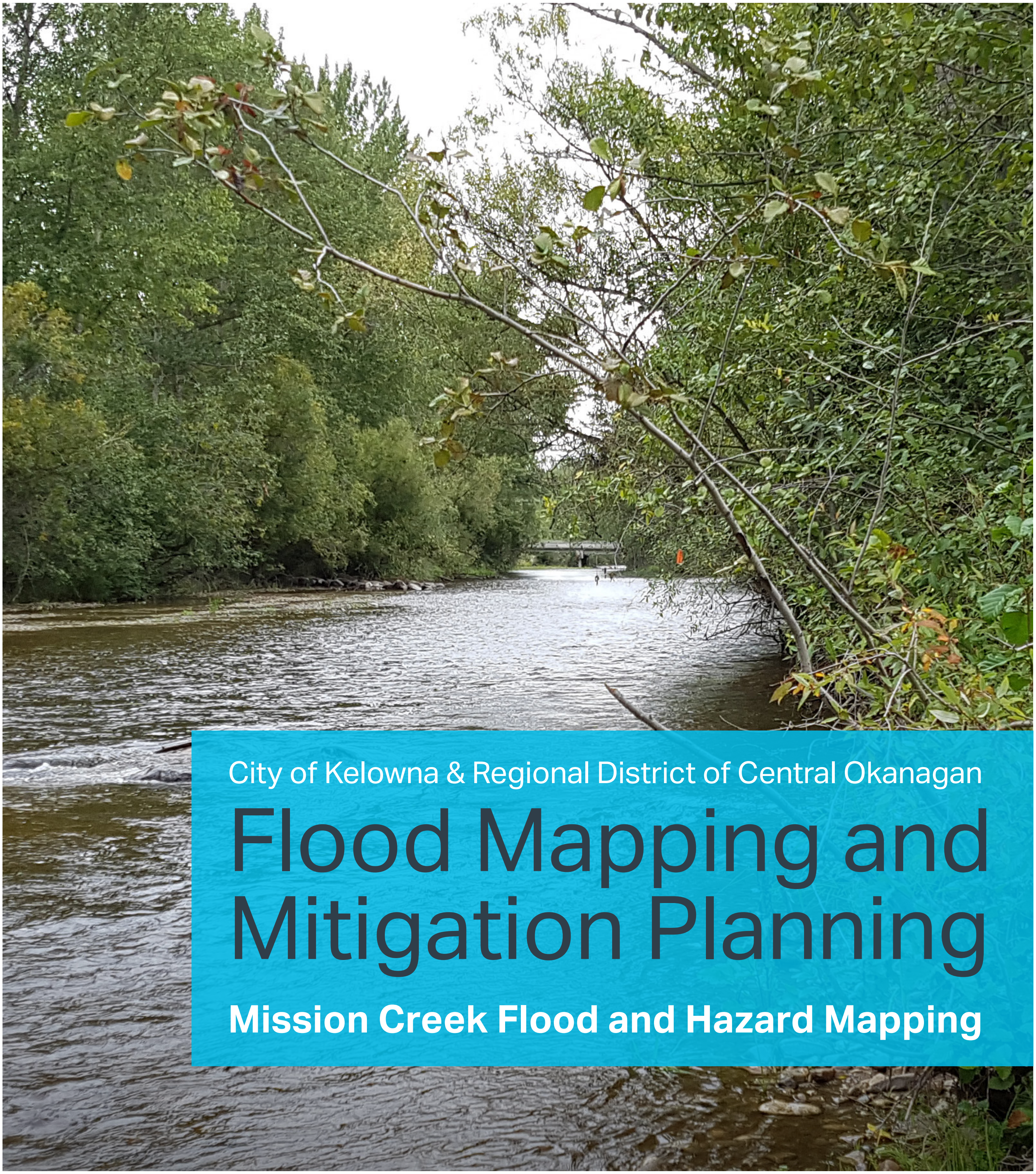

City of Kelowna & Regional District of Central Okanagan

Flood Mapping and Mitigation Planning

Mission Creek Flood and Hazard Mapping

Prepared by:
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Date Prepared: May 2020

Project #: 60613804

AECOM

Regional District of Central Okanagan

City of Kelowna

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May 8, 2020

Project #
60613804

Dear Ms. Lange:

Subject: Flood Modelling and Mitigation Planning Project
Mission Creek Basin Flood Mapping Study

AECOM is pleased to provide our final report for the Mission Creek Basin Flood Mapping Project.

The report includes a review of the existing information and data used, identifies and maps the flood inundated areas and the associated flood hazards within the study limits based on the hydraulic modelling results, and provides some recommendations for flood mitigation.

Thank you for the opportunity to assist the Reginal District of Central Okanagan (RDCO), as well as the City of Kelowna on their efforts towards safer environment along Mission Creek. AECOM wishes the outcomes of this study will be helpful for future flood mitigation planning.

Should you have any inquiries, please do not hesitate to contact me.

Sincerely,
AECOM Canada Ltd.

Marcel LeBlanc, P.Eng.
Water Resources Market Sector Leader, Water,
Western Canada
Marcel.LeBlanc@aecom.com

HF:blb

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AECOM: 2015-04-13

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11/5/20
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Aug 21, 2020

Executive Summary

AECOM was retained in August 2019 by the City of Kelowna (the City) and the Regional District of Central Okanagan (RDCO) to carry out a flood mapping and mitigation planning study for both Mill Creek and Mission Creek. Funding for the study was provided by the Union of BC Municipalities (UBCM) to RDCO through the Community Emergency Preparedness Fund (CEPF) under the Flood Risk Assessment, Flood Mapping and Flood Mitigation Category. AECOM, the City and RDCO acknowledge that the project lies on the traditional territory of the Syilx/Okanagan Peoples. The objectives of the study are to develop hydraulic models based on updated LiDAR data, using the Mission Creek model for dike breach analysis at critical areas, producing flood hazard maps, and developing conceptual mitigation options to reduce the identified flood hazards. The flood mapping, being the ultimate deliverable of the study, will assist the RDCO and City of Kelowna in gaining a better understanding of flood risk and hazard management along Mission Creek. This executive summary of the report presents the main findings of the study pertaining to Mission Creek, while another report has been submitted for Mill Creek.

Mission Creek is the largest tributary to Okanagan Lake in BC with an estimated watershed area of approximately 860 km^2. Its watershed is regulated through four reservoirs in the upper watershed portion north of Big White Ski Resort; namely, Belgo Reservoir, Greystoke Lake, Fish Hawk Reservoir and James Lake all of which are controlled by the Black Mountain Irrigation District (BMID). The creek is also ecologically important, as it is a fish-bearing stream and important habitat for Kokanee salmon. The study area spans a creek length of approximately 45.5 km extending a few kilometers from the upper limit at Joe Rich Area up to the Three Forks Road Bridge (station 43.5 km) to the lower limit at Okanagan Lake (station 0). The creek has an average slope of approximately 1.4% between stations 22 km (about 3 km below the BMID water intake) and 45 km; whereas the reach between stations 19 km and 22 km has much steeper slopes ranging from 11% to 19%. From station 19 km and downstream to the lake, the creek has average slopes of 1% or less within the City; flattening as it approaches the mouth. Most of the upper creek above the City limits flows in a heavily forested mountainous area. The lower creek lies within Westbank First Nation's Mission Creek Indian Reserve No. 8. Within the study area limits there is a total of seven road bridge crossings; in addition to a total of five pedestrian bridges across the creek within the City.

The creek is partially diked within the City. The right bank dike (when looking downstream along the creek) extends from Lakeshore Road Bridge up to around Ziprick Road. The left bank dike extends from approximately 200 m upstream from Lakeshore Road Bridge up to Casorso Road Bridge; then resumes from around 1.1 km upstream from Casorso Road Bridge to approximately 1 km upstream from KLO Road Bridge. A setback dike was constructed in 2016 between Casorso Road Bridge and Gordon Drive Bridge along the left bank; as part of the Mission Creek Restoration Initiative (MCRI). MCRI is a is a multi-phase and multi-stakeholder partnership that was established in 2002 with the purpose of re-naturalizing the lower reaches of Mission Creek. MCRI has federal and provincial government partners; in addition to representatives from local government and non-governmental organizations, as well as Westbank First Nation. Portions of the dikes were also raised in 2018 and in 2019 based on recommendations from the 2014 Tetra Tech's Lower Mission Creek Hydraulic Capacity Study and following the 2013, 2017 and 2018 significant floods within the region.

The current study is considered as part of the Regional Floodplain Management Plan that was developed for RDCO in 2016 by Associated Environmental Consultants Inc. (AE) that stemmed from the Regional Floodplain Management Framework completed by Clarke Geoscience in 2014. That Framework has been part of the vision of the Regional Growth Strategy (Bylaw No. 1336 adopted on June 23, 2014) and consisted of three main phases; Phase 1: developing a regional floodplain management plan (RFMP), Phase 2: flood hazard and risk assessment, and Phase 3: flood risk mitigation strategies.

For the purpose of the current study, AECOM expanded the 2014 Tetra Tech's 1D HEC-RAS model that covered only up to station 8.603 km (XS-58C); the upstream end of the lower reach ending about 635 m upstream from Ziprick Road. Expanding the 1D model was two folds: a) developing the lower reach model into a 1D/2D coupled unsteady flow model updated with 2019 surveyed cross sections that Northwest Hydraulic Consultants (NHC) provided and 2019 LiDAR data; and b) extending the 1D model up to station 44.469 km at Joe Rich Area using 2018 LiDAR data.

Unsteady flow model runs were performed using the lower reach model for the 20-year and the 200-year design flood discharges per the 2017 Professional Practice Guidelines for Flood Mapping of the Association of the Professional Engineers and Geoscientists of British Columbia (APEGBC). The unsteady modelling results of the 200-year design flows show that the left non-diked floodplain upstream from Casorso Road Bridge and around Lakeshore Road Bridge become flooded.

The floodwater in the area upstream from Casorso Road Bridge overtops Casorso Road and Swamp Road, then floods the Mission Recreation Park area between Swamp Road and Gordon Drive. Later in time, the floodwater overtops Gordon Drive and floods parts of the area up to Lakeshore Road. The non-diked area around Lakeshore Road Bridge becomes flooded up to Bluebird Road; some of the areas west of Bluebird Road become flooded as well. A dike breach simulation at the 200-year design flow for the corner location of the setback dike between Casorso Road Bridge and Gordon Drive Bridge indicate more flood inundation areas on the south up to Old Meadows Road compared to the no-breach scenario. Also, more areas west of Gordon Drive become flooded as a result of the dike breach.

The unsteady modelling results of the 200-year design flood also indicate overtopping of some parts of the north dike along the reaches downstream from Casorso Road Bridge and upstream from KLO Road Bridge. As the floodwater overtops the north dike in those locations, it spreads to the west and north reaching the low relief areas in the floodplain.

Steady flow model runs were also performed using the upper reach model for the 20-year and the 200-year design flood discharges. The flood depth mapping results indicate some areas that are inundated at the 200-year flood discharge conditions. These inundated areas include: the left floodplain upstream from East Kelowna Bridge for approximately 400 m, as well as the Peace Valley Mobile Home Park near station 12.500 km within the Scenic Canyon Regional Park; some floodplain areas near the BMID water intake at station 23.750 km; the floodplains downstream and upstream from Highway 33 Bridge that have some private properties; the floodplains downstream from Three Forks Road Bridge up to station 42.890 km.

AECOM used the flood mapping results for the 200-year design flows to assess the hazard levels in the inundated areas of the floodplain based on the UK Flood Hazard Rating Formula referenced in APEGBC Professional Practice Guidelines for Flood Mapping.

Based on the study outcomes, AECOM proposes the following conceptual flood mitigation measures:

- Structural Measures:
  - Raising the existing north dike along the right bank within the City where it is overtopped.
  - Constructing a new dike along the non-diked reach upstream from Casorso Road Bridge on the left bank. Or, constructing a flood barrier along the east side of Casorso Road south of the bridge to prevent the road overtopping from the impounded floodwater.
  - Constructing dikes in the flooded areas around East Kelowna Road Bridge and the Home Mobile Park within the Regional Scenic Canyon Park.
  - Dry floodproofing the buildings and facilities that are prone to flooding within the Mission Recreation Park between Casorso Road Bridge and Gordon Drive Bridge, near KLO Road Bridge, and around Hwy 33 Road Bridge.

- Non-structural Measures:
  - Issuing public flood warnings for people to avoid being in the flood prone areas prior to predictions of extreme flood events in the creek.
  - Increasing public awareness in flood prone areas.
  - Encouraging land use regulation changes and strengthening policies; for example, through bylaws, Owners and Contractors Protective (OCP) policies, Development Permits, subdivisions, engineering standards, flood proofing, building codes, enforcement, etc.
  - Restoring the natural ecological function of floodplains and riparian areas where appropriate.
  - Expanding on flood mitigation strategies in Phase 3 of the Regional Floodplain Management Plan.

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1. Introduction

1.1 Background

AECOM was retained in August 2019 by the City of Kelowna (the City) and the Regional District of Central Okanagan (RDCO) to carry out a flood mapping and mitigation planning study for Mill Creek and Mission Creek. The study is part of a collaborative work between the City and RDCO. Funding for the study was provided by the Union of BC Municipalities (UBCM) to RDCO through the Community Emergency Preparedness Fund (CEPF) under the Flood Risk Assessment, Flood Mapping and Flood Mitigation Category. AECOM, the City and RDCO acknowledge that the project lies on the traditional territory of the Syilx/Okanagan Peoples.

This report documents the details of the current study for only Mission Creek; another separate report has been issued for Mill Creek.

The study is considered as part of the Regional Floodplain Management Plan that was developed for RDCO in 2016 by Associated Environmental Consultants Inc. (AE) that stemmed from the Regional Floodplain Management Framework completed by Clarke Geoscience in 2014. That Framework was part of the vision of the Regional Growth Strategy (Bylaw No. 1336 adopted on June 23, 2014). The Framework consisted of the following three phases:

- Phase 1: Developing a regional floodplain management plan that was completed in 2016 by AE
- Phase 2: Flood hazard and risk assessment
- Phase 3: Flood risk mitigation strategies

The outcomes of Phase 1 included identifying Mill Creek and Mission Creek as being the highest flood prone streams in the Region with flood-prone areas scoring the highest estimated preliminary flood risk ratings. Phases 2 and 3 are still in progress, and the current study is part of them.

The Okanagan Basin Water Board (OBWB) has also been involved through securing funds; in collaboration with the City and RDCO, for providing two sets of LiDAR data:

- initial 2018 LiDAR data for the Region; that LiDAR was flown prior to some dike raises along the creek and covered Mission Creek's basin up to the Joe Rich Area, which is the upper limit of the current study, and
- updated high resolution 2019 LiDAR data for the lower reach of Mission Creek within the City; this LiDAR was provided in January 2020 and captured the latest dike raises along the creek.

In 2014, Tetra Tech EBA Inc. completed a hydraulic capacity modeling study of the lower Mission Creek; a reach approximately 8.605 km long from the mouth at Okanagan Lake up to Gerstmard Road within the City. The goal of the current study is to further develop that model up to the Joe Rich Area that is located approximately 46 km upstream from the mouth, for flood mapping and mitigation planning purposes.

AECOM obtained 2019 surveyed cross sections of the lower Mission Creek from NHC, which also provided peak flow estimates at seven points of interest along the full reach model up to Joe Rich Area. The peak flow estimates were developed by NHC based on statistical analyses of the available flood records from the existing Water Survey of Canada (WSC) stream gauges in the region; in addition to simulated daily peak flow data from 1996 to 2017 developed through AE's RAVEN hydrologic model.

1.2 Study Objectives

The study has the following objectives:

- Identifying flood hazard areas along the creek within the study limits,
- Assessing the flood hazard levels according to regulatory standards, and
- Recommending mitigation plans to reduce the identified flood hazards.

1.3 Scope of Work

The scope of work can be summarized as follows:

- Developing a hydraulic model of the creek based on updated LiDAR data,
- Producing detailed flood hazard mapping of the study area, and
- Performing a dike breach analysis of the critical areas along the diked-reach of the creek within the City.

1.4 Steering Committee

The steering committee consists of the following designates from the following parties:

- Robinson Puche – Project Manager and the primary contact for the City,
- Luke Dempsey – Secondary contact for the City,
- Janelle Taylor – Primary contact for RDCO,
- Todd Cashin – Secondary contact for RDCO, and
- Marcel LeBlanc – Project Manager for AECOM.

The role of the steering committee was to provide direction to the technical team, and to review and monitor progress relative to the scope of work, budget and schedule established for the project. In addition to the steering committee, Westbank First Nations were also contacted and informed of the project.

1.5 Stakeholder Consultation

AECOM met and consulted with the following stakeholders:

- Black Mountain Irrigation District (BMID); represented by Bob Hrasko,
- Glenmore-Ellison Improvement District; represented by Dawn Williams, and
- BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNR); represented by Shaun Reimer.

During the meeting and consultations, AECOM provided an overview of the project and collected relevant information from the stakeholders.

2. Study Area

2.1 Mission Creek and Study Area Limits

Mission Creek watershed has an area of approximately 860 km^2; the creek is the largest tributary to Lake Okanagan in BC. There are several tributaries to the creek within the study area. AECOM has identified 10 points of interest (POI) along the creek where peak flow or inflow hydrograph data will be required for the hydraulic modeling and flood mapping. Apart from WSC 08NM116 and the Upper Mission Creek sub-basin outlet, the POI were primarily selected at the confluences of the significant tributaries along the creek. Table 2-1 lists the co-ordinates of these POI. Figure 2-1 shows the creek and its tributaries within the study area; in addition to the identified POI. Priest and Rumohr Creeks are considered as a single inflow point upstream from Casorso Road Bridge; this is the same location where Tetra Tech included a lateral inflow hydrograph for the runoff of the south watersheds in their 2014 model.

Table 2-1: Points of interest for the hydrologic inflows along Mission Creek

Point of Interest	Description	Approximate Location	
		Easting (m)	Northing (m)
1	Confluence of Priest Creek	322699	5524397
2	Confluence of Rumohr Creek	324526	5524912
3	Confluence of KLO Creek (Gallaghers Canyon)	330049	5523968
4	Confluence of Hydraulic Creek	331190	5523863
5	Confluence of Daves Creek	335826	5524905
6	Confluence of Grouse Creek	341093	5525403
7	Confluence of Belgo Creek	345174	5526087
8	Confluence of Joe Rich Creek	345651	5525829
9	Confluence of Pearson Creek	351789	5528149
10	Upper Mission Creek	351742	5528200

The creek is characterized by high sinuosity in its upper reaches above the City. The creek is braided in many parts within the study area and there has been significant erosion and aggradation that occurred over time. Gravel bars were observed during the field reconnaissance and could also be identified from the aerial imagery and the LiDAR data layer.

The study area upper limit is at the Joe Rich Area up to the Three Forks Road Bridge and including the parcel with PID 011-808-586 of RDCO. The lower limit is the creek mouth at Okanagan Lake. The reach has a stream length of approximately 44.470 km within UTM Zone 11N. Table 2-2 lists the UTM co-ordinates of the study area limits.

Table 2-2: Co-ordinates of the upper and lower limits of the study area

Location	Easting (m)	Northing (m)
Upper limit above Three Forks Road Bridge	352081.85	5528926.85
Lower limit at Okanagan Lake	320670.87	5524149.93

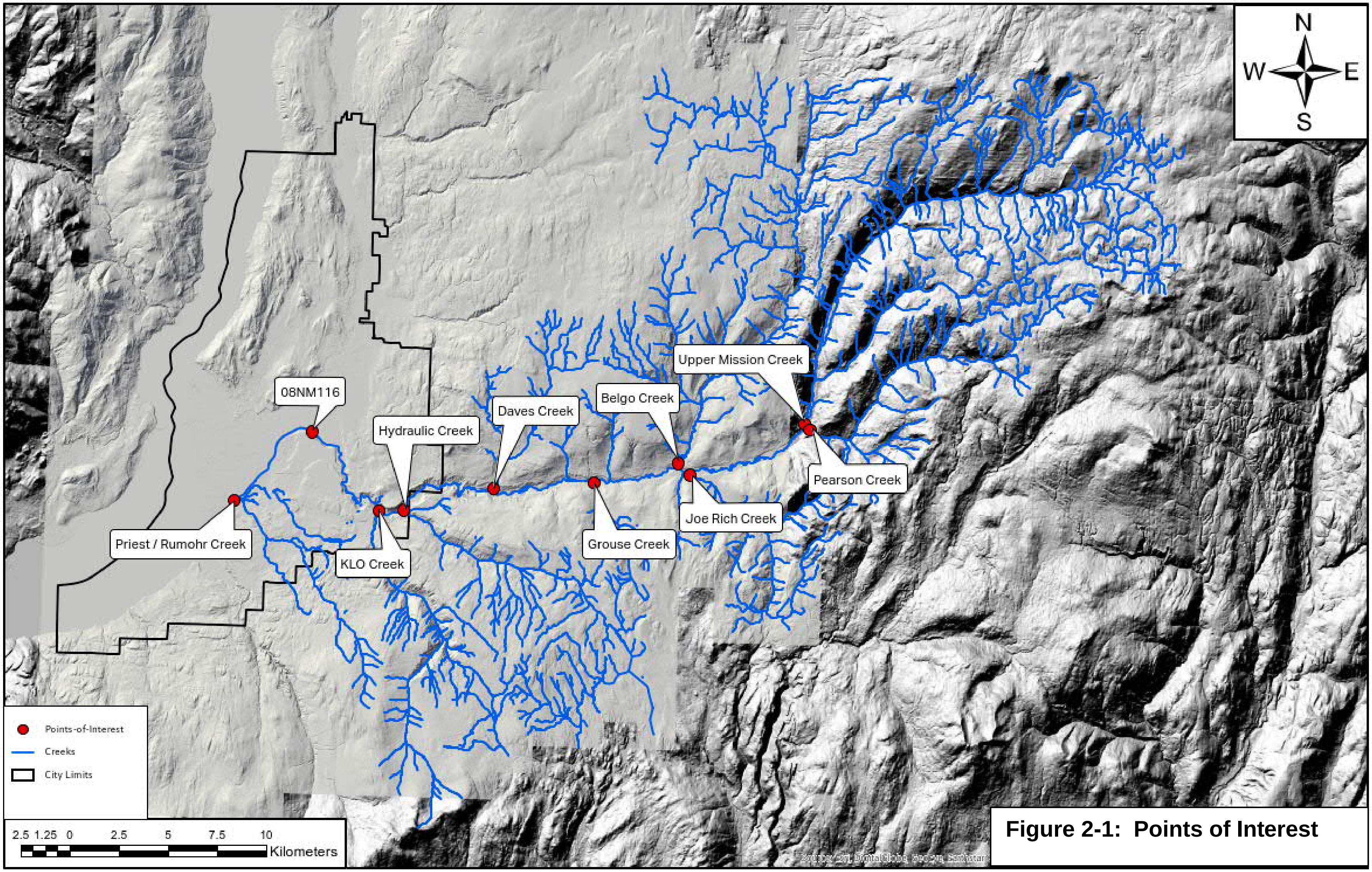


Figure 2-1: Mission Creek major tributaries and the points of interest

2.2 Landcover, Topography and Main Watershed Features

The study area is mountainous in most of its upper part above the City limits. The mountains are covered with intensive mountain pine trees that would naturally result in rainfall abstraction. In 2003; however, a large wildfire starting in Okanagan Mountain Provincial Park and proceeding into the Crawford neighbourhood resulted in significant damages to the trees. Pine trees in the region are typically also attacked by mountain pine beetles. These factors; in addition to climate change, are likely to result in increased runoff from the watershed.

Figure 2-2 shows a longitudinal profile of the creek within the study area based off the 2019 survey and LiDAR data for the lower and upper reaches, respectively. It is shown that the creek may be divided into four reaches as follows:

- Reach 1: the upper reach between stations 22.0 km and 44.5 km (the upper limit of the study area) that has an average slope of approximately 1.4%.
- Reach 2: the middle reach between stations 19.1 km and 22.0 km that has few significant drops in elevation over short distances with steep slopes ranging from approximately 11% to 19%.
- Reach 3: the lower reach between stations 8.5 km (the approximate upper limit of Tetra Tech's 2014 model) and 19.2 km with an average slope of about 1%.
- Reach 4: the lowest reach within the City that flattens out gradually at milder slopes up to the mouth at Okanagan Lake; the alluvial fan reach.

The profile shown in Figure 2-2 is similar to Figure 3-5 of the AE 2016 Report.

Mission Creek is the Stream Name as listed in the BC Water License Database. There are presently 144 water licenses listed, with the largest licensee BMID. During summer periods, BMID provides approximately 150ML/d to a population of 22,500 on 9,000 service connections. BMID has a water treatment plant and reservoirs at their intake structure just outside the eastern city limits.

There are four reservoirs in the upper watershed of Mission Creek north of Big White Ski Resort. Namely, Belgo Reservoir, Greystoke Lake, Fish Hawk Reservoir and James Lake all of which are controlled by BMID.

From the upper watersheds, the creek flows south and then into the City parallel to Hwy 33. At approximately Pyman Road and Hwy 33 the creek flows southwest, continues through Scenic Canyon Regional Park, then north to Mission Creek Regional Park. At the bridge crossing of East Kelowna Road, the creek flows through a diked channel to Lakeshore Road Bridge and into Lake Okanagan. The creek flows primarily through agricultural land until crossing under Gordon Drive. The diked area has walking biking trails and is know as the Mission Creek Greenway, maintained by RDCO.

The lowest creek reach; approximately 470 m long downstream of Lakeshore Road Bridge, has houses and condos off Truswell Road and Capozzi Road that are usually impacted by flooding from high creek flows and high Okanagan Lake levels. That reach is not diked along the creek banks, except for privately constructed floodwalls at some properties.

Some of the worst flooding occurred in 1997, when there were six natural landslides. One of the landslides completely blocked the creek for a short period of time.

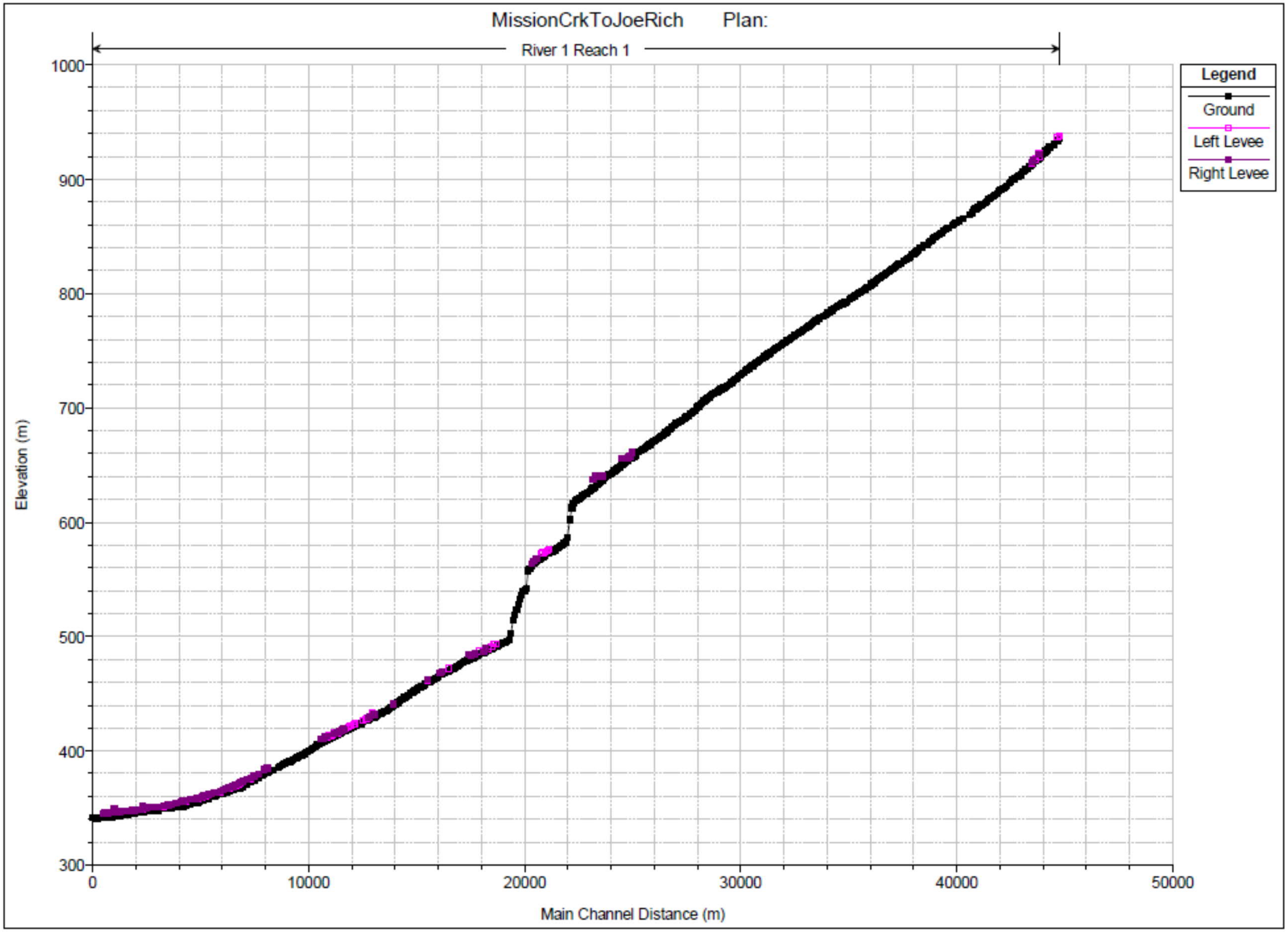


Figure 2-2: Longitudinal profile of the creek within the study area

In 2017, the region experienced widespread flooding due to snowpack buildup at the upper watershed combined with high water levels at Okanagan Lake. In 2018, the region experienced for a second time, record flood flows that resulted from rapid spring snowmelt of a high snowpack buildup during the previous winter. The recurring flooding in the area seems to be of the spring freshet that is characterized by high spatial variability.

2.3 Key Structures

The study area has multiple road and pedestrian bridge crossings; in addition to an inline submerged weir, water intakes and an inlet diversion structure connected to Mill Creek. The lower reach is also diked for most of its length. Table 2-3 lists the key structures along the creek within the study area and their UTM Zone 11N co-ordinates; arranged from upstream to downstream. Table 2-4 lists the diked reaches within the lower creek and their approximate locations; they match with Table 3-2 of AE 2016 Report describing the existing flood infrastructure for the lowest reaches of Mission Creek.

Table 2-3: Key structures along Mission Creek within the study area

Location	Easting (m)	Northing (m)
Three Forks Road Bridge	351785.02	5528162.62
Hwy 33 Bridge	345780.69	5525921.49
Pedestrian Bridge 5 (Chase/Smoothing Stones)	328531.32	5524747.78
Pedestrian Bridge 4 (Cedars/Whittaker)	328396.55	5525301.64
Pedestrian Bridge 3 (Friends of Mission/Denby)	328250.04	5525693.95
East Kelowna Road Bridge	328115.05	5526244.49
Pedestrian Bridge 2 (Cottonwoods)	326264.82	5528021.20
Pedestrian Bridge 1 (Kokanee)	325406.50	5527731.18
KLO Road Bridge	324444.90	5526017.21
Inline weir	323955.49	5525607.97
Casorso Road Bridge	322661.89	5524397.85
Gordon Drive Bridge	321551.31	5523876.30
Lakeshore Road Bridge	321131.72	5524111.17

Table 2-4: Diked reaches along lower Mission Creek*

Reach	Bank Side	Start Station (m)	End Station (m)
From Lakeshore Road Bridge to the upstream model extent	North	0+498	8+603
From 1.487 km downstream from KLO Road Bridge to 0.927 km upstream from KLO Road Bridge	South	3+269	5+779
From Lakeshore Road Bridge to Casorso Road Bridge	South	0+498	2+300

**Source: BC Water Atlas; stations follow the HEC-RAS model stationing starting at the lake.*

3. Review of Historical and Existing Data

3.1 General

AECOM contacted the following parties to obtain historical and existing data that are relevant to the development of the study outcomes:

- The City,
- RDCO,
- BC Ministry of Transportation,
- BC FLNR,
- OBWB, and
- BMID.

3.2 Existing Reports

The following documents were reviewed to obtain relevant data and information for the study:

- Grainger and Associates Consulting Ltd. and Streamworks Unlimited, February 2010. Mission Creek Hydrological Assessment; prepared for BC Ministry of Environment.

  AECOM used this report to gain information on the environmental and infrastructure elements at risk within the Mission Creek watershed. The documented risk ratings and the proposed mitigation measures were also useful information. The report also mentions climate change effects that would have impacted BMID water demand, supply and timing.

- Burge Ecohydraulics, March 2010. Mission Creek Channel and Streamway Width Assessment; prepared for the City and Mission Creek Restoration Initiative.

  Findings of that report were useful in providing information on critical flooding areas and sedimentation zones along Mission Creek; in addition to diking recommendations.

- Water Management Consultants, March 2010. Mission Creek Water Use Plan; prepared for Mission Creek Watershed Partnership c/o BMID.

  AECOM used that report to obtain background information on the major water licensee holders on Mission Creek; including BMID and Southeast Kelowna Irrigation District (SEKID). The report states that the Mission Creek basin is highly regulated; except for Pearson Creek which is the largest unregulated tributary of Mission Creek. It also includes useful information on the reservoir operations and water supply plans at the intakes of these licensees that would affect the flows in the creek.

- Tetra Tech EBA Inc., March 2014. Lower Mission Creek Hydraulic Capacity Study; prepared for BC FLNR.

  AECOM used this report to identify the critical reaches along Mission Creek that are vulnerable to flooding due to deficient freeboard. The 2014 surveyed cross section data off Tetra Tech's HEC-RAS model were used as bathymetry data for the creek channel and were synthesized into the 2018-LiDAR terrain data for the floodplain. The inflow hydrographs at the upper end and upstream of Casorso Road Bridge of their model were used for the unsteady flow dike breach simulations.

- Dobson Engineering Ltd., December 2015. Mission Creek Setback Dike Engineered Design Report; prepared for Mission Creek Restoration Initiative.

  The report includes detailed engineering design information of the setback dike that was useful in modeling the dike. It also provides some design criteria for enhancing the fish habitat within the area between Casorso Road bridge and Gordon Drive bridge that can be used for verifying the hydraulic model results. Additionally, the report has extreme flood data and high-water marks that are useful for the model calibration.

- Associated Environmental Consultants Inc., May 2016. Appendix L – Mission Creek Working Document Version 1; prepared for OBWB, Okanagan Nation Alliance (ONA) and FLNR.

  This document provides useful information on the available hydrometric stations within Mission Creek watershed. AECOM used this information for assessing the hydrological inputs in the hydraulic model.

- Associated Environmental Consultants Inc., June 2016. Regional Floodplain Management Plan: Phase 1; prepared for RDCO.

  This report provided good background information on the Regional Floodplain Management Framework (RFMF). The report also provides summary of emergency flood response locations; some of these locations are along Mission and Mill Creeks.

- Dobson Engineering Ltd. and Urban Systems, June 2018. Ideal and Greystoke Reservoirs Inundation Modeling Summary Report; prepared for BMID and RDCO.

  AECOM used this report for order-of-magnitude design flood and mean annual flow estimates based on their regression analyses. The mean annual flow estimates would be used as an initial condition for the creek base flow prior to the design flood. The report also includes useful information on some of the flood risk areas along Mission Creek that were used for comparison against the results of the current study. The report mentions some flood hazard criteria as well; however, AECOM opted to use other more suitable criteria referenced in APEGBC Flood Mapping Guidelines. The report provides estimates for warning times of simulated breaches of Ideal and Greystoke Reservoirs.

- LiDAR and Aerial Imagery Acquisition Specifications for the Okanagan Valley Watershed, 2018. Request for Proposal.

  AECOM used the provided accuracy and resolution information of the imagery acquisition to estimate the suitable mesh resolution for the 2D floodplain modeling.

- 2019 Orthophotos provided by the City.

  These orthophotos were used as background for the flood mapping; given their high resolution of 0.100 m.

- Associated Environmental Consultants Inc., September 2019. Kelowna Flood Risk Assessment Report; prepared for the City.

  AECOM used this report as background information for the Okanagan Lake water levels; as well as for comparing the vertical adjustments from the old CGVD28 and the new CGVD2013 data.

3.3 Existing HEC-RAS Model

The existing 2014 Tetra Tech HEC-RAS model was approximately 8.605 km long from Mission Creek's mouth up to Gerstmar Road. It is a 1D model with 84 surveyed cross sections that generally did not extend far enough into the floodplain; except for the cross sections that intersected the setback dike below Casorso Road Bridge. The model was primarily developed to asses the hydraulic conveyance capacity of the creek.

3.4 Okanagan Basin Water Board Hydrologic Model

AECOM understands OBWB has retained AE and NHC to carry out hydrologic studies for the Okanagan Basin. These studies are still in progress; they include watershed rainfall/runoff modeling, as well as Okanagan Lake water level and wave impact assessment.

AE developed the RAVEN hydrologic model of the basin that was used to provide daily stream flow estimates for the different tributaries for the period 1996-2017; i.e. 21-year record length. The model included sub-basin delineations of all the tributaries to the creek, except for Priest/Rumohr Creek. Such flow data record is not adequately long to estimate extreme flood discharges at different locations along the creek. NHC, therefore, carried out flood frequency analysis for the available flood records of Water Survey of Canada (WSC) stream gauge WSC 08NM116 "Mission Creek near East Kelowna", which has the longest record duration of 67 years. WSC 08NM116 is located near the upstream end of the 2014 Tetra Tech model of the lower creek reach; close to Ziprick Road within the City (refer to Figure 2-1).

NHC considered WSC 08NM116 as a reference station for estimating the peak flows at the selected POI. Their analysis included non-stationarity effects of the available WSC 08NM116 flow records. They provided scaling factors for estimating the peak flows at the POI above WSC 08NM116, based on AE's daily flows rather than peak instantaneous flows. It is to be noted as well that the daily flows NHC used were naturalized flows. NHC analysis also included estimating climate change impacts. Their estimated peak flows and climate change impact factors are later presented in Section 5.4 "Design Discharge and Climate Change Impact Factor Estimations".

For the purpose of dike breach analyses and because such breaches typically occur within relatively short hours, the daily flow estimates that AE provided were deemed inappropriate to use. Instead, AECOM used the hourly 2013 flood hydrograph that Tetra Tech developed in 2014 for WSC 08NM116 and scaled it to the peak flow estimates that NHC provided.

3.5 Lidar, Survey and GIS Data

A fundamental piece of data that allows for the development of 2D hydraulic models is LiDAR (Light Detection and Ranging). This information was collected for OBWB and provided to AECOM by the City. The LiDAR dataset provides a continuous digital elevation model (DEM), which is used as a reference surface for modelling overland flooding.

The City initially provided 2018 LiDAR data that was processed into a 1m x 1m DEM, and informed that the LiDAR was intentionally flown during the time of low flows, to reflect most of the creek geometry. In January 2020, RDCO provided another terrain surface, which was developed from a LiDAR that was flown in late 2019; after the latest 2018 dike raises. That provided 2019 LiDAR data covered the lower reach of Mission Creek within the City.

AECOM used the 2018 LiDAR surface to cut several cross sections that extended adequately into the flood plain, to capture the estimated design flood boundaries along the upper creek reach. This approach was deemed appropriate given the LiDAR was flown at low flows and there is no available recent creek survey for that long reach. This same approach was also adopted in Dobson and Urban System's 2018 Dam Inundation Study of Ideal Lake and Greystokes Lake.

The 2018 LiDAR data east limit was a few kilometers short of the upper east limit of the study area at Three Forks Road Bridge. AECOM used a 2014 DEM that RDCO provided for the missing LiDAR coverage. A merged terrain file of the 2018 LiDAR surface and the 2014 DEM was used for modeling the flood plain and channel within the upper reach of Mission Creek above the City.

For the lower reach of the creek, AECOM utilized the updated NHC 2019 survey data of the cross sections; to account for the channel bathymetry of the creek. The 2019 LiDAR data that RDCO provided in January 2020 replaced the 2018 LiDAR, since the 2019 LiDAR was flown after the latest 2018 dike raises.

The survey data were used to model the 1D creek channel, while the LiDAR data were used to model the 2D flood plain. The surveyed cross section data were reviewed and geo-referenced according to the proper horizontal coordinate system; NAD 1983 UTM Zone 11N. Because the elevations of the surveyed cross sections were in the old CGVD28 vertical datum, AECOM adjusted the elevations to be in the new CGVD2013. Vertical adjustments were computed using Natural Resources Canada's GPS-H desktop tool (converting vertical datum heights from CGVD28 to CGVD2013). This tool can be found from the Government of BC's website (https://www2.gov.bc.ca/gov/content/data/geographic-data-services/georeferencing/geoid-model-data).

AECOM also reviewed the City Open Data Utilities GIS database of the storm mains along Mission Creek. The storm drainage sewer system was found to be limited to the area south of the creek and west of Gordon Drive with a relatively sparse spatial coverage. After consultation with the City, it was agreed to model the 2D floodplain without considering the sub-surface storm drainage system for more conservative flood mapping outcomes.

3.6 As Built Data

AECOM obtained as-built data of the existing structures on Mission Creek within the study area from different sources; including RDCO, FLNR and the City. The key existing structures have been previously listed in Section 2.3.

Within the lower creek reach in the City, AECOM used the City Open Data Infrastructure Drawings Map Viewer to obtain as-built drawings of:

- Lakeshore Road Bridge, and
- Gordon Drive Bridge.

The Casorso Road Bridge and KLO Road Bridge had no as-built drawings on the Map Viewer at the time of this study; their geometry data were taken from the bridge data editor in Tetra Tech 2104 HEC-RAS model.

For the East Kelowna Road Bridge, AECOM used Drawing No. 34-S1 obtained from a bridge maintenance report that was provided by the City. The City also provided as-built drawings of the diversion structure connecting between Mill and Mission Creeks.

For all the pedestrian bridges across the creek, RDCO provided design drawings that were used to model those bridges.

For the upper reaches above the City limits, RDCO provided as-built drawings of the Highway 33 Bridge. For the Three Forks Road, AECOM obtained as-built drawings from FLNR, but the drawings did not include actual elevations. AECOM assumed bridge deck elevations off the 2014 DEM.

All the bridge data were adjusted to the new vertical datum CGVD2013.

3.7 Historical Flood Data and Lake Levels

Most of the tributaries that discharge in Mission Creek (refer to Table 2-1 and Figure 2-1) have available WSC stream gauge stations at their mouth or along their streams. In addition, there are few other WSC stream gauges along Mission Creek itself. The peak flow data were available only for the gauges listed in Table 3-1 through Environment Canada and Climate Change (ECCC) Data Explorer; Version 2.1.8 published in October 2016. Table 3-1 also includes other attributes of the three gauges including the peak floods of record.

WSC 08NM116 “Mission Creek near East Kelowna” is the gauge with the longest record duration of 67 years; NHC considered it as a reference station for estimating the peak flows at the selected POI. It is located near the upstream end of the lower reach model; close to Ziprick Road within the City.

Table 3-1: Water Survey of Canada (WSC) stream gauge stations near the points of interest along Mission Creek

Serial	Label	Name	Easting (m)	Northing (m)	Years of Record	Length of Record (Years)	Drainage Area (km^2)	Peak Flood of Record (m^3/s) and its (Year)
1	08NM116	Mission Creek near East Kelowna	326604	5527850	1949-2016	67	795	115 (2013)
2	08NM057	Mission Creek Rutland Diversion	328200	5527474	1922-1930	8	---	
3	08NM016	Mission Creek near Rutland	331993	5524820	1910-1912; 1919-1946	29	622	
4	08NM239	Mission Creek below B.M.I.D. Intake	335858	5524453	1980	1	---	
5	08NM137	Daves Creek near Rutland	336579	5526441	1965-1986	21	31.1	3.14 (1975)
6	08NM225	Belgo Creek near the Mouth	345565	5526423	1976-1982	6	190	
7	08NM172	Pearson Creek near the Mouth	351905	5528098	1970-1987	17	73.6	17.4 (1976)
8	08NM233	Mission Creek above Pearson Creek	351848	5528193	1977-1982	5	233	

According to Table 3-4 of AE 2016 Report, flood events in Mission Creek have occurred historically due to different flood mechanisms; including: rain, rain-on-snow, and snowmelt. Significant flooding in the creek happened typically in late spring and summer of 1942, 1983, 1990, 1997, 2006, 2012, and 2013.

While the most recent ECCC Data Explorer version includes peak flood records for the stream gauge WSC 08NM116 up to only 2013, it is known from media sources, the City and RDCO that the region experienced extreme flooding in 2017 and 2018. NHC provided AECOM with flood records for WSC 08NM116 after 2013. These records indicate that the 2017 and 2018 peak flows were approximately 107.3 m^3/s and 124.6 m^3/s, respectively. In 2014, Tetra Tech estimated the 200-year peak flow at WSC 08NM116 at 124 m^3/s, which is close to the 2018 peak flow that NHC provided.

The flood of June 1990 was mainly due to rainfall and resulted in widespread flooding within Mission Creek watershed; particularly in the community of Joe Rich. According to AE 2016 Report, that storm event resulted in six debris failures on the hillslope above Philpott Road north of Hwy 33 crossing. It is also reported that Okanagan Lake water levels rose to approximately 15 inches higher than the normal June high water levels. That resulted in flooding the area near the creek mouth and in damaging the nearby shoreline properties.

For Okanagan Lake water levels, Tetra Tech 2014 Report indicates a full pool target lake level at an elevation of 342.48 m, which corresponds to approximately 342.71 m in the new CGVD2013 vertical datum. Tetra Tech included also other lake levels with the highest level at an elevation of 343 m (approximately 343.24 m in the CGVD2013 datum) that corresponds to the 200-year lake level.

AE 2019 Report lists different Okanagan Lake water levels based on frequency analyses of the observed lake levels at WSC 08NM083. In their Table 2-15, the estimated 5-year and 200-year lake water elevations in the old CGVD28 datum are 342.67 m and 343.27 m, respectively.

AE's 200-year lake water elevation is 0.27 m higher than Tetra Tech's 2014 estimate; the difference may be attributed to the longer record AE used in their analyses. Tetra Tech's full pool target lake water elevation is 0.19 m lower than AE's estimated 5-year elevation.

For the purpose of this study, and as is described later in Section 6 "Flood Hazard and Risk Mapping", AECOM adopted the estimated 20-year and 200-year peak flood discharges along Mission Creek for flood mapping development. This is following APEGBC Flood Mapping Guidelines.

For the Okanagan Lake water level, AECOM considers the full pool target lake level as a boundary condition; assuming it is highly unlikely that the watershed and the lake will both experience the 200-year hydrologic conditions simultaneously.

It is to be noted that AE added a blanket vertical datum conversion factor of 0.255 m to convert from the old CGVD28 datum to the new CGVD2013 datum. This value is quite close to that obtained by AECOM through Natural Resources Canada's GPS-H desktop tool being 0.233 m at the lake near the creek mouth.

4. Field Reconnaissance

On September 18, 2019, AECOM visited Mission Creek to assess its main channel, the floodplain areas and the key hydraulic structures along the creek within the study limits. Three AECOM staff attended the visit along with two City staff. Specific points of interest that were observed during the visit include the key bridge crossings previously listed in Table 2-3; in addition to the south dike within the City, particularly the reach between Casorso Road Bridge and Gordon Drive Bridge.

The field reconnaissance report describing the details of the visit is included in Appendix A of this report.

5. HEC-RAS Model Development

5.1 Model Set Up

Two models were established:

1. The Upper Reach Model: a steady state 1D model for flood mapping production along the upper creek reach using peak flows that were obtained from NHC at the points of interest shown previously in Figure 2-1.
2. The Lower Reach Model: an unsteady state 1D/2D model for flood mapping production and dike breach analyses along the lower reach; using simulated inflow hydrographs.

5.1.1 The Upper Reach Model

The geometry file of Tetra Tech's 2014 Model Scenario 4, which included the proposed Lakeshore Bridge at that time and the setback dike between Gordon Drive Bridge and Casorso Road Bridge, was extended upstream to the upper limit of the study area.

The geometric data of the bridges were revised and updated within the lower reach based on the as-built drawings. In addition, new bridges were added within the upper reach; their as-built drawings were obtained from FLNR and RDCO. All bridge elevations were adjusted based on the new CGVD2013 vertical datum.

The cross-section data of the channel within the lower reach were also updated with NHC 2019 surveyed cross sections. NHC also provided some newly surveyed cross sections that AECOM included in the model. The elevations were adjusted to the new CGVD2013 vertical datum.

Cross sections within the upper reach were initially cut at a spacing that ranged between 500 m and 850 m across the creek. Intermediate cross sections were further established at a spacing of 300 m or less using local interpolation between each two successive initial cross sections. All interpolated cross sections were then adjusted by cutting them from the LiDAR terrain. They were also extended in RAS-Mapper to capture the entire floodplain; hence avoiding any artificial glass wall end effects that may affect the flood extents. The modelled upper reach between river stations 8+682.55 and 44+469.91 has a total of 401 cross sections; with an average intermediate spacing between cross sections of approximately 100 m.

Ineffective flow areas, bank stations and Manning's roughness coefficient were assigned based on examining the land use, land cover and stream geometric properties as viewed in aerial imagery and the LiDAR data layer. Table 5-1 lists the default values of Manning's roughness coefficient "n" that were deemed appropriate for the study area.

Table 5-1: Default values of Manning's roughness coefficient "n"

Feature	n
Natural channels (regular and straight)	0.03 – 0.07
Low vegetation	0.04 – 0.06
High vegetation	0.07 – 0.09
Natural channels (irregular with pools and meanders)	0.04 – 0.15
Forested floodplain	0.090 or larger

5.1.2 The Lower Reach Model

The lower reach model was developed as a sub-model of the full reach model. Within the lower reach, the surveyed cross-sections were trimmed at the highest dike or bank points, to allow connecting the 1D channel to the 2D floodplain mesh.

A mesh resolution of 10m x 10m was used for both the north and south floodplains. Where needed, extra computational points were added for a more refined mesh. Both the north and south 2D meshes were extended adequately away from the channel to capture the flood boundaries of the 200-year design flood. It is to be noted that the simulated floodplain depths and extents are highly sensitive to the mesh resolution, with finer mesh sizes leading to longer computational times.

Shape files of the buildings were obtained from the City Open Data website and added to the 2D floodplain. The buildings were assigned a much higher value of Manning's "n"; a value of 10 was found reasonable, to have no flow at their footprints.

Boundary condition lines were added along the lake coast to allow flow interaction between the 2D floodplain mesh and the lake.

Lateral structures that were spatially geo-referenced along the lower reach were established to allow the connection between the 1D model of the creek channel and the 2D model of the floodplain. In addition, the lateral structures allowed for the dike breach analyses.

5.2 Initial and Boundary Conditions

Initial base flows along the creek were used in the unsteady model for the lower reach. An initial base flow of 30 m^3/s was deemed reasonable to use given that it is approximately half of the estimated 2.3-year flood discharge of 63.6 m^3/s reported in Table 8.1 of Tetra Tech 2014 Report. This is also supported by Figure 3-7 of AE 2016 Report that shows 30 m^3/s as the mean daily discharge for WSC 08NM116 in June; based on data from 1949 to 2013.

The Okanagan Lake water level reported in AE 2019 Report was used as a downstream boundary condition, after adjusting it for the new CGVD2013 vertical datum. The adjusted water level is 342.91 m.

Further details on the initial and boundary conditions for the Upper Reach and Lower Reach Models are described next.

5.2.1 The Upper Reach Model

The upstream boundary condition for the full reach model was set to be the normal depth assuming uniform flow at the bed slope of 1.4% for the upper reach (see Section 2.2 and Figure 2-2).

5.2.2 The Lower Reach Model

The selected initial base flow of 30 m^3/s was applied at all the cross sections along the lower reach model; such base flow helped stabilize the unsteady flow simulation model.

The adjusted Okanagan Lake water level of 342.91 m was applied as a downstream boundary condition at the most downstream cross section in the 1D channel model. The same lake level was also applied as a stage hydrograph along the boundary condition lines representing the coastal periphery of the floodplain 2D mesh.

The established lateral structures along the lower reach model defined the overflow boundary condition between the channel and the floodplain.

For the non-diked reaches; for example: downstream of Lakeshore Road Bridge, the lateral structures were modeled using normal 2D equation domain as an overflow computation method. This option simulates overflow from the main channel onto the floodplain when the water surface elevations exceed the highest elevations of the 1D channel cross sections.

For the diked-reaches along the lower Mission Creek, the lateral structures were modelled assuming weir flow equation for overtopping or during breach. A weir coefficient of 0.5 was deemed reasonable given the flow is lateral onto the floodplain. Dike breach parameters were selected based on referenced values and in consultation with RDCO. The breach parameters are further described in Section 5.6.2 “Model Runs and System Assessment – Unsteady State Scenario”.

An inflow hydrograph at the most upstream cross section of the lower reach was used as a boundary condition; this is the approximate location of WSC 08NM116, which has the longest available flow record among other WSC stream gauges along the creek. Another lateral inflow hydrograph at the confluence of Priest/Rumohr Creeks was used as a boundary condition. The location of this lateral inflow hydrograph is the same as that in Tetra Tech’s 2014 model; it is applied at the river station 2+337.718. AECOM maintained the same hydrograph shapes that Tetra Tech used in their 2014 model for the 2013 flood while adjusting their peaks to match the recent peak flow estimates provided by NHC.

5.3 Model Calibration and Verification

Model calibration was done using high water marks (HWM) that NHC surveyed in November 2019 at some locations along the lower reach. One additional HWM that was observed during AECOM’s 2019 field reconnaissance at Highway 33 Bridge was also used. The calibration was mainly done by adjusting the Manning’s roughness coefficient (n) and the locations of the ineffective flow areas and levees in the modelled cross sections.

Table 5-2 lists the HWM locations and elevations as obtained from NHC 2019 survey and after adjusting their elevations to the new vertical datum of CGVD2013 using Natural Resources Canada's GPS-H desktop tool.

As indicated earlier in Section 3.7 “Historical Flood Data, Flood Mechanisms and Lake Levels”, the observed 2018 flood discharge as provided by NHC at WSC 08NM116 (124.64 m^3/s) matched the 200-year flood estimate that Tetra Tech reported in 2014 (124 m^3/s) based on their frequency analysis. With the 2019 surveyed and observed HWM in Table 5-2; and given that no extreme floods occurred in 2019, it is highly likely that those HWM are retained from the 2018 flood.

Table 5-2: Highwater Mark (HWM) location and elevation

Location	Easting (m)	Northing (m)	Nearest Cross Section/River Station	Surveyed Elevation (m)	Vertical Datum Adjustment (m)	Adjusted Elevation (m)
Hwy 33 Bridge (upstream pier face)	345780.69	5525921.49	35+736.33	808.3 *	0.327	808.627
Hwy 33 Bridge (downstream pier face)	345780.69	5525921.49	35+699.09	807.6 *	0.327	807.927
Downstream KLO Bridge (north side)	324405.757	5526023.298	4+840.351	356.526	0.250	356.776

Location	Easting (m)	Northing (m)	Nearest Cross Section/River Station	Surveyed Elevation (m)	Vertical Datum Adjustment (m)	Adjusted Elevation (m)
Downstream KLO Bridge (south side)	324428.25	5526002.587	4+840.351	356.806	0.250	357.056
Downstream Casorso Road Bridge	322641.57	5524393.958	2+301.703	347.930	0.246	348.176
Downstream end of the setback dike	322136.788	5524114.595	1+659.637	346.783	0.242	347.025
Upstream Gordon Drive Bridge	321546.532	5523977.625	1+050.673	344.560	0.239	344.799
Downstream Gordon Drive Bridge	321510.68	5523953.097	1+009.137	344.650	0.239	344.889

**These two elevations at Hwy 33 Bridge were estimated based on tape measurements below the bridge girder soffit during the field reconnaissance and the as-built drawings of the bridge.*

A model calibration run using the lower reach unsteady model was performed, while adopting the inflow hydrograph shape of the 2013 flood used in the 2014 Tetra Tech model. The inflow hydrographs at the upstream boundary and below Priest/Rumohr Creek; at the cross-section river station 2+337.718 right upstream of Casorso Road Bridge, were scaled to the corresponding 2018 flood discharges. The base flow of 30 m^3/s previously described in Section 5.2 “Initial and Boundary Conditions” was also used. The lake level was set to the elevation of 342.91 m as mentioned earlier in Section 3.7 “Historical Flood Data, Flood Mechanisms and Lake Levels” representing downstream boundary condition line for the floodplain 2D mesh and for the most downstream cross section in the 1D channel.

Because Priest/Rumohr Creek sub-basin delineation was not provided by AE, NHC did not provide its peak flows. Hence, AECOM delineated its sub-basin and used Equation 5-1 to estimate its peak flow referenced to those of WSC 08NM116.

$$\boldsymbol{Q_2} = \boldsymbol{Q_1}\left(\frac{\boldsymbol{A_2}}{\boldsymbol{A_1}}\right)^{\mathbf{0.785}}$$ **Equation 5-1**

Equation 5-1 is reported in Tetra Tech’s 2014 Report and is referenced to “Report on British Columbia Streamflow Inventory” issued by the Ministry of Environment, Lands and Parks in 1998.

A second model calibration run was performed using the steady state model for the upper reach. The 10 POI in Table 2-1 were reduced to seven POI, after aggregating those of KLO and Hydraulic Creeks, and Belgo and Joe Rich Creeks; due to being geographically close (see Figure 2-1). AECOM used the 2018 peak discharge of 124.64 m^3/s at WSC 08NM116 and the scaling factors that NHC provided for the aggregated POI, to estimate the peak flows at each POI.

Table 5-3 presents the estimated drainage areas, NHC scaling factor and the estimated cumulative peak discharge of the 2018 flood at the major POI along the creek. In Table 5-3, AE provided estimates of the sub-basin drainage areas at POI 2 to POI 7, while AECOM estimated the drainage area of the sub-basin at POI 1. According to NHC, the instantaneous peak flows at POI 3 to POI 7 are obtained by multiplying the instantaneous peak flow at the lower POI with its scaling factor.

Table 5-3: The estimated drainage areas and 2018 peak discharges at the major points of interest on Mission Creek

POI	Description	Drainage Area (km^2)	NHC Scaling Factor	Cumulative Discharge, Q (m^3/s)
1	Downstream from Priest/Rumohr Creek	40.5	---	136.78
2	At WSC 08NM116	786*	1.00	124.64
3	Downstream from KLO/Hydraulic Creek	777	0.92	124.64
4	Downstream from Daves Creek	605	0.98	112.21
5	Downstream from Grouse Creek	544	0.99	109.85
6	Downstream from Belgo Creek	504	0.77	109.19
7	Downstream from Pearson Creek	260	---	82.14
8	Mission Creek above Pearson Creek	233**	---	47.96

** For the drainage area at POI 2, the ECCC Data Explorer reports 795 km^2; AECOM used 786 km^2 as provided by AE for consistency.*

*** AECOM used this value as obtained from ECCC Data Explorer for WSC 08NM233 "Mission Creek above Pearson Creek" rather than 186.4 km^2 that would result from subtracting AE's estimated drainage area at POI 7 of 260 km^2 from the drainage area of WSC 08NM172 "Pearson Creek near the Mouth" (refer to Table 3-1). The discharge at POI 8 was applied as an upstream boundary condition in the upper reach model.*

While performing the calibration runs, different values of the Manning's roughness coefficient (n) were assigned to the different channel reaches based on the geomorphological characteristics of the creek. For example, the upper braided and meandering reaches were assigned larger n-values than the lower straight and regular reaches. The results of the final calibration runs are presented in Table 5-4. These results are deemed acceptable given there are many factors that may have changed from the time of the 2018 flood and the time NHC surveyed the lower reach cross-sections in 2019. Examples of such factors include debris movement, channel erosion and deposition; in addition to the uncertainties of the RAVEN hydrologic modelling and the NHC scaling factors being based on daily peak flows rather than instantaneous peak flows.

Table 5-4: Calibration results

Location	Nearest Cross Section/River Station	Adjusted Surveyed HWM Elevation (m)	Simulated High Water Elevation (m)	Difference Between Surveyed and Simulated HWM Elevations (m)
Hwy 33 Bridge (upstream pier face)	35+736.33	808.627	808.14	0.487
Hwy 33 Bridge (downstream pier face)	35+699.09	807.927	807.95	-0.023
Downstream KLO Bridge (north side)	4+840.351	356.776	357.10	-0.324
Downstream KLO Bridge (south side)	4+840.351	357.056	357.10	-0.044
Downstream Casorso Road Bridge	2+301.703	348.176	348.26	-0.084
Downstream end of the setback dike	1+659.637	347.025	347.09	-0.065
Upstream Gordon Drive Bridge	1+050.673	344.799	345.43	0.631
Downstream Gordon Drive Bridge	1+009.137	344.889	345.30	-0.411

The calibrated model results are verified based on information from the City staff obtained during the field reconnaissance; in addition to other available flood information from previous reports, websites and media sources.

For example, the simulated 2018-year flood highwater mark elevation at KLO Bridge provides a freeboard below the bridge lower deck of approximately 0.22 m, which matches well with images obtained from the news and what the City staff mentioned.

Another evidence of model verification is presented in Figure 5-1 (a) that shows a snapshot of the flood depth map from the calibration run at the maximum water level. It shows the area west of Swamp Road and south from the creek flooded all the way to the lake. This matches with Figure 5-1 (b) that shows the flood watch map for the 2017 flood that is published at the Central Okanagan Emergency Operations website (https://www.castanet.net/news/Kelowna/196861/Flood-watch-maps-issued) for the high water advisory. It is to be noted that the 2017 flood discharge was less than the 2018's; NHC's provided data reports approximately 107.3 m^3/s for the 2017 flood.

a)

b)

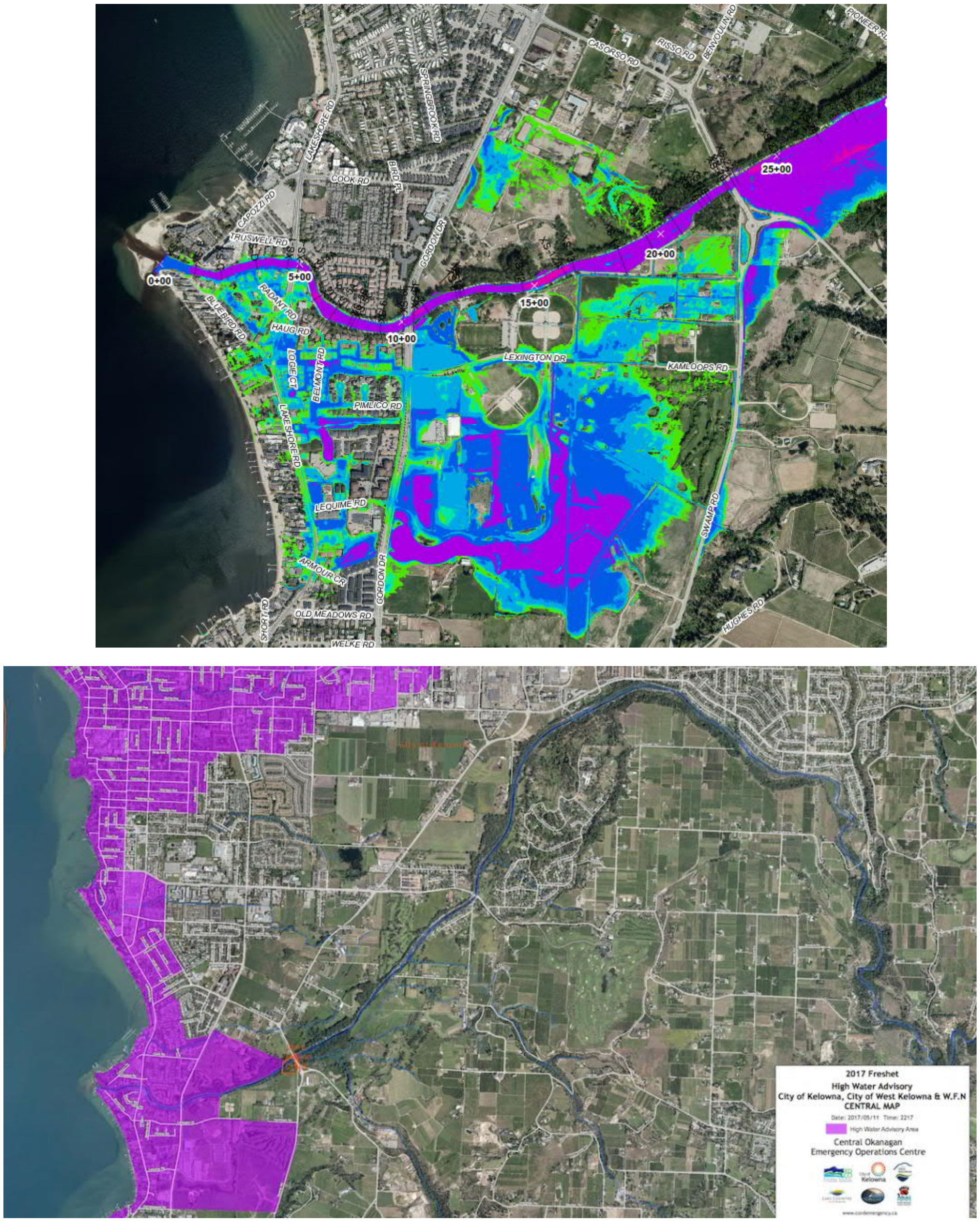


Figure 5-1: a) Snapshot from the calibration run; b) Flood watch map for the 2017 freshet (Source: Central Okanagan Emergency Operations)

5.4 Design Discharge and Climate Change Impact Factor Estimations

The following two design discharges were considered in this study based on APEGBC Flood Mapping Guidelines:

- the 20-year peak flood discharge, and
- the 200-year peak flood discharge.

Estimates of these design flood discharges at the aggregated POI 2 to POI 7 previously presented in Table 5-3 and Figure 2-1 were provided by NHC. AECOM estimated the design discharges at POI 1 and POI 8 as mentioned earlier in Section 5.3 "Model Calibration and Verification". NHC also estimated the climate change impact factor to be a 10% increase to the design flood discharges. Table 5-5 lists the estimated design flood discharges at the different POI with and without the climate change impact factor. It is to be noted NHC's 200-year design flood discharge estimate without climate change at WSC 08NM116 is 32% larger than Tetra Tech's 2014 estimate.

Table 5-5: The estimated design flood discharges

Serial	POI	20-year Peak Flood (m^3/s)		200-year Peak Flood (m^3/s)	
		Without Climate Change	With Climate Change	Without Climate Change	With Climate Change
1	Downstream from Priest/Rumohr Creek	127.0	138.5	180.4	198.5
2	At WSC 08NM116	114.7	126.2	164.4	180.8
3	Downstream from KLO/Hydraulic Creek	114.7	126.2	164.4	180.8
4	Downstream from Daves Creek	103.3	113.6	148.0	162.8
5	Downstream from Grouse Creek	101.1	111.2	144.9	159.4
6	Downstream from Belgo Creek	100.5	110.5	144.0	158.4
7	Downstream from Pearson Creek	75.6	83.1	108.3	119.2
8	Mission Creek above Pearson Creek	11.2	12.3	63.3	69.6

For the purpose of generating the required flood maps, the design discharges with climate change impacts were used. Table 5-6 lists the final cumulative design discharges and the closest cross section river stations as inflow change locations where the flows were applied in the model.

Table 5-6: The inflow locations of the final estimated design flood discharges

Serial	Inflow Location	Description	Cross Section River Station	Final Design Discharge (m^3/s)	
				20-year Flood	200-year Flood
1	Downstream from Priest/Rumohr Creeks	Upstream of Casorso Road Bridge	2+337.718	138.5	198.5
2	WSC 08NM116	Near Ziprick Road	8+331.684	126.2	180.8
3	Downstream from KLO/Hydraulic Creeks	Near Gallaghers Canyon	15+700.9	126.2	180.8
4	Downstream from Daves Creek	Near BMID Reservoirs	23+822	113.6	162.8
5	Downstream from Grouse Creek	0.8 km southwest of Hitching Post Resort on Hwy 33	30+015.27	111.2	159.4
6	Downstream from Belgo/Joe Rich Creeks	Below the start of Three Forks Road off Hwy 33	35+040.3	110.5	158.4
7	Downstream from Pearson Creek	Below Three Forks Road Bridge	43+469.51	83.1	119.2
8	Most upstream model boundary	Above Upper Mission Creek POI	44+469.91	12.3	69.6

5.5 Dike Breach Analysis

AECOM investigated different criteria for the dike breach analysis; including the breach location and width, the breach formation time and the breach failure mode. There are typically two breach failure modes: overtopping and piping. According to the US Army Corps of Engineers 2014 Training Document “TD-39: Using HEC-RAS for Dam Break Studies”, the ultimate breach size and breach formation time are much more critical in the estimation of the breach outflow hydrographs than the actual failure initiation mode.

APEGBC Flood Mapping Guidelines references an ultimate breach width of 200 m for large rivers; such as Fraser River, and 100 m for smaller rivers. Mission Creek is considered a small river. After consultation with RDCO and the City and given that the average creek width along the diked lower reach of the creek is approximately 30 m, it was deemed reasonable to consider a maximum breach width of only 20 m. Assuming breach widths larger than the creek width may result in more lateral flow across the breach than through flow along the main channel. This becomes hydraulically unreasonable, as it would result in switching the hydraulic control from the main channel to the dike breach.

For the breach locations, it was agreed with the City and RDCO that the south floodplain between Casorso Road Bridge and Gordon Drive Bridge is the most critical. This is justified due to being geographically at low relief west of Swamp Road; in addition to having multiple recreational and valued asset properties including: The Ball Diamond grounds and Kinsmen Media Centre, Mission Dog Park, Trapalanda Farms horseback riding, Michaelbrook Golf Club, Kinsmen Softball Complex, the soccer playgrounds, H2O Adventure and Fitness Centre, as well as Kelowna Mission Library, AK Hockey Skatemill & Skills Centre and Capital News Centre (see Figure 5-2).

For earthen/rockfill dams, Table 3 of the above-mentioned TD-39 Document recommends average breach failure times ranging from 0.1 hr to 4 hr. The same table recommends average breach widths ranging from 0.5 to 5 times the dam height. Applying these criteria to the dike along the south bank of the creek between Casorso Road Bridge and Gordon Drive Bridge with an average dike height of 2 m results in an average breach width varying between 1 m and 10 m. This supports the assumption of the maximum breach width of 20 m previously mentioned in this section. In addition, a breach formation time of 0.5 hr was considered reasonable.

The selected dike for breach was observed during the field reconnaissance to be in a good condition. Hence, an overtopping failure mode has been considered more reasonable than a piping mode. The location for the dike breach was selected based on observing the highest water surface profile along the creek during the 200-year flood model run assuming no breach. The location where the dike was overtopped was found to be near the corner point of the setback dike between cross sections 14 and 14A at river stations 1+833.166 and 1+952.603; respectively. At that location, the dike crest has an elevation of approximately 347.26 m and the water elevation corresponding to the 200-year flood is approximately 347.36 m. A final bottom elevation for the breach was assumed to be 346.50 m. A default breach weir coefficient of 1.44 was considered and the breach side slopes were assumed 2H:1V.

The longitudinal profile of the minimum tailwater 2D mesh cells south of the selected breach location showed lowest elevations between Swamp Road and the Kinsmen Media Centre where the Trapalanda Farms horseback riding facility is located.

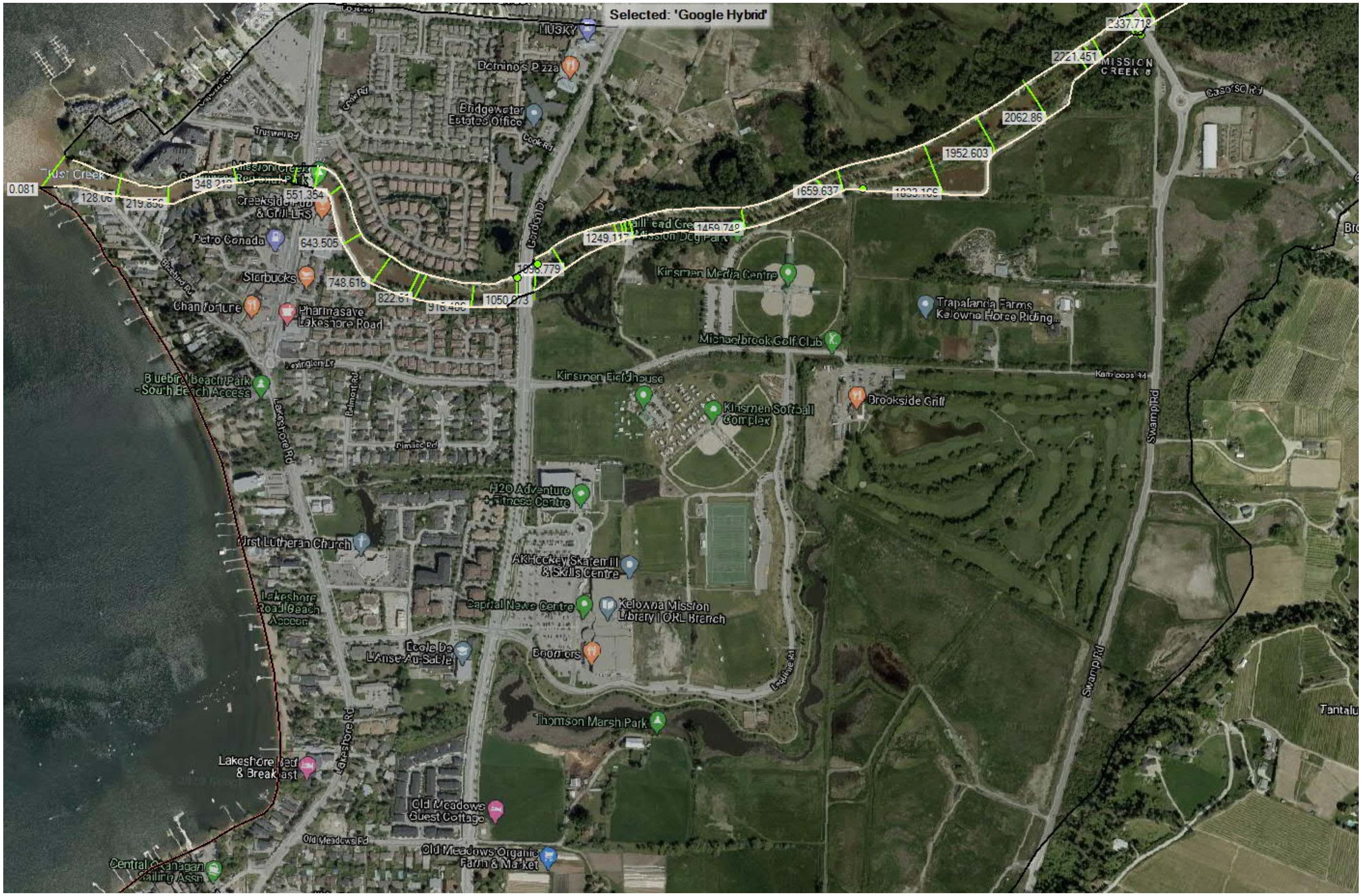


Figure 5-2: Aerial view of the recreational area west of Swamp Road to the lake shore

5.6 Model Runs

5.6.1 The Upper Reach Model

The following two model runs were performed for the upper reach of Mission Creek:

- Steady state simulation of the 200-year peak flood discharges with climate change at the POI previously listed in Table 5-6.
- Steady state simulation of the 20-year peak flood discharges with climate change at the POI previously listed in Table 5-6.

5.6.2 The Lower Reach Model

The following four model runs were performed for the lower reach of Mission Creek:

- Unsteady state simulation of the 20-year flood discharge with climate change.
- Unsteady state simulation of the 200-year flood discharge with climate change.
- Unsteady state simulation of the 200-year flood discharge with climate change assuming dike breach near the corner point of the setback dike between cross sections 14 and 14A at river stations 1+833.166 and 1+952.603; respectively.

The modelling results of the steady state simulation and the unsteady state simulation at the maximum flow conditions were merged in Arc-GIS to develop the mapping of the 20-year and 200-year flood recurrences.

The modelling results of the unsteady state 200-year flood simulations within the lower reach were also used to examine the development of the flood wave for the dike breach and no-breach scenarios.

6. Flood Hazard Mapping and Results

The following resources were reviewed in the development of the flood hazard mapping standards and criteria for this study:

- MMM Group Ltd. National Floodplain Mapping Assessment Final Report (2014).
- APEGBC Professional Practice Guidelines for Flood Mapping in BC (V1.0, 2017).
- AECOM National Principles, Best Practices and Guidelines for Flood Mapping (Draft report prepared for Natural Resources Canada, 2017).
- APEGBC Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate on BC (Version 2.1, 2018).
- Federal Flood Mapping Guidelines Series (Version 2.0, 2018).
- The United States Federal Emergency Management Agency (FEMA) Guidance for Flood Risk Analysis and Mapping – Flood Depth and Analysis Grids (2018).
- FEMA Policy Standards for Flood Risk Analysis and Mapping (FEMA Policy #FP 204-078-1; Rev 9, 2019).

Flood hazard maps usually include more information than merely the flood boundaries that are shown in flood inundation maps. Such extra information includes water depth, velocity and hazard class, which is typically some form of depth and velocity derivative.

6.1 Flood Hazard Mapping Standards

6.1.1 Topographic Standards

Accuracy
The minimum requirements for digital elevation models (DEMs) are 10 m x 10 m horizontal resolution (preferably 5 m x 5 m), and 0.5 m vertical resolution (preferably 0.3 m).

Datum
1983 North American Datum (NAD83) for horizontal control and 1928 Canadian Geodetic Vertical Datum (CGVD28) for vertical control. CGVD2013 has recently replaced CGVD28.

Projection and Coordinate System
Universal Transverse Mercator (UTM) is the adopted projection and the co-ordinates are expressed in meters as northings and eastings within the UTM grid.

In this study, AECOM used NAD83 and CGVD2013 for horizontal and vertical data, respectively. UTM Zone 11N co-ordinates were used and the DEM and LiDAR data that RDCO provided satisfy the standard accuracy.

6.1.2 Design Flood Standards and Climate Change Considerations

In most of BC, flood maps have been produced with the larger of the 200-year flood or the flood of record; in addition to the 20-year flood as the design floods.

The 200-year or the flood of record design flood levels are used to establish design elevations for flood mitigation works. The 20-year flood levels are used in compliance with the Health Act requirements for septic systems.

For the current study, AECOM developed the flood mapping using the 20-year and 200-year design floods with the climate change impact factor added; in addition to a base flow simulating the mean annual summer discharge in June. Climate change impact factors were provided by NHC through their current Okanagan Basin study.

6.2 Flood Hazard Mapping Criteria

Hazard Ratings
Hazard ratings combine effects of inundation depth, flow velocity and floating debris potential. Color-coded standards are favourable than shades of one color. Maps can show depth or velocity variations, as well as hazard ratings.

AECOM adopted the below UK flood hazard formula as referenced in APEGBC Flood Mapping Guidelines. AECOM obtained more details on the formula from a supplementary note that was issued by UK Environment Agency and HR Wallingford in 2008.

UK Flood Hazard Rating Formula:

Hazard Rating (HR) = flooding depth (d) x [velocity (v) +0.5] + debris factor (DF)

DF = 0, 0.5, or 1 depending on if the debris will lead to significantly greater hazard, as well as the depth and velocity values. Table 6-1 describes the different hazard ratings and their classifications.

Table 6-1: Hazard to people classification according to UK hazard rating formula

Hazard Rating (HR)	Hazard Degree	Description
< 0.75	Low	Caution (flood zone with shallow flowing water or deep standing water)
0.75 – 1.25	Moderate	Danger for some; i.e. children, elderly and infirm (flood zone with deep or fast flowing water)
1.25 – 2.00	Significant	Danger for most; includes general public (flood zone with deep fast flowing water)
> 2.00	Extreme	Danger for all; includes emergency services (flood zone with deep fast flowing water)

Dike Breach
An account on the dike breach parameters and the selection of their values and has been previously presented in Section 5.5 “Dike Breach Analysis”.

Scale
APEGBC Guidelines cite the current coastal flood mapping guidelines recommended by Kerr Wood Leidal Assoc. (KWL) in 2011 being minimum of 1:10,000 and preferable 1:5,000.

AECOM used a scale of 1:10,000 for flood mapping due to the nature of Mission Creek being diked in the lower reach and a gorge-like stream in the upper reach.

6.3 Development of Mapping using RAS-Mapper

RAS-Mapper was used to develop the initial flood hazard maps. Results of flow depths and velocities were exported as raster based on terrain data into Arc-GIS for post-processing.

6.4 Verification of Mapping using ARC-GIS

In areas where the floodplain is at lower elevations than the channel or the dike, RAS-Mapper extends the computed water surface profile in any 1D cross section to where the profile intersects the LiDAR data in the floodplain. This occurs even when there are levees/dikes set up in the cross section and the HEC-RAS geometry editor shows no water in the floodplain. Therefore, post-processing of the flood data in the floodplain at some cross sections where this issue occurred had to be carried out.

These 1D cross sections in the upper reach model were carefully reviewed in HEC-RAS against the LiDAR terrain surface and aerial imagery to verify the flood extents. Where needed, post-processing in Arc-GIS was done to develop the final mapping.

6.5 Final Flood Hazard Mapping and Results

Arc-GIS was used to produce the final flood hazard maps. The UK flood hazard formula was coded in Arc-GIS to define the different hazard ratings.

Two sets of flood hazard maps were developed for the different model runs:

- Flood depth maps, and
- Flood hazard rating maps.

The following sections describe the flood mapping results.

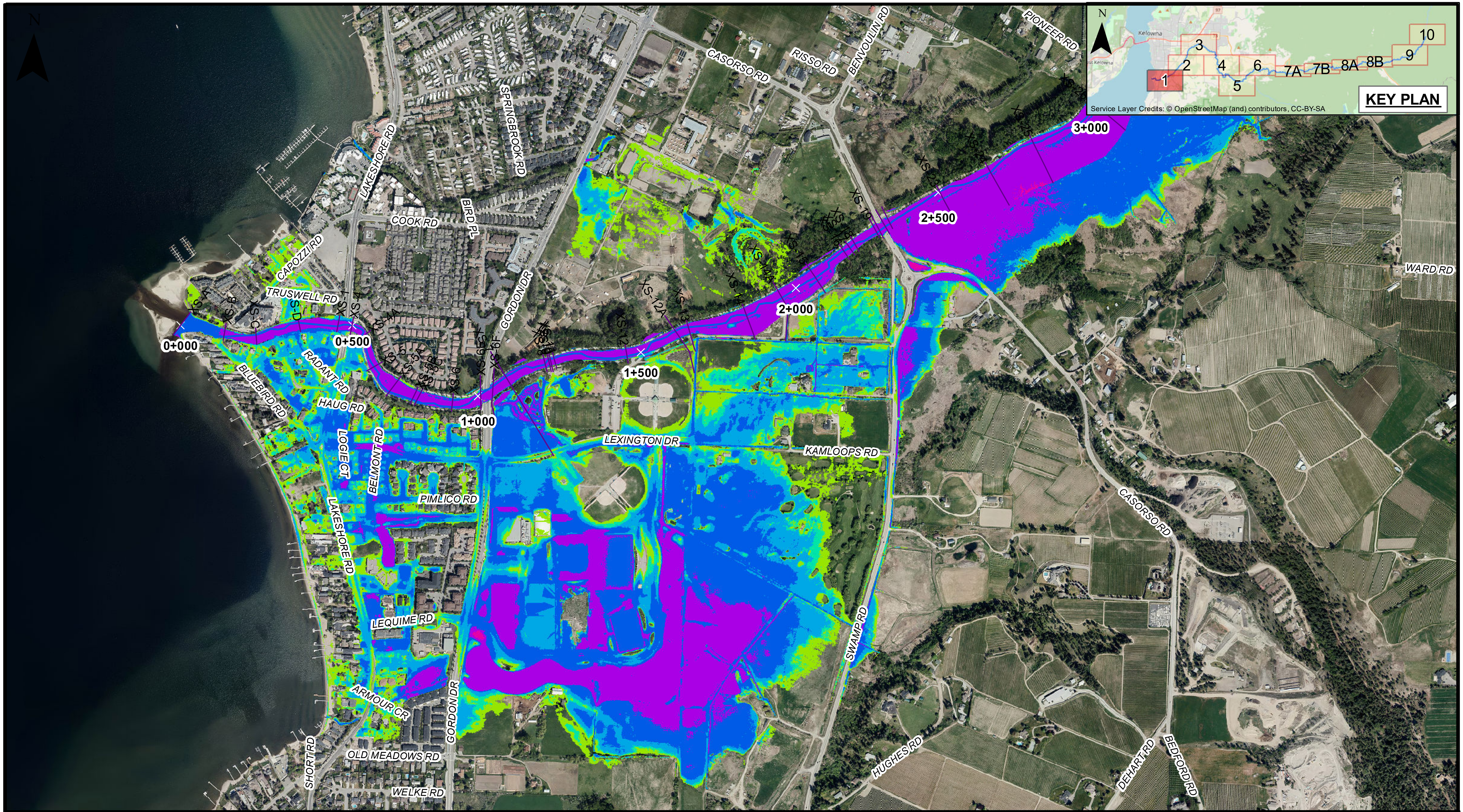
6.5.1 Mapping Results for Peak Flood Design Discharge Conditions

Table 6-1 compares between the flood impacts of the 20-year and 200-year design floods.

Figures 6-1 and 6-2 show the flood depth mapping results for the 20-year and 200-year peak flood design discharges along the creek within the study area.

Table 6-2: Comparison between the 20-year and 200-year flood impacts

Location	20-year Flood Inundated Areas	200-year Flood Inundated Areas	Flood Impacts
The north floodplain within the lower reach	Only a small area across from the setback dike between Casorso Rd and Gordon Dr, and part of the non-diked area downstream from Lakeshore Rd Bridge (Figure 6-1; Sheet 1/10)	More areas get flooded primarily due to overtopping of some parts of the right bank dike upstream from KLO Rd Bridge (Figure 6-2; Sheets 1-4/11)	During the 20-year flood, the depths are primarily within 0.40 m. During the 200-year flood, excess depths of 0.80 m to 1.60 m exist in the wetland between Casorso Rd and Richter St north of Lanfranco Rd, a low relief area north of the intersection of Richter St with Lakeshore Rd, and Watt Park near the lake coast along Watt Rd. Munson Pond south of Munson Rd has depths of about 0.80 m and a localized stream across Gordon Dr northwest of the pond has depths exceeding 2.0 m. Kelowna Wastewater Treatment Facility south of Raymer Ave is partially flooded with depths below 0.40 m. The area between Casorso Rd and Gordon Dr has depths generally below 0.80 m
The south floodplain within the lower reach	Upstream from KLO Rd Bridge Upstream from Casorso Rd Bridge West of Swamp Rd to the lake	The same areas inundated during the 20-year flood, but with wider flooding extents and larger flood depths	During the 20-year flood, the area upstream from KLO Rd Bridge has depths up to 0.80 m. Local ponds have excess depths up to 1.60 m. One house next to the bridge crossing has depths below 0.40 m; all other residences are outside the flood fringe. Upstream from Casorso Rd, some residences near station 3+656 have depths from 0.40 m to 0.80 m. Most of the area west of Swamp Rd to the lake has depths up to 0.80 m. The maximum flood depth of 2.0 m occurs in Thomson Marsh Park wetland and some ponds around it. Some areas along the stream discharging into the wetland, the Kelowna Mission Library parking lot, the Capital News Center and the playgrounds east of it have depths from 0.80 m to 1.60 m. During the 200-year flood, the flood fringe extends farther south and east. Some residences along Parsons Rd southwest of KLO Rd Bridge have depths up to 0.40 m. The flooded area upstream from Casorso Rd extends to KLO Rd; with depths from 1.60 m to 2.0 m. West of Swamp Rd, Thomson Marsh Park wetland and some of the ponds around it have depths above 2.0 m. The depths in some areas along the stream discharging into the wetland, the Kelowna Mission Library parking lot, the Capital News Center and the playgrounds east of it have depths from 1.20 m to 2.0 m. More areas west of Gordon Drive become flooded with depths generally below 0.80 m.
The upper reach	Near East Kelowna Rd Bridge (Figure 6-1; Sheets 4 and 5/10) Residences near Hwy 33 Bridge (Figure 6-1; Sheet 8B/10)	The same areas inundated during the 20-year flood, but with wider flooding extents and larger flood depths	During the 20-year flood, the area near East Kelowna Rd Bridge and the Peace Valley Mobile Home Park within the Scenic Canyon Regional Park have depths from 0.50 m to 1.0 m; except for the left floodplain upstream from the bridge where depths may reach 2.0 m. Some residences near Hwy 33 Bridge have depths up to 1.0 m. During the 200-year flood, depths exceed 2.0 m southwest of the East Kelowna Rd Bridge and elsewhere they are generally below 2.0 m. The depths around Hwy 33 Bridge reach 2.0 m in some places.



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

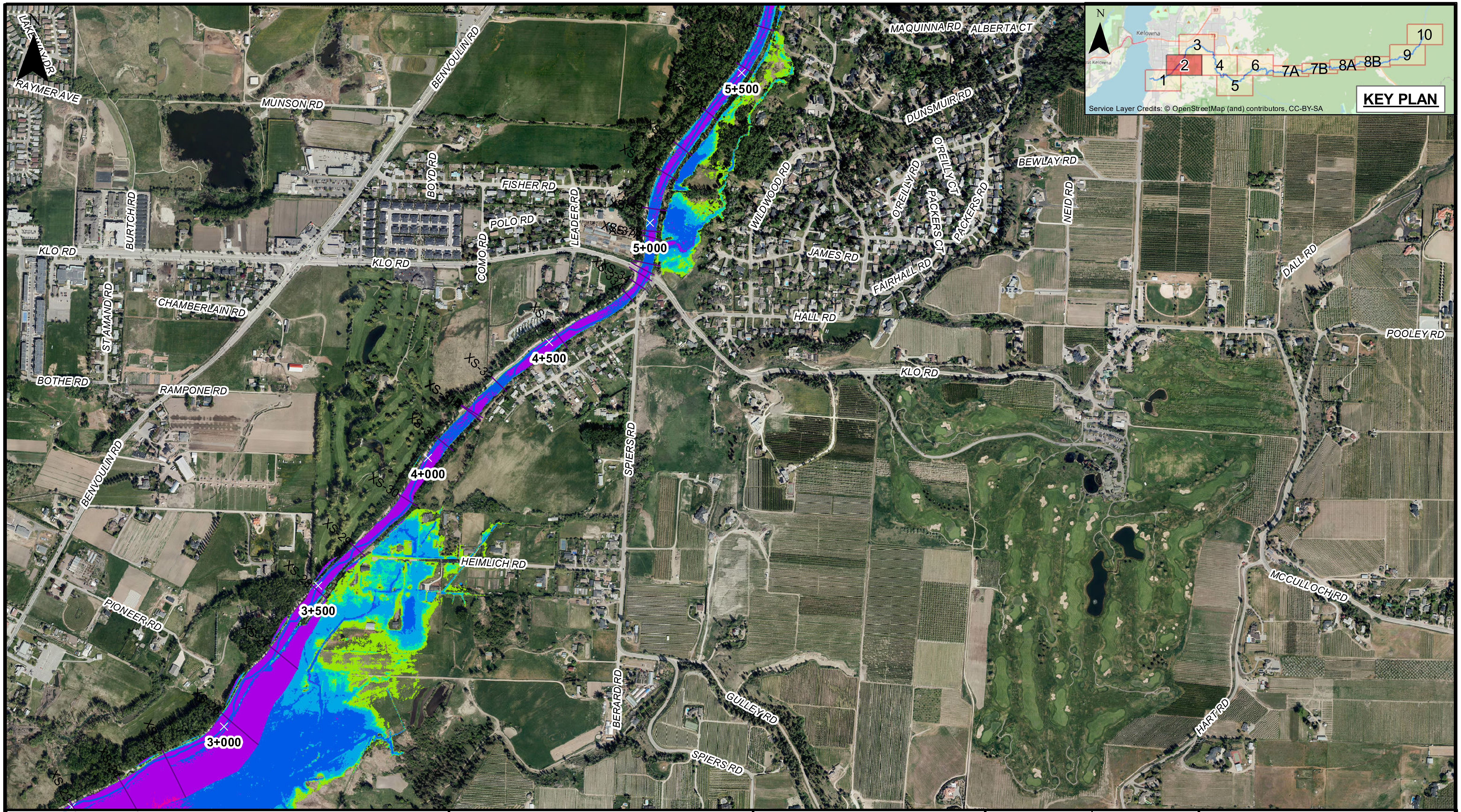
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	1 / 10



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

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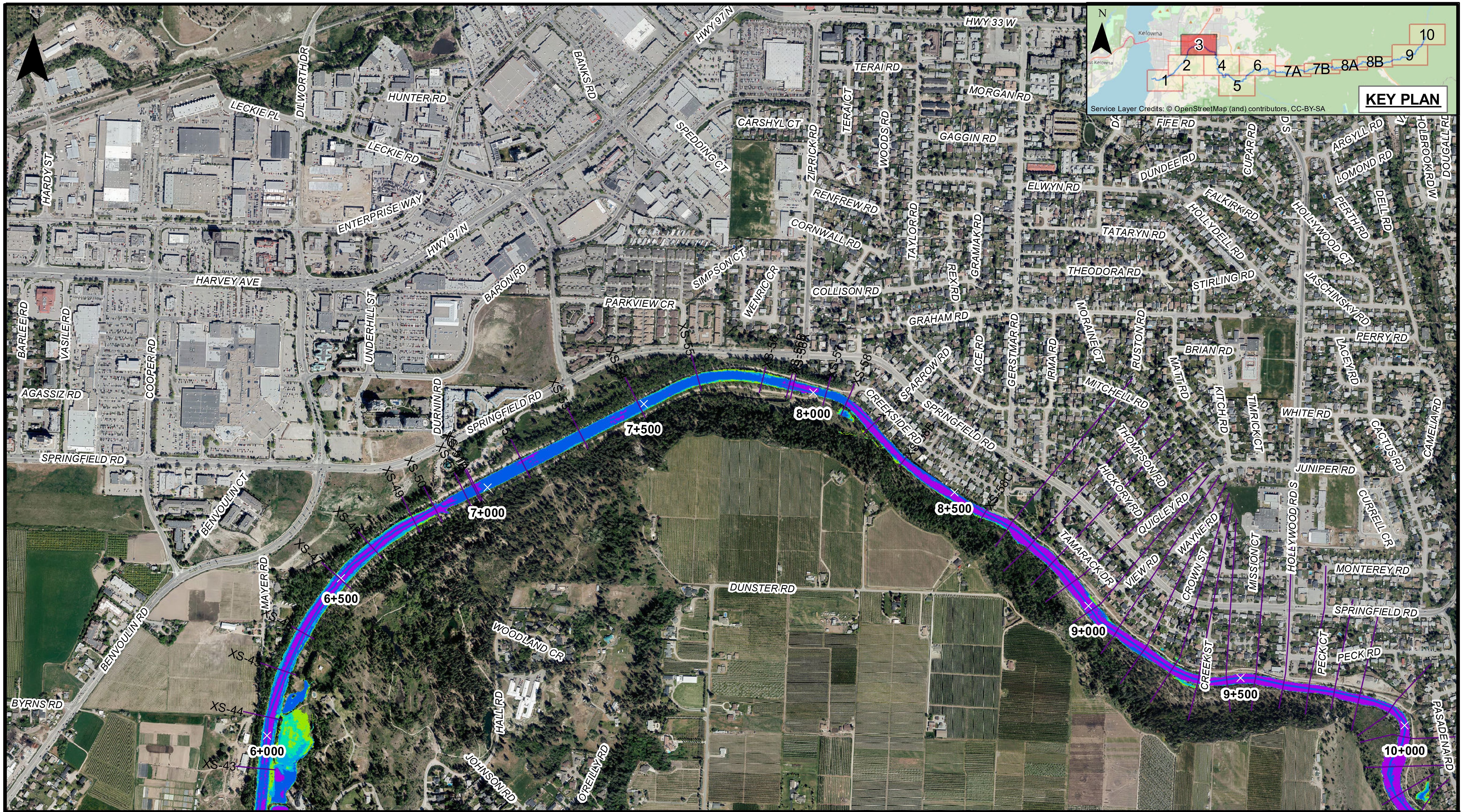
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	2/10



0	100	200	400	600	800	1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

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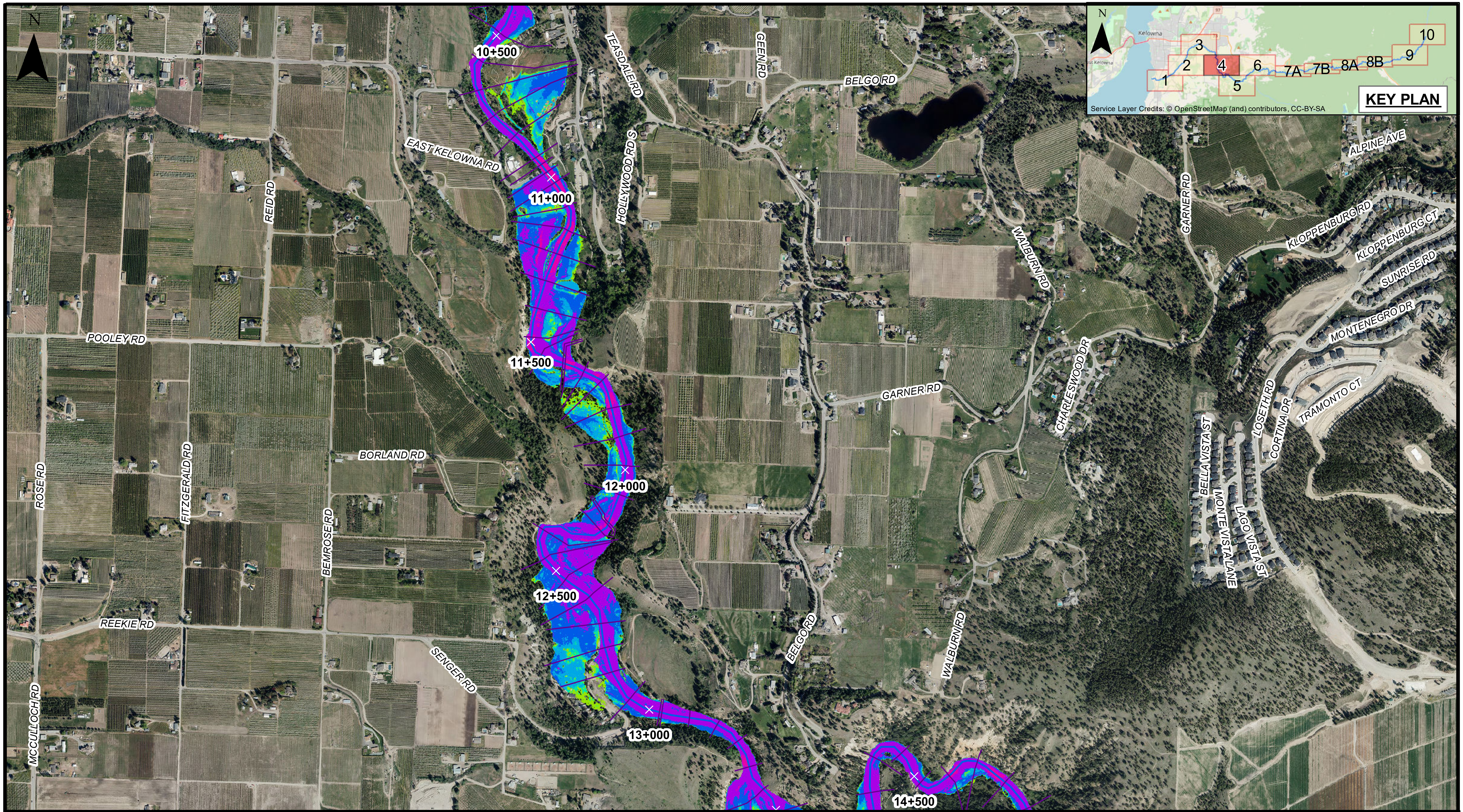
Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	3/10



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

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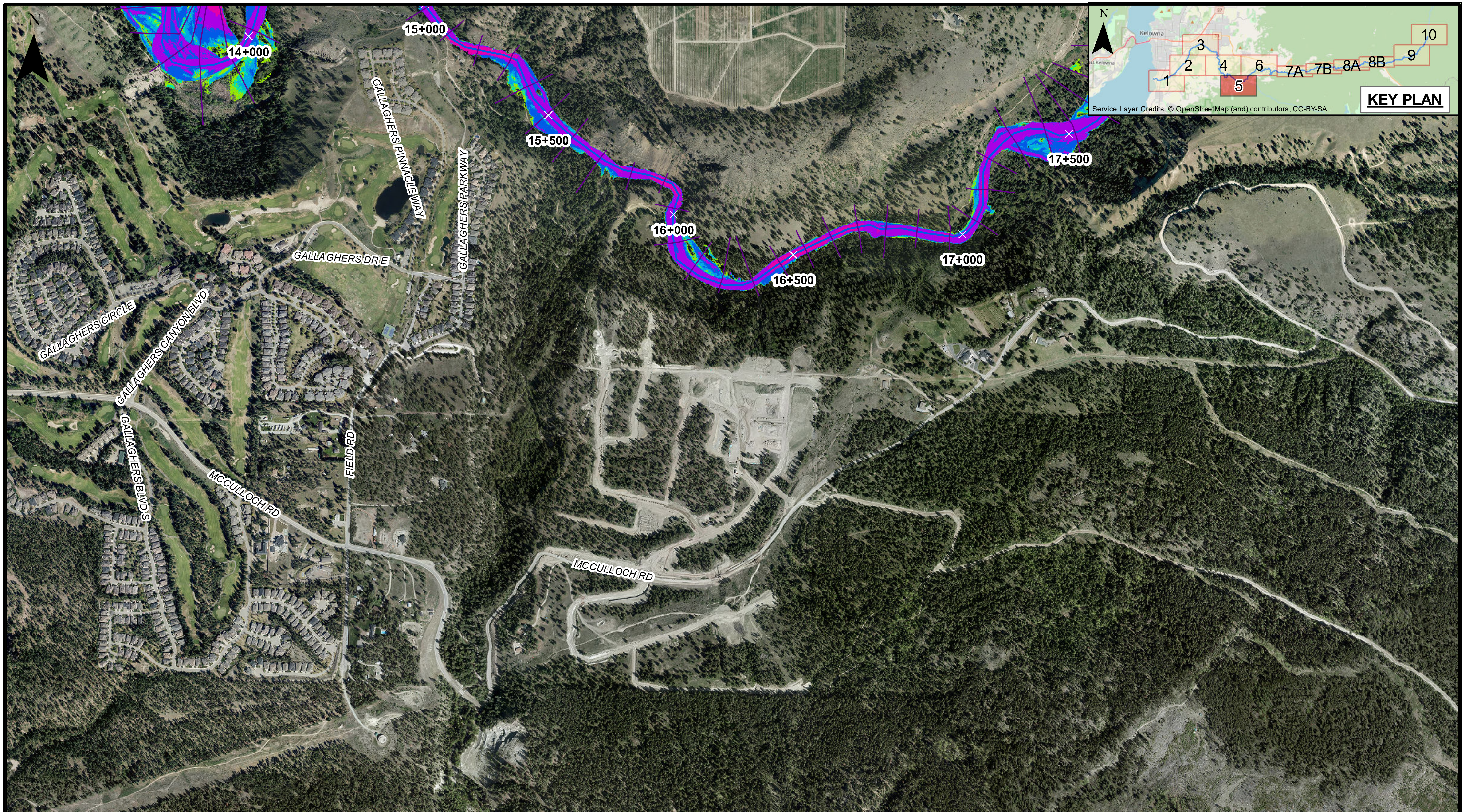
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	4 / 10



0 100 200 400 600 800 1,000
Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

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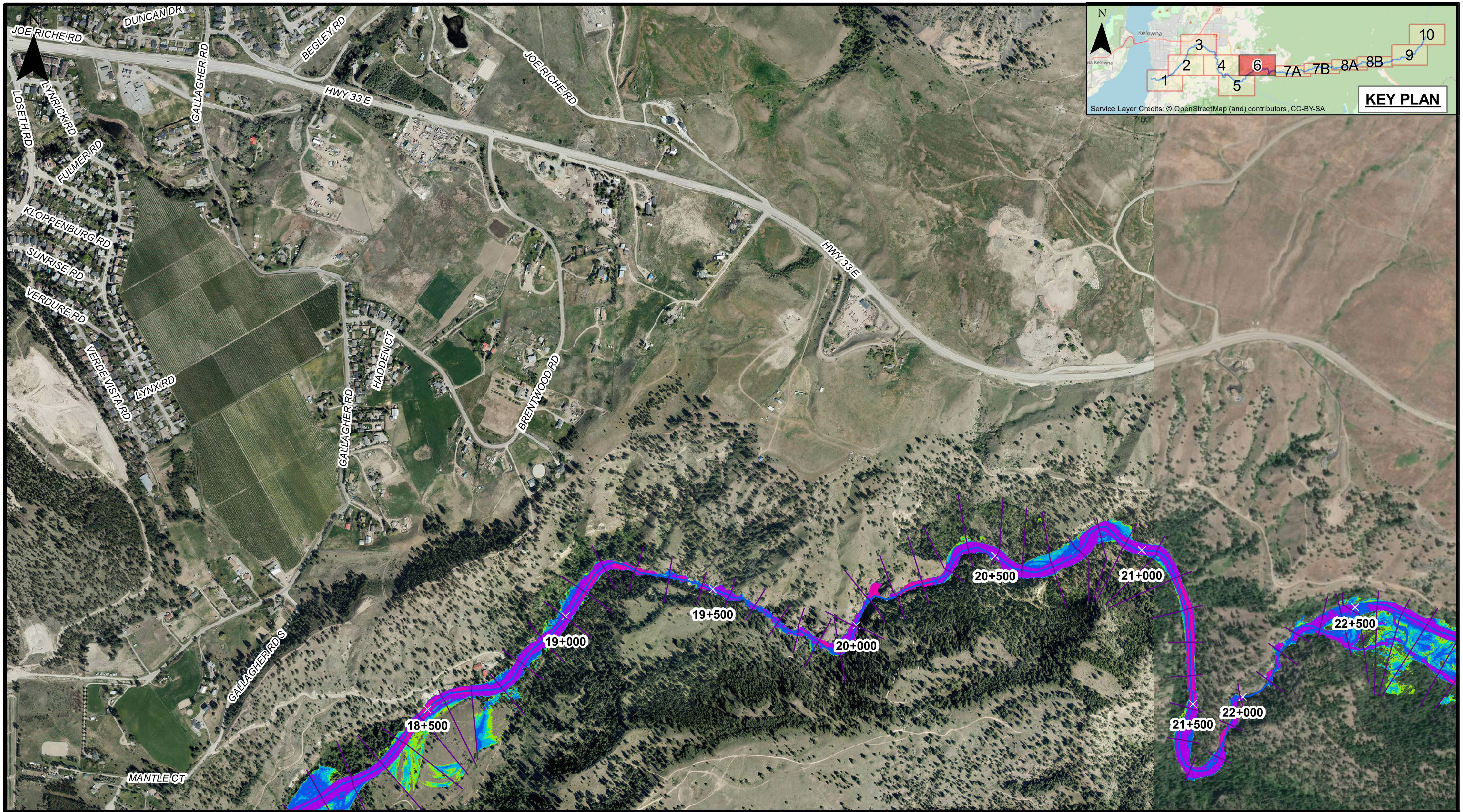
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge
Mission Creek

REV NO.	SHEET
0	5 / 10



Legend:

Mission Creek

Maximum Flooding Depth (m)

< 0.15	0.26 - 0.5	1.01 - 2.0
0.16 - 0.25	0.51 - 1.0	> 2.0

NO.	DATE	ENG.	BY	SUBJECT
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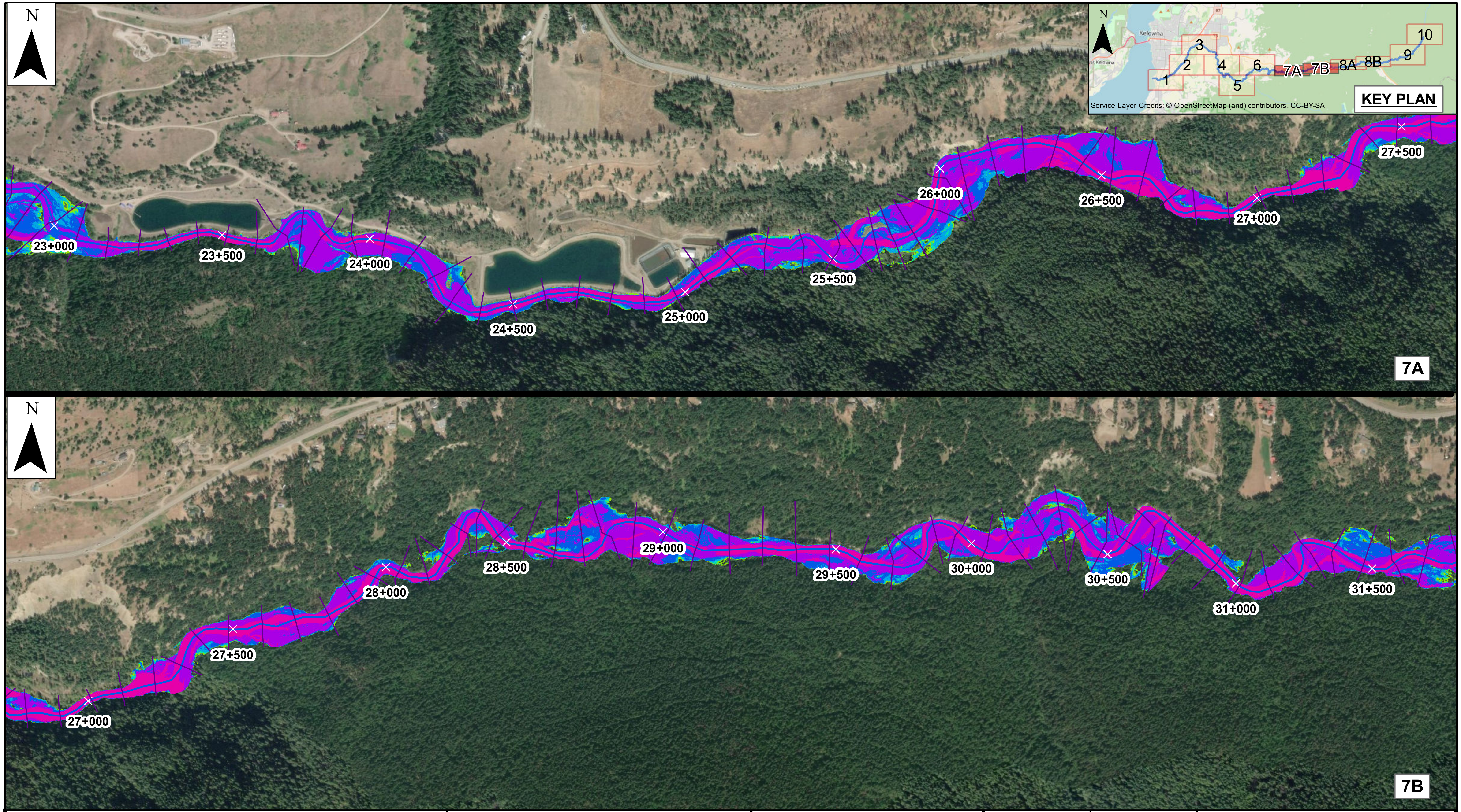
Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	6/10



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

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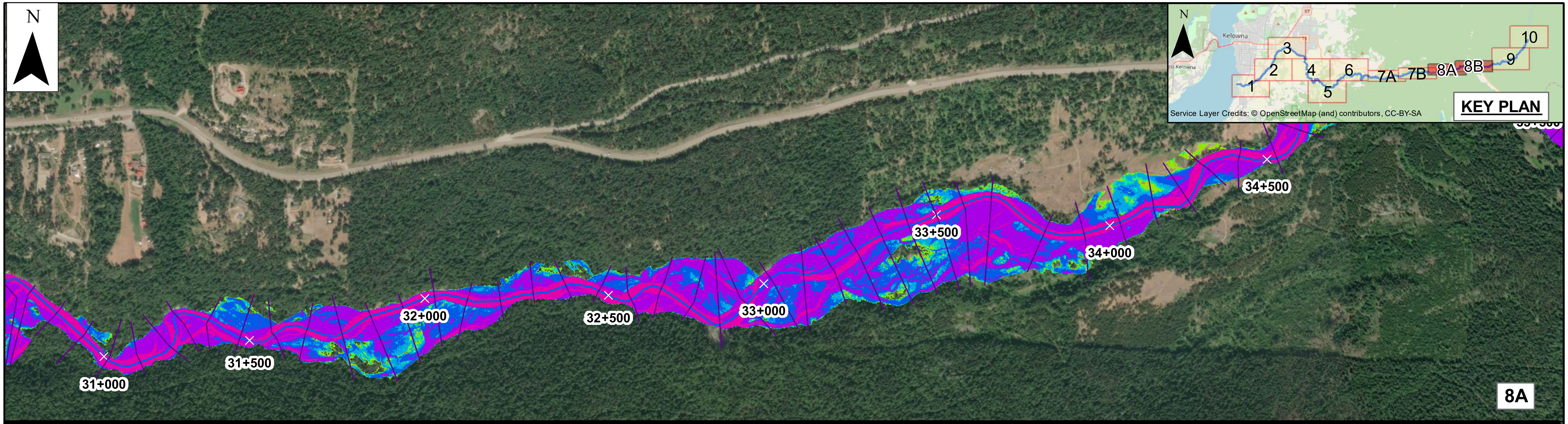
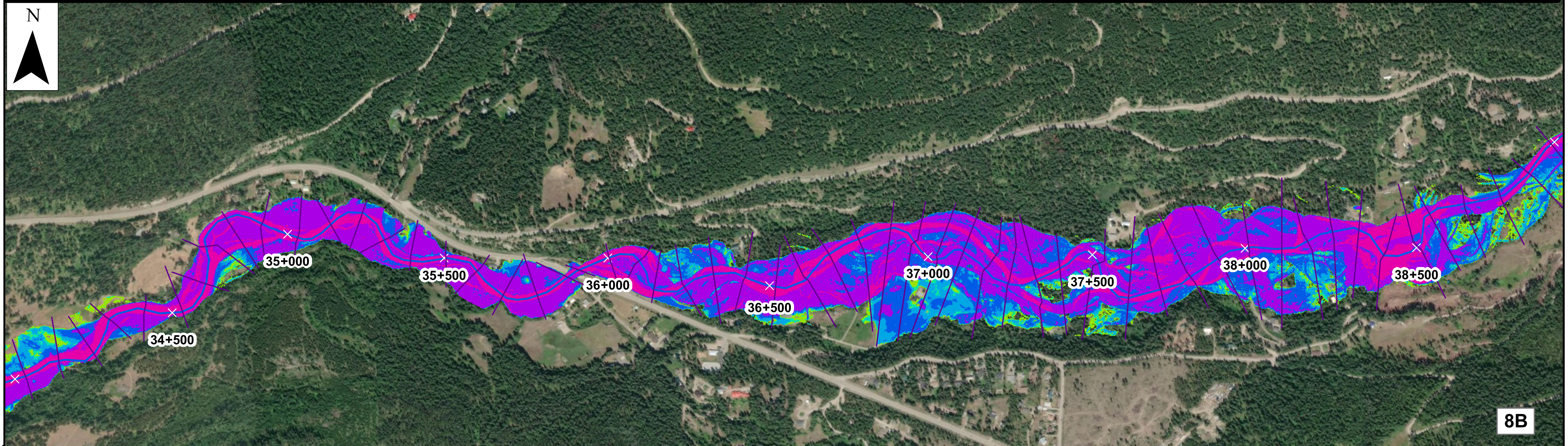
Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	7 / 10





Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

NO.	DATE	ENG.	BY	SUBJECT
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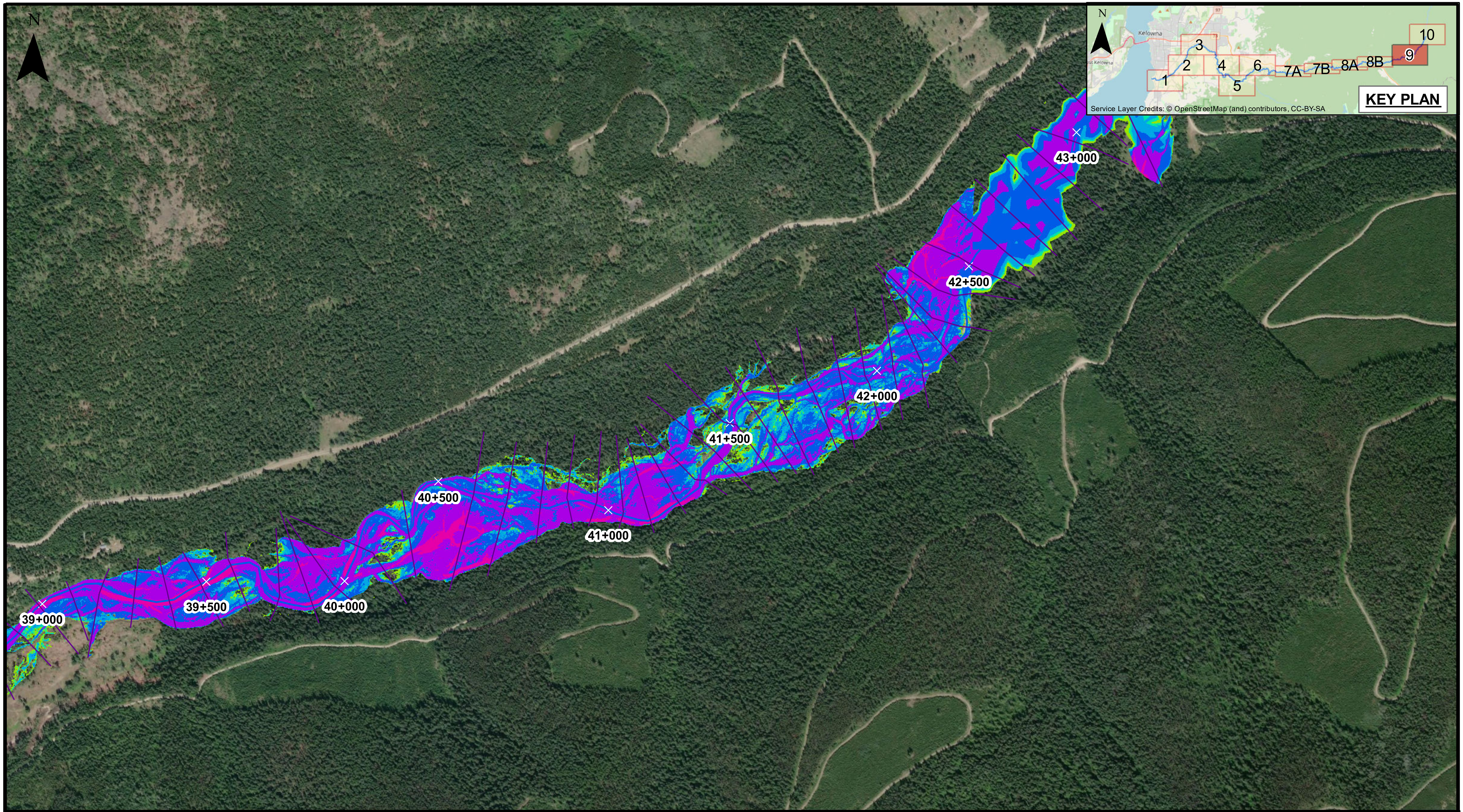
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge
Mission Creek

REV NO.	SHEET
0	8 / 10



0 100 200 400 600 800 1,000
Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

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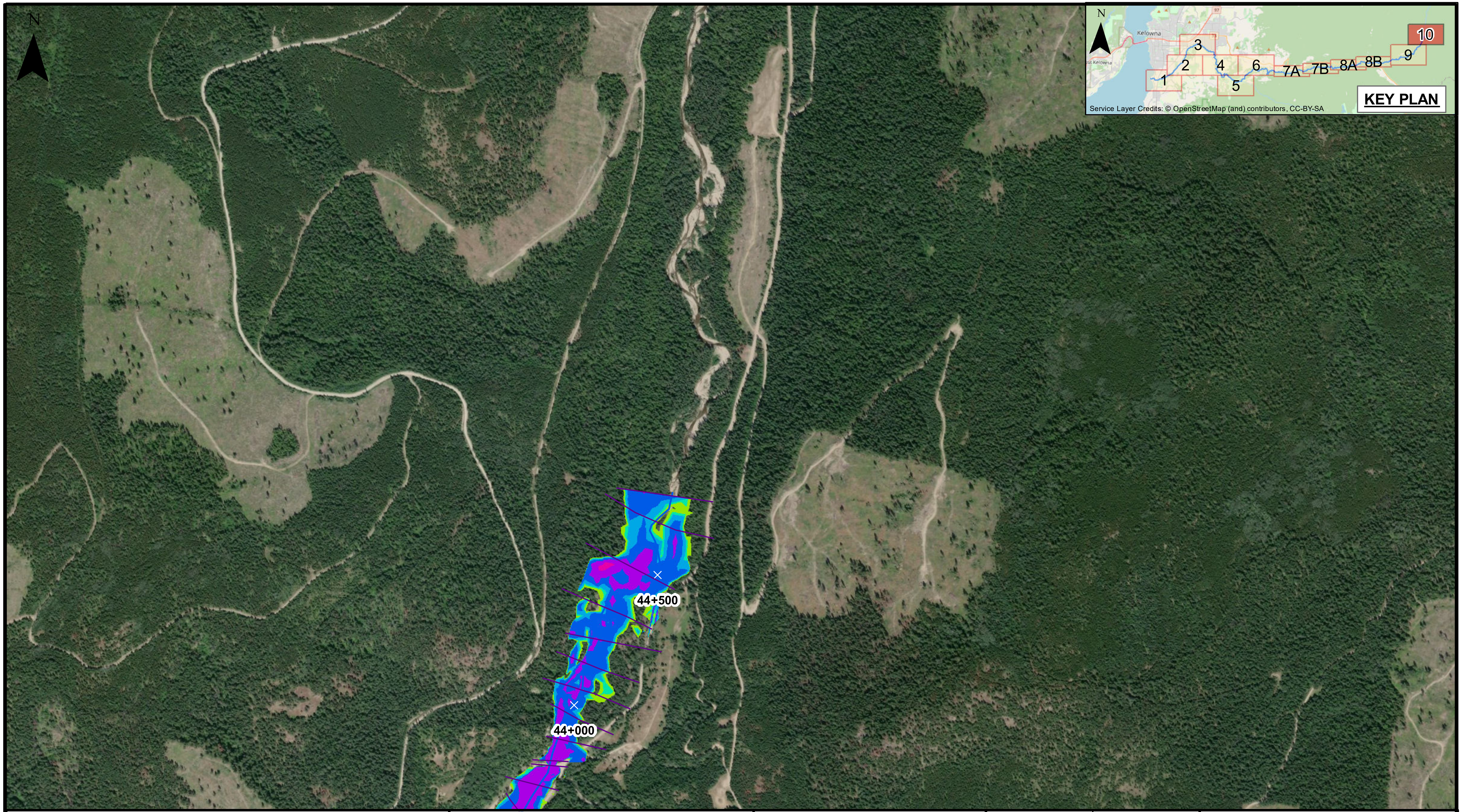
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge Mission Creek

REV NO.	SHEET
0	9/10



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

< 0.15	0.26 - 0.5	1.01 - 2.0
0.16 - 0.25	0.51 - 1.0	> 2.0

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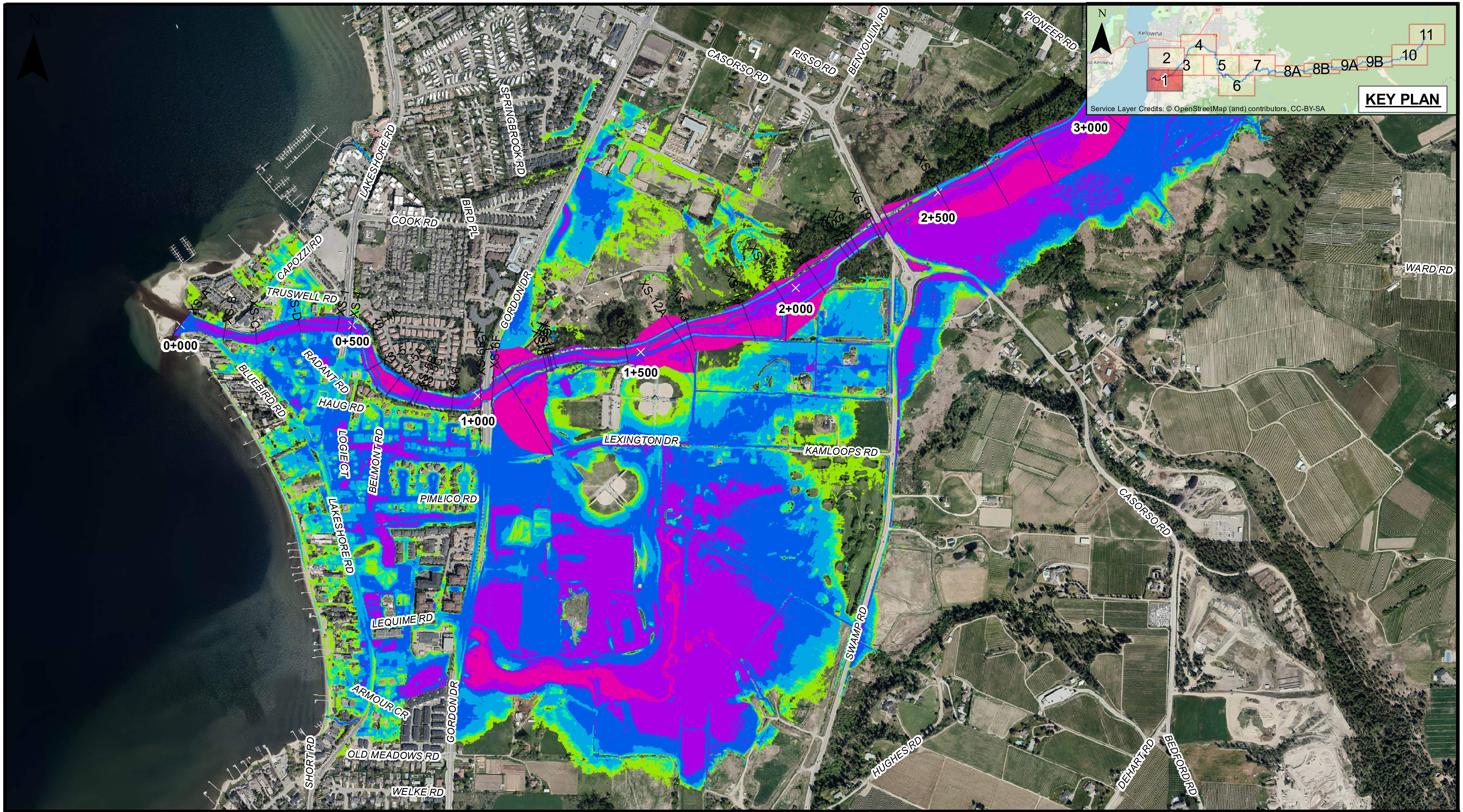
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-1: Flood Depth Map for 20-Year Design Discharge

Mission Creek

REV NO.	SHEET
0	10/10



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

< 0.15	0.26 - 0.5	1.01 - 2.0
0.16 - 0.25	0.51 - 1.0	> 2.0

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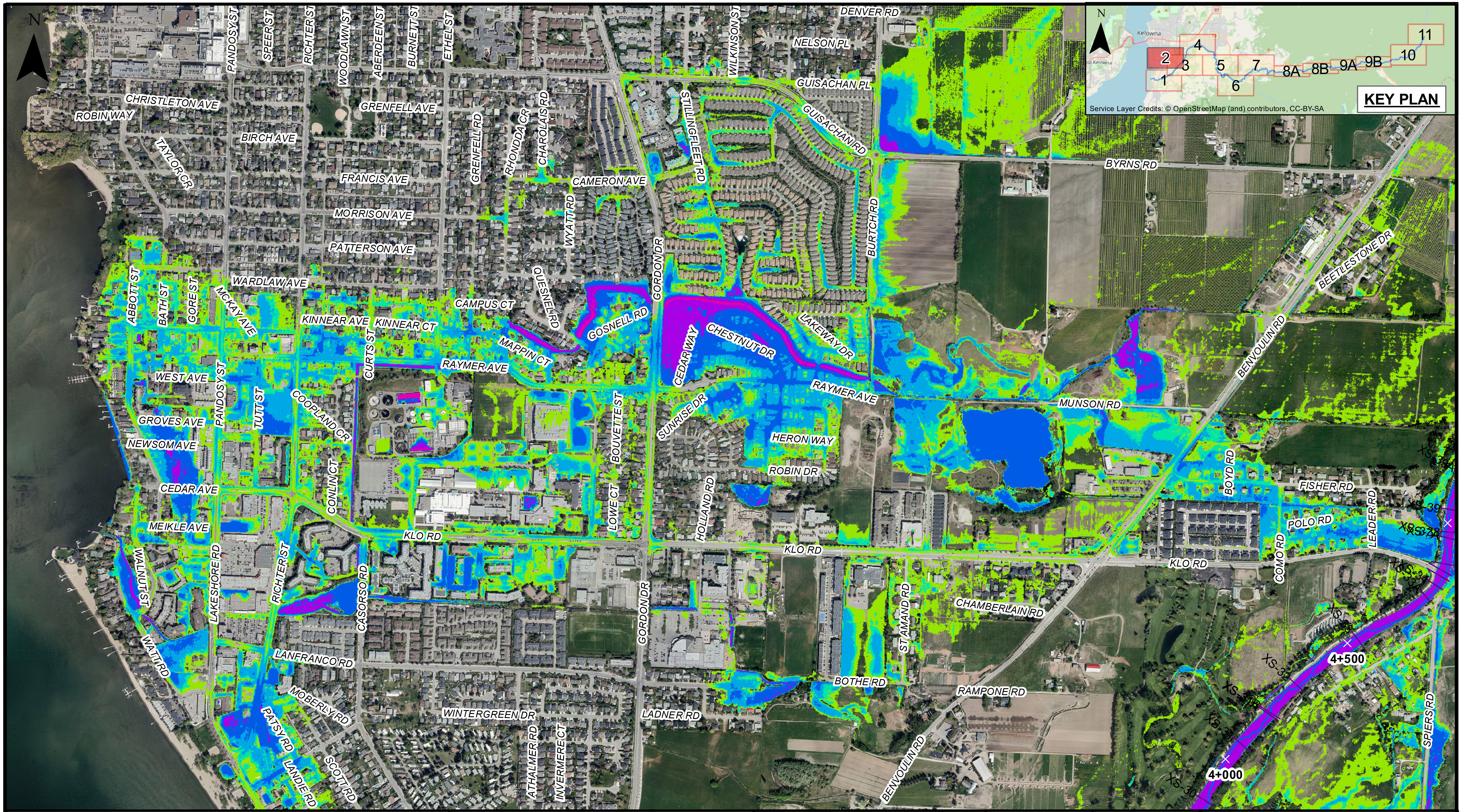
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	1 / 11



0	100	200	400	600	800	1,000 Meters

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

City of Kelowna

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Regional District of Central Okanagan

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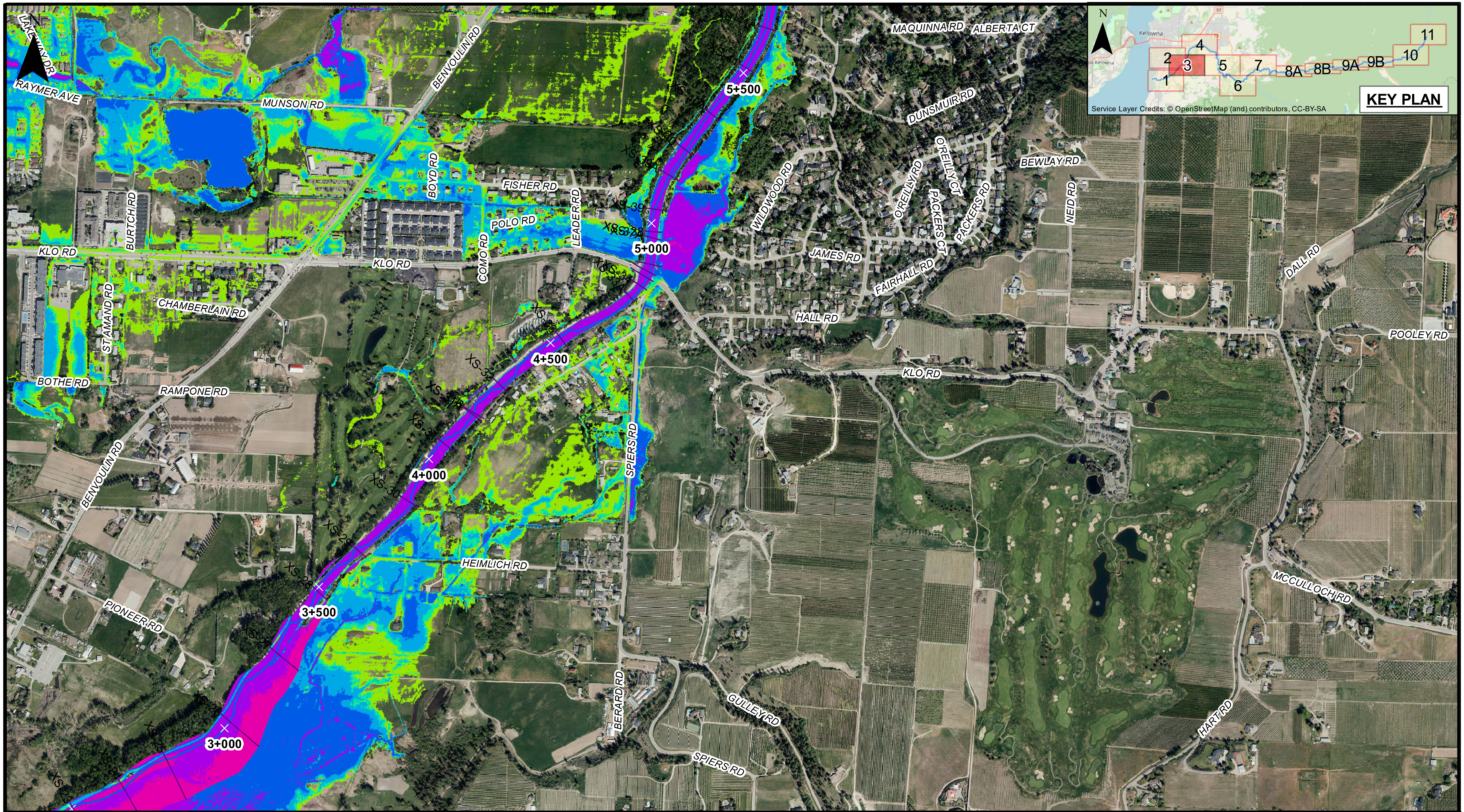
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	2 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

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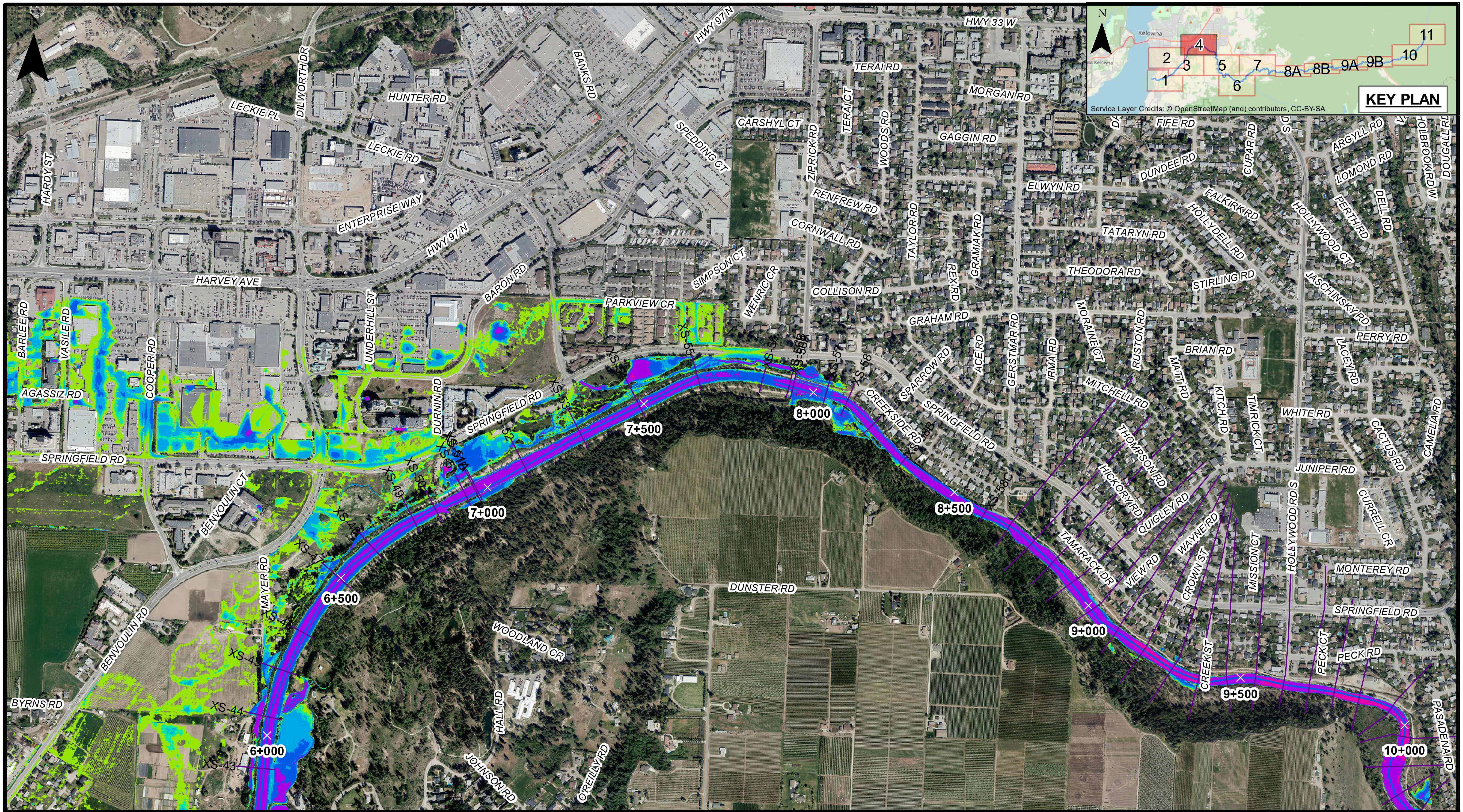
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	3 / 11



Legend:

Mission Creek

Maximum Flooding Depth (m)

< 0.15

0.16 - 0.25

0.26 - 0.5

0.51 - 1.0

1.01 - 2.0

> 2.0

City of Kelowna

AECOM

Regional District of Central Okanagan

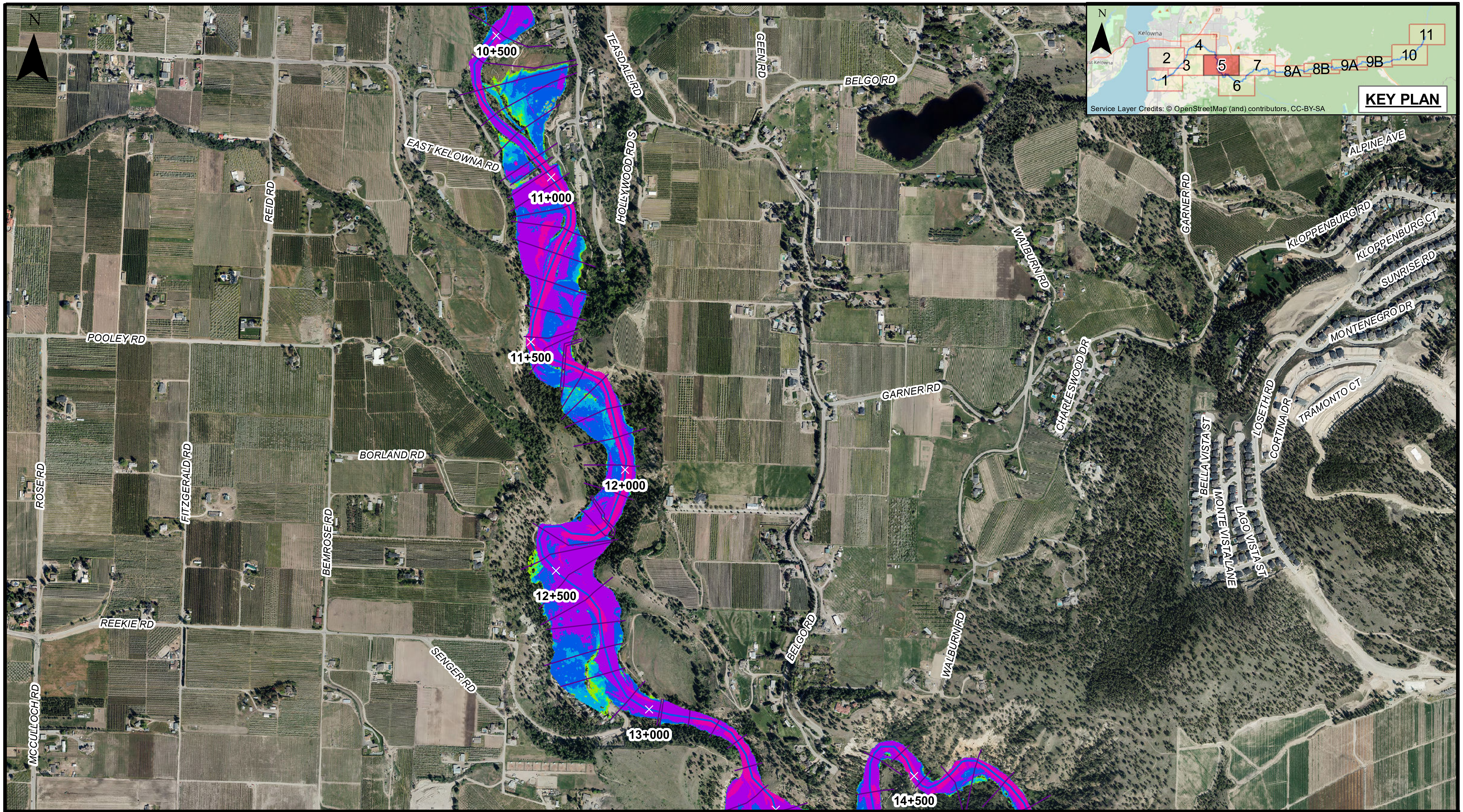
NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	4/11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
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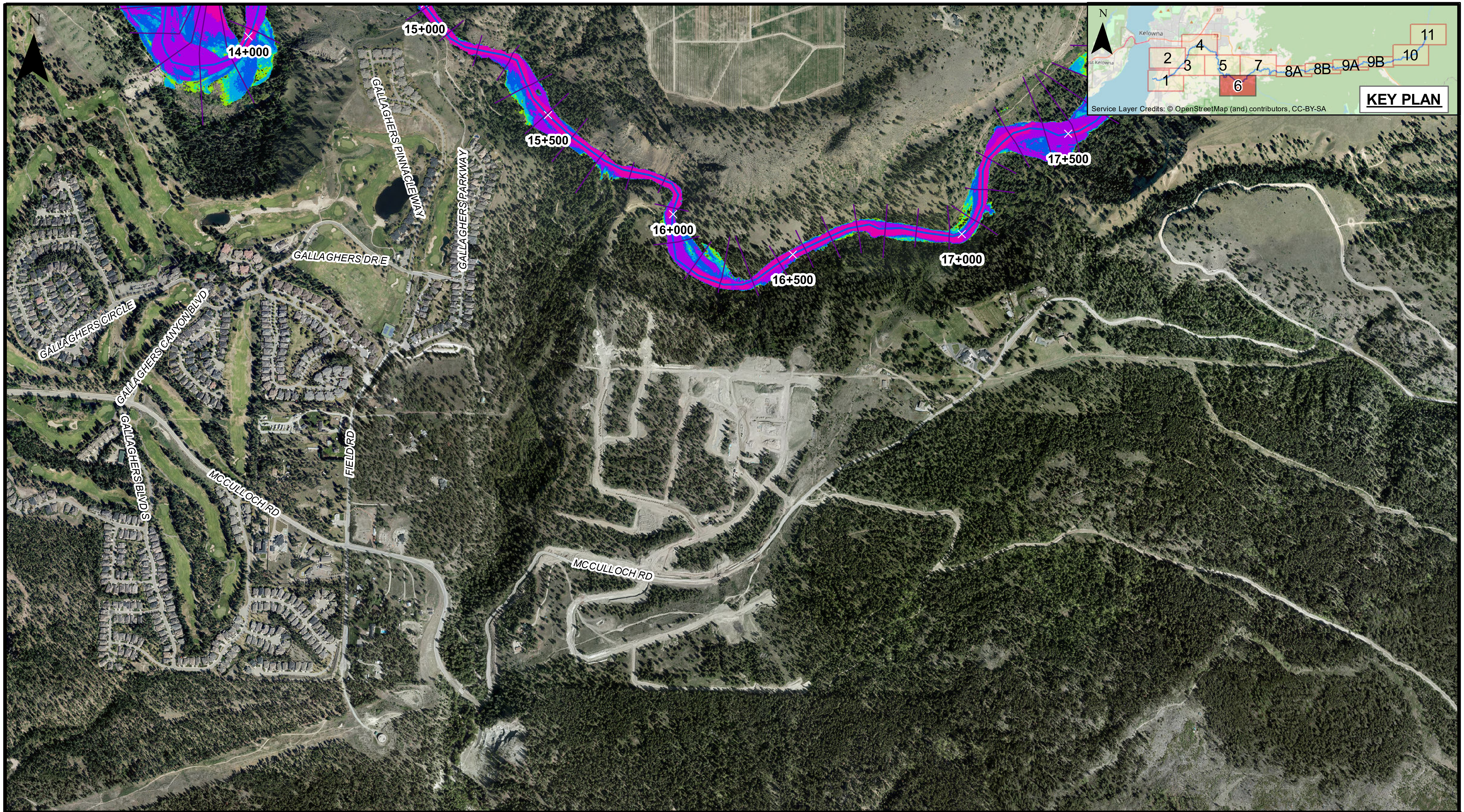
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	5/11



0 100 200 400 600 800 1,000 Meters

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

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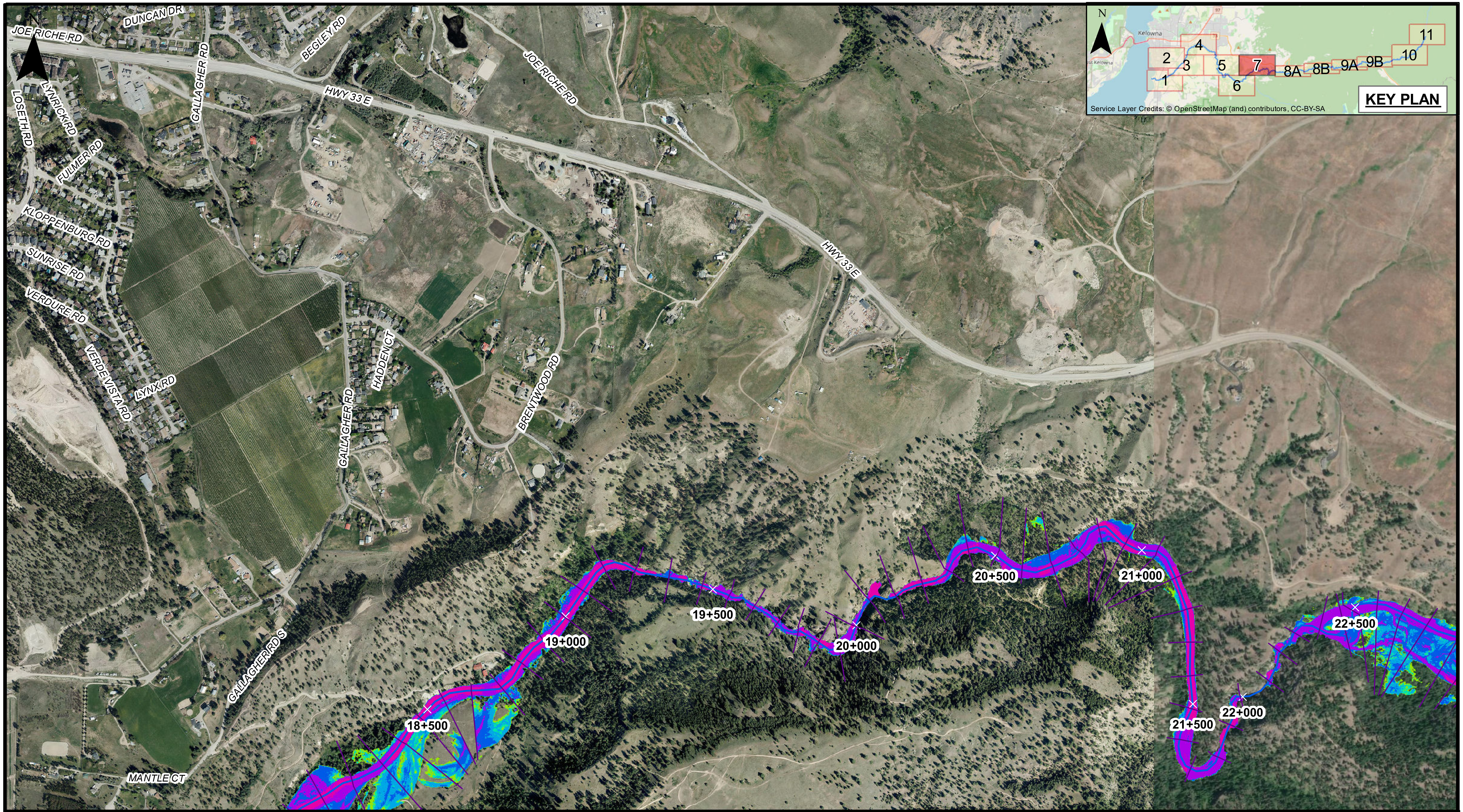
Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	6 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

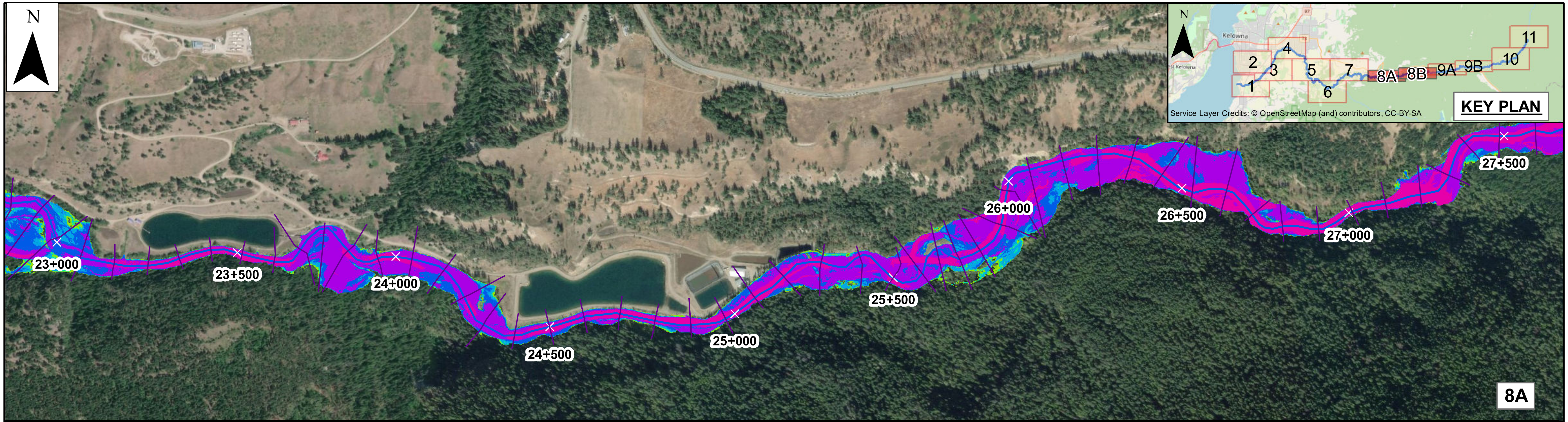
AECOM

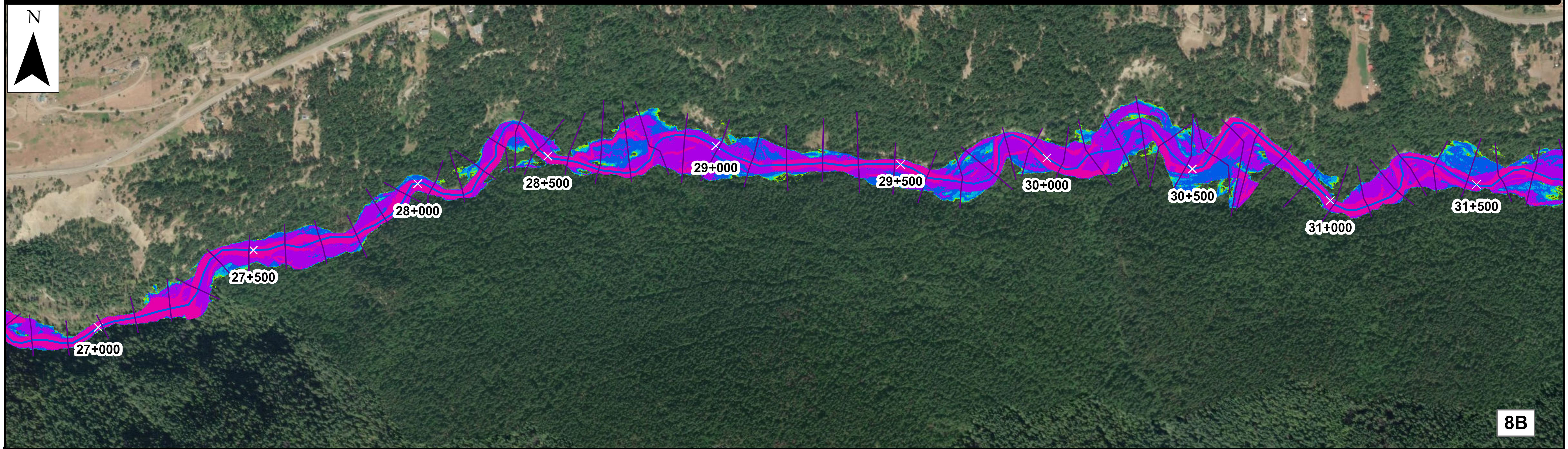
Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	7 / 11





0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

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Regional District of Central Okanagan

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SCALE:	1:10,000
DRAWN:	B. TROITSKY
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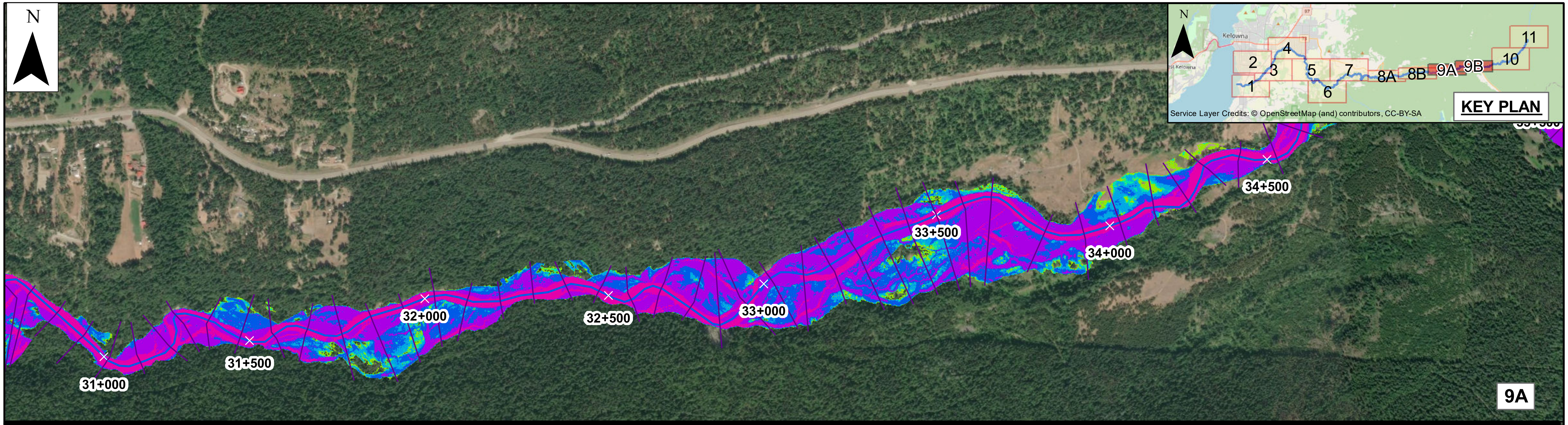
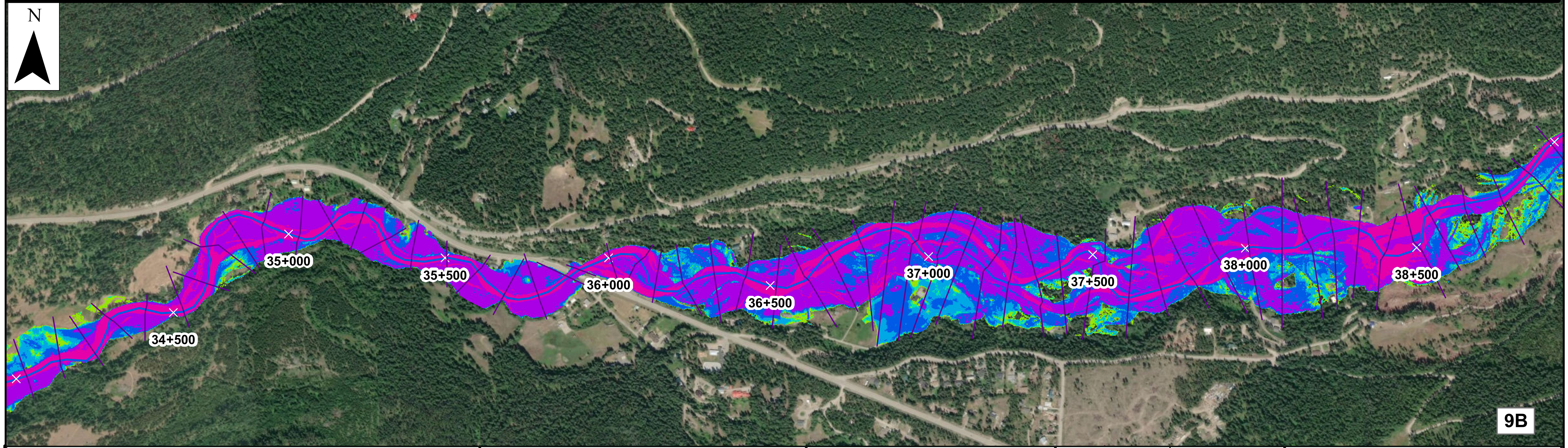
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	8/11





0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

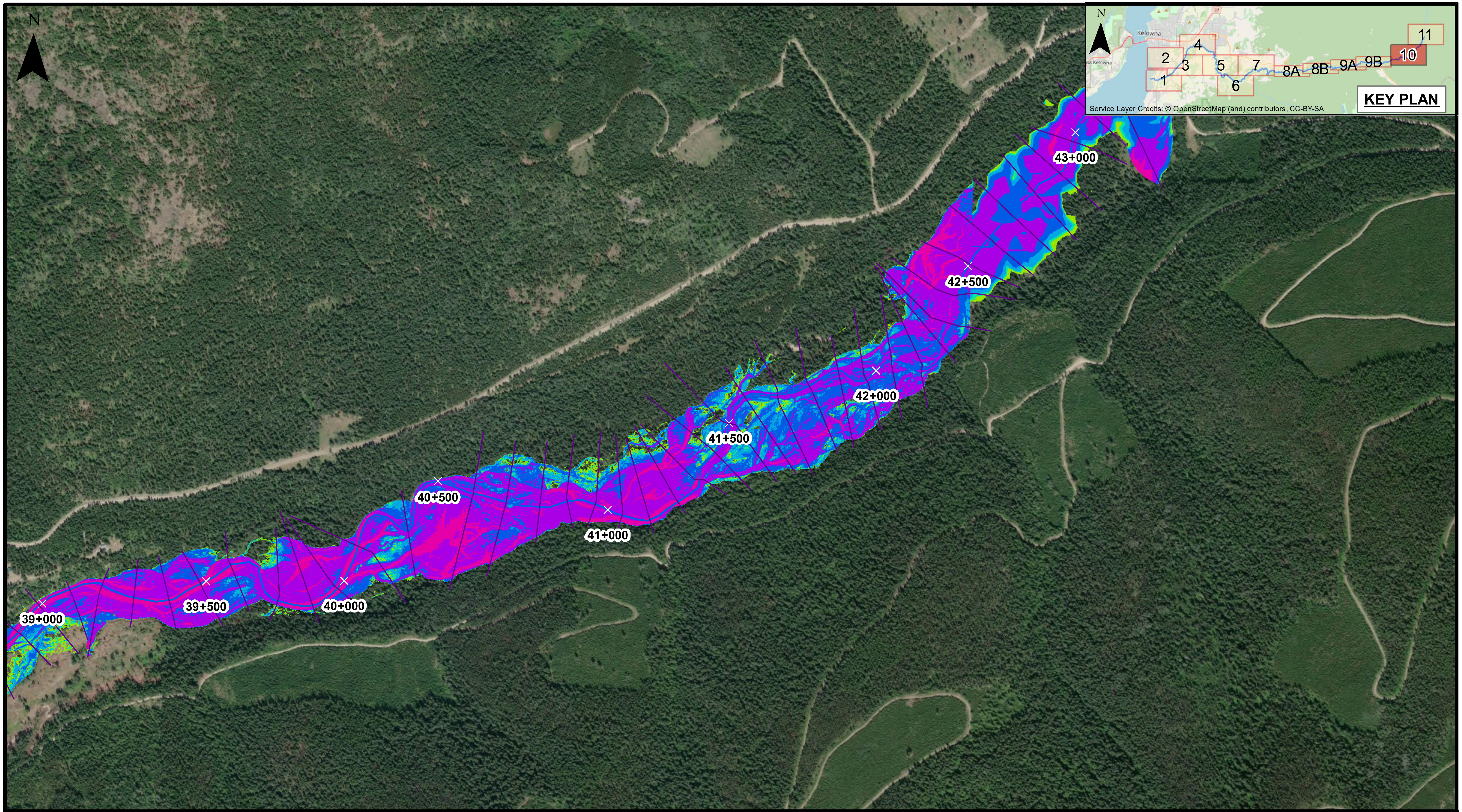
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	9 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

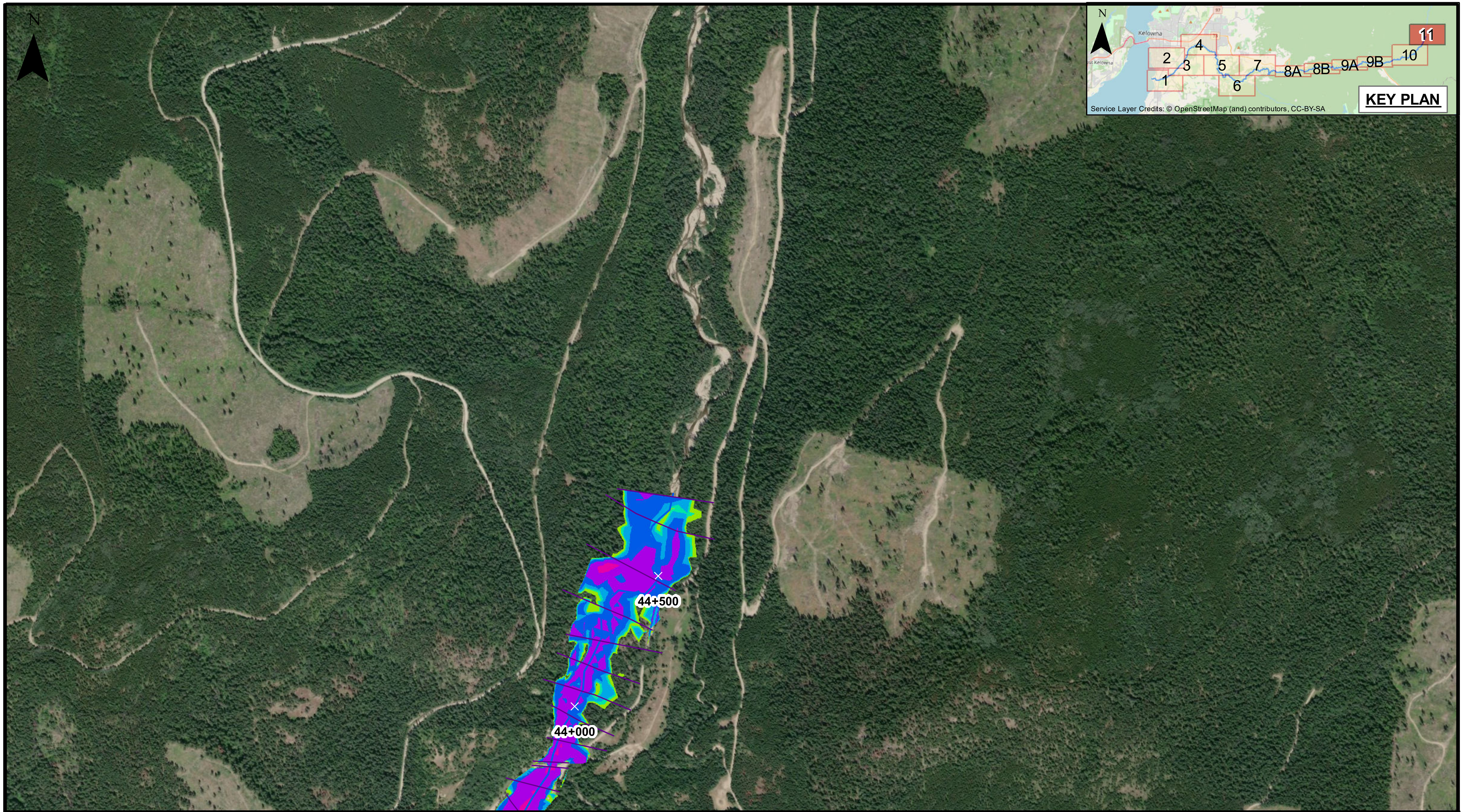
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	10 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

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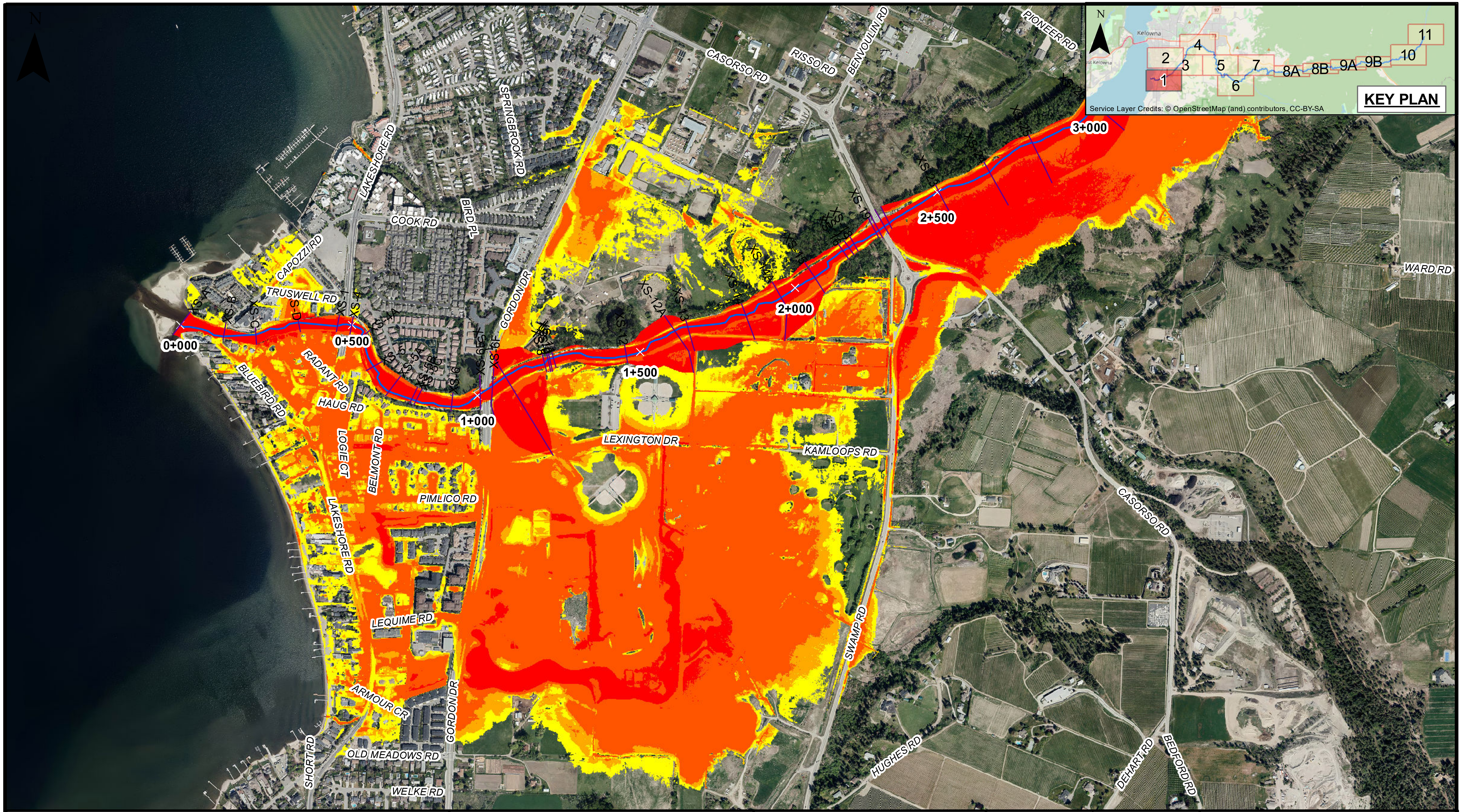
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-2: Flood Depth Map for 200-Year Design Discharge
Mission Creek

REV NO.	SHEET
0	11 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

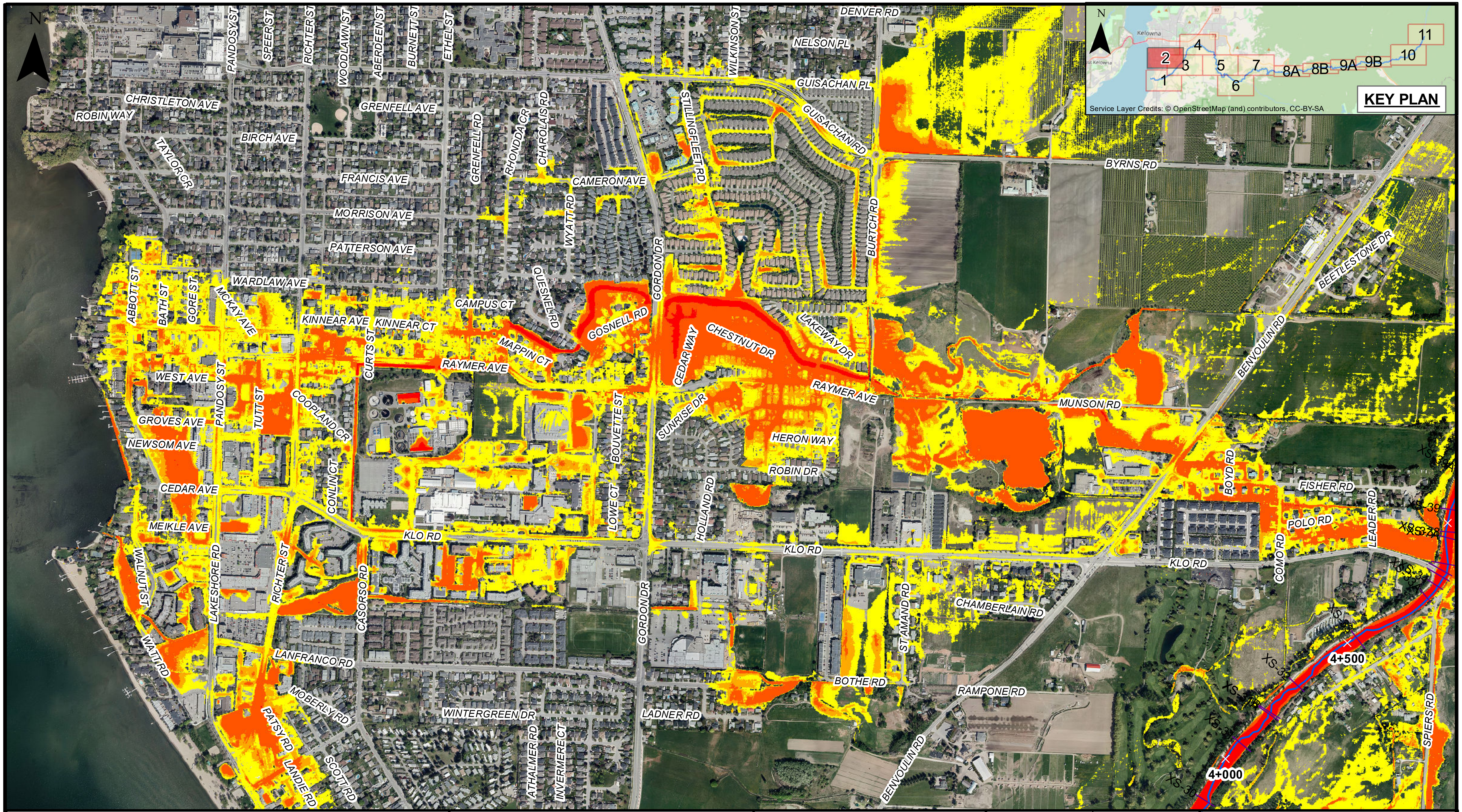
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge
Mission Creek

REV NO.	SHEET
0	1 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

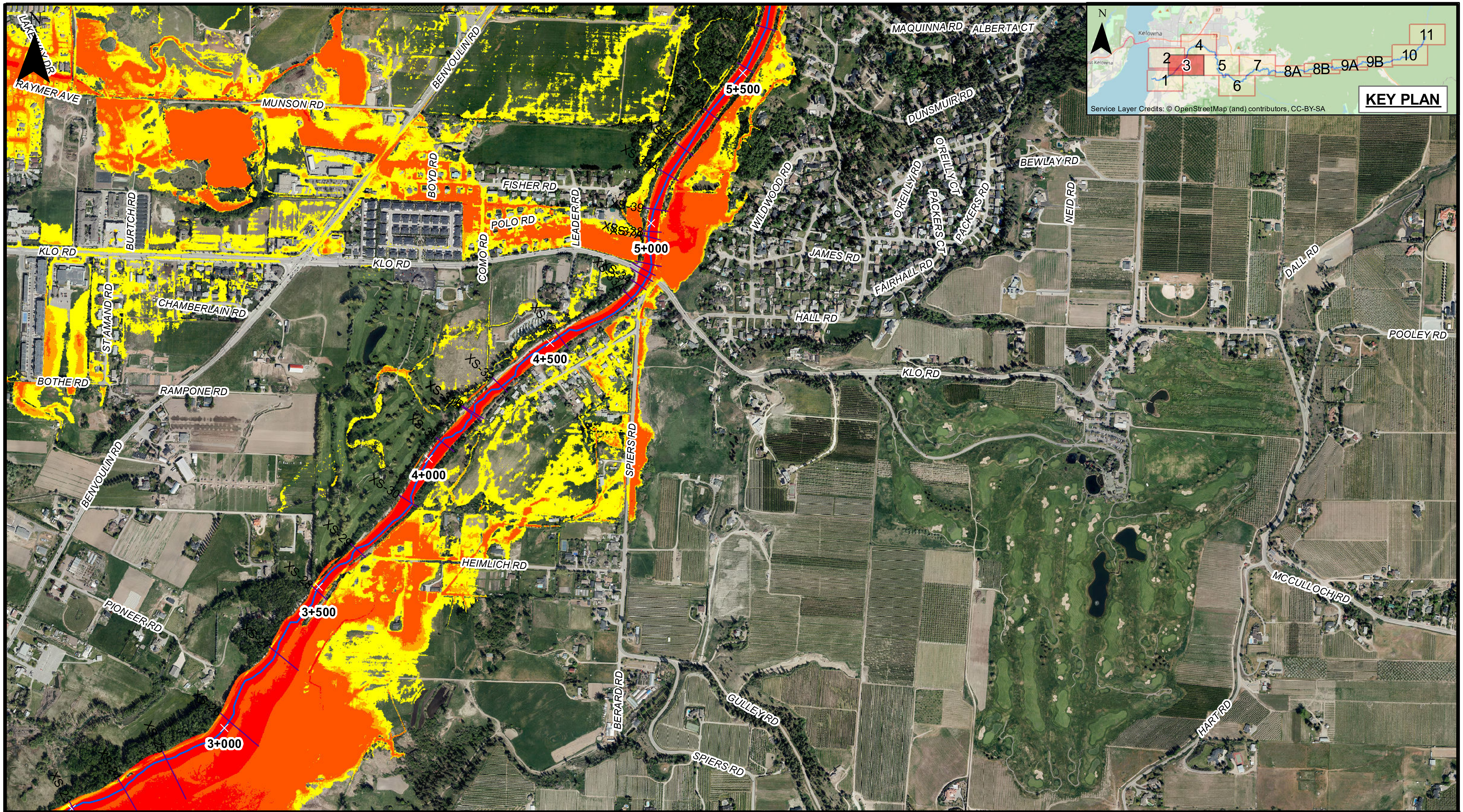
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	2/11



NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

0 100 200 400 600 800 1,000 Meters

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

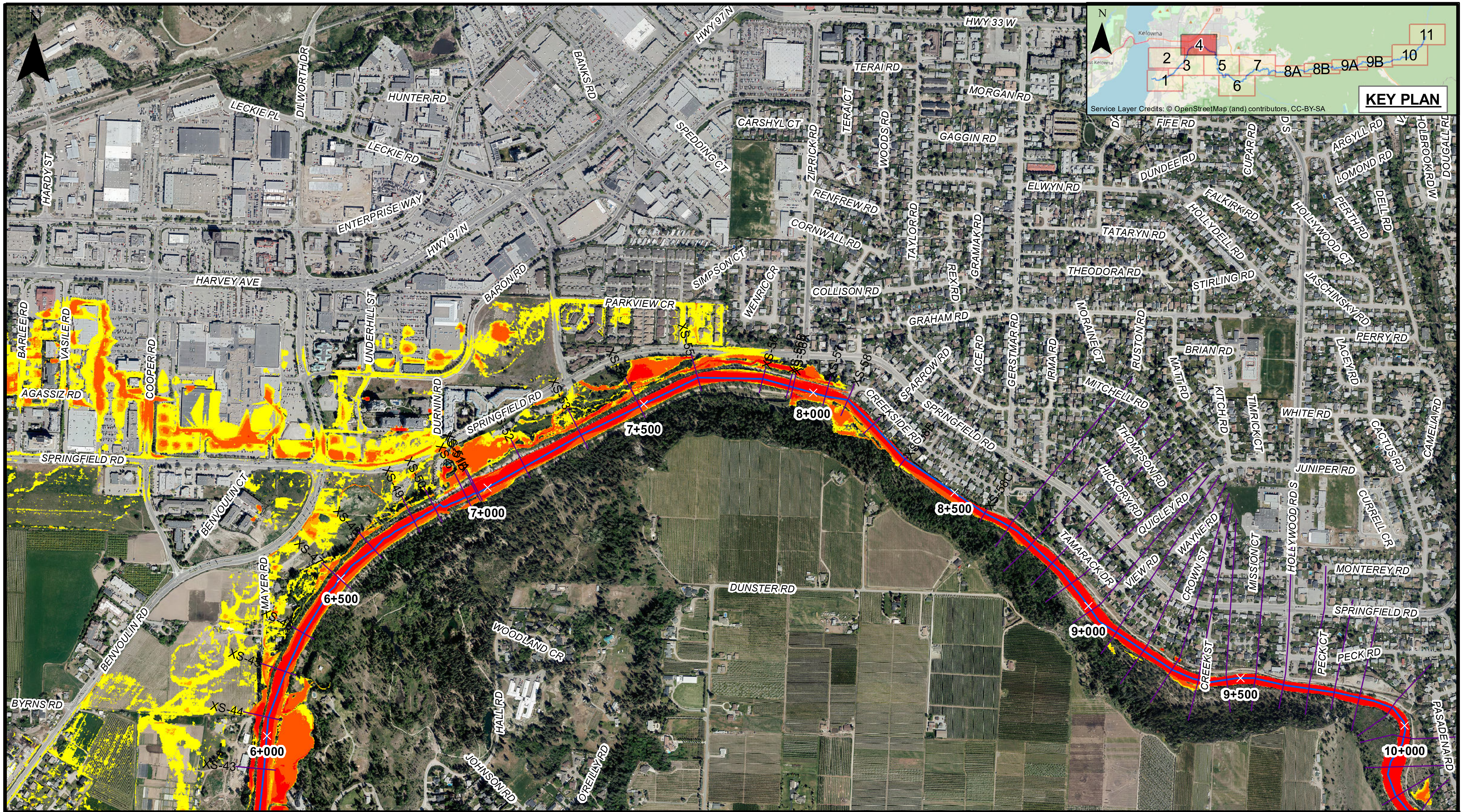
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	3 / 11



0	100	200	400	600	800	1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

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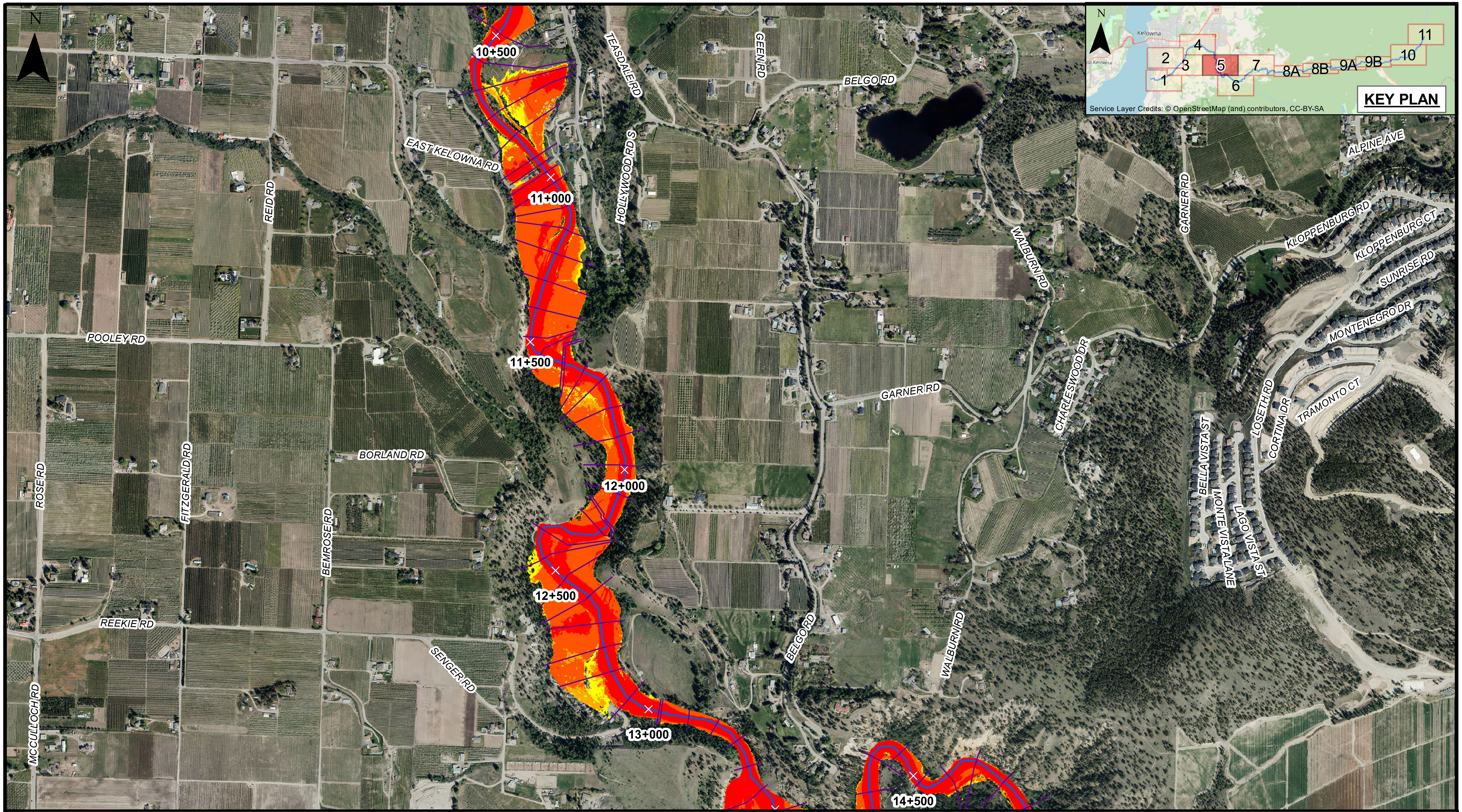
Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	4 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

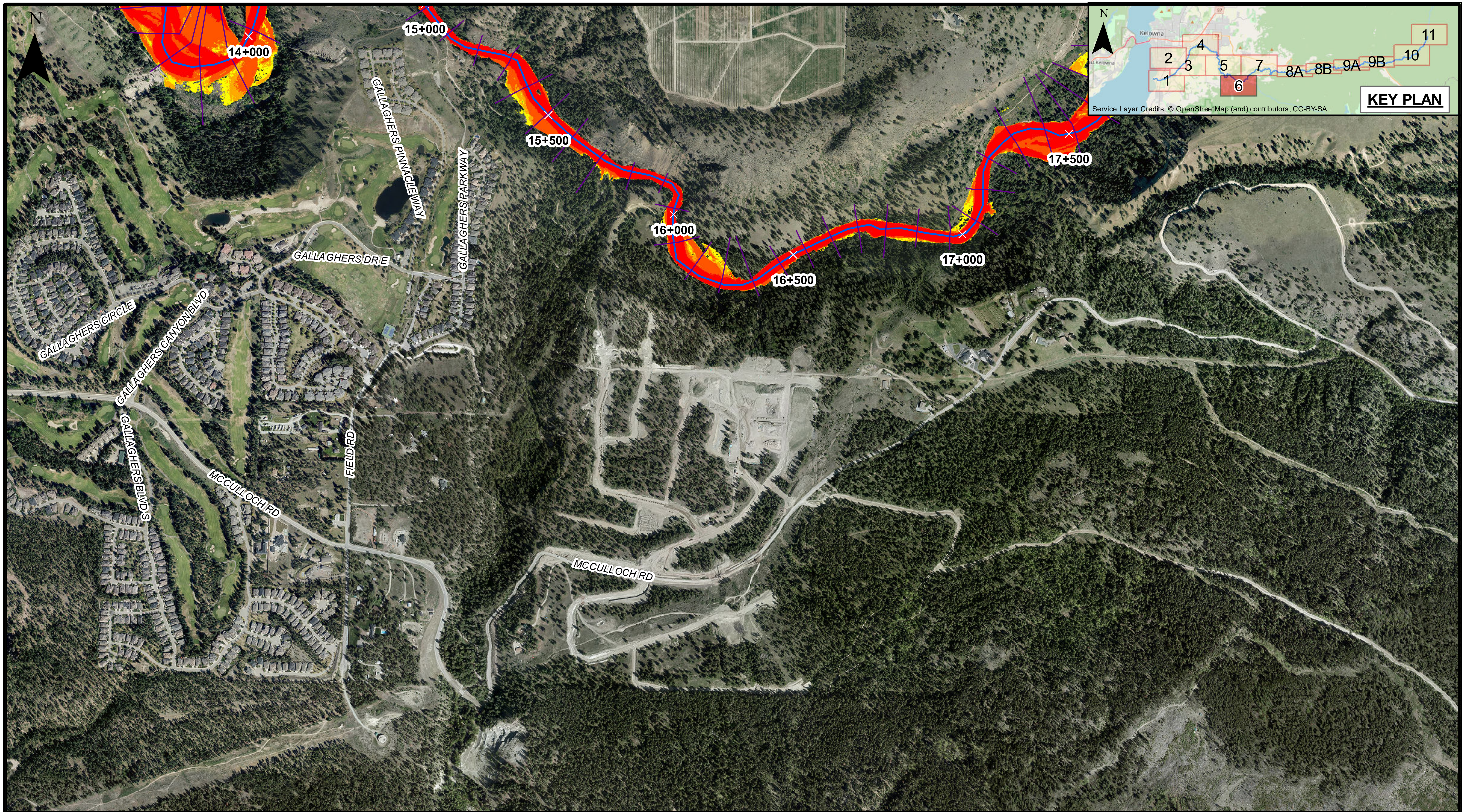
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	5 / 11



Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

City of Kelowna

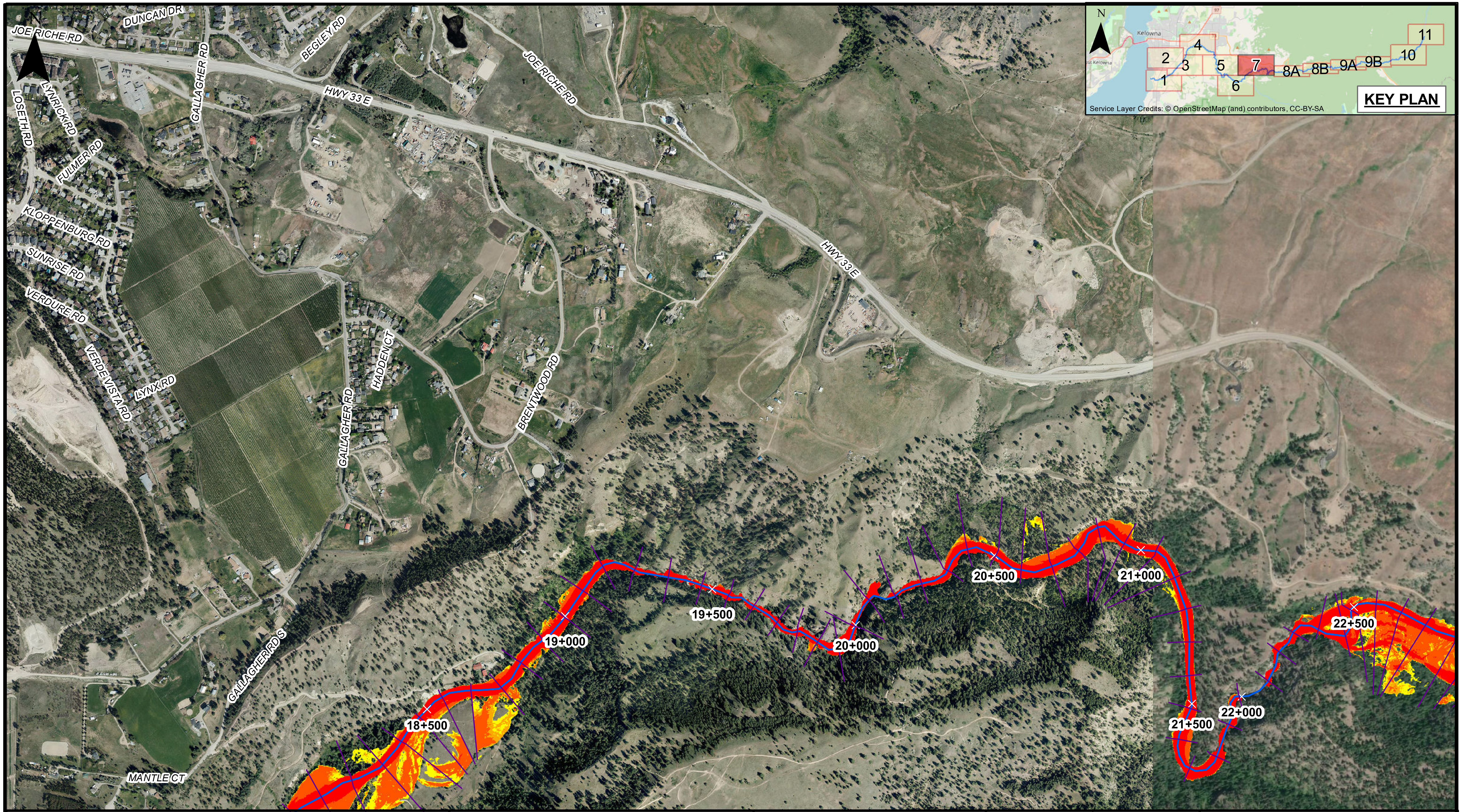
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	6 / 11



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

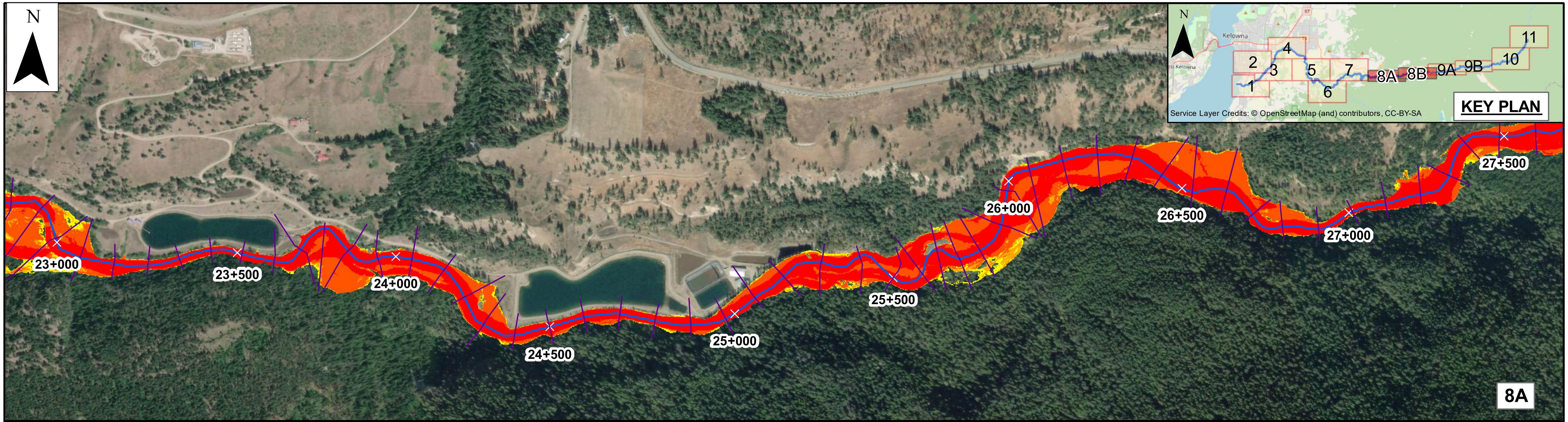
AECOM

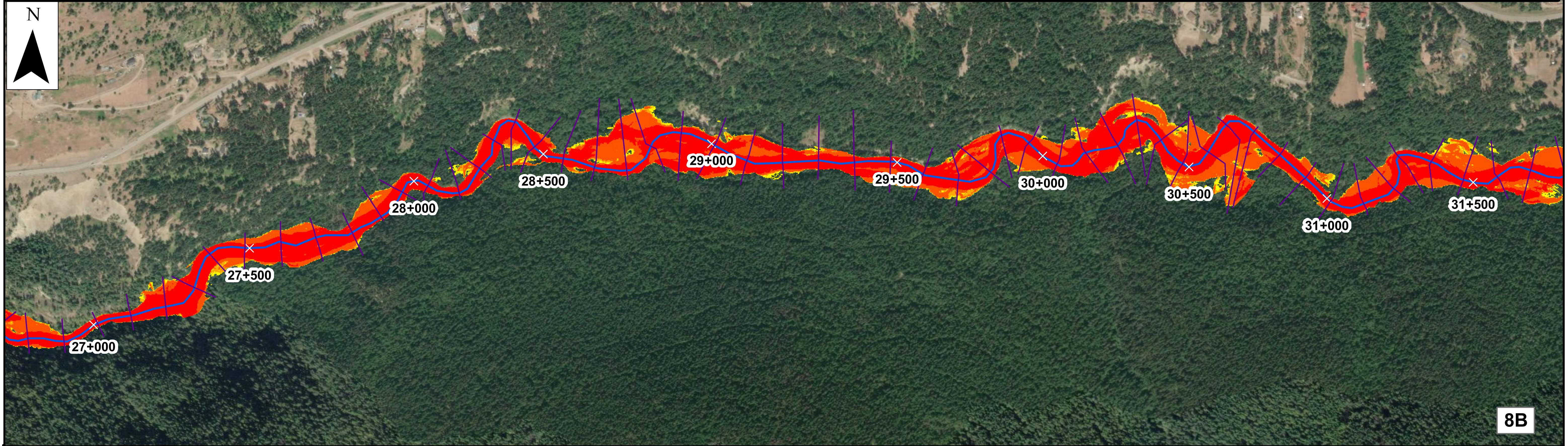
Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	7 / 11





0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

AECOM

Regional District of Central Okanagan

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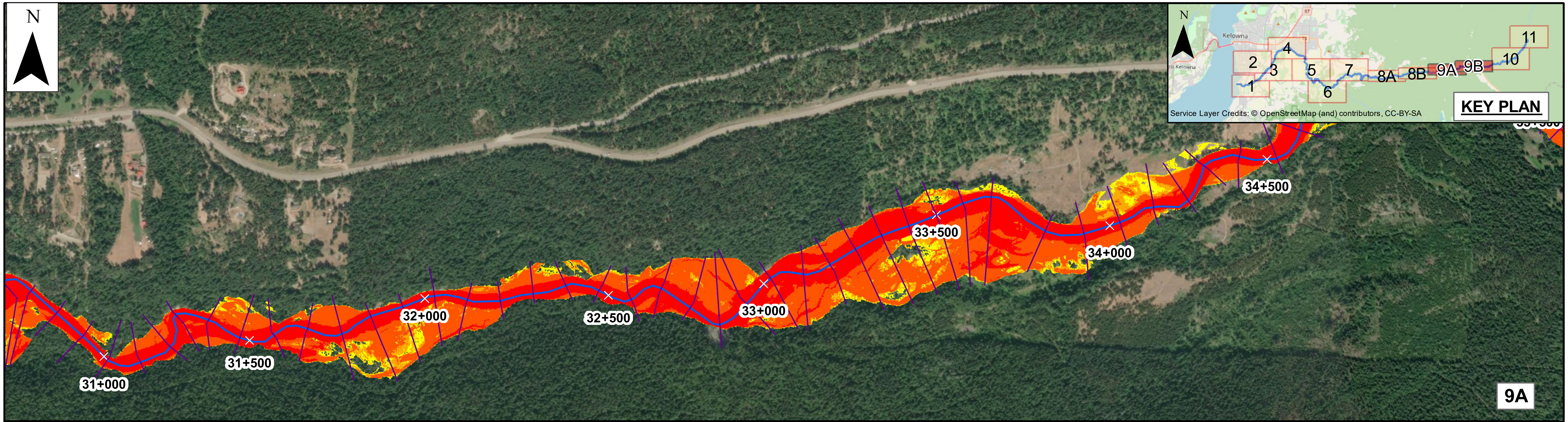
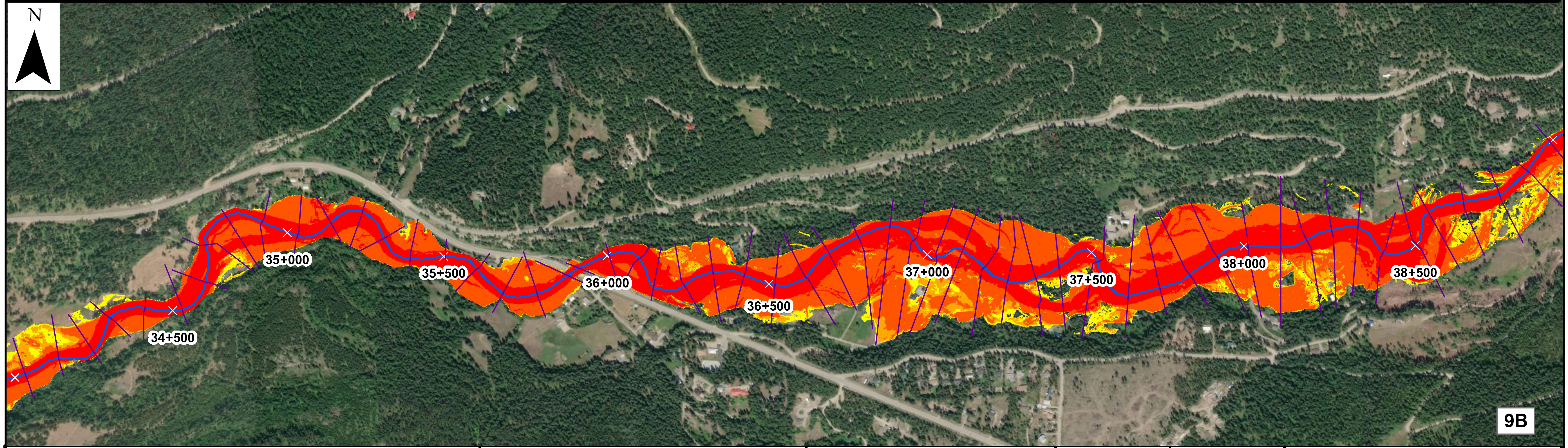
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	8/11





0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

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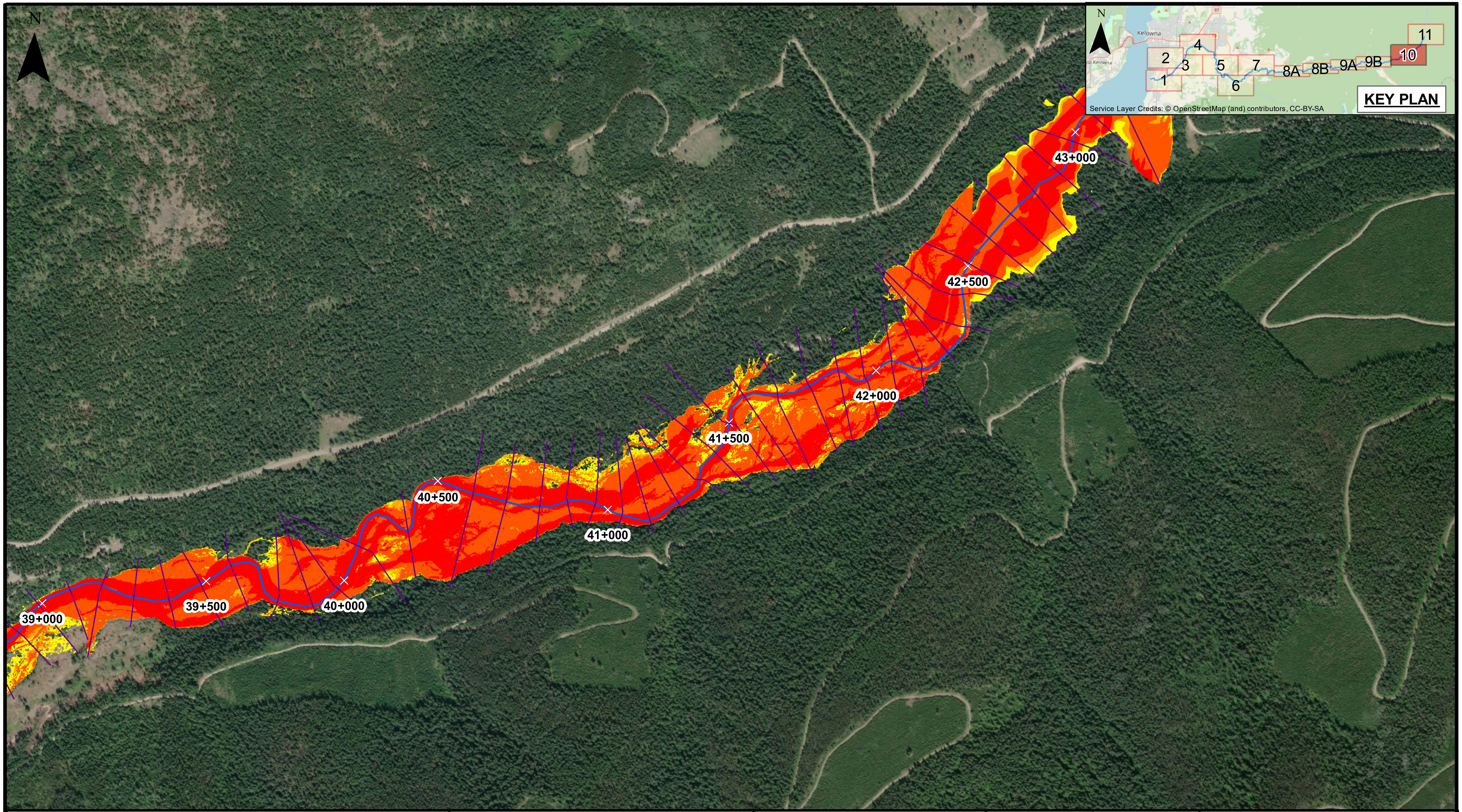
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	9 / 11



0 100 200 400 600 800 1,000 Meters

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

City of Kelowna

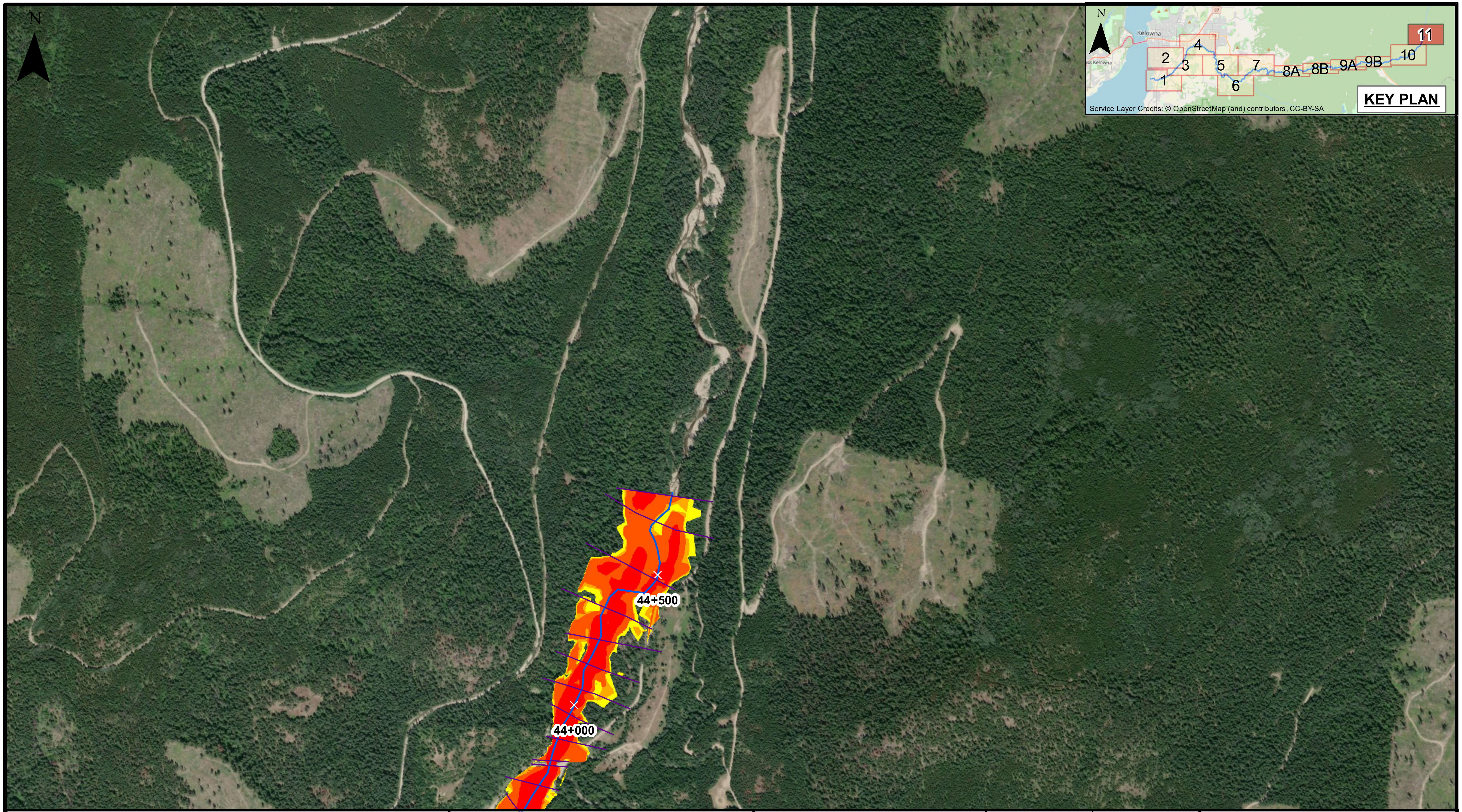
AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	10/11



NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

City of Kelowna

AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-3: Flood Hazard Rating for 200-Year Design Discharge
Mission Creek

REV NO.	SHEET
0	11/11

6.5.2 Note on the 200-year Design Flood Wave Development in the Lower Reach

The unsteady flow hydrograph shape adopted from Tetra Tech 2014 model for the 2013 flood has a duration of six days; with the time to peak around 1:00 PM of the third day. That hydrograph was scaled to the current study estimated peak design discharges. The video stream of the unsteady flow simulation of the 200-year design flood was carefully observed in RAS-Mapper. The following sequence of events on the flood wave development within the lower reach were noted:

- Flooding of the south non-diked floodplain upstream from Casorso Road Bridge (see Figure 6-2; Sheet 1/11). Flooding in this area happens due to the floodplain being non-diked; in addition to that location being the confluence of Priest/Rumohr Creeks.

- Floodwater overtopping Casorso Road and Swamp Road. Flooding extends into most of the facilities within the Mission Recreation Park area and ultimately reaches the wetland in Thomson Marsh Park.

- As the flood peak is approached, the following areas become flooded:
  - The non-diked area further downstream on the south between Bluebird Road and Lakeshore Road.
  - The area upstream from KLO Road Bridge; floodwater overtops the dikes and flows to the low lands of the north floodplain as well as to parts of the south floodplain.
  - The area across from the setback dike on the north floodplain.

- Floodwater overtopping Gordon Drive and eventually Lakeshore Road on the south floodplain. Much of the area between Gordon Drive and Lakeshore Road becomes flooded up to near Old Meadows Road to the south. Some areas along the coast west of Lakeshore Road get flooded as floodwater overtops Lakeshore Road.

- As the flood hydrograph progresses past the peak, floodwater starts receding in some areas of the floodplain.

With the dike breach scenario, the above sequence of events occurs with the flood extents on the south floodplain west of Swamp Road becoming slightly wider and less areas across from the setback dike on the north floodplain are flooded (compare Sheet 1/10 of Figure 6-1 and Figure 6-3, respectively).

With the 20-year design flood scenario, on the north floodplain, only part of the areas bounded between Casorso Road and Gordon Drive, and that downstream from Lakeshore get flooded. The sequence of flood events described above for the 200-year design flood scenario pertaining to the south floodplain applies; expect that the flood boundaries are much narrower (compare Sheets 1/10 and 1/11 of Figures 6-1 and 6-2, respectively).

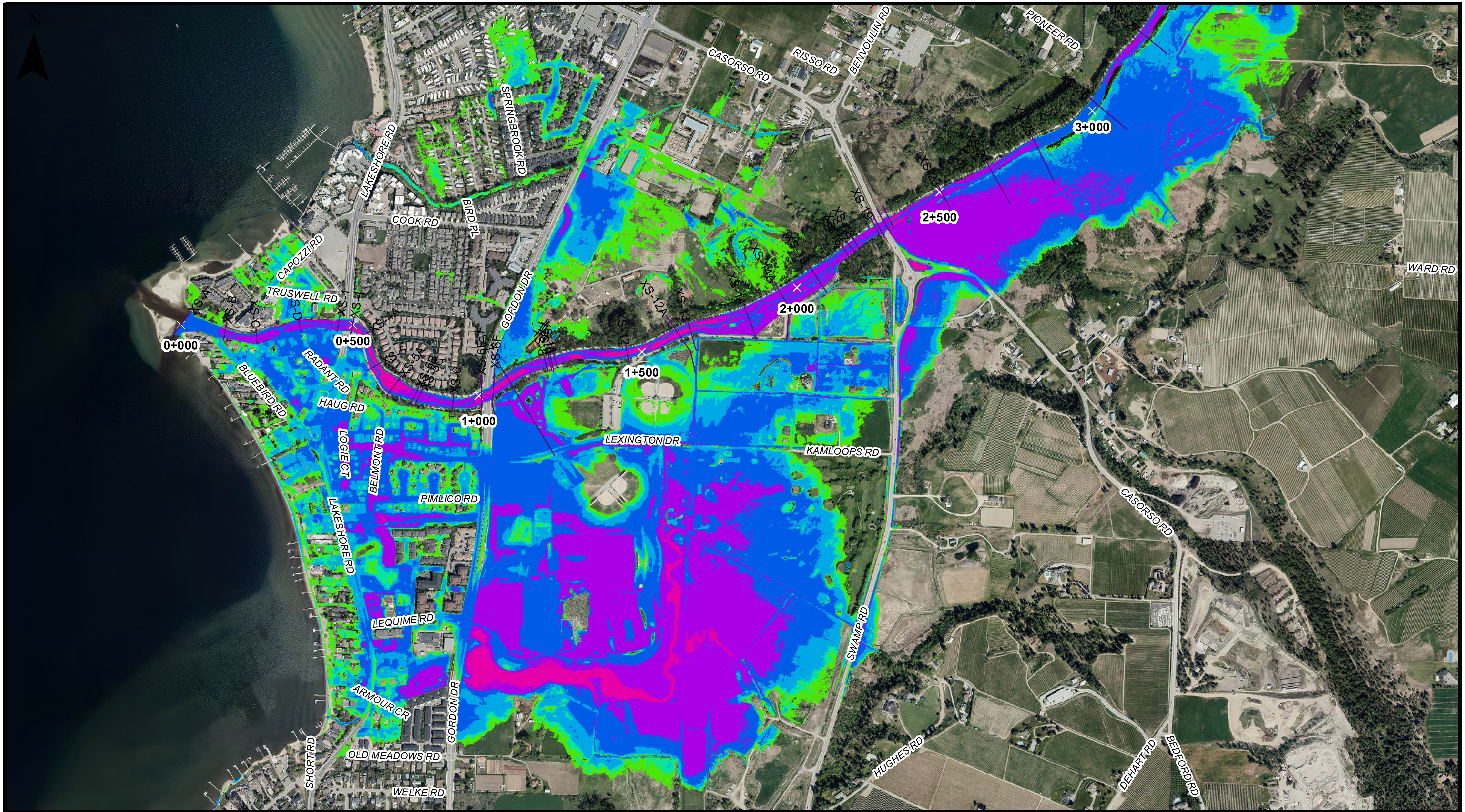
6.5.3 Mapping Results for Dike Breach Scenarios

Figure 6-4 shows the flood depth map results of the 200-year peak flood design discharge for the dike breach scenario.

In Figure 6-4, it is shown that more areas are flooded of the Mission Recreation Park; particularly the Mission Dog Park, part of the Ball Diamond grounds by Kinsmen Media Centre, the H2O Adventure and Fitness Centre and the soccer playground to its east (compare with Figure 6-2; Sheet 1/11).

The flood boundaries have also extended further east and south reaching Old Meadows Guest Cottage along Old Meadows Road. The floodwater volume increases due to the dike breach result in flooding these areas; in addition to slightly more areas along the coast west of Gordon Drive and Lakeshore Road.

Figure 6-5 shows the flood hazard rating map results of the 200-year peak flood design discharge for the dike breach scenario at Location 1. It is shown that the areas at significant and extreme hazards are larger compared to Figure 6-3 (Sheet 1/11) for the no-breach scenario; particularly along Thomson Marsh Park wetland and the stream discharging into it.



0 100 200 400 600 800 1,000 Meters

NO.	DATE	ENG.	BY	SUBJECT

REVISIONS

Legend:

Mission Creek

Maximum Flooding Depth (m)

- < 0.15
- 0.16 - 0.25
- 0.26 - 0.5
- 0.51 - 1.0
- 1.01 - 2.0
- > 2.0

City of Kelowna

AECOM

Regional District of Central Okanagan

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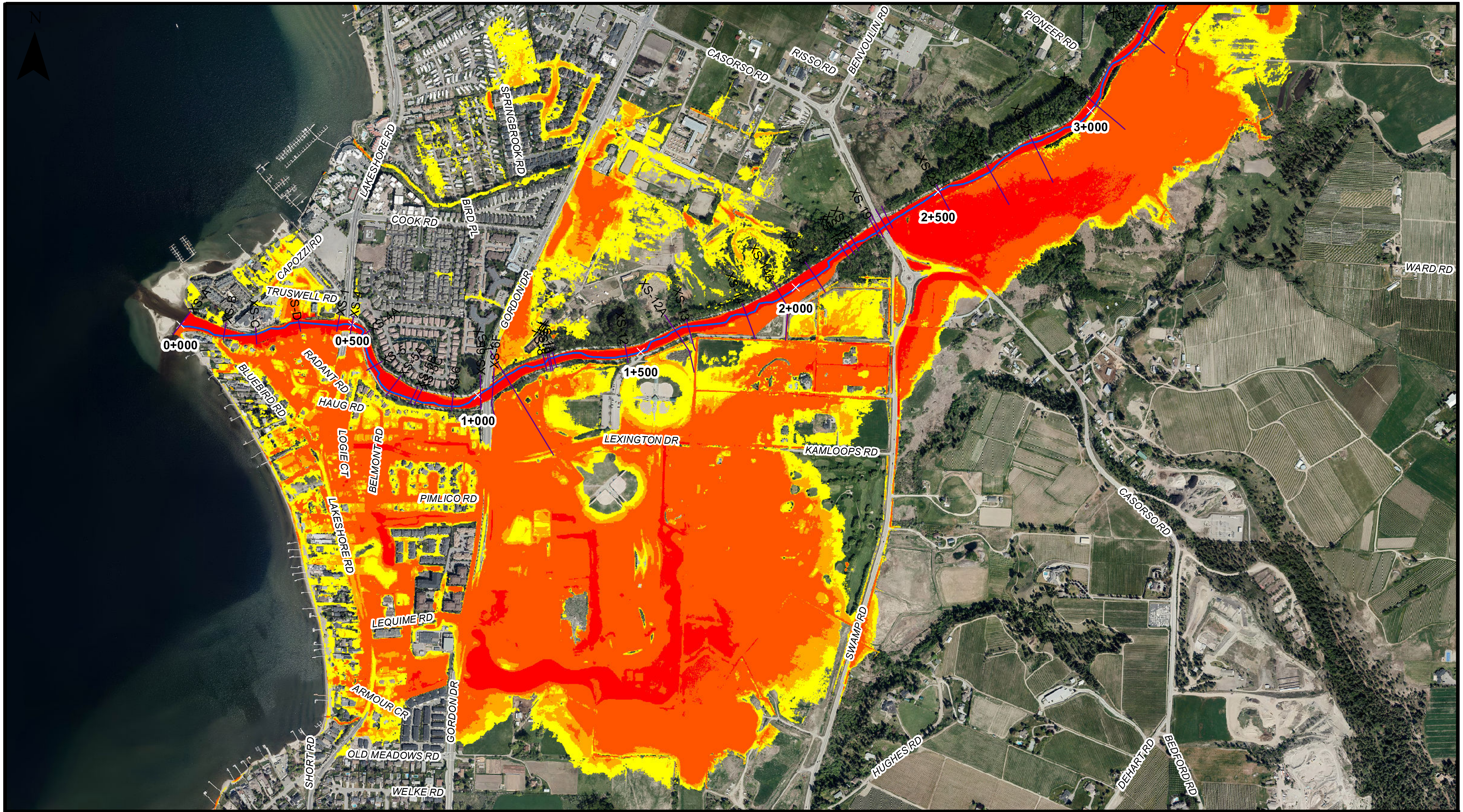
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-4: Flood Depth Map for the Dike Breach at the 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	1/1



0 100 200 400 600 800 1,000 Meters

Legend:

Mission Creek

Flood Hazard Classification

- <0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.0 (Significant)
- >2.0 (Extreme)

NO.	DATE	ENG.	BY	SUBJECT
REVISIONS				

City of Kelowna

AECOM

Regional District of Central Okanagan

PROJECT NO.	60613804
SCALE:	1:10,000
DRAWN:	B. TROITSKY
APPROVED:	-
PROJECTION:	UTM ZONE 11N
DATE:	2020-05-08

Figure 6-5: Flood Hazard Map for the Dike Breach at the 200-Year Design Discharge Mission Creek

REV NO.	SHEET
0	1/1

7. Flood Mitigation Measures

7.1 Potential Flood Mitigation Measures

7.1.1 The Upper Reach

Based on the flood mapping results of the upper reach, the following flood mitigation measures are proposed:

- Constructing a new earthen dike along the left bank bordering the Peace Valley Mobile Home Park between river stations 12+536.2 and 12+846.81; for a length of approximately 350 m.
- Issuing public flood warnings for people to avoid being in the Scenic Canyon Regional Park prior to predictions of extreme flood events in the creek. This can be part of the emergency preparedness program "The Regional District of Central Okanagan Emergency Program" that is coordinated by the Kelowna Fire Department on behalf of the RDCO, the cities of Kelowna and West Kelowna, districts of Lake Country and Peachland and Westbank First Nation.
- Dry floodproofing the residences around Hwy 33 either by elevating their grounds or ensuring there are adequate areas of basement windows along their sides, to avoid static and dynamic pressures of floodwater and flotation risks.
- Dry floodproofing the facilities at high and extreme flood hazard; particularly within the recreational area between Casorso Road Bridge and Gordon Drive Bridge.

7.1.2 The Lower Reach

Based on the unsteady simulation results of the 200-year design flood, the following flood mitigation measures are proposed for the lower reach.

For the currently non-diked reach upstream from Casorso Road Bridge, one of the below two measures may be adopted:

- Constructing a new earthen dike along that reach upstream. This new dike should have a culvert with a flap gate at the lowest location near the bridge, to allow for outflows from Priest/Rumohr Creeks.
- Constructing a flood barrier along the east side of Casorso Road south of the Casorso Road Bridge for approximately 400 m. This flood barrier will prevent the floodwater from overtopping the road and flooding the area between Casorso Road and Gordon Drive south of the creek.

For the currently non-diked reach downstream from Lakeshore Road Bridge, it is proposed to:

- Construct a new earthen dike along the south bank of the creek downstream from the bridge and up to river station 0+219.856 (XS-C) for an approximate distance of 250 m.

For the parts of the north dikes that are overtopped between STA 1+700 and Casorso Road Bridge (STA 2+350), and upstream from KLO Bridge (STA 5+000) and up to STA 8+000, it is proposed to raise the dikes by at least 1.0 m above the highest water surface elevation.

8. Conclusions and Recommendations

8.1 Conclusions

AECOM developed two hydraulic models for the study area based on the available hydrologic data inputs that NHC provided, the models' computational efficiency and the scope of work:

- A coupled 1D/2D unsteady flow simulation model for the lower reach up to the upstream end of the 2014 Tetra Tech's model; a reach length of approximately 8.6 km.
- An extended 1D steady flow simulation model for the upper reach between the upstream end of the lower reach model and the upstream end of the study area above Three Forks Road Bridge crossing; ending at station 45.5 km.

The lower reach model was calibrated using the 2018 flood discharge record at the gauge station WSC 08NM116 of approximately 124.64 m^3/s. According to Tetra Tech's 2014 Report, the observed 2018 flood discharge corresponds to the 200-year flood discharge estimate based on the frequency analysis they did for WSC 08NM116 records up to 2013. For the current study, NHC provided 200-year flood discharge estimate of 164.4 m^3/s at WSC 08NM116 and recommended 10% increase for climate change impacts resulting in a design flow of 180.8 m^3/s.

The following main conclusions are drawn from the modelling and flood mapping results:

- The current study 200-year design flow estimate is 45% larger than the 2018 flood record.
- The 200-year design flow simulation results indicate that some portions of the existing dike system are overtopped; these portions were not overtopped during the calibration run with the 2018 flood record. Such portions include the dikes on either bank upstream from KLO Road Bridge and the right bank dike downstream from Casorso Road Bridge.
- Flooding of the south floodplain west of Swamp Road occurs due to Casorso Road being overtopped by the impounded floodwater upstream from the Casorso Road Bridge crossing.
- Due to the dike breach, the flood extents on the south floodplain west of Swamp Road increases farther up to Old Meadows Road compared to the no-breach scenario. Also, more areas west of Gordon Drive become flooded.
- The current study 20-year design flow estimate of 126.2 m^3/s results in flooding the south floodplain west of Swamp Road for the same above reason of overtopping Casorso Road.
- While the above findings are based on conservative hydrologic estimates of the design flood, they provide guidance for the flood mitigation planning efforts to protect the flood prone areas.

8.2 Recommendations

- For more accurate flood mapping along the upper reach, it is recommended to update the model with bathymetric survey of the creek rather than LiDAR data, especially along areas that have residences or facilities; such as East Kelowna Bridge, the Mobile Home Park and Highway 33.

- Mission Creek watershed has quite a large area of approximately 860 km^2. The watershed is also highly regulated in its upstream part by many dams, lakes and reservoirs. AECOM recommends updating the hydrologic modelling of Mission Creek's watershed as new data become available for more accurate design flood estimations.

- AECOM recommends developing inflow hydrographs at the POI along the creek and calibrating them using the peak flows that NHC provided. These hydrographs can be used for developing an unsteady 2D or 1D/2D coupled model for the upper reach that will account for routing effects; hence producing more accurate flood mapping. Running 2D or 1D/2D models; however, will take long computational times, especially for such long upper reach.

Appendix A

Field Reconnaissance Report

PROJECT NO.	60613804 DATE September 25, 2019		
PROJECT NAME	Flood Mapping and Mitigation Planning	OWNER	City of Kelowna
		REP.	Robinson Puche; Luke Dempsey
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Summary

On September 18, 2019, AECOM visited Mission Creek to assess its main channel, the floodplain areas and key hydraulic structures along the creek within the study limits. The visit started around 8:30 AM at Lakeshore Road Bridge located approximately 470 m upstream of the creek mouth at Okanagan Lake. This report includes photos of the sites that were visited along the creek and summarizes important findings that can be used to evaluate some hydraulic modeling parameters. For direction convention while describing the photos, left and right banks are so termed assuming looking downstream. For the sake of sequentially describing the sites in this report, the start site is selected to be that at the creek mouth moving further upstream through the subsequent sites. The end site is near the top of Three Forks Road.

GENERAL COMMENTS:

Site No. 1: Creek Mouth and the Area Downstream of Lakeshore Road Bridge	Latitude (N)	Longitude (W)
	49˚ 50’ 34.93”	119˚ 29’ 37.16”

Photo1.

Looking downstream at the delta (alluvial fan) by the creek mouth at Okanagan Lake

- The City indicated that currently no dredging activities are taking place; sediments are deposited along the creek
- In 2003, a large wildfire starting in Okanagan Mountain Park and proceeding into the Crawford neighborhood resulted in increased runoff from the watershed

Photo2.

Looking downstream at the delta (alluvial fan) by the creek mouth at Okanagan Lake

- Alluvial deposits are shown
- Part of a private concrete dike along the right bank on a property off Trusswell Road is seen

Photo3. Signs of local erosion along the right bank near the mouth of Mission Creek • Exposed roots	
Photo4. Looking at the left bank between Lakeshore Road Bridge and the creek mouth • Shallow water depths of approximately 0.30 m were observed during the site • Boulders and gravel characterize the creek bed material	

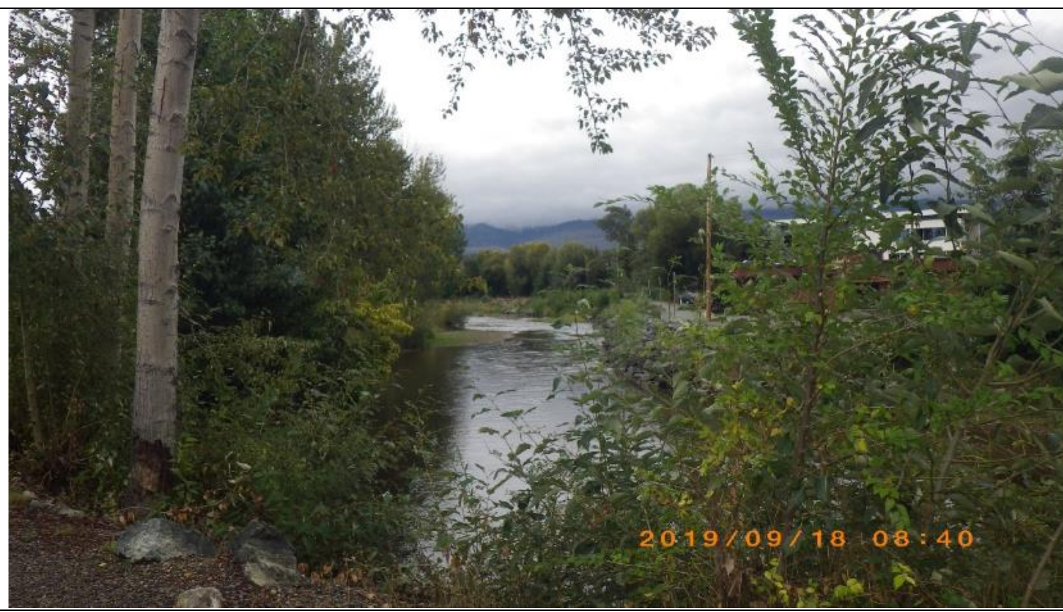
Site No. 2: Lakeshore Road Bridge	Latitude (N)	Longitude (W)
	49˚ 50' 34.36"	119˚ 29' 15.58"
Photo1. Looking upstream along the creek from top of the bridge • Sediments are observed along the left bank; indicative of bend erosion		
Photo2. Looking further upstream along the creek from the right bank by the bridge • Sediment deposition along the right bank due to bend scour is seen at the far end • Some vegetation along the banks are observed		

Photo3.

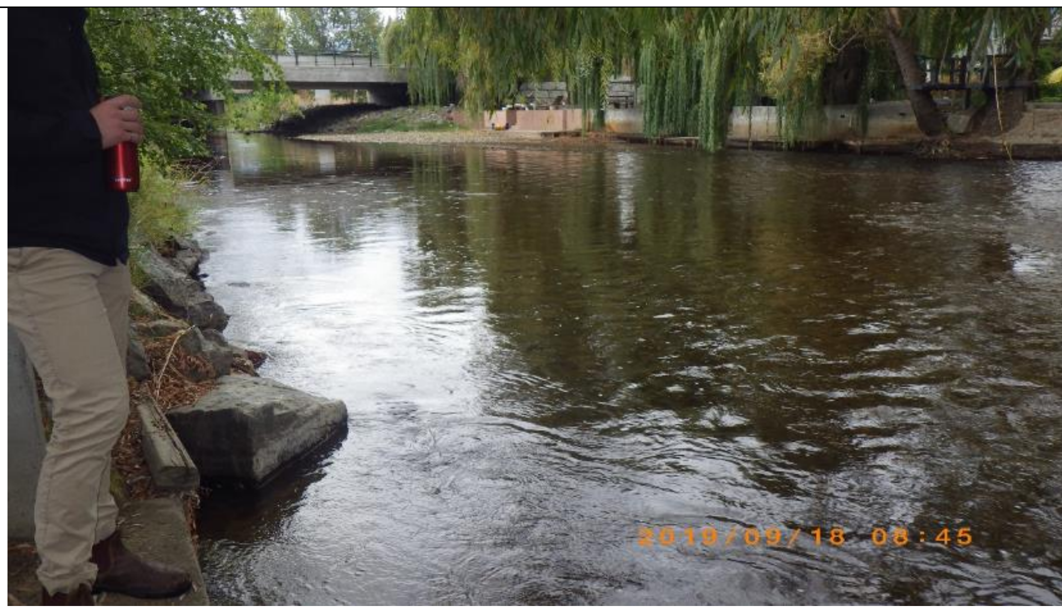
Looking along the creek at the bridge upstream face from the right bank

Construction of the bridge was completed in November 2014

Photo4.

Looking at the bridge piers from the right bank

- Shallow water depths of approximately 0.30 m were observed during the site
- High water marks during extreme flood events are seen on the piers

Photo5. Looking downstream along the creek from the right bank under the bridge • The City indicated there will be large development in the area north of the bridge off Truswell Road along the creek's right floodplain	
Photo6. Looking at the left bank downstream of the bridge • High water marks are seen along the concrete dikes along the bank	

Site No. 3: Gordon Drive Bridge and its Upstream Diked Area	Latitude (N)	Longitude (W)
	49˚ 50’ 28.41”	119˚ 28’ 56.47”
Photo1. Looking upstream along the creek from the left bank below the bridge • The channel geometry seems regular with trapezoidal cross section		
Photo2. Looking downstream along the creek from the left bank by the bridge • Sediment deposition in the form of gravel bars are seen on the left opening		

Photo3. Looking at the outlet headwall of an outfall structure on the left bank near the bridge • The outfall pipe seemed clogged; it was not obvious at the time of the visit • Another inaccessible headwall was observed at the east side of Gordon Drive Bridge's south abutment; the City indicated it is connected to Michael Brook Marsh area.	
Photo4. Looking at the bridge piers from the left bank • Sand deposits and vegetation are observed along the left bank near the bridge	

Photo5.

Looking at the floodplain south of the left diked bank

- The City indicated this area gets flooded during extreme events
- The photo shows a local private property east of Gordon Drive Bridge that drains flood water into the creek
- The City indicated groundwater table is few meters deep and the soil is characterized by clayey strata

Photo6.

A small drainage outfall pipe across the left diked bank near the property shown in Photo 5.

Photo7.

Looking downstream along the creek from the left bank; earthen dykes are observed along both banks

- The channel seems fairy regular with trapezoidal cross sections
- Side slope vegetation is observed on both banks
- The path along the dykes is part of the Mission Creek Greenway Trail

Photo8.

Looking at the right bank; a hydrometric station that BC Ministry of Environment operated seasonally is observed

Photo9. Looking at the floodplain south of the left diked bank • The City indicated this area had flooding history; including the neighboring baseball diamonds.	
Photo10. Looking upstream at the creek from the left bank where the new setback dike starts • Debris is observed along the left bank	

<table>
<tr><td>Site No. 4: Casorso Road Bridge</td><td>Latitude (N)
49˚ 50' 45"</td><td>Longitude (W)
119˚ 28' 01"</td></tr>
<tr><td>Photo1.

Looking downstream from the right bank east of the bridge

• Debris is observed within the bridge opening
• High water marks are observed on the piers indicating flood water levels were near the bottom of the bridge girder</td><td colspan="2"></td></tr>
<tr><td>Photo2.

Looking downstream along the creek from the right bank east of the bridge

• Debris and gravel bar are observed</td><td colspan="2"></td></tr>
</table>

Photo3.

Looking southeast from the right bank east of the bridge at the left bank

- A wetland with excessive vegetation and trees are observed

<table>
<tr><td rowspan="2">Site No. 5: KLO Road Bridge and its Downstream Diked Area</td><td>Latitude (N)</td><td>Longitude (W)</td></tr>
<tr><td>49˚ 51’ 39”</td><td>119˚ 26’ 35”</td></tr>
<tr><td>Photo1.

Looking downstream from the left bank south of the bridge

• An outfall pipe is observed; its flap gate was missing/sheared off
• A local weir extending to about mid-width of the creek is observed on the left; presumably to provide head for a local private irrigation intake just downstream of the outfall pipe</td><td colspan="2"></td></tr>
<tr><td>Photo2.

Looking upstream at the right bank south of the bridge

• An intake pipe with a trash rack is observed</td><td colspan="2"></td></tr>
</table>

Photo3. Looking upstream at the southside face of KLO Bridge • Naturally deposited sediments are observed filling the left opening and half of the middle opening • The City mentioned that during the 2017 flood, high water almost reached the bridge soffit • The City indicated they may replace the existing bridge with a single-span bridge; the existing bridge was likely built before the right-bank dike and the proposed bridge is presently being designed	
Photo4. Looking downstream along the creek from top of the bridge • Vegetation along the side slopes of both banks is observed	

Photo5.

Looking upstream along the creek from top of the bridge

Photo6.

Looking upstream at the bridge southside face from the right bank

Photo7.

Looking across the creek from the right bank

- A gravel bar is observed in the middle of the channel
- A freeboard of approximately 1 m is observed along the left bank during low flows at the time of the visit

Photo8.

Looking across the creek at the left bank

- Sediments and vegetation seem extending along the left bank constricting the channel to almost half width

Photo9.

An irrigation water intake on the right bank

Photo10.

Looking across the creek at the right bank

- A manual gate valve appears on the right bank in the middle of the view; indicative of possible intake structure at this location
- A gravel weir seems extending across the creek in the middle of the view

Site No. 6: The Area near Mission Creek Regional Park and Mill Creek Diversion Structure Outlet	**Latitude (N)**	**Longitude (W)**
	49˚ 52' 34.96"	119˚ 25' 55.12"
Photo1. Looking upstream along the creek from top of a foot bridge crossing near Mission Creek Regional Park • A gravel bar and vegetation are seen on the left • Rocks, boulders and gravel characterize the creek bed material • Spawning salmon were observed in the creek		
Photo2. Looking downstream along the creek from top of the foot bridge • The rocky creek bed persists all along		

Photo3. Nearby regulated irrigation district diversion channel along the right bank. The diversion structure from Mill Creek to Mission Creek crosses underneath this channel.	
Photo4. Headwall of Mill Creek diversion structure outlet on the right bank of Mission Creek	

Photo5. Mill Creek diversion structure outlet at Mission Creek; negligible outflow was observed during the visit	
Photo6. Looking downstream along the creek from the right bank • A slanted gravel weir is seen across the creek	

Site No. 7: Near Gerstmar Road (Upstream End of TetraTech 2014 HEC-RAS Model)	**Latitude (N)**	**Longitude (W)**
	49˚ 52' 35.35"	119˚ 24' 34.51"
Photo1. Looking downstream along the creek • Rocks and gravel characterize the creek bed material • WSC 08NM116 Station is located on the right bank approximately 300 m downstream		
Photo2. Looking upstream along the creek • Extensive trees along both banks and the rocky bed are persistent features		

Site No. 8: East Kelowna Road Bridge Crossing and its Upstream Area up to a Pedestrian Bridge	**Latitude (N)**	**Longitude (W)**
	49˚ 51' 53.24"	119˚ 23' 24.31"
Photo1. Looking upstream from the right bank at the downstream face of East Kelowna Road Bridge • The bridge has two openings with the pier shifted towards the left bank	 	
Photo2. Looking downstream along the creek from the right bank downstream of the bridge • The rocky creek bed and extensive trees on the side slopes persist all along	 	

Photo3.

Abandoned trout pond along the right bank upstream of East Kelowna Road Bridge

Photo4.

Looking upstream at the creek near the pedestrian bridge along the Greenway trail

Photo5. Looking along the right bank upstream of the pedestrian bridge • Exposed roots indicative of creek erosion • An outfall cantilever pipe is seen at the far right view discharging into the creek; during the visit no outflow was observed from the pipe	
Photo6. Looking upstream along the creek from the right bank; fairly deep cliffs exist in this area	

<table>
<tr><td rowspan="2">Site No. 9: Daves Creek Bridge Crossing near the Confluence with Mission Creek west of BMID Stevens Reservoir</td><td>Latitude (N)</td><td>Longitude (W)</td></tr>
<tr><td>49˚ 51’ 14.55”</td><td>119˚ 17’ 2.45”</td></tr>
<tr><td>Photo1.

Looking upstream along Daves Creek from the bridge near BMID’s treatment plant

• Daves Creek is a narrow stream with excessive vegetation and trees on the floodplain
• Boulders and gravel characterize the creek bed material</td><td colspan="2"></td></tr>
<tr><td>Photo2.

Looking downstream along the creek from the bridge

• The rocky creek bed and extensive trees on the side slopes persist all along</td><td colspan="2"></td></tr>
</table>

Photo3. Looking upstream at the bridge from the southeast bank	

Site No. 10: Belgo Creek - Highway 33 Bridge Crossing near the Confluence with Mission Creek	Latitude (N)	Longitude (W)
	49˚ 52' 03"	119˚ 09' 12.64"
Photo1. Looking at the bridge opening from the left bank north of Highway 33 in Joe Rich Area		
Photo2. A closer look at the bridge opening from the left bank north of Highway 33 • Rocky material characterizes the creek bed		

<table>
<tr>
<td>

Photo3.

Looking upstream along Belgo Creek from the left bank north of Highway 33

- Debris across the creek and large rocks and stones are observed

</td>
<td></td>
</tr>
</table>

Site No. 11: Highway 33 Bridge Crossing at Joe Rich Area	Latitude (N)	Longitude (W)
	49˚ 51' 57"	119˚ 08' 48"

Photo1.

Looking upstream from the left bank at the downstream face of the bridge

- The bridge has a single circular concrete pier

Photo2.

Looking downstream along the creek from the left bank downstream of the bridge

- The rocky creek bed and extensive trees on the side slopes persist all along

Photo3. The high-water mark on the upstream side of the pier was measured at approximately 1.60 m below the bridge girder soffit The high-water mark on the downstream side was about 0.65 m – 0.70 m below the upstream mark	
Photo4. Looking upstream at the creek from the left bank	

Photo5. Looking at the right bank downstream of the bridge from the left bank • Properties on the floodplain are likely flooded during extreme flood events	
Photo6. A side drainage channel along the fence of a private property (Russels Morgans) that discharges into the creek	

Photo7. Fast flowing water in the channel within the Russels Morgans property (see Photo6) • This property likely gets flooded due to backwater effects when the creek experiences extreme floods	

Site No. 12: Three Forks Road Bridge Crossing and Pearson Creek Bridge Crossing near the Confluence with Mission Creek	Latitude (N)	Longitude (W)
	49˚ 53’ 15.22”	119˚ 03’ 50”
Photo1. An aerial view showing both crossings and the confluence		
Photo2. Looking at the confluence from Three Forks Road Bridge across Mission Creek • Pearson Creek bridge is seen at the far-left view in the photo • Boulders and gravel characterize Mission Creek bed material		

Photo3. Looking upstream along Mission Creek from Three Forks Road Bridge • Tall trees are observed along both banks	
Photo4. Looking upstream at Three Forks Bridge from the left bank south of Mission Creek crossing	

Photo5.

Looking upstream along Pearson Creek from the bridge crossing

Photo6.

Looking upstream at Pearson Creek bridge from the right bank west of the crossing

AECOM

Regional District of Central Okanagan

City of Kelowna