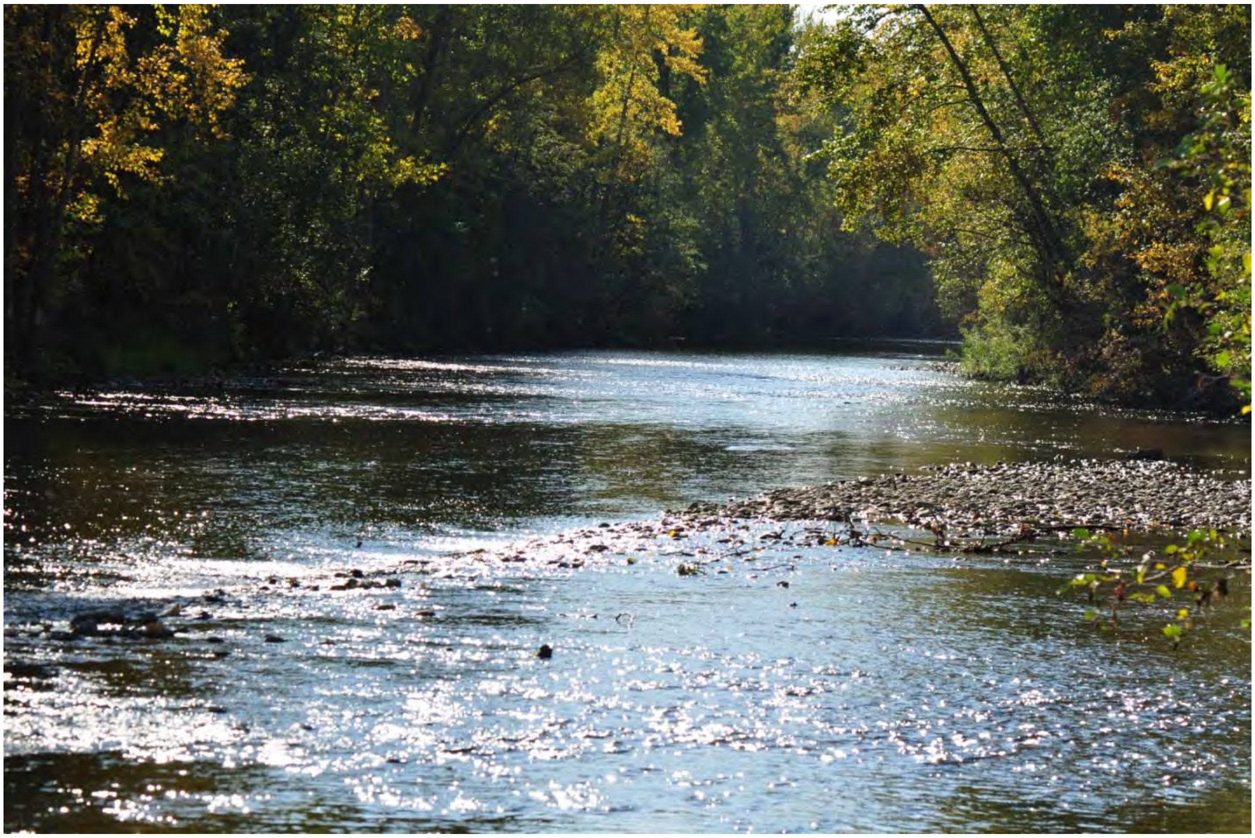
Mission Creek Setback Dike Engineered Design Report



Prepared for

MISSION CREEK
RESTORATION INITIATIVE

Prepared by

DOBSON
Engineering Ltd.

December 2015

Executive Summary

Mission Creek is the largest tributary to Okanagan Lake in terms of volume and fish habitat potential. The Mission Creek watershed is approximately 800 km^2 with a main channel length of approximately 75 km across the Okanagan Valley's uplands and large fan adjacent to Okanagan Lake. With construction of flood protection dikes along the main channel in the 1950s, Mission Creek has lost more than 60% of its channel length on the fan, 80% of its spawning and rearing habitat, and 75% of its wetland and riparian areas.

The Mission Creek Restoration Initiative (MCRI) is a multi-phase, multi-stakeholder partnership formed in 2008 to restore natural hydrological and biological functions and processes to the lower reaches of Mission Creek in the City of Kelowna, BC. The MCRI was primarily created to address kokanee stock decline in Okanagan Lake. Consequently, the goal of the MCRI is to improve native fish stocks that would in turn result in local recreational and economic benefits. The Mission Creek Restoration Initiative focuses on the lower 12 km of the mainstem channel from the East Kelowna Road Bridge to Okanagan Lake.

The Setback Dike Project was developed to improve hydrological function and connectivity, and spawning, rearing and holding habitat for native kokanee, rainbow trout and mountain whitefish. The proposed setback dike will be situated on a parcel of land adjacent to Mission Creek near Casorso Road that was purchased by MCRI. This project has been undertaken in conjunction with the MCRI, Urban Systems and LGL Limited (professional consulting firms), and the University of British Columbia. Survey data of the section were provided by the City of Kelowna.

The Setback Dike Project focuses on relocating a 475 m section of dike on the south bank of the creek between Casorso Road and Gordon Drive. A setback distance of up to ~5 channel widths between the dikes will be feasible on the Mission Creek Setback Dike Project. This setback distance of up to ~150 m will result in more defined pool-riffle-run habitats, well-sorted substrates, braided channels with numerous islands, and ecological interfaces of pools and riparian zones to provide stream-side cover and useable energy sources for large areas of functional fish habitat (i.e., pool, riffle and run mesohabitats with species-specific preferred depths velocities, substrates and cover). The proposed design includes restoring the floodplain using overflow weirs and meander notches to encourage water onto the floodplain during most freshets. In addition there are two overflow weirs that will allow flow from the main channel to re-water the existing side channel as well as four meander notches that have been strategically located to coincide with existing point bars along the north bank of the main channel. The upstream meander notch includes one of the overflow weirs to provide for outflow to the main channel and access for fish at all flows. Large woody debris (LWD) cover structures will be added to each of the meander notches. The LWD will be sourced from trees salvaged during removal of the existing dike or during construction of the proposed setback dike. No instream work is

scheduled during the removal of the existing dike and construction of the new dike that is scheduled to occur between November 2105 and March 31 2016.The construction of the overflow weirs and meander notches are scheduled for 2016 during the normal instream work window for Mission Creek.

Design parameters, criteria and constraints with regards to the engineering design are summarized in the table below.

Parameter	Criteria & Constraints
Biological	• Provide high quality rearing habitat for juvenile and adult rainbow trout and mountain whitefish; • Provide high quality holding habitat for adult rainbow trout and mountain whitefish; • Provide high quality spawning habitat for kokanee, rainbow trout and mountain whitefish; • Create side channel habitat to provide short term rearing and flood flow refugia; • Preferred spawning velocities of ~0.15-0.91 m/s to accommodate kokanee and rainbow trout during fall and spring, respectively, spawning periods; • Preferred spawning substrate sizes of ~6-102 mm; • Cover that includes instream large woody debris and overhanging riparian vegetation in pools and larger boulders in riffles; and • Abundant and diverse floodplain vegetation.
Flow Management and Flood Protection	• Accommodate a Q_{200} of 144 m^3/s; • Consistent with provincial dike design criteria including freeboard of 0.6 m, crest elevation based on current data, crest width of 4 m, dike slopes of 2:1, drainage; and • Provide equipment access for dike management.
Physical Constraints / Design Limitations	• Prevent impacts to the adjacent Okanagan Indian Band IR #8; • Ensure public walkway access for Mission Creek Greenway; • Suitable soils to support relocated dike; • Minimize disturbance to wildlife trees and riparian vegetation; • Incorporate bank protection; and • Minimize disturbance to adjacent private lands.

Setting back the dike and establishing a wide floodplain will serve many purposes including: habitat restoration, erosion reduction, water quality improvements, groundwater recharge, wildlife habitat and migration corridors, and reduction of flood hazard risks. Undeveloped, natural floodplains provide stream energy dissipation during floods and in turn provide lower velocity refuge areas for a variety of aquatic species. These lower velocity areas also promote the wide dispersal and deposition of sediment and organic debris over the floodplain surface.

It was concluded that the site conditions for the setback dike alignment within Lot EPP21089 were suitable for the construction of the setback dike. The existing dike will provide a sufficient volume of suitable material for the construction of the new setback dike. The existing dike material does not meet provincial specifications in silt/clay sized material but additional fine grained material will be added as the new dike is constructed.

The setback dike design is consistent with provincial regulations and guidelines and will accommodate peak flow conditions. Due to the project's location, public considerations were incorporated into both the design and construction phases. For example, the walking path was realigned in the setback dike design to tie into the existing path connections at the Casorso Road Bridge (east) and the existing dike (west).

If construction work is planned carefully, the existing dike can be removed in the dry with no detrimental impacts on the water quality in the creek. Setback dike construction should be scheduled during the low water period in Mission Creek when the groundwater levels along the setback alignment are low. This would typically be from September – March. Instream construction of the meander pools and large woody debris cover structures should occur during the 'least risk' fisheries work window – 22 July to 24 August.

In summary, the anticipated benefits associated with the proposed setback dike project on Mission Creek include:

- a reduction in flood stage as a consequence of a wider stream valley with a central channel and floodplain;
- increased floodplain flows and thus floodplain channels, diversity and interaction with active channel
- fine sediment deposition on the floodplain during flood events;
- increased stability and quality of spawning gravel in riffles and runs;
- increased shading and cover with the development of riparian areas beside the central channel;
- restoration of in-channel and floodplain refugia habitats for fish that allows them to escape high velocities during flood-flow events; and
- increased diversity and abundance of various terrestrial and aquatic wildlife species resulting from the establishment of riparian areas, floodplain wetlands and sloughs.

Following the spring freshet in 2016 and in subsequent years, FLNRO staff will evaluate the effects of floods on the new floodplain to determine if additional connectivity between mainstem and the floodplain is required to prevent fish stranding as flows recede. Any additional instream work would be scheduled for the normal instream work window later in the year.

The following design report for the Mission Creek Setback Dike Project is divided into three sections. Biological Considerations focuses on the ecological benefits associated with setting the dike back from the channel, and identifies the preference characteristics of fish rearing and spawning habitats for kokanee, rainbow trout and mountain whitefish which were then incorporated as physical criteria in the design. Detailed Engineering Design provides design information for the setback dike component of the project. Construction Implementation Strategy provides details on the construction implementation plan including estimated construction costs and schedule options.

Acknowledgements

The Mission Creek Restoration Initiative would like to acknowledge the following individuals for their invaluable contributions to this project:

- Todd Cashin, Suburban & Rural Planning Manager, City of Kelowna;
- Tara White, R.P.Bio., Sr. Fisheries Biologist, Fish & Wildlife Branch, FLNRO, Penticton;
- Shaun Reimer, PEng., Public Safety & Protection, FLNRO, Penticton.

The Mission Creek Restoration Initiative would also like to acknowledge the work completed by University of British Columbia Okanagan Faculty of Engineering students, Jordan Beach, Dylan de Sousa and Jacob Paul who prepared the initial conceptual design report as part of their ENGR 499 course, and their Faculty Supervisor Dr. Bahman Naser. Much of the detail incorporated in this report has been drawn from the students ENGR 499 Conceptual Design Report – Mission Creek Dike Setback Design Project. A special note of thanks is given to Jacob Paul who put in a lot of additional time to revise the design drawings after he had completed his course and graduated. Thank you all for all your time and effort that you dedicated to this project. The fish in Mission Creek thank you also.

Contributors

The Mission Creek Restoration Initiative would like to thank the following for their financial contributions to the design phase of the project:

- Habitat Conservation Trust Fund
- Okanagan Basin Water Board
- UBCO – in-kind

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. Introduction

This report has been prepared to summarize the planning and design work that has been completed to relocate an existing ~475 m long section of dike on the south side of Mission Creek between Casorso Road and Gordon Drive (Figure 1). The proposed habitat improvements to restore the floodplain include using overflow weirs and meander notches to provide improved pool habitat and to encourage the return to more naturalized flow patterns are also described. The Mission Creek Restoration Initiative (MCRI) acquired Lot EPP21089 adjacent to the creek. This parcel of land offers the opportunity to remove the existing dike that is located along the bank of the channel and to construct a setback dike that would allow this reach of the creek to re-establish some of its natural functions.

1.1. Background

The Mission Creek mainstem was diked and channelized in the 1950s to provide flood protection to adjacent private lands. As a result of these past changes, the creek's ecosystem was severely impacted. Elements of the creek such as: channel length, spawning and rearing habitats, as well as wetland and riparian areas were adversely affected.

Mission Creek is Okanagan Lake's most important kokanee producing stream. Hence, recovery of the Okanagan Lake kokanee population, via the Okanagan Lake Action Plan, has been considered the top priority for the Ministry of Forests, Range and Natural Resource Operations (FLNRO) and the Region 8 Fisheries Program for more than a decade. The MCRI was formed in 2008 to address the declining kokanee populations and habitat degradation concerns in Mission Creek noted in the Okanagan Lake Action Plan. The MCRI is a dedicated working group of representatives from local, provincial, and federal governments; non-profit organizations; and First Nations. This project is being undertaken under the auspices of the MCRI.

The restoration of habitat in Mission Creek is fundamental to overall fish stock recovery. The proposed removal of a section of the existing dike and construction of a setback dike, in combination with creation of meander notches with pools and LWD within the Mission Creek channel, will allow a section of the creek to return to a more natural, complex and diverse habitat state that will assist in restoring depressed fish stocks and potentially some species at risk. It will also restore some habitat quality and quantity, reduce flood risks, biodiversity, cultural and recreational values. The design philosophy is to create a self-sustaining ecosystem by restoring natural processes, both physical and biological, and to re-establish hydrologic connectivity between the river channel, floodplain, riparian corridor and adjacent upland habitat. For example, floodplain that was isolated by the existing dike will be restored constructing overflow weirs and meander pools along the left bank of the channel to encourage a more natural flow pattern.

In recent years, Mission Creek peak flows have been increasing and at times have exceeded the current capacity of the channel. The Lower Mission Creek Hydraulic Capacity Study (LMCHCS) completed by Tetra Tech EBA (2014) for FLNRO provided an updated estimate of the effectiveness of the current channel and dike design. The study produced an updated 200-year flood profile for the lower reaches of Mission Creek based on a maximum instantaneous flow of 144 m^3/s and a maximum daily flow of 118 m^3/s at the Casorso Road Bridge. These discharge values were used in the design of the setback dikes. Other relevant references included: historical hydrometric data from Water Survey of Canada for the station Mission Creek near East Kelowna (station ID 08NM116); hydrology and hydraulic studies; Mission Creek Water Use Plan; fish habitat assessment and restoration plans; and research by Dr. Leif Burge including Analysis of Sedimentation and Sediment Mitigation Strategies for Mission Creek (Burge 2009) and Mission Creek Channel and Streamway Width Assessment (Burge 2010). The City of Kelowna engaged Levelton Consultants Ltd. to complete a geotechnical assessment of the soils in the project area to identify the various soil layers, their depths and their capacity to support the proposed setback dike.

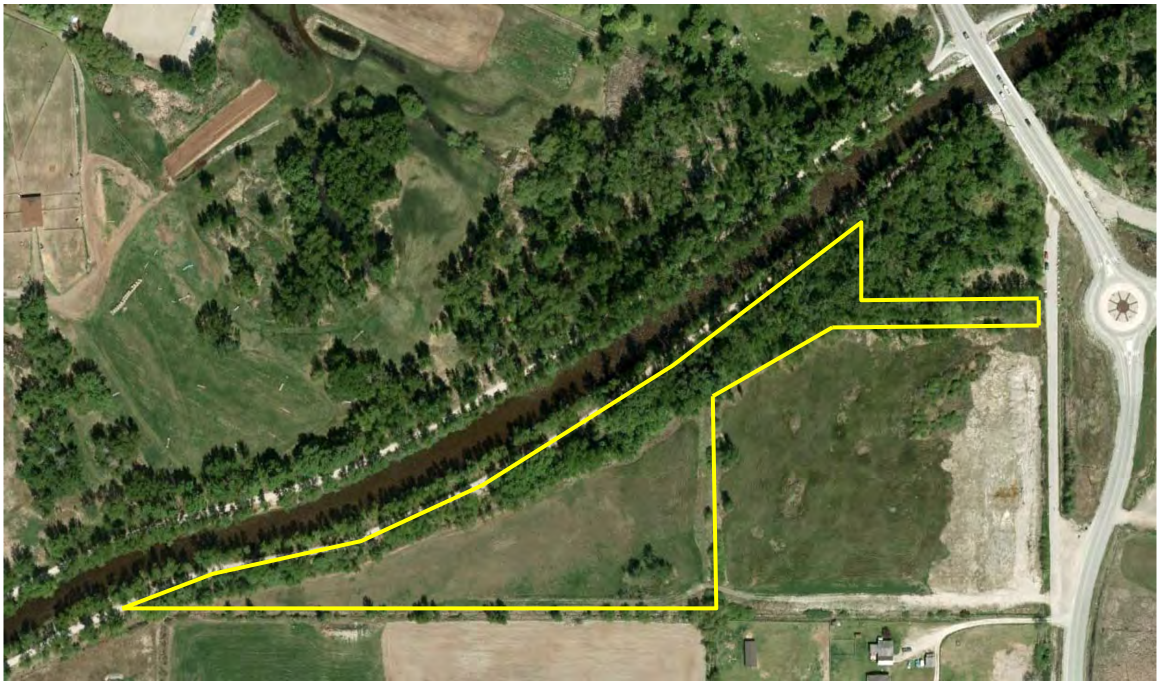


Figure 1. Mission Creek Setback Dike Project Area (Google Earth Pro, 12 May 2012)

Preparing to develop a project such as this one involved a review of similar projects in the area relative to design and construction methods and an evaluation of the effectiveness and performance of each completed project. The City of Kelowna constructed a section of dike on Mission Creek downstream of the project area in 2012 that helped to inform the design of the proposed setback dike. Another similar project was the Okanagan River Restoration Initiative (ORRI) near Oliver, BC. This project apportioned some flow through old oxbows and meanders along reaches of the river that had been channelized in the early 1950s and restored habitat and diversified channel patterns. Given the similarity between the ORRI project and the MCRI's long-term goals the lessons learned on that project were very useful.

The following report establishes the biological and hydrological criteria for the design, discusses some conceptual restoration options, and provides the engineering design for the MCRI's setback dike demonstration project for the reach of Mission Creek between the Casorso Road and Gordon Drive bridges.

2. Biological Considerations

2.1. Ecological Benefits

River ecosystems are based on interactions between the main channel and adjacent low velocity habitats during overbank flooding (Welcomme 1989). In comparison to a natural stream, a channelized stream with parallel diking is confined to a single thread channel with slight sinuosity and a higher flow velocity and shear stress for a given discharge. Vegetation removal from the area for maintenance of the diked channel is undertaken in order to decrease roughness, increase flood conveyance, and lower flood stages within the channel. However, these maintenance practices can exacerbate bed and bank erosion and sediment transport. For example, increased channel bed erosion can cause channel incision and over-steepened streambanks, leading to accelerated bank erosion.

Diking also disconnects the floodplain from being inundated by floodwaters, inhibiting natural geomorphic processes that allow for sediment deposition and storage on the floodplain (Anonymous 2002). As occurs in Mission Creek, sediments produced by erosion of banks and from upstream sediment sources that would naturally be stored on the floodplain or channel are routed to downstream lower gradient reaches where they accumulate. The aggraded sediments then may need to be physically removed from the channel to prevent the channel bed (and water table) from being higher than the surrounding residential and agricultural lands.

Man's understanding of the natural behaviour of streams has increased tremendously over the last decade. We now realize that natural hydrologic and geomorphic processes establish the pools, riffles, glides, point bars, undercuts and cover that fish require during the various phases of their life history. Gore and Shields (1995) have suggested that the sustained ecosystem function of river ecosystems is dependent upon maintenance of watershed and floodplain integrity. Furthermore, they state that renewal of physical and biological interactions between the main channel, backwaters and floodplains is central to the rehabilitation of rivers. The ecological values of floodplain habitats along leveed rivers has been restored on the Danube River in the Czech Republic by constructing new dikes more distant from the channel (i.e., setback dikes) (Gore and Shields 1995). The setback dikes have permitted controlled inundation of floodplains within their borders and allowed the river to meander within a belt-width prescribed by dike dimensions.

Although complete recovery of geomorphic processes and ecological functions of Lower Mission Creek is possible by removal of the existing dikes, this would compromise flood protection for the City of Kelowna, as well as stream-side residents. The dikes also serve a purpose of maintenance access and provide an important component of the Mission Creek Greenway Project, functioning as trails for recreational access. Recovery of stream processes and functions is still possible, however, by re-setting the dikes where feasible as setback dikes on either both sides or one side of the mainstem channel. Observations of the existing channel demonstrate that even a 10 to 20 m widening of the channel, to a width of 40 to 50 m between dikes, can result in bar formation, better pool and riffle definition, some substrate sorting to improve the quality and quantity of spawning gravels, and the creation of a few small vegetated islands.

Setback dikes are generally constructed parallel to the stream but placed far enough from the active channel to allow overbank flooding and some natural floodplain function. In 1938, prior to channelization, the active channel widths (i.e., wetted and gravel bars) averaged between 60 and 80 m between KLO Road and the present-day Regional Park (Gaboury and Slaney 2003). The recommended degree of setback is variable, but Cowx and Welcomme (1998) suggest that the minimum setback distance between dikes should be 7 to 10 channel widths to restore the majority of floodplain functions. A setback distance of up to ~8 channel widths between the dikes will be feasible on the Mission Creek Setback Dike Project. This setback distance of up to ~150 m will result in more defined pool-riffle-run habitats, well-sorted substrates, braided channels with numerous islands, and ecological interfaces of pools and riparian zones to provide stream-side cover and useable energy sources for large areas of functional fish habitat (i.e., pool, riffle and run mesohabitats with species-specific preferred depths velocities, substrates and cover). Allowing flood flows to enter historic overflow channels on the Mission Creek floodplain will also provide additional refuge areas, and potentially short term fish rearing habitats.

With a setback dike design, a portion of fine sediment load (sand and silt) would be deposited on the floodplains. The increased stability of spawning gravels and reduced in-channel sedimentation should improve egg incubation success at riffle and pool tail-out spawning areas in the main channel. The gravel substrate will also be less consolidated or cemented, which will improve spawning and incubation success for salmonids such as kokanee, who concentrate within this section during spawning.

Setting back the dikes serves many purposes including: habitat restoration, erosion reduction, water quality improvements, groundwater recharge, wildlife migration corridors, and reduction of flood hazard risks. Dikes directly affect floodplain extent and connectivity with the stream channel, which then affects habitat. Undeveloped, natural floodplains provide stream energy dissipation by reducing velocities and providing areas for sediment deposition including organic debris. These low velocity areas provide refuge areas for aquatic species during floods and are excellent habitat for a wide variety of fish and wildlife species.

Meandering channels are more stable and provide a greater variety of flow conditions and aquatic habitat diversity than channelized streams (Keller and Brookes 1984). Meandering channels have been reconstructed in some channelized rivers of Denmark (Anonymous circa 1997), Germany (Glitz 1983) and the U.S. (Gore and Shields 1995) over the past 20 years. Creation of regularly spaced meander pools on the left bank of Mission Creek would improve rearing and holding habitats for salmonids, and create more stable gravel accumulations at pool tail-outs. A deeper pool with instream large woody debris (LWD) cover would provide important refugia, rearing and holding areas for trout, mountain whitefish and kokanee.

In summary, the anticipated benefits associated with the proposed setback dike project on Mission Creek include:

- a reduction in flood stage as a consequence of a wider stream valley with a central channel and floodplain;
- increased floodplain flows and thus floodplain channels, diversity and interaction with active channel
- fine sediment deposition on the floodplain during flood events;
- increased stability and quality of spawning gravel in riffles and runs;
- increased shading and cover with the development of riparian areas beside the central channel;
- restoration of in-channel and floodplain refugia habitats for fish that allows them to escape high velocities during flood-flow events; and
- increased diversity and abundance of various terrestrial and aquatic wildlife species resulting from the establishment of riparian areas, floodplain wetlands and sloughs.

The design for the Mission Creek Setback Dike Project will not only consider and address fish and wildlife habitat issues but also other design and infrastructure components of the present channelized system, including flooding and flood routing, and land drainage.

2.2. Design Components

2.2.1. Preference Criteria for Spawning and Rearing Habitat

Habitat preferences for spawning and rearing habitats of kokanee, rainbow trout and mountain whitefish inhabiting streams should be the basis for fish habitat criteria in the engineering design for the Mission Creek Setback Dike Project. Habitat preference information for these three target species have been assembled from Whyte et al. (1997) and Ennis (1995) (Table 1).

Table 1. Habitat preferences for kokanee, rainbow trout and mountain whitefish inhabiting streams

Physical Habitat	Spawning/Egg Incubation			Rearing			
	Kokanee	Rainbow Trout	Mountain Whitefish	Rainbow Trout		Mountain Whitefish	
				Juvenile	Adult	Juvenile	Adult
Season	fall	spring	fall	all	all	all	all
Mesohabitat	riffle, pool tail-out	riffle, pool tail-out	riffle	riffle, pool	riffle, pool	riffle, run, pool, off-channel, backwaters	riffle, run, pool
Dominant substrate type	gravel & cobble	gravel with <5% fines	gravel & cobble	cobble & boulder		sand & gravel	gravel & cobble
Substrate size (mm)	13-102	6-52		0.1-0.4	0.5-0.8		
Depth range (m)	0.06-0.46	0.18-2.50		0.3-1.2		<3.0	
Water velocity (m/s)	0.15-0.91	0.48-0.91		0.08-0.20	0.2-0.3	slow to moderate	moderate to fast
Cover	-	-	-	cobble & boulder (riffle); LWD (pool); overhanging veg.		cutbanks, LWD, aquatic vegetation	

2.2.2. Floodplain and Riparian Habitat

Floodplains provide a hydrologic function by conveying and storing major floodwaters (Sparks 1995). In comparison to the existing channel, it is estimated that a wider stream valley that incorporates floodplains could lower the flood stage at 144 cms by ~0.15 m. A shallower flood depth (similar to a natural river) would reduce the tractive force, increasing the stability of spawning gravels in mainstem riffles and pool tail-outs.

Channelized or diked streams lack the vegetated riparian buffers and floodplains that take up nutrients and ameliorate the effect of increased nutrient-loading of rivers, streams and lakes by run-off from fertilized lands (Sparks 1995). Planting of a diverse riparian area of trees, shrubs, grasses and forbs should be included in the setback dike design option. The establishment of riparian areas along the existing channel will:

- provide diverse habitats for terrestrial and aquatic wildlife;
- provide corridors for wildlife movement;
- provide instream LWD cover and organic matter for watercourses;
- provide overhanging cover;
- stabilize the streambanks and reduce erosion;
- control temperature in the watercourse through shading; and
- restore the visual quality and amenity of the landscape.

2.2.3. Side Channel Habitat

Historic creek channels are currently present but dewatered behind the left bank dike on Mission Creek. Restoring flow onto the floodplain from the mainstem would provide short term rearing habitats and flood flow refugia for the target fish species. It is anticipated that greater ecological benefits would accrue if portions of the floodplain were inundated at relatively frequent flow events such as ≥1 in 2 year flows. As fish stranding may occur as flood flows recede, it will be important to ensure that the floodplain is connected to the mainstem of Mission Creek to allow for fish passage. Each channel inlet should also be armoured to reduce channel bed and bank erosion, and to maintain the discharge threshold when the channel is inundated.

In summary, relevant physical fish habitat criteria in the engineering design should include:

- Provide high quality rearing habitat for juvenile and adult rainbow trout and mountain whitefish;
- Provide high quality holding habitat for adult rainbow trout and mountain whitefish;
- Provide high quality spawning habitat for kokanee, rainbow trout and mountain whitefish;
- Create side channel habitat to provide short term rearing and flood flow refugia;
- Preferred spawning velocities of ~0.15-0.91 m/s to accommodate kokanee and rainbow trout during fall and spring, respectively, spawning periods;
- Preferred spawning substrate sizes of ~6-102 mm;
- Cover that includes instream large woody debris and overhanging riparian vegetation in pools and larger boulders in riffles; and
- Abundant and diverse floodplain vegetation.

3. Detailed Engineering Design

3.1. Objectives and Deliverables

The objectives and deliverables for the Mission Creek Setback Dike Project were established through discussions with Todd Cashin (City of Kelowna), Don Dobson (Urban Systems), Bahman Naser (UBCO), and Shaun Reimer (FLNRO). The main objective of this project was to design a setback dike alignment within a ~475 m reach of Mission Creek. The project area is located on the south side of the creek downstream of the Casorso Road Bridge and upstream of the Gordon Drive Bridge. The area of interest was analyzed to determine the size and location requirements of the setback dike using the Mission Creek Floodplain Map[1]. Finally, an optimal floodplain area and dike size was chosen to withstand the estimated updated 1:200 year discharge including a factor of safety. The setback dike design was completed to both provincial and City of Kelowna standards.

The deliverables of the Mission Creek Setback Dike Project included:

1. Preparation of conceptual design options for review;
2. Selection of the optimal design; and
3. Preparation of “For Construction” drawings of the engineered design.

The design drawings are provided in Appendix B of this report.

[1] EcoCat: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1886

3.1. Overview of Project Work

The City of Kelowna provided Geographic Information System Database including survey information pertaining to Mission Creek cross sections, the existing dikes (both North and South banks), and the property lines for the purchased and adjacent land parcels. This information was used to create a base drawing that was used for design. Flow data were obtained from the Water Survey of Canada hydrometric gauging station Mission Creek near East Kelowna (Station no. 08NM116).

The city arranged for material testing of soil samples collected at selected sites within Lot EPP21089 by the Levelton Consultants Ltd. (Levelton report is provided in Appendix A). The soils data were analyzed to determine the material layers and respective depths. This information was required in order to determine if the soils in the proposed alignment for the setback dike would support the dike.

The alignment for the proposed setback dike was determined based on a variety of key elements including the availability of property to the MCRI, design guidelines and restrictions, biological criteria such as high quality habitat preferences for salmonid rearing and spawning, species and areal extent of riparian vegetation, and thermal and floodwater refugia, and flow management and flood protection criteria such as the Q_{200}, provincial dike design criteria, vehicular access for dike management and freeboard and crest elevations. Physical project constraints/limitations included: preventing impacts to the adjacent Okanagan Indian Band IR #8, maintaining a walkway access, and determining the effects of soil composition on the various design components of the setback dike project. The technical design of the setback dike cross section was then undertaken using the Dike Design and Construction Guide, Best Management Practices for British Columbia (2003).

The alignment and cross section of the dike was used along with the topographic survey data for the site to calculate the required fill volume for construction. The volume of the existing dike was calculated using the cross section data provided by the City and estimated to be ~10,450 m^3. The material testing results for the existing dike were used to determine the percent composition of these existing materials as compared to the required standards for the new dike.

3.1.1. Design Considerations and Constraints

The design of the Mission Creek Setback Dike included the consideration of the following:

- biological criteria;
- flow management and flood protection criteria; and
- physical constraints/design limitations.

The design parameters, criteria and constraints with regards to the engineering design are summarized in Table 2.

Table 2. Engineering design constraints and criteria

Parameter	Criteria & Constraints
Biological	• Provide high quality rearing habitat for juvenile and adult rainbow trout and mountain whitefish; • Provide high quality holding habitat for adult rainbow trout and mountain whitefish; • Provide high quality spawning habitat for kokanee, rainbow trout and mountain whitefish; • Create side channel habitat to provide short term rearing and flood flow refugia; • Preferred spawning velocities of ~0.15-0.91 m/s to accommodate kokanee and rainbow trout during fall and spring, respectively, spawning periods; • Preferred spawning substrate sizes of ~6-102 mm; • Cover that includes instream large woody debris and overhanging riparian vegetation in pools and larger boulders in riffles; and • Abundant and diverse floodplain vegetation.
Flow Management and Flood Protection	• Accommodate a Q_{200} of 144 m^3/s; • Consistent with provincial dike design criteria including freeboard of 0.6 m, crest elevation based on current data, crest width of 4 m, dike slopes of 2:1, drainage; and • Provide equipment access for dike management.
Physical Constraints / Design Limitations	• Prevent impacts to the adjacent Okanagan Indian Band IR #8; • Ensure public walkway access for Mission Creek Greenway; • Suitable soils to support relocated dike; • Minimize disturbance to wildlife trees and riparian vegetation; • Incorporate bank protection; and • Minimize disturbance to adjacent private lands.

Table 3 summarizes the maximum annual flows in Mission Creek since 1969. The maximum annual flow recorded was 115 m^3/s in 2013 and the minimum annual flow was 39 m^3/s in 1992. The maximum and minimum water depths recorded to date are 2.14 m and 0.53 m, respectively. Each cross section within the design reach was analyzed separately using the results from the LMCHCS to determine the appropriate crest elevations for the setback dike.

The floodplain volume was maximized within the given area to provide the greatest benefit for flood risk reduction and restoration of fish habitat. To ensure the water depth and flow rate were within allowable limits, the 200-year flood levels were established along the reach using the results from the LMCHCS. Crest elevations of the setback dike were determined using the floodplain elevation values and adjustments extrapolated from the LMCHCS results to ensure a consistent slope throughout the setback dike.

Table 3. Mission Creek annual maximum flows (Water Survey of Canada)

Year	Max Flow (m^3s)	Year	Max Flow (m^3s)
1969	97.7	1992	39
1970	48.1	1993	66.4
1971	70.2	1994	42.8
1972	91.2	1995	40.8
1973	43.9	1996	63.1
1974	77.6	1997	97.6
1975	56.4	1998	52.8
1976	76.5	1999	65.7
1977	45.3	2000	65.5
1978	54.4	2001	46.2
1979	55.2	2002	66.5
1980	57.2	2003	46.4
1981	72.5	2004	58.5
1982	55.9	2005	67.1
1983	69.4	2006	87.8
1984	61.1	2007	47.6
1985	69	2008	76.1
1986	84.9	2009	41.6
1987	49.4	2010	52.9
1988	49	2011	66.2
1989	45.4	2012	N/A
1990	75.5	2013	115
1991	65.5		

A constraint limiting the location of the dike was the restricted geographical area and ground conditions of Lot EPP21089. If the existing sub-soil along the proposed setback dike alignment was not able to support the dike due to lack of stability, then an alternative option that would restrict the volume of flows on the floodplain would be developed that involved creating slots in the existing dike to allow a controlled flow of water through the slots. For this alternative, narrow side channels would be constructed on the floodplain to provide fish rearing areas. The slots would limit the flows into the side channels during freshet flows and maintain the majority of the freshet flows in the existing main channel. Although this alternative is not the preferred design option, it would still diversify and restore the rearing habitat along this reach.

The second design constraint was to design the project so the flow stays within the hydraulic limits of the dike. With a varied cross section the depth of water must be calculated at every point to ensure there will be no chance of water overtopping the dike. A decreased flow rate will directly decrease the depth of flow within the expanded channel reach. The decrease in depth of flow can be accomplished by creating a wider floodplain that will allow for an increased channel cross sectional area. For many other reasons a lower stage for a given flood flow can be beneficial. These include reductions in required riprap armouring, decreased erosion and transport of fine soils and gravels, and a more functional habitat for fish spawning, rearing and holding.

The City of Kelowna has agreed to a setback of the outside toe of the new dike at 0.3 m off the adjacent property line. According to the Dike Design and Construction Guide, Best Management Practices for British Columbia (2003), the minimum radius of curvature for the setback dike to prevent side bank erosion is 15 m.

There are also several minor physical constraints associated with this project. Two bridges have recently been constructed on Mission Creek: Casorso Road Bridge (2007) and Gordon Drive Bridge (2010). Due to the estimated design lives of these bridges, it will be necessary to leave the alignment of Mission Creek unaltered at both bridge crossings.

In addition, there is a walking path along the crest of the existing dike that parallels the creek. When the old section of the dike is removed and the new setback dike is installed the walking path (Mission Creek Greenway) must be re-instated as well. The constraint associated with this task is determining the start and finish locations of the existing walking path and tying in the new path with the existing path using a constant slope.

Figure 2 illustrates the typical cross section of the setback dike. Riprap armouring will be placed along a ~150 m section of the dike adjacent to the side channel as indicated on the design drawings in Appendix B. It is proposed to incorporate willow stakes in the toe rock of the riprap to encourage rapid revegetation in that zone as per Figure 5. The use of cottonwood plantings in riprap is not permitted. Riparian vegetation and large trees will be left undisturbed as much as possible to protect the existing natural riparian and wetland habitats. The side slopes of the dike on the creek side will be a 2.5:1. The dike will have a graveled top width of 4 m to accommodate equipment access and a public walking path. The backside slope of the dike will be 2:1.

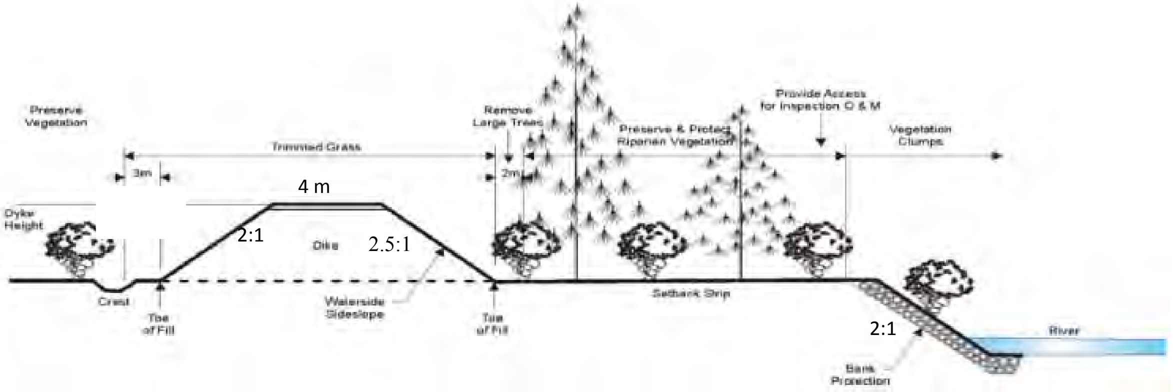


Figure 2. Typical setback dike cross section (Dike Design and Construction Guide, Best Management Practices for British Columbia 2003)

3.1.2. Design Flood Elevations

Figure 3 illustrates the Mission Creek Floodplain Mapping that was completed in 1984. The same cross sections were resurveyed in 2014 as part of the LMCHCS and were used to determine the updated 200-year flood elevations. The cross sections and updated elevations (including freeboard of 0.6 m) used for this project are summarized in Table 4.

Table 4. Cross sections used for the setback dike project with 2014 elevations

Cross section ID	2014 elevation (m)
XS-15	347.97
XS-14A	347.61
XS-14	347.49
XS-13	347.14

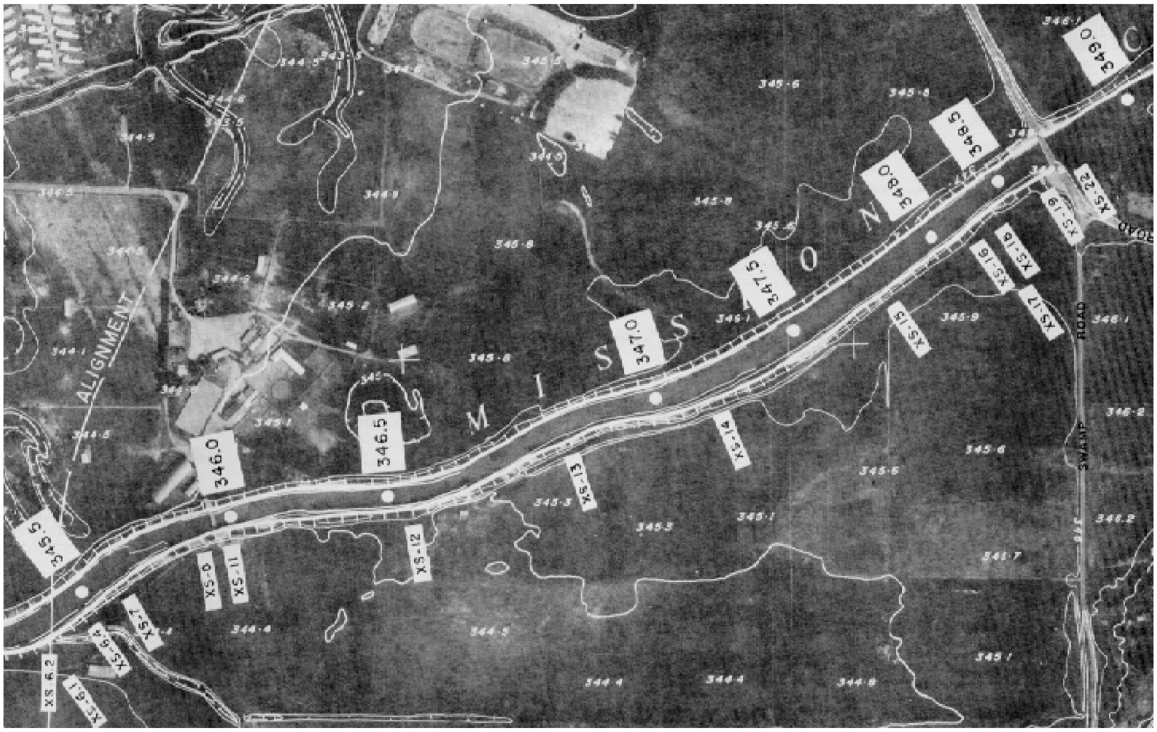


Figure 3. Mission Creek Floodplain Map (Ministry of Environment, Water Management Branch 1984)

3.2. Setback Design

3.2.1. Feasibility Analysis

In designing a setback dike for Mission Creek it was necessary to analyze all options that fit both the project requirements and project constraints. A review of the project goals and constraints led to the creation of two feasible designs. The first design option involved removing the existing dike on the south edge of the Mission Creek and constructing a new setback dike along the perimeter of Lot EPP21089. This option required that the foundation conditions along the proposed new alignment were suitable to support the dike. If it was determined that the foundation conditions along the proposed new alignment were not suitable to support the dike, then the second option was to leave most of the existing dike in place and construct a series of slots in the dike that would allow a controlled flow of water through the dike to create a network of side channels behind the dike that would restore fish rearing areas along this reach. This was not the preferred option as it would limit hydrologic connectivity and processes as well as the amount of new habitat created.

The Levelton Consulting Ltd. Geotechnical Assessment Report revealed that the foundation conditions along the proposed new alignment were suitable to support the new setback dike (Levelton 2015 – Appendix A). Therefore the existing dike could be completely removed increasing the channel width from ~40 m to a maximum of ~150 m allowing opportunities for the creek to create a more naturalized pattern along this reach.

3.2.2. Floodplain Expansion

The setback dike design involved the creation of an expanded floodplain through the removal of the existing dike. The overall goal of the MCRI is to restore former habitat that existed before the creek was constrained by dikes through restoring the floodplain and incorporating additional channel meanders. This project is the first step in re-establishing some of the habitat and complexity that existed before the channel was diked. The estimated new habitat area created by this project is estimated to be ~18,000 m^2.

3.2.3. Setback Dike Alignment

The alignment of a dike follows the property lines of Lot EPP21089 with the intent to maximize the opportunity to create new habitat area while maintaining the existing natural wetland habitat and environmental sustainability, providing a wider floodway with increased flow capacity, reducing peak flood levels, reducing flow velocity and bank erosion, and reducing long-term maintenance costs.

The setback dike design requirements were summarized in section 3.1.1. In creating the alignment it was also necessary to consider future projects and long terms goals for the area. The long-term goal for this section of the Mission Creek is to have a continuous setback dike extending from Casorso Road to Gordon Drive and incorporating all available floodplain area to reduce the risk of flooding. The intent is to remove the existing dike and construct the setback dike and then allow the creek to naturally develop new meander patterns in the expanded reach over future freshets. The progress of the development of expanded habitat will be monitored annually. Initially it is intended that the peak freshet flows would continue to flow down the existing main stem channel while allowing for overflow and meandering into the setback area. If it is determined that it is appropriate to assist with expanding suitable habitat, suitable designs will be considered as required.

The minimum offset required from the property line to dike toe is specified as 7.5 m in the Dike Design and Construction Guide, Best Management Practices (2003). However, since the land on which the dike will be constructed is owned by the City and since the province will have a right-of-way for dike maintenance over the entire property, the setback was reduced to 0.3 m to maximize the floodable area. Figure 4 illustrates the proposed alignment of the new dike, the existing dike to be removed, as well as the proposed setback dike.

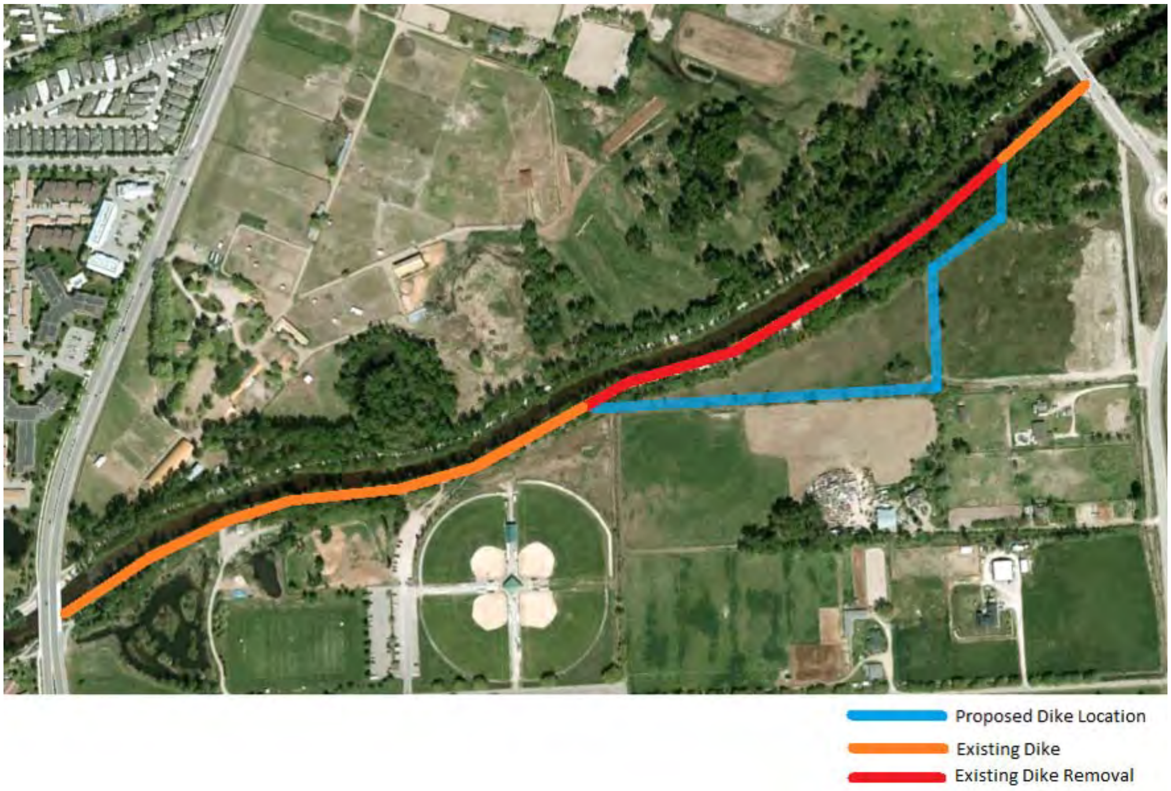


Figure 4. Mission Creek Setback Dike Overview (Google Maps 2015)

3.2.4. Setback Dike Height

Once the alignment was established the crest height of the setback dike was determined based on the updated survey data and results from the Lower Mission Creek Hydraulic Capacity Study Kelowna, BC (Tetra Tech EBA Inc. for FLNRO 2014). The standard design flood in British Columbia is the flood with the annual probability of occurrence of 0.5%, or the 1 in 200 year flood. The crest elevation must then be designed using the higher of 1 in 200 year instantaneous discharge plus 0.3 m freeboard or the 1 in 200 year maximum daily discharge plus 0.6 m freeboard (Dike Design and Construction Guide, Best Management Practices for British Columbia 2003). The design flow (maximum daily discharge) provided in the Lower Mission Creek Hydraulic Capacity Study was 144 m^3/s. The Lower Mission Creek Hydraulic Capacity Study also provided updated dike crest elevations along the creek including the project area that were used to guide the determination of the dike crest elevation for the setback dike. The cross sections that are adjacent to the proposed setback dike alignment are summarized in Table 4.

3.2.5.Riprap Armouring

As the channel adjusts and meanders into the setback area, there is a potential for flows to impinge on the dike, especially during freshet flows. During these conditions there is a risk that the dike face may be eroded or the toe of the dike undermined by scouring if not protected with riprap. The outside bends of the creek can be subjected to greater hydraulic forces and are typically more susceptible to scour or erosion. To prevent possible damage to the dike it is proposed that riprap armouring be used. Although riprap provides the best permanent protection against erosion during high flows in those areas subject to the direct force of the flow, blasted rock is not particularly aesthetically pleasing and it does inhibit the establishment of vegetation that benefits fish and other aquatic organisms. At the time of construction it is proposed to armour ~150 m of the new dike adjacent to the side channel where erosion may occur during freshet flows (refer to design drawings in Appendix B). Since the intent is to remove the existing dike down to a height of ~0.5 m above the main channel bed so that initially there will be overflow into the expanded floodplain when flows exceed the average annual flow, it is anticipated that it will take a number of years before sections of the main channel will migrate into the wider floodplain. As the channel does migrate across the floodplain additional sections of the dike can be armoured as required to prevent erosion.

The sizing of riprap armouring is based on river flow velocities and bank slope angles. As an initial guideline, assuming a design flow velocity of 4 m/s and a maximum dike waterside slope of 2:1, Levelton Consultants Ltd. recommended a Class 250 riprap with a nominal thickness of 1,000 mm, with the average dimension of angular rock being approximately 565 mm based on Ministry of Transportation and Infrastructure guidelines. Based on the results from similar projects constructed on the Okanagan River, FLNRO staff recommended that riprap would be placed along the entire length of the setback dike. A sample cross section of the riprap design from the Dike Design and Construction Guide, Best Management Practices for British Columbia (2003) is shown in Figure 5. As illustrated in Figure 5, the riprap armouring extends to the top of the dike to accommodate higher flow rates, and further below the toe of the slope to prevent scouring.

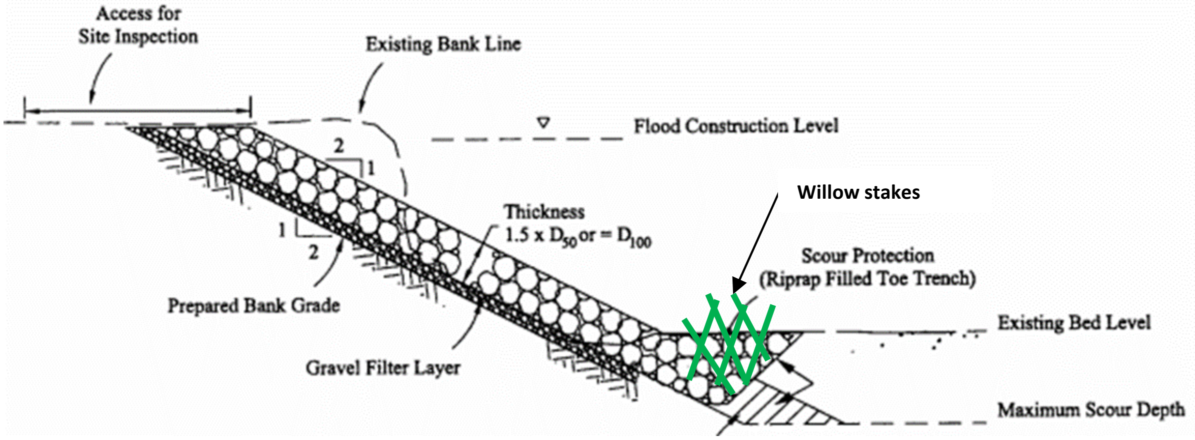


Figure 5. Riprap design cross section (Dike Design and Construction Guide, Best Management Practices for British Columbia 2003)

3.2.6. Geotechnical Considerations

Levelton Consultants Ltd. completed soil gradations in the existing dike and nearby soil stockpiles that might be used in the dike construction to determine if the soils were consistent with the provincial requirements. In order to prevent seepage, a fill containing 15% of silt or clay sized particles by weight is required. The resulting material tests of the stockpiles indicated that the percentage of fines in the existing dike that is slightly less than required at 10.2%. As a result, the material will have to be combined with either the stockpile material of the north berm on site (which had a fines content of 20.5%) or an offsite material with a higher fines content. The recommended aggregate gradation is provided in Table 5.

Table 5. Recommended Dike Fill Gradation

Sieve Size (mm)	% Finer Than
150	100
75	75-100
37.5	60-100
19	50-90
4.75	40-70
0.425	25-50
0.075	15-35

The Levelton testing of the soils from the auger holes along the proposed alignment determined that the long-term settlement of the sub-grade soils are expected to be ~100 mm. Based on this limited settlement it was determined that the sub-grade soils were suitable to support the proposed dike.

3.2.7. Design Specifications

The setback dike design will result in the removal of the existing dike down to ~0. 50 m above the bed of the creek. A ~0.50 m depth is equivalent to the approximate depth of the mean annual flood. The material removed will be used to construct the new dike. This design will contain the annual flood within the existing channel while allowing the south bank to be overtopped during flows above the mean annual flood. This approach will provide an opportunity for the creek to re-establish a more natural channel pattern.

There is an existing side channel near the upstream end of the project area that was isolated by the existing dike. It is proposed to construct two overflow weirs to provide flow into the side channel. The overflow weirs would be ~3 m wide and have an invert elevation slightly lower than the average annual high water level designed to assist in restoration of the floodplain. The habitat will be connected to the main channel at the west end through the second meander notch. A ~3 m wide outlet channel to the mainstem will allow fish egress from the side channel as flood flows recede. Where possible the existing mature trees along the bank of the creek in this section will be preserved.

It was noted during the field assessments that there are several point bars along the north side of the main channel through the project area. These offer the opportunity to construct corresponding meander notches with pools along the south side of the channel that would encourage the channel to restore a more natural meander pattern. Four meander notches will be constructed once the existing dike is removed. The first will be located adjacent to the side channel and will include an overflow weir. The second is located immediately downstream of the west end of the existing side channel. The third notch will be located ~100 m downstream of the second and the fourth ~100 m downstream of the third. The notches will each be ~30 m long, extending ~5 m into the bank and have a maximum depth of 0.5 m deeper than the adjacent channel to improve pool habitat. Large woody debris (LWD) structures that are comprised of several logs (~18 m long) with root wads attached will be embedded in the bank at each meander pool to provide instream cover. The approximate locations of meander notches are shown on the design drawings in Appendix B.

The construction of the overflow weirs and the meander notches is scheduled for 2016 during the normal instream work window for Mission Creek.

Following the 2016 freshet and in subsequent years, FLNRO staff will evaluate the effects of the freshet on the new floodplain to determine if additional connectivity between mainstem and side channel habitats is required to prevent fish stranding in the side channel as flows recede. These works would typically be undertaken later in the year during the normal instream work window.

There is an abundance of mature cottonwood trees and some alder clumps along the edge of the existing channel and also embedded in the south side of the dike. The intent is to preserve as much of the healthy trees as practical. An arborist will be engaged to recommend which trees to save. Those trees that are over-mature or unhealthy, or determined to be danger trees will be either removed or stubbed as appropriate.

The existing dike will be removed down to the original natural ground level or to a level 0.5 m above the adjacent stream bed, whichever is greater. In no circumstance will any work occur in the wet during the removal of the existing dike. Silt fence will be installed, where necessary, to prevent sediment from spilling into the water.

The new dike will extend over a length of ~540 m and require ~9,200 m^3 of material. The recommended design will have a crest width of ~4 m, with slopes of 2H:1V on the landside and 2.5H:1V on the waterside, with a potential for a steeper waterside slope with armouring. The constructed dike material is to be compacted to a minimum of 97% with a moisture content within 2% of optimum, which will be tested on site with standard Proctor tests. These design criteria are consistent with the requirements in the Dike Design and Construction Guide, Best Management Practices for British Columbia (MWLAP 2003). To facilitate the access of equipment inside the dike area two access points will be identified near both ends of the new dike. The easterly access point may be located near the second corner of the dike near the revegetated area. The access point could be used as a view point with a picnic table and information signage however it must be understood that if access is required at that site that it may require the removal of any signage and improvements. The costs to replace the signs etc would be the responsibility of the MCRI not the province.

Levelton Consulting Ltd. found the existing dike material contained a fine grained soil component lower than required. Therefore, existing dike material will have to be mixed on-site with an engineering fill to meet the recommended dike fill gradation outlined in Table 5. Due to the age and condition of the existing dike the variance in material properties is unknown and therefore will require further investigation to determine the actual quantity of re-useable material. The existing dike also contains a larger quantity of material than is required by the proposed dike therefore it can be assumed that a large majority of the material may be re-used. The excess material from the existing dike will be dealt with in one of three ways dependant on the quality. If the material is clean gravel it may be used by the City for another project that requires fill or the material could be hauled back to the City's gravel pit.

3.3. Summary

a. The site conditions for the setback dike alignment within lot EPP21089 are suitable for the construction of the dike.
b. With the setback dike, the channel and floodplain width would be widened to ~150 m from the existing channel width of ~40 m.
c. The floodplain area adjacent to the setback dike is suitable for creating additional off-channel habitat as the creek develops new channels through the area.
d. Restoration of the floodplain should be assisted by constructing overflow weirs near the upstream end of the project area and four meander notches adjacent to existing point bars on the north side of the channel, to encourage a more naturalized flow pattern.
e. No instream work will occur during the removal of the existing dike.
f. Instream work is scheduled for 2016 during the normal instream work window for Mission Creek.
g. Large wood (root wads including attached tree trunks) from trees removed during construction should be added to each of the meander notches to improve the fish habitat.

h. There is a more than adequate material in the existing dike along the south side of the Mission Creek channel to construct the new dike.
i. The existing dike material does not meet the provincial specifications in silt/clay sized material but additional fine grained material can be added as the new dike is constructed.
j. The existing dike will be removed in the dry with no detrimental impacts on the water quality in the creek. In no case will material be removed in the zone below 0.5 m above the stream bed. Where necessary silt fence will be installed on the dike to prevent sediment from spilling in the water during the removal phase.
k. It should be possible to complete the construction of the setback dike within the period from September – February, assuming a mild winter.
l. Every effort will be made to retain native trees (primarily black cottonwoods) during construction, including stripping of the existing dike to the specified elevation. In addition, trees identified for removal will be stubbed if it does not impact design objectives and safety requirements.

3.4. Recommendations

The following recommendations are provided:

a. The alignment for the setback dike should follow the alignment recommended in Figure 4 and the plans in Appendix B.
b. Dike construction should be scheduled during the low water period in Mission Creek when the groundwater levels along the setback alignment are low. This would typically be from September – March.
c. Instream construction of the overflow weirs and meander notches including the placement of large woody debris cover structures should be scheduled during the normal instream work window for Mission Creek in 2016.Appropriate steps to isolate instream work areas will be mandatory.
d. The footprint for the setback dike should be stripped to mineral soil and the stripped material removed to a suitable storage site for future use.
e. Construction of the setback dike should commence from both the upstream and downstream ends allowing the existing dike to be removed from the mid-point towards each end. This approach would allow construction to proceed faster.
f. As noted above, the existing dike material requires additional fines, i.e., sand to meet the recommended dike fill gradation. This can be accomplished by adding 5% silt/clay to the fill as it is placed, e.g., add one truck of silt/clay for every 10 truckloads of dike material.
g. Fill should be placed in 300 mm lifts and then compacted 97% using standard Proctor tests.
h. No frozen fill should be used.
i. Riprap should be placed after the dike structure is completed.
j. Setback dike works should be completed by no later than March 31, 2016 and instream construction by September 2016.

4. Construction Implementation Strategy

4.1. Construction Schedule

The proposed tasks and estimated start and completion dates are summarized in Table 6.

Table 6. Proposed construction tasks and schedule

Task #	Description	Start Date	Completion Date
1	Survey and stake new dike alignment	September	October
2	Live tree assessment and danger tree assessment	October	October
3	Remove trees from dike and new alignment	October	October
4	Permitting	October	November
5	Strip and dispose of top soil from new alignment	November	December
6	Place gravel sub-grade on new alignment with material from existing dike	November	December
7	Construct new dike	December	March 2016
8	Install groundwater monitoring piezometers	December	January 2016
9	Armour 150 m of dike at east end	February	February 2016
10	Construct overflow weirs	July	August 2016
11	Connect side channel outlet to meander 2	July	August 2016
12	Construct meander notches and place LWD	July	August 2016
13	Site clean up	March	March 2016
14	Replace fencing	March	March 2016
15	Install access control barriers	March	March 2016
16	Install signage	March	March 2016

4.2. Cost Estimate

The preliminary estimated cost for the project is ~$380,000 that includes a $26,000 contingency. For details on the cost estimates refer to the spreadsheet in Appendix C.

4.3. Environmental Management Planning

An Environmental Protection Plan has been developed to provide regulatory direction for all construction activities. This EPP was developed to address potential environmental impacts during the removal of the existing dike, construction of the setback dike, and creation of meander notches. The EPP provides site specific guidance to the contractor and onsite environmental representatives, for the placement of erosion control materials and mitigation measures to ensure that sediment and drainage are managed properly. This EPP also includes guidance for water quality management, fuel spills, construction waste, material storage, archaeological resources and restoration and clean up procedures, and environmental monitoring.

In regard to environmental risk associated with this project, there is a low risk of sediment being released during removal of the existing dike since the work will be scheduled during low flows and the excavation work will not be connected to the creek as the toe of the existing dike is several meters away from the bank of the channel.

During the construction of the meander notches in 2016, which will occur at the water's edge, appropriate approvals will be in place and the work areas will be isolated from the creek using turbidity curtains. There will be an environmental management plan prepared in advance and approved by FLNRO as well as an onsite environmental monitor during any instream work. This risk would be minimized by working during the normal instream work window, under low discharges, completing the excavation of meanders and floodplains outside of the existing dikes before connecting through the dikes, and using cofferdams or turbidity curtains as required, to isolate the work area.

5. Effectiveness Monitoring

Assuming construction is initiated on priority works, as outlined above, monitoring should determine the effectiveness of the restoration works at meeting the restoration objectives. The restoration objectives for the priority works are:

- to maintain flood protection up to the design flow of 144 cms;
- to maintain existing drainage networks and water withdrawal off-takes;
- a groundwater monitoring plan is being prepared that will include the installation of piezometers at strategic locations to monitor the groundwater levels, before , during and after construction.
- to increase the quantity and quality of spawning and rearing habitat for salmonids;
- to improve the stability of salmonid spawning substrates;
- to improve aesthetics and wildlife habitat;
- to increase and maintain biodiversity within the river corridor; and
- to re-establish some of the physical structure, and hydraulic and geomorphic processes that are characteristic of natural rivers.

Monitoring of the proposed restoration works should occur prior to and after construction and pertain to: the native fish populations and habitat; surface and groundwater levels; extent and impact of flooding on lands outside of the dikes; and sediment transport and deposition. The target fish species for the effectiveness monitoring should include kokanee, rainbow trout and mountain whitefish. A more holistic monitoring program could also include wildlife species that would be affected by the restoration project along with growth and survival of riparian and floodplain vegetation.

Monitoring parameters to determine fish utilization, particularly for spawning and rearing, should involve spawner counts, and determining fry, juvenile and adult densities. Egg incubation success should, where feasible, be evaluated for the target species. Egg incubation success should be related to the characterization of the spawning habitats of kokanee, rainbow trout and mountain whitefish. This should include velocity, depth, substrate size analysis and slope measurements. Regular engineering level surveys of the channel and floodplain will monitor sediment transport and deposition rates, and any changes in topography. The evaluation of these monitoring results will guide the implementation of further restoration activities on Mission Creek.

6. References

Anonymous. circa 1997. The River Brede. Committee for Technical and Environmental Matters, County of Sonderjylland, Denmark. 16p.
Anonymous. 2002. Stream habitat restoration guidelines: levee removal and setback (Draft). Washington Department of Fish and Wildlife, and Ecology, Inter-Fluve Inc., and U.S. Fish and Wildlife Service.
Burge, L.M. 2009. Analysis of Sedimentation and Sediment Mitigation Strategies for Mission Creek.
Burge, L.M. 2010. Mission Creek Channel and Streamway Width Assessment. Burge Ecohydraulics.
Cowx, I.G. and R.L. Welcomme (eds.). 1998. Rehabilitation of Rivers for Fish. Fishing News Books, Blackwell Science Ltd. London.
Ennis, G.L. [ed.] Literature reviews of the life history, habitat requirements and mitigation/compensation strategies for selected fish species in the Peace, Liard and Columbia River drainages of British Columbia. Dept. Fisheries and Oceans Canada, Vancouver, BC.
Federal Highways Administration. Design of Riprap Revetment. Retrieved from Federal Highways Administration website April 1st, 2015: http://fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec11.sl.pdf
Gaboury, M. and P. Slaney. 2003. Mission Creek habitat restoration feasibility. Prepared for Ministry of Water, Land and Air Protection, Penticton, B.C., by LGL Limited, Sidney, B.C., and P. Slaney Aquatic Science Inc., Coquitlam, B.C.
Golder Associates Ltd. & Associated Engineering Ltd. 2003. Dike Design and Construction Guide, Best Management Practices For British Columbia. Ministry of Water, Land and Air Protection, pp. 1-110.
Google Maps. 2015. [Mission Creek, Kelowna][Street Map]. Retrieved from https://maps.google.ca/maps?cid=5690550183007667447&q=Kelowna,+BC&output=classic&dg=crsh

Glitz, D. 1983. Artificial channels - the “ox-bow” lakes of tomorrow. Garten+Landschaft No. 2: 109-111.

Gore, J.A. and F.D. Shields Jr. 1995. Can large rivers be restored? BioScience 45(3):109-111.

Keller, E.A. and A. Brookes. 1984. Consideration of meandering in channelization projects: selected observations and judgments. In Proc. Conf. Rivers ‘83, River Meandering, C. Elliott [ed.], Amer. Soc. of Civil Engineers, New York. 384p.

Ministry of Environment, Water Management Branch. 1984. Floodplain Mapping Mission Creek [map] (1:5,000).

Mission Creek Restoration Initiative. 2014. *The Restoration Project.* Retrieved from Mission Creek Restoration Initiative: www.missioncreek.ca/restoration--project/

Sparks, R.E. 1995. Need for ecosystem management of large rivers and their floodplains. BioScience, Vol. 45, No.3: 168-182.

Tetra Tech EBA Inc. 2013. Lower Mission Creek Hydraulic Capacity Study Kelowna, BC. File V13203141-01. Retrieved from http://www.missioncreek.ca/resources/ October 30th, 2014.

Ward, A. 2001. Stream stability protection setback. FAV Engineering, Ohio State University. 5p.

Water Office Canada. 2015. Historical Data. Retrieved on March 4, 2015. https://wateroffice.ec.gc.ca/report/report_e.html?mode=Table&type=realTime&stn=08NM116&dataType=&startDate=2015-04-03&endDate=2015-04-10&prm1=46&prm2=47

Welcomme, R.L. 1989. Floodplain fisheries management. P 209-234 In Gore, J.A. and G.E. Petts. (eds.) Alternatives in regulated river management. CRC Press, Boca Raton, Florida.

Whyte, I.W., S. Babakaiff, M.A. Adams and P.A. Giroux. 1997. Restoring fish access and rehabilitation of spawning sites. *In* Slaney, P.A. and D. Zaldokas [eds.] Fish Habitat Rehabilitation Procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9.

Williams, G.P. 1986. River meanders and channel size. Journal of Hydrology 88: 147-164.

This report has been prepared by:

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
D. A. DOBSON

D.A. Dobson, PEng

APPENDICES

Appendix A. Levelton Consultants Ltd. - Geotechnical Assessment Report, Mission Creek Dikes – Phase 1 East

LEVELTON

GEOTECHNICAL ASSESSMENT REPORT
MISSION CREEK DIKES – PHASE 1 EAST
KELOWNA, BC

Prepared for:

City of Kelowna
1435 Water Street
Kelowna, BC
V1Y 1J4

Attention: Mr. Todd Cashin
Manager / Deputy Approving Officer

Prepared by:

Levelton Consultants Ltd.
#108 – 3677 Hwy 97 N, Kelowna, BC
V1X 5C3

February 27, 2015
R715-0268-00

TABLE OF CONTENTS

PAGE NO.

1. INTRODUCTION

Levelton Consultants Ltd. (Levelton) presents herein our geotechnical assessment report to the City of Kelowna (CoK) for the proposed Mission Creek Dikes – Phase 1 East design project. The project consists of replacing a section of existing dike along the south side of Mission Creek as part of the Mission Creek Restoration Initiative (MCRI).

The scope of this geotechnical assessment was outlined in our proposal of January 27, 2015 (our file: P715-0287-00). Authorization to proceed with the proposed scope of work was received from CoK by e-mail on February 2, 2015.

Based on the available information at the time of this report, we understand there is a long term plan to realign the Mission Creek Dike on the south side of Mission Creek between Casorso Road and Gordon Drive. A preliminary dike alignment was provided to us from a past MCRI report, and our investigation and report is based on future dike development along the general alignment indicated on the attached Figure 1. The extent of our investigation included the east half of the alignment, from Casorso Road at the east end to the Mission Recreation Park fields at the west end.

Our assessment and recommendations for dike design are based on the following reference documents:

- Lower Mission Creek Hydraulic Capacity Study, Tetra Tech EBA, March 2014.
- Dike Design and Construction Guide, Best Management Practices for British Columbia, Province of British Columbia, BC Ministry of Forests, Lands and Natural Resource Operations, July 2003.
- Seismic Design Guidelines for Dikes, Province of British Columbia, 2nd Edition, BC Ministry of Forests, Lands and Natural Resource Operations, June 2014 (referred to hereafter as the "Seismic Guidelines").
- Design Guidance for Levee Underseepage, U.S. Army Corps of Engineers, May 2005

2. PROPOSED CONSTRUCTION

Based on the provided information, our analysis and design recommendations are based on the following:

- A new dike design is required for the proposed alignment south of the existing Mission Creek Dike, as illustrated on Figure 1;
- The new dike will feature a crest height of approximately 4m above surrounding grade (which we have approximated to be 345m geodetic). This equates to a proposed crest elevation of approximately 349m and is based on a predicted flood elevation of 348.26m at the Casorso Road bridge and includes a 0.6m freeboard;
- The new dike will be based on the "Setback Dike" template contained in the Dike Design Guidelines referenced above. Recommended side slopes, crest width and dike composition will be discussed in the course of this report;

- The CoK is interested in re-using the existing dike fill during construction of the realigned dike, and has access to a large stockpile of potential dike fill material along the east edge of 3850 Swamp Road. The approximate stockpile location is identified on Figure 1.

3. FIELD WORK AND LABORATORY TESTING

3.1 FIELD INVESTIGATION

The subsurface exploration was undertaken on February 11, 2015 and consisted of five solid stem auger holes (AH15-01 to AH15-05) advanced using a track mounted drill rig. The auger holes were advanced to a depth of between 3 and 9 m below existing grade. Dynamic Cone Penetration Tests (DCPTs) were conducted at AH15-01, AH15-03 and AH15-03 to assess the *in-situ* relative density / consistency of the soils. The approximate locations of the auger holes are shown on Figure 1.

Geotechnical personnel from Levelton selected the auger hole locations, logged the soil and groundwater conditions encountered at the auger holes, and collected disturbed soil samples from the auger flights for laboratory testing.

Soil logs with description of the soil and groundwater conditions encountered at the auger holes are attached in Appendix A.

3.2 LABORATORY TESTING

Disturbed soil samples collected from our subsurface investigation were submitted to our laboratory for testing. All samples were tested for moisture content, and select samples were subjected to a grain size analysis to assist in classifying the encountered soil types.

Levelton also collected a number of samples from bulk fill sources the CoK is considering for use in the new dike construction. The samples were collected from:

- The stockpile on 3850 Swamp Road – south end;
- The stockpile on 3850 Swamp Road – north end; and,
- Combined sample of existing dike fill sampled west of Casorso Road Bridge.

The results of the grain size analyses are attached in Appendix B.

4. GEOTECHNICAL INFORMATION

4.1 SURFICIAL GEOLOGY

It is of importance to understand the geologic setting of the site, as it provides evidence of past events that influence the strength and compressibility of a soil deposit. The surficial geology of the area was interpreted from Geological Survey of Canada Open File 6146, which describes the area as fluvial floodplain sediments consisting of sand, gravelly sand, gravel and organic debris.

4.2 SOIL CONDITIONS

The soil conditions encountered at the auger holes conducted by Levelton at the project site were generally consistent with the published surficial geology. A general summary of the soil conditions is provided in the following paragraphs. The description provided on the soil logs in Appendix A should be used in preference to the summary description provided below.

All five auger holes along the proposed dike alignment were conducted on farm land or rural vacant property; the ground cover at each auger hole consisted of low vegetation including grasses and fallow field crops. In general, the auger holes encountered surficial deposits of silt topsoil with organics to depths of 0.2 to 0.9m.

At AH15-01 to AH15-03, a deposit of loose grey sand was encountered below the topsoil, extending to depths of 2.2 to 2.4m. At AH15-02 and AH15-03, the loose grey sand was underlain by compact sand and gravel and compact sand to depths of 3m and 3.5m, respectively. AH15-02 was terminated in the sand and gravel deposit, while AH15-03 encountered a deposit of loose grey sand with organic silt seams extending to a depth of 4m, which was underlain by compact sand to the termination depth at 6m.

At AH15-01, the loose grey sand was underlain by a layer of very soft silt extending to a depth of 3m. The silt was in turn underlain by compact sand to the termination depth at 9m; the lowest 3m of the compact sand deposit featured occasional organic silt and ash seams.

AH15-04 and AH15-05 the topsoil was underlain by sandy silt that extended to a depth of 1m. In AH15-04, the sandy silt was underlain by loose grey sand to extending to a depth of 1.3m; the sand was in turn underlain by soft grey silt that extended to 1.8m below grade. The silt was underlain by compact sand that extended to the termination depth at 4.5. A 0.3m thick layer of loose sand with organic seams was encountered within the sand deposit at a depth of 3.2m.

In AH15-05, the sandy silt was underlain by compact sand and silty sand deposits, with occasional silt and ash seams at 3m and 8.4m depth. This auger hole was terminated in sand / silty sand at a depth of 9m below grade.

4.3 SURFACE AND GROUNDWATER CONDITIONS

Based on available information from the CoK web map, we estimate that the boreholes were conducted at a geodetic elevation of approximately 345m. The water level observed in ditches and standing water throughout the site was at an approximate elevation of 344m during the field investigation. Based on available information, the average water level in Mission Creek is estimated to fluctuate around elevation 346m near the Casorso Road Bridge.

Groundwater was encountered at a depth of between approximately 0.7 and 0.9m below existing grade in the auger holes at the time of drilling. The groundwater elevation in the auger holes was generally consistent with the elevation of the standing water observed in ditches and low lying areas throughout the site, but is lower than the estimated Mission Creek water level. The groundwater level would be anticipated to fluctuate seasonally.

5. DISCUSSION & RECOMMENDATIONS

5.1 GENERAL

Based on the Levelton subsurface explorations, a new dike conforming to the "Setback Dike" template contained in the Dike Design Guidelines referenced above is considered feasible from a geotechnical perspective. The existing native soils will have adequate bearing capacity to support the proposed dike structure. Some consolidation of the soft / loose subgrade soils is expected due to the weight of the new dike fill, but it is expected that long term settlement will not greatly affect the proposed dike structure.

Our analysis indicates that, in general, a properly constructed section of dike as proposed herein will have satisfactory stability under static and seismic conditions, in accordance with the Seismic

Guidelines. In addition, it is our opinion that the dike section will be acceptably stable under rapid drawdown conditions.

The key to maintaining the long term stability of the dike will be in the selection, placement and compaction of suitable dike fill material.

5.2 DIKE TEMPLATE

We understand the proposed new dike alignment will require the design of a Setback Dike, as illustrated in Section 2.8.1 Figure 1 of the Dike Design and Construction Guide, Best Management Practices for British Columbia, July 2003 (Dike Design Guide). This figure is reproduced below.

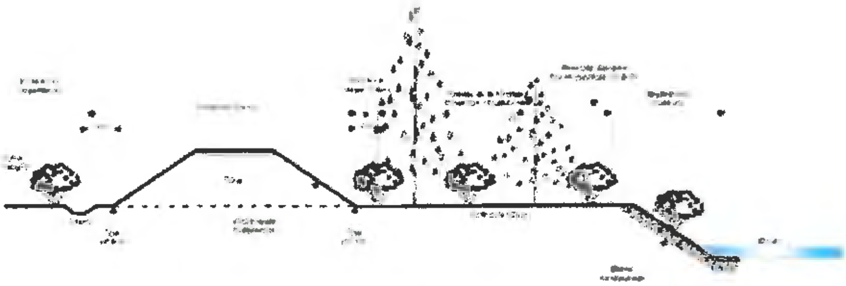


Figure 1 – Setback Dike

Based on the available information, our experience with dike design, and the current standards included in the Dike Design Guide, we are proposing a dike with the following general design:

- A dike crest width of 4m;
- A landside dike side slope of minimum 2.5H:1V (Horizontal:Vertical);
- A waterside dike side slope of minimum 3H:1V. A steeper waterside slope of 2H:1V could be considered with appropriate rip-rap armoring; and,
- A gravel running surface treatment on the dike crest.

5.3 SEISMIC CONSIDERATIONS

5.3.1 Dike Stability Considerations

Seismic Requirements for Dikes

The Seismic Guidelines are intended for use by those responsible for the seismic design, construction, inspection, alteration, and rehabilitation of "high consequence dikes." Based on the proximity of the dikes to low-lying residential areas, we have assumed the Mission Creek dikes will be considered as "high consequence" and the guidelines will generally apply.

The intent of the guidelines is to specify the level of performance that dikes should provide under the influence of three levels of design earthquake: the 1 in 100 year return period earthquake (Earthquake Shaking Level 1, or EQL-1), the 1 in 475 year return period earthquake (EQL-2), and the 1 in 2475 year return period earthquake (EQL-3). The specifications under the various return period earthquakes are summarized as follows:

- EQL-1: No significant damage to internal structures, and post-seismic flood protection ability is not compromised. Maximum allowable vertical and horizontal displacements are less than 0.3m.
- EQL-2: Some repairable damage to internal structures, and post-seismic flood protection is not compromised. Maximum allowable vertical displacement is 0.15m, and the maximum allowable horizontal displacement is 0.3m.
- EQL-3: Significant damage to internal structures, post-seismic flood protection ability is possibly compromised. Maximum allowable vertical displacement is 0.5m, and the maximum allowable horizontal displacement is 0.3 to 0.9m.

It should be recognized that the Seismic Guidelines do not explicitly mandate that "high consequence" dikes be designed as "post-disaster" structures; rather, the Seismic Guidelines provide specifications for dike performance that are generally consistent with a post-disaster definition under short and intermediate return period earthquakes, and partially consistent under long return period earthquakes, with consideration of the applicability and completeness of such specifications left to the local authorities having jurisdiction (in this case, the CoK).

Analyses

For the review of the dike stability, a limit equilibrium analysis was completed under various conditions. A representative cross-section was developed for the dike alignment based on site observations and available information. Soil and groundwater conditions were determined from the auger hole investigation and estimated for the proposed dike structure. Limit equilibrium slope stability assessments were completed using the computer program Rocscience *SLIDE 5.0*, a two-dimensional slope stability analysis program. For the analysis a dike waterside slope of 2H:1V, with rip rap armoring, was considered; basing the analysis on the premise that this dike layout is considered more conservative than analyzing the more stable 3H:1V waterside slope model.

The soil units and parameters used for the slope stability analyses are provided in Table 1.

Table 1 – Estimated Soil Parameters for Seismic Slope Stability Analysis

Soil Unit	Friction Angle (degrees)	Unit weight (KN/m^3)	Cohesion (KN/m^2)
Rip-Rap	45	20	0
Engineered Dike Fill	38	17	0
Loose Sand	32	15	0
Soft Silt	30	14	0 / 20*
Deep Compact Sand	34	16	0

*apparent cohesion was applied for seismic and rapid-draw-down analyses

The soil properties were estimated based on laboratory testing, *in-situ* testing, published data, and engineering judgement. The soil layering and groundwater levels were inferred based on the information available when this report was prepared, and engineering judgement. The topography and water levels utilized for the development of the analysis were based on the available information.

Factors of Safety (FoS) against slope instability under static, and 1 in 2475 year return period (A2475) seismic conditions were determined. Based on the results of the A2475 seismic conditions, no additional seismic analysis was conducted for the 1 in 100 and 1 in 475 year return periods. The seismic loading was applied as a pseudo-static horizontal force based on the Peak

Ground Acceleration (PGA) values for the site. The following Peak Ground Acceleration (PGA) values for the 1:475 and 1:2475 earthquake return period were determined:

Return Period	PGA
1 :475	0.07g
1 :2475	0.14g

Stability Results

The results of the pseudo-static slope stability analyses are provided in Table 2.

Table 2 – Dike Stability Analysis Results

Earthquake Condition	Peak Ground Acceleration	Factor of Safety
Static	0	1.74
Static (rapid drawdown)	0	1.72
A2475 (1 in 2475)	0.14g	1.66

Compliance with Seismic Guidelines for Dikes

The results of the analyses indicate that during the static loading case, rapid drawdown loading case, and the 1:2475 earthquake event the dike sections maintained a FoS greater than 1. These results indicates that the dike section would experience no significant instability induced movement; satisfying the EQL-1, EQL-2 and EQL-3 guidelines.

The results of the stability analyses are attached in Appendix C.

Limitations

The geotechnical assessment of the proposed dike was completed only over the extent of the current project area, and with consideration to the proposed dike layout described previously. Estimates of stability, displacements, and settlements were based on the subsurface exploration conducted by Levelton and information that was provided to Levelton prior to the preparation of the report. Changes to the design, including different configurations, construction limits, etc. may require additional review.

5.3.2 Liquefaction Susceptibility and Estimated Post-Liquefaction Movements

A liquefaction analysis was conducted using the Seed Simplified Method. The analysis was based on the A2475 A_{max} values and a typical soil profile developed from the results of our subsurface investigation. Under the 1 in 100 year seismic loading condition, no zones of potentially liquefiable soils were identified and under the 1 in 475 year event, the liquefaction zones were minimal. Under the 1 in 2475 earthquake loading, there are zones of potentially liquefiable soils in the granular deposits. In the case of a design earthquake, it is expected that these soils could liquefy and result in an estimated vertical displacement on the order of 100mm and a horizontal displacement on the order of 400mm. Liquefaction movements of this magnitude are generally considered acceptable for dike sections of this type.

5.4 DIKE SEEPAGE CONSIDERATIONS

Seepage analysis was conducted for the proposed dike template and expected subgrade soils. Potential seepage losses through and below the dike were analyzed based on the calculated hydraulic gradient and assumed soil conditions for the dike fill and subgrade soils.

The values for the coefficient of hydraulic conductivity (k_h) in the horizontal direction adopted in the analysis for the various soil strata encountered in our subsurface investigation were based on correlations of soil properties and previous experience with similar soils. The values of horizontal hydraulic conductivity (k_h) used in the seepage analysis model are summarized in Table 3.

Table 3 – Hydraulic Conductivity of Site Soils

Soil Unit	Coefficient of Hydraulic Conductivity, k_h (m/sec)
Dike Fill (Silty Sand)	1×10^{-7}
Sand some Silt	5×10^{-6}
Silt trace Sand	1×10^{-9}

The results of the seepage analyses carried out for the typical dike section indicate that the seepage through and beneath the dike section modeled are estimated on the order of 1L / day / linear meter of dike. This amount of seepage is considered nominal, and it is expected that no landside toe drainage provisions would be required in the dike design.

An important consideration in the assessment of dike stability is the potential for underseepage or piping on the landward side of the dike. By determining the exit gradient at the landward toe of the dike and in the foundation soils further inland, a FoS against piping can be determined. Guidelines for severity of underseepage based on hydraulic gradient have been developed by the United States Army Corps of Engineers (USACE 2005). The Canadian Foundation Engineering Manual 4th Edition (2006) recommends a FoS of 2 to 3. Based on our analysis, the FoS of the analyzed dike cross-section is 4.7, which is considered acceptable.

5.5 DIKE SETTLEMENT

Construction of a new 4m high dike embankment will induce consolidation of the underlying native soils. Settlement analysis was conducted for a typical soil profile and a 4m high dike using the computer program *Settle 3d* by RocScience.

The majority of native soils encountered at the site to the depth explored are granular deposits that will exhibit immediate settlement during the placement and compaction of the dike fill. The immediate settlement will occur before the final fill grading and will not affect the constructed dike crest elevation. A number of boreholes encountered soft silt deposits at relatively shallow depth that would experience longer term consolidation due to the new load applied by the embankment fill. Long term post construction settlements of the dike crest are expected to be on the order of 100mm.

5.6 SITE PREPARATION

5.6.1 General

The conditions along the proposed dike alignment typically consist of vegetated silt topsoil underlain by granular deposits. Based on these conditions, it is expected that the proposed dike fills could be placed near the existing grades following site clearing and stripping. The general construction steps would include stripping of surficial organics and topsoil from the dike footprint, compacting the anticipated granular subgrade, placing and compacting the new dike fill, and installing the surface treatment atop the dike crest.

5.6.2 Subgrade Preparation

Site preparation in the agricultural and vacant rural areas should consist of the removal of any vegetation, topsoil, and soft / loose deposits to expose competent subgrade consisting of the native loose to compact sand. Based on the auger holes, stripping depths of about 0.5 to 0.9m below existing grade may be necessary to remove these materials and expose competent inorganic soil subgrade. Greater or lesser stripping depths may be necessary in localized areas remote from the auger hole locations.

We recommend the granular subgrade be compacted with vibratory equipment prior to the placement of any fill. Subgrade soils should be compacted to not less than 95% of their Standard Proctor Dry Density (SPMDD) prior to fill placement. The Geotechnical Engineer should review the stripped and compacted subgrade prior to the placement of any fill.

Fill required to construct the dike to the required height and width should consist of dike fill as discussed in Section 5.8 (below).

5.7 EXCAVATIONS

5.7.1 Unsupported Excavations

Temporary unsupported excavations should be conducted in accordance with the Workers Compensation Board WorkSafe BC regulations. A maximum inclination of 1H:1V is considered appropriate for temporary excavations deeper than 1.2 m where worker access is required. The water table is located at relatively shallow depth and was encountered at a depth of 0.7m to 0.9m at the time of the investigation. Excavations below the water table would require specialized dewatering.

Surcharge loads from soil stockpiles, construction vehicles, and construction material stockpiles should be avoided by keeping such items away from the excavation crest a minimum horizontal distance equal to the depth of the excavation. Temporary excavations that will be located adjacent to surcharge loads should be approved by a Geotechnical Engineer prior to excavation.

All temporary unsupported excavations requiring worker access should be approved in writing by a Geotechnical Engineer prior to workers entering or working adjacent to such excavations.

5.8 ENGINEERED FILLS

5.8.1 Gradation of Dike Fill

To limit seepage through the dike during flood events, utilization of low permeability fill for dike construction is required. We consider that fill which contains at least 15% silt or clay sized particles by weight will have a suitably low permeability, while still having generally good "constructability" characteristics. The silt or clay particles will fill the gaps between the coarser sand and gravel grains such that the permeability of the soil matrix will be equivalent to that of a silt deposit. A grain size distribution for the proposed dike fill is provided in Table 4.

Table 4 – Recommended Dike Fill Material

Sieve Size	% Finer Than
150 mm	100
75 mm	75 – 100
37.5 mm	60 –100
19 mm	50 – 90
4.75 mm	40 – 70
0.425 mm	25 – 50
0.075 mm	15 – 35

Alternatively, the dikes could be constructed utilizing silt or clay soils (more than 50% by weight passing the 0.075mm sieve size) that have a moisture content within 2 percent of their optimum moisture content for compaction, as established by the Standard Proctor test (ASTM D-698).

5.8.2 Dike Fill Placement Recommendations

General dike fill placement recommendations are as follows:

1. All sources of candidate dike fill should be approved by the Geotechnical Engineer prior to placement at the site. This should include gradation analysis and Standard Proctor tests on representative samples of the material by the Geotechnical Engineer;
2. The existing surface vegetation and topsoil should be stripped and a competent sand subgrade exposed / prepared;
3. The approved fill should be compacted to not less than 97% of the material's SPMDD, as confirmed by in-place density testing by the Geotechnical Engineer. The moisture content of the compacted fill should be within 2% of optimum, as determined by the in-place density testing and Standard Proctor test;
4. Fill material should be placed and compacted in lifts no greater than 300mm in thickness using a smooth drum roller. A sheep foot roller may be required depending on the fines content of the actual dike fill. The lift thickness should be reduced to 150mm where a vibratory plate compactor is used. The lift thickness should not be increased without prior written approval from the Geotechnical Engineer;
5. The constructed fill slope should be over-built at least 300mm beyond its final position and then trimmed back to the final position after compaction;
6. The Geotechnical Engineer should be retained to conduct in-place soil density testing using a nuclear densometer on each lift of fill. Representative samples of the dike fill material should also be collected during construction for Standard Proctor and gradation analysis testing to confirm the material is consistent with the recommendations provided in this report.

As the recommended dike fill material contains a significant fine-grained component, its moisture content would need to be closely controlled during placement and compaction. This may cause construction delays if the material is placed in less than ideal weather conditions.

5.8.3 Filter Gradation

To prevent piping along utility lines, if any, that are to extend through the dike, a suitable granular filter should be placed adjacent to the pipes. Based on the specification for the dike fill material provided above in Table 4, we recommend that the filter material consist of sandy gravel / sand and gravel with the gradation provided in Table 5.

Table 5 – Recommended Filter Material Gradation

Sieve Size	Percent Passing by Weight
75 mm	100
12.5 mm	50 – 80
9.51 mm	38 – 70
2.36 mm	20 – 50
1.18 mm	15 – 40
0.3 mm	8 – 15
0.075 mm	0 – 6

The filter zone should be 0.5m thick and be placed along the landside one third portion of the conduits. The remainder of the conduit should be backfilled with dike fill material as discussed above.

It should be noted that, because the specification for the dike fill material consists of an upper and lower limit for various particle sizes, some refinement of the filter material specification may be necessary based on the grain size distribution of the dike fill material actually used in construction. Levelton should be given the opportunity to review and conduct grain size analysis testing of the proposed dike fill and filter material prior to use to confirm the acceptability of the materials. Dike filter material should be compacted to 97% of its SPMDD.

5.8.4 Engineered Fill

We recommend that fill required to establish the desired grades, outside of the dike profile, consist of 100mm minus pit-run sand and gravel with less than 8% fines (material passing the 0.075 mm sieve) by weight, or a Geotechnical Engineer approved equivalent.

The engineered fill should be placed in discrete lifts of a maximum of 300mm in thickness and be compacted to not less than 100% of the material's SPMDD. The Geotechnical Engineer should conduct in-place soil density testing on the fill as it is being placed to confirm that adequate compaction is achieved.

5.8.5 Potential Dike Fill Sources

The samples of three potential sources of dike fill material were submitted to our laboratory for grain size analysis. The grain size distribution results for the three samples are provided in

Appendix B, and the results have been plotted against the gradation specification recommended for dike fill in Section 5.8.1 above.

In general, the material sampled from the berm stockpile on 3850 Swamp Road consisted of sand and gravel with a fines content (material passing the 0.075mm sieve) varying from 14.5% to 20.5%. These samples generally conform to our recommended dike fill specification, and it is our opinion that the stockpiled material would be suitable for use as dike fill based on the samples collected.

The material sampled from the existing dike consisted of gravel and sand, some silt. This material is in general conformance with the recommended dike fill gradation; however the fines content is only 10.2% and is less than the minimum of 15% recommended. Since the material contains less fines than recommended, it may have a higher permeability than the recommended dike fill. Therefore, if the existing dike fill will be re-used to construct the new dike, consideration should be given mixing the existing dike fill with a soil having a higher fines content in order to produce a material meeting the dike fill gradation recommendation.

The grain size analyses and comments provided above are based on discrete test results from localized test samples. Additional samples should be collected and tested prior to use as dike fill to determine the consistency of the materials and suitability for use as dike fill.

5.8.6 Dike Running Surface

It is recommended that, if the surface of the dike is to remain unpaved, the running surface consist of 19 mm minus crushed sand and gravel a minimum of 150 mm in thickness placed over the Geotechnical Engineer approved compacted dike fill and compacted to not less than 100% of the material's SPMDD. A gravel running surface of this material and thickness would be suitable for maintenance access by foot, occasional service vehicles and potential pedestrian path use.

If more frequent traffic for service vehicles is required, Levelton can provide additional recommendations for a more robust road structure or an asphalt concrete surface.

5.9 EROSION CONTROL

If armoring is required on the waterside slope of the dike to control erosion, it is recommended that the dike design include "rip-rap" angular rock protection.

The rip-rap size would be based on river flow velocities and bank slope angles. Detailed recommendations for rip rap size can be provided once river hydraulics information is available. As an initial guideline, assuming a design flow velocity of 4m/s and a dike waterside slope of 2H:1V or flatter, Class 250 kg rip-rap would be recommended.

As an initial preliminary guideline the angular rock layer placed on the waterside dike face should consist of MOTI Class 250 Rip-Rap with a nominal thickness of 1000mm. The average dimension of angular rock should be approximately 565mm, and the specified gradation is provided in Table 6.

Table 6: Gradation of MOTI Class 250 Rip-Rap

Percentage Larger Than Given Rock Mass (kg)		
85%	50%	15%
25	250	750

The controlled placement of rock shall produce a rock mass of at least the nominal thickness along the waterside dike face. The rock shall be manipulated as necessary to provide a stable mass and a uniform surface with the least voids possible.

The rip-rap would need to be underlain by a suitable filter layer or appropriate geotextile to limit the potential for erosion of soil beneath the rip-rap.

6. FURTHER GEOTECHNICAL SERVICES

The design was in a preliminary stage when this report was prepared and our analysis and design recommendations are based on information available at the time it was prepared. The Geotechnical Engineer should be retained to review the geotechnical aspects of the drawings and specifications during the detailed design stage. Further analysis may be required for revised dike configurations, or to respond to queries from approving authorities.

Further guidance on the scope of construction reviews can be given during the detailed design phase, but generally the Geotechnical Engineer should be retained to review the following aspects of the construction:

- Review the stripped surfaces prior to fill placement to establish they are in accordance with the this report and the design;
- Review candidate sources of dike fill and filter materials prior to placement; and,
- Monitor the placement and compaction of the dike fill, filter materials and rip-rap armoring to establish compliance with the design.

7. LIMITATIONS & CLOSURE

This geotechnical assessment report has been prepared by Levelton Consultants Ltd. exclusively for the City of Kelowna, and their appointed agents. The opinions, conclusions and recommendations contained in this report reflect our judgment in light of the information provided to us at the time that it was prepared.

Any use of this report by third parties, or any reliance on or decisions made based on it, are the responsibility of such third parties. Levelton does not accept responsibility for damages suffered, if any, by a third party as a result of their use of this report.

The soil logs appended to this report provide description of the soil and groundwater conditions encountered at discrete auger holes. Soil conditions along the dike alignment in areas remote from the auger hole locations may differ from those encountered at the auger hole locations.

The attached Terms of Reference should be read in conjunction with and form an integral part of this report.

We trust this information meets your immediate requirements. If you have any questions or require further information, please contact the undersigned.

LEVELTON CONSULTANTS LTD.

Original Signed By:

Per:	Thomas Dueckman, EIT Junior Geotechnical Engineer	Per: Paul Ell, P.Eng. Senior Geotechnical Engineer

Reviewed By: Michael Gutwein, P.Eng.
Senior Geotechnical Engineer

LEVELTON

TERMS OF REFERENCE FOR GEOTECHNICAL REPORTS ISSUED BY LEVELTON CONSULTANTS LTD.

1. STANDARD OF CARE

Levelton Consultants Ltd. ("Levelton") prepared and issued this geotechnical report (the "Report") for its client (the "Client") in accordance with generally-accepted engineering consulting practices for the geotechnical discipline. No other warranty, expressed or implied, is made. Unless specifically stated in the Report, the Report does not address environmental issues.

The terms of reference for geotechnical reports issued by Levelton (the "Terms of Reference") contained in the present document provide additional information and caution related to standard of care and the use of the Report. The Client should read and familiarize itself with these Terms of Reference.

2. COMPLETENESS OF THE REPORT

All documents, records, drawings, correspondence, data, files and deliverables, whether hard copy, electronic or otherwise, generated as part of the services for the Client are inherent components of the Report and, collectively, form the instruments of professional services (the "Instruments of Professional Services"). The Report is of a summary nature and is not intended to stand alone without reference to the instructions given to Levelton by the Client, the communications between Levelton and the Client, and to any other reports, writings, proposals or documents prepared by Levelton for the Client relative to the specific site described in the Report, all of which constitute the Report.

TO PROPERLY UNDERSTAND THE INFORMATION, OBSERVATIONS, FINDINGS, SUGGESTIONS, RECOMMENDATIONS AND OPINIONS CONTAINED IN THE REPORT, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. LEVELTON CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT AND ITS VARIOUS COMPONENTS.

3. BASIS OF THE REPORT

Levelton prepared the Report for the Client for the specific site, development, building, design or building assessment objectives and purpose that the Client described to Levelton. The applicability and reliability of any of the information, observations, findings, suggestions, recommendations and opinions contained in the Report are only valid to the extent that there was no material alteration to or variation from any of the said descriptions provided by the Client to Levelton unless the Client specifically requested Levelton to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information, observations, findings, suggestions, recommendations and opinions contained in the Report, or any component forming the Report, are for the sole use and benefit of the Client and the team of consultants selected by the Client for the specific project that the Report was provided. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION OR COMPONENT WITHOUT THE WRITTEN CONSENT OF LEVELTON. Levelton will consent to any reasonable request by the Client to approve the use of this Report by other parties designated by the Client as the "Approved Users". As a condition for the consent of Levelton to approve the use of the Report by an Approved User, the Client must provide a copy of these Terms of Reference to that Approved User and the Client must obtain written confirmation from that Approved User that the Approved User will comply with these Terms of Reference, such written confirmation to be provided separately by each Approved User prior to beginning use of the Report. The Client will provide Levelton with a copy of the written confirmation from an Approved User when it becomes available to the Client, and in any case, within two weeks of the Client receiving such written confirmation.

The Report and all its components remain the copyright property of Levelton and Levelton authorises only the Client and the Approved Users to make copies of the Report, but only in such quantities as are reasonably necessary for the use of the Report by the Client and the Approved Users. The Client and the Approved Users may not give, lend, sell or otherwise disseminate or make the Report, or any portion thereof, available to any party without the written permission of Levelton. Any use which a third party makes of the Report, or any portion of the Report, is the sole responsibility of such third parties. Levelton accepts no responsibility for damages suffered by any third party resulting from the use of the Report. The Client and the Approved Users acknowledge and agree to indemnify and hold harmless Levelton, its officers, directors, employees, agents, representatives or sub-consultants, or any or all of them, against any claim of any nature whatsoever brought against Levelton by any third parties, whether in contract or in tort, arising or related to the use of contents of the Report.

TERMS OF REFERENCE FOR GEOTECHNICAL REPORTS ISSUED BY LEVELTON CONSULTANTS LTD. (continued)

5. INTERPRETATION OF THE REPORT

a. **Nature and Exactness of Descriptions**: The classification and identification of soils, rocks and geological units, as well as engineering assessments and estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1 above. The classification and identification of these items are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations or assessments utilizing the standards of Paragraph 1 involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to changes over time and the parties making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or when the Client has special considerations or requirements, the Client must disclose them to Levelton so that additional or special investigations may be undertaken, which would not otherwise be within the scope of investigations made by Levelton or the purposes of the Report.

b. **Reliance on information**: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site investigation and field review and on the basis of information provided to Levelton. Levelton has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Levelton cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.

c. **Additional Involvement by Levelton**: To avoid misunderstandings, Levelton should be retained to assist other professionals to explain relevant engineering findings and to review the geotechnical aspects of the plans, drawings and specifications of other professionals relative to the engineering issues pertaining to the geotechnical consulting services provided by Levelton. To ensure compliance and consistency with the applicable building codes, legislation, regulations, guidelines and generally-accepted practices, Levelton should also be retained to provide field review services during the performance of any related work. Where applicable, it is understood that such field review services must meet or exceed the minimum necessary requirements to ascertain that the work being carried out is in general conformity with the recommendations made by Levelton. Any reduction from the level of services recommended by Levelton will result in Levelton providing qualified opinions regarding adequacy of the work.

6. ALTERNATE REPORT FORMAT

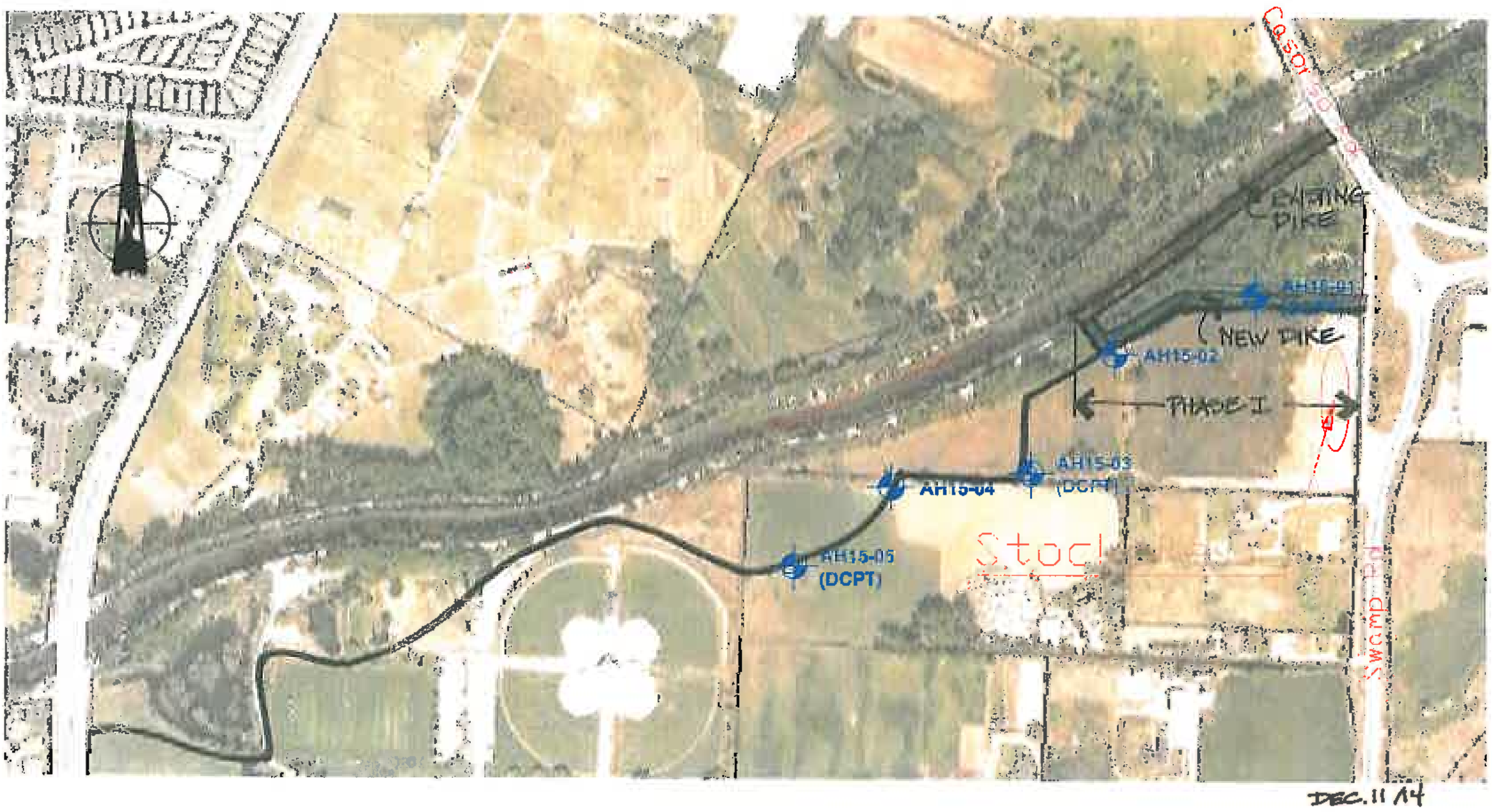
When Levelton submits both electronic and hard copy versions of the Instruments of Professional Services, the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding upon Levelton. The hard copy versions submitted by Levelton shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions; furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed and sealed versions of the Instruments of Professional Services maintained or retained, or both, by Levelton shall be deemed to be the overall originals for the Project.

The Client agrees that the electronic file and hard copy versions of Instruments of Professional Services shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Levelton. The Client warrants that the Instruments of Professional Services will be used only and exactly as submitted by Levelton.

The Client recognizes and agrees that Levelton prepared and submitted electronic files using specific software or hardware systems, or both. Levelton makes no representation about the compatibility of these files with the current or future software and hardware systems of the Client, the Approved Users or any other party. The Client further agrees that Levelton is under no obligation, unless otherwise expressly specified, to provide the Client, the Approved Users and any other party, or any or all of them, with specific software and hardware systems that are compatible with any electronic submitted by Levelton. The Client further agrees that should the Client, an Approved User or a third party require Levelton to provide specific software or hardware systems, or both, compatible with the electronic files prepared and submitted by Levelton, for any reason whatsoever included but not restricted to an order from a court, then the Client will pay Levelton for all reasonable costs related to the provision of the specific software or hardware systems, or both. The Client further agrees to indemnify and hold harmless Levelton, its officers, directors, employees, agents, representative or sub-consultant, or any or all of them, against any claim or any nature whatsoever brought against Levelton, whether in contract or in tort, arising or related to the provision or use or any specific software or hardware provided by Levelton.

🟧 REMOVE EXISTING DIKE
🟦 BUILD NEW DIKE
▬ LONG TERM - NEW DIKE

Mission Creek Restoration Initiative



Note: Test Hole Locations are Approximate

LEGEND
AH15-XX AUGER HOLE
AH15-XX (DCPT) AUGER HOLE WITH DYNAMIC CONE PENETRATION TEST

ADAPTED FROM: N/A
DATE: N/A
PROJECT NO.: N/A

This drawing is the sole property of Levelton Consultants Ltd. and cannot be used or duplicated in any way without the expressed written consent of Levelton Consultants. The general contractor shall verify all dimensions and report any discrepancies to Levelton Consultants Ltd.

LEVELTON
108-3677 Hwy 97 N,
Kelowna, BC, V1X 5C3
p:250-491-9778
f:250-491-8729
www.levelton.com

TITLE: Site Plan - Augerhole Locations
PROJECT: Mission Creek Dike Replacement
ADDRESS: 3830, 3850, 3990 Swamp Road
CLIENT: The City of Kelowna

DSN:
CHK: PE
DWN: TD

SCALE: NTS
DATE: Feb. 27 2015
PROJECT NO.: R715-0268-00
DRAWING NO.: FIGURE 1

Appendix A

Soil Logs

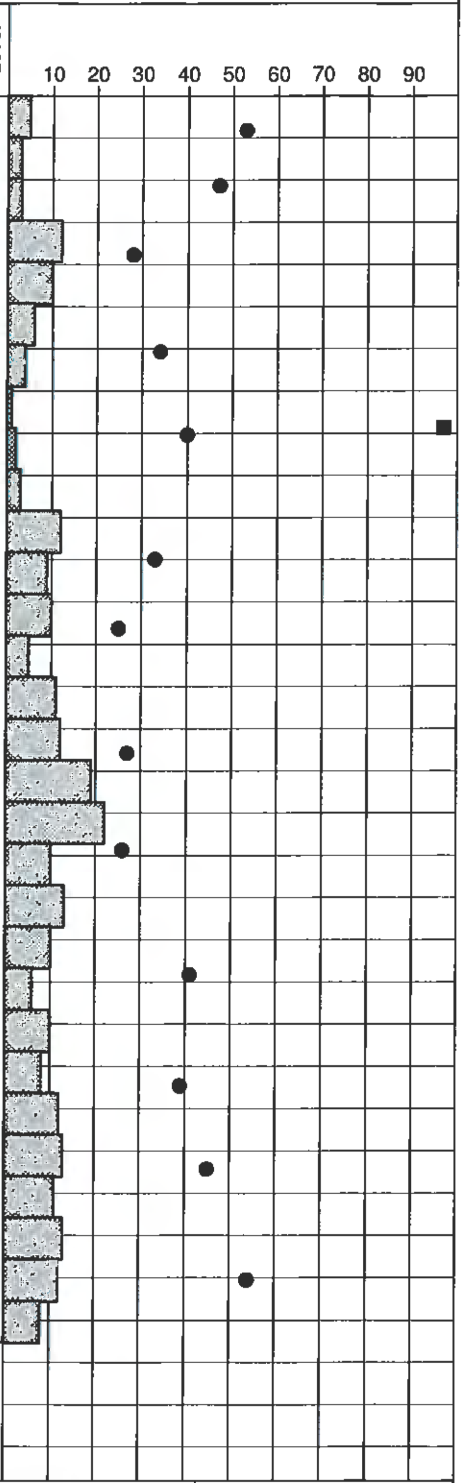
LEVELTON
Levelton Consultants Ltd.
#108 - 3677 Highway 97N
Kelowna, B.C. V1X 5C3
Tel: 250-491-9778
Fax: 250-491-9729
www.levelton.com

3830, 3850, 3990 Cassorso Road
Kelowna, BC
Dike Replacement

AH15-01

Pg 1 of 1
Project No: R715-0268-00
Northing: 5524245 Easting: 322590

Description	C	N	Type	Water Level
Soft brown <u>SILT</u> topsoil, trace sand, roots and organics, moist.	▥		G	
Very loose, grey <u>SAND</u> some silt, wet.	▥		G	▼ Feb 11 2015
Compact, grey brown silty <u>SAND</u>, mottled, wet.	▥		G	
Loose, grey <u>SAND</u>, some silt, wet.	▥		G	
Very soft, grey <u>SILT</u>, trace sand, wet.	▥		G	
Compact, grey <u>SAND</u>, some silt, wet.	▥ ▥ ▥ ▥		G G G G	
Interlayered compact, grey <u>SAND</u>, some silt, and firm, grey brown silty <u>SAND</u>. Occasional organic silt and ash seams 50-100mm thick.	▥ ▥ ▥ ▥		G G G G	
Bottom of hole at 9.00 meters				



C: Condition of Sample
Good ▨
Disturbed ▥
No Recovery ☐

Type: Type of Sampler
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

N: Number of Blows
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type: Trip Hammer
DYNAMIC CONE PENETRATION TEST: ▨
Blow Count: Number of blows of a 140 lb (64 kg) hammer dropped 30in. (750mm) to produce 12in. (300mm) of penetration of a 2in. (50mm) diameter cone.

- ● Moisture Content %
- ▶ Plastic Limit %
- ◀ Liquid Limit %
- ▼ Ground Water Level
- ∞ Shear strength in kPa (Torvane or Penetrometer)
- ✕ Shear strength in kPa (Unconfined)
- ⊗ Shear strength in kPa (field vane)
- ☒ Remolded strength in kPa
- ■ Percent Passing # 200 sieve

Drill Method:
Solid Stem Auger / DCPT
Date Drilled: 11/02/2015
By: TD

THIS LOG IS FOR GEOTECHNICAL PURPOSES ONLY
THIS LOG IS THE SOLE PROPERTY OF LEVELTON CONSULTANTS LTD AND CANNOT BE USED OR DUPLICATED IN ANY WAY WITHOUT EXPRESS WRITTEN PERMISSION.

LEVELTON
Levelton Consultants Ltd.
#106 - 3677 Highway 97N
Kelowna, B.C. V1X 5C3
Tel: 250-491-9778
Fax: 250-491-9729
www.levelton.com

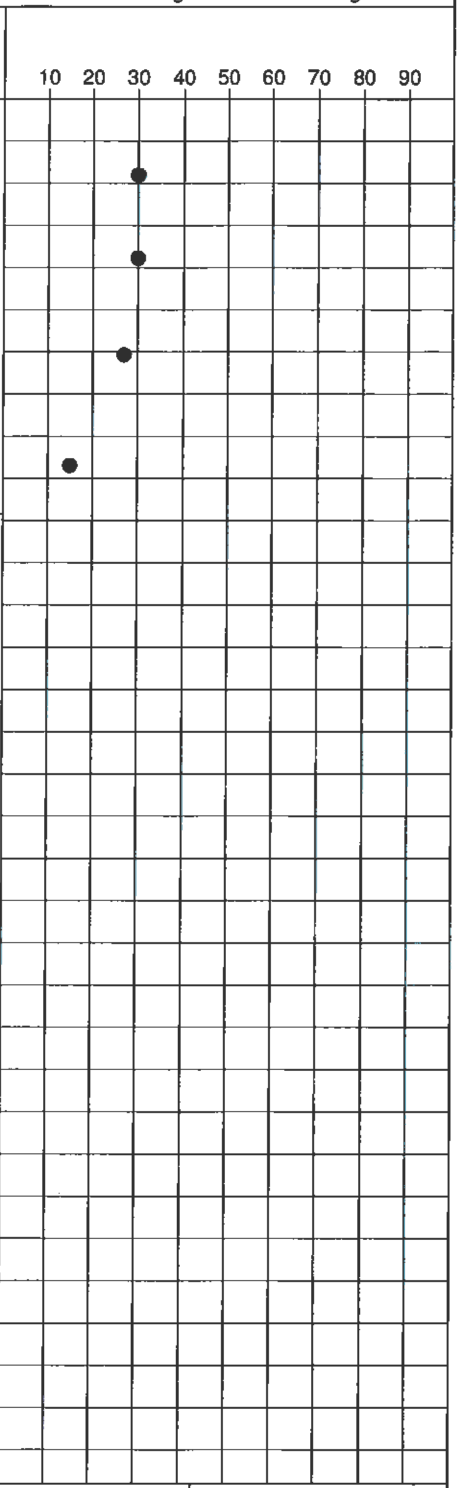
3830, 3850, 3990 Cassorso Road
Kelowna, BC
Dike Replacement

AH15-02

Pg 1 of 1
Project No: R715-0268-00
Northing: 5524202 Easting: 322448

Description	C	N	Type	Water Level
Soft brown <u>SILT</u> topsoil, trace sand, roots and organics, moist.	▥		G	▼ Feb 11 2015
Loose, grey <u>SAND</u>, some silt, wet.	▥ ▥		G G	
Compact, grey <u>SAND</u> and gravel, trace silt, wet.	▥		G	
Bottom of hole at 3.00 meters				

Depth (m): 2, 4, 6, 8
Depth (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32



C: Condition of Sample
Good ▨
Disturbed ▥
No Recovery ☐

Type: Type of Sampler
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

N: Number of Blows
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type:

● Moisture Content %
▶ Plastic Limit %
◀ Liquid Limit %
▼ Ground Water Level
⊗ Shear strength in kPa (Torvane or Penetrometer)
✕ Shear strength in kPa (Unconfined)
⊗ Shear strength in kPa (field vane)
⊠ Remolded strength in kPa
■ Percent Passing # 200 sieve

Drill Method: Solid Stem Auger
Date Drilled: 11/02/2015
By: TD

Levelton Consultants Ltd.
#108 - 3677 Highway 97N
Kelowna, B.C. V1X 5C3
Tel: 250-491-9778
Fax: 250-491-9729
www.levelton.com

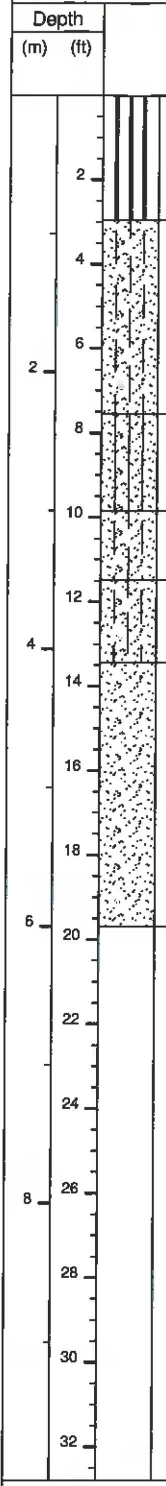
3830, 3850, 3990 Cassorso Road
Kelowna, BC
Dike Replacement

AH15-03

Pg 1 of 1

Project No: R715-0268-00

Northing: 5524118 Easting: 322376



Description

Soft, brown SILT topsoil, trace sand, roots and organics, moist.

Loose, grey SAND, some silt, wet.

Compact, grey brown silty SAND, mottled, wet.

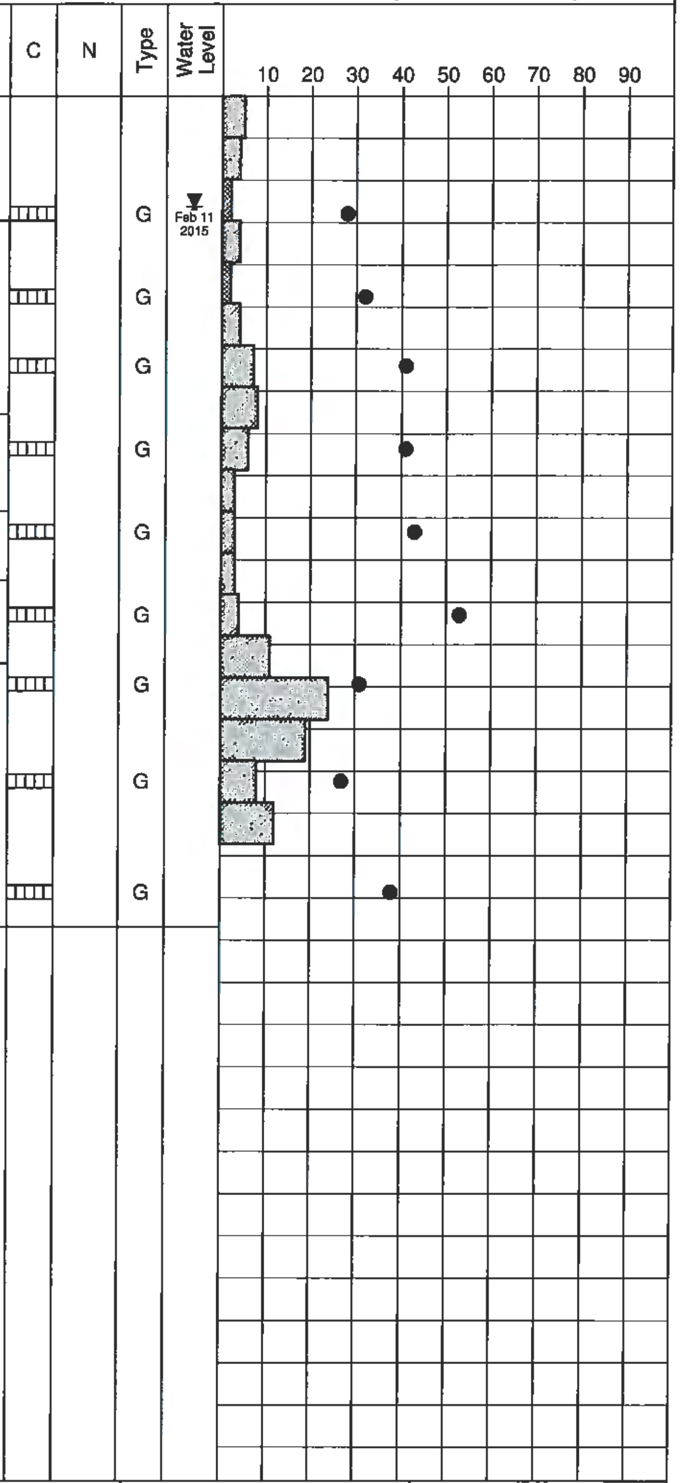
Compact, grey SAND, some silt, wet.

Loose grey SAND, some silt, wet.

Occasional organic silt seams 50-100mm thick.

Compact, grey SAND, trace silt, trace gravel, interlayered fine and coarse deposits.

Bottom of hole at 6.00 meters



C: Condition of Sample
Good ▨
Disturbed ▥
No Recovery ☐

Type: Type of Sampler
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

THIS LOG IS FOR GEOTECHNICAL PURPOSES ONLY
THIS LOG IS THE SOLE PROPERTY OF LEVELTON CONSULTANTS LTD AND CANNOT BE USED OR DUPLICATED IN ANY WAY WITHOUT EXPRESS WRITTEN PERMISSION.

N: Number of Blows
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type: Trip Hammer

DYNAMIC CONE PENETRATION TEST: ▨
Blow Count: Number of blows of a 140 lb (64 kg) hammer dropped 30in. (750mm) to produce 12in. (300mm) of penetration of a 2in. (50mm) diameter cone.

● Moisture Content %
▶ Plastic Limit %
◀ Liquid Limit %
▼ Ground Water Level
∞ Shear strength in kPa (Torvane or Penetrometer)
✕ Shear strength in kPa (Unconfined)
⊗ Shear strength in kPa (field vane)
☒ Remolded strength in kPa
■ Percent Passing # 200 sieve

Drill Method:
Solid Stem Auger / DCPT
Date Drilled: 11/02/2015
By: TD

LEVELTON

Levelton Consultants Ltd.
#108 - 3677 Highway 97N
Kelowna, B.C. V1X 5C3
Tel: 250-491-9778
Fax: 250-491-9729
www.levelton.com

3830, 3850, 3990 Cassorso Road
Kelowna, BC
Dike Replacement

AH15-04

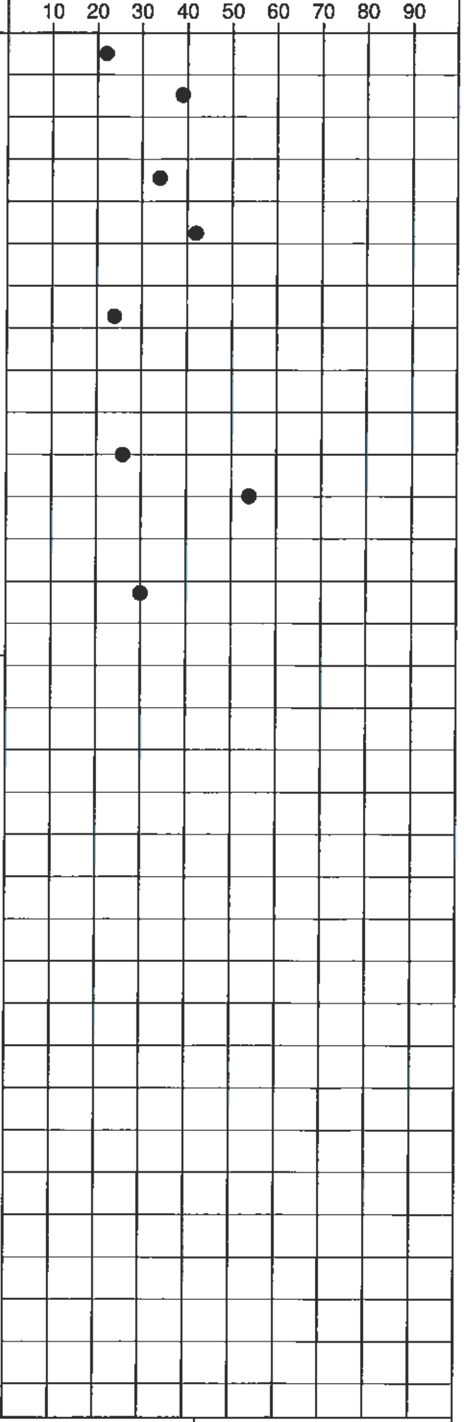
Pg 1 of 1

Project No: R715-0268-00

Northing: 5524086 Easting: 322249

Description	C	N	Type	Water Level
Loose, brown SILT topsoil, trace sand, roots and organics, moist.	▥		G	
Soft, brown sandy SILT, wet.	▥		G	
Occasional organic silt seams 50mm thick.				▼ Feb 11 2015
Loose, grey SAND, some silt, wet.	▥		G	
Soft, grey SILT, some sand, wet.	▥		G	
Occasional organic silt and ash seams 50mm thick.				
Compact, grey SAND, some silt, wet.	▥		G	
	▥		G	
Loose, grey SAND trace silt, wet.	▥		G	
Occasional organic silt seams 50mm thick.				
Compact, grey SAND trace silt, wet.	▥		G	
Bottom of hole at 4.50 meters				

Depth (m): 2, 4, 6, 8
Depth (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32



C: Condition of Sample
Good ▨
Disturbed ▥
No Recovery ☐

Type: Type of Sampler
SPT : 2 In. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

N: Number of Blows
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type:

- ● Moisture Content %
- ► Plastic Limit %
- ◄ Liquid Limit %
- ▼ Ground Water Level
- ✖ Shear strength in kPa (Torvane or Penetrometer)
- X Shear strength in kPa (Unconfined)
- ⊗ Shear strength in kPa (field vane)
- ☒ Remolded strength in kPa
- ■ Percent Passing # 200 sieve

Drill Method:
Solid Stem Auger
Date Drilled: 11/02/2015
By: TD

THIS LOG IS FOR GEOTECHNICAL PURPOSES ONLY
THIS LOG IS THE SOLE PROPERTY OF LEVELTON CONSULTANTS LTD AND CANNOT BE USED OR DUPLICATED IN ANY WAY WITHOUT EXPRESS WRITTEN PERMISSION.

LEVELTON
Levelton Consultants Ltd.
#108 - 3677 Highway 97N
Kelowna, B.C. V1X 5C3
Tel: 250-491-9778
Fax: 250-491-9729
www.levelton.com

3830, 3850, 3990 Cassorso Road
Kelowna, BC
Dike Replacement

AH15-05

Pg 1 of 1

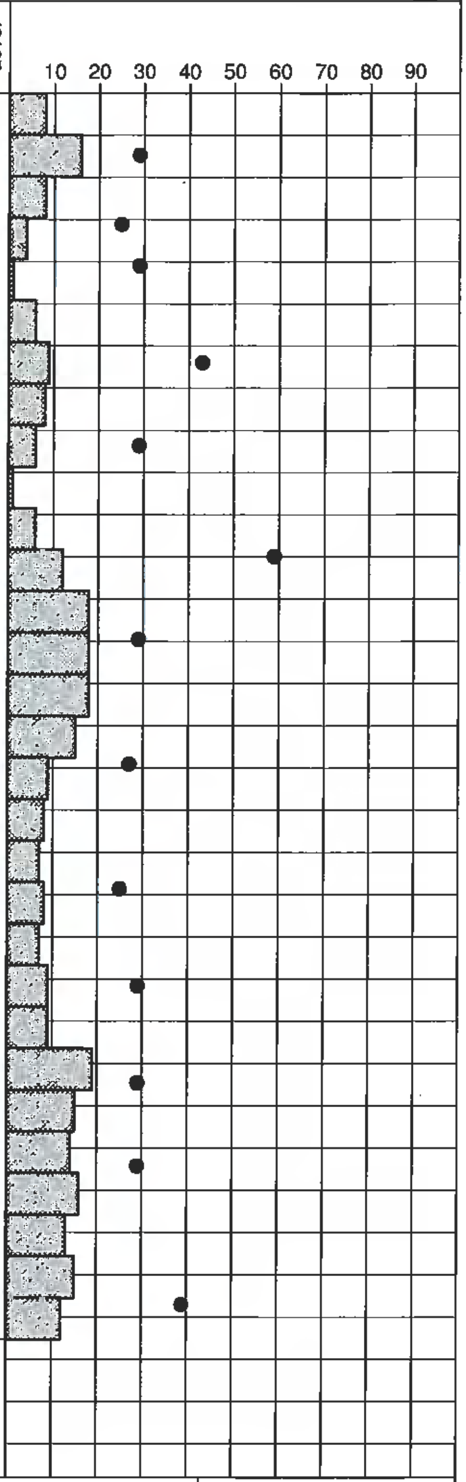
Project No: R715-0268-00

Northing: 5524038 Easting: 322161

Description	C	N	Type	Water Level
Soft to firm, brown SILT topsoil, trace sand, roots and organics, moist.	▥		G	
Soft, brown sandy SILT, wet.	▥		G	▼ Feb 11 2015
Compact, grey brown silty SAND, mottled, wet.	▥		G	
Compact, light grey SAND, some silt, wet.	▥		G	
Compact, grey brown silty SAND, mottled, wet.	▥		G	
Interlayered compact, grey SAND, trace silt and compact, grey brown silty SAND, wet. Occasional organic silt and ash seams 50mm thick.	▥		G	
Compact grey SAND, trace silt, wet.	▥ ▥ ▥ ▥ ▥ ▥		G G G G G G	
Interlayered compact, grey SAND, trace silt, and compact, grey brown silty SAND, wet. Occasional organic silt and organics in seams 50mm thick.	▥		G	

Bottom of hole at 9.00 meters

Depth (m): 2, 4, 6, 8
Depth (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32



C: Condition of Sample	**Type: Type of Sampler**	**N: Number of Blows**
Good ▨	SPT : 2 in. standard	WH : Weight of Hammer
Disturbed ▥	ST : Shelby	WR : Weight of Rod
No Recovery ☐	FP : Fixed Piston	Standard Penetration Test : ASTM D1586
	G : Grab	Hammer Type: Trip Hammer
	CORE	

DYNAMIC CONE PENETRATION TEST: ▨
Blow Count: Number of blows of a 140 lb (64 kg) hammer dropped 30in. (750mm) to produce 12in. (300mm) of penetration of a 2in. (50mm) diameter cone.

- ● Moisture Content %
- ► Plastic Limit %
- ◄ Liquid Limit %
- ▼ Ground Water Level
- ∞ Shear strength in kPa (Torvane or Penetrometer)
- ✕ Shear strength in kPa (Unconfined)
- ⊗ Shear strength in kPa (field vane)
- ☒ Remolded strength in kPa
- ■ Percent Passing # 200 sieve

Drill Method:
Solid Stem Auger / DCPT
Date Drilled: 11/02/2015
By: TD

THIS LOG IS FOR GEOTECHNICAL PURPOSES ONLY

Appendix B

Grain Size Analysis Results

LEVELTON

Levelton Consultants Ltd.

Fraser Valley Group and Southern Interior

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

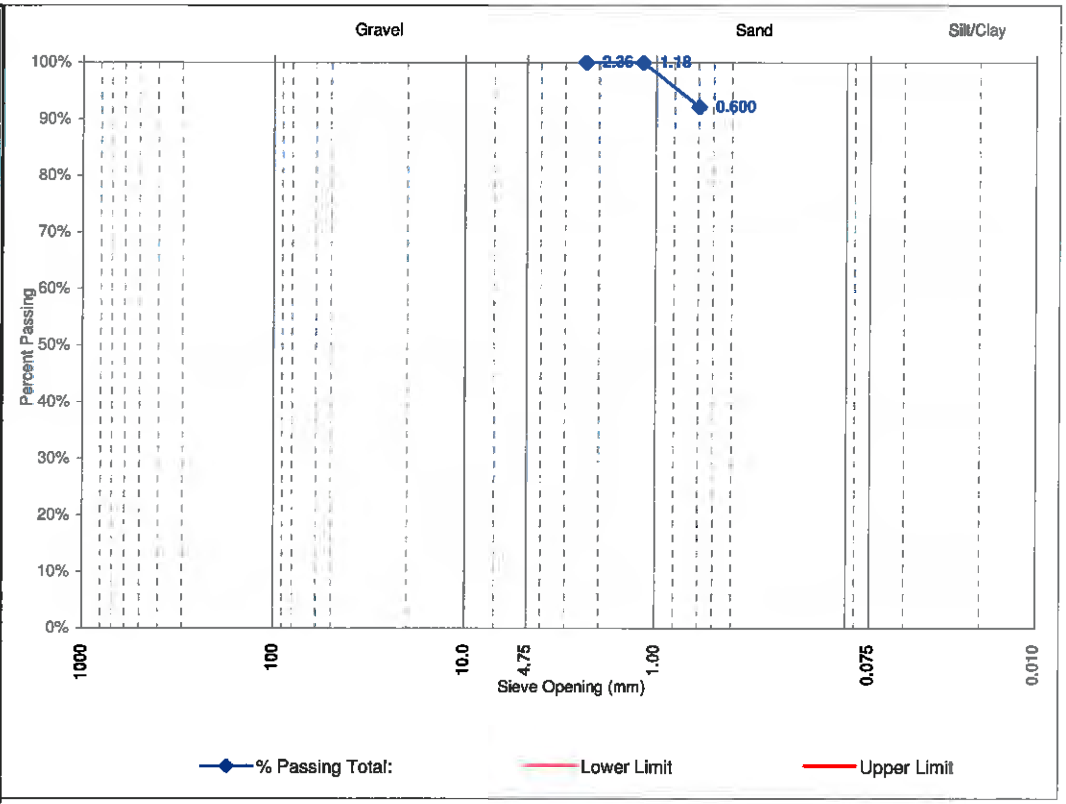
Sample Location: AH1501-G5
Supplier:
Material Type: SILT, trace Sand
Usage:
Specification:

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 19, 2015
Sieve No. 1

Moisture Content (as received): 35%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0			
75.0			
50.0			
37.5			
25.0			
19.0			
12.5			
9.51			
4.75			
2.36			
1.18			
0.600	100.0%		
0.425			
0.300	100.0%		
0.150	100.0%		
0.075	92.2%		



Remarks:

Levelton Consultants Ltd.

Reporting of these results constitutes a testing service only.
No engineering interpretation of the results is expressed or implied.
Engineering review and interpretation of these results can be provided upon written request.

Per:

Levelton Consultants Ltd.

Fraser Valley Group and Southern Interior

LEVELTON

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

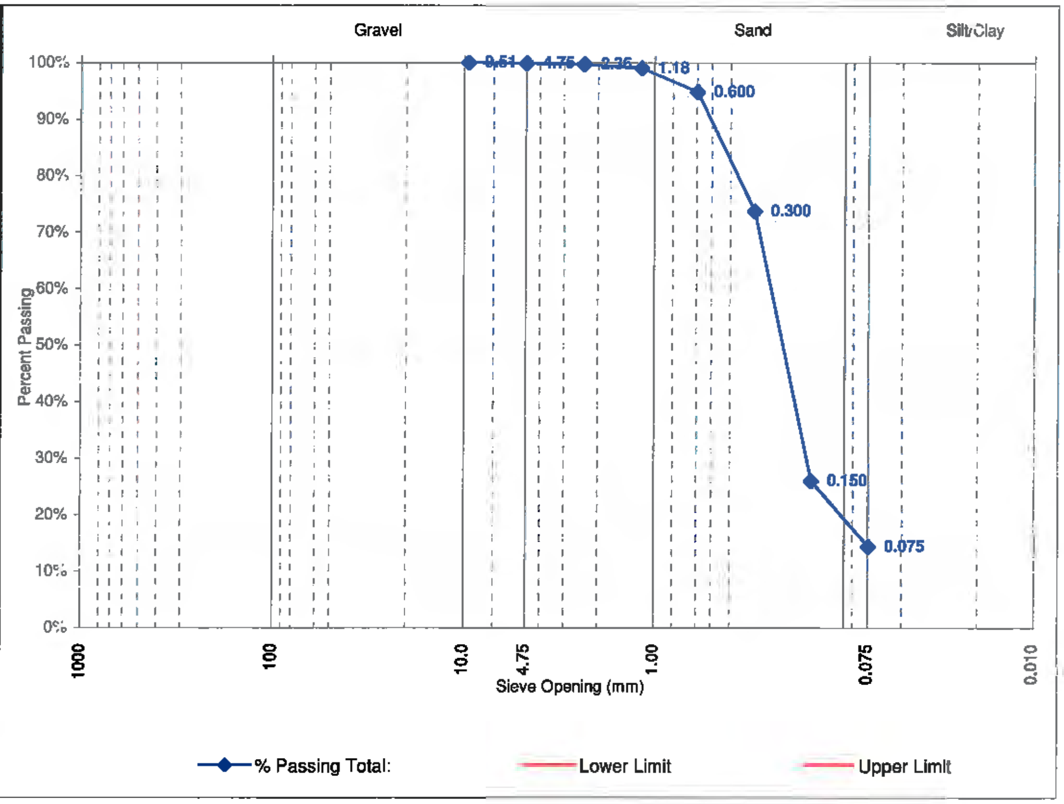
Sample Location: AH1502-G2
Supplier:
Material Type: SAND, some Silt
Usage:
Specification:

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 19, 2015
Sieve No. 2

Moisture Content (as received): 28%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0			
75.0			
50.0			
37.5			
25.0			
19.0			
12.5			
9.51	100.0%		
4.75	99.9%		
2.36	99.7%		
1.18	99.0%		
0.600	94.8%		
0.425			
0.300	73.7%		
0.150	26.0%		
0.075	14.4%		



Remarks: ______________________________

Levelton Consultants Ltd.

Per: ______________________

Levelton Consultants Ltd.

Fraser Valley Group and Southern Interior

LEVELTON

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

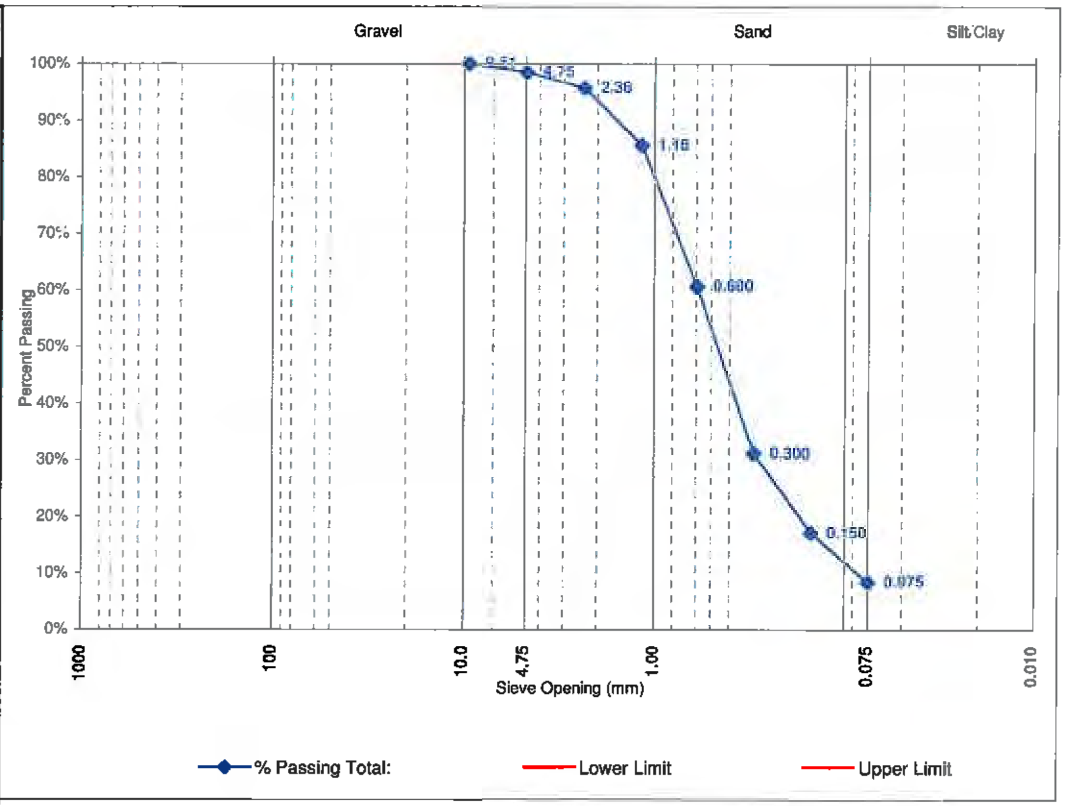
Sample Location: AH1503-G8
Supplier:
Material Type: SAND, trace silt, trace gravel
Usage:
Specification:

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 19, 2015
Sieve No. 3

Moisture Content (as received): 24%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0			
75.0			
50.0			
37.5			
25.0			
19.0			
12.5			
9.51	100.0%		
4.75	98.5%		
2.36	95.7%		
1.18	85.6%		
0.600	60.6%		
0.425			
0.300	31.0%		
0.150	17.0%		
0.075	8.3%		



Remarks: ______________________________

Levelton Consultants Ltd.

Reporting of these results constitutes a testing service only.
No engineering interpretation of the results is expressed or implied.
Engineering review and interpretation of these results can be provided upon written request.

Per: ______________________

Levelton Consultants Ltd.

Fraser Valley Group and Southern Interior

LEVELTON

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

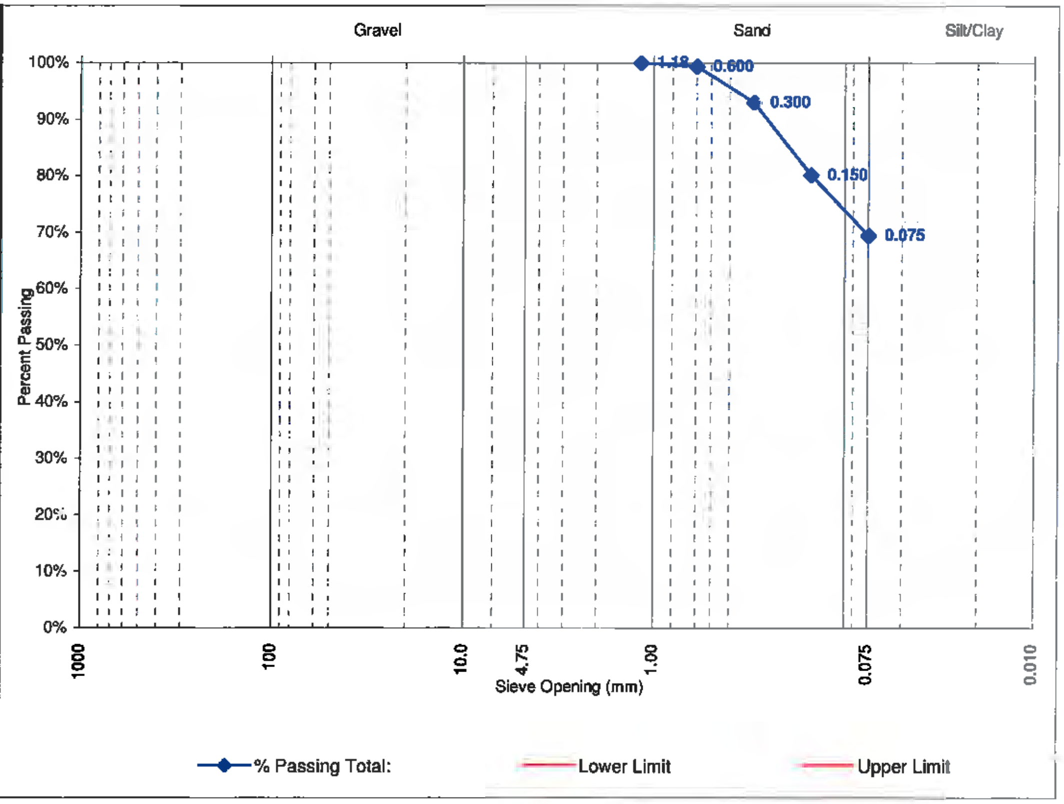
Sample Location: AH1504-G2
Supplier:
Material Type: Sandy SILT
Usage:
Specification:

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 19, 2015
Sieve No. 4

Moisture Content (as received): 30%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0			
75.0			
50.0			
37.5			
25.0			
19.0			
12.5			
9.51			
4.75			
2.36			
1.18	100.0%		
0.600	99.3%		
0.425			
0.300	93.0%		
0.150	80.1%		
0.075	69.4%		



Remarks:

Levelton Consultants Ltd.

Per:

LEVELTON

Levelton Consultants Ltd.

Fraser Valley Group and Southern Interior

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

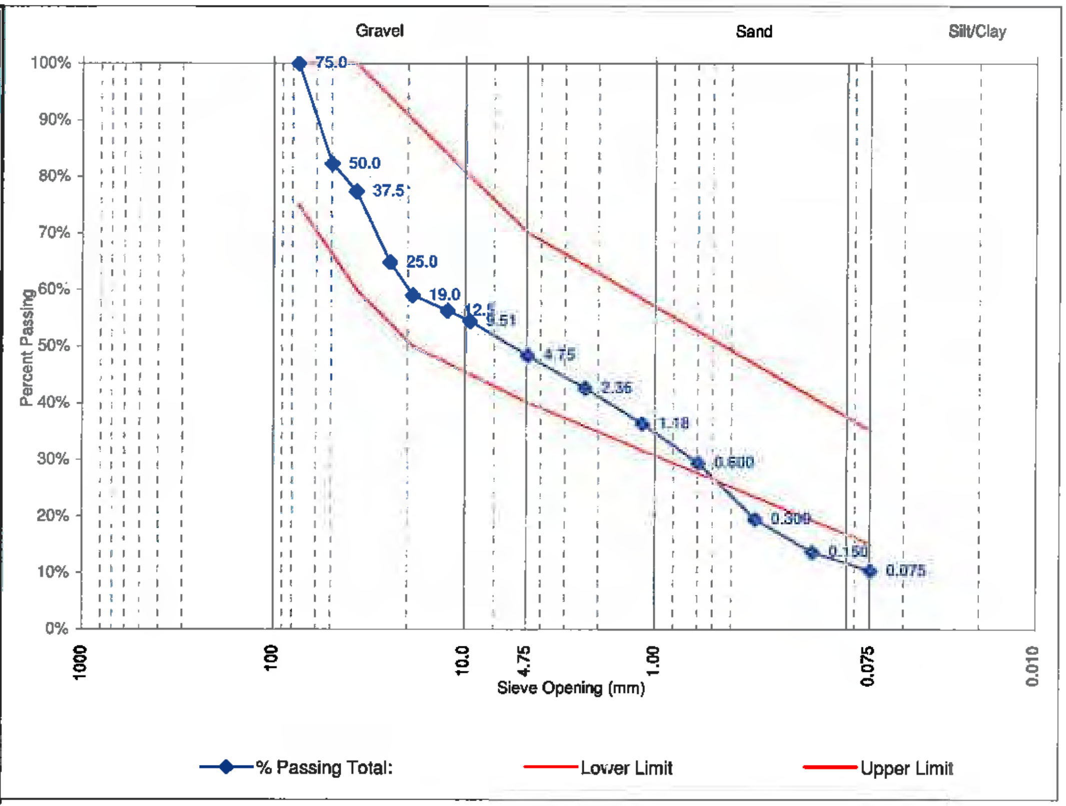
Sample Location: Existing Dike Fill
Supplier:
Material Type: GRAVEL and SAND, some Silt
Usage:
Specification: 5.8.1 Recommended Dike Fill Material

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 12, 2015
Sieve No. 5

Moisture Content (as received): 15%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0			
75.0	100.0%	100	75
50.0	82.2%		
37.5	77.3%	100	60
25.0	64.8%		
19.0	59.0%	90	50
12.5	56.3%		
9.51	54.4%		
4.75	48.3%	70	40
2.36	42.5%		
1.18	36.3%		
0.600	29.3%		
0.425		50	25
0.300	19.4%		
0.150	13.5%		
0.075	10.2%	35	15



Remarks: ______________________________

Levelton Consultants Ltd.

Per: ______________________

Levelton Consultants Ltd.
Fraser Valley Group and Southern Interior

LEVELTON

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

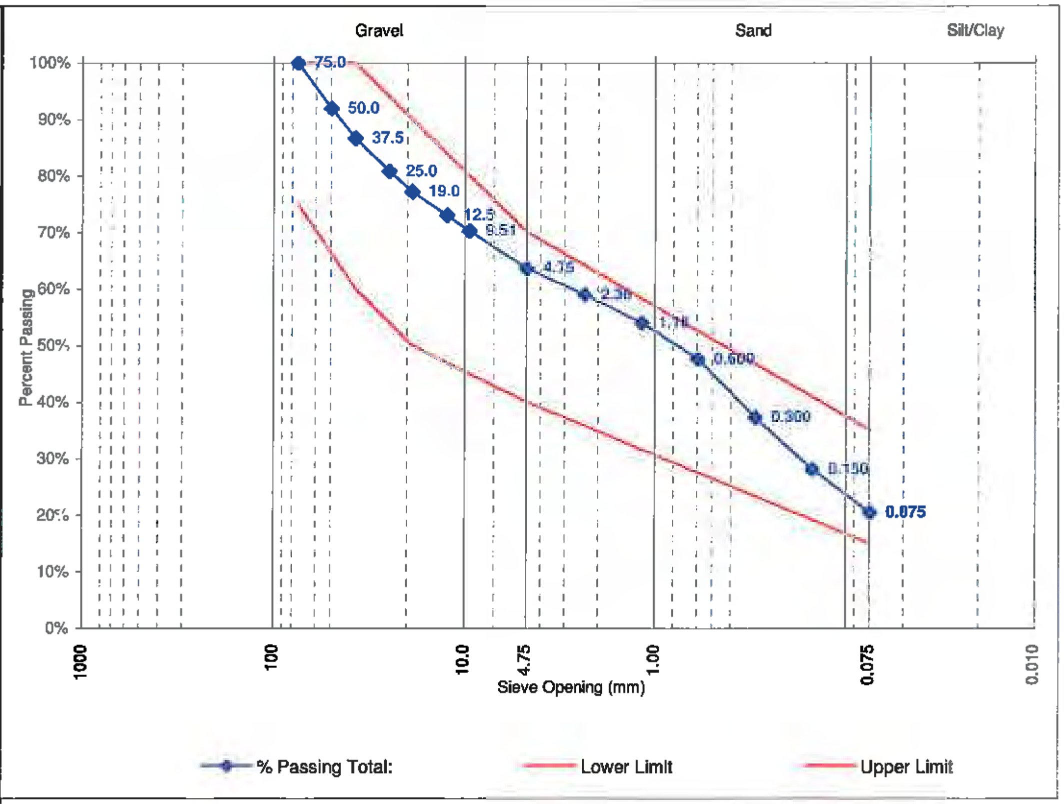
Sample Location: Stockpile - North Berm
Supplier:
Material Type: Silty SAND and Gravel
Usage: Engineered Fill
Specification: 2.8.1 Recommended Dike Fill

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 17, 2015
Sieve No. 6

Moisture Content (as received): 15%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0			
75.0	100.0%	100	75
50.0	92.0%		
37.5	86.7%	100	60
25.0	80.8%		
19.0	77.2%	90	50
12.5	73.1%		
9.51	70.2%		
4.75	63.6%	70	40
2.36	58.9%		
1.18	54.0%		
0.600	47.6%		
0.425		50	25
0.300	37.2%		
0.150	28.1%		
0.075	20.5%	35	15



Remarks: ____________________

Levelton Consultants Ltd.

Per: ____________________

Levelton Consultants Ltd.

Fraser Valley Group and Southern Interior

LEVELTON

#110, 34077 Gladys Avenue
Abbotsford, BC V2S 2E8
Tel: (604) 855-0206
Fax: (604) 853-1186
Email: abbotsford@levelton.com

#301, 19292-60 Avenue
Surrey, BC V3S 3M2
Tel: (604) 533-2992
Fax: (604) 533-0768
Email: surrey@levelton.com

#108, 3677 Hwy 97N
Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com

Client: Mr Todd Cashin - City of Kelowna
Project: Mission Creek Dike - Phase 1 East
Site Address: Casorso Road to Gordon Drive, Kelowna, BC

File No.: R715-0268-00
Task:

Report of Grain Size Analysis

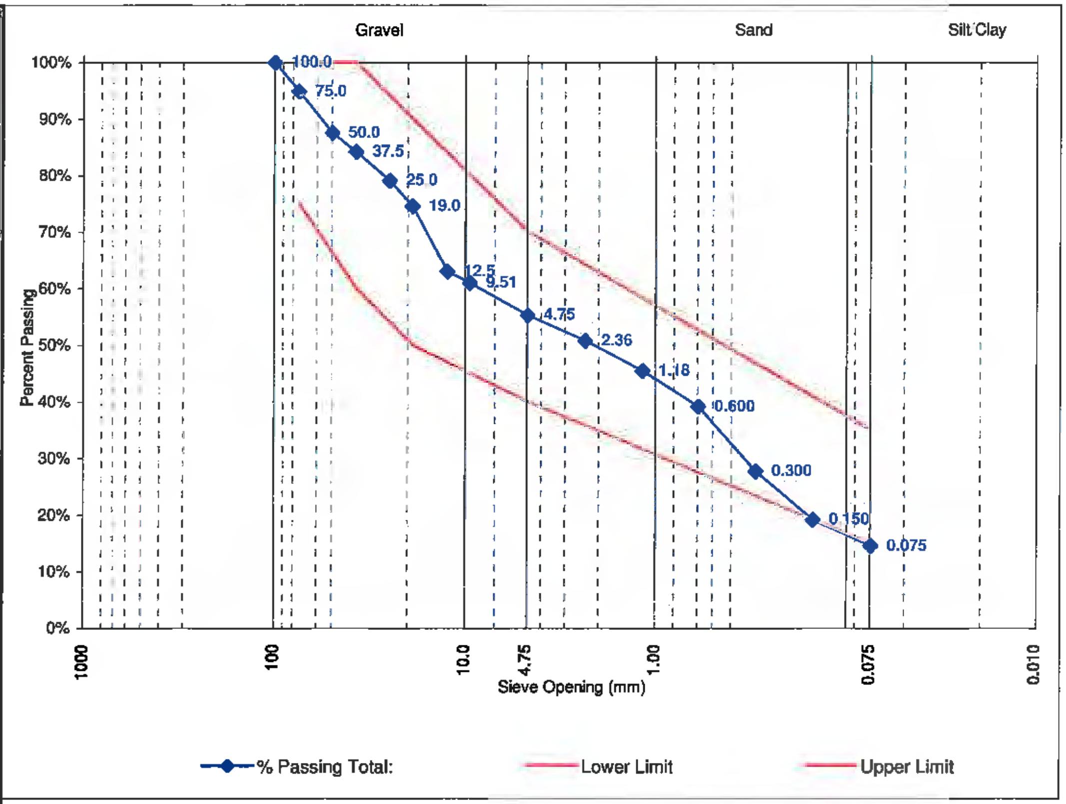
Sample Location: Stockpile - South Berm
Supplier:
Material Type: GRAVEL and SAND, some silt
Usage: Engineered Fill
Specification: 2.8.1 Recommended Dike Fill

Sampled By: TD
Tested By: MP
Date Sampled: February 11, 2015
Date Tested: February 19, 2015
Sieve No. 7

Moisture Content (as received): 11%

Washed Sieve

Screen Opening (mm):	% Passing Total:	Specification	
		Upper Limit	Lower Limit
150.0			
100.0	100.0%		
75.0	94.9%	100	75
50.0	87.5%		
37.5	84.2%	100	60
25.0	79.1%		
19.0	74.5%	90	50
12.5	63.0%		
9.51	61.0%		
4.75	55.3%	70	40
2.36	50.7%		
1.18	45.5%		
0.600	39.1%		
0.425		50	25
0.300	27.7%		
0.150	19.1%		
0.075	14.5%	35	15



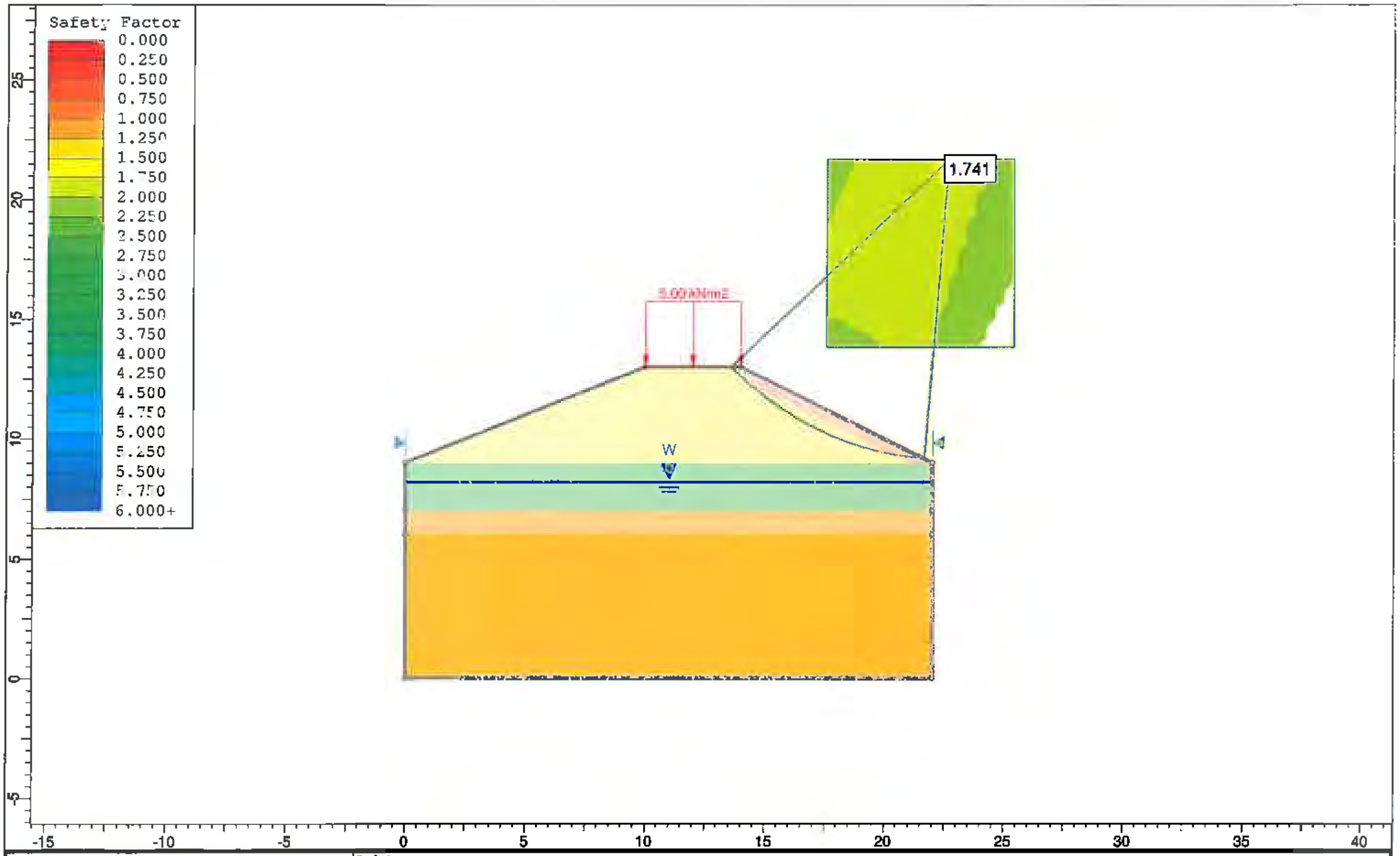
Remarks: ______________________________

Levelton Consultants Ltd.

Per: ____________________

Appendix C

Slope Stability Analysis Results



SLIDEINTERPRET 6.033

Project Mission Creek Dike

Analysis Description 4m high dike with 2:1 slope - static

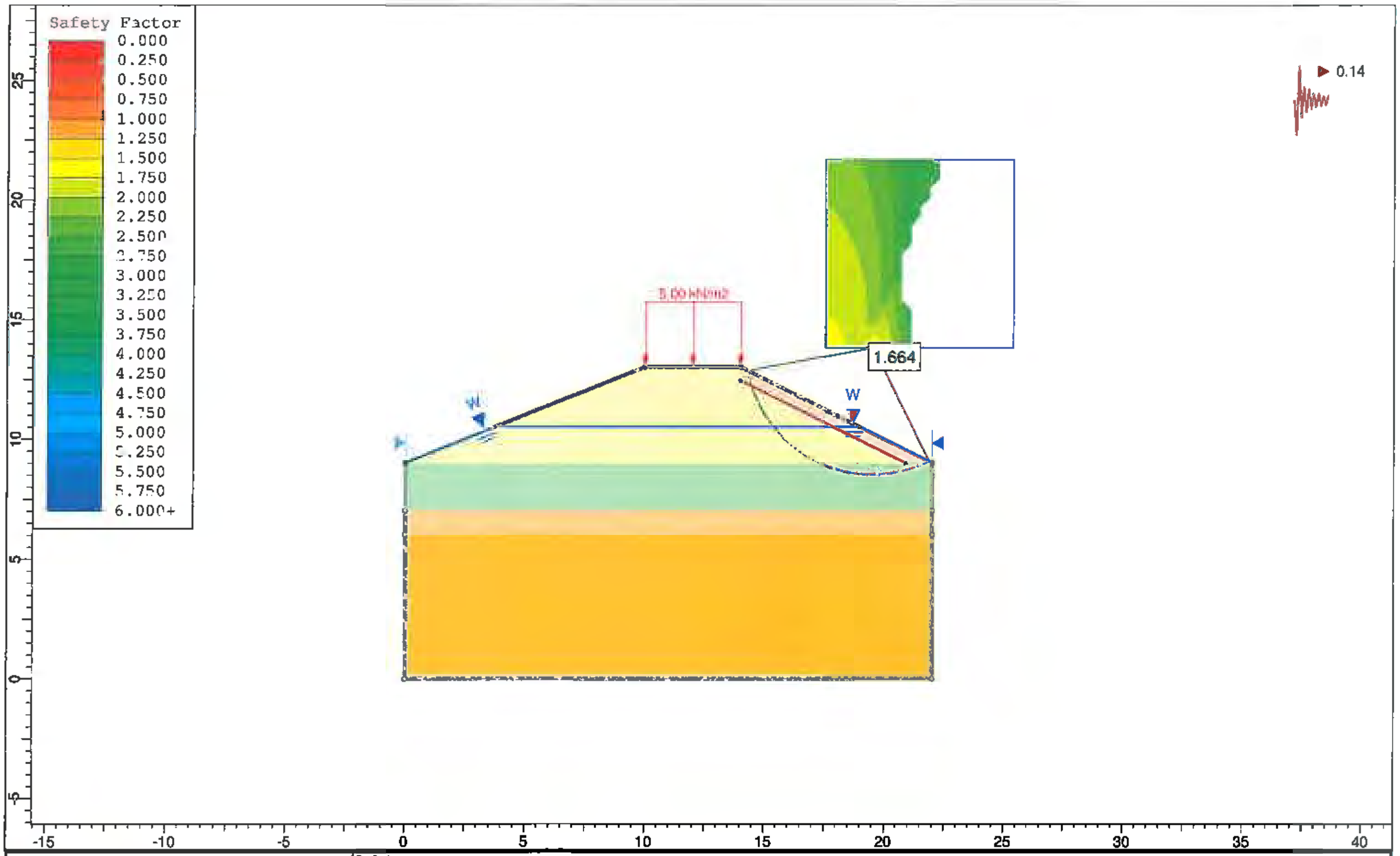
Drawn By TD

Scale 1:224

Company Levelton

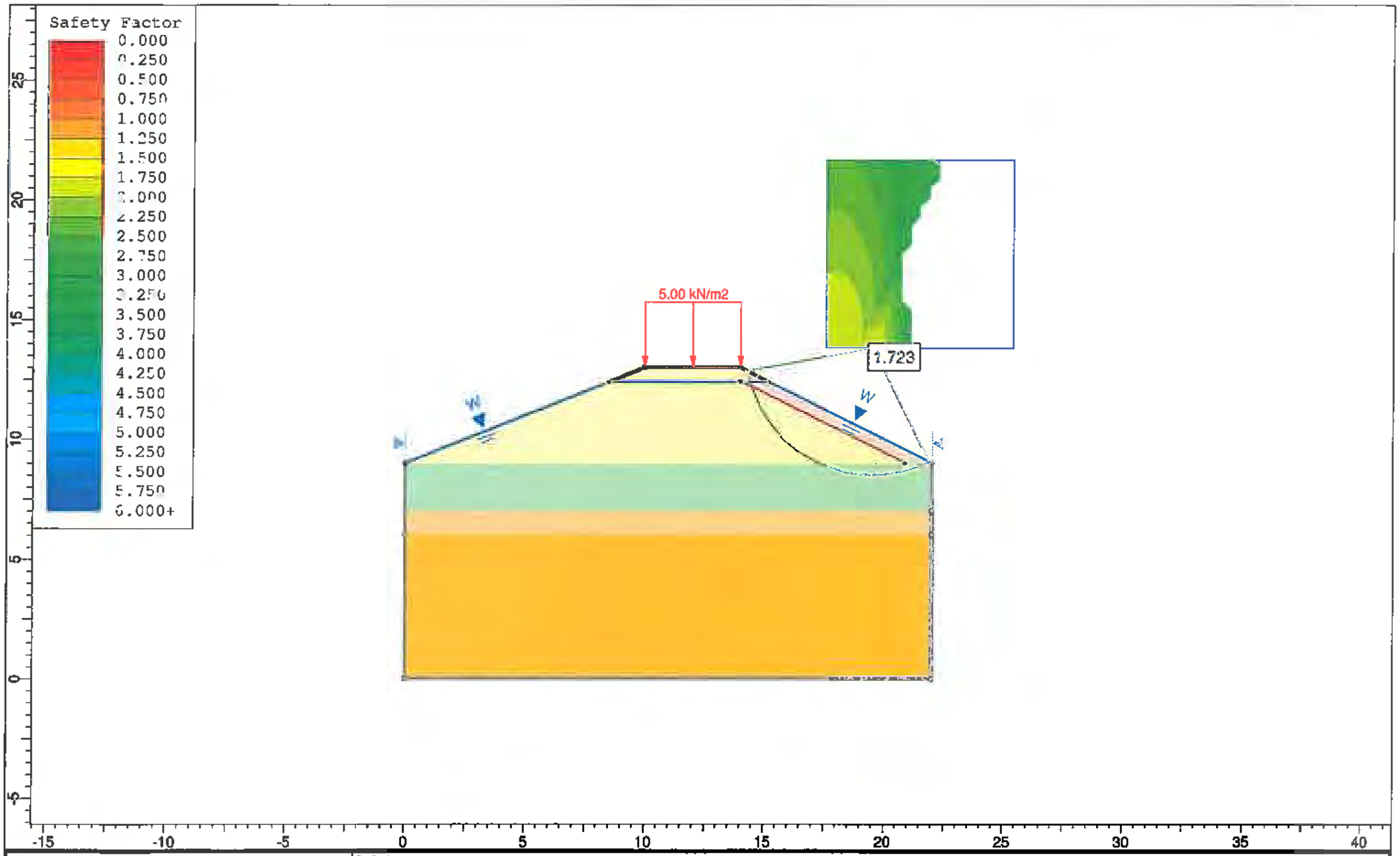
Date 26/02/2015, 8:48:10 AM

File Name Mission Creek 2 to 1 4m dike.slim



Project	Mission Creek Dike				
Analysis Description	4m high dike with 2:1 slope - seismic				
Drawn By	TD	*Scale*	1:224	*Company*	Levelton
Date	26/02/2015, 8:48:10 AM			*File Name*	Mission Creek 2 to 1 4m dike.slim

SLIDEINTERPRET 6.033



SLIDEINTERPRET 6.033

Project	**Mission Creek Dike**		
Analysis Description	4m high dike with 2:1 slope - rapid draw down		
Drawn By	TD	*Scale*	1:224
Company	Levelton		
Date	26/02/2015, 8:48:10 AM	*File Name*	Mission Creek 2 to 1 4m dike.slim

Appendix B. Design Drawings

Q:\Ouellette_James\MCRI\DWG\PROD-MCRI-SBD.dwg, 1-PLAN, 2015-10-27 10:42 am jouellette

ATTENTION
This drawing is prepared for the sole use of -
No representations of any kind are made by Urban Systems Ltd. or its employees to any party with whom Urban Systems Ltd. does not have a contract.

WARNING
Utilities or structures shown on this drawing were compiled from information supplied by various parties and may not be complete or accurate. Expose and conclusively confirm the location in the field all underground utilities and structures indicated on this drawing, all underground utilities in the area of the proposed work and any utilities or structures reasonably apparent from an inspection of the proposed work. Urban Systems Ltd. assumes no responsibility for loss or damage caused by third party negligence or failure to comply with the above.

DISCLAIMER
The seal and signature of the undersigned on this drawing certifies that the design information contained in these drawings accurately reflects the original design and the material design changes made during construction, that were brought to the undersigned's attention. These drawings are intended to incorporate addenda, change orders and other material design changes, but not necessarily all site instructions. The undersigned does not warrant or guarantee, nor accept any responsibility for the accuracy or completeness of information supplied by others contained in these drawings, but does, by sealing and signing, certify that the information, if accurate and complete, provides a system which substantially complies in all material respects with the original design intent.

SURVEY INFORMATION
Prepared by: CITY OF KELOWNA
Coordinate System: NAD 83
Compilation Date: FEB 2015

RE-ISSUED FOR CONSTRUCTION
OCTOBER 27, 2015
urbansystems.ca

Professional Seals

#	Date	Issue / Revision	App
1	2015-09-30	ISSUED FOR CONSTRUCTION	DD
2	2015-10-27	REVISED TO INCLUDE ADDITIONAL DETAIL	DD
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

MISSION CREEK
RESTORATION INITIATIVE

URBAN
systems

Scale
HORIZ. SCALE = 1:750

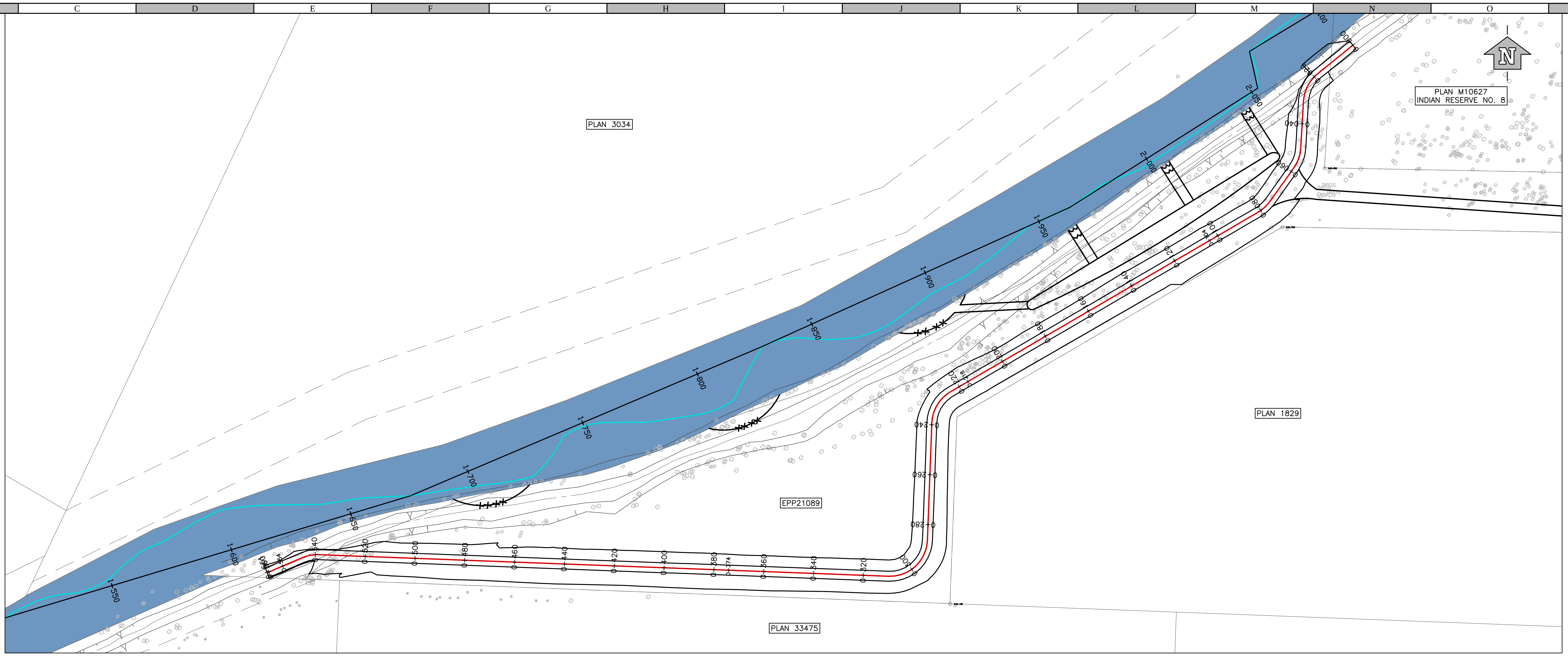
Quality Control by D. Dobson
Designed by J. Paul, D. deSousa, J. Beach
Drawn by J. Paul

MISSION CREEK DIKE SETBACK

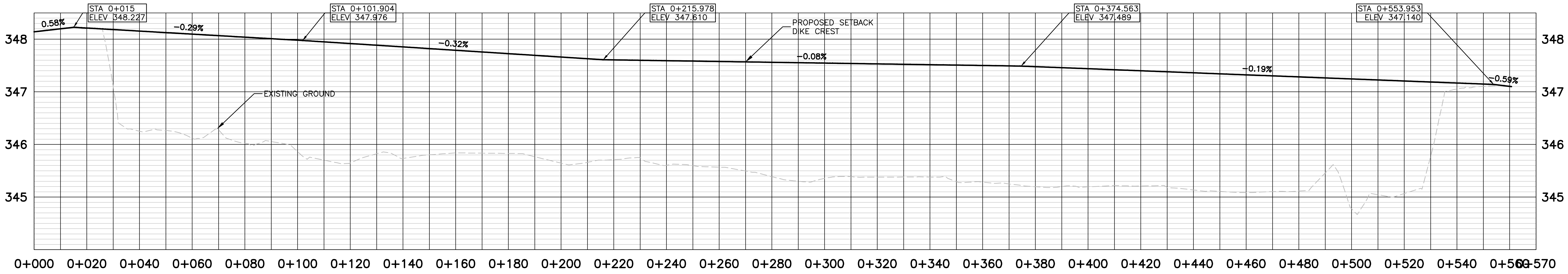
OVERVIEW PLAN

Sheet Number 1 of 3

Project Number	Drawing Number	Revision
002091.0008.01	-	2



Setback Dike CL 0+000 to 0+570 x20.0



C:\Users\jouellette\Desktop\MCRI\DWG\PROD-MCRI-SBD.dwg, 2-PLAN & PROFILE, 2015-09-29 12:42 pm jouellette

ATTENTION

This drawing is prepared for the sole use of -
No representations of any kind are made by Urban Systems Ltd. or its employees to any party with whom Urban Systems Ltd. does not have a contract.

WARNING

Utilities or structures shown on this drawing were compiled from information supplied by various parties and may not be complete or accurate. Expose and conclusively confirm the location in the field all underground utilities and structures indicated on this drawing, all underground utilities in the area of the proposed work and any utilities or structures reasonably apparent from an inspection of the proposed work. Urban Systems Ltd. assumes no responsibility for loss or damage caused by third party negligence or failure to comply with the above.

DISCLAIMER

The seal and signature of the undersigned on this drawing certifies that the design information contained in these drawings accurately reflects the original design and the material design changes made during construction, that were brought to the undersigned's attention. These drawings are intended to incorporate addenda, change orders and other material design changes, but not necessarily all site instructions. The undersigned does not warrant or guarantee, nor accept any responsibility for the accuracy or completeness of information supplied by others contained in these drawings, but does, by sealing and signing, certify that the information, if accurate and complete, provides a system which substantially complies in all material respects with the original design intent.

SURVEY INFORMATION

Prepared by: CITY OF KELOWNA
Coordinate System: NAD 83
Compilation Date: FEB 2015

ISSUED FOR
CONSTRUCTION
SEPTEMBER 30, 2015
urbansystems.ca

Professional Seals

#	Date	Issue / Revision	App
1	2015-09-30	ISSUED FOR CONSTRUCTION	DD
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

MISSION CREEK
RESTORATION INITIATIVE

URBAN
systems

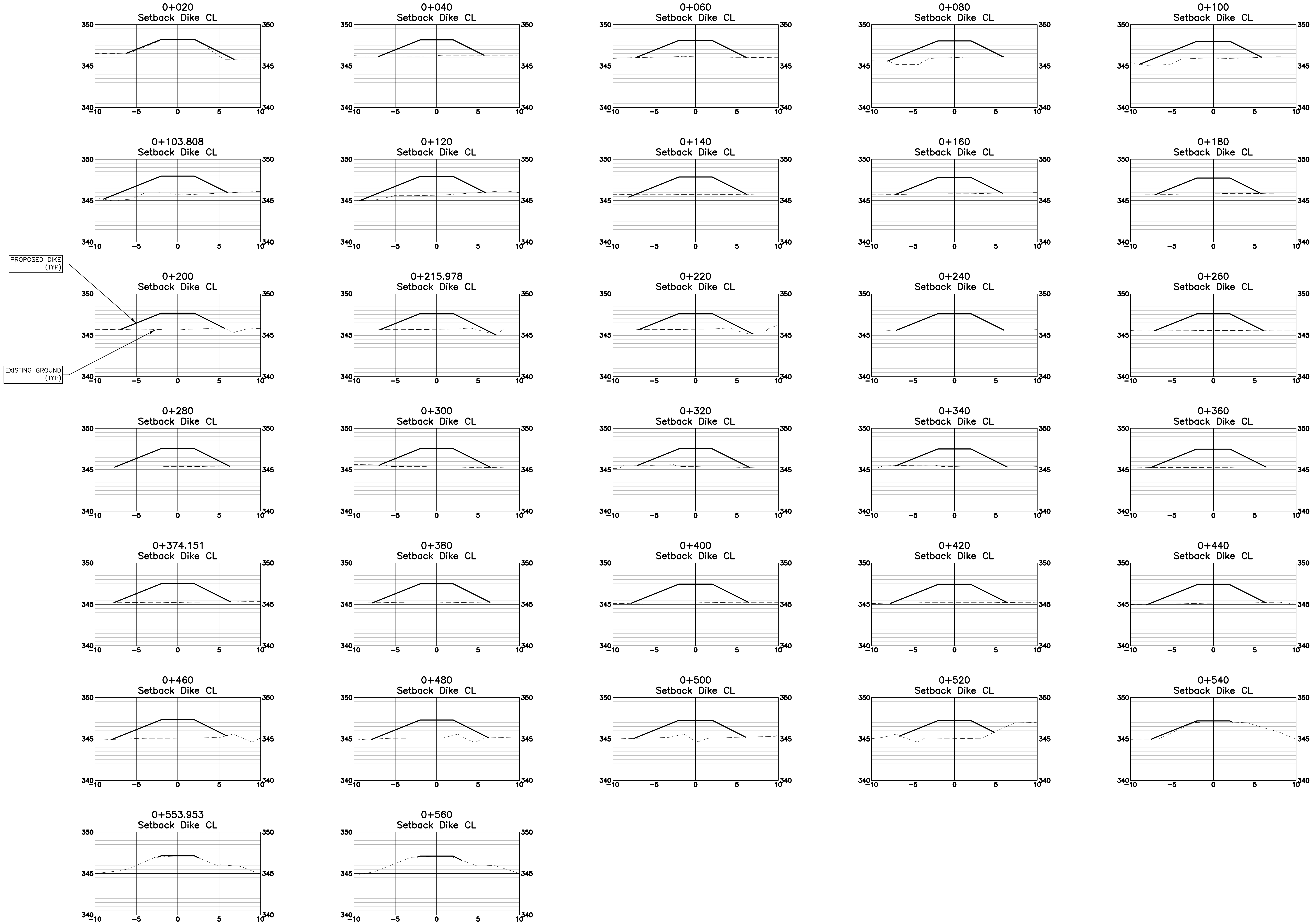
Scale
HORIZ. SCALE = 1:1000

Quality Control by D. Dobson
Designed by J. Paul, D. deSousa, J. Beach
Drawn by J. Paul

MISSION CREEK DIKE
SETBACK
PLAN & PROFILE

Sheet Number 2 of 3

Project Number	Drawing Number	Revision
002091.0008.01	-	-



C:\Users\jouellette\Desktop\MCRI\DWG\PROD-MCRI-SBD.dwg, 3-CROSS SECTIONS, 2015-09-29 12:43 pm jouellette

ATTENTION
This drawing is prepared for the sole use of -
No representations of any kind are made by Urban Systems Ltd. or its employees to any party with whom Urban Systems Ltd. does not have a contract.

WARNING
Utilities or structures shown on this drawing were compiled from information supplied by various parties and may not be complete or accurate. Expose and conclusively confirm the location in the field all underground utilities and structures indicated on this drawing, all underground utilities in the area of the proposed work and any utilities or structures reasonably apparent from an inspection of the proposed work. Urban Systems Ltd. assumes no responsibility for loss or damage caused by third party negligence or failure to comply with the above.

DISCLAIMER
The seal and signature of the undersigned on this drawing certifies that the design information contained in these drawings accurately reflects the original design and the material design changes made during construction, that were brought to the undersigned's attention. These drawings are intended to incorporate addenda, change orders and other material design changes, but not necessarily all site instructions. The undersigned does not warrant or guarantee, nor accept any responsibility for the accuracy or completeness of information supplied by others contained in these drawings, but does, by sealing and signing, certify that the information, if accurate and complete, provides a system which substantially complies in all material respects with the original design intent.

SURVEY INFORMATION
Prepared by: CITY OF KELOWNA
Coordinate System: NAD 83
Compilation Date: FEB 2015

ISSUED FOR
CONSTRUCTION
SEPTEMBER 30, 2015
urbansystems.ca

Professional Seals

#	Date	Issue / Revision	App
1	2015/09/30	ISSUED FOR CONSTRUCTION	DD
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

MISSION CREEK
RESTORATION INITIATIVE

URBAN
systems

Scale
HORIZ. SCALE = 1:250
VERT. SCALE = 1:250

Quality Control by D. Dobson
Designed by J. Paul, D. deSousa, J. Beach
Drawn by J. Paul

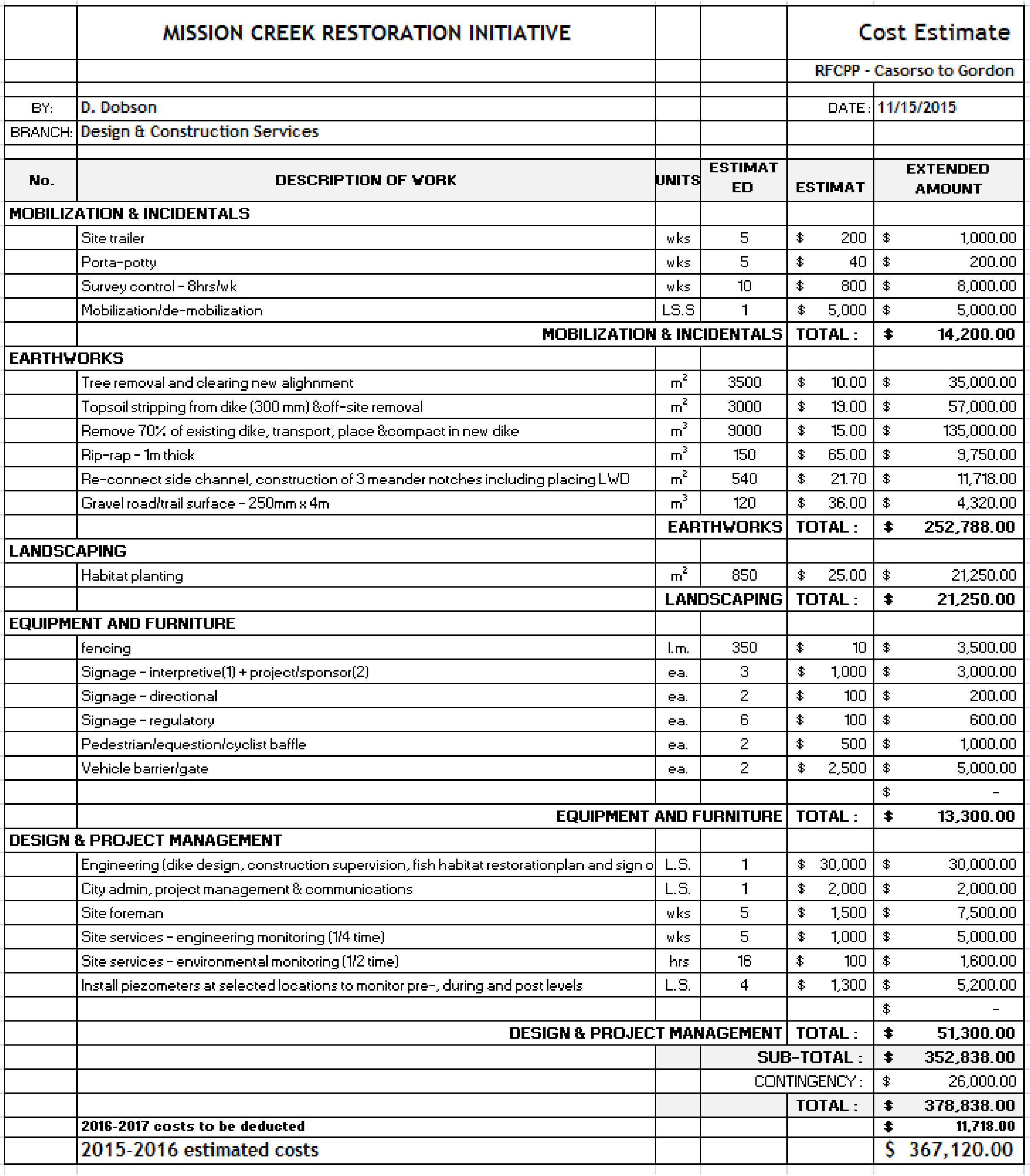
MISSION CREEK DIKE
SETBACK

SETBACK DIKE CL CROSS-SECTIONS

Sheet Number 3 of 3

Project Number	Drawing Number	Revision
002091.0008.01	-	-

Appendix C. Detailed Cost Estimates



	MISSION CREEK RESTORATION INITIATIVE			**Cost Estimate**	
				RFCPP - Casorso to Gordon	
BY:	D. Dobson			DATE:	11/15/2015
BRANCH:	Design & Construction Services				
No.	**DESCRIPTION OF WORK**	**UNITS**	**ESTIMATED**	**ESTIMAT**	**EXTENDED AMOUNT**
MOBILIZATION & INCIDENTALS					
	Site trailer	wks	5	$ 200	$ 1,000.00
	Porta-potty	wks	5	$ 40	$ 200.00
	Survey control - 8hrs/wk	wks	10	$ 800	$ 8,000.00
	Mobilization/de-mobilization	LS.S	1	$ 5,000	$ 5,000.00
	MOBILIZATION & INCIDENTALS			**TOTAL :**	**$ 14,200.00**
EARTHWORKS					
	Tree removal and clearing new alighnment	m^2	3500	$ 10.00	$ 35,000.00
	Topsoil stripping from dike (300 mm) &off-site removal	m^2	3000	$ 19.00	$ 57,000.00
	Remove 70% of existing dike, transport, place &compact in new dike	m^3	9000	$ 15.00	$ 135,000.00
	Rip-rap - 1m thick	m^3	150	$ 65.00	$ 9,750.00
	Re-connect side channel, construction of 3 meander notches including placing LWD	m^2	540	$ 21.70	$ 11,718.00
	Gravel road/trail surface - 250mm x 4m	m^3	120	$ 36.00	$ 4,320.00
	EARTHWORKS			**TOTAL :**	**$ 252,788.00**
LANDSCAPING					
	Habitat planting	m^2	850	$ 25.00	$ 21,250.00
	LANDSCAPING			**TOTAL :**	**$ 21,250.00**
EQUIPMENT AND FURNITURE					
	fencing	l.m.	350	$ 10	$ 3,500.00
	Signage - interpretive(1) + project/sponsor(2)	ea.	3	$ 1,000	$ 3,000.00
	Signage - directional	ea.	2	$ 100	$ 200.00
	Signage - regulatory	ea.	6	$ 100	$ 600.00
	Pedestrian/equestion/cyclist baffle	ea.	2	$ 500	$ 1,000.00
	Vehicle barrier/gate	ea.	2	$ 2,500	$ 5,000.00
					$ -
	EQUIPMENT AND FURNITURE			**TOTAL :**	**$ 13,300.00**
DESIGN & PROJECT MANAGEMENT					
	Engineering (dike design, construction supervision, fish habitat restorationplan and sign o	L.S.	1	$ 30,000	$ 30,000.00
	City admin, project management & communications	L.S.	1	$ 2,000	$ 2,000.00
	Site foreman	wks	5	$ 1,500	$ 7,500.00
	Site services - engineering monitoring (1/4 time)	wks	5	$ 1,000	$ 5,000.00
	Site services - environmental monitoring (1/2 time)	hrs	16	$ 100	$ 1,600.00
	Install piezometers at selected locations to monitor pre-, during and post levels	L.S.	4	$ 1,300	$ 5,200.00
					$ -
	DESIGN & PROJECT MANAGEMENT			**TOTAL :**	**$ 51,300.00**
				SUB-TOTAL :	**$ 352,838.00**
				CONTINGENCY :	$ 26,000.00
				TOTAL :	**$ 378,838.00**
	2016-2017 costs to be deducted				**$ 11,718.00**
	2015-2016 estimated costs				$ 367,120.00