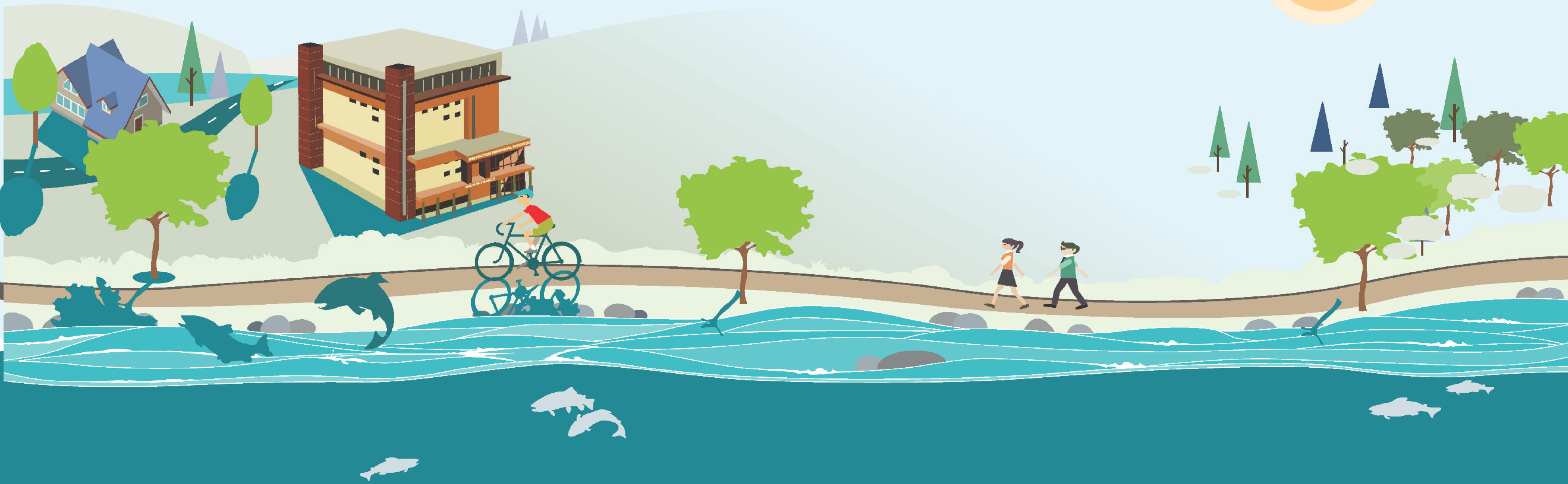
ELLIS CREEK

MASTER PLAN

CITY OF Penticton



Prepared by:
Stantec Consulting Limited.

Stantec

March 18, 2020

SOUTH OKANAGAN SIMILKAMEEN CONSERVATION PROGRAM

PENTICTON INDIAN BAND

Okanagan Nation Alliance

PENTICTON INDUSTRIAL DEVELOPMENT ASSOCIATION

Penticton Flyfishers

wise design

Freshwater Fisheries Society of BC

Adjacent Landowners

BRITISH COLUMBIA

Water Management | Fish and Wildlife

ACKNOWLEDGEMENTS

The Ellis Creek Master Plan has been a collaborative effort. We would like to acknowledge the time and effort invested to this planning process directly and indirectly by all participants.

The project team has collaborated with a wide variety of stakeholders to characterize Ellis Creek and identify the key limitations that control the system. Local knowledge has been applied with technical expertise to guide future design and construction projects that will ultimately implement the principles defined herein.

The Ellis Creek Master Plan would not have been possible without the contribution and collaboration of many people. Our sincere gratitude is extended to the numerous City staff, committee members and consultants who engaged themselves in the planning process and supported the outcome.

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Description	Date
Draft Master Plan	October 16, 2019
Final Master Plan	February 21, 2020
Revised Master Plan	March 18, 2020

Introduction

Ellis Creek has always been an important part of Penticton, but the channel is currently out of balance because of historical floods and pressure from urbanization. We have a plan that will restore balance to Ellis Creek. There is great social and environmental value in restoring Ellis Creek, including flood protection, improved fish habitat, and enhanced aesthetics.

The City of Penticton (the City) identified problems with Ellis Creek and initiated the development of a plan of action for the long-term revitalization of the Ellis Creek corridor. The Ellis Creek Master Plan (ECMP) sets the long-term direction to address flood control, erosion, deposition, and improve fish habitat, through the naturalization of the creek. Stantec Consulting Ltd. was engaged to lead the preparation of the Ellis Creek Master Plan in collaboration with the Penticton and Ellis Creek Restoration Committee (PECRC).

PURPOSE AND OBJECTIVES

The purpose of the Ellis Creek Master Plan is to:

- Gain a **holistic understanding of the key factors** controlling the Ellis Creek channel
- **Develop sustainable naturalization solutions** for Ellis Creek that reduce flooding risks
- **Recommend** an implementation strategy with risk-based prioritizations to guide Master Plan actions
- Gain and incorporate **public feedback** into the Master Plan

Specific objectives of the Master Plan are to:

Stabilize Ellis Creek Channel

Decrease erosion and sedimentation within the channel to stabilize the bed and banks. For example, severely degraded and unstable reaches on Ellis Creek can be stabilized, mitigating sediment inputs into the Creek and reducing aggradation downstream.

Improve Ecological Function

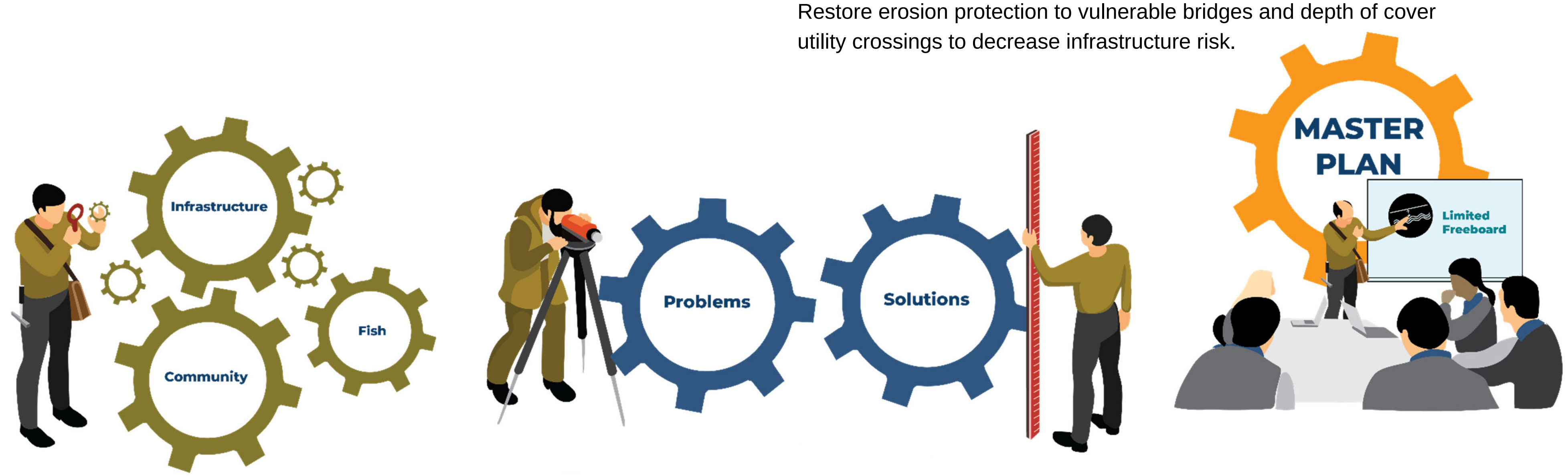
Rehabilitate the Ellis Creek channel and floodplain to enhance Kokanee and rainbow trout habitat. Other riparian and species will also benefit.

Increase Flood Resiliency

Decrease flooding on Ellis Creek through assessment of the flood hazard and implementation of flood protection measures.

Decrease Infrastructure Risk

Restore erosion protection to vulnerable bridges and depth of cover utility crossings to decrease infrastructure risk.



PLANNING PROCESS

Stantec worked with City staff and the Penticton and Ellis Creek Restoration Committee on the completion of the Master Plan. Penticton City Council established the Penticton Creek Restoration Committee. City Council then expanded the committee's mandate to include Ellis Creek at which point the committee became known as the Penticton and Ellis Creek Restoration Committee.

The Master Plan was developed in three phases starting with a series of technical assessments. Next, the information from the technical assessments were evaluated to inform the recommendations. Finally, recommendations were developed that included concept designs for the naturalization of Ellis Creek.

Due to the complex and interrelated nature of the problems on Ellis Creek, several technical assessments were completed to inform the Master Plan. Assessment tasks ranged from engineering reviews to environmental and cultural assessments. Specifically, the following tasks were completed:

- Existing conditions mapping
- Reaches and land ownership review
- Design flow analyses
- Fish habitat assessment
- Erosion and sedimentation study
- Cultural and heritage inventory mapping
- Hydrogeology desktop assessment
- Infrastructure risk evaluation
- Culvert crossing options analysis
- Reach by reach description
- Revitalization options and recommended solution
- Reach prioritization
- Cost estimates
- Public engagement

The Plan is intended to be implemented as separate projects, that include detail design, preparation of tender documents, construction, contract administration and environmental monitoring. Individual projects are prioritized within the Plan to aid in obtaining funding and scheduling the mitigation of the most critical issues first.

PUBLIC ENGAGEMENT

Stantec has conducted a thorough consultation and engagement process with support from the City of Penticton Staff, Committee members and C4Wise Communications. The Master Plan was prepared and consolidated into graphical presentation boards and PowerPoint presentation slides. The presentation media were used to engage the public across online engagement and face-to-face public events.

A summary of engagement activities completed, findings and resulting actions are described herein.

Figure 1. Farmers Market Public Engagment Session

What's been done?

- Oct 15 – Nov 15, 2019: "Shape your City" public engagement online
- Oct 15, 2019: Penticton Indian Band and City Council presentations
- Oct 19, 2019: Farmers Market display and public review session
- Oct 23, 2019: Penticton Community Center presentation
- Nov 1, 2019: Cantex and Pentiction Industrial Associate presendations

What have we heard?

Over 160 comments received from public, stakeholders and committee members

General acceptance and support for restoration of Ellis Creek

Key comments requiring revisions to the Ellis Creek Master Plan

Specific objections to aspects of the plan

Important comments for consideration

Ellis Creek Overview

Ellis Creek is an urban stream that flows through the City of Penticton, from the east side of the Okanagan Valley to the Okanagan River between Okanagan Lake and Skaha Lake (Figure 2). The extents of the project begin at the Ellis Creek Dog Park bridge and extend roughly 5 km upstream to a diversion structure (See map on page 4).

Important characteristics of Ellis Creek include:

- **Urbanization** has encroached and resulted in a straightened channel through the City
- **Confinement** of the channel for over 80 years
- Construction of a diversion structure (1966) permanently **altered sediment transport** characteristics
- **Floods** may inundate large areas of Penticton
- Active **erosion** threatens infrastructure
- Sediment **deposition** impacts fish passage / spawning
- Tributary to **Okanagan River**
- Important **Salmon and Trout habitat**
- **Elevated ground water**
- Eleven **bridge** crossings
- One **drop structure** which is a fish barrier most of the year

In the spring of 2017 and particularly 2018, unusually high freshet flows eroded parts of Ellis Creek bed and banks and damaged infrastructure. The 2017 high flows eroded the creek bed exposing and breaking water mains and exposing gas lines at Dartmouth Road. In the spring of 2018 high flows eroded the creek banks in the area east of Dartmouth Road. Bed load from this erosion was transferred downstream with deposition between Government Street Bridge and Main Street. During the 2018 flood, the took emergency measures to remove bed material to provide sufficient freeboard at several bridge crossings. One key issue to be resolved by the Ellis Creek Master Plan is erosion and sedimentation control.

The Okanagan Nation Alliance coordinated improvements to fish passage at the sedimentation basin between the bridge on Highway 97 and the road culvert on Industrial Avenue. Construction of the improvements were completed in 2018.

In the fall of 2019, the City of Penticton excavated material, deposited in 2018, that decreased capacity the Industrial Street Bridge. The instream works were permitted through the Ministry of Forest Lands and Natural Resource Operations and Rural Development.

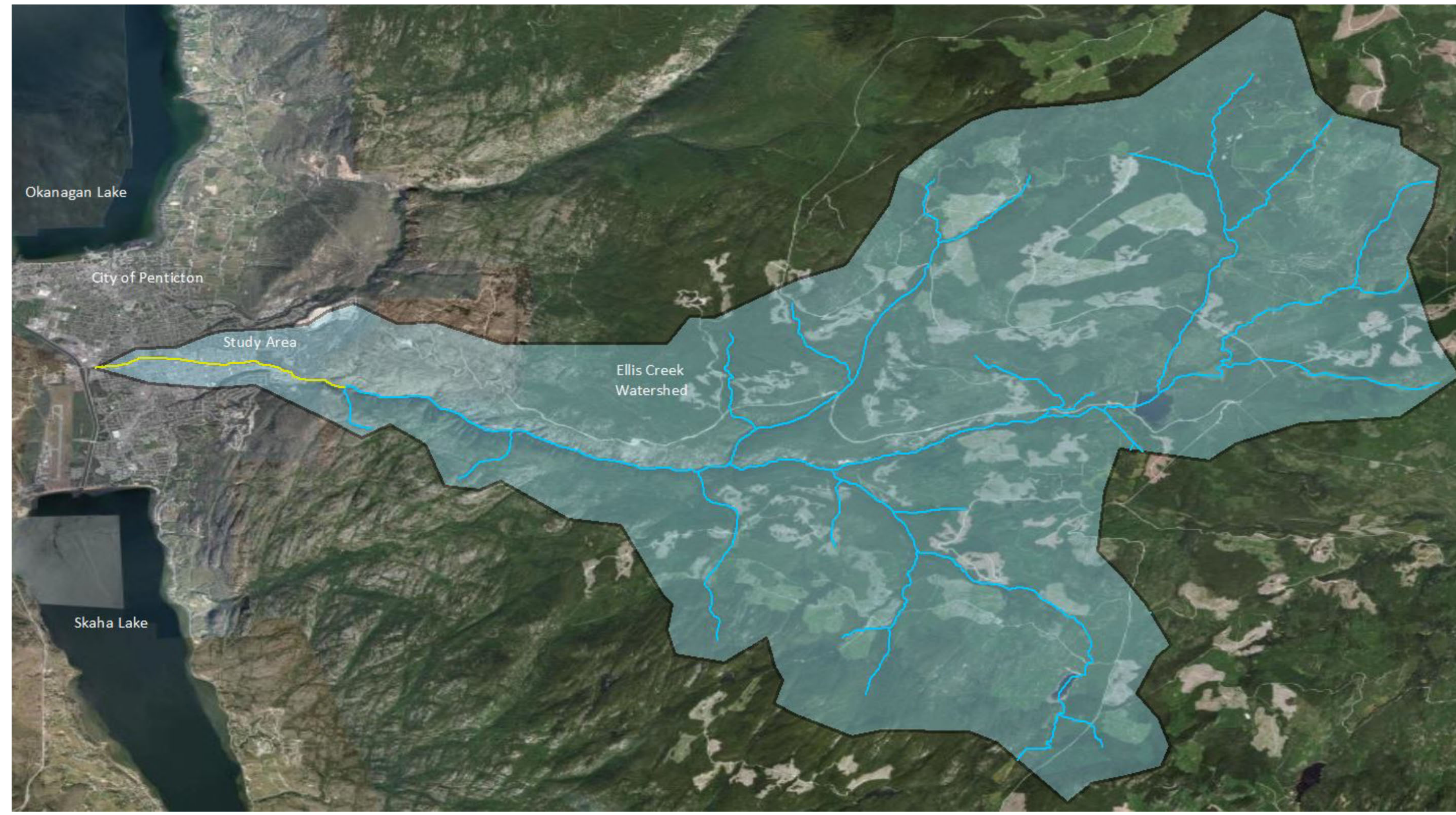
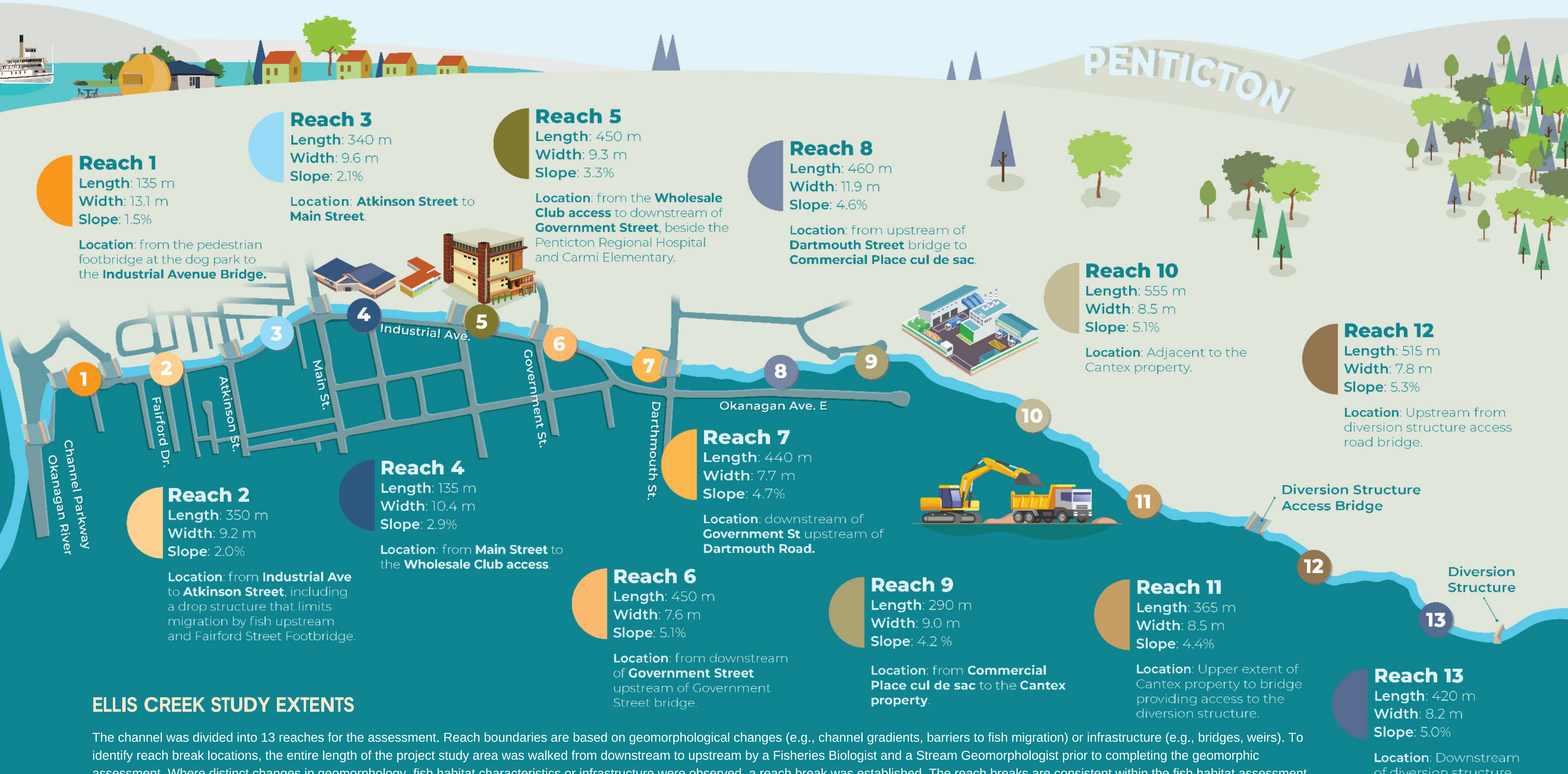


Figure 2. Ellis Creek Watershed



ELLIS CREEK STUDY EXTENTS

The channel was divided into 13 reaches for the assessment. Reach boundaries are based on geomorphological changes (e.g., channel gradients, barriers to fish migration) or infrastructure (e.g., bridges, weirs). To identify reach break locations, the entire length of the project study area was walked from downstream to upstream by a Fisheries Biologist and a Stream Geomorphologist prior to completing the geomorphic assessment. Where distinct changes in geomorphology, fish habitat characteristics or infrastructure were observed, a reach break was established. The reach breaks are consistent within the fish habitat assessment, sediment and erosion study, the infrastructure risk assessment of Ellis Creek and the naturalization planning.

History of Ellis Creek

Major events have significantly altered Ellis Creek. The most important events include three historical dam breaches in 1921, 1941 and 1942 and the construction of the diversion dam in 1966. Additional floods are known to have occurred in 1972, 1983, 1998, 2006 2017, and 2018.

On May 19 to 21, 1921 the 82 m long and 1-year old Ellis Creek No. 3 dam failed, releasing ~ 370 000 m^3 of water. Ellis Creek overflowed the channel banks in many places causing extensive flooding and damage throughout Penticton (Tannant and Skermer 2013).

Breach of Ellis Creek No. 4 Dam (May 1941)

Flood Damage on IR2 From the Breach of Ellis Creek No. 4 Dam (May 1941)

Breach of the Temporary Timber Spillway on Ellis Creek No. 4 Dam (May 1942)

Resulting Flood Damage Downstream of Breach on Ellis Creek No. 4 Dam (May 1942)

On May 12, 1941, the Ellis Creek No. 4 dam failed, releasing ~ 740 000 m^3 of water that reached Penticton. The flood destroyed the Ellis Creek intake, as well as portions of the North and South Ellis flumes. The floodwaters in Penticton inundated orchards and residences, streets and the highway. Debris from the floodwaters were transported to the Okanagan River where a log jam formed.

On May 23, 1942, the Ellis Creek No. 4 dam partially failed in the site repaired from the previous breach. The floodwaters caused further damage in Penticton.

Ellis Creek Channel Excavation for Flood Control (taken between 1950 and 1957)

The channel was excavated following the flooding due to the dam breaches to increase the conveyance of flood flows. This channelization of the creek, altered the natural processes of sediment transport and deposition and fish habitat.

Photo SOURCE: Penticton Museum Archives. Used with permission.

Completed Diversion Structure that Defines Upstream Limit of Study Area (1966)

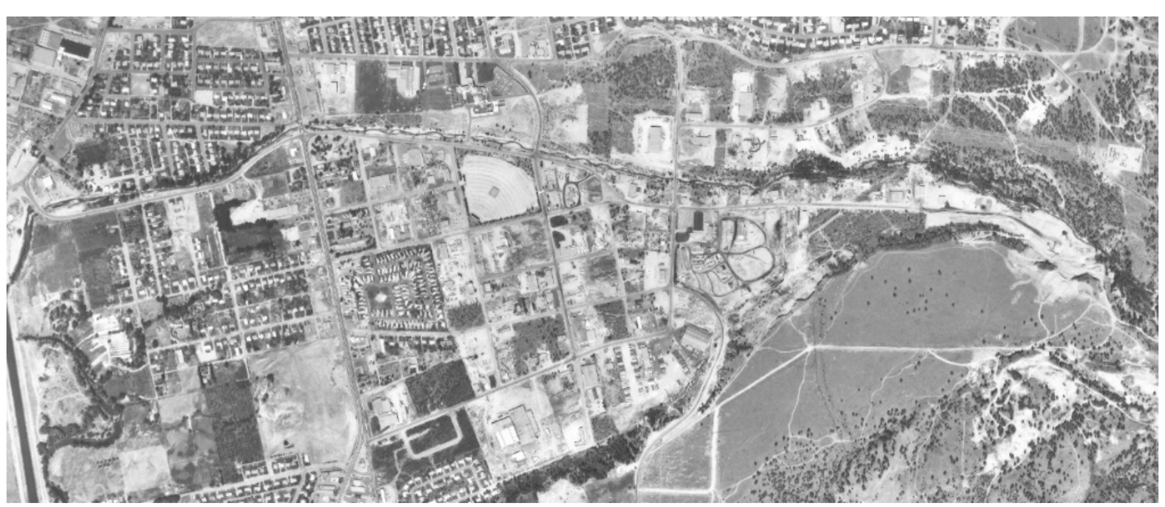
The diversion structure at the upstream end of the study area was constructed in 1966 to divert water from Ellis Creek for irrigation. This structure and the associated reservoir prevent sediment transport from upstream of the structure into the study reach. No substantial tributaries or other water and sediment inflows are present within the study reach. Sediment within the study reach therefore comes from the bed and banks of the channel within the study area.

Ellis Creek: 1938

Aerial photography of Ellis Creek exists from as early as 1938. Photographic evidence of the condition of Ellis Creek prior to the 1921 dam breach could not be found. The channel was likely braided prior to the breach based on the evidence of relic bars seen on the surface of the alluvial fan. The 1938 photograph shows extensive braiding and avulsion channels from the head of the alluvial fan, likely related to the 1921 dam breach flood. Numerous abandoned channels or channels that flow infrequently are seen throughout the fan. The photograph shows that the Ellis Creek channel is largely confined by urbanization west of Main Street in 1938. The confluence between Ellis Creek and the Okanagan River is natural. The Okanagan River not channelized or straightened.

Ellis Creek: 1951

The aerial photograph from 1951 shows evidence of the dam breach flood events in 1941 & 1942. The channel is braided and evidence of extensive overland flooding is seen at the head of the fan. The channel remains confined west of Main Street. The Okanagan River follows its original course.



Ellis Creek: 1974

The aerial photograph from 1974 shows evidence of mining operations at the head of the fan. The channel has braided bars and evidence of overland flooding is seen at the head of the fan. The channel remains confined west of Main Street and additional urbanization is seen in the upper fan. The Okanagan River is channelized and straightened. A sedimentation basin utilizes a former meander of the River at downstream of the former confluence to capture sediment from Ellis Creek before it enters the new Okanagan River channel.

SOURCE: Photographs from the Penticton Museum Archives. Used with permission.

Ellis Creek 2017

Urbanization has narrowed the Ellis Creek channel to 50% of the 1974 width between Government Street and Main Street. The urbanized channel no longer resembles natural braded channel morphology typical of some alluvial fans. Roads and ten bridges cross the creek along the lower 2.9 km of the channel upstream of the Okanagan River. Anecdotal observations from residents suggest that the channel was historically excavated for flood control, although the exact locations and volumes of excavation are not known.

Ellis Creek Channel is Impacted by Urbanization (photo taken next to Industrial Avenue near Main Street)

Characterizing Ellis Creek

The Ellis Creek Master Plan is informed by a series of technical assessments. The technical assessments are focused on characterizing the existing conditions through the study area. Results from the technical assessments were evaluated and compiled to develop recommendations for the restoration of Ellis Creek.

The content and purpose for each of the key technical assessments conducted as part of the Plan are described here. Further information for each technical assessment is summarized on subsequent pages of the Master Plan. The final submission for the assessments has been compiled into a supporting document package and issued separately.

The key findings from each of the assessments are used to evaluate and rank key system components for risk and to support the development of recommendations for the Plan. Key findings for each assessment have been graphically presented in Figure 3.

1. Design Flow Analyses

Stantec has completed an assessment of Ellis Creek flow characteristics including a flood frequency analysis, a low flow analysis, and an assessment of fish spawning periods. The design flows were developed in conjunction with the PECRC and have been endorsement by the Committee.

2. Fish Habitat Assessment

This report provides data summarizing the fish habitat assessment program conducted in October 2018. Included in this report are details on the methods of data collection, target species and life-stages identified for the assessment, biophysical data collected, and the results of a preliminary habitat ranking priority assessment. This report is used to help identify habitat enhancement options in Ellis Creek

3. Erosion & Sedimentation Study

This report summarizes the erosion and sedimentation assessment program conducted in October 2018. Included in this report are details on the methods of data collection, bank erosion assessment, aggradation and degradation assessment and sediment transport modelling. This report is used to characterize Ellis Creek morphology and support the development of conceptual mitigation options for Ellis Creek.

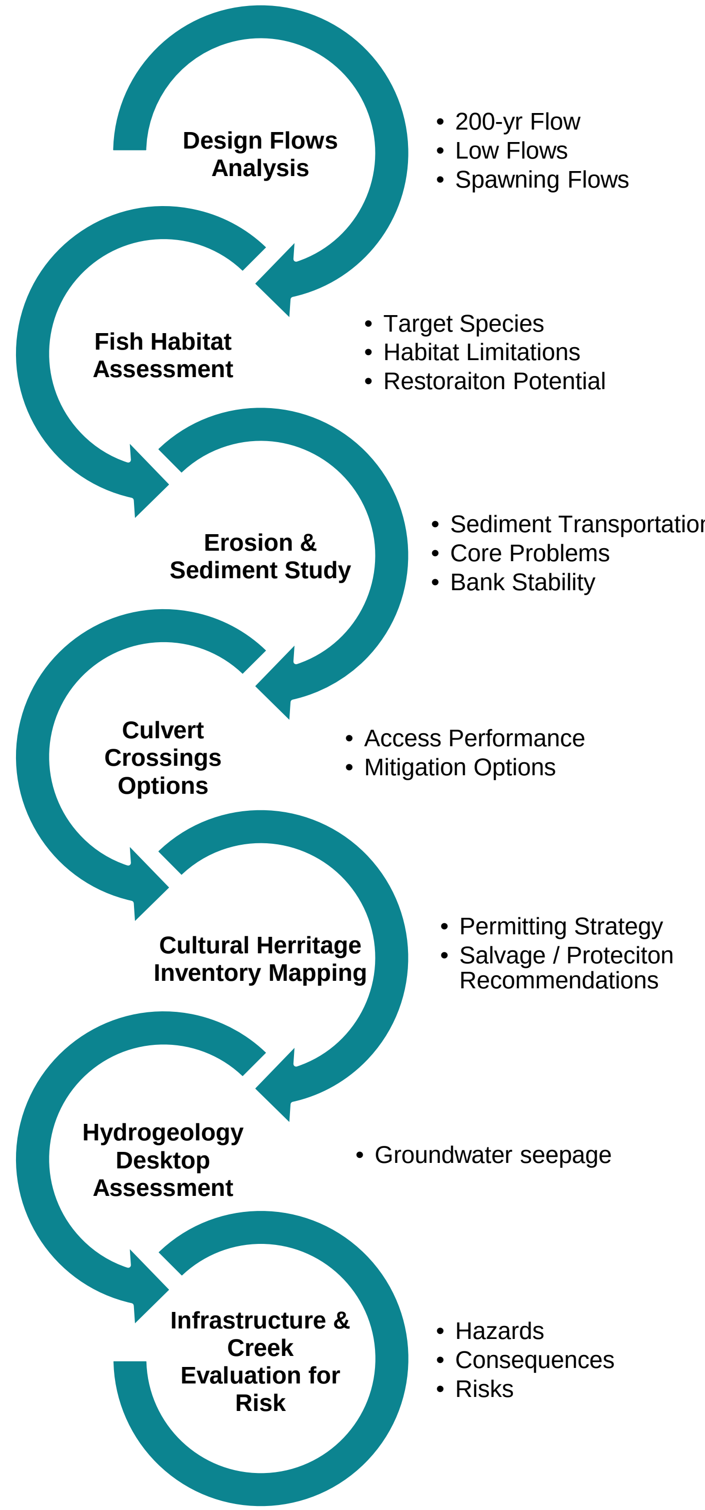


Figure 3. Sumary of Technical Assessments for Master Plan

4. Cultural Heritage Inventory Mapping *

Cultural heritage values were assessed and recommendations are provided based on the cultural heritage values observed during the Cultural Heritage Inventory Mapping (CHIM) exercise. While all cultural heritage values observed are the focus of this project, it is understood that the water, fish and a healthy ecology are of inherent cultural heritage value to the Syilx people. The cultural heritage values are to be used at the detail design phase to protect heritage and cultural values near Ellis Creek restoration sites.

* The CHIM study contains sensitive information that will not be released to the general public.

5. Groundwater Desktop Assessment

Stantec assessed the causes of high ground water levels near Ellis Creek. The primary objective was to assess if the emergency channel excavation works, conducted in response to the 2018 freshet event, resulted in increased groundwater levels within areas of observed high groundwater near Ellis Creek. The secondary objectives were to identify other likely causes of increased groundwater levels, and to provide concepts for groundwater management.

6. Infrastructure & Creek Evaluation for Risk

Stantec conducted a risk review to identify hazards, categorize consequences and evaluate the risks to infrastructure along 13 reaches on Ellis Creek within the study area. Four key hazard categories, including bridge conveyance, channel freeboard, utility exposure and bank stability, where identified and explored through the process. Understanding the key risk factors directly informs the concept solution preparation and reach by reach description of recommended actions.

7. Culvert Crossing Options

Stantec has prepared an assessment memo evaluating three existing accesses that cross Ellis Creek between Main Street and Government Street. During the 2018 high water events, flooding was observed at culverts under these accesses and required a viable strategy to mitigation future flooding in this area. The performance of the accesses was evaluated against several criteria to inform recommendations at each crossing.

DESIGN FLOWS

The Ellis Creek watershed is on the eastern side of the Okanagan Valley, draining to west. The watershed has an area of 159 km^2 and is located in the South Thompson Plateau Hydrologic Zone 24 (Obedkoff 1998). The flow within Ellis Creek is not currently monitored by the Water Survey of Canada. Two reservoirs are located within the watershed. Reservoirs typically influence stream hydrographs by attenuating peak flows.

Understanding the flow regime is an important step in the naturalization of Ellis Creek. The range of creek flows is used to size the channel, determine the stable rock size and design low flow channels for fish habitat. Stantec assessed the flow characteristics of Ellis Creek to determine the design flows. Four design flows were determined:

- Flood flow
- Extreme low flow
- Spring spawning flow
- Fall spawning flow

Flood Flow

For the purposes of the flood design flow, it was assumed that the flow reservoirs did not affect the discharge within Ellis Creek (i.e. naturalized conditions); this produces a conservative (larger) flow for channel design. Due to the small impoundment area of these structures, the reservoirs likely quickly fill during flood flows and therefore have a minimal retention of flood waters.

The 200-year flow was selected for the design flood. The 200-year flow has a 0.5 % Annual Exceedance Probability (AEP) or a 0.5% chance of being exceeded in any given year. A flood frequency analysis was completed to determine the 200-year flow. Three different methods were compared to determine the flood flow. The single-station scaling method was selected. The Water Survey of Canada (WSC) hydrometric station on Vaseux Creek (08NM171) was selected as a proxy for Ellis Creek for the following reasons:

- Proximity to Ellis Creek (32 km)
- Same hydrologic zone as Ellis Creek (South Thompson Plateau Hydrologic Zone 24)
- Similar watershed area to Ellis Creek
- Similar drainage direction (east to west) to Ellis Creek
- Length of record (46 years)

A semi-synthetic peak instantaneous discharge record was developed based on the mean daily and peak instantaneous discharges. Peak instantaneous values for Vaseux ranged from 4.67 m^3/s (2001) to 27.7 m^3/s (1998). Aquarius© software was used to fit the Log Pearson Type III and Generalized Extreme Value (GEV) distributions to the data. The GEV distribution was selected because it produced the best data at high discharges. The results of the analysis are presented in Table 1. Twenty percent was added to the 200-year instantaneous value to account for the effects of climate change and ten percent was added to account for land use change, such as logging, fires or insect infestations, in the basin. The increase in discharge from the Carmi Road development was also added to the design flood. Figure 4 displays the flood frequency analysis for Ellis Creek.

Table 1. 200-Year Flood Design Flow

Return Period (Years)	Discharge (m^3/s)	20% for Climate Change (m^3/s)	10% for Land Use Change (m^3/s)	Carmi Development Diversion (m^3/s)	Design Flow (m^3/s)
200	38.5	7.70	3.85	1.14	51.2

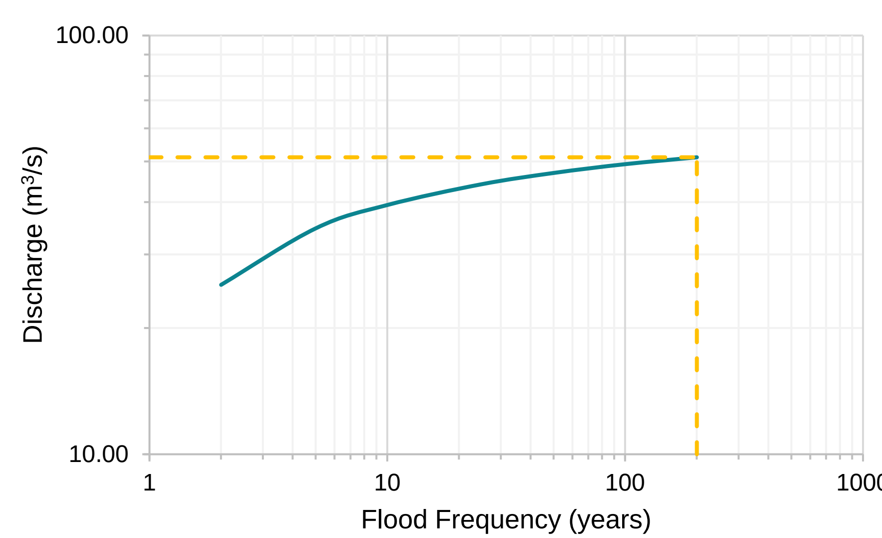


Figure 4. Flood Frequency Analysis for Ellis Creek

Note: The 200-year return period and associated discharge is represented by the dashed orange line.

Climate is predicted to change in the Okanagan. The Pacific Climate Impacts Consortium projects a decrease in winter snowfall (-42% to -8%) and spring snowfall (-89% to -18%), in addition to an increase in winter rainfall (2% to 26%) and decrease in summer precipitation (-37% to -1%) based on global and regional climate model results (PCIC 2013). Ellis Creek peak flows occur during the snowmelt driven freshet. A decrease in snowpack would lower those peaks. However, the increase in winter precipitation and higher temperatures may increase the frequency of rain-on-snow peak floods, which have the potential to produce larger peak flows than snow melt alone. The CC-IDF tool from Western University predicts 100-year precipitation events in the Ellis Creek watershed to increase by 26% by 2100 for the business as usual scenario (Western University 2018). Based on these climate projections and the high consequence of flooding downstream within Ellis Creek, a 20% climate change factor was applied to account for increase in peak discharge.

The flood flow was discussed with the PECRC, including representatives from the Ministry of Forests, Lands, Natural Resources Operations and Rural Development.

Extreme Low Flow

Extreme low flows are generally calculated based on the seven-day average low flow (7Q). Historical low flows within Ellis Creek were assessed in the “Preliminary Water Management Plan for the Ellis Creek Watershed, Penticton, BC” report by Golder (2008) using Water Survey of Canada (WSC) station data for Ellis Creek. A discharge of 0.042 m^3/s, representing 10% of the mean annual discharge (MAD) of 0.42 m^3/s was selected as the low flow. This flow is released from the Ellis Creek diversion structure for extreme flows based on the Golder (2008) results. Additional low flow analyses were completed by Stantec to characterize naturalized low flow conditions and summer low flow conditions.

To assess naturalized low flow conditions, a 7Q analysis was completed using the scaled WSC Vaseux Creek station data. Vaseux Creek data was selected based on reasoning outlined in the flood frequency analysis section above. A time-series of mean daily discharges at the station was assembled, with data beginning in October 1970 and ending in October 2018. Verified and published historical data was used where available (1970-2016) and was supplemented with 2017 and 2018 unverified data to capture the two recent years of extreme discharges. This created a dataset spanning 47 years. A seven-day rolling average discharge (7Q) was calculated for the entire dataset to determine the lowest seven-day average discharge for each year. A minimum annual 7Q of 0.016 m^3/s was calculated for 2007, while a maximum annual 7Q of 0.178 m^3/s was calculated for 1998. The dataset was imported into the Aquarius© software package and applied to the GEV and Log Pearson

Type III distributions, with the 2-, 5-, 10- 25-, 50-, 100- and 200-year seven-day average return periods generated. Both distributions fit the data reasonably well, and GEV was selected for continued analysis. 7Q discharge data was then scaled to the Ellis Creek site using the Watt (Watt 1989) and Eaton (Eaton, Church and Ham 2002) methods and are presented in Table 2. The 10-year return period seven-day low flow (7Q10) is typically selected for design purposes.

A second seven-day low flow analysis was completed for the summer using scaled Vaseux Creek data. Summer 7Q low flow return period discharges are larger than the annual 7Q return period discharges, with the annual 7Q low flow generally occurring during winter months (Table 2).

Table 2. Ten Year, Seven-day Low Flow Discharges for Vaseux Creek (08NM171) and Ellis Creek

Season	Vaseux Creek (m^3/s)	Ellis Creek (m^3/s)
Winter (lowest annual flow)	0.041	0.050
Summer (seasonal flow)	0.058	0.070

The discharge recommended by Golder (Golder 2008) of **0.042 m^3/s** was chosen as the extreme low flow to be consistent with the operations of the diversion on Ellis Creek.

Bankfull Flow

An estimate of bankfull flow can be used in natural channel design to inform channel size. The mean annual flood is often used to estimate bankfull discharge. The mean annual flood was calculated from the Vaseux Creek station data by averaging the mean annual daily peak flows. These values were then weighted based on the difference in drainage basin area between Ellis and Vaseux creeks. The bankfull flow was estimated to be **13.9 m^3/s**.

Spawning Flow Assessment

Spawning in the Okanagan occur during May to July for Rainbow Trout and September and October for Kokanee and Sockeye. For these months, the mean monthly discharge (MMD) was calculated using a scaled single station approach described previously. Known average monthly water use (Golder 2008) was subtracted from the MMD to determine design flows and these are presented in Table 3.

Table 3. Ellis Creek Spawning Window Discharges

Month	Mean Monthly Discharge (m^3/s)	Monthly Water Use (m^3/s)	Design Flow (m^3/s)
May	3.26	0.033	**3.22**
October	0.197	0.017	**0.180**

The final design flows are shown in Table 4.

Table 4. Design Flows

Design Flow Category	Discharge (m^3/s)
Design Flood Event (200-year)	51.2
Extreme Low Flow (10% MAD)	0.042
Spring Spawning Flow (May MMD)	3.22
Fall Spawning Flow (October MMD)	0.180
Bankfull Flow (Mean Annual Flood)	13.9

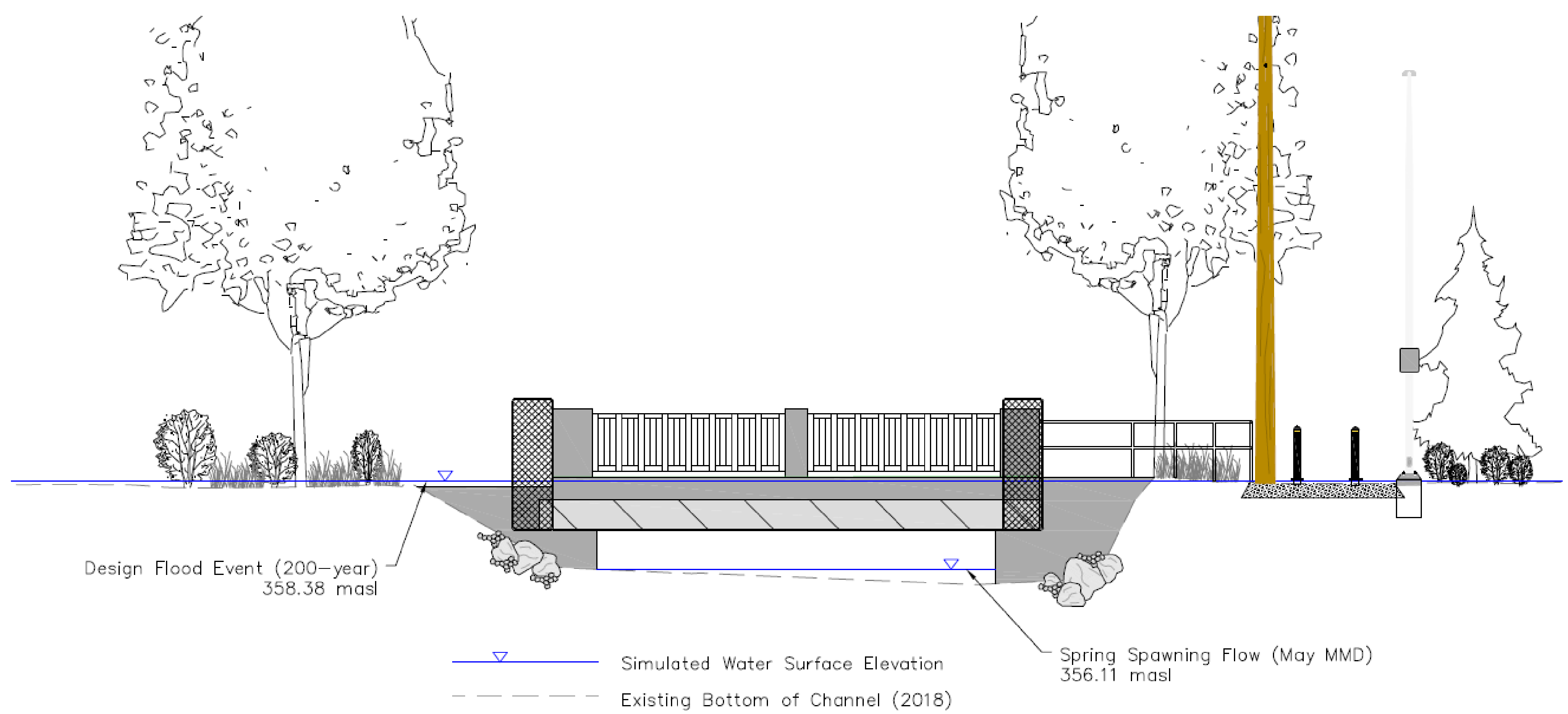


Figure 5. Simulated Water surface Elevation Coresponding to 200-year Flow and May MMD

FISH HABITAT

A number of problems impact different life stages of species that occur in Ellis Creek. Recent limited improvements have been made to the system. For example, a weir located at the downstream limit of the sedimentation basin used to create a barrier to fish migration. The sedimentation basin is located between the Okanagan River and the bridge at the dog park. This weir was reconstructed in 2018 to provide fish passage. Another barrier to upstream fish migration used to exist at a concrete weir over a sanitary sewer line. A bypass channel for fish migration was added to this structure but was damaged during the recent floods.

Restoration of the channel can greatly improve fish habitat. An assessment of the fish habitat within Ellis Creek was completed in 2018 to:

- Document the existing riparian and fish habitat conditions of Ellis Creek
- Identify priority reaches where fish habitat may be improved

The results of the analysis are documented in the Ellis Creek Fish Habitat Assessment Report (Stantec, 2018).

Historic fisheries records indicate that rainbow trout (*Oncorhynchus mykiss*), kokanee salmon (*O. nerka*), longnose dace (*Rhinichthys cataractae*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*) and sculpin species (Cottidae spp.) have been documented in Ellis Creek. Ellis Creek is a primary tributary to the Okanagan River and to Skaha Lake and it is possible that other salmonid species (e.g., sockeye and steelhead) present in these waterbodies could utilize habitat within Ellis Creek to carry out one, or more, life history requirements.

Rainbow trout and kokanee salmon are the target species for fish habitat restoration in Ellis Creek. Low numbers of kokanee have recently been observed spawning in Ellis Creek and rainbow trout are resident within the study area. Anadromous fish (sockeye and steelhead) are also target species.

The committee identified the following target species and life-stages for the fish habitat assessment:

- Spawning, rearing and overwintering rainbow trout
- Spawning and rearing steelhead
- Spawning kokanee
- Spawning sockeye

The life-stage periodicities and preferred spawning conditions of each of the target species in Ellis Creek are shown in Table 5 and Table 6, respectively.

Habitat Suitably indices for velocity and depth provide the ranges of preferred values.

Table 5. Rainbow Trout, Steelhead Salmon, Kokanee Salmon, and Sockeye Salmon Life-stage Use in Okanagan Basin Streams

Fish Species	Life Stage			
	Spawning	Incubation	Juvenile Rearing	Overwintering
Rainbow trout	May 17 – Jul 16	May 17 – Aug 24	Jan 1 – Dec 31	Oct 1 – Apr 30
Steelhead salmon	Apr 4 – Jun 26	May 17 – Aug 26	Jan 1 – Dec 31	Oct 1 – Apr 30
Kokanee salmon	Sep 1 – Oct 8	Sep 1 – Mar 31	NA*	NA*
Sockeye salmon	Sep 16 – Oct 31	Sep 16 – Feb 14	NA*	NA*

NOTES:

Data are based on Salmonid Species-specific life stage periodicities observed in Okanagan Basin Streams of the Okanagan Basin Water Board 2016 report (Eyjolfson, Z. & Enns, J 2017).

*Sockeye/kokanee salmon outmigrate from creeks and streams to rear in lacustrine habitats.

Table 6. Rainbow Trout, Steelhead Salmon, Kokanee Salmon, and Sockeye Salmon Preferred Spawning Habitat in Streams

Fish Species	Preferred Spawning Habitat				References
	Water Depth (m)	Cover	Substrate (mm)	Velocity (m/s)	
Rainbow trout	[2] 0.2-2.5	Vegetated bank*	[1] 25-50	[2] 0.3-0.9	[1]Davis et al., 2018 [2]Ford et al., 1995
Steelhead Trout	[3] 0.3-1.0	Overhead riparian, woody debris, substrate margins*	[1] 25-75-	[3] 0.6-0.8	[1]Davis et al., 2018 [3]Bjorn & Reiser 1991
Kokanee salmon	0.09-0.54	-	[1] 30	0.15-0.78	Ptolemy, 2016 [1]Davis et al., 2018
Sockeye salmon	0.2 – 0.6	-	18-70*	0.4 – 0.9	Long et al., 2006

Fish Habitat Assessment

Ellis Creek is a narrow, steep gradient, cobble-gravel bedded channel with steeper bed slope and coarser substrates found in upstream areas. Gradients within the study area were found to range between 2% to 8% with riffle, pool, and glide meso-habitats. Substrates are dominated by boulders and cobbles throughout most of the study area, while sands and gravels are found in sparse patches, mostly downstream of large boulders. Channel bed and bank erosion was observed throughout the study area and, in several areas, significant bank erosion has resulted in bank undermining and unstable conditions.

The fish habitat within each reach was assessed and assigned a value of poor, moderate or good for each of the four habitat types: rearing, overwintering, migration and spawning. An assessment of habitat value was completed based on the biophysical data collected in the field The definition of each value for each habitat type is presented in Table 7 and the assessment scores are shown in Table 8. More detailed results from the fish habitat assessment are presented in the reach by reach descriptions in this document (page 38).

The greatest factors limiting the population of salmonids in the lower reaches of Ellis Creek are spawning and overwintering habitat. Recent floods in 2017 and 2018 caused erosion and deposition within the channel bed and banks. The erosion and sedimentation section (page 15) describes these patterns in more detail. The floods altered the fish habitat, particularly in reaches 4 and 5, where deposition of cobbles and boulders has infilled and simplified the channel.

Rearing habitat is generally moderate in Ellis Creek, but poor in the depositional reaches 4 and 5, and good in the more natural upstream reaches 11 to 13.

Overwintering habitat is limited in Ellis Creek. Pools greater than 0.2 m were not observed in reaches 1 to 5 and 10. Reaches 6 to 8 had pools between 0.2 m 0.5 m deep. The upstream reaches 9 and 11 to 13 are more natural and contain good overwintering habitat.

Except for reaches 4 and 5, Ellis Creek generally provides moderate habitat for the migration of fish. The lack of water volume during low flows creates barriers to migration for some life stages.

Erosion has caused a general coarsening of the bed. The area of spawning habitat within the lower reaches of study area is typically poor to moderate, providing limited habitat for the target species.

Table 7. Definition of Habitat Values for Each Habitat Type

Habitat Type	Habitat Parameter	Low	Moderate	High
Juvenile rearing	LWD pieces per bankfull channel width	<1	1-2	>2
	Boulder cover in gravel-cobble riffles	<10%	10-30%	>30%
	Overhead Cover	<10%	10-20%	>20%
	Interstices in cobble- or boulder-dominant substrate	Filled with sands or small gravels	Reduced with sands	Clear
	Pool depth	<0.2 m	>0.2 m and <0.5 m	>0.5 m
Overwintering	Pool depth	<0.2 m	>0.2 m and <0.5 m	>0.5 m
	Velocity	Flows greater than 0.5 m/s or stagnate (i.e., no flow)	Moderate velocity between 0.3 m/s to 0.5 m/s	Low velocity between 0.15 m/s to 0.3 m/s
	Cover (i.e., boulder complex, woody debris, undercut banks, etc.)	<10%	10-30%	>30%
Migration	Physical or velocity barriers	Barrier preventing upstream migration for juvenile and adult life-stages during moderate or high flow conditions.	No physical barriers but potential velocity barrier to upstream migration during high flow conditions.	No barriers preventing juvenile or adult life-stage migration during all flow conditions
Spawning	Gravel substrate	Isolated pockets of suitable spawning gravels	Small pockets of suitable spawning gravels distributed throughout the reach.	Extensive areas of spawning gravels

Fish Habitat Improvement and Priority Analysis

To identify the highest priority reaches for restoration of fish habitat, each reach was assessed based on the long-term viability of habitat enhancement. Improvement potential is a qualitative measure developed with site knowledge of each reach and the potential for habitat improvement based on the definitions in Table 7. The potential for habitat improvement within each reach is shown in Table 8, with 1 indicating improvement from Poor to Moderate or from Moderate to Good, 2 indicating improvement from habitat Poor to Good, and 0.5 indicating improvement half way between two categories. In this way the existing habitat conditions were compared to the potential improvements, considering the preferred life history requirements of the identified target species. The improvement values for each of the four habitat types were then summed and assigned into equal bins to determine the habitat improvement priority from for highest to lowest priority (1 to 5) for each reach.

Reaches 4, and 5 were calculated to have an improvement rank of 1, indicating there is a highest need to improve habitat in these reaches. Reaches 4 and 5 have a high improvement rank because of the extensive bank erosion and channel aggradation that occurred in this area. Reaches 4 and 5 have no functional riparian vegetation, limited in-stream cover, no spawning potential, shallow depths, and poor migration and therefore have a high capacity for habitat improvements.

Reaches 1 and 10 had an improvement rank of 2. The spawning and overwintering habitat in Reach 1 and 10 were assessed as poor, demonstrating an opportunity for improvement. The lower reaches of small creeks are typically where kokanee and sockeye spawn, therefore Reach 1 is considered an important location for habitat enhancements based on its position within the system and importance for migration to upstream habitats. Migration is considered moderate and, in several sections, shallow depths associated with riffle habitats may become obstacles to larger species migrating to spawn (e.g., sockeye). Deeper pools may be added to both reaches to improve overwintering habitat.

Reaches 2, 3, 6 and 7 were calculated to have an improvement rank of 3, indicating a moderately high need to improve fish habitat in these sections. Reaches 2 and 3 are considered as important locations for potential habitat enhancements based on their position within the system and importance for migration to upstream habitats. Migration in these reaches is considered moderate, with the weir over the sanitary line in Reach 2 presenting a partial barrier to fish passage, as well as, shallow depths associated with riffle habitats limiting fish passage. Spawning habitat was assessed to be moderate while overwintering habitat was assessed as poor in Reaches 2 and 3. Reaches 6 and 7 display poor spawning habitat and moderate overwintering habitat, with potential to improve both habitat features.

Reaches 8 was calculated to have an improvement rank of 4, with rearing and overwintering habitat requiring improvement.

Reaches 9, 11, 12 and 13 were calculated to have an improvement rank of 5. These reaches currently provide the best overall habitat complexity and value throughout the Ellis Creek. Large deep pools, boulders, overhanging vegetation and undercut banks provide good rearing potential. Spawning is opportunistic; however, gravel patches were larger and deeper, providing higher value than reaches lower in Ellis Creek. No habitat enhancement is recommended in Reaches 12 and 13, which should be used as a benchmark of functional habitat when designing enhancement options in the other reaches.

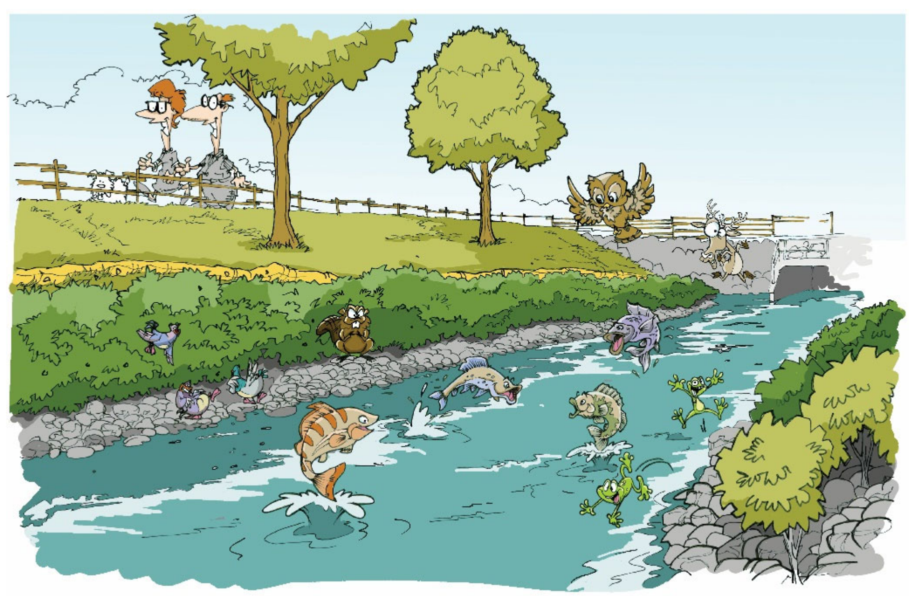


Table 8. Reach by Reach Summary of Four Fish Habitat Characteristics and Potential Improvement

Reach	Fish Habitat Priority Ranking Criteria												Restoration Priority	
	Spawning			Rearing			Overwintering			Migration			Sum of Scores	Improvement Rank
	Poor	Mod.	Good	Poor	Mod.	Good	Poor	Mod.	Good	Poor	Mod.	Good	Sum of Scores (max=8)	1 Most Potential 5 Least Potential
	1	2	3	1	2	3	1	2	3	1	2	3		
1	X	1.5			X	1	X		2		X		4.5	2
2		X	0.5		X	1	X		2		X		3.5	3
3		X	0.5		X	1	X		2		X		3.5	3
4	X	1		X		2	X		2	X	1		6	1
5	X	1		X		2	X		2	X	1		6	1
6	X	1			X	1		X	1		X		3	3
7	X	1			X	1		X	1		X		3	3
8		X			X	1		X	1		X		2	4
9		X			X	1			X		X		1	5
10	X	1			X	1	X		2		X		4	2
11		X				X			X		X		0	5
12	X	1				X			X		X		1	5
13		X				X			X		X		0	5

LEGEND

X	Current Condition
1	Improvement potential (0.5 to 2)

Habitat Restoration Criteria

A natural channel design approach is recommended to improve fish habitat within Ellis Creek. The design of reaches for Ellis Creek should be designed to mimic natural creek channel morphology and processes. Projects should address lack of spawning areas, lack of effective pools, and provide concentration of low flows within one or two low flow channels at the design stage. Although maintenance may be required following large freshet events, the goal of the approach is for spawning gravels to deposit within the restored channel, thereby maintaining spawning habitat. Spawning areas should be designed to be stable at a 2-year (preferably 5-year) flow. Pools for overwintering should be designed with a minimum residual depth of 0.8 m. Native riparian vegetation should be planted to create cover within the channel and strengthen the banks through root growth. Migration of fish upstream should be increased through removal of barriers, limiting velocities to allow for passage within the channel, and concentration of low flows.

EROSION AND SEDIMENTATION

Ellis Creek shows a pattern of upstream areas experiencing erosion and downstream areas experiencing deposition, typical of alluvial an alluvial fan. Studying the **geomorphology** of Ellis Creek sheds light into the underlying processes that are occurring within the system, what processes are out of balance and how to control or repair the system. Geomorphology is the study of the shape of the earth and includes the study of the form of stream channels and processes that shape the channels. The geomorphology of Ellis Creek study area was assessed in four ways:

- Field assessment
- Aggradation / degradation assessment
- Bank erosion hazard assessment
- Sediment transport Study

Field Assessment

A field assessment of the geomorphology of Ellis Creek was completed in October and November 2018 by a two-person crew, led by a fluvial geomorphologist and supported by an environmental surface water field technician. The project study area was visually reviewed from the confluence with the Okanagan River channel to the City reservoir approximately 5 km upstream. Channel characteristics and flood damage were documented along the entire length of the study area.

The geomorphic characteristics of the channel were measured or estimated in the field using Stantec's channel assessment procedure. Specifically, Stantec's Fluvial Geomorphology field cards (Figure 6) were used to document channel conditions, including channel shape, sediment patterns, bed stability and bank characteristics.

The geomorphic assessment did not investigate water quality. Ellis Creek is known to have periodic elevated concentrations of suspended sediment within the water column. This fine sediment is known to negatively affect aquatic organisms, including fish. Understanding the water quality of Ellis Creek, including the source and fate of fine sediment would aid in the management of the system.

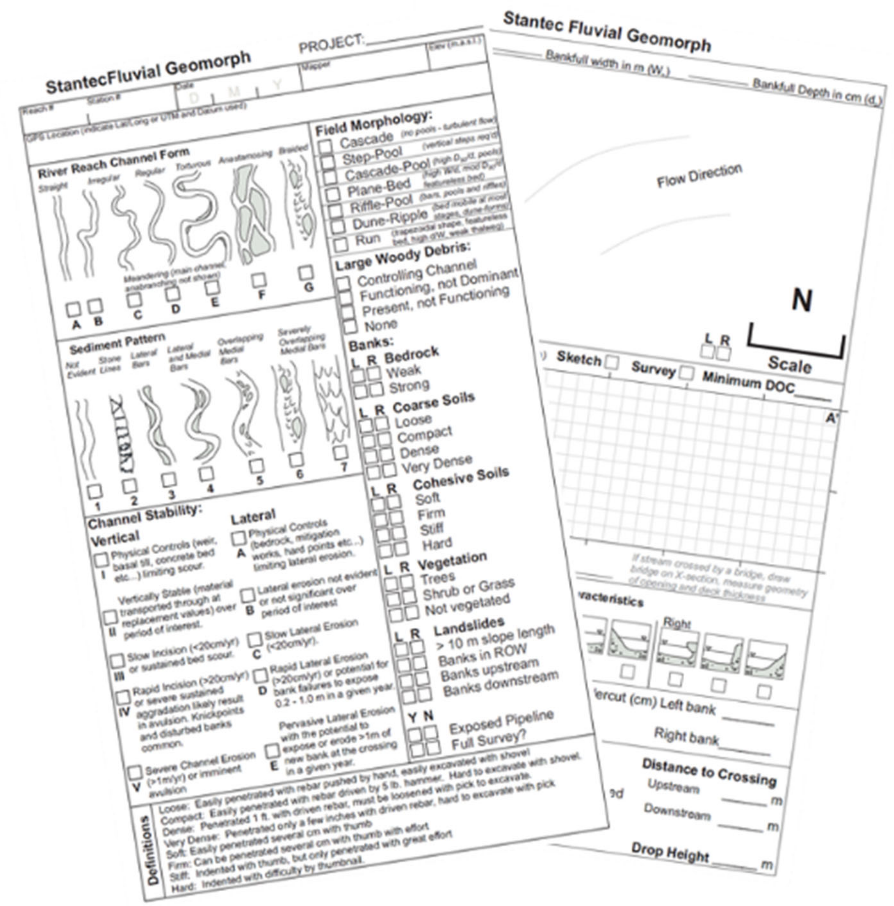


Figure 6. Stantec's Fluvial Field Cards Used in Assessment of Ellis Creek

Assessments were completed at a representative location within each reach. The size of the sediment on the bed was measured within each reach to determine the grain size distribution using the Wolman pebble count method. Channel depth and width were measured at three locations within each reach.

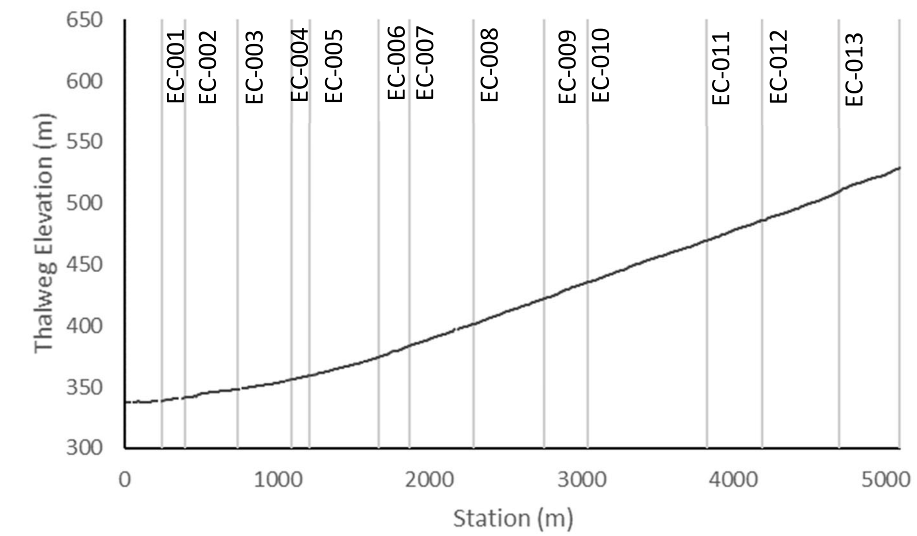


Figure 7. Ellis Creek Longitudinal Profile

The longitudinal profile is a plot of the elevation of the lowest portion of the stream channel (called the thalweg) against the distance downstream. The slope of a river channel generally decreases downstream, with high slopes in the headwaters and low slopes at the mouth. This pattern creates a concave profile downstream which encourages erosion in the upper reaches and deposition in the lower reaches.

Overall, the slope of the Ellis Creek channel bed decreases downstream from Reach 13 to Reach 1, with reaches 12 and 13 displaying the highest slopes. Patterns exist within the overall decrease. The Ellis Creek longitudinal profile is generally straight from Reach 13 to Reach 6 and then concave from Reach 6 to Reach 1. The slope increases downstream in Reaches 10 and 11 and decreases at Reach 9. The slope then increases between Reach 9 and Reach 6; this increase in slope is likely related to the degradation of the bed through these reaches. The slope then decreases downstream between Reaches 5 to 1, following the expected pattern.

Aggradation / Degradation

Aggradation is a channel process where the elevation of the channel bed increases through time due to the net accumulation of sediment transported from upstream reaches. Aggradation commonly causes a decrease in the channel conveyance capacity, and results in an increase in flood hazard. Measurements of the elevation of the pre-event channel are not available to compare to the current condition. Aggradation was estimated based on the channel characteristics, including:

- High channel bed width
- The presence of large bars
- The absence of channel banks or banks that are shallower than normal bankfull depths
- Abundance of recently deposited sediment
- Decreases in bridge openings compared to pre-event condition

Degradation is a channel process where the elevation of the channel bed decreases through time due to the net transport of bed sediment out of a reach under high flow conditions. Degradation may expose underground utilities and destabilize channel banks. Degradation generally increases the height and slope of the channel banks, thereby decreasing bank stability.

Degradation was estimated based on the channel characteristics, including:

- Low channel bed width
- Channel bed cross-sectional morphology including small steps on the bed
- Undercut banks
- Presence of nick points on channel bed
- Exposed utilities
- Increase in bridge openings and exposed footings

The basis for the estimates of aggradation or degradation were:

- Topographic Survey provided by the City
- LiDAR data set provided by the City
- Geomorphic assessment observations
- Bridge inspection reports from 2016 (inspection reports from 2006 were also reviewed)

The amount of channel bed aggradation and degradation was assigned to bins for each reach based on site observations. The bins and ranking scheme are shown in Table 9.

Estimation of aggradation or degradation was completed using available information on the previous condition of the channels (e.g. photographs at bridges for comparison). We are fortunate to have photographic documentation of the bed level at the crossings of Ellis Creek in 2016 (completed by Watson Engineering), prior to the 2017 flood. The analysis is limited to the recent events of 2017 and 2018. Events that caused degradation or aggradation prior to 2017 are excluded from the analysis.

Table 9. Ranks for Estimated Aggradation or Degradation

Channel Condition Rank	Estimated Depth of Aggradation / Degradation
Stable	+/- 0.25
Low	0.25–0.50
Moderate	0.50–0.75
High	0.75–1.00
Extreme	> 1.00

The Ellis Creek channel shows evidence of aggradation in some reaches and degradation in other reaches. Results of the analysis are found in Table 11.

Aggradation in Ellis Creek Channel (Industrial Avenue Bridge)

Degradation in Ellis Creek Channel (Dartmouth Road Bridge)

BANK EROSION

The banks within some reaches in Ellis Creek are highly unstable. An analysis of bank stability was conducted to document the bank erosion hazard and inform the Infrastructure and Creek Evaluation for Risk. The Ellis Creek channel banks are generally natural. The channel is not extensively hardened with riprap and therefore an assessment of natural channel bank stability was deemed appropriate. There is evidence of excavation and anecdotal reports of excavation of the channel bed following floods to increase channel capacity, and this was accounted for in the interpretation of the results. Right and left banks are discussed as if looking downstream. The results of the analysis are consistent with field observations of bank erosion.

The Bank Erosion Hazard Index (BEHI), based on Rosgen (2001), was used to evaluate the bank erosion hazard for each reach. The BEHI method was chosen for this project because it provides a repeatable, defendable methodology that is widely used (e.g., van Eps et al., 2004; Kwan & Swanson, 2014) and incorporates easily quantifiable channel parameters that are known to control the stability of a bank, including:

- Bank height and bankfull height
- Root depth and density in banks
- Bank angle
- Bank surface protection, including bank material

To complete the BEHI methodology, a representative location was chosen for each reach for the analysis. The representative locations were consistent with the fisheries assessment completed by Stantec (Stantec, Ellis Creek Fish Habitat Assessment 2018) and geomorphology assessment sites. Topographic survey and LiDAR data provided by the City, and geomorphic site assessment observations were used as input parameters in the analysis. A cross-section was surveyed at each representative reach location. The characteristics used in the assessment are shown in Figure 8. The bank erosion hazard is ranked from Low to Extreme. The rating system was modified from Rosgen (2001) and is shown in Table 10. Results of the analysis are found in Table 11.

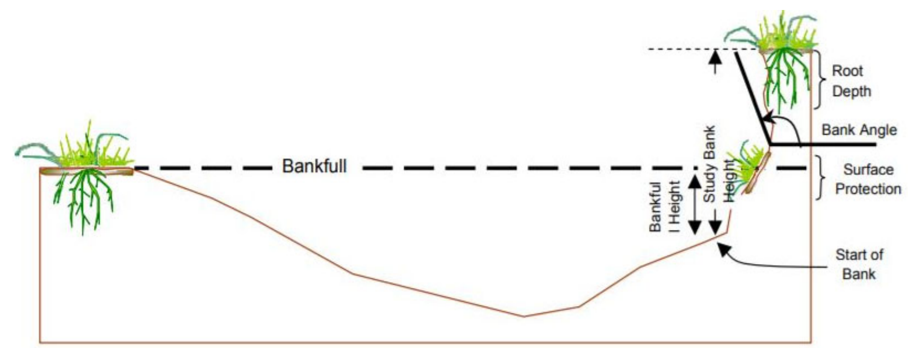


Figure 8. Bank Characteristics Used in BEHI Analysis

Table 10. BEHI Rating Scheme

BEHI Index	Rating	Estimated Bank Instability
5 to 19.9	Low	Bank erosion not evident or not significant
20 to 29.9	Moderate	Potential for bank erosion (< 0.20 m/yr)
30 to 39.9	High	Potential for modest bank erosion (0.20–0.50 m/yr)
40 to 45.9	Very High	Potential for rapid bank erosion (0.50–1.00 m/yr)
46 to 50	Extreme	Potential for pervasive bank erosion (> 1.00 m/yr)

Note: assessed on observed conditions at the time of the field inspection, effects of significant flooding are not reflected in the projection

Source: Modified from (Rosgen 2001)

Unstable Ellis Creek Bank

Sediment Transport

Sediment is eroded and transported downstream under high flow conditions. Deposition of eroded sediment can cause issues for fish habitat and infrastructure, such as decreased freeboard at bridges and culverts. In general, entrainment, transport, and deposition of sediment along a riverbed are functions of the driving force (shear stress) exerted by flow on the bed sediments and the resisting force (sediment size and distribution).

Sediment transport and mobility was assessed as part of the sedimentation and erosion study. Sediment transport was assessed through modelling of sediment transport rates for each reach. Sediment mobility was assessed through comparison of the driving force and the resisting force per reach. Several driving variables were analyzed to understand the sediment transport and mobility within Ellis Creek.

The results for width, width-to-depth ratio, bed grain size, bed slope, and shear stress at the design flood were interpreted to inform the sediment transport rates and sediment mobility for the design flood. The variables were interpreted based on the patterns of change from upstream to downstream to inform sediment transfer. The bankfull channel width and depth were measured in the field at three locations within each reach and averaged. Bed grain size included the D_{10}, D_{50}, and D_{90} determined from the pebble counts conducted in the field. Shear stresses for the design flood and bed slope were determined as an average for all cross-sections within each reach from the one-dimensional hydraulic (HEC-RAS) model developed for the Infrastructure and Risk Assessment.

Summary of Findings

A general pattern emerges from the analysis of the sedimentation and erosion within the 13 reaches of Ellis Creek. Sediment from upstream of the diversion structure (dam) is deposited in the reservoir created by the dam. This deposition leaves the reaches downstream of the dam starved of sediment. This means that bedload sediment within the study area is produced from the bed and the banks of the channel downstream of the dam. The dam also limits the supply of spawning gravel into downstream reaches.

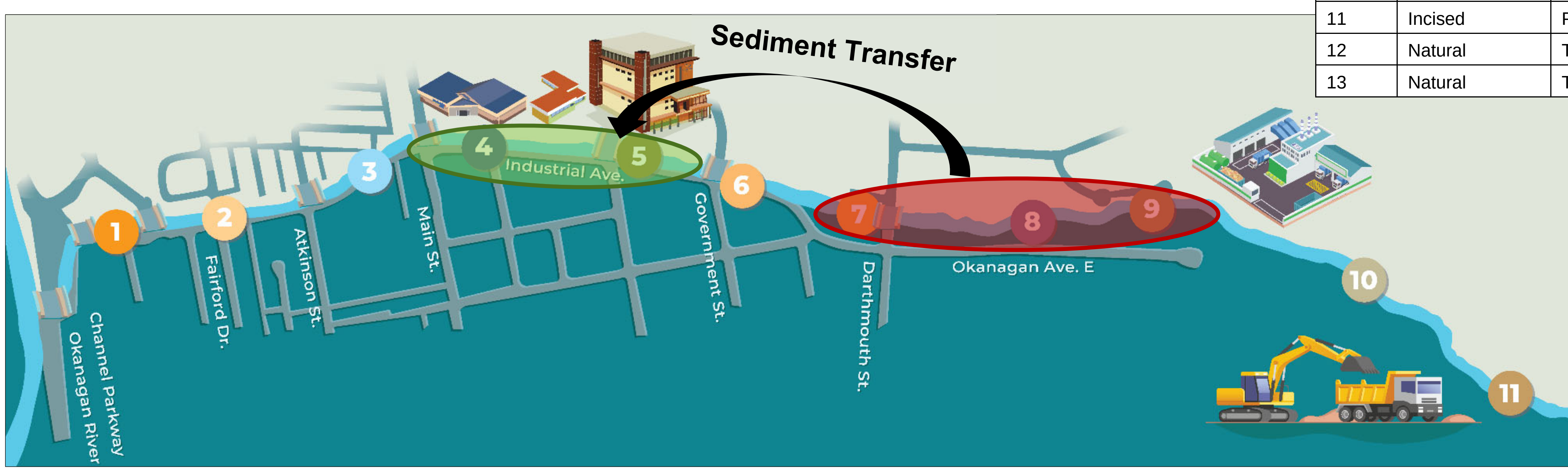
Sediment degradation and aggradation problems within Ellis Creek are linked. Sediment is largely produced between Government Street and the Cantex bridge and deposited between the Government Street Bridge and the Main Street Bridge. Specifically, the analysis shows that the majority of the bedload sediment is produced from Reaches 9 to 7 (with less from Reaches 10 and 11) and deposited in Reaches 5, 4, and ultimately within Reach 1 and the sedimentation basin immediately downstream of Reach 1 near the Okanagan River. The aggraded bed materials in Reaches 4, 5 are coarse while finer material's deposed in Reach 1.

The reaches may be classified according to their geomorphic characteristics into natural, channelized, deeply incised, incised, aggradational and transitional. The geomorphic classification, sediment transport type, BEHI class and aggradation/degradation class and interaction between production and deposition of sediment are shown in Table 11.

Table 11. Results of Sedimentation and Erosion Assessments

Reach	Channel Type	Sediment Transport type	Bank Erosion Hazard Index	Aggradation / Degradation Class
1	Aggraded	Deposition	Low	+ 0.75 -1 m
2	Channelized	Transfer	Low	+/- 0.25 m
3	Channelized	Transfer	Low	+/- 0.25 m
4	Aggraded	Deposition	Low	+ 0.5 - 0.75 m
5	Aggraded	Deposition	Low	+ >1.0 m
6	Transitional	Transfer	Low	± 0.25 m
7	Deeply Incised	Production (Most)	Very high	- >1.0 m
8	Deeply Incised	Production (Most)	Very high	- 0.75 – 1.0 m
9	Deeply Incised	Production (Most)	High	- 0.75 – 1.0 m
10	Incised	Production	Moderate	- 0.25 – 0.5 m
11	Incised	Production	Low	+/- 0.25 m
12	Natural	Transfer	Low	+/- 0.25 m
13	Natural	Transfer	Low	+/- 0.25 m

Sediment Transfer



The relationship between the channel longitudinal profile, degradation, aggradation and bank stability is summarized in a channel evolution model developed by Schumm et al. (1984) and shown in Figure 9. The channel evolution model may be applied to Ellis Creek. Reaches 13 to 12 are interpreted to be in Class I without channel incision. Reaches 11 and 10 may be Class II, with knickpoints and precursor knickpoints. Reaches 9 to 6 may be Class III showing evidence of degradation. Reaches 5 and 4 may be Class V with evidence of aggradation of the material transported from upstream. Reaches 3 and 2 are channelized (Class II) while reach 1 is aggraded (Class V).

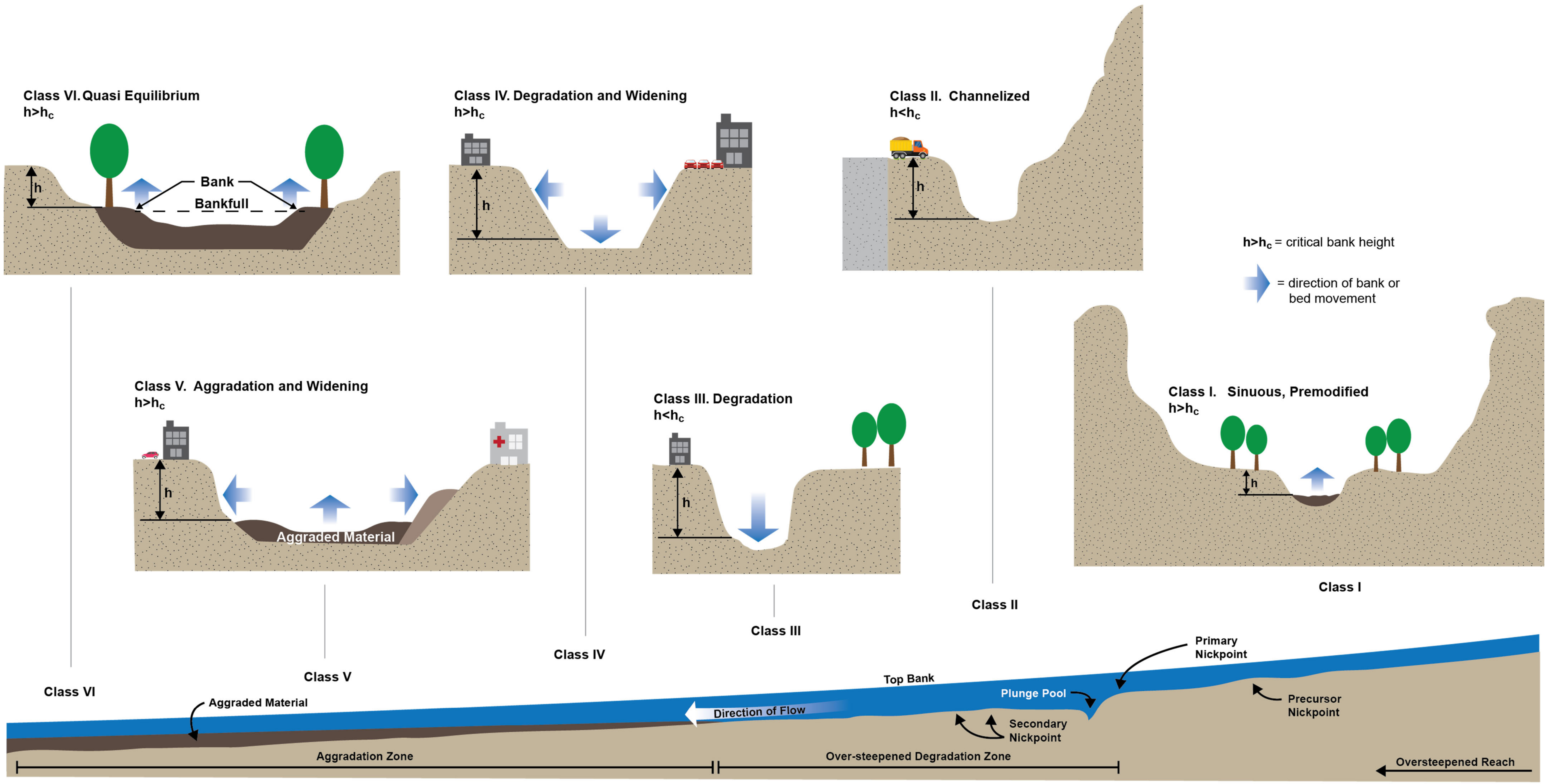


Figure 9. Channel Evolution Model (Modified from Schumm et al. 1984)

CULTURAL AND HERITAGE

A Cultural and Heritage Inventory Mapping (CHIM) assessment report was completed by 4 Seasons Heritage Consulting and Penticton Indian Band (PIB). The purpose was to complete a high-level survey to identify cultural heritage items of value to the Syilx people. The following is a summary table (Table 12) of the cultural heritage values identified through this project.

Table 12. Ellis Creek Summary CHIM Observations Table

Cultural Heritage Feature	Number Identified
Archaeological Potential	20
Archaeological Potential (polygon)	8
Culturally Modified Tree	1
Faunal Sign (Bear)	1
Faunal Sighting (Mountain Sheep)	3
Faunal Habitat (Den/Burrow/Habitat)	4
Plant Communities or Plants of Significance	5*
Vesicular Basalt	1
Industrial Landscape	1**
Fortis Pipeline Crossing	1
TOTAL	**45**

*Plant communities may be larger or continuous through more natural or park-like settings, one notably unhealthy community in Reach 4.

**Industrial landscape is associated with gravel quarry and processing area that has significantly altered a large area.

Within the scope of this project, all cultural heritage values were assessed for the cultural heritage values observed during the CHIM project. The recommendations are provided based on these values. While all cultural heritage values observed are the focus of this project, it is understood that the water, fish and a healthy ecology are of inherent cultural heritage value to the Syilx people. As such, the following recommendations are provided with regard to the CHIM project specific cultural heritage values, while comprehending that all are considered connected to one another inclusive of the Syilx people, past, present and future.

Archaeology

All archaeological sites, whether recorded or not and whether intact or disturbed, are protected by the *Heritage Conservation Act* (HCA). As such any impact to an archeological site requires an HCA Site Alteration Permit.

While it was beyond the scope of this project to subsurface test for archaeological sites, it is reasonable to assume that some of the landforms identified with archaeological potential will contain intact and/or disturbed archaeological deposits with varying degrees of density that could help better understand both the local and regional archaeology of the South Okanagan.

Archaeological sites, recorded or unidentified, intact or disturbed are protected under the HCA (*Heritage Conservation Act*), and that in addition to standards provided under the HCA by the Archaeology Branch all of the cultural heritage values identified during this project are considered significant to the Syilx people.

The City of Penticton recognizes and respects the Okanagan (Syilx) people's traditional ways and the relationship they have with the land. All design and construction activities for Ellis Creek should be collaborative and inclusive with the Penticton Indian Band and Okanagan Nation Alliance and specifically with the Elders. The Elders should be meaningfully engaged to identify their traditional culture, values, and intimate knowledge of the area through the design of each Reach.

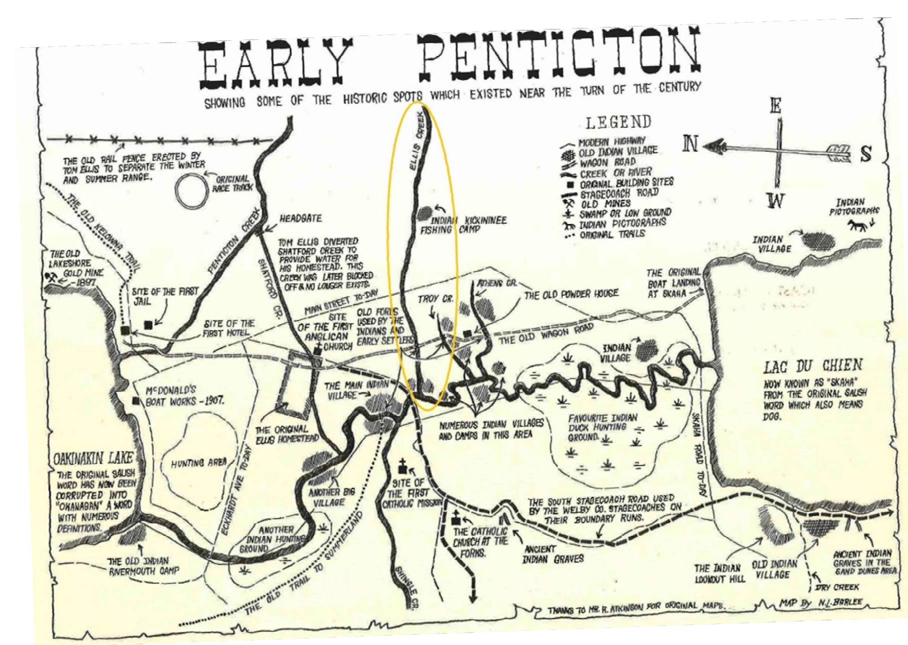


Figure 10. Barlee and Atkinson Map based on 1930 Atkinson work (Penticton Museum)

Recommendations

The following general recommendations are provided in advance of future development activities:

1. The Penticton Indian Band and Okanagan Nation Alliance and specifically with the Elders should be meaningfully engaged to identify their traditional culture, values, and intimate knowledge of the area through the design of each Reach
2. It is recommended that HCA permitted testing of landforms with archaeological potential be undertaken in advance of creek naturalization activities.
3. Consistent with the 2016 Penticton Creek CHIM recommendations, it is recommended that the City of Penticton take out and renew annually, an HCA Blanket Permit to assist with any potential land altering work they undertake.
4. It is recommended that an archaeological and/or cultural heritage resource management strategy guide be developed by City of Penticton managers that includes communication protocols for guidance including a chance finds procedure.
5. It is recommended and encouraged that this strategy and chance finds document be created with active participation from and oversight provided by the Penticton Indian Band Department of Natural Resources.
6. In consideration of this, it is recommended that the City of Penticton and/or their representatives in advance of seeking a Blanket HCA Permit, inform contractors that archaeological sites in BC are protected from intentional or accidental disturbance by Section 13 of the HCA.
7. Further to the above, increased education regarding archaeology and cultural heritage values is encouraged, monitoring of known sites to limit the illegal collection of artifacts is recommended.
8. All areas with significant plant communities or significant concentrations are recommended to be:
   a. Avoided or,
   b. Salvaged and replanted in support of restoration using local seed stock or,
   c. Provided to PIB for redistribution for replanting at their discretion

GROUNDWATER DESKTOP ASSESSMENT

Groundwater seepage and abnormally high groundwater levels were observed by City staff and land owners located south of Ellis Creek following the 2018 flood (Figure 11). A desktop assessment of groundwater conditions near Ellis Creek was completed by Stantec at the request of the City of Penticton. The assessment is documented in the Technical Opinion Memorandum - ECMP Hydrogeology Desktop Assessment (Stantec 2019).

The primary objective of this work was to assess if the Ellis Creek emergency channel excavation works, conducted in response to the 2018 freshet event, resulted in increased groundwater levels within areas of observed seepage near Ellis Creek. The secondary objectives were to identify other likely causes of increased groundwater levels, and to provide concepts for groundwater management.

Information collected during a site visit in November 2018, along with a desktop review of existing documents (groundwater level, borehole descriptions, aquifer test, weather, snowpack, interpretation of aerial photographs) informed the assessment of groundwater conditions in the areas of concern (Figure 12).

Figure 11. Water Seepage in a Parking Garage

Figure 12. Location of Areas of Concern for Seepage

Monitoring of groundwater levels at different locations in and around the areas of concern was initiated as part of this project. The monitoring program should continue to document the groundwater conditions. Collected data will inform planning mitigation measures through understanding the flow rates and the drawdown required for successful dewatering. The discharge and level of Ellis Creek should also be monitored.

Groundwater Recharge

Groundwater recharge in the area of concern is generally from:

- Regional groundwater flow
- Ellis Creek
- Residential storm sewer infiltration

The regional groundwater flow occurs within the overlapping Ellis Creek and Penticton Creek alluvial fans. Alluvial fan stratigraphy is complex, with thicker coarse sediment layers that pinch out laterally, and thin downslope over long distances. The alluvial fans form an aquifer beneath much of the City. Groundwater levels fluctuate naturally through the year, with levels generally highest in the late summer and lowest before the freshet.

General hydrogeological conditions are artesian in the areas of concern, as suggested by the presence of springs and artesian flow measured at the Warren Avenue municipal well. Groundwater flow tends to be more energetic near the summit of the fan, within narrow subsurface channels, to eventually reach the lower-energy bottom of the fan. Stratigraphic conditions may restrict water flow near the toe of the fan. Groundwater flow restriction can create pressure in groundwater, resulting in elevated groundwater levels and artesian conditions.

The type of aquifer adds to the complexity of the site. The Ellis Creek aquifer is likely a "leaky aquifer", with shallow intervals of the aquifer providing water vertically to the deeper intervals (like those intercepted by the Warren Avenue municipal well) that experience greater lateral contribution. Water in the shallower intervals tend to accumulate when recharge exceeds the rate leaking to deeper intervals, causing groundwater to rise. At the same time, deeper aquifer conditions are artesian, which would provide water upward rather than percolating downward (at locations towards the Okanagan River).

Ellis Creek contributes to groundwater locally. Flow measurements taken from Ellis Creek in November 2018 show discharge decreasing downstream. These measurements indicate that the creek was losing water into the ground at a rate of 0.0386 m^3/s.

Residential storm water infiltration recharges the groundwater, with residential roof top runoff contributing to shallow aquifer recharge. This recharge is evenly distributed in the areas of concern compared to recharge from Ellis Creek which occurs along the creek channel.

Reasons for the Rise in Groundwater

Multiple sources of water likely contributed to the rise in groundwater near Ellis Creek. The emergency channel excavation works performed on Ellis Creek east of Main Street may have contributed to recharge the shallow aquifer. However, recharge of the aquifer may have occurred in this location prior to the freshet of 2018. Data suggest that the measured recharge along Ellis Creek east of Main Street would not raise groundwater levels to cause the observed seepage and other sources of water likely contributed to the high groundwater. The deposition of cobbles and boulders during the flood likely increased groundwater levels locally by raising the channel bed. Emergency channel excavation works decreased the elevation of the channel bed and therefore may have decreased groundwater recharge and may even result in lower groundwater.

Elevated groundwater in the area may be related to the location of former creek channels. Two creeks predate the urbanization of Penticton near Ellis Creek. Athens Creek spring was located where the Penny Lane shopping centre is now. Troy Creek appears to be an abandoned branch of Ellis Creek, originating, pooling and meandering at or near locations of the properties of concern for groundwater seepage (Figure 13). The precise location of Troy Creek and Athens Creek prior to residential and commercial development is not known by Public Works staff. Interpretation of historical aerial photographs and interviews of long-time residents indicate that, prior to development, groundwater springs occurred west of Main Street. Most of the properties of concern seem to be related to the buried Troy Creek, and high-water levels at Atkinson Street are likely related to the buried Athens Creek. The south branch of Troy Creek may currently be captured by the storm sewage system south of Troy Avenue.

Climate change may have also contributed to increased ground water levels. Annual precipitation at Penticton has increased since 1960. Groundwater levels may increase with increasing precipitation, and it is possible that the high-groundwater levels represent a new normal for this part of Penticton.

Figure 13. Reconstructed Path of Troy Creek (SOURCE: historian Randy Manuel)

Recommended Concepts

Four options for managing groundwater are:

- Regional groundwater management;
- Controlling recharge;
- Local on-demand dewatering and,
- Stormwater management.

Inclusion one or more of the recommended concepts should be considered in the long term since changes in weather patterns may cause high groundwater levels that may become more frequent in the future.

Implementation of a regional groundwater management system is to have the highest cost option. An example of regional groundwater control is the use of pressure relief wells. A field of pressure relief wells intercept groundwater to lower the water table regionally. Warren Avenue Municipal Well is currently acting as a pressure relief well by discharging its water under artesian pressure into Warren Avenue Oxbow. One advantage of such an approach is that by taking advantage of artesian pressures no energy is needed. One disadvantage of such an approach would be the high construction cost to implement the pressure relief well field.

Controlling groundwater recharge is important in the short-term to decrease groundwater levels. There is no recharge baseline data available, therefore groundwater monitoring is required to document conditions and identify recharge areas. The Main Street crossing of Ellis Creek is near the head of the buried Troy Creek. This is an area of high recharge and controlling infiltration here should be explored. Lowering the bed of Ellis Creek to pre-flood elevations may decrease recharge rates locally.

Local on-demand dewatering is a proven effective option. Water is pumped from shallow wells to lower the groundwater level locally. Private dewatering was observed at some of the properties of concern. Current dewatering installations may be overwhelmed if groundwater levels continue to rise and some locations currently cannot maintain groundwater below critical levels. It is recommended to keep current dewatering in operation, and existing installations should be maintained and enhanced to cope with increased groundwater conditions. A more robust and reliable dewatering system is recommended. One advantage of the local approach is that groundwater is managed directly at the problem site. One disadvantage of the approach is that each system may be different depending on requirements at each individual property, potentially leading to elevated costs for construction, operation and maintenance.

Stormwater currently infiltrates into the ground, contributing to groundwater recharge. Although this is generally considered a best management practice, in situations of rapid rise of groundwater level, delaying the recharge from storm water would decrease the suddenness of the impact and allow some time to implement groundwater level controls solutions. Examples of such approach could be the extensive use of green roofs and walls, water storage like lakes and ponds as parts of urban parks water features, creation of wetlands, naming few proven methods.

INFRASTRUCTURE RISK

Stantec conducted a risk review to identify hazards, categorize consequences and evaluate the risks to infrastructure along Ellis Creek within the study area. The risk review included four key hazard categories: bridge conveyance, channel freeboard, utility exposure and bank stability. An understanding the key risk factors was used to inform the concept designs for each reach.

Desktop Review

Stantec conducted a desktop review of records, including recent bridge inspection reports, a recent flood risk assessment, municipal and private utility information as well as historical photographs and mapping from the Penticton archives. Key findings and conclusions were derived from the information to inform the technical assessment.

Key findings of the desktop review were:

- Ellis Creek has been a controlled system for over 80 years.
- Urbanization has encroached on the natural floodplain and confined most of the Ellis Creek Channel through the City extents.
- Ellis Creek channel is prone to significant flooding events resulting in widespread erosion, mobilization of coarse channel material and woody debris and consequential deposition in the lower reaches of the Creek.
- There was permanent alteration in the sediment transport characteristics of Ellis Creek following installation of the diversion structure.
- Historic Troy and Athens Creeks align with areas of elevated ground water conditions.
- Industrial Ave bridge culvert replaced in 2007
- Government St bridge and roadway widened in 2000
- Most crossings identified as “structure basically in good condition” (Watson Engineering 2016)
- Structural maintenance recommended for Main St bridge and replacement/upgrades recommended for Diversion Access Rd bridge (Watson Engineering 2016)
- Channel works recommended at all bridges (excluding Industrial Ave bridge culvert) (Watson Engineering 2016)
- Progressive aggradation and degradation documented in photos

A total of 25 buried utility crossings were evaluated. The in-situ depth of cover at many utility crossings is unknown. Table 13 summarizes the type of crossings identified.

Table 13. Summary of Known Utilities Crossing Ellis Creek

Type of Crossing	# Crossings on Ellis Creek
Buried watermain	11
Buried sanitary gravity main	3
Buried sanitary force main	2
Buried primary conductor	1
Buried FortisBC gas line	5
Buried Telus conduit	3

Tetra Tech Canada Inc. was retained by the City of Penticton to undertake a flood risk assessment and mitigation planning study encompassing all creeks and lakes located within the City of Penticton municipal boundaries (Tetra Tech 2018). Stantec reviewed the draft report provided by Tetra Tech and considered the findings in developing the Master Plan Infrastructure and Creek Evaluation for Risk review. Although the Master Plan evaluation is an early stage planning exercise, we found our results to generally agree with the draft Tetra Tech assessment.

Site Assessment

The Creek was visually assessed by Stantec’s team of professionals during October and November in 2018. The site assessment was focused on existing infrastructure with supplemental information collected along the way to inform the master planning exercise.

Key findings include:

- Seven (7) open bottom culverts and four (4) clear-span bridges
- Notable reduction in opening area at Government St to EC Dog Park bridge caused by sediment deposition
- Notable erosion at Dartmouth Rd bridge
- Three (3) exposed/damaged utility crossings at Dartmouth Rd Bridge
- Numerous damaged/non-functional stormwater outfalls

Deposition at East Hospital Access Bridge

Channel Erosion at Dartmouth Road Bridge

Disloged Stormwater Outfall

Technical Assessment

Hydraulic models can predict the depth, velocity and extent of water during floods. A one-dimensional hydraulic model was prepared to simulate design flows through Ellis Creek. A scour assessment was conducted to estimate the scour potential at each of the known utility crossings. The hydraulic model and scour assessment results were used to inform the risk evaluations within each reach. A summary of the assessment methods used are described in further detail below.

HYDRAULIC ANALYSIS

A one-dimensional hydraulic (HEC-RAS) model was developed to assess existing site conditions along Ellis Creek. HEC-RAS is a modelling software, developed by the US Army Corp of Engineers, capable of modelling one-dimensional steady flows.

Substantial channel degradation has confined the 200-year flows within the channel banks through several reaches of Ellis Creek. However, some areas downstream of the Government Street Bridge are predicted to experience widespread flooding during the design flood flow event. The limited opening area at the modeled bridge structures constricts flow, resulting in backwatering and bank overtopping. Increased velocities through the structures are observed within the model, consistent with backwater pressure forcing water through the structures. The increased velocities are likely to result in pronounced scour around constrictions. These results match the expected system behavior.

A summary of key hydraulic model results at structures and throughout the channel are provided in Appendix B.

SOURCE: 2018. Penticton Western News, Kristi Patton. Warning issued to watch creek levels in Okanagan-Samilkameen

UTILITY EXPOSURE ASSESSMENT

Natural scour is a process by which the channel bed is eroded during high flows. Natural scour was assessed using data collected in the field and hydraulic modelling results. A total of 17 buried utility crossings were evaluated. Utilities within culvert embankments or spanning the channel above grade were not assessed. The in-situ depth of cover at each crossing is unknown. The input parameters and corresponding are provided in Appendix B.

Exposed Pipe Upstream from Dartmouth Road Bridge

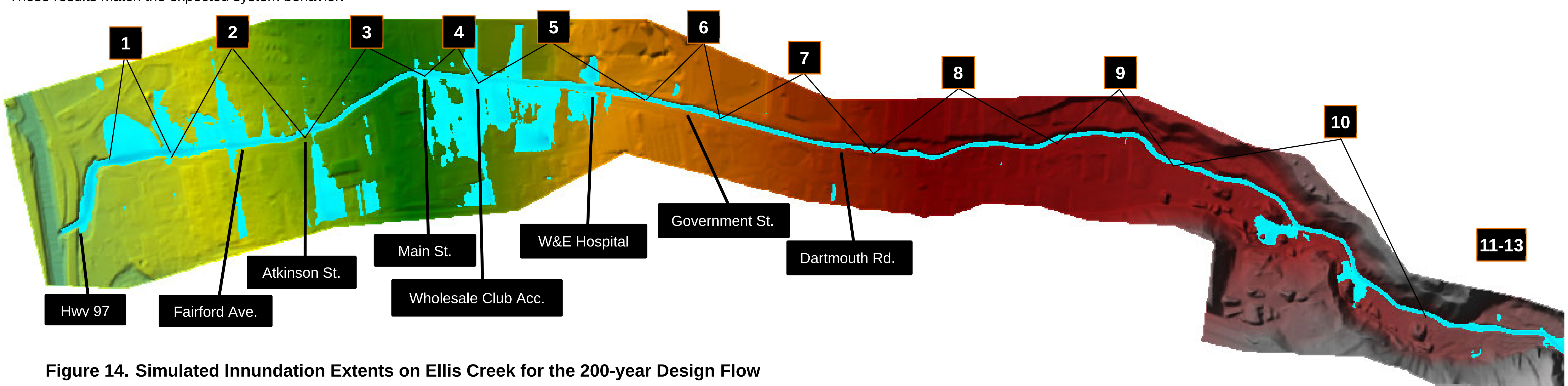


Figure 14. Simulated Innundation Extents on Ellis Creek for the 200-year Design Flow

Infrastructure Risk Evaluation

A risk review was performed to identify hazards, categorize consequences and evaluate the risks to City owned infrastructure. A map was produced to depict the areas at risk (Figure 16). An appropriate level of effort for the risk review was selected based on the Ellis Creek Master Plan (ECMP) objectives. The risk evaluation is a scenario-based evaluation in the context of the 200-year return period design event, however risk-based evaluations have also been considered for specific infrastructure elements along the creek to develop risk rankings for each channel reach. The goal of the risk evaluation is to inform prioritization of channel works throughout Ellis Creek.

Four key hazards and associated risks have been identified and are discussed in further detail below.

INADEQUATE FLOW CONVEYANCE AT BRIDGES

Ten (10) of the 11 bridge crossings on Ellis Creek within the study area do not convey the 200-year design flow event (Figure 15). Live-bed conditions (i.e. bedload transport) occur at the Site in conjunction with the design flow event and will also influence the total conveyance capacity of the crossings.

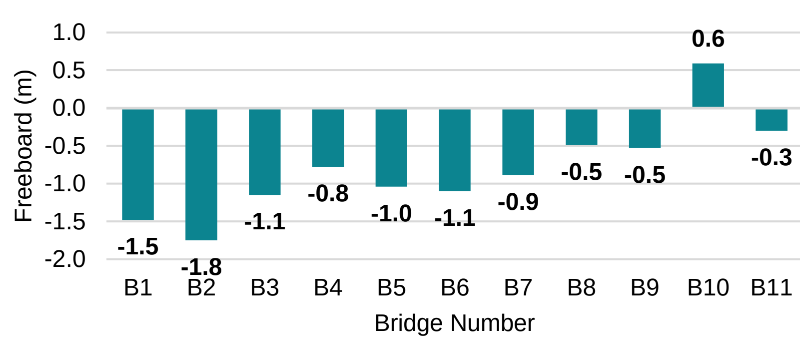


Figure 15. Summary of Freeboard at Ellis Creek Bridges

The primary hazards resulting from flow constriction are loading of the superstructure and overtopping of the roadway. Vulnerable structure points such as the shear pins or bearing pads may be exposed to forces beyond their capacity. The roadway embankments for the bridge crossings are not intended to be overtopped and are vulnerable to erosion and foundation undermining if overtopping occurs. Where the bridge overtopping is modelled to occur, we have considered the adjacent land use in developing the consequence rating for the reach. Critical infrastructure such as hospitals receive the highest consequence ranking followed by inhabited dwellings, businesses and finally uninhabited areas.

INSUFFICIENT CHANNEL FREEBOARD

Nine (9) of the 13 channel reaches are modelled to over top their banks during the 200-year design event resulting in the flooding of adjacent lands. The primary hazards resulting from insufficient channel freeboard are overland flooding and consequential impacts on health, safety and property. Several major and minor collector transportation routes including Government Street, Main Street, and Industrial Avenue as well as other roadways would be directly affected and likely experience closures as a result of the flooding.

BURIED UTILITY CROSSING EXPOSURE

A total of 25 utility crossings were identified with 8 estimated to have a high likelihood of exposure during the design event. Hydraulic parameters were considered in conjunction with areas of degradation to formulate the likelihood values at each utility crossing.

Channel degradation and confinement of the channel corridor have significantly lowered the channel bed throughout the middle reaches in Ellis Creek. There is prominent evidence of deeply incised channels through reaches 7–10 with erosion depths ranging between 0.25 m to greater than 1.0 m. Utilities through these reaches are at a greater risk of exposure than utilities in other reaches as a result.

Although the risk evaluation is limited to the design event, it is prudent to consider exposure risks at the listed crossings during events with return periods lower than the 200-year design flow event. Specifically, the utility crossings located in degraded reaches have a high likelihood of low depth of cover and therefore are more likely to be vulnerable to damage during lower return period events. A summary of the natural scour potential is illustrated (Figure 16) by ranges of estimated scour depth in meters below channel bottom.

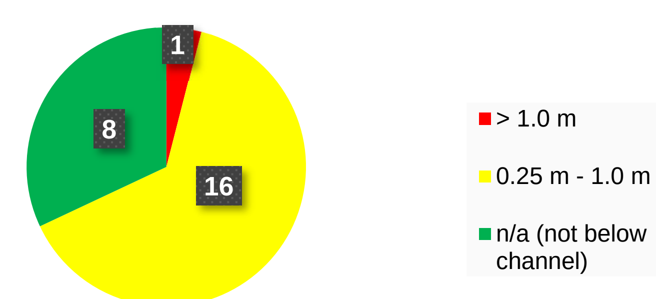


Figure 16. Summary of Potential Scour Depths at Utility Crossings

BANK EROSION

There are structures and linear infrastructure located within close proximity to the top of the channel bank which are vulnerable to failure should the bank erosion occur. Identifying areas with structures at risk informs the concept development stage of the Ellis Creek Mater Plan.

Table 14 summarizes the bank stability condition within each reach along Ellis Creek. Refer to the Erosion and Sedimentation section (p. 15) for more details.

Table 14. Summary of Bank Erosion Potential

Reach No.	Bank Erosion Hazard Index (BEHI)	Estimated Bank Instability
1	Low	Bank Erosion not evident or not significant
2	Low	Bank Erosion not evident or not significant
3	Low	Bank Erosion not evident or not significant
4	Low	Bank Erosion not evident or not significant
5	Low	Bank Erosion not evident or not significant
6	Low	Bank Erosion not evident or not significant
7	Very High	Potential for rapid bank erosion (0.50 to 1.00 m/yr)
8	Very High	Potential for rapid bank erosion (0.50 to 1.00 m/yr)
9	High	Potential for moderate bank erosion (0.20 to 0.50 m/yr)
10	Moderate	Potential for bank erosion (<0.20 m/yr)
11	Low	Bank Erosion not evident or not significant
12	Low	Bank Erosion not evident or not significant
13	Low	Bank Erosion not evident or not significant

COMPOUNDING HAZARDS

In review of natural hazards, it is prudent to consider the compounding effect of several hazards occurring simultaneously. Hydraulic conveyance is directly related to the opening area provided at the channel cross-section. Where debris or bedload restrict this opening, hydraulic conveyance will decrease. Bedload deposition and floating debris accumulation have the potential to occur together at the bridge crossings, potentially amplifying the hydraulic forces applied to the structure and embankments.

Infrastructure Risk Ranking Results

The risks associated with a 200-year flow event are rated based on the likelihood and consequence of the hazard occurring resulting in a risk rating between 1 (high risk) and 5 (low risk). The hazards identified in this review have been qualitatively assessed to inform the likelihood of occurrence. The consequences are based on qualitative scale of adverse impacts to public health, infrastructure and environment.

Each risk category is weighted equally. The risk ranking criteria is summarized in Table 15, the definitions for likelihood and consequence for each of the hazard categories are summarized in Table 16 and Table 17 and are detailed in Appendix B.

Table 15. Risk Ranking Criteria

Consequence			
High	3	2	1
Medium	4	3	2
Low	5	4	3
	Low		

Likelihood

RESULTS

A summary of the key factors contributing to the risk ranking are listed herein. Understanding the key risk factors directly informs the concept solution preparation and reach by reach description of recommended actions.

Reaches 1–5 are especially prone to flooding during the design flow events, resulting in overtopping the bridges and widespread overland flooding. Substantial aggradation throughout these reaches has significantly reduced the conveyance capacity of the channel and bridge crossings. Limited freeboard on the southern bank bordering the Cantex property results in overland flooding vulnerability. The bridges with low clearance align with areas with high aggradation risk.

Exposure potential for buried utility crossings is estimated in many of the reaches with key exposure potentials identified immediately downstream from Main Street, upstream from Government Street bridge, downstream of the Cantex property, and upstream from the City’s diversion structure access road bridge. Pronounced degradation in reaches 7–10 has likely diminished the depth of cover for buried utility crossings within these reaches. The utility exposure likelihood was adjusted to a “high” likelihood value where the scour potential overlaps with a high degradation risk ranking.

Degraded reaches 7–9 are characterized by widespread bank instability. The steep channel banks are eroding, largely because of channel degradation. Structures are located within 5 m of the top of bank throughout these reaches are at risk of damage as a result of slope failure.

Table 16. Likelihood and Consequence Definitions

Likelihood	Bridge & Culvert Clearance *	Overland Flood Susceptibility **	Utility Exposure Potential	Bank Stability
High	< 0.3 m clearance	< 0 m freeboard	> 1.0 m scour potential	High bank erosion potential (>20 cm/yr)
Medium	0.3 to 1.0 m clearance	0 to 0.3 m freeboard	0.5 to 1.0 m scour potential	Moderate bank erosion potential (<20cm/yr)
Low	> 1.0 m clearance	> 0.3 m freeboard	0 to 0.5 m scour potential	Bank erosion not evident / insignificant

* Clearance is the distance between the design water surface elevation at the bottom of the bridge structure.

** Freeboard is the distance between the design water surface elevation and the top of bank.

Table 17. Consequence Definition

Consequence	Bridge & Culvert Clearance	Overland Flood Susceptibility	Utility Exposure Potential	Bank Stability
High	Arterial or major collector roadway	Critical infrastructure in adjacent lands	Sanitary, gas or large diameter (>200 mm) watermain	Structure within 5 m of bank
Medium	Minor collector roadway or critical access	Inhabited adjacent lands	Small diameter watermain (<200 mm)	Structure within 10 m of bank
Low	Other roadway	Uninhabited adjacent lands	Abandoned, decommissioned or crossing through bridge	No structures within 5 m of bank

Table 18. Infrastructure Risk Ranking Summary

Reach No.	Risk Ranking				
	Bridge/Culvert Clearance	Overland Flood Susceptibility	Utility Exposure Potential	Bank Stability	Combined Reach Based Risk
1	1	2	3	5	3
2	3	2	2	5	3
3	1	2	1	5	2
4	3	2	5	5	4
5	2	1	5	5	3
6	1	3	2	4	3
7	4	4	2	2	3
8	5	4	5	1	4
9	5	3	2	1	3
10	5	2	5	4	4
11	3	3	1	5	3
12	5	3	5	5	5
13	5	3	5	5	5
	1 - Very High Risk	2 - High Risk	3 - Moderate Risk	4 - Low Risk	5 - Negligible Risk

MAIN ST TO GOVERNMENT ST BRIDGE CROSSING OPTIONS

Three multi-plate arch type bridges (Wholesale Club Bridge, West Hospital Bridge, and East Hospital Bridge) cross Ellis Creek between Main Street and Government Street. The purpose of these bridge crossings is to provide vehicle access/egress between Industrial Avenue and various developments north of Ellis Creek. Stantec reviewed these three bridges to provide recommendations on whether the bridges are required in the current transportation network to provide access across Ellis Creek Flooding was observed at these bridges during the 2018 high water events.

Existing Conditions

Understanding the existing conditions and future development plans in the area defines the constraints/limitations for crossing requirements. Any future changes to existing bridge configurations or locations will have both direct and indirect impacts on the block bound by Carmi Avenue, Government Street, Industrial Avenue, and Main Street.

The total vulnerability of each of the bridge structures was defined in the City of Penticton Flood Risk Assessment (Tetra Tech 2018). Vulnerability is defined as the probability or degree of loss of an element of interest due to a hazard of a certain level of destructive power. The overall vulnerability rating for each of the three structures is categorized as “Very High”.

Traffic

A total of 17 existing access points service the various developments within the block bound by Main Street, Carmi Avenue, Government Street, and Industrial Avenue. Traffic volumes along the Industrial Avenue corridor were obtained from the Traffic Impact of Proposed Wholesale Club, Main Street (T.J. Ward Consulting Group Inc. 2006) and the Transportation Study for the PRH Patient Care Tower, Penticton B.C. (IBI Group 2014). During the projected peak hour periods, 2-way traffic volumes range from 500 vehicles per hour on the east side of the corridor to 1,300 vehicles per hour at the Main Street approach. This indicates that corridor-wise traffic performance may not be an issue as there is spare capacity along the corridor.

Hydraulic Assessment

Stantec developed a hydraulic model to simulate the flow conveyance at the bridge structures for the design flood. Figure 17 illustrate a cross section of the model at the West hospital Bridge. The grey object denotes the bridge and the blue depicts the water level during the design flood. The cross section shows the view facing downstream.

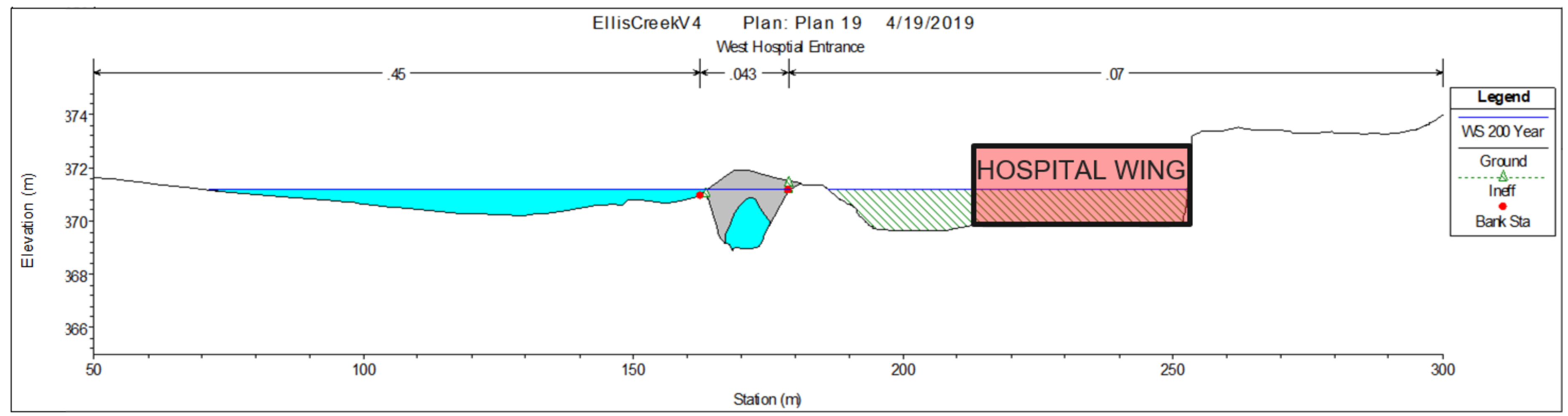


Figure 17. West Hospital Access I2, Looking Downstream (West)

Each of the bridge crossings over Ellis Creek along Industrial Avenue are partially blocked by sediment deposition and are predicted to backwater and flood the adjacent lands during the design flow. For example, the simulated flood water surface elevation at the West Hospital Access inundates the hospital’s south wing Westview residence.

Option Development

Three viable options were developed and evaluated based on the site constraints and hydraulic results. The options include:

- Option 1: Maintain All three Bridges and Complete Channel Works
- Option 2: Remove Wholesale Club Bridge and Complete Channel Works
- Option 3: Remove West Hospital Bridge and Complete Channel Works

Option 1 involves solely completing Channel Works (excavating aggraded materials) for the creek, the capital cost would be relatively low. However, in comparison to Option 2 and 3, the liability and maintenance costs are higher as Channel Works alone may not be sufficient to prevent overland flooding to a level acceptable to the City and the existing three bridges would still need to be maintained. Ongoing excavation works following large flow events is anticipated. Existing traffic and accessibility would be maintained.

In addition to completing Channel Works, **Option 2** involves the removal of the Wholesale Club Bridge as well as installing parking lot improvements along the south side of the property. As a result, the capital cost will be higher than Option 1. In terms of liability, risk of overland flooding may be further reduced with the removal of Wholesale Club Bridge and maintenance costs will be lower as only two bridge structures will need to be maintained. There could be some potential traffic and accessibility concerns with this option.

In addition to completing Channel Works, **Option 3** includes the removal of West Hospital Bridge, installation of a service road, land requirements, and a potential power pole relocation. The option has the highest capital cost out of the three proposed options. Liability and risk of overland flooding may further be reduced with the removal of the West Hospital Bridge. Out of the three options, Option 3 could be most advantageous because of the greatest reduction in flood risk to the vulnerable psychiatric wing located in close proximity to the creek. Although access to the psychiatry wing is expected to function at the same level, some existing parking stalls might be impacted and the new service road grade could be steeper than desired.

Recommendations

Stantec recommends the City proceed with implementing Option 1 – Maintain All Existing Bridge Crossings and Complete Channel Works. The main reasons are as follows:

- There is still service life in the bridge structures.
- Completing Channel Works may decrease flood risk to an acceptable level.
- Completing Channel Works is most cost-effective.
- There are no permanent impacts to the access to adjacent businesses, traffic operations, or adjacent lands.

It will be critical to monitor the flow and creek performance during high water events once Option 1 has been implemented.

FUTURE CONSIDERATIONS

If Channel Works alone do not decrease the risk to a level acceptable to the City or if the bridges reach the end of their serviceable life, it is recommended to proceed with Option 2 and/or Option 3 in conjunction with stakeholder consultation. It is highly recommended to consult with Wholesale Club and the Interior Health Authority to gain an understanding of their current and long-term access needs, specifically:

- When the City meets with Interior Health, it is recommended they discuss potential flood risks and see if there is an interest to remove the West Hospital Bridge.
- Any future development of the Wholesale Club lands should consider the removal of the Wholesale Club Bridge as part of any development plans.

A formal Traffic Impact Assessment should be completed to confirm the impacts to the surrounding area. Additional steps may include reviewing funding avenues, completing a creek evaluation, design development, securing appropriate land rights, completing an environmental assessment and obtaining permitting, and implementing the design.

Evaluating Ellis Creek

Our aim is to gain a holistic understanding of the key factors limiting Ellis Creek with the end goal of developing sustainable naturalization solutions.

Through the characterization of Ellis Creek, several key considerations for a stable and healthy creek have been identified. These considerations represent the challenges that must be addressed to repair Ellis Creek. It is important to consider not only the individual challenges, but also how they are connected.

By overlaying the considerations in similar reaches, we can develop a roadmap for system wide solutions that maximize the benefit for each of the key considerations. With compiled reach information we can also tailor naturalization solutions for each of the problematic reaches of the system. The key considerations and their locations are listed herein and depicted in the map below.

REACH 1-3 KEY CONSIDERATIONS

- Very high flood risk
- Flat, narrow & aggraded channel
- Poor fish habitat
- Poor fish passage at weir structure
- Identified culture and heritage sites

REACH 4-5 KEY CONSIDERATIONS

- Very high flood risk
- Shallow & aggraded channel
- Poor fish habitat
- Overtopping of East and West Hospital culverts
- Identified culture and heritage sites

REACH 6-11 KEY CONSIDERATIONS

- Steep, narrow & degraded channel
- High level of bank erosion
- Poor fish habitat
- Limited freeboard at diversion structure access road bridge
- Very high utility crossing exposure potential
- Identified culture and heritage sites

REACH 12-13 KEY CONSIDERATIONS

- Overtopping of diversion structure access road
- Utility crossing exposure potential
- Identified culture and heritage sites

CORE PROBLEMS

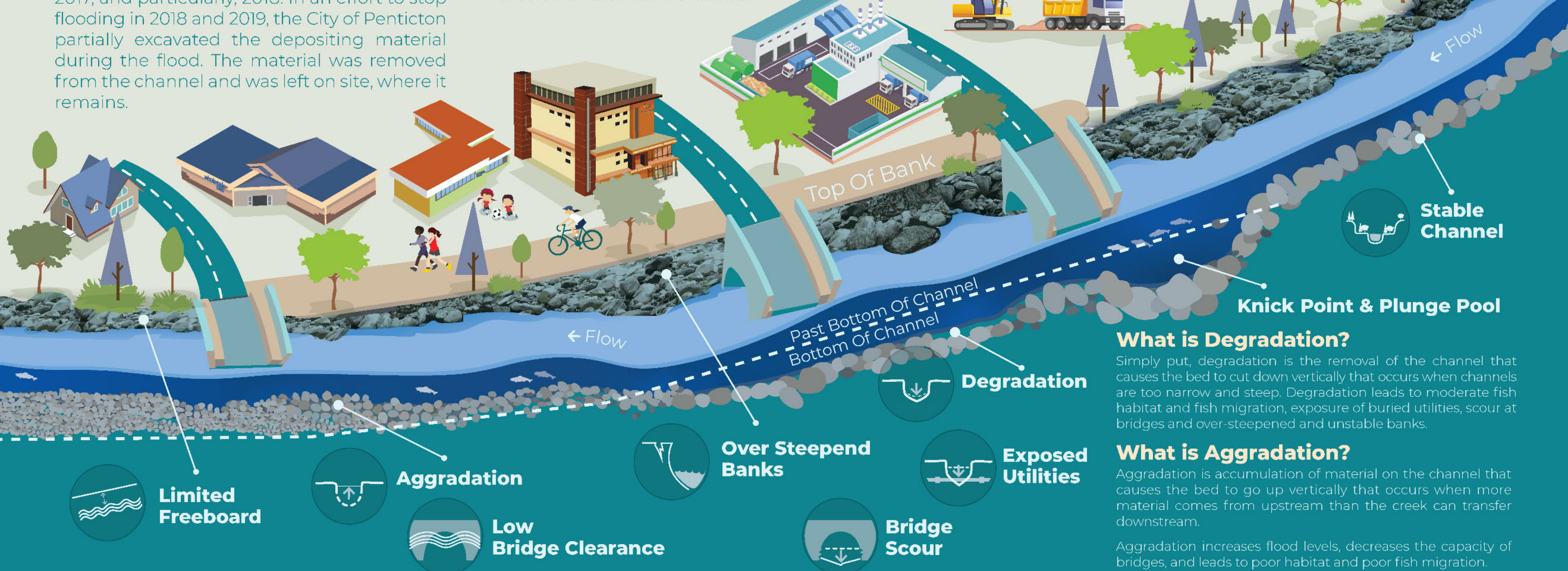
Degradation and aggradation within Ellis Creek are out of balance, with areas upstream experiencing extreme erosion and areas downstream experiencing extreme deposition. Channel instability is not the only problem afflicting Ellis Creek, however it is the core problem because most of the key considerations within Ellis Creek are directly influenced by sediment transport and general channel stability.

DEPOSITION

This area of Ellis Creek experienced deposition of gravel, cobbles and boulders that were produced from erosion upstream. Much of the deposition occurred during the floods of 2017, and particularly, 2018. In an effort to stop flooding in 2018 and 2019, the City of Penticton partially excavated the depositing material during the flood. The material was removed from the channel and was left on site, where it remains.

EROSION

This area of Ellis Creek experienced erosion of gravel, cobbles and boulders from the bed and banks of the creek channel. Much of the erosion occurred during the floods of 2017 and 2018. Two types of erosion occurred: degradation and bank erosion. Degradation has exposed utilities and steepened the channel banks. The steepening of the banks has accelerated erosion of the channel banks.



What is Degradation?

Simply put, degradation is the removal of the channel that causes the bed to cut down vertically that occurs when channels are too narrow and steep. Degradation leads to moderate fish habitat and fish migration, exposure of buried utilities, scour at bridges and over-steepened and unstable banks.

What is Aggradation?

Aggradation is accumulation of material on the channel that causes the bed to go up vertically that occurs when more material comes from upstream than the creek can transfer downstream.

Aggradation increases flood levels, decreases the capacity of bridges, and leads to poor habitat and poor fish migration.

CORE SOLUTIONS

The goal of the plan is to return balance to erosion and deposition processes by altering the channel slope, width, stabilizing the channel bed and banks and creating floodplains. Increasing the general stability and restoring some of the natural sediment transport characteristics in Ellis Creek will positively impact most of the key considerations within Ellis Creek.

Degradation Solutions

Core solutions to degradation include widening the channel, increasing the elevation of the channel bed, constructing steps and pools or backwatered riffles to stabilize the bed, creating floodplains that are connected to the channel, increasing or maintaining depth of cover at water main crossings, and stabilizing banks with riprap armour and bioengineering. Planting riparian vegetation and construction of fish habitat structures will increase the complexity fish habitat, . These solutions will:

- Decrease erosion and thus decrease sediment input
- Maintain constant sediment transport rates downstream
- Restore depth of cover to utilities
- Improve fish habitat

Aggradation Solutions

Core solutions to aggradation include excavating the channel, constructing pools, riffles and steps, channel bars, and floodplains. Planting riparian vegetation, construction of fish habitat structures and adding spawning substrate will increase the complexity fish habitat, These solutions will:

- Increase channel depth
- Maintain constant sediment transport downstream
- Minimize flooding
- Increase fish habitat

Naturalizing Ellis Creek

The Ellis Creek corridor is an important asset to many stakeholders. Conscientious planning of restoration works is needed if we are to achieve sustainable rehabilitation of the Ellis Creek corridor through the City of Penticton. Natural channel design is the recommended technique to maximize the physical and biological processes.

NATURAL CHANNEL DESIGN TECHNIQUE

Just as the limitations within each reach are connected throughout the system, so are our recommendations for naturalization of Ellis Creek. For example, to mitigate the aggradation occurring in the lower reaches, the degrading upstream reaches must first stabilized. General channel stability is integral to many of the hazards identified including bridge conveyance limitations, overland flooding, utility exposure and bank stability.

The naturalization recommendations presented are based on the key considerations outlined in the technical assessments and have been refined through engagement with key stakeholders. Although there are many competing interests, the recommendations focus on developing a functional creek corridor that increases flood resiliency, maintains accessibility for the community and enhances wildlife habitat and passage.

We applied a natural channel design approach to revitalizing Ellis Creek. The channel planform and pattern of sediment on the bed of a channel depends on the slope of the channel (Montgomery and Buffington, 1998; Figure 18 and Figure 19). These ideas were used in the development of the concept designs for Ellis Creek.

Channel Planform and Bed Sediment Pattern

Channel planform and bed sediment pattern can be constructed within their natural slope range to naturalize a stream. Ellis Creek displays slopes between 0.015 and 0.053 m/m (1.5 – 5.3%). These slopes relate to step-pool, plane bed and riffle-pool sediment patterns. The conceptual designs therefore use these three sediment patterns.

Engineering channel conditions to mimic the appropriate planforms will increase the sustainability of the restored channel corridor. Ellis Creek is not a true natural system due to extensive urbanization and channel confinement. Therefore, natural channel design must be accompanied by sound engineering judgment when restoring Ellis Creek through the City.

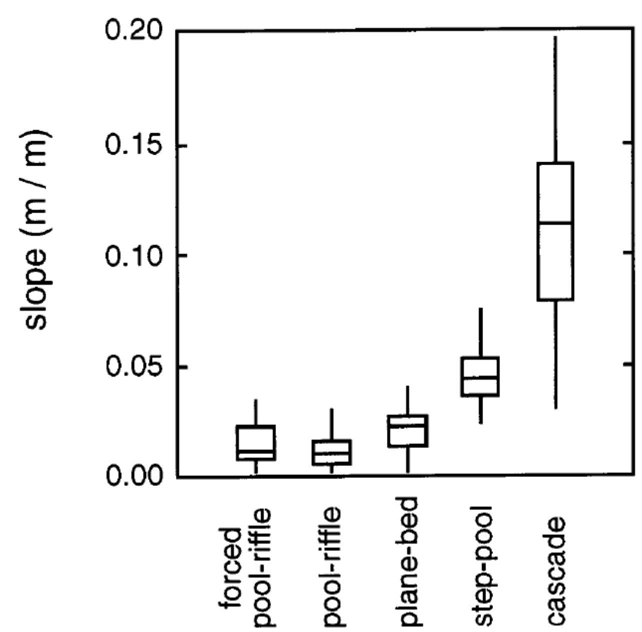


Figure 18. Slope Ranges for Different Sediment Patterns (from Montgomery and Buffington, 1998)

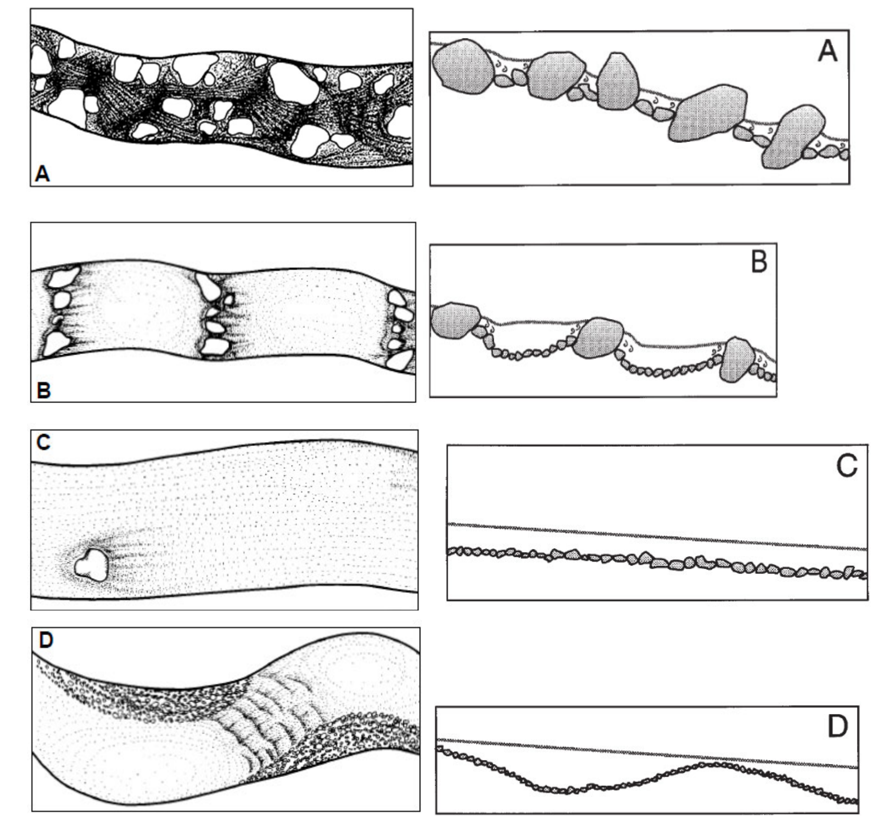


Figure 19. Planform and Bed Sediment Patterns for (A) Cascade, (B) Step Pool, (C) Plane Bed, (D) Riffle Pool (from Montgomery and Buffington, 1998)

Step-Pool Channel Design

Step Pool are generally used in channels that are starved of sediment with slopes between ~4 and 5%.

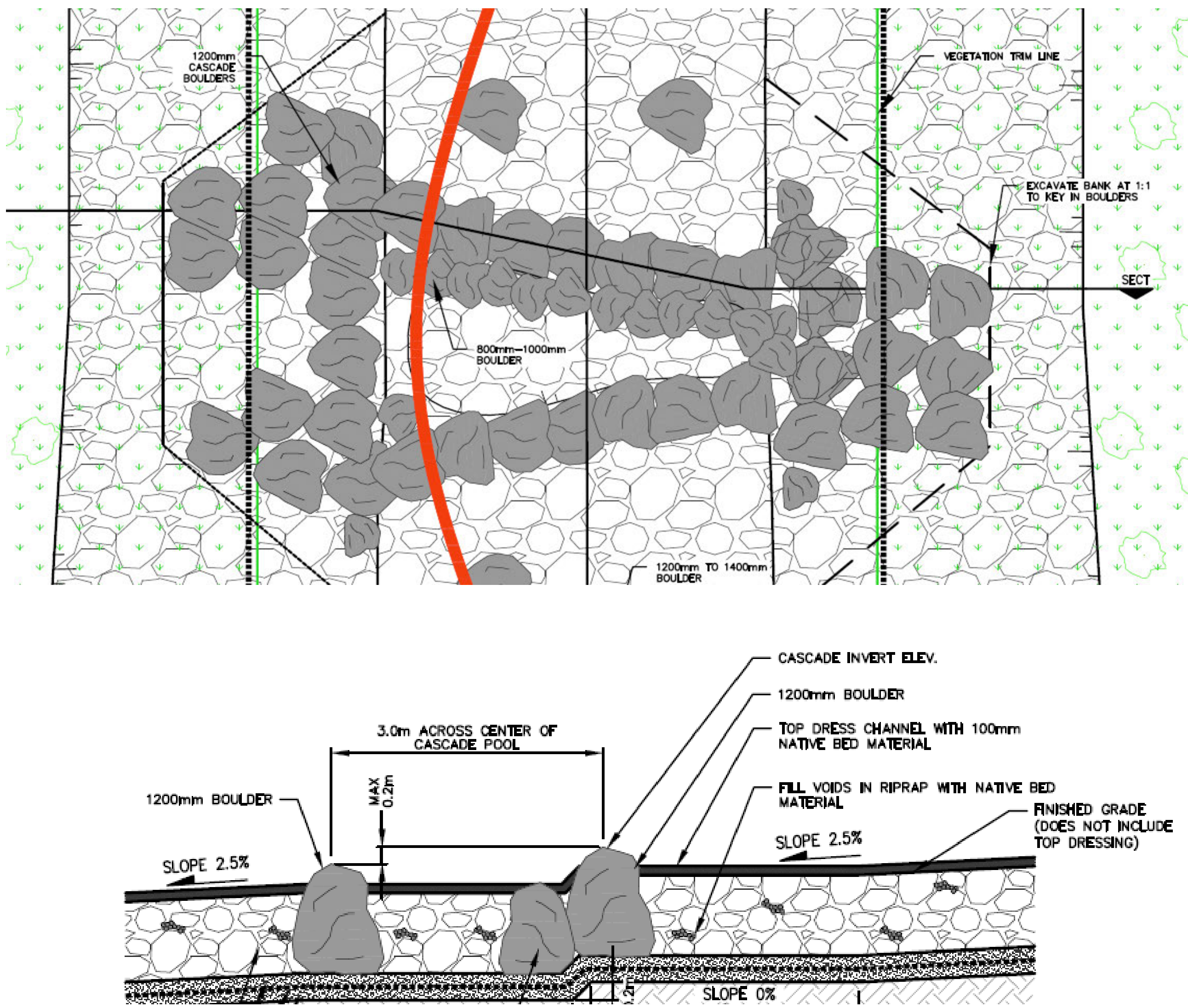


Figure 20. Step-Pool Channel Deisgn Example (for discussion purposes only)

Riffle-Pool Channel Design

Riffle Pool are generally used in channels that have active sediment transport with slopes between ~1 and 2%.

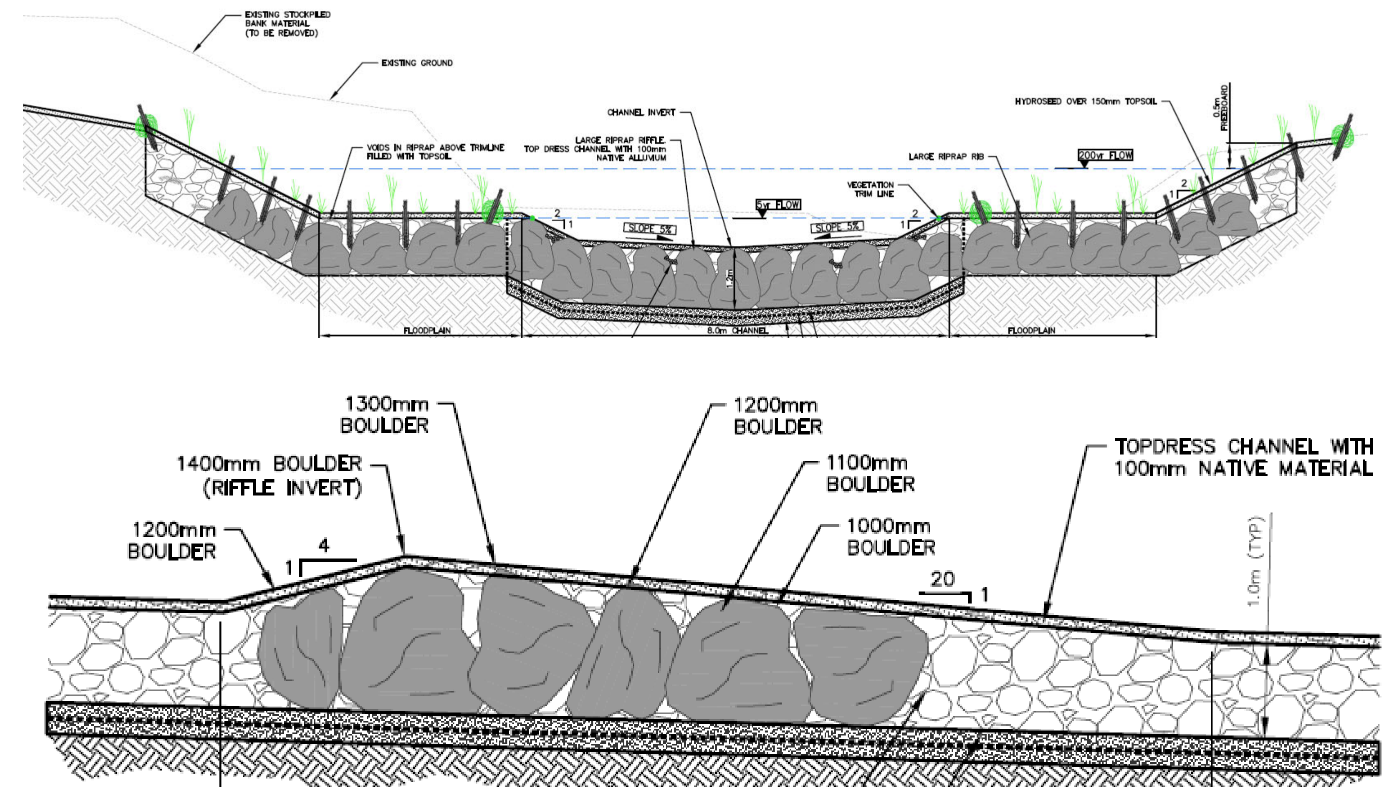


Figure 21. Riffle-Pool Channel Deisgn Example (for discussion purposes only)

DESIGN SOLUTIONS

The recommended design solutions employ a natural channel design approach. Several types of structures may be constructed to simulate natural features. These features may include steps, riffles, pools, boulder clusters, and rootwads. Bank stabilization will be required in upstream reaches. Examples of some of the features are presented here. Individual projects may utilize some or all of these features or may incorporate other features from the literature as the science evolves.

Design of fish migration is important to the success of the restoration of Ellis Creek. The design of Reach 1 needs to carefully consider how it ties downstream into the sedimentation basin. The design of Reach 2 needs to consider fish passage past the weir at the sanitary sewer line and if the sanitary line needs to be moved so that the weir can be removed. Fish passage is required at all but the lowest of flows.

Natural channel design techniques, including boulder clusters, root-wads and riparian vegetation cover, are recommended throughout the Reaches to supplement the channel design techniques and support aquatic habitat and migration.

Natural Channel Design Objectives

We have prepared a list of primary objectives that guide the naturalization recommendations for each reach. The objectives are to:

- **Stabilize** Ellis Creek Channel
- **Improve** Ecological Function
- **Increase** Flood Resiliency
- **Decrease** Infrastructure Risk
- **Increase** Aesthetics and Park Values

Specific design objectives are applicable to each of the sections outlined in the channel evaluation. These design objectives are intended to guide detailed design activities by addressing the common problems specified within the section.

A summary of design objectives for each region are outlined herein accompanied by a photograph illustrating the proposed design solutions.

Reach 1–3 Design Objectives

Riffle-pool with **habitat features** to:

- Increase conveyance in channel
- Increase conveyance under bridges
- Convey sediment into sedimentation basin downstream
- Increase spawning and rearing habitat
- Restore fish passage at weir in Reach 2

Reach 4–5 Design Objectives

Plane-bed with **habitat features** to:

- Increase channel capacity
- Increase conveyance under bridges
- Increase rearing and overwintering habitat

Reach 6–11 Design Objectives

Step-pool or **backwatered riffle** with **habitat features** to:

- Stabilize bed and banks
- Decrease aggradation in Reaches 4 & 5 downstream
- Increase cover on Dartmouth Rd Bridge abutments
- Increase rearing and overwintering habitat
- Improve fish passage at boulders downstream of Dartmouth Rd

Reach 12–13 Design Objectives

Chanel **bank revetment** with **habitat features** and access road **grading** to:

- Increase freeboard along diversion structure access road
- Stabilize banks scouring the diversion structure access road

ALTERNATIVE SOLUTIONS

Several alternative techniques were developed as part of the Master Plan. Natural channel design is the recommended approach, however there are instances where alternative solutions may be appropriate to achive the design objectives.

A summary of the alternative solutions is outlined herein along with a description of how each alternative may be applied. Alternatives are specified in applicable reaches within the Reach by Reach Overview section that follows.

The alternatives presented have limitations and consequences that must be further considered in detail before opting to apply an alternative as part of the restoration project. However, there are likely areas that could benefit from the application of an alternative solution to accommodate the system wide natural channel design.

Acquire Land for Constructed Floodplain (Reaches 1–5)

Natural channel design can become more effective given more space to implement low energy channel geometry. Ideally, wide constructed floodplains are the preferred means of mitigating design flow events. Where possible, the City may wish to acquire land in the lower reaches to accommodate widened floodplains.

Stormwater elements such as wetland features could utilize wider floodplains to improve storm water quality before it enters Ellis Creek.

Formalize Flood Control Berms (Reaches 1–5)

Flood barriers and dykes can be used to contain channel flows. This solution can accompany natural channel works where space limitations restrict the widening of the channel or development of floodplains. Barriers may be effective in conveying water, however they do increase the water surface elevation during high flow events and this can negatively impact groundwater conditions throughout the communities adjacent to the Creek.

Introduce Spawning Platforms (Reaches 1–3)

Spawning platforms may be constructed from logs and rocks installed on the bed of low gradient reaches of Ellis Creek. The features are used to retain gravel used for spawning. The grain size of the gravel can be specified to accommodate target species preferences.

Remove Bridges (Dog Park, West Hospital and/or Wholesale Club)

We recommend the City consider removing these bridges in the event the channel mitigations are not sufficient in mitigating the design flow event. Currently, they restrict flow

Install Sediment Basis

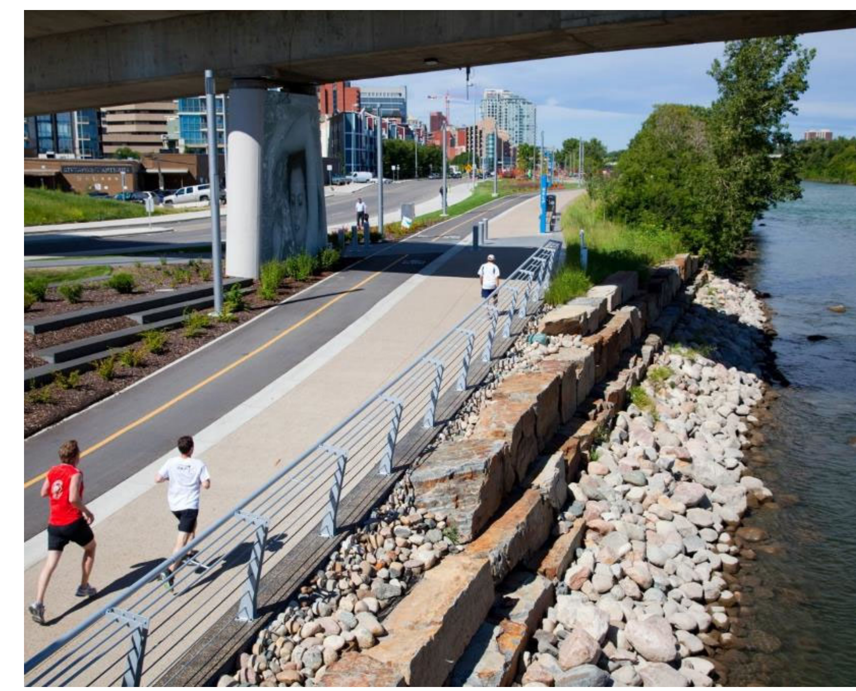
Additional sedimentation basins are not recommended on Ellis Creek as they do not mitigate the core sediment management problem. Unwanted side effects such as impeding fish passage and decreased water quality diminish the suitability of using basins along the Creek. There is limited space for sedimentation basins within the reaches of deposition along the Creek. Land acquisition for basins would be cost ineffective compared to completing the recommended natural channel works.

Remove and Replace Dartmouth Road Bridge

As the Dartmouth Road bridge the end of its serviceable life, we recommend removing and replacing with a clear span structure that can accommodate the design flow.

Stabilize Constrained Channel Sections with Riprap, Stacked Boulders or Retaining Walls (Reaches 7–11)

Riverbank retaining walls constructed from dimensional stone could be used to stabilize the banks and reduce the overall width of the wetted channel. Where legitimate constraints are found to limit the space available for a conventional channel widening, this alternative approach may be viable. However, we do not recommend application of this alternative to large extents of channel or as a replacement for natural channel design as it will increase the creeks hydraulic energy and increase scour potential.



Engineer Hardened Channel Sections to Limit Footprint In Select Areas (Reaches 10 & 11)

Grouted riprap and grade control structures are capable of stabilizing channel bed and banks. Hardened channel sections typically require less space when compared to natural channel design. However, this technique results in a ridged protection that is prone to undermining. Again, we do not recommend application of this alternative to large extents of channel or as a replacement for natural channel design as it will increase the creeks hydraulic energy and increase scour potential. With low fish habitat values, permit approvals are more difficult.

Peak Flow Bypass (Reaches 10 & 11)

A peak flow bypass pipe could be used to reduce peak flows in the main channel. Bypass pipes are limited by the constructible pipe capacity and would likely require extensive disturbance to existing infrastructure along Industrial Avenue. In light of the high degree of disturbance and long-term maintenance requirements, a peak flow bypass is likely cost prohibitive and is not recommended.

Large Capacity Reservoir (Reach 13)

A large reservoir could allow further control of the flows within Ellis Creek. Reducing peak discharges and increasing base flows during spawning periods would be possible. Construction of a reservoir is not recommended largely due to the cultural, environmental and capital costs associated with the loss of portions of Ellis Creek corridor in the reservoir.

TIMELINE & APPROACH

The proposed restoration approach is divided into immediate, short term and long-term objectives. Natural channel design is the recommend approach to restore balance to the system. Naturalizing the function of Ellis Creek in the short term will compound into larger benefits in the long term. Alternative approaches considered and corresponding recommendations are also discussed herein.

Regulatory requirements are an important consideration when planning restoration works. Permit approvals can be time consuming and must be accounted for in the lead time requirements for each of the project reaches.

Monitoring of the completed channel restoration works and subsequent maintenance are critically important in the success of the proposed approach. Monitoring is used to track the successes and failures of the system and gather data that can inform future works. Maintenance is required to sustain the restored channel in a functional condition. Both monitoring and maintenance are crucial elements in mitigating flood related disasters and stewarding the Ellis Creek greenway for the public to enjoy. Monitoring and maintenance goals are discussed herein.

Immediate Works

The project has identified key shortcomings regarding peak flow conveyance on Ellis Creek. Ten out of the eleven bridge crossings will not convey the peak design flow and are in various states of disrepair. Given the potential flood risk present at these bridge crossings, it is recommended that immediate mitigation activities are completed to alleviate some of the flood risk that exists.

Several buried utilities are at an increased risk of exposure or may be exposed already. These utilities should be reviewed at the earliest opportunity to ensure their depth of cover and protection is sufficient. We recommend monitoring these crossing sites closely during high flow events and supplementing with temporary cover as required to maintain the depth of cover. Permanent erosion protection measures should replace all temporary mitigation measures within short succession.

The banks adjacent to several industrial properties should be reviewed at the earliest opportunity to evaluate the specific risk to adjacent infrastructure and or channel blockage from a land slide. Retreat from the unstable banks should be considered and compared against temporary mitigations to stabilize the banks.

Short Term Works (within 20-year horizon)

The short term works are intended to:

- Mitigate aggradation and degradation
- Enhance fish habitat
- Restore depth of cover to utilities
- Increase flow conveyance
- Improve parks and aesthetic values
- Improve capacity of bridges

Zoning and land acquisition is required to support the natural channel design objectives. Zoning strategies may be implemented to encourage naturalization of the Ellis Creek corridor.

Long Term Works (beyond 20 years)

The long-term works are a set of objectives that are not achievable in the short term. Improvements to Ellis Creek should occur over a time period longer than 20 years. Long term works may include:

- Removal of bridges as they reach the end of their serviceable life.
- Acquisition of land along the creek to increase the size of the floodplain and enhance linear parks.
- During bridge replacements, widen bridge openings to extend across the floodplain. This allows for migration of animals upstream and downstream and area for walking trails.

Regulatory Considerations

Regulatory consultation with federal, Provincial and Municipal agencies is required for each project. All in water works must take place within the provincially mandated fish construction window for Ellis Creek. The following regulations will apply to each project initiated under this Master Plan:

Federal

- Project review under the *Fisheries Act*: Submission of a Request for Review to Fisheries and Oceans Canada. Pending the outcome of DFO's review, a *Fisheries Act* Authorization for the harmful alteration, disruption or destruction of fish habitat may be required

Provincial

- Approval to make changes in and about a stream under Section 11 of the *Water Sustainability Act*
- *Dike Maintenance Act*
- *Wildlife Act*
- *Riparian Areas Regulation*
- *Heritage Conservation Act*

Regulatory consultation will identify any additional requirements for projects. The Penticton Indian Band and Okanagan Nation Alliance should also be engaged at the onset of each project to identify any cultural and heritage values.

Future Monitoring

Post construction monitoring programs should be identified in the early phases of the project. Based regulatory requirements, and Best Management Practices, annual reviews should be completed.

Specific monitoring requirements will be determined once regulatory approvals are received. It is anticipated the following monitoring plans will be required:

- Environmental flow needs (hydrometric stations)
- Fish and fish habitat (including riparian health)
- Geomorphology (bank erosion, sedimentation, and degradation)
- Infrastructure (bridges and utilities)

Maintenance

Maintenance of the channel or structures may be required as identified through the monitoring program. Ellis Creek is an urban water course therefore channel restoration will not fully restore natural channel processes of erosion, transport and deposition. Maintenance will fall in to four main categories:

Fish Habitat - Fish habitat will need to be maintained. Overwintering pools may infill with sediment through time in downstream reaches. Small spawning gravels may be transported downstream away from the spawning platforms. Root wads may eventually rot and need replacement.

Bank Armour - Bank armour may be displaced during large flows and need replacement. Structures used as grade control my require maintenance following large flows.

Sediment Removal - Particularly in reaches 4, 5 and 1 but also 2 and sediment may need to be removed from under bridges.

Scour Protection – Areas that are vulnerable to scour and/or adjacent to sensitive infrastructure will need recurring maintenance to maintain scour protection measures.

Reach by Reach Overview

The reach by reach overview provides a summary of the existing conditions and the proposed concept solutions within each of the reaches. The purpose of the reach overview is to define the reach specific concept solutions and discuss alternative solution options.

The existing conditions are described, including the geomorphology, fish habitat, cultural and heritage and infrastructure risk. The geomorphic condition is defined as Natural, Aggraded or Degraded for each reach to define where the primary channel condition and guide the concept design criteria. The key problems afflicting the reach are summarized at the conclusion of the first page for each reach.

Concept design recommendations, options and alternatives are compiled following the existing conditions information. Design objectives and key constraints are presented. Conceptual designs to solve the problems within each reach are defined and accompanied by a conceptual design section depicting the recommended solution. Alternative solutions are also defined within each reach overview. Each of the concept solutions are annotated with a notation indicating the recommended timeframe for implementation (refer to the Timeline & Approach section for details).

Reach 1

EXISTING CONDITION: AGGRADED

Reach Length	135 m
Bankfull Width	13.1 m
Bankfull depth	0.52 m
Bed Slope	1.5 %
Grain Size (D_{50})	Fine Cobble
Grain Size (D_{90})	Coarse Cobble
Aggradation/Degradation	+ 0.75 -1 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 1 is the downstream-most reach within the assessment. It extends 135 m upstream from the dog park Pedestrian Footbridge to the Industrial Avenue Bridge. The channel is straight and the slope is low. The bankfull channel is relatively wide and shallow. The channel width narrows from upstream to downstream (15.6 m upstream compared to 11.4 m downstream). The bank heights measure approximately 1.5 to 2.5 m in the downstream section and increases in height to 5.0 m at the Industrial Avenue Bridge at the upstream end of the reach. The bed material is predominantly fine cobble. The banks are covered with small trees, shrubs and grasses, providing moderate bank stability. The bed sediment is rounded to sub-rounded and is organized in a riffle-pool pattern. An elongate medial bar extends the length of the reach, with approximately 2/3 of low flow along the left side, and the remaining 1/3 along the right side. Large woody debris is present in the channel but is not functioning as channel control. The channel bed has aggraded. No bank erosion was observed.

Fish Habitat

Cover for fish within Reach 1 is high, consisting of overhanging vegetation and boulders, and some woody debris; no deep pools or undercuts are present. Channel banks are defined as steep fine/cobble slopes with tall vegetation and no functional riparian habitat.

Fish Habitat Value	
Spawning:	Poor
Rearing:	Moderate
Overwintering:	Poor
Migration:	Moderate

A sedimentation basin is located immediately downstream of Reach 1. The outlet of the sedimentation basin was reconstructed by the Okanagan Nation Alliance in 2018 to allow fish passage. Reach 1 connects to the upper extent of the sediment basin and conveys sediment into the basin.

Cultural and Heritage

One area with archaeological potential was identified within Reach 1. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/infrastructure

Reach 1 is prone to design flow events overtopping the bridges resulting in widespread overland flooding. Substantial aggradation throughout the reach has significantly reduced the conveyance capacity of the channel and Ellis Creek Dog Park and Industrial Avenue bridge crossings. The bridge clearance "high" likelihood parameter aligns with areas with a high aggradation risk ranking.

	Comments	Risk Ranking *
Bridge / Culvert Clearance	Overtopping bridge culverts @ EC Dog Park & Industrial Ave Adjacent lands area inhabited	1
Buried Utility Exposure Potential	Moderate scour potential @ 200 mm watermain (WM-377)	3
Overland Flooding Susceptibility	Overtopping channel banks and high aggradation hazard Inhabited adjacent lands	2
Bank Stability	Bank erosion not evident or not significant	4
Total Reach Ranking		3

* 1 is High and 5 is Low

PROBLEMS
Aggraded Channel
Shallow Bank Depth
Limited Channel Conveyance Capacity
Poor Spawning and Overwintering Habitat
Flood Risk

* Immediate Actions

Inadequate conveyance of flow at the Industrial Avenue Bridge is a key concern. The City conducted mitigative excavations at the downstream extent of the bridge in 2019. Additional excavations upstream and within the culvert is necessary to convey design flows. We recommend monitoring this bridge closely during high flow events and clearing debris as required to accommodate flow requirements.

Refer to the "Timeline & Approaches" section for further discussion on immediate mitigation activities.

CONCEPTUAL DESIGN

Objectives

- Increase flood capacity
- Increase spawning and rearing habitat
- Increase flow conveyance at Dog Park bridge and Industrial bridge
- Consider the sedimentation basin downstream
- Consider existing pathway network connectivity

Constraints

- Elevation of outlet control of sedimentation basin is 338.85 m

Concept Options

OPTION I

Excavate channel and regrade with riffle pool sequence and naturalized lateral bars. Establish channel grade line from the existing sediment basin and maintain sediment transportation into the basin. Develop sediment monitoring and maintenance plan to manage incoming sediment.

Pros: Naturalized design with low maintenance requirements.

Con: Less spawning habitat.

OPTION II

Excavate channel and regrade with spawning platforms. Establish channel grade line from the existing sediment basin and maintain sediment transportation into the basin. Develop sediment monitoring and maintenance plan to manage incoming sediment.

Pros: Increase potential for spawning area.

Cons: Potential for maintenance requirements.

Alternative Solutions

- Acquire land for larger constructed floodplain
- Install flood barrier
- Remove Dog Park bridge
- Excavate wide floodplain at dog park

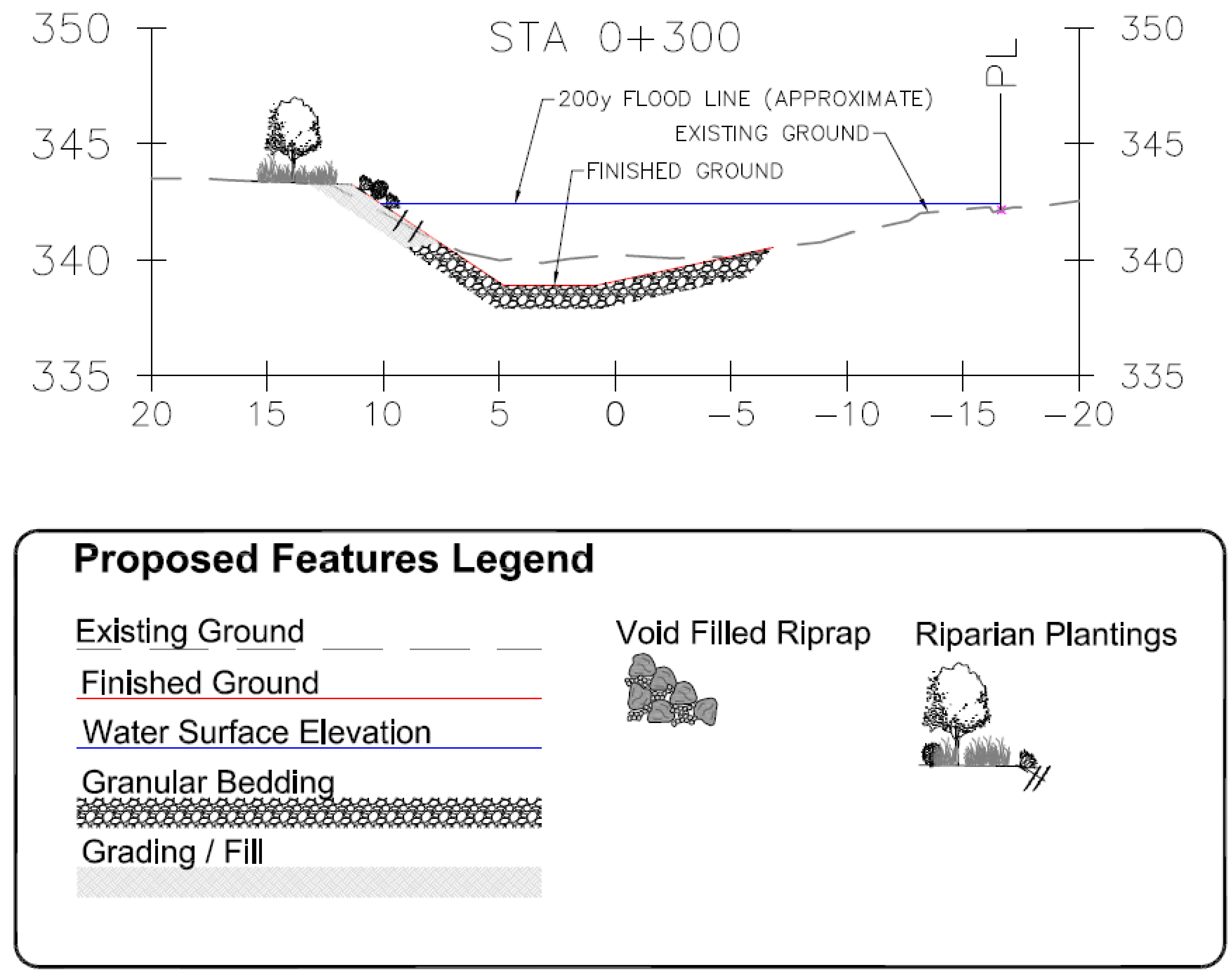
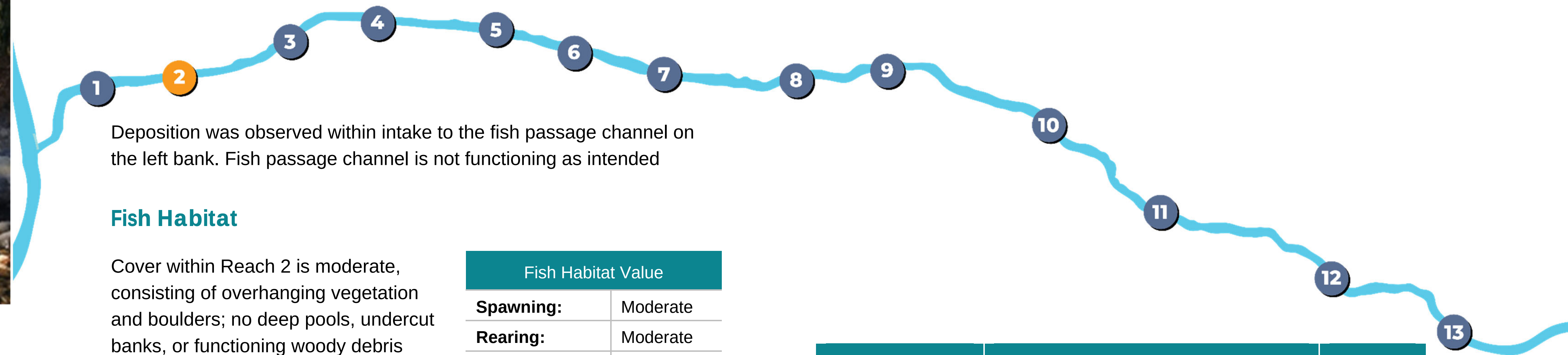


Figure 22. Cross Section of Proposed Concept Design for Reach 1 (looking downstream)



Reach 2

EXISTING CONDITION: CHANNELIZED

Reach Length	350 m
Bankfull Width	9.2 m
Bankfull Depth	0.38 m
Bed Slope	2.2 %
Grain Size (D_{50})	Fine Cobble
Grain Size (D_{90})	Coarse Cobble
Aggradation/Degradation*	+/- 0.25 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 2 extends 350 m upstream from the Industrial Avenue Bridge to the Atkinson Street Bridge, including Fairford Pedestrian Bridge. The creek has been channelized due to urbanization. The channel is straight with no distinct sediment pattern. The average bankfull channel is 9.2 m wide and 0.38 m deep. The bed material is predominantly fine cobble. Channel bed elevation in this reach is controlled by a weir structure spanning the channel approximately 70 m upstream of the Industrial Avenue Bridge. A line of boulders has been placed across the channel approximately 8 m upstream of the weir, resulting in pooling of channel flow on the approach to the weir. The channel is wider downstream of the weir (10.9 m) compared to upstream (8.8 m). Bankfull depth was observed to be deeper downstream of the weir (0.5 m) compared to upstream (0.2 m). Large woody debris is present in the channel but does not provide any functional control on flow or sediment stability.

Deposition was observed within intake to the fish passage channel on the left bank. Fish passage channel is not functioning as intended

Fish Habitat

Fish Habitat Value	
Spawning:	Moderate
Rearing:	Moderate
Overwintering:	Poor
Migration:	Moderate

Cover within Reach 2 is moderate, consisting of overhanging vegetation and boulders; no deep pools, undercut banks, or functioning woody debris were present. Channel banks are defined by steep boulder slopes with limited vegetation and no functional riparian habitat. Minor erosion was observed on the channel banks, and was limited to the upstream extents near Atkinson Street. Overall, the channel banks appear relatively stable at low flows but are vulnerable to significant erosion under flood conditions.

The concrete weir is a barrier to upstream fish migration. A narrow (2 m to 4 m) riffle-pool channel was constructed on the left bank to allow fish passage upstream of the weir. The fish passage channel requires regular maintenance due to deposition of sediment. On the day of observation, the fish passage channel inlet culvert (300 mm) was 50% plugged with shallow water depths (<0.1 m) at the inlet. Flows over the weir have scoured a deep pool approximately 30 m^2 in size. Immediately upstream of the weir, a series of boulders have been placed into the channel in a “U-shaped” formation. This boulder complex is improving the overall functionality of the reach and has resulted in formation of a scour pool, a limited habitat feature throughout most of the reach.

Cultural and Heritage

One area with archaeological potential and two plant communities were identified within Reach 2. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/infrastructure

Reach 2 is prone to design flow events overtopping the bridges resulting in widespread overland flooding. Substantial aggradation throughout the reach has significantly reduced the conveyance capacity of the channel and Fairford Drive bridge crossing. The sanitary crossing weir restricts fish passage and collects debris.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Overtopping bridge @ Fairford Drive Adjacent lands area inhabited	3
Buried Utility Exposure Potential	Moderate scour potential @ 525 mm concrete sanitary gravity main (SSGM-1176-1175) and 150 mm watermain (WM-1299) Moderate scour potential @ 60 mm Fortis BC gas line immediately upstream from Fairford Drive bridge (A68-523/1968)	2
Overland Flooding Susceptibility	Overtopping channel banks and moderate aggradation hazard Inhabited adjacent lands	2
Bank Stability	Bank erosion not evident or not significant	4
Total Reach Ranking		**3**

* 1 is High and 5 is Low

PROBLEMS
Channelized
Poor Overwintering Habitat
Flood Risk
Limited Fish Passage

* Immediate Actions

An options analysis should be completed to evaluate several alternatives for the Fariford Bridge, including a partial removal or reconstruction of the bridge with revised abutments to accommodate the 200-year design flow. An assessment of flow capacity and sediment transport is recommended for this analysis.

Refer to the “Timeline & Approaches” section for further discussion on immediate mitigation activities.

CONCEPTUAL DESIGN

Objectives

- Increase flood channel capacity
- Increase rearing habitat
- Increase flow conveyance at Industrial Ave and Fariford Dr Bridge
- Consider existing pathway network connectivity

Constraints

- Sanitary sewer line with concrete weir limiting fish passage
- Fairford pedestrian bridge

Concept Options

OPTION I

- Remove Fairford Drive pedestrian bridge
- Lower channel by 1.5 m at Fairford Pedestrian Bridge
- Remove concrete weir and relocate sanitary line.
- Add riffle pool sequence to replace weir – add fish habitat complexity for rearing
- Develop sediment monitoring and maintenance plan to manage incoming sediment.

Pros: Improves flood flow conveyance. Maintains channel grade through reach to maintain consistent velocities and shear stresses downstream. Improved fish habitat.

Cons: Decreased pedestrian access. Cost to relocate sanitary sewer.

OPTION II

- Retain Fairford Pedestrian Bridge
- Relocate sanitary line
- Lower channel by up to 0.5 m at Fairford Drive Pedestrian Bridge
- Add riffle pool sequence – add fish habitat complexity for rearing
- Add flood protection berms or barriers
- Develop sediment monitoring and maintenance plan to manage incoming sediment.

Pros: Maintains pedestrian access. Better fish habitat.

Cons: Channel grade changes through the reach. Increased potential for erosion as velocities / shear stresses increase in lower section of reach. Cost to relocate sanitary sewer. Land needs / costs for berms or barriers.

Alternative Solutions

- Replace Fairford bridge with longer structure
- Acquire land for larger constructed floodplain
- Install flood barrier

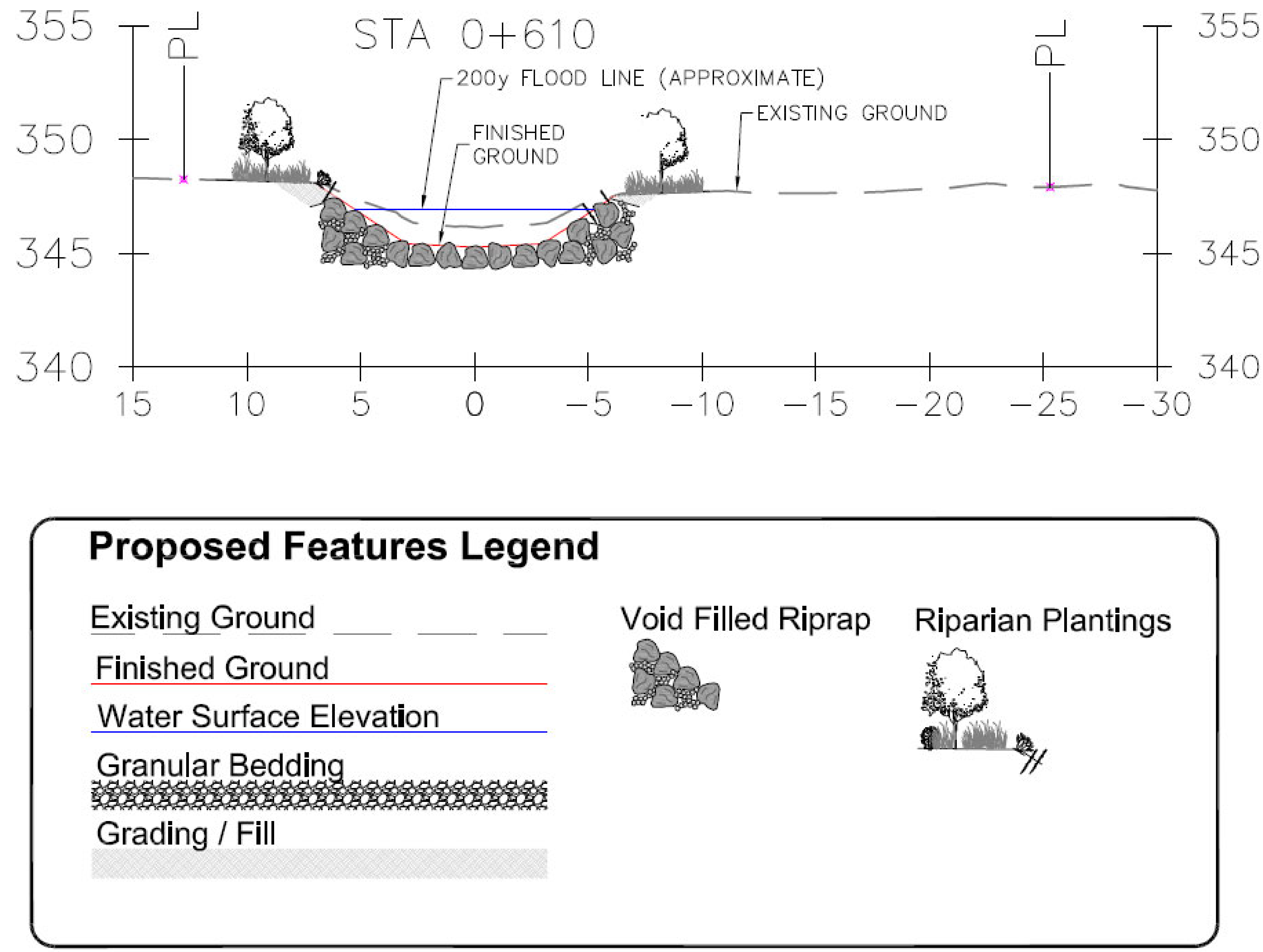


Figure 23. Cross Section of Proposed Concept Design for Reach 2 (looking downstream)

Reach 3

EXISTING CONDITION: CHANNELIZED

Reach Length	340 m
Bankfull Width	9.6
Bankfull Depth	0.52 m
Bed Slope	2.1 %
Grain Size (D_{50})	Fine Cobble
Grain Size (D_{90})	Coarse Cobble
Aggradation/Degradation*	+/- 0.25 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 3 extends 340 m between the Atkinson Street Bridge and the Main Street Bridge. The bankfull channel is 9.6 m wide and 0.52 m deep. The bed material is predominantly fine cobble. The channel bends slightly to the southwest at the upstream end of the reach, maintaining a consistently straight planform to the downstream end of the reach, where it bends slightly to redirect the channel to the west into Reach 2. The creek has been channelized due to urbanization, but the bed is generally stable. The sediment pattern on the bed is characterized by boulder lines which span the channel at irregular intervals. Pools are largely absent from the reach. No woody debris was observed along the banks or in the channel within this reach.

Fish Habitat

Fish Habitat Value	
Spawning:	Moderate
Rearing:	Moderate
Overwintering:	Poor
Migration:	Moderate

Cover within Reach 3 is moderate, consisting of mostly boulders and some overhanging vegetation; no deep pools, undercut banks, or functioning woody debris was present. Channel banks are defined by steep boulder slopes with limited vegetation and limited functional riparian habitat. Minor erosion was observed throughout the reach and vertical banks were observed with evidence of old rip-rap adjacent to the Industrial Avenue East in several locations.

Cultural and Heritage

Two areas with archaeological potential were identified within Reach 3. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

Reach 3 is prone to design flow events overtopping the bridges resulting in widespread overland flooding. Substantial aggradation throughout the reach has significantly reduced the conveyance capacity of the channel and Atkinson Street and Main Street bridge crossings.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Overtopping structure @ Atkinson St culvert & Main St bridge Adjacent lands area inhabited	1
Buried Utility Exposure Potential	Moderate scour potential @ 250 mm watermain (WM-1560)	1
Overland Flooding Susceptibility	Overtopping channel banks and low aggradation hazard Inhabited adjacent lands	2
Bank Stability	Bank erosion not evident or not significant	4
Total Reach Ranking		2

* 1 is High and 5 is Low

PROBLEMS
Channelized
Poor Overwintering Habitat
Flood Risk (Conveyance at Main Street bridge)
Moderate Scour Risk for Watermain

* Immediate Actions

Main street bridge is a critical transportation corridor managed by the province. Given the critical nature of this corridor and the elevated flood risk, we recommend mitigations be expedited outside of the prioritization recommendations listed as part of the master plan. Excavation of aggraded materials immediately upstream, inside and downstream of the bridge is recommended to increase the conveyance at the crossing. During material removal, known utility crossings should be reviewed for scour potential and protected accordingly.

We also recommend monitoring this bridge closely during high flow events and clearing debris as required to accommodate flow requirements. Refer to the “Timeline & Approaches” section for further discussion on immediate mitigation activities.

CONCEPTUAL DESIGN

Objectives

- Increase rearing and overwintering habitat
- Increase flow conveyance at Atkinson and Main Street Bridges
- Consider existing pathway network connectivity

Constraints

- Atkinson and Main Street Bridges

Concept

- Tie in from Reach 4 upstream
- Plane bed with boulder clusters for habitat complexity
- Instream structures to create and maintain scour pools
- Develop sediment monitoring and maintenance plan to manage incoming sediment.

Alternative Solutions

- Acquire land for larger constructed floodplain
- Install flood barrier
- Install spawning platforms

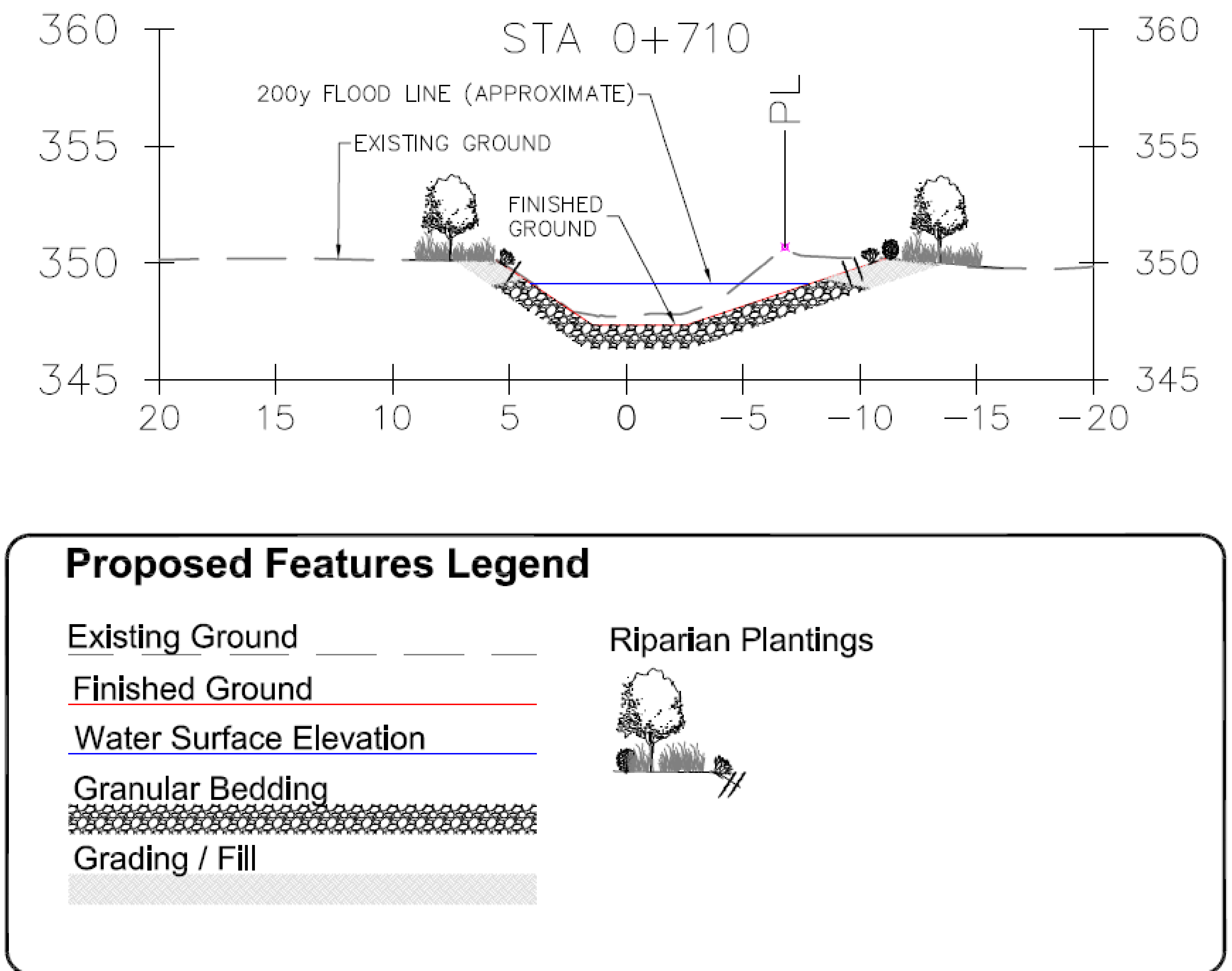


Figure 24. Cross Section of Proposed Concept Design for Reach 3 (looking downstream)

Reach 4

EXISTING CONDITION: AGGRADED

Reach Length	135 m
Bankfull Width	10.4
Bankfull Depth	0.38 m
Bed Slope	2.9 %
Grain Size (D_{50})	Fine Cobble
Grain Size (D_{90})	Coarse Cobble
Aggradation/Degradation*	+ 0.5 - 0.75 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 4 includes 135 m of straight channel extending up from the Main Street Bridge to the Wholesale Club arch culvert. The channel bed has aggraded in this reach, with the channel flowing through poorly organized stone lines. The average bankfull channel width is 10.4 m and depth is 0.4 m. Width varies throughout the reach, measuring approximately 11.4 m and 11.7 m in the upstream and downstream sections, respectively, while the center section of the reach is 8.2 m wide. The bed material is predominantly fine cobble with course cobble in some locations. Aggraded channel bed material was excavated from the reach and placed along the banks during emergency response in 2018, and this is likely the reason for the decreased width in the middle of the reach. Woody debris was not observed in substantial quantities in this reach.

Fish Habitat

Fish Habitat Value	
Spawning:	Poor
Rearing:	Poor
Overwintering:	Poor
Migration:	Poor

In its current state, Reach 4 is providing limited functional fish habitat value to Ellis Creek. The channel is defined by a low gradient cobble-boulder riffle. Cover within Reach 4 is moderate, consisting of boulders and limited overhanging vegetation; no deep pools, undercut banks or functioning woody debris was present. Banks appear are currently stable with little erosion occurring; however, significant deposition was observed throughout the reach, and is assumed to be material from upstream. Minor erosion of channel banks and industrial development has considerably impacted the riparian habitat in Reach 4, which in its current state is providing limited functional value to the creek.

Cultural and Heritage

One area with archaeological potential was identified within Reach 4. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

Reach 4 is prone to design flow events overtopping the bridges resulting in widespread overland flooding. Substantial aggradation throughout the reach has significantly reduced the conveyance capacity of the channel and Wholesale Club bridge crossing.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Overtopping bridge culvert @ Wholesale Club Access Adjacent lands area inhabited	3
Buried Utility Exposure Potential	No buried city utilities crossings identified	5
Overland Flooding Susceptibility	Overtopping channel banks and moderate aggradation hazard Inhabited adjacent lands	2
Bank Stability	Bank erosion not evident or not significant	5
Total Reach Ranking		**4**

* 1 is High and 5 is Low

PROBLEMS
Aggraded Channel
Limited Channel Conveyance Capacity
Poor Spawning, Rearing, Overwinter and Migration Habitat
Flood Risk

* Immediate Actions

Inadequate conveyance of flow at the Wholesale Club Bridge is a key concern. We recommend that addressing this situation be prioritized and expedited accordingly by the Master Plan or separately if within City of Penticton capacity to deliver.

Excavation of aggraded materials immediately upstream, inside and downstream of the bridge is recommended to increase the conveyance at the crossing. During material removal, known utility crossings should be reviewed for scour potential and protected accordingly.

We also recommend monitoring this bridge closely during high flow events and clearing debris as required to accommodate flow requirements. Refer to the “Timeline & Approaches” section for further discussion on immediate mitigation activities.

CONCEPTUAL DESIGN

Objectives

- Decrease sediment input from reaches 7-11 upstream
- Increase flood channel capacity
- Increase rearing and overwintering habitat
- Increase flow conveyance at Main Street Bridge and Wholesale Club Bridge
- Consider existing pathway network connectivity

Constraints

- Main Street Bridge
- Wholesale Club Bridge
- Design in reach 4 is effective only after sediment supply from upstream reaches 7-11 is reduced through restoration efforts

Concept Options

OPTION I

- Plane bed with boulder clusters
- Floodplains and root wads for fish habitat complexity
- Increase elevation of pathway to add berm on north side of channel for additional flood control
- Use flood barrier on south side of channel

Pros: Maintains access to Wholesale Club.

Cons: Backwater produced from Wholesale Club Bridge, trail berm/ flood barrier costs and land requirements

OPTION II

- Remove Wholesale Club Bridge
- Plane bed with boulder clusters
- Floodplains and root wads for fish habitat complexity
- Lower channel to improve flood flow conveyance

Pros: Backwater produced from Wholesale Club bridge eliminated.

Cons: Reduced accessibility to Wholesale Club.

Alternative Solutions

- Acquire land for larger constructed floodplain
- Install flood control barrier

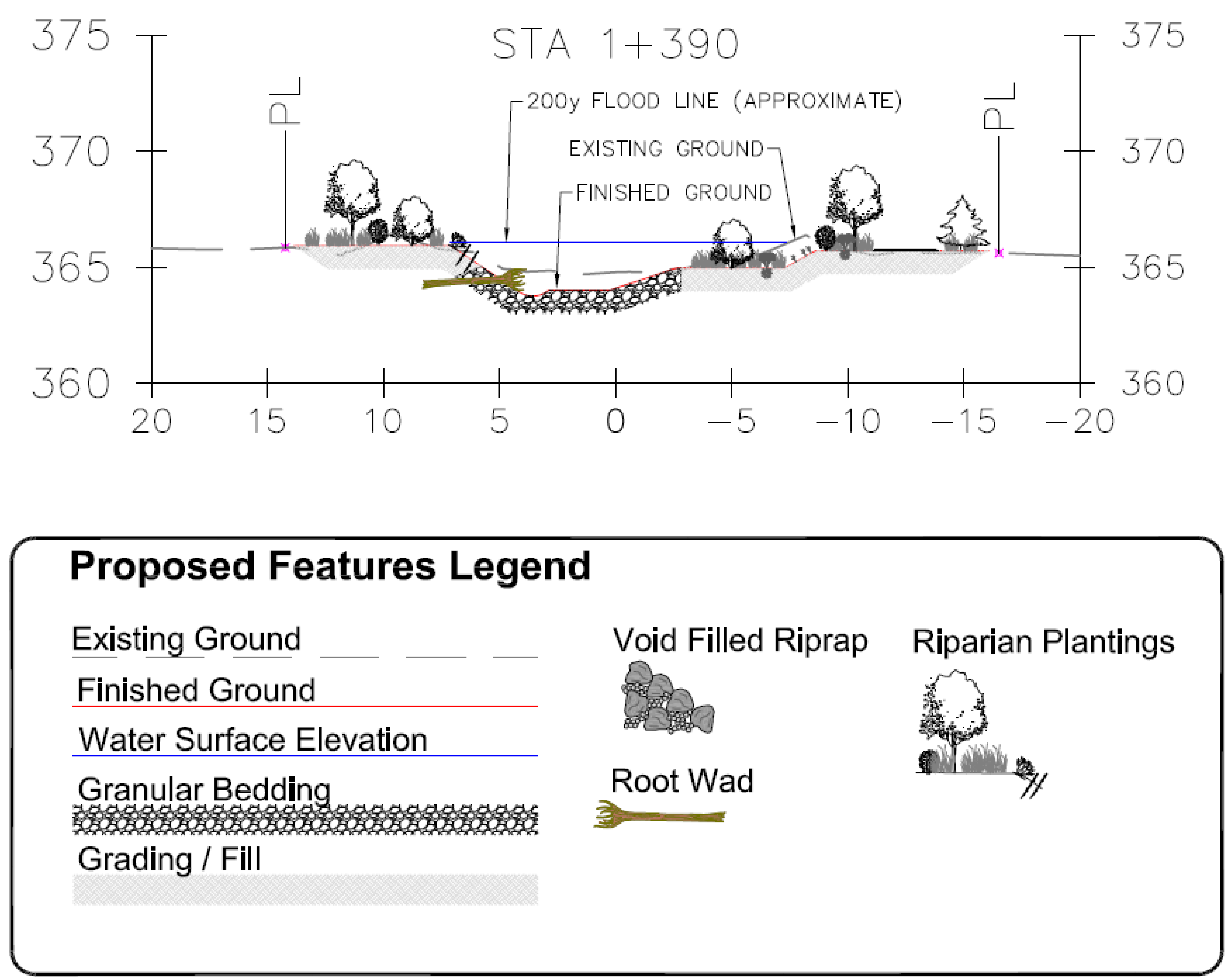
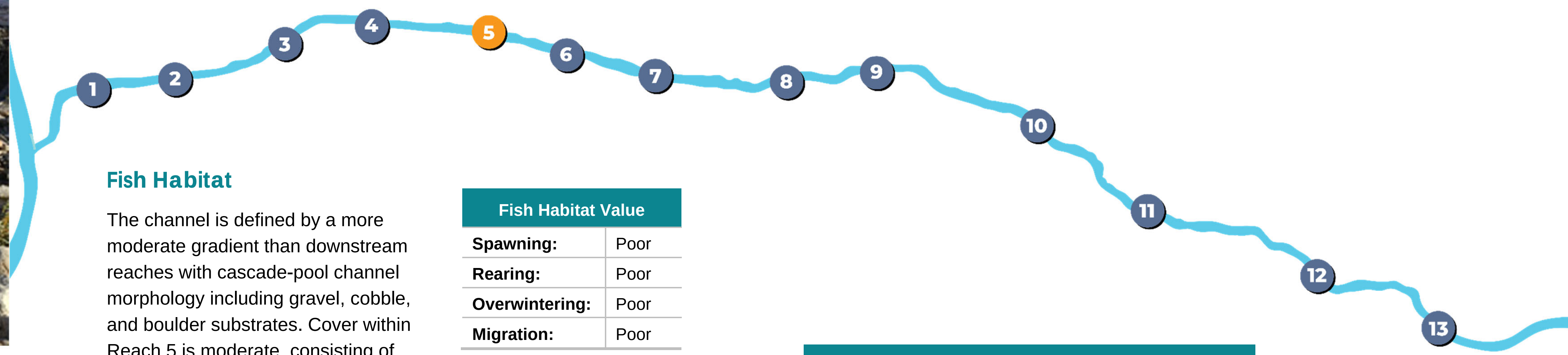


Figure 25. Cross Section of Proposed Concept Design for Reach 4 (looking downstream)



Reach 5

EXISTING CONDITION: AGGRADED

Reach Length	450 m
Bankfull Width	9.3 m
Bankfull Depth	0.55 m
Bed Slope	3.3 %
Grain Size (D_{50})	Fine Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	+ >1.0 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 5 is 450 m long, extending from the Wholesale Club multiplate arch culvert to 90 m upstream of the Penticton Regional Hospital East Entrance arch culvert. The channel is straight, with stone lines forming cascade pools due to the higher slope compared to downstream reaches. The bed material is predominantly fine cobble. Vegetation is sparse in this reach, with individual mature deciduous trees spaced out along both banks. Similar to Reach 4, excess bed material was excavated from the channel during emergency response and placed on the banks. Berms constructed of cobbles occur on much of both sides of the channel, and tree trunks are buried within the berms.

Fish Habitat

Fish Habitat Value	
Spawning:	Poor
Rearing:	Poor
Overwintering:	Poor
Migration:	Poor

The channel is defined by a more moderate gradient than downstream reaches with cascade-pool channel morphology including gravel, cobble, and boulder substrates. Cover within Reach 5 is moderate, consisting of boulders making up all the available cover; no deep pools, undercut banks or functioning woody debris was present. The banks are moderately unstable and steep with loose boulder and cobble substrate and limited vegetation and no functional riparian habitat. Banks were disturbed during past flood with machine access points and berms built on both channel banks.

Cultural and Heritage

No areas with archaeological potential were identified within reach 5. However, the Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/infrastructure

Reach 5 is prone to design flow events overtopping the bridges resulting in widespread overland flooding. Substantial aggradation throughout the reach has significantly reduced the conveyance capacity of the channel and Hospital Entrance bridge crossings.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Overtopping bridge culvert @ West & East Hospital Entrance Critical infrastructure (hospital) in adjacent lands	1
Buried Utility Exposure Potential	Buried 219 mm DP FortisBC gas line with moderate scour potential immediately upstream from Fairford bridge (U-95G/1984)	2
Overland Flooding Susceptibility	Overtopping channel banks and stable channel Critical infrastructure (hospital) in adjacent lands	1
Bank Stability	Bank erosion not evident or not significant	5
Total Reach Ranking		**2**

* 1 is High and 5 is Low

PROBLEMS
Aggraded channel
Limited Channel Conveyance Capacity
Poor Spawning, Rearing, Overwinter and Migration Habitat:
Overtopping of East and West Hospital Culverts
Flood Risk

* Immediate Actions

Inadequate conveyance of flow at the East and West Hospital access bridges is a key concern. These access roads are important access ways for the psychiatric facility and service bay of the regional hospital. We recommend that addressing this situation be prioritized and expedited accordingly by the Master Plan or separately if within City of Penticton capacity to deliver.

Excavation of aggraded materials immediately upstream, inside and downstream of the bridge is recommended to increase the conveyance at the crossing. During material removal, known utility crossings should be reviewed for scour potential and protected accordingly.

We also recommend monitoring this bridge closely during high flow events and clearing debris as required to accommodate flow requirements. Refer to the “Timeline & Approaches” section for further discussion on immediate mitigation activities.

CONCEPTUAL DESIGN

Objectives

- Increase flood channel capacity
- Increase rearing and overwintering habitat
- Increase flow conveyance at West Hospital Bridge, East Hospital Bridge and Government Street Bridge
- Consider existing pathway network connectivity

Constraints

- West Hospital Bridge
- East Hospital Bridge
- Effective only after sediment supply from upstream reaches 7-11 is reduced through restoration efforts

Concept Options

OPTION I

- Plane bed with boulder clusters
- Floodplains and root wads for fish habitat complexity
- Lower channel to improve flood flow conveyance

Pros: Retain access to the West Hospital Entrance.

Cons: Backwater produced from West Hospital Bridge.

OPTION II

- Remove West Hospital Bridge
- Plane bed with boulder clusters
- Floodplains and root wads for fish habitat complexity
- Increase elevation of pathway to add berm on north side of channel
- Add flood barrier on south side of channel

Pros: Backwater produced from West Hospital Bridge eliminated.

Cons: Loose access to the West Hospital Entrance. Cost, land needs for flood protection

Alternative Solutions

- Acquire land for larger constructed floodplain
- Install flood control barrier

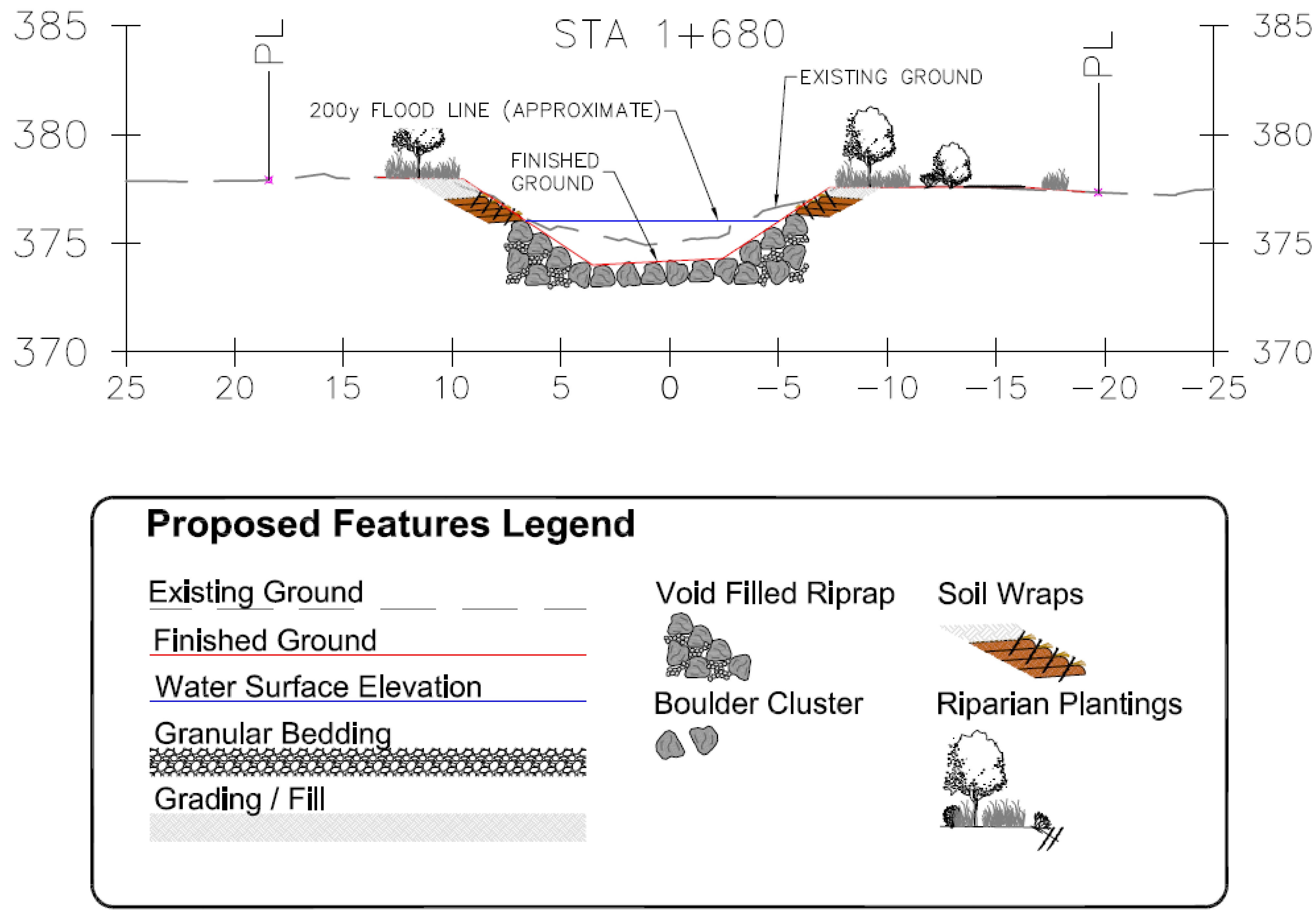
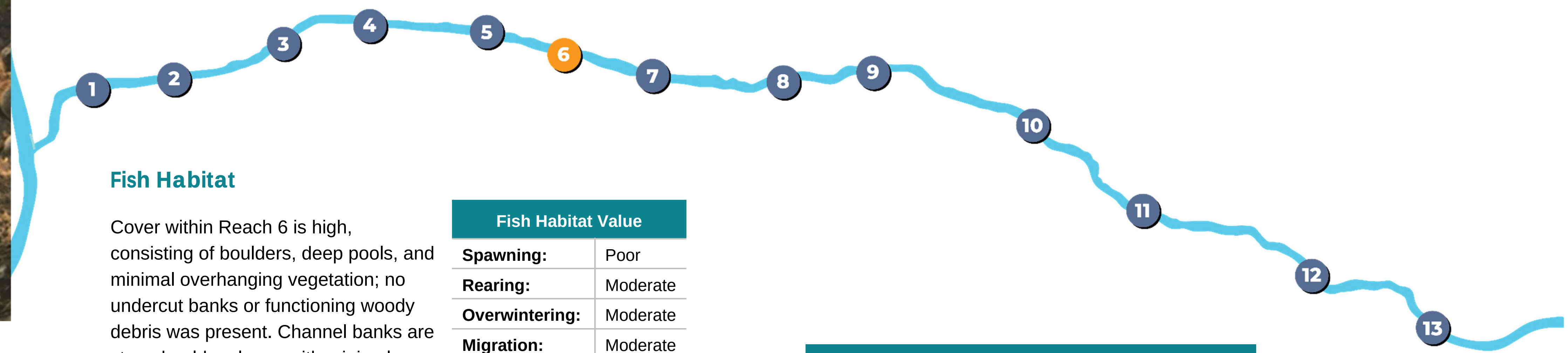


Figure 26. Cross Section of Proposed Concept Design for Reach 5 (looking downstream)



Reach 6

EXISTING CONDITION: TRANSITIONAL

Reach Length	200 m
Bankfull Width	7.6 m
Bankfull Depth	0.68 m
Bed Slope	5.1 %
Grain Size (D_{50})	Coarse Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	± 0.25 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 6 is 200 m long, extending from 90 m upstream of the Penticton Regional Hospital East Entrance arch culvert to 90 m upstream of the Government Street Bridge. This reach marks the transition between erosion being the dominant process upstream to deposition being the dominant process downstream, resulting in a change in features compared to downstream reaches. The reach is straight, flowing over a bed with a cascade-pool morphology with stone lines spanning the channel. The bed material is predominantly coarse cobble. The channel is steeper (5.1 %) compared to downstream reaches, with stone lines that are closer together along the bed. Lateral bars are present in this reach. The channel is disconnected from the floodplain.

The banks are built-up with excavated sediment downstream of Government Street Bridge. Trees line the banks above the placed material. The bankfull channel width is relatively narrow in this reach, averaging 7.6 m across and the bankfull depth is 0.7 m.

Fish Habitat

Fish Habitat Value	
Spawning:	Poor
Rearing:	Moderate
Overwintering:	Moderate
Migration:	Moderate

Cover within Reach 6 is high, consisting of boulders, deep pools, and minimal overhanging vegetation; no undercut banks or functioning woody debris was present. Channel banks are steep boulder slopes with minimal vegetation and no functional riparian zone. Minor erosion was evident but significantly less than previous reaches. In-stream habitat exceeds that of downstream reaches, however, overhead protection, bank stability and riparian habitat were still limiting factors for functional fish habitat.

Cultural and Heritage

No areas with archaeological potential were identified within Reach 6. However, the Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/infrastructure

Reach 6 has clearance limitations at Government Street bridge. As the transitional reach between aggradation to degradation there is an increasing risk of utility exposure here.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Negative freeboard (retained) @ Government Street Critical infrastructure (hospital) in adjacent lands	1
Buried Utility Exposure Potential	Moderate scour potential @ 450 mm watermain (WM-3764) Two FortisBC gas lines upstream from Government St (4500001349/2003 & A68-356/1968)	2
Overland Flooding Susceptibility	Ample freeboard and low aggradation hazard Critical infrastructure (hospital) in adjacent lands	3
Bank Stability	Bank erosion not evident or not significant	4
Total Reach Ranking		**3**

* 1 is High and 5 is Low

PROBLEMS
Narrow and Incised Channel
Steep Channel Bed
Poor Spawning Habitat
Insufficient Freeboard at Government Street Bridge
Moderate Scour Risk for Watermain

* Immediate Actions

Clearance between the bridge and the design flow water surface elevation at the Government Street Bridge is limited. We recommend monitoring this bridge closely during high flow events and clearing debris as required to accommodate flow requirements. Refer to the "Timeline & Approaches" section for further discussion on immediate mitigation activities.

The City's watermain crossing and FortisBC gas line crossings within Reach 6 have a moderate scour potential. These utilities should be reviewed at the earliest opportunity to ensure their depth of cover and protection is sufficient.

CONCEPTUAL DESIGN

Objectives

- Increase rearing and overwintering habitat
- Stabilize bed and banks
- Tie into channel grading downstream
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

- Government Street Bridge

Concept

- Step-pool sequence to stabilize bed and increase fish habitat complexity
- Lower water main at Government Street Bridge to increase depth of cover
- Stabilize banks with bioengineering or armouring

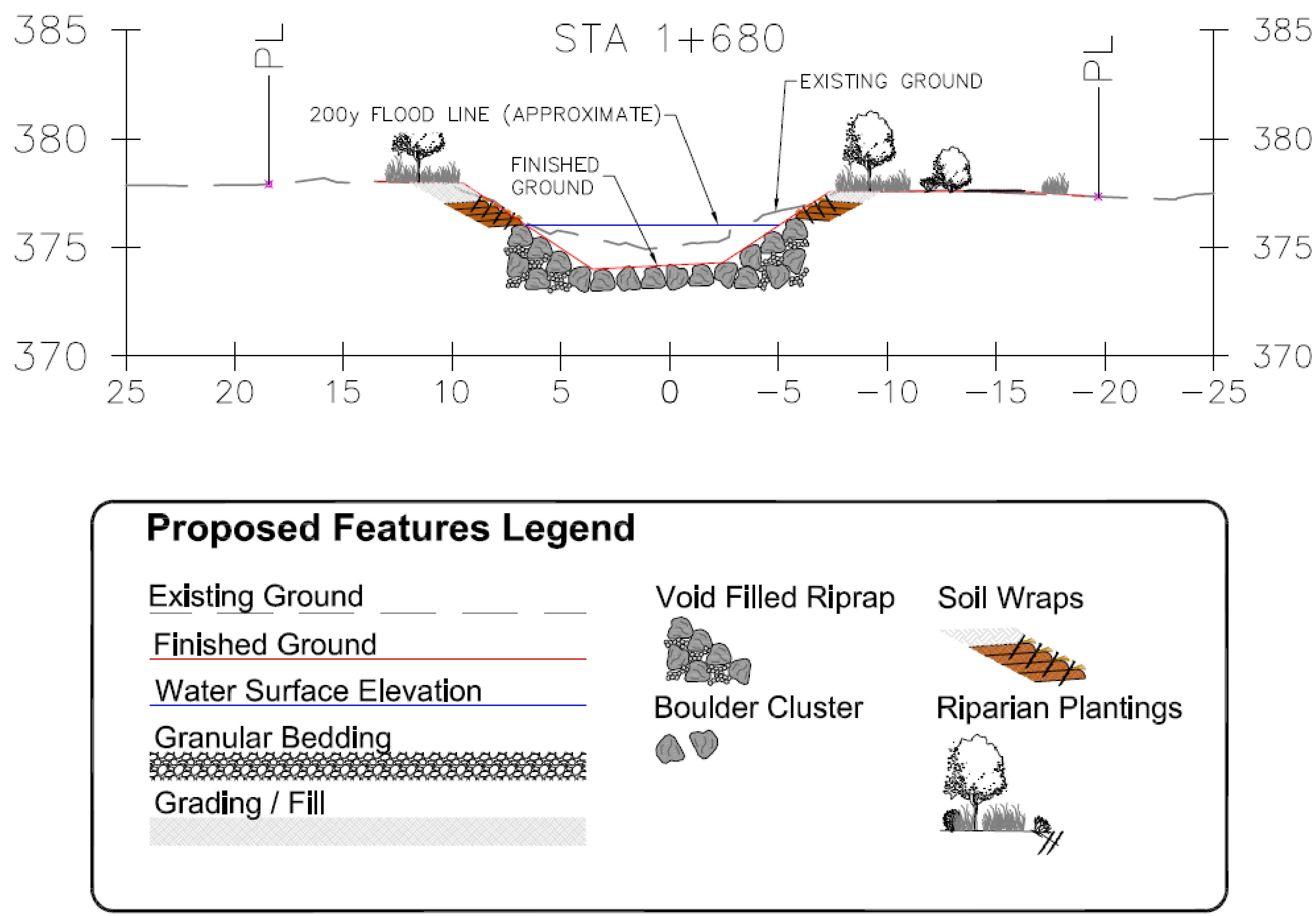


Figure 27. Cross Section of Proposed Concept Design for Reach 6 (looking downstream)

Reach 7

EXISTING CONDITION: DEEPLY INCISED

Reach Length	440 m
Bankfull Width	7.7 m
Bankfull Depth	0.84 m
Bed Slope	4.7 %
Grain Size (D_{50})	Coarse Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	- >1.0 m
Bank Erosion Hazard Index**	High

Geomorphology

Reach 7 is 440 m long, extending from 90 m upstream of the Government Bridge to 120 m upstream of the Dartmouth Bridge. The bankfull channel is 7.7 m and the bankfull depth is 0.84 m. The bed material is arranged in a step-pool morphology, with a high gradient (4.7 %). The bed material is predominantly coarse cobble. Channel banks are defined by steep boulder slopes with limited vegetation. Substantial bank undercutting was observed on both sides of the channel throughout the entire reach to Dartmouth Bridge. Woody debris was not observed to have a functioning presence in this reach. The channel is disconnected from the floodplain. The channel has degraded, and the banks are unstable.

Fish Habitat

Fish Habitat Value	
Spawning:	Poor
Rearing:	Moderate
Overwintering:	Moderate
Migration:	Moderate

Cover within Reach 7 is moderate, consisting of deep pools and limited overhanging vegetation; no undercut banks or functioning woody debris was present. Channel banks are defined by steep boulder slopes with limited vegetation and limited functioning riparian zone. Significant erosion was observed on both sides of the banks throughout the entire reach to the Dartmouth Bridge.

Cultural and Heritage

No areas with archaeological potential were identified within Reach 7. However, the Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/infrastructure

Notable utility exposure potential is present in Reach 7. Pronounced degradation has likely diminished the designed depth of cover for buried utility crossings within this reach. Significant bank instability coincides with structures within close proximity to the top of bank at risk of damage or loss.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Limited freeboard @ Dartmouth Rd Adjacent lands area inhabited	4
Buried Utility Exposure Potential	Moderate scour potential @ 200 mm sanitary gravity main (SSGM-1846-1828) and 300 mm watermain (WM-4030 *) Extreme degradation hazard Abandoned watermain (WM-2562) and FortisBC gas line (2800403069)	1
Overland Flooding Susceptibility	Ample freeboard Inhabited adjacent lands	4
Bank Stability	Potential for rapid bank erosion (50 to 100 cm/yr)	1
Total Reach Ranking		**3**

* 1 is High and 5 is Low

PROBLEMS
Deeply Incised Channel
Steep Bed
Narrow Channel
Bed Degrading
Poor Spawning Habitat
High Bank Erosion
Limited Freeboard at Dartmouth Rd Bridge
Moderate scour potential Sanitary Main

* Immediate Actions

The City's sanitary gravity main crossing has a moderate scour potential. This utility should be reviewed at the earliest opportunity to ensure their depth of cover and protection is sufficient. We recommend monitoring this crossing site closely during high flow events and supplementing with temporary cover as required to maintain the depth of cover. Permanent erosion protection measures should replace all temporary mitigation measures within short succession. Refer to the "Timeline & Approaches" section for further discussion on immediate mitigation activities.

The banks adjacent to the industrial properties should be reviewed at the earliest opportunity to evaluate the specific risk to adjacent infrastructure and or channel blockage from a landslide. Retreat from the unstable banks should be considered and compared against temporary mitigations to stabilize the banks.

CONCEPTUAL DESIGN

Objectives

- Stabilize bed and banks.
- Decrease aggradation in Reaches 4 & 5 downstream
- Increase cover on Dartmouth Street Bridge abutments
- Increase rearing and overwintering habitat
- Protect buried utility crossings
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

- Dartmouth Street Bridge
- Proximity of industrial land uses

Concept

- Widen Channel
- Increase elevation of channel bed
- Create floodplain that is connected to the channel
- Step-pool sequence to stabilize bed and increase fish habitat complexity
- Stabilize banks with riprap armour and bioengineering

Alternative Solutions

- Stabilize channel banks with riprap, stacked blocks or retaining walls
- Peak flow bypass

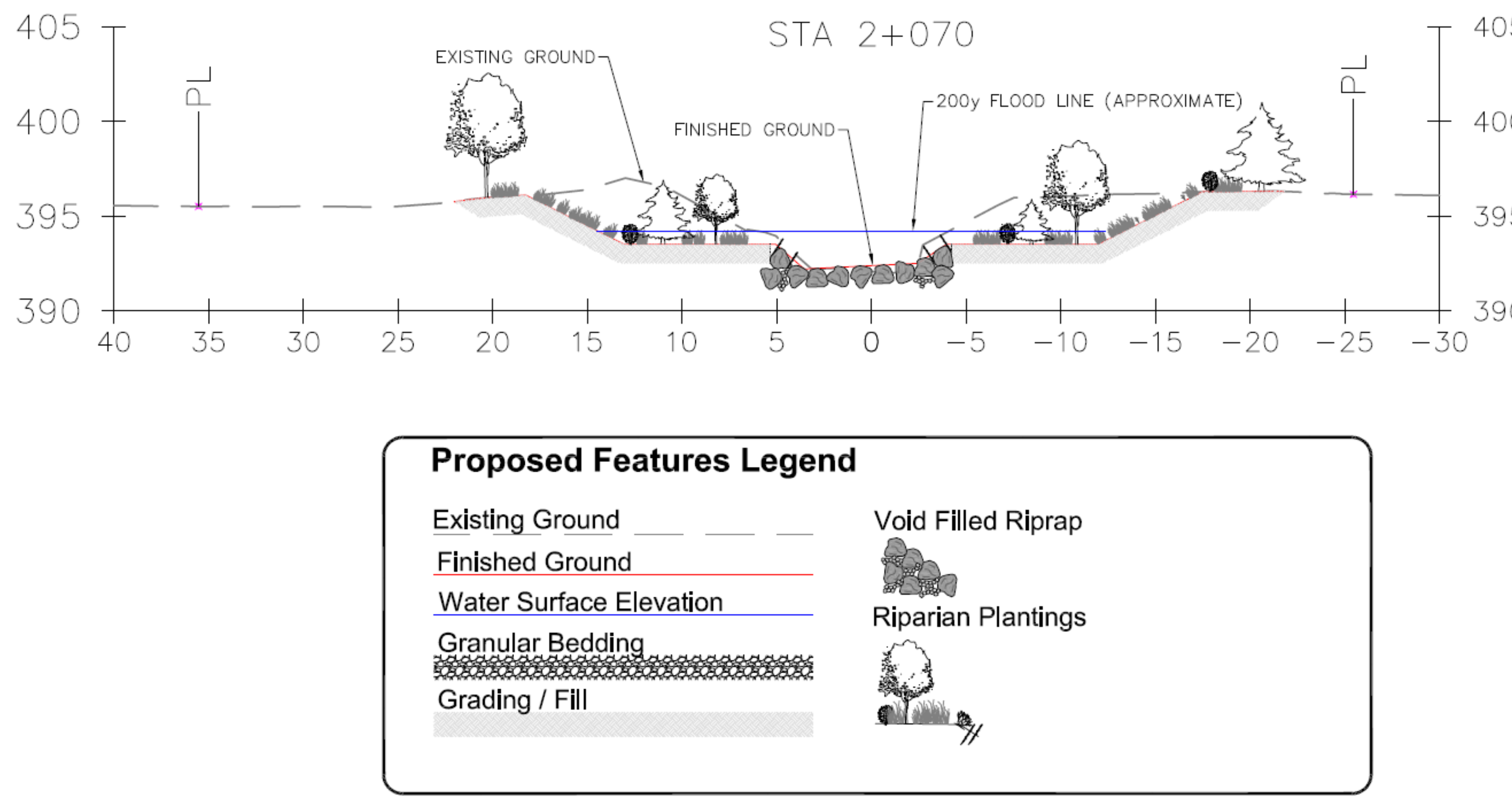


Figure 28. Cross Section of Proposed Concept Design for Reach 7 (looking downstream)

Reach 8A/8B

EXISTING CONDITION: DEEPLY INCISED

Reach Length	460 m
Bankfull Width	10.9 m
Bankfull Depth	0.83 m
Bed Slope	4.6 %
Grain Size (D_{50})	Coarse Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	- 0.75 – 1.0 m
Bank Erosion Hazard Index**	Very High

Geomorphology

Reach 8 extends 460 m parallel to Okanagan Avenue East upstream of Reach 7. The bankfull channel width is 10.9 m and varies with distance downstream where the channel is narrower upstream (8.43 m) compared to downstream (15.85 m). Average reach bankfull depth is 0.83 m, with measured bankfull depths of 0.79 m to 0.91 m throughout the reach. The bed material is predominantly coarse cobble. The channel is high gradient (4.6%) and the bed is arranged in a step-pool sediment morphology. The channel is disconnected from the floodplain. The channel has degraded, and the banks are unstable.

Fish Habitat

Fish Habitat Value	
Spawning:	Moderate
Rearing:	Moderate
Overwintering:	Moderate
Migration:	Moderate

Cover within Reach 8 is moderate, consisting of boulders, deep pools and some undercut structures; no overhanging or functioning woody debris was present. Channel banks are defined by steep boulder slopes with a limited amount of vegetation; however, riparian habitat improves, and bank erosion decreases near the upstream section of Reach 8. There is significant erosion observed on both banks.

Cultural and Heritage

There are several areas with archaeological potential and cultural value within Reach 8. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/infrastructure

Notable utility exposure potential is present in Reach 8. Pronounced degradation has likely diminished the designed depth of cover for buried utility crossings within this reach. Significant bank instability coincides with structures within close proximity to the top of bank at risk of damage or loss.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	No bridges/culverts Inhabited adjacent lands	5
Buried Utility Exposure Potential	No buried city utilities crossings identified	5
Overland Flooding Susceptibility	Ample freeboard Inhabited adjacent lands	4
Bank Stability	Potential for rapid bank erosion (50 to 100 cm/yr)	1
Total Reach Ranking		**4**
* 1 is High and 5 is Low		

PROBLEMS
Deeply Incised Channel
Steep Bed
Narrow Channel
Bed Degrading
Very High Bank Erosion

* Immediate Actions

The banks adjacent to the industrial properties should be reviewed at the earliest opportunity to evaluate the specific risk to adjacent infrastructure and or channel blockage from a landslide. Retreat from the unstable banks should be considered and compared against temporary mitigations to stabilize the banks. Refer to the “Timeline & Approaches” section for further discussion on immediate mitigation activities.

CONCEPTUAL DESIGN

Objectives

- Stabilize bed and banks.
- Decrease aggradation in Reaches 4 & 5 downstream
- Increase rearing and overwintering habitat
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

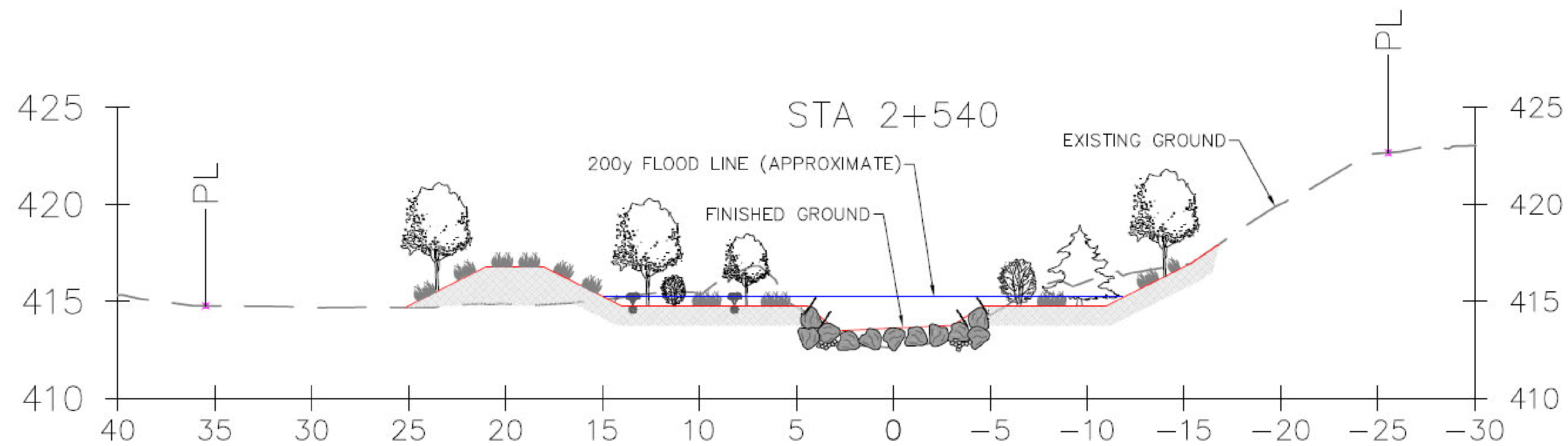
- Industrial uses of park land near Ellis Creek Channel
- Duration of "Least Risk Work Window" as identified by FLNRORD limits the amount of work that can be completed in each calendar year, therefore the concept design is separated equally into A and B reach sections to accommodate works within this window
- Continuity between reach designs, therefore reach sections A and B should be developed in detail design by the same designer although they may be constructed separately

Concept Options

- Widen Channel
- Increase elevation of channel bed
- Create floodplain that is connected to the channel
- Step-pool sequence to stabilize bed and increase fish habitat complexity
- Stabilize banks with riprap armour and bioengineering

Alternative Solutions

- Stabilize channel banks with riprap, stacked blocks or retaining walls
- Peak flow bypass



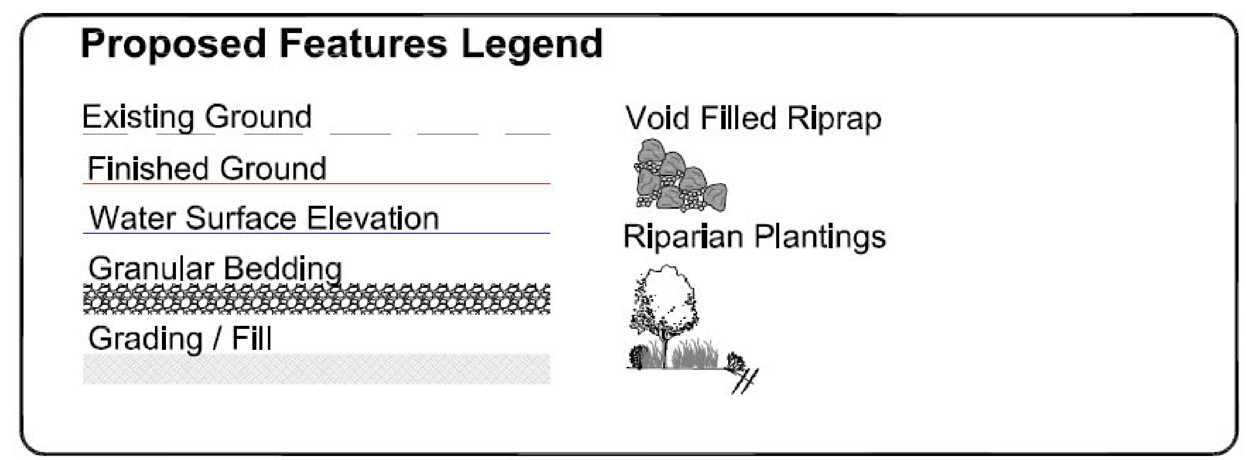
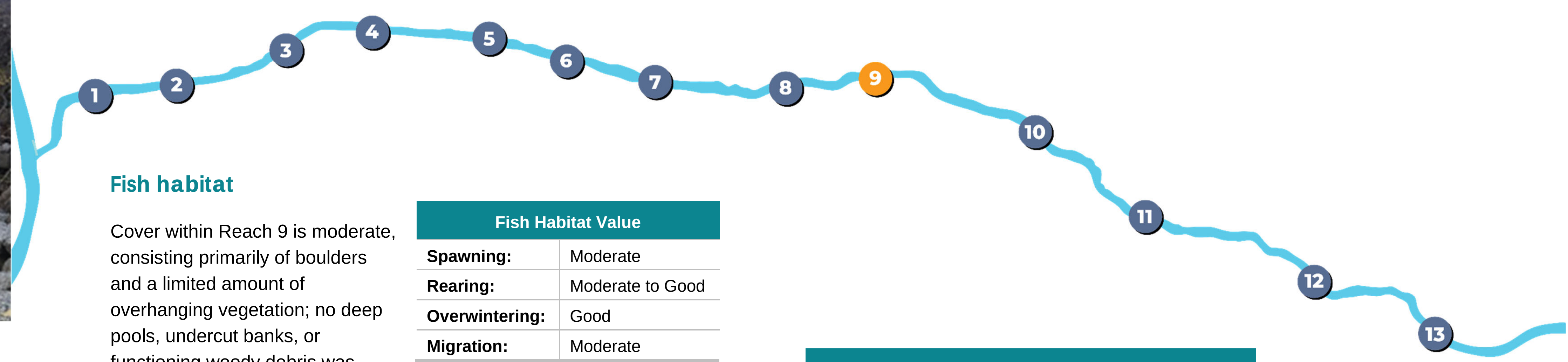


Figure 29. Cross Section of Proposed Concept Design for Reach 8 (looking downstream)



Reach 9

EXISTING CONDITION: DEEPLY INCISED

Reach Length	290 m
Bankfull Width	9.0 m
Bankfull Depth	0.94 m
Bed Slope	4.2 %
Grain Size (D50)	Fine Cobble
Grain Size (D90)	Boulder
Aggradation/Degradation*	- 0.75 – 1.0 m
Bank Erosion Hazard Index**	High

Geomorphology

Reach 9 extends 290 m parallel to Okanagan Avenue East to the western edge of the Cantex-Okanagan Construction property. The average bankfull channel width is 9.0 m and the bankfull depth is 0.94 m, with measured width and depth ranges remaining relatively consistent throughout the reach. The channel is defined by a high gradient (4.2%), with step-pools formed in a cobble and boulder bed. Woody debris was observed in the reach during the channel assessment, exerting functional control on the channel, but not exerting a dominant control on channel stability. The channel is disconnected from the floodplain. The channel has degraded, and the banks are unstable.

Fish habitat

Fish Habitat Value	
Spawning:	Moderate
Rearing:	Moderate to Good
Overwintering:	Good
Migration:	Moderate

Cover within Reach 9 is moderate, consisting primarily of boulders and a limited amount of overhanging vegetation; no deep pools, undercut banks, or functioning woody debris was present. Channel banks are defined by steep boulder slopes with limited vegetation. A minor amount of erosion was observed along this reach.

Cultural and Heritage

No areas with archaeological potential were identified within reach 9. However, the Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

Notable utility exposure potential is present in Reach 9. Pronounced degradation has likely diminished the designed depth of cover for buried utility crossings within this reach. Significant bank instability coincides with structures within close proximity to the top of bank at risk of damage or loss.

The City's public works department has become aware of possible tension cracks along the north bank of the channel within Reach 9. A large bank failure here could block the confined channel and retain water. Uncontrolled releases from this blockage could be detrimental to public safety and infrastructure downstream.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	No bridges/culverts Inhabited adjacent lands	5
Buried Utility Exposure Potential	Moderate scour potential @ 250 mm watermains (WM-474 and WM-927) High degradation hazard	1
Overland Flooding Susceptibility	Limited freeboard Inhabited adjacent lands	3
Bank Stability	High potential for bank erosion (20 to 50 cm/yr)	1
Total Reach Ranking		**3**

* 1 is High and 5 is Low

PROBLEMS
Deeply Incised Channel
Steep Bed
Narrow Channel
Bed Degrading
Very High Bank Erosion

* Immediate Actions

The City's watermain crossing has a moderate scour potential. This utility should be reviewed at the earliest opportunity to ensure their depth of cover and protection is sufficient. We recommend monitoring this crossing site closely during high flow events and supplementing with temporary cover as required to maintain the depth of cover. Permanent erosion protection measures should replace all temporary mitigation measures within short succession.

The banks adjacent to the industrial properties should be reviewed at the earliest opportunity to evaluate the specific risk to adjacent infrastructure and or channel blockage from a landslide. Retreat from the unstable banks should be considered and compared against temporary mitigations to stabilize the banks. Specific attention should be provided to the potential geohazard conditions with Reach 9 including review of the tension cracks and recommendations by a licensed geotechnical engineer.

Refer to the "Timeline & Approaches" section for further discussion on immediate mitigation activities.

CONCEPTUL DESIGN

Objectives

- Stabilize bed and banks.
- Decrease aggradation in Reaches 4 & 5 downstream
- Increase rearing and overwintering habitat
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

- Industrial uses of park land near Ellis Creek channel
- Future industrial and residential development plans by Cantex

Concept Option

- Widen Channel
- Increase elevation of channel bed
- Create floodplain that is connected to the channel
- Step-pool sequence to stabilize bed and increase fish habitat complexity
- Stabilize banks using riprap armour and bioengineering

Alternative Solutions

- Stabilize channel banks with riprap, stacked blocks or retaining walls
- Peak flow bypass

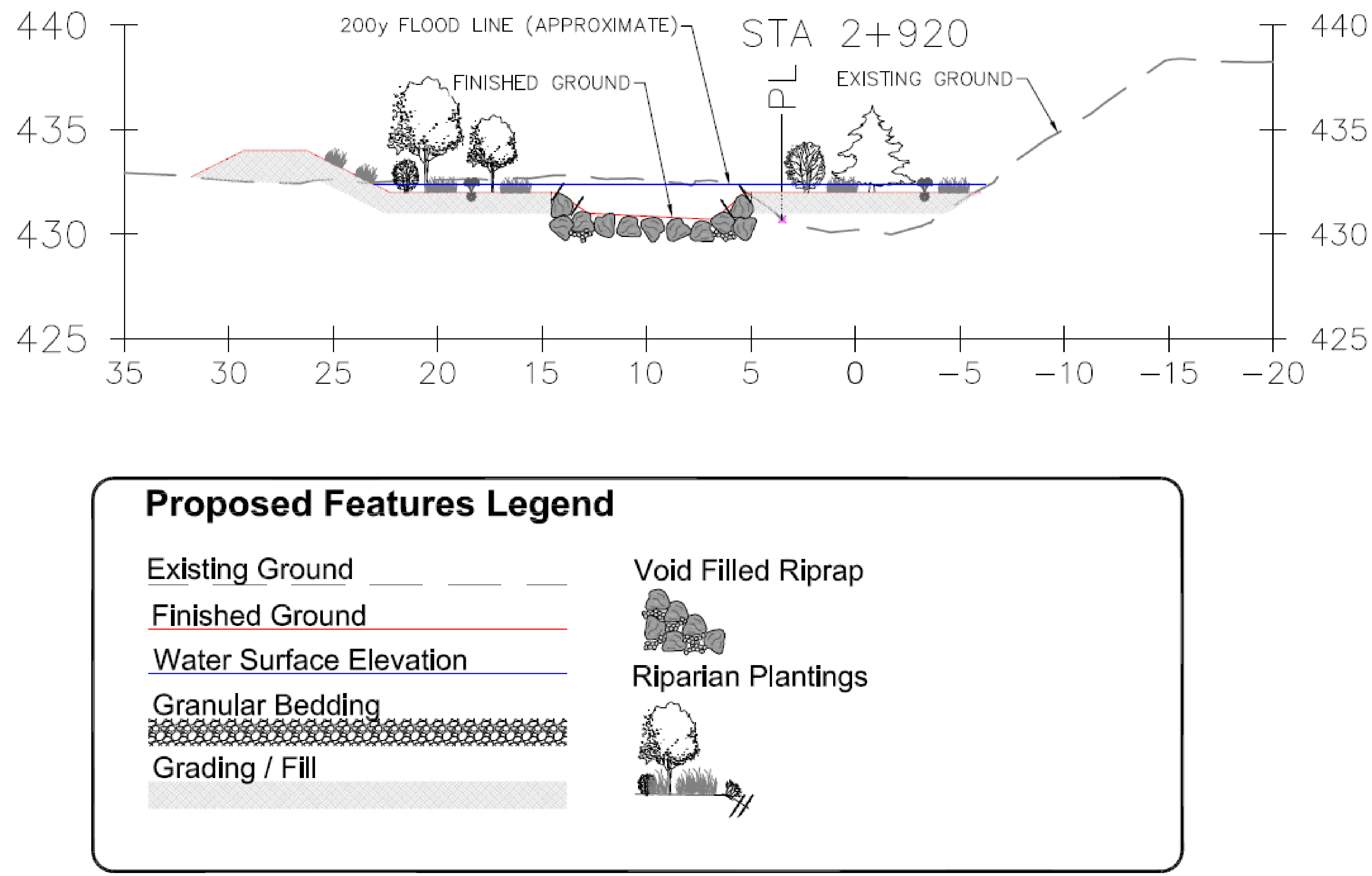


Figure 30. Cross Section of Proposed Concept Design for Reach 9 (looking downstream)

Reach 10A/10B

EXISTING CONDITION: INCISED

Reach Length	555 m
Bankfull Width	8.5 m
Bankfull Depth	1.40 m
Bed Slope	5.1 %
Grain Size (D_{50})	Coarse Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	- 0.25 – 5.0 m
Bank Erosion Hazard Index**	Moderate

Geomorphology

Reach 10 extends 555 m upstream of Reach 9, paralleling Cantex-Okanagan Construction property. The channel is very steep (5.1 %). The bankfull channel width is 8.5 m and the bankfull depth is 1.40 m. An observed narrowing trend was observed in channel width with distance upstream, with a measured bankfull width of 10 m in the lower reach and 5.6 m in the upper reach. The bed material is predominantly coarse cobble. Channel geometry is largely controlled by the presence of bedrock in this reach. Trees and shrubs were observed along the banks. No functioning woody debris was present in the channel. The channel is likely to degrade further, destabilizing the banks.

Fish Habitat

Cover within Reach 10 is moderate, consisting of deep pools, boulders, and some overhanging vegetation; no functioning woody debris was present. Channel banks are defined by steep boulder/cobble slopes with limited vegetation and some functional riparian habitat. Minor erosion and rip-rap along the banks was observed throughout the reach.

Fish Habitat Value	
Spawning:	Poor
Rearing:	Moderate
Overwintering:	Poor
Migration:	Moderate

Cultural and Heritage

Reach 10 is identified as altered, and there were no areas identified with archaeological potential. However, the Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

Utility exposure potential is present in Reach 10. Degradation has likely diminished the designed depth of cover for buried utility crossings within this reach. The channel banks are confined on the north side. Low channel banks on the south side result in high flooding potential.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	No bridges/culverts Inhabited adjacent lands	5
Buried Utility Exposure Potential	No buried city utilities crossings identified Moderate degradation potential	5
Overland Flooding Susceptibility	Overtopping channel banks Inhabited adjacent lands	2
Bank Stability	Moderate potential for bank erosion (<20cm/yr)	4
Total Reach Ranking		**4**

* 1 is High and 5 is Low

PROBLEMS
Incised Channel
Steep Chanel Bed
Poor Spawning and Overwintering Habitat
Moderate Bank Erosion
Moderate Bed Degradation

CONCEPTUAL DESIGN

A predesign should be completed for the area of Ellis Creek that runs through the Cantex property that would see the City and Cantex working with the regulators to develop an Ellis Creek and Subdivision concept that works to meet the needs of all three parties.

Objectives

- Stabilize bed and banks.
- Decrease aggradation in Reaches 4 & 5 downstream.
- Increase rearing and overwintering habitat.
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

- Cantex and PIB property
- Future industrial and residential development of the Cantex property
- Duration of “Least Risk Work Window” as identified by FLNRORD limits the amount of work that can be completed in each calendar year, therefore the concept design is separated equally into A and B reach sections to accommodate works within this window
- Continuity between reach designs, therefore reach sections A and B should be developed in detail design by the same designer although they may be constructed separately

Concept Options

- Widen Channel
- Create floodplain that is connected to the channel
- Step-pool sequence to stabilize bed and increase fish habitat complexity
- Stabilize banks with riprap armour and bioengineering

Alternative Solutions

- Stabilize channel banks with riprap, stacked blocks or retaining walls
- Engineer hardened channel sections to limit footprint in select areas
- Peak flow bypass

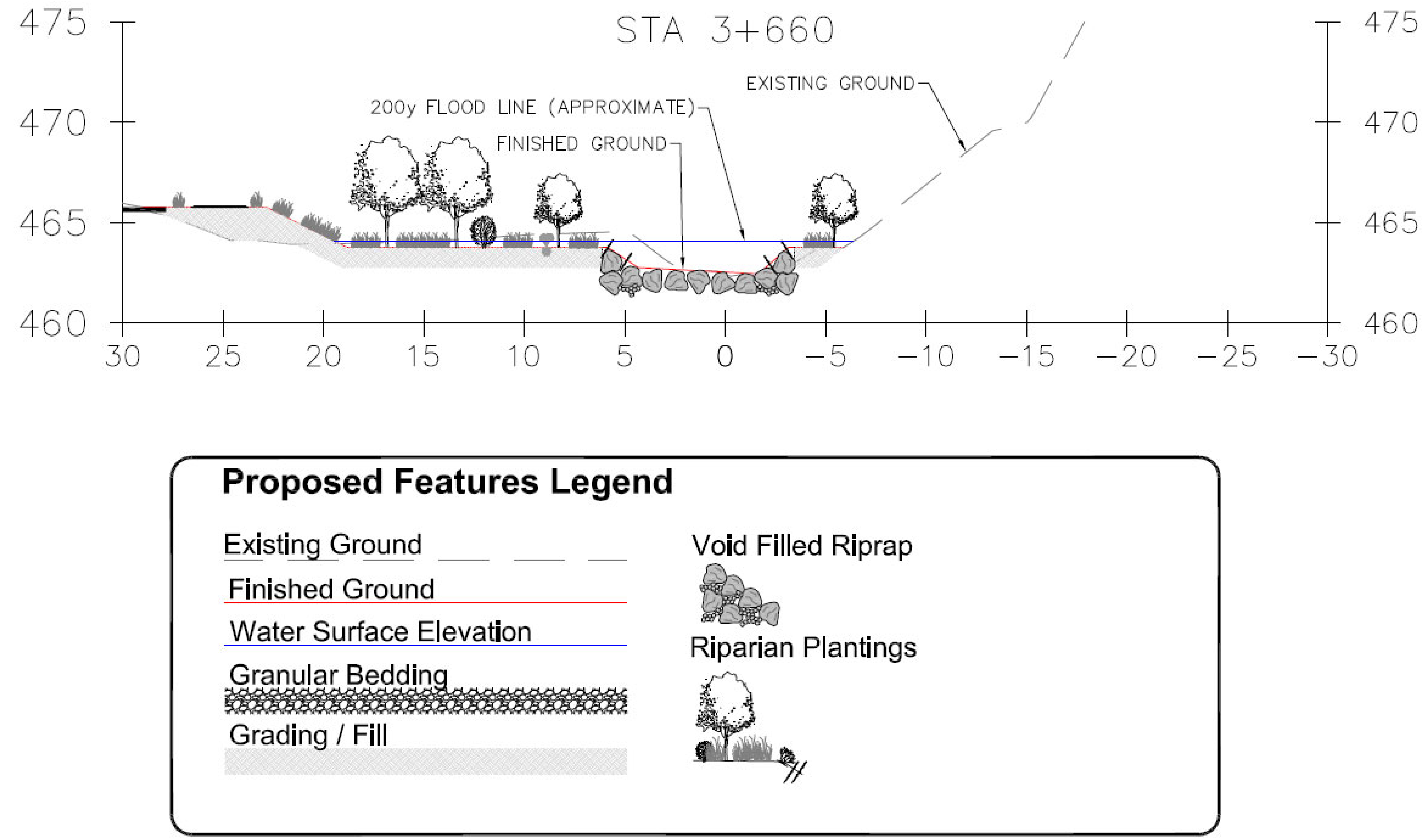
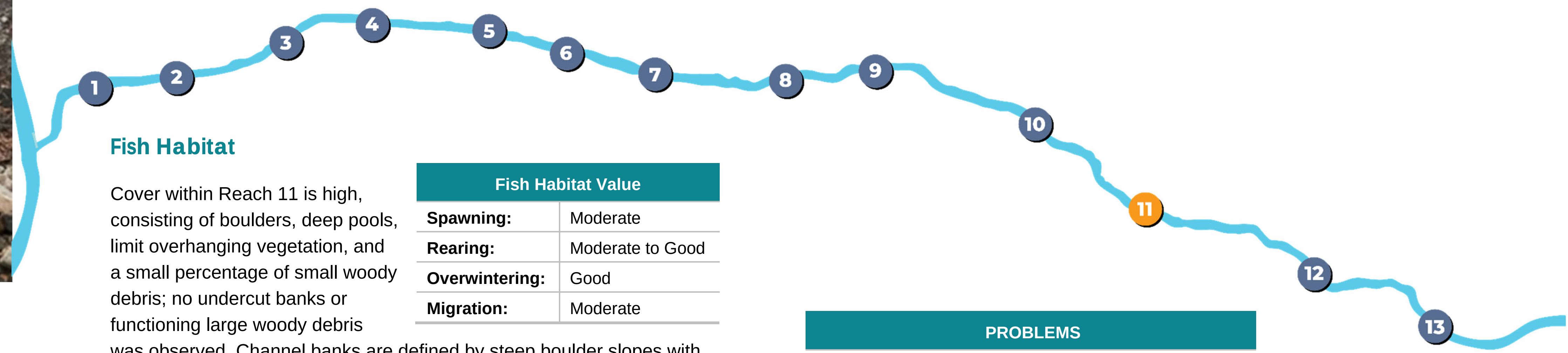


Figure 31. Cross Section of Proposed Concept Design for Reach 10 (looking downstream)



Reach 11

EXISTING CONDITION: INCISED

Reach Length	365 m
Bankfull Width	8.1 m
Bankfull Depth	0.91 m
Bed Slope	4.4 %
Grain Size (D_{50})	Fine Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	+/- 0.25 m
Bank Erosion Hazard Index**	Moderate

Geomorphology

Reach 11 extends 365 m upstream from the edge of the gravel pile within the Cantex-Okanagan Property. The channel bed is steep (4.4 %). The bed material is arranged in a step-pool morphology. The bankfull channel width is 8.1 m and the bankfull depth is 0.9 m; measurements in the lower, middle, and upper sections of the reach show an overall increase in width and decrease in depth moving downstream. The bed material is predominantly fine cobble. The Diversion Access Bridge crossing is located within this reach. Large woody debris is present in the channel but does not provide any observable increase in stability. The channel is likely to degrade further, destabilizing the banks.

Fish Habitat

Fish Habitat Value	
Spawning:	Moderate
Rearing:	Moderate to Good
Overwintering:	Good
Migration:	Moderate

Cover within Reach 11 is high, consisting of boulders, deep pools, limit overhanging vegetation, and a small percentage of small woody debris; no undercut banks or functioning large woody debris was observed. Channel banks are defined by steep boulder slopes with minimal vegetation and a functioning riparian zone. The right bank is eroded significantly from the Diversion Access Bridge extending approximately 50 to 75 m downstream. Banks are reinforced with rip rap on river right throughout much of the reach and river right has large section of bedrock.

Cultural and Heritage

Reach 11 was identified to have multiple areas with archaeological potential and intact landforms with cultural resources present. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

Degradation has likely diminished the designed depth of cover for buried utility crossings within this reach resulting utility exposure potential throughout Reach 11. The channel banks are confined on the north side and are low channel on the south side result in high flooding potential. The diversion structure access road is in disrepair and is vulnerable to damage during a design flow event.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	Overtopping Diversion Access Road bridge crossing	3
Buried Utility Exposure Potential	High scour potential @ 250 mm watermain (WM-2113) and a 2nd moderate potential crossing Low degradation hazard	1
Overland Flooding Susceptibility	Overtopping channel banks Inhabited adjacent lands	3
Bank Stability	Bank erosion not evident or not significant	5
Total Reach Ranking		**3**

* 1 is High and 5 is Low

PROBLEMS
Incised Channel
Steep Slope
Narrow Channel
Flood Hazard
Flood hazard for access road to the diversion dam
High Scour Potential at Watermain
Moderate Bank Erosion

* Immediate Actions

The City's watermain crossing has a high scour potential. This utility should be reviewed at the earliest opportunity to ensure their depth of cover and protection is sufficient. We recommend monitoring this crossing site closely during high flow events and supplementing with temporary cover as required to maintain the depth of cover. Permanent erosion protection measures should replace all temporary mitigation measures within short succession.

Refer to the "Timeline & Approaches" section for further discussion on immediate mitigation activities.

Reach 11

CONCEPTUAL DESIGN

Objectives

- Stabilize bed and banks
- Decrease aggradation in Reaches 4 & 5 downstream
- Increase rearing and overwintering habitat
- Replace access road bridge with one capable of conveying the design flow
- Achieve minimum 300 mm freeboard from design flow event along access road
- Stabilize vulnerable channel banks adjacent to access road
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

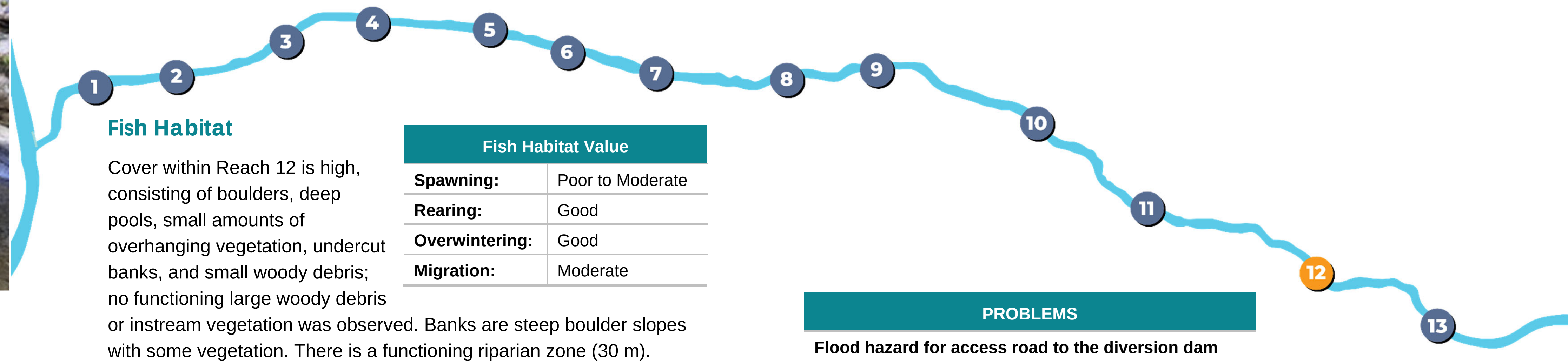
- Diversion structure access road bridge
- Future industrial and residential development of the Cantex property
- Topography (canyon walls)

Concept Options

- Widen Channel
- Create floodplain that is connected to the channel
- Step-pool sequence to stabilize bed and increase fish habitat complexity
- Stabilize banks using riprap armour and bioengineering
- Remove and replace Diversion Structure access road bridge
- Raise access road to achieve min freeboard

Alternative Solutions

- Stabilize channel banks with stacked blocks or retaining walls
- Engineer hardened channel sections to limit footprint in select areas
- Peak flow bypass



Reach 12

EXISTING CONDITION: NATURAL

Reach Length	515 m
Bankfull Width	7.8 m
Bankfull Depth	1.03 m
Bed Slope	5.3 %
Grain Size (D_{50})	Coarse Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	+/- 0.25 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 12 extends 515 m meters and starts immediately upstream of the Diversion Access Bridge crossing of Ellis Creek. The bankfull channel width is 7.8 m and the bankfull depth is 1.0 m, with little variability observed along the reach. The banks are dominated by boulders and bedrock throughout much of the reach. The bed material is predominantly cobble. Woody debris is present in the channel, but does not exert any control on stability.

Fish Habitat

Fish Habitat Value	
Spawning:	Poor to Moderate
Rearing:	Good
Overwintering:	Good
Migration:	Moderate

Cover within Reach 12 is high, consisting of boulders, deep pools, small amounts of overhanging vegetation, undercut banks, and small woody debris; no functioning large woody debris or instream vegetation was observed. Banks are steep boulder slopes with some vegetation. There is a functioning riparian zone (30 m). Banks were observed to have some minor erosion and bank failure, but limited and infrequent.

Cultural and Heritage

Reach 12 is in a canyon setting multiple areas with archaeological potential and intact landforms with cultural resources present. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

The channel floodplain is confined on both sides by steep rock walls. The access road has sections that are below the design flow water surface elevation during a design flow event.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	No bridges/culverts	5
Buried Utility Exposure Potential	No buried city utilities crossings identified Side channel that may be vulnerable to channel switching Stable channel	5
Overland Flooding Susceptibility	Overtopping channel banks Uninhabited adjacent lands	3
Bank Stability	Bank erosion not evident or not significant	5
Total Reach Ranking		**5**

* 1 is High and 5 is Low

PROBLEMS
Flood hazard for access road to the diversion dam
Spawning poor to moderate

CONCEPTUAL DESIGN

Objectives

- Achieve minimum 300 mm freeboard from design flow event along access road
- Stabilize vulnerable channel banks adjacent to access road
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

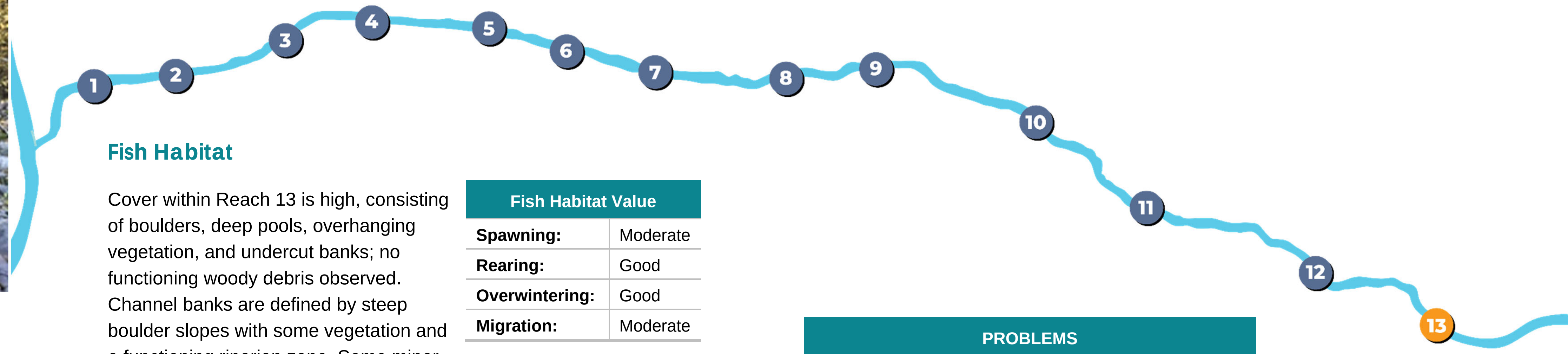
- Topography (rock walls)

Concept

- Raise access road to achieve min 300 mm freeboard from design water surface elevation.
- Construct riprap revetments on channel banks adjacent to vulnerable section of access road.

Alternative Solutions

- Stabilize channel banks with stacked blocks or retaining walls



Reach 13

EXISTING CONDITION: NATURAL

Reach Length	420 m
Bankfull Width	8.2 m
Bankfull Depth	1.21 m
Bed Slope	5.0 %
Grain Size (D_{50})	Coarse Cobble
Grain Size (D_{90})	Boulder
Aggradation/Degradation*	+/- 0.25 m
Bank Erosion Hazard Index**	Low

Geomorphology

Reach 13 extends 420 m downstream of the Ellis Creek dam. The bankfull channel width is 8.2 m and the bankfull depth is 1.2. The channel is defined by a high gradient (5%), step-pool morphology with stone lines on the bed. No functioning woody debris was observed in the reach. Channel banks are defined by steep boulder slopes with some vegetation and bedrock outcrops. Minor bank erosion was observed in discrete sections throughout the reach. The bed material is coarse cobble.

Fish Habitat

Cover within Reach 13 is high, consisting of boulders, deep pools, overhanging vegetation, and undercut banks; no functioning woody debris observed. Channel banks are defined by steep boulder slopes with some vegetation and a functioning riparian zone. Some minor erosion was observed throughout the reach.

Fish Habitat Value	
Spawning:	Moderate
Rearing:	Good
Overwintering:	Good
Migration:	Moderate

Cultural and Heritage

Reach 12 is in a canyon setting multiple areas with archaeological potential and intact landforms with cultural resources present. The Penticton Indian Band and Okanagan Nation Alliance and specifically, the Elders should be meaningfully engaged to identify traditional cultural values, and intimate knowledge within the Reach.

Flood/Infrastructure

The channel floodplain is confined on both sides by steep rock walls. The access road has sections that are below the design flow water surface elevation during a design flow event.

	Comments	Risk Ranking*
Bridge / Culvert Clearance	No bridges/culverts	5
Buried Utility Exposure Potential	No buried city utilities crossings identified, note parallel sections that may be vulnerable to channel switching Stable channel	5
Overland Flooding Susceptibility	Overtopping channel banks Uninhabited adjacent lands	5
Bank Stability	Bank erosion not evident or not significant	5
Total Reach Ranking		**5**

* 1 is High and 5 is Low

PROBLEMS
Flood hazard for access road to the diversion dam

CONCEPTUAL DESIGN

Objectives

- Achieve minimum 300 mm freeboard from design flow event along access road
- Stabilize vulnerable channel banks adjacent to access road
- Consider expansion of the pathway network from Hospital to diversion structure

Constraints

- Topography (rock walls)
- Diversion structure

Concept

- Raise access road to achieve min 300 mm freeboard from design water surface elevation.
- Construct riprap revetments on channel banks adjacent to vulnerable section of access road.

Alternative Solutions

- Construct large reservoir to mitigate peak flows

Recommendations

- Plan and implement flood mitigation measures at vulnerable channel sections and at aggraded bridges*
- Review and protect vulnerable utility crossing sites *
- Improve fish passage past weir (Reach 2)
- Monitor and maintain bridges
- Stabilize channel and banks to mitigate degradation and sediment deposits into creek (Reaches 6–11) *
- Introduce fish habitat features and/or passage structures to enrich habitat and improve fish passage
- Excavate channel to restore conveyance capacity (Reaches 1–5)
- Remove Fairford Bridge and weir structure (Reach 2)
- Develop floodplains and restore vegetation (Reaches 4–11)
- Relocate utilities (sanitary main in Reach 2, water main in Reach 6)
- Install grade control elements to mitigate utility exposure (Reaches 7–10)
- Remove and replace diversion structure access road bridge (Reach 11)
- Improve access road to secure access to the diversion structure during a 200-year event (Reaches 11–13)
- Manage storm water discharge points to improve water quality (all Reaches)
- Consider existing pathway network connectivity to restored channel reaches (all Reaches)
- Consider expansion of the pathway network from Hospital to diversion structure (Reaches 6–13)

*** Urgent works required, refer to reach by reach section for more details.**

ALTERNATIVE SOLUTIONS

- Formalize lateral structures (flood protection berms) to contain channel flows (Reaches 1-5)
- Remove bridges (Dog Park, West Hospital and/or Wholesale Club)
- Introduce spawning platforms (Reach 1-3)
- Remove and replace Dartmouth Road bridge
- Stabilize constrained channel sections with riprap, stacked boulders or retaining walls (Reaches 8 & 9)
- Engineer hardened channel sections to limit footprint in select areas (Reach 10 & 11)

Prioritizing Ellis Creek Naturalization

The naturalization of Ellis Creek is a large endeavor that is expected to take decades to complete. The work therefore needs to be divided into packages that can be completed in one year during the fisheries least risk window and have costs that may be covered by annual funding. The prioritization of naturalization of the Ellis Creek Reaches was based on the results of the technical assessments. Risks were weighted to inform the prioritization. The approach was to weight the core problems (degradation and bank stability) highest and secondary problems (bridge and culvert clearance, flooding, utility exposure and fish habitat) lower because secondary problems are created by the core problems. Actions are prioritized from 1 (highest priority) to 13 (lowest priority) (Table 19).

Table 19. Reach Prioritiation Ranking

Reach No.	Bridge/Culvert Clearance Ranking	Overland Flood Susceptibility Ranking	Utility Exposure Potential Ranking	Bank Stability Ranking	Degradation - sediment input	Habitat Priority Score	Overall score	Prioritization Ranking
Weight	0.1	0.1	0.1	0.2	0.2	0.3	5	13
1	1	2	3	4	5	2	3.00	5
2	3	2	2	4	5	3	3.40	10
3	1	2	2	4	5	3	3.20	6
4	3	2	5	5	5	1	3.30	8
5	1	1	2	5	5	1	2.70	2
6	1	3	2	4	5	3	3.30	9
7	4	4	1	1	1	3	2.20	1
8 A/B	5	4	5	1	1	4	3.00	3 * **
9	5	3	1	1	2	5	3.00	4 **
10 A/B	5	2	5	4	3	2	3.20	7 *
11	3	3	1	5	5	5	4.20	11
12	5	3	5	5	5	5	4.80	12 **
13	5	3	5	5	5	5	4.80	13 **

* Reach 8 and 10 have been split to accommodate the 6 week allowable instream construction window. The priority rankings criteria apply to the entire reach. The priority of section A and B within each reach are therefore considered equal.

** Where reach rankings have resulted in equal rankings, the prioritization has been given to the downstream reach to suit constructability.

Opinion of Probable Cost

An opinion of probable cost has been prepared for the proposed naturalization works on Ellis Creek. Engineers and Geoscientists of British Columbia and the Consulting Engineers of British Columbia have developed a cost estimate classification (EGBC, CEBC 2009) that is widely used in the consulting industry. We have prepared our opinion of probable costs in accordance with a Class ‘C’ estimate according including a 30% contingency. The costs have been estimated based on key scope items that influence the overall project cost including:

- Engineering and Administration
- Construction
- Environmental Management
- Culture and Heritage Monitoring
- Contingency

Lump sum costs and unit rates have been used to define the construction costs for the recommended naturalization option within each reach. Unit rates are based on industry costs for similar instream naturalization projects recently executed throughout the Okanagan Valley. Where the construction durations are estimated to exceed six weeks, we have split the reaches into sub reaches. Work will need to be completed in smaller sections to accommodate the environmental fish windows that will be applied to the construction projects.

The estimates do not include land acquisition costs, inflation or complementary park works outlined in the city’s official community plan. A summary of the reach costs is presented in Figure 32 below and detailed reach costs are attached in Appendix D.

Figure 32. Construction Cost Summary

Reach No.	Estimate Naturalization Cost
Reach 1	$ 1,060,000
Reach 2	$ 2,180,000
Reach 3	$ 770,000
Reach 4	$ 900,000
Reach 5	$ 2,700,000
Reach 6	$ 1,790,000
Reach 7	$ 3,410,000
Reach 8a	$ 2,150,000
Reach 8b	$ 2,660,000
Reach 9	$ 3,160,000
Reach 10a	$4,350,000
Reach 10b	$2,540,000
Reach 11	$2,520,000
Reach 12	$420,000
Reach 13	$260,000
Total	**$ 30,880,000**

Note: all estimates are in 2019 dollars and reflect Option 1 where applicable.

Conclusions

The Ellis Creek Master Plan was developed in three stages. First, technical assessments were completed to understand Ellis Creek. Second, all the information was synthesized to identify the core problems. Third, recommendations were developed to identify core solutions to the core problems.

The primary technical assessments that informed the master plan were:

9. Design Flows
10. Erosion and Sedimentation
11. Infrastructure and Creek Evaluation for Risk
12. Culvert Crossing Options
13. Fish Habitat
14. Cultural and Heritage
15. Hydrogeology desktop assessment

One important result from the technical assessments was the prediction of widespread flooding in the urban area of Penticton during a 200-yer return period design flood. There are many intangible impacts associated with overland flooding that can cause significant hardship for communities. For example, disrupted business and recovery costs associated with cleanup can negatively impact the local economy. Long lasting consequences such as environmental damage by surface water contamination and societal difficulties due to the stress of the event and aftermath. Although they are difficult to quantify, these intangible impacts can erode the community in general. Mitigating the potential overland flooding risk even by a small amount can often have positive repercussions throughout the community.

Fish habitat was found to be of low value in many of the reaches. A fish migration barrier low in the system limits accesses to upstream habitat.

The core problems within Ellis Creek were found to be:

Degradation that leads to moderate fish habitat and fish migration high infrastructure risk and unstable banks.

Aggradation that leads to poor habitat and poor fish migration and increased flood hazard.

Core solutions for degradation include:

- Stabilize channel bed and banks, widen channel and floodplain
- Decrease sediment input
- Maintain constant sediment transport downstream
- Restore depth of cover to utilities
- Increase fish habitat

Core solutions for aggradation include:

- Excavate aggraded sediment and mitigate degradation upstream
- Increase channel depth
- Minimize flooding
- Maintain constant sediment transport downstream
- Increase fish habitat

Conceptual design approach is:

The design solutions use natural channel design to restore natural balance to Ellis Creek. Naturalization features include step-pools, riffle, pools, channel bars, root wads, and boulder clusters. These features provide channel stability and fish habitat. Removal of the barrier to fish migration in Reach 2 opens upstream habitat.

Recommendations for the next steps for the Master Plan include:

- Conducting immediate mitigations to address specific risks to public safety and infrastructure
- Fostering public support
- Focusing on key priorities to meet objectives
- Applying for funding
- Design and construction of high priority sites
- Development of action plans for short term and long-term solutions
- Reviewing and revising the master plan in future years as naturalization works are implemented

Supplementary activities to support the Master Plan include:

- Review stormwater management strategies for Ellis Creek in conjunction with integrated master planning study commencing in 2020
- Review active transport strategies for Ellis Creek corridor pathways in conjunction with the integrated master planning study commencing in 2020
- Conduct a predesign for the area of Ellis Creek that runs through the Cantex property that would see the City and Cantex working with the regulators to develop an Ellis Creek and Subdivision concept that works to meet the needs of all three parties

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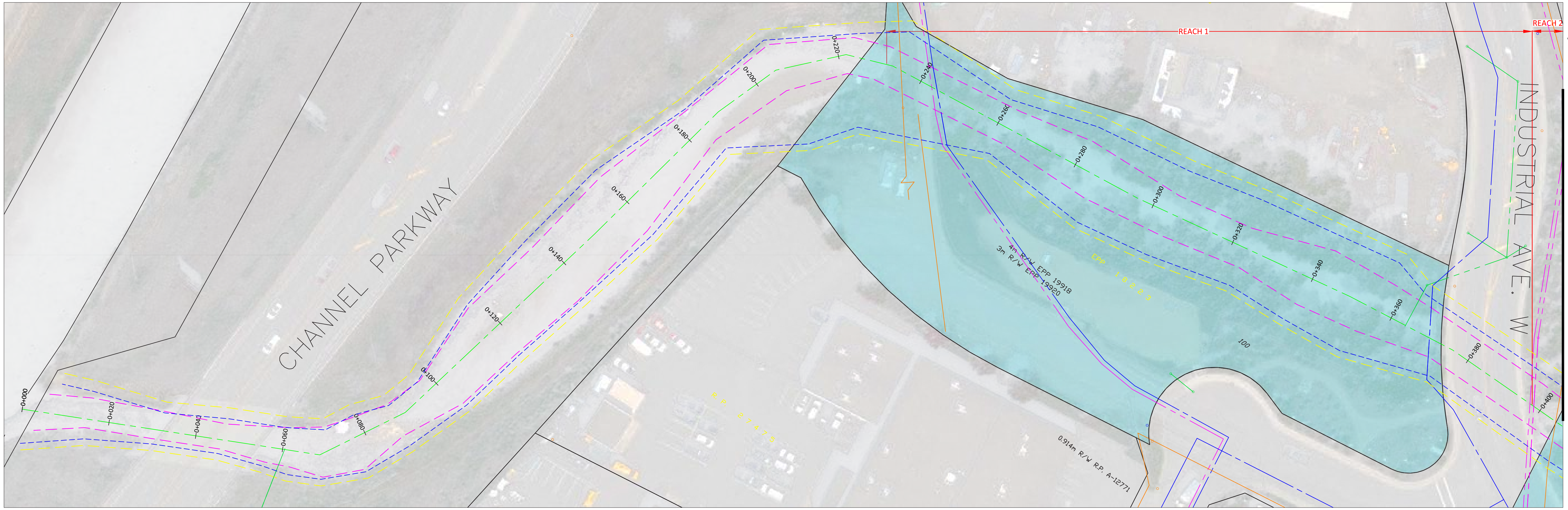
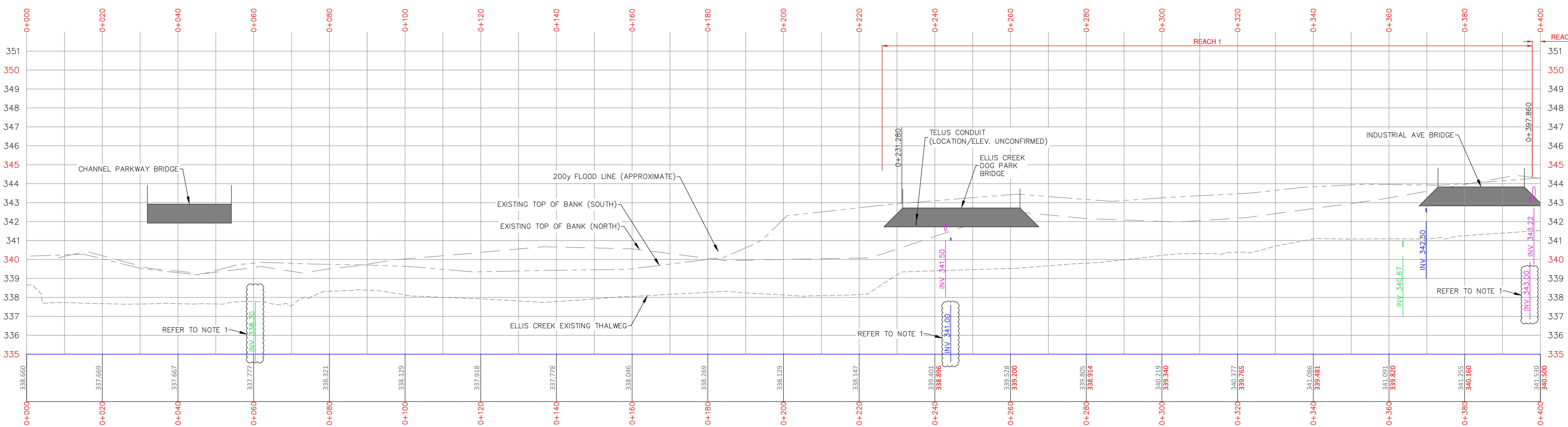
Appendices

Appendix A Existing Conditions Mapping





\\CA0047-PPFSS01\workgroup\01117\active\111710068_ellis_creek_master_plan\06_drawing\02_sheets\C201_OG 1-500.dwg ORIGINAL SHEET SIZE: 22 x 34"

Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

- Gas main
- Electrical cable/telephone
- Sanitary sewer
- Storm sewer
- Domestic watermain
- Creek CL
- Property line
- Bottom of Bank
- Top of Bank
- City Owned Property
- Sanitary manhole
- Storm manhole
- Double catch basin
- Side inlet catch basin
- Top inlet catch basin
- Catch basin manhole
- Storm oil interceptor
- Water valve
- Water curb stop
- Water hydrant
- Water air valve
- Street light
- Power pole
- Electrical service box
- Electrical vault
- Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

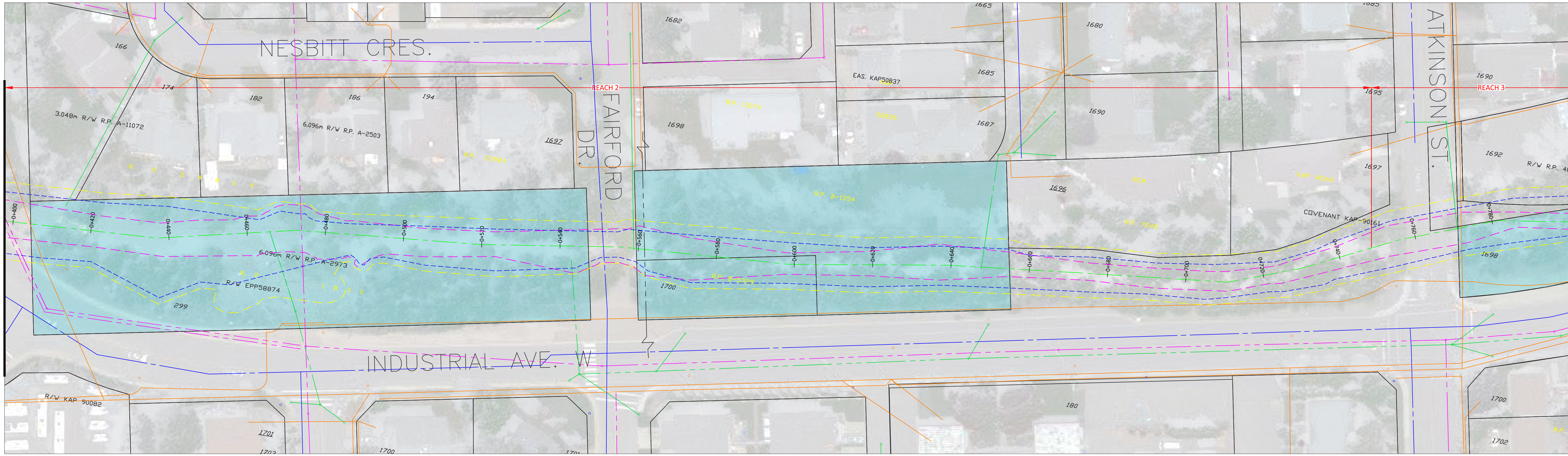
Scale horiz.	1:500
Scale vert.	1:100
Sheet	1 of 13
Drawn by	CM
Approved by	SK
Plot date	2019/09/20

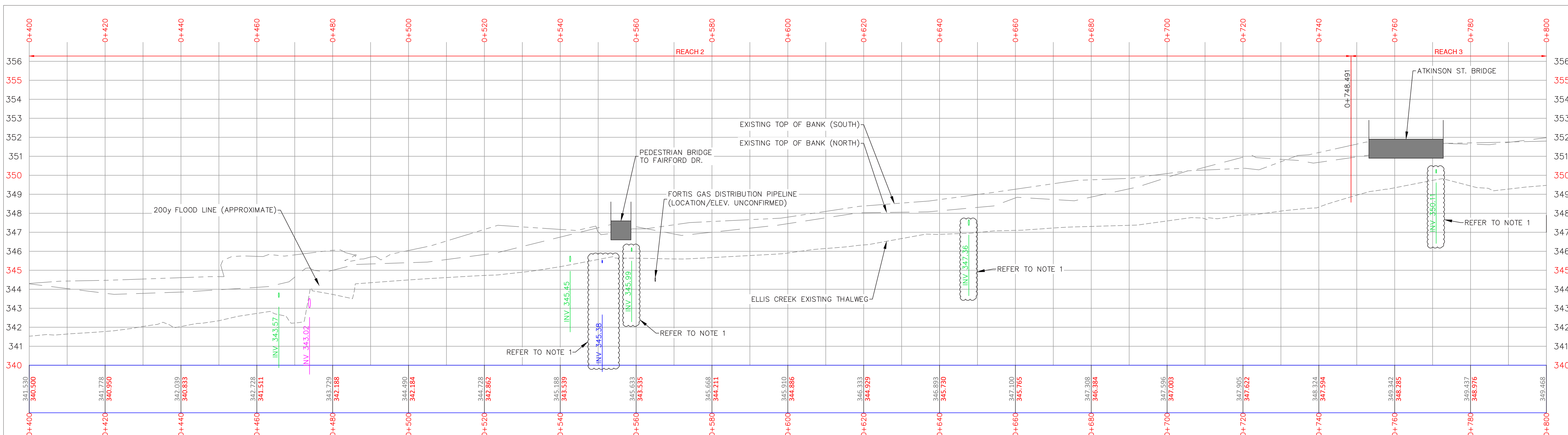
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 0+000 - 0+400 EXISTING CONDITIONS - REACH 1 & 2

Drawing No.: C201

Revision No.: 1





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main	City Owned Property	Water valve
Electrical cable/telephone	Sanitary manhole	Water curb stop
Sanitary sewer	Storm manhole	Water hydrant
Storm sewer	Double catch basin	Water air valve
Domestic watermain	Side inlet catch basin	Street light
Creek CL	Top inlet catch basin	Power pole
Property line	Catch basin manhole	Electrical service box
Bottom of Bank	Storm oil interceptor	Electrical vault
Top of Bank		Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 2 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

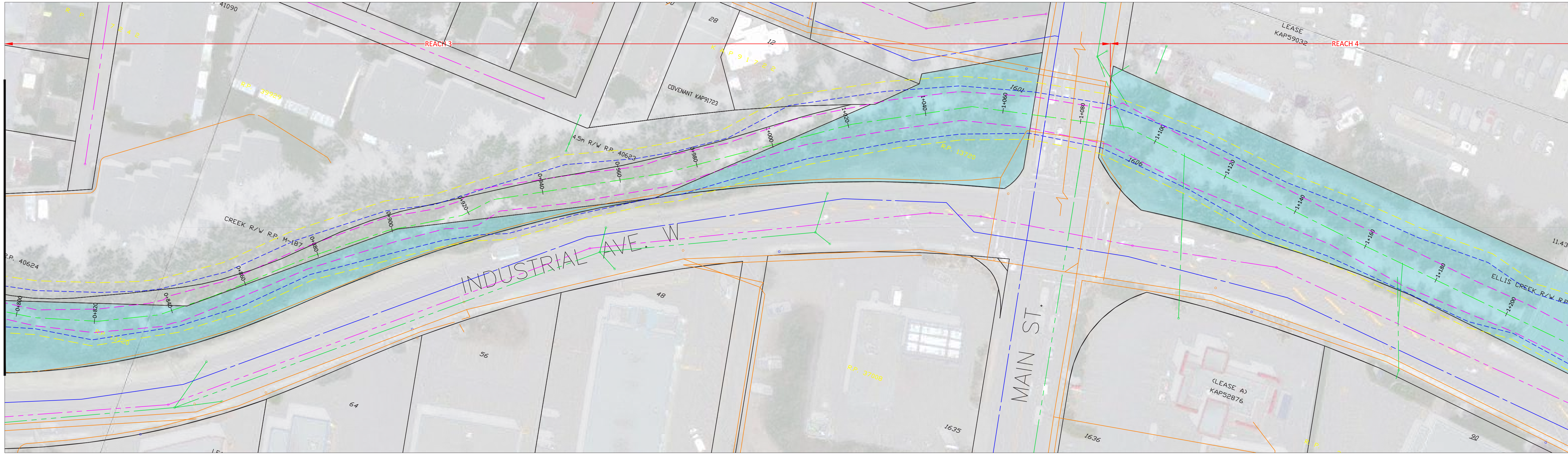
Project: ELLIS CREEK MASTER PLAN

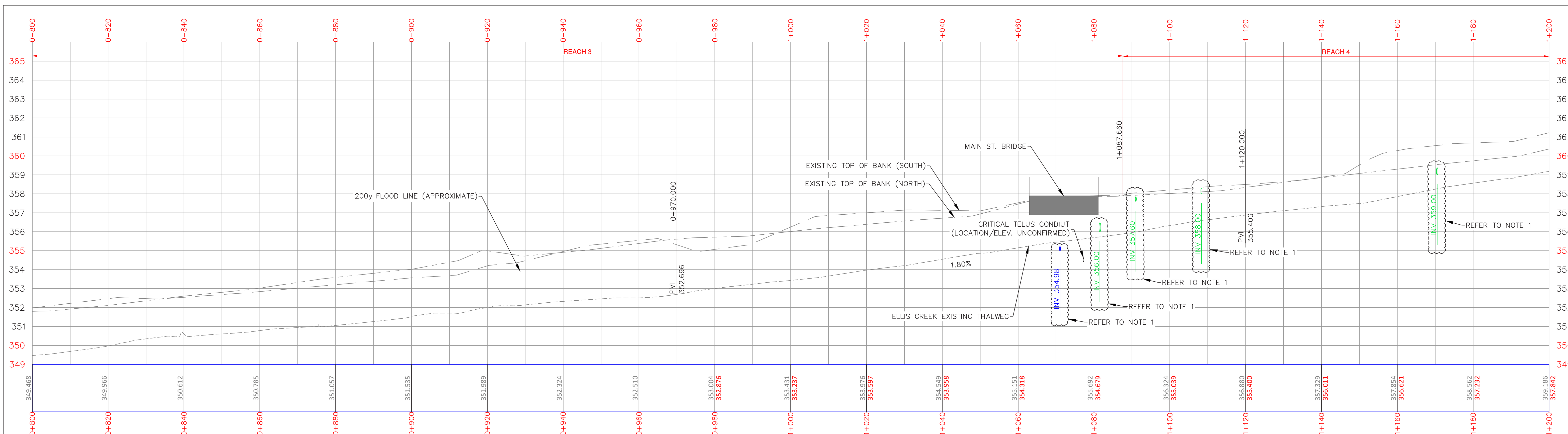
Title: PLAN PROFILE STATION 0+400 - 0+800 EXISTING CONDITIONS - REACH 2 & 3

Drawing No. C202

Revision No. 1

\\CA0047-PPFSS01\workgroup\01117\active\111710068_ellis_creek_master_plan\05_drawing\02_sheets\C201_0G 1-500.dwg ORIGINAL SHEET SIZE: 22 x 34"





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

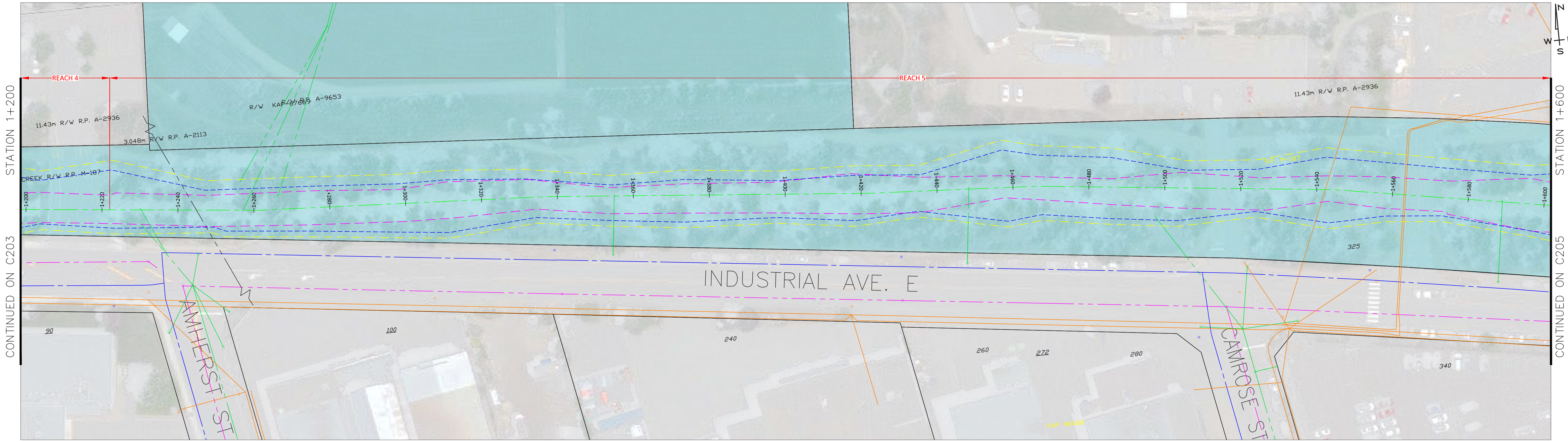
Scale horiz. 1:500
Scale vert. 1:100
Sheet 3 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

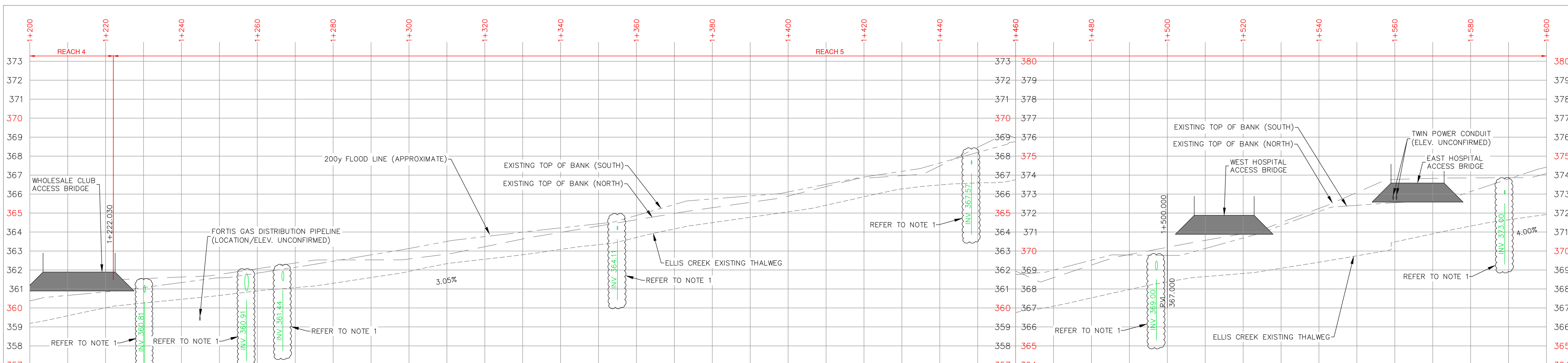
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 0+800 - 1+200 EXISTING CONDITIONS - REACH 3 & 4

Drawing No. C203

Revision No. 1





Station	Existing	Design
1+200	359.186	357.842
1+220	360.007	358.453
1+240	360.455	359.063
1+260	360.896	359.674
1+280	361.300	360.284
1+300	361.924	360.895
1+320	362.567	361.505
1+340	363.083	362.116
1+360	363.715	362.726
1+380	364.494	363.337
1+400	365.064	363.947
1+420	365.860	364.558
1+440	366.481	365.168
1+460	366.757	365.779
1+480	367.529	366.389
1+500	368.371	367.000
1+520	368.817	367.800
1+540	369.410	368.600
1+560	370.479	369.400
1+580	371.313	370.200
1+600	371.926	371.000

Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 4 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

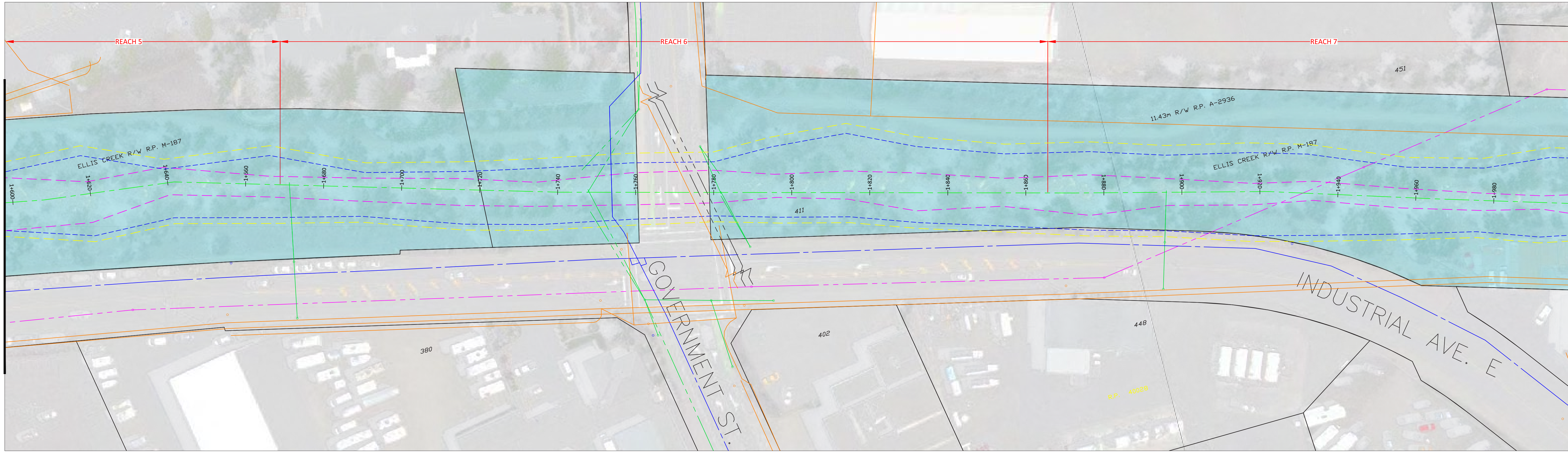
Project: ELLIS CREEK MASTER PLAN

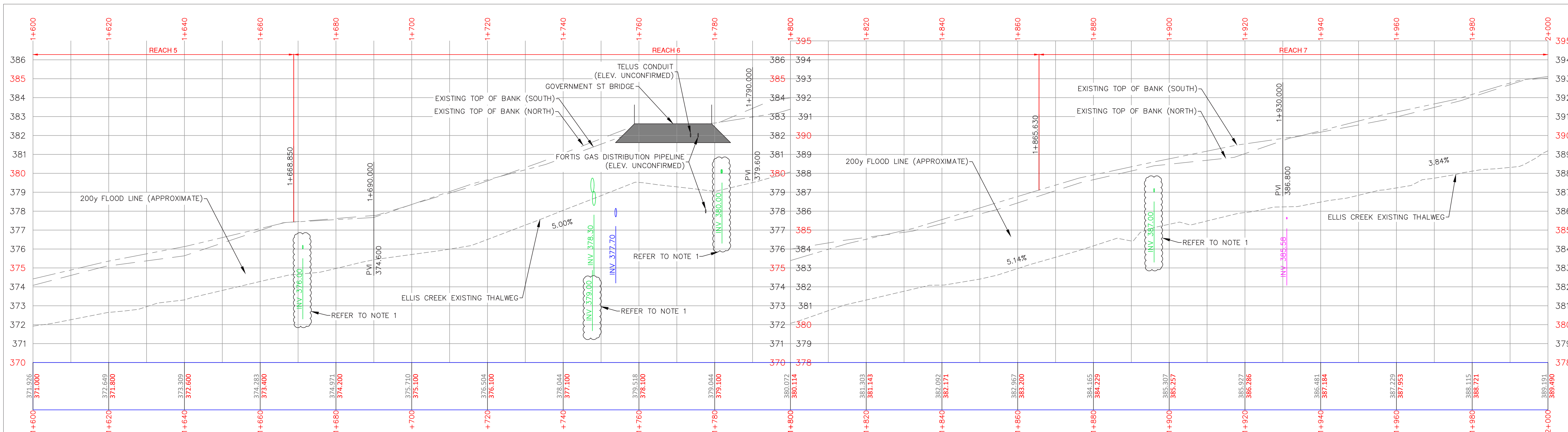
Title: PLAN PROFILE STATION 1+200 - 1+600 EXISTING CONDITIONS - REACH 5 & 6

Drawing No. C204

Revision No. 1

\\CA0047-PPFSS01\workgroup\01117\active\111710066_ellis_creek_master_plan\06_drawing\02_sheets\C201_OG 1-500.dwg ORIGINAL SHEET SIZE: 22 x 34"





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main	City Owned Property	Water valve
Electrical cable/telephone	Sanitary manhole	Water curb stop
Sanitary sewer	Storm manhole	Water hydrant
Storm sewer	Double catch basin	Water air valve
Domestic watermain	Side inlet catch basin	Street light
Creek CL	Top inlet catch basin	Power pole
Property line	Catch basin manhole	Electrical service box
Bottom of Bank	Storm oil interceptor	Electrical vault
Top of Bank		Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 5 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

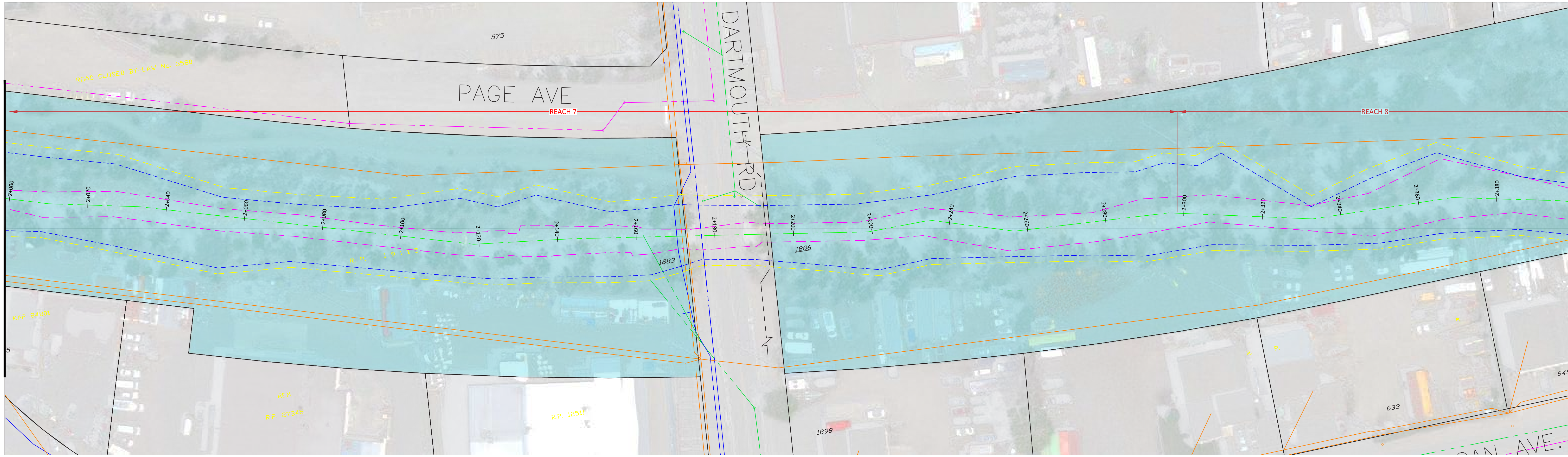
Project: ELLIS CREEK MASTER PLAN

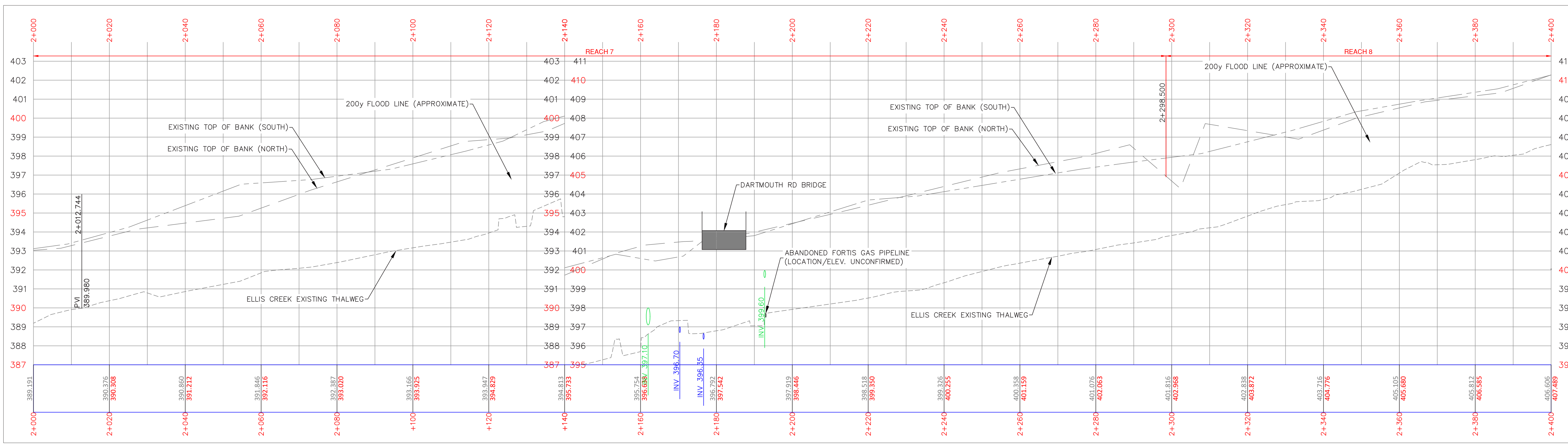
Title: PLAN PROFILE STATION 1+600 - 2+000 EXISTING CONDITIONS - REACH 6 & 7

Drawing No. C205

Revision No. 1

\\CA0047-PPFSS01\workgroup\01117\active\111710066_ellis_creek_master_plan\06_drawing\02_sheets\C201_0G 1-500.dwg ORIGINAL SHEET SIZE: 22 x 34"





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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank
City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor
Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

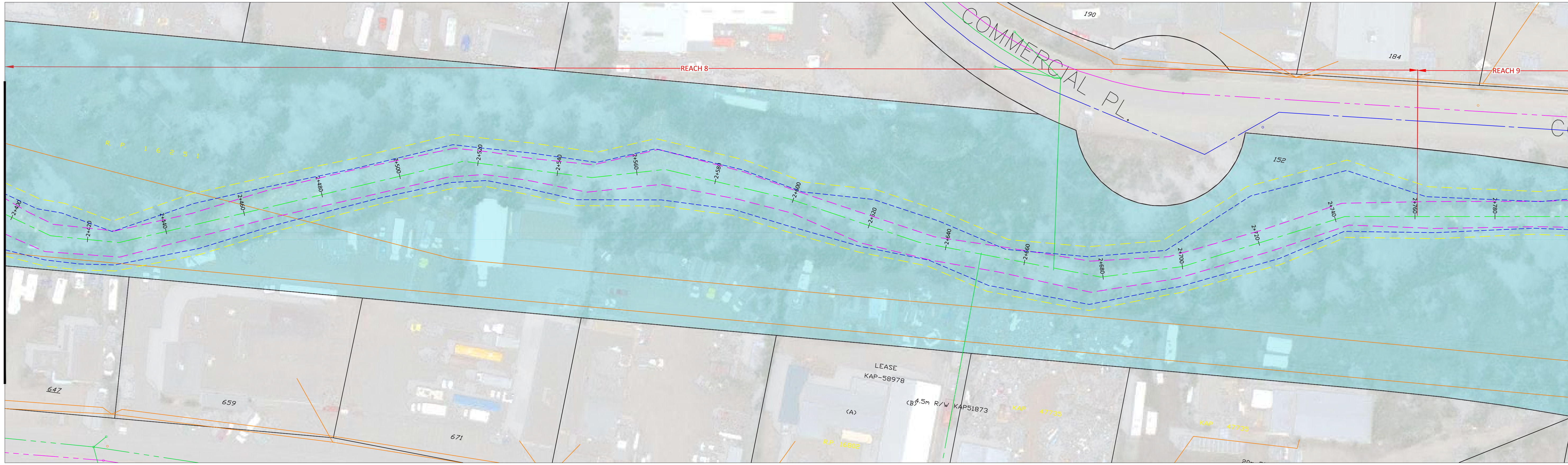
Scale horiz. 1:500
Scale vert. 1:100
Sheet 6 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

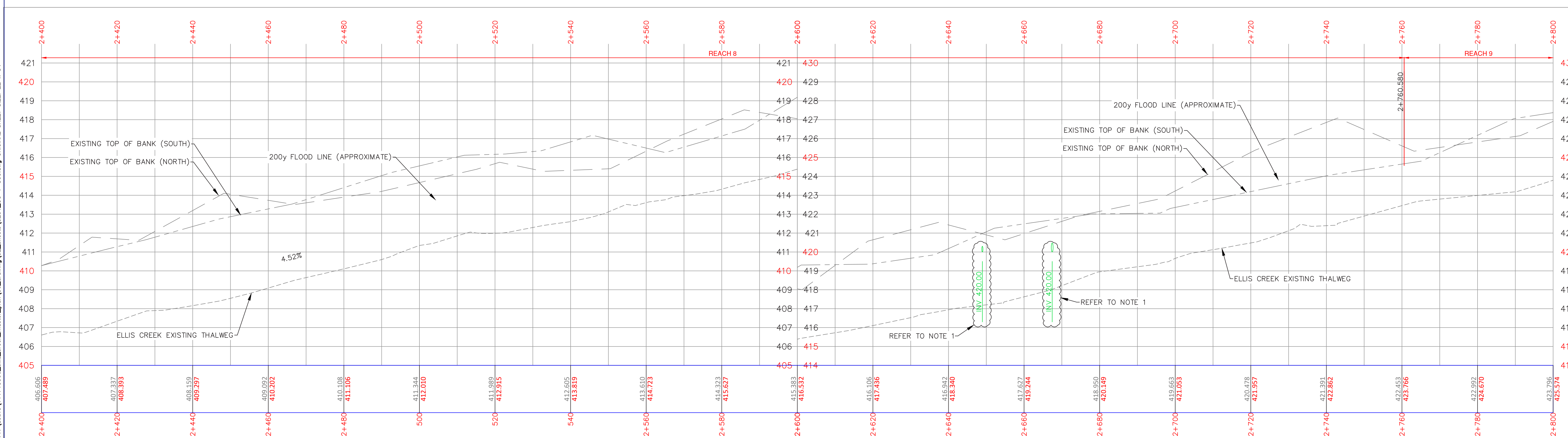
Project
ELLIS CREEK MASTER PLAN

Title
PLAN PROFILE STATION 2+000 - 2+400
EXISTING CONDITIONS - REACH 7 & 8

Drawing No.
C206

Revision No.
1





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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank

City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor

Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

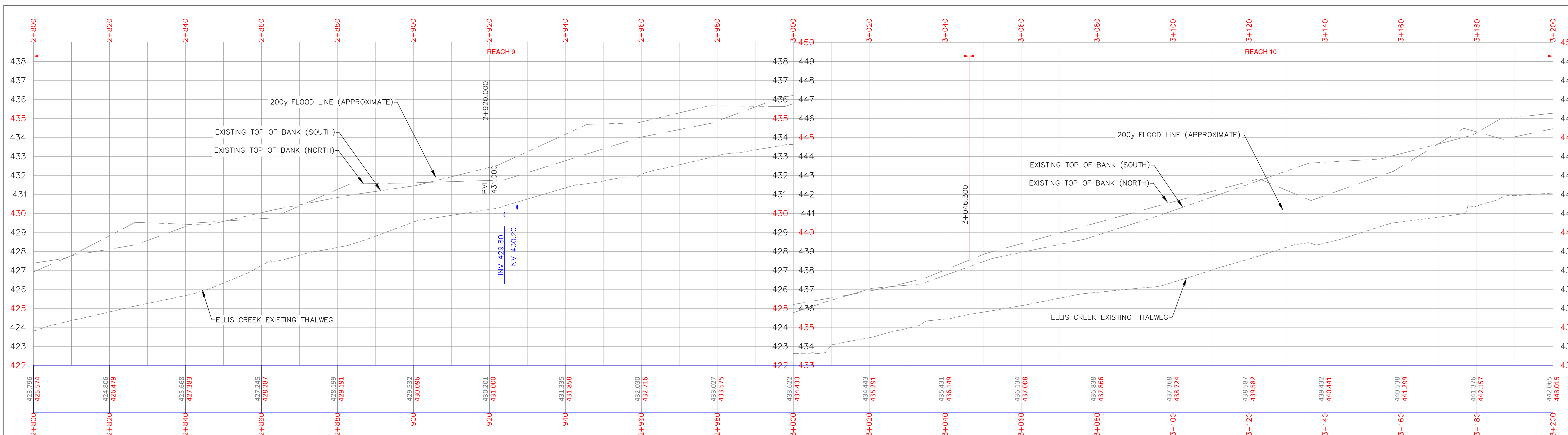
Scale horiz. 1:500
Scale vert. 1:100
Sheet 7 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 2+400 - 2+800 EXISTING CONDITIONS - REACH 8, 9 & 10

Drawing No. C207

Revision No. 1



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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank
City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor
Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

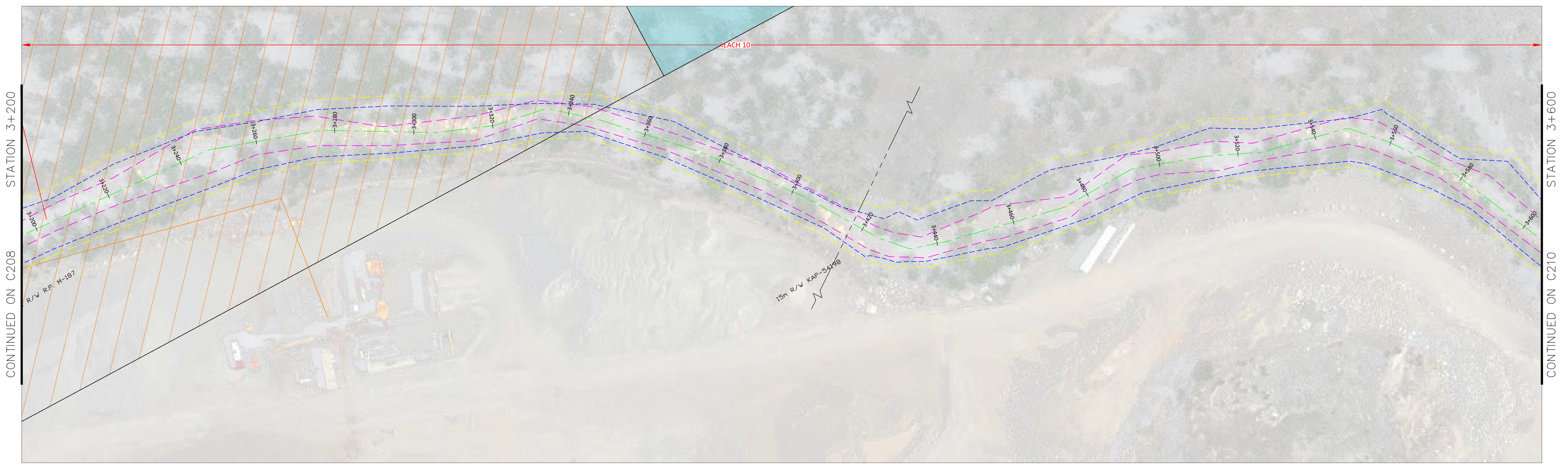
Scale horiz. 1:500 (0, 5, 15, 25m)
Scale vert. 1:100 (0, 1, 3, 5m)
Sheet 8 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

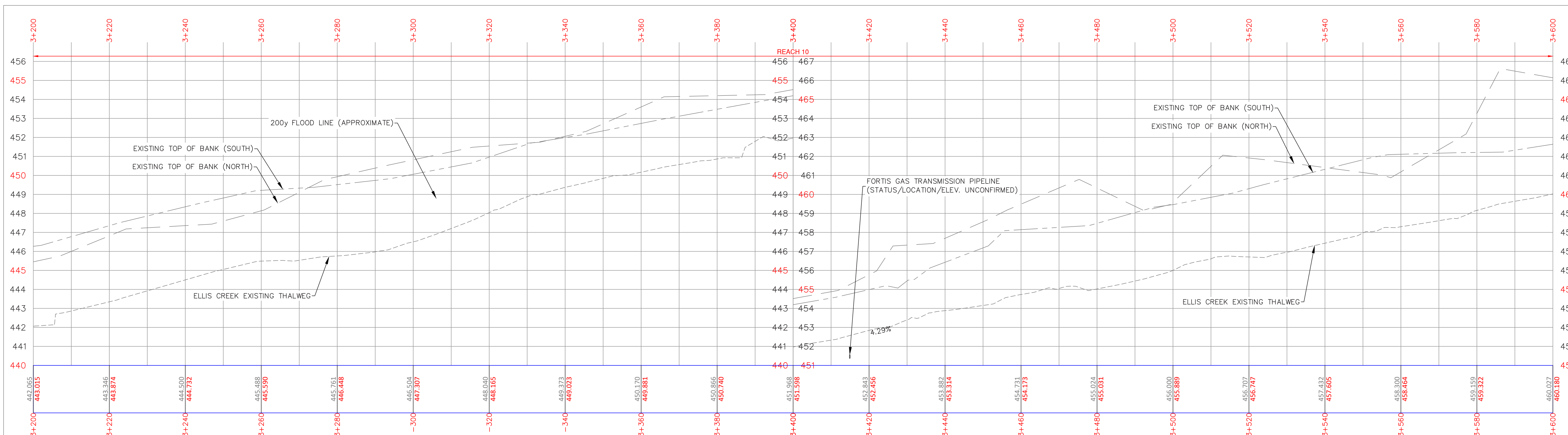
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 2+800 - 3+200 EXISTING CONDITIONS - REACH 9 & 10

Drawing No. C208

Revision No. 1





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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main · Electrical cable/telephone · Sanitary sewer · Storm sewer · Domestic watermain · Creek CL · Property line · Bottom of Bank · Top of Bank · City Owned Property · Sanitary manhole · Storm manhole · Double catch basin · Side inlet catch basin · Top inlet catch basin · Catch basin manhole · Storm oil interceptor · Water valve · Water curb stop · Water hydrant · Water air valve · Street light · Power pole · Electrical service box · Electrical vault · Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

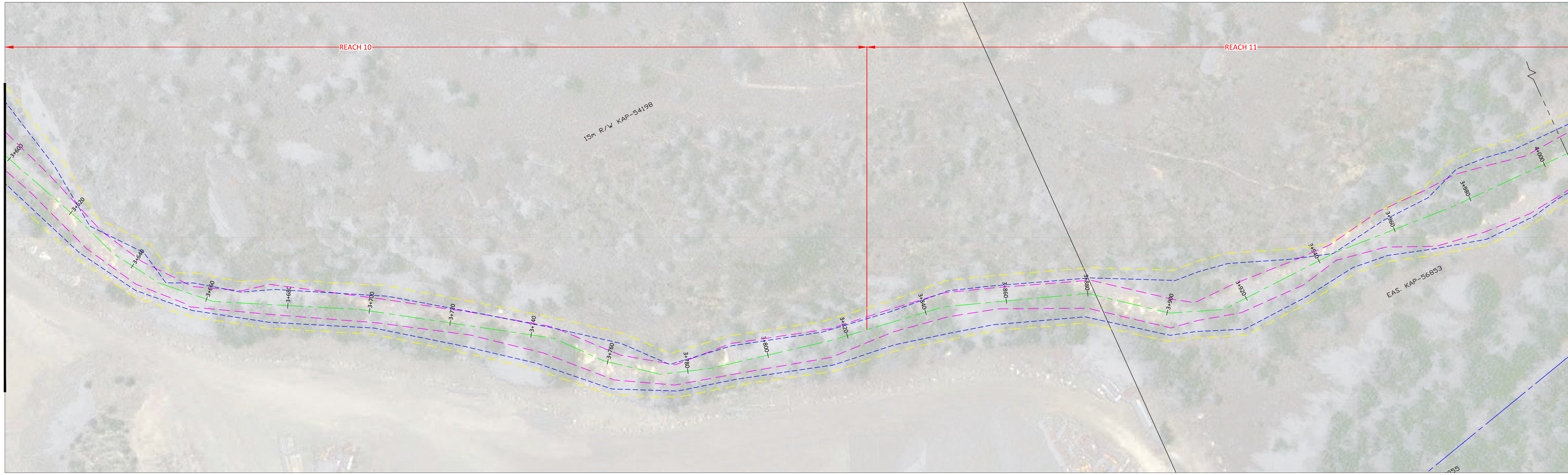
Scale horiz.	1:500 (0 5 15 25m)
Scale vert.	1:100 (0 1 3 5m)
Sheet	9 of 13
Drawn by	CM
Approved by	SK
Plot date	2019/09/20

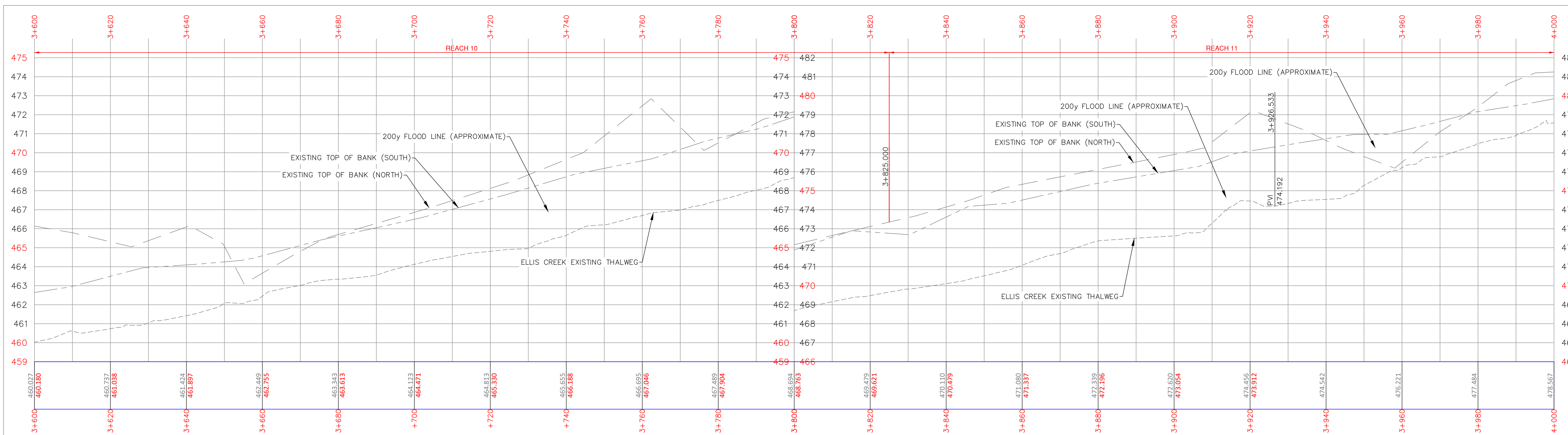
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 3+200 - 3+600 EXISTING CONDITIONS - REACH 10 & 11

Drawing No. C209

Revision No. 1





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank
City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor
Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 10 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

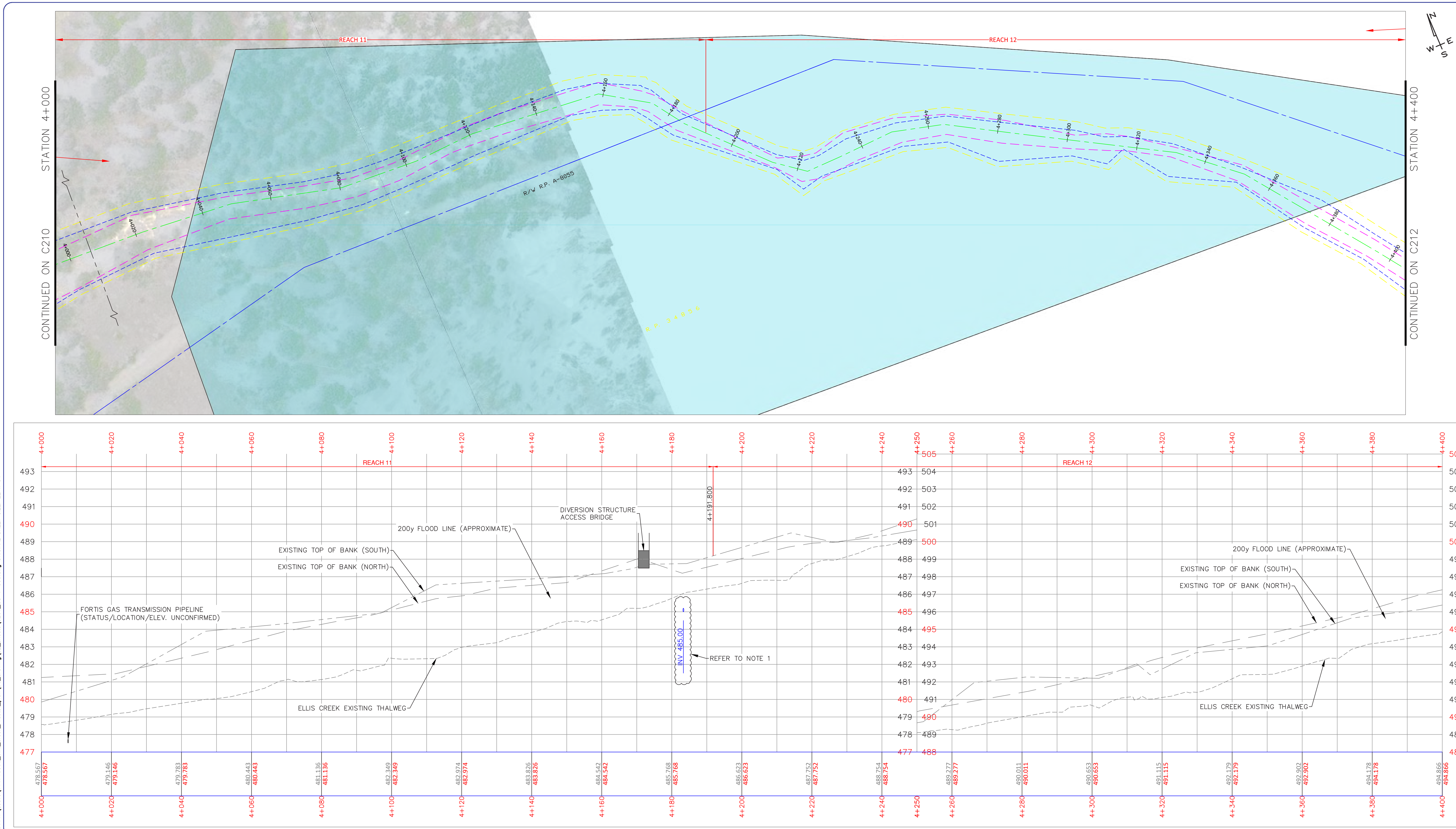
Project
ELLIS CREEK MASTER PLAN

Title
PLAN PROFILE STATION 3+600 - 4+000
EXISTING CONDITIONS - REACH 10 & 11

Drawing No.
C210

Revision No.
1

\\CA0047-PPFSS01\workgroup\01117\active\111710066_ellis_creek_master_plan\06_drawing\02_sheets\C201_OG 1-500.dwg ORIGINAL SHEET SIZE: 22 x 34"



Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

- Gas main
- Electrical cable/telephone
- Sanitary sewer
- Storm sewer
- Domestic watermain
- Creek CL
- Property line
- Bottom of Bank
- Top of Bank
- City Owned Property
- Sanitary manhole
- Storm manhole
- Double catch basin
- Side inlet catch basin
- Top inlet catch basin
- Catch basin manhole
- Storm oil interceptor
- Water valve
- Water curb stop
- Water hydrant
- Water air valve
- Street light
- Power pole
- Electrical service box
- Electrical vault
- Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

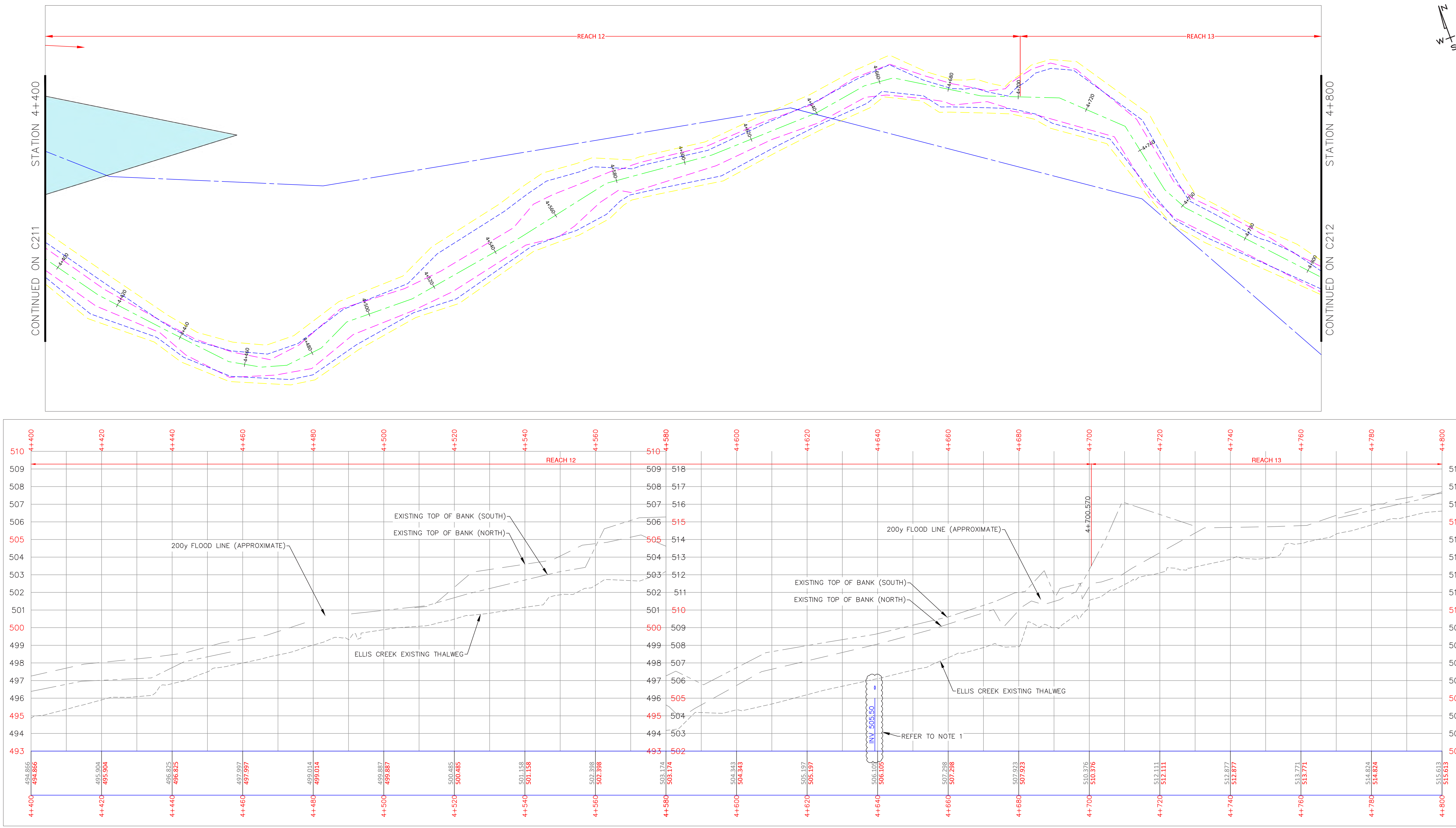
Scale horiz.	1:500 (0 5 15 25m)
Scale vert.	1:100 (0 1 3 5m)
Sheet	11 of 13
Drawn by	CM
Approved by	SK
Plot date	2019/09/20

Project
ELLIS CREEK MASTER PLAN

Title
PLAN PROFILE STATION 4+000 - 4+400
EXISTING CONDITIONS - REACH 11 & 12

Drawing No.
C211

Revision No.
1



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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main	City Owned Property	Water valve
Electrical cable/telephone		Water curb stop
Sanitary sewer	Sanitary manhole	Water hydrant
Storm sewer	Storm manhole	Water air valve
Domestic watermain	Double catch basin	Street light
Creek CL	Side inlet catch basin	Power pole
Property line	Top inlet catch basin	Electrical service box
Bottom of Bank	Catch basin manhole	Electrical vault
Top of Bank	Storm oil interceptor	Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

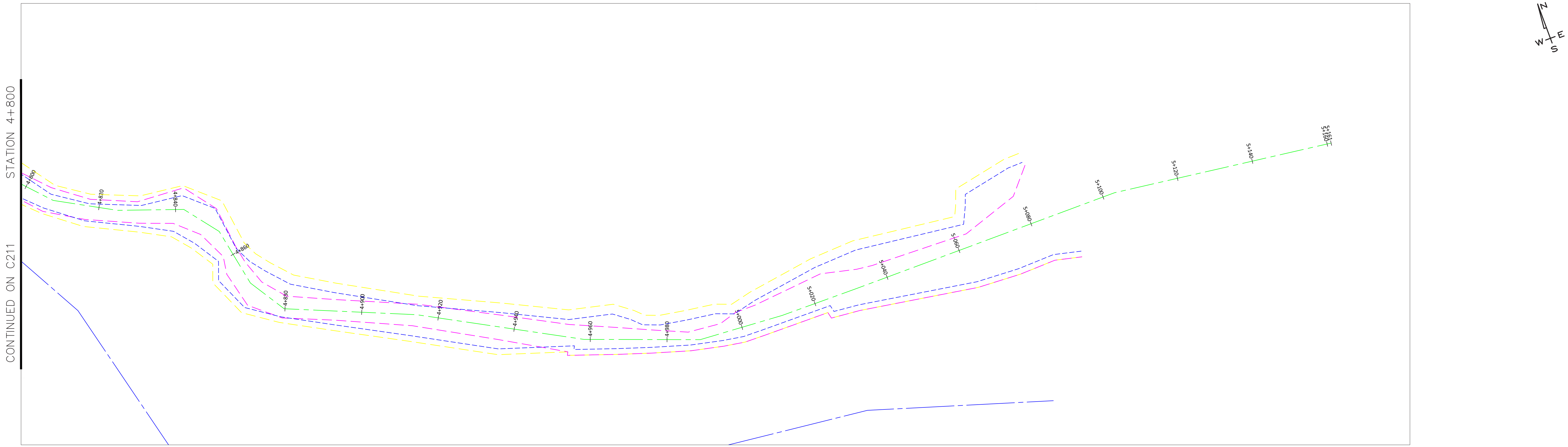
Scale horiz.	1:500
Scale vert.	1:100
Sheet	12 of 13
Drawn by	CM
Approved by	SK
Plot date	2019/09/20

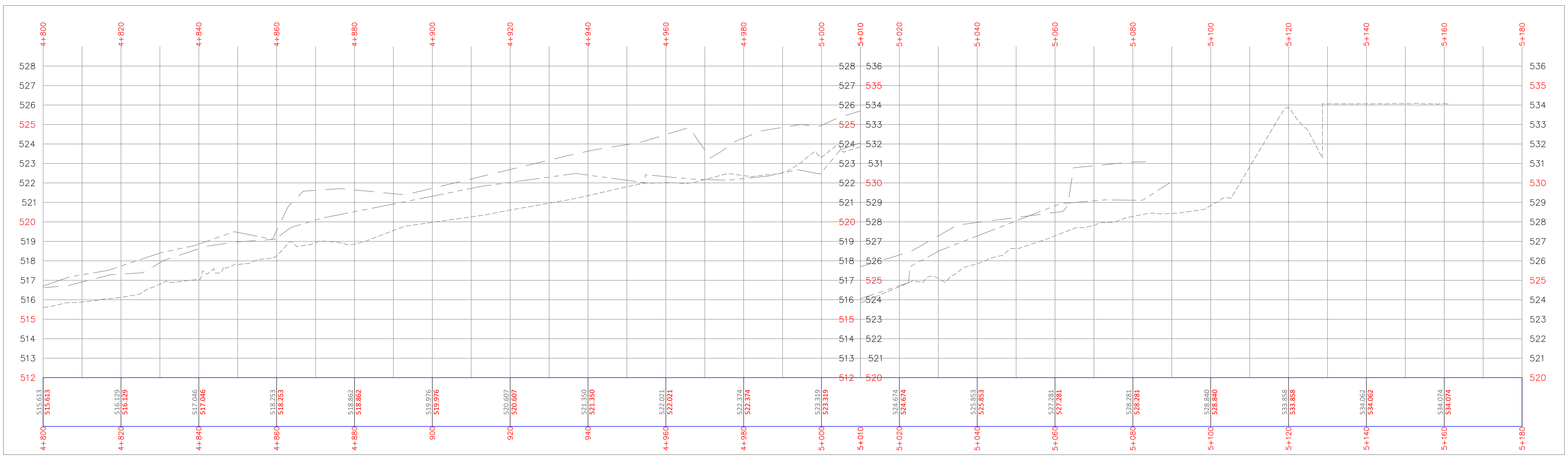
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 4+400 - 4+800 EXISTING CONDITIONS - REACH 12 & 13

Drawing No.: C212

Revision No.: 1





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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

- Gas main
- Electrical cable/telephone
- Sanitary sewer
- Storm sewer
- Domestic watermain
- Creek CL
- Property line
- Bottom of Bank
- Top of Bank
- City Owned Property
- Sanitary manhole
- Storm manhole
- Double catch basin
- Side inlet catch basin
- Top inlet catch basin
- Catch basin manhole
- Storm oil interceptor
- Water valve
- Water curb stop
- Water hydrant
- Water air valve
- Street light
- Power pole
- Electrical service box
- Electrical vault
- Electrical transformer

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500 (0 5 15 25m)
Scale vert. 1:100 (0 1 3 5m)
Sheet 12 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

Project
ELLIS CREEK MASTER PLAN

Title
PLAN PROFILE STATION 4+800 - 5+161
EXISTING CONDITIONS - REACH 13

Drawing No.
C212

Revision No.
1

Appendix B Risk Review Details

Bridge and Culvert Risk Ranking

Reach No.	ID No.	Description	Observations	Thalweg Elevation (masl)	Soffit Elevation (masl)	Deck or Roadway Width	Opening Area (m^2)[2])	200-year Water Surface Elevation (masl)	Bridge/Culvert or Channel Freeboard (m)	Channel Aggradation Hazard Rank	Likelihood	Consequence	Bridge/ Culvert Clearance Risk Ranking
1	B1	Multi-plate arch @ Ellis Creek Park	Center bar aggradation and creek right toe scour below bridge Evidence of backwatering and scour on NE and SE abutments/wingwalls CMP well on SE embankment and monitoring equipment on NE embankment	338.98	341.72	31.0	13.9	343.2	-1.5	2	High	Low	3
1	B2	Multi-plate arch @ Industrial Avenue	Aggradation limiting bridge conveyance Outfall in NW embankment blocked and submerged	341.2	342.83	30.4	8.3	344.58	-1.8	2	High	Med	2
2	B3	Steel girder clear-span pedestrian bridge @ Fairford Drive	Minor aggradation and scour Seepage through timber headwall with Sulphur odor Outfall in SW embankment and partially blocked outfall headwall	345.54	346.6	2.7	7.9	347.75	-1.1	3	High	Low	3
3	B4	Multi-plate arch @ Atkinson Street	Aggradation and limited clearance Scour on u/s headwall Over steepened banks with evidence of erosion	348.95	350.9	19.6	8.2	351.68	-0.8	4	High	Low	3
3	B5	Steel girder clear-span bridge @ Main Street	Significant aggradation and severely limited clearance Scour along SE wing wall Foundation cracks on downstream N and S headwalls Pool on downstream side Outfall in NE and SE embankments and partially blocked outfall below bridge	355.77	356.89	18.2	8.3	357.93	-1.0	4	High	High	1
4	B6	Multi-plate arch @ Superstore Access	Significant aggradation and severely limited clearance Evidence of backwatering and scour on NE and SE abutments/wingwalls Outfall in SE embankments blocked	359.64	360.89	19	2.7	361.99	-1.1	3	High	Low	3
5	B7	Multi-plate arch @ West Hospital Entrance	Significant aggradation and very shallow channel depth Steep grades on approach roads Visible deformation inside corrugated culvert	368.92	370.88	15.8	8.1	371.77	-0.9	5	High	Med	2
5	B8	Multi-plate arch @ East Hospital Entrance Buried electrical utility crossing within embankment	Significant aggradation Channel constricted laterally at bridge opening with visible bank scour u/s Aging headwall concrete Outfalls in NE embankment low and exposed, SE outfall eroded and failed	370.85	372.58	14	9	373.07	-0.5	5	High	High	1
6	B9	Multi-plate arch @ Government Street	Significant aggradation Scour along SE wing wall Outfall in NE and SE over steepened embankments, NW outfall blocked	379.07	381.62	20.4	15.3	382.15	-0.5	4	High	High	1
7	B10	Timber girder clear-span bridge @ Dartmouth Road	Exposed footings with evidence of undermined patch jobs Exposed and damaged utility crossing immediately u/s and d/s Large boulders installed over steel casing crossing downstream Outfall in NE, SE and SW abutments	396.98	401.08	11.6	23.6	400.49	0.6	-	Med	Low	4

Reach No.	ID No.	Description	Observations	Thalweg Elevation (masl)	Soffit Elevation (masl)	Deck or Roadway Width	Opening Area (m^2)[2])	200-year Water Surface Elevation (masl)	Bridge/Culvert or Channel Freeboard (m)	Channel Aggradation Hazard Rank	Likelihood	Consequence	Bridge/ Culvert Clearance Risk Ranking
8		no bridges								-	Low	Low	5
9		no bridges								-	Low	Low	5
10		no bridges								-	Low	Low	5
11	B11	Diversion Access Road @ Ellis Creek	Large boulders forming step pool u/s Overall poor superstructure condition with visibly deformations is girders Visible bank erosion and dislodged bank boulders Channel scour and mobilization of form material u/s from bridge	485.19	487.49	3.1	15.7	487.75	-0.3	-	High	Low	3
12		no bridges								5	Low	Low	5
13		no bridges								5	Low	Low	5

Overland Flood Susceptibility Risk Ranking

Reach No.	Description	Observations	Channel Freeboard (m)	Aggradation Hazard Rank	Likelihood	Consequence	Overland Flood Susceptibility Ranking
1	Representative section for EC Dog Park pathway to Industrial Ave	Overtopping channel banks and high aggradation hazard Inhabited adjacent lands	-0.91 RS	2	High	Med	2
2	Representative section for Industrial Ave to Atkinson St	Overtopping channel banks and moderate aggradation hazard Inhabited adjacent lands	-0.78 RS	3	High	Med	2
3	Representative section for Atkinson St to Main St	Overtopping channel banks and low aggradation hazard Inhabited adjacent lands	-0.20 RS	4	High	Med	2
4	Representative section for Main St to Superstore access	Overtopping channel banks and moderate aggradation hazard Inhabited adjacent lands	-0.17 LS	3	High	Med	2
5	Representative section for Superstore access to D/S of Government St	Overtopping channel banks and stable channel Critical infrastructure (hospital) in adjacent lands	-1.32 LS	5	High	High	1
6	Representative section for D/S of Government St to U/S of Government St	Ample freeboard and low aggradation hazard Critical infrastructure (hospital) in adjacent lands	0.92 LS	4	Low	High	3
7	Representative section for U/S of Government St to U/S of Dartmouth Rd	Ample freeboard Inhabited adjacent lands	1.32 LS	-	Low	Med	4
8	Representative section for U/S of Dartmouth Rd to D/S of Cantex property	Ample freeboard Inhabited adjacent lands	1.87 LS	-	Low	Med	4
9	Representative section for D/S of Cantex property to low extent of Cantex property	Limited freeboard Inhabited adjacent lands	0.30 LS	-	Med	Med	3
10	Representative section for Adjacent to the Cantex property	Overtopping channel banks Inhabited adjacent lands	-0.19 LS	-	High	Med	2
11	Representative section for Upper extent of Cantex property to City's diversion structure access road bridge	Overtopping channel banks Inhabited adjacent lands	-0.18 LS	-	High	Low	3
12	Representative section for Upstream from City's diversion structure access road bridge	Overtopping channel banks and diversion structure access road Uninhabited adjacent lands	-0.79 RS	5	High	Low	3
13	Representative section for Downstream from diversion structure	Overtopping channel banks and diversion structure access road Uninhabited adjacent lands	-0.40 RS	5	High	Low	3

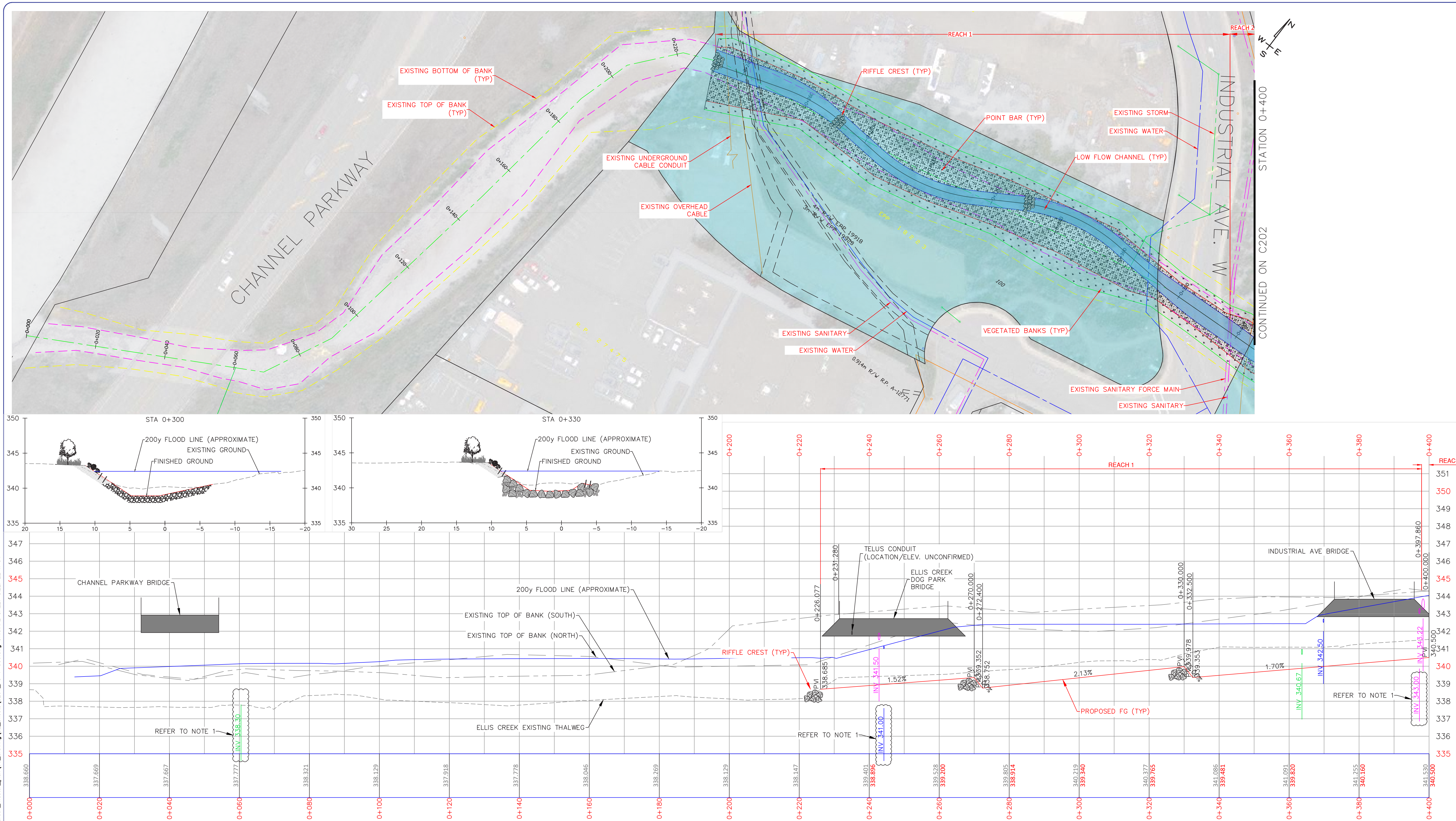
Buried Utility Exposure Risk Ranking

Reach No.	ID No.	Description	Observations	Design Discharge (m^3)	200-year Water Surface Elevation (masl)	Avg. Hydraulic Depth (m)	Avg. Velocity (m/s)	Hydraulic Radius (m)	Top Width (m)	Thalweg Elevation (masl)	Channel Bed D_{50} (mm)	Fbo	Channel Slope (m/m)	Natural Scour Potential (m)	Degradation Risk	Likelihood	Consequence	Utility Exposure Risk Ranking
1	SSPM-20	Buried 450 mm PVC sanitary forced main within Ellis Creek Dog Park walkway culvert embankment	Appears to be within the Ellis Creek Dog Park walkway culvert embankment.											n/a	-	Low	Low	5
1	WM-4016	Buried 400 mm PVC watermain within Ellis Creek Dog Park walkway culvert embankment	Appears to be within the Ellis Creek Dog Park walkway culvert embankment.											n/a	-	Low	Low	5
1	Tel-1	Buried Telus duct within Ellis Creek Dog Park walkway culvert embankment	Appears to be within the Ellis Creek Dog Park walkway culvert embankment.											n/a		Low	Low	5
1	WM-377	Buried 200 mm PVC watermain	Appears to cross under channel.	51.2	343.22	1.74	1.66	1.65	17.27	340.96	104	2	0.0114	0.58	-	Med	Med	3
1	SSPM-4	Buried 150 mm PVC sanitary forced main within Industrial Ave culvert embankment	Appears to be within Industrial Ave culvert embankment.											n/a	-	Low	Low	5
1	SSGM-1918-1917	Buried 600 mm PVC sanitary gravity main within Industrial Ave culvert embankment	Appears to be within Industrial Ave culvert embankment.											n/a	-	Low	Low	5
2	SSGM-1176-1175	Buried 525 mm concrete sanitary gravity main within weir embankment @ Quebec St	Appears to cross channel within weir embankment. Aggradation and drift d/s of weir plunge pool blocking fish ladder entrance Scour on weir and spillway Significant bypass intake blockage and damage throughout bypass Protruding bank armouring d/s with evidence of hydraulic constriction and high water	51.2	345.53	1.08	2.32	1.01	16.99	343.51	104	2	0.017	0.59	-	Med	High	2

Reach No.	ID No.	Description	Observations	Design Discharge (m^3)	200-year Water Surface Elevation (masl)	Avg. Hydraulic Depth (m)	Avg. Velocity (m/s)	Hydraulic Radius (m)	Top Width (m)	Thalweg Elevation (masl)	Channel Bed D_{50} (mm)	Fbo	Channel Slope (m/m)	Natural Scour Potential (m)	Degradation Risk	Likelihood	Consequence	Utility Exposure Risk Ranking
2	WM-1299	Buried 150 mm cast iron watermain	Appears to be cross under channel downstream form Fairford Dr bridge.	51.2	346.58	1.12	2.57	1.04	13.35	345.24	104	2	0.0143	0.84	-	Med	Med	3
2	A68-523/1968	Buried 60 mm DP FortisBC gas line	Appears to cross under channel ~ 2.1 m upstream from Fairford Dr bridge ROW.	51.2	347.75	1.93	0.86	1.76	14.5	345.54	104	2	0.0143	0.64	-	Med	High	2
3	WM-1560	Buried 250 mm cast iron watermain	Appears to cross channel below Main St bridge deck.	51.2	356.97	1.38	2.91	1.27	12.78	355.03	83	1.8	0.0308	0.80	-	High	High	1
3	Tel-2	Critical underground Telus duct through steel pipe spanning channel above ground	Appears to cross over the channel through a steel pipe immediatelty upstream from Main St bridge.											n/a		Low	Low	5
5	U-95G/1984	Buried 219 mm DP FortisBC gas line	Appears to cross under channel upstream from Superstore bridge.	51.2	361.97	1.12	1.47	1.1	13.2	360.37	95	1.9	0.0291	0.89		Med	High	2
5	UC-1	Buried 2 x 3 phase primary underground conductor within East Hospital access culvert embankment	Appears to be within East Hospital access culvert embankment.											n/a	-	Low	Low	5
6	WM-3764	Buried 450 mm steel watermain	Appears to cross under channel immediately downstream from Government St culvert.	51.2	379.98	1.57	3.92	1.38	10.49	377.98	180	2.1	0.0488	0.69	-	Med	High	2
6	Tel-3	Buried Telus duct within Government St culvert embankment	Appears to be within the Government St culvert embankment.											n/a		Low	Low	5
6	4500001349/2003	Buried 168 mm DP/PE FortisBC gas line inside 323 mm sleeve	Appears to cross under channel through a 323 mm sleeve upstream from Government St bridge.	51.2	382.15	2.53	1.8	2.31	16.16	379.07	180	2.1	0.0523	0.58		Med	High	2
6	A68-356/1968	Buried 60 mm DP FortisBC gas line	Appears to cross under channel upstream from Government St bridge.	51.2	382.15	2.53	1.8	2.31	16.16	379.07	180	2.1	0.0523	0.58		Med	High	2
7	SSGM-1846-1828	Buried 200 mm PVC sanitary gravity main	Appears to cross under channel.	51.2	388.15	1.23	3.47	1.13	11.99	386.11	164	2	0.04	0.87	1	High	High	1
7	WM-4030	Buried 300 mm ductile iron	Appears to be buried riprap spanning the channel.	51.2	399.81	2.44	2.22	1.97	13.22	396.52	164	2	0.0458	0.90	1	High	High	1

Reach No.	ID No.	Description	Observations	Design Discharge (m^3)	200-year Water Surface Elevation (masl)	Avg. Hydraulic Depth (m)	Avg. Velocity (m/s)	Hydraulic Radius (m)	Top Width (m)	Thalweg Elevation (masl)	Channel Bed D_{50} (mm)	Fbo	Channel Slope (m/m)	Natural Scour Potential (m)	Degradation Risk	Likelihood	Consequence	Utility Exposure Risk Ranking
		watermain below large riprap																
7	WM-2562	Exposed 200 mm cast iron watermain, appears to be abandoned in place	Exposed pipe is collapsed immediately downstream of Dartmouth Rd bridge., appears to be abandoned.	51.2	399.81	2.44	2.22	1.97	13.22	396.52	164	2	0.0458	0.90	1	High	Low	3
7	2800403069	Exposed 114 mm DP FortisBC gas line, identified by FortisBC as abandoned	Exposed pipe is severely damaged immediately upstream form Dartmouth Rd bridge, appears to be abandoned.	51.2	400.46	2.06	2.69	1.52	9.27	397.54	164	2	0.0458	0.95	1	High	Low	3
9	WM-474	Buried 250 mm PVC watermain	Appears to cross under channel.	51.2	431.98	1.33	3.62	1.21	10.6	430.05	121	1.9	0.048	0.99	2	High	High	1
9	WM-927	Buried 250 ductile iron watermain	Appears to cross under channel.	51.2	431.98	1.33	3.62	1.21	10.6	430.05	121	1.9	0.048	0.99	2	High	High	1
11	WM-2113	Buried 250 mm ductile iron watermain	Appears to cross under channel.	50.06	487.85	1.32	3.34	1.25	11	485.87	105	2	0.041	0.88	4	Med	High	2
11	WM-2113	Buried 250 mm ductile iron watermain	Appears to cross under channel.	50.06	508.53	1.24	3.26	1.11	9.9	506.72	105	2	0.058	1.12	4	High	High	1

Appendix C Conceptual Designs



Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

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Engineering

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Scale horiz.	1:500
Scale vert.	1:100
Sheet	1 of 13
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Plot date	2019/09/20

Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 0+000 - 0+400 OPTION 1 CONCEPT - REACH 1 & 2

Drawing No.: C201

Revision No.: 1

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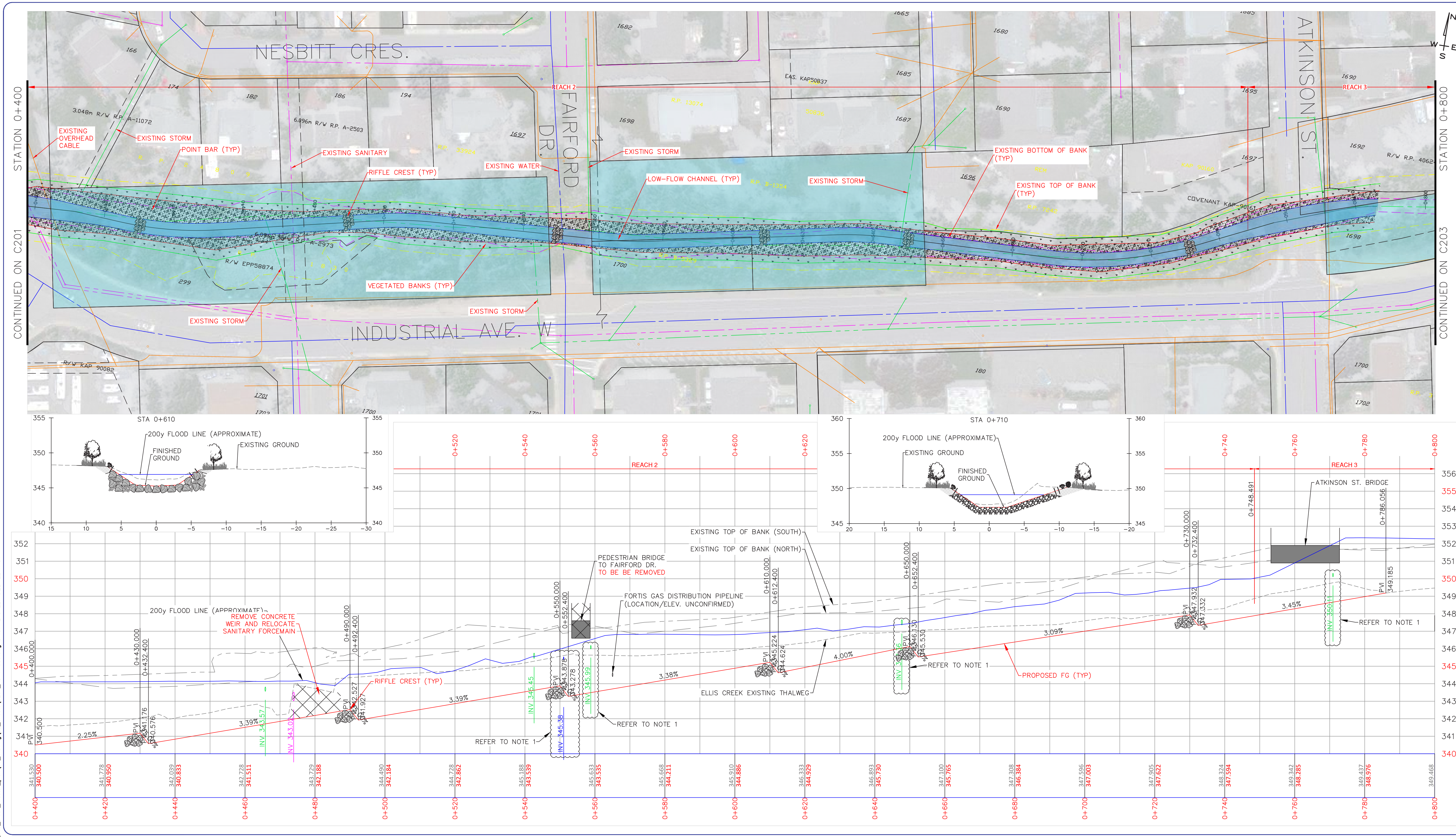

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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

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1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

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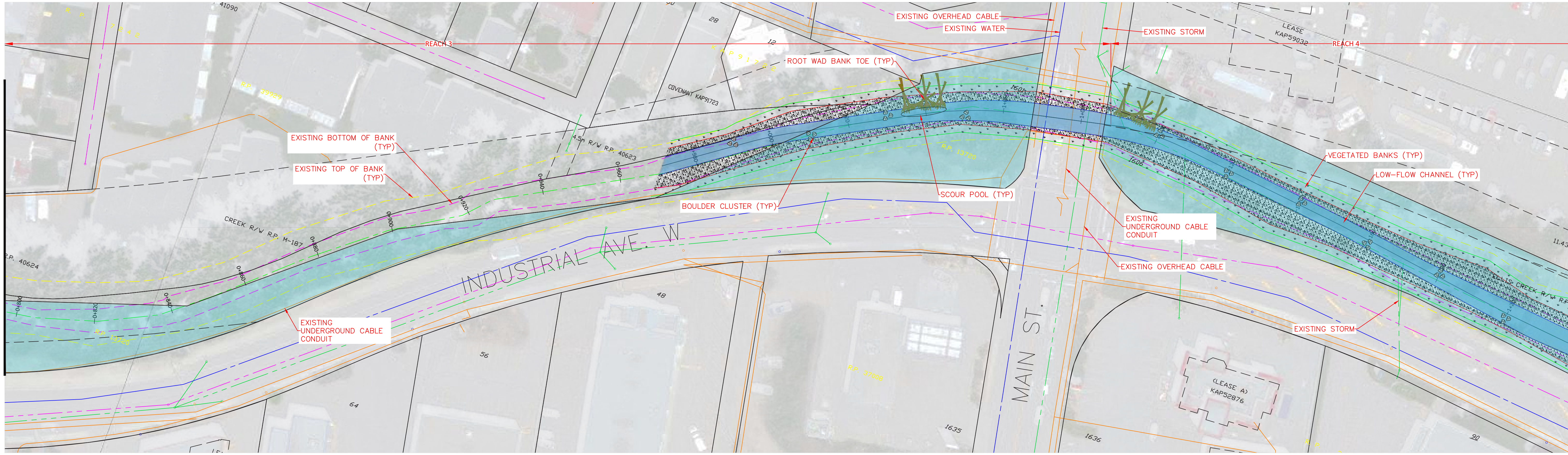
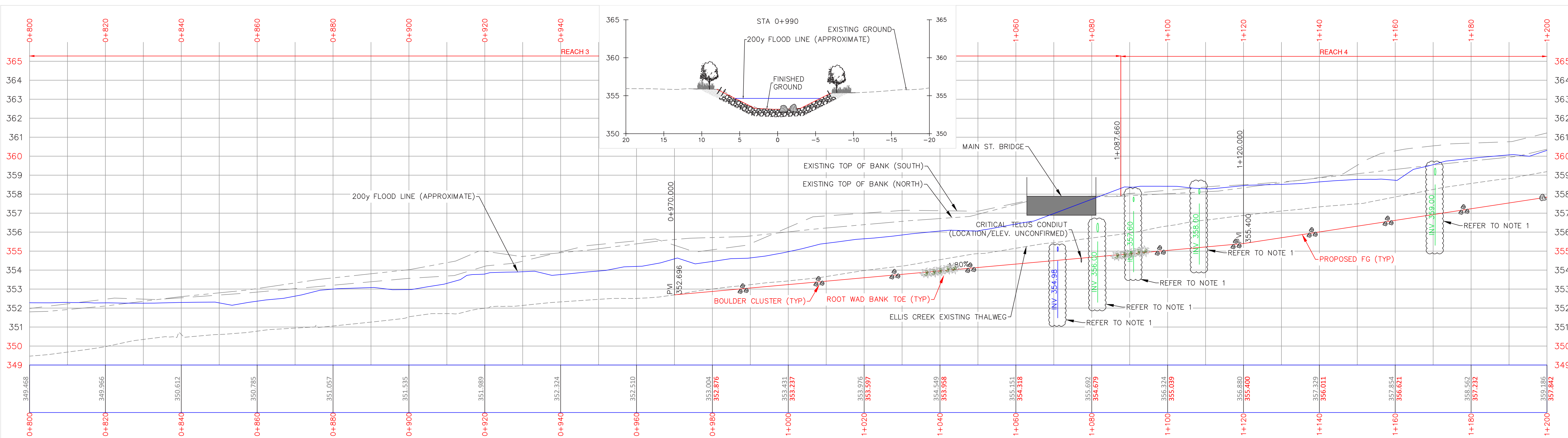
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 0+400 - 0+800 OPTION 1 CONCEPT - REACH 2 & 3

Drawing No. C202

Revision No. 1





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank
City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor
Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

Proposed

Creek CL
Bottom of Bank
Top of Riprap
Top of Bank
Watercourse
Riprap
Vegetation
Rock Riffle
Boulder Cluster
Root Wad
Granular Bedding
Grading / Fill
Void Filled Riprap
Boulder Cluster
Soil Wraps
Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

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Project
ELLIS CREEK MASTER PLAN

Title
PLAN PROFILE STATION 0+800 - 1+200
OPTION 1 CONCEPT - REACH 3 & 4

Drawing No.
C203

Revision No.
1

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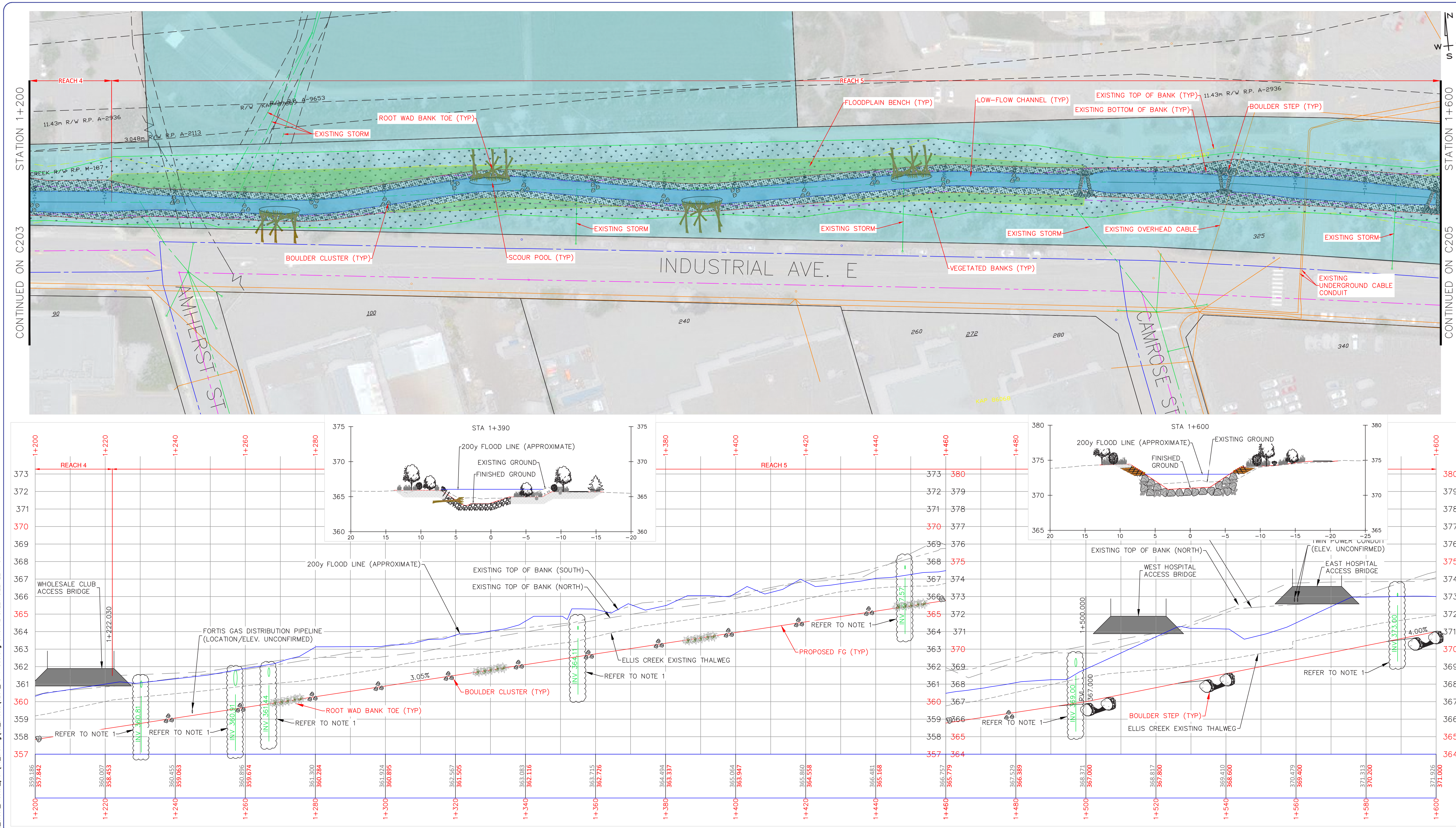

Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
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Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 1+200 - 1+600 OPTION 1 CONCEPT - REACH 5 & 6

Drawing No. C204

Revision No. 1

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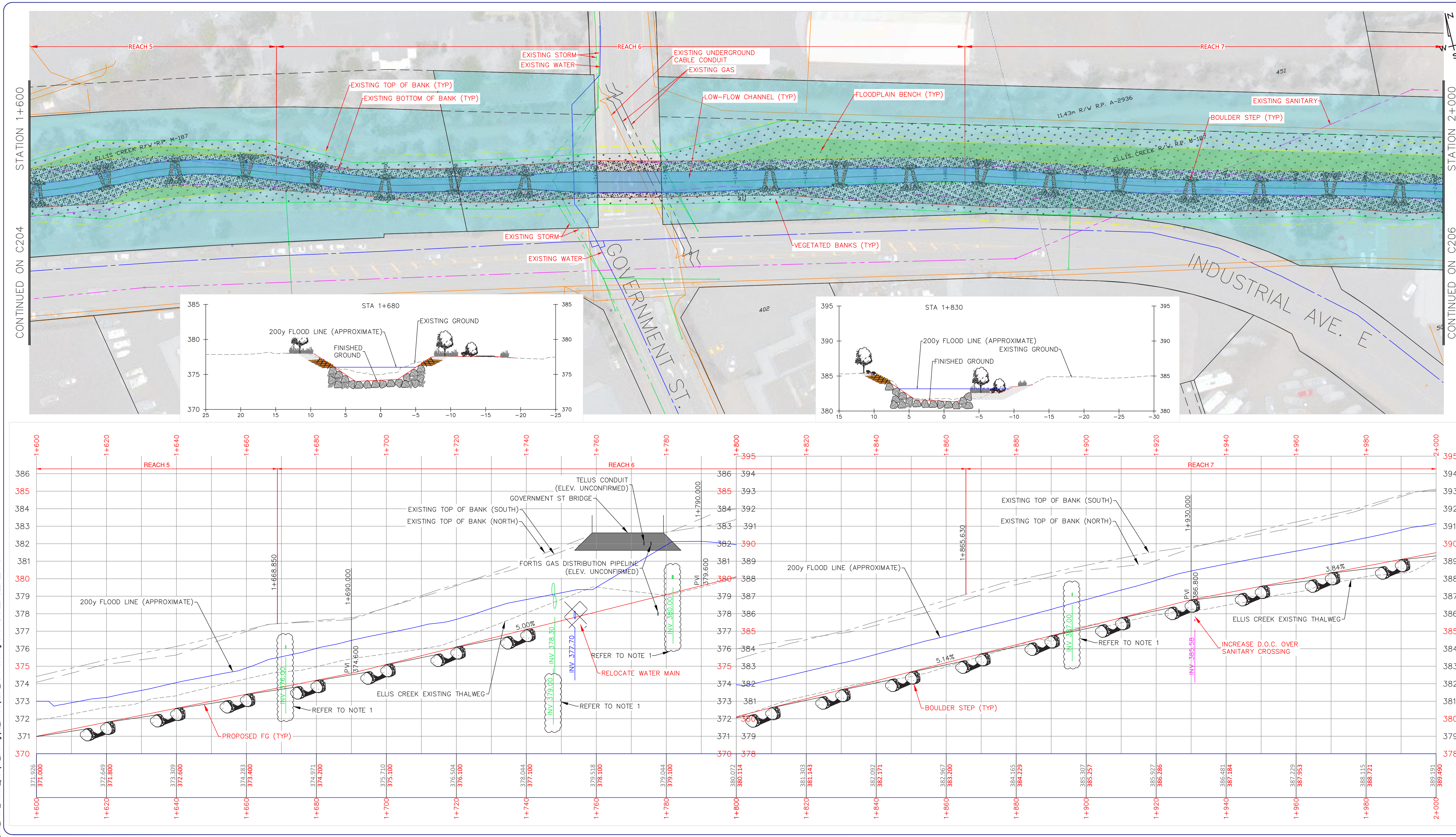

Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main, Electrical cable/telephone, Sanitary sewer, Storm sewer, Domestic watermain, Creek CL, Property line, Bottom of Bank, Top of Bank, City Owned Property, Sanitary manhole, Storm manhole, Double catch basin, Side inlet catch basin, Top inlet catch basin, Catch basin manhole, Storm oil interceptor, Water valve, Water curb stop, Water hydrant, Water air valve, Street light, Power pole, Electrical service box, Electrical vault, Electrical transformer

Proposed

Creek CL, Bottom of Bank, Top of Riprap, Top of Bank, Watercourse, Riprap, Vegetation, Rock Riffle, Boulder Cluster, Root Wad, Granular Bedding, Grading / Fill, Void Filled Riprap, Boulder Cluster, Soil Wraps, Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

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Sheet 5 of 13
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Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 1+600 - 2+000 OPTION 1 CONCEPT - REACH 6 & 7

Drawing No. C205

Revision No. 1

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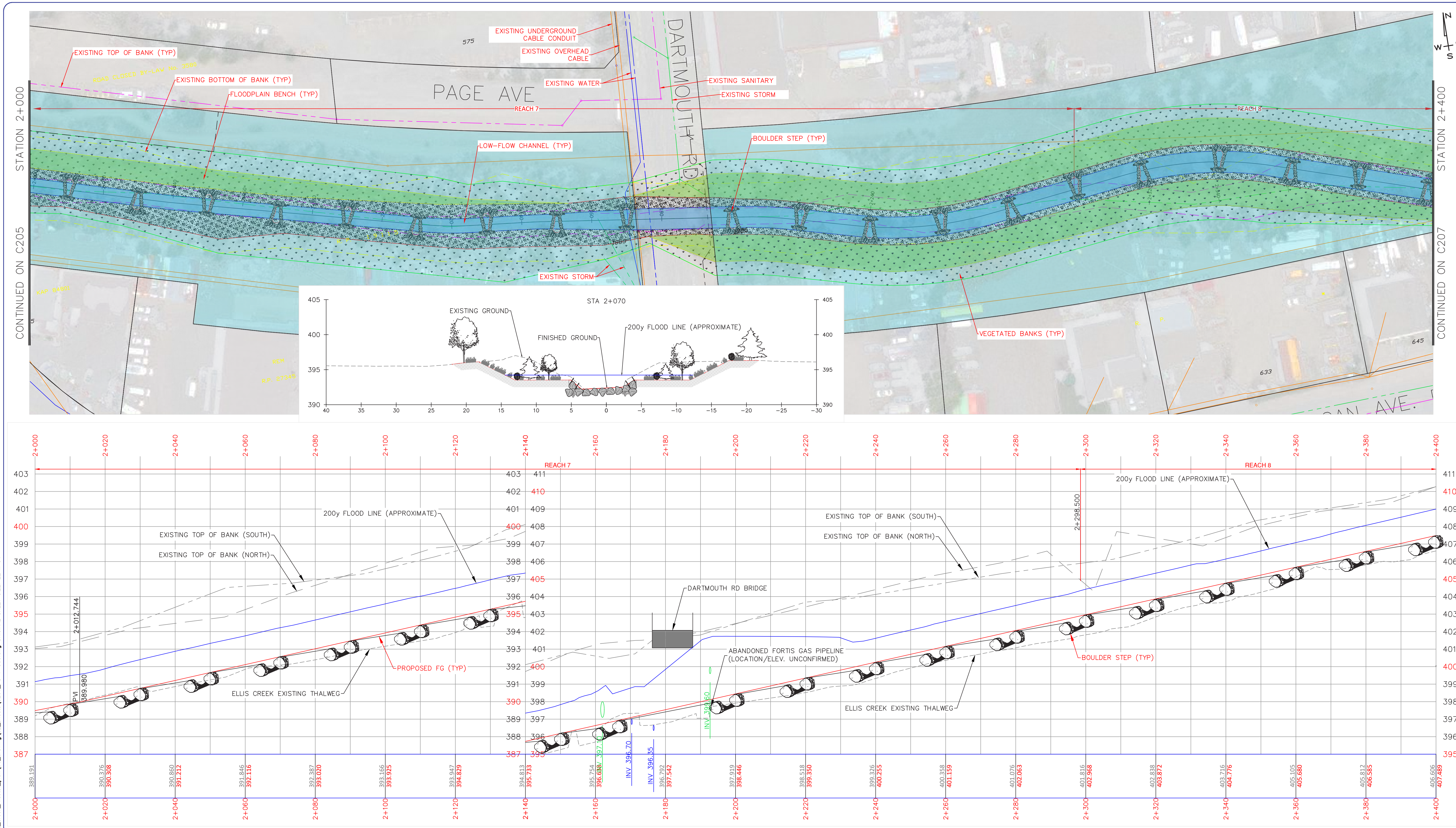

Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

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Sheet 6 of 13
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Approved by SK
Plot date 2019/09/20

Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 2+000 - 2+400 OPTION 1 CONCEPT - REACH 7 & 8

Drawing No. C206

Revision No. 1

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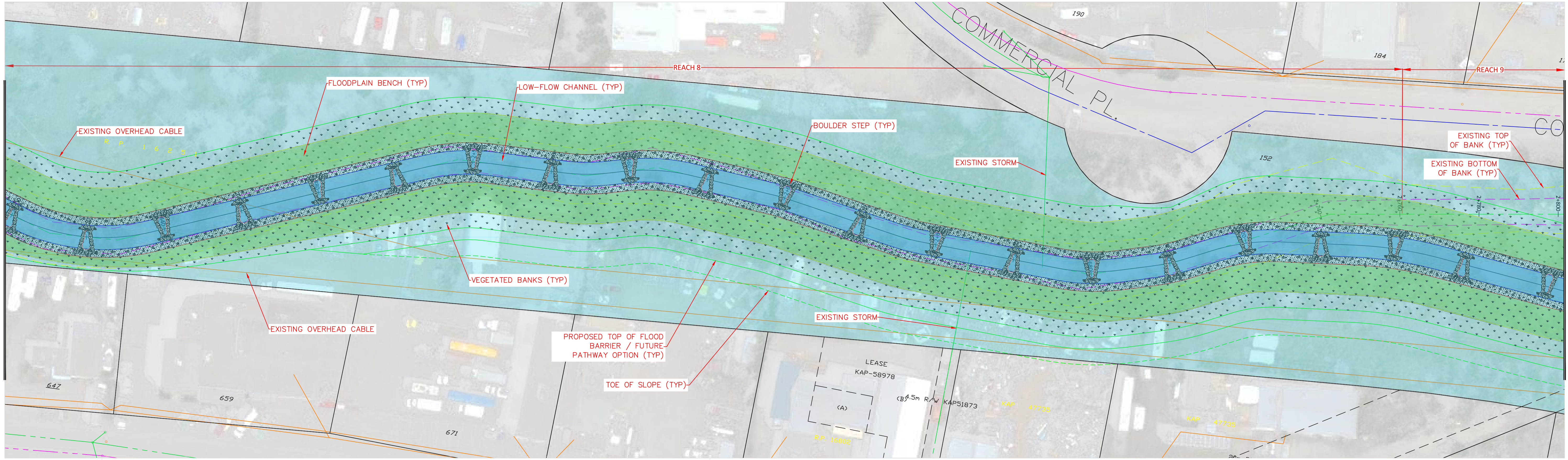

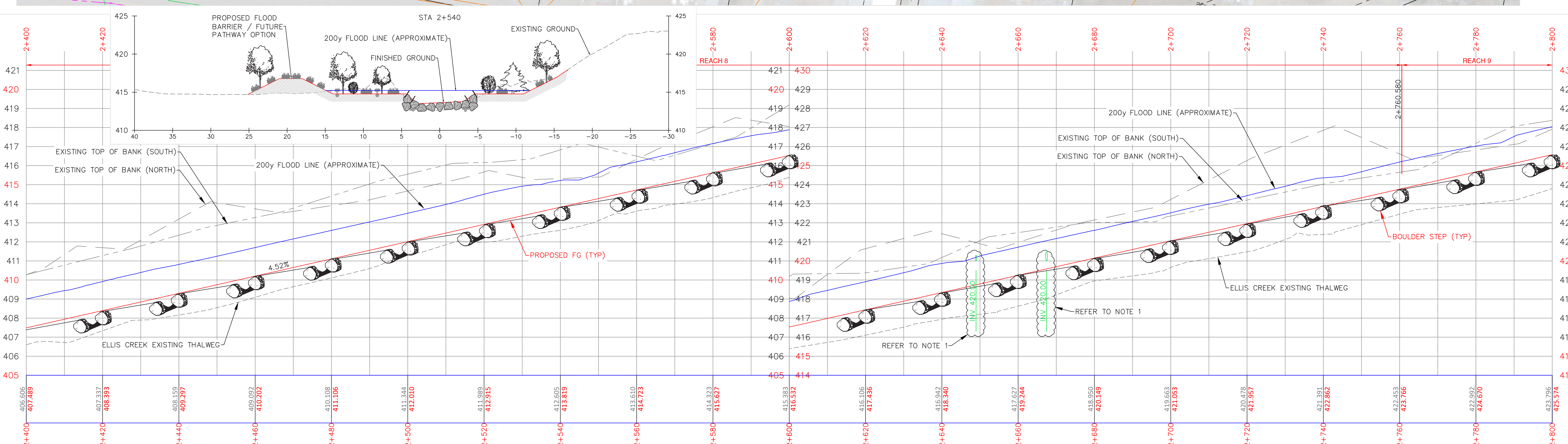

Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank
City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor
Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

Proposed

Creek CL
Bottom of Bank
Top of Riprap
Top of Bank
Watercourse
Riprap
Vegetation
Rock Riffle
Boulder Cluster
Root Wad
Granular Bedding
Grading / Fill
Void Filled Riprap
Boulder Cluster
Soil Wraps
Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz.	1:500
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Sheet	7 of 13
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Approved by	SK
Plot date	2019/09/20

Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 2+400 - 2+800 OPTION 1 CONCEPT - REACH 8, 9 & 10

Drawing No. C207

Revision No. 1

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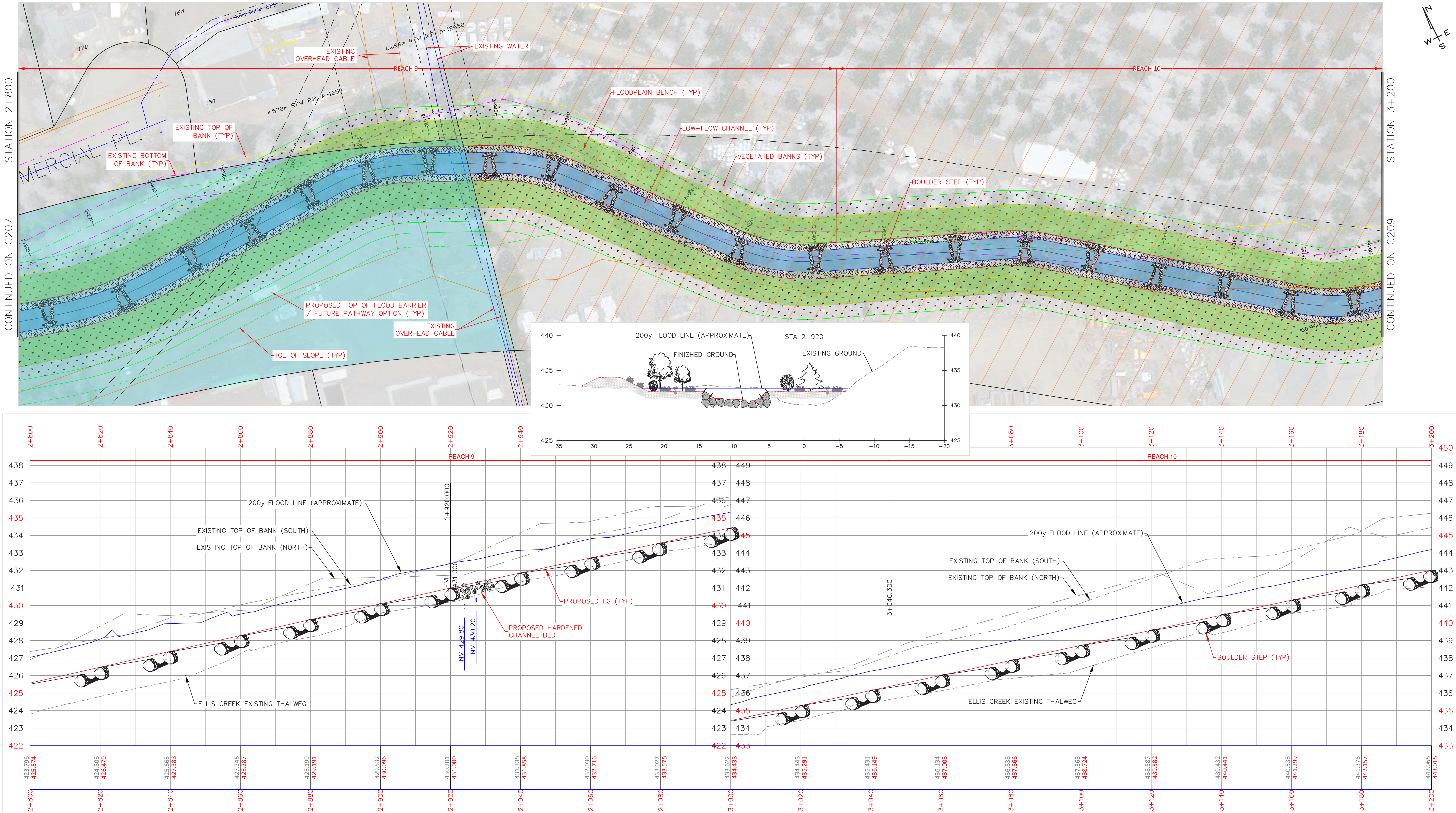

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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

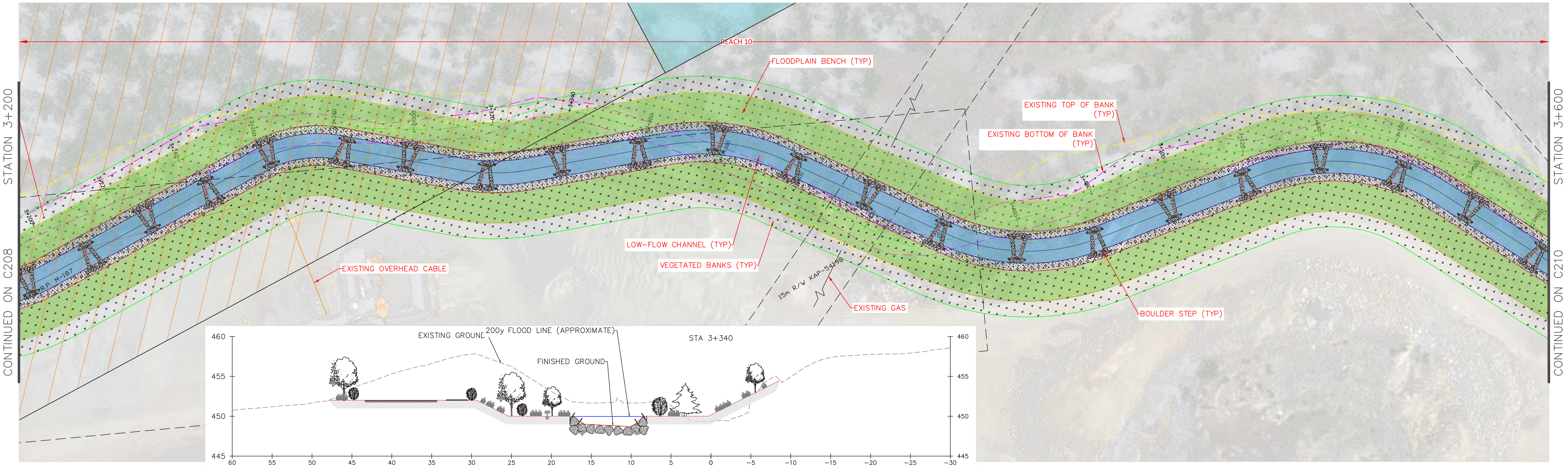
Scale horiz.	1:500
Scale vert.	1:100
Sheet	8 of 13
Drawn by	CM
Approved by	SK
Plot date	2019/09/20

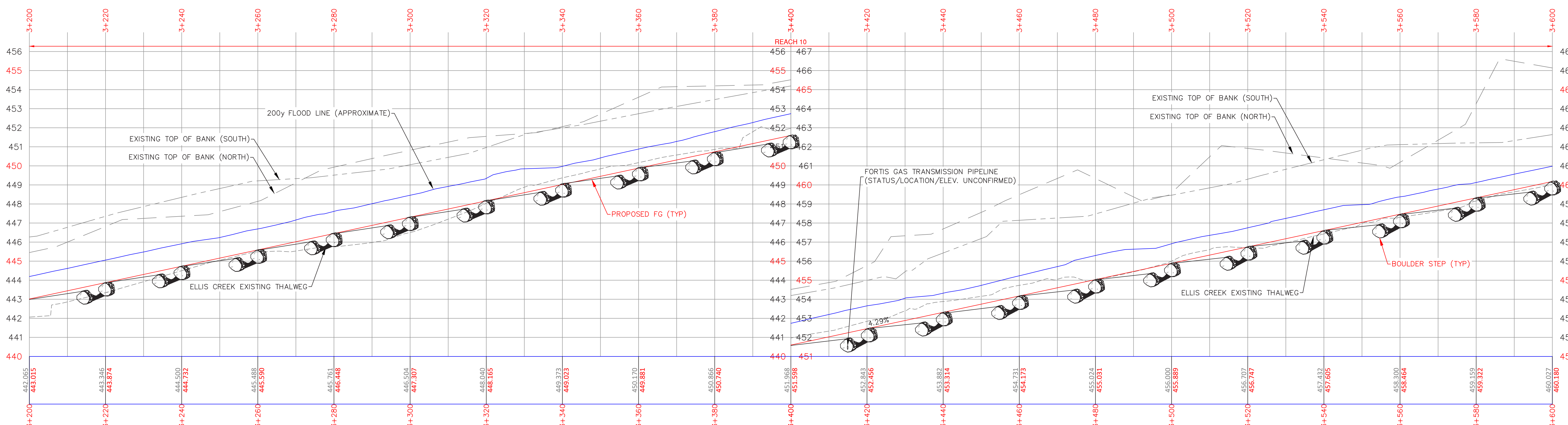
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 2+800 - 3+200 OPTION 1 CONCEPT - REACH 9 & 10

Drawing No.: C208

Revision No.: 1





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 9 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

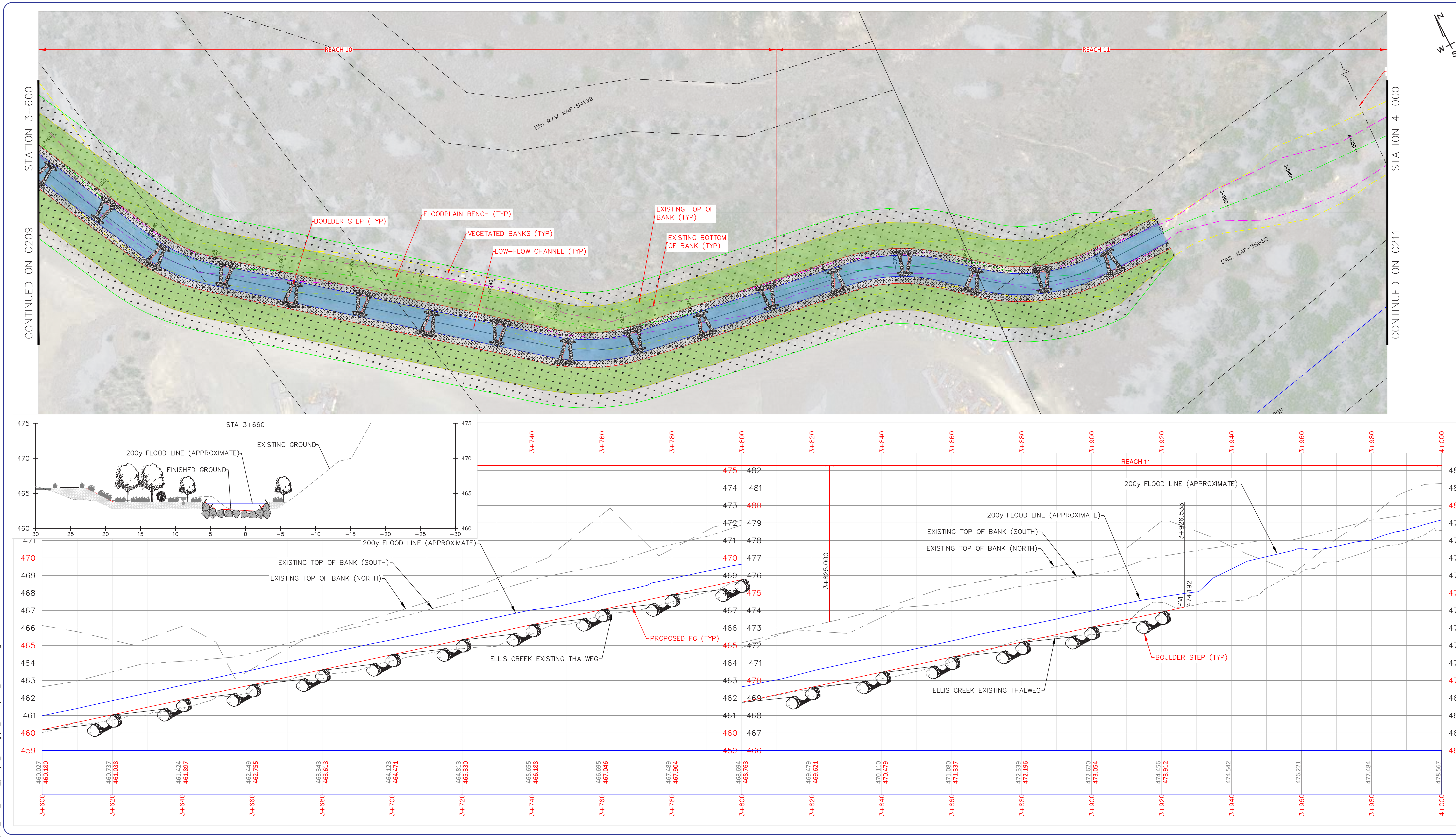
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 3+200 - 3+600 OPTION 1 CONCEPT - REACH 10 & 11

Drawing No. C209

Revision No. 1

V:\01117\active\111710066_ellis_creek_master_plan\05_drawing\02_sheets\C201_FG 1-500.dwg ORIGINAL SHEET SIZE: 22 x 34"



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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz.	1:500
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Sheet	10 of 13
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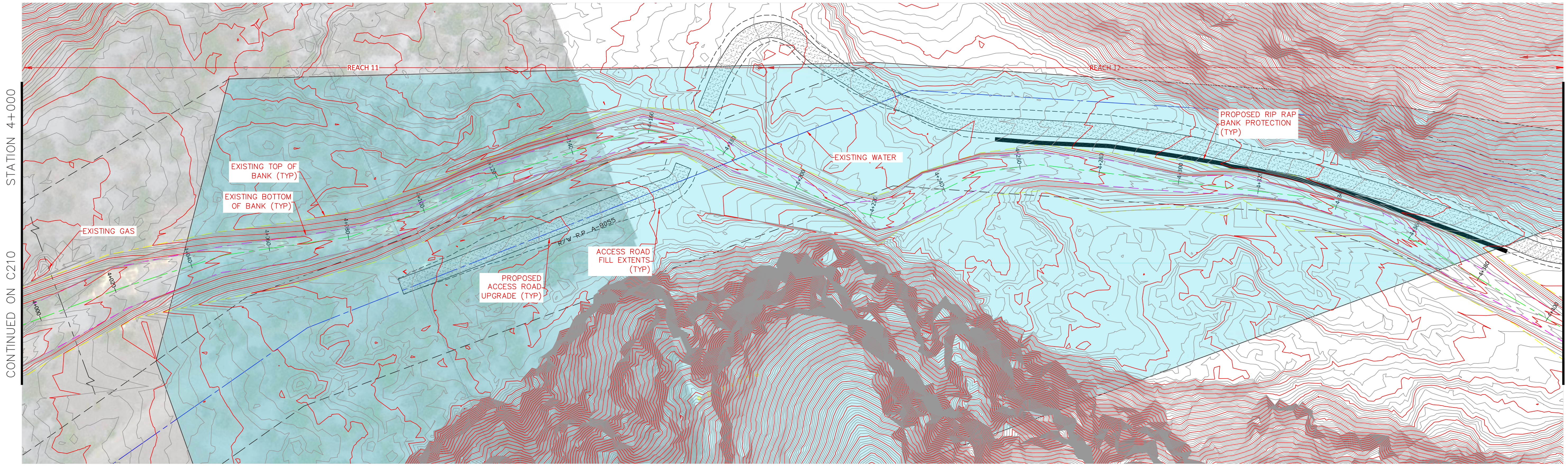
Plot date	2019/09/20

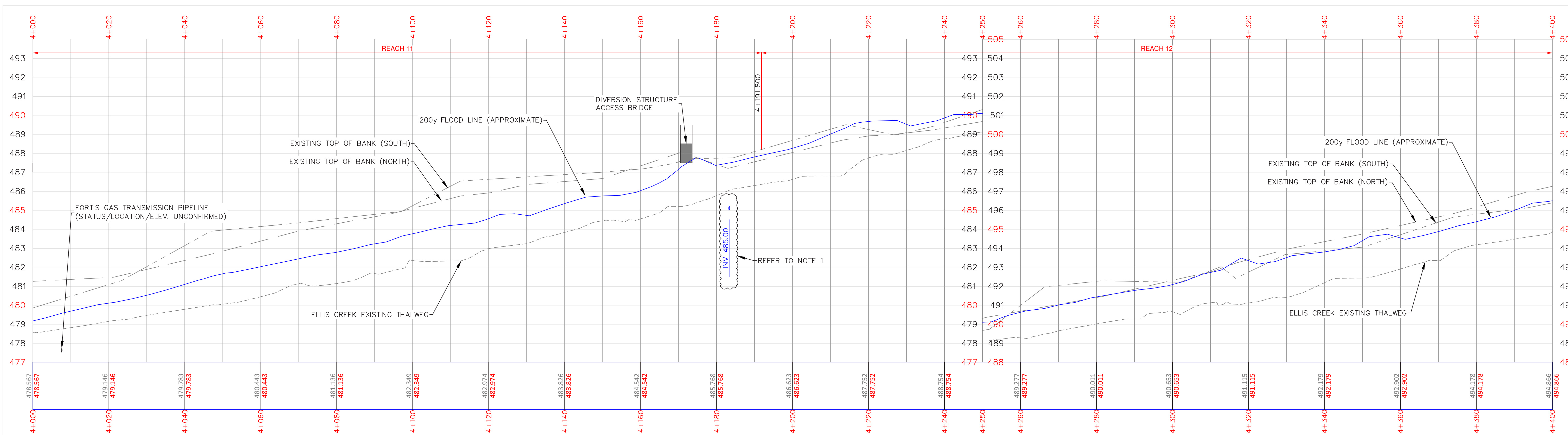
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 3+600 - 4+000 OPTION 1 CONCEPT - REACH 10 & 11

Drawing No. C210

Revision No. 1





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 11 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 4+000 - 4+400 OPTION 1 CONCEPT - REACH 11 & 12

Drawing No. C211

Revision No. 1

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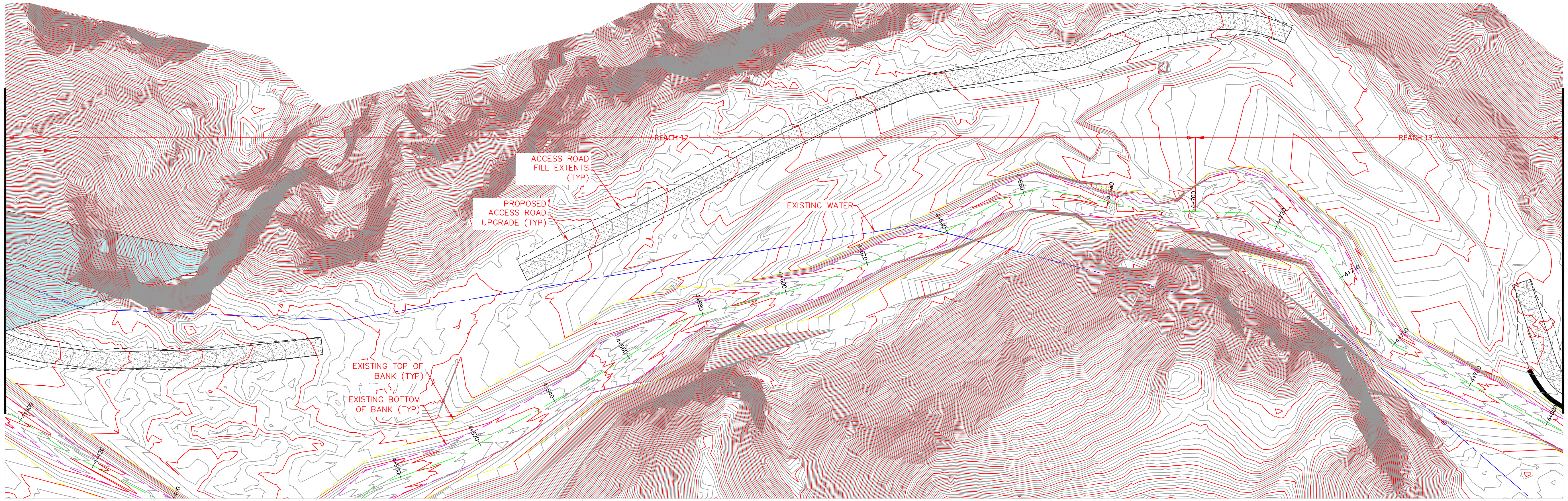

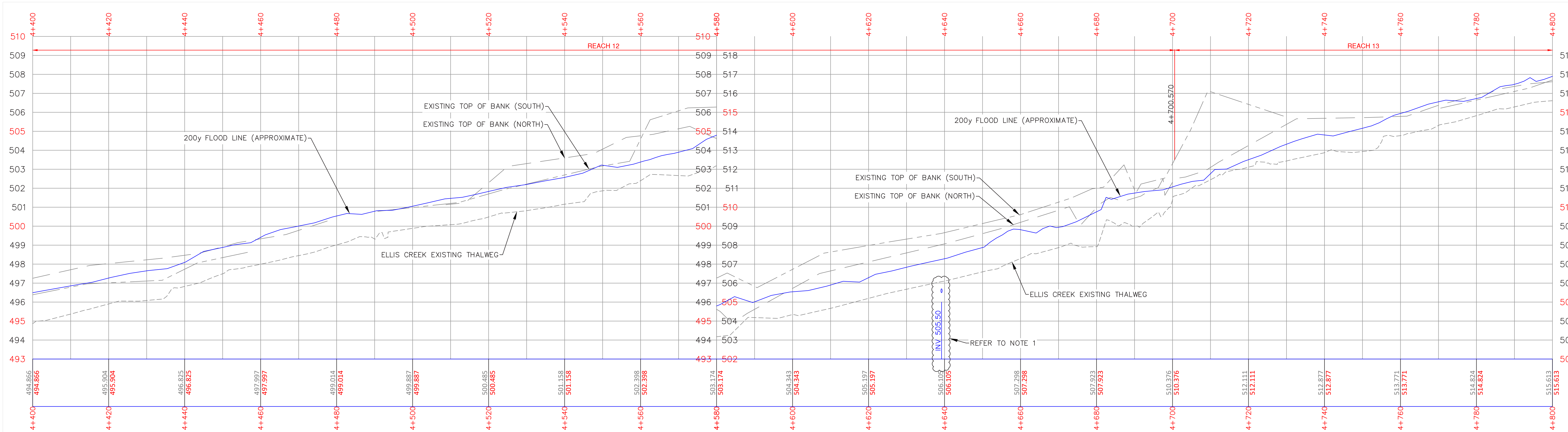

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Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main; Electrical cable/telephone; Sanitary sewer; Storm sewer; Domestic watermain; Creek CL; Property line; Bottom of Bank; Top of Bank; City Owned Property; Sanitary manhole; Storm manhole; Double catch basin; Side inlet catch basin; Top inlet catch basin; Catch basin manhole; Storm oil interceptor; Water valve; Water curb stop; Water hydrant; Water air valve; Street light; Power pole; Electrical service box; Electrical vault; Electrical transformer

Proposed

Creek CL; Bottom of Bank; Top of Riprap; Top of Bank; Watercourse; Riprap; Vegetation; Rock Riffle; Boulder Cluster; Root Wad; Granular Bedding; Grading / Fill; Void Filled Riprap; Boulder Cluster; Soil Wraps; Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

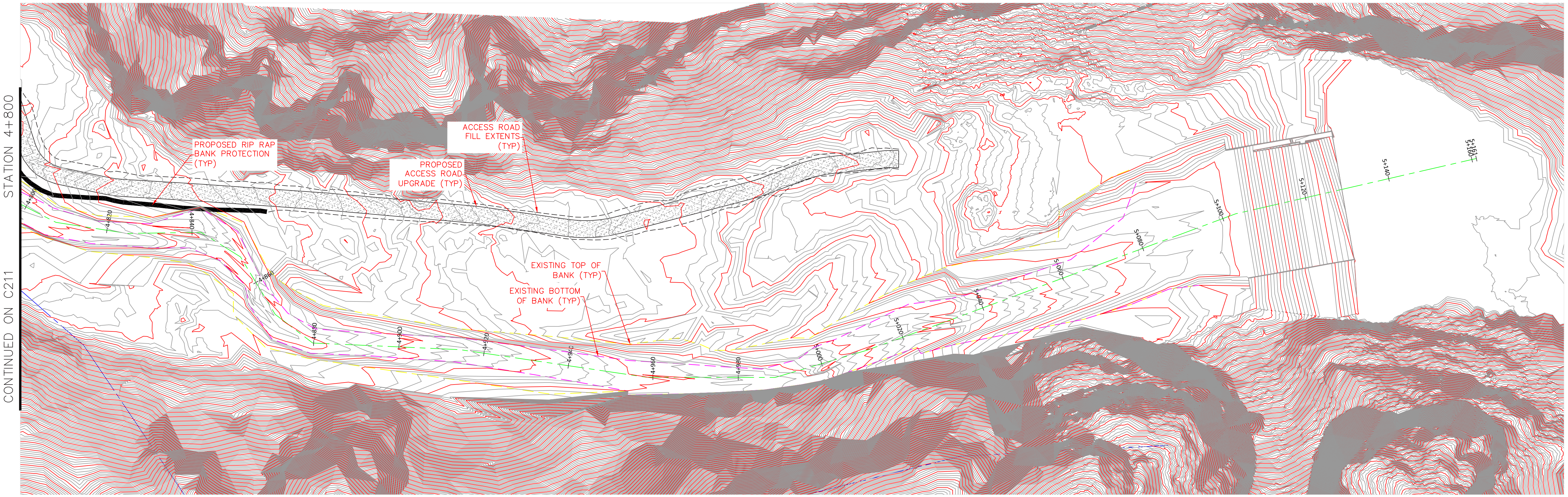
Scale horiz.	1:500
Scale vert.	1:100
Sheet	12 of 13
Drawn by	CM
Approved by	SK
Plot date	2019/09/20

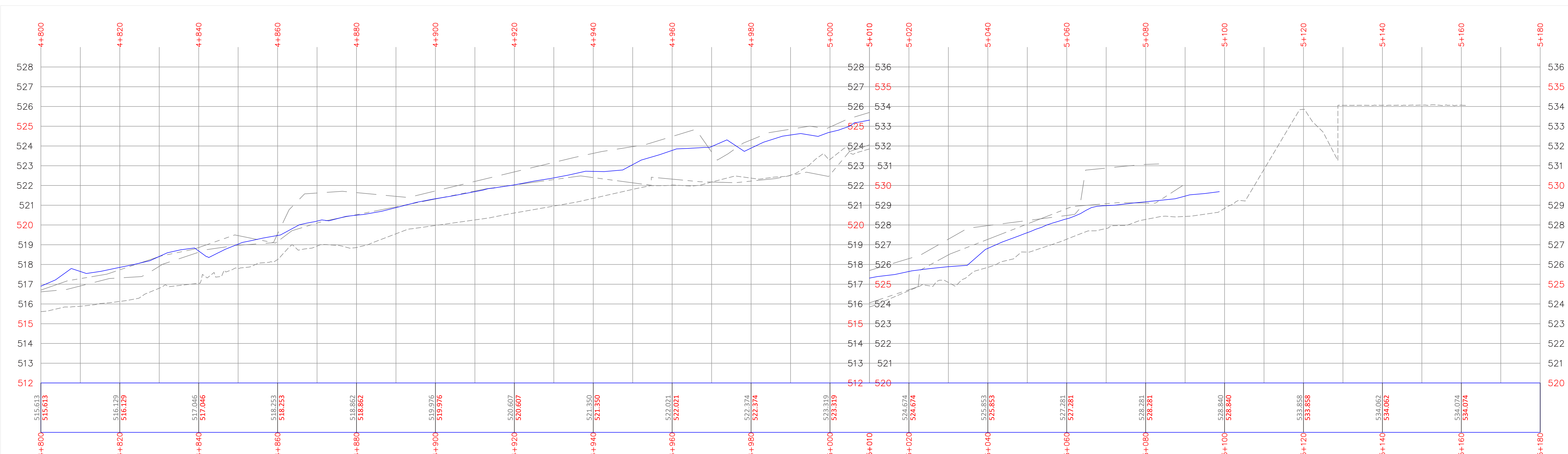
Project: ELLIS CREEK MASTER PLAN

Title: PLAN PROFILE STATION 4+400 - 4+800 OPTION 1 CONCEPT - REACH 12 & 13

Drawing No. C212

Revision No. 1





Notes:

1. ELEVATIONS OF CROSSING UTILITY UNKNOWN. DISPLAYED LOCATION FOR REFERENCE ONLY.
2. THALWEG IS THE LINE CONNECTING THE LOWEST POINTS OF SUCCESSIVE CROSS-SECTIONS ALONG ELLIS CREEK.

Existing

Gas main
Electrical cable/telephone
Sanitary sewer
Storm sewer
Domestic watermain
Creek CL
Property line
Bottom of Bank
Top of Bank
City Owned Property
Sanitary manhole
Storm manhole
Double catch basin
Side inlet catch basin
Top inlet catch basin
Catch basin manhole
Storm oil interceptor
Water valve
Water curb stop
Water hydrant
Water air valve
Street light
Power pole
Electrical service box
Electrical vault
Electrical transformer

Proposed

Creek CL
Bottom of Bank
Top of Riprap
Top of Bank
Watercourse
Riprap
Vegetation
Rock Riffle
Boulder Cluster
Root Wad
Granular Bedding
Grading / Fill
Void Filled Riprap
Boulder Cluster
Soil Wraps
Riparian Plantings

No.	Date (YYYY/MM/DD)	By	Revisions	CKD
1	2020/02/14	CJM	ISSUED FOR PLANNING	SK

CITY OF Penticton Engineering

Engineers Seal

Scale horiz. 1:500
Scale vert. 1:100
Sheet 13 of 13
Drawn by CM
Approved by SK
Plot date 2019/09/20

Project
ELLIS CREEK MASTER PLAN

Title
PLAN PROFILE STATION 4+800 - 5+161
OPTION 1 CONCEPT - REACH 13

Drawing No.
C213

Revision No.
1

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Appendix D Opinion of Probable Cost

Description	Reach 1	R each 2	R each 3	R each 4	R each 5	R each 6	R each 7	R each 8a	R each 8b	R each 9	R each 10a	R each 10b	R each 11	Reach 12	Reach 13
Construction	$490,000	$1,050,000	$350,000	$410,000	$1,340,000	$840,000	$1,680,000	$1,060,000	$1,320,000	$1,550,000	$2,240,000	$1,280,000	$1,250,000	$270,000	$160,000
Engineering, Administration and PM	$270,000	$520,000	$190,000	$230,000	$670,000	$460,000	$840,000	$530,000	$660,000	$780,000	$1,010,000	$570,000	$620,000	$30,000	$20,000
Construction Management	$10,000	$30,000	$10,000	$10,000	$20,000	$20,000	$30,000	$20,000	$20,000	$30,000	$30,000	$30,000	$20,000	$5,000	$5,000
Culture and Heritage Monitoring	$10,000	$30,000	$10,000	$10,000	$20,000	$20,000	$30,000	$20,000	$20,000	$30,000	$30,000	$30,000	$20,000	$5,000	$5,000
Environmental Monitoring	$30,000	$50,000	$30,000	$30,000	$30,000	$30,000	$50,000	$30,000	$30,000	$50,000	$50,000	$50,000	$30,000	$10,000	$10,000
Reach Sub-Total	$810,000	$1,680,000	$590,000	$690,000	$2,080,000	$1,370,000	$2,630,000	$1,660,000	$2,050,000	$2,440,000	$3,360,000	$1,960,000	$1,940,000	$320,000	$200,000
Contingency (~30%)	$240,000	$500,000	$180,000	$210,000	$620,000	$410,000	$790,000	$500,000	$610,000	$730,000	$1,000,000	$590,000	$580,000	$100,000	$60,000
Reach Total	**$1,060,000**	**$2,180,000**	**$770,000**	**$900,000**	**$2,700,000**	**$1,790,000**	**$3,410,000**	**$2,150,000**	**$2,660,000**	**$3,160,000**	**$4,350,000**	**$2,540,000**	**$2,520,000**	**$420,000**	**$260,000**