beach and alluvial deposits from littoral sediment deposition during Holocene marine transgression (Lapen, 2000). The elevation of bedrock surfaces varies considerably across the Puget Lowland, which contributes to the variability in thickness and irregular distribution of overlying Pleistocene glacial deposits.

3.1.1 Everson Glaciomarine Drift

The Everson Interstade glaciomarine drift was deposited between 13,500 and 11,300 years ago, during a recessional period when marine waters invaded the study area and the primary sediment input was from floating glacial ice (Lapen, 2000). As the glaciers calved and ablated, melting glacial ice released predominantly fine grained sediment entrained in the ice into the marine waters, where it settled and was deposited as glaciomarine diamicton. While generally massive, the glaciomarine sediment deposits may exhibit localized stratification, sorting or cross-bedding, particularly where coarser sediment is encountered (Lapen, 2000). The deposits have been described as "distinctive blue-gray, fossiliferous, stony mud with till-like mixtures, marine clay, and some deltaic sand and gravel" (Easterbrook et. al., 2007; see cover photo). The unconsolidated, saturated, and fine-grained glaciomarine drift sediment has less shear strength when compared to compacted, clast-supported glacial deposits. The Everson Interstade glaciomarine deposits are subdivided into two member units separated by the Deming sand, a roughly 10 meter thick unit of subaerial, fluvial sands and gravels deposited during a potential brief regressive period (Easterbrook, 1963); the sand overlies Kulshan glaciomarine drift and underlies Bellingham glaciomarine drift, which share common sediment sources and depositional environments but differ in stratigraphic sequencing.

3.1.2 Sumas Outwash

Following glacial recession during the Everson Interstade, glacial advance during the Sumas Stade resulted in the localized incision of the underlying glacial sequence by meltwater channels and the deposition of glacial outwash on top of Everson glaciomarine sediment (Bellingham member). Constrained to ages greater than 10,000 years B.P., the Sumas Stade deposits are the youngest glacial deposits mapped within the study area; they are described as "loose, moderately to well-sorted gravel with local boulders, sandy gravel, minor gravelly medium to coarse sand, and rare sand to silt" (Lapen, 2000). The outwash deposits occur in variable thicknesses across Whatcom County, ranging from 3 to 280 m (Lapen, 2000). Bedding is typically planar and well stratified. The deposits may be disconformable with Everson Interstade glaciomarine drift deposits, as the fluvial outwash channels often incised into or otherwise reworked the underlying glaciomarine drift plains.

3.2 Modern Fluvial Geomorphic Setting

The modern fluvial geomorphology of the Squalicum Creek CMZ study area is characterized by the interaction between anthropogenic modifications and ongoing natural processes, which uniquely shapes the channel morphology in both urban and unimproved stream segments. The Squalicum Creek mainstem and associated sub-watershed tributaries predominantly occupy relict glacial outwash channels, where rivers once drained meltwater from continental glacial ice. Following the retreat of the glaciers, vast outwash deposits and relict erosional features remained. During the Holocene, sea levels fell (regression), which promoted incision from channels that discharged into the sea; the modern stream channels within the study area are no exception, as evidence by the over-steepened banks and abandoned terraces that are encountered throughout the lower reaches. This incision resulted in a characteristic underfit (Sec. 3.4.5) alluvial plain that is particularly well represented in the lower mainstem of Squalicum Creek. Bank-face exposures throughout the study area often reveal thick sequences of soil derived from glacial drift material, and where native soil development is thin or absent, exposures of fine-grained, semi-consolidated glaciomarine diamicton are common, occasionally mantled by stratified, unconsolidated, and poorly-sorted sand, gravel, and cobble glacial outwash sediment. The relative erodability of these materials can vary considerably.

The prevalence of glacial outwash sediment in the channel bedload was noted in all sub-watersheds and was particularly ubiquitous in the lower reaches, where the winnowing effects of fluvial transport resulted in a gravel and cobble bed composition. Clastic outwash sediment was commonly observed in and downstream from transport reaches, where flow velocities were sufficient to erode and/or transport gravel-sized sediment; in contrast, stream segments with slow moving water and abundant pools functioned as fine-grained sediment traps, with a bed composition dominated by silt, clay, and organic detritus. A corresponding increase in water turbidity was observed in these stream segments. Pools or slack water segments were frequently observed either upstream or downstream from hydromodifications, where abrupt changes to channel morphology or flow regime (by constriction, re-route, or directional alteration) created conditions that supported the detention and/or impoundment of hydrology.

3.3 General Watershed Hydrogeology

The five sub-watersheds of the study area comprise most of the greater Squalicum Creek basin. The study area captures contributing drainage from sheet flow (runoff), groundwater, and direct precipitation across a drainage area of nearly 5,000 acres. Elevations range from approximately 445 feet (NAVD 88) at the southeastern extent of the study area southwest of Toad Lake to sea level near the outlet into Bellingham Bay near Roeder Avenue and Squalicum Way, a distance of roughly 6.5 stream miles (Figure 1).

During our preliminary assessment, we used the US Geological Survey (USGS) StreamStats (v 3.0) program to compute the basic hydrologic characteristics in each of the so-called sub-watersheds (Lawson and Clancy et. al, 2015). Due to extensive urbanization, StreamStats computed the prediction error to be approximately 50%. A reach-specific hydrologic analysis was completed to shed light on actual flow metrics; the methods describing the analysis and results are provided below (Sec. 4.4, Appendix II).

3.3.1 Lower Squalicum Creek Sub-Watershed

Lower Squalicum Creek can be geologically characterized as an under-fit stream (see Sec. 3.4.5 below) occupying a historic glacial outwash channel. The hydrologic functions of the stream are greatly influenced by this geomorphology where they are not restricted or otherwise controlled by anthropogenic modifications. According to StreamStats, the larger Squalicum Creek basin drains an area of approximately 13.3 mi^2 and has a mean annual precipitation of 40.7 inches. StreamStats also estimated peak-flow statistics to be 233 cubic feet per second (cfs) during a 2-year (PK2) period, and 407 cfs during a 10-year (PK10) period. A mean basin slope of 4.26% grade was computed from the 30-meter Digital Elevation Model [DEM]. Given these approximate parameters, the “Lower” Squalicum Creek sub-watershed can be characterized as a fourth-order low-gradient stream with a moderate amount of complexity. Stream braiding and off-channel formation does occur within the relict outwash channel, although much of the potential for lateral movement of the channel is reduced by extensive bank modifications. The ongoing Squalicum Creek Re-route Project will potentially restore many of these channel processes in affected areas. Bug Lake and Sunset Pond are two notable anthropogenic hydromodifications that have substantially changed the natural flow regime.

Near the mouth of Lower Squalicum Creek (Reaches A-1 and A-2, Appendix I), the stream can be characterized as an incised stream network has incised into Holocene deltaic and estuarine deposits as well as the underlying Pleistocene glaciomarine drift deposits. Once joined by its largest tributary Spring Creek, the lower sub-watershed becomes a fifth-order stream due to the increase in combined discharge. StreamStats was unable to calculate statistics for the entire sub-watershed due to the extent of urbanization; however, we hypothesize that flow values near the mouth would be similar to those presented above, with an anticipated increase in flow volumes downstream from the confluence with Spring Creek. Lateral movement of the channel has been restricted since the development of Squalicum Way, and the increased channelization has resulted in a corresponding increase in discharge within the stream segment.

3.3.2 Lower Spring Creek Sub-Watershed

The Lower Spring Creek basin is similar in size to the Baker Creek basin and both Baker and Spring Creeks share many common characteristics. For example, the both the Spring Creek basin and Baker Creek basin drain areas of less than 5 mi^2 (4.94 mi^2), and both share a similar estimated mean annual precipitation of 34.1 inches. Spring Creek differs from Baker Creek in that its average annual discharge is slightly larger, and as a fourth-order stream, Spring Creek has greater estimated peak flows. StreamStats estimates peak flows to be 75.4 cfs for PK2 and 132 cfs for PK10. In addition, at 3.03% grade the sub-watershed has a more gradual mean basin slope than its counterpart.

The hydrology of Lower Spring Creek has been greatly impacted by urbanization, particularly in the vicinity of commercial developments along the Meridian Street corridor. Much of the Lower Spring Creek channel has become so heavily armored that the potential for lateral movement is virtually non-existent; in other areas, streamflow has been routed away from the former active channel and is now conveyed by underground culverts and aqueducts. Furthermore, stream banks near the mouth of Spring Creek (managed by Bellingham Golf and Country Club) have been heavily armored to prevent bank erosion, with a corresponding decrease in the lateral movement potential of the stream channel.

3.3.3 Lower Baker Creek and Baker Creek Tributaries Sub-Watersheds

The Lower Baker Creek sub-watershed includes the smaller and largely fragmented and/or urbanized tributaries of Telegraph and Irongate Creeks. Baker Creek is a third-order stream, the headwaters of which lie northeast of the city limits. The larger Baker Creek basin drains approximately 4.08 mi^2 of land, with a mean slope-percent grade comparable to the Squalicum Creek main stem of 5.33%. As expected, mean annual precipitation is estimated to be 35.4 inches, which is more or less consistent with the other sub-watersheds given the estimated percent error of the StreamStats model. StreamStats also predicted PK2 and PK10 flows as 67.4 cfs and 118 cfs, respectively. Due to the substantial urbanization of the area, Baker Creek and its tributaries likely exhibit a "flashy" hydrologic regime, in which flow volume is largely influenced by precipitation and stormwater runoff from impervious surfaces routed into the channel by ditches and culverts. This hydrologic regime is associated with rapid-onset flooding events, which occur frequently in the Lower Baker Creek sub-watershed.

3.3.4 Lower Toad Creek Sub-Watershed

The Lower Toad Creek sub-watershed is part of the larger Squalicum Creek basin, but resembles a very different channel form due to its mean basin slope and stream order. Unlike the Squalicum Creek mainstem, Toad Creek resembles a headwater stream (first-order) which drains an area of less than 2.0 mi^2 and has a mean basin slope of 12.9% grade. StreamStats estimated mean annual precipitation to be 41.7 inches and peak-flow statistics to be only 46 cfs during a 2-year (PK2) period, and 82 cfs during a 10-year (PK10) period. Toad Creek is fed primarily by Toad Lake, and although stormwater management infrastructure does exist within the basin, the watercourse exhibits a flow regime that can be described as “natural” compared to other study streams. The banks of Toad Creek are largely composed of bedrock and/or consolidated glacial sediment deposits, resulting in stable to moderately stable stream banks.

3.4 Stream Channel Forms

During our preliminary field assessment of the Squalicum Creek basin, we identified five common geomorphic stream channel forms. These channel forms were used to help identify the dominant drivers and characteristics of channel migration in the field. After field data collection was completed, the observed channel forms were compared with collected and modeled hydrologic data to aid in evaluating erosion susceptibility and identify common or correlative trends within and between stream reaches. Examples of the identified characteristic geomorphic channel forms are shown below (Table 1).

3.4.1 Urban Stream Channel

Modified or urban stream channels are generally characterized by highly channelized, armored, or piped channel courses in which the stream channel position is fixed and channel migration processes such as lateral erosion and vertical incision are restricted by anthropogenic hydromodifications. Many stream segments with concrete retaining walls, culverts, flow control structures, or other modifications also exhibited reduced channel complexity and impaired habitat function. Several stream networks within the study area are highly urbanized, particularly tributaries within the Lower Spring and Lower Baker Creek sub-watersheds.

3.4.2 Emerging-Incised Stream Channel (High Incision)

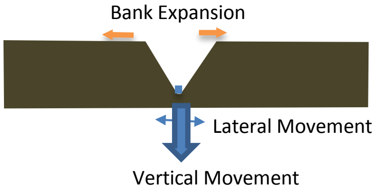
Highly incised or emerging-incised channels are typically characterized by steep sidewalls, attributable to rapid vertical channel incision. This channel form can arise naturally or as a channel response to hydromodifications. This channel form results in little to no alluvial plain and typically exhibits a fairly straight channel form. The steep bank gradient and hydraulic undercutting caused by ongoing vertical incision may result in bank slope failures, which cause stream banks to retreat during periods of elevated discharge and is often the catalyst for channel migration or avulsion in stream segments exhibiting this morphology.

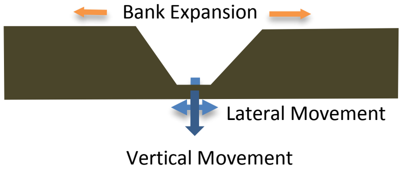
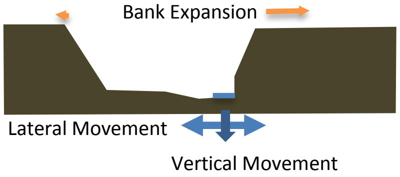
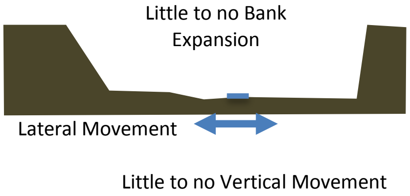
3.4.3 Immature-incised Stream Channel (Moderate Incision)

The immature-incised stream channel is characterized by moderately steep sidewalls and evidence of both vertical incision and lateral migration. This channel form evolved from an emerging-incised headwater stream and differs from the emerging-incised channel form in that a developing alluvial plain is often present. Channel length is also greater than in emerging headwater streams, as more active lateral migration processes promote increased sinuosity. Floodplains which develop as a result of this channel form are often constrained by the valley margin walls, and even frequently recurring floods have the potential to inundate the entire alluvial plain.

3.4.4 Mature-incised Wandering Stream Channel (Low Incision)

Channels characterized by mature-incised wandering streams have steep valley margin headwalls, broad and highly active lateral migration, and moderately-sized alluvial plains. This channel form can evolve from the immature-incised stream channel form, although mature-incised stream types typically exhibit substantially greater rates of lateral migration than vertical incision. The channel type forms a broad alluvial valley, resulting in an expansive floodplain in which only large floods have the potential to inundate the entire alluvial plain between both valley walls. In addition, channel length and sinuosity are greater than that of immature-incised stream types due to the greater valley width. Valley expansion tends to be a localized occurrence, as lateral migration predominantly occurs within the alluvial plain rather than at the valley margin. In mature-incised stream channel types, bank slope also tends to be less than in immature-incised headwater streams.

Channel Form	Stream Characteristics	Channel Migration
Urban Stream Channel 	• Hydromodifications (riprap, culvert or conveyance infrastructure, etc.) • Ditched or artificially channelized and armored	Fluvial processes and channel migration processes non-existent or severely impaired.
Emerging-incised Stream Channel (High Incision) 	• Over-steepened profile • “V” shaped cross section • Steep banks • Constricted or non-existent alluvial plain • Regular bank retreat	Channel migration processes driven by both vertical incision and lateral channel migration. Rate of bank retreat from mass-wasting processes is slower overall and more localized.

Immature-incised Stream Channel (Moderate Incision)  	• Less steep profile • Decreased "V" shaped cross section with a narrow alluvial plain • Reduced bank slope • Less uniform bank expansion	Channel migration process is driven by both vertical incision and lateral channel migration. Rate of bank retreat from colluvial or landslide hill-slope processes is slower overall and more localized.
Mature-incised Wandering Stream Channel (Low Incision)  	• Reduced channel profile • Broader alluvial plain • Locally steep banks present, but banks more gently graded overall • Localized bank retreat w/ greater spatial and temporal variability	Channel migration is primarily horizontal with less vertical incision. Bank retreat predominantly attributable to concentrated stream erosion, associated mass-wasting processes occurs less frequently.
Under-fit Stream Channel  	• Broad alluvial plain • Locally steep banks, infrequent erosion into bank • Lacks bank expansion and vertical incision; deposition and aggradation more prevalent	Channel migration is lateral across a broad alluvial valley; bank retreat attributable to mass-wasting processes is relatively slow.

3.4.5 Under-fit Stream Channel

Under-fit stream channels typically contain low gradient streams; in this study, all under-fit streams exist within relict glacial outwash channels, such as upper Squalicum Creek in the Squalicum Creek sub-watershed. An under-fit stream exhibits a characteristic morphology in which the channel is incised within a much larger ancestral stream channel and terrace network. This condition is common in former glacial outwash channels, where the dramatic reduction in hydrology associated with the melting of the continental ice sheet allowed channels once fed by glacial meltwater to be occupied by tributaries fed by local surface and groundwater inputs.

4 Methodology

The methods implemented in our study to delineate the CMZ for regulatory and restoration planning purposes generally utilized the methodologies and guidelines developed by Ecology (Rapp and Abbe, 2003; Ecology, 2014). Ecology's *A Framework for Delineating Channel Migration Zones* (2003) was the general guideline used to develop the Historic Migration Zone

(HMZ), Erosion Hazard Area (EHA), and Avulsion Hazard Zone (AHZ) areas. A concise summary of the Ecology methods used to delineate Channel Migration Zones is as follows:

Equation 1. $CMZ = (HMZ + EHA + AHZ) - DMA$

For our GIS analyses and the equation above:

- The **HMZ** was delineated using historical spatial information (maps, air photos, survey records, and LiDAR). Because it was difficult to discern natural channel locations from historical air photos due to the extent of channel modifications in the available historical record, we relied heavily on the LiDAR topography to interpret historic channel occupied areas.

- The **EHA** is the potential estimated extent of lateral channel migration due to bank erosion. Lateral erosion is not necessarily limited to the floodplain or areas inundated during a 100-year flood event. For this study geotechnical hazards related to fluvial processes are incorporated into the EHA, and are shown as an overlay on the accompanying maps and figures.

- The **AHZ** is defined as areas where rapid channel abandonment (avulsion) and reoccupation or capture of a relict channel or topographic low within the floodplain is possible or likely. The AHZ also includes areas where flooding can result in temporary channelized flows outside of the main channel, such as a levee or dam breach.

- The **DMA** includes areas within the HMZ that are removed from potential channel occupation because of existing infrastructure and/or structural development. Particular attention was given to DMAs identified as potential restoration areas or where private structures and/or roadways had been constructed within the DMA.

The erosion and avulsion hazards analysis “takes into account trends in channel movement, context of disturbance history and changes in boundary conditions, as well as topography, bank erodibility, hydrology, sediment supply and woody debris loading” (Rapp et al, 2003). It predicts possible hazard areas based on contemporary and historic observations of ongoing fluvial processes.

4.1 Data and Conceptual Modeling

The Squalicum CMZ study began with a characterization the geologic and geomorphic conditions influencing channel migration, which preceded an extensive desktop and field evaluation of the potential for erosion, avulsion, and hillslope (geotechnical) processes and hazards to impact areas adjacent to the stream within a 100-year time frame. The ultimate goal of each of the analyses was to map historic channel locations and identify potential erosion and avulsion hazard areas. Many challenges were encountered in the historical aerial photo analysis, such as disturbed conditions prior to the earliest air photo and vegetative cover obscuring the channel locations; therefore, our study relied heavily upon existing remote sensing imagery, particularly the 2013 Bellingham LiDAR Digital Elevation Model (DEM). We also integrated previous studies, existing field data, and peer-reviewed literature into our analysis; field verification of existing conditions within the Squalicum mainstem as well as Baker and Spring Creeks was also conducted where appropriate, per the project scope and final work plan. After the field mapping was completed, digital mapping of channel forms and stream attributes was performed using the ESRI ArcGIS platform. The resulting geodatabase and associated geospatial feature class data was digitized in the NAD 1983 State Plane Washington North FIPS 4601 (US Feet) coordinate system. Project execution began with an extensive evaluation of existing data following a July 21, 2015 kickoff meeting and contract execution in October 30, 2015. A detailed work plan was collectively developed by representatives from the City and the consulting team.

4.2 Preliminary Desktop Analysis and GIS Assessment

CMZ characterization began to develop in the initial GIS assessment and was continually updated based on new findings and field evaluations. In general, the desktop analyses included:

1. **Study Area Delineation**. This delineation was completed by isolating the Squalicum Creek channel and dividing it into sub-watersheds. The study area was delineated using existing stream data provided by the City of Bellingham and the *Bellingham Habitat Restoration Technical Assessment* (Lawson and Clancy et. al, 2015). The network of streams and tributaries was then clipped in ArcGIS based on the City of Bellingham boundary and Urban Growth Area (2012).

2. **Study Area Buffer Creation**. The Channel Migration Zone study area was buffered in ArcGIS to a distance of 200 feet on both sides of the stream centerline. This distance was determined by the hydrology team as an appropriate distance for applying the project scope.

3. **Topographical Assessment**. Two-foot elevation contours were created in ArcGIS 3D Analyst. The source file for elevation contours is the mosaic dataset *HFBE Shaded Relief* and *DEM,* provided by the City of Bellingham (COB 2013).

4. **Reach Delineation**. Stream reaches were divided into 1:4,860-scale sections, such that each section fit onto an 8.5x11-inch sheet of printer paper for field mapping. Each section was subsequently evaluated with regard to channel form type and migration processes (Section 3.4 above). In addition, a slope analysis was performed using 3D Analyst in ArcGIS and City of Bellingham Digital Elevation Model (DEM) data, providing graduated ranges of elevation.

5. **Vegetation Assessment**. Vegetation categories including grasses, immature, mature and urban were identified as representative of the project area by the hydrology team. The study area was delineated according to these vegetation categories using 2013 aerial imagery and local knowledge of the stream drainage area and geographic features. A more detailed qualitative study was also conducted during field analyses, which involved implementing several vegetative cover plots per section (Sec. 4.3.3).

4.3 Erosion Hazard Area – Erosion and Geotechnical Setbacks

The Squalicum EHA was mapped in accordance with Washington State Department of Ecology methodology, whereby the EHA is developed by integrating stream bank Erosion Setbacks (ES) with any adjacent Geotechnical Setbacks (GS). According to these methods, the ES is determined empirically from measurements of bank erosion over time taken at representative transects along a stream reach. The average amount of time it takes for a channel meander to migrate downstream is integrated with the time it takes for the channel to move from one side of the valley bottom to another. The resulting value (a given distance per year) is then multiplied by the planning period (design life of the CMZ) to calculate the ES. In order for this methodology to be applied to given stream segment, historical aerial photographs and/or a robust survey and mapping record is a requirement. Unfortunately, the lack of such a detailed historical record in the study area precluded a quantitative approach for estimating erosion rates. Instead, a conservative methodology based upon qualitative field observations of sedimentological and botanical (particularly bank-face vegetation) evidence as well as channel and bank morphology, bank composition, and other field indicators of scour and/or mass wasting processes was used to map the ES in the study area.

The greatest estimated lateral erosion rates hypothesized at two or more representative locations in a given geomorphic stream segment were then extrapolated to characterize the entire segment. The delineated ES reflects potential lateral erosion rates over a 100-year planning period ranging from 50 feet (average of 6-inches of lateral erosion potential per year) in geomorphic stream segments with relatively low potential for significant bank erosion to 100 feet (average of 1-foot of lateral erosion potential per year) in stream segments where the observed channel characteristics suggest greater potential for lateral erosion over the planning period. Wherever the ES contacts an adjacent GS, the EHA was expanded to include the entire affected area and the more conservative (greater) setback was adopted. This includes areas where future channel migration could result in interaction between the ES and GS, such as where a given stream segment is separated from nearby steep slopes by an erodible alluvial terrace. Although the channel may not be presently eroding the toe of the nearby steep slope, in many cases such a scenario could potentially occur within the planning period due to future channel migration.

4.4 CMZ Field Methods

Although standard field methods for basin-wide characterization of the CMZ have not yet been developed, there are well-established state and federal protocols for conducting stream assessments at a basin-wide scale. Our field methods were based upon adapted US Environmental Protection Agency (USEPA) Environmental Monitoring and Assessment Program (EMAP) rapid assessment protocols, which have been successfully implemented by multiple jurisdictions to achieve various scientific goals. Although these methods are often used to characterize in-stream habitat or perform assessments of water quality, there is great applicability to basic analyses of geomorphology and hydrologic processes. In order to reframe the EMAP methods into a geologic context, *A Methodology for Delineating Planning-level Channel Migration Zones* (Ecology, 2015) was used to help create applicable field methods for identifying CMZ characteristics.

Due to the prevalence of hydromodifications throughout the Squalicum Creek watershed, we used a “targeted-reach” approach in which highly constricted channel segments (i.e. the drainage ditch adjacent to Meridian Street) were excluded. Using LiDAR imagery, we were able to group stream segments based on geologic features (i.e. the glacial outwash channel underlying Lower Squalicum Creek).

4.4.1 **General Data Collection Protocols**

Squalicum Creek and its tributaries were divided into stream sections of various lengths, typically ~3,500 feet on average, (Figure 2) which were then transposed onto 8.5x11-in sheets at a 1:4,860 scale. Each reach was then labeled with a coded identifier (A-1, A-2, A-3, etc.; B-1, B-2, B-3, etc.) based on the tributary (i.e. Baker Creek, Spring Creek, or the Squalicum Creek mainstem) and the order in which it was to be surveyed. Using LiDAR and aerial imagery of each stream reach as a guide, surveyors collected geomorphic data *in situ* using corresponding 8.5x11-in mylar sheets while traveling upstream. Areas exhibiting qualifying characteristics of HMZs, EHAs, and AHZs were noted and marked with a Garmin GPS (60CSx), while a qualitative assessment of stream bank erosion susceptibility (low, moderate, severe, or armored) was performed by shading bank segments on the mylar sheets to indicate the appropriate classification (Appendix IV).

In addition to bank erosion susceptibility data, surveyors also collected data at stream transects via modified field forms (adapted from *A Methodology for Delineating Planning-level Channel Migration Zones* [Ecology, 2015]; [Appendix IV]). For each target reach, transects were generated by ArcGIS at 500 foot intervals on the existing Squalicum Creek polyline, creating approximately 6-8 transects per reach. At each transect, surveyors collected bankfull width (Bf_w) and bankfull height (Bf_h) in order to model average stream velocity (and discern to what extent it influences erosion susceptibility). Surveyors also collected data for bank composition (dominant and subdominant substrate size: sand/silt, clay, gravel, cobble, boulder, etc.) and vegetative cover, as it relates to bank stability at each transect and "half-transect" (every 250ft).

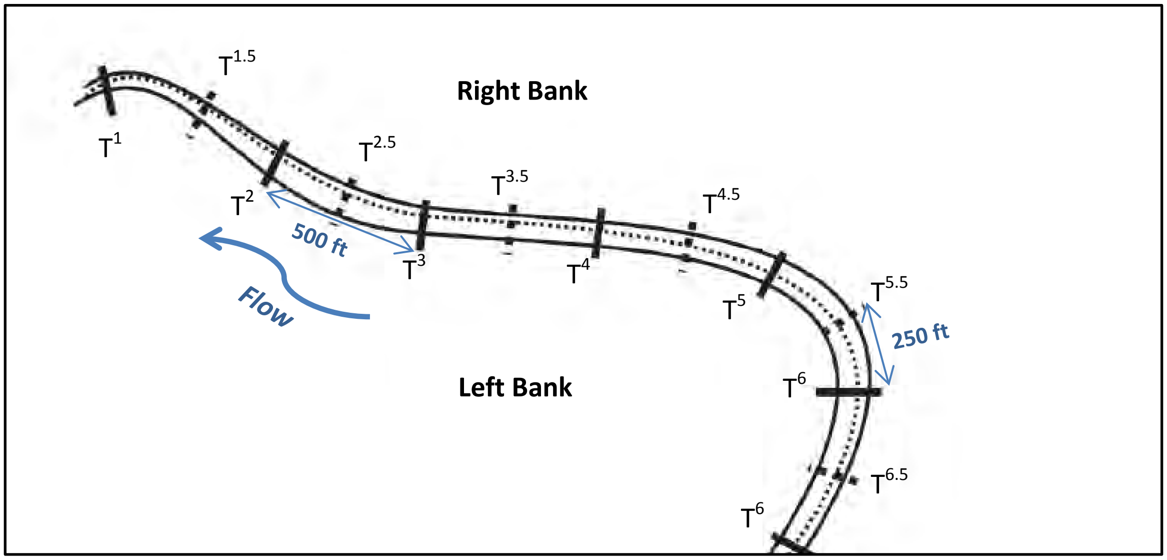


Figure 2. Reach layout geometry for field data collection of bankfull measurements, bank composition and vegetative cover. *Reach Transects (500-ft apart) are denoted by "T" with whole number superscript, while "half transects" (between transects at 250-ft) are denoted by the previous transect number plus 0.5 superscript. Vegetative cover plots (qualitative % cover per vegetative layer) consist of a rectangular area, 250-ft in length and a width equal to the bankfull width (Bf_w) plus 50-ft landward of Bf_w from the left and right banks respectively.*

4.4.2 Field Evaluation of Bank Erosion Susceptibility

Bank erosion was evaluated during the field mapping exercise and categorized as low, moderate, severe, or armored in accordance with the following classification scheme (Table 3). With the exception of armored bank surfaces, each field mapping determination relied upon the presence of at least three of the defined qualifying indicators to support the classification. Where evidence for two disparate ratings was encountered, or the site was determined to be "actively eroding" the more conservative (severe) rating was assigned.

The color scheme in Table 3 below corresponds to the mapped bank conditions in Appendix II. So-called "actively eroding" determinations for bank erosion susceptibility are identified by red shading, which corresponds to areas rated as "severe".

4.4.3 Vegetative Cover Assessment

Vegetative cover plots (Figure 2) were created to give a qualitative assessment of percent cover per vegetative layer, i.e. herb, shrub, and tree (canopy) layers. To rapidly gather vegetative cover data, surveyors would often stand at the center of each plot (between half and full transects) and assess cover on the left and right banks. Percent cover was estimated per layer, each layer having a maximum of 100% cover. On the field data sheets, surveyors used "slash" shorthand to ease data collection; therefore, a bank that was very sparsely vegetated in the herb layer with a moderate amount of shrubs and a dense canopy of trees might be represented as: 2%/35%/80%, or simply 2/35/80.

Table 3. Bank Erosion Field Classification System

Bank Erosion Susceptibility Rating	***Qualifying Indicators***
Armored	• Anthropogenic alterations of bank surface present; may include rock/rip-rap, wood, concrete, or metal armoring.
Low	• Bank composed of competent material (consolidated or semi-consolidated sediment, cobbles, bedrock, etc.); • No evidence of active scour or recent, historical, or ongoing mass wasting; • Bank surfaces contain established vegetation; • Stream segment lacks hydrology and/or sinuosity to produce lateral erosion; • Bank surfaces do not exceed a 1:3 slope (33% grade).
Moderate	• Bank composed of erodible, semi-consolidated or unconsolidated material; • Some evidence of active scour and/or historical mass wasting; • Bank surface partially vegetated, some bare scoured

🟨	surfaces may be present; • Stream exhibits evidence of sufficient hydrology and/or sinuosity to erode and transport bank material; • Bank surfaces may reach and occasionally exceed 1:1 slope (100% grade).
🟥 **Severe (Actively Eroding)**	• Bank composed of erodible, semi-consolidated or unconsolidated material; • Abundant evidence of active scour and/or mass wasting; • Bank surface scoured and stripped of vegetation; • Stream exhibits evidence of sufficient hydrology and sinuosity to erode and transport bank material; • Bank surfaces exceed 1:1 slope (100% grade), vertical banks common.

4.5 Hydrology Assessment and Manning's Equation

Stream hydrology in the Squalicum Creek basin has been substantially modified by stormwater management infrastructure and urbanization, and even natural streamflow characteristics can be difficult to accurately model. However, using open-source online tools such as StreamStats (USGS), Manning's Equation (Equation 2), and an existing hydrologic model for calculating open-channel flow (O'Shae, NRCS), we were able to estimate average bankfull flow characteristics in reaches where field data was collected (Appendix II).

Equation 2.

$$Q = \frac{k}{n} A R_h^{\frac{2}{3}} \sqrt{S}$$

For our analysis the values in Manning's equation above represent:

- ***Q*** is the estimated flow rate (ft^3/s, [cfs]).
- ***n*** is the Manning's roughness coefficient determined to be between 0.027 and 0.030 in Squalicum Creek (Barnes, 1967).
- ***A*** is the cross-sectional area, or flow area (ft^2), interpreted as an average value derived from the field collected Bf_w and $Bf_{h.}$
- ***R_h*** is the hydraulic radius (ft), which for this analysis was generated by imputing field data into an existing hydrologic model (O'Shae, NRCS).
- ***S*** is the slope of the hydraulic grade line, which was estimated in each reach from the LiDAR imagery.
- ***k*** is equal to 1.486, a conversion factor between SI and English units.

From the open-channel flow model (O'Shea, NRCS), we input our average values for Bf_w and Bf_h and estimate bankfull flow (cfs) using simplified parameters for average bank slope. Estimates of the hydrologic grade (***S***) were calculated using the change in height from reach beginning and reach end (via the DEM) and a line of best-fit parallel to reach length. For Manning's roughness coefficient (***n*** or sometimes N) we referenced *Roughness Characteristics of Natural Channels*

(Barnes, 1967) and determined that the roughness coefficient was between 0.027 and 0.030 for all reaches. After inputting the values above, the model computed values for the wetted width, wetted perimeter, and the hydraulic radius (all in feet); as well as stream velocity (feet per second [fps]) and flow (cfs) for the minimum and maximum values for ***n*** (Appendix II).

4.6 Final CMZ Mapping

Final mapping of the erosion, avulsion, and geotechnical hazard potential was integrated with field mapping information and the desktop mapping effort. The final delineation relied on the following assumptions:

- A 100-year time frame was assumed with respect to erosion or avulsion hazard potential;
- Existing hydromodifications and infrastructure were assumed to have no influence on erosion or avulsion potential.

The EHA and DMA were digitized at 1:1,000 scale over the City of Bellingham's 2013 LiDAR mosaic, with an estimated accuracy of +/- 15ft. The HMZ and AHZ areas were determined to fall completely within the current Erosion Setback and were thus absorbed into the ES layer. A combination of analysis tools in ArcToolbox were utilized to isolate and merge overlapping polygons, ultimately producing a consolidated CMZ.

5 Results & Discussion

5.1 CMZ Maps

The CMZ for each study reach was delineated using the methods described above, spatially referenced field indicators, and the professional judgment of staff geologists and field scientists. In order to create a spatial representation of our analyses, we have attached two separate map books as appendices to this report: 1) *Appendix I – Proposed Regulatory CMZ Map Book* and 2) *Appendix II – CMZ Data Analysis Map Book*. Each page (or "reach map") in Appendix I shows the results of a concatenation of data layers displayed in corresponding reach map pages of Appendix II. Appendix II shows the summation of the data collected in the field data sheets (Appendix IV), as well as additional field data. The foundation for CMZ mapping began with the HMZ mapping and integrated the erosion and avulsion hazard areas as described below.

5.1.1 Bank Erosion Susceptibility (Erosion Hazard Areas - EHAs)

Erosion Setbacks (ESs)

Our field evaluation of bank erosion susceptibility (Sec. 4.3.2) was instrumental in informing our delineation of the ES and the greater EHA, which has numerous long-term planning and land use management applications. The regulatory EHA also includes the GS, which draws from a range of geomorphic slope stability indicators that are distinct and separate from the bank erosion susceptibility field classification system described above. For more information regarding the GS determination, please refer to Section 4.2.

Each of the "severe" bank erosion determinations (Appendix II) indicates either an area where bank erosion potential is high, or an area that can generally be described as "actively eroding". A planning-level value of 1 foot per year of erosion potential was determined for areas in which a "high erosion potential" was interpreted. Detailed site-specific analysis may demonstrate that values greater than or lesser than this planning-level value may occur. These determinations may also highlight reaches where bank stabilization efforts may be needed if risk is high. Areas demarcated "moderate" for bank erosion susceptibility were not immediately eroding at the time of the field analysis but they may have a relatively high potential for future erosion. A planning-level erosion rate of 0.5 feet per year was provided for high erosion potential in these areas. It is possible that the reaches where "moderate" areas are in abundance may be well suited for long-term stream restoration efforts under certain conditions. While "moderately" susceptible areas possess a few or many of the erosion factors described above (Table 2), they are also inherently less hazardous and more accessible than actively eroding areas and may be more conducive for large environmental engineering projects such as the ongoing Squalicum Creek Re-route Project.

Bank composition, which was described at each field transect, was another factor that helped to determine erosion susceptibility and where high banks were present, recommended geotechnical setbacks. Throughout Squalicum Creek and its tributaries, the dominant channel bank substrate was silt, sand, and gravel/cobble (outwash) or clay with variable abundances of gravel and/or cobble drop stones (glaciomarine drift). The distribution of these substrate types influences the relative rates of erosion across the basin. For example, glaciomarine drift, which is composed almost entirely of lean clay, is older and more cohesive than the unconsolidated sand, silt, and gravel associated with outwash deposits, and therefore is less prone to erosion and transport. Glaciomarine drift channel banks are denoted by “CL” (for clay) at reach transects in the field data sheets (Appendix IV).

Geotechnical Setback (GSs)

In the study area, where steep, actively eroding slopes composed of unconsolidated glacial sediment are the rule rather than the exception, Geotechnical Setbacks (GS) add a critical factor of safety to the delineated ES and capture potentially hazardous slopes within the EHA that could otherwise be overlooked during the CMZ determination. Geotechnical Setbacks (GS) of up to 100 feet from the crown (convex crest) of the slope were assigned to steep slopes equal to or greater than 30% grade located in and adjacent to the HMZ that also exhibited one or more of the following geomorphic characteristics:

1) Desktop and/or field indicators of historical, recent, or ongoing mass wasting processes, including erosion and slope retreat;
2) Desktop and/or field indicators of unstable topography, including but not limited to planar or convergent slopes, colluvial hollows, and arcuate (scallop-shaped) slopes with steep headwalls;
3) Potential for erosion at the toe of the slope by fluvial processes (channel migration) over the 100-year planning period;
4) Evidence of hydrology (natural seeps or springs, channelized surface runoff);
5) Permeable soils or sediment overlying impermeable sediment or bedrock.

Other factors that contributed to the GS determination included: Bank and slope height; bank and slope composition; vegetation; and adjacent land use. In the City of Bellingham, development in and around geologically hazardous areas is regulated under the Critical Areas Ordinance (BMC 16.55). The designated GS and EHA is intended to supplement rather than supplant the existing regulatory framework by highlighting areas where fluvial process occurring within the CMZ have potential to exacerbate, accelerate, or otherwise influence slope processes in and around regulated geologically hazardous areas.

<u>Other Factors Potentially Influencing Erosion Rates</u>

Vegetative Characteristics

The field evaluation of vegetative cover informed our determination of the erosion susceptibility of reach banks, especially in segments where susceptibility was high. In addition, the vegetative cover allowed for reach-wide averages for each stratum and each bank. For the most part, reach averages for percent cover reflected an overwhelming dominance of invasive species in vegetation plots; these species included Himalayan Blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), and reed canarygrass (*Phalaris arundinacea*). Where percent cover was greater than 80% in shrub and herbaceous layers (Appendix IV), this generally indicated that invasive species dominated the vegetative strata. In many cases a dominant invasive species may increase the long-term erosion susceptibility; for example the relict flood terraces in reaches A-1 and A-2 of Lower Squalicum Creek (Appendix II) are dominated by *R. armeniacus*, which forms dense mats that shade out other more robust trees and shrubs. *H. helix* and *P. arundinacea* were observed to be affecting the erosion susceptibility in a similar fashion, with the species having shallow root systems and invasive life-history strategies.

Hydrology Characteristics

In reaches where bankfull data was gathered, our modeled average flows were more or less consistent with USGS StreamStats-modeled PK10 flows. Although the modeled data (and modeled hydrologic data in general) can provide important information about average basin-wide characteristics, each has considerable margins of error. For example, an Ecology streamflow study conducted in Lower Squalicum Creek (Springer, 2009) indicated that flows were between 0 – 265 cfs throughout the period of record, 10/1/2008 – 1/8/2009. When compared to our bankfull-estimated flows, we would expect to see values near the upper limit of this range; however, average bankfull flows estimated for reach A-1 using the O'Shae model yielded 460 cfs (for a high *n* value). It is important to note that average flow and average bankfull flow (flows at flood stage) are two separate variables, and we would generally expect bankfull flows to be somewhat greater than average flows. We surmise, however, that our estimated values for bankfull flow (which should be between the PK2 and PK10 flows calculated by StreamStats) are at least slightly greater than actual flow, and most closely resemble flows in a 10-year flood event.

The greatest potential for error most likely resulted from field approximations of bankfull height. Surveyors must rely on context clues, such as debris piles, vegetation, and qualitative criteria, to determine bankfull height, and these criteria are more obvious during PK10 events. Moreover, when modeling average bankfull flow, we used a simplified trapezoidal geometry to estimate the hydraulic radius, whereas we would expect stream banks to resemble a variety of channel forms.

Given that our estimated bankfull flow most likely resembles PK10 flows, we can view this data in the context of the CMZ such that in reaches with greater "bankfull flows" there is greater potential for erosion during PK10 events, especially where erosion susceptibility is "severe". In many areas, erosion rates could be reduced considerably by providing increased floodplain accessibility and connectivity.

5.1.2 Avulsion Hazard Zones (AHZs)

As a predominantly low-gradient incised stream whose channel occupies a highly modified urban corridor across much of the study area, the Squalicum CMZ contains no true AHZs (Sec. 1.5). By definition, AHZs include "secondary channels, relic channels, and swales, that are at risk of channel occupation outside of the HMZ" (Abbe and Cygnia, 2003). Although some hydraulic connectivity with relic channel forms (in the form of backwater channels) was observed in the lower reaches of Squalicum Creek, these areas were well within the HMZ, as defined in Section 4. While a rapid geomorphic channel response to extreme flood conditions such as those encountered during a 100-year event could conceivably result in the reactivation of relic channels and the development of new channel forms within the Squalicum Creek alluvial plain, it is unlikely that such an event would result in any permanent alteration of the prevailing channel alignment beyond the HMZ in a manner consistent with channel avulsion. Channel confinement resulting from deep historical vertical incision is evident in much of the study area, and the topographic isolation of adjacent relic stream terraces further inhibits the potential for AHZ development.

5.1.3 Detached Migration Areas (DMAs)

The DMA is a non-technical, policy based area. Depending upon the criteria used for generating a DMA, Squalicum CMZ may contain numerous Detached (or “Disconnected”) Migration Areas (DMA) or none at all, as is the legacy of over 100 years of anthropogenic stream channel modification and urban development. The purpose of the DMA mapping is to illustrate the extent of human encroachment on the historic CMZ for the purpose of identifying and spatially representing areas with potential for aquatic and/or riparian habitat restoration. The DMA delineation can also be a valuable tool for identifying man-made constraints on channel processes and for anticipating and avoiding land use conflicts when planning stream management or restoration actions. For the purpose of this analysis, all areas that have evidence of either having been an area of historic or geomorphic stream channel occupation or could be within an area of future channel occupation were included in the CMZ and no DMA criteria or exclusions were applied to the mapping provided in this analysis.

Closure

This report was submitted by:

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1084
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Exp. 05/21/2017

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Statement of Limitations

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6 References

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Appendix I – Proposed Regulatory CMZ Map Book

Squalicum Creek
Channel Migratioin Zone

1812 Cornwall Avenue
Bellingham, WA 98225
info@elementsolutions.org
Phone: 360.671.9172

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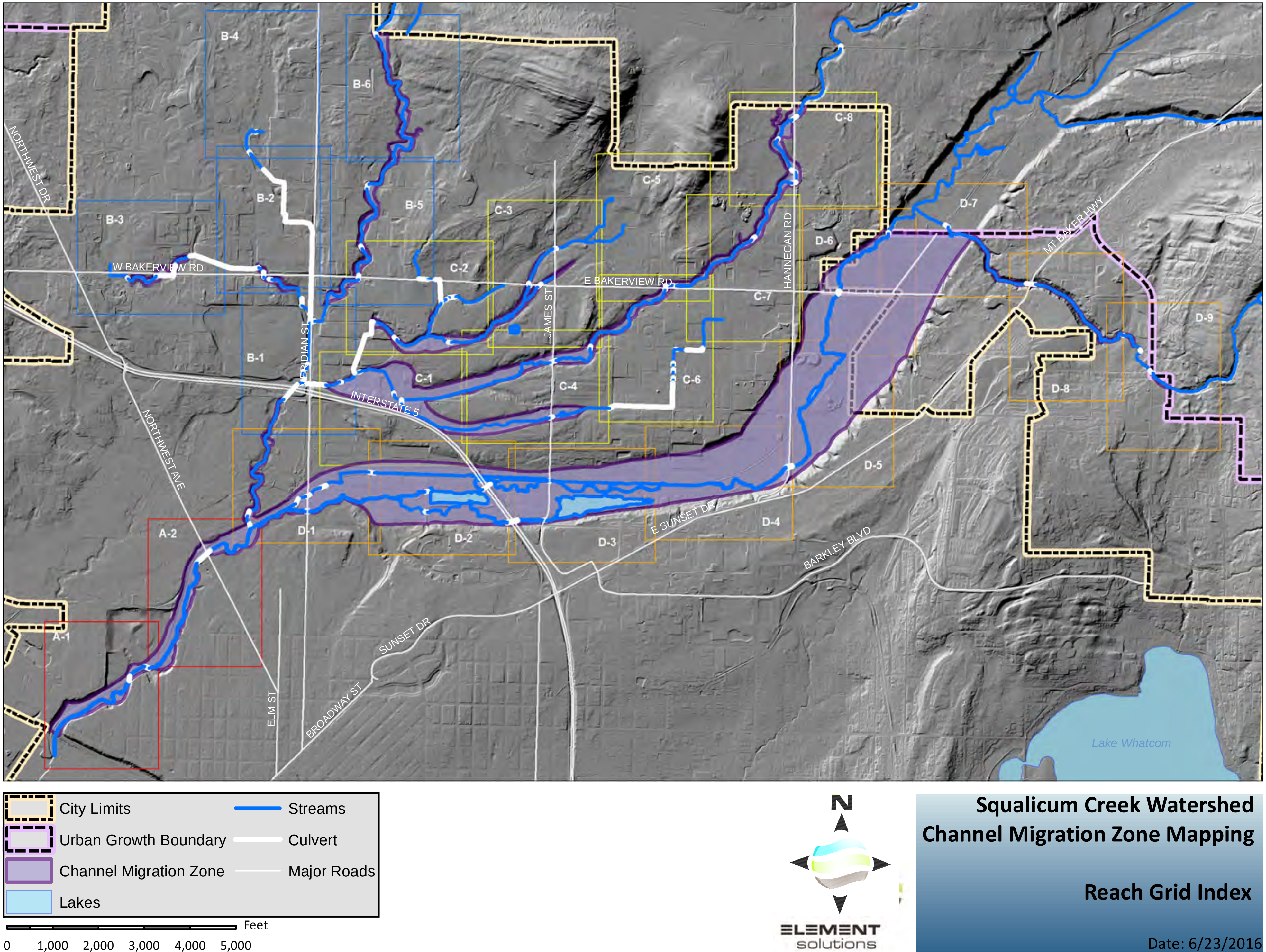
Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach Grid Index

Date: 6/23/2016



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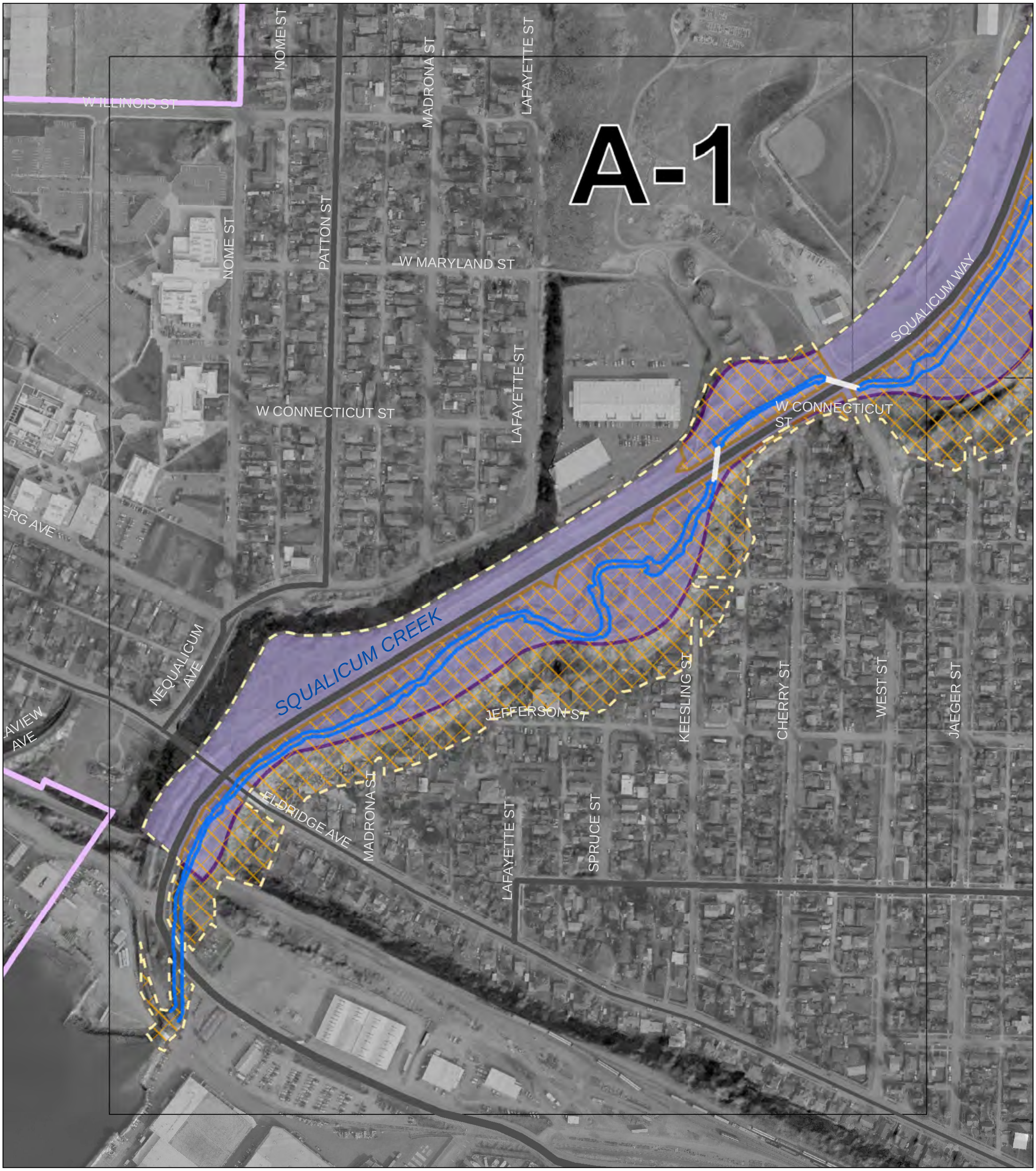

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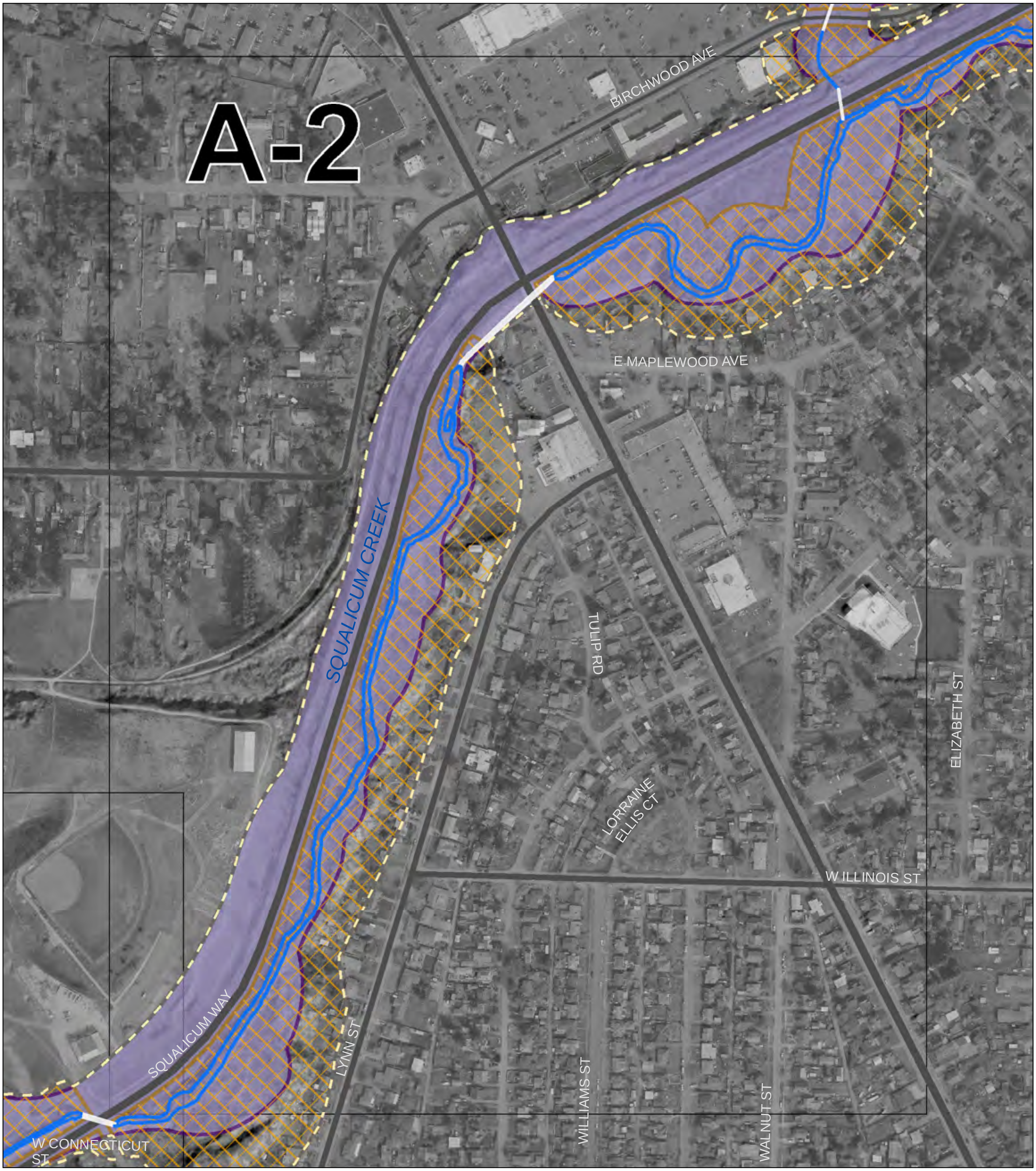
Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: A-1

Date: 9/7/2016



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Squalicum Creek Watershed Channel Migration Zone Mapping

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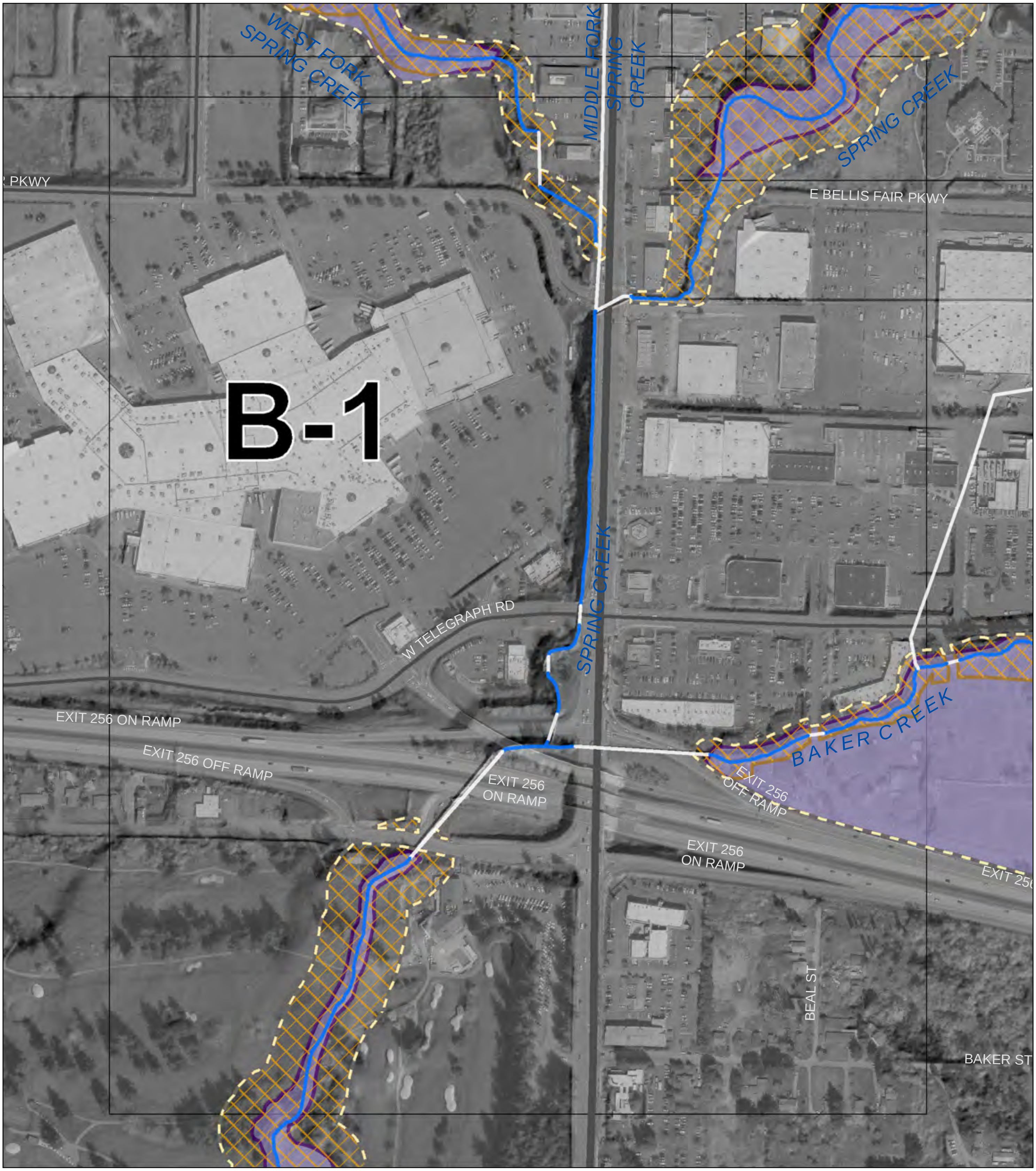
Date: 9/7/2016



Streams
Culvert
Lakes
Channel Migration Zone (CMZ)
Erosion Hazard Area (EHA)
Historic Migration Zone (HMZ)
City Boundary
Urban Growth Area

0 200 400 600 800 1,000 Feet

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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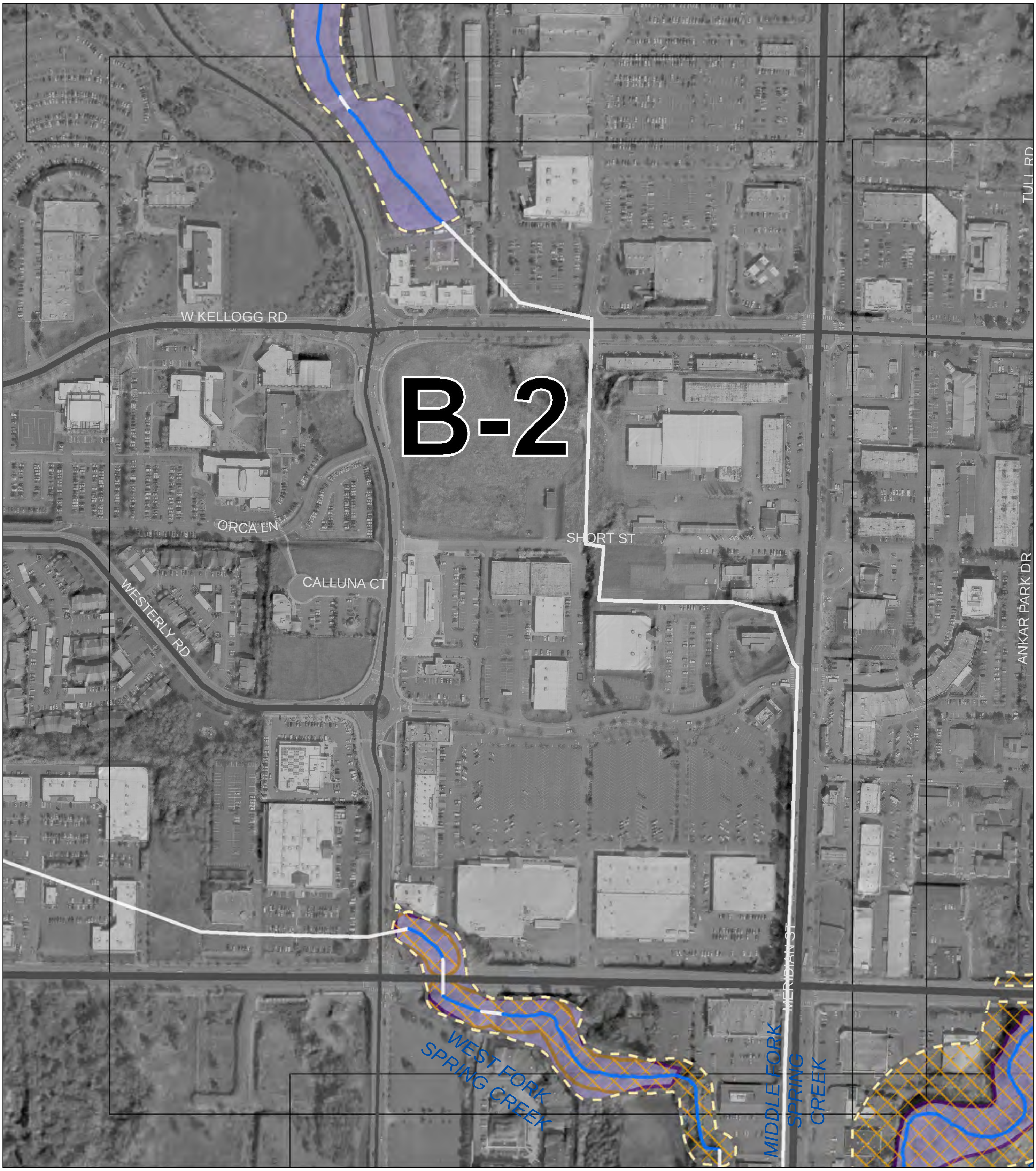

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▬	Culvert	▨	Erosion Hazard Area (EHA)
▭	Lakes	▭	Historic Migration Zone (HMZ)
		▭	City Boundary
		▭	Urban Growth Area

0 200 400 600 800 1,000 Feet

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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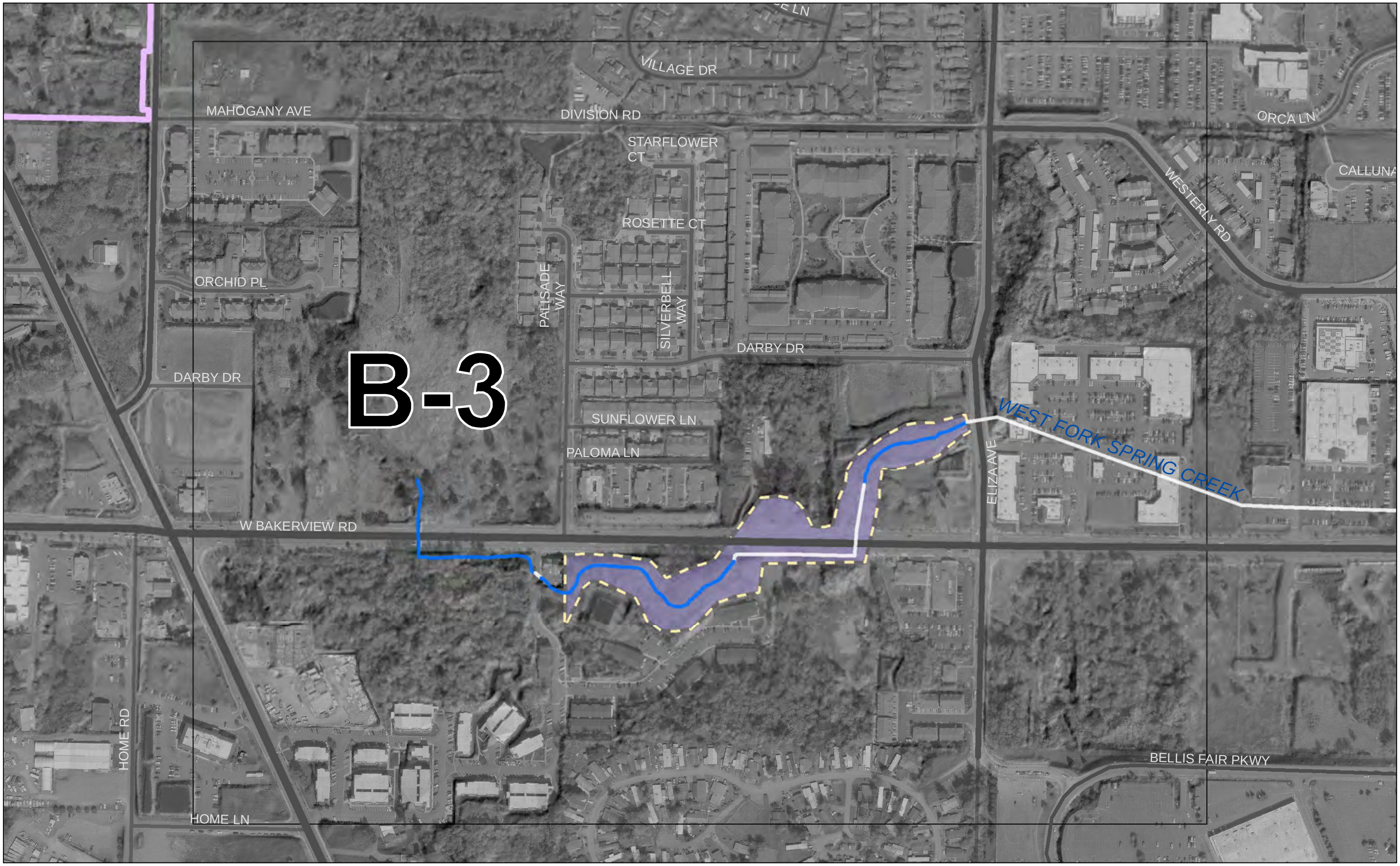

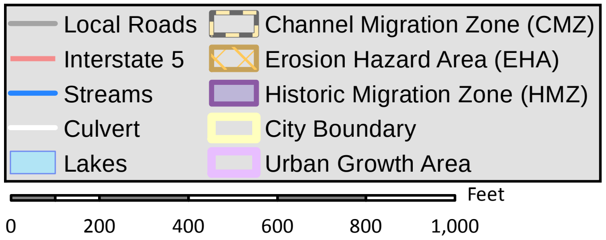

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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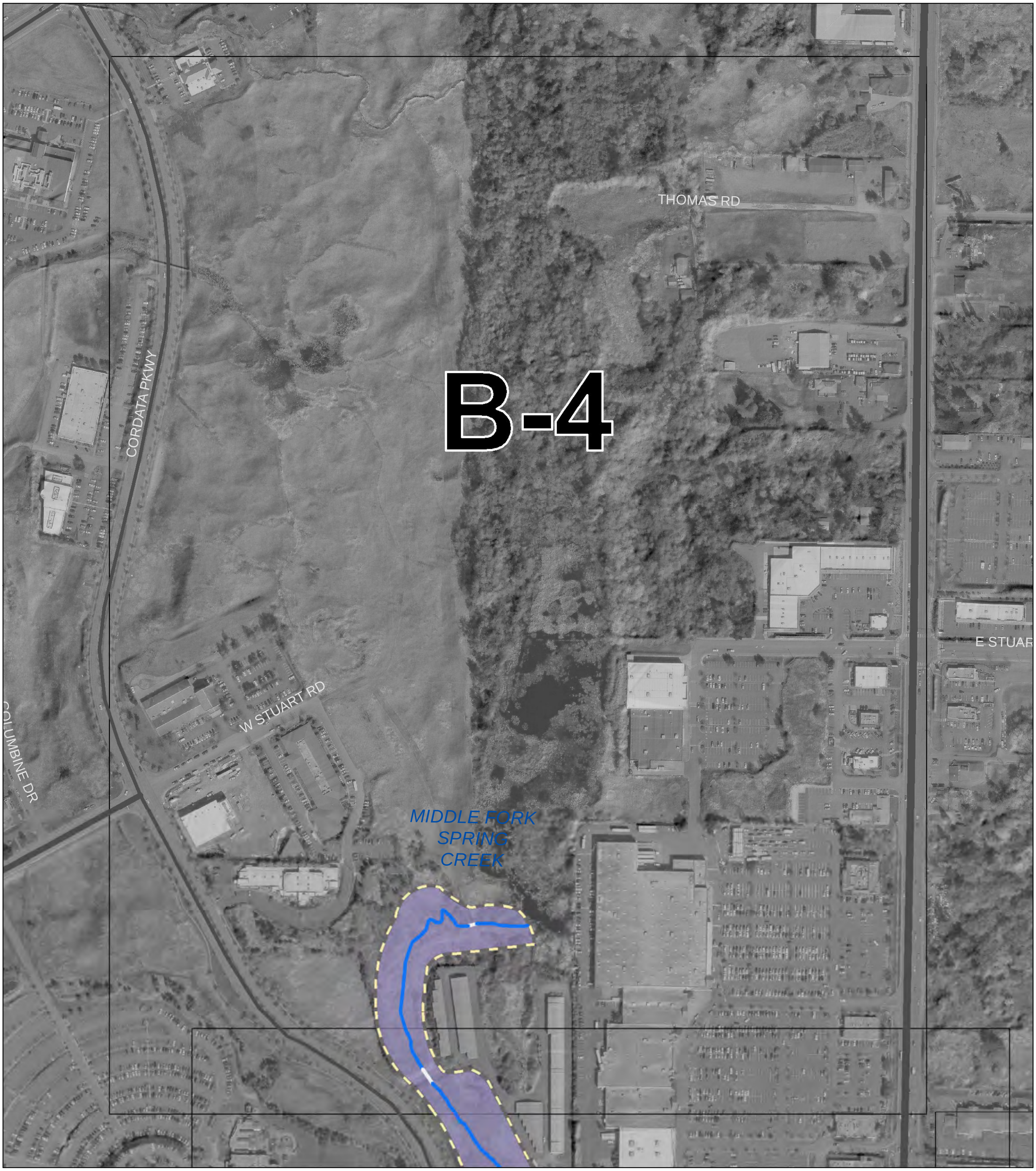

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Squalicum Creek Watershed Channel Migration Zone Mapping

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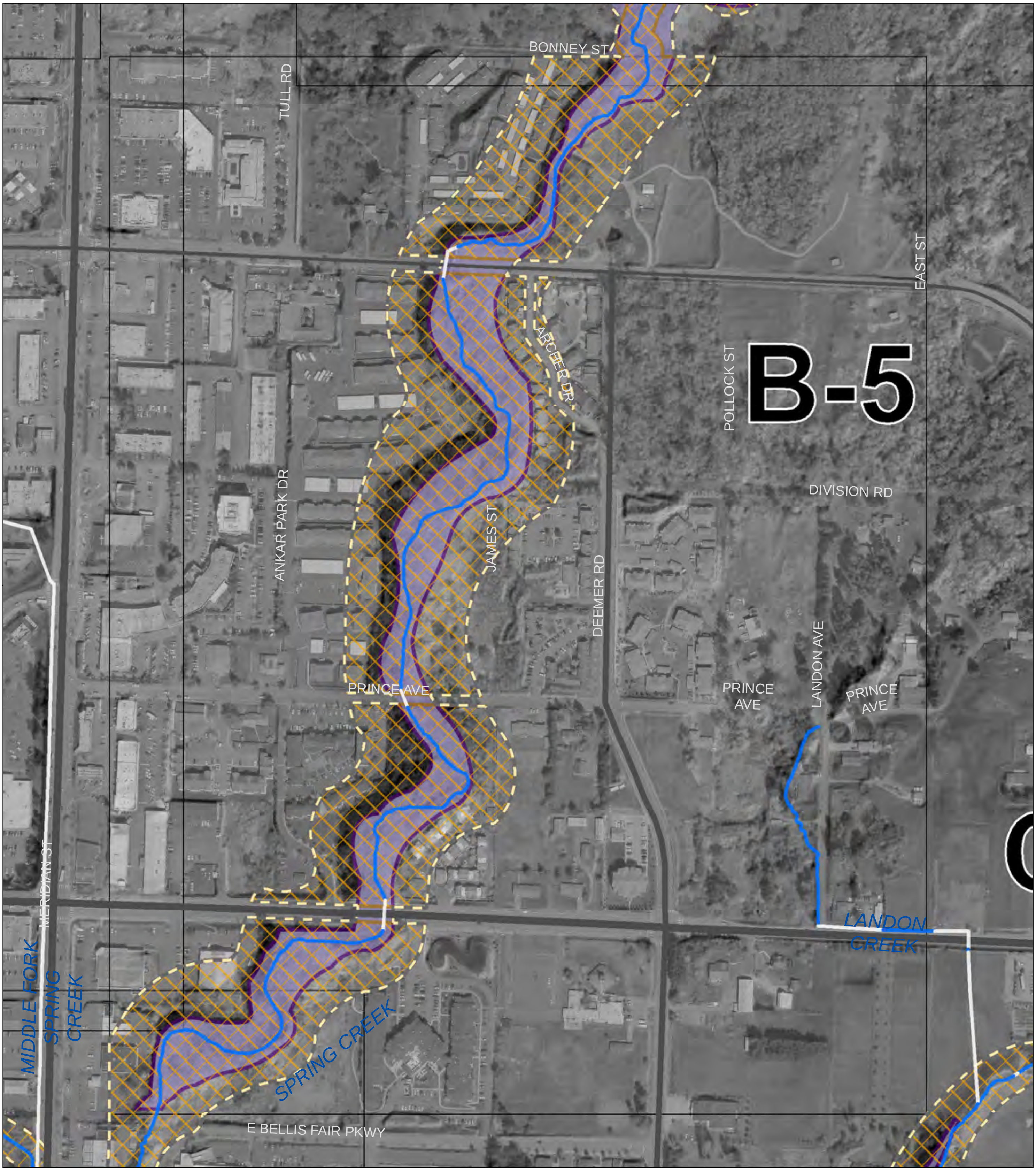

Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: B-5

Date: 9/7/2016

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solutions
info@elementsolutions.org

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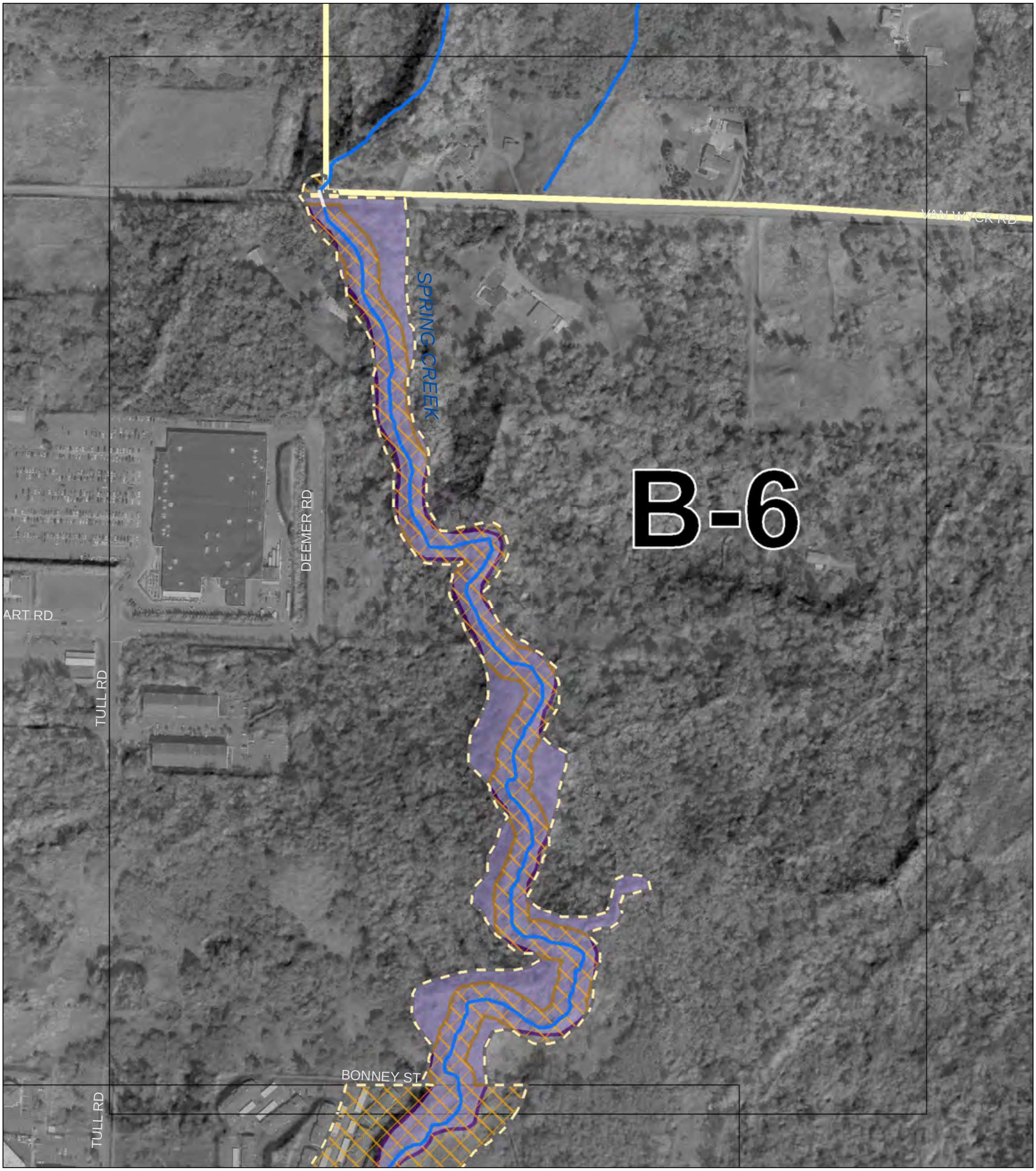

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Squalicum Creek Watershed Channel Migration Zone Mapping

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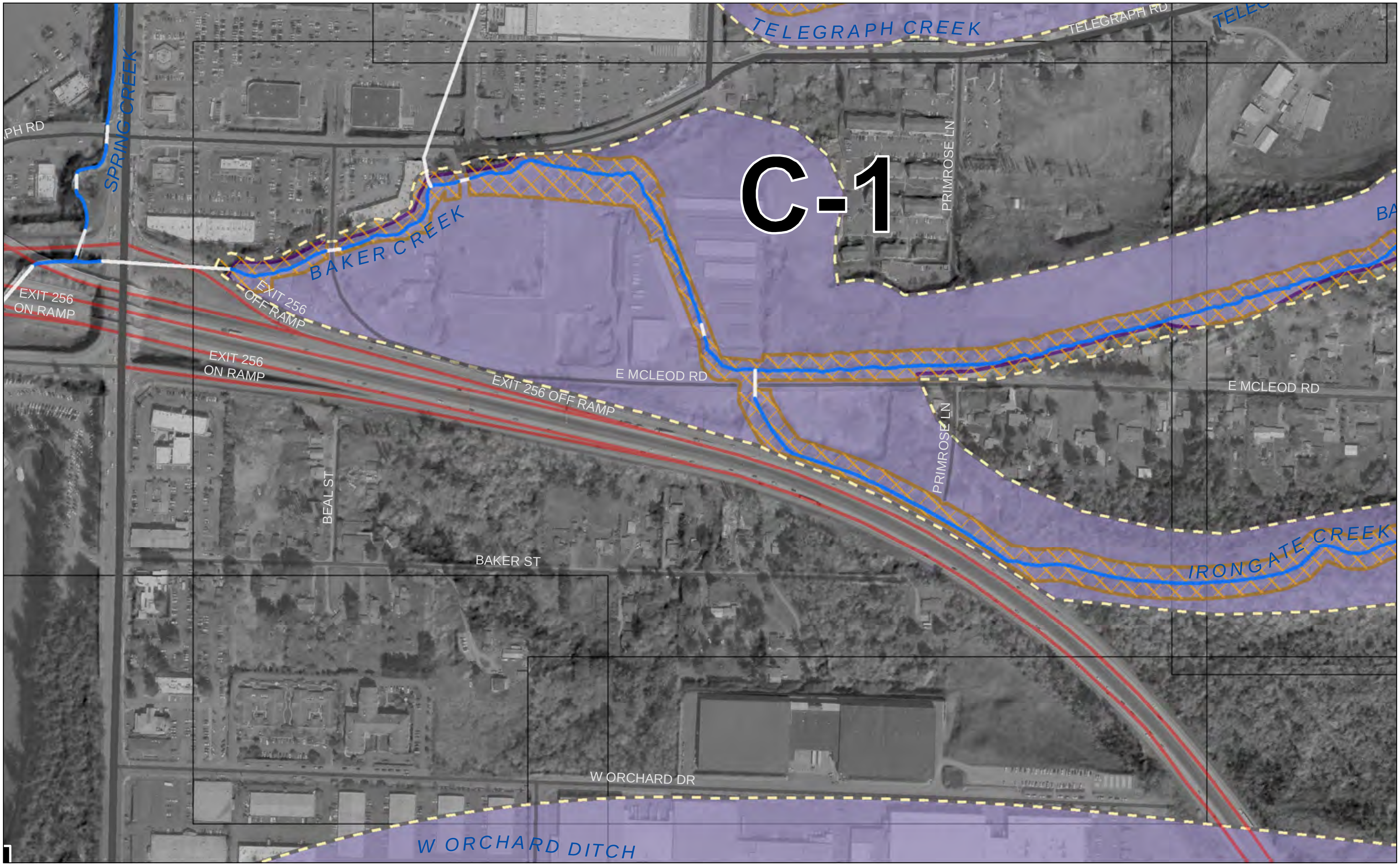

- Local Roads
- Interstate 5
- Streams
- Culvert
- 🟦 Lakes
- ▨ Channel Migration Zone (CMZ)
- ▨ Erosion Hazard Area (EHA)
- 🟪 Historic Migration Zone (HMZ)
- City Boundary
- Urban Growth Area

Feet

0 200 400 600 800 1,000

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\Figures\Maps\CMZ_LANDSCAPE.mxd

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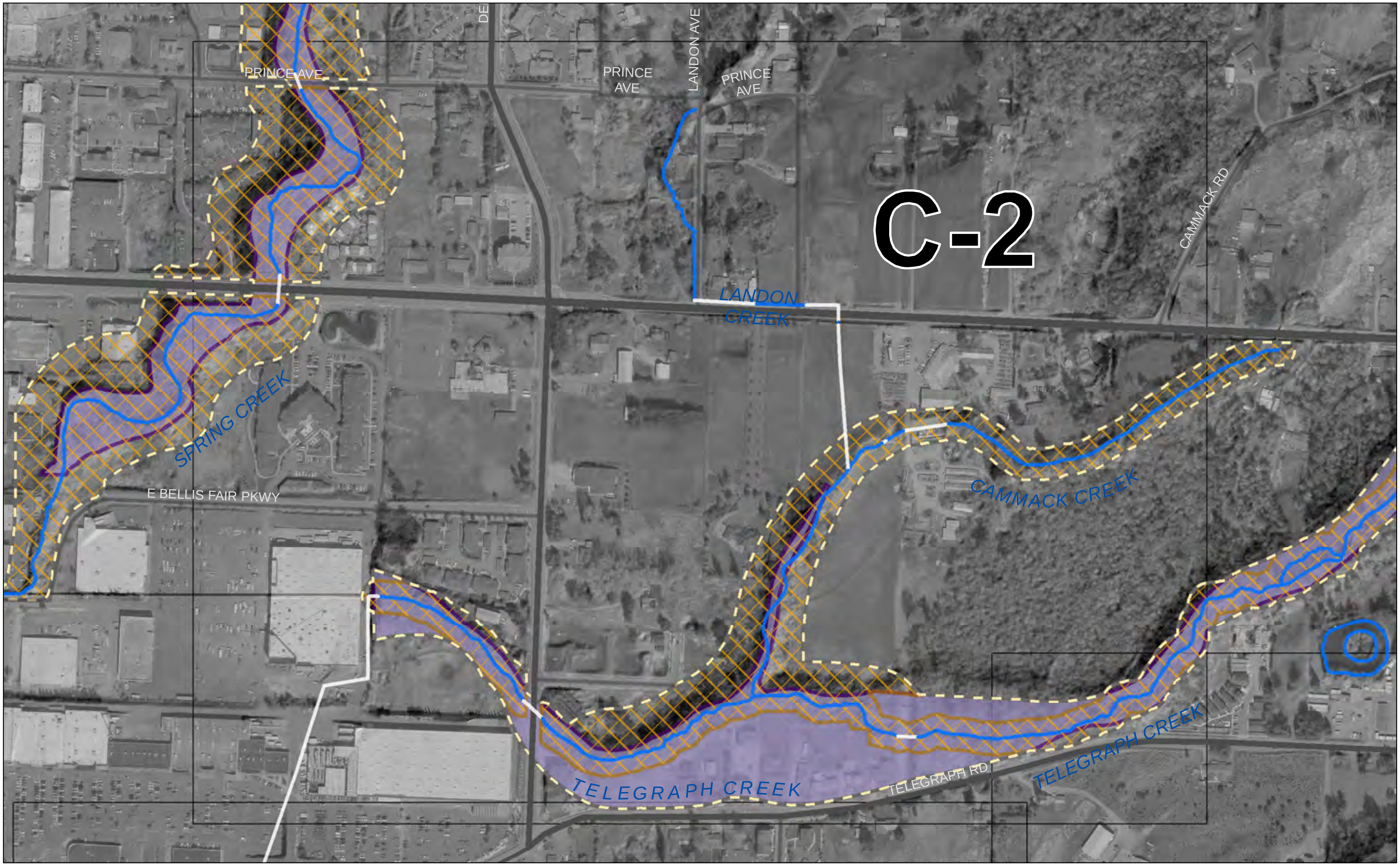
Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: C-1

Date: 9/7/2016



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Squalicum Creek Watershed
Channel Migration Zone Mapping

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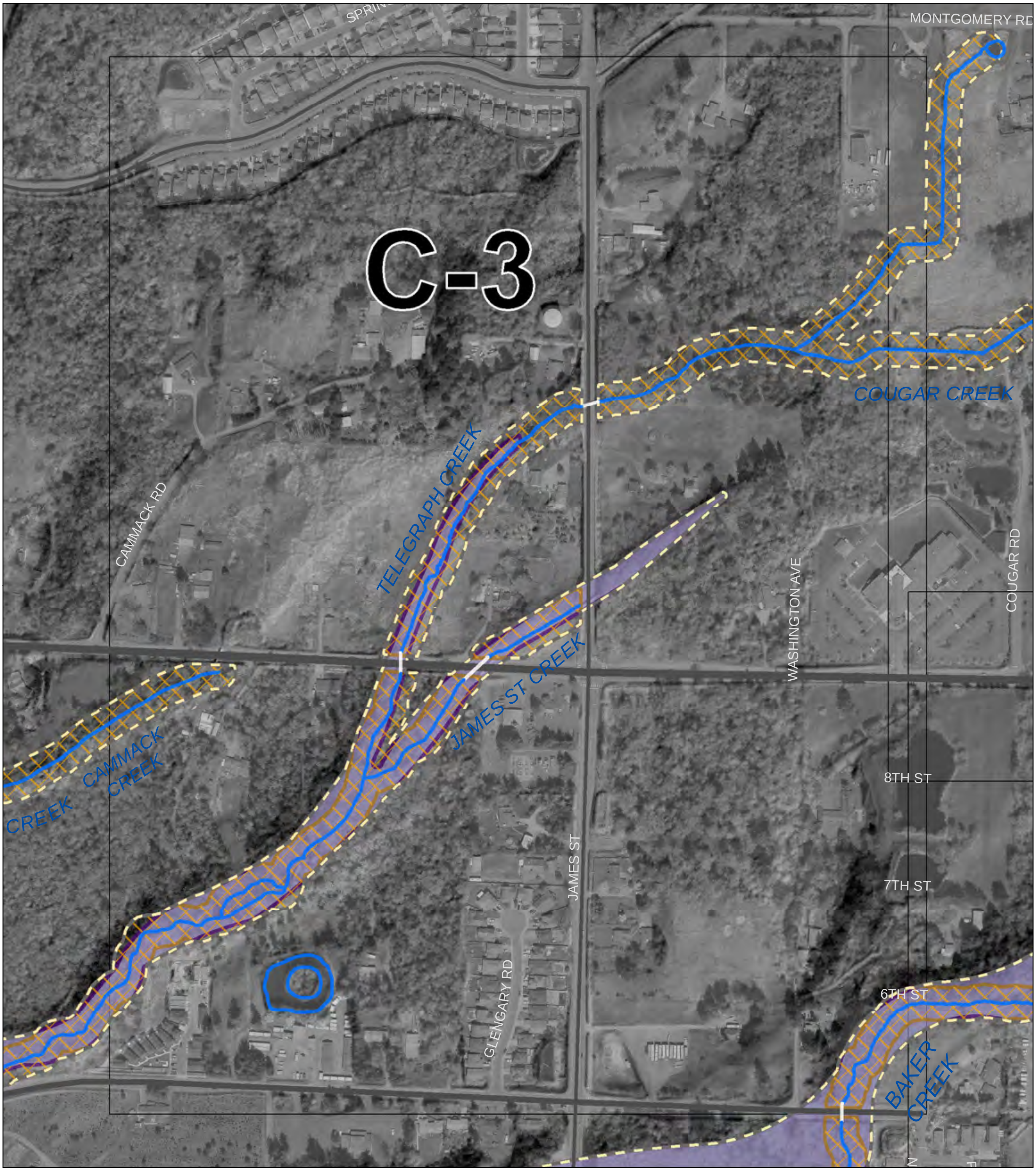

━	Streams	▨	Channel Migration Zone (CMZ)
━	Culvert	▨	Erosion Hazard Area (EHA)
▭	Lakes	▨	Historic Migration Zone (HMZ)
		▭	City Boundary
		▭	Urban Growth Area

Feet
0 200 400 600 800 1,000

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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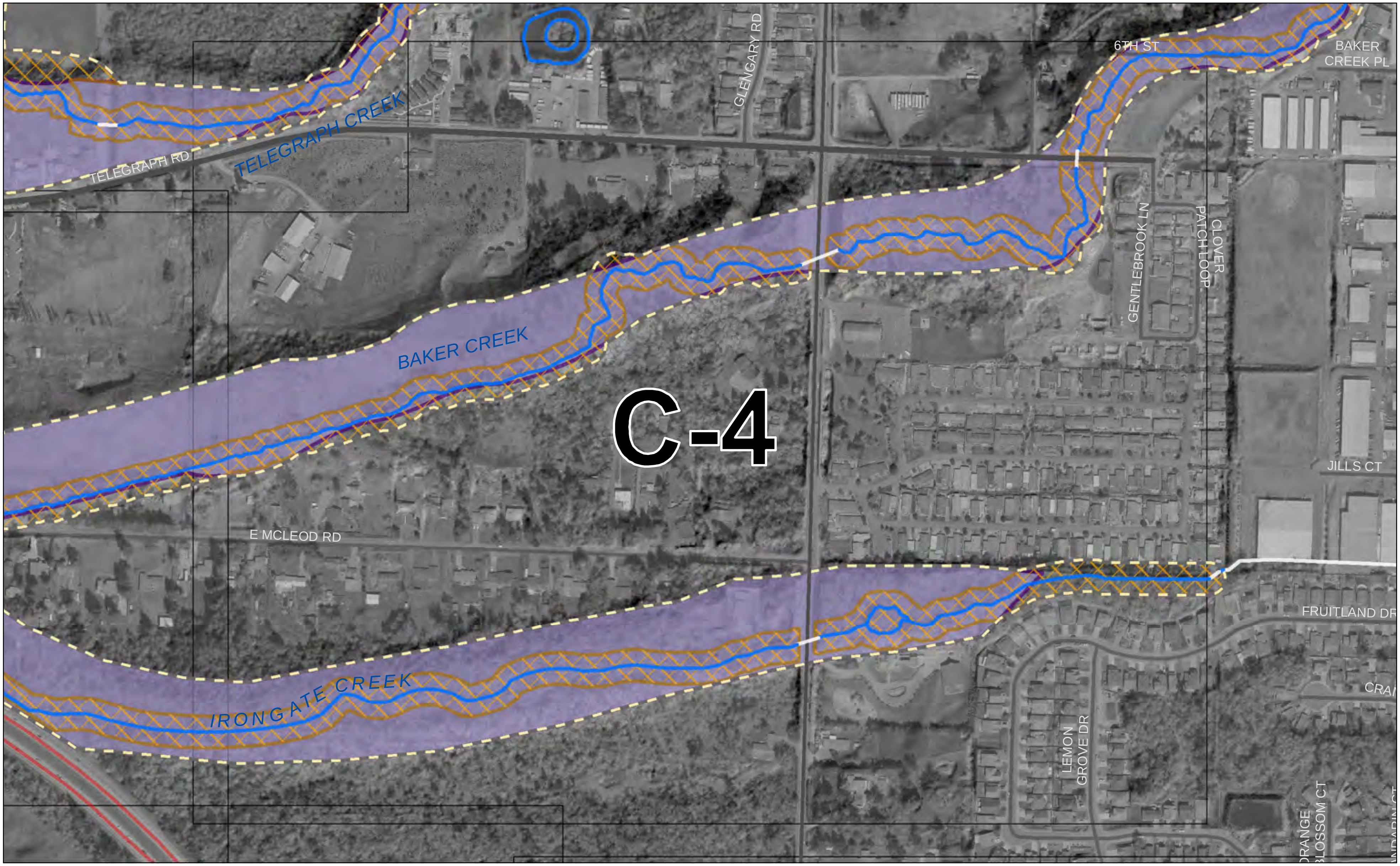

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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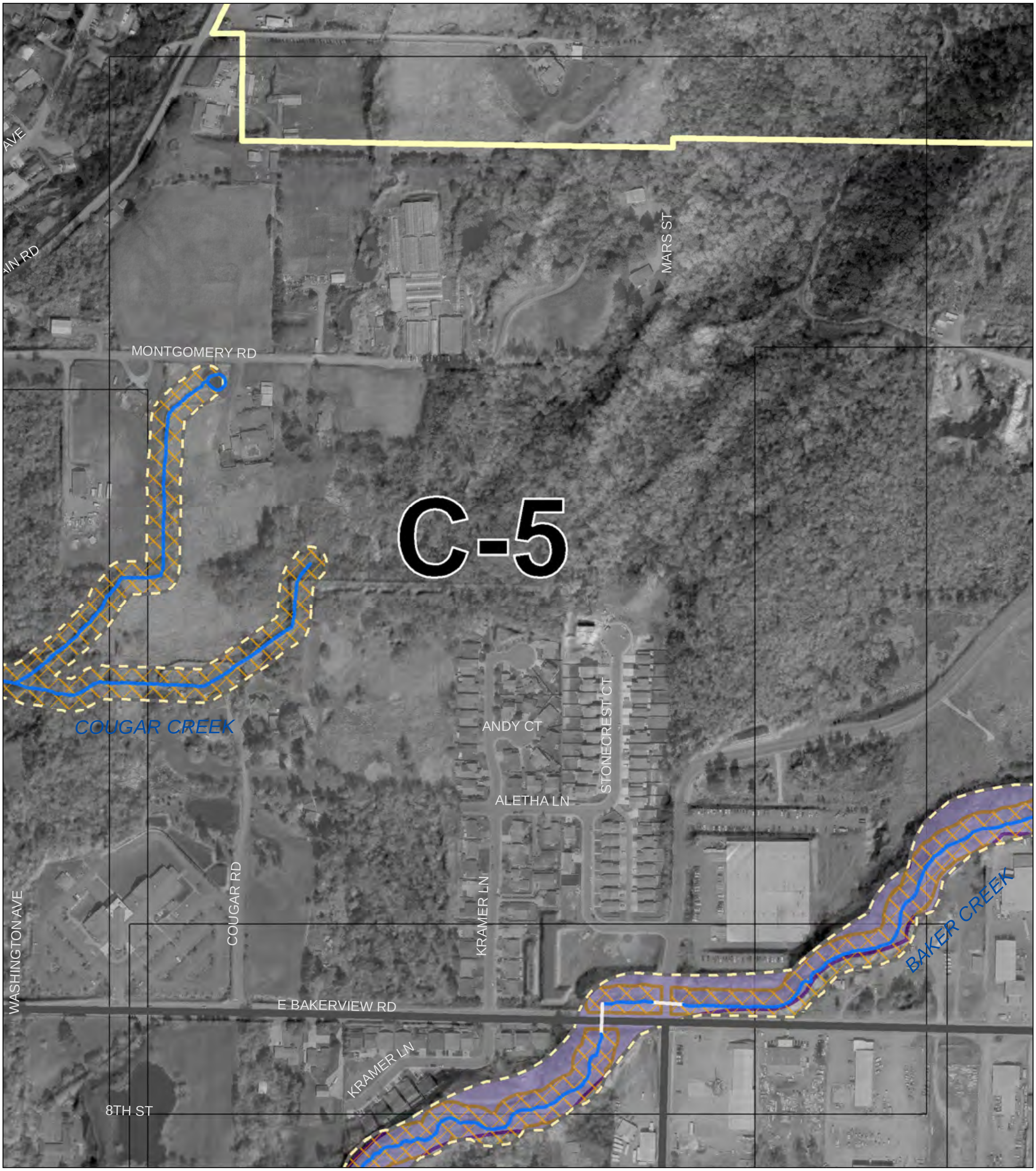

Streams	Channel Migration Zone (CMZ)
Culvert	Erosion Hazard Area (EHA)
Lakes	Historic Migration Zone (HMZ)
	City Boundary
	Urban Growth Area

0 200 400 600 800 1,000 Feet

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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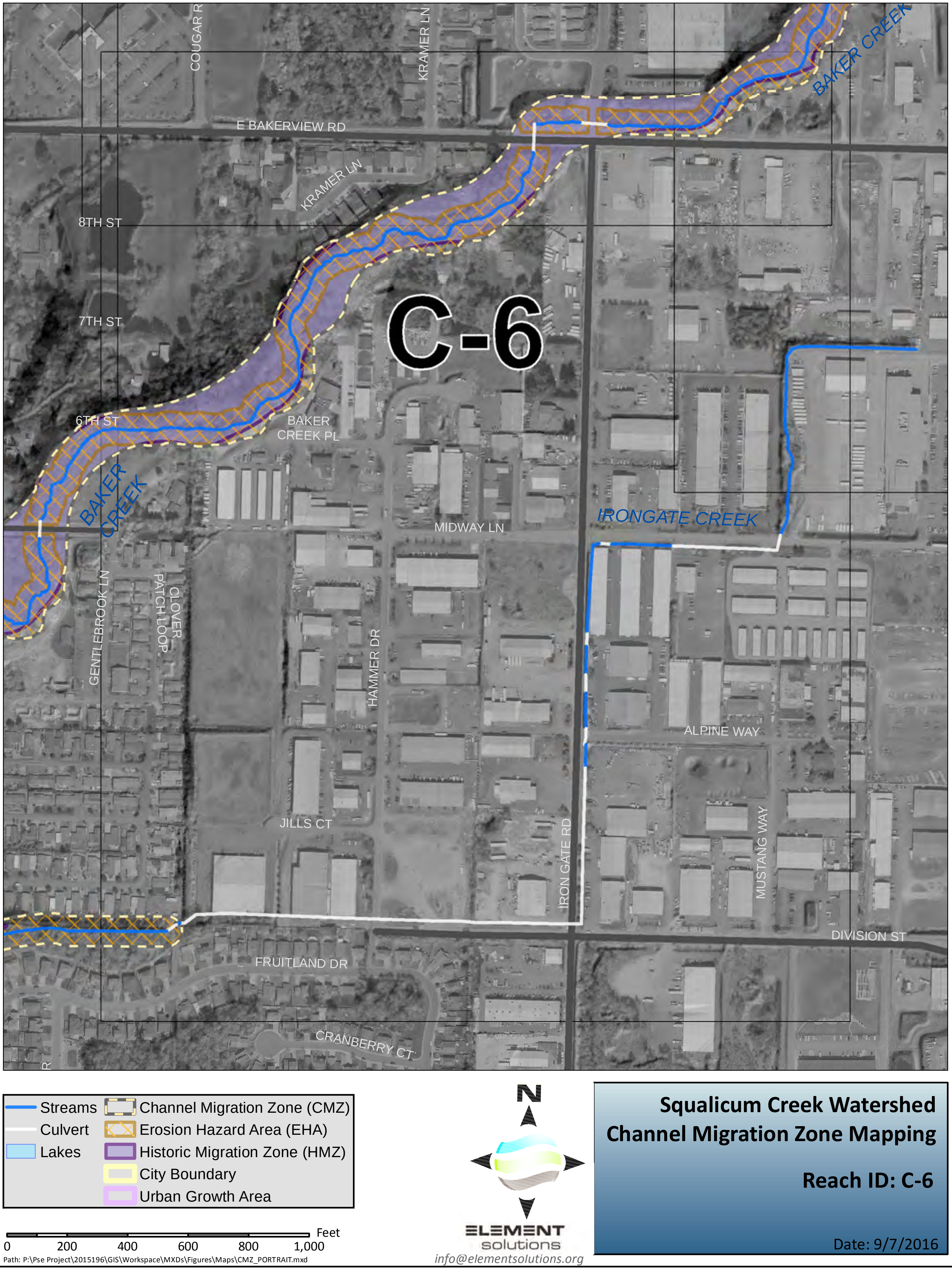

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Squalicum Creek Watershed Channel Migration Zone Mapping

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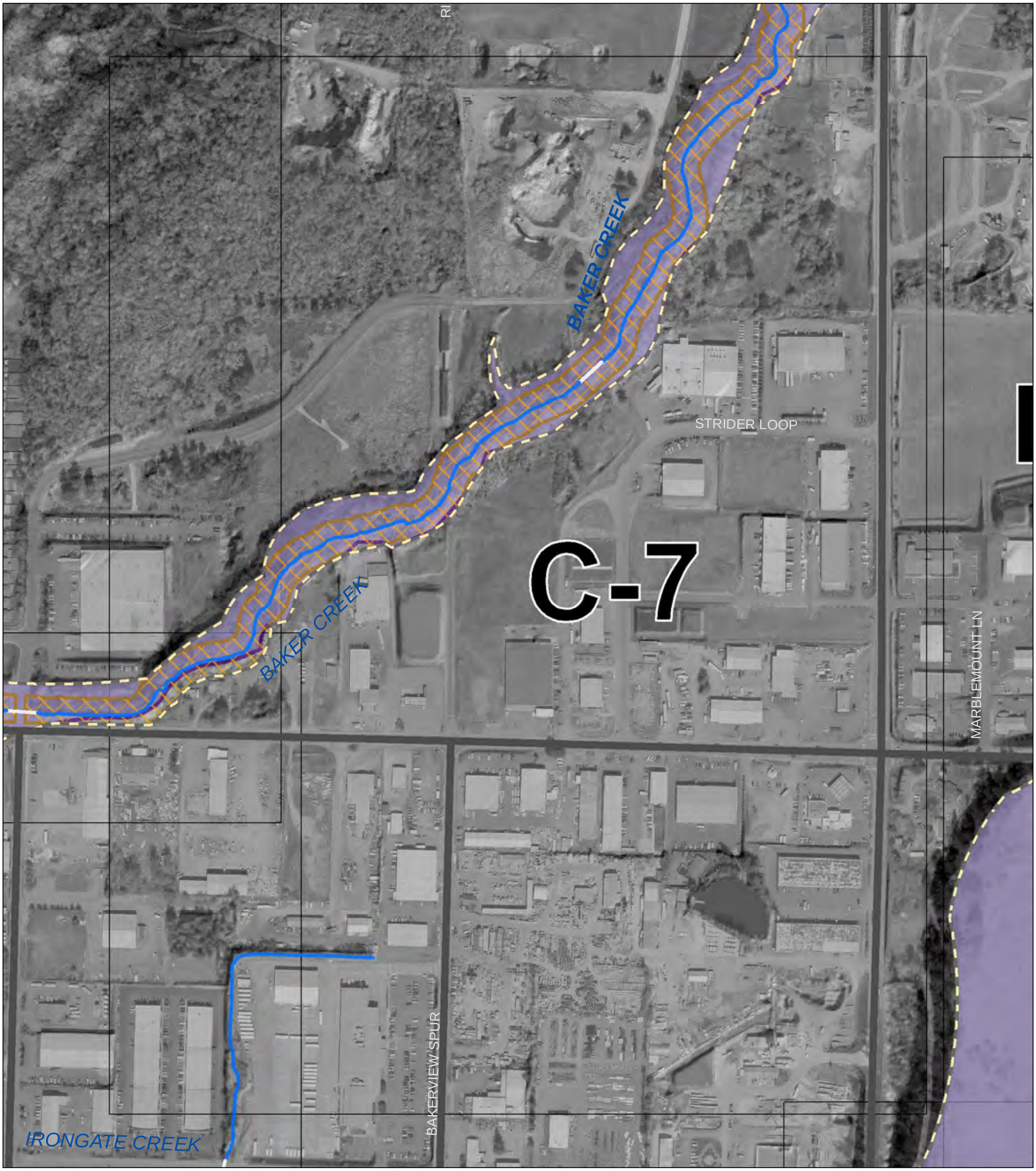

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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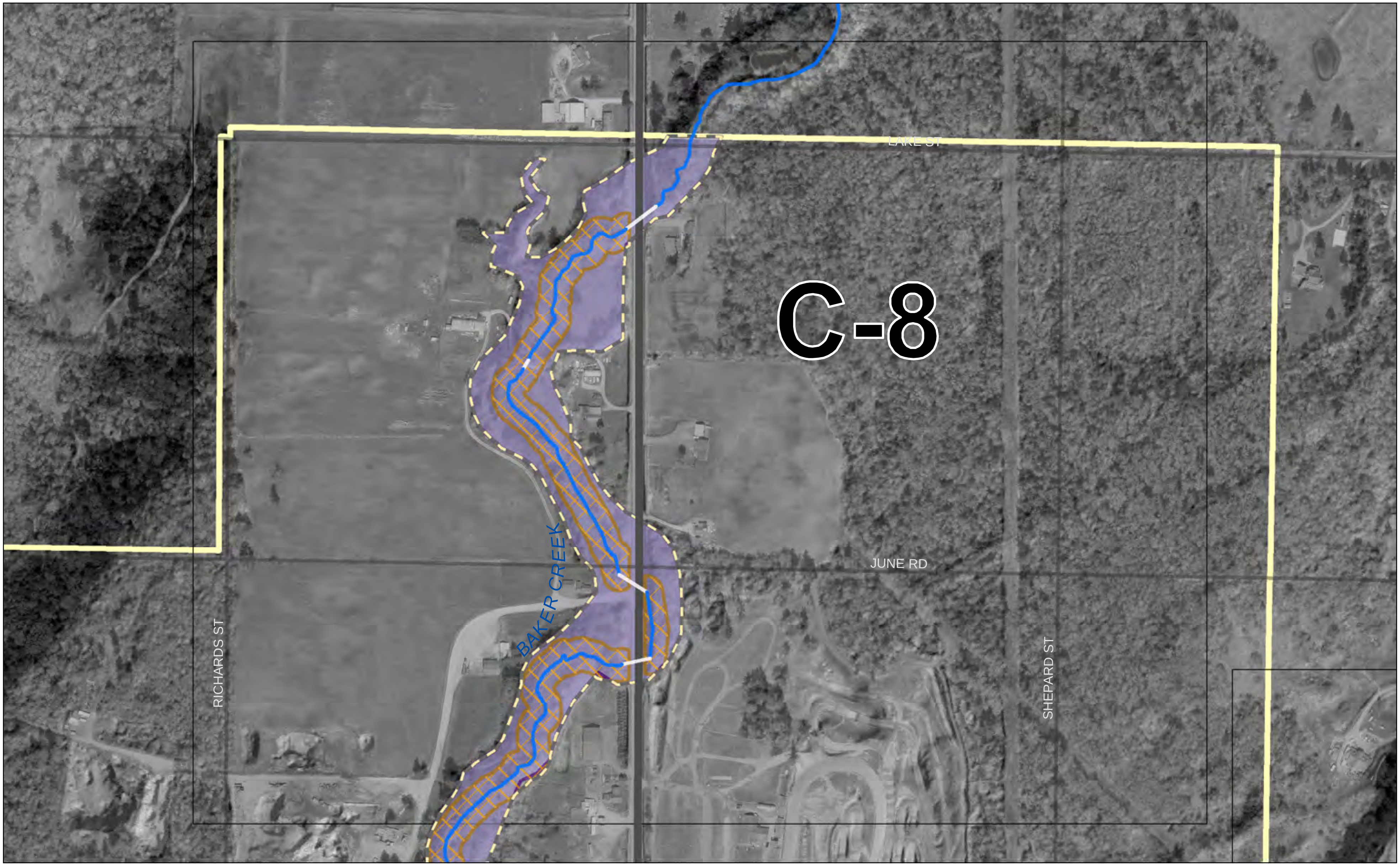

Local Roads
Interstate 5
Streams
Culvert
Lakes
Channel Migration Zone (CMZ)
Erosion Hazard Area (EHA)
Historic Migration Zone (HMZ)
City Boundary
Urban Growth Area

0 200 400 600 800 1,000 Feet

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Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: C-8

Date: 9/7/2016

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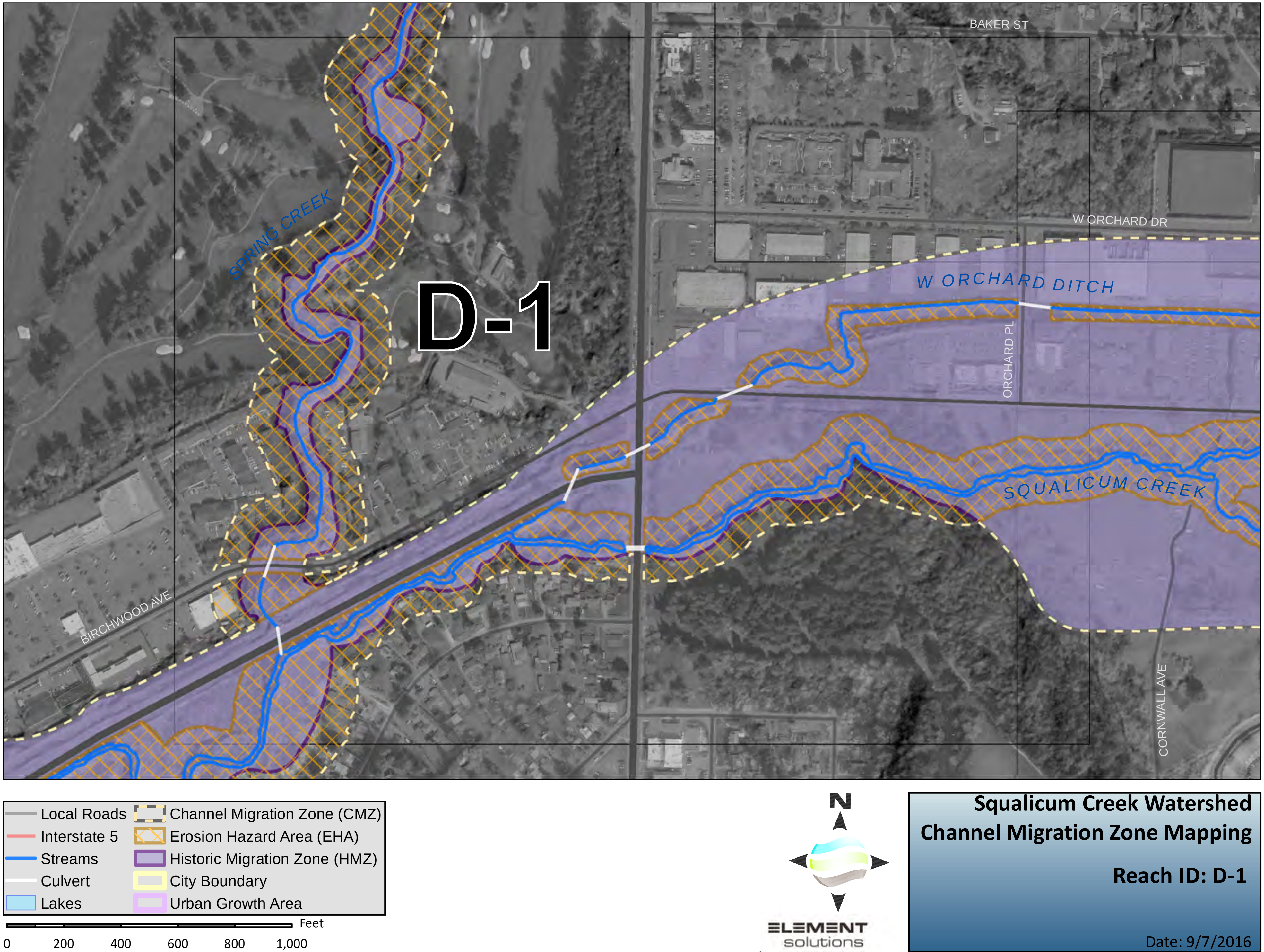

Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: D-1

Date: 9/7/2016

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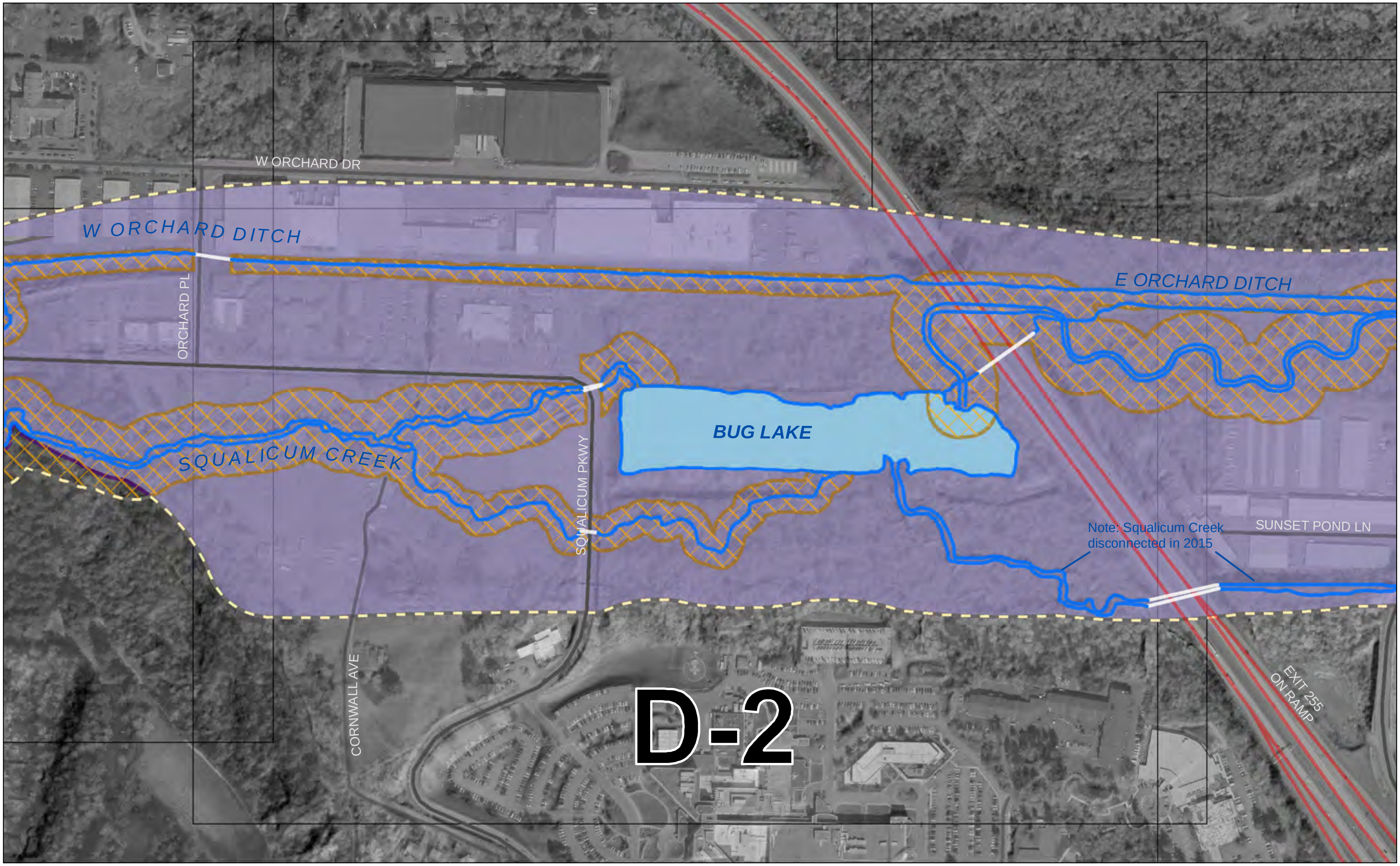

▬	Local Roads	▭	Channel Migration Zone (CMZ)
▬	Interstate 5	▨	Erosion Hazard Area (EHA)
▬	Streams	▭	Historic Migration Zone (HMZ)
▬	Culvert	▭	City Boundary
▭	Lakes	▭	Urban Growth Area

Feet

0 200 400 600 800 1,000

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Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: D-2

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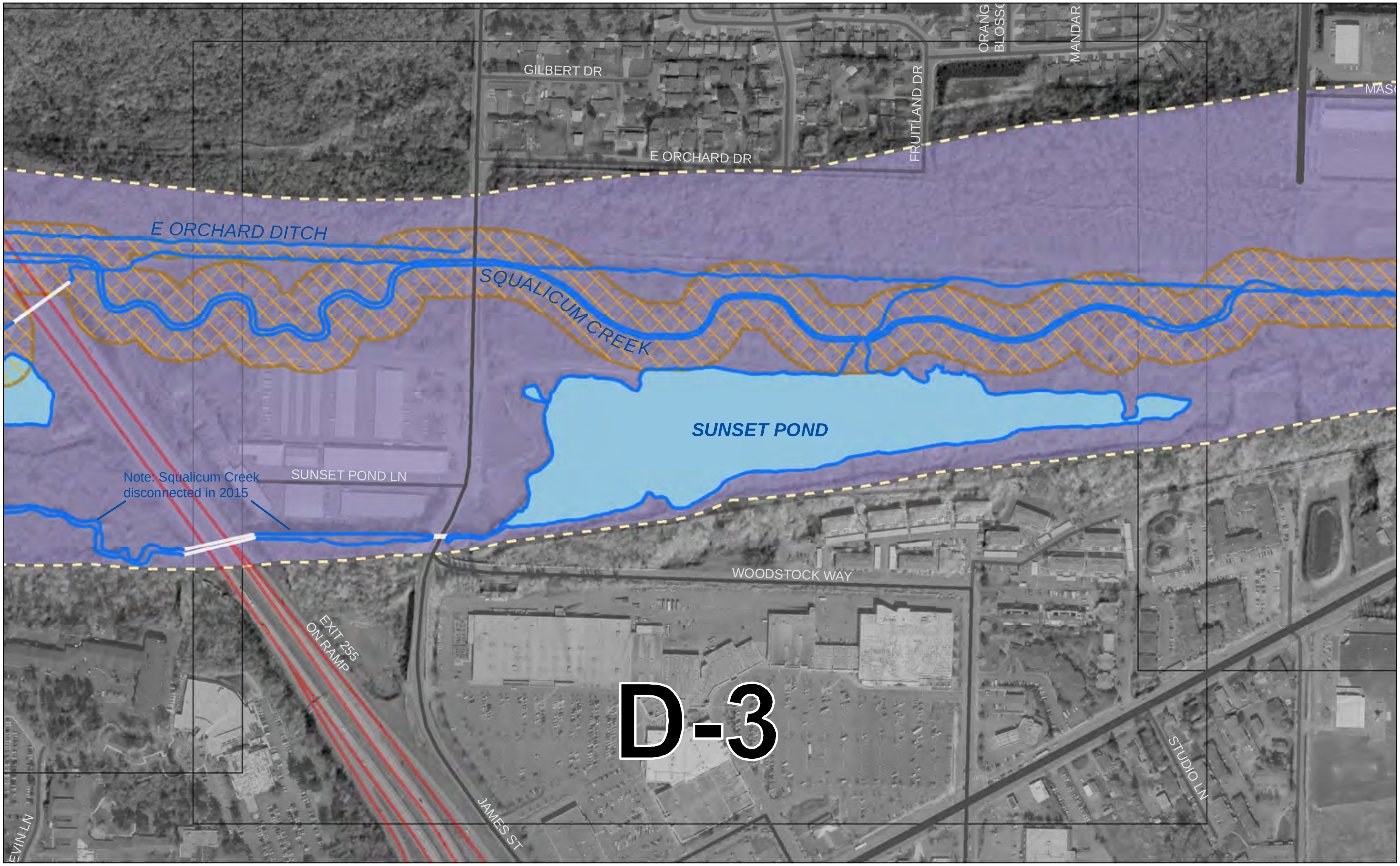

- Local Roads
- Interstate 5
- Streams
- Culvert
- Lakes
- Channel Migration Zone (CMZ)
- Erosion Hazard Area (EHA)
- Historic Migration Zone (HMZ)
- City Boundary
- Urban Growth Area

Feet
0 200 400 600 800 1,000

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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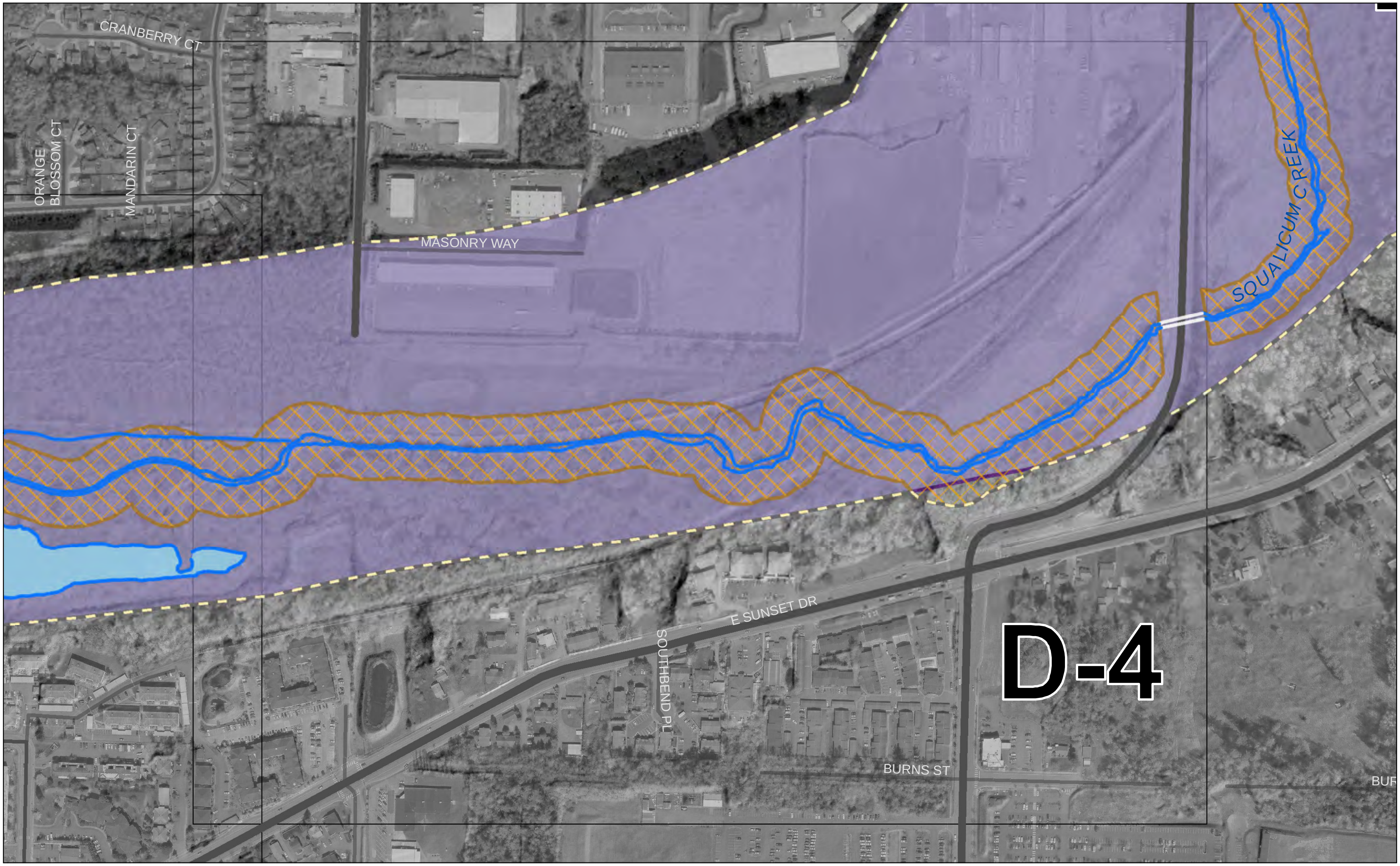

Local Roads
Interstate 5
Streams
Culvert
Lakes
Channel Migration Zone (CMZ)
Erosion Hazard Area (EHA)
Historic Migration Zone (HMZ)
City Boundary
Urban Growth Area

Feet
0 200 400 600 800 1,000

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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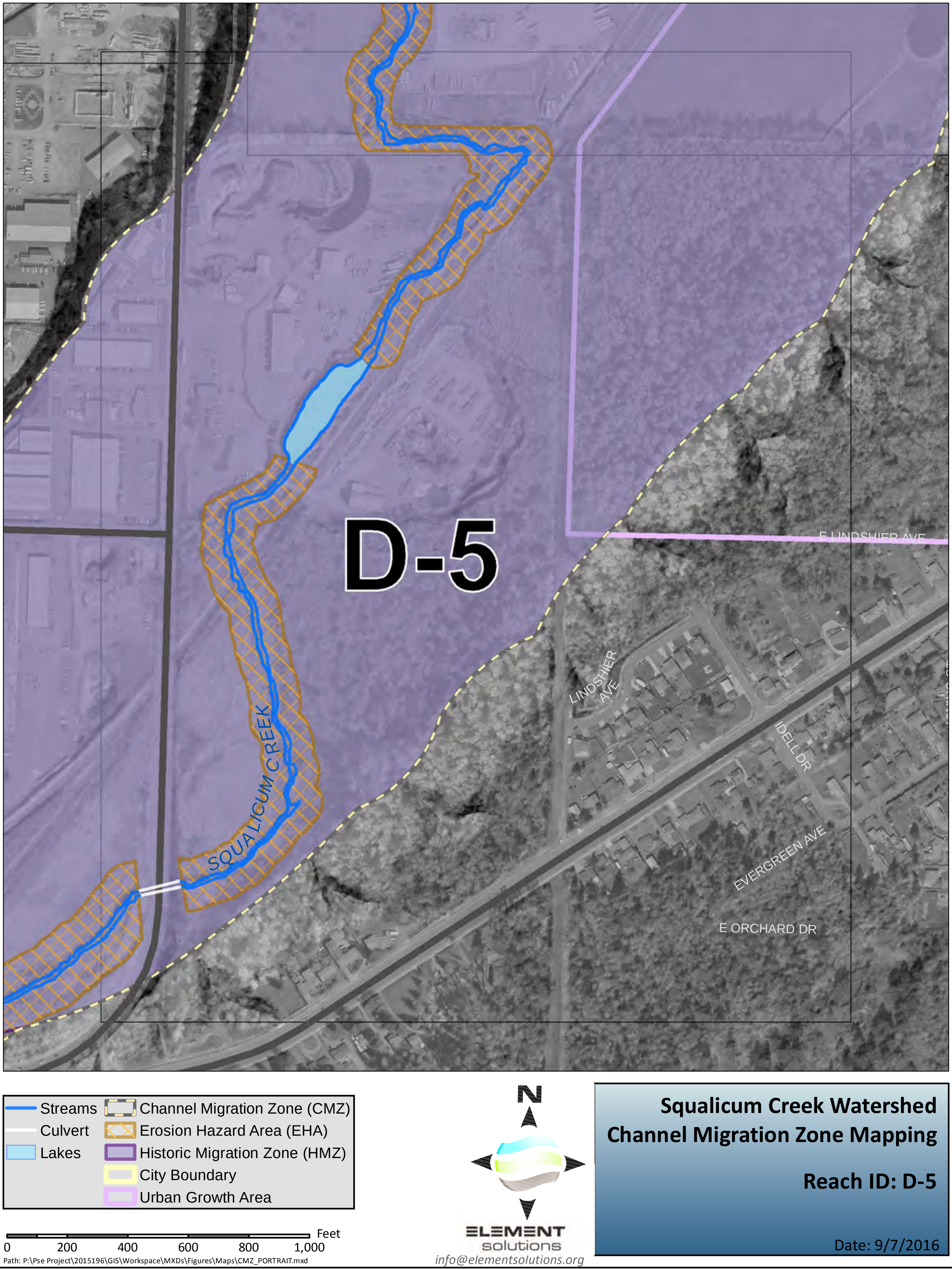

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Channel Migration Zone Mapping

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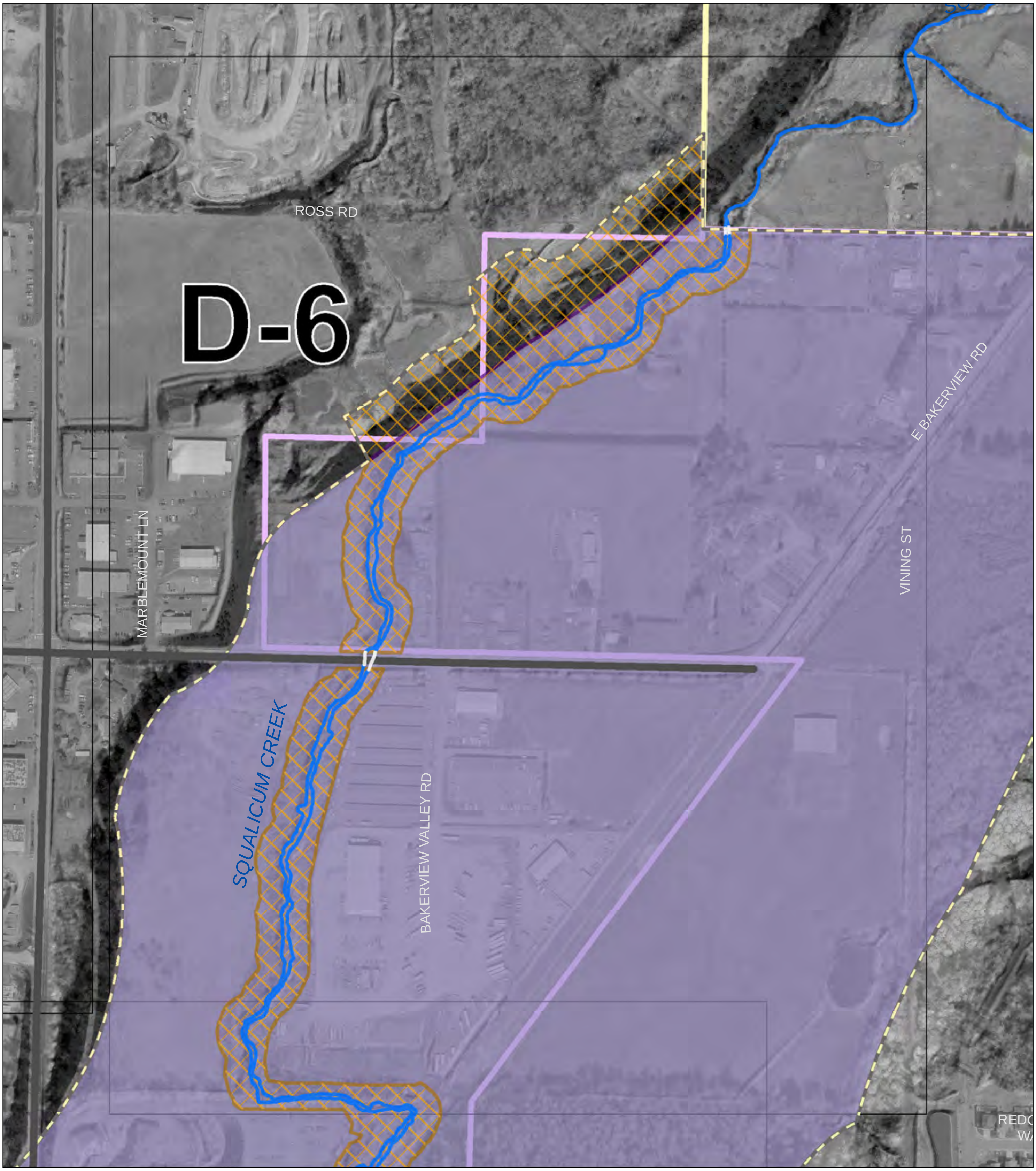

- ━ Streams
- ━ Culvert
- ▭ Lakes
- ▨ Channel Migration Zone (CMZ)
- ▨ Erosion Hazard Area (EHA)
- ▭ Historic Migration Zone (HMZ)
- ▭ City Boundary
- ▭ Urban Growth Area

0 200 400 600 800 1,000 Feet

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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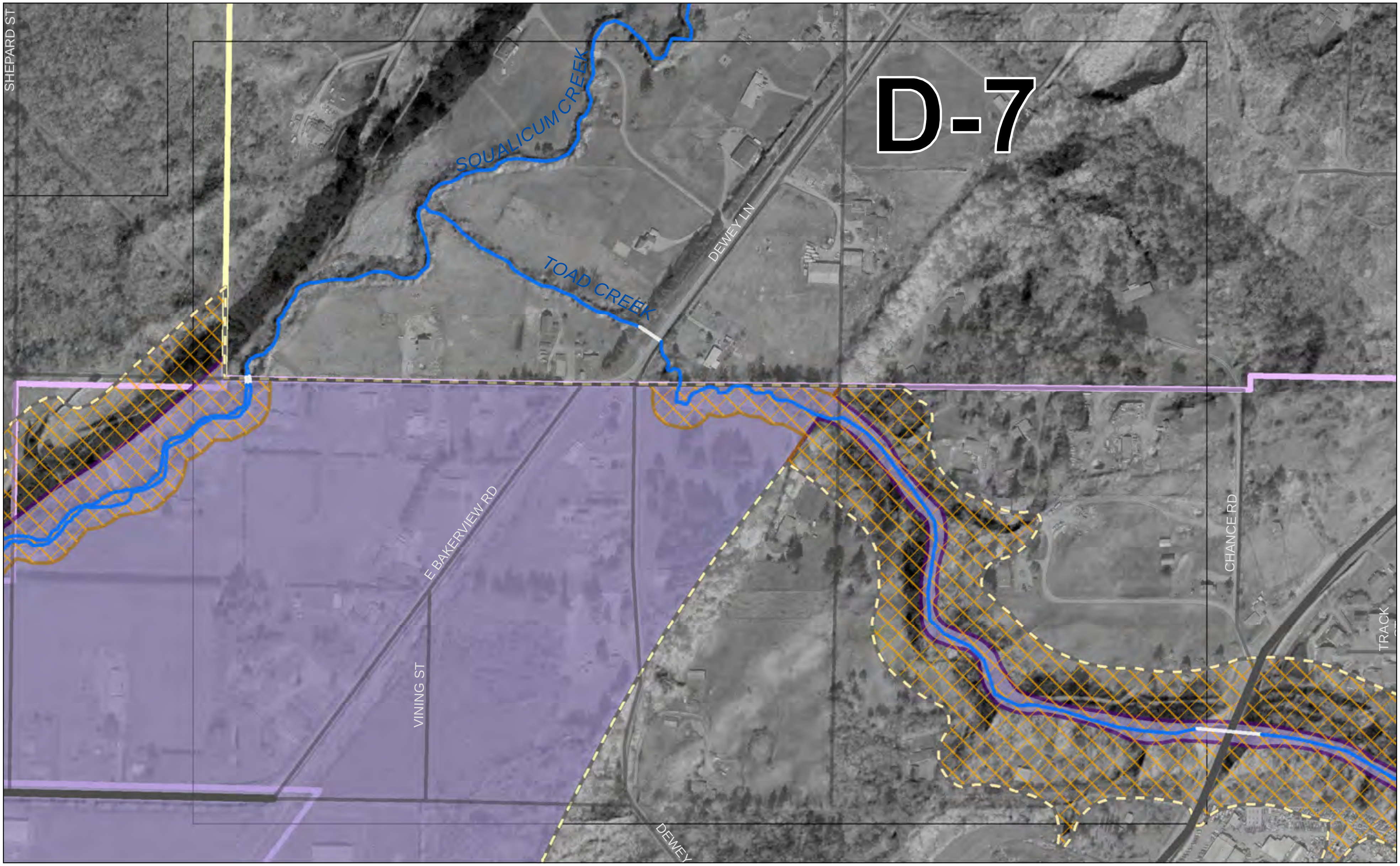

— Local Roads
— Interstate 5
— Streams
— Culvert
▭ Lakes

▨ Channel Migration Zone (CMZ)
▨ Erosion Hazard Area (EHA)
▨ Historic Migration Zone (HMZ)
▭ City Boundary
▭ Urban Growth Area

Feet
0 200 400 600 800 1,000

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Squalicum Creek Watershed
Channel Migration Zone Mapping

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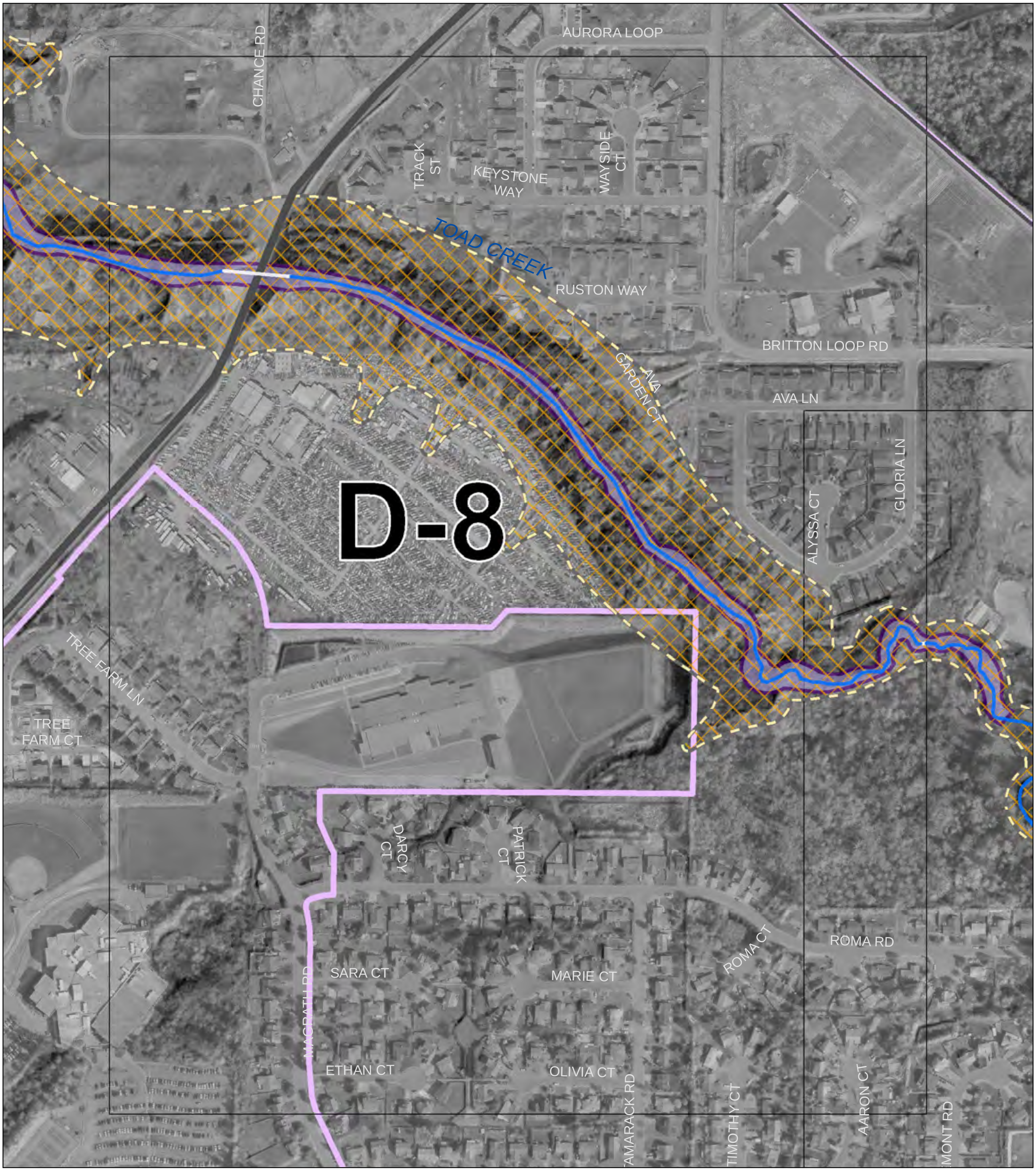
Date: 9/7/2016



Streams
Culvert
Lakes
Channel Migration Zone (CMZ)
Erosion Hazard Area (EHA)
Historic Migration Zone (HMZ)
City Boundary
Urban Growth Area

Feet
0 200 400 600 800 1,000

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ELEMENT solutions
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Squalicum Creek Watershed Channel Migration Zone Mapping

Reach ID: D-8

Date: 9/7/2016

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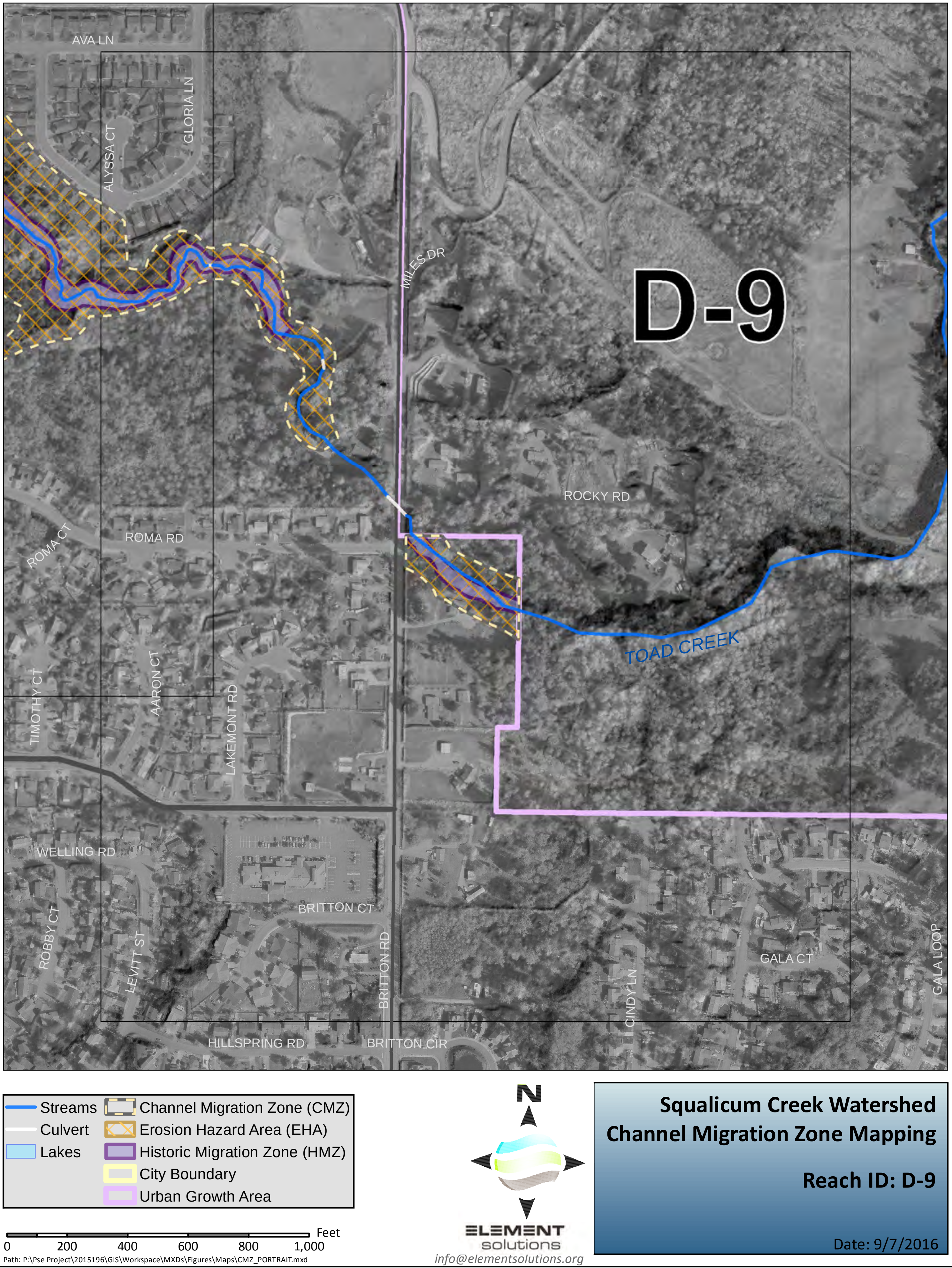

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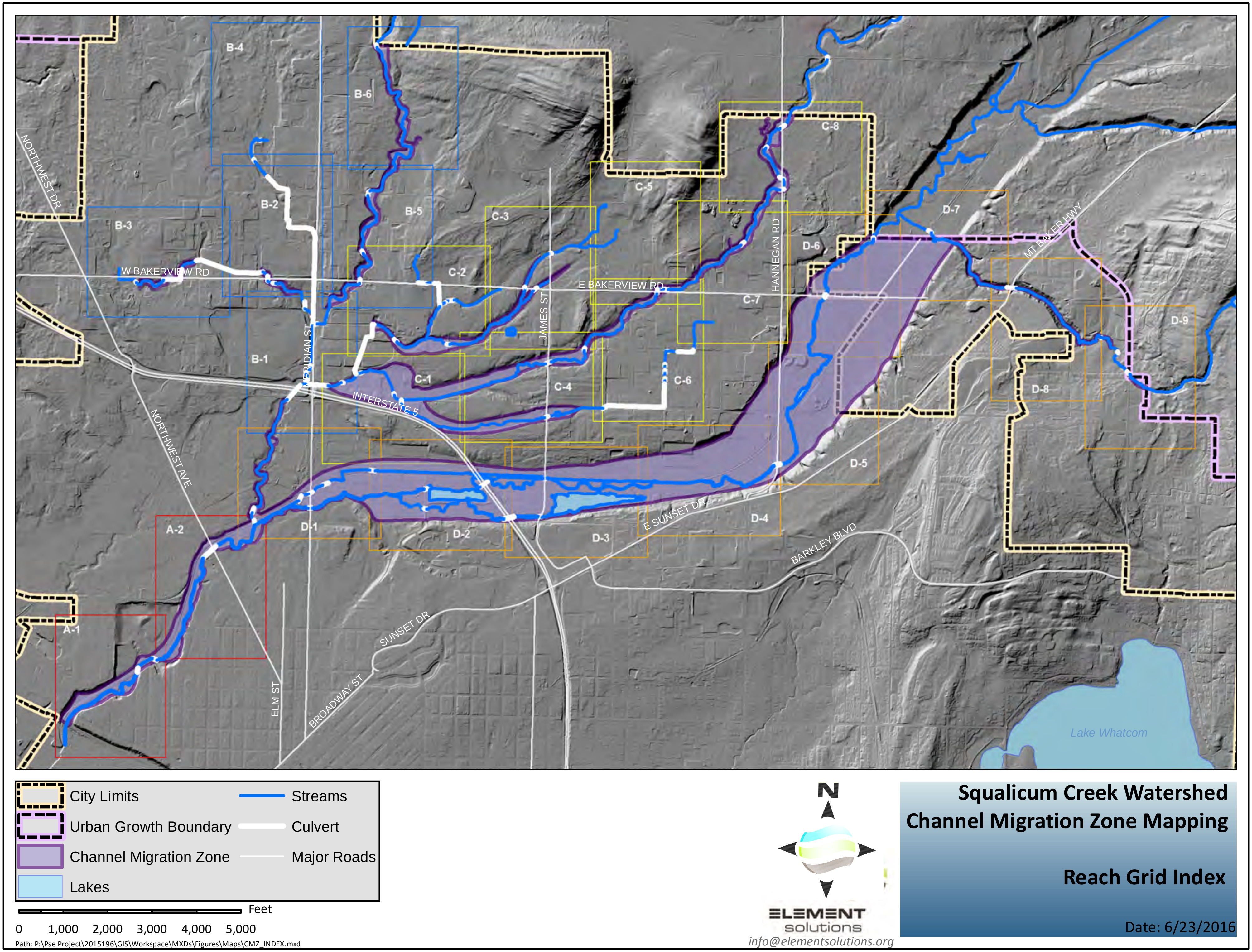
Squalicum Creek Watershed
Channel Migration Zone Mapping

Reach ID: D-9

Date: 9/7/2016

Appendix II – CMZ Data Analyses Map Book



Squalicum Creek Watershed Channel Migration Zone Mapping

Reach Grid Index

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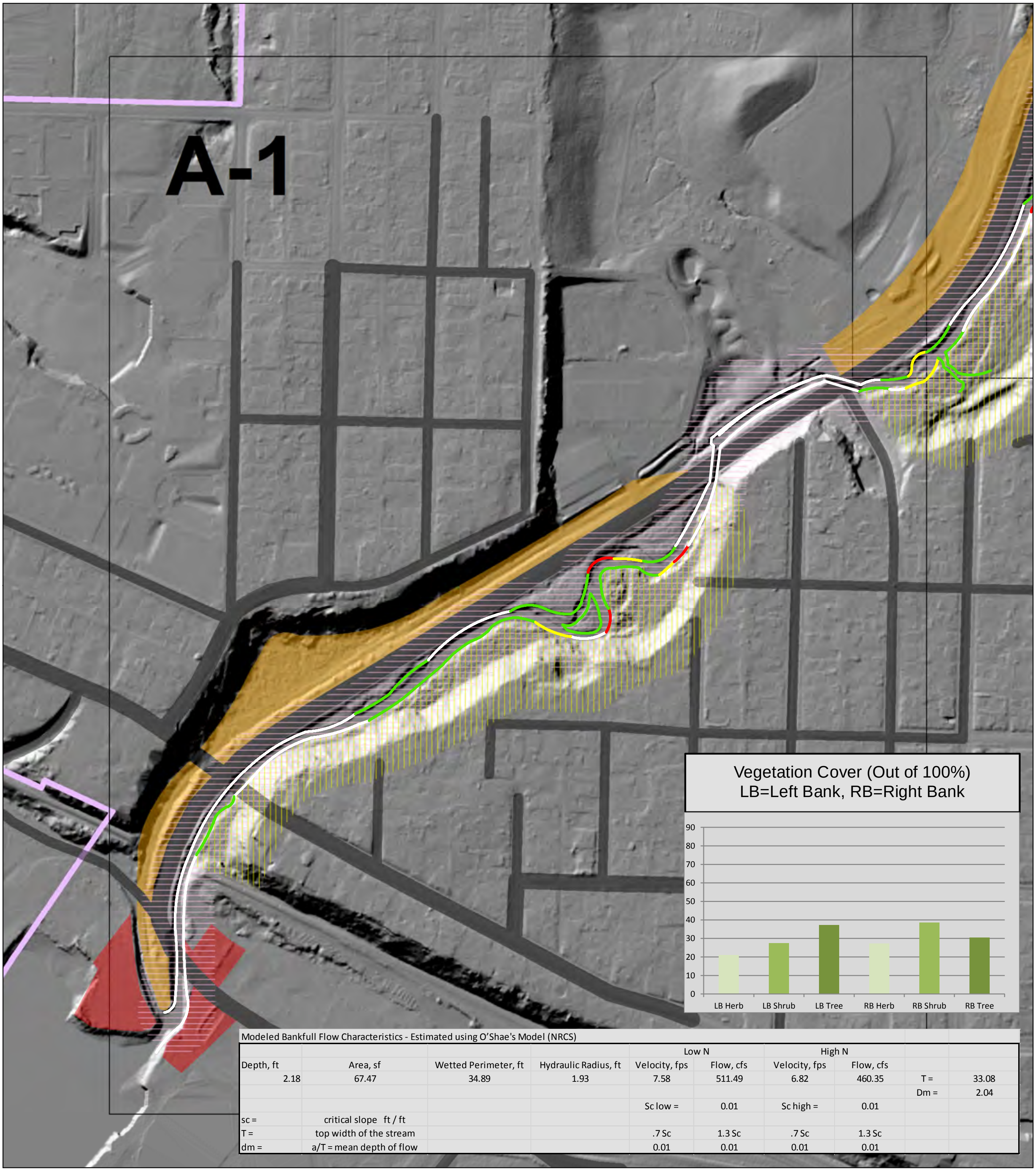

Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs		
2.18	67.47	34.89	1.93	7.58	511.49	6.82	460.35	T =	33.08
								Dm =	2.04
				Sc low =	0.01	Sc high =	0.01		
sc =	critical slope ft / ft								
T =	top width of the stream			.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
dm =	a/T = mean depth of flow			0.01	0.01	0.01	0.01		

Erosion Hazard Areas

▤	Erosion Setback
▥	Geotechnical Setback

Detached Migration Areas

■	Infrastructure
🟥	Private
🟧	Public

Bank Category

—	Actively Eroding
—	Medium Erosion Potential
—	Low Erosion Potential
—	Bank Armoring

N

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Squalicum Channel Migration Study

Reach ID: A-1

Date: 2/11/2016

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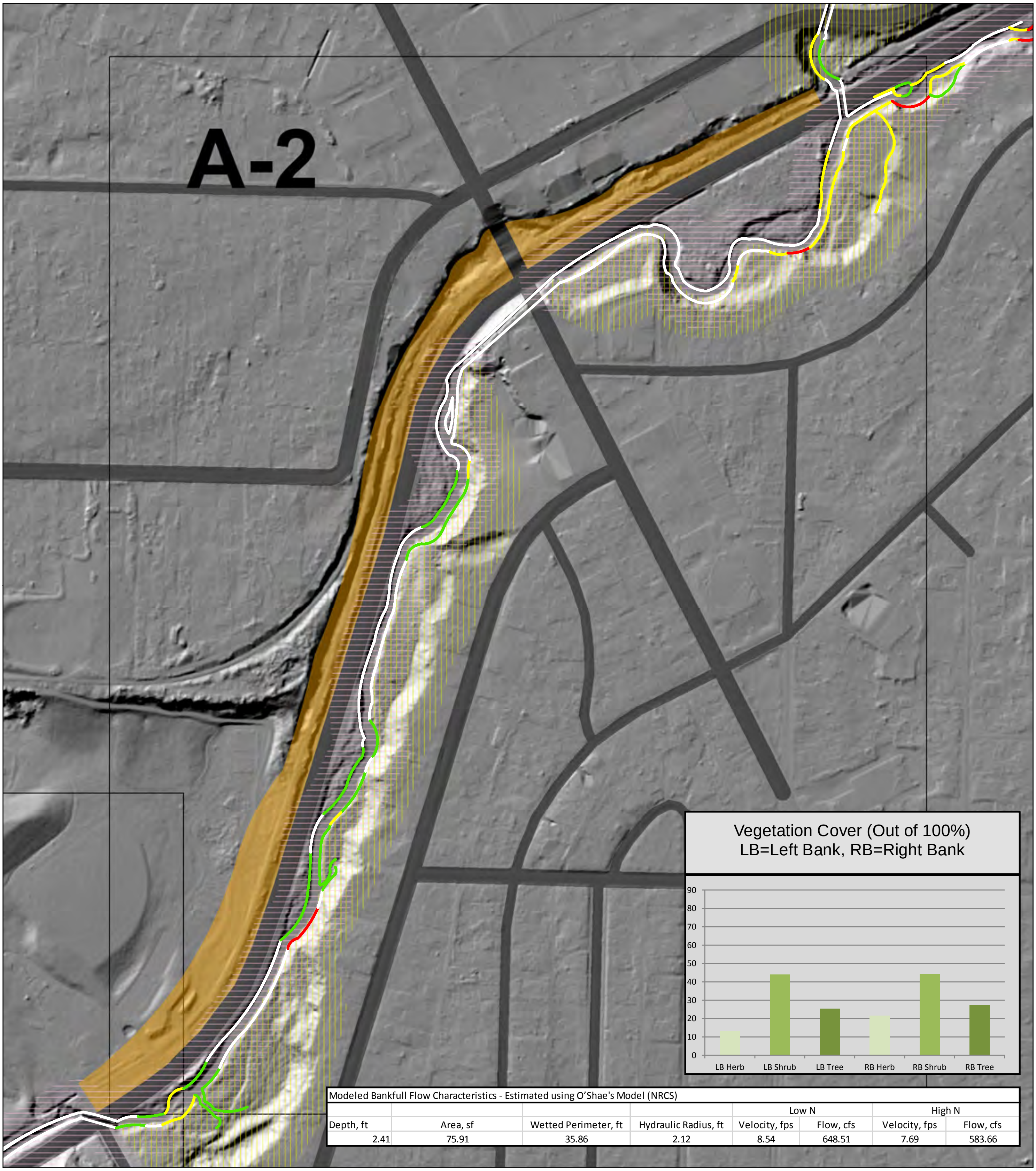

Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.41	75.91	35.86	2.12	8.54	648.51	7.69	583.66

Erosion Hazard Areas

- ▤ Erosion Setback
- ▥ Geotechnical Setback

Detached Migration Areas

- ■ Infrastructure
- 🟥 Private
- 🟧 Public

Bank Category

- 🟥 Actively Eroding
- 🟨 Medium Erosion Potential
- 🟩 Low Erosion Potential
- ⬜ Bank Armoring

0 100 200 300 400 500 FEET

N

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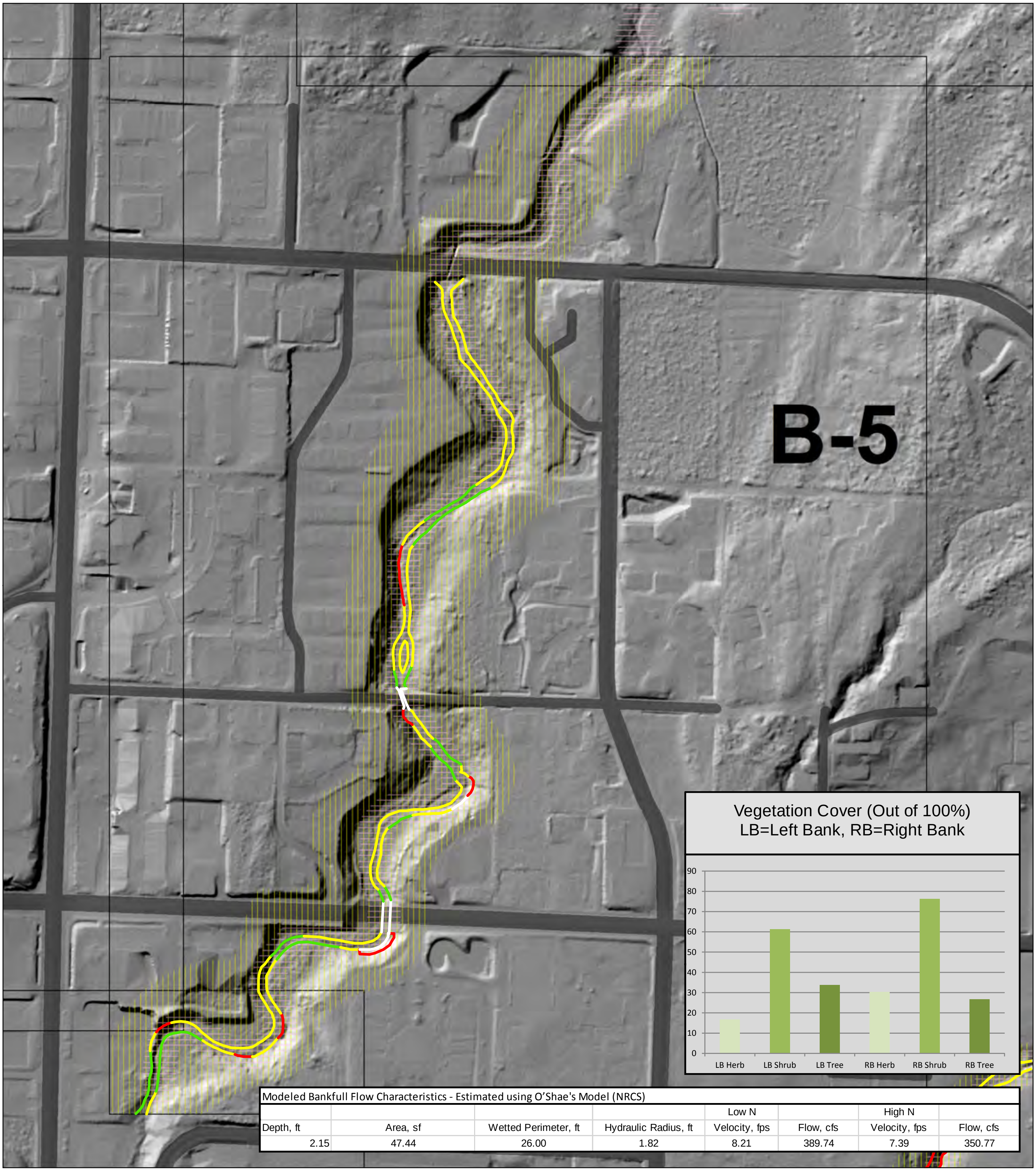
info@elementsolutions.org

Squalicum Channel Migration Study

Reach ID: A-2

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.15	47.44	26.00	1.82	8.21	389.74	7.39	350.77

Erosion Hazard Areas

☰	Erosion Setback
‖‖‖	Geotechnical Setback

Detached Migration Areas

■	Infrastructure
🟥	Private
🟨	Public

Bank Category

🟥	Actively Eroding
🟨	Medium Erosion Potential
🟩	Low Erosion Potential
⬜	Bank Armoring

0 100 200 300 400 500 FEET

N

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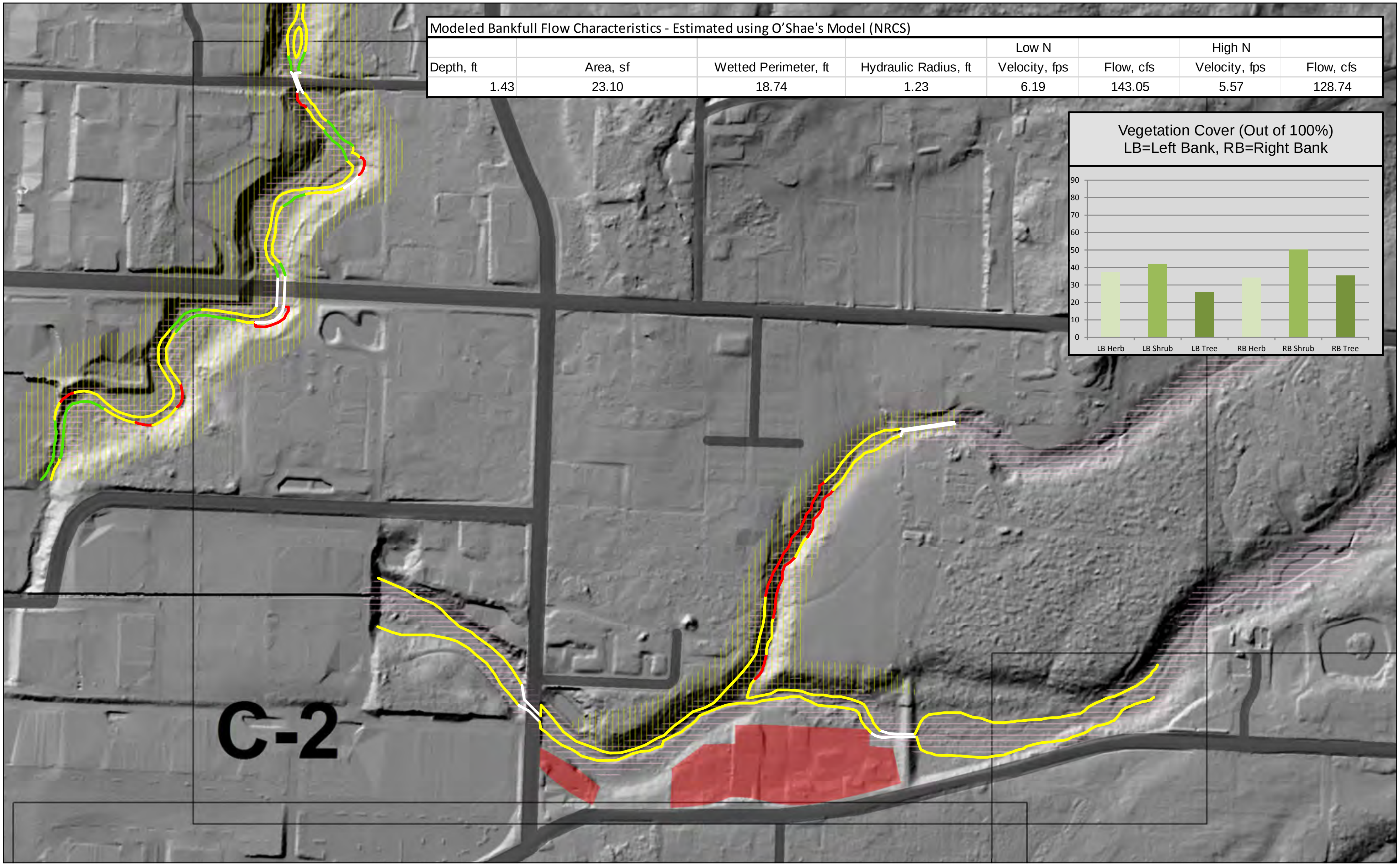
Squalicum Channel Migration Study

Reach ID: B-5

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
1.43	23.10	18.74	1.23	6.19	143.05	5.57	128.74

Detached Migration Areas

- Infrastructure
- Private
- Public

Erosion Hazard Areas

- Erosion Setback
- Geotechnical Setback

Bank Category

- Actively Eroding
- Medium Erosion Potential
- Low Erosion Potential
- Bank Armoring

Notes:

0 200 400 600 800 1,000 FEET

N

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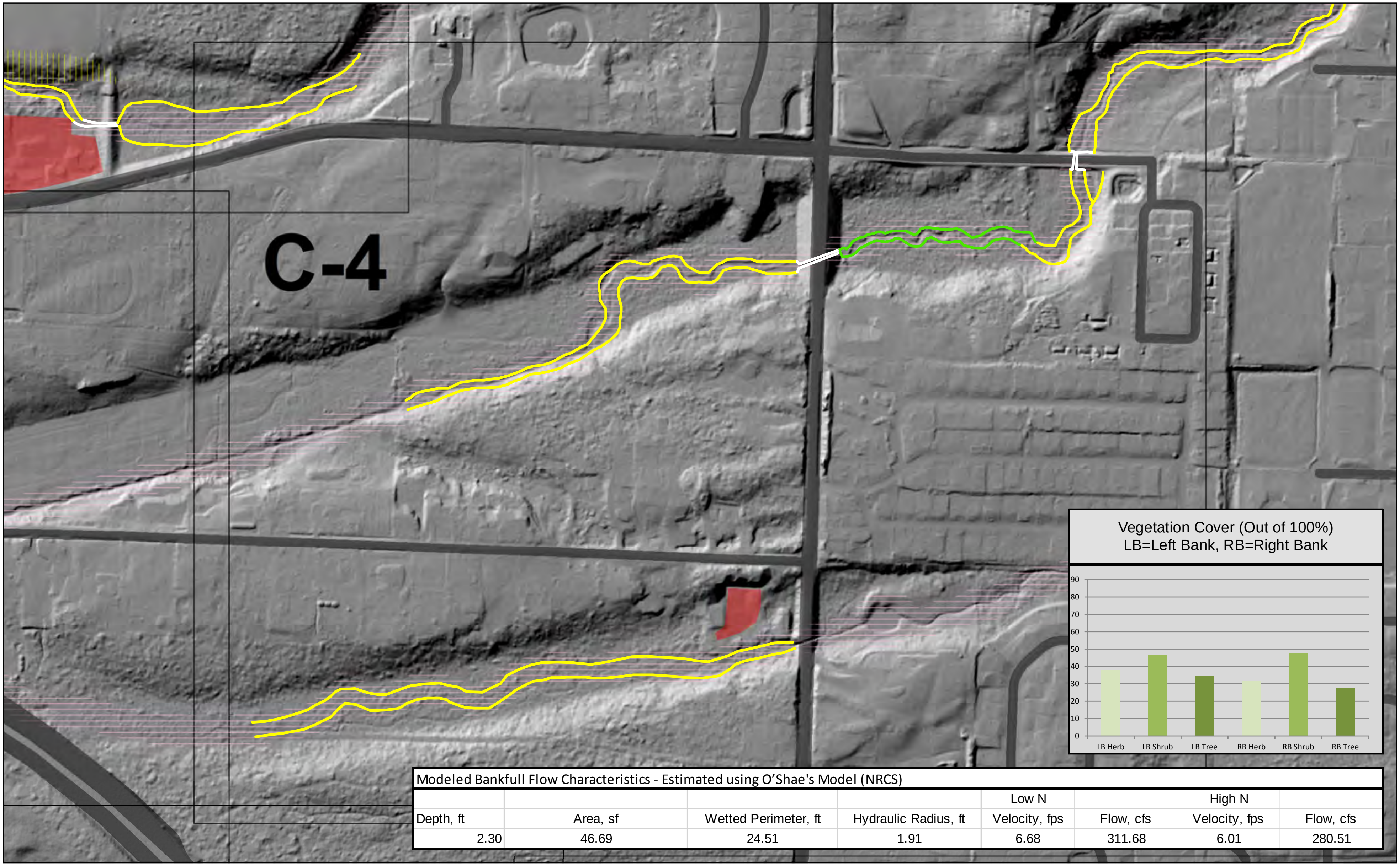
Squalicum Channel Migration Study

Reach ID: C-2

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_LANDSCAPE_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.30	46.69	24.51	1.91	6.68	311.68	6.01	280.51

Detached Migration Areas

- ▨ Infrastructure
- 🟥 Private
- 🟨 Public

Erosion Hazard Areas

- ▤ Erosion Setback
- ▥ Geotechnical Setback

Bank Category

- Actively Eroding
- Medium Erosion Potential
- Low Erosion Potential
- Bank Armoring

Notes:

0 200 400 600 800 1,000 FEET

N

ELEMENT solutions

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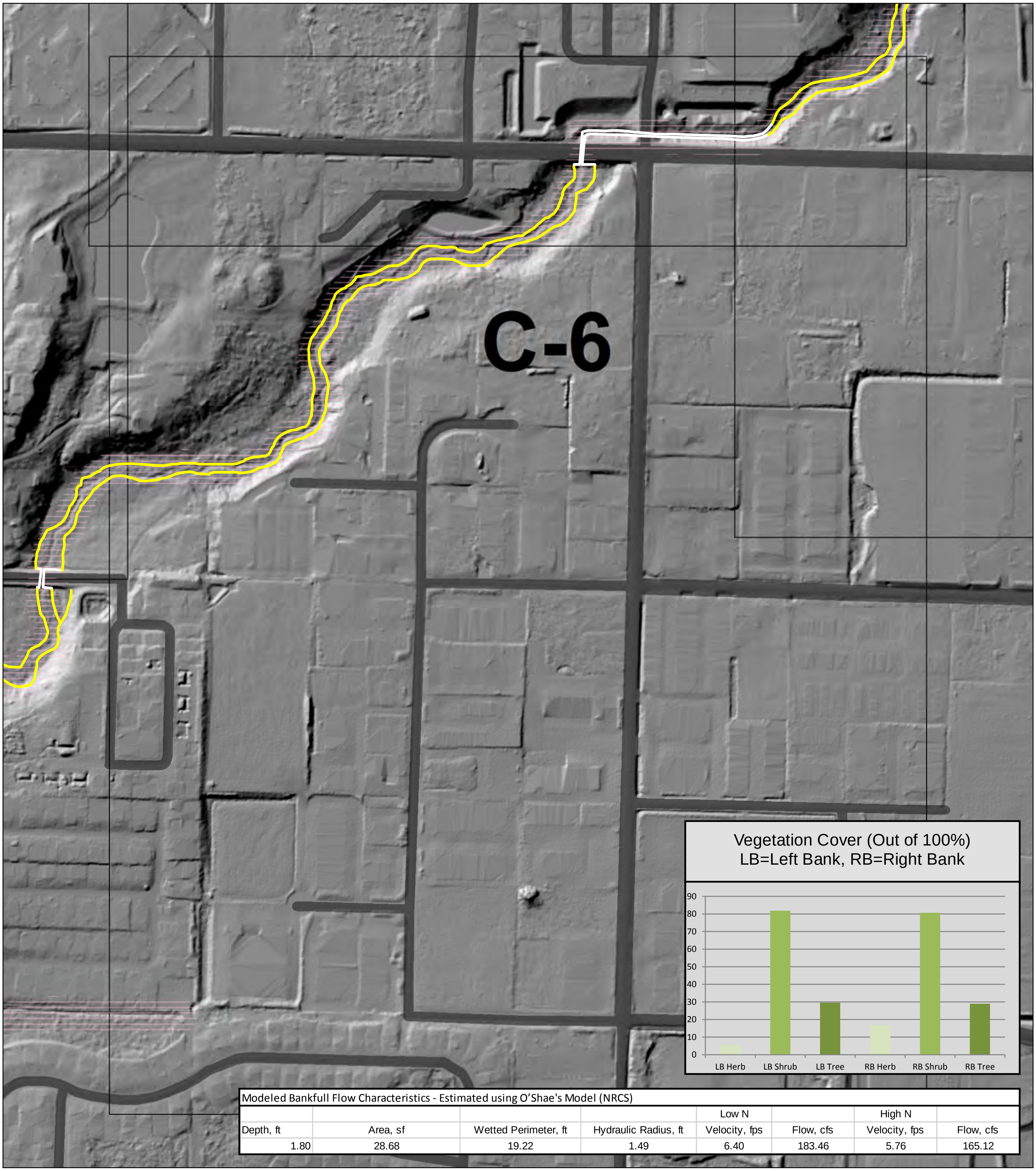
Squalicum Channel Migration Study

Reach ID: C-4

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_LANDSCAPE_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O’Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
1.80	28.68	19.22	1.49	6.40	183.46	5.76	165.12

Erosion Hazard Areas

☰	Erosion Setback
‖	Geotechnical Setback

Detached Migration Areas

■	Infrastructure
🟥	Private
🟨	Public

Bank Category

🟥	Actively Eroding
🟨	Medium Erosion Potential
🟩	Low Erosion Potential
⬜	Bank Armoring

FEET
0 100 200 300 400 500

N

ELEMENT solutions

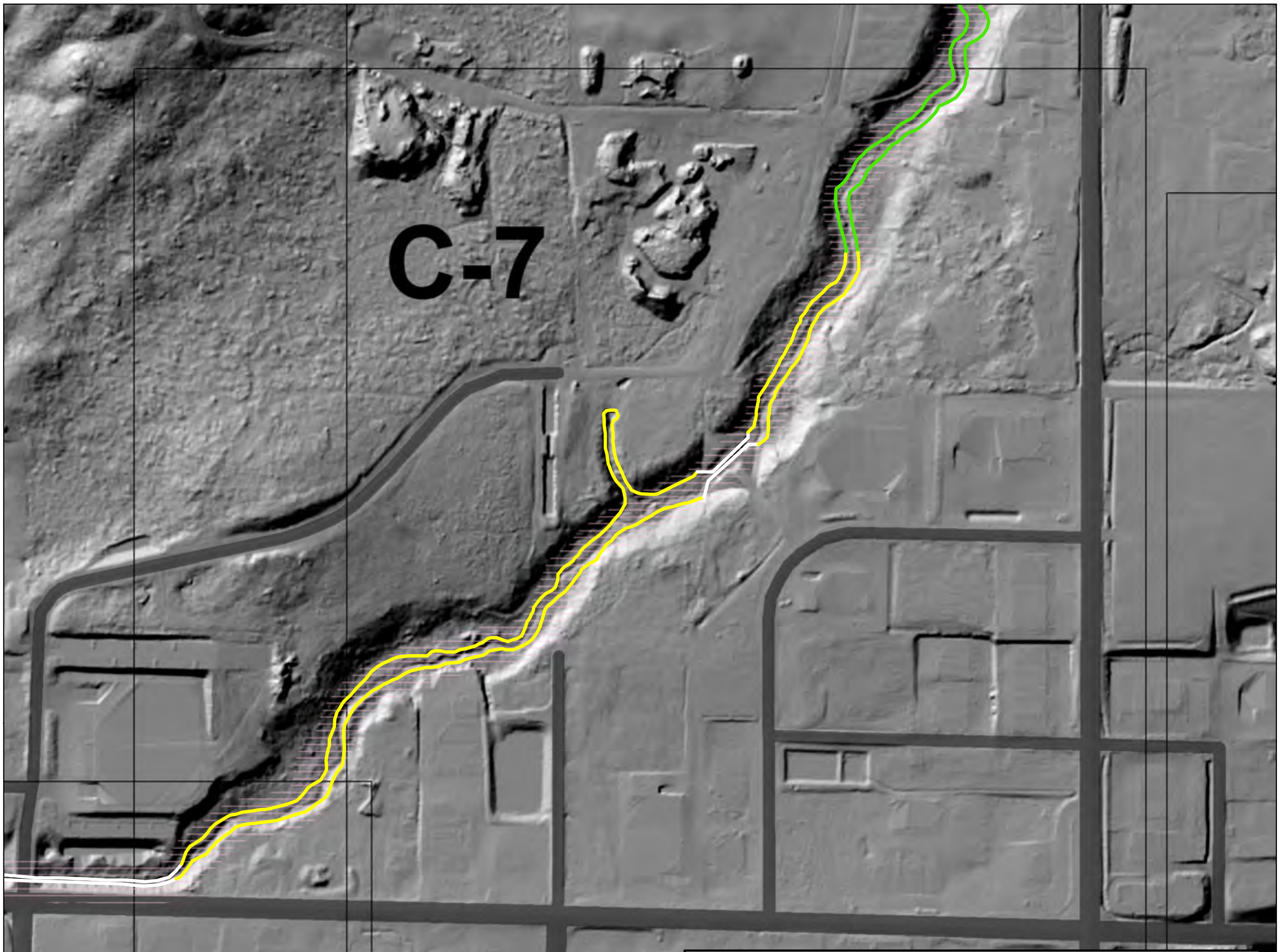
Squalicum Channel Migration Study

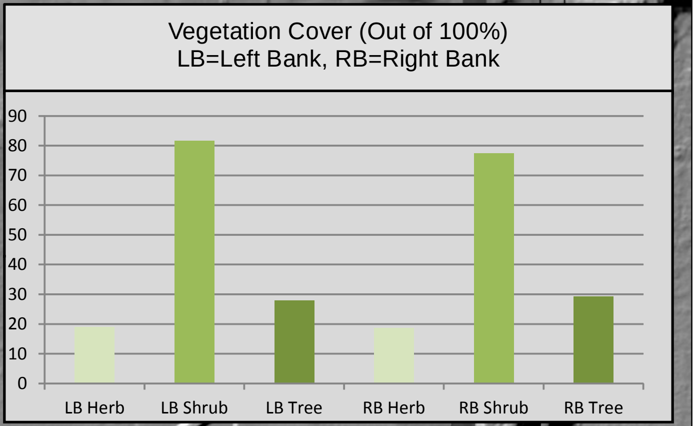
Reach ID: C-6

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd

info@elementsolutions.org

Date: 12/21/2015





Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
1.78	23.34	16.40	1.42	5.20	121.31	4.68	109.18

Erosion Hazard Areas

- ☰ Erosion Setback
- ▥ Geotechnical Setback

Detached Migration Areas

- ■ Infrastructure
- 🟥 Private
- 🟨 Public

Bank Category

- — Actively Eroding
- — Medium Erosion Potential
- — Low Erosion Potential
- — Bank Armoring

0 100 200 300 400 500 FEET

N

ELEMENT solutions

info@elementsolutions.org

Squalicum Channel Migration Study

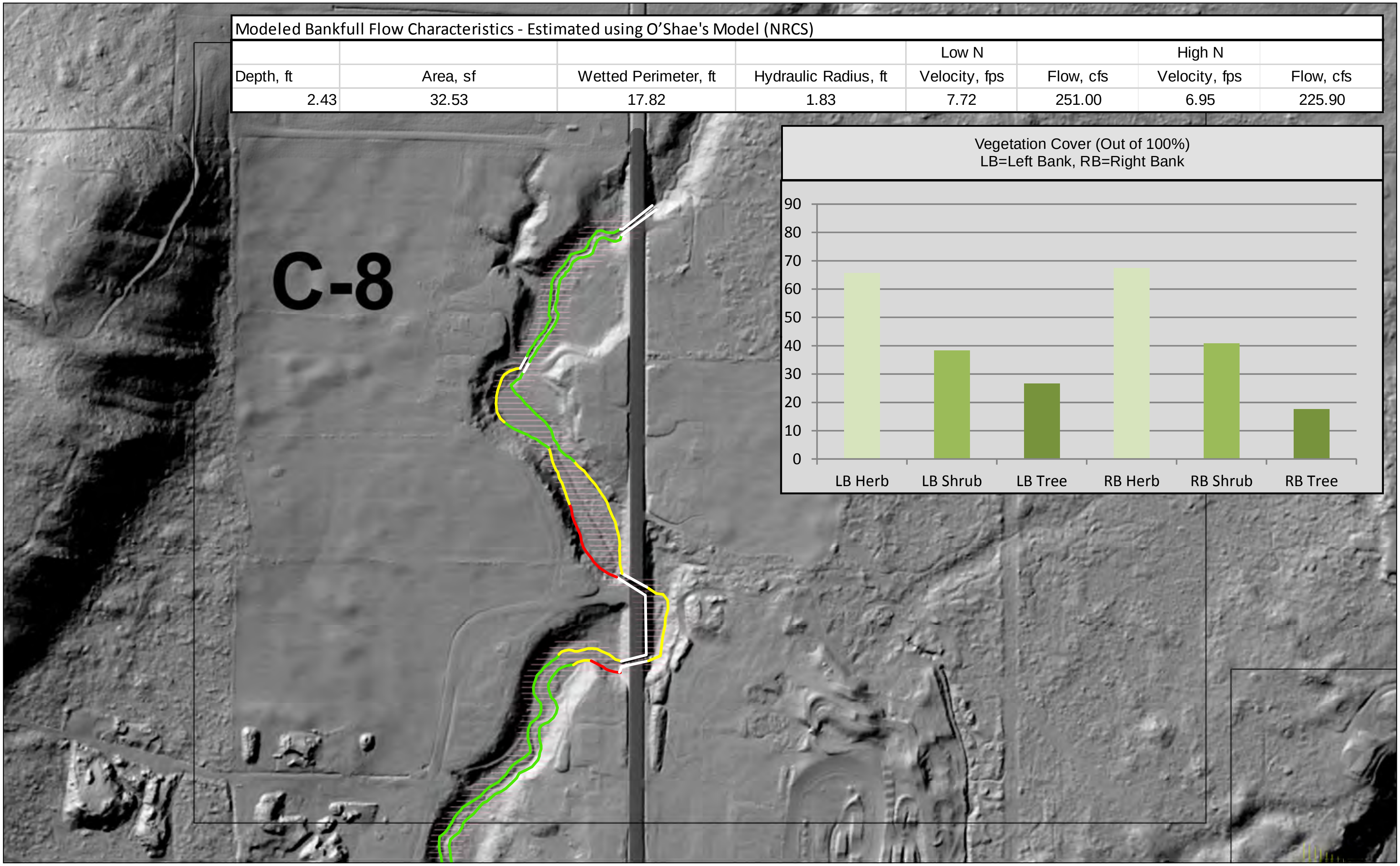
Reach ID: C-7

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd

Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.43	32.53	17.82	1.83	7.72	251.00	6.95	225.90



Detached Migration Areas

- ▨ Infrastructure
- 🟥 Private
- 🟨 Public

Erosion Hazard Areas

- ≡ Erosion Setback
- ||| Geotechnical Setback

Bank Category

- — Actively Eroding
- — Medium Erosion Potential
- — Low Erosion Potential
- — Bank Armoring

Notes:

FEET
0 200 400 600 800 1,000

N

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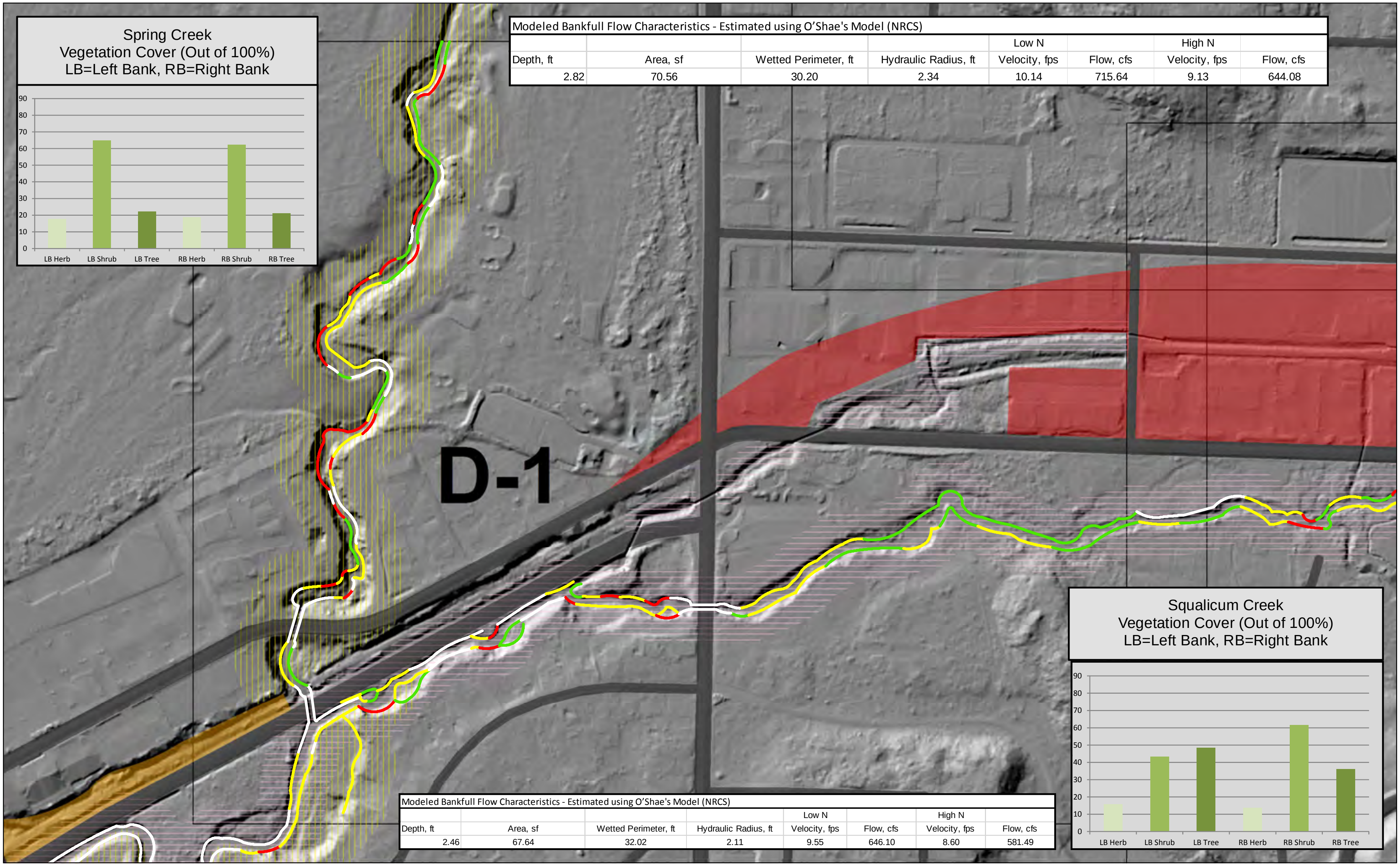
Squalicum Channel Migration Study

Reach ID: C-8

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_LANDSCAPE_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.82	70.56	30.20	2.34	10.14	715.64	9.13	644.08

Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.46	67.64	32.02	2.11	9.55	646.10	8.60	581.49

Detached Migration Areas

- ▨ Infrastructure
- 🟥 Private
- 🟧 Public

Erosion Hazard Areas

- ▤ Erosion Setback
- ▥ Geotechnical Setback

Bank Category

- Actively Eroding
- Medium Erosion Potential
- Low Erosion Potential
- Bank Armoring

Notes:

0 200 400 600 800 1,000 FEET

N

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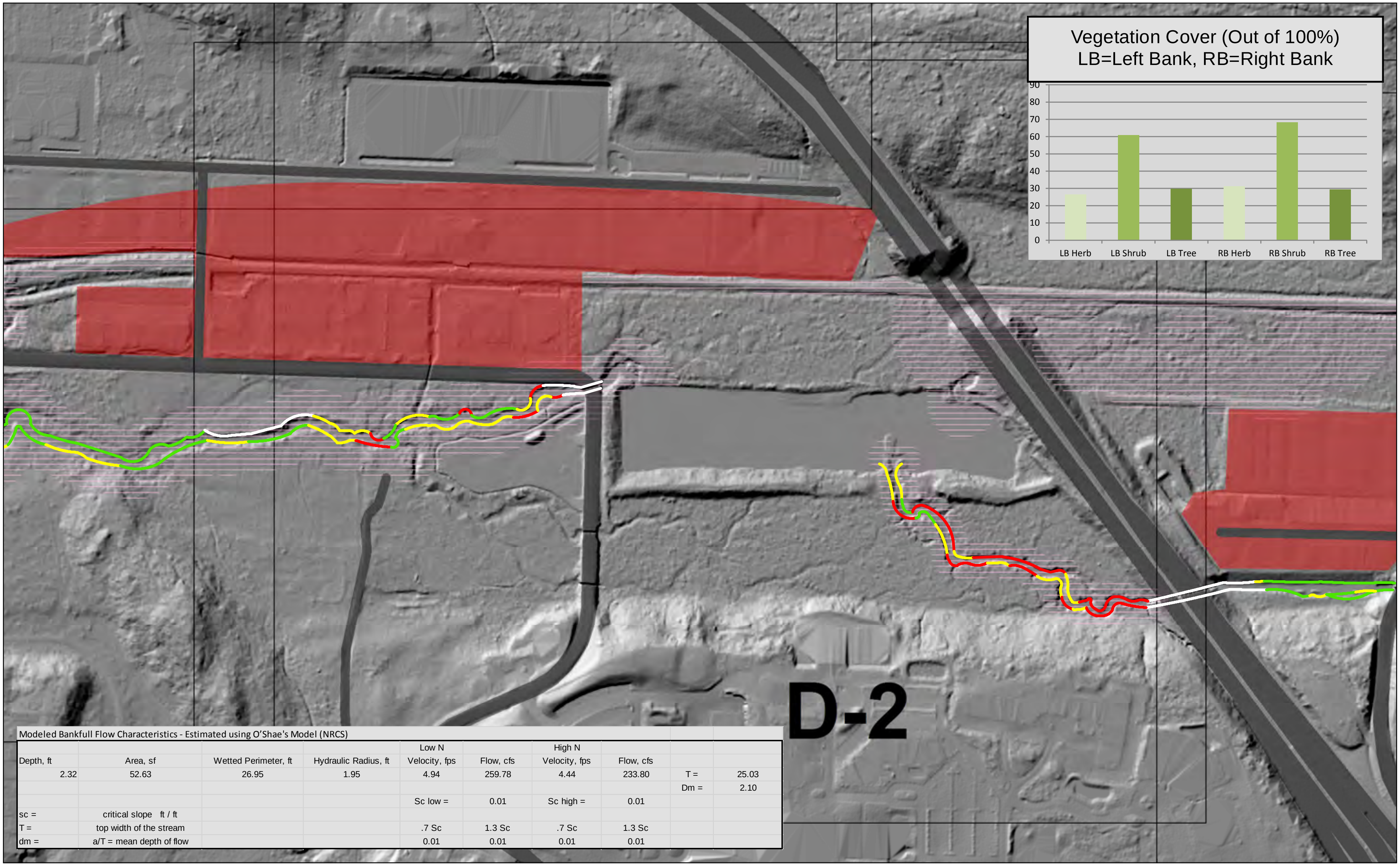
Squalicum Channel Migration Study

Reach ID: D-1

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_LANDSCAPE_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs		
2.32	52.63	26.95	1.95	4.94	259.78	4.44	233.80	T =	25.03
								Dm =	2.10
				Sc low =	0.01	Sc high =	0.01		
sc =	critical slope ft / ft								
T =	top width of the stream			.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
dm =	a/T = mean depth of flow			0.01	0.01	0.01	0.01		

Erosion Hazard Areas

- ▤ Erosion Setback
- ▥ Geotechnical Setback

Detached Migration Areas

- ■ Infrastructure
- 🟥 Private
- 🟧 Public

Bank Category

- ━ Actively Eroding
- ━ Medium Erosion Potential
- ━ Low Erosion Potential
- ━ Bank Armoring

Notes:

0 200 400 600 800 1,000 FEET

N

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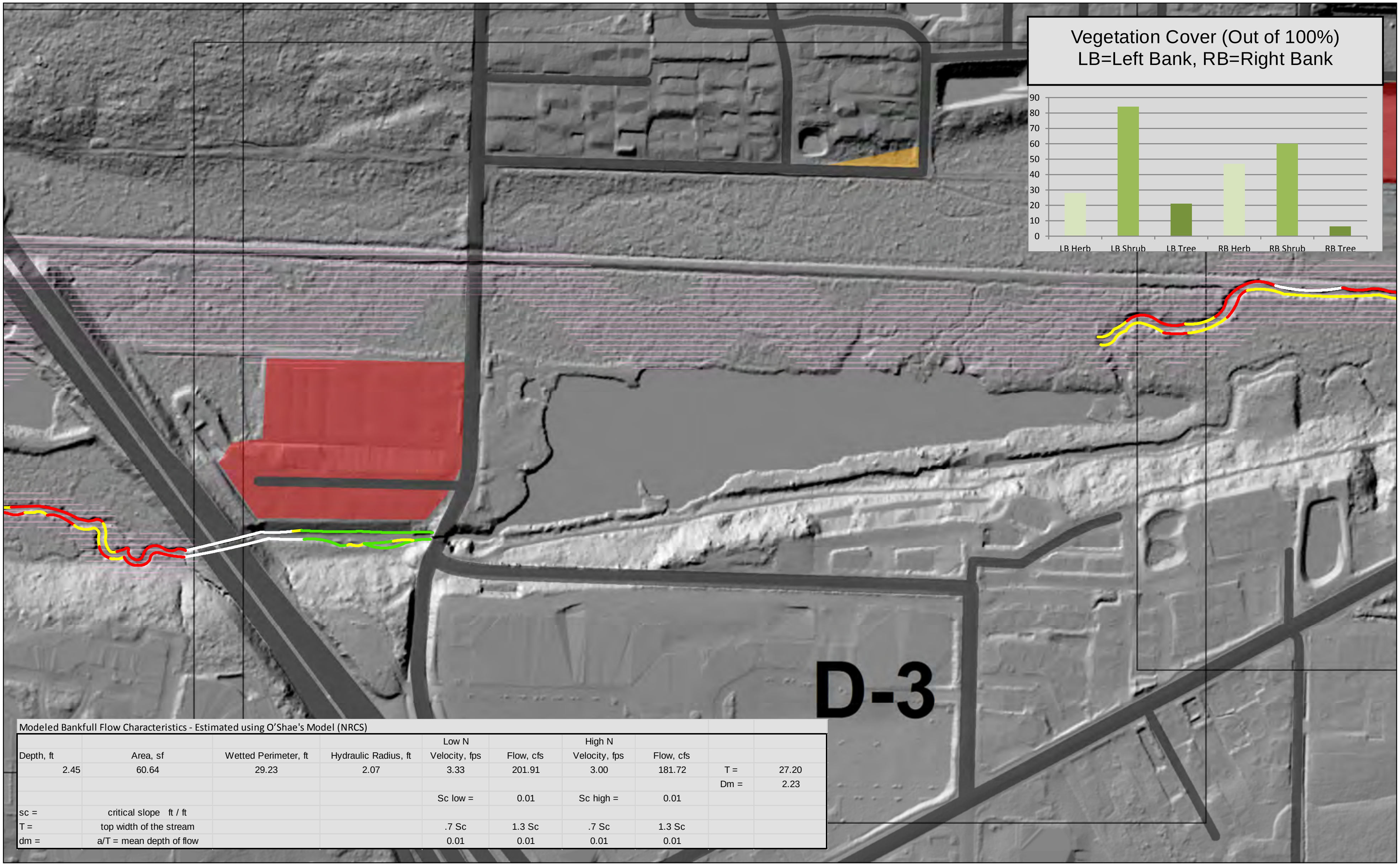
Squalicum Channel Migration Study

Reach ID: D-2

Date: 2/11/2016

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\Figures\Edit_1\maps\Comp_LANDSCAPE.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs		
2.45	60.64	29.23	2.07	3.33	201.91	3.00	181.72	T =	27.20
								Dm =	2.23
				Sc low =	0.01	Sc high =	0.01		
sc =	critical slope ft / ft								
T =	top width of the stream			.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
dm =	a/T = mean depth of flow			0.01	0.01	0.01	0.01		

Erosion Hazard Areas

- ▨ Erosion Setback
- ▨ Geotechnical Setback

Detached Migration Areas

- ■ Infrastructure
- 🟥 Private
- 🟨 Public

Bank Category

- — Actively Eroding
- — Medium Erosion Potential
- — Low Erosion Potential
- — Bank Armoring

Notes:

FEET
0 200 400 600 800 1,000

N

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Squalicum Channel Migration Study

Reach ID: D-3

Date: 2/11/2016

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\Figures\Edit_1\maps\Comp_LANDSCAPE.mxd

Modeled Bankfull Flow Characteristics - Estimated using O’Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.62	60.18	27.78	2.17	3.43	206.26	3.08	185.63

Detached Migration Areas
- ▨ Infrastructure
- 🟥 Private
- 🟨 Public

Erosion Hazard Areas
- ☰ Erosion Setback
- ||| Geotechnical Setback

Bank Category
- 🟥 Actively Eroding
- 🟨 Medium Erosion Potential
- 🟩 Low Erosion Potential
- ⬜ Bank Armoring

Notes:

FEET
0 200 400 600 800 1,000

N

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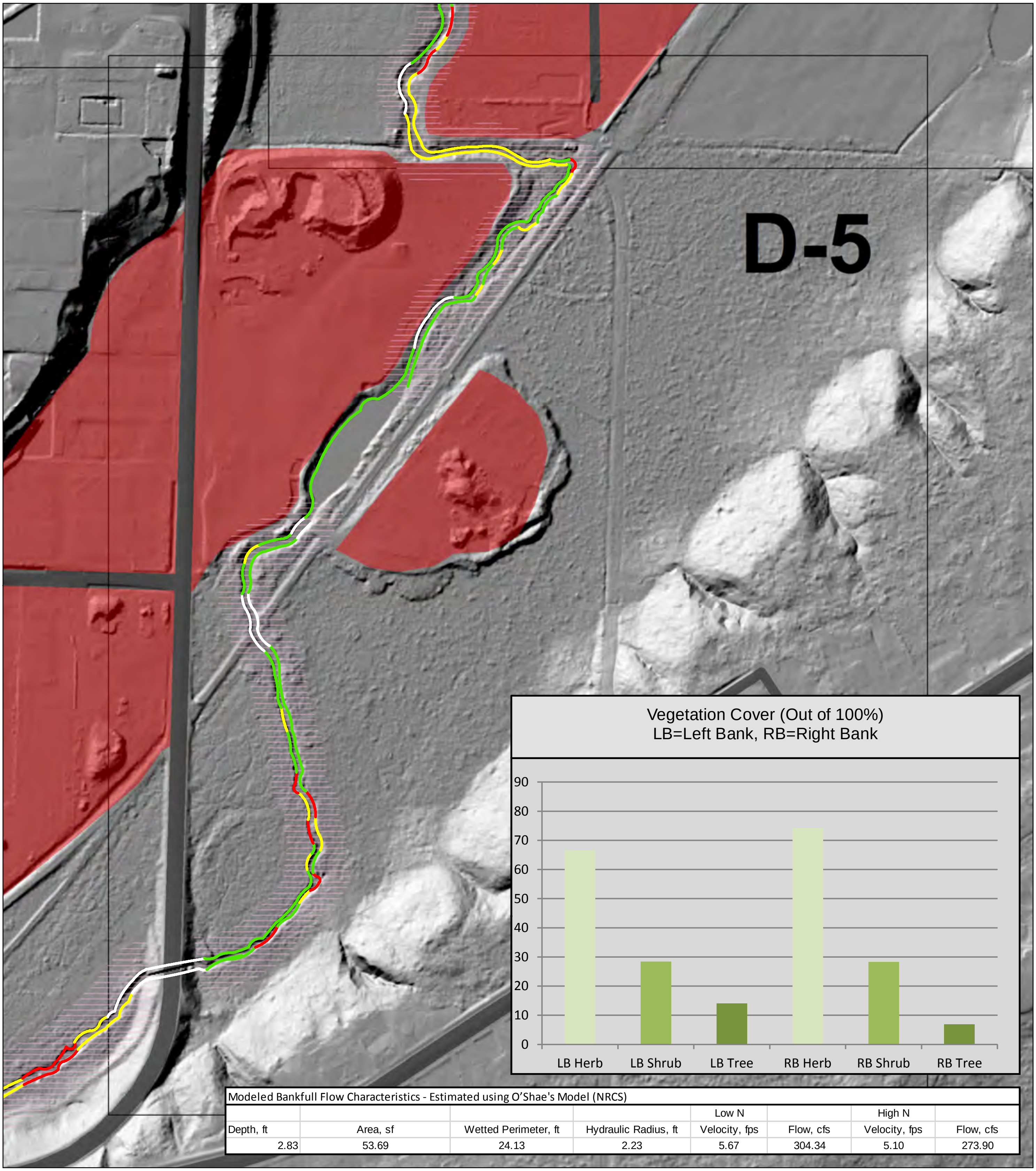
Squalicum Channel Migration Study
Reach ID: D-4

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_LANDSCAPE_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
2.83	53.69	24.13	2.23	5.67	304.34	5.10	273.90

Erosion Hazard Areas

▤ Erosion Setback

▥ Geotechnical Setback

Detached Migration Areas

■ Infrastructure

■ Private

■ Public

Bank Category

— Actively Eroding

— Medium Erosion Potential

— Low Erosion Potential

— Bank Armoring

0 100 200 300 400 500 FEET

N

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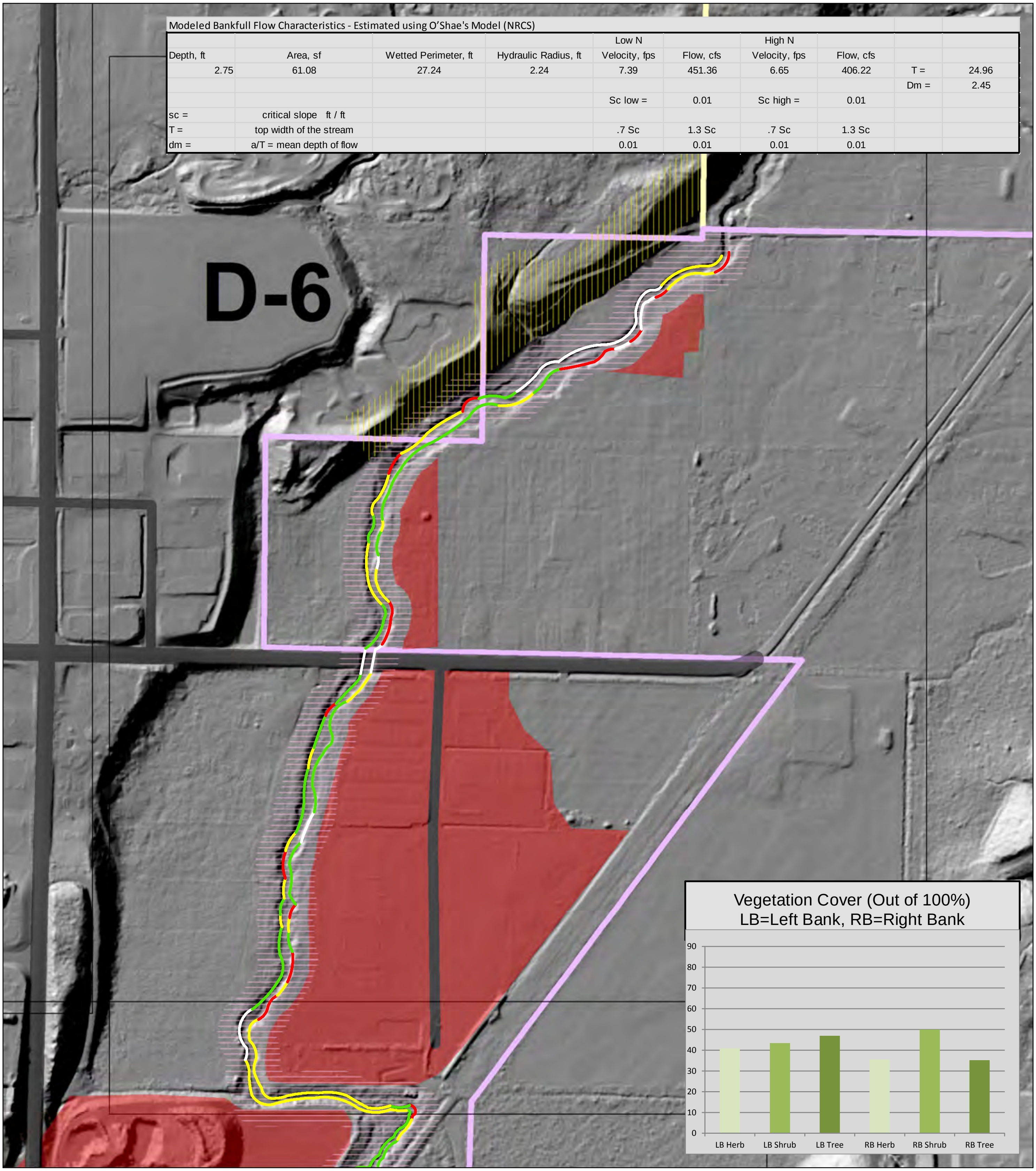
Squalicum Channel Migration Study

Reach ID: D-5

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs		
2.75	61.08	27.24	2.24	7.39	451.36	6.65	406.22	T =	24.96
								Dm =	2.45
				Sc low =	0.01	Sc high =	0.01		
sc =	critical slope ft / ft								
T =	top width of the stream			.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
dm =	a/T = mean depth of flow			0.01	0.01	0.01	0.01		

Erosion Hazard Areas

▨	Erosion Setback
▨	Geotechnical Setback

Detached Migration Areas

■	Infrastructure
■	Private
■	Public

Bank Category

—	Actively Eroding
—	Medium Erosion Potential
—	Low Erosion Potential
—	Bank Armoring

N

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Squalicum Channel Migration Study

Reach ID: D-6

Date: 2/11/2016

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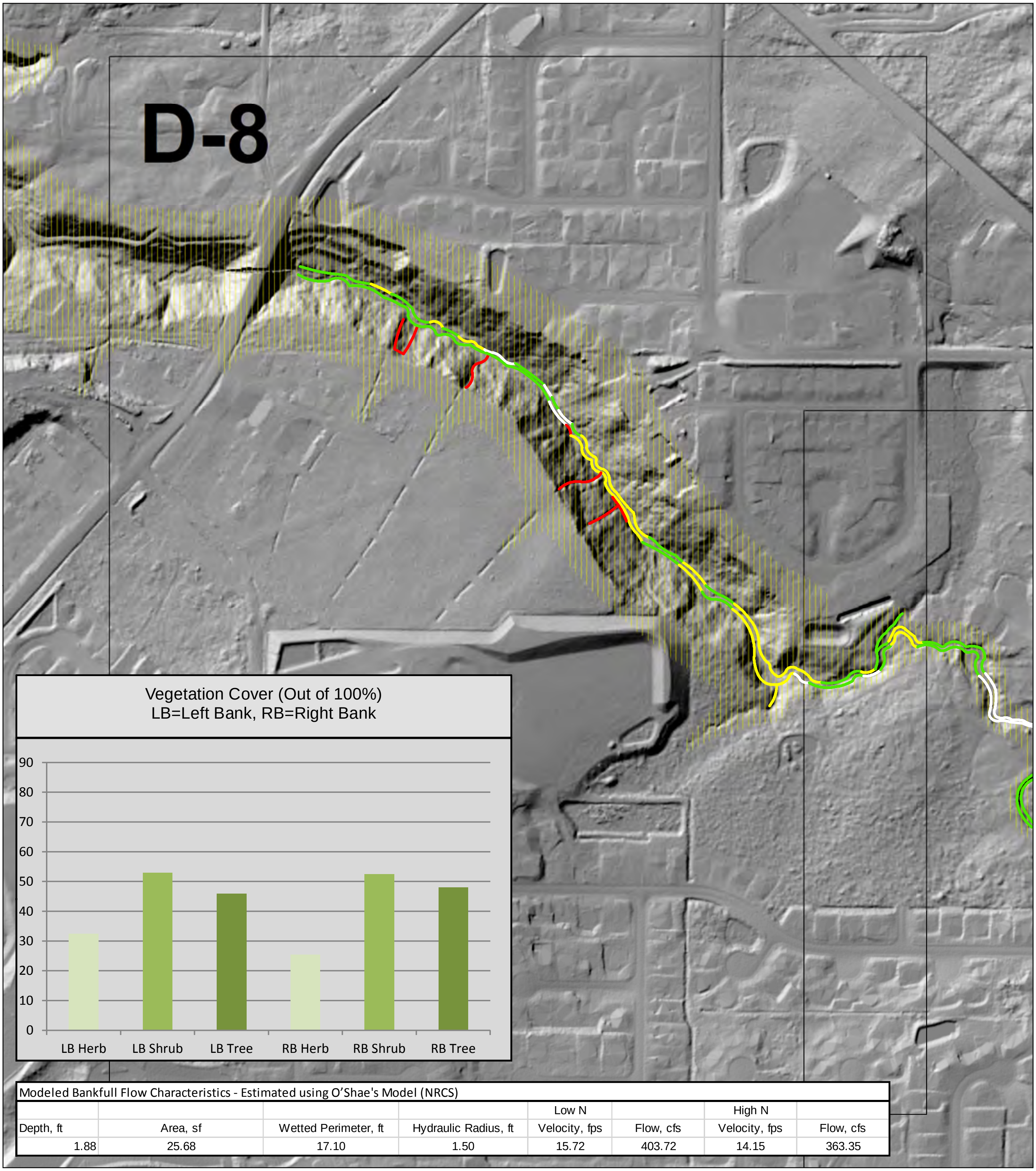

Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
1.88	25.68	17.10	1.50	15.72	403.72	14.15	363.35

Erosion Hazard Areas

- Erosion Setback
- Geotechnical Setback

Detached Migration Areas

- Infrastructure
- Private
- Public

Bank Category

- Actively Eroding
- Medium Erosion Potential
- Low Erosion Potential
- Bank Armoring

0 100 200 300 400 500 FEET

N

ELEMENT solutions

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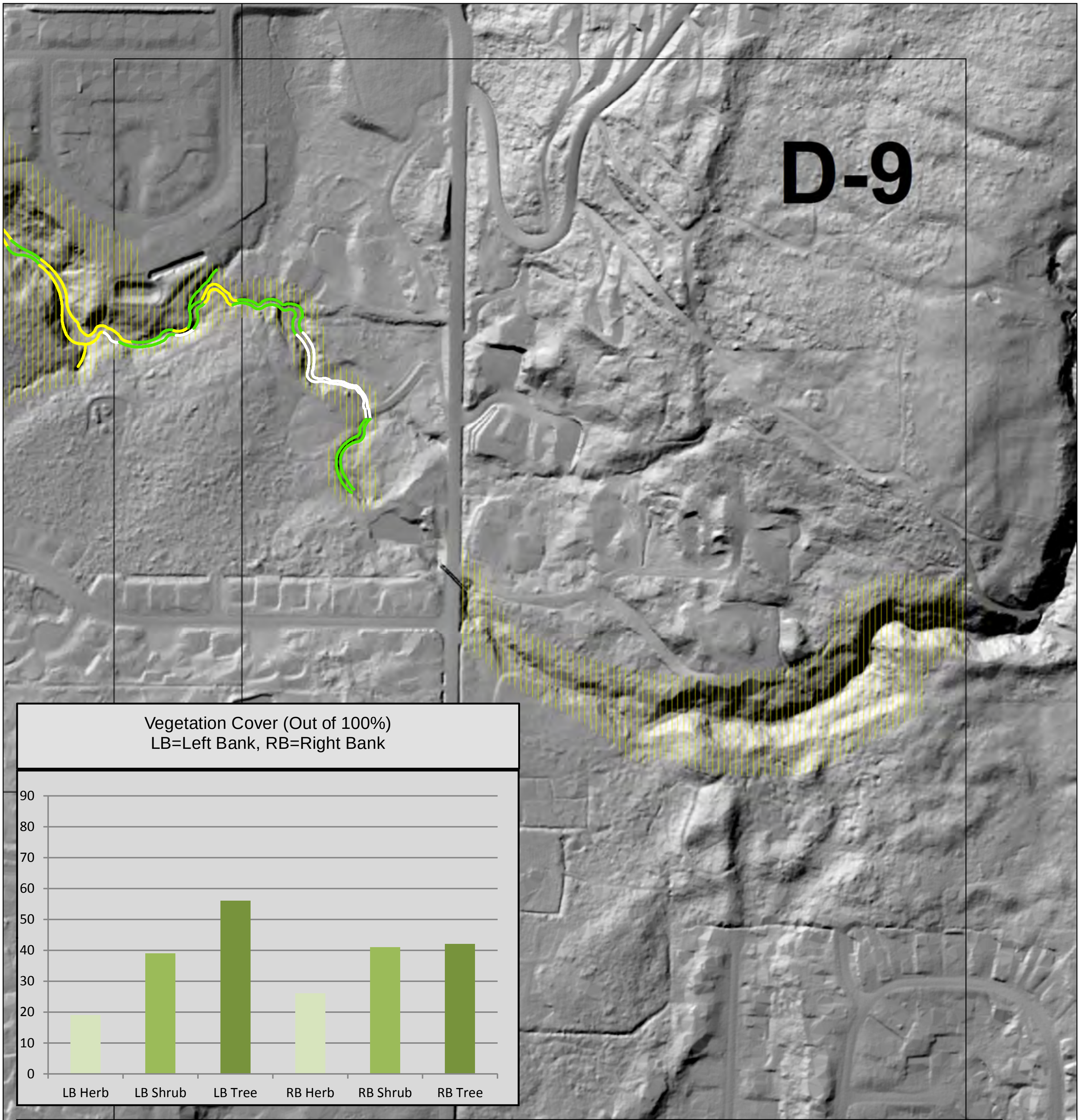
Squalicum Channel Migration Study

Reach ID: D-8

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd



Modeled Bankfull Flow Characteristics - Estimated using O'Shae's Model (NRCS)

				Low N		High N	
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs
1.37	12.80	11.87	1.08	14.72	188.39	13.24	169.55

Erosion Hazard Areas

- ☰ Erosion Setback
- ||||| Geotechnical Setback

Detached Migration Areas

- ■ Infrastructure
- ■ Private
- ■ Public

Bank Category

- — Actively Eroding
- — Medium Erosion Potential
- — Low Erosion Potential
- — Bank Armoring

0 100 200 300 400 500 FEET

N

ELEMENT solutions

info@elementsolutions.org

Squalicum Channel Migration Study

Reach ID: D-9

Date: 12/21/2015

Path: P:\Pse Project\2015196\GIS\Workspace\MXDs\DDP_PORTRAIT_B.mxd

Appendix III – Reach Photos

Lower Squalicum Creek Sub-basin - Reach A-1

Photo 1: Active Erosion site, partially armored.

Photo 2: Installed LWD near mouth.

Photo 3: Armored banks with blackberry.

Photo 4: Relict bank armoring.

Photo 5: Undercut banks below maturing alders.

Photo 6: Wide banks of Lower Squalicum with gravel.

Lower Squalicum Creek Sub-basin - Reach A-2

Photo 7: "Wing dam" with severe erosion in background.

Photo 8: Relict stormwater feature.

Photo 9: Glaciomarine drift "clayey" banks.

Photo 10: Glaciomarine drift bank demonstrating "resistance" to erosion.

Lower Spring Creek Sub-basin - Reaches B-1 and B-5

Photo 11: Urban Baker Ck. Above tributary confluence.

Photo 12: Culvert "mouth" of tributaries.

Photo 13: Banks lacking vegetation neat I-5.

Photo 14: Culvert wetland near Bakerview Rd.

Photo 15: Upper stream segment of B-5.

Photo 16: Bank erosion in reach B-5.

Baker Creek Tributaries Sub-basin - Reach C-2

Photo 17: Evidence of later erosion.

Photo 18: Channel modification on private property.

Photo 19: Stormwater control structure.

Photo 20: Wetland upstream of stormwater structure.

Photo 21: Bank modifications upstream of Baker Ck.

Photo 22: Gravel flood terrace in Cornwall Park.

Photo 23: Severe undercut bank behind Hospital.

Photo 24: Thick underbrush, bank erosion.

Photo 25: Active erosion in D-6.

Photo 26: Canarygrass field wetland in D-5.

Appendix IV – Reach Data Sheets

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID/ ~~Transect #~~ A-1 Date 11/6/15 Assessed by AC, LP
Stream Name Squalicum, Lower, MS. Reviewed by
Average Channel Slope
Reach Breaks *Rivermile Upstream Downstream
Channel Planform *Type
*Description

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill): Glacial Outwash
Features Observed (GPS Point Name) *Meander Scrolls
*Abandoned Channels Y *Active Side Channels Y
Active Erosion/deposition? Height of Bank & slope? (GPS: Erh1, Erh2
Indication of aggradation/incision
Other Fluvial Landforms
*Low-lying areas *Terraces
***Veg/unveg?** ***Hydro Mod. Type**
Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder)
Bank Composition Right bank: Left bank:
Avulsion Hazard Areas (AHAs) *Mapped?
*Diagnostic Landscape Features
Elevation of Channel (from Bfh)
Conveyance Ability

3 -Veg Cover (%H/S/T), Est. Rate of Errosion (L/M/H), Bank Composition (Sa/Si/G/C/B)

Remeasure - LH LB in field

Transect	Rb (%H/S/T)	Lb	Rb (L/M/H)	Lb	RB (Comp)	LB (Comp)	Bfw	Bfh
1	10/30/15	50/40/5	L	L	B (F)	Si / G	33.5	2.4
2 1.5	10/40/20	70/25/10	L	M	B / (F)	Si / Si	←	—
3 2	5/12/50	20/40/30	L	M	B(F)	B(F)	25	1.5
4 2.5	0/5/60	30/20/60	M	M	G / C	B	═	
5 3	25/15/40	5/40/70	H	M	B / G	C / Si	38.3	3.1
6 3.5	15/70	10/90	L	M	B (F)	S	═	
7 4	25/75/50	20/70/10	H	H	Si, G	B (F)	27.3	2.9
Notes: 4.5	10/40/40	5/60/30	H		S, G	S, G	~~20.0~~	~~1.8~~
5	70/40/10	10/10/50			B, S	B(F)/S	24.0	1.8
5.5	5/70/10	40/20/15			B (F)	B(F)	—	
6	10/10/15	10/25/25			B(F) / S	C/B(F)	25.3	1.4
6.5							—	
7								

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: A-2
Date: 11/11/15
Assessed by: AC, MG
Stream Name: Squali (Lower M/S)
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: Mostly sunny st @ 10:30 (Stage @ 10:45)

2 - Mapped Conditions

Glacial outwash

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform. Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

(CL clay
(S/G/C/B)
E

3 - Field Data: Bankfull	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp**	
			Rbank	Lbank	Rbank	Lbank
Transect 0.5	-	–	20/40/50	30/30/10	G/S	S
1 (wide clay)	30.2'	1.4'	10/40/40	20/30/50	S/BF	Si
1.5	-	-	5/60/40	10/70/20	BF/S	S
2	27.5	1.8'	40/50/10	5/90/20	S	G/S/BF
2.5	-	-	40/40/20	2/30/20	S/BF	S
3	33.5	3.3	5/50/40	5/50/40	S/BF/C	S/C
Flat 3.5 Not dry	-	-	50/40/40	60/10/40	BF/S	BF/S
L Bank *4 clay	19.6	2.4	0/40/20	10/70/30	BF/S	*Clay/S
4.5	-	-	2/70/20	2/30/10	S/C	*Clay
5	39.2	1.6	20/30/30	10/70/20	S/BF	Clay/S
* 5.5 Culv	-	-	2/[illegible]/5	2/5/2	—	—
6 culv	21.4	2.3	2/5/1	5/10/10	BF	BF
6.5	-	-	10/60/10	2/10/40	BF/S	S/G
7	31.8	4.1	50/40/20	10/50/30	S/CL	BF -
7.5 End	-	-	15/90/35	30/15/30	S/G	CL
8						

restoration site ⓡ Bank

clay
"

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID B-5 Date 12/10/15 Assessed by AC MG

Stream Name Spring Ck Reviewed by

Average Channel Slope

Reach Breaks Rivermile Upstream Downstream

Channel Planform Type

Description Rainy, overcast

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill): **Meander Scrolls**

*Features Observed (GPS F*doned Channels Active Side Channels

Active Erosion/deposition? Height of Bank & slope?

Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas Terraces

Sub Reaches w/o veg Hydro Mod. Type

Predominant Bed load size and Range?

(sand, silt, gravel, cobble, boulder) Right bank: Left bank:

Bank Composition

Avulsion Hazard Areas (AHAs) Mapped?

Diagnostic Landscape Features

Elevation of Channel (from Bfh)

Conveyance Ability

3 - Field Data

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
1	22.0	2.8	5/30/60	50/80/5	S	S
1.5	-	-	15/40/40	60/80/30	S	S
2	13.5	1.5	10/90/50	20/80/15	S	S
2.5	-	-	2/95/10	5/90/30	S	S
3	12.7	2.4	20/80/20	30/85/25	S	Armored
3.5	-	-	20/15/60	5/90/10	S/BE	Armored
4	32.8	2.6	85/15/35	60/20/40	S	S
4.5	-	-	10/95/15	40/30/30	Armored	S
5	19.6	1.3	40/40/40	60/50/70	S/C	S
5.5	-	-	2/95/30	2/95/15	CL/SC	S
6	18.9	2.3	2/95/30	2/95/15	S	CL/G
6.5	-	-	20/95/15	30/70/35	S	S
~~**7**~~						
~~7.5~~	~~-~~	~~-~~				
~~**8**~~						
8.5	—	—	5/95/40	2/95/30	S	S

B4 culv.

stream wL complex

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID C-2
Date 12/10/15
Assessed by AC NB
Stream Name Baker Ck
Reviewed by
Average Channel Slope
Reach Breaks Rivermile Upstream Downstream
Channel Planform Type
Description Rainy / overcast

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls
*Features Observed (GPS F*doned Channels
Active Side Channels
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas
Terraces
Sub Reaches w/o veg
Hydro Mod. Type

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

HBB cannot access

N. Trib

S. Trib

Wetland *

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect 0.5	–	–	10/95/15	5/95/30	S	S
~~1~~						
1.5	-	-	10/30/10	60/40/5	S	S
2	9.8	1.5	10/20/10	30/40/30	S	S
2.5	-	-	30/50/30	20/70/5	S	CL/S
3	8.9	1.6	80/15/20	10/70/10	S	S
3.5	-	-	35/20/35	20/20/30	S	S
4	8.1	1.2	5/20/70	30/20/70	S	S
4.5	-	-	15/60/40	5/95/40	S	S
5	7.5	1.4	80/20/5	85/20/5	S	S
5.5	-	-	10/90/20	10/90/40	S	S
6	7.4	1.5	20/20/10	60/40/30	S/Bf	S/Bf
6.5	-	-	80/10/20	80/30/20	S	S
7	46.4*	1.4	70/80/30	30/70/60	S	S
7.5	-	-	60/70/50	40/70/60	S	S
8						

*WL

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: C-4 | Date: 10/11/15 | Assessed by: AC NB

Stream Name: Baker Ck | Reviewed by:

Average Channel Slope:

Reach Breaks Rivermile Upstream: Downstream:

Channel Planform Type:

Description: Cold, partly cloudy - Notes: slow flowing, deep many side channels/WLs

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):

Meander Scrolls:

*Features Observed (GPS F*doned Channels: Active Side Channels:

Active Erosion/deposition? Height of Bank & slope?

Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas: Terraces:

Sub Reaches w/o veg: Hydro Mod. Type:

Predominant Bed load size and Range?

(sand, silt, gravel, cobble, boulder) Right bank: Left bank:

Bank Composition

Avulsion Hazard Areas (AHAs) Mapped?

Diagnostic Landscape Features

Elevation of Channel (from Bfh)

Conveyance Ability

3 - Field Data

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
SKIP **1**						
1.5	-	-				
start@ N.Trib **2**	23.0	2.3	10/80/30	30/50/10	S/CL	S/CL
2.5	-	-	60/30 30	5/80/20	S~~/CL~~	S/CL
3	13.6	2.4	60/5/40	10/80 30	S	S/cl
3.5	-	-	10/40/60	10/70/20	S	S
4	17.3	2.3	2/30 30	30/80 35	S/CL	S/CL
4.5	-	-	5/85/25	30/60 20	S/CL	S/CL
5	13.4	2.1	5/80/30	5/80 30	CL/S	S/CL
5.5	-	-	5/80/70	5/20/20	S	S
RCG **6**	13.6	2.5	98/5/5	98/10 10	S	S
6.5	-	-	98/15/10	97/10/10	S	S
7	17.1	2.2	40/60/20	20/60/25	S	S
7.5	-	-	60/50/35	40/70/35	Armored	S
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: C-6
Date: 12/11/15
Assessed by: AC NB
Stream Name: Baker ck
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: sunny, cold

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

skipped
skip
Bfw
Bfh

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
1						
1.5	-	-	2/85/40	2/98/20	S	S
2	11.1	1.7	10/50/35	2/90/20	S	S
2.5	-	-	2/98/20	0/98/30	S	S
3			2/98/36	2/98/30	S	S
3.5	-	-	2/70/50	50/30/40	S	S
4	19.0	2.5	10/60/50	70/30/40	S	S
4.5	-	-				
5						
5.5	-	-	2/92/10	2/92/10	S	S
6	12.3	1.2	2/98/20	2/98/35	S	S
6.5	-	-	15/80/30	20/85/35	S	S
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: C-7
Date: 12/11/12
Assessed by: AC NB
Stream Name: Baker Ck
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream:
Downstream:
Channel Planform Type:
Description: P. cloudy, cold

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision
Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
1						
1.5	-	-				
2	13.9	2.5	5/98/10	5/98/20	S	S
2.5	-	-	5/70/60	2/98/10	S	S
3	15.2	1.6	5/20/70	10/50/40	S	S
3.5	-	-	10/80/50	60/20/15	S	S
4	8.2	1.4	20/70/40	20/60/30		
4.5	-	-	85			
5						
5.5	-	-				
6	8.2	1.6	85/10/50	85/10/20	S	S
~~6.5~~	~~-~~	~~-~~	~~85/40/40~~	~~85/40/20~~	~~S~~	~~S~~
7						
7.5	-	-				
8						
C-8 1	10.8	2.7	70/40/30	85/30/40	S	S
1.5	—	—	10/98/35	20/98/40	S	S
2	—	—				

Skip

Skip

58

Transferred

WL

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: C-8
Date: 12-11-15
Assessed by: A C NB
Stream Name: Baker Ck
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: P. Cloudy, Cold

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs) Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data: Bankfull	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp**	
			Rbank	Lbank	Rbank	Lbank
Transect .5	—	—	85/40/20	85/30/20	S/CL	S/CL
1	10.8	2.7	70/40/30	~~20/98/40~~ → 85/30/40		↙ ↓
1.5	-	-	10/98/35	20/98/40	↓	↓
Skip ~~2~~						
~~2.5~~						
wetld 3	—	—	30/20/35	6/98/35		
3.5	-	-	20/85/30	30/20/80		
RCGWL 4	10.6	2.6	98/5/0	98/10/5		
4.5	-	-	98/5/5	98/10/5		
5	11.4	2.0	98/10/2	85/20/10		
5.5	-	-	98/16/2	85/20/5	↓	↓
6						
6.5	-	-				
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: D-1
Date: 11/23/15
Assessed by: N.B., A.C.
Stream Name: Lower Squalicum
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: 40-50°F, Overcast, chance of rain.

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform. Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

Dom/Sub Dom

Silt/Sand, Clay, Gravel, cobble, boulder
F (man made)

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
1	17'	2.9'	70/30/80	40/80/70	CL	S/C
1.5	X	X	10/80/50	10/80/70	S/G	S/C
2	16.1'	1.6'	10/60/20	10/60/30	B/S	B
2.5	-	-	50/60/20	10/50/40	S/CL	B/CL
3	22.2'	2.4'	5/40/40	2/50/30	CL/S	CL/S
3.5	-	-	2/20/20	5/40/10	S/Bf	CL/Bf
4	27.8'	3.0'	2/30/60	5/70/40	S/G	S
4.5	-	-	10/80/30	10/90/5	S	S
5	27.2'	1.7'	2/50/30	5/80/5	S/G	S/G
5.5	-	-	2/10/80	10/40/60	S	S
6	38.2'	2.9'	2/2/30	20/50/10	S/BR	S/BR
6.5	-	-	20/40/80	20/50/80	S	S
7	27'	2.7'	20/50/70	30/60/20	S	S
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID D-1

Date 11/23/15

Assessed by N.B, A.C.

Stream Name Lower Squalicum

Reviewed by

Average Channel Slope

Reach Breaks Rivermile Upstream

Downstream

Channel Planform Type

Description 40-50°F, Overcast, chance of rain.

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):

Meander Scrolls

*Features Observed (GPS F*doned Channels

Active Side Channels

Active Erosion/deposition? Height of Bank & slope?

Indication of aggradation/incision

Other Fluvial Landform. Low-lying areas

Terraces

Sub Reaches w/o veg

Hydro Mod. Type

Predominant Bed load size and Range?

(sand, silt, gravel, cobble, boulder) Right bank: Left bank:

Bank Composition

Avulsion Hazard Areas (AHAs)

Mapped?

Diagnostic Landscape Features

Elevation of Channel (from Bfh)

Conveyance Ability

Silt, Sand, Clay, Gravel, cobble, boulder
F (man made)

3 - Field Data

	Bfw	Bfh	Veg Cover (%H/S/T)		Bank Comp (S/CL/G/C/B) Dom/Sub Dom	
			Lbank	Rbank	Lbank	Rbank
Transect						
1	17'	2.9'	70/30/80	40/80/70	CL	S/C
1.5	X	X	10/80/50	10/80/70	S/G	S/C
2	16.1'	1.6'	10/60/20	10/60/30	B/S	B
2.5	-	-	50/60/20	10/50/40	S/CL	B/CL
3	22.2'	2.4'	5/40/40	2/50/30	CL/S	CL/S
3.5	-	-	2/20/20	5/40/10	S/Bf	CL/Bf
4	27.8'	3.0'	2/30/60	5/70/40	S/G	S
4.5	-	-	10/80/30	10/90/5	S	S
5	27.2'	1.7'	2/50/30	5/80/5	S/G	S/G
5.5	-	-	2/10/80	10/40/60	S	S
6	38.2'	2.9'	2/2/50	20/50/10	S/BR	S/BR
6.5	-	-	20/40/80	20/50/30	C	S
7	27'	2.7'	20/50/70	30/60/20	S	S
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID D-1

Date 12/9/15

Assessed by AC MG

Stream Name Spring ck

Reviewed by

Average Channel Slope

Reach Breaks Rivermile Upstream Downstream

Channel Planform Type

Description P. cloudy, sunny, cold

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):

Meander Scrolls

*Features Observed (GPS F*doned Channels

Active Side Channels

Active Erosion/deposition? Height of Bank & slope?

Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas

Terraces

Sub Reaches w/o veg

Hydro Mod. Type

Predominant Bed load size and Range?

(sand, silt, gravel, cobble, boulder) Right bank: Left bank:

Bank Composition

Avulsion Hazard Areas (AHAs)

Mapped?

Diagnostic Landscape Features

Elevation of Channel (from Bfh)

Conveyance Ability

3 - Field Data

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
1	29.2	1.5	10/20/30	20/30/20	S/G	S/G
1.5	-	-	5/90/10	5/95/40	S/G	S/G
2	22.5	2.5	2/95/10	5/35/40	S/G	S/G
2.5	-	-	2/95/30	5/95/30	S/G	S
3	21.2	3.1	2/95/30	5/70/20	S/G	S/G
3.5	-	-	50/40/5	50/40/2	S/Bo	S/Bo
4	22.2	3.8	20/50/30	5/40/20	S	S/G
4.5	-	-	5/20/25	40/30/10	S/G	S/G
5	19.5	3.0	60/30/20	60/30/15	S	S
5.5	-	-	30/50/5	10/80/30	S	S/Bo
6	18.8	3.0	10/80/50	2/90/5	S	S
6.5	-	-				
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: D-2
Date: 11/30/15 12/1/15
Assessed by: AC, MG
Stream Name: Lower Squalicum
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: Clear skys - Cold - icy (Day 1) / Overcast (day 2)

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision
Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

11/30/15
12/1/15

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect (0.5)	–	–	5/80/70	5/80/70	S/G	S/G
1	27.6	3.7	10/80/60	50/70/60	S/G	S/G
1.5	-	-	30/80/15	95/40/45	S/G	S/G
2	11.4	1.9	90/20/5	60/30/20	S/G	S/G
2.5	-	-	70/20/10	20/60/30	S/G	S/G
3	26.4	2.0	40/50/2	70/40/30	S/CF	BF/S
3.5	-	-	2/90/30	5/80/30	S	S/
4	20.2	2.1	5/90/40	5/90/35	S	S/G
4.5	-	-	10/90/30	10/40/20	S	S
5	17.6	2.7	30/20/45	10/90/20	S/CL	S
5.5	-	-	15/90/20	5/90/2	S	S
6	19.2	2.3	30/30/30	40/50/20	S/CL	S
6.5	-	-				
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: D-3
Date: 12/2/15
Assessed by: AC MG
Stream Name: Lower Squali
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: Overcast, cold

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect (0.5)	—	—	30/80/20	30/40/10	S/CL	S/G
1	19.8	2.0	10/80/20	70/40/5	S/CL	S/CL
1.5	-	-	10/80/20	70/40/5	S	S
2	24.8	2.9	80/90/10	60/90/2	S	S
2.5	-	-	30/90/5	5/90/10	S/GL	S
3						
3.5	-	-				
4						
4.5	-	-				
5						
5.5	-	-				
6						
6.5	-	-				
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: D-4
Date: 12/3/15
Assessed by: AC/MG
Stream Name: Lower Squalicum
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: over-cast, chance of rain

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs) Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect (0.5)	—	—	15/95/2	15/90/5	S/G	S
1	19.2	2.8	2/95/10	80/2/10	S	S
1.5	-	-	2/95/30	80/2/10	S	S
2	19.7	2.1	5/95/9	80/2/5	S	S/cF
2.5	-	-	5/75/30	80/5/5	S	S/cF
3	20.7	2.5	20/40/35	40/20/15	S	S
3.5	-	-	30/40/15	70/20/5	S	S
4	18.6	3.9	45/10/45	30/75/45	S	S
4.5	-	-	50/40/30	30/80/20	S/CL	S
5	19.2	2.6	90/20/0	80/20/0	S/CL	S/CL
5.5	-	-	80/10/40	95/5/0	S/CL	S/CL
6	15.9	2.8	70/5/30	90/10/10	S/CL	S/G
6.5	-	-	80/5/20	95/5/5	S/CL	BC/S
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: 0-5
Date: 2/4/15
Assessed by: AC / MG
Stream Name: lower Squalicum
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: Overcast, chance rain.

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision
Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data

	Bfw	Bfh	Veg Cover (%H/S/T)		Bank Comp (S/CL/G/C/B)	
			Lbank	Rbank	Lbank	Rbank
Transect			*RCG	*RCG		
1	14.2	3.7	95/20/2	100/10/0	S/CL	S/CL
1.5	-	-	100/0/0	100/0/0	S/CL	S/CL
2	13.2	2.5	100/0/5	100/0/0	CL/S	CL/S
2.5	-	-	100/15/20	100/2/0	S/G	CL/S
3	13.2	2.1	80/30/45	100/2/0	CL/S	CL/S
3.5	-	-	80/20/15	100/5/0	S	S
4	20.2	2.0	30/50/5	20/80/2	S/G	S
4.5	-	-	20/80/20	10/70/0	S	S
5	19.7	4.1	90/20/20	70/40/30	S/CL	S/CL
5.5	-	-	70/20/10	70/40/20	S/CL	S/CL
6	16.2	2.6	35/5/10	40/70/20	S/CL	S/CL
6.5	-	-	30/80/5	90/20/10	S/CL	S/CL
7						
7.5	-	-				
8						

*@ u/s culvert includes rd.

skip Transect on map

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID D-6

Date 12-04-15

Assessed by AC, NB

Stream Name Squalicum Creek (Lower)

Reviewed by

Average Channel Slope

Reach Breaks Rivermile Upstream Downstream

Channel Planform Type

Description Partially Cloudy / Sunny, 50-60°F.

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):

Meander Scrolls

*Features Observed (GPS F*doned Channels

Active Side Channels

Active Erosion/deposition? Height of Bank & slope?

Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas

Terraces

Sub Reaches w/o veg

Hydro Mod. Type

Predominant Bed load size and Range?

(sand, silt, gravel, cobble, boulder)

Right bank: Left bank:

Bank Composition

Avulsion Hazard Areas (AHAs)

Mapped?

Diagnostic Landscape Features

Elevation of Channel (from Bfh)

Conveyance Ability

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect						
1	12.2"	2.4"	90/5/2	90/10/2	S/CL	S/CL
1.5	-	-	75/60/60	30/80/10	S/CL	S/CL
2	14.2	3.1	40/60/50	20/90/10	S/CL	S/B^f
2.5	-	-	10/60/60	20/50/20	S/CL	S/CL
3	17.5	4.0	40/50/50	10/80/30	S/CL	S/CL
3.5	-	-	30/50/70	10/40/80	B^f/G	S/CL
4	32.0	1.9	90/40/50	20/60/80	S/CL	S
4.5	-	-	40/60/50	30/40/60	S/CL	S/CL
5	17.5	1.7	10/80/20	40/30/60	S	S
5.5	-	-	60/30/70	5/90/30	S/CL	S/CL
6	29.2	2.9	20/40/60	2/80/20	S	S
6.5	-	-	30/80/40	2/80/30	S	S/G
7	15.9	1.8	30/30/80	40/10/50	S	S
7.5	-	-	30/10/40	50/20/30	S/G	S/B^f
8	17.2	4.2	50/10/20	50/20/20	S/B^f	B^f/S
8.5	–	–	60/30/30	70/30/30	S/B^f	S/B^f

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: D-9
Date: 12/17/15
Assessed by: AC NB
Stream Name: Tead Ck
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile, Upstream: Downstream:
Channel Planform Type:
Description: overcast, drizzling

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform. Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs) Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data

	Bfw	Bfh	Veg Cover (%H/S/T)		Bank Comp (S/CL/G/C/B)	
			Lbank	Rbank	Lbank	Rbank
Transect						
1	8.9	1.5	15/30/80	10/30/60	BR/s	BR/B
1.5	-	-	10/5/80	15/70/30	S	S
2	6.2	1.2	60/40/20	5/80/30	S	S
2.5	-	-	5/60/40	90/5/10	BF	BF
3	7.9	1.4	5/20/60	10/20/80	S	S
3.5	-	-				
4						
4.5	-	-				
5						
5.5	-	-				
6						
6.5	-	-				
7						
7.5	-	-				
8						

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID : D-8
Date 12/7/15
Assessed by AC / NB
Stream Name : Toad CK
Reviewed by
Average Channel Slope
Reach Breaks Rivermile Upstream Downstream
Channel Planform Type
Description over cast, chance rain

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls
*Features Observed (GPS F*doned Channels
Active Side Channels
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision
Other Fluvial Landform: Low-lying areas
Terraces
Sub Reaches w/o veg
Hydro Mod. Type
Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder)
Right bank:
Left bank:
Bank Composition
Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features
Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data	**Bfw**	**Bfh**	**Veg Cover (%H/S/T)**		**Bank Comp (S/CL/G/C/B)**	
			Lbank	Rbank	Lbank	Rbank
Transect ~~0.5~~			~~20/15/30~~			
1	12.2	1.8	10/40/60	20/60/40	S	S
1.5	-	-	20/70/50	10/30/50	S	S
2	14.0	1.6	70/10/90	50/10/40	S	S
2.5	-	-	40/50/30	20/15/60	S/G	S
3	12.2	1.7	20/70/50	10/70/50	S	S
3.5	-	-	40/30/50	50/20/50	S/C	S/CL
4	6.6	2.5	30/50/40	30/60/10	S/G	S/G
4.5	-	-	10/30/50	30/70/60	S	S
5	13.9	1.8	40/40/60	20/60/60	S/BR	S/BR
5.5	-	-	15/80/30	15/80/30	BR/S	S
6						
6.5	-	-				
7						
7.5	-	-				
8						

* guess looking up/s

Planning-Level CMZ - Reach Datasheet

1 - Reach Characteristics

Reach ID: D-8
Date: 12/7/15
Assessed by: AC / NB
Stream Name: Toad CK
Reviewed by:
Average Channel Slope:
Reach Breaks Rivermile Upstream: Downstream:
Channel Planform Type:
Description: over cast, chance rain

2 - Mapped Conditions

Geology Type (e.g. glacial, alluvial, colluvial, fill):
Meander Scrolls:
*Features Observed (GPS F*doned Channels:
Active Side Channels:
Active Erosion/deposition? Height of Bank & slope?
Indication of aggradation/incision

Other Fluvial Landform: Low-lying areas:
Terraces:
Sub Reaches w/o veg:
Hydro Mod. Type:

Predominant Bed load size and Range?
(sand, silt, gravel, cobble, boulder) Right bank: Left bank:
Bank Composition

Avulsion Hazard Areas (AHAs)
Mapped?
Diagnostic Landscape Features

Elevation of Channel (from Bfh)
Conveyance Ability

3 - Field Data	Bfw	Bfh	Veg Cover (%H/S/T)		Bank Comp (S/CL/G/C/B)	
			Lbank	Rbank	Lbank	Rbank
Transect ~~0.5~~			~~70/15/30~~			
1	12.2	1.8	10/40/60	20/60/40	S	S
1.5	-	-	20/70/50	10/30/50	S	S
2	14.0	1.6	70/10/40	60/10/40	S	S
2.5	-	-	40/50/30	20/15/60	S/G	S
3	12.2	1.7	20/70/50	10/70/50	S	S
3.5	-	-	40/30/60	50/20/50	S/C	S/CL
4	6.6	2.5	30/50/40	30/60/40	S/G	S/G
4.5	-	-	40/70/50	30/70/60	S	S
5	13.9	1.8	40/50/60	20/60/60	S/BR	S/BR
5.5	-	-	15/80/30	15/80/30	BR/S	S
6						
6.5	-	-				
7						
7.5	-	-				
8						

* guess looking up/s