ISINTOK RESERVOIR
FLOOD INUNDATION REPORT

District of Summerland
January 10, 2012

Agua Consulting Inc.
"Engineered Water Solutions"

January 10, 2012

District of Summerland
9215 Cedar Avenue, Box 159
Summerland, BC
V0H 1Z0

Attention: Don Darling, Director of Engineering and Public Works

Re: Isintok Reservoir Flood Inundation Report

Dear Don:

Please find the enclosed Isintok Reservoir Flood Inundation Report. This report summarizes the impact of varying types of potential dam failures, displays the extent of the inundated areas, and estimates the potential for loss of human life and damage to property. Recommendations such as monitoring and warning plans have been included in the conclusions of this report.

We trust that the content of this report meets your expectations. We thank you for the opportunity to be of service.

Yours truly,

Bob Hrasko, P.Eng.
Agua Consulting Inc.
RJH/rh

DISTRICT OF SUMMERLAND

ISINTOK RESERVOIR FLOOD INUNDATION REPORT

Prepared for:

District of Summerland
9215 Cedar Avenue, Box 159
Summerland, BC V0H 1Z0

Prepared by:

Agua Consulting Inc
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January 10, 2012

Project No. 023-012

ACKNOWLEDGEMENTS

This report was prepared by R.J. (Bob) Hrasko, P.Eng. of Agua Consulting Inc., Aaron Hahn, EIT, AScT of Hahn Engineering Consulting, and with the assistance of two individuals. Scott Lee and Shawn Hughes of the District of Summerland were particularly helpful in collecting as-constructed and operational details for the District's utilities. Their efforts and commitment to this endeavour are appreciated.

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BC DSR	British Columbia Dam Safety Regulation
CAD	Computer Assisted Drafting
CDA	Canadian Dam Association
cms	Cubic Metres Per Second
DOS	District of Summerland
EPP	Emergency Preparedness Plan
HEC-RAS	Hydrologic Engineering Centers River Analysis System
km	Kilometres
km/h	Kilometres per Hour
m	Metres
MAD	Mean Annual Discharge
MoE	Ministry of Environment

1. INTRODUCTION

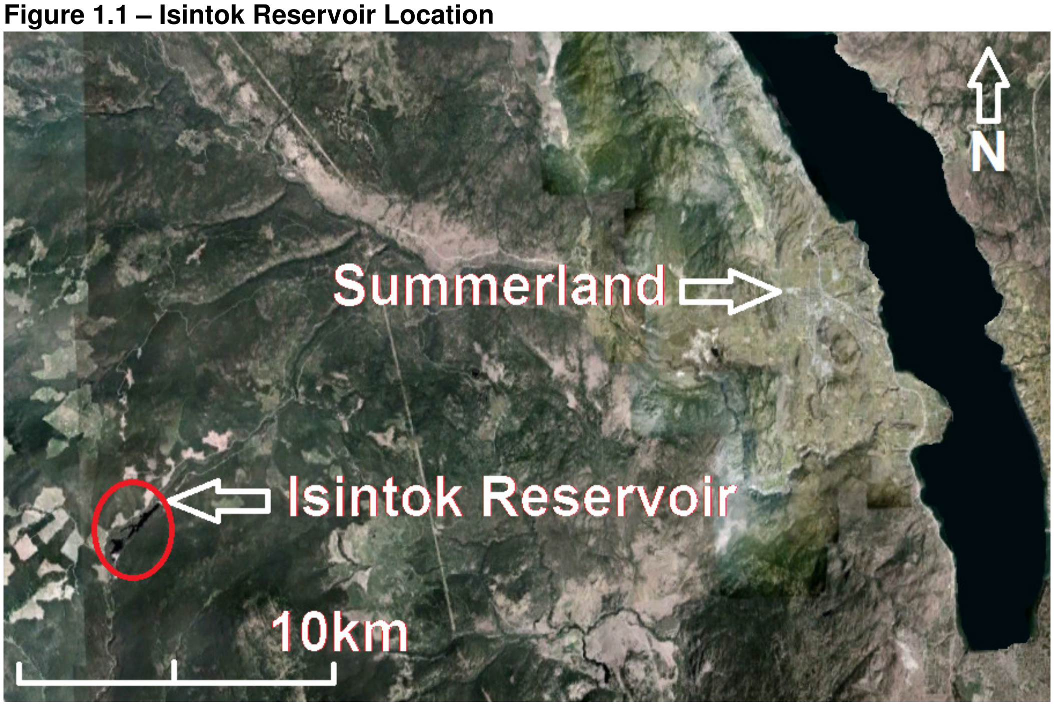
1.1 GENERAL

The Isintok Reservoir provides storage water to the District of Summerland. The water is conveyed along a 42 kilometre water course to the Summerland intake via Isintok Creek and Trout Creek. The purpose of this report is to assess the risks associated with a breach of Isintok Dam. This report identifies resulting flood zones, wave travel times, and identifies structures and infrastructure at risk. The consequence of failure for the Isintok Dam has been classified as High.

1.2 BACKGROUND

Isintok Reservoir is located 12 kilometres upstream from Trout Creek main stem and another 6 kilometres west of the District of Summerland's main drinking water intake. At a distance of 18 kilometres from the District's intake, Isintok Reservoir is the closest reservoir to the District Intake.

Figure 1.1 – Isintok Reservoir Location



Isintok Reservoir at full-pool has a surface elevation of approximately 1650 m and a total area of 38.7 ha. Isintok Reservoir is annually filled by a sub-catchment area of approximately 1600 ha (16.0 km^2). With a total live storage volume of 1364 ML, Isintok Reservoir comprises about 7% of the total District-wide storage capacity.

The Isintok Dam is an earth filled Dam having a crest length of approximately 140 m, a height of 9.2 m, and a crest of 4.0 m. It has an upstream side-slope of 2:1 and a downstream side-slope of 3:1.

Figure 1.2 – Isintok Dam

Figure 1.3 – Isintok Gate Control and Outlet, and Spillway

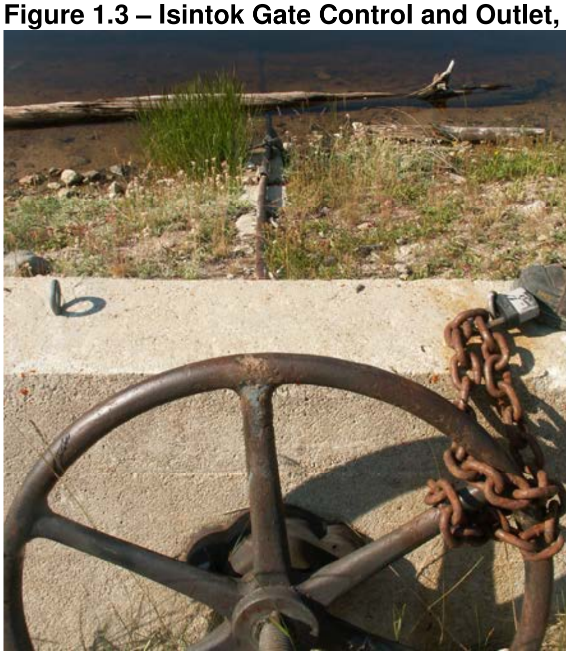
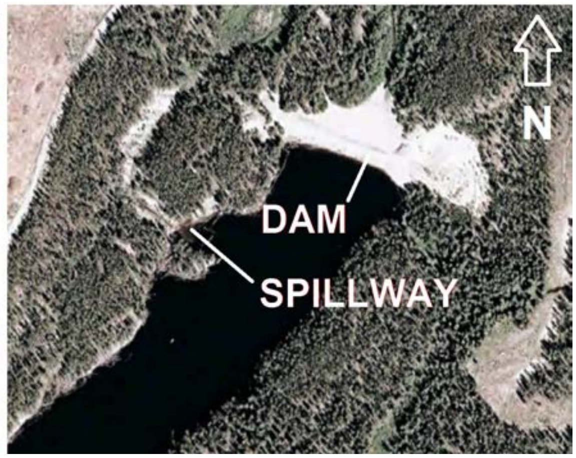


Figure 1.4 – Isintok Reservoir's Spillway and Location



1.3 PROJECT OBJECTIVES

The following details the primary objectives of this report:

- To develop a model capable of characterizing the flow resulting from a breach of Isintok Dam along various cross-sections throughout the Isintok Creek and Trout Creek water course;
- To create flood inundation mapping detailing probable flood zones with depths;
- To determine the degree of potential impact to life, personal property, environment, and key infrastructure assets in the flood inundated areas; and
- To supply supporting documentation for the Isintok Reservoir's Emergency Preparedness Plan (EPP) as per the Canadian Dam Association's (CDA) Dam Safety Guidelines.

1.4 SCOPE OF REPORT

This report was prepared by completing the following list of tasks:

- Assemble all available information required to characterize an Isintok Dam breach including: the size and geometry of Isintok Reservoir, the construction of the Isintok Dam, the topography of Isintok's water course, the location of sensitive areas, etc;
- Construct a viable computer model able to simulate the breach of Isintok Dam;
- Provide flood inundation mapping indicating the areas at risk;
- Provide graphs and tables detailing the breach wave characteristics along several locations of the water course (includes peak flows, time to wave, time to peak flow, duration of elevated waters, maximum increase in water elevation, and maximum average flow velocity);
- Identify the approximate population and infrastructure that may be affected including road crossings, water infrastructure, residential property, etc.

1.5 RELATED REPORTS & REFERENCES

The following references were used in the preparation, review, and writing of this document.

ASCE Fall Convention	Some Limitations of Dam-Breach Flood Routing Models	October 1981
British Columbia Dam Safety Regulation	Water Act	September 2011
Canadian Dam Association	Dam Safety Guidelines	July 2007
District of Summerland Engineering and Public Works – Agua Consulting Inc	District of Summerland Engineering and Public Works	November 2008
District of Summerland Engineering and Public Works – EarthTech Canada Inc	Watershed Risk Assessment	June 2002
Environment Canada	Hydrometric Data – Camp Creek at Mouth Near Thirsk	October 2011
Journal of Hydraulic Engineering	Breaching Characteristics of Dam Failures	May 1984
Maryland Dam Safety	Dam Break Analysis & Hazard Classifications	October 1996
Ministry of Environment	Consequence of Failure Classification: A Guide for Initial Assessment	June 2011
Ministry of Environment	Trout Creek Water Use Plan Fisheries Report: Overview of Fish and Fish Habitat Resources and Aquatic Ecosystem Flow Requirements in Trout Creek	September 2005
Ministry of Forests, Lands and Natural Resource Operations British Columbia	Dam Failure Consequence Classification Conversion Guideline for Dams in British Columbia	August 2011
Natural Resources Canada: Earth Sciences Centre	Geogratis	August 2011
Office of Hydrology and National Weather Service	NWS-Dam Break Flood Forecasting Model	April 1988
United States Bureau of Reclamation	Flood Hazard Charts	April 1988
US Army Corps of Engineers	HEC-RAS River Analysis System: User manual & Release Notes Version 4.1	January 2010

2. DESIGN APPROACH

2.1 DAM SAFETY REQUIREMENTS AND CONSEQUENCE OF FAILURE

The Ministry of Environment (MoE) and the Canadian Dam Association (CDA) assess the dams throughout BC in accordance with consequence of failure classification. The classifications criteria taking precedence for the Isintok Dam is the British Columbia Dam Safety Regulation (BC DSR). According to this criterion, the Isintok Dam is considered to be of HIGH consequence in the event of failure. The classification rating guidelines are listed in Table 2.1.

Table 2.1 – BC Dam Failure Consequences Classification Table (BC DSR, 2011)

Consequence Classification NEW BC Dam Safety Regulation 108/2011	Population at Risk	Loss of Life		Environment and Cultural Values[2]		Infrastructure & Economics[2]		Consequence Classification OLD BC Dam Safety Regulation 44/2000
	BC Reg. 108/2011 Only	BC Reg. 108/2011	BC Reg. 44/2000[(3)]	BC Reg. 108/2011	BC Reg. 44/2000	BC Reg 108/2011	BC Reg. 44/2000	
Low	None	No possibility of loss of life	Minimal	Minimal short-term and no long-term loss or deterioration	No significant loss of habitat or sites	Minimal economic losses mostly limited to dam owner's property	< $100K Minimal	Very Low
Significant	Temporary Only	Low potential for multiple loss of life[6]	Some Possible	No significant loss or deterioration incl. Important habitat Restoration or compensation possible	Loss or deterioration of regionally important habitat & sites – High chance for restoration or compensation	Low economic losses to buildings, services, public transportation, infrastructure, etc.	< $1M Limited Infrastructure, Public, Commercial	Low
High	Permanent Residents	< 10	< 10[(4)]	Significant loss or deterioration incl. Important habitat Restoration or compensation possible	Same as below	High economic losses to buildings, services, public transportation, commerce, infrastructure, etc.	< $10M[(4)] Same as below	High (Low[4])
Very High	Permanent Residents	< 100	< 100	Significant loss or deterioration incl. critical habitat Restoration or compensation impractical	Loss or deterioration of Nationally & Provincially important habitat & sites – High chance for restoration or compensation	Very high economic losses to **important** buildings, services, transportation, infrastructure, commerce etc. **Or** severe damage to residential areas	< $100M Substantial Infrastructure, Public, Commercial	High (High[4])
Extreme	Permanent Residents	>100	>100	Major loss or deterioration incl. critical habitat Restoration or compensation impossible	Loss or deterioration of Nationally & Provincially important habitat & sites – Low chance for restoration or compensation	Extremely high economic losses to **critical** buildings, services, transportation, infrastructure, commerce etc. **Or** destruction or severe damage to residential areas	>$100M Very High Infrastructure, Public, Commercial, Residential	Very High

1 This table contains abridged descriptions of the dam failure consequences. Attachment 1 contains the full descriptions from BC Regulation 108/2011. In all cases the Regulation takes precedence over information contained in this table.
2 Names for these categories in BC Reg. 44/2000 are "Environmental and Cultural Losses" and "Economic and Social Losses" respectively.
3 Conservative estimate of loss of life amongst population affected by the flood waters (may equal Population at Risk).
4 Sub-classifications of "High (Low)" and "High (High)" and associated thresholds were established by policy in 1998 for use in the BC Dam Safety Program risk-based assessment.
5 A temporary population (e.g. in recreational areas) could be quite large and a "sunny-day" failure could result in multiple fatalities.

Since the classification given to the Isintok Dam is HIGH, an Emergency Preparedness Plan (EPP) is required. This report has been conducted in accordance with the requirements. Components of this plan will form a part of the EPP.

2.2 SOFTWARE EMPLOYED

In order to create a viable simulation of an Isintok Dam breach, a computer was required to complete the numerous calculations. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 4.1.0 was selected. This software package is state-of-the-art and widely used in the civil engineering industry. It was selected due to its ability to model various types of dam breaches and it is capable of importing geometric data from computer assisted drafting (CAD) software. In addition, CAD software called Carlson Civil Suite and AutoCAD was used to create the model's input geometry and inundation maps.

2.3 ISINTOK INFLOW AND FAILURE MODE

There are predominantly two types of dam failure modes – overtopping and piping. (1) An overtopping failure is one that occurs when the water flows over the crest of the dam. The velocities of the water will begin to displace material forming a trough. This trough will quickly grow in size and ultimately release most of the water from the reservoir. (2) A piping failure is one that is formed by a leak within the dam. Similar to an overtopping failure, the velocity of the water through the leak will displace embankment material causing the opening to enlarge. Although this type of failure can occur anywhere in the dam's structure, they are most likely to fail at the dam's outlet piping.

An analysis of an overtopping and piping failure of the Isintok was conducted. Due to the overwhelming similarities between the overtopping and piping failure flow hydrographs and breach durations, only the piping failure hydrographs for 1.0-hour and 2.5-hour breaches have been employed.

3. HEC-RAS MODEL

3.1 HEC-RAS

The Hydrologic Engineering Centers River Analysis System (HEC-RAS) is a simulation software developed by the US Army Corps of Engineers and has been developed to manage rivers, harbours, and other public works under their jurisdiction. The HEC-RAS software has found wide acceptance among hydraulic engineers and researchers due to its robust channel flow analysis capabilities and its ability to determine floodplain areas. Furthermore, HEC-RAS uses steady and unsteady state modeling routines and dam breach modules – thus making the software ideal for dam breach modeling. Due to its extensive capabilities, cost, and compatibility with CAD software packages, HEC-RAS was chosen to simulate the Isintok Dam breach.

The following sections of this report are largely based on the two modeling routines employed by HEC-RAS – (1) the Froelich equations for dam breach hydrograph determination and (2) the use of the implicit finite difference method coupled with the Saint-Venant equations for unsteady flow determination. Due to the complexity of the solving routines, it is necessary to thoroughly review the output solutions for stability and correctness. The solution found by HEC-RAS has been compared to similar historical dam breaches, hand calculations and water volume checks. All comparisons and checks indicate that the solution found by HEC-RAS is stable and trustworthy.

3.2 CREEK BASE FLOW INPUT

Initially a creek base flow input parameter is entered. According to a 2005 Department of Fisheries report, the outflow of the Trout Creek watershed is estimated to be ten times the outflow from the Camp Creek watershed. Furthermore, the mean annual discharge (MAD) and maximum flow at the District of Summerland's diversion (~19 kilometres from Trout Creek Mouth) was considered to be 2.9 cms and 5.1 cms respectively. For the purpose of this exercise, a base flow of 10 cubic metres per second was selected. Although 10 cms base flow is conservatively large for upstream stations along the water course, this elevated base flow is negligible when compared to peak flows resulting from a dam breach. Figure 3.1 in Appendix A shows the catchment area for Isintok Reservoir.

3.3 GEOGRAPHICAL INPUT AND ACCURACY

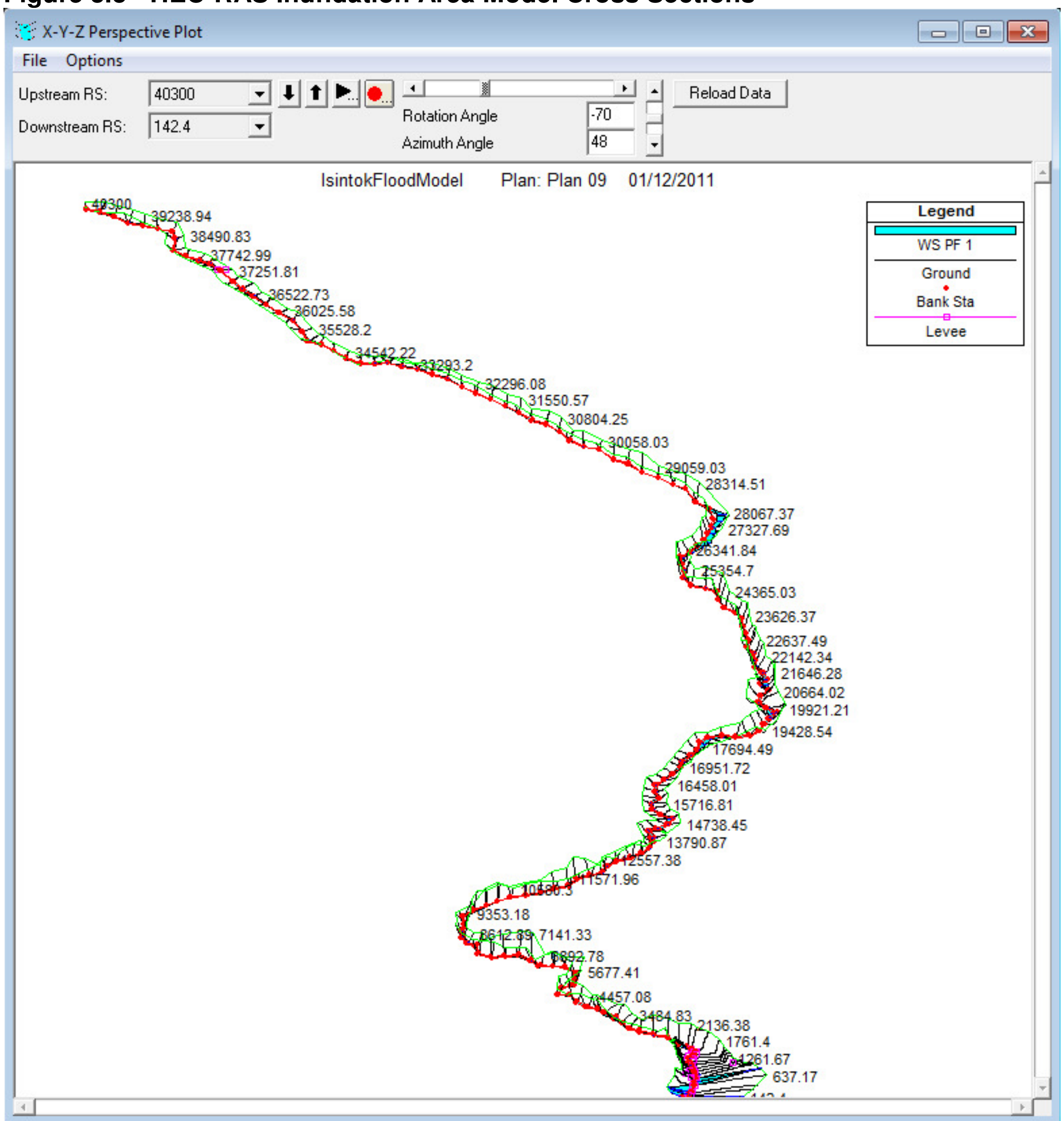
Topographical information characterizing the water course must also be entered in the program. The water course from Isintok Reservoir to Okanagan Lake is approximately 40 kilometres (see Figure 3.2 in Appendix A). A three-dimensional surface detailing the entire water course was created in CAD using one metre and ten metre (best available) contour data collected from the District of Summerland and the Natural Resources Canada Earth Sciences Centre respectively. Although the data is coarse in the upland and rural areas, it is sufficient to accurately simulate the attenuation and time delay characteristics of a dam failure breach wave.

The CAD surface of the water course was then divided into 100 metre and 200 metre cross-sections for urban and rural areas respectively. The cross-sections were exported from the CAD software and imported directly into the HEC-RAS model. Several cross-sections were then screened for errors and then either simplified or removed. Finally, parameters including Manning's open-channel flow coefficients, reach lengths, left and right bank stations, levee locations, and other key inputs were entered. A summary of the Manning coefficients and a display of the cross-sections imported are displayed in Table 3.1 and Figure 3.3.

Table 3.1 - HEC-RAS Manning Coefficients

Description	Manning Coef.
Earth channel - stony, cobbles	0.04
Floodplains - pasture, farmland	0.04
Floodplains - light brush	0.05
Floodplains - heavy brush	0.08
Floodplains - trees	0.15

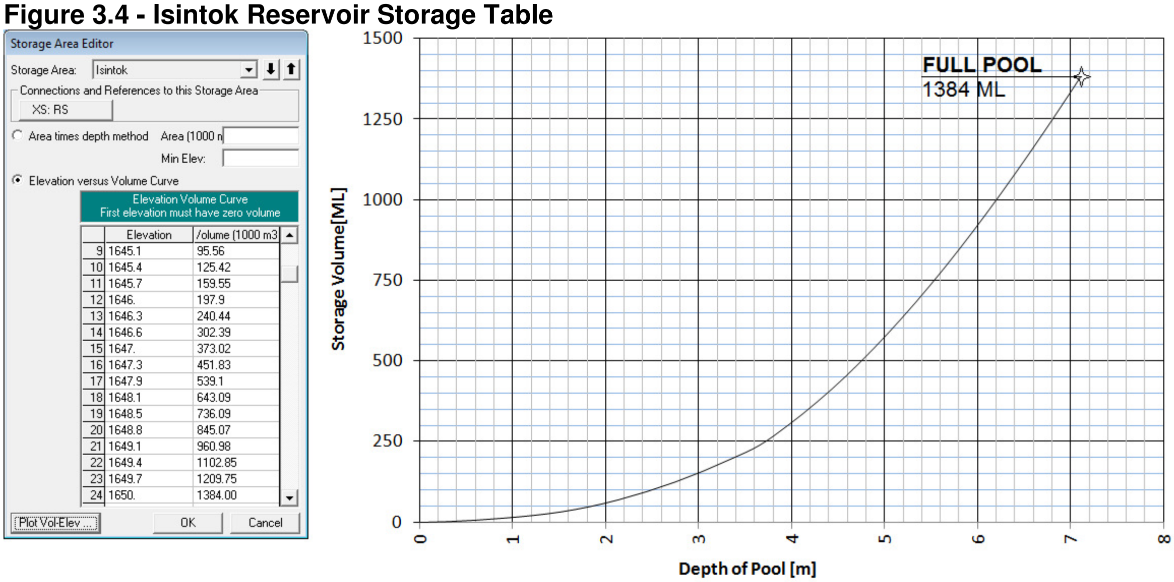
Figure 3.3 - HEC-RAS Inundation Area Model Cross Sections



3.4 MODEL BOUNDARIES

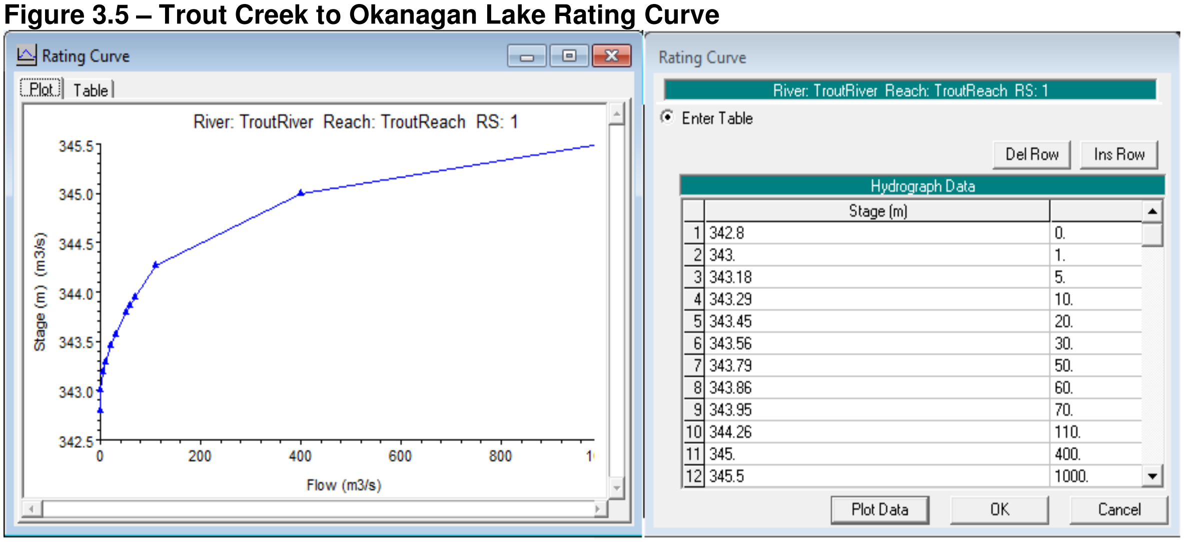
As an input boundary, the Isintok Reservoir elevation and storage volume relationship needed to be entered. Figure 3.4 illustrates the stage volume relationship of Isintok Dam.

Figure 3.4 - Isintok Reservoir Storage Table



As an output boundary, a rating curve was needed to describe the hydraulic capacity between the Trout Creek mouth and Okanagan Lake. This was derived by using the newly created HEC-RAS model and simulating a variety of flow rates using the steady state routine. The resulting boundary condition found in Figure 3.5 was derived using a high water level (HWL) of 343.0 m for Okanagan Lake.

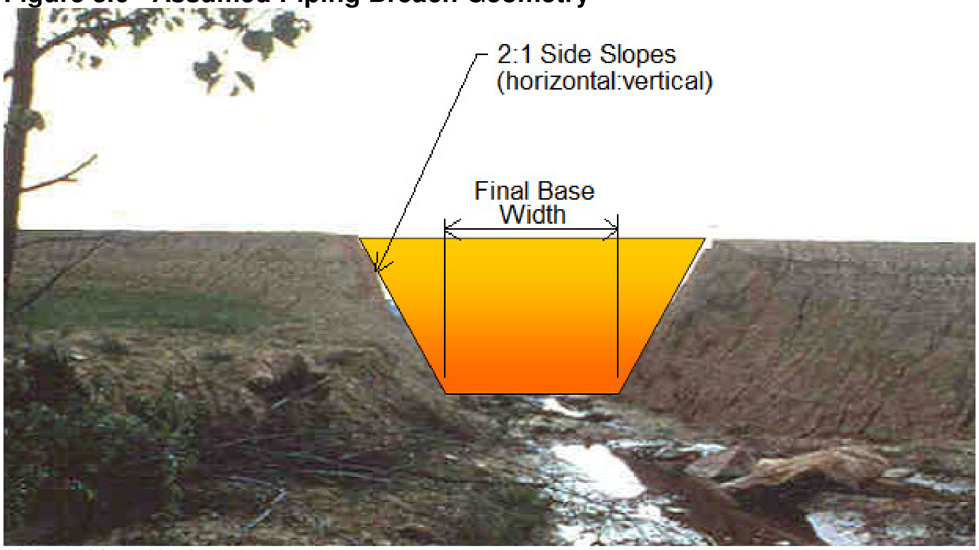
Figure 3.5 – Trout Creek to Okanagan Lake Rating Curve



3.5 PIPING BREACH PARAMETERS

Key inputs dictating the characteristics of the breach wave were entered for a piping failure. Based on research from several reports and papers, it was concluded that a piping breach of the Isintok Dam would transpire over a period of 1 to 2.5 hours. Furthermore, due to the type and volume of material in the dam, the surface area of the reservoir, the volume of storage water, the geometry of the dam construction, and the geographic boundaries, the breach channel geometry was assumed have 2:1 side slopes and a 15 m final base width. The parameters used to characterize the piping failure are detailed in Table 3.2 and illustrated in Figure 3.6 and Figure 3.7.

Figure 3.6 –Assumed Piping Breach Geometry*



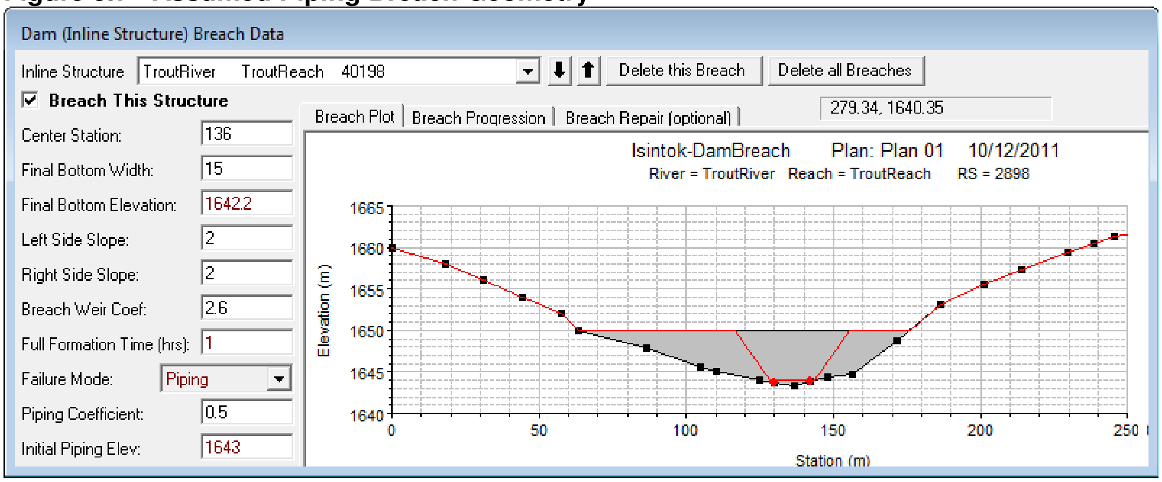
*Adapted from Harrington, 1996

Table 3.2 – HEC-RAS Piping Failure Parameters

Description	Value
Final Bottom Width (m)	15
Final Bottom Elevation (m)	1642.2
Left Side Slope (x H:1 V)	2
Right Side Slope (x H:1 V)	2
Full Formation Time (hr)	1 & 2.5*
Orifice Piping Coefficient	0.5
Initial Piping Elevation	1643

*Two simulations conducted (1.0 hrs and 2.5 hrs)

Figure 3.7 –Assumed Piping Breach Geometry



4. DAM BREACH AND HYDRAULIC ROUTING ANALYSIS

4.1 PIPING FAILURE BREACH RESULTS

The HEC-RAS model described in the previous section was used to simulate 1.0 and 2.5 hour-long piping breach failures. The resulting wave characteristics for the 1.0 and 2.5 hour breaches are detailed in Tables 4.1 and 4.2 respectively.

Table 4.1 - 1.0 Hour Dam Breach Results*

Station	40+200	20+400	14+740	2+990	1+100	0+487
Station Description	Below Isintok	Kettle Xing	Bathville Xing	Ped Bridge	Above HwY97	Near Mouth
Peak Discharge [cms]	376	289	252	163	153	143
Time to Wave Arrival [hr]	0.05	1.54	2.48	4.04	4.32	4.47
Time to Peak Flow [hr]	0.91	2.29	3.20	5.14	5.41	5.83
Duration of Elevated Water Level [hr]*	3.16	3.89	4.44	6.66	4.95	5.62
Maximum Increase in Water Elevation [m]	1.96	1.62	1.61	2.41	0.93	1.06
Maximum Average Flow Velocity [m/s]	10.81	4.29	4.34	5.46	2.83	2.35

*Stations are measured in metres from Trout Creek mouth to Isintok Reservoir. Recorded times are in hours and are recorded from the beginning of the breach.

Table 4.2 - 2.5 Hour Dam Breach Results*

Station	40+200	20+400	14+740	2+990	1+100	0+487
Station Description	Below Isintok	Kettle Xing	Bathville Xing	Ped Bridge	Above HwY97	Near Mouth
Peak Discharge [cms]	231	180	144	93	88	84
Time to Wave Arrival [hr]	0.13	1.98	3.09	4.88	5.21	5.54
Time to Peak Flow [hr]	1.95	3.53	4.91	7.35	7.83	8.43
Duration of Elevated Water Level [hr]*	3.81	4.69	5.51	7.75	8.33	8.18
Maximum Increase in Water Elevation [m]	1.43	1.18	1.13	1.73	0.64	0.79
Maximum Average Flow Velocity [m/s]	9.28	3.62	3.57	4.70	2.31	2.03

*Stations are measured in metres from Trout Creek mouth to Isintok Reservoir. Recorded times are in hours and are recorded from the beginning of the breach.

As listed in Table 4.1, the 1.0-hour breach travels significantly faster than the 2.5-hour breach. With a travel time of 4.47 hours through the 40 kilometre water course, the 1.0-hour wave is larger, more intense, and travels an average of almost 24% faster than the 2.5 hour wave. The increase in water elevation is also greater for the 1.0-hour breach; however, the duration of elevated flood waters is significantly longer for the 2.5-hour breach. The levels of elevated water and maximum flows at each station are described in the following section.

4.2 INUNDATION MAPPING

The maximum resulting surface profiles obtained from the 1.0-hour piping breach simulation was exported back to CAD for inundation plotting. There are two plots detailing the inundated areas and potential flood depths, Figure 4.1 and Figure 4.2. The first plot displays the rural upland area and the second displays the corridor through the District of Summerland in lower Trout Creek.

Figure 4.2 displays a large flooded area just upstream from the Highway 97 crossing. This is a result of the narrow cross section under the Highway 97 bridge. Although the plot shows the flood waters extending north approximately 800 m along Highway 97's west ditch, it is likely that the duration of the peak elevated flood waters will not be sufficient to extend the water this far. The model acts conservatively in this case due to its limitations in modeling hydraulic capacity perpendicular to the creeks alignment.

Since only maximum water elevations are shown in the inundation mapping, it is important to note that damage would be created by not only the depth of flooding, but also the higher velocities. Table 4.1 in the previous section describes average velocities of the channel of up to approximately 10 m/s (36 km/h). The max velocities experienced at any station would be significantly higher. The narrower flood sections in the inundation plots are potentially much more hazardous. The following section describes the hazard levels associated with various flow velocities and water depths.

4.3 IMPACT OF DAM FAILURE TO LIFE AND PERSONAL PROPERTY

A failure of the Isintok Dam carries a high potential for loss of life and damage to personal property. Although the extent of damage cannot be determined exactly, the hazard level for all areas inundated by flood waters can be estimated for adults, cars, and houses by flood depth and velocity as shown in Figures 4.3, 4.4 and 4.5 respectively.

Figure 4.3 – Estimated Hazard Level for Adults (USBR, 1988)

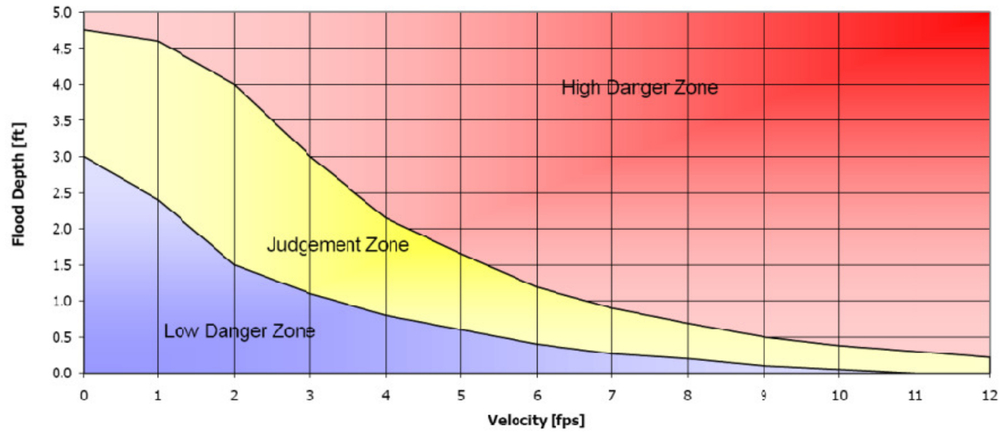


Figure 4.4 – Estimated Hazard Level for Cars (USBR, 1988)

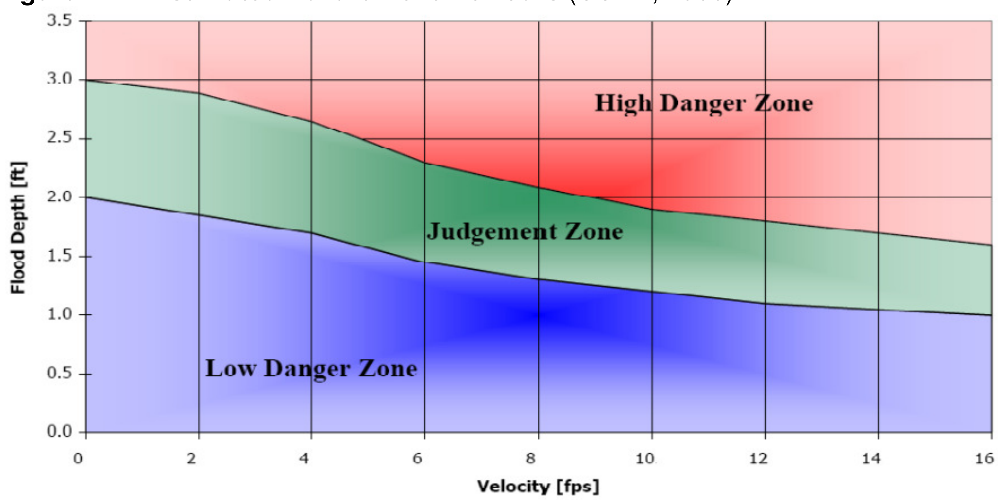
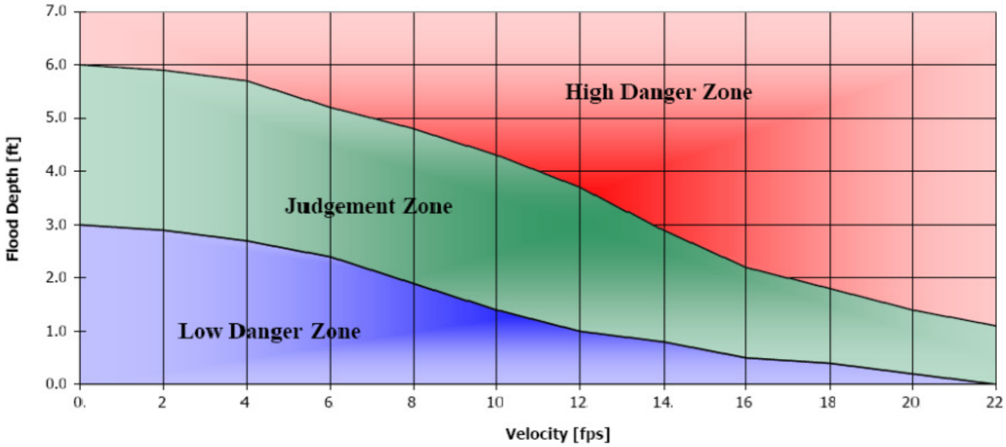


Figure 4.5 – Estimated Hazard Level for Houses (USBR, 1988)



A total of 56 building structures are located within the flood inundated areas, most of which are residences with hazard level ranging from low to high danger. Although the hazard level is varies, the structures residing along Trout Creek would be seriously damaged. A list of addresses has been listed in Table ~~4.3.1~~ in the Appendix A.

Assuming approximately 3 residents per structure, there are 168 persons at risk with the addition of temporary residents. Approximately 30% of this population is estimated to be residing in the rural upland area while the remaining population reside near the mouth of Trout Creek in the District of Summerland.

4.4 IMPACT OF DAM FAILURE TO ROADS AND OTHER PUBLIC INFRASTRUCTURE

There are 2 bridge crossings along Isintok Creek and another 8 along Trout Creek. All bridges will likely be washed away with the exception of the Highway 97 crossing and the Kelowna Valley Railway Bridge and pedestrian crossing. However, the high flow velocities along the abutments of the Hwy 97 crossing may cause significant damage.

Due to the destruction or damage to the bridges, access to rural areas on the south side of Trout Creek will be drastically hindered. Furthermore, earth embankments along the railway and parts of Bathville Road are at risk to erosion. Table 4.3 details the bridges that will be impacted by the breach wave.

Table 4.3 – Impact to Bridge Structures*

Xing No.	Crossing	Creek	Damage*
1	Limited Use Road	Isintok	Extreme
2	Bathville Road	Isintok	Extreme
3	Limited Use Road	Trout	Extreme
4	Kettle Place	Trout	Extreme
5	Private Access	Trout	Extreme
6	Private Access	Trout	Extreme
7	Bathville Road	Trout	Extreme
8	Pedestrian	Trout	None
9	KVR Crossing	Trout	None
10	Highway 97	Troute	Moderate

*Damage ratings are estimated.

The District of Summerland's main drinking water intake may also be at risk. At a location of approximately 16 kilometres from Trout Creek's mouth, the intake relies on an in-stream weir to divert water into an open flume. Under the conditions of a 1.0-hour dam breach, this structure will experience approximately 280 cms of flow and an average flow velocity in excess of 4 m/s. This impact could damage or washout the weir structure and deactivate the District's main drinking water intake.

5. DAM CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The failure of the Isintok Dam will produce a large and fast traveling flood wave. It will cause severe damage to the environment, roadways, bridges, private property, and public infrastructure as well as pose an extreme safety risk to local residents.

The following is a summary of the conclusions of this report:

C-1 The Isintok Dam is considered to be of HIGH consequence in the event of failure;

C-2 The estimated time to full formation for a piping or overtopping breach failure is between 1 and 2.5 hours;

C-3 The maximum flood wave predicted has a peak discharge 376 cms at the dam and attenuates to approximately 143 cms near the Trout Creek Mouth;

C-4 The estimated travel time for the maximum predicted flood wave is approximately 4.47 hours from time of breach initiation until wave arrival at the Trout Creek mouth;

C-5 Flood inundated areas are illustrated on Figure 4.1 and 4.2;

C-6 A total of approximately 56 structures located in areas of flooding. Although the hazard level varies, the structures residing along Trout Creeks will likely be seriously damaged or destroyed. A list of addresses indicating their level of hazard has been included in the Appendix A;

C-7 Approximately 168 permanent residents are at risk with additional seasonal or temporary residents also at risk. Approximately 30% of these residents reside in upland rural areas;

C-8 There are 10 bridge structures along the Isintok to Okanagan Lake water course. It is estimated that 7 bridges will be destroyed or damaged and the Highway 97 crossing is at risk of erosion damage;

C-9 Access to the upland south side of Trout creek and areas along Isintok creek will be rendered inaccessible by motor vehicle and heavy erosion to the railroad embankments is expected;

C-10 Water supply from Trout Creek will likely be out-of-service due to damage that would be experienced at the District's open flume diversion.

5.2 RECOMMENDATIONS

Considering the conclusions presented above, the following recommendations have been presented.

R-1 It is recommended that the DoS should take every precaution to undertake all preventative requirements as set out by the MoE and CDA. These precautions should be carried out as soon as possible;

R-2 An early warning system able to detect sudden increases of flow below the Isintok Reservoir should be installed. A weir or similar measuring infrastructure should be installed immediately and located at the base of the earth dam and should be maintained and monitored by operations staff. In time, this weir should be fitted with means of remotely communicating a high flow alarm. Furthermore, means of communicating the alarm to the appropriate authorities for initiation of the EPP should be put in place;

R-3 It is recommended that the inundation maps and property addresses generated from this report be incorporated into the District of Summerland Emergency Response Plan. Furthermore, the District of Summerland staff and emergency service personnel should be made aware of these documents and their whereabouts;

R-4 The Emergency response planning should account for the potential damage to the primary water supply source for Summerland. In addition, the inaccessibility to the south side of Trout creek and areas along Isintok creek should be considered.

R-5 The District of Summerland should consider means in which to install remote monitoring equipment and radio links to have long-term recorded data for dam seepage and spillway flows;

R-6 It has been noted that the spillway at the Isintok Reservoir may have restricted capacity. A review of the spillway's width and capacity should be carried out to determine whether or not improvements would reduce the risk of overtopping failure of Isintok Dam;

R-7 A review of Highway 97 bridge and abutment armouring should be carried out with the Ministry of Transportation to determine what improvements might reduce the risk of loss of this primary transportation corridor;

R-8 This report should form as an appendix to the Comprehensive District of Summerland Dam Safety Review that is currently underway.

APPENDIX A - REPORT FIGURES

Table A.1 – Inundated Structures List: Through Summerland along Trout Creek

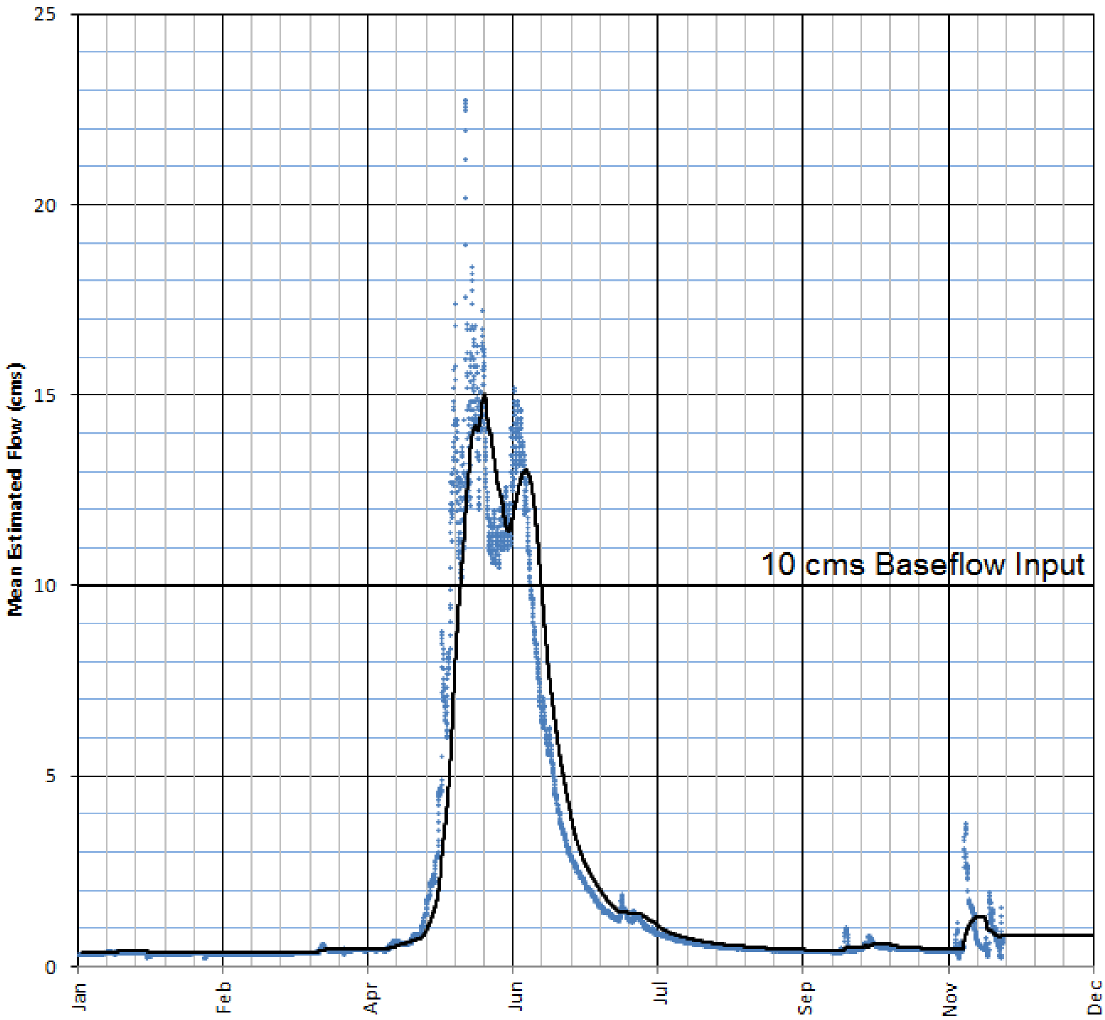
no.	street	description
4810	Croil Ave	Residence
4811	Croil Ave	Residence
901	Dent St	Residence
903	Dent St	Residence
906	Dent St	Residence
913	Dent St	Residence
914	Dent St	Residence
4201	Highway 97	Residence
4203	Highway 97	Residence
5218	Highway 97 97	Residence
5408	Highway 97 97	Residence
2106	Johnson St	Residence
2110	Johnson St	Residence
3919	Moragn St	B
3919	Morgan St	A
4200	Morgan St	PRV
4204	Morgan St	Residence
4204	Morgan St	Pickers Cabin
5609	Pine Ave	Residence
5013	Towgood	Residence
5015	Towgood	Residence
5011	Towgood Pl	A
5011	Towgood Pl	B*
4211	Williams Ave	Residence
4218	Williams Ave	Residence
4405	Williams Ave	Residence
4406	Williams Ave	Residence
4415	Williams AVe	Residence
4416	Williams Ave	Residence
4417	Williams Ave	Residence
4420	Williams Ave	Residence
4615	Williams Ave	Residence
4620	Williams Ave	Residence
4803	Williams Ave	Residence
4816	Williams Ave	A
4816	Williams Ave	B
2107	Willow Ave	A
2107	Willow Ave	B
4620	Woods Ave	Residence
4809	Woods Ave	Residence

*Plus all seasonal trailers

Table A.2 – Inundated Structures List: Upland Areas Street Names (All Structures as Identified by Figure 4.1)

street name	no. Structures
Bathville Rd	3
Hillside Rd	1
Kereluk Rd N	3
Kereluk Rd S	1
Deans Rd	4
Princton Summerland Rd	2
Kettle Pl	3

Figure A.1 - HEC-RAS Estimated Base Flow for Trout Creek*



*The Trout Creek flow has been estimated from an adjacent catchment area of known outflow. The raw data shown in blue was collected from hydrological data collected at the base of Camp Creek and multiplied by 10 times. The solid line displays a 15-day moving average of this data (removes real-time spikes in flow).

Table A.3 - Output Data for 1.0hr and 2.5hr Dam Breaches

	STN [m]	Q [cms]	W.S.Elev [m]	Crit. Elev. [m]	E.G.Elev. [m]	Vel.Ch. [m/s]	Froude [#]
1.0 HR Breach	40+200	367.83	1645.85	1647.19	1650.51	10.81	2.29
	20+400	289.77	678.16	678.09	678.92	4.29	0.93
	14+740	252.64	619.07	619.24	620.00	4.34	1.15
	2+990	163.58	407.19	407.62	408.71	5.46	1.38
	1+100	153.72	351.15	-	351.45	2.83	0.75
	0+487	145.70	345.32	345.28	345.49	2.35	0.70
2.5 HR Breach	40+200	246.21	1645.40	1646.44	1648.99	9.28	2.20
	20+400	179.74	677.66	677.53	648.22	3.62	0.89
	14+740	143.98	618.69	618.78	619.32	3.57	1.10
	2+990	93.57	406.60	406.90	407.73	4.70	1.32
	1+100	88.28	350.79	-	351.00	2.31	0.70
	0+487	83.77	345.14	345.00	345.30	2.03	0.66

Figure A.2 - Flow and Water Elevation Graph Example

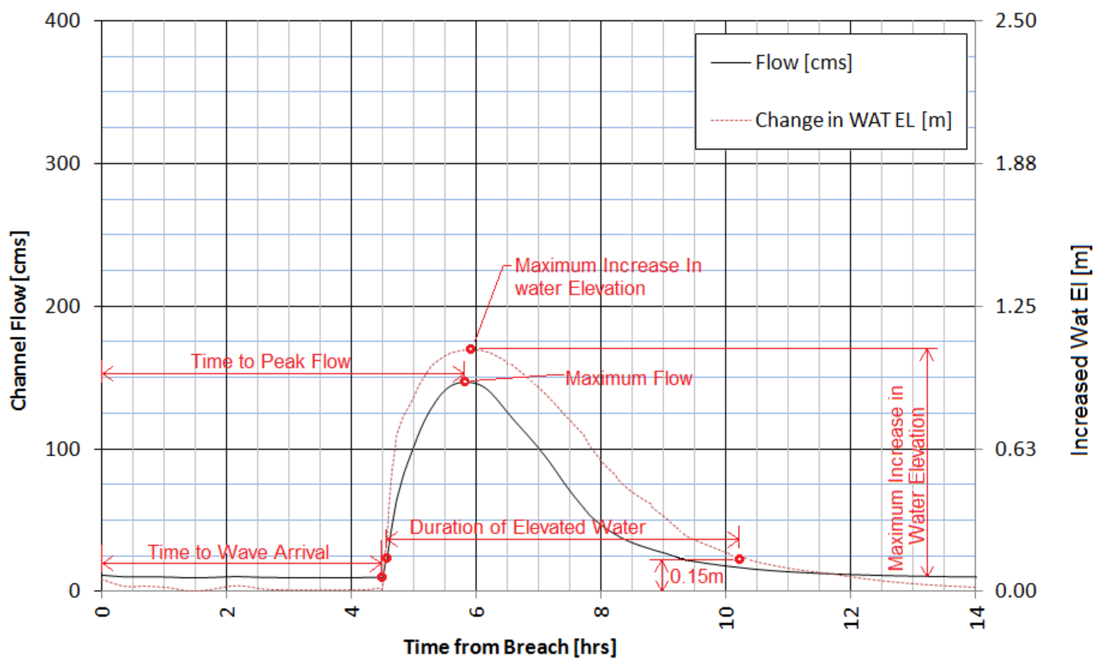


Figure A.3 - Output for Station 40+200 - 1.0 Hour Dam Breach Duration
(200m downstream of Isintok Dam)

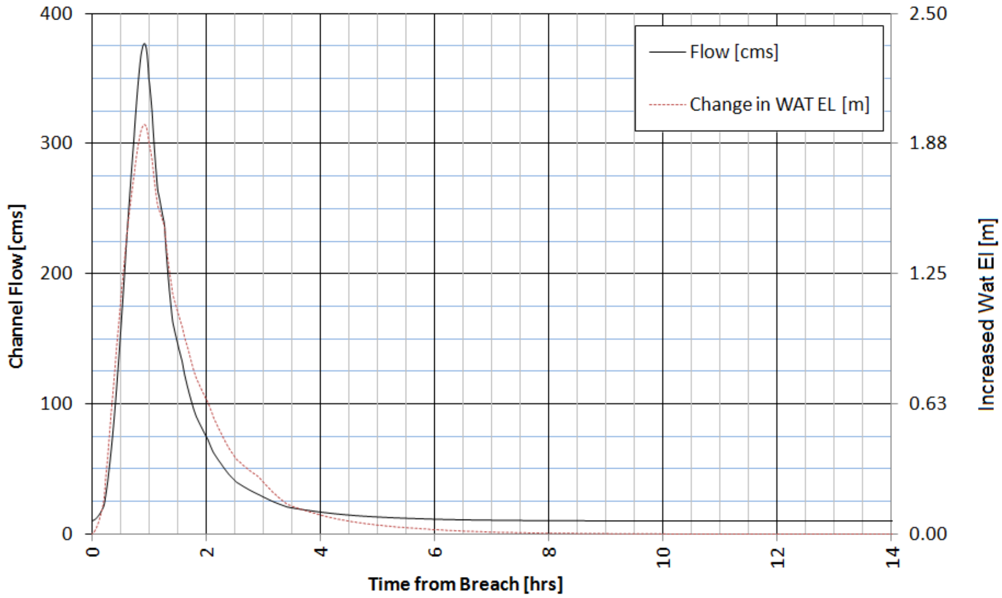


Figure A.4 - Output for Station 40+200 - 2.5 Hour Dam Breach Duration
(200m downstream of Isintok Dam)

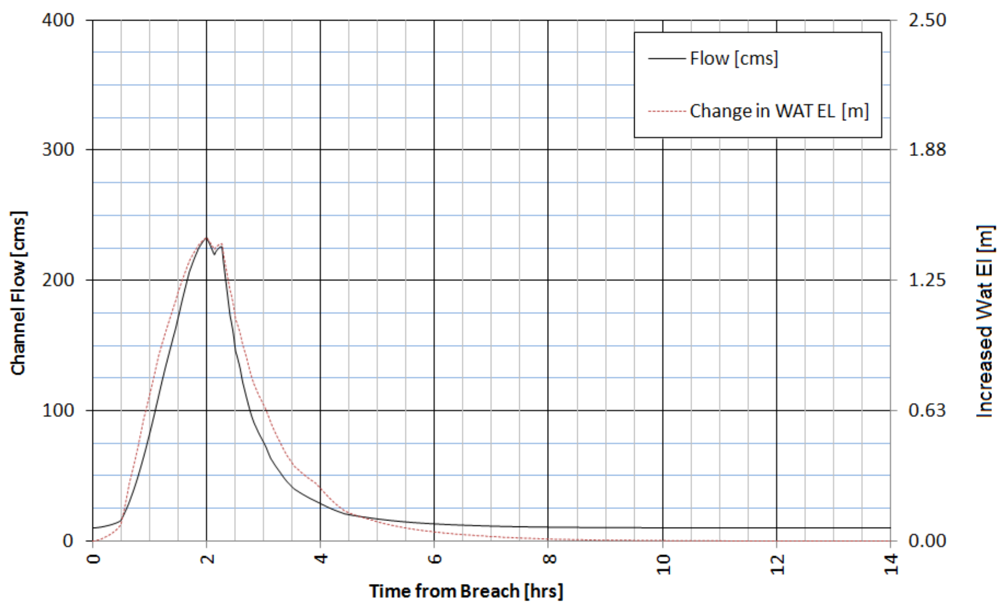


Figure A.5 - Output for Station 20+400 - 1.0 Hour Dam Breach Duration
(Kettle Place Crossing)

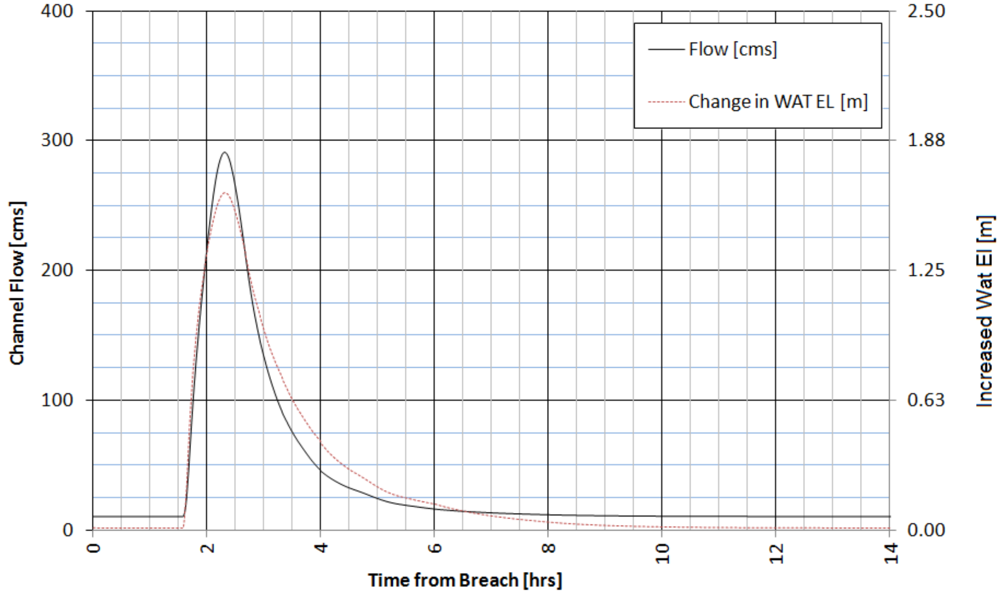


Figure A.6 - Output for Station 20+400 – 2.5 Hour Dam Breach Duration
(Kettle Place Crossing)

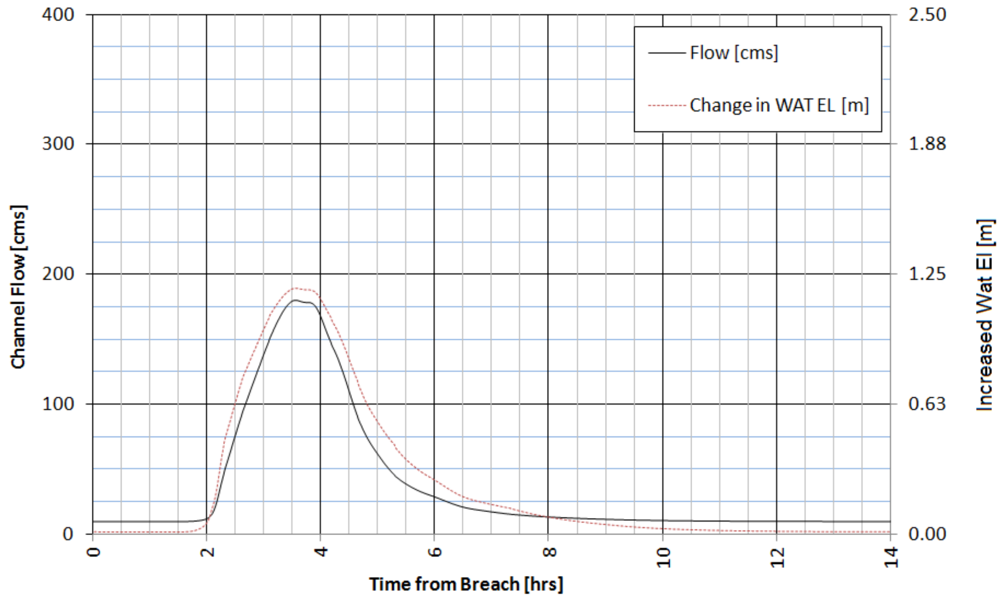


Figure A.7 - Output for Station 14+740 - 1.0 Hour Dam Breach Duration
(Bathville Road Crossing)

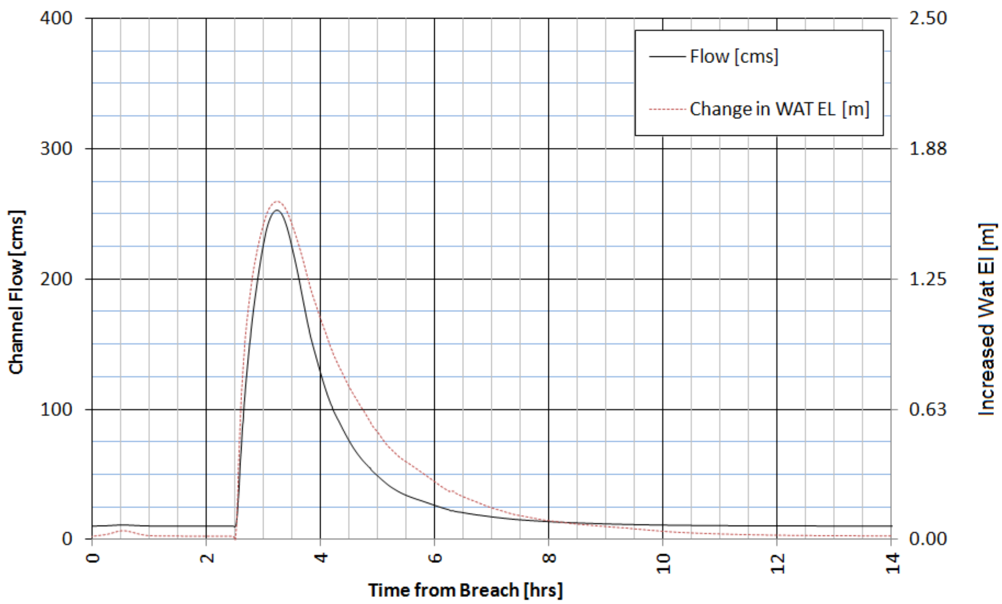


Figure A.8 - Output for Station 14+740 – 2.5 Hour Dam Breach Duration
(Bathville Road Crossing)

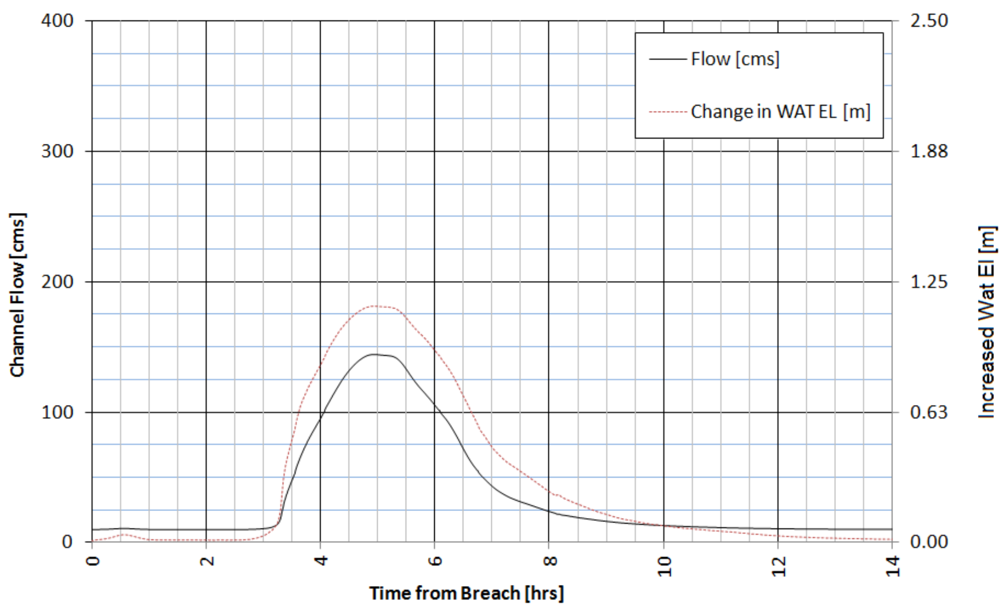


Figure A.9 - Output for Station 2+990 - 1.0 Hour Dam Breach Duration
(Pedestrian Bridge Upstream to KVR Bridge)

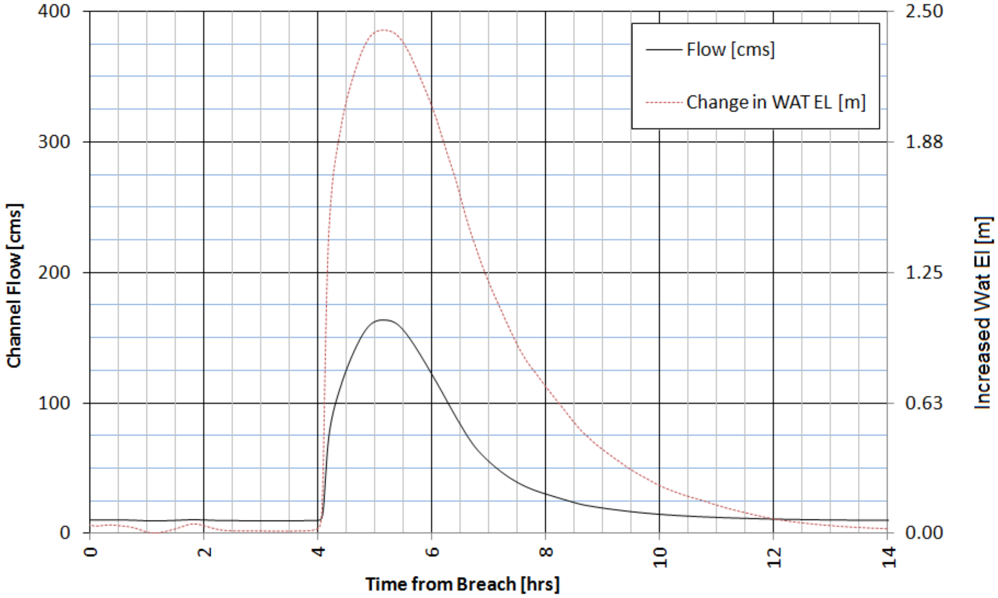


Figure A.10 - Output for Station 2+990 – 2.5 Hour Dam Breach Duration
(Pedestrian Bridge Upstream to KVR Bridge)

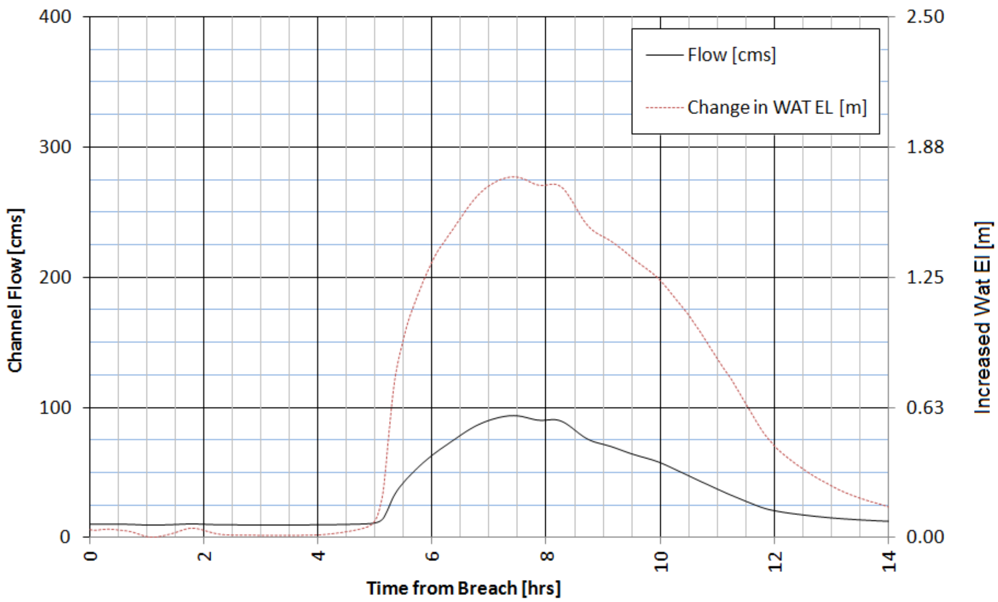


Figure A.11 - Output for Station 1+100 - 1.0 Hour Dam Breach Duration
(~400m upstream of Hwy 97 Crossing)

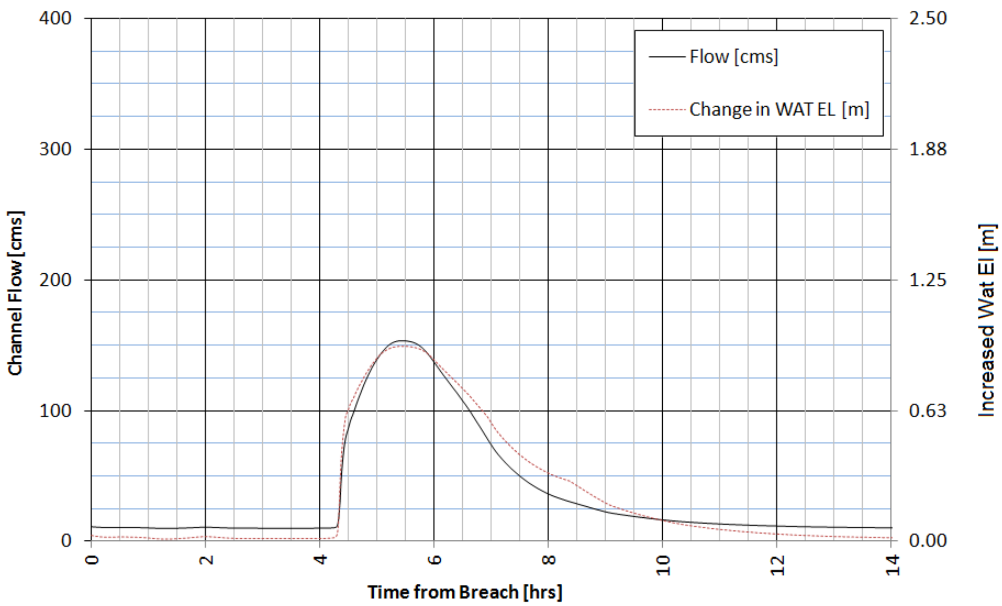


Figure A.12 - Output for Station 1+100 – 2.5 Hour Dam Breach Duration
(~400m upstream of Hwy 97 Crossing)

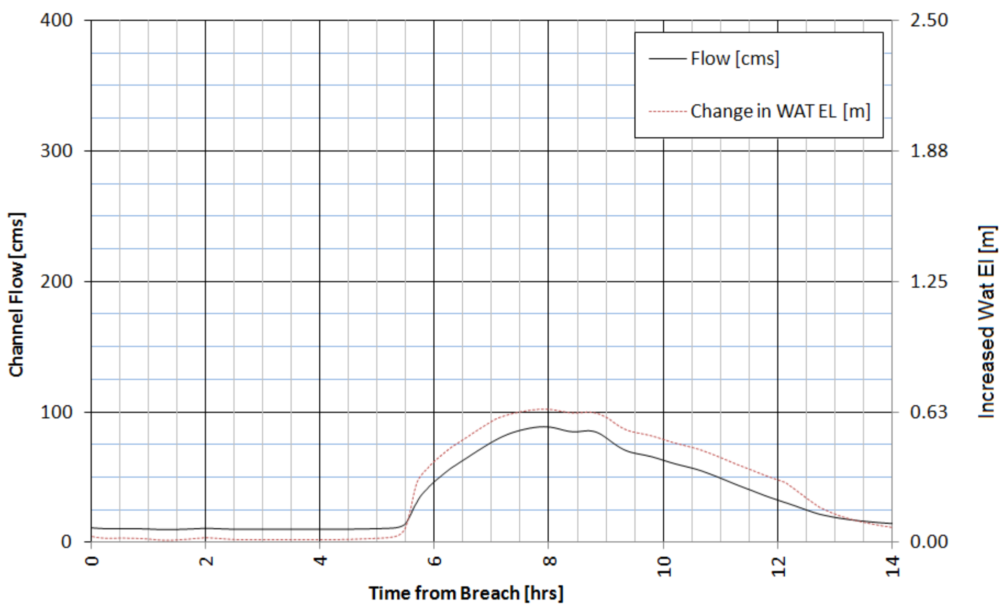


Figure A.13 - Output for Station 0+487 - 1.0 Hour Dam Breach Duration
(Between Trout Creek Mouth and Hwy 97 Crossing)

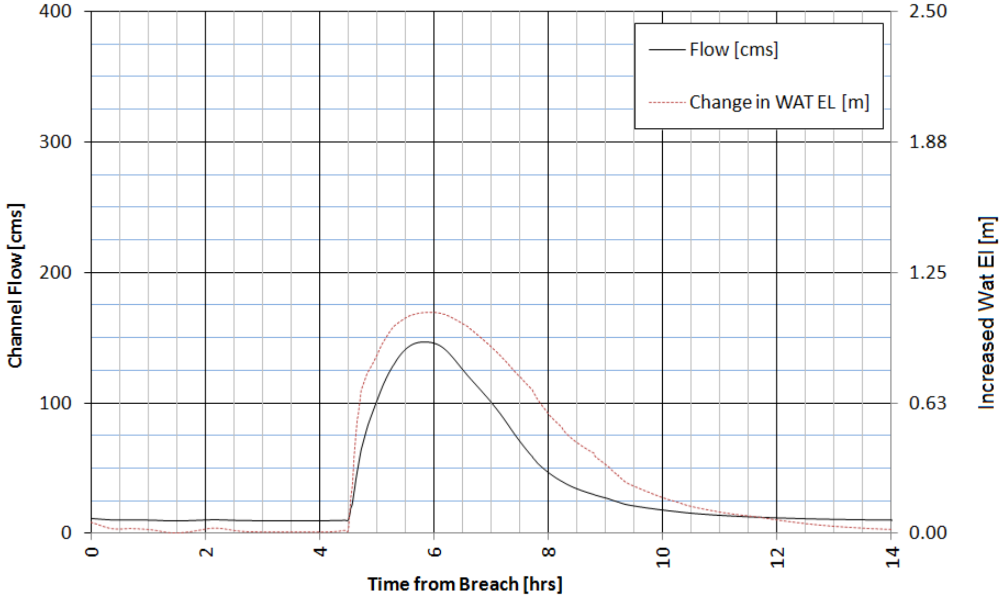
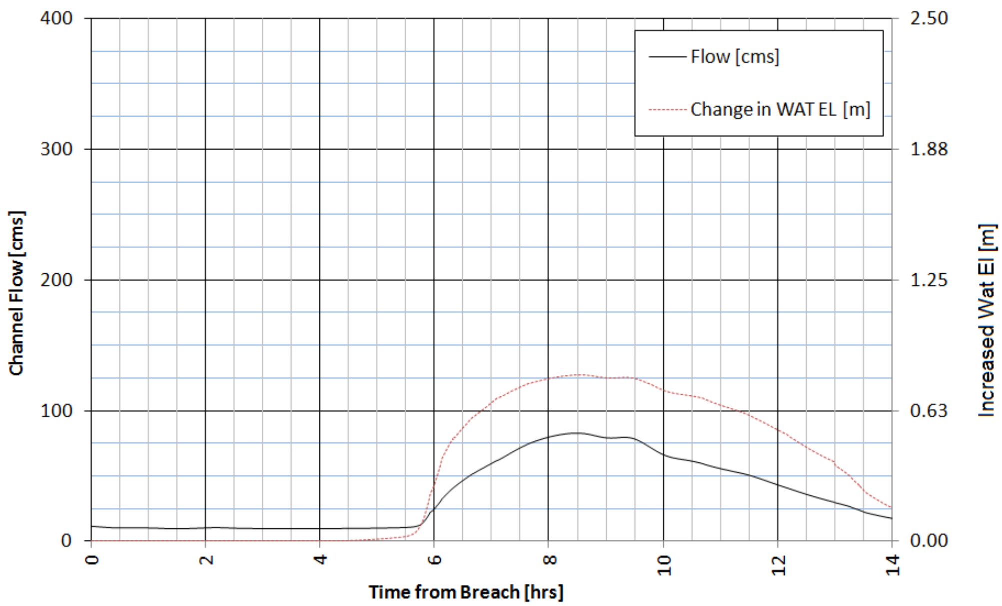


Figure A.14 - Output for Station 0+487 – 2.5 Hour Dam Breach Duration
(Between Trout Creek Mouth and Hwy 97 Crossing)



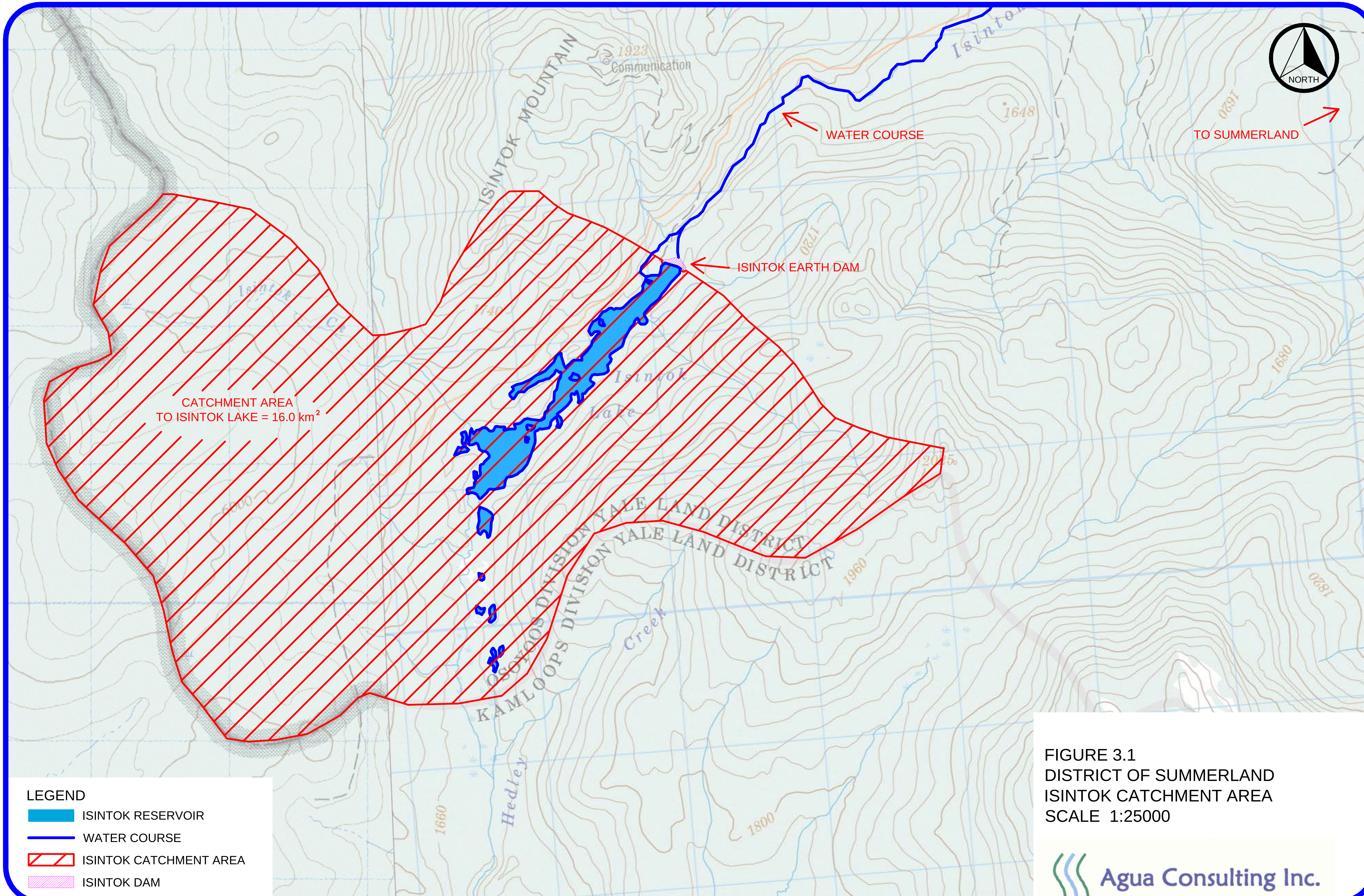


FIGURE 3.1
DISTRICT OF SUMMERLAND
ISINTOK CATCHMENT AREA
SCALE 1:25000

Agua Consulting Inc.
"Engineered Water Solutions"

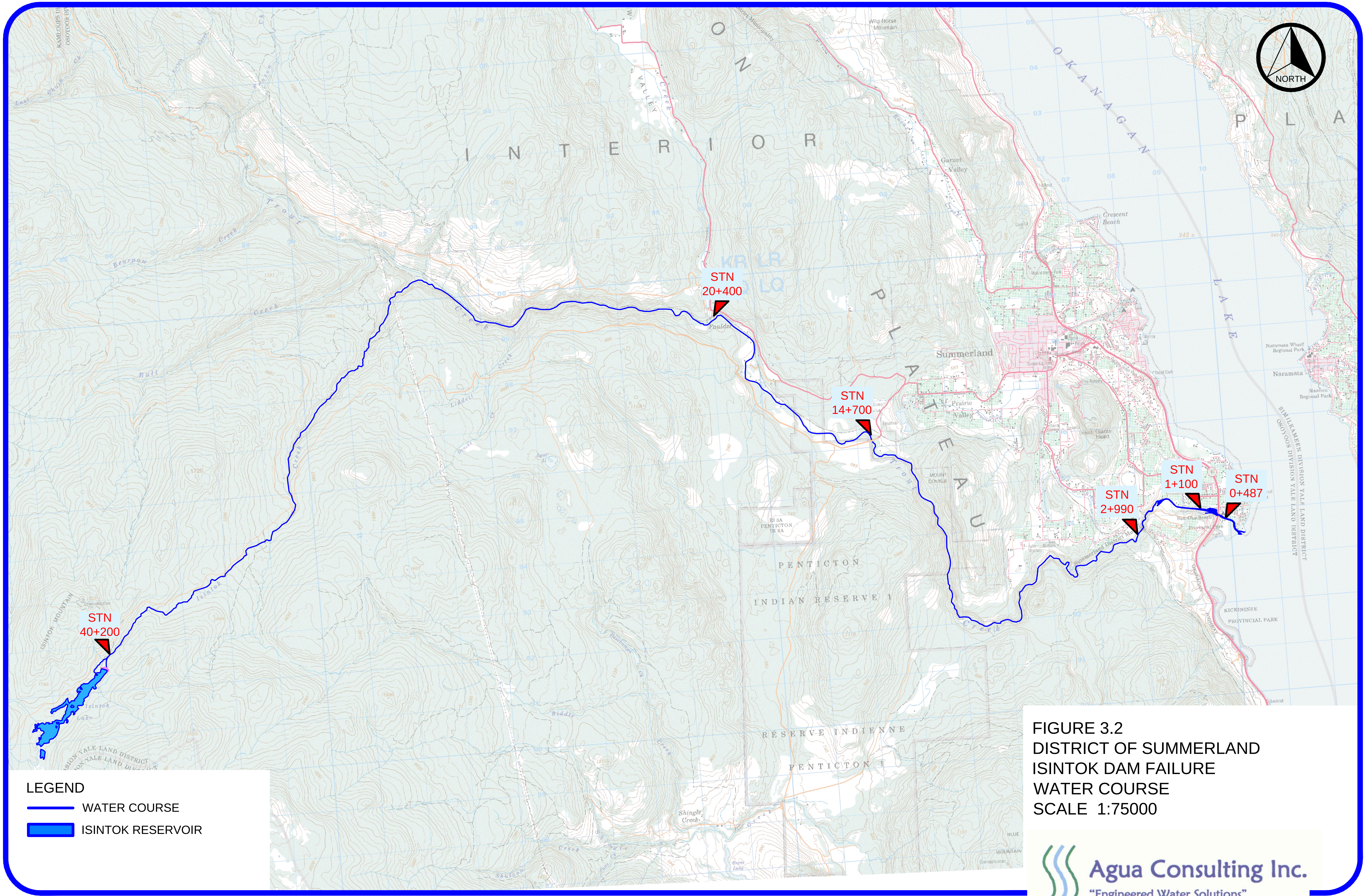
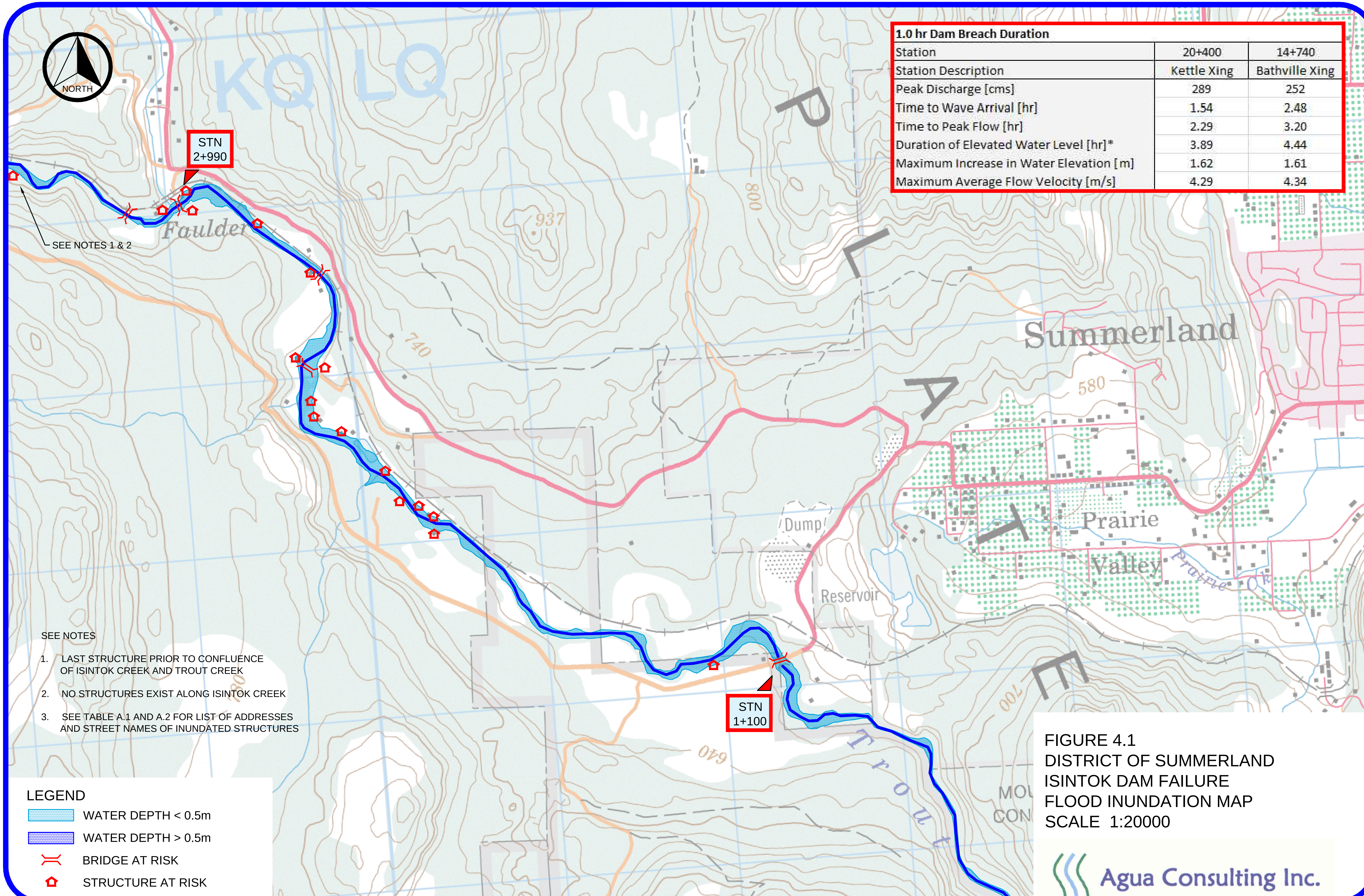


FIGURE 3.2
DISTRICT OF SUMMERLAND
ISINTOK DAM FAILURE
WATER COURSE
SCALE 1:75000

Agua Consulting Inc.
"Engineered Water Solutions"



1.0 hr Dam Breach Duration		
Station	20+400	14+740
Station Description	Kettle Xing	Bathville Xing
Peak Discharge [cms]	289	252
Time to Wave Arrival [hr]	1.54	2.48
Time to Peak Flow [hr]	2.29	3.20
Duration of Elevated Water Level [hr]*	3.89	4.44
Maximum Increase in Water Elevation [m]	1.62	1.61
Maximum Average Flow Velocity [m/s]	4.29	4.34

SEE NOTES

1. LAST STRUCTURE PRIOR TO CONFLUENCE OF ISINTOK CREEK AND TROUT CREEK
2. NO STRUCTURES EXIST ALONG ISINTOK CREEK
3. SEE TABLE A.1 AND A.2 FOR LIST OF ADDRESSES AND STREET NAMES OF INUNDATED STRUCTURES

LEGEND

- WATER DEPTH < 0.5m
- WATER DEPTH > 0.5m
- BRIDGE AT RISK
- STRUCTURE AT RISK

FIGURE 4.1
DISTRICT OF SUMMERLAND
ISINTOK DAM FAILURE
FLOOD INUNDATION MAP
SCALE 1:20000

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"Engineered Water Solutions"

1.0 hr Dam Breach Duration			
Station	2+990	1+100	0+487
Station Description	Ped Bridge	Above HwY97	Near Mouth
Peak Discharge [cms]	163	153	143
Time to Wave Arrival [hr]	4.04	4.32	4.47
Time to Peak Flow [hr]	5.14	5.41	5.83
Duration of Elevated Water Level [hr]*	6.66	4.95	5.62
Maximum Increase in Water Elevation [m]	2.41	0.93	1.06
Maximum Average Flow Velocity [m/s]	5.46	2.83	2.35

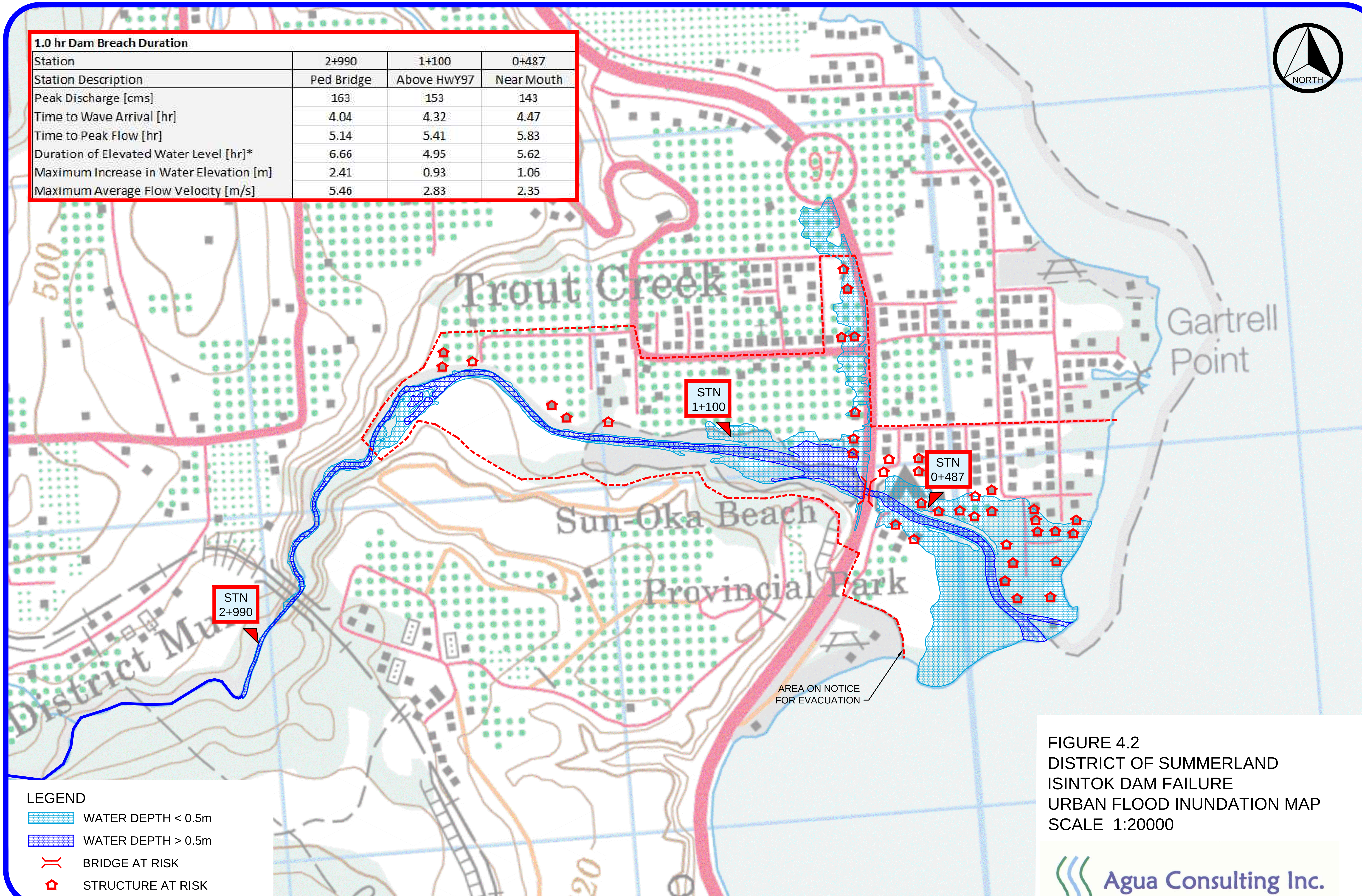

FIGURE 4.2
DISTRICT OF SUMMERLAND
ISINTOK DAM FAILURE
URBAN FLOOD INUNDATION MAP
SCALE 1:20000

Agua Consulting Inc.
"Engineered Water Solutions"