UPPER BOW RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

FINAL REPORT

Prepared for:

Alberta Government

Alberta Environment and Parks

26 June 2017

NHC Ref. No. 3001178

nhc
northwest hydraulic consultants
water resource specialists

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Prepared by:

Northwest Hydraulic Consultants Ltd.
North Vancouver, BC

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EXECUTIVE SUMMARY

Alberta Environment and Parks (AEP) retained Northwest Hydraulic Consultants Ltd. (NHC) in September 2015 to complete a river hazard study for the Bow River. The roughly 118 km long study reach extends from the Banff National Park boundary, located approximately 5 km upstream of the Town of Canmore, to Bearspaw Dam, near the City of Calgary western boundary. Within the Town of Canmore, the study area incorporates Policeman Creek, a channel roughly 6.5 km long situated on the Bow River floodplain and running parallel to the Bow River main channel. In addition, the study area includes three tributaries: the lower 1 km long reach of Exshaw Creek at the Hamlet of Exshaw; the lower 5 km of Bighill Creek at the Town of Cochrane; and the lower 5 km of Jumpingpound Creek at the Town of Cochrane.

The study is being conducted under the provincial Flood Hazard Identification Program (FHIP). Project stakeholders include the provincial government, Stoney First Nation, local authorities, and the public.

The overall objectives of this project are to identify and assess river related hazards and enhance public safety along the Bow River and the three tributaries included in the study area. The intent is to reduce potential future flood damages and disaster assistance costs to the federal, provincial, and local governments, as well as First Nations. New floodplain maps will inform land use planning decisions, assist with developing flood mitigation options and facilitate emergency response planning.

The Upper Bow River Hazard Study includes multiple components and deliverables. This report describes the results from the survey and base data collection phase of the project and forms the first of the study reports.

The objectives of the survey and base data collection are to complete the following tasks: river cross section survey; hydraulic and flood control structure data collection; survey and LiDAR-derived Digital Terrain Model (DTM) data integration; and aerial imagery acquisition.

River cross section surveys were conducted on the Bow River, Policeman Creek, Exshaw Creek, Jumpingpound Creek, and Bighill Creek in October 2015 and April/May 2016. Cross section surveys consisted of a combination of bathymetric and RTK GPS ground surveys. These surveys complement the LiDAR-derived DTM collected in 2015 by Airborne Imaging Inc. A total of 587 cross sections were surveyed, with 184 of the cross sections being re-surveyed along the alignment of previously surveyed cross sections. Geometric details of 50 bridge crossings, 21 culverts, and five flood control structures were collected. The overall accuracy of the measurements is considered to be ±0.07 m horizontally and vertically for the bathymetric points and ±0.05 m horizontally and vertically for the ground surveyed RTK points.

The October 2015 survey data was compared to the LiDAR-derived DTM. The comparison shows that, of 1,495 survey points selected, 92 percent are within 0.15 m of the LiDAR elevations and 96 percent are within 0.20 m.

Orthoshop Geomatics Ltd. collected colour aerial imagery for the study area on June 3rd, 2016 and used this imagery to generate 30 cm resolution colour-balanced ortho-rectified mosaics.

The collection of survey and base data will be used to support subsequent components of this study, primarily hydraulic modelling, flood mapping, flood risk assessment, and channel stability investigations.

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. (NHC) would like to express appreciation to Alberta Environment and Parks (AEP) for initiating this project, making available extensive background information and providing advice and support throughout the survey work. Key AEP representatives were Jane Eaket, P.Eng. (Project Manager) and Peter Onyshko, P.Eng. (Alternate Project Manager).

Special thanks are expressed to individuals from the Town of Canmore, the Municipal District of Bighorn, and the Town of Cochrane for assisting with the site visits and for providing valuable data for this study. Special thanks are also expressed to representatives from Stoney First Nation, specifically Ken Christensen and Stephan Doutre, as well as the Bearspaw, Chiniki, and Wesley liaisons who assisted with the field survey. Thanks are also expressed to individuals from Alberta Transportation and TransAlta for providing data and background information.

2016 aerial imagery was collected and processed by Orthoshop Geomatics Ltd.

The following NHC personnel were part of the study team and participated in the survey component of the study. Monica Mannerström, P.Eng. (Project Manager) ensured the overall direction of the project and survey work. Field surveys were planned, coordinated, and overseen by Dale Muir, P.Eng. (Survey Manager) who, during the surveys, was the main contact between AEP representatives, NHC office and field staff. Will Skitmore (survey lead) provided technical support and was responsible for the planning and processing of the control survey. Sarah North, GISP (GIS Specialist) and Vanessa O'Connor, P.Eng. (Project Hydraulic Engineer) assisted with the survey planning.

In the field, the fall 2015 survey crews were led by Daniel Arnold, PEng. (Survey Lead) with the assistance of Ken Roy (Survey Lead). Control, bathymetric and topographic surveys were conducted over a period of five weeks by teams of surveyors comprised of Daniel Arnold, Ken Roy, Justin Finn, Kyle Vetch, Lance Costain, Curtis Croisetiere, James Snyder, Antonio D'Agnone, Kate Neigel. Explore Surveys Inc. assisted with the river survey, providing a two-man crew (Wade Williams and James Revet) to help out over the duration of ten days.

The spring 2016 field survey was completed by Ken Roy (Survey Lead) and Aaron Snyder.

Post-processing of survey data and data verification were done by Ken Roy, James Snyder, Aaron Snyder, Sarah North and Vanessa O'Connor. This report was authored primarily by Vanessa O'Connor and Sarah North with contributions from other team members. Monica Mannerström and Dale Muir reviewed the report. Office support throughout the duration of the surveys component of the study was provided by Amber Loeppky and Carol Griffiths.

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1 INTRODUCTION

1.1 Project Background

Alberta Environment and Parks (AEP) retained Northwest Hydraulic Consultants Ltd. (NHC) in September 2015 to complete a river hazard study for the Upper Bow River, along a reach defined between the Banff National Park boundary at the upstream end and Bearspaw Dam at the downstream end. The study is being conducted under the provincial Flood Hazard Identification Program (FHIP).

The Bow River has been exposed to severe flooding in the past, with three extreme events occurring from the late 1800s to early 1900s, two around 1930, and, more recently, in 2013.

For the Bow River reach within the current study limits, provincial flood hazard mapping was previously prepared for Cochrane (Alberta Environment, 1990), Canmore (W-E-R Agra, 1993), and Municipal District (M.D.) of Bighorn (Acres, 1996). The Cochrane study was completed by Alberta Environment in 1986 with an addendum issued in 1990. The study reach covered 21 km of the Bow River (from Bearspaw Dam to upstream of the Town of Cochrane boundary) and the lower 4.5 to 5 km reaches of Jumpingpound and Bighill Creeks (two tributaries discharging to the Bow River within the Town of Cochrane limits). The M.D. of Bighorn study, completed by Acres International Ltd., includes a 15 km reach of the Bow River from the west boundary of Bow Valley Provincial Park to Dead Man Flats and includes the lower one kilometre reach of Exshaw Creek. The Canmore study completed by W-E-R Agra Ltd. covered a 20 km reach of Bow River from Dead Man's Flats, through the Town of Canmore (including Policeman Creek), to the Banff National Park boundary.

AEP identified a need to update and expand the coverage of this mapping following the 2013 floods. Stakeholders of the present project are the Government of Alberta, the Town of Canmore, the M.D. of Bighorn, Stoney Nakoda First Nation, Rocky View County, the Town of Cochrane, and the public.

1.2 Project Objectives

The overall objectives of this project are to identify and assess river related hazards and enhance public safety along the Bow River and three tributaries included in the study area. The intent is to reduce potential future flood damages and disaster assistance costs to the federal, provincial, and local governments, as well as First Nations. New floodplain maps will inform land use planning decisions, assist with developing flood mitigation options and facilitate emergency response planning.

Specific study components, as outlined in the AEP Upper Bow River Hazard Study Terms of Reference, are:

- survey and base data collection;
- hydraulic model development, calibration and validation;
- open water flood inundation map production;

- open water flood hazard identification;
- ice jam assessment and associated flood hazard identification;
- governing flood hazard map production;
- flood risk assessment and inventory; and
- channel stability investigation.

The results of each component will be summarized in individual stand-alone reports. The current report describes the results from the survey and base data collection phase of the project and forms the first of the Upper Bow River Hazard Study reports.

The objectives of the survey and base data collection phase of the project are to complete the following tasks:

- river cross section survey;
- hydraulic and flood control structure data collection;
- survey and LiDAR-derived Digital Terrain Model (DTM) data integration; and
- aerial imagery acquisition.

1.3 Study Area and Reach

From the Bow River headwaters at Bow Lake (Elev. 1940 m), just north of Lake Louise, the river flows in a south-easterly to easterly direction over nearly 600 km before draining into the South Saskatchewan River. The Upper Bow River study area comprises a roughly 118 km long reach, extending from the Banff National Park boundary, located approximately 5 km upstream of the Town of Canmore, to Bearspaw Dam, near the City of Calgary western boundary. Within the Town of Canmore, the study area incorporates Policeman Creek, an inlet controlled high water channel roughly 6.5 km long situated on the floodplain and running parallel to the Bow River main channel. In addition, the study area includes three tributaries:

- the lower 1 km long reach of Exshaw Creek at the Hamlet of Exshaw;
- the lower 5 km of Bighill Creek at the Town of Cochrane; and
- the lower 5 km of Jumpingpound Creek at the Town of Cochrane.

Flow is regulated both on the Bow River main stem and on several tributaries. In addition to the Bearspaw Dam at the downstream end, the Ghost, Horseshoe Falls, and Kananaskis Dams also impound the river. The study area is shown in Figure 1.

STONEY NO. 142B

M.D. OF BIGHORN

STONEY NO. 142, 143, 144

CANMORE

ROCKY VIEW COUNTY

TSUU T'INA NATION NO. 145

COCHRANE

CALGARY

MORLEY

SEEBE

EXSHAW

Ghost River

Ghost Reservoir

Lac des Arcs

Bow River

Bighill Creek

Jumpingpound Creek

Exshaw Creek

Policeman Creek

Ghost Dam

Horseshoe Dam

Kananaskis Dam

Bearspaw Dam

STUDY LIMIT

KM 115

KM 110

KM 105

KM 100

KM 95

KM 90

KM 85

KM 80

KM 75

KM 70

KM 65

KM 60

KM 55

KM 50

KM 45

KM 40

KM 35

KM 30

KM 25

KM 20

KM 15

KM 10

KM 5

KM 0

DRAFT

Alberta Government

nhc northwest hydraulic consultants

Model Stream Network (with chainage)

Dam

Summer Village

Town

City

First Nations Land

County or Municipal District

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:200,000

0 1 2 3 4 5 6 7 8 KM

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178

Date: 22-NOV-2016

UPPER BOW RIVER HAZARD STUDY

STUDY AREA

FIGURE 1

\MSN_\\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Fig_T1_StudyArea2.mxd

2 SURVEY PROGRAM AND DATA

2.1 Procedures

The survey was completed in two phases. The first phase of survey work took place during the month of October 2015 with up to four crews of survey specialists working concurrently to complete the work before the onset of winter and ice forming on the river. The dates and reaches surveyed by each crew are summarised in Table 1.

Table 1 Overview of Reaches Surveyed October 2015, by Date and Crew

Date October 2015		Crew 1			Crew 2			Crew 3			Crew 4		
		Stream	From km	To km	Stream	From km	To km	Stream	From km	To km	Stream	From km	To km
Wed	7							survey control			Exshaw	0	1
Thu	8							survey control					
Fri	9										Policeman	0	3
Sat	10										Policeman	3	6.5
Sun	11												
Mon	12										Bighill	0	2
Tue	13										Bighill	2	4.5
Wed	14	equipment									Bighill	4.5	6.5
Thu	15	Bow	87	93	Bow	87	93	Bow	77	80	Bighill	structures	
Fri	16	control			Bow	95	96	Bow	77	85	Jumping pound	0	2
Sat	17	equipment			Bow	89	103	Bow	80	87	Jumping pound	2	5
Sun	18	Bow	93	104	Bow	104	106	Bow	104	118			
Mon	19	Bow	104	113	Bow	99	108	Bow	104	105			
Tue	20	Bow	108	109	Bow	structures		Bow	74	77			
Wed	21	Bow	102	111	Bow	106	111	Bow	109	109			
Thu	22							Bow	87	113			
Fri	23							Bow	43	91			
Sat	24	Bow	6	9									
Sun	25	Bow	0	11									
Mon	26	Bow	17	20				Bow	37	42			
Tue	27	Bow	11	17				Bow	31	42			
Wed	28							Bow	25	31			
Thu	29	Bow	20	25				Bow	83	102			
Fri	30	Bow	86	104				Bow	misc				

Notes:

1. River stations were rounded to the nearest kilometre.
2. Overlap in surveyed reaches can be attributed to:
   - data at one cross section having been collected over multiple days (i.e., structure survey done separately);
   - a ground crew and a boat crew working in tandem; and
   - Bow River cross sections not being surveyed in sequence.

The second phase of surveying took place from April 26th to May 27th, 2016. This survey included cross sections on the Bow River at Stoney Nakoda First Nation, survey of the Morley Bridge, as well as additional surveying at several locations throughout the study area.

The field program included:

- river cross section survey;
- hydraulic structure data collection (bridges and culverts);
- flood control structure data collection;
- other feature data collection;
- LiDAR and aerial imagery tie-in survey; and
- tie in of AEP local high water mark benchmarks.

Processed survey data are provided in 3-Degree Transverse Mercator (3TM) 114 Canadian Spatial Reference System North American Datum of 1983 (NAD83 CSRS) horizontal coordinates and HTv2.0 geoid. The vertical datum is the Canadian Vertical Datum of 1928 (CGVD28).

2.2 Cross Sections

Surveyed cross section locations were selected to ensure adequate representation of the channel geometry in the hydraulic model and to support historical cross section comparisons by re-surveying along the same alignments as previously surveyed sections. A total of 587 cross sections were surveyed with 184 of the sections being re-surveyed along the alignment of historical sections. The Survey Results Map (Sheets 1 to 10) show the location of the surveyed cross sections. The data is colour-coded according to the survey data type (historical versus new cross section locations), and the locations of dams, bridges, culverts, and flood control structures are also shown.

The number and spacing of surveyed cross sections are summarized in Table 2 for the Bow River, Policeman Creek, and the three tributaries. In Table 2, the Bow River was divided into three sub-reaches measuring roughly 40 km each. Values are also reported for these three sub-reaches.

Table 2 Summary of Surveyed Cross Sections

Description	Reach length (km)	Reach start stationing (km)	Reach end stationing (km)	Total number of sections	Number of historic sections resurveyed	Max spacing (m)	Min spacing (m)	Avg spacing (m)
Bow River - All	118.1	0	118.1	368	132	1703	15	321
Bearspaw Dam to Ghost Dam	42.1	0	42.1	157	54	973	27	266
Ghost Dam to Horseshoe Dam	31.8	42.1	73.9	71	n/a	1703	54	438
Horseshoe Dam to Banff Park Boundary	44.2	73.9	118.1	140	78	893	15	303
Policeman Creek	6.5	0	6.5	73	17	280	2	85
Exshaw Creek	1.3	0	1.3	22	3	168	9	64
Jumpingpound Creek	5.2	0	5.2	47	20	220	46	113
Bighill Creek	5.0	0	5.0	77	16	182	3	64

During the survey planning phase, the location and number of sections were refined to obtain an appropriate hydraulic representation of the Bow River, Policeman Creek and the tributaries (Exshaw Creek, Jumpingpound Creek, and Bighill Creek) to be modelled. The number of sections along Ghost and Bearspaw reservoirs was decreased (i.e., increasing section spacing) while sections were added between historic sections in other more hydraulically complex reaches of the Bow River (primarily near Cochrane and Canmore), Policeman Creek and along the tributaries (Exshaw Creek, Jumpingpound Creek, and Bighill Creek). The minimum cross section spacing typically occurs at bridge crossings, while the maximum cross section spacing occurs along wide uniform reaches, such as Bearspaw and Ghost reservoirs. On average, sections are spaced every 320 m on the Bow River and every 50 to 100 m on Policeman Creek and the tributaries (Exshaw Creek, Jumpingpound Creek, and Bighill Creek).

The surveyed cross section data will be used to define the channel and bank geometry for the hydraulic model cross sections. Cross section data within the overbank areas will be derived from the LiDAR-derived DTM.

Processed cross section survey data is provided digitally in Appendix E.

The following minimum data was captured:

- seven points within the wetted portion of the section;
- edge of water at both banks;
- major slope breaks (greater than 2 m horizontal or vertical distance from adjacent points) to top of bank;

- top of bank; and
- two additional data points above top of bank extending 10 m or farther from the edge of bank.

Geo-referenced photographs taken at cross sections were compiled in GIS. The information is provided digitally with this report.

NHC's survey data may be supplemented by bathymetric survey data for the Ghost Reservoir collected by Golder in April and July 2015 (Golder, 2015a), Bow River survey data collected by Golder in October and November 2015 (Golder, 2015b), and survey data for Canmore collected by McElhanney Consulting Services Ltd. in Spring 2015 (undocumented data received from Blair Birch, Town of Canmore, July 10, 2015).

2.3 Longitudinal Profiles

Longitudinal profiles of the Bow River, Policeman Creek and the tributaries (Exshaw Creek, Jumpingpound Creek, and Bighill Creek) are included in the Maps and Drawings section. The profiles show the surveyed thalweg elevations and surveyed water surface elevations at each cross section. Also included for reference are locations of confluences, dams, and WSC gauges.

Water surface elevations were extracted from the LiDAR-based DTM along the Bow River stream centreline and are plotted for comparison. At cross sections with islands or multiple branched channels, more than two water surface elevations were surveyed and plotted. Differences in water surface elevations between the main and side channels were typically observed at these cross sections.

2.4 Hydraulic Structures

A total of 50 bridge crossings and 21 culverts were surveyed within the study area. Information on bridges was collected either by survey or from design or record drawings and survey-verified. Design drawings were provided by Alberta Transportation and by municipalities of Canmore and Cochrane. The structures surveyed by NHC are shown on the Survey Results Map (Sheets 1 to 10) and are described in the following sections and tables.

2.4.1 Bridges

During data collection, the following items were recorded for each bridge:

- Top of roadway profile (centerline)
- Span length
- Bridge width
- Top elevation (top of curb or solid guard rail – upstream and downstream side)
- Low chord elevation (soffit – upstream and downstream)

- Piers:
  - Number
  - Location
  - Width
  - Type (e.g., concrete, pile bent, etc.)
  - Shape (e.g., round nose, wedge shape, etc.).

In addition, for each bridge crossing, one cross section was surveyed at each of the following locations:

- Upstream of contraction reach (approximately half to one channel width upstream)
- Approximately one to two metres upstream of upstream face
- Approximately one to two metres downstream of downstream face (not required for narrow pedestrian bridges)
- Downstream of expansion reach (approximately one channel width downstream)

Photographs looking towards the bridge and towards the channel – upstream and downstream – were taken at each crossing and are included in Appendix B and the GIS photo database (Appendix E).

The surveyed bridges are listed in Table 3. Complete details on each structure are included in Appendix B.

Table 3 List of Surveyed Bridges

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID
12	Bow River	21,225	Cochrane	River Avenue	Alberta Transportation	111
15	Bow River	23,403	Cochrane	Cowbow Trail/Hwy 22	Alberta Transportation	76609
17	Bow River	27,374	near Cochrane	CP Rail	CP Rail	mile 25.7
11	Bow River	54,457	Morley	Morley Road	Alberta Transportation	611
8	Bow River	77,639	Seebe	Hwy 1X	Alberta Transportation	75111
30	Bow River	79,676	Seebe	CP Rail	CP Rail	mile 53.1
42	Bow River	104,509	Canmore	Hwy 1 E	Alberta Transportation	74353
32	Bow River	104,549	Canmore	Hwy 1 W	Alberta Transportation	74353
70	Bow River	109,212	Canmore	Bow River Pedestrian Bridge	Canmore	BG03
31	Bow River	109,223	Canmore	Bridge Road	Alberta Transportation	00167 (BG02)

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID
51	Bow River	109,929	Canmore	Spur Line Trail (Engine Bridge)	Canmore	81692 (BG20)
74	side channel (Bow River)	25,010	Cochrane	Walking Trail	Cochrane	-
69	side channel (Bow River)	108,615	Canmore	Walking Trail	Canmore	BG15
55	side channel (Bow River)	109,929	Canmore	Spur Line Trail	Canmore	81694 (BG18)
63	side channel (Bow River)	110,852	Canmore	Walking Trail	Canmore	BG30
71	Bighill Creek	208	Cochrane	Walking Trail	Cochrane	-
317	Bighill Creek	372	Cochrane	Walking Trail	Cochrane	-
316	Bighill Creek	581	Cochrane	Walking Trail	Cochrane	-
77	Bighill Creek	992	Cochrane	Walking Trail	Cochrane	-
76	Bighill Creek	1,207	Cochrane	Walking Trail	Cochrane	-
315	Bighill Creek	1,722	Cochrane	Walking Trail	Cochrane	-
314	Bighill Creek	1,812	Cochrane	Walking Trail	Cochrane	-
313	Bighill Creek	2,158	Cochrane	Walking Trail	Cochrane	-
312	Bighill Creek	2,754	Cochrane	CP Rail	CP Rail	mile 23.6
311	Bighill Creek	2,786	Cochrane	Walking Trail	Cochrane	-
14	Bighill Creek	2,814	Cochrane	Bow Valley Trail/Hwy 1A	Alberta Transportation	521
310	Bighill Creek	3,385	Cochrane	Walking Trail	Cochrane	-
309	Bighill Creek	3,794	Cochrane	Walking Trail	Cochrane	-
308	Bighill Creek	4,360	Cochrane	Walking Trail	Cochrane	-
318	side channel (Bighill Creek)	164	Cochrane	Walking Trail	Cochrane	-
72	side channel (Bighill Creek)	185	Cochrane	Walking Trail	Cochrane	-
16	Jumpingpound Creek	647	Cochrane	George Fox Trail	Alberta Transportation	283
24	Exshaw Creek	111	Exshaw	Diamond Drive	M.D. Bighorn	-
25	Exshaw Creek	155	Exshaw	CP Rail	CP Rail	mile 57.0
304	Exshaw Creek	451	Exshaw	Walking Trail	M.D. Bighorn	-
43	Policeman Creek	1,552	Canmore	Wastewater Treatment Plant Road	Canmore	BG33
2	Policeman Creek	2,793	Canmore	Spring Creek Gate	Canmore	79434 (BG24)
45	Policeman Creek	3,147	Canmore	Walking Trail	Canmore	BG31
46	Policeman Creek	3,699	Canmore	8 Street	Alberta Transportation	71563 (BG06)
47	Policeman Creek	3,876	Canmore	10 Street	Alberta Transportation	80959 (BG07)

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID
4	Policeman Creek	4,328	Canmore	Walking Trail	Canmore	81618 (BG08)
66	Policeman Creek	4,717	Canmore	Walking Trail	Canmore	BG09
65	Policeman Creek	4,853	Canmore	Walking Trail	Canmore	BG28
61	Policeman Creek	5,103	Canmore	Walking Trail	Canmore	BG10
60	Policeman Creek	5,252	Canmore	Walking Trail	Canmore	BG11
303	Policeman Creek	5,648	Canmore	Walking Trail	Canmore	-
302	Policeman Creek	5,668	Canmore	Golf Course	Canmore Golf Course	-
301	Policeman Creek	6,022	Canmore	Unknown	Unknown	-
3	side channel (Policeman Creek)	3,360	Canmore	Walking Trail	Canmore	unknown (possibly BG40)
62	side channel (Policeman Creek)	5,331	Canmore	Walking Trail	Canmore	BG38

2.4.2 Culverts

Similar to bridge crossings, the following data were surveyed for culverts:

- Top of roadway profile (centerline)
- Type (e.g., concrete, CMP, etc.)
- Entrance condition (e.g., projecting from fill, mitered to slope, head wall type, etc.)
- Diameter
- Length
- Invert elevation – upstream and downstream.

Additional cross sections, similar to those at bridge crossings (detailed above), were surveyed upstream and downstream of large culverts that act effectively as bridges crossing the main channel or tributaries.

The surveyed culverts are listed in Table 4 and detailed information on each culvert is provided in Appendix B.

Table 4 List of Surveyed Culverts

NHC ID	Stream Name	River Station (m)	Municipality	Road / Trail	Owner	Owner ID
405	Bow River	87,721	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn	
204	Bow River	87,904	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn	
404	Bow River	88,087	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn	
203	Bow River	88,251	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn	
202	Bow River	88,420	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn	
201	Bow River	91,122	near Exshaw	Lac Des Arcs proposed inlet structure	M.D. Bighorn	
407	side channel (Bow River)	23,505	Cochrane	Walking trail	Cochrane	
33	side channel (Bow River)	96,000	Lac Des Arcs	Gravel Road	unknown (possibly M.D. Bighorn)	
164	side channel (Bow River)	105,661	near Canmore	Trans-Canada Highway - Hwy 1	Alberta Transportation	74363
168	side channel (Bow River)	105,880	near Canmore	Trans-Canada Highway - Hwy 1	Alberta Transportation	74364
81	Bighill Creek	480	Cochrane	Griffin Road W	Alberta Transportation	76989
75	Bighill Creek	1,519	Cochrane	Glenpatrick Road	Cochrane	
83	Bighill Creek	2,498	Cochrane	Glenbow Drive	Alberta Transportation	81092
26	Exshaw Creek	206	Exshaw	Bow Valley Trail - Hwy 1A	Alberta Transportation	71734
64	Policeman Creek	4,923	Canmore	8 Avenue	Canmore	81617 (BG27)
196	Policeman Creek	5,003	Canmore	17 Street	Canmore	81616 (BG26)
59	Policeman Creek	5,957	Canmore	Golf course	Canmore Golf Course	BG25
401	Policeman Creek	6,435	Canmore	Canmore Dyke	AEP	
175	side channel (Policeman Creek)	4,159	Canmore	7 Avenue	Canmore	
197	side channel (Policeman Creek)	4,256	Canmore	Pedestrian pathway	Canmore	BG29
155	side channel (Policeman Creek)	4,877	Canmore	8 Avenue	Canmore	

2.5 Flood Control Structures

There are two flood control structures (dykes) located along the Bow River in Canmore, one along the Bow River in Cochrane, and one along Jumpingpound Creek in Cochrane (Table 5). The locations of the flood control structures are indicated on the Survey Results Map (Sheets 1 to 10). Prior to the site inspection, orthophotos were used to preliminarily identify the flood control structures. The locations of flood control structures were confirmed through consultation with local authorities and during the site inspection and field survey.

The geometric details of the flood control structures were defined by (1) surveying a crest profile and (2) surveying cross sections at upstream and downstream extents, at river cross section locations, as well as any locations that were expected to be necessary to adequately represent the structure in the hydraulic model and for flood mapping. In addition, culverts and gates in flood control structures were located and their type, shape, and dimensions documented. These culverts are included in Table 4.

Georeferenced photographs of all flood control structures are included in the GIS database (Appendix E).

2.6 Other Features

Other anthropogenic features within the study reach that may impact hydraulics were not surveyed but are described in this section. The only exceptions to this are the Lac des Arcs dust control dykes and the Cochrane Riverfront Park berm, which were surveyed.

- The CPR railway parallels the river, and in some locations, the railway ballast and side slope armoring encroach on the river channel.
- There are many culverts through road or railway embankments. These were identified based on imagery and information received from Alberta Transportation, Canadian Pacific Railway (CPR), and local authorities.
- Two dust control dykes in Lac des Arcs were surveyed and are described in Table **6**. These dykes, built in 1994, control the Lac des Arcs water level during the winter to reduce the dust problem caused by blowing lake bed sediments when water levels are low.
- The Cochrane Riverfront Park berm was surveyed and is described in Table **6**. The berm is not a clearly defined flood control structure.
- A berm along the right bank of Exshaw Creek restricts the creek away from the cement plant.
- Four dams owned and operated by TransAlta are located within the study reach and are listed in Table **7**.

Table 5 List of Flood Control Structures

NHC ID	Name	Owner	Length (m)	Description	Location					
					Stream	River Station (m)	Easting at Start	Northing at Start	Easting at End	Northing at End
2	Riverfront Park nature playground berm	Cochrane	220	North side of Bow River, downstream of Hwy. 22 bridge, surrounding playground	Bow River	23,260	-33,919	5,672,030	-33,903	5,672,029
3	Jumpingpound Creek dyke	Cochrane	168	East side of Jumpingpound Creek downstream of George Fox Trail Bridge	Jumpingpound Creek	485	-34,942	5,672,270	-34,871	5,672,118
6	Canmore dyke	AEP	2484	Southwest side of Bow River through Canmore	Bow River (Rundle Tailrace Channel)	108,780	-96,189	5,662,273	-95,686	5,661,543
7	Canmore dyke	AEP	5176	Northeast side of Bow River through Canmore	Bow River	107,350	-96,561	5,665,000	-94,616	5,660,764

Notes:

1. Northing and easting provided in 3TM.
2. Flood control structures were surveyed by NHC in 2015.

Table 6 Other Features

NHC ID	Name	Owner	Length (m)	Description	Location					
					Stream	River Station (m)	Easting at Start	Northing at Start	Easting at End	Northing at End
1	Riverfront Park berm	Cochrane	319	Irregular berm, adjacent to north side of Bow River, downstream of Hwy. 22 bridge	Bow River	23,020	-33,937	5,671,999	-33,715	5,671,771
4	Lac des Arcs (east) dyke	MD Bighorn	1053	East dust control dyke	Bow River	87,450	-82,665	5,658,486	-81,754	5,658,065
5	Lac des Arcs (west) dyke	MD Bighorn	613	West dust control dyke	Bow River	91,100	-84,145	5,658,798	-84,388	5,658,284

Notes:

1. Northing and easting provided in 3TM.
2. Other features were surveyed by NHC in 2015.

Table 7 List of Dams

NHC Dam ID	Name	Stream	River Station (m)	Easting	Northing	Year Built
1	Bearspaw Dam	Bow River	0	-19,795	5,662,771	1954
2	Ghost Dam	Bow River	42,150	-49,459	5,676,119	1929
3	Horseshoe Dam	Bow River	73,850	-72,535	5,665,117	1911
4	Kananaskis Dam	Bow River	77,490	-74,422	5,662,910	1913

Note: Northing and easting provided in 3TM.

2.7 Survey Standards and Accuracy

2.7.1 Survey Control and Network Adjustment

A total of 22 survey control points were established by setting up base station receivers to record raw GPS observations over existing Alberta Survey Control Monuments (ASCM) and new NHC control points. The NHC control points were set in locations that were accessible and evenly distributed in the study reach. Two survey control networks were established – one project encompassing network from Canmore area to Cochrane/Calgary established in October 2015. The other network, covering the Stoney/Ghost reach, was added in April/May 2016. The extent of the Stoney/Ghost network was tied into the master project network. The raw GPS observations were processed using Trimble Business Center v3.60 software to create a control point network between the ASCM locations and NHC control points.

Upon completion of the bathymetric and ground survey, the control points were adjusted by converting the points to NAD83 CSRS (2002) HTv2.0. The network adjustment was performed by holding constant the coordinates and elevations of five ASCM control points (7, 12, 52, 53, and 55). One of the control points (55) was listed in ASCM CSRS Subset Data published by AEP's Geodetic Control Unit. The other four control points (7, 12, 52 and 53), were established through long term GPS raw observations with a minimum duration of four hours. These data were submitted to the online National Research Council Canada Precise Point Positioning (NRC Can-PPP) and the results were used in the network adjustment (See Appendix C). The second network adjustment, for the Stoney/Ghost reach, was performed by holding constant ASCM control points 3 on the downstream end and 55 on the upstream end.
The resulting control points are listed in Table 8.

Table 8 List of Survey Control Points

Point Name	Easting	Northing	Elevation (m)	Code
1	-20,446.597	5,665,076.952	1,097.305	NHC 1860
2	-24,371.159	5,669,466.457	1,110.076	NHC 072
3	-34,261.764	5,671,899.195	1,128.597	ASCM 139709
4	-36,859.699	5,674,454.966	1,157.719	NHC 1924
5	-40,731.768	5,676,118.431	1,170.671	NHC 409
6	-45,554.079	5,675,820.344	1,162.457	NHC 139
7	-50,501.169	5,675,879.938	1,229.053	NHC 250
8	-56,210.485	5,683,630.011	1,295.714	NHC 1635
9	-57,480.396	5,673,079.305	1,213.061	NHC 1874
10	-74,482.828	5,662,575.619	1,284.067	NHC 625
11	-81,588.7	5,658,397.096	1,295.13	NHC 1798
12	-96,311.849	5,665,419.694	1,329.268	NHC 126
NHC003	-68,096.486	5,665,657.972	1,271.901	NHC 003
NHC101	-67,949.753	5,670,170.195	1,282.729	NHC 101
NHC104	-64,003.475	5,670,038.360	1,247.411	NHC 104
9	-57,480.417	5,673,079.304	1,213.080	NHC 1874
52	-25,352.385	5,664,686.309	1,189.92	ASCM 754127
53	-29,593.169	5,671,734.117	1,229.921	ASCM 15404
54	-85,888.024	5,657,424.89	1,294.334	ASCM 487363
55	-88,699.811	5,656,541.571	1,298.93	ASCM 341404
57	-92,932.262	5,659,890.199	1,305.113	ASCM 120758
59	-95,166.464	5,661,779.671	1,308.681	ASCM 210765

Table 9 shows the horizontal and vertical differences (deltas) between the final NHC adjusted network and the results from the static NRC Can-PPP GPS raw observations. Note that some of these observations were taken over shorter durations of 1 to 2 hours. The control network processing report along with network adjustment report can be found in Appendix C. These values confirm that the NHC surveyed control points are within ± 3 cm horizontally and vertically of the computed values by NRC Can PPP, online correction service. The horizontal and vertical closures obtained more than exceed the relative precision requirements.

Table 9 Adjusted Network Compared to CSRS-PPP

Point	Difference in Easting (m)	Difference in Northing (m)	Difference in Elevation (m)
1	-0.011	0.006	-0.005
2	-0.022	0.008	-0.011
3	-0.012	0.012	-0.021
4	-0.026	0.013	-0.022
5	-0.022	0.005	-0.037
6	-0.006	0.000	-0.015
7	0	0	0
8	0.028	-0.008	-0.029
9	-0.008	-0.008	-0.002
10	-0.005	0.006	0.004
11	-0.01	0.001	0.025
12	0	0	0
52	0	0	0
53	0	0	0
54	0.011	0.011	0.003
55	0.017	-0.001	0.003
57	-0.013	0.004	-0.006
59`	-0.01	0.003	-0.007
NHC003	-0.026	0.001	0.013

2.7.2 Accuracy

The bathymetric surveys were carried out using a boat mounted Sonarmite depth sounder that measured water depths to an accuracy of ±0.01 m, coupled with a Trimble or Topcon RTK GPS system measuring three-dimensional positional data with an accuracy of ±0.02 m. Additional positional errors are added due to the movement of the boat and synchronization errors between sounder, GPS, and recording. The topographic surveys were completed with the RTK GPS. The overall accuracy of the measurements is considered to be ±0.07 m horizontally and vertically for the bathymetric points and ±0.05 m horizontally and vertically for the ground surveyed RTK points.

To ensure accuracy during the topographic surveys, daily checks were performed. After setting up the base station over a control point, the surveyor staked out an adjacent control point and compared results to ensure any discrepancies in the data were within 0.05 m. For the bathymetric portion of the survey, checks were performed by comparing points logged on the RTK survey controller to the Hypack bathymetric data collection software, in order to ensure antennae heights and coordinate system parameters matched within 0.05 m. In addition, a daily verification was done to ensure the physically measured water depth was ±0.03 m of the raw depth sounder output.

2.8 LiDAR-Derived DTM

The LiDAR data was collected for the study area by Airborne Imaging Inc. for AEP on September 10th and 11th and October 5th and 11th, 2015 (Airborne Imaging, 2016). The western portion of the study area was covered by the flights on September 10th and 11th and October 5th. The eastern half of the study area was covered by the flights on October 5th and 11th. The LiDAR-derived DTM is reported to have a vertical accuracy of ±0.15 m at 95% on hard, flat, open surfaces, based on a set of independently collected verification points.

The LiDAR control survey points were provided by AEP and surveyed by NHC to allow direct tie in with the river and ground surveys. NHC compared a number of October 2015 survey points to the LiDAR-derived DTM. For this comparison, points were selected that correspond to the bare earth LiDAR surface and are on relatively flat surfaces (slopes equal to two degrees or less, based on the LiDAR-derived DTM). Points that may overlap with the LiDAR water surface were excluded. Points in heavily vegetated areas were not excluded, as there was no straightforward way to do this; this may increase the reported error.

The comparison shows that, of 1,495 survey points selected, 92 percent are within 0.15 m of the LiDAR-derived DTM elevations and 96 percent are within 0.20 m.

These results were also examined separately by reach. There is significantly lower correlation between the survey and LiDAR-derived DTM on Bighill Creek (60 percent of points are within 0.15 m and 92 percent are within 0.30 m). Bighill Creek is heavily vegetated, which is likely the main reason for the lower correlation in that location. The point comparison is summarized in Table **10**.

Table 10 Comparison of NHC Survey to LiDAR-derived DTM

Category	Point Count	Percentage
All points	1,495	100.0 %
Elevation difference less than 0.15 m	1,368	91.5 %
Elevation difference less than 0.20 m	1,428	95.5 %
Elevation difference less than 0.30 m	1,464	97.9 %
Elevation difference less than 0.40 m	1,477	98.8 %
Elevation difference less than 0.50 m	1,481	99.1 %

Comparisons of dyke profiles and a selection of cross section profiles between the NHC survey data and the LiDAR-derived DTM show a good fit, generally within 0.10 m. For the Jumpingpound Creek dyke and the Lac des Arcs dykes, the NHC survey data appears to be about 0.05 to 0.10 m higher than the LiDAR-derived DTM. For the Canmore dykes, the NHC survey data appears to be comparable to or slightly higher (i.e., 0.05 m) than the LiDAR-derived DTM. These errors are within the stated accuracy of the LiDAR-derived DTM.

3 AERIAL IMAGERY ACQUISITION

Orthoshop Geomatics Ltd. (OGL) collected colour aerial imagery for the study area on June 3rd, 2016 and used this imagery to generate colour-balanced ortho-rectified mosaics. OGL's "QA/QC Documentation" memo is included in Appendix D.

Image collection, orthophoto creation, and data delivery conforms to AEP's "General Specifications for Acquiring Aerial Photography" (2015).

Image acquisition specifications are as follows:

- RGB and near infrared imagery was collected.
- Image resolution is 30 cm.
- Imagery is cloud, haze, fog and snow free, and was collected with a minimum of 30 degree sun angle.
- Minimum forward overlap is 60%. Minimum side overlap is 50%.
- The Lidar DTM created by Airborne Imaging (2016) was used for ortho-rectification.
- Seven ground control points, surveyed by NHC, were used to ensure horizontal accuracy.
- Horizontal accuracy of the orthophotos is 0.58 metres RMSE.

Data deliverables are as follows:

- Orthophoto mosaics in 8-bit GeoTIFF format with associated TFW world files.
  - Image mosaics are tiled into quarter townships.
  - The NoData values are set to 255 for all images.
  - The horizontal coordinate system and datum is 3TM NAD83 CSRS.
- Stereo images in TIFF format.
- Stereo metadata consisting of two feature classes with attribution (image center points, image footprints).
- Ortho metadata consisting of FGDC .xml format files (one file per orthophoto).
- An index map showing the area of each orthophoto tile in shapefile format.
- A flight plan and flight report.
- Manufacturer camera calibration report.
- Aerial triangulation report containing the final exterior orientation parameters with image identifiers matching the image names.

- A flight index map in unsecured PDF format.
- An Aerial Imagery Acquisition memorandum which documents aerial imagery collection, orthophoto production and quality assessment details.

Two copies of all deliverables were provided by OGL on USB 3.0 portable hard drives, accompanied by a transmittal letter.

4 ADDITIONAL BASE DATA

Base data collected to date are summarized in Appendix A. Data categories are listed below.

- Topography – notably the 2015 Lidar survey (Airborne Imaging, 2016) and other recent topographic and bathymetric surveys
- Imagery – notably AEP's 2013 post-flood imagery, and the 2016 imagery described above
- Administrative – such as city, town and First Nation Lands boundaries
- Land use / land cover
- Transportation – roads and rail from local and regional sources
- Utilities
- Facilities – such as boat launches
- Hydrography
- Historic Flood Mapping – for Canmore, Bighorn/Exshaw, and Cochrane
- Historic Flood Information – high water marks and historic flood reports
- Hydrometric Stations
- Structures – dams, flood control structures, bridges and culverts
- NHC Survey – survey points and photos
- Modelling – data layers built to support hydraulic modelling, such as cross section lines, stream network line and bank lines.

5 CONCLUSIONS

The collection of survey and base data primarily supports hydraulic modelling, flood mapping, flood risk assessment, and channel stability investigations.

River cross section surveys were conducted on the Bow River, Policeman Creek, Exshaw Creek, Jumpingpound Creek and Bighill Creek in October 2015 and April/May 2016. Cross section surveys consisted of a combination of bathymetric and RTK GPS ground surveys completed to complement the LiDAR-derived DTM. A total of 587 cross sections were surveyed with 184 of the cross sections being re-surveyed along the alignment of previously surveyed cross sections. Geometric details of 50 bridge crossings, 21 culverts, and five flood control structures were collected. The overall accuracy of the measurements is considered to be ±0.07 m horizontally and vertically for the bathymetric points and ±0.05 m horizontally and vertically for the ground surveyed RTK points.

The October 2015 survey data was compared to the LiDAR-derived DTM. The comparison shows that, of 1,495 survey points selected, 92 percent are within 0.15 m of the LiDAR elevations and 96 percent are within 0.20 m.

Orthoshop Geomatics Ltd. collected colour aerial imagery for the study area on June 3rd, 2016 and used this imagery to generate 30 cm resolution colour-balanced ortho-rectified mosaics.

6 REFERENCES

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MAPS AND DRAWINGS

115°28'W 115°26'W 115°24'W 115°22'W 115°20'W

51°10'N

51°8'N

Carrot Creek

STUDY LIMIT

118 KM

116 KM

114 KM

112 KM

Bow River

Harvie Heights

M.D. OF BIGHORN

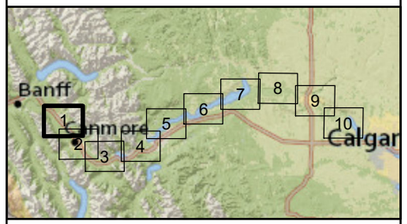
M.D. OF BIGHORN

CANMORE

DRAFT

Alberta Government

nhc
northwest hydraulic consultants



NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
- Model Stream Network (with chainage)
- City
- Town
- County or Municipal District
- First Nations Land
- Summer Village
- Protected Area Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | *Date: 05-JUN-2017*

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 1 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

115°24'W 115°22'W 115°20'W 115°18'W

51°6'N

51°4'N

CANMORE

M.D. OF BIGHORN

M.D. OF BIGHORN

114 KM

142 KM

6 KM

110 KM

4 KM

Policeman Creek

108 KM

2 KM

0 KM

1 KM

Bow River

104 KM

102 KM

Canmore

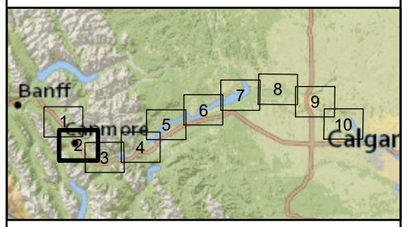
Canmore Creek

Stones Canyon Creek

Gap

Alberta Government

nhc
northwest hydraulic consultants



NHC Fall 2015 and Spring 2016 Survey

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- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
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- City
- Town
- County or Municipal District
- Protected Area Boundary
- First Nations Land
- Summer Village

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | Date: 05-JUN-2017

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 2 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

115°18'W 115°16'W 115°14'W 115°12'W

51°4'N

51°2'N

M.D. OF BIGHORN

CANMORE

102 KM

100 KM

98 KM

96 KM

94 KM

92 KM

90 KM

88 KM

Gap Lake

Lac des Arcs

Bow River

Dead Man's Flats

Fall Creek

Cairnes Creek

Marsh Creek

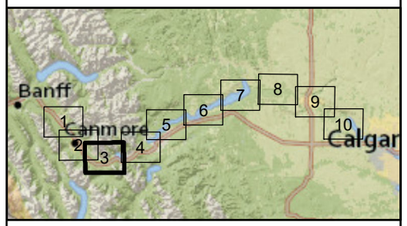
Stewart Creek

Pigeon Creek

DRAFT

Alberta Government

nhc
northwest hydraulic consultants



NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
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- City
- Town
- First Nations Land
- Summer Village
- County or Municipal District
- Protected Area Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | Date: 05-JUN-2017

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 3 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

115°10'W 115°8'W 115°6'W 115°4'W

51°6'N

51°4'N

M.D. OF BIGHORN

Kananaskis Dam

SEEBE

Seebe

76 KM

78 KM

80 KM

Bow River

82 KM

84 KM

86 KM

STUDY LIMIT

Exshaw Creek

EXSHAW

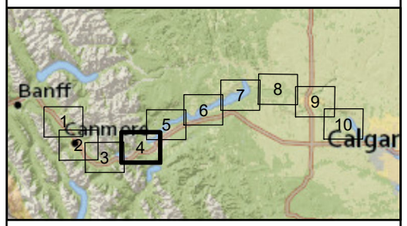
Exshaw

Lac des Arcs

Chilver Lake

Alberta Government

nhc
northwest hydraulic consultants



NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
- Model Stream Network (with chainage)
- City
- Town
- County or Municipal District
- Protected Area Boundary
- First Nations Land
- Summer Village

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | Date: 05-JUN-2017

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 4 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

115°4'W 115°2'W 115°0'W 114°58'W

51°8'N

51°6'N

M.D. OF BIGHORN

STONEY NO. 142, 143, 144

Bow River

70 KM

66 KM

68 KM

72 KM

74 KM

76 KM

Horseshoe Dam

Kananaskis Dam

SEEBE

Bighorn No 8

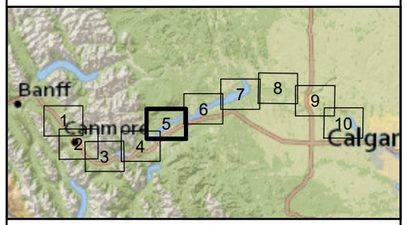
Ozada

M.D. OF BIGHORN

STONEY NO. 142, 143, 144

Alberta Government

nhc
northwest hydraulic consultants



NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
- Model Stream Network (with chainage)
- City
- Town
- County or Municipal District
- Protected Area Boundary
- First Nations Land
- Summer Village

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | *Date: 05-JUN-2017*

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 5 OF 10

MSN_\\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

114°56'W 114°54'W 114°52'W 114°50'W

51°12'N

51°10'N

51°8'N

M.D. OF BIGHORN

STONEY NO. 142, 143, 144

Joshua Creek

Joshua Creek

Jacob Creek

Bow River

50 KM

52 KM

54 KM

56 KM

58 KM

60 KM

62 KM

64 KM

MORLEY

Morley

Chiniki Creek

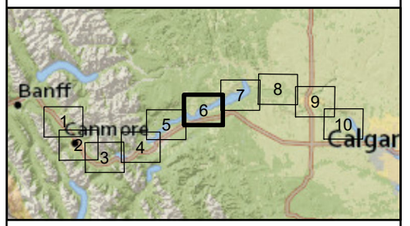
M.D. OF BIGHORN

STONEY NO. 142, 143, 144

DRAFT

Alberta Government

nhc
northwest hydraulic consultants



NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
- Model Stream Network (with chainage)
- City
- Town
- First Nations Land
- Summer Village
- County or Municipal District
- Protected Area Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | *Date: 05-JUN-2017*

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 6 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

114°48'W 114°46'W 114°44'W 114°42'W 114°40'W

51°14'N

51°12'N

51°10'N

M.D. OF BIGHORN

STONEY NO. 142, 143, 144

ROCKY VIEW COUNTY

Ghost River

STUDY LIMIT

Bow River

Ghost Dam

42 KM

40 KM

44 KM

46 KM

48 KM

50 KM

Ghost Lake

Cheneka

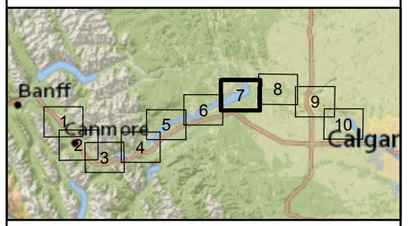
Spencer Creek

Banff

Canmore

Calgary

DRAFT



NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
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DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | Date: 05-JUN-2017

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 7 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

Classification: Public

114°40'W 114°38'W 114°36'W 114°34'W 114°32'W

51°14'N

51°12'N

ROCKY VIEW COUNTY

STONEY NO. 142, 143, 144

ROCKY VIEW COUNTY

Wildcat

Beaupre Creek

Grand Valley Creek

Mclennan Creek

Mclennan Creek

Bow River

38 KM

36 KM

34 KM

32 KM

30 KM

28 KM

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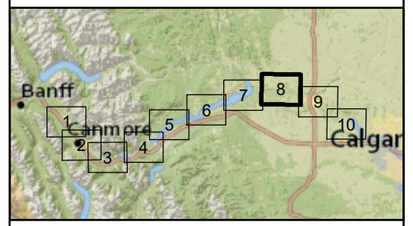

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- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
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- Dam
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- Town
- County or Municipal District
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- Summer Village
- Protected Area Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | *Date: 05-JUN-2017*

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 8 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

114°30'W 114°28'W 114°26'W 114°24'W

51°12'N

51°10'N

STUDY LIMIT

ROCKY VIEW COUNTY

Bighill Creek

Horse Creek

Cochrane

COCHRANE

26 KM

0 KM

24 KM

0 KM

2 KM

4 KM

Jumpingpound Creek

STUDY LIMIT

22 KM

Bow River

20 KM

18 KM

16 KM

14 KM

12 KM

Glenbow

DRAFT

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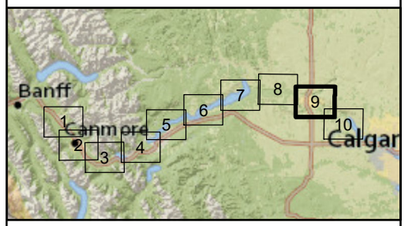

NHC Fall 2015 and Spring 2016 Survey

- Survey Points
- Historic Section, NHC Re-surveyed 2015
- Surveyed Section, NHC 2015 or 2016
- Culvert
- Bridge
- Dam
- Flood Control Structure
- Other Feature
- Model Stream Network (with chainage)
- City
- Town
- County or Municipal District
- First Nations Land
- Summer Village
- Protected Area Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Job: 3001178 | *Date: 05-JUN-2017*

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 9 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

Classification: Public

114°24'W 114°22'W 114°20'W 114°18'W

51°10'N

51°8'N

51°6'N

ROCKY VIEW COUNTY

Bearspaw

Bow River

14 KM

12 KM

10 KM

8 KM

6 KM

4 KM

2 KM

STUDY LIMIT

Bearspaw Dam

Glenbow Lake

Springbank Airport

DRAFT

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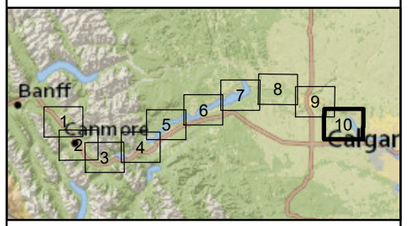

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0 400 800 1,200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

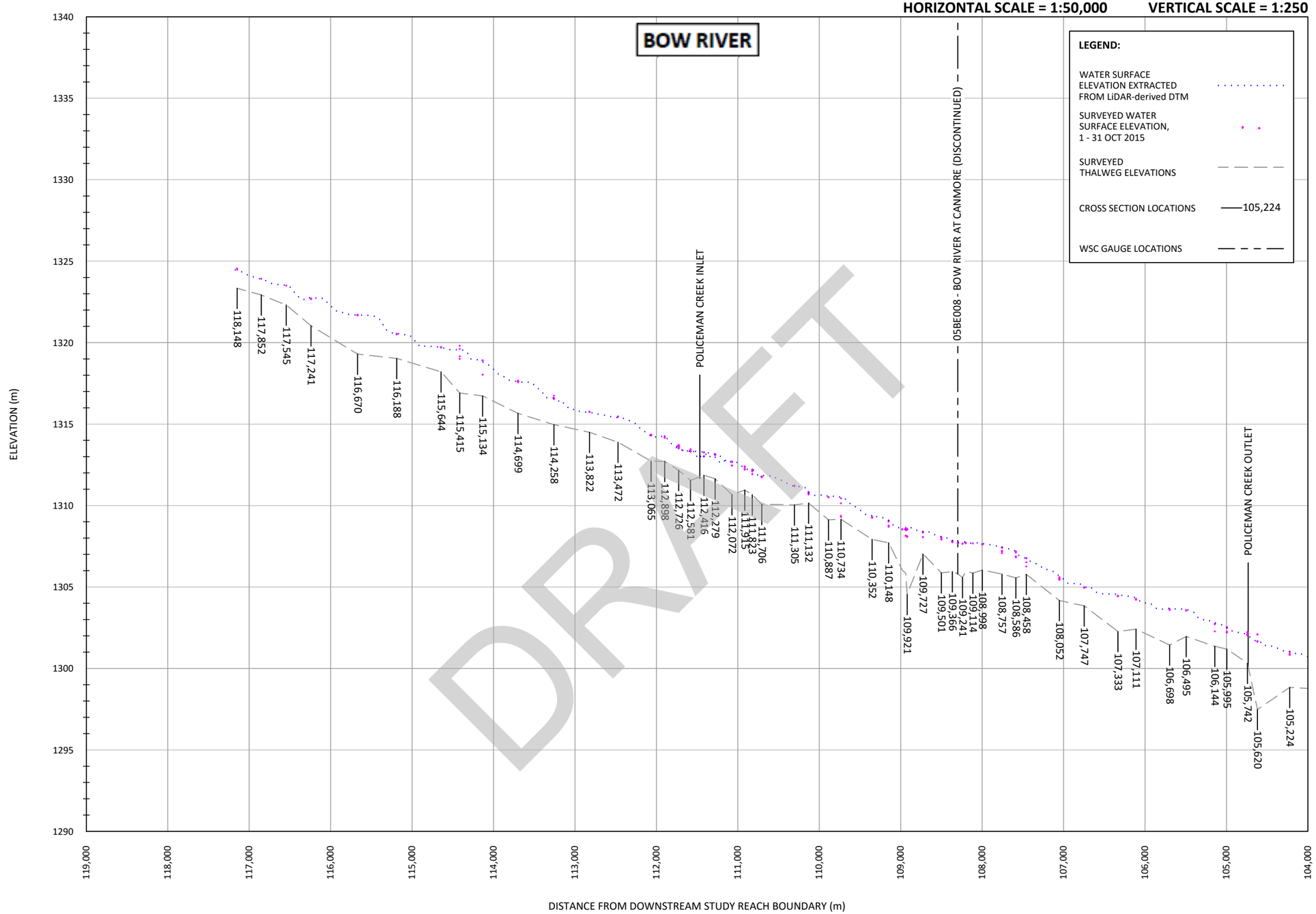
Job: 3001178 | *Date: 05-JUN-2017*

UPPER BOW RIVER HAZARD STUDY SURVEY RESULTS MAP

SHEET 10 OF 10

MSN, \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\90 GIS\3001178_MSN_Map_T1_SurveyResults5.mxd

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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NOTES:

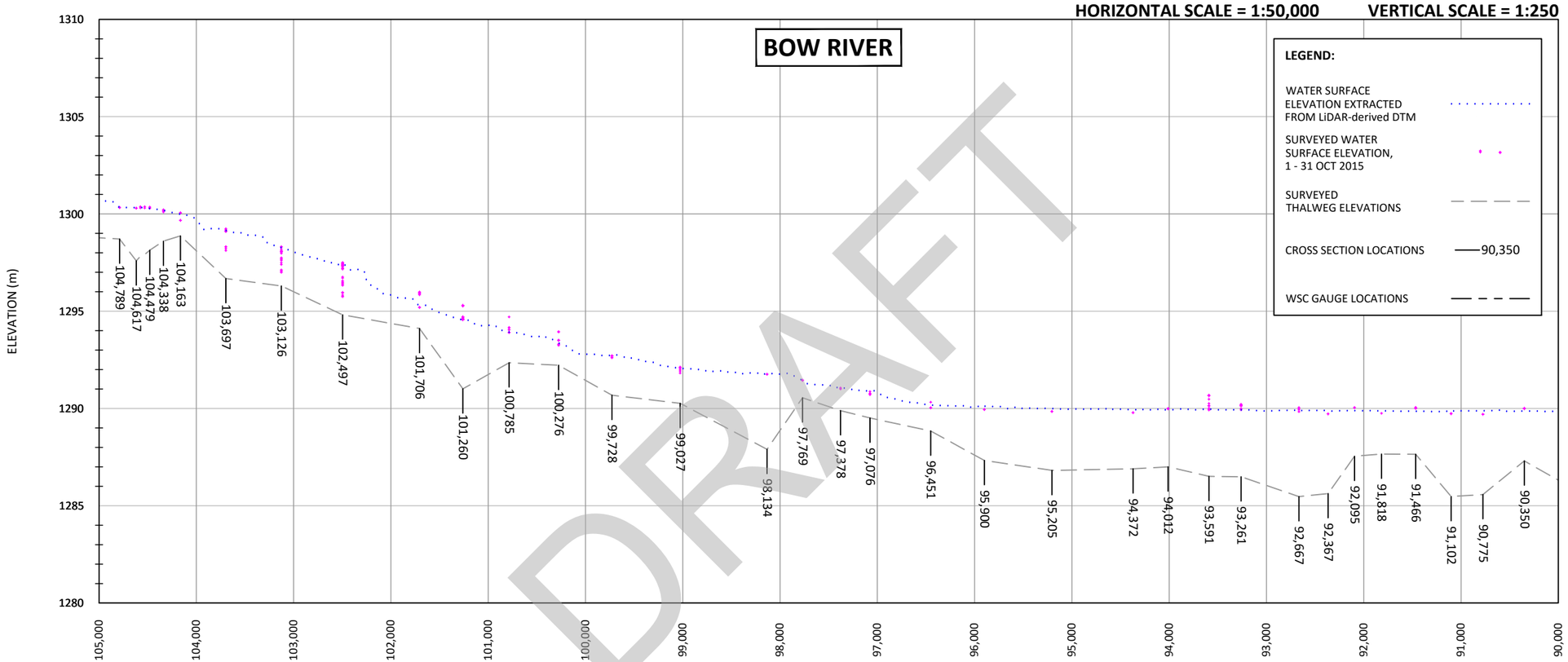
1. REFER TO MAP SHEETS 1 TO 10 FOR A PLAN VIEW OF THE STUDY REACH FEATURES AND THE SURVEYED CROSS SECTIONS.
2. CHANNEL SURVEY CONDUCTED BY NHC IN 2015 (OCT. 1 TO 31).
3. LiDAR DATA ACQUISITION BY AIRBORNE IMAGING INC. IN 2015 (SEPT. 10 TO 11, OCT. 5 AND 11).

UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

PROJECT NUMBER	
DRAWING NUMBER	3001178-001
SHEET NUMBER	1 of 10

HORIZONTAL SCALE = 1:50,000 **VERTICAL SCALE = 1:250**



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NOTES:

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3. LiDAR DATA ACQUISITION BY AIRBORNE IMAGING INC. IN 2015 (SEPT. 10 TO 11, OCT. 5 AND 11).

UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

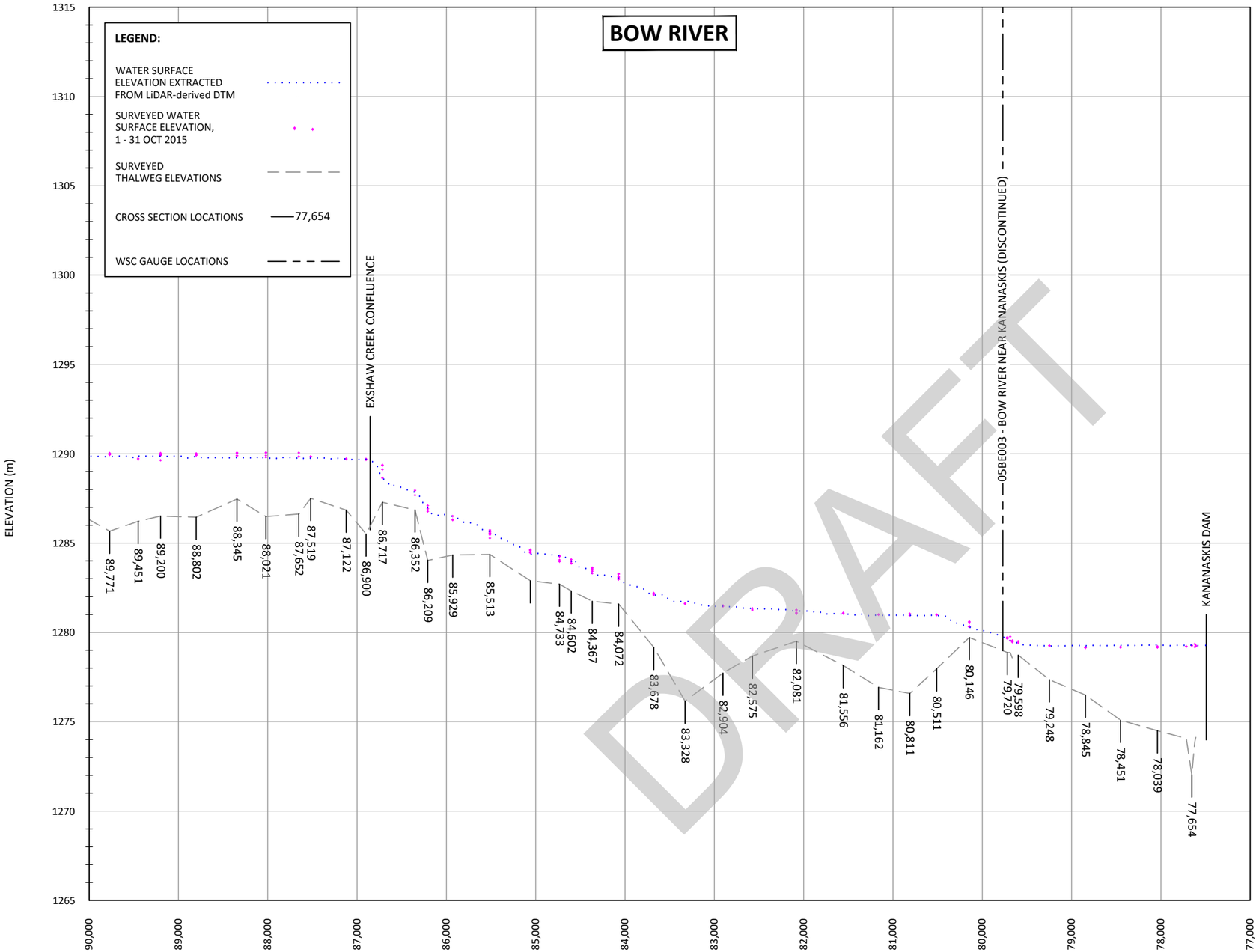
PROJECT NUMBER

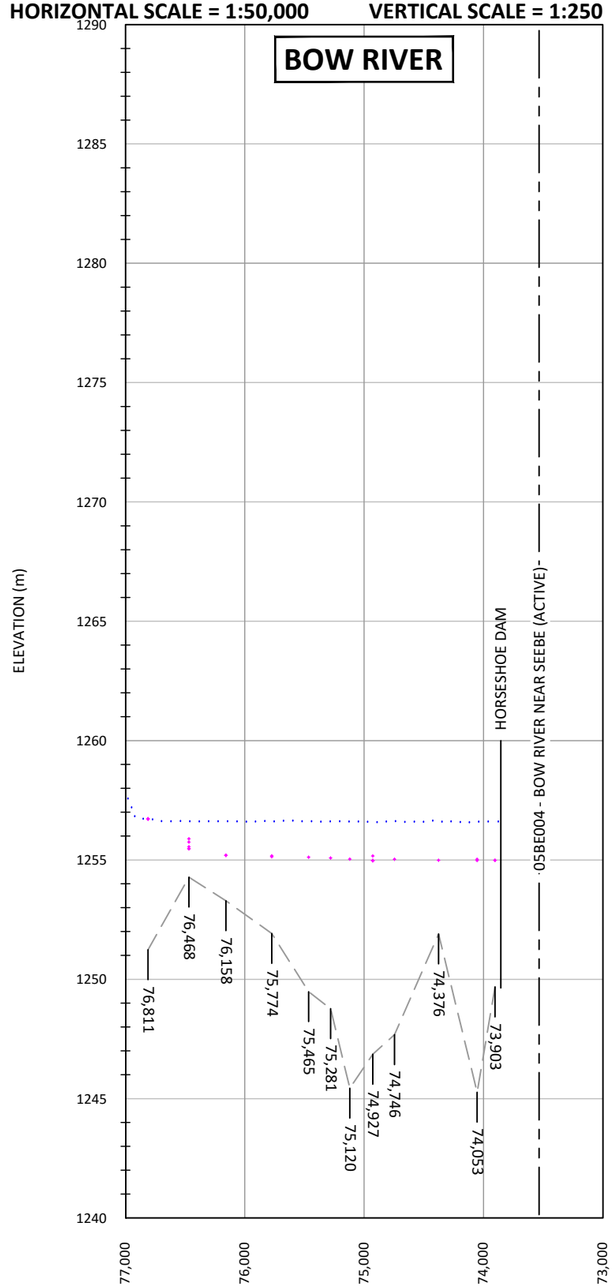
DRAWING NUMBER 3001178-002

SHEET NUMBER

2 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250





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UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

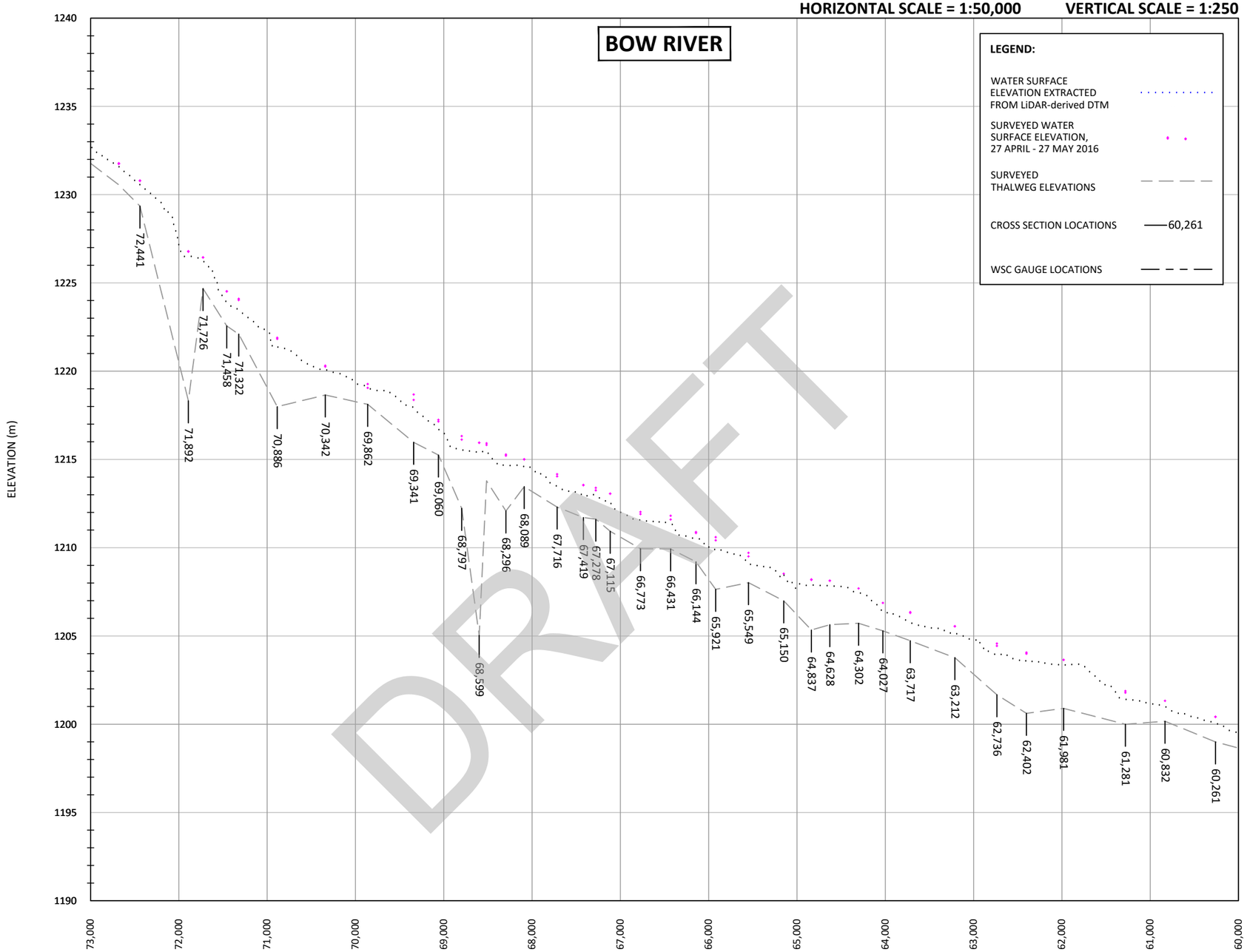
PROJECT NUMBER

DRAWING NUMBER 3001178-003

SHEET NUMBER

3 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

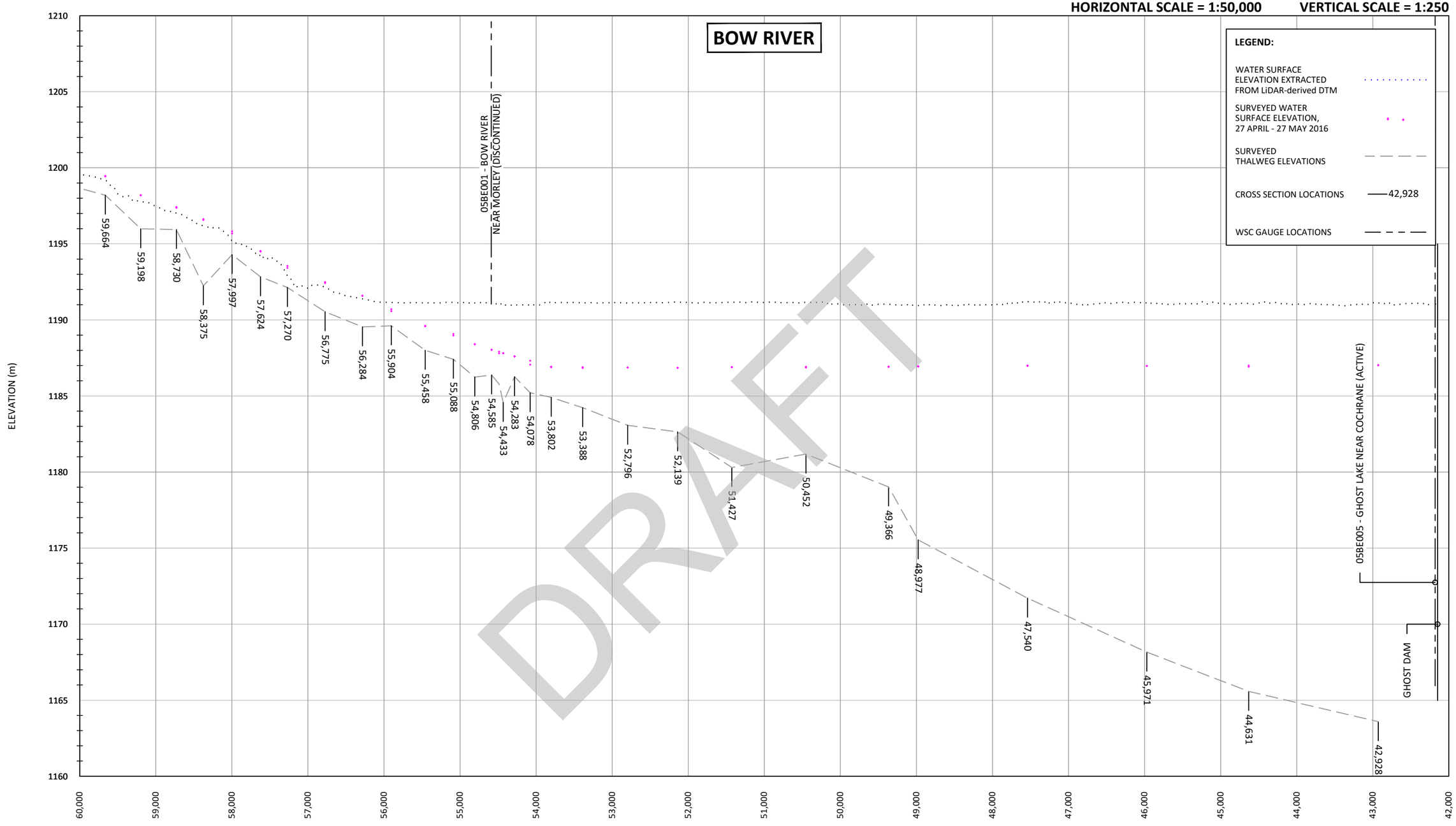
PROJECT NUMBER

DRAWING NUMBER 3001178-004

SHEET NUMBER

4 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

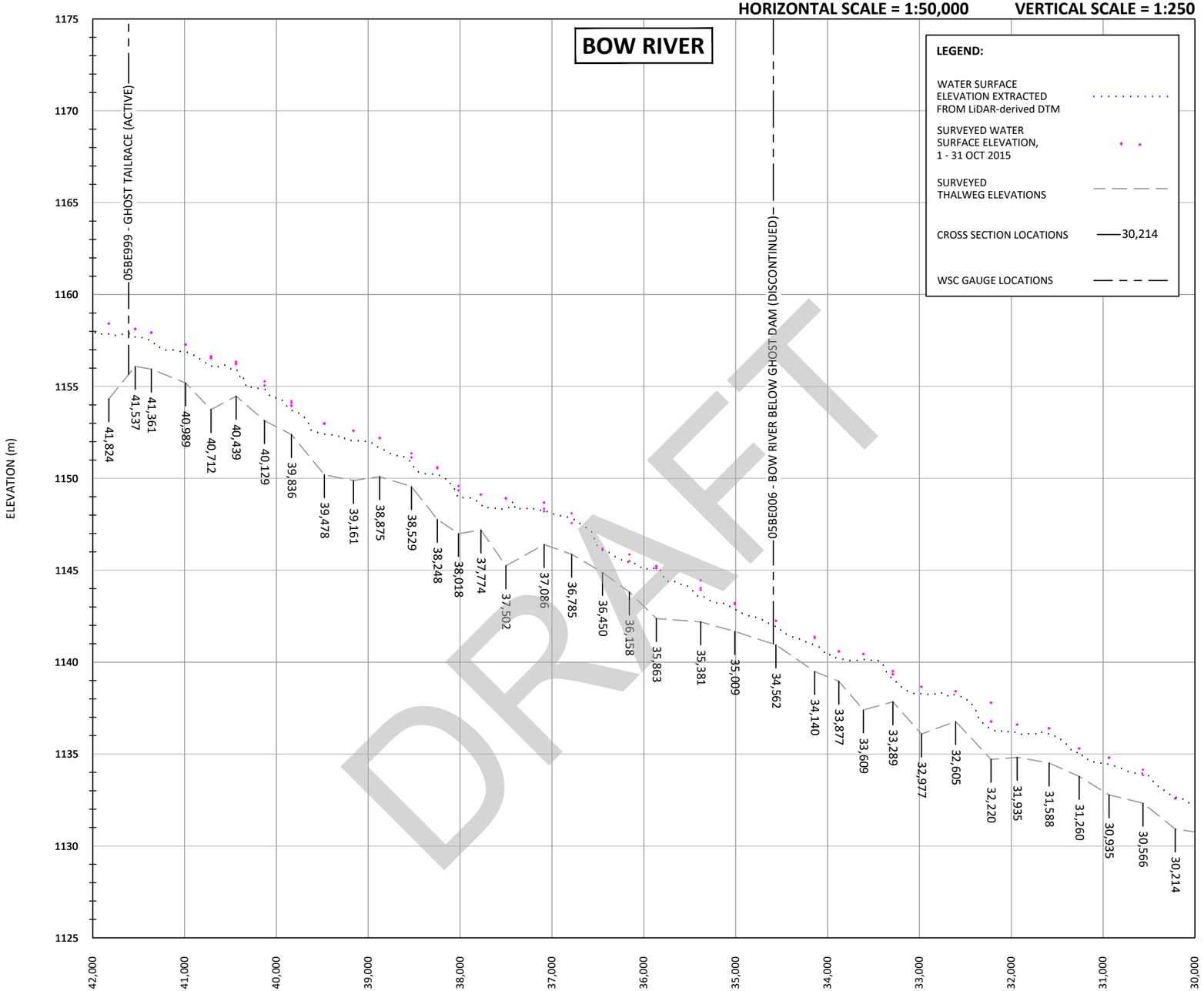
PROJECT NUMBER

DRAWING NUMBER 3001178-005

SHEET NUMBER

5 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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3. LiDAR DATA ACQUISITION BY AIRBORNE IMAGING INC. IN 2015 (SEPT. 10 TO 11, OCT. 5 AND 11).

UPPER BOW RIVER HAZARD STUDY

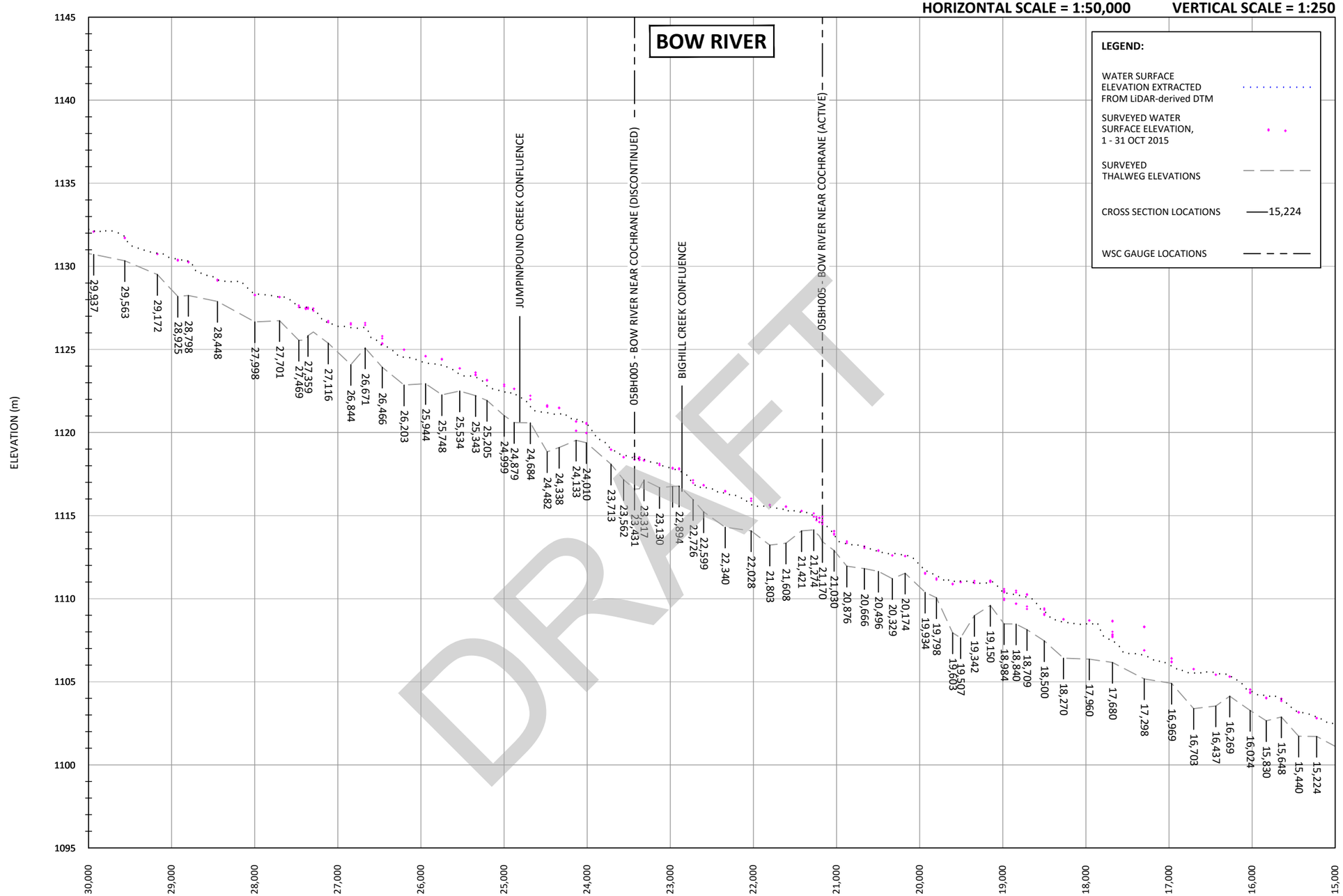
SURVEYED THALWEG AND WATER LEVEL PROFILES

PROJECT NUMBER

DRAWING NUMBER 3001178-006

SHEET NUMBER 6 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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NOTES:

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2. CHANNEL SURVEY CONDUCTED BY NHC IN 2015 (OCT. 1 TO 31).
3. LiDAR DATA ACQUISITION BY AIRBORNE IMAGING INC. IN 2015 (SEPT. 10 TO 11, OCT. 5 AND 11).

UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

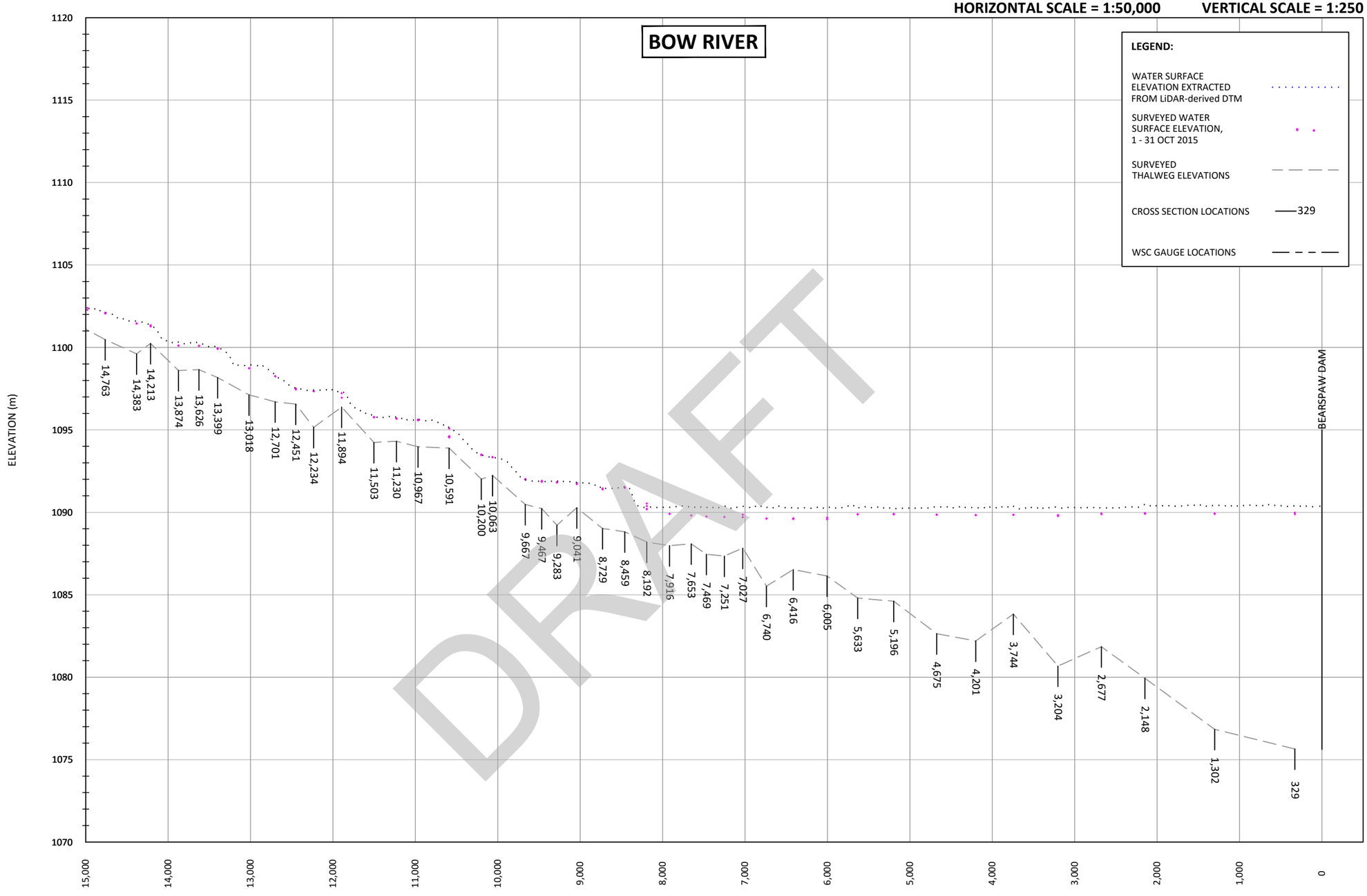
PROJECT NUMBER

DRAWING NUMBER 3001178-007

SHEET NUMBER

7 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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NOTES:

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UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

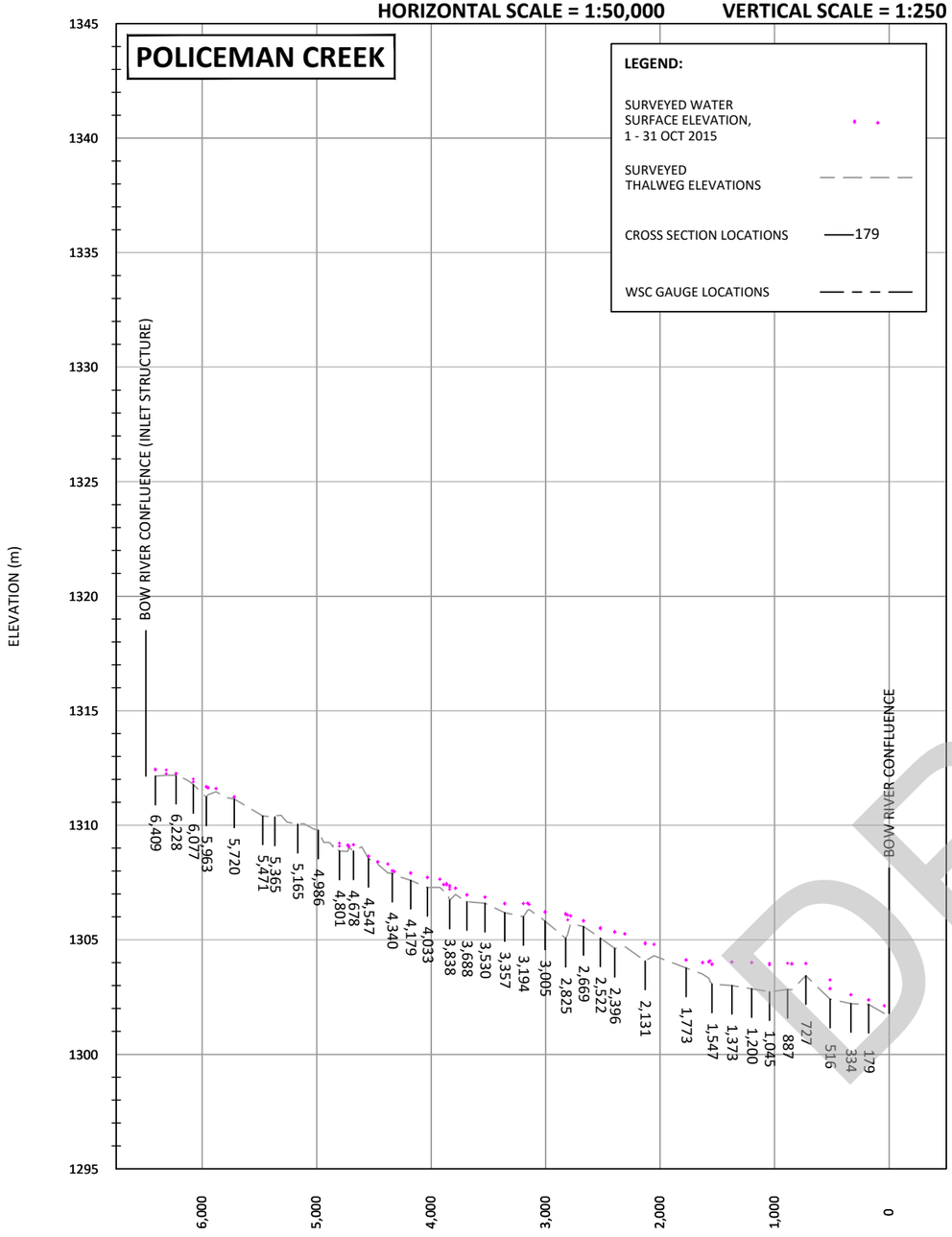
PROJECT NUMBER

DRAWING NUMBER 3001178-008

SHEET NUMBER

8 of 10

HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250



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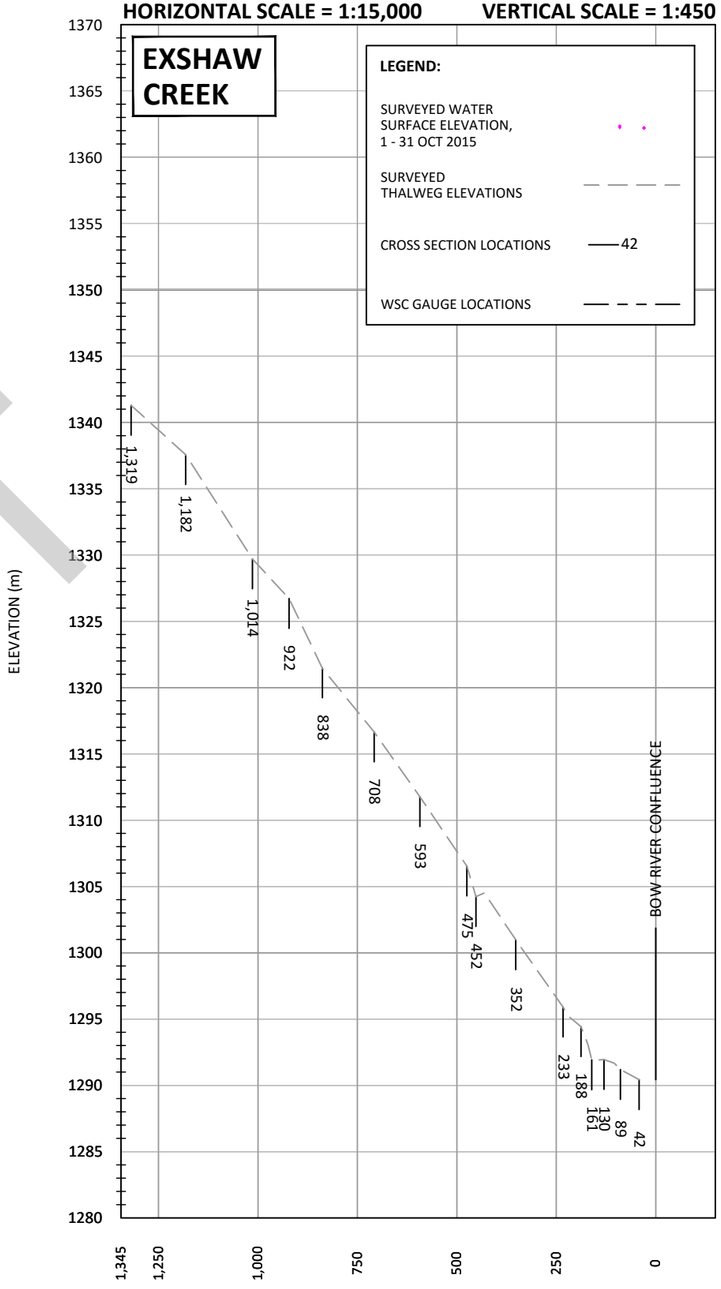

Alberta Government

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2. CHANNEL SURVEY CONDUCTED BY NHC IN 2015 (OCT. 1 TO 31).
3. LiDAR DATA ACQUISITION BY AIRBORNE IMAGING INC. IN 2015 (SEPT. 10 TO 11, OCT. 5 AND 11).
4. NO WATER ELEVATIONS WERE SURVEYED BETWEEN 4+986 AND 5+720 DUE TO DRY BED CONDITION FOR POLICEMAN CREEK.
5. NO WATER ELEVATIONS WERE SURVEYED DUE TO DRY BED CONDITIONS FOR EXSHAW CREEK.

UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

PROJECT NUMBER

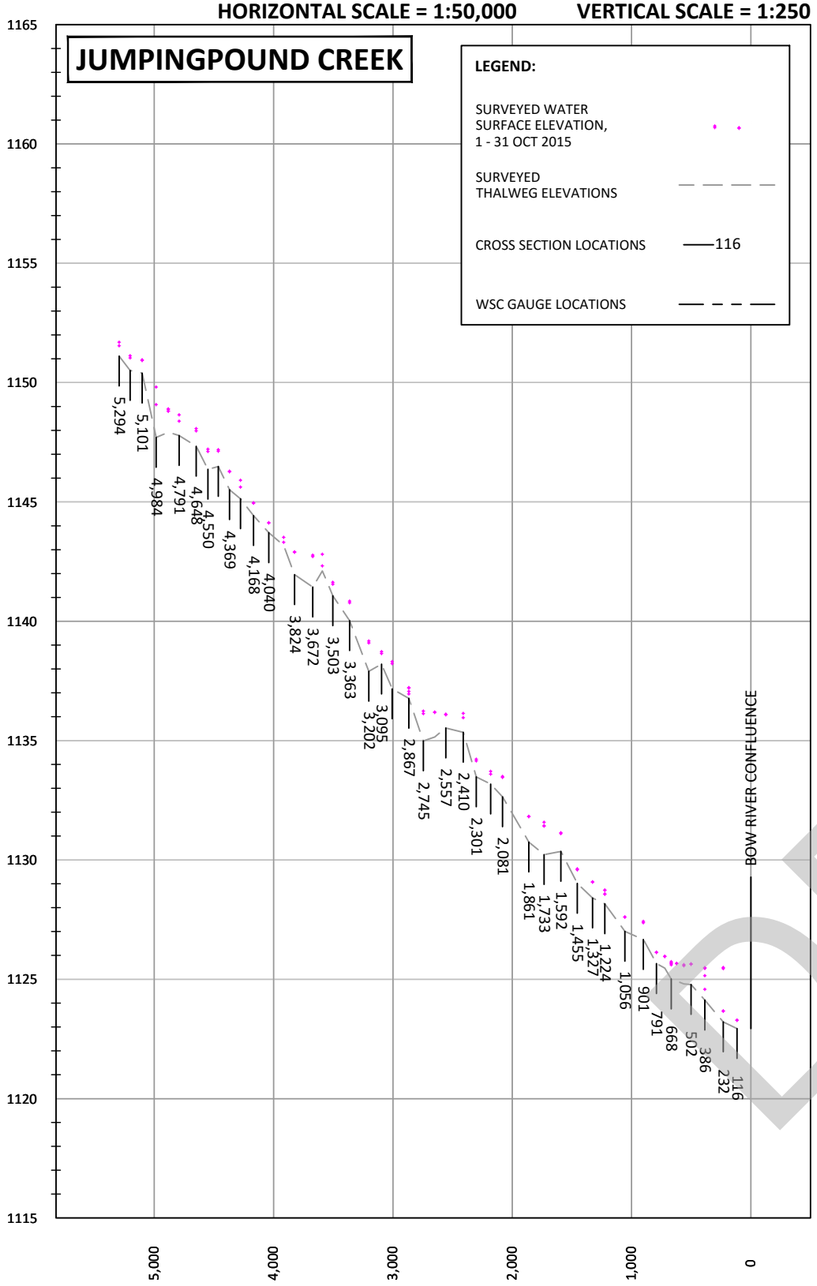
DRAWING NUMBER 3001178-009

SHEET NUMBER

9 of 10

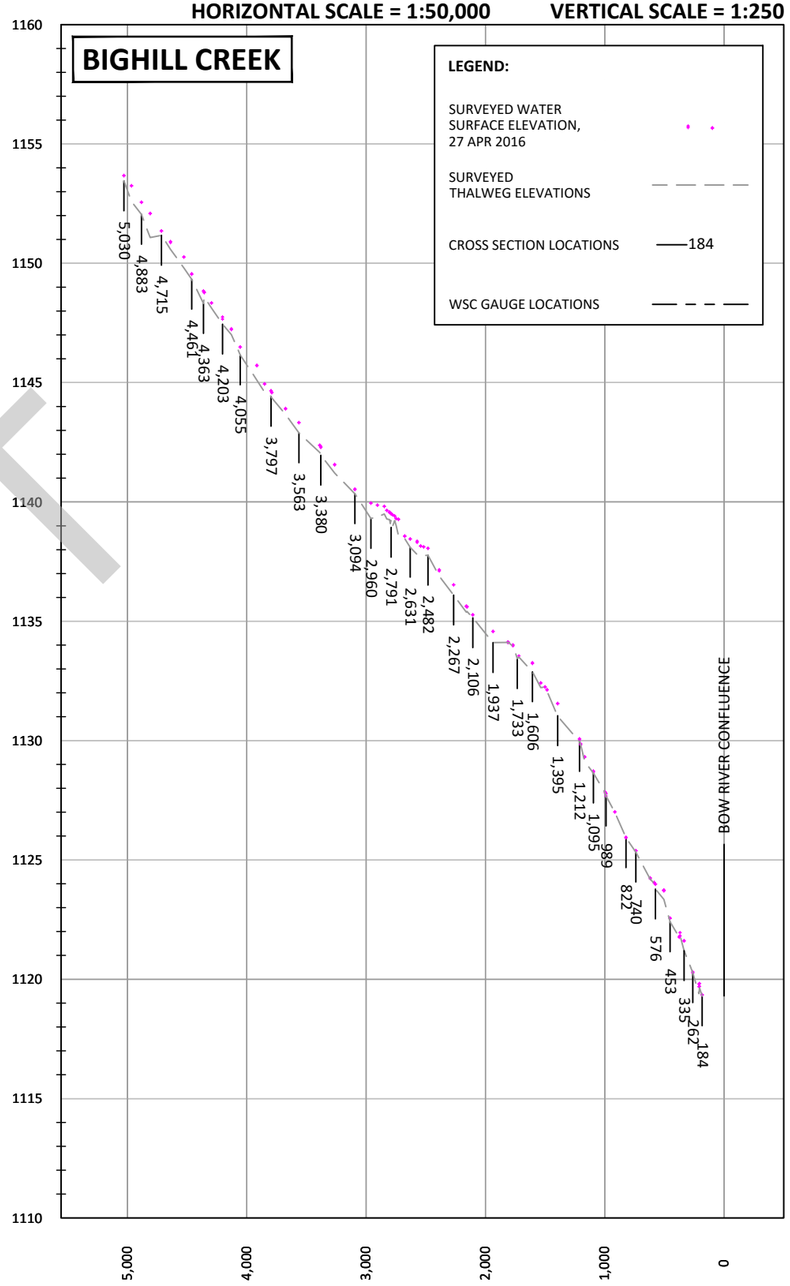
HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250

JUMPINGPOUND CREEK



HORIZONTAL SCALE = 1:50,000 VERTICAL SCALE = 1:250

BIGHILL CREEK



Alberta Government

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UPPER BOW RIVER HAZARD STUDY

SURVEYED THALWEG AND WATER LEVEL PROFILES

PROJECT NUMBER	
DRAWING NUMBER	3001178-010
SHEET NUMBER	10 of 10

APPENDIX A
BASE DATA COLLECTED

Table A1. Base Data Collected

Category	Data Type	Location	Date	Description	File Type	From	Status and Notes
Topography							
	LiDAR	u/s of Upper Bow chainage 72,300 (east of Exshaw)	10, 11-Sep & 5, 11-Oct-2015	full feature and bare earth	LAS, TIFF, FLyr	AEP	received
	LiDAR	d/s of Exshaw	10, 11-Sep & 5, 11-Oct-2015	full feature and bare earth	LAS, TIFF, FLyr	AEP	received
	DTM	various	unknown	small localized DTMs		AEP	requested 28-Sep-2015; not yet received; may not be required once LiDAR is available
	1:20,000 scale DEM	AOI	unknown			AltaLIS	available for download from Altalis, assumed same as CDEM
	DEM and hillshade	AOI	1984-1990	CDEM	TIFF	NRCan	downloaded
	1:50,000 scale contours	AOI	unknown	contours	FLyr	CanVec (NRCan)	downloaded
	1:20,000 scale contours	AOI	1975-1999	Provincial Base Mapping Program	FLyr	AltaLIS	downloaded
	Base topo mapping	AOI	unknown		WMS	Esri & NRCan	in ArcGIS via WMS; if required, we can also download topo basemap rasters
	Contours	Canmore	2013	1 m contours	FLyr	Canmore	downloaded
	Bathymetric and Lidar Survey	Canmore	Spring 2015	bathymetric survey, dike crest survey and Lidar data collected by McElhanney	TXT	Canmore	received
	Bathymetric Survey	Ghost Reservoir	April & July 2015	bathymetric survey by Golder	XLS	Golder/AEP	received
	Bathymetric and Topographic Survey	Bow River	Sep, Oct-2015	bathymetric and topographic section surveys of Upper Bow River, approx 30 sections	CSV, XLS	Golder/AEP	received
Imagery							
	2016 orthophotos	AOI	03-Jun-2016	Orthophotos will be used in final map products	GeoTIFF	Orthoshop	Received
	Base imagery	AOI	various	Orthophoto and satellite imagery	WMS	Esri & various sources	in ArcGIS via WMS (slow to display)
	Airphotos near bridges	near bridges	unknown	Historic airphotos near bridges		AT	available on request - NHC to request
	2013 post-flood imagery	AOI	21-Aug-13	2013 post-flood imagery; Upper Bow project area acquired 21-Aug-2013	Image Service; KMZ; GeoTIFF	AEP	in ArcGIS via Image Service (see LYR file in folder); in Google Earth via KMZ; files also provided by AEP
	2014 SPOT6 imagery	AOI	2014	2014 SPOT6 satellite imagery; 1.5m resolution	Web; GeoTIFF	AEP	can view on website; files also provided by AEP

Category	Data Type	Location	Date	Description	File Type	From	Status and Notes
Administrative							
	Indian Reserves	AOI	2005	Indian Reserve polygons	FLyr	AltaLIS	downloaded
	City, Town, Summer Village and Settlement boundaries	AOI	2010-2015	City, Town, Summer Village and Settlement areas	FLyr	AltaLIS	downloaded
	Municipal District and County boundaries	AOI	2015	Municipal Districts and Counties	FLyr	AltaLIS	downloaded
	Culture Points	AOI	2014	point locations of Hamlets, Localities and Townsites	FLyr	AltaLIS	downloaded
	Park land	AOI	unknown	parks and protected areas	FLyr	AEP	received
Land Use / Land Cover							
	Land use districts	Canmore	unknown		FLyr	Canmore	downloaded
	Vegetation cover	AOI	unknown	areas of vegetation cover	FLyr	CanVec (NRCan)	downloaded
Transportation							
	Roads	Canmore	unknown	roads	FLyr	Canmore	downloaded
	Trails	Canmore	unknown	rails	FLyr	Canmore	downloaded
	Roads	Cochrane	unknown	roads	FLyr	Cochrane	downloaded
	Pathways	Cochrane	unknown	pathways	FLyr	Cochrane	downloaded
	Major highways	AOI	unknown	major highways	FLyr	CRP	downloaded
	Road segments	AOI	1981 - 2014	road segments	FLyr	AltaLIS	downloaded
	Road segments	AOI	unknown	road segments	FLyr	NRN (NRCan)	downloaded
	Railroad segments	AOI	unknown	railroad segments	FLyr	NRWN (NRCan)	downloaded
Utilities							
	Powerlines	AOI	1981 - 2014	powerlines	FLyr	AltaLIS	downloaded
	Pipelines	AOI	1981 - 2014	pipelines	FLyr	AltaLIS	downloaded
Facilities							
	Facility points	AOI	1981 - 2014	man made structures of importance	FLyr	AltaLIS	downloaded

Category	Data Type	Location	Date	Description	File Type	From	Status and Notes
	Boat launches	AOI	2015	boat launch & possible launch point locations	KMZ, FLyr	NHC	created
Hydrography							
	Creeks	Cochrane	unknown		FLyr	Cochrane	downloaded
	Water features	Cochrane	unknown		FLyr	Cochrane	downloaded
	Streams	AOI	unknown		FLyr	NHN	downloaded
	Historic banklines near bridges	near bridges	unknown	historic banklines near bridges, mapped from airphotos	FLyr	AT	available on request - NHC to request
Previous AEP Flood Mapping							
	Cross section locations	Canmore, Bighorn/Exshaw, Cochrane	1990, 1993, 1996	locations from previous flood hazard modelling	FLyr	AEP	received
	100-year floodway	Canmore, Bighorn/Exshaw, Cochrane	1990, 1993, 1996	from previous flood hazard modelling	FLyr	AEP	received
	100-year floodfringe	Canmore, Bighorn/Exshaw, Cochrane	1990, 1993, 1996	from previous flood hazard modelling	FLyr	AEP	received
	100-year flood extents	Canmore, Bighorn/Exshaw, Cochrane	1990, 1993, 1996	from previous flood hazard modelling	FLyr	AEP	received
	HEC-2 models	Canmore, Bighorn/Exshaw, Cochrane	1990, 1993, 1996	from previous flood hazard modelling	HEC2, FLyr	AEP	received; NHC converted some files to GIS
Historic and Past Flood Information							
	HWM	AOI	1976, 1981, 1986 - 1990, 2012, 2013	compiled from HWM reports	FLyr	AEP, AT, WSC	recieved; NHC converted to GIS
	Historic and past flood information	Canmore, Bighorn/Exshaw, Cochrane	various	misc (HWM, photos, reports, records….)	misc	stakeholders, railroads, WSC, AEP, AT, PAA, newspapers, AGL	some materials received; more to be provided
Hydrometric Stations							
	WSC stations	AOI	various	station locations	FLyr	WSC	downloaded and edited to include gauge status during 2013 flood
	WSC station flow and water level data	AOI	various	hydrometic rating curves, recorded flows and water levels	misc	WSC	received
	TransAlta stations	AOI	various	station locations	FLyr	TransAlta	downloaded and edited to include gauge status during 2013 flood
	TransAlta station flow and water level data	AOI	various	recorded flows and water levels	.xlsx	TransAlta	received; rating curves unavailable

Category	Data Type	Location	Date	Description	File Type	From	Status and Notes
	Design flows and water levels	AOI	2015	.xlsx or other		AEP/Golder	to be provided
	Design flow locations	AOI	2015	points	FLyr	AEP/Golder	to be provided
Structures							
	Dams	AOI	2015	point locations of dams	FLyr	NHC	created
	Flood control structures	AOI	2015	dikes	FLyr	NHC Survey	created from field surveys
	Flood control structure details	AOI			DWG or PDF	AEP/Canmore/MD Bighorn	received
	Hydraulic structures	AOI	2015	bridges and culverts	FLyr	NHC Survey	created from field surveys
	AT hydraulic structures	AOI	2015	location of Alberta Transportation bridges (.kmz)	KMZ, FLyr	AT	received
	Road points, including bridges	AOI	unknown	road bridges, etc.	FLyr	AltaLIS	downloaded
	Railway points, including bridges	AOI	unknown	rail bridges, etc.	FLyr	AltaLIS	downloaded
	All bridge and culvert locations	AOI	2015	approximate locations of bridges and culverts, created for field survey planning	FLyr	NHC	compiled based on AT data and imagery
	Bridge and culvert details and file numbers	AOI	various	database with bridge/culvert details such as rivers, tribs, flood records.	MDB	AT	received
	Bridge and culvert geometry	AOI	various	drawings with details	PDF	AT	received available data from contact at AT and extracted from the Hydrotechnical Information System (HIS)
	Bridge and culvert geometry	AOI		drawings with details		railroads	will not be provided by CP
	Bridge and culvert geometry	AOI		drawings with details		municipalities	received
	Dam geometry	AOI		Ghost, Kananaskis, Bearspaw, Horseshoe		TransAlta	not required
	Dam operations	AOI		Ghost, Kananaskis, Bearspaw, Horseshoe		TransAlta	not required
NHC Survey							
	Survey data points	AOI	2015, 2016	point survey data from NHC's fall 2015 and spring 2016 ground and bathymetric surveys	FLyr	NHC	completed
	Survey field photos	AOI	2015, 2016	photos from NHC's fall 2015 and spring 2016 surveys, including point locations	JPEG, FLyr	NHC	completed
Modelling							
	Cross section locations	AOI	2015	Bow River and tributaries	FLyr	NHC	created for survey and model planning, updated to reflect survey data collected, includes historic cross section locations

Category	Data Type	Location	Date	Description	File Type	From	Status and Notes
	Bank lines	AOI	2015	Bow River and tributaries	FLyr	NHC	digitized based on imagery and survey points
	Network line	AOI	2015	Bow River and tributaries	FLyr	NHC	calibrated routes with zero chainage starting at downstream point
	Land use (roughness values)	AOI	2015	polygons	FLyr	NHC	digitized based on imagery and survey points (in progress)

Notes:

- Communities: Canmore, Cochrane, MD of Bighorn, Rocky View County, Stoney Nakoda First Nation
- CRP = Calgary Regional Partnership
- AT = Alberta Transportation
- AOI = Area of Interest
- FLyr = GIS shapefile or geodatabase feature layer

APPENDIX B
HYDRAULIC STRUCTURES

Table B1. Summary of Hydraulic Structure Data (Bridges)

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID	Design Drawing /Info	Type of Bridge	Descrip.	Span (m)	Width (m)	Number of Piers	Skew (°)	Elevation (m GD)			Survey Status	Survey by	In Model	Model Comment
														Top Chord	Deck	Low Chord				
12	Bow River	21,225	Cochrane	River Avenue	Alberta Transportation	111	yes	Paved road bridge	steel truss bridge	145	7.49	1	0	1,121.20	1,121.20	1,119.95	NHC Surveyed 2015	Crew 1	YES	pipe crossing on downstream side, approx. 0.3 m above deck but not used
15	Bow River	23,403	Cochrane	Cowbow Trail/Hwy 22	Alberta Transportation	76609	yes	Highway bridge	steel beam bridge	150	11.78	3	25	1,128.10	1,127.70	1,125.70	NHC Surveyed 2015	Crew 1	YES	
17	Bow River	27,374	near Cochrane	CP Rail	CP Rail	mile 25.7	yes	Rail bridge	steel truss bridge	120.6	6.3	1	32	1,136.24	1,136.24	1,134.74	NHC Surveyed 2015	Crew 3	YES	
11	Bow River	54,457	Morley	Morley Road	Alberta Transportation	611	yes	Highway bridge	steel truss bridge	93	10.8	2	15	1,197.65	1,197.45	1,196.08	NHC Surveyed 2016	Crew 5	YES	
8	Bow River	77,639	Seebe	Hwy 1X	Alberta Transportation	75111	yes	Highway bridge	concrete beam bridge	135.3	10.64	3	0	1,285.44	1,285.22	1,283.20	NHC Surveyed 2015	Crew 3	YES	
30	Bow River	79,676	Seebe	CP Rail	CP Rail	mile 53.1	yes	Rail bridge	steel truss bridge	144.3	7.5	2	0	1,284.35	1,284.35	1,283.40	NHC Surveyed 2015	Crew 3	YES	
42	Bow River	104,509	Canmore	Hwy 1 E	Alberta Transportation	74353	yes	Highway bridge	concrete arch bridge	137.6	15.4	3	30	1,306.55	1,306.55	1,302.58	NHC Surveyed 2015	Crew 3	YES	
32	Bow River	104,549	Canmore	Hwy 1 W	Alberta Transportation	74353	yes	Highway bridge	concrete arch bridge	137.6	15.4	3	30	1,306.55	1,306.55	1,302.58	NHC Surveyed 2015	Crew 3	YES	
70	Bow River	109,212	Canmore	Bow River Pedestrian Bridge	Canmore	BG03	no	Pedestrian bridge	timber beam bridge	73.8	4.17	2	0	1,312.50	1,312.20	1,311.21	NHC Surveyed 2015	Crew 3	YES	
31	Bow River	109,223	Canmore	Bridge Road	Alberta Transportation	00167 (BG02)	yes	Paved road bridge	steel beam bridge	86	8.66	2	0	1,312.47	1,312.20	1,310.92	NHC Surveyed 2015	Crew 3	YES	
51	Bow River	109,929	Canmore	Spur Line Trail (Engine Bridge)	Canmore	81692 (BG20)	yes	Pedestrian bridge	steel truss bridge	95.2	8.3	1	0	1,313.15	1,313.13	1,312.33	NHC Surveyed 2015	Crew 3	YES	
74	side channel (Bow River)	25,010	Cochrane	Walking Trail	Cochrane	-	no	Replaced 2015	timber beam bridge	7.33	2.76	0	0	1,126.87	1,126.64	1,126.26	NHC Surveyed 2015	Crew 1	NO	on floodplain, not connected to channel flow
69	side channel (Bow River)	108,615	Canmore	Walking Trail	Canmore	BG15	no	Pedestrian bridge	timber beam bridge	11.29	2.88	0	0	1,309.80	1,309.80	1,308.78	NHC Surveyed 2015	Crew 3	NO	on floodplain, not connected to channel flow
55	side channel (Bow River)	109,929	Canmore	Spur Line Trail	Canmore	81694 (BG18)	no	Pedestrian bridge	steel truss bridge	40.65	6.76	2	0	1,311.90	1,311.90	1,310.94	NHC Surveyed 2015	Crew 3	YES	

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID	Design Drawing /Info	Type of Bridge	Descrip.	Span (m)	Width (m)	Number of Piers	Skew (°)	Elevation (m GD)			Survey Status	Survey by	In Model	Model Comment
														Top Chord	Deck	Low Chord				
63	side channel (Bow River)	110,852	Canmore	Walking Trail	Canmore	BG30	no	Pedestrian bridge	timber beam bridge	1.15	1.9	0	0	1,311.63	1,311.62	1,311.49	NHC Surveyed 2015	Crew 3	NO	on floodplain, not connected to channel flow
71	Bighill Creek	208	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	7.5	2.8	0	0	1,122.12	1,121.98	1,121.60	NHC Surveyed 2015	Crew 4	YES	
317	Bighill Creek	372	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	5.6	1.5	0	0	1,123.45	1,123.23	1,123.16	NHC Surveyed 2015	Crew 4	YES	
316	Bighill Creek	581	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	8	2.5	0	0	1,126.15	1,126.00	1,125.20	NHC Surveyed 2015	Crew 4	YES	
77	Bighill Creek	992	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	27.63	1.25	2	0	1,130.13	1,131.10	1,129.83	NHC Surveyed 2015	Crew 4	YES	
76	Bighill Creek	1,207	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	6.03	1.5	0	0	1,131.76	1,131.70	1,131.30	NHC Surveyed 2015	Crew 4	YES	
315	Bighill Creek	1,722	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	6	1.5	0	0	1,135.70	1,135.57	1,135.17	NHC Surveyed 2015	Crew 4	YES	
314	Bighill Creek	1,812	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	6	1.5	0	0	1,136.26	1,136.12	1,135.72	NHC Surveyed 2015	Crew 4	YES	
313	Bighill Creek	2,158	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	7.2	1.2	0	0	1,138.20	1,138.00	1,137.65	NHC Surveyed 2015	Crew 4	YES	
312	Bighill Creek	2,754	Cochrane	CP Rail	CP Rail	mile 23.6	yes	Rail bridge	concrete beam bridge	10	4.6	0	0	1,143.42	1,143.20	1,142.20	NHC Surveyed 2015	Crew 4	YES	
311	Bighill Creek	2,786	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	5.5	1	0	0	1,140.60	1,140.60	1,140.00	NHC Surveyed 2015	Crew 4	NO	small pedestrian bridge parallel to high flow direction
14	Bighill Creek	2,814	Cochrane	Bow Valley Trail/Hwy 1A	Alberta Transportation	521	yes	Highway bridge	concrete beam bridge	11	14.17	0	35	1,143.30	1,143.05	1,142.46	NHC Surveyed 2015	Crew 4	YES	
310	Bighill Creek	3,385	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	11.7	2.5	0	0	1,144.55	1,144.24	1,143.84	NHC Surveyed 2015	Crew 4	YES	
309	Bighill Creek	3,794	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	5.1	2.3	2	0	1,145.85	1,145.85	1,145.60	NHC Surveyed 2015	Crew 4	YES	
308	Bighill Creek	4,360	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	5.6	1.7	0	0	1,150.85	1,150.30	1,150.00	NHC Surveyed 2015	Crew 4	YES	

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID	Design Drawing /Info	Type of Bridge	Descrip.	Span (m)	Width (m)	Number of Piers	Skew (°)	Elevation (m GD)			Survey Status	Survey by	In Model	Model Comment
														Top Chord	Deck	Low Chord				
318	side channel (Bighill Creek)	164	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	4	2.7	0	0	1,122.40	1,122.25	1,121.85	NHC Surveyed 2015	Crew 4	NO	on floodplain, not connected to channel flow
72	side channel (Bighill Creek)	185	Cochrane	Walking Trail	Cochrane	-	no	Pedestrian bridge	timber beam bridge	3.7	2.95	0	0	1,121.85	1,121.75	1,121.48	NHC Surveyed 2015	Crew 4	NO	on floodplain, not connected to channel flow
16	Jumpingpound Creek	647	Cochrane	George Fox Trail	Alberta Transportation	283	yes	Paved road bridge	concrete beam bridge	50	10	1	40	1,131.96	1,130.10	1,129.20	NHC Surveyed 2015	Crew 4	YES	
24	Exshaw Creek	111	Exshaw	Diamond Drive	M.D. Bighorn	-	no	Paved road bridge	steel beam bridge	12	0	0	0	1,295.25	1,295.10	1,294.40	NHC Surveyed 2015	Crew 4	YES	
25	Exshaw Creek	155	Exshaw	CP Rail	CP Rail	mile 57.0	yes	Paved road bridge	steel beam bridge	22.8	0	0	0	1,297.26	1,296.20	1,295.17	NHC Surveyed 2015	Crew 4	YES	
304	Exshaw Creek	451	Exshaw	Walking Trail	M.D. Bighorn	-	no	Pedestrian bridge	timber beam bridge	16.8	0	0	0	1,307.85	1,307.73	1,307.38	NHC Surveyed 2015	Crew 4	YES	
43	Policeman Creek	1,552	Canmore	Wastewater Treatment Plant Road	Canmore	BG33	yes	Gravel road bridge	steel beam bridge	20.62	5.49	0	0	1,307.50	1,307.50	1,306.40	NHC Surveyed 2015	Crew 4	YES	
2	Policeman Creek	2,793	Canmore	Spring Creek Gate	Canmore	79434 (BG24)	yes	Paved road bridge	concrete beam bridge	14.51	11.2	0	0	1,309.05	1,309.05	1,307.81	NHC Surveyed 2015	Crew 4	YES	
45	Policeman Creek	3,147	Canmore	Walking Trail	Canmore	BG31	no	Pedestrian bridge	timber arch bridge	24.9	2.26	0	0	1,309.34	1,309.34	1,308.34	NHC Surveyed 2015	Crew 4	YES	
46	Policeman Creek	3,699	Canmore	8 Street	Alberta Transportation	71563 (BG06)	yes	Paved road bridge	concrete beam bridge	8.37	13.96	0	0	1,308.40	1,308.40	1,307.80	NHC Surveyed 2015	Crew 4	YES	
47	Policeman Creek	3,876	Canmore	10 Street	Alberta Transportation	80959 (BG07)	yes	Paved road bridge	concrete beam bridge	20.15	13.73	2	0	1,309.36	1,308.97	1,308.60	NHC Surveyed 2015	Crew 4	YES	
4	Policeman Creek	4,328	Canmore	Walking Trail	Canmore	81618 (BG08)	yes	Pedestrian bridge	timber beam bridge	13.99	2.03	2	0	1,309.98	1,309.98	1,309.37	NHC Surveyed 2015	Crew 4	YES	
66	Policeman Creek	4,717	Canmore	Walking Trail	Canmore	BG09	yes	Pedestrian bridge	timber beam bridge	28.07	1.27	2	0	1,310.31	1,310.31	1,309.98	NHC Surveyed 2015	Crew 4	YES	
65	Policeman Creek	4,853	Canmore	Walking Trail	Canmore	BG28	yes	Pedestrian bridge	timber beam bridge	6.85	1.26	0	0	1,310.53	1,310.53	1,310.12	NHC Surveyed 2015	Crew 4	YES	
61	Policeman Creek	5,103	Canmore	Walking Trail	Canmore	BG10	yes	Pedestrian bridge	timber beam bridge	32.07	1.68	4	0	1,131.52	1,131.52	1,311.15	NHC Surveyed 2015	Crew 4	YES	

NHC ID	Stream Name	River Station (m)	Municipality	Road/Trail	Owner	Owner ID	Design Drawing /Info	Type of Bridge	Descrip.	Span (m)	Width (m)	Number of Piers	Skew (°)	Elevation (m GD)			Survey Status	Survey by	In Model	Model Comment
														Top Chord	Deck	Low Chord				
60	Policeman Creek	5,252	Canmore	Walking Trail	Canmore	BG11	yes	Pedestrian bridge	timber beam bridge	21.97	1.42	2	0	1,311.51	1,311.51	1,311.18	NHC Surveyed 2015	Crew 4	YES	
303	Policeman Creek	5,648	Canmore	Walking Trail	Canmore	-	no	Pedestrian bridge	timber beam bridge	0	0	0	0	1,312.20	1,312.20	1,311.70	NHC Surveyed 2015	Crew 4	YES	
302	Policeman Creek	5,668	Canmore	Golf Course	Canmore Golf Course	-	no	Pedestrian bridge	timber beam bridge	5.3	3.7	0	0	1,312.30	1,312.30	1,312.15	NHC Surveyed 2015	Crew 4	YES	
301	Policeman Creek	6,022	Canmore	Unknown	Unknown	-	no	Abandoned pedestrian bridge	steel beam bridge	2.8	0	0	0	1,312.65	1,312.65	1,312.20	NHC Surveyed 2015	Crew 4	NO	abandoned pedestrian bridge
3	side channel (Policeman Creek)	3,360	Canmore	Walking Trail	Canmore	unknown (possibly BG40)	no	Pedestrian bridge	unknown	12.4	2.25	0	0	1,307.88	1,307.88	1,307.23	NHC Surveyed 2015	Crew 4	NO	on floodplain, not connected to channel flow
62	side channel (Policeman Creek)	5,331	Canmore	Walking Trail	Canmore	BG38	no	Pedestrian bridge	timber beam bridge	35.58	1.4	7	0	1,131.59	1,311.60	1,311.12	NHC Surveyed 2015	Crew 3	NO	on floodplain, not connected to channel flow

Table B2a. Summary of Hydraulic Structure Data (Culvert Locations)

NHC ID	Stream Name	River Station (m)	Municipality	Road or Trail	Owner	Owner ID	Design Drawing/Info	In Model	Model Comment
405	Bow River	87,721	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn			no	accounted for in permeable embankment
204	Bow River	87,904	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn		no	no	accounted for in permeable embankment
404	Bow River	88,087	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn			no	accounted for in permeable embankment
203	Bow River	88,251	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn		no	no	accounted for in permeable embankment
202	Bow River	88,420	near Exshaw	Lac Des Arcs Dike	M.D. Bighorn		no	no	accounted for in permeable embankment
201	Bow River	91,122	near Exshaw	Lac Des Arcs proposed inlet structure	M.D. Bighorn		no	no	accounted for in permeable embankment
407	side channel (Bow River)	23,505	Cochrane	Walking trail	Cochrane			no	on floodplain, not connected to main flow
33	side channel (Bow River)	96,000	Lac Des Arcs	Gravel Road	unknown (possibly M.D. Bighorn)		no	no	on floodplain, not connected to main flow
164	side channel (Bow River)	105,661	near Canmore	Trans-Canada Highway - Hwy 1	Alberta Transportation	74363	yes	yes	culvert through highway embankment
168	side channel (Bow River)	105,880	near Canmore	Trans-Canada Highway - Hwy 1	Alberta Transportation	74364	yes	yes	culvert through highway embankment
81	Bighill Creek	480	Cochrane	Griffin Road W	Alberta Transportation	76989	yes	yes	
75	Bighill Creek	1,519	Cochrane	Glenpatrick Road	Cochrane		no	yes	
83	Bighill Creek	2,498	Cochrane	Glenbow Drive	Alberta Transportation	81092	no	yes	
26	Exshaw Creek	206	Exshaw	Bow Valley Trail - Hwy 1A	Alberta Transportation	71734	yes	yes	
64	Policeman Creek	4,923	Canmore	8 Avenue	Canmore	81617 (BG27)	no	yes	
196	Policeman Creek	5,003	Canmore	17 Street	Canmore	81616 (BG26)	no	yes	
59	Policeman Creek	5,957	Canmore	Golf course	Canmore Golf Course	BG25	no	yes	
401	Policeman Creek	6,435	Canmore	Canmore Dyke	AEP		yes	yes	inlet structure through Canmore dyke
175	side channel (Policeman Creek)	4,159	Canmore	7 Avenue	Canmore		no	yes	
197	side channel (Policeman Creek)	4,256	Canmore	Pedestrian pathway	Canmore	BG29	yes	yes	
155	side channel (Policeman Creek)	4,877	Canmore	8 Avenue	Canmore		no	yes	

Note: Culvert barrel details are included in Table B2b and can be related to the culvert location using the NHC ID field.

Table B2b. Summary of Hydraulic Structure Data (Culvert Barrel Details)

NHC ID	Stream Name	River Station (m)	Culvert Shape	Material	Barrel Length (m)	Diameter, Rise or Height (m)	Span or Width (m)	Upstream Invert Elev. (m)	Downstream Invert Elev. (m)	Entrance Condition	Comment
405	Bow River	87,721			15	0.9		1,289.84	1,289.84		
204	Bow River	87,904	round	CSP	15	0.845	N/A	1,289.85	1,289.84		
404	Bow River	88,087		CSP	13	0.9	0.9	1,289.86	1,289.79		
203	Bow River	88,251	round	CSP	13.36	0.83	N/A	1,289.95	1,289.91		
202	Bow River	88,420	round	CSP	12.93	0.755	N/A	1,290.02	1,289.79	mitred to conform to slope	flapper gate d/s
201	Bow River	91,122	round	CSP	13.03	0.55	N/A	1,290.10	1,289.80		
407	side channel (Bow River)	23,505	square	concrete	4.5	1.8	1.2	1,120.10	1,119.90	no fill	"bridge" made up of 4 concrete culverts, inverts vary, photos
33	side channel (Bow River)	96,000			0	0		0	0		
164	side channel (Bow River)	105,661	round	CSP	72.3	1.19	N/A	1,301.71	1,301.69		
168	side channel (Bow River)	105,880	round	CSP	74.43	1.87	N/A	1,301.99	1,301.49		
168	side channel (Bow River)	105,880	round	CSP	74.43	0.69	N/A	1,303.66	0		
81	Bighill Creek	480	round	CSP	36.64	4.74	N/A	1,123.08	1,122.56	mitred to conform to slope	culvert with pedestrian bridge/walkway inside, area under walkway modelled as blocked
75	Bighill Creek	1,519	ellipse	CSP	33.51	6.95	6.95	1,135.84	1,135.74	mitred to conform to slope	added depth blocked = 3.6 m
83	Bighill Creek	2,498	arch	concrete	27.4	3.3	9.1	1,138.10	1,138.30	mitred to conform to slope	
26	Exshaw Creek	206	ellipse	SPCSP	14	3	12	1,295.67	1,294.93		
64	Policeman Creek	4,923	round	CSP	23.99	1.48	N/A	1,309.50	1,309.19	projecting from fill	
64	Policeman Creek	4,923	round	CSP	21.11	0.77	N/A	1,309.97	1,309.56	projecting from fill	
196	Policeman Creek	5,003	round	CSP	29	1	N/A	1,309.97	1,309.68	projecting from fill	
196	Policeman Creek	5,003	round	CSP	29	0.7	N/A	1,310.10	1,310.07	projecting from fill	
59	Policeman Creek	5,957	round	CSP	5.7	1.1	N/A	1,311.22	1,311.28	mitred to conform to slope	
401	Policeman Creek	6,435	round	CSP	28	0.5	N/A	1,312.75	1,312.05	projecting from fill	inverted T structure through Canmore Dyke, trash rack and flap gate
175	side channel (Policeman Creek)	4,159	ellipse	CSP	12.33	0.72		1,308.41	1,308.36	projecting from fill	
175	side channel (Policeman Creek)	4,159	ellipse	CSP	13.25	0.7		1,308.47	1,308.35	projecting from fill	
197	side channel (Policeman Creek)	4,256	round	CSP	6.42	0.9	N/A	1,308.22	1,308.18	mitred to conform to slope	
197	side channel (Policeman Creek)	4,256	round	CSP	6.56	0.87	N/A	1,308.29	1,308.17	projecting from fill	
155	side channel (Policeman Creek)	4,877	round	CSP	20.35	1.07	N/A	1,309.59	1,309.26	projecting from fill	
155	side channel (Policeman Creek)	4,877	round	CSP	21.1	0.855	N/A	1,309.17	1,309.18	projecting from fill	

Note: Culvert location information is included in Table B2a and can be related to the culvert barrel details using the NHC ID field.

APPENDIX B: PHOTO PLATE REPORT – HYDRAULIC STRUCTURES

LIST OF PHOTOGRAPHS

Note that structure locations are identified by river and river station (in metres), e.g., “Bow River, 21,230”.

Bridge Photo 82. Policeman Creek, 2,793
Bridge Photo 83. Policeman Creek, 3,147
Bridge Photo 84. Policeman Creek, 3,147
Bridge Photo 85. Policeman Creek, 3,699
Bridge Photo 86. Policeman Creek, 3,876
Bridge Photo 87. Policeman Creek, 4,328
Bridge Photo 88. Policeman Creek, 4,328
Bridge Photo 89. Policeman Creek, 4,328
Bridge Photo 90. Policeman Creek, 4,717
Bridge Photo 91. Policeman Creek, 4,717
Bridge Photo 92. Policeman Creek, 4,717
Bridge Photo 93. Policeman Creek, 4,853
Bridge Photo 94. Policeman Creek, 4,853
Bridge Photo 95. Policeman Creek, 5,103
Bridge Photo 96. Policeman Creek, 5,103
Bridge Photo 97. Policeman Creek, 5,252
Bridge Photo 98. Policeman Creek, 5,252
Bridge Photo 99. Policeman Creek, 5,648
Bridge Photo 100. Policeman Creek, 5,648
Bridge Photo 101. Policeman Creek, 5,668
Bridge Photo 102. Policeman Creek, 5,668
Bridge Photo 103. Policeman Creek, 6,022
Bridge Photo 104. Side channel of Policeman Creek, 3,360
Bridge Photo 105. Side channel of Policeman Creek, 5,331
Bridge Photo 106. Side channel of Policeman Creek, 5,331

Culvert Photo 1. Bow River, 87,721
Culvert Photo 2. Bow River, 87,904
Culvert Photo 3. Bow River, 88,087
Culvert Photo 4. Bow River, 88,251
Culvert Photo 5. Bow River, 88,420
Culvert Photo 6. Bow River, 88,420
Culvert Photo 7. Bow River, 91,122
Culvert Photo 8. Side channel of Bow River, 23,505
Culvert Photo 9. Side channel of Bow River, 96,000
Culvert Photo 10. Side channel of Bow River, 105,661
Culvert Photo 11. Side channel of Bow River, 105,661
Culvert Photo 12. Side channel of Bow River, 105,880
Culvert Photo 13. Side channel of Bow River, 105,880
Culvert Photo 14. Bighill Creek, 480 (upstream)
Culvert Photo 15. Bighill Creek, 480 (downstream)
Culvert Photo 16. Bighill Creek, 480
Culvert Photo 17. Bighill Creek, 1,519 (downstream)

1 BRIDGES

1.1 BOW RIVER

Bridge Photo 1. Bow River, 21,225

Bridge Photo 2. Bow River, 21,225

Bridge Photo 3. Bow River, 21,225

Bridge Photo 4. Bow River, 21,225

Bridge Photo 5. Bow River, 23,403

Bridge Photo 6. Bow River, 23,403

Bridge Photo 7. Bow River, 23,403

Bridge Photo 8. Bow River, 27,374

Bridge Photo 9. Bow River, 27,374

Bridge Photo 10. Bow River, 27,374

Bridge Photo 11. Bow River, 54,457

Bridge Photo 12. Bow River, 54,457

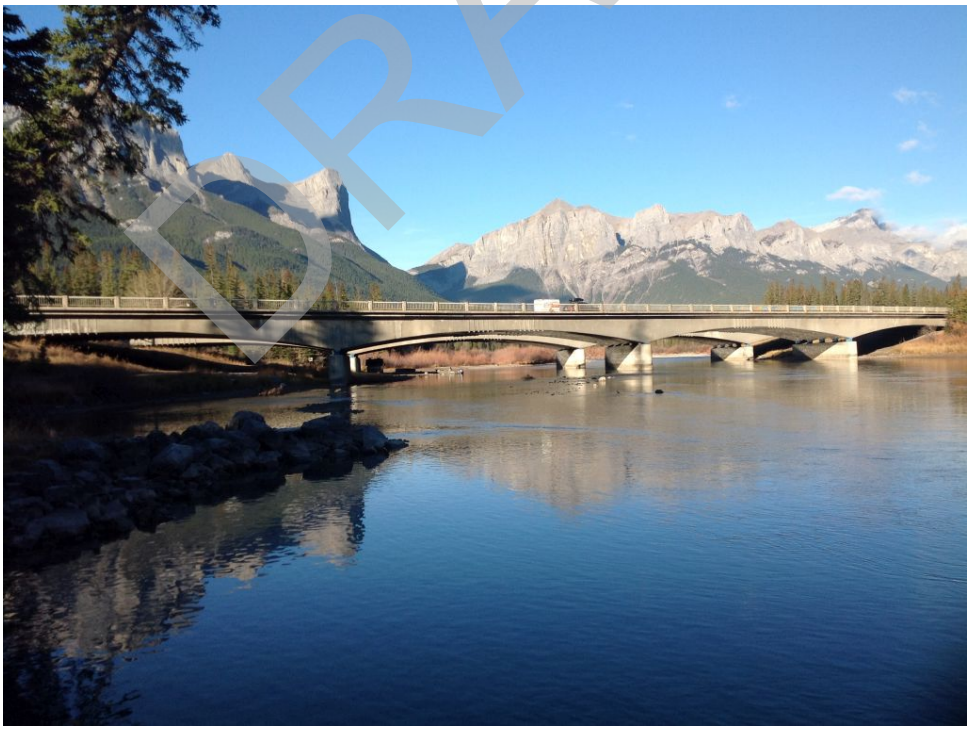
Bridge Photo 13. Bow River, 77,639

Bridge Photo 14. Bow River, 77,639

Bridge Photo 15. Bow River, 77,639

Bridge Photo 16. Bow River, 79,676

Bridge Photo 17. Bow River, 79,676



Bridge Photo 18. Bow River, 104,509 and 104,549 (downstream)

Bridge Photo 19. Bow River, 104,509 and 104,549 (upstream)

Bridge Photo 20. Bow River, 109,212

Bridge Photo 21. Bow River, 109,212

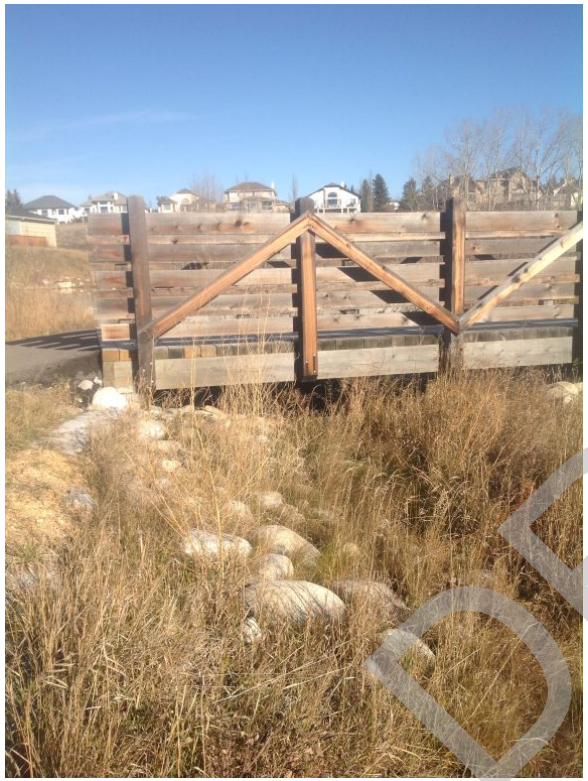
Bridge Photo 22. Bow River, 109,223

Bridge Photo 23. Bow River, 109,223

Bridge Photo 24. Bow River, 109,929

Bridge Photo 25. Bow River, 109,929

Bridge Photo 26. Side channel of Bow River, 25,010



Bridge Photo 27. Side channel of Bow River, 25,010

Bridge Photo 28. Side channel of Bow River, 25,010

Bridge Photo 29. Side channel of Bow River, 108,615

Bridge Photo 30. Side channel of Bow River, 109,929

Bridge Photo 31. Side channel of Bow River, 109,929

Bridge Photo 32. Side channel of Bow River, 110,852

1.2 BIGHILL CREEK

Bridge Photo 33. Bighill Creek, 208

Bridge Photo 34. Bighill Creek, 208

Bridge Photo 35. Bighill Creek, 372

Bridge Photo 36. Bighill Creek, 372

Bridge Photo 37. Bighill Creek, 372

Bridge Photo 38. Bighill Creek, 581

Bridge Photo 39. Bighill Creek, 581

Bridge Photo 40. Bighill Creek, 992

Bridge Photo 41. Bighill Creek, 992

Bridge Photo 42. Bighill Creek, 992

Bridge Photo 43. Bighill Creek, 1,207

Bridge Photo 44. Bighill Creek, 1,207

Bridge Photo 45. Bighill Creek, 1,722

Bridge Photo 46. Bighill Creek, 1,722

Bridge Photo 47. Bighill Creek, 1,812

Bridge Photo 48. Bighill Creek, 1,812

Bridge Photo 49. Bighill Creek, 2,158

Bridge Photo 50. Bighill Creek, 2,158

Bridge Photo 51. Bighill Creek, 2,754

Bridge Photo 52. Bighill Creek, 2,754

Bridge Photo 53. Bighill Creek, 2,754

Bridge Photo 54. Bighill Creek, 2,786

Bridge Photo 55. Bighill Creek, 2,814

Bridge Photo 56. Bighill Creek, 2,814

Bridge Photo 57. Bighill Creek, 2,814

Bridge Photo 58. Bighill Creek, 2,814

Bridge Photo 59. Bighill Creek, 3,385

Bridge Photo 60. Bighill Creek, 3,385

Bridge Photo 61. Bighill Creek, 3,385

Bridge Photo 62. Bighill Creek, 3,385

Bridge Photo 63. Bighill Creek, 3,794

Bridge Photo 64. Bighill Creek, 3,794

Bridge Photo 65. Bighill Creek, 4,360

Bridge Photo 66. Bighill Creek, 4,360

Bridge Photo 67. Bighill Creek, 4,360

Bridge Photo 68. Side channel of Bighill Creek, 164

Bridge Photo 69. Side channel of Bighill Creek, 164

Bridge Photo 70. Side channel of Bighill Creek, 164

Bridge Photo 71. Side channel of Bighill Creek, 185

1.3 JUMPINGPOUND CREEK

Bridge Photo 72. Jumpingpound Creek, 647

Bridge Photo 73. Jumpingpound Creek, 647

1.4 EXSHAW CREEK

Bridge Photo 74. Exshaw Creek, 111

Bridge Photo 75. Exshaw Creek, 111

Bridge Photo 76. Exshaw Creek, 155

Bridge Photo 77. Exshaw Creek, 155

Bridge Photo 78. Exshaw Creek, 451

1.5 POLICEMAN CREEK

Bridge Photo 79. Policeman Creek, 1,552

Bridge Photo 80. Policeman Creek, 1,552

Bridge Photo 81. Policeman Creek, 1,552

Bridge Photo 82. Policeman Creek, 2,793

Bridge Photo 83. Policeman Creek, 3,147

Bridge Photo 84. Policeman Creek, 3,147

Bridge Photo 85. Policeman Creek, 3,699

Bridge Photo 86. Policeman Creek, 3,876

Bridge Photo 87. Policeman Creek, 4,328

Bridge Photo 88. Policeman Creek, 4,328

Bridge Photo 89. Policeman Creek, 4,328

Bridge Photo 90. Policeman Creek, 4,717

Bridge Photo 91. Policeman Creek, 4,717

Bridge Photo 92. Policeman Creek, 4,717

Bridge Photo 93. Policeman Creek, 4,853

Bridge Photo 94. Policeman Creek, 4,853

Bridge Photo 95. Policeman Creek, 5,103

Bridge Photo 96. Policeman Creek, 5,103

Bridge Photo 97. Policeman Creek, 5,252

Bridge Photo 98. Policeman Creek, 5,252

Bridge Photo 99. Policeman Creek, 5,648

Bridge Photo 100. Policeman Creek, 5,648

Bridge Photo 101. Policeman Creek, 5,668

Bridge Photo 102. Policeman Creek, 5,668

Bridge Photo 103. Policeman Creek, 6,022

Bridge Photo 104. Side channel of Policeman Creek, 3,360

Bridge Photo 105. Side channel of Policeman Creek, 5,331

Bridge Photo 106. Side channel of Policeman Creek, 5,331

2 CULVERTS

2.1 BOW RIVER

Culvert Photo 1. Bow River, 87,721

Culvert Photo 2. Bow River, 87,904

Culvert Photo 3. Bow River, 88,087

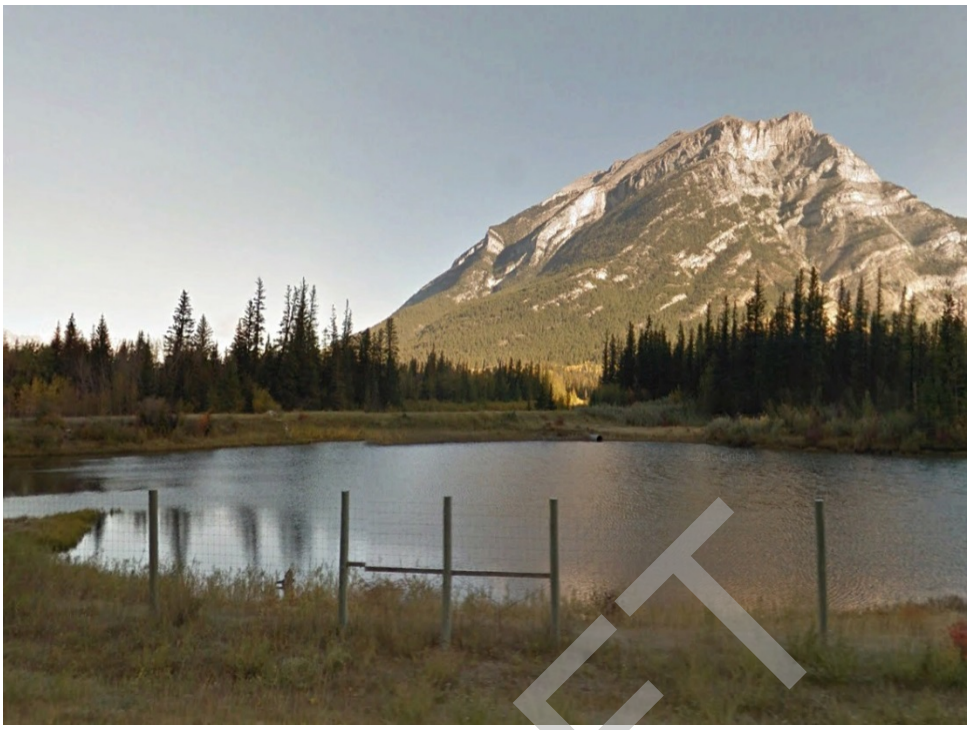
Culvert Photo 4. Bow River, 88,251

Culvert Photo 5. Bow River, 88,420

Culvert Photo 6. Bow River, 88,420

Culvert Photo 7. Bow River, 91,122

Culvert Photo 8. Side channel of Bow River, 23,505



Culvert Photo 9. Side channel of Bow River, 96,000

Culvert Photo 10. Side channel of Bow River, 105,661

Culvert Photo 11. Side channel of Bow River, 105,661

Culvert Photo 12. Side channel of Bow River, 105,880

Culvert Photo 13. Side channel of Bow River, 105,880

2.2 BIGHILL CREEK

Culvert Photo 14. Bighill Creek, 480 (upstream)

Culvert Photo 15. Bighill Creek, 480 (downstream)

Culvert Photo 16. Bighill Creek, 480

Culvert Photo 17. Bighill Creek, 1,519 (downstream)

Culvert Photo 18. Bighill Creek, 1,519 (upstream)

Culvert Photo 19. Bighill Creek, 2,498 (downstream)

Culvert Photo 20. Bighill Creek, 2,498 (upstream)

Culvert Photo 21. Bighill Creek, 2,498 (upstream)

2.3 EXSHAW CREEK

Culvert Photo 22. Exshaw Creek, 206

2.4 POLICEMAN CREEK

Culvert Photo 23. Policeman Creek, 4,923

Culvert Photo 24. Policeman Creek, 4,923

Culvert Photo 25. Policeman Creek, 5,003

Culvert Photo 26. Policeman Creek, 5,003

Culvert Photo 27. Policeman Creek, 5,957

Culvert Photo 28. Policeman Creek, 6,435

Culvert Photo 29. Policeman Creek, 6,435

Culvert Photo 30. Side channel of Policeman Creek, 4,159

Culvert Photo 31. Side channel of Policeman Creek, 4,256

Culvert Photo 32. Side channel of Policeman Creek, 4,256

Culvert Photo 33. Side channel of Policeman Creek, 4,877

Culvert Photo 34. Side channel of Policeman Creek, 4,877

Culvert Photo 35. Side channel of Policeman Creek, 4,877

Culvert Photo 36. Side channel of Policeman Creek, 4,877

Culvert Photo 37. Side channel of Policeman Creek, 4,877

APPENDIX C
SURVEY NETWORK ADJUSTMENT REPORTS

Project File Data		Coordinate System	
Name:	P:_Projects (Active)\TEMP 3001178\Network Ties\BowRiverControl4 CSRSHT2.vce	Name:	Canada
Size:	337 KB	Datum:	NAD 1983 (Canada)
Modified:	3/3/2016 9:23:02 AM (UTC:-8)	Zone:	CM114W
Time zone:	Pacific Standard Time	Geoid:	Canada Geoid Model HT2_0
Reference number:		Vertical datum:	
Description:			
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.000 m

Centring Error: 0.000 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment:	2
Network Reference Factor:	1.00
Chi Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	80

Post Processed Vector Statistics

Reference Factor:	1.00
Redundancy Number:	80.00
A Priori Scalar:	3.00

Control Coordinates Comparisons

Values shown are control coordinates minus adjusted coordinates.

Point ID	ΔEasting (Metre)	ΔNorthing (Metre)	ΔElevation (Metre)	ΔHeight (Metre)
3	0.012	-0.012	0.021	?
54	-0.008	-0.008	0.011	?
6	0.006	0.000	0.015	?

Control Point Constraints

Point ID	Type	East σ (Metre)	North σ (Metre)	Height σ (Metre)	Elevation σ (Metre)
12	Grid	Fixed	Fixed		Fixed
52	Grid	Fixed	Fixed		Fixed
53	Grid	Fixed	Fixed		Fixed
55	Grid	Fixed	Fixed		Fixed
7	Grid	Fixed	Fixed		Fixed

Fixed = 0.000001(Metre)

Adjusted Grid Coordinates

Point ID	Easting (Metre)	Easting Error (Metre)	Northing (Metre)	Northing Error (Metre)	Elevation (Metre)	Elevation Error (Metre)	Constraint
1	-20446.597	0.004	5665076.952	0.006	1097.305	0.021	
10	-74482.828	0.008	5662575.619	0.010	1284.067	0.028	
11	-81588.700	0.009	5658397.096	0.012	1295.130	0.036	
12	-96311.849	?	5665419.694	?	1329.268	?	ENe
2	-24371.159	0.004	5669466.457	0.005	1110.076	0.021	
3	-34261.764	0.005	5671899.195	0.007	1128.597	0.016	
4	-36859.699	0.006	5674454.966	0.007	1157.719	0.023	
5	-40731.768	0.006	5676118.431	0.007	1170.671	0.022	
52	-25352.385	?	5664686.309	?	1189.920	?	ENe
53	-29593.169	?	5671734.117	?	1229.921	?	ENe
54	-85888.024	0.009	5657424.890	0.012	1294.334	0.034	
55	-88699.811	?	5656541.571	?	1298.930	?	ENe
57	-92932.262	0.009	5659890.199	0.012	1305.113	0.023	
59	-95166.464	0.011	5661779.671	0.014	1308.681	0.025	
6	-45554.079	0.006	5675820.344	0.007	1162.457	0.019	

7	-50501.169	?	5675879.938	?	1229.053	?	ENe
8	-56210.485	0.006	5683630.011	0.009	1295.714	0.034	
9	-57480.396	0.008	5673079.305	0.011	1213.061	0.023	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Metre)	Height Error (Metre)	Constraint
1	N51°07'17.41341"	W114°17'31.43244"	1081.437	0.021	
10	N51°05'40.36967"	W115°03'47.97171"	1271.312	0.028	
11	N51°03'21.68933"	W115°09'49.70051"	1282.878	0.036	
12	N51°07'00.68911"	W115°22'32.27688"	1317.564	?	ENe
2	N51°09'38.91375"	W114°20'54.31179"	1094.326	0.021	
3	N51°10'55.81622"	W114°29'24.16921"	1113.247	0.016	
4	N51°12'17.94163"	W114°31'38.87746"	1142.476	0.023	
5	N51°13'10.82577"	W114°34'59.02157"	1155.615	0.022	
52	N51°07'04.06582"	W114°21'43.60080"	1174.250	?	ENe
53	N51°10'51.41230"	W114°25'23.73771"	1214.370	?	ENe
54	N51°02'47.97716"	W115°13'29.59450"	1282.293	0.034	
55	N51°02'17.85976"	W115°15'53.13961"	1286.999	?	ENe
57	N51°04'03.79541"	W115°19'33.43245"	1293.293	0.023	
59	N51°05'03.60978"	W115°21'29.94709"	1296.925	0.025	
6	N51°12'59.86840"	W114°39'07.37604"	1147.683	0.019	
7	N51°13'00.29950"	W114°43'22.30632"	1214.574	?	ENe
8	N51°17'09.16194"	W114°48'20.85578"	1281.555	0.034	
9	N51°11'27.29963"	W114°49'20.29175"	1199.057	0.023	

Adjusted ECEF Coordinates

Point ID	X (Metre)	X Error (Metre)	Y (Metre)	Y Error (Metre)	Z (Metre)	Z Error (Metre)	3D Error (Metre)	Constraint
1	-1650569.621	0.007	-3656956.839	0.013	4942882.014	0.017	0.022	
10	-1700684.526	0.011	-3636630.563	0.018	4941146.561	0.023	0.031	
11	-1708480.554	0.013	-3636667.303	0.022	4938462.386	0.029	0.039	
12	-1719666.044	?	-3625586.958	?	4942741.351	?	?	ENe
2	-1652764.995	0.007	-3652236.226	0.013	4945636.026	0.017	0.022	
3	-1661025.070	0.007	-3646465.356	0.010	4947141.089	0.013	0.018	
4	-1662592.604	0.009	-3643596.861	0.015	4948754.658	0.018	0.025	
5	-1665600.672	0.008	-3640830.739	0.013	4949788.869	0.018	0.024	
52	-1655195.696	?	-3655281.837	?	4942695.308	?	?	ENe
53	-1656843.521	?	-3648553.327	?	4947134.550	?	?	ENe
54	-1712701.749	0.012	-3635576.634	0.021	4937806.903	0.027	0.037	
55	-1715541.641	?	-3635041.146	?	4937225.270	?	?	ENe
57	-1718335.282	0.012	-3630908.634	0.015	4939288.423	0.020	0.027	
59	-1719771.004	0.013	-3628639.722	0.017	4940452.830	0.022	0.031	
6	-1670091.279	0.008	-3639058.059	0.012	4949570.551	0.015	0.021	
7	-1674600.827	?	-3637019.777	?	4949631.039	?	?	ENe
8	-1677363.993	0.011	-3629184.522	0.020	4954497.906	0.028	0.036	
	-1681847.015		-3636132.494		4947817.889			

9		0.010		0.015		0.020	0.026	

Error Ellipse Components

Point ID	Semi-major axis (Metre)	Semi-minor axis (Metre)	Azimuth
1	0.007	0.005	3°
10	0.012	0.010	176°
11	0.014	0.011	178°
2	0.007	0.005	12°
3	0.008	0.006	17°
4	0.009	0.008	14°
5	0.009	0.007	15°
54	0.014	0.011	2°
57	0.015	0.011	19°
59	0.018	0.014	8°
6	0.009	0.007	18°
8	0.011	0.008	0°
9	0.014	0.010	179°

Adjusted GNSS Observations

Transformation Parameters

Deflection in Latitude: -0.016 sec **(95%)** 0.102 sec
Deflection in Longitude: -0.077 sec **(95%)** 0.532 sec
Azimuth Rotation: 0.028 sec **(95%)** 0.038 sec
Scale Factor: 0.99999974 **(95%)** 0.00000014

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual

10 --> 4 (PV43)	**Az.**	71°38'55"	0.046 sec	0.071 sec	0.764
	ΔHt.	-128.849 m	0.024 m	0.039 m	1.482
	Ellip Dist.	39456.406 m	0.008 m	0.032 m	2.775
52 --> 1 (PV18)	**Az.**	85°09'55"	0.228 sec	-0.336 sec	-2.488
	ΔHt.	-92.815 m	0.021 m	-0.019 m	-1.511
	Ellip Dist.	4921.779 m	0.004 m	-0.002 m	-0.782
7 --> 6 (PV7)	**Az.**	90°07'36"	0.318 sec	-0.054 sec	-0.235
	ΔHt.	-66.892 m	0.019 m	-0.016 m	-2.348
	Ellip Dist.	4947.805 m	0.006 m	-0.003 m	-0.668
54 --> 11 (PV28)	**Az.**	76°18'19"	0.365 sec	0.359 sec	2.336
	ΔHt.	0.584 m	0.019 m	0.048 m	1.701
	Ellip Dist.	4407.938 m	0.005 m	-0.002 m	-0.782
54 --> 11 (PV83)	**Az.**	76°18'19"	0.365 sec	-1.212 sec	-2.327
	ΔHt.	0.584 m	0.019 m	0.019 m	1.769
	Ellip Dist.	4407.938 m	0.005 m	0.005 m	1.364
5 --> 6 (PV65)	**Az.**	266°00'30"	0.347 sec	0.678 sec	0.992
	ΔHt.	-7.930 m	0.018 m	0.051 m	2.088
	Ellip Dist.	4831.888 m	0.007 m	-0.025 m	-1.409
3 --> 53 (PV44)	**Az.**	91°38'36"	0.294 sec	-0.141 sec	-0.289
	ΔHt.	101.122 m	0.016 m	0.039 m	1.884
	Ellip Dist.	4671.922 m	0.005 m	0.001 m	0.069
5 --> 6 (PV64)	**Az.**	266°00'30"	0.347 sec	0.556 sec	0.606
	ΔHt.	-7.930 m	0.018 m	0.052 m	1.791
	Ellip Dist.	4831.888 m	0.007 m	-0.010 m	-0.348
54 --> 12 (PV26)	**Az.**	306°32'03"	0.180 sec	-0.130 sec	-1.739
	ΔHt.	35.275 m	0.024 m	-0.005 m	-0.793
	Ellip Dist.	13136.683 m	0.010 m	-0.002 m	-0.729
53 --> 1 (PV33)	**Az.**	125°43'07"	0.095 sec	0.129 sec	1.165
	ΔHt.	-132.937 m	0.019 m	-0.001 m	-0.018
	Ellip Dist.	11313.766 m	0.005 m	0.007 m	1.545

53 --> 3 (PV75)	**Az.**	271°41'43"	0.294 sec	-0.160 sec	-0.380
	ΔHt.	-101.122 m	0.016 m	0.020 m	1.523
	Ellip Dist.	4671.922 m	0.005 m	0.001 m	0.170
10 --> 11 (PV12)	**Az.**	238°42'56"	0.196 sec	-0.107 sec	-0.695
	ΔHt.	11.569 m	0.025 m	-0.025 m	-1.271
	Ellip Dist.	8243.599 m	0.006 m	0.009 m	1.506
10 --> 54 (PV85)	**Az.**	244°52'06"	0.165 sec	-0.400 sec	-1.492
	ΔHt.	10.985 m	0.024 m	-0.015 m	-0.875
	Ellip Dist.	12514.597 m	0.007 m	0.006 m	0.978
3 --> 10 (PV2)	**Az.**	256°34'03"	0.024 sec	-0.003 sec	-0.895
	ΔHt.	158.079 m	0.020 m	0.005 m	0.849
	Ellip Dist.	41290.139 m	0.005 m	-0.001 m	-1.437
53 --> 3 (PV74)	**Az.**	271°41'43"	0.294 sec	-0.120 sec	-0.287
	ΔHt.	-101.122 m	0.016 m	0.019 m	1.424
	Ellip Dist.	4671.922 m	0.005 m	0.004 m	0.551
7 --> 8 (PV10)	**Az.**	323°03'29"	0.142 sec	-0.135 sec	-1.213
	ΔHt.	66.984 m	0.021 m	-0.014 m	-1.378
	Ellip Dist.	9626.630 m	0.008 m	0.001 m	0.153
59 --> 12 (PV15)	**Az.**	341°28'33"	0.641 sec	0.377 sec	1.360
	ΔHt.	20.639 m	0.027 m	-0.010 m	-1.197
	Ellip Dist.	3815.930 m	0.014 m	-0.001 m	-0.127
55 --> 57 (PV14)	**Az.**	307°22'00"	0.455 sec	0.137 sec	1.009
	ΔHt.	6.295 m	0.023 m	-0.008 m	-1.336
	Ellip Dist.	5396.933 m	0.009 m	-0.002 m	-1.070
5 --> 12 (PV3)	**Az.**	258°39'01"	0.046 sec	0.040 sec	1.282
	ΔHt.	161.968 m	0.030 m	-0.013 m	-0.830
	Ellip Dist.	56602.661 m	0.010 m	-0.001 m	-0.086
53 --> 2 (PV32)	**Az.**	113°08'35"	0.200 sec	0.134 sec	1.027
	ΔHt.	-120.046 m	0.022 m	0.004 m	0.212
	Ellip Dist.	5693.644 m	0.004 m	0.003 m	1.254

53 --> 7 (PV23)	**Az.**	280°53'09"	0.038 sec	-0.026 sec	-0.616
	ΔHt.	0.212 m	0.016 m	0.010 m	0.563
	Ellip Dist.	21316.780 m	0.003 m	-0.004 m	-1.254
2 --> 52 (PV17)	**Az.**	191°19'43"	0.184 sec	-0.136 sec	-0.912
	ΔHt.	79.924 m	0.024 m	0.019 m	0.824
	Ellip Dist.	4880.270 m	0.006 m	0.005 m	1.254
53 --> 1 (PV80)	**Az.**	125°43'07"	0.095 sec	0.038 sec	0.155
	ΔHt.	-132.937 m	0.019 m	0.027 m	1.222
	Ellip Dist.	11313.766 m	0.005 m	0.006 m	0.545
3 --> 4 (PV52)	**Az.**	314°08'58"	0.445 sec	0.050 sec	0.079
	ΔHt.	29.230 m	0.020 m	0.029 m	1.204
	Ellip Dist.	3644.652 m	0.007 m	0.001 m	0.047
53 --> 1 (PV79)	**Az.**	125°43'07"	0.095 sec	0.276 sec	1.130
	ΔHt.	-132.937 m	0.019 m	0.023 m	1.145
	Ellip Dist.	11313.766 m	0.005 m	0.007 m	0.627
5 --> 4 (PV5)	**Az.**	112°47'39"	0.416 sec	-0.004 sec	-0.018
	ΔHt.	-13.141 m	0.021 m	-0.011 m	-1.139
	Ellip Dist.	4214.611 m	0.007 m	-0.001 m	-0.259
57 --> 59 (PV13)	**Az.**	309°11'23"	0.888 sec	0.191 sec	0.613
	ΔHt.	3.633 m	0.027 m	-0.010 m	-1.067
	Ellip Dist.	2926.025 m	0.012 m	-0.006 m	-0.994
53 --> 3 (PV25)	**Az.**	271°41'43"	0.294 sec	0.077 sec	0.421
	ΔHt.	-101.122 m	0.016 m	-0.014 m	-0.626
	Ellip Dist.	4671.922 m	0.005 m	-0.003 m	-0.992
5 --> 6 (PV8)	**Az.**	266°00'30"	0.347 sec	-0.123 sec	-0.512
	ΔHt.	-7.930 m	0.018 m	-0.009 m	-0.949
	Ellip Dist.	4831.888 m	0.007 m	0.000 m	0.040
4 --> 3 (PV6)	**Az.**	134°07'13"	0.445 sec	-0.355 sec	-0.909
	ΔHt.	-29.230 m	0.020 m	0.006 m	0.464
	Ellip Dist.	3644.652 m	0.007 m	0.000 m	-0.038

8 --> 9 (PV9)	**Az.**	186°14'06"	0.152 sec	0.064 sec	0.715
	ΔHt.	-82.498 m	0.023 m	-0.010 m	-0.891
	Ellip Dist.	10627.500 m	0.010 m	0.001 m	0.256
10 --> 4 (PV53)	**Az.**	71°38'55"	0.046 sec	-0.060 sec	-0.723
	ΔHt.	-128.849 m	0.024 m	-0.013 m	-0.418
	Ellip Dist.	39456.406 m	0.008 m	0.011 m	0.869
10 --> 11 (PV86)	**Az.**	238°42'56"	0.196 sec	0.047 sec	0.499
	ΔHt.	11.569 m	0.025 m	0.011 m	0.412
	Ellip Dist.	8243.599 m	0.006 m	-0.002 m	-0.833
53 --> 9 (PV22)	**Az.**	272°25'55"	0.072 sec	0.006 sec	0.247
	ΔHt.	-15.302 m	0.019 m	0.004 m	0.800
	Ellip Dist.	27921.779 m	0.007 m	-0.002 m	-0.656
53 --> 4 (PV21)	**Az.**	290°11'52"	0.203 sec	-0.023 sec	-0.184
	ΔHt.	-71.892 m	0.022 m	-0.016 m	-0.485
	Ellip Dist.	7759.892 m	0.006 m	0.003 m	0.786
1 --> 2 (PV16)	**Az.**	317°58'24"	0.200 sec	0.005 sec	0.027
	ΔHt.	12.891 m	0.018 m	0.001 m	0.021
	Ellip Dist.	5888.673 m	0.005 m	0.002 m	0.668
53 --> 1 (PV78)	**Az.**	125°43'07"	0.095 sec	0.181 sec	0.657
	ΔHt.	-132.937 m	0.019 m	0.015 m	0.610
	Ellip Dist.	11313.766 m	0.005 m	0.007 m	0.520
53 --> 8 (PV19)	**Az.**	293°45'03"	0.051 sec	0.002 sec	0.087
	ΔHt.	67.195 m	0.021 m	0.011 m	0.601
	Ellip Dist.	29156.897 m	0.006 m	-0.001 m	-0.411
1 --> 2 (PV4)	**Az.**	317°58'24"	0.200 sec	0.035 sec	0.206
	ΔHt.	12.891 m	0.018 m	0.003 m	0.481
	Ellip Dist.	5888.673 m	0.005 m	-0.002 m	-0.299
53 --> 5 (PV24)	**Az.**	291°09'20"	0.121 sec	-0.002 sec	-0.035
	ΔHt.	-58.750 m	0.022 m	0.009 m	0.441
	Ellip Dist.	11971.423 m	0.006 m	0.000 m	-0.078

53 --> 6 (PV20)	**Az.**	284°01'49"	0.096 sec	0.014 sec	0.269
	ΔHt.	-66.681 m	0.021 m	0.002 m	0.086
	Ellip Dist.	16477.038 m	0.005 m	0.000 m	0.136

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
1	53	**Az.**	305°49'15"	0.095 sec	1 : 2388239	1 : 2386663
		ΔHt.	132.933 m	0.021 m		
		ΔElev.	132.616 m	0.021 m		
		Ellip Dist.	11313.763 m	0.005 m		
10	11	**Az.**	238°42'56"	0.191 sec	1 : 1347470	1 : 1341479
		ΔHt.	11.567 m	0.026 m		
		ΔElev.	11.063 m	0.026 m		
		Ellip Dist.	8243.597 m	0.006 m		
12	54	**Az.**	126°25'01"	0.167 sec	1 : 1358811	1 : 1366557
		ΔHt.	-35.270 m	0.034 m		
		ΔElev.	-34.934 m	0.034 m		
		Ellip Dist.	13136.679 m	0.010 m		
12	59	**Az.**	161°27'45"	0.635 sec	1 : 279689	1 : 280215
		ΔHt.	-20.639 m	0.025 m		
		ΔElev.	-20.587 m	0.025 m		
		Ellip Dist.	3815.929 m	0.014 m		
2	1	**Az.**	137°55'46"	0.202 sec	1 : 1098848	1 : 1099774
		ΔHt.	-12.889 m	0.022 m		
		ΔElev.	-12.771 m	0.022 m		
		Ellip Dist.	5888.671 m	0.005 m		
2	52	**Az.**	191°19'43"	0.182 sec	1 : 882261	1 : 880929
		ΔHt.	79.924 m	0.021 m		
		ΔElev.	79.844 m	0.021 m		

		Ellip Dist.	4880.268 m	0.006 m		
2	53	**Az.**	293°12'05"	0.199 sec	1 : 1303169	1 : 1288725
		ΔHt.	120.044 m	0.021 m		
		ΔElev.	119.845 m	0.021 m		
		Ellip Dist.	5693.643 m	0.004 m		
3	10	**Az.**	256°34'03"	0.042 sec	1 : 6088752	1 : 6084869
		ΔHt.	158.065 m	0.029 m		
		ΔElev.	155.470 m	0.029 m		
		Ellip Dist.	41290.128 m	0.007 m		
3	4	**Az.**	314°08'58"	0.446 sec	1 : 513536	1 : 514924
		ΔHt.	29.229 m	0.021 m		
		ΔElev.	29.122 m	0.021 m		
		Ellip Dist.	3644.651 m	0.007 m		
3	53	**Az.**	91°38'36"	0.289 sec	1 : 895099	1 : 894212
		ΔHt.	101.124 m	0.016 m		
		ΔElev.	101.324 m	0.016 m		
		Ellip Dist.	4671.921 m	0.005 m		
4	10	**Az.**	252°03'58"	0.056 sec	1 : 4448089	1 : 4440605
		ΔHt.	128.836 m	0.037 m		
		ΔElev.	126.348 m	0.037 m		
		Ellip Dist.	39456.395 m	0.009 m		
4	5	**Az.**	292°50'15"	0.415 sec	1 : 607705	1 : 607366
		ΔHt.	13.140 m	0.021 m		
		ΔElev.	12.952 m	0.021 m		
		Ellip Dist.	4214.609 m	0.007 m		
4	53	**Az.**	110°07'00"	0.201 sec	1 : 1283964	1 : 1284846
		ΔHt.	71.895 m	0.023 m		
		ΔElev.	72.202 m	0.023 m		
		Ellip Dist.	7759.889 m	0.006 m		
5	12	**Az.**	258°39'01"	0.024 sec	1 : 9695533	1 : 9671535
		ΔHt.	161.949 m	0.022 m		
		ΔElev.	158.597 m	0.022 m		

		Ellip Dist.	56602.646 m	0.006 m		
5	53	**Az.**	111°01'51"	0.118 sec	1 : 2144543	1 : 2149054
		ΔHt.	58.755 m	0.022 m		
		ΔElev.	59.250 m	0.022 m		
		Ellip Dist.	11971.420 m	0.006 m		
5	6	**Az.**	266°00'30"	0.350 sec	1 : 705077	1 : 703823
		ΔHt.	-7.932 m	0.018 m		
		ΔElev.	-8.214 m	0.018 m		
		Ellip Dist.	4831.887 m	0.007 m		
52	1	**Az.**	85°09'55"	0.232 sec	1 : 1125670	1 : 1120133
		ΔHt.	-92.813 m	0.021 m		
		ΔElev.	-92.615 m	0.021 m		
		Ellip Dist.	4921.778 m	0.004 m		
53	6	**Az.**	284°01'49"	0.095 sec	1 : 2996203	1 : 2996868
		ΔHt.	-66.687 m	0.019 m		
		ΔElev.	-67.464 m	0.019 m		
		Ellip Dist.	16477.034 m	0.005 m		
53	7	**Az.**	280°53'09"	0.000 sec	1 : 0	1 : 0
		ΔHt.	0.204 m	0.000 m		
		ΔElev.	-0.868 m	0.000 m		
		Ellip Dist.	21316.774 m	0.000 m		
54	10	**Az.**	64°44'33"	0.155 sec	1 : 1864064	1 : 1852296
		ΔHt.	-10.982 m	0.024 m		
		ΔElev.	-10.267 m	0.024 m		
		Ellip Dist.	12514.594 m	0.007 m		
54	11	**Az.**	76°18'19"	0.359 sec	1 : 914723	1 : 911268
		ΔHt.	0.585 m	0.019 m		
		ΔElev.	0.797 m	0.019 m		
		Ellip Dist.	4407.937 m	0.005 m		
55	57	**Az.**	307°22'00"	0.453 sec	1 : 576492	1 : 578604
		ΔHt.	6.293 m	0.023 m		
		ΔElev.	6.183 m	0.023 m		
		Ellip Dist.	5396.932 m	0.009 m		

57	59	**Az.**	309°11'23"	0.882 sec	1 : 235891	1 : 236769
		ΔHt.	3.632 m	0.026 m		
		ΔElev.	3.569 m	0.026 m		
		Ellip Dist.	2926.024 m	0.012 m		
6	7	**Az.**	270°10'55"	0.309 sec	1 : 869034	1 : 865104
		ΔHt.	66.890 m	0.019 m		
		ΔElev.	66.596 m	0.019 m		
		Ellip Dist.	4947.804 m	0.006 m		
8	53	**Az.**	113°27'09"	0.060 sec	1 : 4249457	1 : 4260957
		ΔHt.	-67.184 m	0.034 m		
		ΔElev.	-65.793 m	0.034 m		
		Ellip Dist.	29156.889 m	0.007 m		
8	7	**Az.**	142°59'36"	0.158 sec	1 : 1198470	1 : 1198678
		ΔHt.	-66.981 m	0.034 m		
		ΔElev.	-66.661 m	0.034 m		
		Ellip Dist.	9626.628 m	0.008 m		
8	9	**Az.**	186°14'06"	0.156 sec	1 : 1005044	1 : 1002925
		ΔHt.	-82.497 m	0.032 m		
		ΔElev.	-82.653 m	0.032 m		
		Ellip Dist.	10627.497 m	0.011 m		
9	53	**Az.**	92°07'15"	0.080 sec	1 : 3441373	1 : 3443235
		ΔHt.	15.313 m	0.023 m		
		ΔElev.	16.860 m	0.023 m		
		Ellip Dist.	27921.772 m	0.008 m		

Date: 3/3/2016 9:23:10 AM	Project: P:_Projects (Active)\TEMP 3001178\Network Ties\BowRiverControl4 CSRSHT2.vce	Trimble Business Center

Project File Data		Coordinate System	
Name:	\\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\01 Survey and Base Data\1.1 River XS Survey\Control Surveys\Bow River Control at Stony.vce	Name:	Canada/NAD 1983
Size:	77 KB	Datum:	NAD 1983 (Canada)
Modified:	4/26/2016 9:43:34 PM (UTC:-6)	Zone:	CM114W
Time zone:	Mountain Standard Time	Geoid:	Canada Geoid Model HT2_0
Reference number:		Vertical datum:	
Description:			
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.000 m

Centring Error: 0.000 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2

Network Reference Factor: 1.24

Chi Square Test (95%): Passed

Precision Confidence Level: 95%

Degrees of Freedom: 22

Post Processed Vector Statistics

Reference Factor: 1.24

Redundancy Number: 22.00

A Priori Scalar: 3.00

Control Coordinates Comparisons

Values shown are control coordinates minus adjusted coordinates.

Point ID	ΔEasting (Metre)	ΔNorthing (Metre)	ΔElevation (Metre)	ΔHeight (Metre)
9	0.021	0.001	-0.019	-0.020

Control Point Constraints

Point ID	Type	East σ (Metre)	North σ (Metre)	Height σ (Metre)	Elevation σ (Metre)
3	Grid	Fixed	Fixed		Fixed
55	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Metre)					

Adjusted Grid Coordinates

Point ID	Easting (Metre)	Easting Error (Metre)	Northing (Metre)	Northing Error (Metre)	Elevation (Metre)	Elevation Error (Metre)	Constraint
3	-34261.764	?	5671899.195	?	1128.597	?	ENe
55	-88699.811	?	5656541.571	?	1298.930	?	ENe
9	-57480.417	0.005	5673079.304	0.007	1213.080	0.032	
NHC003	-68096.486	0.004	5665657.972	0.007	1271.901	0.020	
NHC101	-67949.753	0.004	5670170.195	0.007	1282.729	0.024	
NHC104	-64003.475	0.008	5670038.360	0.013	1247.411	0.025	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Metre)	Height Error (Metre)	Constraint
3	N51°10'55.81624"	W114°29'24.16923"	1113.247	?	ENe
55	N51°02'17.85975"	W115°15'53.13961"	1286.999	?	ENe
9	N51°11'27.29959"	W114°49'20.29283"	1199.076	0.032	
NHC003	N51°07'22.96526"	W114°58'21.89819"	1258.701	0.020	
NHC101	N51°09'49.03374"	W114°58'17.41724"	1269.450	0.024	
NHC104	N51°09'46.40553"	W114°54'54.24398"	1233.865	0.025	

Adjusted ECEF Coordinates

Point ID	X (Metre)	X Error (Metre)	Y (Metre)	Y Error (Metre)	Z (Metre)	Z Error (Metre)	3D Error (Metre)	Constraint
3	-1661025.070	?	-3646465.355	?	4947141.089	?	?	ENe
55	-1715541.641	?	-3635041.146	?	4937225.270	?	?	ENe
9	-1681847.039	0.009	-3636132.497	0.020	4947817.903	0.025	0.033	
NHC003	-1693888.048	0.007	-3637069.908	0.013	4943127.718	0.016	0.022	
NHC101	-1692327.626	0.007	-3633925.683	0.015	4945968.595	0.019	0.025	
NHC104	-1688764.602	0.010	-3635628.032	0.016	4945889.933	0.022	0.029	

Error Ellipse Components

Point ID	Semi-major axis (Metre)	Semi-minor axis (Metre)	Azimuth
9	0.009	0.006	180°
NHC003	0.009	0.005	2°
NHC101	0.008	0.005	3°
NHC104	0.016	0.010	7°

Adjusted GNSS Observations

Transformation Parameters

Azimuth Rotation: 0.023 sec **(95%)** 0.028 sec

Scale Factor: 0.99999997 **(95%)** 0.00000011

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
3 --> NHC003 (PV16)	**Az.**	259°10'01"	0.048 sec	0.023 sec	0.627
	ΔHt.	145.455 m	0.020 m	0.021 m	2.082
	Ellip Dist.	34407.836 m	0.006 m	0.003 m	0.583
NHC101 --> NHC003 (PV5)	**Az.**	181°06'22"	0.205 sec	-0.192 sec	-2.068
	ΔHt.	-10.749 m	0.024 m	-0.018 m	-1.121
	Ellip Dist.	4514.804 m	0.007 m	0.002 m	0.618
55 --> NHC101 (PV13)	**Az.**	55°43'08"	0.057 sec	0.020 sec	0.618
	ΔHt.	-17.549 m	0.024 m	-0.047 m	-2.064
	Ellip Dist.	24826.079 m	0.006 m	0.003 m	0.813
9 --> 55 (PV9)	**Az.**	241°26'55"	0.044 sec	-0.014 sec	-0.656
	ΔHt.	87.923 m	0.032 m	0.034 m	1.478
	Ellip Dist.	35330.309 m	0.006 m	-0.001 m	-0.211
55 --> NHC003 (PV10)	**Az.**	65°08'53"	0.068 sec	-0.010 sec	-0.217
	ΔHt.	-28.298 m	0.020 m	-0.039 m	-1.393
	Ellip Dist.	22530.652 m	0.006 m	-0.003 m	-0.796
3 --> NHC101 (PV18)	**Az.**	266°40'49"	0.048 sec	-0.001 sec	-0.027
	ΔHt.	156.204 m	0.024 m	-0.012 m	-0.530
	Ellip Dist.	33734.583 m	0.006 m	-0.004 m	-1.279
9 --> 3 (PV15)	**Az.**	92°16'08"	0.072 sec	0.000 sec	0.004
	ΔHt.	-85.829 m	0.032 m	-0.020 m	-1.165
	Ellip Dist.	23250.336 m	0.006 m	0.001 m	0.491
NHC101 --> NHC104 (PV2)	**Az.**	91°09'24"	0.651 sec	0.021 sec	0.069
	ΔHt.	-35.585 m	0.023 m	-0.010 m	-1.163
	Ellip Dist.	3948.664 m	0.007 m	0.004 m	1.053
9 --> NHC003 (PV6)	**Az.**	234°24'12"	0.128 sec	0.080 sec	0.842

	ΔHt.	59.625 m	0.035 m	-0.012 m	-0.389
	Ellip Dist.	12953.547 m	0.007 m	0.002 m	0.414
55 --> 3 (PV14)	**Az.**	73°15'41"	0.028 sec	-0.013 sec	-0.598
	ΔHt.	-173.753 m	0.000 m	-0.030 m	-0.792
	Ellip Dist.	56565.726 m	0.006 m	-0.004 m	-0.436
55 --> NHC104 (PV11)	**Az.**	60°21'31"	0.085 sec	-0.018 sec	-0.224
	ΔHt.	-53.134 m	0.025 m	0.010 m	0.525
	Ellip Dist.	28144.564 m	0.010 m	-0.006 m	-0.638
NHC003 --> NHC104 (PV3)	**Az.**	42°18'00"	0.336 sec	-0.078 sec	-0.343
	ΔHt.	-24.836 m	0.024 m	0.008 m	0.608
	Ellip Dist.	5995.322 m	0.011 m	0.001 m	0.131

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
3	55	**Az.**	253°51'52"	0.000 sec	1 : 0	1 : 0
		ΔHt.	173.753 m	0.000 m		
		ΔElev.	170.333 m	0.000 m		
		Ellip Dist.	56565.725 m	0.000 m		
3	9	**Az.**	272°31'40"	0.064 sec	1 : 4626530	1 : 4644213
		ΔHt.	85.829 m	0.032 m		
		ΔElev.	84.483 m	0.032 m		
		Ellip Dist.	23250.335 m	0.005 m		
3	NHC003	**Az.**	259°10'01"	0.042 sec	1 : 7692863	1 : 7700332
		ΔHt.	145.455 m	0.020 m		
		ΔElev.	143.304 m	0.020 m		
		Ellip Dist.	34407.836 m	0.004 m		
3	NHC101	**Az.**	266°40'49"	0.041 sec	1 : 7742682	1 : 7764809
		ΔHt.	156.204 m	0.024 m		
		ΔElev.	154.132 m	0.024 m		
		Ellip Dist.	33734.582 m	0.004 m		
55	NHC003	**Az.**	65°08'52"	0.061 sec	1 : 4553575	1 : 4518268
		ΔHt.	-28.298 m	0.020 m		
		ΔElev.	-27.029 m	0.020 m		
		Ellip Dist.	22530.651 m	0.005 m		
55	NHC101	**Az.**	55°43'08"	0.050 sec	1 : 4688175	1 : 4653744
		ΔHt.	-17.549 m	0.024 m		
		ΔElev.	-16.201 m	0.024 m		
		Ellip Dist.	24826.079 m	0.005 m		
55	NHC104	**Az.**	60°21'31"	0.084 sec	1 : 2865920	1 : 2842420
		ΔHt.	-53.134 m	0.025 m		
		ΔElev.	-51.519 m	0.025 m		
		Ellip Dist.	28144.563 m	0.010 m		
9	55	**Az.**	241°26'55"	0.040 sec	1 : 6359289	1 : 6340807

		ΔHt.	87.923 m	0.032 m		
		ΔElev.	85.850 m	0.032 m		
		Ellip Dist.	35330.308 m	0.006 m		
9	NHC003	**Az.**	234°24'12"	0.130 sec	1 : 1848402	1 : 1841489
		ΔHt.	59.625 m	0.035 m		
		ΔElev.	58.821 m	0.035 m		
		Ellip Dist.	12953.547 m	0.007 m		
NHC101	NHC003	**Az.**	181°06'22"	0.206 sec	1 : 602924	1 : 602822
		ΔHt.	-10.749 m	0.024 m		
		ΔElev.	-10.828 m	0.024 m		
		Ellip Dist.	4514.804 m	0.007 m		
NHC101	NHC104	**Az.**	91°09'24"	0.654 sec	1 : 530293	1 : 530175
		ΔHt.	-35.585 m	0.023 m		
		ΔElev.	-35.318 m	0.023 m		
		Ellip Dist.	3948.664 m	0.007 m		
NHC104	NHC003	**Az.**	222°20'42"	0.340 sec	1 : 526379	1 : 524488
		ΔHt.	24.836 m	0.024 m		
		ΔElev.	24.490 m	0.024 m		
		Ellip Dist.	5995.322 m	0.011 m		

Date: 6/23/2016 4:50:26 PM	Project: \\mainfile-van\Projects\Active\3001178 Upper Bow River Flood Hazard Study\01 Survey and Base Data\1.1 River XS Survey\Control Surveys\Bow River Control at Stony.vce	Trimble Business Center

CSRS-PPP (V 1.05 34613)

0093

Data Start	Data End	Duration of Observations
2015-10-18 17:16:30.000	2015-10-19 00:07:00.000	6h 50m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.011m		2.0m / 1.797m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	-0.01 %	1.00 sec / 30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRMR10 NONE	L1= 0.128 m L2= 0.120 m	1.548 m

(APC = antenna phase center; ARP = antenna reference point)

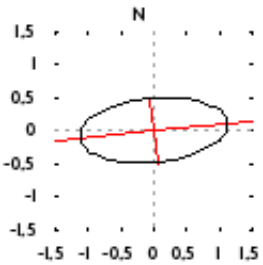
Estimated Position for 00932911.15o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51º 07’ 00.6891’’	-115º 22’ 32.2769’’	1317.564 m
Sigmas(95%)	0.004 m	0.009 m	0.019 m
Apriori	51º 07’ 00.719’’	-115º 22’ 32.322’’	1315.026 m
Estimated - Apriori	-0.908 m	0.867 m	2.538 m

Orthometric Height CGVD28 (HTv2.0)

1329.268 m
(click here for model and accuracy)

95% Error Ellipse (cm)
semi-major: 1.128cm
semi-minor: 0.489cm
semi-major azimuth: 84º 18’ 25.46’’



UTM (North) Zone 11

5664074.751m (N) 613691.451m (E)

Scale Factors
0.99975871 (point)
0.99955200 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP (V 1.05 34613)

55

Data Start	Data End	Duration of Observations
2015-10-07 19:15:30.000	2015-10-07 21:11:00.000	1h 55m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.009m		2.0m / 1.700m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.36 %	5.00 sec / 30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.877 m

(APC = antenna phase center; ARP = antenna reference point)

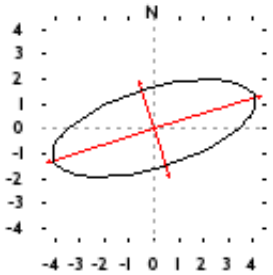
Estimated Position for 71632802.15o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51º 02’ 17.8601’’	-115º 15’ 53.1385’’	1286.998 m
Sigmas(95%)	0.016 m	0.033 m	0.050 m
Apriori	51º 02’ 17.880’’	-115º 15’ 53.189’’	1285.465 m
Estimated - Apriori	-0.622 m	0.982 m	1.533 m

Orthometric Height CGVD28 (HTv2.0)

1298.929 m
(click here for model and accuracy)

95% Error Ellipse (cm)
semi-major: 4.263cm
semi-minor: 1.583cm
semi-major azimuth: 73º 20’ 1.39’’



UTM (North) Zone 11

5655516.044m (N) 621656.914m (E)

Scale Factors
0.99978173 (point)
0.99957981 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP (V 1.05 34613)

7

Data Start	Data End	Duration of Observations
2015-10-23 19:09:00.000	2015-10-23 23:39:30.000	4h 30m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.006m		2.0m / 1.296m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.04 %	1.00 sec / 30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.575 m

(APC = antenna phase center; ARP = antenna reference point)

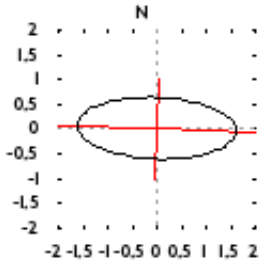
Estimated Position for 75562961.15o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51º 13’ 00.2995’’	-114º 43’ 22.3063’’	1214.574 m
Sigmas(95%)	0.005 m	0.013 m	0.021 m
Apriori	51º 13’ 00.282’’	-114º 43’ 22.393’’	1216.199 m
Estimated - Apriori	0.542 m	1.683 m	-1.625 m

Orthometric Height CGVD28 (HTv2.0)

1229.053 m
(click here for model and accuracy)

95% Error Ellipse (cm)
semi-major: 1.612cm
semi-minor: 0.621cm
semi-major azimuth: 92º 20’ 1.67’’



UTM (North) Zone 11

5676392.789m (N) 659031.194m (E)

Scale Factors
0.99991054 (point)
0.99971995 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP (V 1.05 34613)

52

Data Start	Data End	Duration of Observations
2015-10-05 20:33:30.000	2015-10-06 01:48:00.000	5h 14m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.009m		2.0m / 1.404m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	5.00 sec / 30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRMR10 NONE	L1= 0.128 m L2= 0.120 m	1.387 m

(APC = antenna phase center; ARP = antenna reference point)

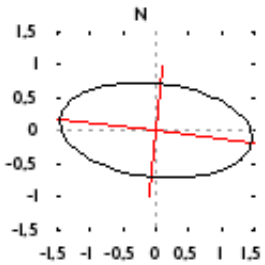
Estimated Position for 93042781.15o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51º 07’ 04.0658’’	-114º 21’ 43.6008’’	1174.250 m
Sigmas(95%)	0.006 m	0.012 m	0.020 m
Apriori	51º 07’ 04.066’’	-114º 21’ 43.635’’	1172.991 m
Estimated - Apriori	-0.019 m	0.657 m	1.259 m

Orthometric Height CGVD28 (HTv2.0)

1189.920 m
(click here for model and accuracy)

95% Error Ellipse (cm)
semi-major: 1.468cm
semi-minor: 0.710cm
semi-major azimuth: 96º 18’ 32.35’’



UTM (North) Zone 11

5666233.692m (N) 684616.726m (E)

Scale Factors
1.00001852 (point)
0.99983424 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP (V 1.05 34613)

53

Data Start	Data End	Duration of Observations
2015-10-06 16:47:00.000	2015-10-07 01:34:30.000	8h 47m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.008m		2.0m / 1.239m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	-0.03 %	5.00 sec / 30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRMR10 NONE	L1= 0.128 m L2= 0.120 m	1.257 m

(APC = antenna phase center; ARP = antenna reference point)

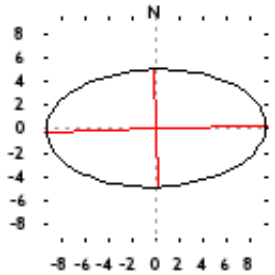
Estimated Position for 93042790.15o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51º 10’ 51.4123’’	-114º 25’ 23.7377’’	1214.370 m
Sigmas(95%)	0.004 m	0.007 m	0.016 m
Apriori	51º 10’ 51.392’’	-114º 25’ 23.811’’	1213.355 m
Estimated - Apriori	0.616 m	1.430 m	1.014 m

Orthometric Height CGVD28 (HTv2.0)

1229.921 m
(click here for model and accuracy)

95% Error Ellipse (mm)
semi-major: 9.369mm
semi-minor: 4.990mm
semi-major azimuth: 88º 24’ 0.83’’



UTM (North) Zone 11

5673103.399m (N) 680091.643m (E)

Scale Factors
0.99999824 (point)
0.99980767 (combined)

(Coordinates from RINEX file used as apriori position)

APPENDIX D
AERIAL IMAGERY

Digital files were supplied under separate cover

ORTHOSHOP
GEOMATICS ENGINEERING

Transmittal

Orthoshop Geomatics 1723-27th. Ave. N.E. Calgary, Alberta, Canada. T2E 7E1 Phone 403.250.7830

To: **Northwest Hydraulic Consultants**
30 Gostick Place

North Vancouver B.C. V7M 3G3

Attention: **Charlene Menezes**

Telephone: **604-980-6011**

Transmittal No.
19766
Fri, Nov 25, 2016

Work order: **10869**

Upper Bow River Hazard Study Historical Project and 2016 Project

– Final copy of data with latest revisions x2

NOV 28 2016

Ship Via	Delivery	Sent From
Purolator	Complete	NC

Add'l Info

19766

Email: mail@orthoshop.com

Project Information

Project #	160IN884
OGL Work Order #	10869
Client	Northwest Hydraulic Consulting Ltd. (NHC) / Alberta Environment and Parks
Project Location	Upper Bow River (Canmore to Calgary, AB)

Projection

Projection	Horizontal Datum	Vertical Datum	Geoid Data
3TM c.m. 114W	NAD83 (CSRS)	CGVD28	HTv2.0

Acquisition Parameters

Area	Date (MM/DD/YY)	Average Flying Height AGL (m)	Camera Focal Length (mm)	Pixel Size (cm)	Photo Overlap (%)	Photo Side Lap (%)	Scan Angle (degrees)	LIDAR Side Lap (%)	Point Density (points/ m^2)
Upper Bow River	06/03/16	2810	53	30	60	50	N/A	N/A	N/A

Aerial Survey Equipment

Component	Description
Aircraft	Cessna 210 Turbo C-GKPL
Camera Head	Leica RCD30 - CH82/83
Camera Lens	Leica RCD30 - NAG-D 3.5/50
Inertial Navigation System	Honeywell MicroIRS - Integrated into Leica ALS70
GPS Receiver	Novatel OEMV - Type 3, Model L12GVQ

Methodology: 2016 Orthophoto Mosaics

Source: 2016 Upper Bow River aerial photo was flown and processed by Orthoshop Geomatics ltd.

Data Processing Methodology:
A flight plan was created for the project area of interest to efficiently meet specifications and follow terrain relief. The project was flown on June 3, 2016 under clear skies.

The raw aerial photos were processed into Tiffs and checked. A GNSS & INS navigation solution was created for the flight in Novatel Inertial Explorer by post processing the raw airborne GNSS & INS data together with GNSS ground stations located nearby in Cochrane and Calgary. Precise point positioning was used to check the coordinates of the ground stations. Precise sensor & boresight calibration information was applied to the navigation solution and it was exported in the desired mapping projection and horizontal & vertical datum. This navigation solution then provided the high accuracy positional and angular information for setting up the imagery in 3D using direct geo-referencing.

The imagery and its direct geo-referencing was setup in Erdas Photogrammetry Suite and checked for

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proper alignment in 3D stereo to the pixel level. Orthophotos were generated using the LIDAR digital elevation model provided by NHC. Seamless orthophoto mosaics were then generated from these orthophotos and clipped to quarter townships. These mosaics were then checked to ensure quality imagery was used. Positional accuracy was verified by using the provided ground control points and in house reference data.

Calibration & Validation:
To ensure high accuracy direct geo-referencing, a full boresight calibration was performed for the Cessna T-210 RCD30 & ALS70 survey equipment on May 31, 2016. This survey system boresight calibration yields precise angular parameters for achieving quality relative and absolute accuracy of the photo exterior orientation parameters. The direct geo-referencing photo setup for the 2016 Upper Bow River flight was then checked for proper alignment in 3D/stereo photogrammetric software (to the pixel level).

QA/QC:
A thorough quality check was performed after each processing step, which maintained efficiency and quality assurance throughout the entire project. The final orthophoto mosaics were carefully checked for any artifacts that may have been missed during data processing. Ground control points and reference data was used to verify positional accuracy.

Horizontal Accuracy: 2016

QA/QC: Ground control point coordinates were provided by NHC for locations that are easily visible within the aerial photography. Locations were chosen by Orthoshop Geomatics. A total of 8 horizontal check points distributed regularly throughout the project were used to determine the horizontal accuracy. (CP8 was no longer present) The horizontal accuracy of the 2016 30cm orthophoto mosaic is approximately 0.58 meters RMSE (1.9 pixels) using the 7 ground control points. The results are shown in the table below.

Upper Bow River 2016: Orthophoto Mosaic Ground Control Check (3TM 114W)							
Point Name	Surveyed Ground Point		Image Measurement Point		dX (m)	dY (m)	dXY (m)
	E (m)	N (m)	E (m)	N (m)			
CP1	-19.640.60	5.665.052.76	-19.641.29	5.665.053.00	-0.69	0.24	0.73
CP2	-23.490.56	5.666.621.53	-23.491.05	5.666.621.66	-0.49	0.13	0.50
CP3	-92.583.60	5.660.828.17	-92.582.96	5.660.828.53	0.64	0.36	0.73
CP4	-95.489.89	5.663.476.32	-95.490.26	5.663.476.62	-0.37	0.30	0.48
CP5	-81.244.61	5.658.918.06	-81.244.50	5.658.917.80	0.11	-0.26	0.28
CP6	-35.625.86	5.674.690.87	-35.625.16	5.674.690.99	0.70	0.12	0.71
CP7	-53.076.89	5.674.613.31	-53.076.43	5.674.613.20	0.46	-0.11	0.47
CP8	-65.702.88	5.666.712.53	*N/A*	*N/A*	--	--	--
				RMSE	***0.57***	***0.22***	***0.58***

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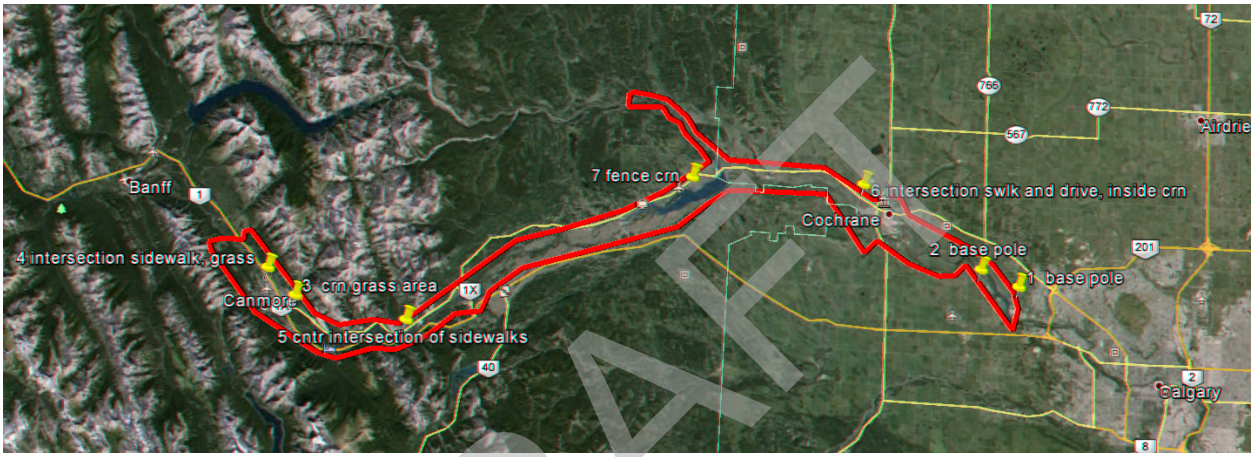
Vertical Accuracy

	Photo	LIDAR
Vertical Accuracy at 95% confidence interval or 2σ	N/A	0.14m

QA/QC: LiDAR data collection and processing done by Airborne Imaging Ltd. Checked by All-Can Engineering and Surveys Ltd.

Ground Control Map



Methodology: Historic 1982 Orthophoto Mosaics

Source: All historical imagery was obtained from the Aerial Photographic Record System (APRS) database by NHC at the recommendation of Orthoshop Geomatics ltd. The original imagery was flown by an RC10 film camera by North West Surveys. The scanned images had damage such as rips in the film, scratches and various particles & blemishes.

Data Processing Methodology:
Photogrammetric triangulation was performed on the historic 1982 imagery. Approximate initial image exterior orientation parameters were established. Automatic tie point generation was used to thoroughly tie the images together. Two sources of control were used for this dataset. Five of the eight provided surveyed ground control points were used (the others were either not present or not visible in the 1982 imagery). An additional 48 control points were created from the 2016 orthophoto and LiDAR data. Unique features were found that were identifiable in both the 2016 and 1982 imagery. These points were spread across the entire project area to provide control in urban and remote areas and for redundancy. The X,Y coordinates were obtained from the 2016 orthophoto and the Z coordinate from the corresponding location in the LIDAR DEM. The image alignment from the triangulation result was checked in stereo 3D using Erdas Photogrammetry Suite.

Orthophoto was generated using the provided LIDAR DEM. Seamless orthophoto mosaics were then generated from these orthophotos and clipped to quarter townships. These mosaics were then checked and patched to ensure the damaged portions were avoided and that the best available images were used when possible. In Adobe Photoshop, larger artifacts in the mosaic imagery were removed when possible

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and image quality was improved. (artifacts exist from damage to the original film or debris caught in the scanning process) Positional accuracy was verified by using the provided ground control points, the 2016 orthophoto mosaics and reference data such as road/railroad centerline vectors.

QA/QC: All imagery was checked for damage and the best scanned images were used in the orthophoto mosaic. Ground control points (where possible), reference data and the 30cm resolution 2016 orthophoto mosaics were used to verify positional accuracy.

Accuracy: 1982

QA/QC: Ground control point coordinates were provided by NHC for locations that are easily visible within the 2016 aerial photography. Five of the eight check points were visible in the 1982 imagery. (the other three did not exist or were not visible in the 75cm resolution imagery) The horizontal accuracy of the 1982 75cm orthophoto mosaic is approximately 1.65 meters RMSE (2.2 pixels) using the 5 ground control points. The results are shown in the table below.

Upper Bow River 1982: Orthophoto Mosaic Ground Control Check (3TM 114W)							
Point Name	Surveyed Ground Point		Image Measurement Point		dX (m)	dY (m)	dXY (m)
	E (m)	N (m)	E (m)	N (m)			
CP2	-23.490.56	5.666.621.53	-23.489.53	5.666.621.01	1.03	-0.52	1.15
CP3	-92.583.60	5.660.828.17	-92.581.39	5.660.828.22	2.21	0.05	2.21
CP5	-81.244.61	5.658.918.06	-81.246.01	5.658.916.56	-1.40	-1.50	2.05
CP7	-53.076.89	5.674.613.31	-53.078.40	5.674.613.56	-1.51	0.25	1.53
CP8	-65.702.88	5.666.712.53	-65.702.98	5.666.713.43	-0.10	0.90	0.91
CP1	-19.640.60	5.665.052.76	*N/A*	*N/A*	--	--	--
CP4	-95.489.89	5.663.476.32	*N/A*	*N/A*	--	--	--
CP6	-35.625.86	5.674.690.87	*N/A*	*N/A*	--	--	--
				RMSE	***1.60***	***0.90***	***1.65***

Supplemental control was created for the 75cm 1982 historical imagery from the 30cm 2016 orthophoto mosaics. Below is a table showing the coordinates and image checks for 41 matched points inside the project area. According to these residuals, the horizontal accuracy of the 1982 orthophoto mosaic relative to the 2016 orthophoto mosaic is approximately 2.17 meters RMSE (2.9 pixels).

Upper Bow River 1982: Additional Control From 2016 Mosaics (3TM 114W)								
Point Name	Report ID	Reference Control Point		Image Measurement Point		dX (m)	dY (m)	dXY (m)
		E (m)	N (m)	E (m)	N (m)			
GCP_1982_01	6330	-18,141.24	5,663,893.83	-18,142.47	5,663,892.24	-1.23	-1.59	2.01
GCP_1982_02	6331	-18,024.13	5,665,467.42	-18,024.88	5,665,467.21	-0.75	-0.21	0.78
GCP_1982_03	6332	-21,399.44	5,661,875.32	-21,399.11	5,661,877.18	0.33	1.86	1.89
GCP_1982_06	6335	-22,907.71	5,664,677.96	-22,908.00	5,664,674.08	-0.30	-3.88	3.89
GCP_1982_07	6336	-20,715.20	5,665,574.57	-20,712.22	5,665,573.90	2.98	-0.67	3.05
GCP_1982_08	6337	-24,611.85	5,669,761.12	-24,611.20	5,669,762.99	0.65	1.87	1.98
GCP_1982_09	6338	-25,544.99	5,670,696.93	-25,546.16	5,670,695.47	-1.17	-1.46	1.87
GCP_1982_10	6339	-26,106.63	5,668,233.81	-26,106.03	5,668,233.31	0.60	-0.50	0.78

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GCP_1982_11	6340	-27,552.22	5,670,809.04	-27,554.04	5,670,811.82	-1.82	2.78	3.32
GCP_1982_13	6342	-36,309.71	5,676,157.73	-36,311.46	5,676,154.78	-1.75	-2.95	3.43
GCP_1982_14	6343	-33,001.99	5,672,895.66	-33,001.24	5,672,894.87	0.75	-0.79	1.09
GCP_1982_15	6344	-32,627.73	5,672,646.54	-32,628.24	5,672,647.44	-0.51	0.90	1.04
GCP_1982_16	6345	-32,641.98	5,670,708.08	-32,643.78	5,670,708.03	-1.80	-0.05	1.80
GCP_1982_17	6346	-31,004.18	5,672,253.74	-31,006.75	5,672,253.33	-2.57	-0.41	2.60
GCP_1982_18	6347	-36,914.32	5,674,080.25	-36,912.45	5,674,079.63	1.87	-0.62	1.97
GCP_1982_19	6348	-43,976.02	5,676,724.14	-43,976.70	5,676,726.21	-0.68	2.07	2.18
GCP_1982_20	6349	-41,518.92	5,672,579.33	-41,518.15	5,672,580.30	0.77	0.97	1.24
GCP_1982_21	6350	-53,216.70	5,679,887.92	-53,217.05	5,679,890.85	-0.35	2.93	2.95
GCP_1982_22	6351	-49,198.83	5,675,455.02	-49,197.73	5,675,456.35	1.10	1.33	1.73
GCP_1982_23	6352	-49,418.85	5,676,420.25	-49,420.70	5,676,418.09	-1.85	-2.16	2.84
GCP_1982_25	6354	-56,816.63	5,670,526.23	-56,817.57	5,670,526.88	-0.94	0.65	1.14
GCP_1982_26	6355	-75,347.30	5,659,698.52	-75,348.41	5,659,697.10	-1.11	-1.42	1.81
GCP_1982_27	6356	-81,418.09	5,658,723.55	-81,419.23	5,658,723.56	-1.14	0.01	1.14
GCP_1982_29	6358	-95,171.28	5,661,897.38	-95,169.03	5,661,897.14	2.25	-0.24	2.26
GCP_1982_30	6359	-95,162.35	5,662,323.01	-95,159.98	5,662,323.51	2.37	0.50	2.42
GCP_1982_31	6360	-93,737.48	5,660,813.20	-93,736.31	5,660,812.52	1.16	-0.68	1.35
GCP_1982_32	6361	-100,759.92	5,669,038.32	-100,758.69	5,669,037.67	1.23	-0.65	1.39
GCP_1982_34	6363	-72,600.33	5,665,121.72	-72,598.97	5,665,121.61	1.36	-0.11	1.37
GCP_1982_35	6364	-75,702.18	5,664,914.10	-75,703.50	5,664,912.76	-1.32	-1.34	1.88
GCP_1982_36	6365	-92,009.34	5,663,133.30	-92,011.99	5,663,134.09	-2.65	0.79	2.77
GCP_1982_37	6366	-97,337.54	5,661,788.48	-97,340.84	5,661,789.45	-3.30	0.97	3.44
GCP_1982_38	6367	-63,525.58	5,667,927.06	-63,524.27	5,667,926.02	1.31	-1.04	1.67
GCP_1982_40	6369	-57,018.05	5,673,229.16	-57,021.00	5,673,229.41	-2.95	0.26	2.96
GCP_1982_41	6370	-85,973.95	5,658,553.50	-85,971.72	5,658,552.77	2.23	-0.73	2.35
GCP_1982_42	6372	-74,110.08	5,662,848.22	-74,109.37	5,662,850.69	0.70	2.47	2.57
GCP_1982_43	6374	-57,480.40	5,673,079.31	-57,478.50	5,673,079.29	1.90	-0.02	1.90
GCP_1982_44	6375	-40,731.77	5,676,118.43	-40,732.85	5,676,118.29	-1.08	-0.14	1.09
GCP_1982_45	6376	-24,371.16	5,669,466.46	-24,370.98	5,669,466.13	0.18	-0.33	0.38
GCP_1982_46	6377	-23,490.56	5,666,621.53	-23,489.14	5,666,622.46	1.42	0.93	1.70
GCP_1982_47	6371	-81,244.61	5,658,918.06	-81,245.81	5,658,915.70	-1.20	-2.36	2.64
GCP_1982_48	6373	-65,702.88	5,666,712.53	-65,701.00	5,666,712.40	1.88	-0.13	1.88
					RMSE	***1.62***	***1.48***	***2.17***

Methodology: Historic 1950 Orthophoto Mosaics

Source: All historical imagery was obtained from the Aerial Photographic Record System (APRS) database by NHC at the recommendation of Orthoshop Geomatics ltd. The original imagery was flown by an Eagle IX film camera by Kenting Aviation. The scanned images had damage such as rips in the film, scratches and various particles & blemishes. Many images also had their fiducial marks covered by a bright over exposed circle. No specific camera identification or camera calibration could be found for this 1950 imagery.

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Data Processing Methodology:
Photogrammetric triangulation was performed on the historic 1950 imagery. Additional steps were required to triangulate this 1950 imagery. With no camera calibration information available, parameters had to be calculated for the fiducial mark coordinates, principal point and camera focal length. Also, bright, over-exposed artifacts covering the fiducial marks in a number of images required for the creation of "virtual fiducial marks" on the camera frame in order to perform interior orientation on the images with these artifacts. Approximate initial image exterior orientation parameters were established. Automatic tie point generation was used to thoroughly tie the images together. None of the eight provided surveyed ground control points existed back in 1950 so control points were established from the 2016 orthophoto and LiDAR data. 42 unique features were found that were identifiable in both the 2016 and 1950 imagery. These points were spread across the entire project area to provide control in urban and remote areas and for redundancy. The X,Y coordinates were obtained from the 2016 orthophoto and the Z coordinate from the corresponding location in the LIDAR DEM. The image alignment from the triangulation result was checked in stereo 3D using Erdas Photogrammetry Suite.

Orthophoto was generated using the provided LIDAR DEM. Seamless orthophoto mosaics were then generated from these orthophotos and clipped to quarter townships. These mosaics were then checked and patched to ensure the damaged portions were avoided and that the best available images were used when possible. The perspective center marks at the center of every Eagle IX image was also patched using the neighboring image. In Adobe Photoshop, larger artifacts in the mosaic imagery were removed when possible and image quality was improved. (artifacts exist from damage to the original film or debris caught in the scanning process) Positional accuracy was verified by using the 2016 orthophoto mosaics and road/railroad centerline reference data.

QA/QC: All imagery was checked for damage and the best scanned images were used in the orthophoto mosaic. Ground control points (where possible), reference data and the 30cm resolution 2016 orthophoto mosaics were used to verify positional accuracy.

Accuracy: 1950

QA/QC: Ground control point coordinates were provided by NHC for locations that are visible within the 2016 aerial photography. None of the eight control point features existed back in 1950 and could not be used for accuracy verification. Instead control points for the 50cm 1950 historical imagery was established from the 2016 30cm orthophoto mosaics and LiDAR data. Unique features were found that were identifiable in both the 2016 and 1950 imagery. On the next page is a table showing the coordinates and image checks for 32 matched points inside the project area. According to these residuals, the horizontal accuracy of the 1950 orthophoto mosaic relative to the 2016 orthophoto mosaic is approximately 2.30 meters RMSE (4.6 pixels).

Upper Bow River 1950: Orthophoto Mosaic Ground Control Check (3TM 114W)

Point Name	Surveyed Ground Point		Image Measurement Point		dX (m)	dY (m)	dXY (m)
	E (m)	N (m)	E (m)	N (m)			
CP1	-19.640.60	5.665.052.76	*N/A*	*N/A*	--	--	--
CP2	-23.490.56	5.666.621.53	*N/A*	*N/A*	--	--	--
CP3	-92.583.60	5.660.828.17	*N/A*	*N/A*	--	--	--
CP4	-95.489.89	5.663.476.32	*N/A*	*N/A*	--	--	--
CP5	-81.244.61	5.658.918.06	*N/A*	*N/A*	--	--	--
CP6	-35.625.86	5.674.690.87	*N/A*	*N/A*	--	--	--
CP7	-53.076.89	5.674.613.31	*N/A*	*N/A*	--	--	--
CP8	-65.702.88	5.666.712.53	*N/A*	*N/A*	--	--	--
				RMSE	**--**	**--**	**--**

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Upper Bow River 1950: Additional Control From 2016 Mosaics (3TM 114W)								
Point Name	Report ID	Reference Control Point		Image Measurement Point		dX (m)	dY (m)	dXY (m)
		E (m)	N (m)	E (m)	N (m)			
GCP_1950_01	10386	-18,141.24	5,663,893.83	-18,140.60	5,663,892.01	0.64	-1.82	1.93
GCP_1950_02	10387	-18,024.13	5,665,467.42	-18,026.35	5,665,468.57	-2.23	1.15	2.51
GCP_1950_03	10388	-21,399.44	5,661,875.32	-21,398.97	5,661,878.51	0.48	3.19	3.22
GCP_1950_06	496	-22,907.71	5,664,677.96	-22,905.98	5,664,674.91	1.73	-3.05	3.51
GCP_1950_07	977	-20,715.20	5,665,574.57	-20,717.31	5,665,577.78	-2.11	3.21	3.85
GCP_1950_08	978	-24,611.85	5,669,761.12	-24,611.26	5,669,758.94	0.59	-2.18	2.26
GCP_1950_09	979	-25,544.99	5,670,696.93	-25,545.52	5,670,697.35	-0.53	0.42	0.68
GCP_1950_10	980	-26,106.63	5,668,233.81	-26,106.83	5,668,233.66	-0.20	-0.15	0.25
GCP_1950_11	981	-27,552.22	5,670,809.04	-27,552.41	5,670,809.88	-0.20	0.84	0.86
GCP_1950_13	1463	-36,309.71	5,676,157.73	-36,312.61	5,676,156.92	-2.90	-0.81	3.01
GCP_1950_14	1464	-33,001.99	5,672,895.66	-33,002.83	5,672,895.30	-0.84	-0.36	0.91
GCP_1950_15	1465	-32,627.73	5,672,646.54	-32,626.58	5,672,646.14	1.15	-0.40	1.22
GCP_1950_16	1650	-32,641.98	5,670,708.08	-32,643.95	5,670,710.69	-1.97	2.61	3.27
GCP_1950_17	1782	-31,004.18	5,672,253.74	-31,005.19	5,672,252.97	-1.01	-0.77	1.27
GCP_1950_18	1924	-36,914.32	5,674,080.25	-36,915.27	5,674,081.45	-0.95	1.19	1.53
GCP_1950_19	1925	-43,976.02	5,676,724.14	-43,973.30	5,676,726.34	2.72	2.20	3.50
GCP_1950_20	1926	-41,518.92	5,672,579.33	-41,517.31	5,672,579.47	1.61	0.14	1.62
GCP_1950_21	2924	-53,216.70	5,679,887.92	-53,218.09	5,679,890.08	-1.39	2.16	2.57
GCP_1950_22	2925	-49,198.83	5,675,455.02	-49,197.49	5,675,456.27	1.34	1.25	1.83
GCP_1950_23	2926	-49,418.85	5,676,420.25	-49,422.57	5,676,417.78	-3.72	-2.47	4.47
GCP_1950_25	3106	-56,816.63	5,670,526.23	-56,816.85	5,670,527.95	-0.23	1.72	1.73
GCP_1950_27	3698	-81,418.09	5,658,723.55	-81,417.76	5,658,724.53	0.33	0.98	1.03
GCP_1950_29	3840	-95,171.28	5,661,897.38	-95,170.95	5,661,898.05	0.33	0.67	0.75
GCP_1950_30	3841	-95,162.35	5,662,323.01	-95,162.11	5,662,323.51	0.24	0.50	0.55
GCP_1950_31	4081	-93,737.48	5,660,813.20	-93,739.44	5,660,812.99	-1.97	-0.21	1.98
GCP_1950_33	4893	-99,078.41	5,663,700.17	-99,076.79	5,663,701.51	1.62	1.34	2.10
GCP_1950_34	4991	-72,600.33	5,665,121.72	-72,600.34	5,665,122.84	-0.01	1.12	1.12
GCP_1950_37	5284	-97,337.54	5,661,788.48	-97,339.54	5,661,788.48	-2.00	0.01	2.00
GCP_1950_38	5388	-63,525.58	5,667,927.06	-63,525.63	5,667,923.30	-0.06	-3.76	3.76
GCP_1950_40	5623	-57,018.05	5,673,229.16	-57,018.88	5,673,229.15	-0.83	-0.01	0.83
GCP_1950_41	6226	-85,973.95	5,658,553.50	-85,972.27	5,658,554.87	1.68	1.37	2.17
GCP_1950_42	6227	-74,110.08	5,662,848.22	-74,109.62	5,662,850.80	0.46	2.58	2.62
					RMSE	***1.50***	***1.73***	***2.30***

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APPENDIX E
DIGITAL FILES

Digital files will be supplied via FTP

Table E1. Survey and Base Data Collection - Digital Data Deliverables

CATEGORY	TITLE	DESCRIPTION	KEY ATTRIBUTE DESCRIPTION	FOLDER or GDB	FILE
SURVEY AND BASE DATA					
	Survey Points, NHC Fall 2015 and Spring 2016	Processed point survey data from NHC's fall 2015 and spring 2016 ground and bathymetric surveys of the Upper Bow River. Esri file geodatabase point feature class.	UnqID = unique ID number for each point; PtID = ID number assigned in field (not unique); N_3TM, E_3TM = northing and easting coordinates in NAD83 CSRS 3TM 114 metres; Elev = point elevation in metres; FieldCrew = field crew that collected the data; Date_?, Time_? = date and time in years, months, days, hours, minutes, seconds (where available); StdCode = standard point code; CodeDesc = description to match StdCode; BasePt = base point used to tie in survey data	UpperBowFHS_Survey.gdb\	SurveyPts
	Survey Points, NHC Fall 2015 and Spring 2016	Processed point survey data from NHC's fall 2015 and spring 2016 ground and bathymetric surveys of the Upper Bow River. CSV text format.	As described above.	n.a.	Survey_pts.csv
	Survey Field Photos, NHC Fall 2015, Spring 2016, and Spring 2017	Photos from NHC's fall 2015 and spring 2016 field surveys, and additional field visit in spring 2017. JPEG images. Most are georeferenced.	n.a.	Photos_Resized\	*.jpg
	Survey Field Photo Points, NHC Fall 2015, Spring 2016, and Spring 2017	Point locations of georeferenced photos from NHC's fall 2015 and spring 2016 field surveys, and additional field visit in spring 2017. Esri file geodatabase point feature class.	Name = photo filename; DateTime = date and time of photo; Direction = direction of photo (not necessarily accurate); RelativePath = relative path to photo image location	UpperBowFHS_Survey_Photos.gdb\	FieldPhotos_pts
	Ungeoreferenced Survey Field Photos, NHC Fall 2015 and Spring 2016	Table listing photos from NHC's fall 2015 and spring 2016 field surveys that are not georeferenced. Esri file geodatabase table.	RelativePath = relative path to photo image location	UpperBowFHS_Survey_Photos.gdb\	FieldPhotos_NoPts
	Stream Centreline	Stream network centrelines, developed for identifying chainage of features along river. Calibrated with reach length. Esri file geodatabase polyline feature class.	StreamName = name of stream to be modelled; Length_m = line length to nearest metre (used for chainage calibration); ReachName = name of reach to be modelled (based on chainage of downstream extent)	UpperBowFHS_Survey.gdb\	StreamNetwork\StreamNtwk2
	Cross section Locations	Cross section lines. Created for survey and model planning, updated to reflect survey data collected, includes historic cross section locations. Some sections will later be extended for hydraulic modelling. Esri file geodatabase polyline feature class.	XSLnID = unique line ID assigned by NHC; StreamName = stream name for hydraulic model; Version = "Historic" for existing section resurveyed by NHC, "NHC 2015" or "NHC 2016" for new section; ChainModel = updated chainage in metres along stream, assigned for hydraulic modelling; SurveyStatus = "NHC Surveyed 2015" or "NHC Surveyed 2016".	UpperBowFHS_Survey.gdb\	CrossSections\NHC_XSSurveyed

CATEGORY	TITLE	DESCRIPTION	KEY ATTRIBUTE DESCRIPTION	FOLDER or GDB	FILE
	Flood Control Structures	Dyke and berm locations, based on field surveys and information from AEP and local agencies. Esri file geodatabase polyline feature class.	Name = descriptive name of structure; Owner = owner of structure; StreamName = stream name for hydraulic model; SurveyStatus = "NHC Surveyed 2015" or "NHC Surveyed 2016"; X_Start, Y_Start, X_End, Y_End = 3TM coordinates of upstream and downstream ends of the feature; FeatureType = "flood control structure" or "other feature".	UpperBowFHS_Survey.gdb\	Structures\Dykes
	Hydraulic Structures - Bridges	Point locations of bridges for hydraulic modelling, based on field surveys. Esri file geodatabase point feature class.	NHC_ID = unique point ID assigned by NHC; StreamName = stream name for hydraulic modelling, or "side channel" for features not directly on modelled reaches; RiverStation = stream chainage; Municipality = municipality where bridge is located; RoadTrail = road or trail name; Owner = owner of structure, where known; OwnerID = ID assigned by owner; Type = bridge type (e.g., pedestrian, road); Desc = bridge description (e.g., timber, concrete, steel); Span = span in metres; Width = width in metres; NoPiers = number of piers; Elev_TC = top chord elevation; Elev_Deck = deck elevation; Elev_LC = low chord elevation; SurveyStatus = "NHC Surveyed 2015" or "NHC Surveyed 2016"; Crew = NHC survey crew; InModel = indicates whether structure will be included in hydraulic model; Photo = indicates whether there is a field photo of the structure; ModelComment = explains why feature is not included in model; ToA_L, ToA_R = top of abutment elevation in metres, left and right; TC_L, TC_M, TC_R = top of curb elevation in metres, left, midspan, right; TD_L, TD_M, TD_R = top of deck elevation in metres, left, midspan, right; LC_L, LC_M, LC_R = low chord elevation in metres, left, midspan, right.	UpperBowFHS_Survey.gdb\	Structures\Bridges

CATEGORY	TITLE	DESCRIPTION	KEY ATTRIBUTE DESCRIPTION	FOLDER or GDB	FILE
	Hydraulic Structures - Culverts	Point locations of culverts for hydraulic modelling, based on field surveys. Additional descriptive information is given in the Culvert attribute table (below). Esri file geodatabase point feature class.	NHC_ID = unique point ID assigned by NHC; StreamName = stream name for hydraulic modelling, or "side channel" for features not directly on modelled reaches; RiverStation = stream chainage; Municipality = municipality or general location; Road_Trail = road or trail name; Owner = owner of structure; OwnerID = ID assigned by owner; InModel = indicates whether structure will be included in hydraulic model; ModelComment = explains why feature is not included in model; Photo = indicates whether there is a field photo of the structure.	UpperBowFHS_Survey.gdb\	Structures\Culverts
	Hydraulic Structures - Culvert attributes	Table describing culvert features. There may be more than one culvert at each point location. Use a "relate" in ArcMap to do a one-to-many join for culvert points to culvert attributes. Esri file geodatabase table.	NHC_ID = unique culvert point ID assigned by NHC (used to link this table to the culvert point table with a one-to-many relate); Info = indicates whether information was available from a design drawing; Survey = NHC survey crew; Shape = culvert shape; Material = culvert material; BarrelLen = barrel length in metres; Diameter = diameter, rise or height in metres; Span = span or width in metres; USInv, DSInv = upstream and downstream invert elevations; Entrance = entrance condition; Comment.	UpperBowFHS_Survey.gdb\	tabCulverts
	Hydraulic Structures - Dams	Point locations of dams, based on orthophoto. Esri file geodatabase point feature class.	Dam_ID = unique point ID assigned by NHC; Name = dam name; StreamName = stream name; Chain = chainage location of feature along stream; 3TM_X, 3TM_Y = easting and northing coordinates in NAD83 CSRS 3TM 114 metres	UpperBowFHS_Survey.gdb\	Structures\Dams