Grassy Mountain
Surface Hydrology Baseline and Effects Assessment

Prepared for

Benga Mining Limited

Prepared by

SRK Consulting (Canada) Inc.
1CM029.011
August 2016

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1 Introduction

Benga Mining Limited (Benga), a wholly owned subsidiary of Riversdale Resources Limited (Riversdale), is proposing to develop the Grassy Mountain Coal Project (the Project), located 150 km south of Calgary, Alberta, and 7 km north of the town of Blairmore, Alberta (Figure 1). The hydrological baseline evaluation and assessment described in this report are intended to support the environmental effects assessment and an application for an Environmental Protection & Enhancement Act (EPEA) Approval for the Project.

Surface water flow affects many aspects of the proposed project and is therefore considered by the following plans and assessments:

- Water quality effects assessment (Hatfield 2016a);
- Aquatic and fisheries effects assessment (Hatfield 2016b);
- Human health effects assessment (Millennium 2016a);
- Wildlife effects assessment (Millennium 2016b);
- Terrestrial effects assessment (Millennium 2016c, 2016d); and
- Hydrogeological effects assessment (Millennium 2016e);

From a Project development perspective, the hydrological assessment was an integral component in the development of the water management plant, closure and reclamation plan, and water quality mitigation plan. In addition, results of the hydrological assessment was used to estimate water use by the Project for water licence considerations.

The report is organized as follows:

- Section 2 describes the analysis of climatic conditions for the site;
- Section 3 includes the baseline hydrology evaluation;
- Section 4 summarizes links to other Project components, and
- Section 5 presents results of the water balance model that are relevant for the hydrological effects assessment
- Section 6 describes the hydrological effects assessment, and
- Section 7 summarizes conclusions.

1.1 Local Study Area

The Local Study Areas (LSA) for aquatic ecology, water quality, and hydrology are congruent and encompass areas where Project activities have the potential to affect aquatic habitat or fish populations and communities. The LSA comprises Blairmore Creek and Gold Creek watersheds. The Project footprint is located entirely within these two watersheds (Figure 2).

Both Blairmore and Gold creek watersheds are located in the eastern slopes of the southern Canadian Rockies. With an area of 5,121 ha and 6,209 ha, respectively, Blairmore and Gold creek watersheds contain watercourses and parts of watercourses identified as critical habitat for westslope cutthroat trout (*Oncorhynchus clarkia lewisi*), a fish species first listed in 2013 as threatened under the *Species at Risk Act*.

1.2 Regional Study Area

The Regional Study Areas (RSA) for aquatic ecology, water quality, and hydrology are also congruent. Project effects have the potential to interact with other projects within the Crowsnest River watershed. Therefore, entire Crowsnest River watershed was included in the RSA to ensure that potential cumulative effects are evaluated at a regional level (Figure 3). Taken together, Blairmore and Gold creeks represent approximately 16% of the watershed area of the Crowsnest River.

1.3 Assessment Cases

The Project EIA considers the following assessment scenarios, as per the ToR and the Guideline for Preparing EIA reports (Government of Alberta 2013):

- **Baseline Case**, which includes existing environmental conditions, existing projects and “approved” activities;
- **Application Case**, which includes the Baseline Case plus the Project; and
- **Planned Development Case (Cumulative Effects)**, which includes the “Application Case” combined with past studies, existing and anticipated future environmental conditions, existing projects or activities, plus other “planned” projects or activities.

For the purposes of defining assessment scenarios, “approved” means approved by any federal, provincial or municipal regulatory authority, and “planned” means any project or activity that has been publicly disclosed prior to the issuance of the Project’s ToR or up to six months prior to the submission of the Project Application and the EIA report, whichever is most recent.

This document considers only the baseline and application cases. Proposed projects forming the Planned Development Case include:

- The proposed Coal Mountain Phase 2 Mine by Teck Coal Ltd. is not located in the Crowsnest River drainage and any effects of this project would be associated with changes in air quality only;
- Future timber operations on Crown Land are assumed to proceed at the same rate as they are currently; and
- It is assumed that Alberta Transportation’s re-alignment of Highway No. 3 will be done in an environmentally-sustainable manner and not adversely affect the water quality or aquatic resources of the Crowsnest River.

None of these projects are expected to affect hydrology within the regional study area. Therefore, a cumulative effects assessment for hydrology was omitted.

2 Climatic Conditions

2.1 Climate Setting

The Project is located in the Rocky Mountains in a valley between the High Rock Mountain Range dividing British Columbia and Alberta and the Livingston Mountain Range (Figure 1). Within this region, precipitation is characteristically lower than in areas with similar latitudes across British Columbia and Alberta.

The region is described as having cold weather without a dry season and cold summers or Köppen-Geiger climate classification of Dfc. This classification is defined as having less than four months with average temperatures greater than 10°C, and the average temperature of the coldest month with temperatures below 0°C (Peel, Finlayson, & McMahon, 2007).

The climate and hydrology is seasonally influenced by the elevation and the location with respect to the Rocky Mountains. Evaporation is characterized by stations with similar latitude (Section 2.6). The elevation of the Project ranges from 1,295 metres above sea level (masl) to 2,080 masl.

2.2 Available Climate Data

2.2.1 Temperature Data

Regional temperature data was obtained from Environment Canada (EC) and was available from 1870 to 2014. Temperature data from two meteorological stations on site was available for the period July to November 2014.

The quality and quantity of data collected by EC was appropriate for use to characterize the Project's climatic conditions. Data from a total of 59 regional meteorological stations available within a 110 km radius from the site with more than 10 years of information are summarized in Table 1 and graphically in Figure 4.

Table 1: Regional meteorological stations with temperature data

Station name	Station ID	Province	Longitude [°]	Latitude [°]	Mean Annual Temperature [°C]	Elevation [masl]	Distance from site [km]	Amount of Information [years]
CROWSNEST	3051R4R	AB	-114.48	49.63	3.79	1303	3	16
BLAIRMORE HQTS RS	30507AC	AB	-114.43	49.62	3.04	1310.6	3	10
COLEMAN	3051720	AB	-114.58	49.63	3.51	1341.1	9	31
CONNELLY CREEK	3031805	AB	-114.22	49.62	4.79	1249	17	22
CORBIN	1151915	BC	-114.65	49.52	2.31	1572.2	20	11
COWLEY	3031918	AB	-114.12	49.68	4	1188.7	24	13
LIVINGSTONE	3053925	AB	-114.38	49.88	1.66	1417	27	7
COWLEY A	3031920	AB	-114.08	49.63	4.01	1182	27	19
BEAVER MINES	3050600	AB	-114.18	49.47	4.42	1257	28	74
CASTLE	3051430	AB	-114.33	49.4	3.26	1360	29	9
NATAL HARMER RIDGE	1155402	BC	-114.83	49.77	0.76	1889.8	30	6
SPARWOOD	1157630	BC	-114.88	49.75	4.53	1137.7	33	29
SPARWOOD CS	1157631	BC	-114.88	49.75	4.44	1136.7	33	15
PINCHER CREEK (AUT)	3035206	AB	-114	49.52	4.91	1189.6	36	15
PINCHER CREEK A	3035202	AB	-114	49.52	5.23	1189.9	36	14
PINCHER CREEK CLIMATE	3035208	AB	-114	49.52	5.25	1190	36	13
PINCHER CREEK TOWN	3035220	AB	-113.97	49.52	4.44	1145.4	38	52
LUNDBRECK	3054080	AB	-114.13	49.92	2.4	1194.2	38	21
PINCHER CREEK	3035201	AB	-113.95	49.5	4.69	1155.2	40	17
FIVE MILE CREEK	3032624	AB	-113.84	49.77	3.97	1295	46	14
FERNIE	1152850	BC	-115.07	49.49	4.84	1001	48	69
ELKFORD	1152653	BC	-114.92	50.02	3.33	1370	54	10
ELKO	1152670	BC	-115.12	49.3	6.25	931	62	28
FORDING RIVER COMINCO	1152899	BC	-114.86	50.15	1.03	1585	63	30
CLARESHOLM WATERWORKS	3031658	AB	-113.71	50.02	5.29	1008	68	44
ABERFELDIE	1150060	BC	-115.37	49.5	6.26	804.7	68	24
CLARESHOLM	3031640	AB	-113.64	50	4.95	1009	71	24
BAYNES LAKE KOOTENAY RIVER	1150690	BC	-115.22	49.23	6.38	800	72	17
STAVELY AAFC	3036099	AB	-113.88	50.18	5.03	1363.6	72	17
WATERTON RIVER CABIN	3057243	AB	-113.83	49.12	4.73	1281	74	15
WATERTON PARK GATE	3056214	AB	-113.81	49.13	5.15	1289	74	17
FT STEELE DANDY CRK	1153034	BC	-115.46	49.52	5.64	856	74	7
WARDNER KTNY HATCHERY	1158692	BC	-115.46	49.47	6.4	760	75	21
CLARESHOLM EXP FARM	3031652	AB	-113.58	50.03	4.43	1033.3	76	12
FORT MACLEOD	3032680	AB	-113.4	49.72	5.6	949.8	76	86
CAMERON FALLS	3051165	AB	-113.92	49.05	4.99	1310.6	77	18
GRASMERE	1153282	BC	-115.07	49.08	6.91	868.7	77	21
CALDWELL	3031000	AB	-113.63	49.17	4.54	1286	80	42
CRANBROOK MAYOOK	1152103	BC	-115.52	49.45	5.22	854	80	11
PEKISKO	3055119	AB	-114.42	50.37	3.2	1415	81	7
PEKISKO	3055120	AB	-114.42	50.37	2.2	1439	81	76
TOBACCO PLAINS	1158200	BC	-115.08	49.02	6.81	701	83	11
NEWGATE	1155490	BC	-115.15	49.02	6.29	708.7	86	40
WASA	1158730	BC	-115.63	49.82	6.08	970	87	22
MONARCH	3034596	AB	-113.16	49.81	5.29	947	95	26
HIGH RIVER	3033240	AB	-114.17	50.48	3.53	1219.2	95	86
CRANBROOK SE	1152109	BC	-115.75	49.48	4.45	1082	95	11
CRANBROOK CITY	1152J02	BC	-115.76	49.51	6.22	926	96	20
CRANBROOK A	1152102	BC	-115.78	49.61	5.86	940	96	41
CRANBROOK A	1152100	BC	-115.77	49.53	5.23	918.4	96	27
KIMBERLEY A	1154200	BC	-115.78	49.73	4.93	914.4	96	23
CRANBROOK	1152090	BC	-115.78	49.5	4.9	918.7	97	28
CARDSTON	3031322	AB	-113.29	49.2	5.65	1136	98	16
HIGHWOOD AU (B1)	3053250	AB	-114.37	50.55	1.39	1580	101	8
POKAPPINI	3035233	AB	-113.63	50.42	3.39	743.7	104	14
CARDSTON	3031320	AB	-113.24	49.13	5.22	1193	105	69
CARWAY	3031400	AB	-113.38	49	4.17	1354	106	77
MARYSVILLE	1154909	BC	-115.96	49.64	5.44	960	109	33
KIMBERLEY PCC	1154203	BC	-115.96	49.63	5.72	889	109	18

2.2.2 Precipitation Data

Regional precipitation data has been collected daily since 1870. Precipitation data from two meteorological stations on site was available for the period July to November 2014. Data from regional climate stations was sufficient to estimate precipitation at the Project site location. Data from a total of 18 regional meteorological stations, 11 precipitation stations and eight evaporation stations with more than 10 years of information is available within a 90 km radius (Table 2, Table 3 and Figure 5). Data coverage for each station in units of days/year are illustrated in Figure 6. Regional data is collected and warehoused by Environment Canada (EC).

Figure 7 through Figure 9 provide precipitation records for three nearby stations: Coleman (10 km west) with 82 years of information, Connelly Creek (17 km east) with 32 years of information, and Beaver Mines (28 km southeast) with 98 years of information.

Table 2: Regional Meteorological Stations with Precipitation Data

Station name	Station ID	Province	Longitude [°]	Latitude [°]	Mean Annual Precipitation (MAP) [mm/yr]	Elevation [masl]	Distance from site [km]	Amount of Information [years]
COLEMAN	3051720	AB	-114.58	49.63	547	1341.1	9	82
CONNELLY CREEK	3031805	AB	-114.22	49.62	568	1249.0	17	32
BEAVER MINES	3050600	AB	-114.18	49.47	637	1257.0	28	98
COWLEY OLIN CREEK	3031926	AB	-114.07	49.70	488	1234.4	28	40
FIVE MILE CREEK	3032624	AB	-113.84	49.77	538	1295.0	46	22
CLARESHOLM MEADOW CREEK	3031F5F	AB	-113.74	49.94	412	1035.0	61	89
ELKO	1152670	BC	-115.12	49.30	552	931.0	62	60
FORDING RIVER COMINCO	1152899	BC	-114.86	50.15	643	1585.0	63	37
CLARESHOLM WATERWORKS	3031658	AB	-113.71	50.02	435	1008.0	68	48
CLARESHOLM	3031640	AB	-113.64	50.00	428	1009.0	71	26
BAYNES LAKE KOOTENAY RIVER	1150690	BC	-115.22	49.23	443	800.0	72	26
FT STEELE DANDY CRK	1153034	BC	-115.46	49.52	503	856.0	74	37
WARDNER KTNY HATCHERY	1158692	BC	-115.46	49.47	428	760.0	75	36
FORT MACLEOD	3032680	AB	-113.40	49.72	414	949.8	76	92
MOUNTAIN VIEW BIRDSEYE	3054722	AB	-113.73	49.12	734	1408.2	79	60
CALDWELL	3031000	AB	-113.63	49.17	632	1286.0	80	78
PEKISKO	3055120	AB	-114.42	50.37	651	1439.0	81	85
MOUNTAIN VIEW	3034720	AB	-113.63	49.13	651	1339.0	83	90

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Table 3: Regional Average Monthly Precipitation and Mean Annual Precipitation

Station name	Monthly Average [mm]												MAP [mm/yr]
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
COLEMAN	40	38	37	42	56	65	44	46	46	40	46	48	547
CONNELLY CREEK	35	36	43	46	74	84	47	43	46	35	43	34	568
BEAVER MINES	43	40	48	59	74	94	45	50	55	43	44	43	637
COWLEY OLIN CREEK	30	23	33	41	61	75	55	48	40	24	28	29	488
FIVE MILE CREEK	20	23	35	44	72	119	49	52	48	29	27	20	538
CLARESHOLM MEADOW CREEK	18	23	31	33	51	71	43	43	36	21	22	19	412
ELKO	54	35	31	36	55	75	38	42	40	41	47	58	552
FORDING RIVER COMINCO	57	40	48	44	64	78	54	50	47	39	54	69	643
CLARESHOLM WATERWORKS	21	18	25	38	59	83	43	49	42	17	19	21	435
CLARESHOLM	15	16	20	36	57	94	47	49	39	26	15	14	428
BAYNES LAKE KOOTENAY RIVER	37	20	30	29	55	65	43	27	29	27	40	42	443
FT STEELE DANDY CRK	40	25	25	38	61	77	45	37	40	29	42	44	503
WARDNER KTNY HATCHERY	35	23	25	30	49	61	41	30	32	23	38	40	428
FORT MACLEOD	19	19	25	30	58	78	45	41	41	20	20	19	414
MOUNTAIN VIEW BIRDSEYE	57	52	61	76	78	96	46	49	59	48	50	62	734
CALDWELL	40	38	46	59	76	96	48	52	57	39	38	42	632
PEKISKO	32	33	45	61	81	109	58	69	62	36	33	33	651
MOUNTAIN VIEW	39	40	49	63	84	101	48	51	58	40	37	42	651

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2.3 Mean Annual Air Temperature

The mean annual air temperature (MAAT) at the site was estimated using historical precipitation data from 59 selected regional stations and correlated with the elevation of each station to the MAAT. Based on a regional linear regression, shown in Figure 10, the MAAT for the Project was determined to be 3.2°C.

2.4 Annual and Monthly Precipitation

The mean annual precipitation (MAP) at the Project was estimated using historical precipitation data from 18 selected regional stations. Based on a regional linear regression between MAP and mean catchment elevation (Figure 11), the MAP at the Project was determined to range between 611 mm/year and 992 mm/year, varying with changes in elevation.

The mean catchment elevations of Blairmore and Gold Creek watersheds are 1,693 masl and 1,868 masl, respectively. The maximum elevation within the Gold Creek watershed is 2514 m versus a maximum of 2,320 m in the Blairmore Creek watershed. As the precipitation regression analysis highlighted, MAP increases with increasing elevation. Based on a simplified regression, MAP for the Gold Creek catchment was estimated at 777 mm, versus 719 mm for the Blairmore Creek catchment.

The average monthly precipitation was estimated using an area average monthly precipitation distribution for regional stations (Figure 12 and Figure 13).

A frequency analysis was performed using the annual precipitation values for the Beaver Mines station because of the length of its data record (between 1912 and 2012), proximity to the site (28 km), and similar MAP and monthly distribution. A two parameter log-normal probability distribution was used for the frequency analysis. Table 4 summarizes the result of the frequency analysis for total annual precipitation at the Project for return periods ranging from a 200-year dry return period (300 mm) to a 200-year wet return period (1,260 mm).

Table 4: Frequency Distribution for Annual Precipitation for the Grassy Mountain Project

Hydrological Condition	Return Period	Annual Precipitation [mm/year]
Wet	200	1260
	100	1180
	50	1090
	20	973
	10	880
	5	778
Median	2	615
Dry	5	487
	10	431
	20	389
	50	347
	100	322
	200	300

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2.5 Short Duration Rainfall

Short duration rainfall was estimated based on a regional analysis and adjusted for the Project based on an average elevation for the project site. Maximum annual 24-hour precipitation from each year of record for all regional stations was compiled, and a frequency analysis was performed to determine the 24-hour rainfall for each return period. A linear regression relationship was developed for each return period relating the 24-hour rainfall to elevation of each station. Based on these linear relationships and the elevation of the Project, the 24-hour rainfall depths for the Project were estimated as an area averaged depth.

The rainfall intensity for a range of durations smaller than 24 hours was calculated by using duration factors obtained from the Rainfall Frequency Atlas for Canada (Hogg & Carr, 1985). The intensity-duration-frequency (IDF) results for storms and rainfall events are presented in Table 5.

Table 5: Intensity-Duration-Frequency (IDF) Estimates for the Grassy Mountain Project

Storm Duration		Average Intensity [mm/hr]							
		Return Period [yrs]							
min	hours	2	5	10	20	25	50	100	200
5	0.08	42.3	65.6	82.5	99.7	105.4	123.6	142.9	163.5
10	0.17	17.0	36.6	51.0	65.8	70.7	86.4	103.1	120.9
15	0.25	25.4	42.4	54.8	67.5	71.7	85.1	99.4	114.5
30	0.50	16.4	26.5	33.7	41.2	43.7	51.6	59.9	68.9
60	1	9.5	15.0	19.1	23.2	24.6	28.9	33.5	38.5
120	2	6.2	9.7	12.3	15.0	15.8	18.6	21.6	24.7
360	6	3.9	5.6	6.9	8.2	8.6	10.0	11.4	13.0
720	12	2.8	4.0	4.8	5.7	6.0	6.9	7.9	8.9
1440	24	2.1	3.0	3.6	4.2	4.4	5.0	5.7	6.4

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2.6 Evaporation

Lake evaporation refers to evaporation from a free-water surface, while actual evapotranspiration refers to evaporation from land surfaces including transpiration from vegetation. Both rates were estimated using the evapotranspiration computer model library in R, which was developed by the University of Adelaide, Australia (Guo & Westra, 2014). The complimentary relationships for areal evapotranspiration (CRAE) and wet-surface evaporation (CRWE) methodologies (Morton, 1983) were used to estimate potential evapotranspiration and lake evaporation, respectively.

The model uses different routines to estimate lake evaporation and land evapotranspiration. The lake evaporation routine was tested against the results of detailed water-budget estimates of 11 lakes in North America and Africa. The evapotranspiration routine was tested against long-term water budget estimates of 143 experimental river watersheds in North America, Ireland, Australia, and New Zealand (Morton, 1983).

Morton's methodologies were applied to eight regional meteorological stations in British Columbia and Alberta with similar latitudes to the Project. Evaporation parameters, including air temperature, dew point temperature, and sunshine hours were obtained from the 1981 to 2010 climate normal from EC (Environment Canada, 2015).

The lake evaporation estimates were compared with the climate normal measured and published by EC from 1951 to 1980 (Environment Canada, 1982). The estimated lake evaporation values for the Project were of similar magnitude to the values published by EC and ranged from 530 to

800 mm/year, with a slight increasing trend with the stations' longitude. Figure 14 presents the regional analysis and regression of annual lake evaporation. Based on this regression, the lake evaporation for the Project was determined to be 738 mm/year. Table 6 and Figure 15 illustrate the estimated and published regional monthly lake evaporation information for the Project using EC climate normal and Morton's CRWE estimations (for select stations), respectively.

Table 6: Monthly Lake Evaporation at Regional Stations

Meteorological Station	Source	Lake Evaporation [mm]												Annual
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
CRANBROOK A	Morton's CRWE	9	17	41	71	107	124	131	108	65	30	11	7	719
LETHBRIDGE A	Morton's CRWE	11	19	45	80	120	140	145	120	72	34	13	9	807
SPRINGBANK A	Morton's CRWE	10	17	40	73	111	130	135	108	64	30	12	8	738
CALGARY INT'L A	Morton's CRWE	10	17	41	74	114	133	139	112	66	30	12	8	756
CASTLEGAR A	Morton's CRWE	8	15	36	63	95	110	118	99	59	26	10	6	645
MEDICINE HAT A	Morton's CRWE	11	17	43	79	121	141	147	121	72	33	12	9	805
RED DEER A	Morton's CRWE	9	15	37	71	111	131	135	107	61	27	10	8	721
KELOWNA A	Morton's CRWE	7	14	36	64	96	112	119	99	58	26	9	6	646
CASTLEGAR A	EC (1951-1980)					119	112	152	151	77				610
KELOWNA A	EC (1951-1980)				83	109	132	154	124	68				670
CALGARY INT'L A	EC (1951-1980)						144	154	130	95				523

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Since variability in the distribution is minimal, the average distribution was applied to the proposed Project. The corresponding average monthly lake evaporation is presented in Table 6 and Figure 16.

Regional actual evapotranspiration displayed a correlation with the meteorological station's latitude with a range of annual values between 150 and 470 mm/year (Figure 17). Monthly evapotranspiration in the region is presented in Table 8 and Figure 18. Actual evapotranspiration is relatively constant during the winter months with an increase during the summer and a peak during the month of June. For the Project, the average annual evapotranspiration was determined to be 262 mm/year and was derived using the regional analysis and monthly distribution estimated based on the observed average in the region (Figure 19). The resulting average monthly actual evapotranspiration for the Project is presented in Figure 20.

Table 7: Regional values for monthly actual evapotranspiration evaporation

Meteorological Station	Source	Actual Evapotranspiration [mm]												Annual
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
CRANBROOK A	Morton's CRAE	12	14	16	16	37	49	28	13	12	13	10	11	231
LETHBRIDGE A	Morton's CRAE	11	16	19	32	63	85	74	44	14	11	8	8	385
SPRINGBANK A	Morton's CRAE	12	17	20	37	72	96	92	66	21	13	10	9	465
CALGARY INT'L A	Morton's CRAE	10	15	19	30	64	88	84	52	15	11	8	8	405
CASTLEGAR A	Morton's CRAE	11	15	17	18	42	55	34	14	13	16	12	10	256
MEDICINE HAT A	Morton's CRAE	11	12	16	12	18	34	17	11	9	3	4	8	155
RED DEER A	Morton's CRAE	14	18	22	34	64	92	95	63	18	14	12	12	458
KELOWNA A	Morton's CRAE	11	16	16	16	37	44	32	16	13	15	10	10	236

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3 Baseline Hydrology

3.1 Regional Watersheds

The Project is situated within the Blairmore Creek and Gold Creek watersheds, which are located east of the High Rocky Mountain range. Blairmore Creek and Gold Creek catchments measure approximately 50 km² and 60 km², respectively, and both discharge into the Crowsnest River. The Blairmore Creek and Gold Creek catchments are part of the Oldman River watershed flowing into the Saskatchewan River ultimately discharging into Lake Winnipeg.

The Blairmore Creek watershed is relatively steep, with an average slope of 22% and elevations ranging between 1,300 and 2,300 m above sea level (masl). Gold Creek has similar geomorphological characteristics with an average slope of 19% and elevations ranging from 1,300 to 2,500 masl.

Figure 21 illustrates the mine footprint relative to the Blairmore Creek and Gold Creek watersheds, which flow into the Crowsnest River and Oldman River through local and regional watersheds. The local watersheds (LSA) are presented by Blairmore Creek and Gold Creek, and the regional watersheds (RSA) are Crowsnest River and Oldman River.

Streamflow data from eight local site specific gauging stations located in the vicinity of the Project and data from eight regional EC gauging stations with natural hydrologic regimes were compiled to evaluate long-term runoff trends for the Project area. These regional stations consisted of daily flow data from 1908 to 2014.

3.2 Local Data

Table 8 summarizes the local streamflow data collected by Benga from eight local gauging stations along Crowsnest River, Blairmore Creek, and Gold Creek. Stations BL-01, BL-02, BL-03, and BL-04 are located along Blairmore Creek (Figure 22). Stations UNC-01 and UNC-02 are located along Unnamed Creek. Station GC-01 is located along Gold Creek and CR-01 is located along the

Crowsnest River. Continuous stage records were obtained at these stations from September 2013 to December 2014, with several gaps evident in the data. The continuous stage records were complemented with spot measurements of stage and flow. Table 9 presents the measured water level and corresponding flow for the local gauging stations. Figure 23 to Figure 27 present the available flow records for BL-01, BL-02, BL-03, and GC-01. The pressure transducers have picked up some anomalies where sharp increases in water levels have been recorded in the winter months and caution should be used in assessing the reliability of this data. Increased confidence in the local data will come from further data gathering around the site.

Preliminary rating curves for each local station were prepared by Hatfield Consultants. Field surveys are ongoing and these flows are based upon a preliminary rating curve which is expected to be updated at a later date.

Table 8: Synthesis of Local Streamflow Data

Gauge Station ID	Watershed	Easting[1] [m]	Northing[1] [m]	Watershed size [km²]	Is pressure transducer available?	Amount of Spot Measurements [N°]	Starting Records	Available Records
BL-01	Blairmore Creek	683555	5500661	48.1	Yes	9	20-Sep-13	23-Dec-16
BL-02	Blairmore Creek	684976	5505089	24.2	Yes	6	18-Oct-13	19-Aug-14
BL-03	Blairmore Creek	684163	5508587	15.4	Yes	7	17-Sep-13	20-Aug-16
BL-04	Blairmore Creek	682891	5510151	8.8	No	3	11-Jun-14	20-Aug-14
CR-01	Crowsnest River	680925	5500619	236.5	Yes	7	21-Sep-13	21-Aug-15
GC-01	Gold Creek	687472	5504582	32.5	Yes	9	19-Sep-13	14-May-16
UNC-01	Unnamed Creek	683939	5506085	6.9	No	4	29-May-14	19-Aug-14
UNC-02	Unnamed Creek	682179	5511085	1.5	No	1	29-May-14	29-May-14

Source: file:///Z:\01_SITES\Grassy Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Hatfield_Data\ProvisionalFlowData_20160602

Notes:
1 Coordinate system UTM Zone 11 U.

Table 9: Measured Water Level and Flow Pairs for Local Streamflow Gauges

Gauge BL-01

Date	Flow [m³/s]	Water Level [m]
20-Sep-13	0.16	98.16
20-Jan-14	0.05	98.10
2-Apr-14	0.08	98.14
28-May-14	2.47	98.49
10-Jun-14	0.72	98.30
7-Jul-14	0.395	98.22
23-Jul-14	0.19	98.16
21-Aug-14	0.112	98.13
23-Mar-16	0.082	98.13

Gauge CR-01

Date	Flow [m³/s]	Water Level [m]
21-Sep-13	2.41	98.407
18-Jan-14	1.36	98.327
4-Apr-14	0.934	98.286
27-May-14	18.8	98.958
6-Sep-14	12	98.16
09-Jun-15	12.0	98.80
07-Jul-15	8.97	98.70
21-Aug-15	2.85	98.42

Gauge BL-02

Date	Flow [m³/s]	Water Level [m]
18-Oct-13	0.05	97.73
19-Jan-14	0.03	97.72
29-May-14	1.64	98.020
11-Jun-14	0.567	97.88
08-Jul-14	0.183	97.98
19-Aug-14	0.043	97.69

Gauge GC-01

Date	Flow [m³/s]	Water Level [m]
21-Sep-13	0.351	97.446
20-Jan-14	0.162	97.385
2-Apr-14	0.117	97.343
28-May-14	2.03	97.684
10-Jun-14	0.802	97.544
09-Jul-14	0.539	97.504
19-Aug-14	0.325	97.442
18-Mar-16	0.117	97.359
14-May-16	0.255	97.416

Gauge BL-03

Date	Flow [m³/s]	Water Level [m]
17-Oct-13	0.0221	-
17-Oct-13	0.039	97.70
19-Jan-14	0.0184	97.70
10-Jun-14	0.42	97.90
11-Jun-14	0.436	97.89
8-Jul-14	0.152	97.78
20-Aug-14	0.030	97.69
20-Mar-16	0.024	97.69

Gauge UNC-01

Date	Flow [m³/s]	Water Level [m]
29-May-14	0.321	97.684
11-Jun-14	0.062	97.607
08-Jul-14	0.041	97.572
19-Aug-14	0.004	97.497

Gauge BL-04

Date	Flow [m³/s]	Water Level [m]
11-Jun-14	0.358	97.08
08-Jul-14	0.105	96.96
20-Aug-14	0.024	96.89

Gauge UNC-02

Date	Flow [m³/s]	Water Level [m]
5/29/2014	0.33	97.817

Sources:file:///Z:\01_SITES\Grassy%20Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Site%20Data\Flow%20Compilation_Rev3b_Site%20Graphs_VM.xlsx

3.3 Regional Data

A regional analysis was developed using streamflow data from gauging stations in the vicinity of the Project area. The Water Survey of Canada (WSC) database was used to access regional station information and data (Water Survey of Canada, 2014). Within 80 km of the Project area, eight stations with unregulated catchment areas less than 1500 km^2 and with a minimum of 20 years of data were selected for the regional analysis (Table 10). Missing data was patched using available data from the from the closest station. Winter flows from Gold Creek near Frank were patched with those of Crowsnest River at Frank. Data for Crowsnest River at Frank was patched with data from Oldman River near Waldron's Corner.

Figure 28 to Figure 31 show the historical flow records for the four closest stations to the site, including Gold Creek near Frank, Crowsnest River at Frank, Racehorse Creek near the Mouth, and Oldman River near Waldron's Corner (Station locations on Figure 22).

Table 10: Regional Gauge Stations for the Grassy Mountain Project

Gauge ID	Regional Gauge Station	Mean Annual Runoff [mm/yr]	Avg. Watershed Elevation [masl]	Watershed Centroid Latitude [°]	Watershed Centroid Longitude [°]	Area by SRK [km²]	Area by EC [km²]	Distance from Site [km]	Amount of Information [years]
05AA030	GOLD CREEK NEAR FRANK	316	1783	49.67	-114.38	63	63	6.16	37
05AA030	CROWSNEST RIVER AT FREANK	386	1711	49.64	-114.55	386	403	6.17	72
05AA030	RACEHOURSE CREEK NEAR THE MOUTH	359	1857	49.80	-114.54	219	218	21.56	46
05AA030	OLDMAN RIVER NEAR WALDRON'S CORNER	280	1857	49.96	-114.47	1448	1446	27.02	59
08NK019	GRAVE CREEK AT THE MOUTH	409	1748	49.82	-114.79	822	84	36.63	29
08NK019	LINE CREEK AT THE MOUTH	483	1985	49.93	-114.74	138	138	38.68	41
08NK019	FORDING RIVER AT THE MOUTH	412	1981	50.08	-114.79	619	621	40.52	44
05BL022	CATARACT CREEK NEAR FORESTRY ROAD	361	2016	50.23	-114.65	166	166	71.89	41

Source: file:
file:///Z:\01_SITES\Grassy%20Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Runoff\Script\ECflow\Grassy%20Mountain%20Update_Rev8-Crownest%20Patched-VM.xlsm

3.4 Blairmore Creek, Gold Creek, Tributaries, and Headwaters

Available local gauge information show a markedly seasonal flow response, with generally similar responses between stations, and between local stations within Blairmore and Gold Creek catchments (Figure 23 to Figure 27) and the long term stations positioned downstream on Gold Creek and Crowsnest River (Figure 28 to Figure 31). Blairmore and Gold creeks discharge into the Crowsnest River. Winter flows are missing from the regional Gold Creek station record.

It is of note that the low flow hydrograph response within Blairmore does not mirror that of flows observed within Gold Creek and the Crowsnest station exactly. Blairmore Creek has a lower baseflow component with decreasing flow volumes upstream within the Blairmore watershed but with a disproportionally higher unit flow within the upper reaches of the catchment. This suggests that baseflow contributions to stream flow is highest in the upper regions of the watershed.

Besides differences in mean catchment elevation, Blairmore and Gold Creeks catchments differ with respect to topography, surficial geology and land cover. For example, a there is a 12.5 km^2 clear cut area within Gold Creek while the Blairmore Creek catchment is entirely forested. Consequently, decreased interception of precipitation and evapotranspiration within the Gold Creek watershed is likely, compared to the similarly sized Blairmore catchment. These and other factors are likely to account for the differences observed between the two watersheds.

Peak response within the local watersheds appear to show good correlation between stations. However, occasional spikes within peak flow response for certain stations demonstrates some variability. However this is potentially due to uncertainty in the preliminary rating curves and inaccuracies at the upper range of estimation where the inferred range is extrapolated beyond the measured range. As hydrological data collection continues, improvements to the rating curve development will help to constrain this uncertainty.

Hydrological analysis for the project, such as runoff, baseflow and low flow within the mine project area were assessed using flows from the local gauging stations coupled with long-term regional records. Analysis of the relationship between the short-term datasets collected on site and the long term Crowsnest River at Frank station was used to validate the correlation between stream flow on the Project Site and regional stream flow. Based on this correlation, the regional stream flow record was used to develop a synthetic long term time series for each catchment as illustrated in

3.5 Mean Annual Runoff

Potential effects to site water runoff (or yield) within the Project area was evaluated by the water and load balance model (SRK 2016a) developed for the Project. The model accounts for all inflows, water uses, reservoirs and outflows from the Project area. In this report, runoff or yield is defined as the portion of precipitation falling within a catchment that is not subsequently lost to evaporative processes. Runoff flows within and out of a catchment via three pathways: overland flow, interflow, and groundwater. Runoff values presented in this section do not differentiate between the three pathways, but represent their total.

Mean annual runoff (MAR) for site was estimated based on regional flow data. MAR was calculated for each WSC gauging station by dividing total flow by the corresponding catchment area. The results are presented with respect to longitude in Figure 32. MAR for the site location was estimated using a best-fit linear regression of runoff vs longitude. From this regional analysis, the MAR for the Project is 323 mm/year.

Figure 32 indicates that MAR for the Crowsnest River near Frank (Station 05AA008) is higher than MAR for the Gold Creek station. A comparison of historical unit flow recorded at the Crowsnest River and the Gold Creek hydrometric stations (Figure 33) shows that unit runoff tend to be higher during peak flow. However, winter flow data was not available for the Gold Creek station, which adds uncertainty to the MAR calculated for this station.

The MAR estimate was checked against the estimated MAP and mean annual evapotranspiration. The difference between the two values (628 mm/year for MAP and 262 mm/year for actual evapotranspiration) is 366 mm/year. This MAR estimation (MAR ≈ MAP – Actual evapotranspiration) is comparable to the estimate using the regional analysis of 323 mm/year.

The flows at Crowsnest River at Frank were corrected on a daily time step using a linear relationship to capture the MAR and monthly runoff distribution estimated at the Project site. This specific flow adjustment produced a 72-year time series associated to the site, which was used for runoff, low flow, and base flow estimations. The adjusted time series for this station is identified as the Site Corrected – Crowsnest River at Frank.

For this analysis, the flow record from the local stations were used to evaluate the correlation between flows at the regional stations downstream. The local gauging stations BL-01, BL-03, CR-01, and GC-01 displayed similar runoff values to the annual runoff predicted at the site. Figure 34 shows unit flow, which is the measured flow divided by catchment area. The local stations follow similar daily patterns as flow at Crowsnest River at Frank. Gold Creek's base unit flows tend to be higher than the values measured at Blairmore Creek. Crowsnest River at Frank flows were found to be on average between the high runoff values at BL-01 and low runoff values from GC-01.

In the water balance model for the Grassy Mountain Project runoff is calculated by multiplying total annual precipitation by a runoff coefficient. Runoff coefficients account for losses such as evapotranspiration, soil storage and groundwater recharge. Specific runoff coefficients were estimated for different types of infrastructure depending on its land use and surface cover characteristics (Table 11).

The runoff coefficient for undisturbed or reclaimed areas was based on estimates of MAP and MAR and was calculated as follows: undisturbed runoff coefficient = MAR/MAP = 323 mm/628 mm = 0.51. Runoff coefficients for unvegetated developed areas such as waste rock storage areas were assumed to be higher (0.60) because of the lack of evapotranspiration and precipitation interception by vegetation. Pit walls are for the most part steep and consists of relatively competent bedrock or overburden material. Such surfaces tend to promote runoff and were assumed to have runoff coefficients of 0.80. Open water surface areas have by definition a runoff coefficient of 1.0. Since a runoff coefficient of 1.0 is used for open water in the water balance model, the model also calculate direct evaporation losses from open water.

Although runoff coefficients were based on MAR (323 mm/year) and MAP (628 mm/year) values for catchment elevations lower than mean catchment elevation for Blairmore Creek and Gold Creek, the coefficients were assumed to be valid for higher elevation areas where MAP are higher (719 mm/year and 777 mm/year for Blairmore and Gold creeks, respectively).

Table 11: Estimated Runoff Coefficients

Land Use	Runoff Coefficient	Comment
Undisturbed and Reclaimed Areas	0.51	Based on hydrology analysis. Accounts for losses due to evapotranspiration, infiltration and storage.
Waste Rock Storage Area	0.60	Assumed value to account for losses due to evapotranspiration and storage.
Backfilled Area	0.60	Assumed value to account for losses due to evapotranspiration and storage.
Pit Walls	0.80	Assumed value applied to the open pit areas. Accounts for losses due to evapotranspiration and storage.
Ponded Area	1.00	Value applied to water surface to account for direct precipitation.

Source: \\VAN-SVR0.van.na.srk.ad\Projects\01_SITES\Grassy Mountain\1CM029.010_Water_Quality_Prediction_Model\100 Expanded Screening\Analysis\Reasonable_Worse_Case_Rev01_spb.xlsm

The monthly average runoff distribution for the site was obtained using the average of the monthly distributions for the region and adjusted by the resultant monthly distribution and the flow record from the local stations (Figure 35). The resultant average monthly runoff for the Project is presented in Figure 36. Even though Gold Creek is the closest station to the site, it could not be used for evaluation of the hydrograph because it does not include measured winter flows.

3.6 Base Flow

The base flow evaluation was based on Site Corrected – Crowsnest River at Frank station flows. A base flow separation analysis was prepared to estimate the proportion of groundwater contributing to creek flows. Surface runoff was separated in two components: quick flow and base flow. Quick flow is defined as the portion of streamflow that comes from either surface runoff or interflow. Baseflow is the portion of streamflow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow. The runoff separation was conducted with the Nathan and McMahon (1990) technique, which is an automated digital filter method constrained by the following two parameters:

- Alpha (α) – Nathan and McMahon (1990) suggests a value between 0.90 and 0.95.
- N – This parameter is the number of times that the digital filter passes over the runoff time series. Higher N numbers make the base flow time series smoother and less dependent on peak flows within the runoff time series.
- The coefficient α was set at 0.95 and N at 5. Table 14 presents the results of the base flow analysis.

The baseflow estimations for Crowsnest River at Frank, Blairmore Creek and Gold Creek are presented in Figure 37.

Table 12: Unit Base Flow for Crowsnest River at Frank and at the Grassy Mountain Project

Location	Base Flow [l/s/km²]											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Blairmore Creek	0.9	0.9	0.9	1.1	2.3	4.4	3.1	2.1	1.7	1.4	1.1	1.0
Gold Creek	1.4	1.4	1.4	1.7	3.5	6.7	4.6	3.1	2.6	2.2	1.7	1.5
Crowsnest River At Frank	2.8	2.7	2.7	3.3	6.9	13.2	9.1	6.2	5.1	4.3	3.4	3.0

Source: file:///Z:\01_SITES\Grassy%20Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Update_2016\RunoffDistribution_v1_FS.xlsx

3.7 Low Flows Analysis

Low flow estimations include seven-day period low flows for a 10-year return period (7Q10) by month and year (i.e., 2-, 5-, 10-, and 100-year return periods). The Blairmore and Gold Creek catchments were estimated using the linear relationship defined for Crowsnest River at Frank, summarised in Section 3.4. Table 13 summarizes the results of the low flow analyses.

Table 13: Seven-Day Low Flow by Month and Frequency for the Grassy Mountain Project

Location	Return Period [years]	7-day low flow [l/s/km²]												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Blairmore Creek	2	1.0	1.0	0.9	1.4	5.3	7.9	3.9	2.3	1.9	1.6	1.3	1.1	0.9
	5	0.8	0.8	0.8	1.0	3.2	5.8	2.8	1.8	1.5	1.3	1.0	0.8	0.7
	10	0.7	0.7	0.7	0.9	2.4	4.9	2.3	1.6	1.3	1.2	0.8	0.7	0.6
	100	0.6	0.6	0.7	0.8	1.1	3.1	1.4	1.1	1.0	1.0	0.6	0.5	0.5
Gold Creek	2	1.5	1.4	1.4	2.1	7.9	11.9	5.8	3.5	2.9	2.4	1.9	1.7	1.3
	5	1.2	1.2	1.2	1.4	4.8	8.7	4.2	2.7	2.2	1.9	1.5	1.3	1.1
	10	1.1	1.1	1.1	1.3	3.6	7.3	3.5	2.4	2.0	1.8	1.3	1.1	1.0
	100	0.9	0.9	1.0	1.2	1.7	4.7	2.1	1.7	1.4	1.5	0.9	0.7	0.7
Crowsnest River at Frank	2	3.0	2.9	2.8	4.1	15.6	23.5	11.4	6.9	5.6	4.8	3.8	3.3	2.6
	5	2.4	2.4	2.3	2.8	9.5	17.1	8.3	5.4	4.4	3.8	2.9	2.5	2.1
	10	2.2	2.2	2.1	2.5	7.1	14.4	6.9	4.7	3.9	3.5	2.5	2.1	1.9
	100	1.7	1.8	2.0	2.3	3.3	9.2	4.1	3.3	2.8	2.9	1.8	1.4	1.4

Source: file:///Z:\01_SITES\Grassy%20Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Update_2016\RunoffDistribution_v1_FS.xlsx

3.8 Peak Flow Analysis

The peak flows were estimated with a frequency analysis conducted over the peak flow data at the Crowsnest River at Frank station. Crowsnest River at Frank station was used because of the longer historical data record. The relationship between the Crowsnest River regional station, the Gold Creek regional station and project stations within the local watersheds was then used to determine watershed specific average unit peak flows. The unit peak flows for the Blairmore and Gold Creek watersheds are presented in Table 14.

The peak flows were estimated using the index flood method, where a frequency analysis was conducted to fit a probability distribution to the peak data at every available regional gauge station. The relationship between the watershed size and the mean annual flood for the region is presented as an average trend and an upper envelope curve in Figure 38. The regional unit peak flows for the average and envelope relationships are presented in Table 14, where the site unit peak flow for a return period of 100 years is estimated to be 0.86 $m^3/s/km^2$.

Table 14 Peak Flow Estimations Based on Local Flow Data

Return Period [years]	Peak Flow [l/s/km²]	
	Blairmore	Gold Creek
2	239	299
5	340	426
10	427	535
25	543	679
50	632	791
100	725	907

Source: file: file:///Z:\01_SITES\Grassy%20Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Update_2016\RunoffDistribution_v1_FS.xlsx

3.9 Sediment Concentrations

The available data for total suspended sediment (TSS) concentration or sediment concentration was reviewed and summarized for the region. The two sources of regional data are from the regional EC gauge and sediment station named Crowsnest River at Frank, and the Gold and Blairmore Creeks habitat report by Hatfield (2016b). Average monthly flows and suspended sediment data recorded at the Crowsnest River at Frank station from 1976 to 1980 are plotted in Figure 39.

The data shows that there generally is a strong correlation between flow and suspended sediment in the Crowsnest River at Frank (Figure 40). However, when hydraulic characteristics such as gradient or water level change, the sediment concentrations can vary by one order of magnitude for the same flow as they are related to the actual sediment particle size at the water course and banks, the stream slope, and seasonal events such as freshet snowmelt. . Thus, flows cannot reliably predict sediment concentrations but can provide an indication of expected suspended solids concentrations.

Hatfield 2016b indicates that Gold Creek and Blairmore Creek have similar geomorphological characteristics in their main steam as in their tributaries with sections protected by gravel and cobbles and longitudinal slopes between 5 and 20% with average watershed slope between 19 and 22%, respectively. The station Crowsnest River at Frank is in an area with a smaller transversal slope with an average watershed slope of 15%. Meandering water courses in the section close to the town of Frank and an increased tendency for small size sediment particles.

Gold Creek and Blairmore Creek have a greater capacity for suspending sediment because of their steeper slopes compared with those of Crowsnest River. However, because of ongoing scour in those streams there is less small sediment particles to be suspended.

Daily maximum sediment concentration data at the Crowsnest River at Frank station is available intermittently from 1972 to 1983, with continuous records during the period from 1976 to 1980. The maximum recorded concentration was 602 mg/L in 1972. The continuous record of the period from 1976 to 1980 represents approximately 1:3 year wet to 1:34 year dry for the complete region of Gold Creek, Blairmore Creek, and Crowsnest River. During winter, the maximum monthly sediment concentration can reach 20 mg/L with an average of 7 mg/L. During summer, the maximum monthly sediment loads can reach 55 mg/L with an average of 17 mg/L. No sediment samples are recorded in the region after 1980.

Monitoring of suspended sediment concentrations over a range of flows and times would be required to refine the sediment regime for Gold Creek and Blairmore Creek.

4 Links to Other Effects Assessment

4.1 Water and Load Balance Model

The water and load balance model (SRK, 2106a) prepared for the Grassy Mountain Project used as input a number of results from the hydrological assessment, including:

- Estimated MAP for Blairmore and Gold creeks (Section 2.4)
- Frequency analysis for total annual distribution (Section 2.4)
- Average monthly precipitation distribution (Section 2.4)
- Average monthly runoff distribution (Section 3.5)
- Runoff coefficient estimates (Section 3.5)

Details on how the hydrological characteristics were incorporated into the load balance model are described in (SRK Consulting Ltd., 2016a).

4.2 Hydrogeological/Groundwater Model Assessment

The hydrogeological modelling assessment (MEMS 2016e) completed for the Grassy Mountain Project relied on base flow estimates developed for Blairmore and Gold Creek catchments (Section 3.6).

4.3 Instream Flow Needs (IFN) Assessment

The instream flow needs assessment carried out as part of the fisheries effects assessment relied on low and peak flow estimates (Sections 3.7 and 3.8) as well as estimated changes to stream flow regimes, which were estimated by the water and load balance model (SRK 2016a). Predicted streamflow changes for different conditions are summarized in Section 5.0. Benga continues to collect information that will support the IFN assessment that will be compiled and submitted in Q1, 2017.

4.4 Water Use Evaluation

Project water use or water demand by the Project was estimated by the water balance model (SRK 2016a) and was therefore indirectly based on the hydrological assessment presented in this report. Model prediction for Project water use are summarized in Section 5.0.

5 Water Use and Flow Changes

Potential effects on hydrology caused by the Project development include:

- Changes to quantity of water flowing from affected catchments caused by water withdrawal and use or changes to catchment runoff characteristics; and
- Changes to timing and intensity of flows resulting from changes to hydrological characteristics and Project water management.

In both cases, water management measures were devised to minimize hydrological effects. The following sections discuss results of the evaluation of water use and flow changes. The results were produced by the water balance model, which is described in (SRK 2016a).

5.1 Project Water Use

Active surface and groundwater licenses within the Municipal District of Crowsnest Pass near the Project site are summarized in Table 15 and active surface and groundwater licences within the Municipal District of Crowsnest Pass near the Project site are summarized in Table 15 and Table 16 respectively. There is a total of 14 surface water licences listed within the regional area, all of which are located within the Crowsnest River watershed area. The watershed area comprises the Crowsnest River and its tributaries, which include Allison Creek, York Creek, Drum Creek, Gold Creek, Blairmore Creek, and Star Creek. There are nine groundwater licences located within the same regional area. The total allocation of these licences amount to 8% of the mean annual flow recorded at the Crowsnest River at Frank gauge station. Of the 23 active licenses, the largest is on Allison Creek, held by Alberta Environment and Parks (AEP).

Table 15: Active surface water licences in the regional area

License No.	License Holder	Source	Maximum Annual Allocation (m^3/year)
00032258-00-00	AEP	Allison Creek	5,083,170
00045849-00-00 (cancelled March 4, 2016)	Municipality of Crowsnest Pass	Tributary to Crowsnest River	339,210
00045622-00-00 (cancelled March 4, 2016)	Municipality of Crowsnest Pass	York Creek	308,380
00038115-00-00	706979 Alberta Ltd.	Allison Creek	277,540
00045625-00-00 (cancelled March 4, 2016)	Municipality of Crowsnest Pass	Drum Creek	254,100
00045980-00-00 (cancelled March 4, 2016)	Municipality of Crowsnest Pass	Gold Creek	250,400
00039493-00-00	Devon Canada Corporation	Crowsnest River	123,350
00035850-00-00 (cancelled March 4, 2016)	Municipality of Crowsnest Pass	Crowsnest River	103,610
00035946-00-00 (cancelled March 4, 2016)	Municipality of Crowsnest Pass	Crowsnest River	98,680
00035136-00-00	Glen Gravel (Glen Ranching Ltd.)	Crowsnest River	61,670
00040056-00-00	Coleman Fish & Game Association	Tributary to Crowsnest River	49,340
00034586-00-00	Edward Cervo	Crowsnest River	32,070
00026653-00-00	Leonard Green	Crowsnest River	27,130
00032992-00-00	Harold Ganske & Ron Mielke	Tributary to Crowsnest River	24,670
		TOTAL:	**7,033,320**

Table 16 Active groundwater licences in the regional area

License No.	License Holder	Source	Maximum Annual Allocation (m³/year)
00034273-00-00	Municipality of Crowsnest Pass	Aquifer from Star Creek Watershed	1,658,609
00034621-00-00	Municipality of Crowsnest Pass	Aquifer from Crowsnest River Watershed near Blairmore	1,234,720
00030473-00-00	AESRD	Aquifer from Allison Creek Watershed	829,640
00140020-00-00	Municipality of Crowsnest Pass	Aquifer from Crowsnest River Watershed near Blairmore	710,000
00034620-00-00	Municipality of Crowsnest Pass	Aquifer from Crowsnest River Watershed near Blairmore	444,050
00029001-00-00	Municipality of Crowsnest Pass	Aquifer from Drum Creek Watershed	263,960
00029757-00-00	Municipality of Crowsnest Pass	Aquifer from Crowsnest River Watershed near Bellevue	186,285
00029000-00-00	Municipality of Crowsnest Pass	Aquifer from Drum Creek Watershed	136,910
00034622-00-00	Municipality of Crowsnest Pass	Aquifer from Crowsnest River Watershed near Blairmore	123,350
		TOTAL:	**5,587,524**

Benga has evaluated the potential impacts on downstream water users as a result of the water management program requirements to contain and use water that lands on the site. There is one licenced user on Blairmore Creek (Golf Course) that has an allocation of 1,233 m³/year, which was also recently cancelled. There was one licenced user on Gold Creek that had an allocation of 250,400 m³/year. Records indicate that AEP may have cancelled this licence on March 4, 2016.

An assessment of annual water use by the Project is important from a water licencing perspective. The water and load balance model for the Grassy Mountain Project was used to estimate net water use by the coal mine operation (SRK Consulting Ltd., 2016a). A complete description of methodology and assumptions used in the development of the water balance model is available in the water and load balance report.

The only true loss of water from the Project area is the moisture associated with the clean coal that is shipped off site to market. However, within the project area there are changes to surface water flows as water is collected, diverted, treated and discharged, and changes to the inventory of water stored in various reservoirs such as ponds, saturated zones and groundwater. In addition, change to surface characteristics of the developed mine areas are expected to result in higher runoff from those areas, which is a net gain in terms of the water balance.

Figure 41 shows the estimated net change to discharge from Blairmore and Gold Creeks (combined) for the following scenarios:

- Average annual precipitation (all years in scenario);
- 1 in 10 dry year (all years in scenario);
- 1 in 10 wet year (all years in scenario);

It is important to note that the water use is subject to operational control during the operations phase. The single largest factor that affect projected water use is the filling of the planned saturated zones. As mining progresses, water accumulating in the open pits will be managed by pumping it to the Raw Water pond for use in the process, or to sedimentation ponds. As mining is completed, pit areas will be backfilled and used to create the saturated zones to treat the selenium enriched water. As long as the saturated backfill zones are used for attenuation of selenium, the operation will pump water out of the saturation zone at whatever rate is required which is an operational decision.

The three periods that show a reduction in annual discharge volumes up to a maximum of about 430,000 m^3/year correspond to the periods when the saturated backfill zones are filling. The scenarios shown in Figure 41 assumes that water is continuously pumped from the saturated zones to a water treatment plant during the operations phase, but that the treatment throughput will be reduced in years when the zones are filling.

Long-term, the annual discharge volume is expected to be greater than baseline conditions by approximately 600,000 m^3/year in years with annual average precipitation. The increase is caused by the higher runoff coefficient associated with the legacy highwalls. Even though the majority of the project foot-print will be reclaimed after closure, the site-wide average runoff coefficient in the post-closure phase is expected to be roughly 0.58 due to the influence of the remaining pit high-walls. Runoff coefficients for natural ground and therefore for baseline conditions is estimated 0.51.

5.2 Streamflow Changes

5.2.1 Average Hydrological Conditions

Potential changes to stream flow was evaluated at various stations along Gold and Blairmore creeks. Figure 42 shows the location of the stations/model nodes in Gold and Blairmore creeks along with catchment delineations for each node.

Estimates of potential changes to stream flow for average hydrological conditions are illustrated in Figure 43 for Gold Creek and Figure 46 for Blairmore Creek. The estimated flow changes are based on the results of the water and load balance model that was developed for the Project (SRK Consulting Ltd., 2016a). The water and load balance model operate on a monthly time-step. Therefore, flows and flow changes are evaluated on the basis of monthly flows. A complete description of methodology and assumptions used in the development of the water balance model is available in the water and load balance report. Estimated stream flow changes includes both surface flow, interflow and base flow (groundwater flow).

A separate assessment was completed for specific changes to the groundwater flow regime (SRK 2016c). Table 17 summarizes predicted changes to base flow in Blairmore Creek, Gold Creek and Daisy Creek, as reported in SRK (2016b). The water balance model incorporated the combined effects of the estimated changes to the groundwater flow regime and to surface flow. The estimated groundwater reduction is caused by interception of open pit mine water and seepage from waste rock areas. The intercepted mine water will be conveyed through the saturated backfills where nitrate and selenium will be attenuated, through a discharge treatment system (if required) at which point the water will be discharged to locations in Blairmore Creek where the water was originally collected. Therefore, the estimated reduction in groundwater flow is matched by an increase in surface water flow at those nodes.

Table 17 Predicted Changes to Base Flows of Blairmore, Gold and Daisy Creeks, Baseline to EOM

Watershed	Station	Average Annual Base Flow at Baseline (L/s)	Year of Peak Reduction	Best Estimate Relative % Difference at Peak Reduction
Blairmore Creek	BL-03	71	2046	-0.015%
	BC-07	102	2037	-23%
	BL-02	111	2037	-25%
	BC-03	172	2030	-30%
	BL-01	192	2030	-27%
	All	199	2030	-26%
Gold Creek	GC-13	31	2041	-10%
	GC-09	126	2041	-13%
	GC-04 (Caudron Creek)	288	2041	-10%
	GC-02	331	2041	-19%
	GC-01	540	2041	-12%
	All	543	2041	-12%
Daisy Creek	D1	257	2041	-0.036%

Source: SRK, 2016c

The proposed open pit intersects portions of the upper reaches of the western catchments for Gold Creek. Water intercepted by those areas may be routed to saturated zones which would discharge to Blairmore Creek. An intermediate step may require the discharge from the saturated zones to be treated for removal of metals. In this instance, the treatment plant would discharge to Blairmore Creek. Therefore, a net loss of flow is anticipated in the lower reaches of Gold Creek. However, the largest flow changes are expected changes are estimated to be just over 10% at the at the GC-02 station. The higher expected flow change is due to the extent of development within the local catchment for that station. The anticipated effect on flows further downstream are lower further downstream because of flow contributions from undisturbed catchments.

For stations other than GC-02, flow changes are estimated to be around or less than 5%. The long-term increase in flow estimates for station GC10, which is located in the upper reaches of Gold Creek is caused by the contribution of flows from the End Pit Lake, which will overflow to Gold Creek when full.

Flows in Blairmore Creek are expected to increase compared to baseline conditions because of the additional contribution of flow from some Gold Creek sub-catchments, but more importantly because of the estimated increase in runoff caused by changes to the hydrological characteristics of the developed mine areas (i.e. increase in runoff coefficients for it walls and waste rock areas). For most of the year, the maximum change to flow is expected to be less than 15% for all stations. Large flow changes are possible during the low flow season (Dec to March). However, the water balance model assumes that the discharge from the saturated zones or water treatment plant will be controlled based on the rate of accumulation of water in the saturated zone and the stream flow conditions in Blairmore Creek.

5.2.2 Dry and Wet Hydrological Conditions

Estimated stream flow changes to Blairmore and Gold creeks for 1 in 10 dry and wet years are shown in Figure 44 and 45, and estimated changes to flows in Blairmore Creek are shown in Figure 47 and 48. The flow changes during dry and wet conditions are similar to the patterns discussed for average conditions and the estimated magnitude of the changes (expressed as percent change) is similar. Both the wet and dry model scenarios assumed that each year in the model scenario was a 1 in 10 wet year or a 1 in 10 dry year, respectively.

6 Effects Assessment

As discussed in Section 1.3, the hydrological effects assessment was completed for the Application Case, which includes the Baseline Case plus the Project. The application case is completed for the LSA only. The Planned Development Case (Cumulative Effects), which includes the “Application Case” combined with past studies, existing and anticipated future environmental conditions, existing projects or activities, plus other “planned” projects or activities was not included because of the absence of anticipated future developments or activities that would significantly affect hydrology in region.

6.1 Valued Components

The potential hydrologic effects of proposed activities at Grassy Project depend on the number, size, and location of the facilities and activities within the watershed at the time. The overall project footprint of 12 km² will extend over Blairmore Creek and Gold Creek watersheds, which together total 112 km². The project foot print will cover approximately 11% of the original watershed.

The valued components (VCs) that have been identified and considered in this assessment include:

- Effect on high, mean and low flows on Blairmore Creek during the operations phase and after closure;
- Effect on high, mean and low flows on Gold Creek during the operations phase and after closure; and
- Effect on sediment concentration on Blairmore Creek and Gold Creek during the operations phase and after closure.

These VCs only include effects in terms of stream flows as measured quantities or changes to TSS as measured by analytical methods. Any effects to aquatic life that may be caused by hydrological changes are evaluated in the IFN assessment and fisheries effects assessment.

6.2 Basis for Effects Assessment

Detailed plans for the Project development and location in relation to water management control facilities during mining are discussed in (SRK 2016a and SRK 2016b). The estimates of stream flow changes were based on the results of water and load balance modelling evaluation, which is described in (2016a). In the water balance model, flows are affected by changes in the catchment areas, extent of mine development, groundwater flow regimes and operational water management such as the rate of discharge from treatment facilities and sedimentation ponds. The estimated effects on surface flows were conducted for each year of operations (2017 through 2042) and for a period of over 50 years after the end of the operation (2043 through 2097).

Estimated flow changes are discussed in Section 5.

6.3 Evaluation Criteria

Table 18 shows the evaluation criteria used to assess the environmental effects. The evaluation criteria are consistent with the criteria used for all effects assessments for the Grassy Project.

6.4 Effects Rating

Table 19 shows the effects ratings during the operational and closure phases for the VCs listed in Section 6.1.

The potential effects to flows in Blairmore Creek and Gold Creek were assessed as changes to monthly flows. The monthly flows estimated by the water balance model, both during baseline conditions (in 2017) and through the life of the mine (2018 to post-closure), were assumed to be mitigated by the operational water management. Mitigation consists of interception, diversion, treatment and release of treated water to Blairmore Creek. For Gold Creek, mitigation consists of the routing of water from the End Pit Lake to the creek when it has filled.

The magnitude of effects depend on the season. During the open water season (April/May through October/November) flows in Blairmore Creek are expected to increase by less than approximately 15%. Winter low flow conditions could change by a greater magnitude. Therefore, the magnitude of flow changes were estimated as low to moderate for Blairmore Creek.

Table 18. Evaluation Criteria for Assessing the Environmental Impact.

Criteria	Criteria Definition[1]	
Magnitude	Nil	No change from background conditions anticipated after mitigation.
	Low	Disturbance predicted to be somewhat above typical background conditions, but well within established or accepted protective standards and normal socio-economic fluctuations, or to cause no detectable change in ecological, social or economic parameters.
	Moderate	Disturbance predicted to be considerably above background conditions but within scientific and socio-economic effects thresholds, or to cause a detectable change in ecological, social or economic parameters within range of natural variability.
	High	Disturbance predicted to exceed established criteria or scientific and socio-economic effects thresholds associated with potential adverse effect, or to cause a detectable change in ecological, social or economic parameters beyond the range of natural variability.
Geographic Extent	Local	Effects occurring mainly within or close proximity to the proposed development area.
	Regional	Effects extending outside of the project boundary to regional surroundings.
	Provincial	Effects extending outside of the regional surroundings, but within provincial boundary.
	National	Effects extending outside of the provincial surroundings, but within national boundary
	Global	Effects extending outside of national boundary.
Duration	Short	Effects occurring within development phase
	Long	Effects occurring after development and during operation of facility
	Extended	Effects occurring after facility closes but diminishing with time.
	Residual	Effects persisting after facility closes for a long period of time.
Frequency	Continuous	Effects occurring continually over assessment periods.
	Isolated	Effects confined to a specified period (*e.g.,* construction)
	Periodic	Effects occurring intermittently but repeatedly over assessment period (*e.g.,* routine maintenance activities).
	Occasional	Effects occurring intermittently and sporadically over assessment period
Reversibility	Reversible in short-term	Effects which are reversible and diminish upon cessation of activities.
	Reversible in long-term	Effects which remain after cessation of activities but diminish with time.
	Irreversible	Effects which are not reversible and do not diminish upon cessation of activities and do not diminish with time.
Project Contribution	Neutral	No net benefit or loss to the resource, communities, region or province.
	Positive	Net benefit to the resource, community, region or province.
	Negative	Net loss to the resource, community, region or province.
Confidence Rating	Low	Based on incomplete understanding of cause-effect relationships and incomplete data pertinent to study area.
	Moderate	Based on good understanding of cause-effect relationships using data from elsewhere or incompletely understood cause-effect relationship using data pertinent to study area.
	High	Based on good understanding of cause-effect relationships and data pertinent to study.
Probability of Occurrence	Low	Unlikely.
	Medium	Possible or probable.
	High	Certain.
Significance	Not Significant	Effects are predicted to be within the range of natural variability and below guideline or threshold levels
	Significant	Effects of the Project are predicted to cause irreversible changes to the sustainability or integrity of a population or resource

Table 19. Summary of Effects Rating on Hydrologic Valued Component (VCs)

VC	Nature of Potential Effect	Mitigation/ Protection Plan	Magnitude	Geographical Extent	Duration	Frequency	Reversibility	Project Contribution	Confidence Rating	Probability of Occurrence	Significance Rating
Potential Effects on High, Average and Low Monthly Flows on Blairmore Creek During and After Mining	Change to monthly flows	Pacing of discharge from the Project Area	Low to Moderate	Local	Long	Continuous	Irreversible	Positive	Moderate	High	Not Significant
Potential Effects on High, Average and Low Monthly Flows on Gold Creek During and After Mining	Change to monthly flows	Routing of end-pit lake to the creek	Low	Local	Long	Continuous	Irreversible	Negative	Moderate	High	Not Significant
Potential Effects on Sediment Concentration in Blairmore Creek and Gold Creek During and After Mining	Change to TSS Concentrations	Sediment and Erosion Control	Low	Local	Long	Periodic	Reversible in short-term	Positive/Negative	Low	High	Not Significant

Monthly flows in Gold Creek is generally expected to be less than 10% and in most cases less than about 5%, which was deemed to be a “low” magnitude. The geographical extent is “local” for both creeks because changes are expected to be noticeable only in the immediate vicinity of the Project area. The duration of the potential effects include both the operational period and closure and was therefore rated “long” and the frequency “continuous”. In terms of reversibility, the potential effects were rated “irreversible” because effects to the hydrological regime are expected to persist long terms and are not expected to gradually return to baseline conditions.

The project contribution was in this assessment viewed in terms of “quantity of flow”. Accordingly, the project contribution was rates “positive” for Blairmore and “negative” for Gold Creek. The assessment could have looked at high and low flows in terms of shorter averaging periods, such as instantaneous peak flows and 7-day low flows. For shorter averaging periods, high flows may be rated “negative” because of the potential for peak flows to change the stream-bed morphology and to induce scour. However, because of the operational flow controls that are expected to be in place for the Grassy Project, both peak flows and low flows are expected to be less variable after development of the Project compared to baseline conditions.

The confidence rating for the assessment was deemed to be moderate. The assessment was based on a good understanding of cause-effect relationships, but estimated monthly flow changes were based on model results that in turn relied on input from regional assessments and hydrological characteristics that are typical of terrain found at the project site. The probability of occurrence was rated high because some changes to the hydrological regime is certain to occur as a result of the Project development.

The overall significance rating for the hydrology assessment for Blairmore and Gold Creeks was judged to be Not Significant. The rating was primarily based on the low magnitude rating for the reduced flow in Gold Creek and the low to moderate rating for estimated increases to flow in Blairmore Creek. Overall, the estimated changes are well within the range of variability that would naturally occur between wet and dry years.

Potential effects related to sediment concentrations in Blairmore and Gold Creeks were also deemed to be Not Significant. This rating is primarily based on the assumption that engineering controls and a sediment and erosion control and prevention plan will be implemented for the Project.

6.5 Crowsnest River

Crowsnest River receives flows from both the Blairmore and Gold Creek catchments, and as such any effects within these catchments has the potential to have an effect on the flows within the larger Crowsnest River. Blairmore and Gold Creek have similar catchment sizes of approximately 50 and 60 km^2, respectively. The Crowsnest River represents a watershed area five to six times bigger than these catchments. Therefore, any effects to flow in the Crowsnest River would be proportionally lower. In addition, the estimated increase of flow in Blairmore Creek and decrease of flow in Gold Creek would diminish effects to the Crowsnest River further. Consequently, hydrological effects judged to be Not Significant to Blairmore and Gold Creeks would also be Not Significant for the Crowsnest River.

7 Conclusions

Baseline hydrological characteristics have been defined for the Grassy mountain project area using available regional and site specific hydrological and meteorological data. The hydrological characterization was used as input to other assessments for the Grassy Project, including the Water and Load Balance Model, the Hydrogeological Model Assessment, the IFN assessment and the Water Use Evaluation.

The water use evaluation concluded that the maximum annual withdrawal of water from Blairmore and Gold Creek catchments (combined) would be on the order of 430,000 m^3/year. The maximum withdrawal rates would occur at times when the saturated zones are filling with water. The fill rate of the saturated zones would be under operational control. Over the long term, the combined flow in Blairmore and Gold Creeks is expected to increase by approximately 600,000 m^3/year because of changes to the terrain and associated runoff coefficients.

The hydrological effects assessment for stream flow in Blairmore and Gold Creeks was focussed on estimated changes to monthly flows in Blairmore and Gold Creeks. The assessment concluded that the overall significance rating for potential effects to the two creeks would be Not Significant. The rating was primarily based on the low magnitude rating for the reduced flow in Gold Creek and the low to moderate rating for estimated increases to flow in Blairmore Creek. Overall, the estimated changes are well within the range of variability that would naturally occur between wet and dry years.

Flow monitoring in Blairmore and Gold Creeks as well as tracking of water use and the inventory of water in ponds and saturated backfill zones are important components of the water management plan for the Grassy Mountain Project. Continous monitoring data will provide the inputs required for the operation to minimize flow effects in Blairmore and Gold creeks and to ensure that water use remain within licenced limits.

Hydrological effects downstream of Blairmore and Gold Creeks, including the Crowsnest River, are expected to be considerably less significant than potential local effects because of the larger catchment areas.

This report, Grassy Mountain Surface Hydrology Baseline and Effects Assessment, was prepared by

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Figures

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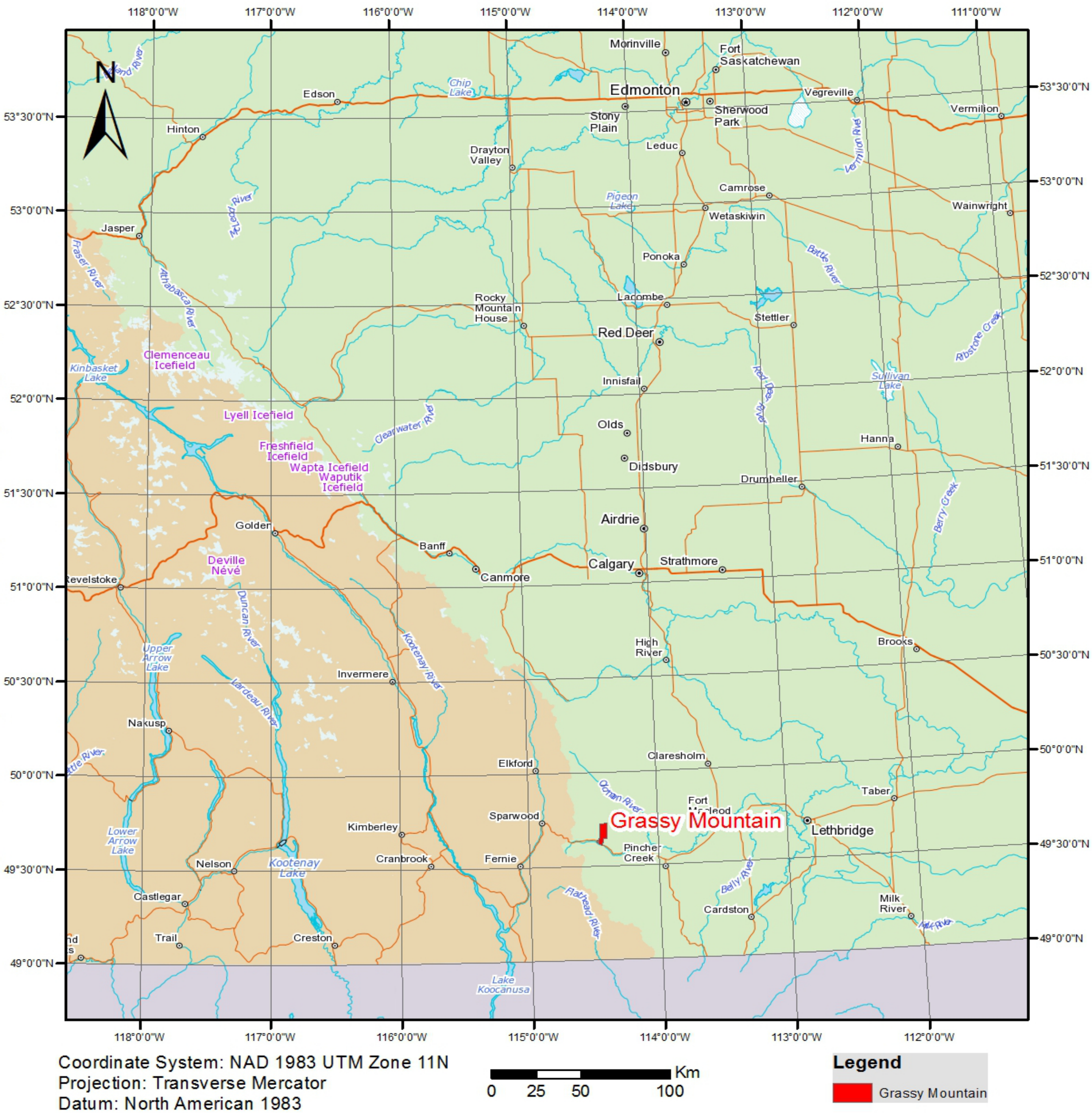

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Hydrology Impact Assessment

Location of the Grassy Mountain Project

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Grassy Mountain Project

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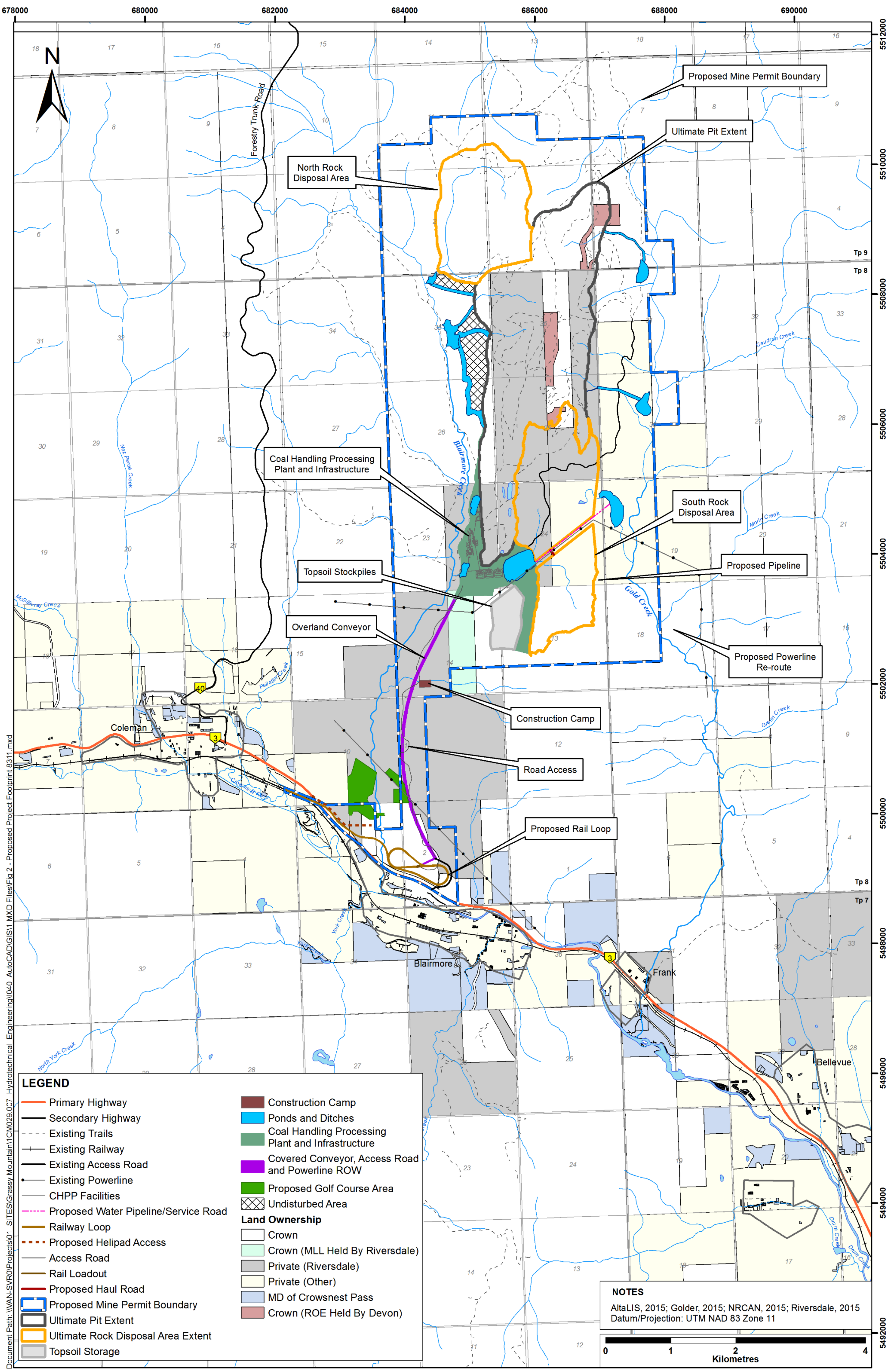

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Grassy Mountain Project

Hydrology Impact Assessment

Proposed Project Footprint

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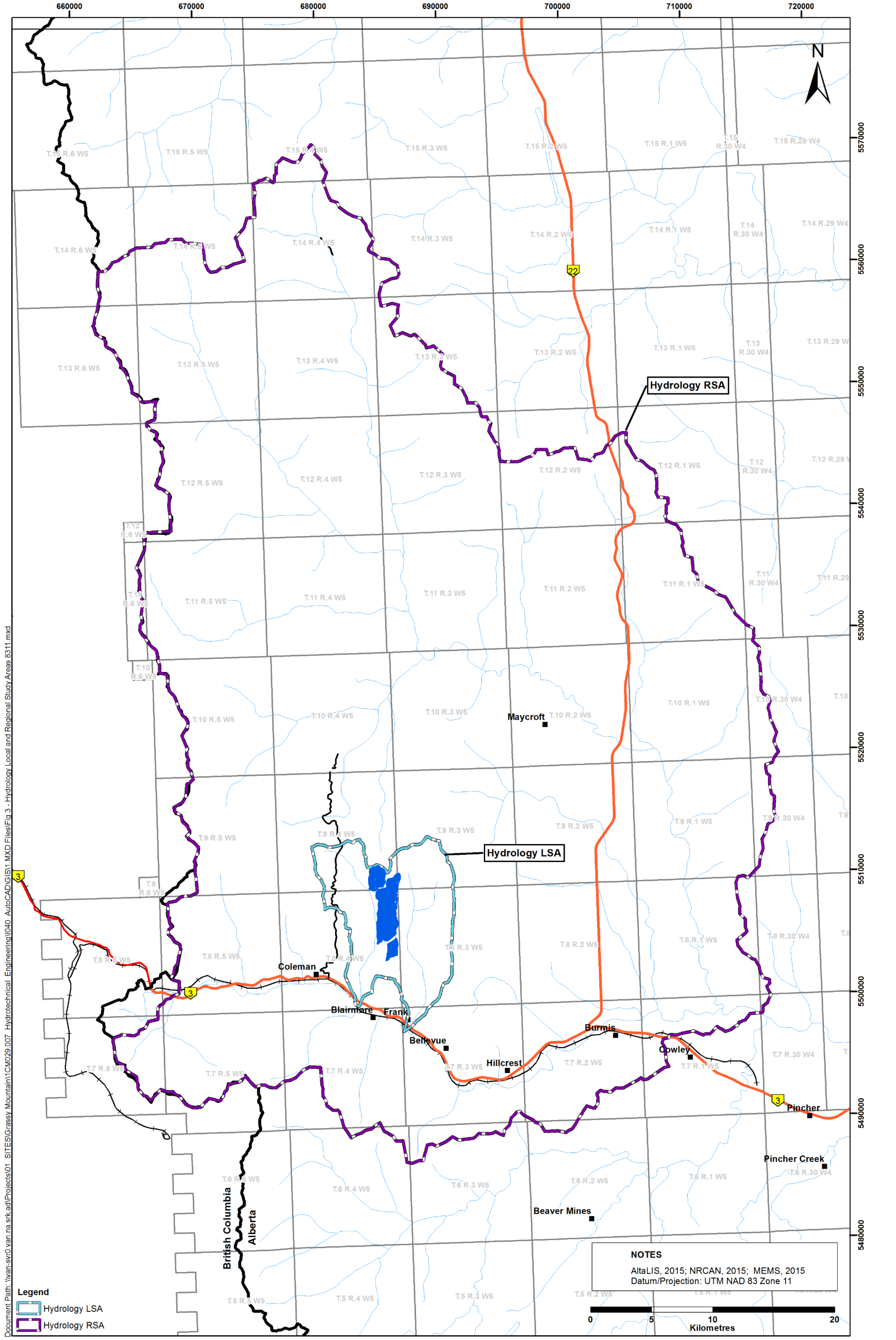

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Hydrology Local and Regional Study Areas

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Grassy Mountain Project

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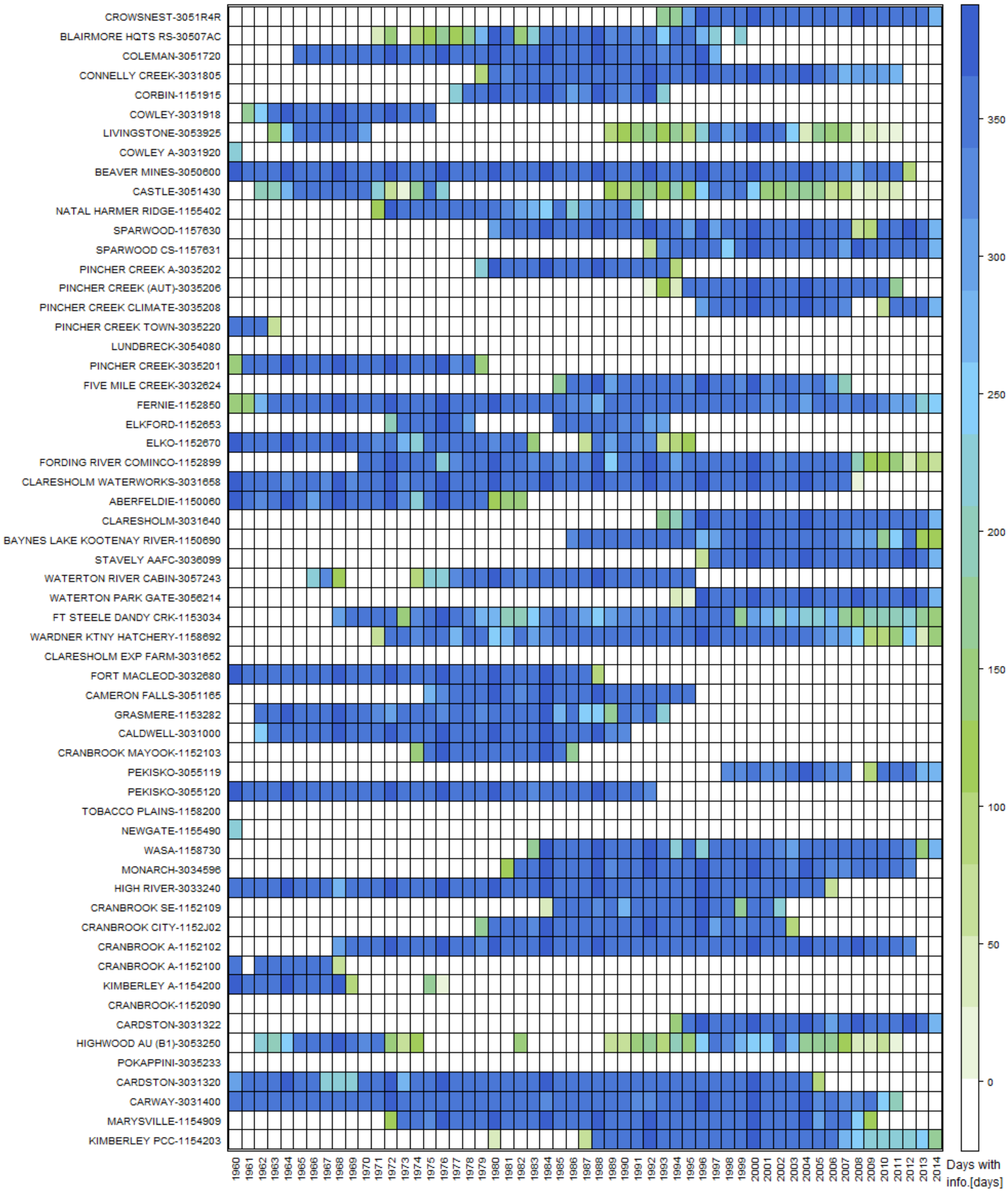

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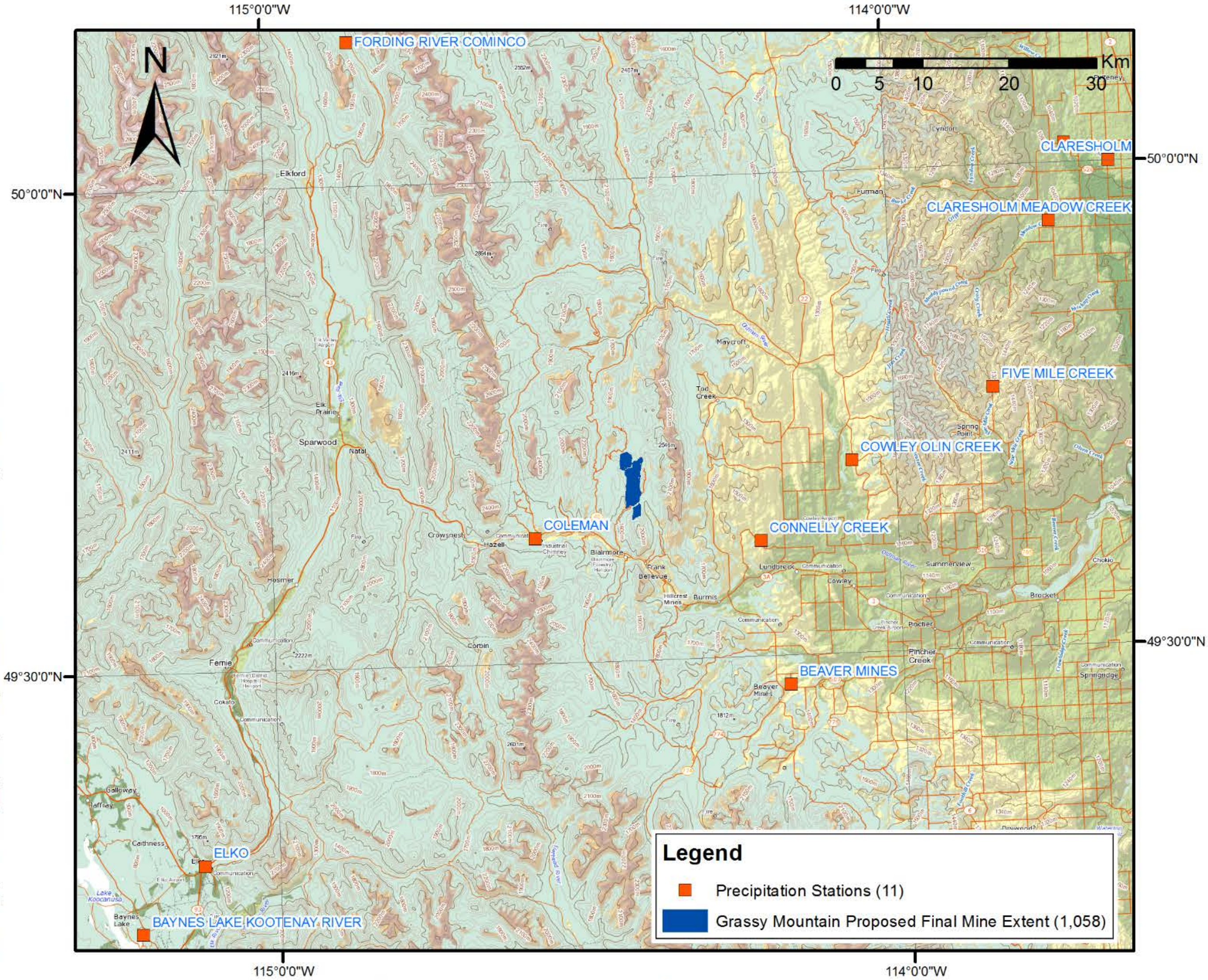

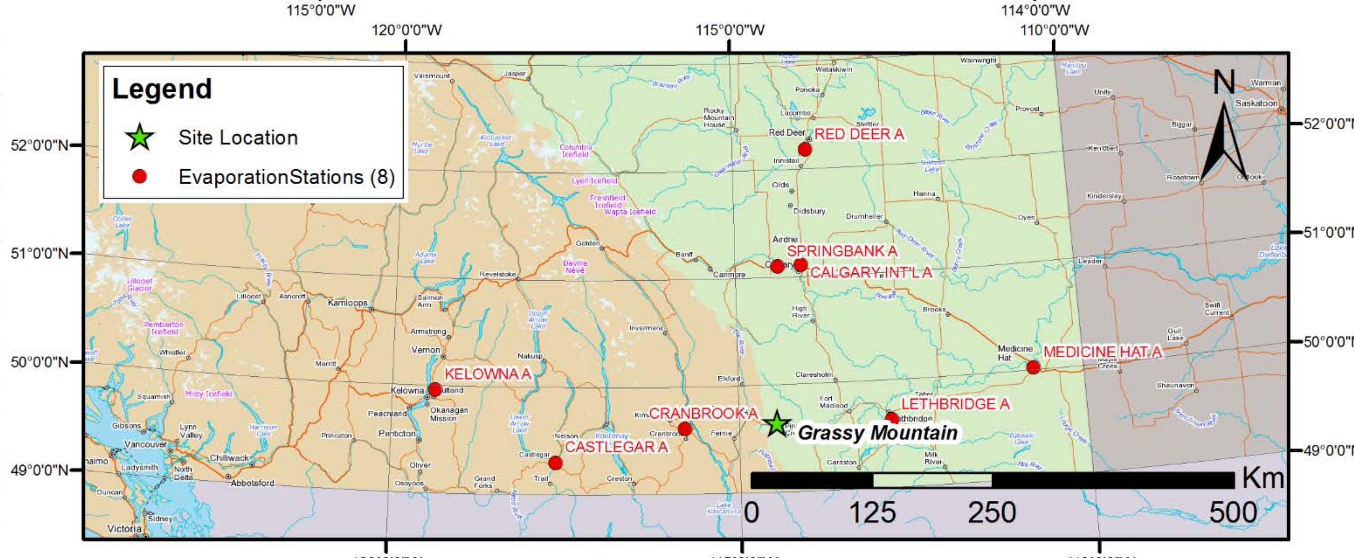

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Hydrology Impact Assessment

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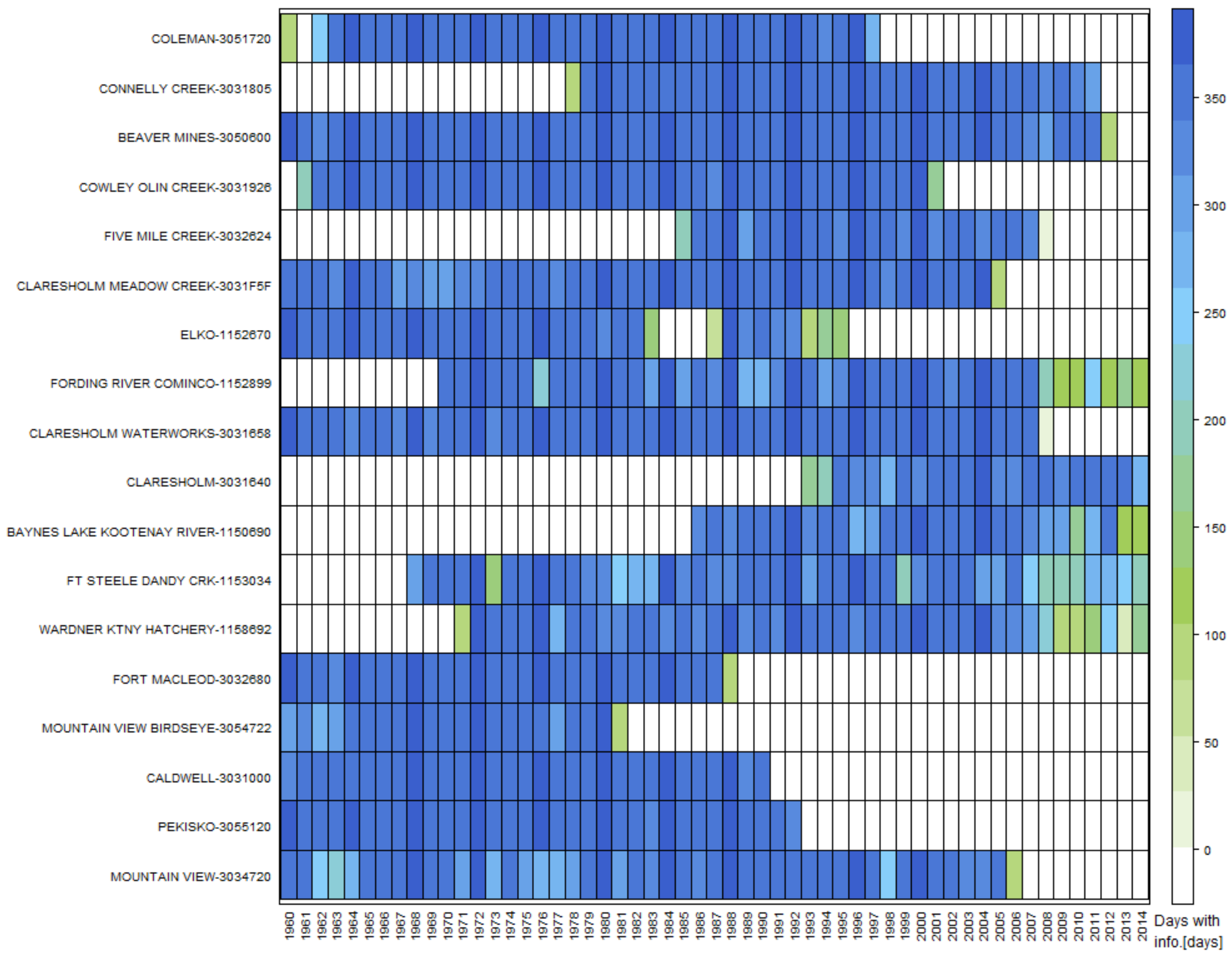

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Hydrology Impact Assessment

Precipitation Data Coverage for Regional Stations from 1960 to today (days/year)

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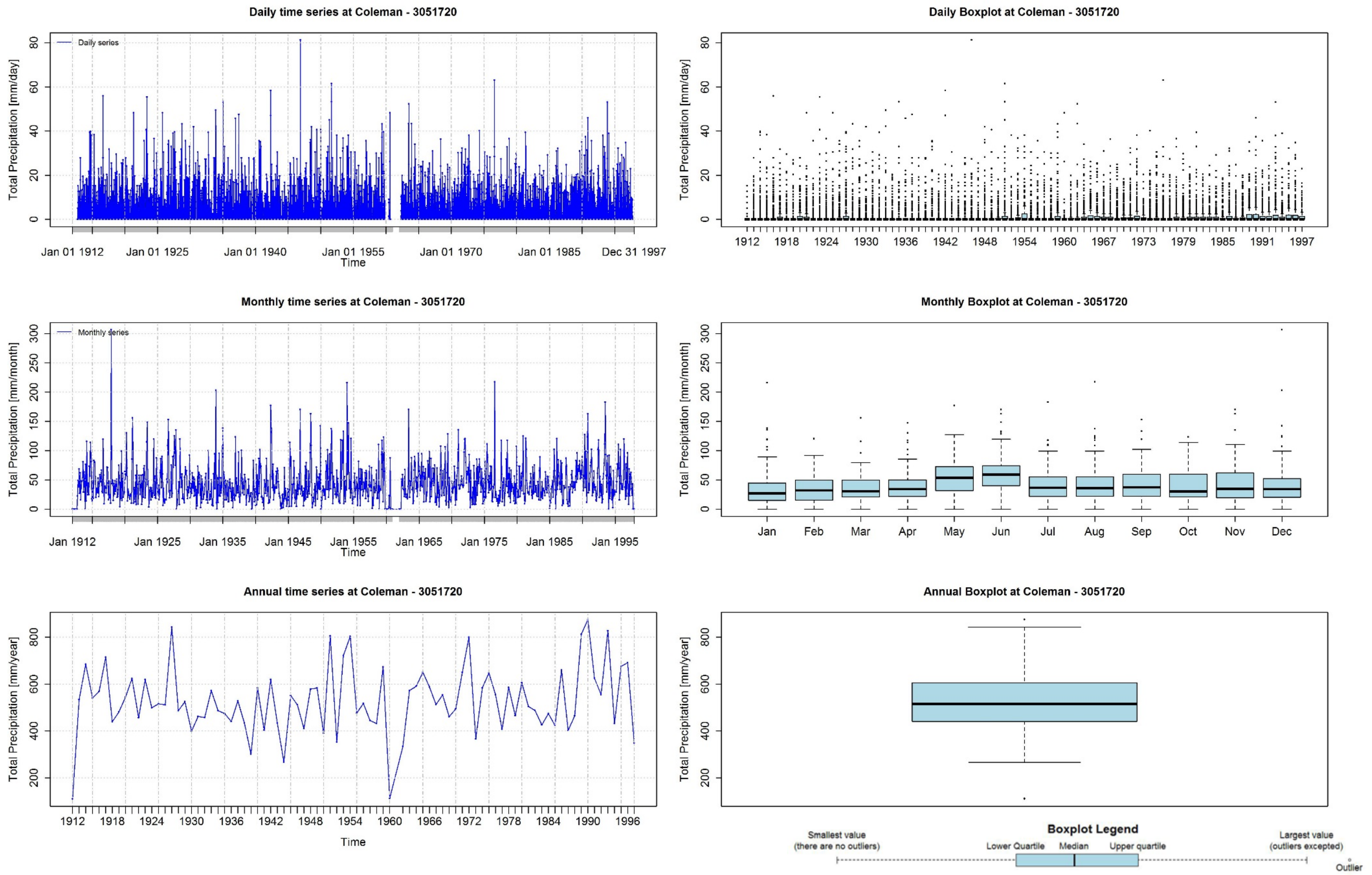

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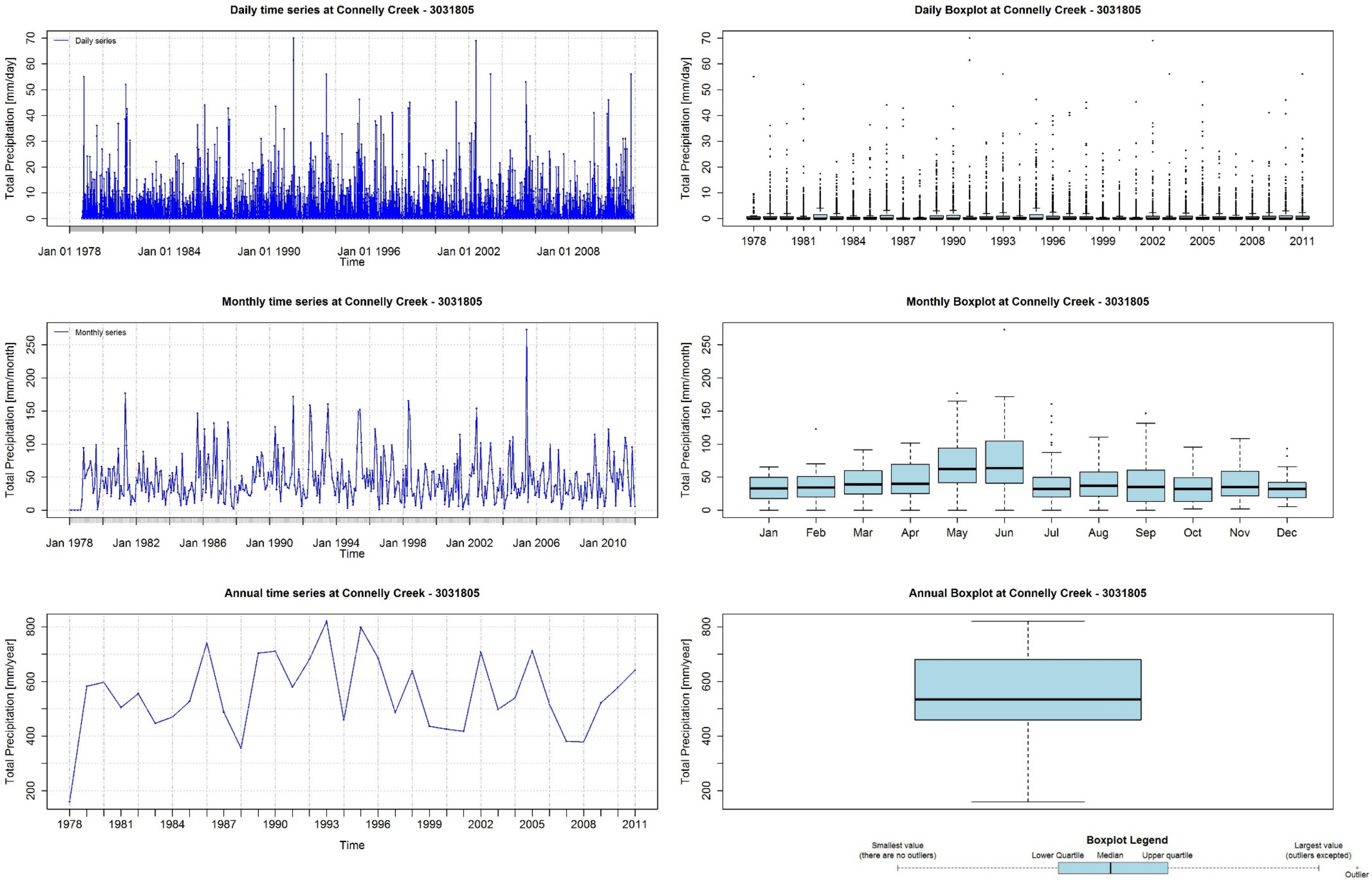

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Hydrology Impact Assessment

Precipitation records for Connelly Creek meteorological station

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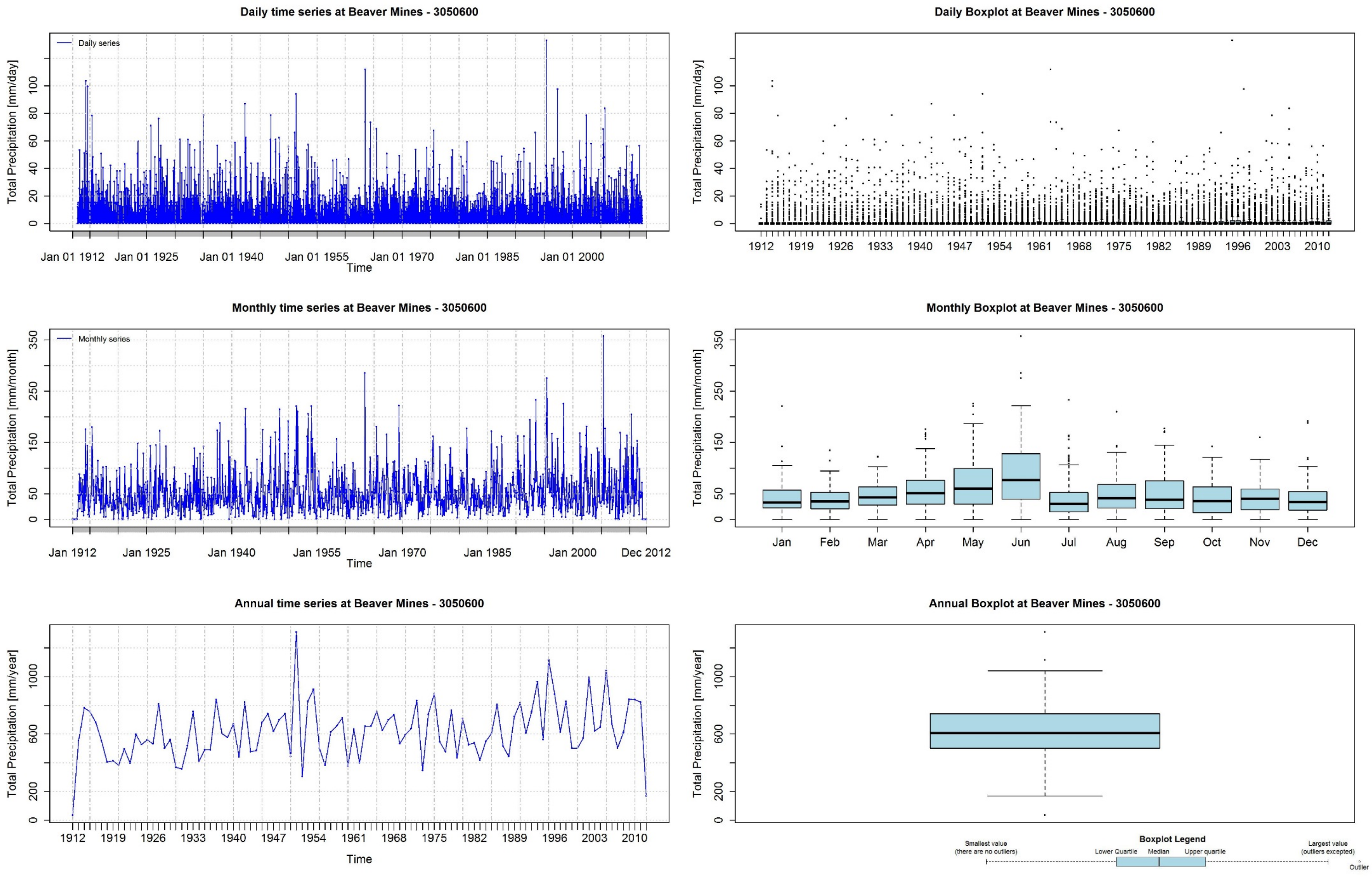

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Hydrology Impact Assessment

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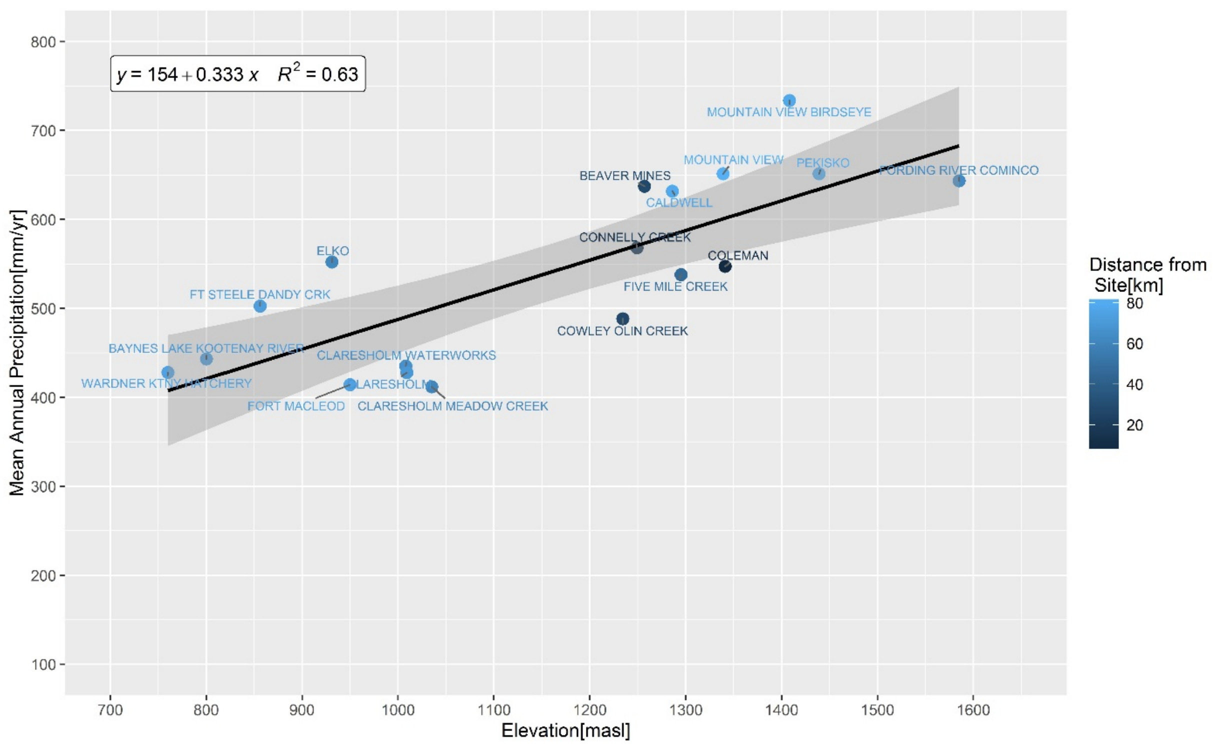

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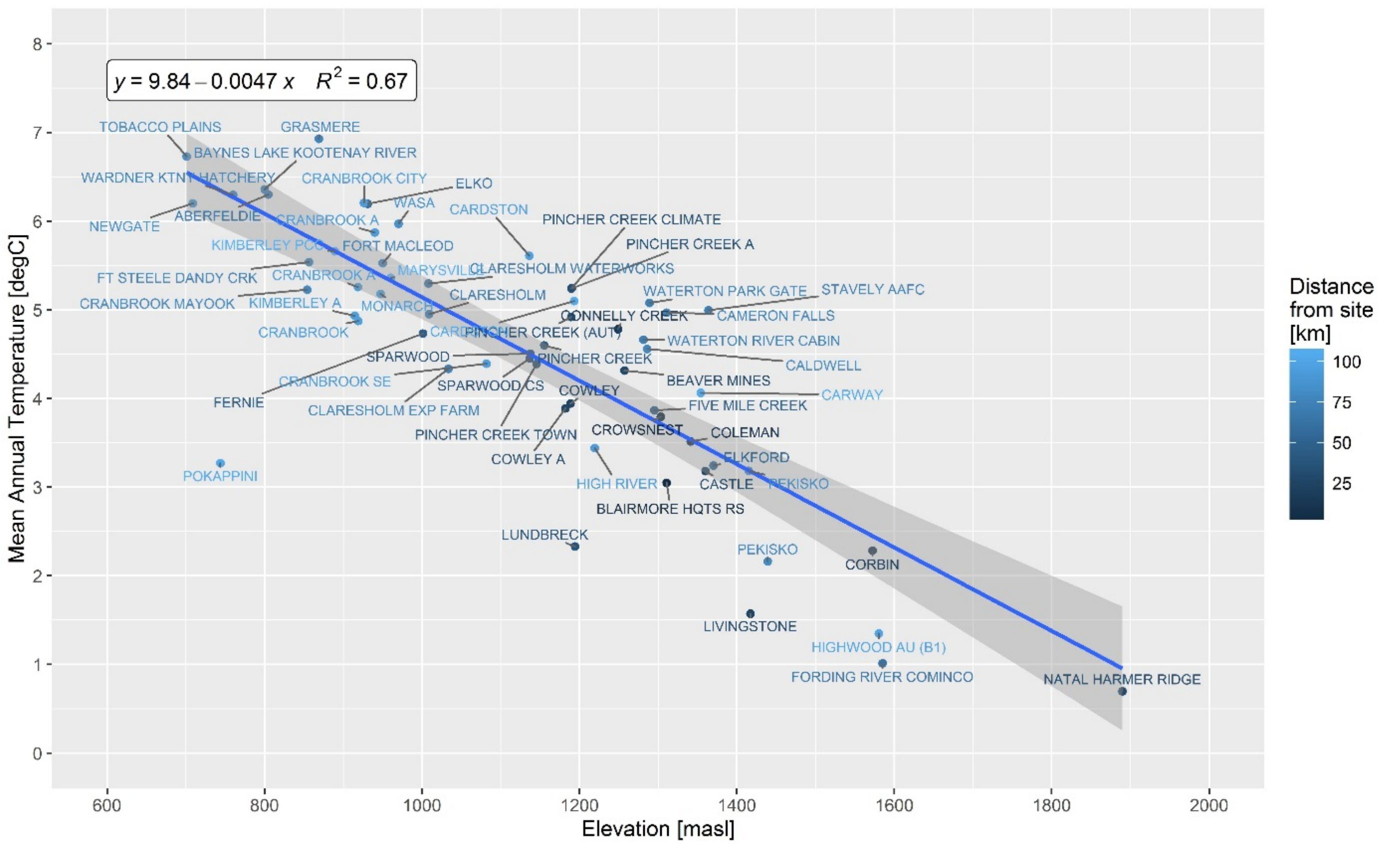
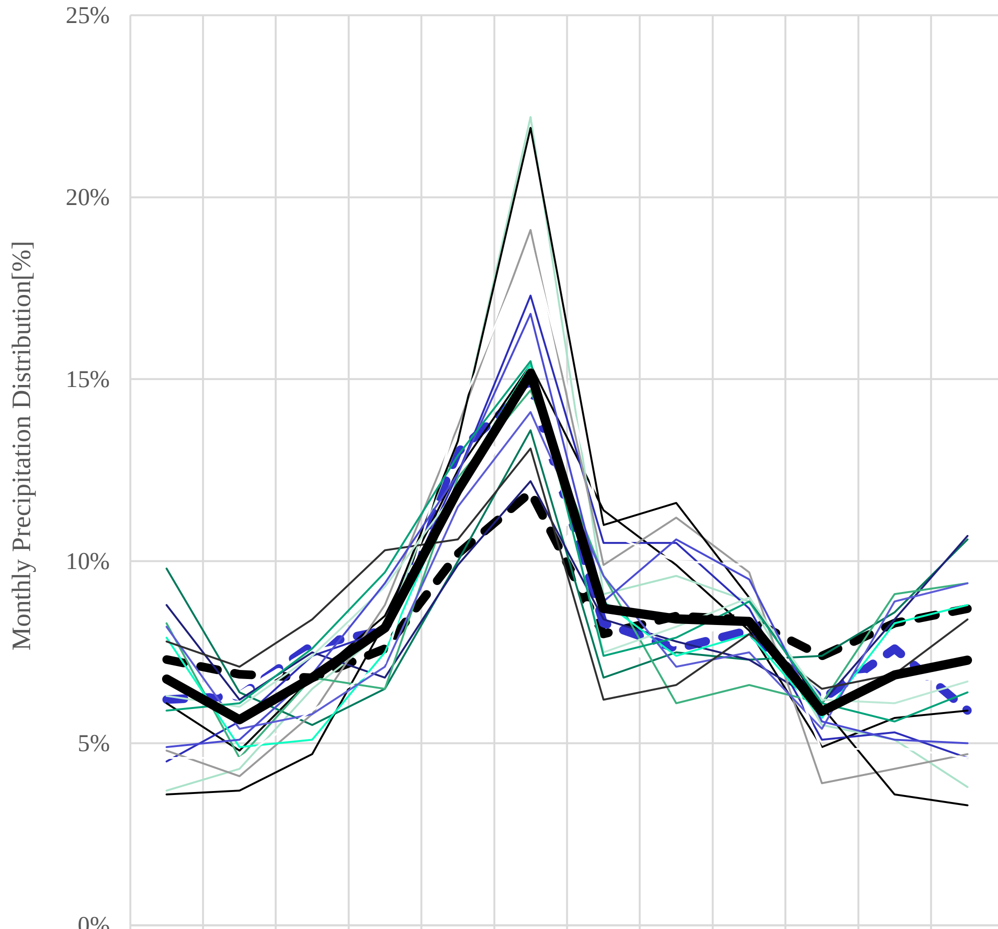
Job No: 1CM029.011 Filename: Z:\01_SITES\Grassy Mountain\1CM029.007_Hydrotechnical_Engineering\!080_Deliverables\Impact Assessment Memo	Grassy Mountain Project	Date: August 2016 · Approved: SJ · Figure: **10**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Regional regression analysis for mean annual precipitation at the Grassy Mountain Project
Job No: 1CM029.011 Filename: Z:\01_SITES\Grassy Mountain\1CM029.007_Hydrotechnical_Engineering\Hydrology\Precipitation	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **11**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COLEMAN	7%	7%	7%	8%	10%	12%	8%	9%	8%	7%	8%	9%
CONNELLY CREEK	6%	6%	8%	8%	13%	15%	8%	8%	8%	6%	8%	6%
BEAVER MINES	7%	6%	8%	9%	12%	15%	7%	8%	9%	7%	7%	7%
COWLEY OLIN CREEK	6%	5%	7%	9%	13%	15%	11%	10%	8%	5%	6%	6%
FIVE MILE CREEK	4%	4%	7%	8%	13%	22%	9%	10%	9%	6%	5%	4%
CLARESHOLM MEADOW CREEK	5%	6%	7%	8%	12%	17%	11%	11%	9%	5%	5%	5%
ELKO	10%	6%	6%	7%	10%	14%	7%	8%	7%	7%	9%	11%
FORDING RIVER COMINCO	9%	6%	8%	7%	10%	12%	8%	8%	7%	6%	8%	11%
CLARESHOLM WATERWORKS	5%	4%	6%	9%	14%	19%	10%	11%	10%	4%	4%	5%
CLARESHOLM	4%	4%	5%	8%	13%	22%	11%	12%	9%	6%	4%	3%
BAYNES LAKE KOOTENAY RIVER	8%	5%	7%	7%	12%	15%	10%	6%	7%	6%	9%	9%
FT STEELE DANDY CRK	8%	5%	5%	8%	12%	15%	9%	7%	8%	6%	8%	9%
WARDNER KTNY HATCHERY	8%	5%	6%	7%	12%	14%	10%	7%	8%	5%	9%	9%
FORT MACLEOD	5%	5%	6%	7%	14%	19%	11%	10%	10%	5%	5%	5%
MOUNTAIN VIEW BIRDSEYE	8%	7%	8%	10%	11%	13%	6%	7%	8%	7%	7%	8%
CALDWELL	6%	6%	7%	9%	12%	15%	8%	8%	9%	6%	6%	7%
PEKISKO	5%	5%	7%	9%	12%	17%	9%	11%	10%	6%	5%	5%
MOUNTAIN VIEW	6%	6%	8%	10%	13%	16%	7%	8%	9%	6%	6%	6%
GRASSY MOUNTAIN (Avg.)	6.8%	5.7%	6.8%	8.2%	11.9%	15.2%	8.7%	8.4%	8.4%	5.9%	6.9%	7.3%

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MILLENNIUM EMS Solutions Ltd.

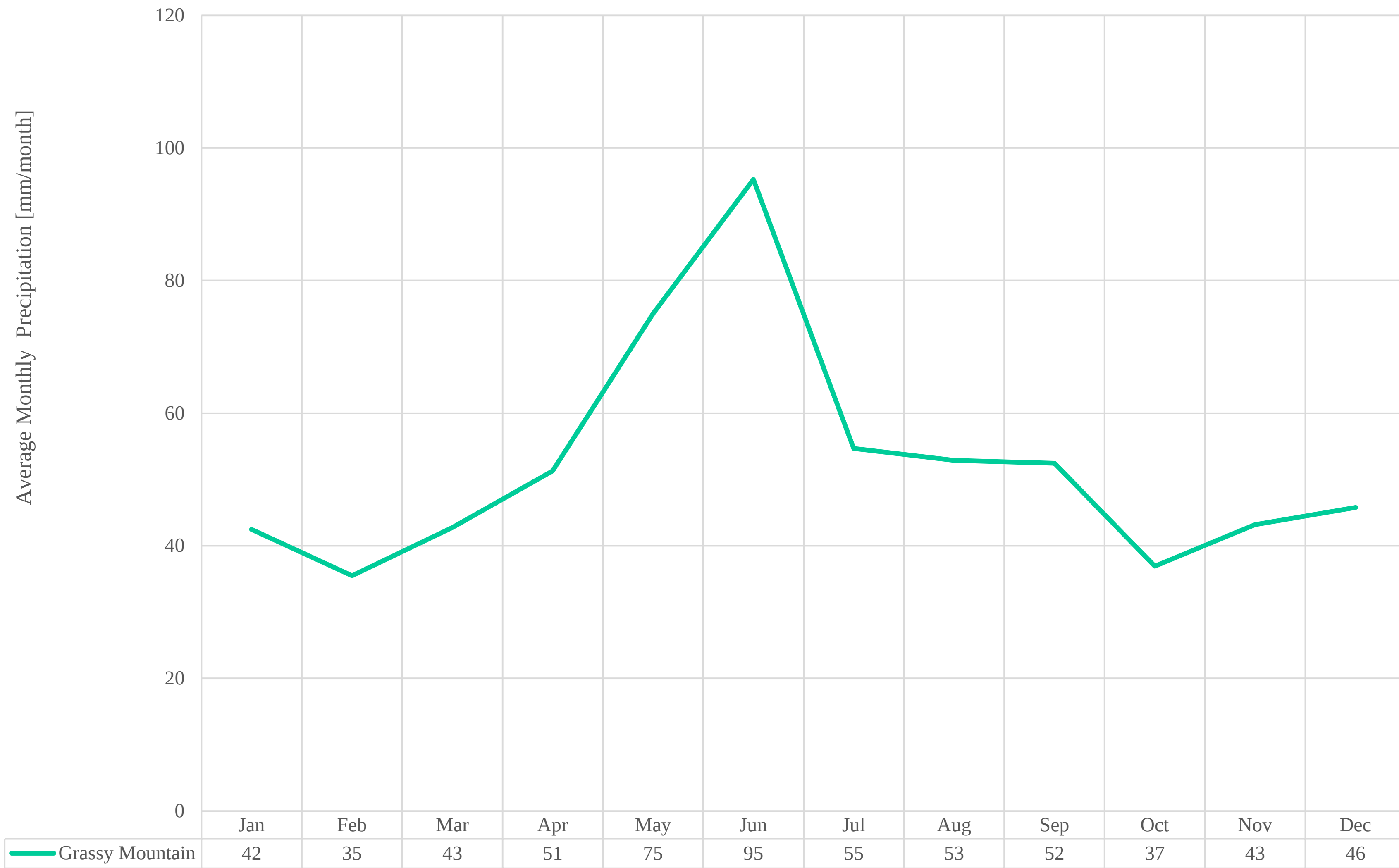
Hydrology Impact Assessment

Regional regression analysis for non-dimensional monthly precipitation distribution at the Grassy Mountain Project

Job No: 1CM029.011
Filename: PrecipitationAnalysis_VM_SPB_Rev4.xlsx

Grassy Mountain Project

Date: August 2016
Approved: SJ
Figure: 12



srk consulting

MILLENNIUM EMS Solutions Ltd.

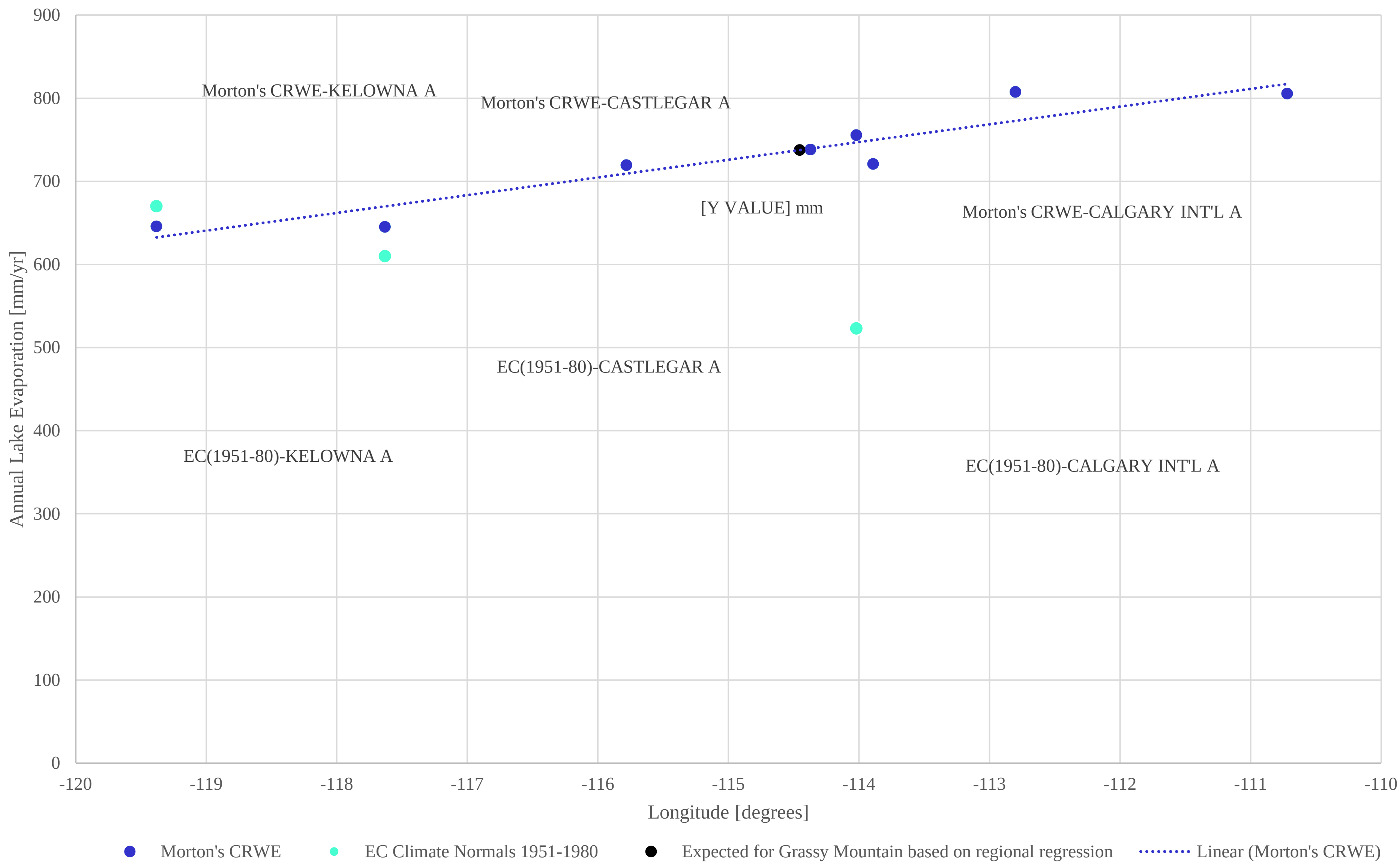
Hydrology Impact Assessment

Average monthly precipitation for the Grassy Mountain Project

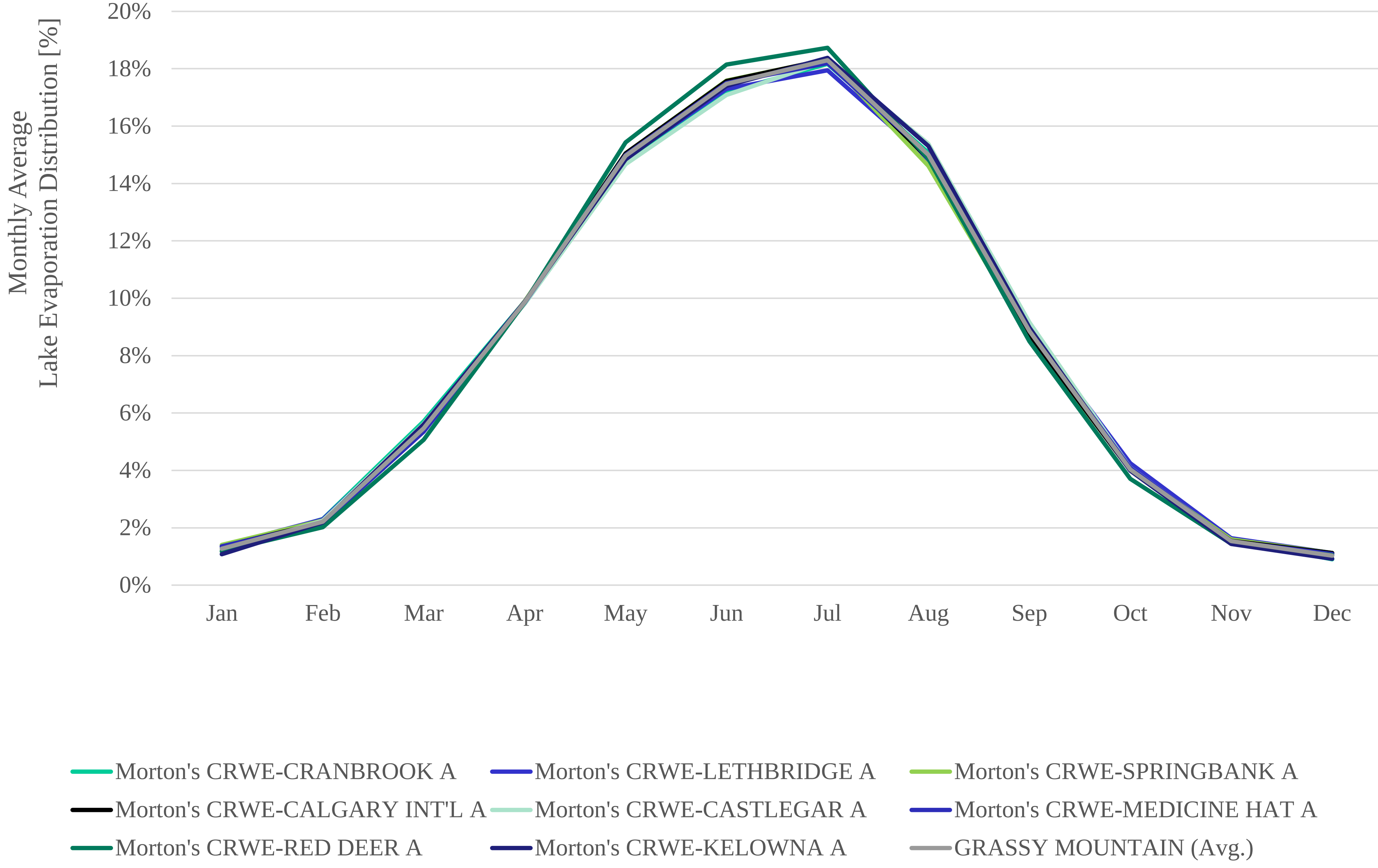
Job No: 1CM029.011
Filename: PrecipitationAnalysis_VM_SPB_Rev4.xlsx

Grassy Mountain Project

Date:	Approved:	Figure:
August 2016	SJ	**13**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Regional analysis and regression for annual lake evaporation at the Grassy Mountain Project
Job No: 1CM029.011 Filename: EvaporationAnalysis_Rev1_SPB.xlsx	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **14**



srk consulting

MILLENNIUM EMS Solutions Ltd.

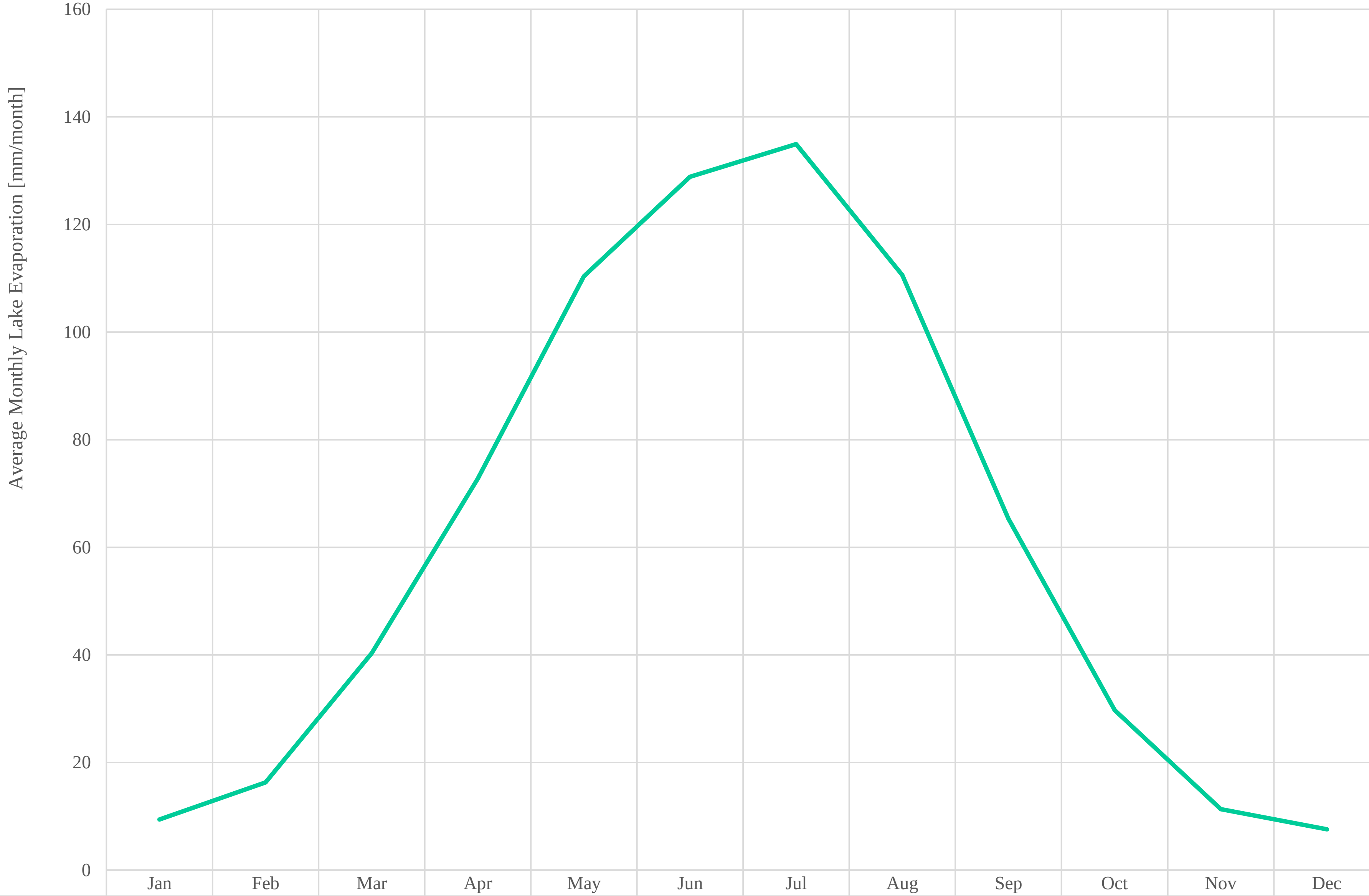
Hydrology Impact Assessment

Regional analysis for monthly lake evaporation distribution for the Grassy Mountain Project

Job No: 1CM029.011
Filename: EvaporationAnalysis_Rev1_SPB.xlsx

Grassy Mountain Project

Date:	Approved:	Figure:
August 2016	SJ	**15**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grassy Mountain	9	16	40	73	110	129	135	111	65	30	11	8

srk consulting

MILLENNIUM EMS Solutions Ltd.

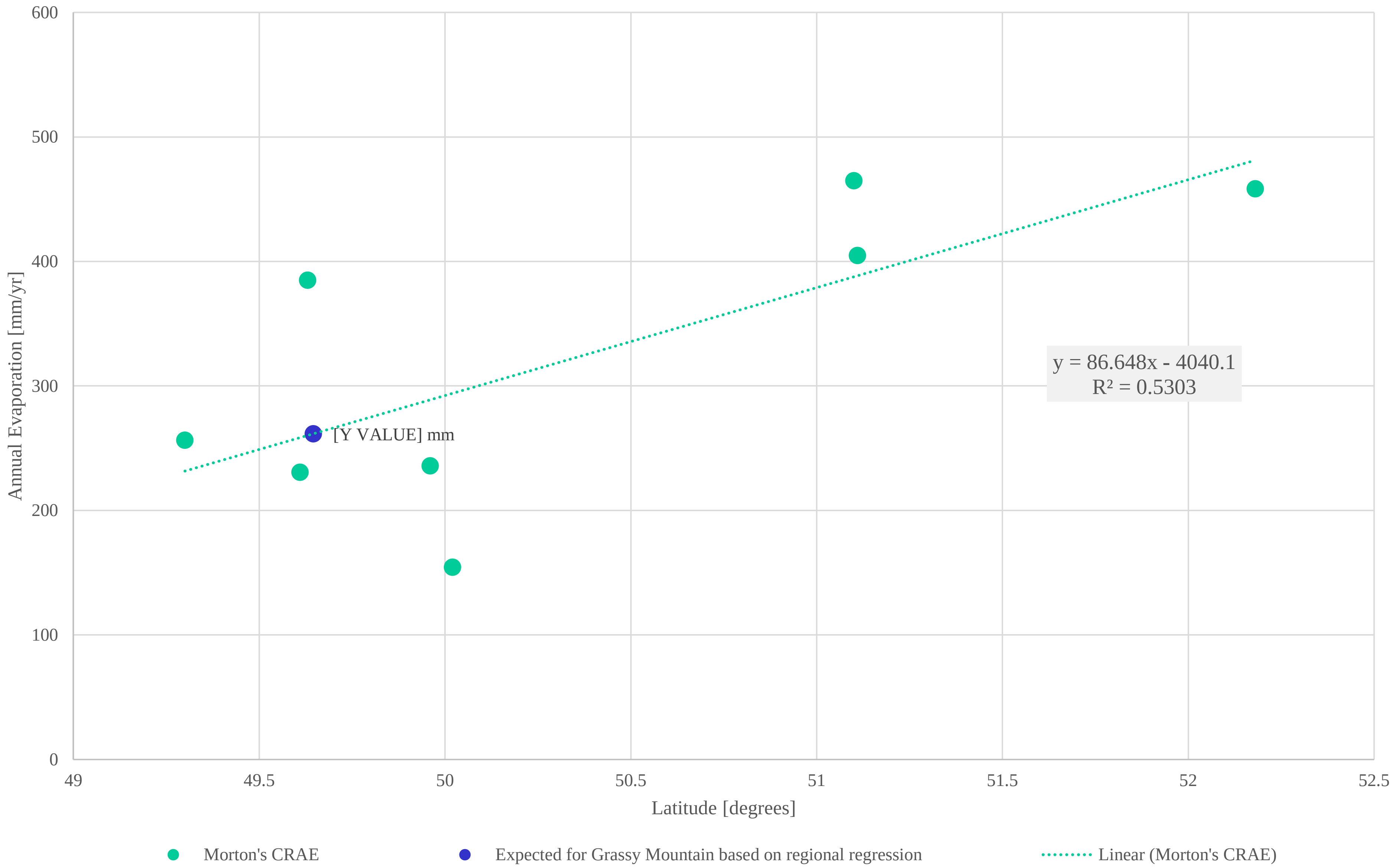
Hydrology Impact Assessment

Average monthly lake evaporation for the Grassy Mountain Project

Job No: 1CM029.011
Filename: EvaporationAnalysis_Rev1_SPB.xlsx

Grassy Mountain Project

Date: August 2016 | Approved: SJ | Figure: **16**



srk consulting

MILLENNIUM EMS Solutions Ltd.

Hydrology Impact Assessment

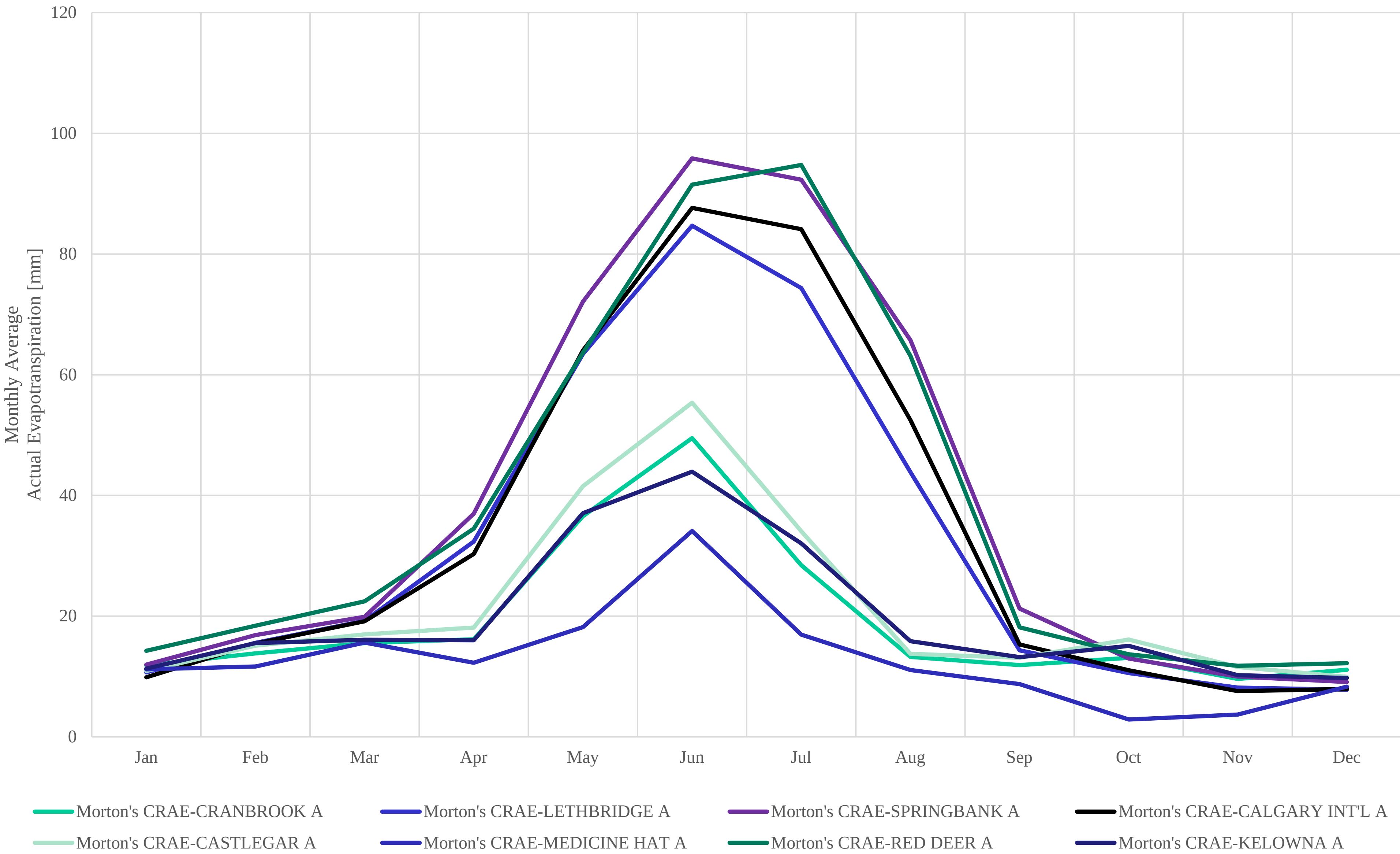
Regional analysis for annual actual evapotranspiration at the Grassy Mountain Project

Job No: 1CM029.011

Filename: EvaporationAnalysis_Rev1_SPB.xlsx

Grassy Mountain Project

Date:	Approved:	Figure:
August 2016	SJ	**17**



srk consulting

MILLENNIUM EMS Solutions Ltd.

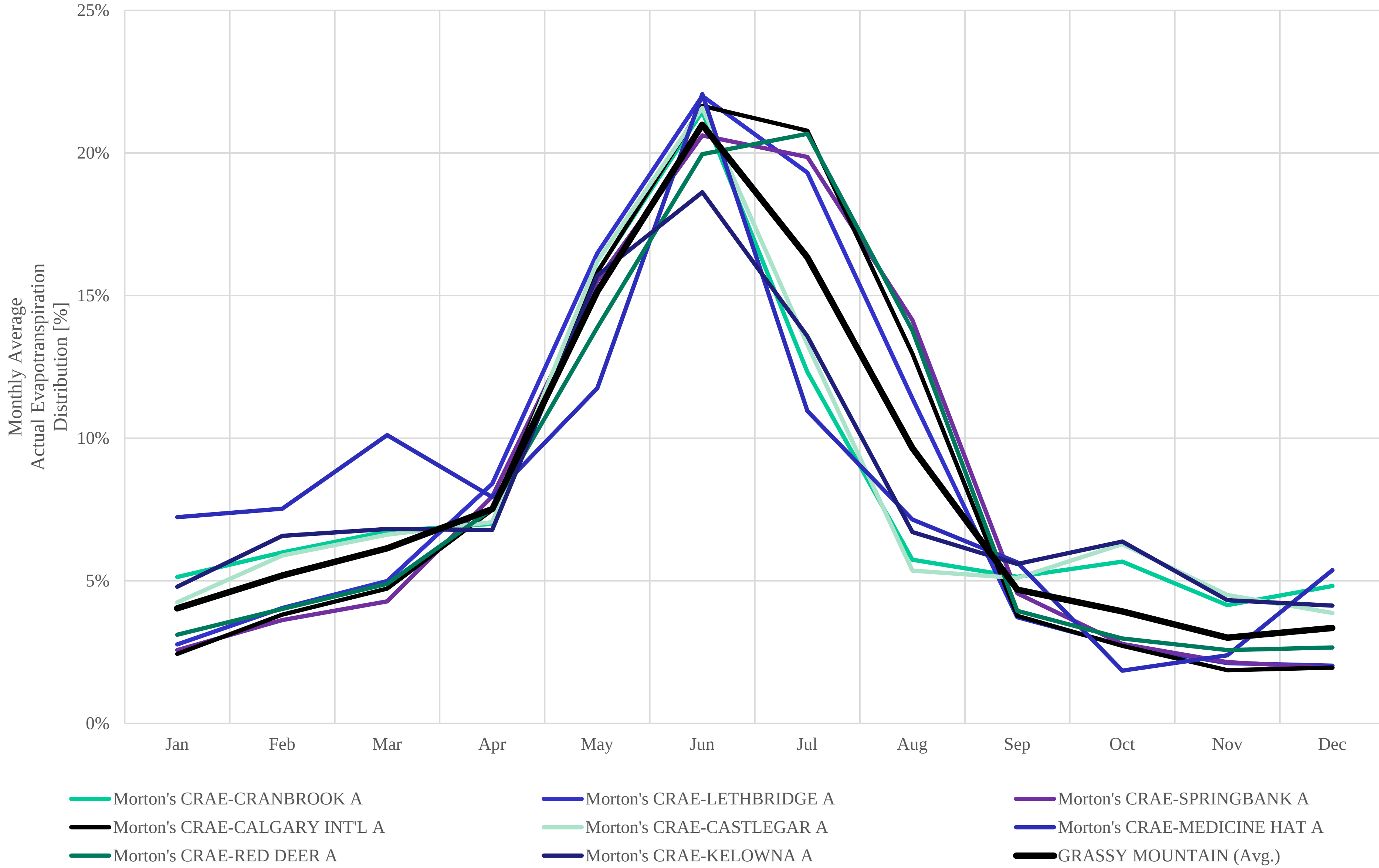
Hydrology Impact Assessment

Regional monthly actual evapotranspiration distribution at the Grassy Mountain Project

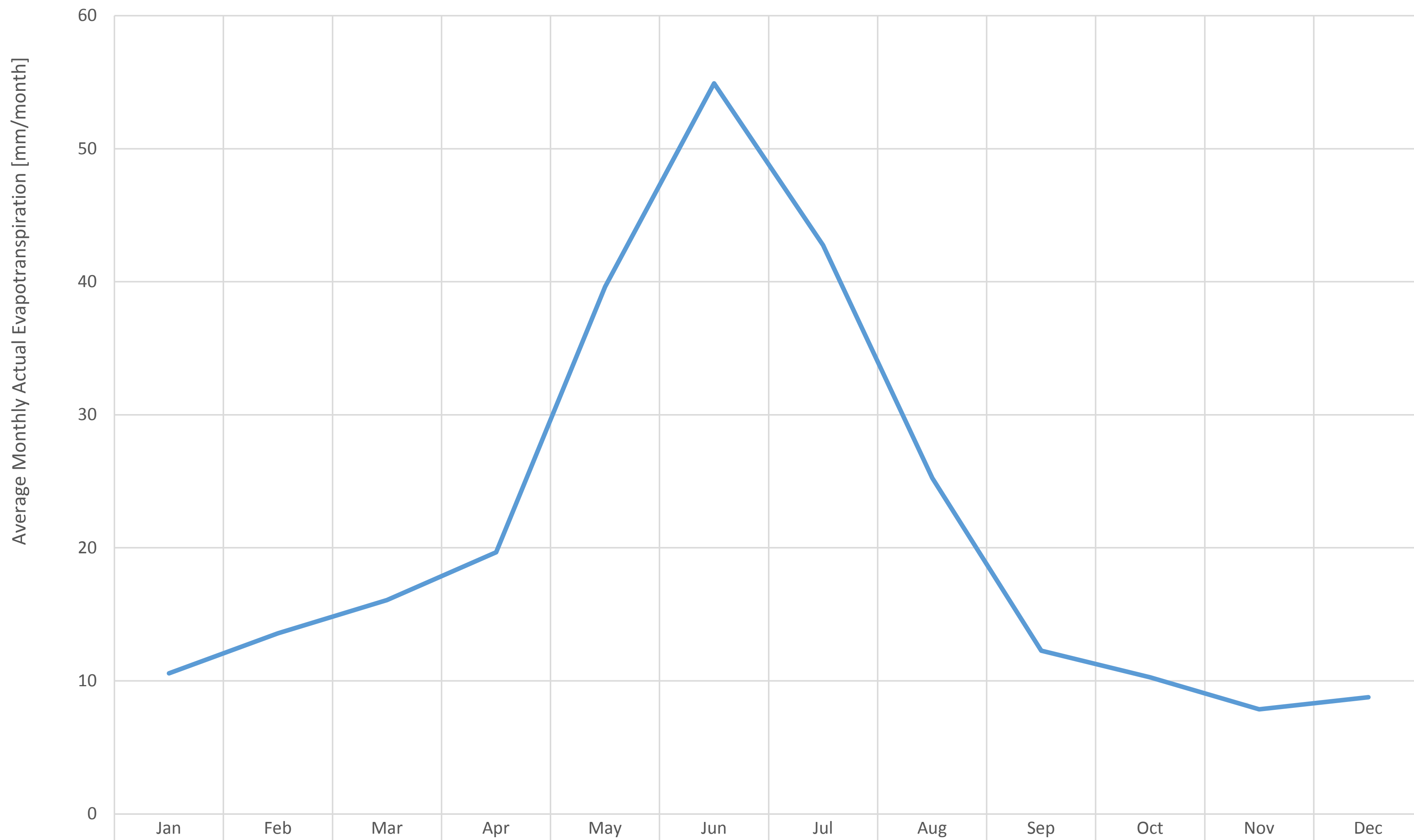
Job No: 1CM029.011
Filename: EvaporationAnalysis_Rev1_SPB.xlsx

Grassy Mountain Project

Date:	Approved:	Figure:
August 2016	SJ	**18**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Regional monthly non-dimensional evapotranspiration distribution at the Grassy Mountain Project
Job No: 1CM029.011 Filename: EvaporationAnalysis_Rev1_SPB.xlsx	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **19**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grassy Mountain	11	14	16	20	40	55	43	25	12	10	8	9

srk consulting

MILLENNIUM
EMS Solutions Ltd.

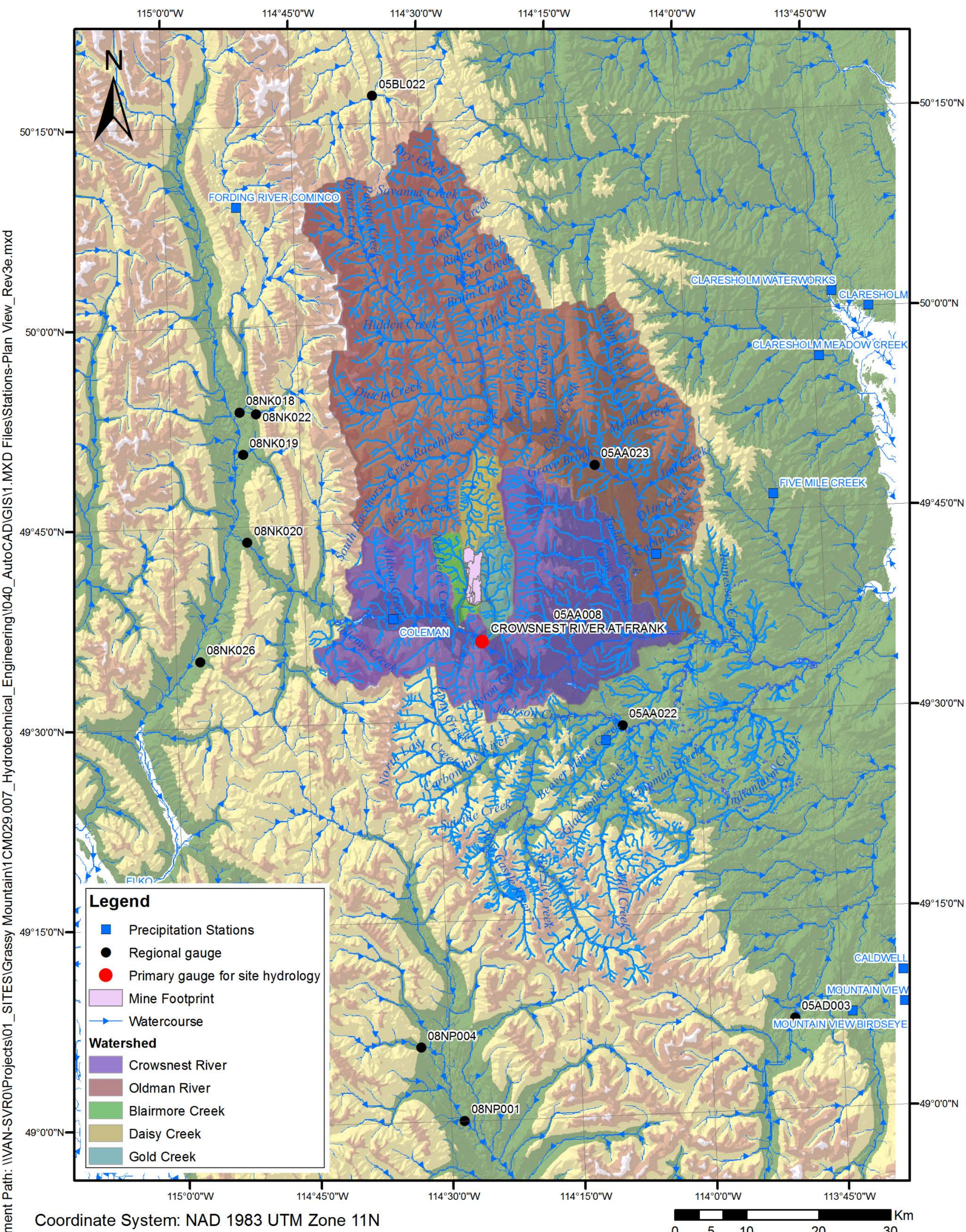
Hydrology Impact Assessment

Average monthly actual evapotranspiration for the Grassy Mountain Project

Job No: 1CM029.011
Filename: EvaporationAnalysis_Rev1_SPB.xlsx

Grassy Mountain Project

Date: August 2016
Approved: SJ
Figure: **20**

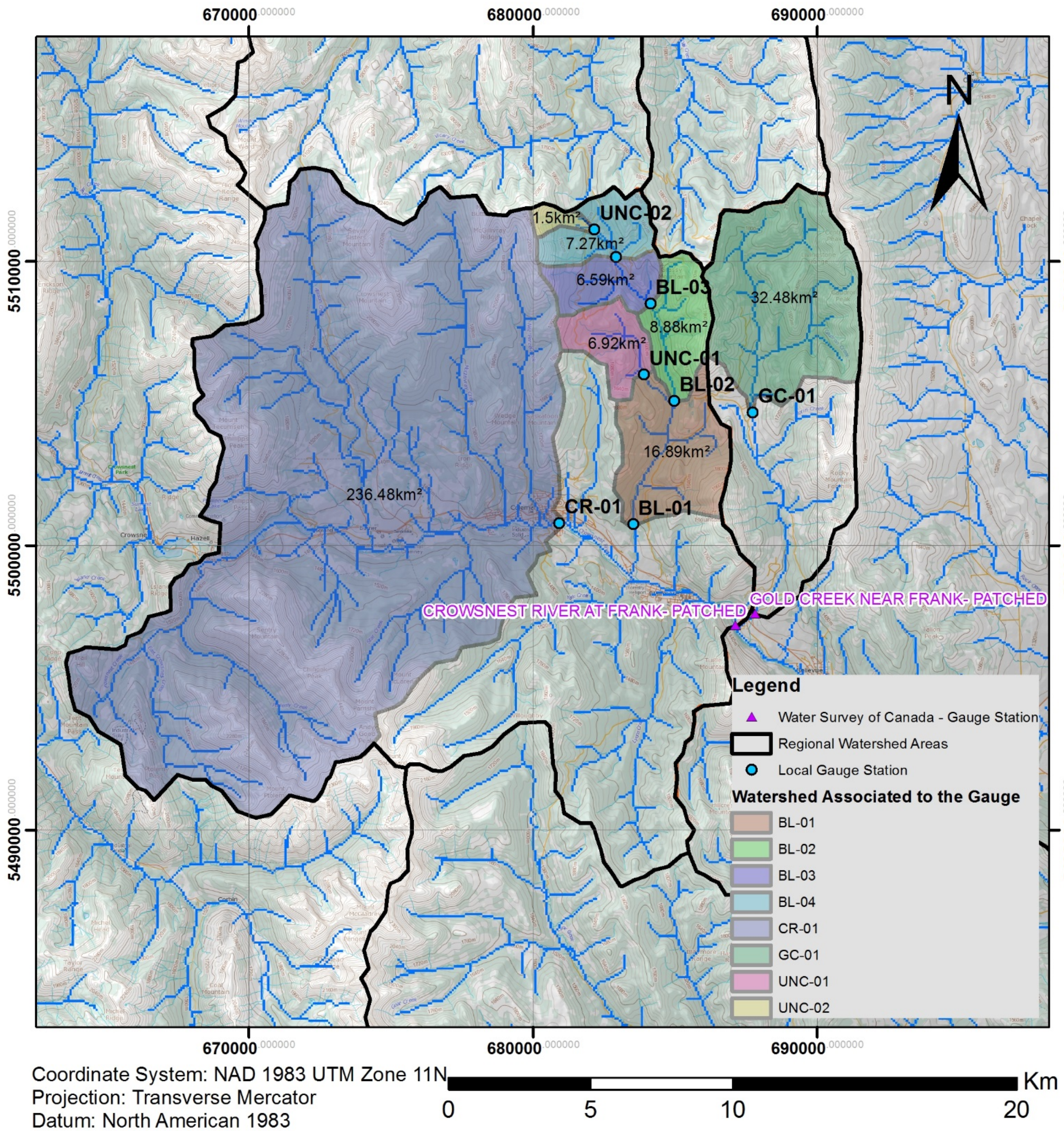


Document Path: \\VAN-SVR0\Projects\01_SITES\Grassy Mountain\1CM029.007_Hydrotechnical_Engineering\!040_AutoCAD\GIS\1.MXD Files\Stations-Plan View_Rev3e.mxd

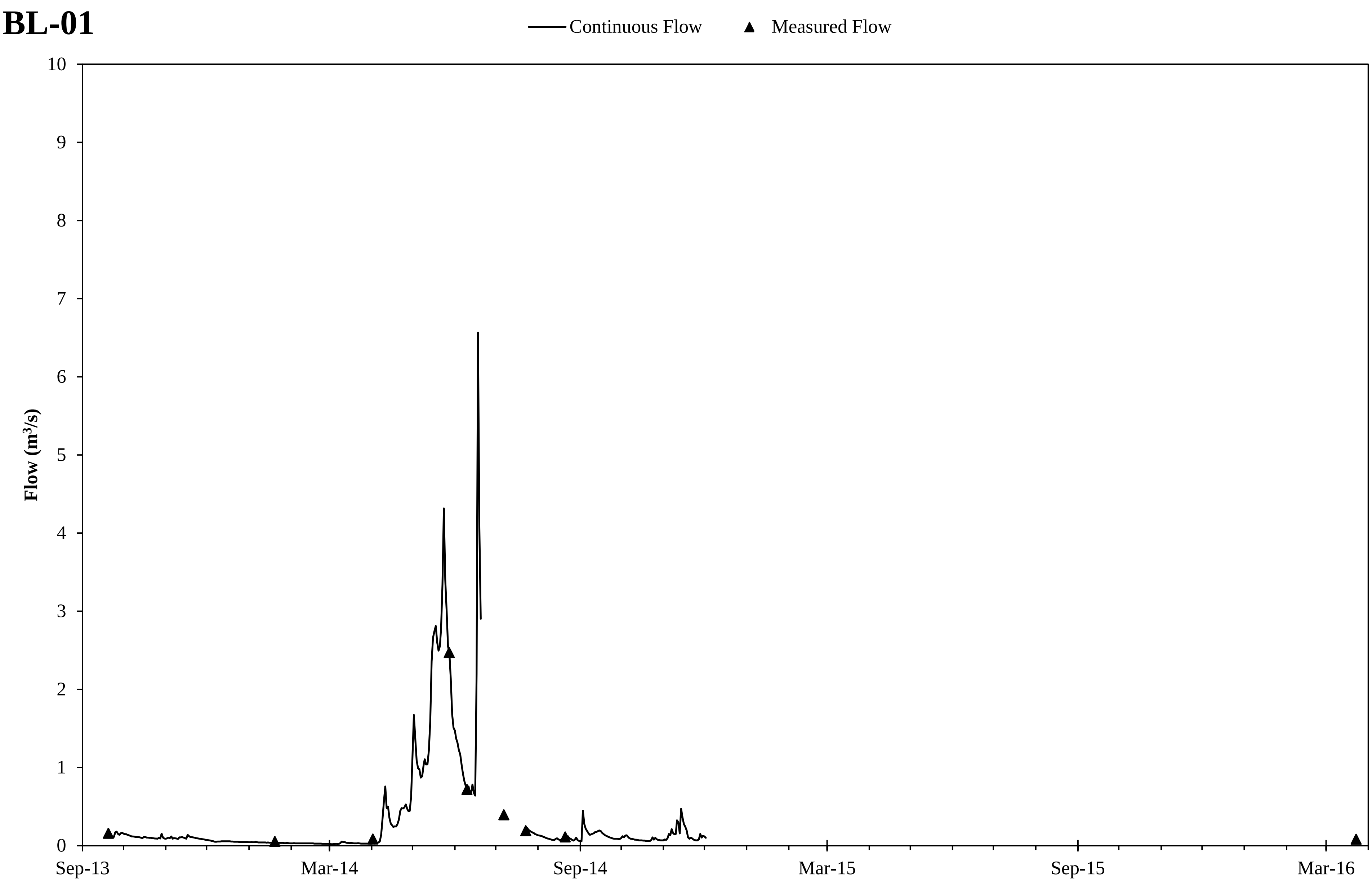
Coordinate System: NAD 1983 UTM Zone 11N
Projection: Transverse Mercator
Datum: North American 1983

srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Local and regional watersheds for the Grassy Mountain Project
Job No: 1CM029.011 Filename: Station-Plan View_Rev3e.mxd	Grassy Mountain Project	Date: August 2016 | Approved: SJ | Figure: **21**

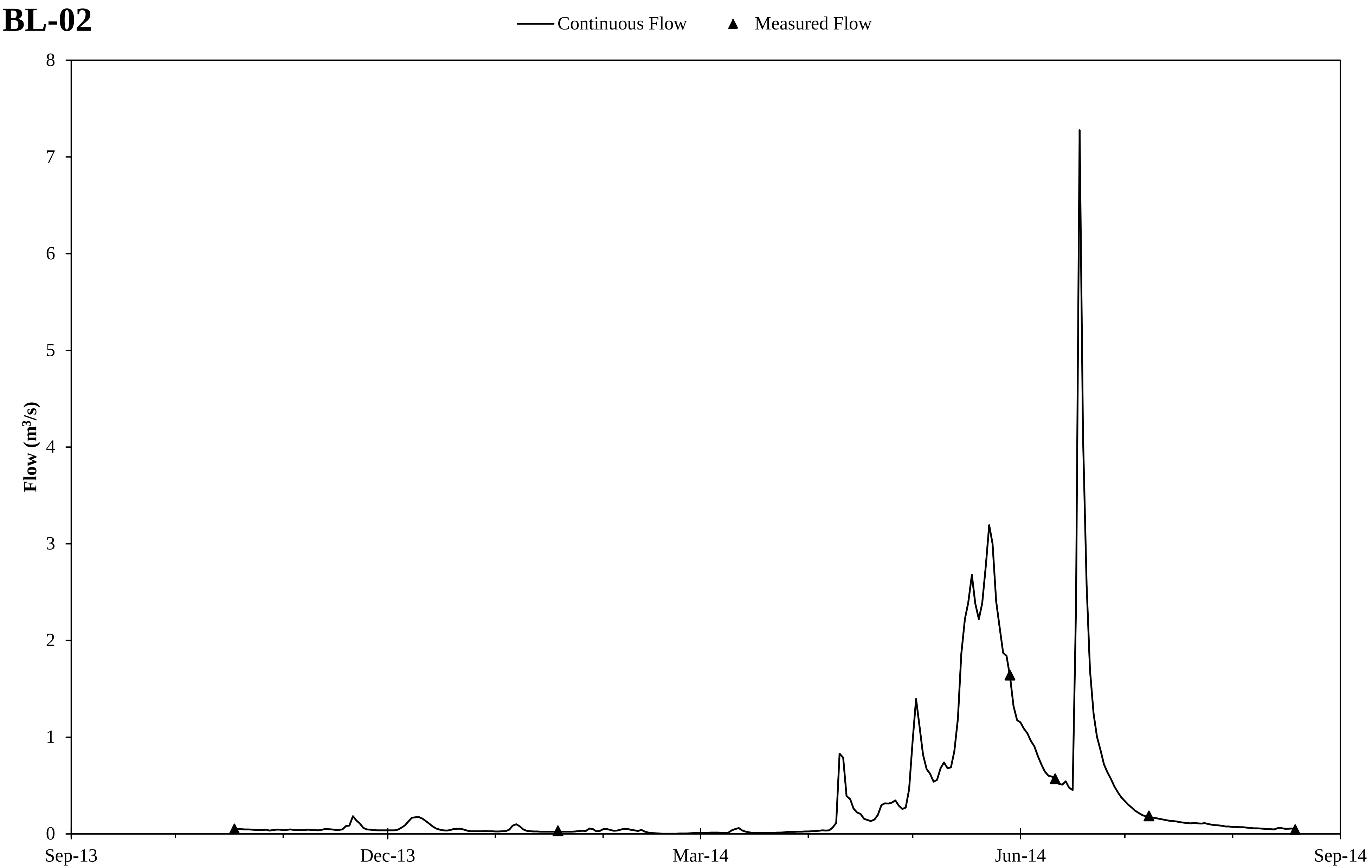
Document Path: \\VAN-SVR0\Projects\01_SITES\Grassy Mountain\1CM029.007_Hydrotechnical_Engineering\040_AutoCAD\GIS\1.MXD Files\Local gauge stations-Rev2.mxd



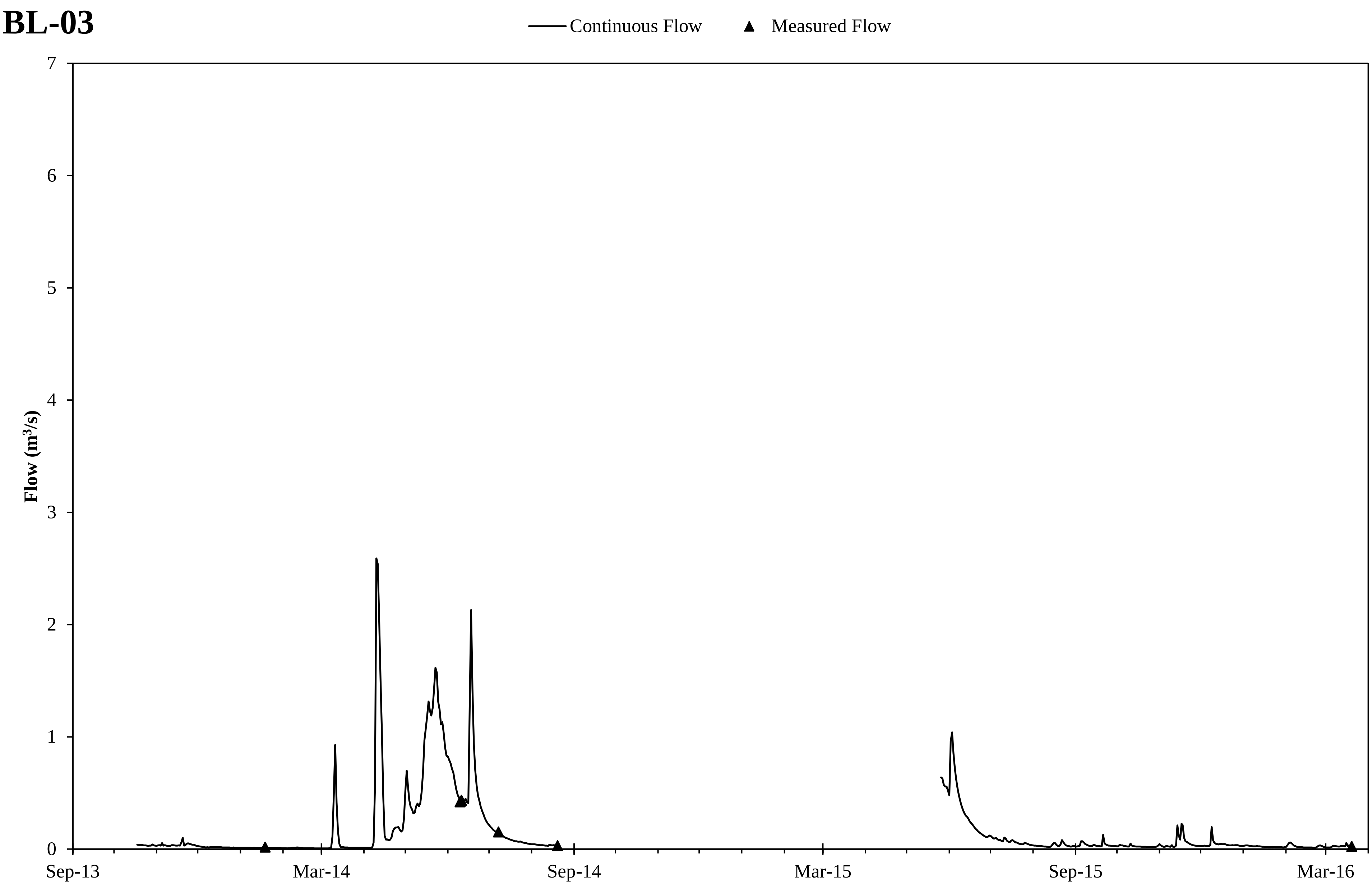
srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Local and regional gauging stations for the Grassy Mountain Project**
Job No: 1CM029.011 Filename: Local gauge stations-rev2.mxd	Grassy Mountain Project	Date: August 2016 · Approved: SJ · Figure: **22**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Flow Records for Local Gauge BL-01 at Blairmore Creek
Job No: 1CM029.011 Filename: ProvisionalFlowData_20160619.xl	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **23**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Flow Records for Local Gauge BL-02 at Blairmore Creek
Job No: 1CM029.011 Filename: ProvisionalFlowData_20160619.xls	Grassy Mountain Project	Date: August 2016 · Approved: SJ · Figure: **24**



srk consulting

MILLENNIUM
EMS Solutions Ltd.

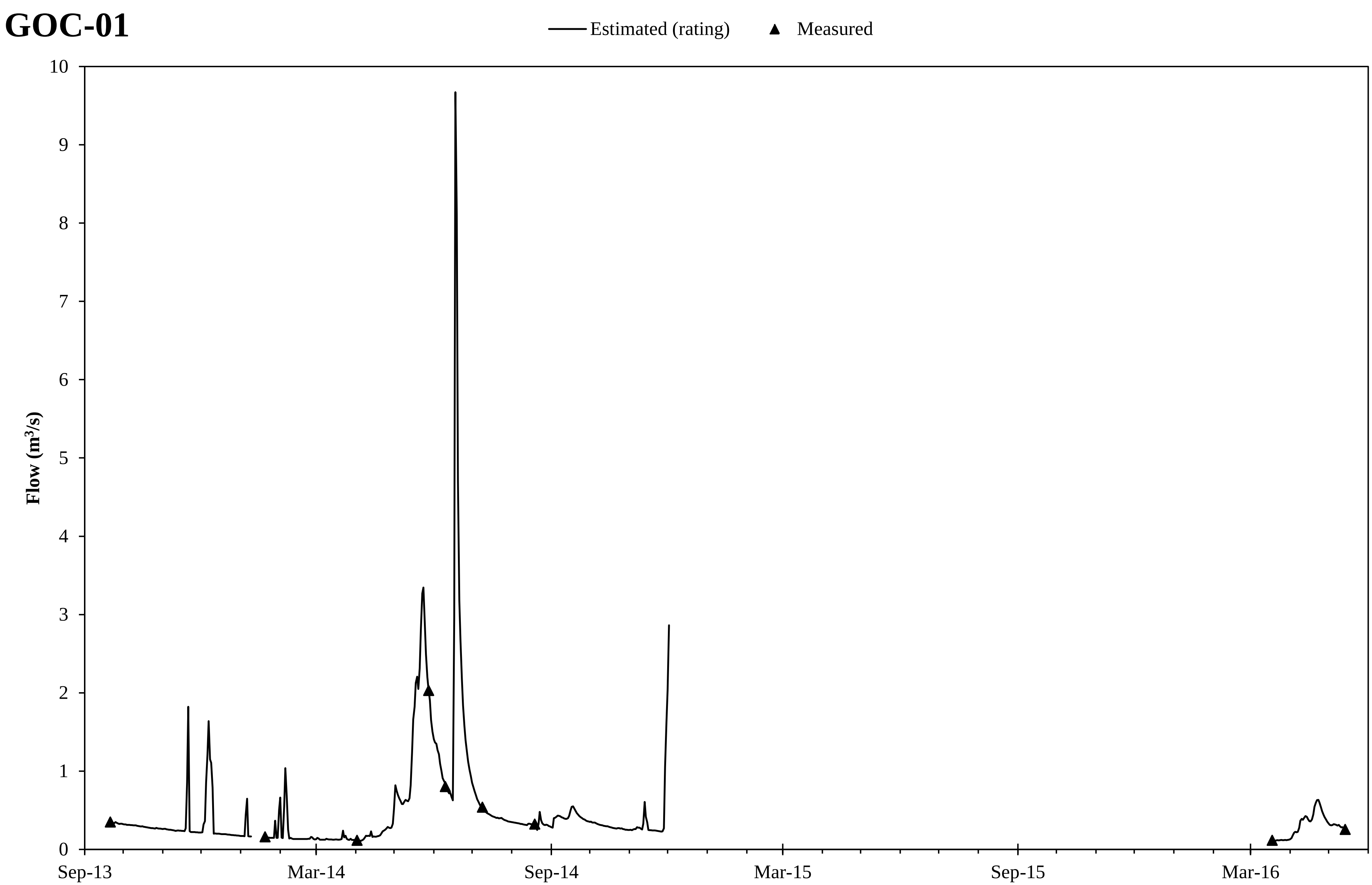
Hydrology Impact Assessment

Flow Records for Local Gauge BL-03 at Blairmore Creek

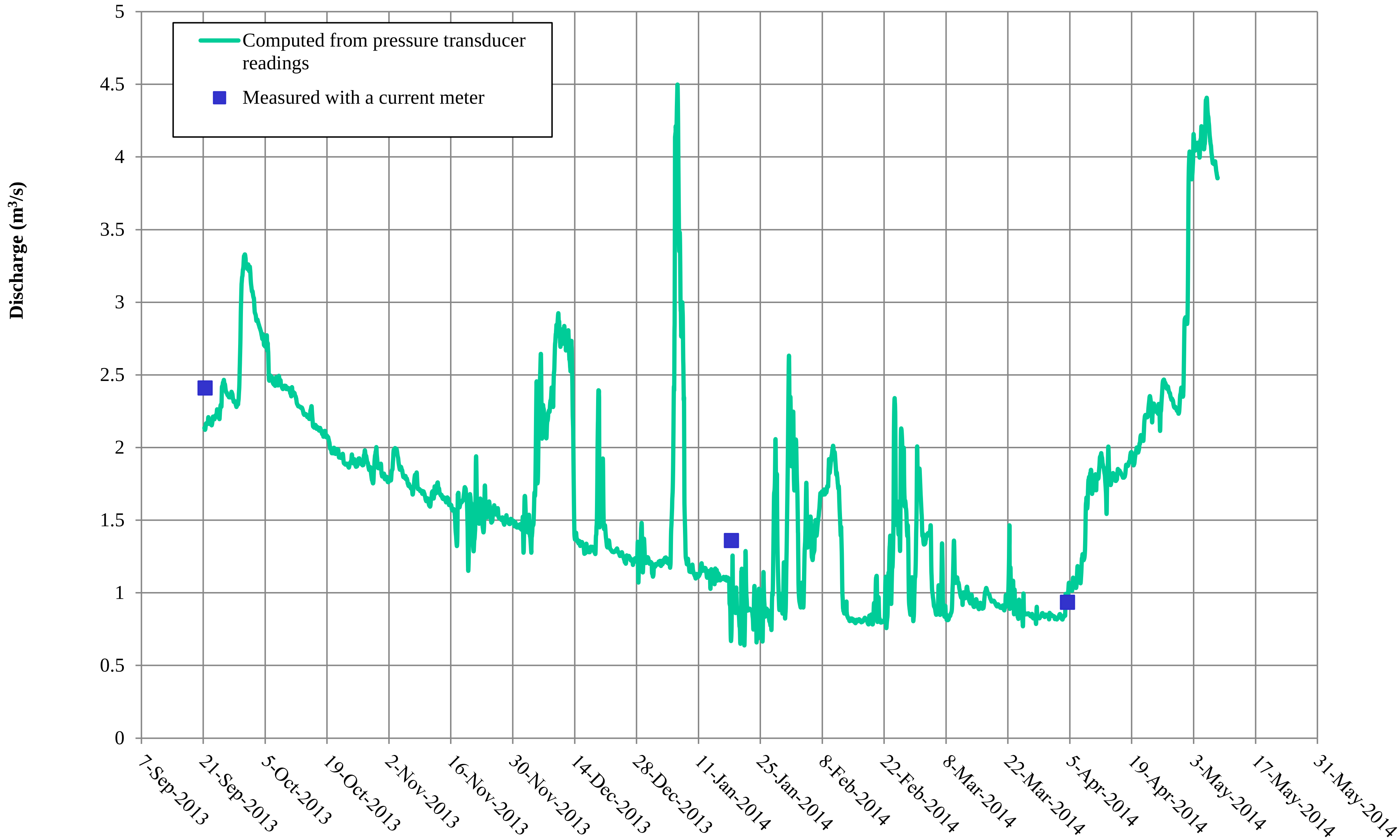
Job No: 1CM029.011
Filename: ProvisionalFlowData_20160619.xls

Grassy Mountain Project

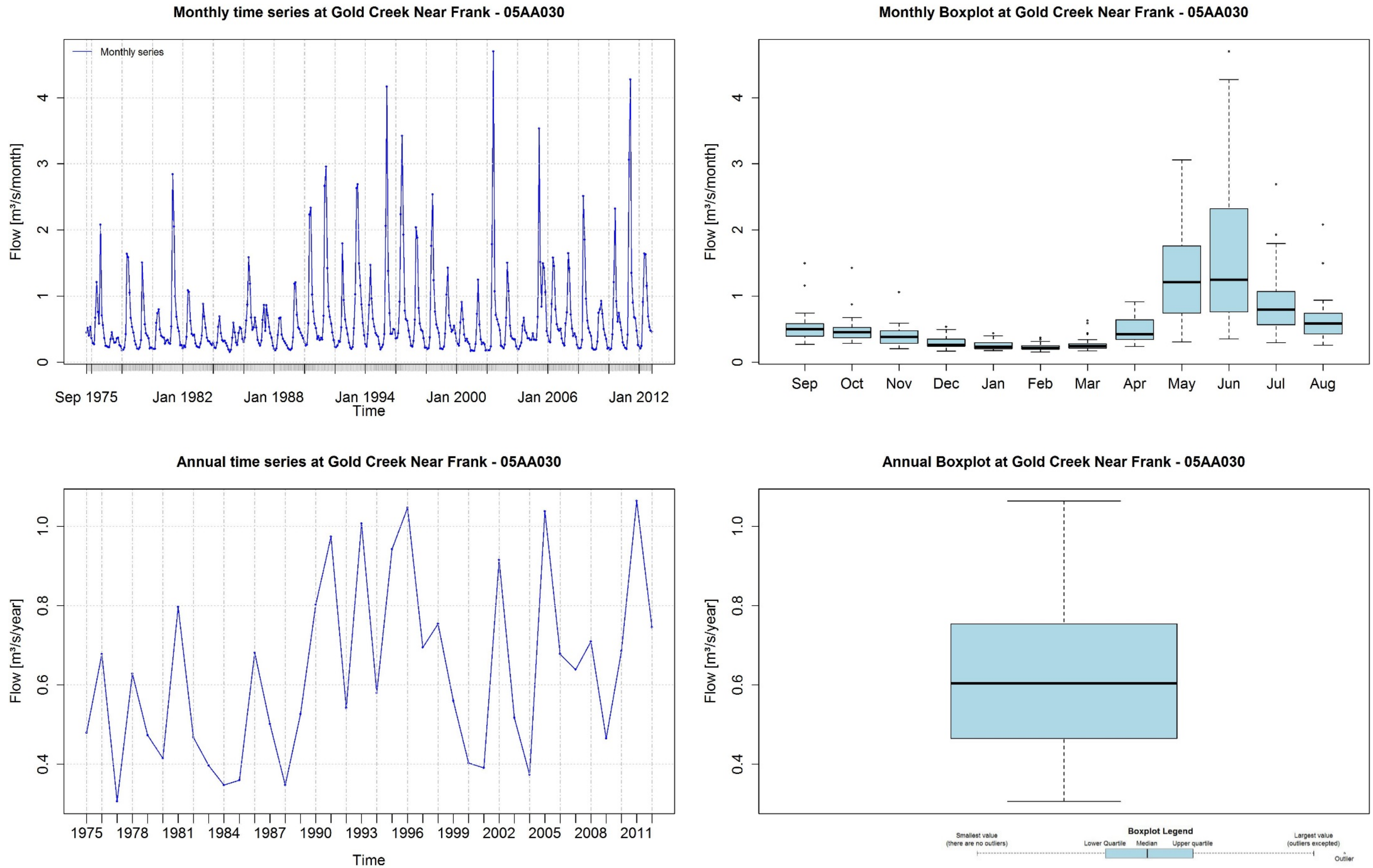
Date: August 2016
Approved: SJ
Figure: 25



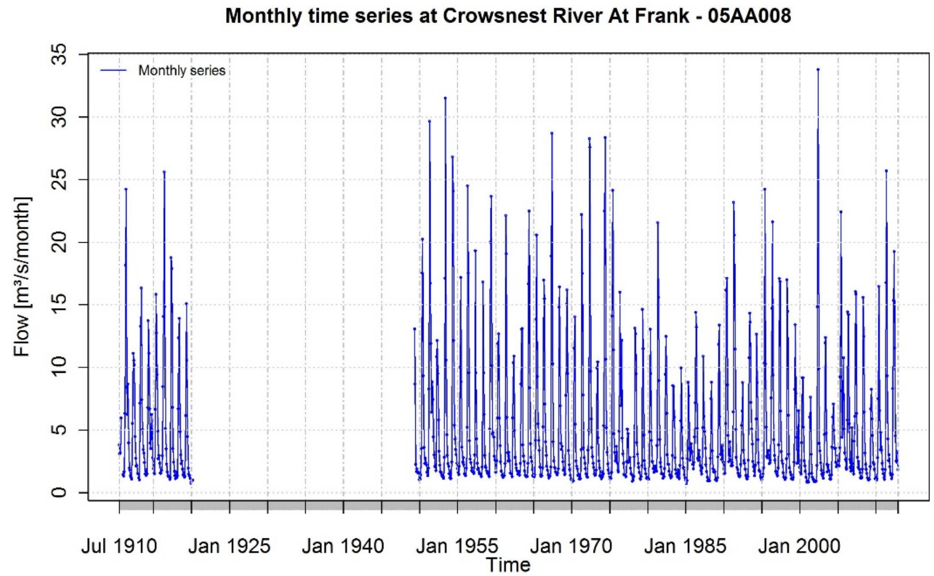
srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Flow Records for Local Gauge GC-1 at Gold Creek
Job No: 1CM029.011 Filename: ProvisionalFlowData_20160619.xls	Grassy Mountain Project	Date: August 2016 | Approved: SJ | Figure: **26**

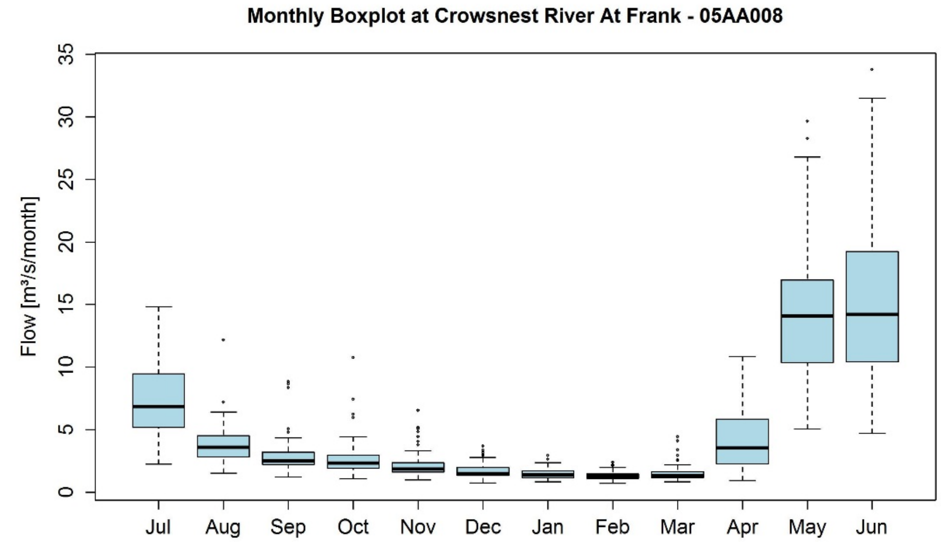


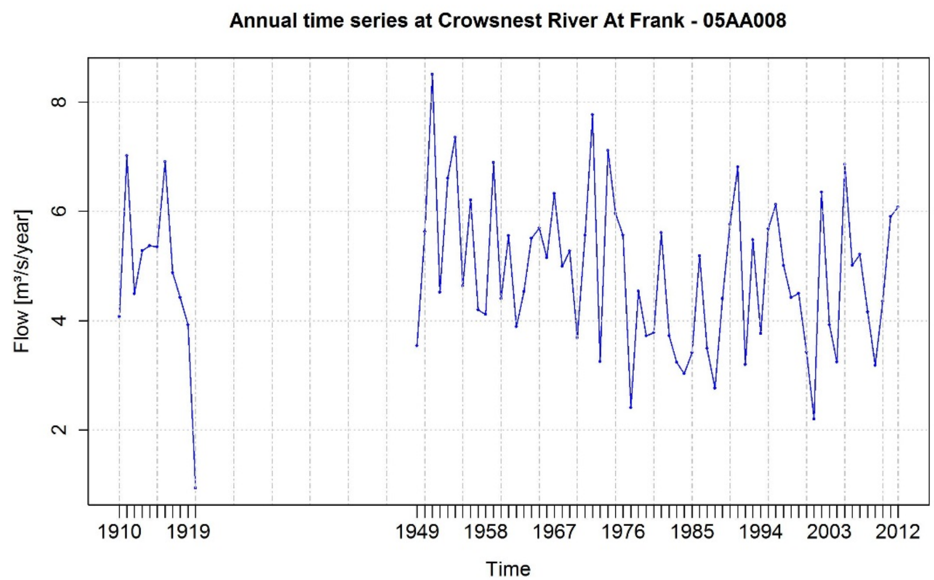
srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Flow Records for Local Gauge CR-1 at Crowsnest River
Job No: 1CM029.011 Filename: FlowCompilation_Rev3b_SiteGraphs_VM.xls	Grassy Mountain Project	Date: August 2016 | Approved: SJ | Figure: **27**

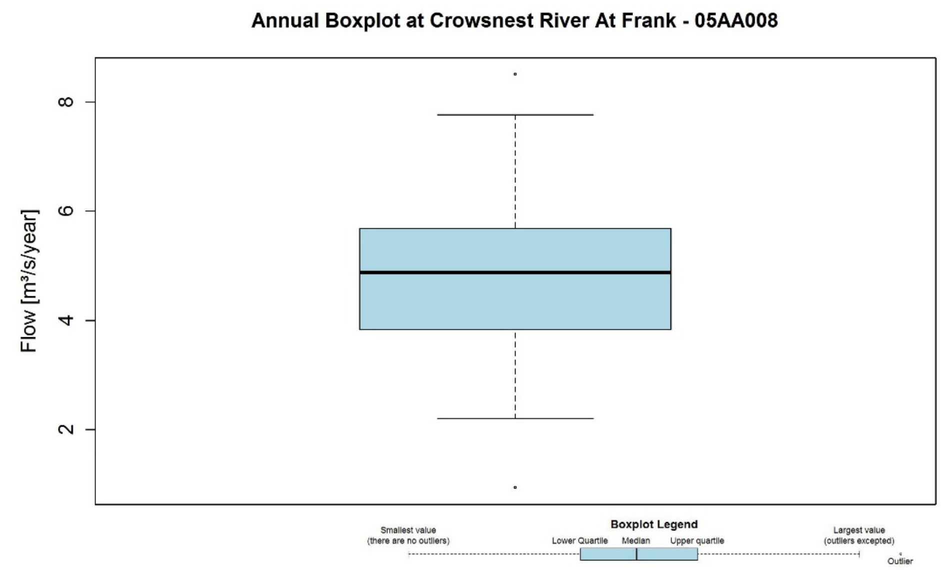


srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Flow Records for Gold Creek at Frank Regional Station**
Job No: 1CM029.011 Filename: Gold Creek Near Frank - 05AA030.tif	Grassy Mountain Project	Date: August 2016 · Approved: SJ · Figure: **28**









srk consulting

MILLENNIUM EMS Solutions Ltd.

Hydrology Impact Assessment

Flow Records for Crowsnest River at Frank Regional Station

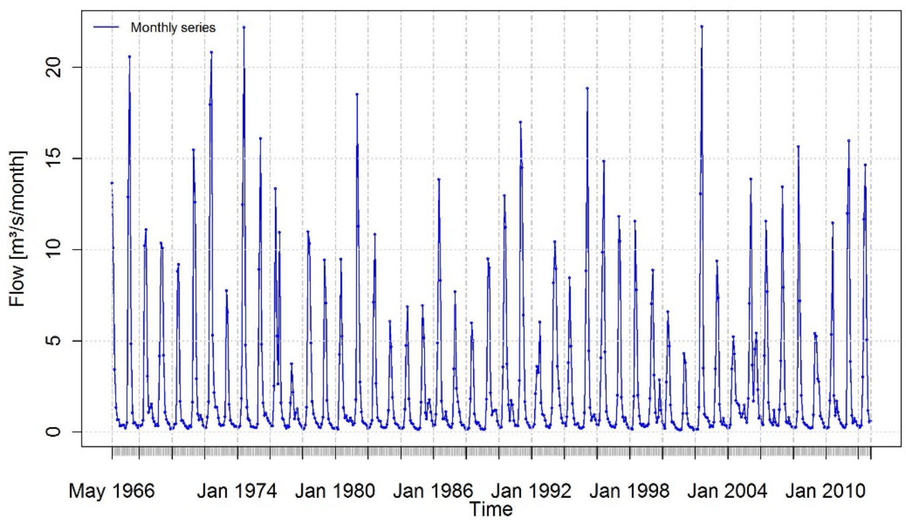
Job No: 1CM029.011

Filename: Crowsnest River At Frank - 05AA008.tif

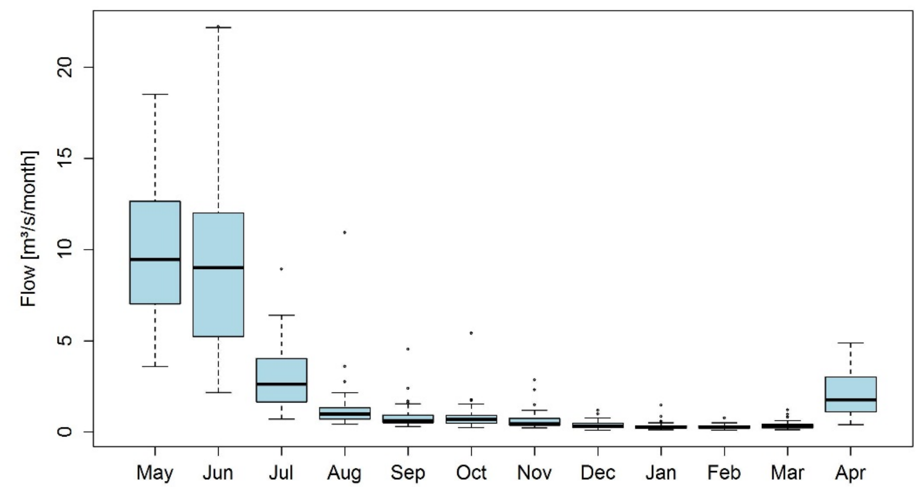
Grassy Mountain Project

Date:	Approved:	Figure:
August 2016	SJ	29

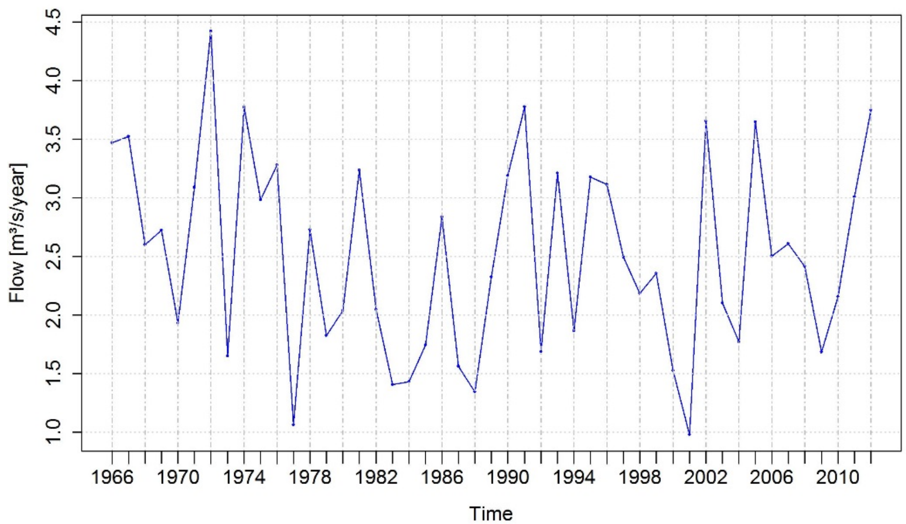
Monthly time series at Racehorse Creek Near The Mouth - 05AA027



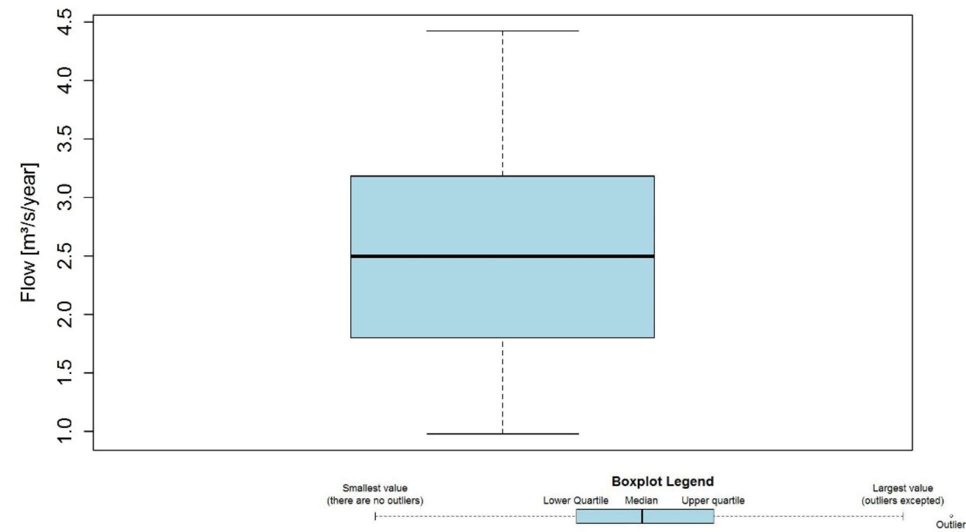
Monthly Boxplot at Racehorse Creek Near The Mouth - 05AA027



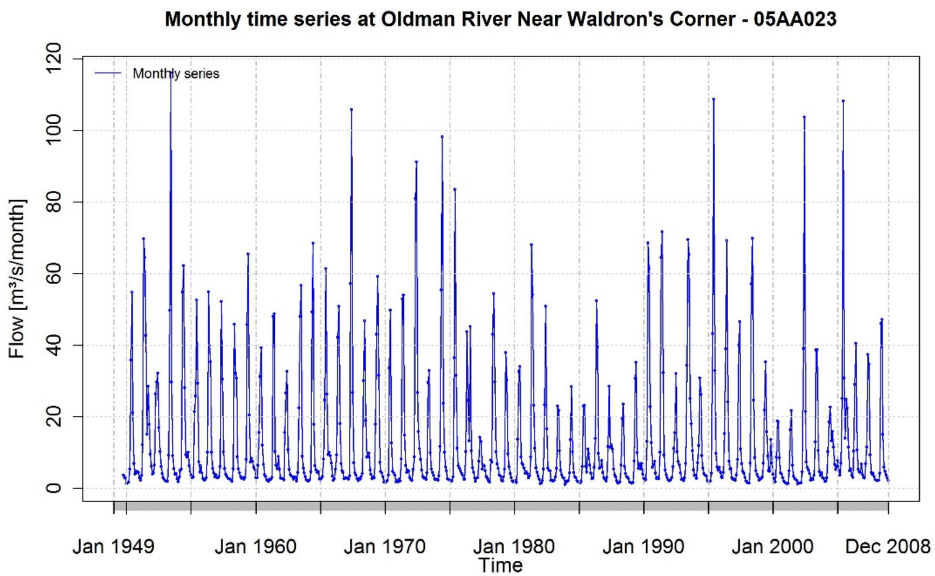
Annual time series at Racehorse Creek Near The Mouth - 05AA027

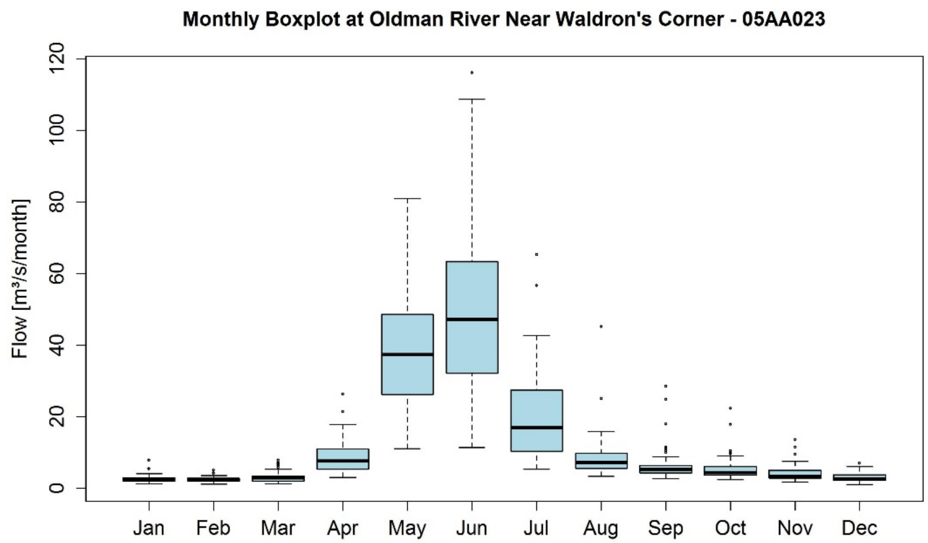


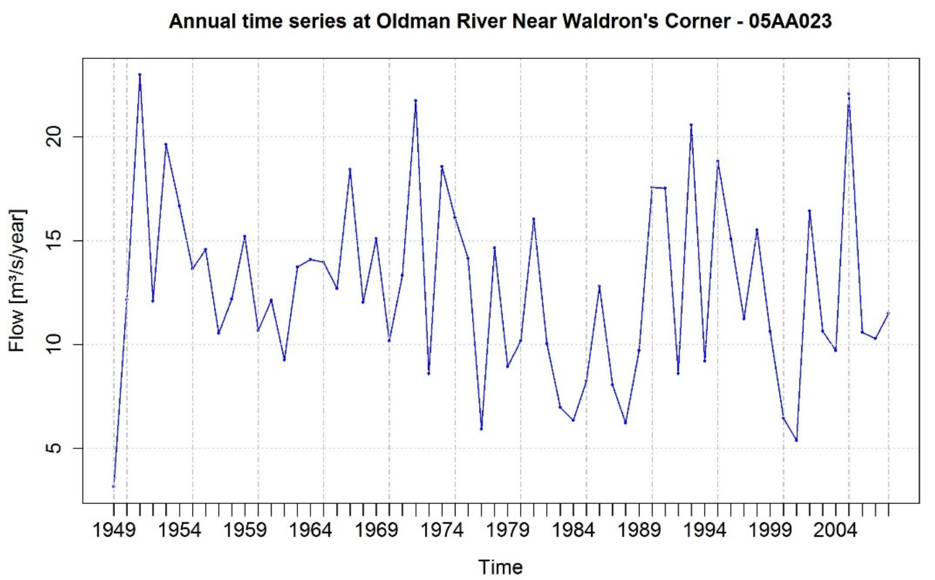
Annual Boxplot at Racehorse Creek Near The Mouth - 05AA027

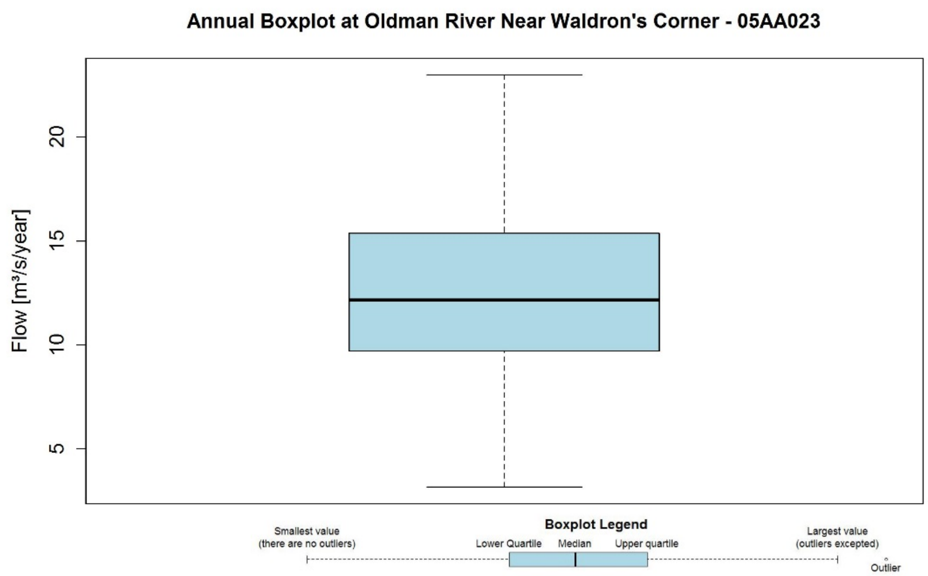


srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Flow Records for Racehorse Creek Near the Mouth Regional Station
Job No: 1CM029.011 Filename: Racehorse Creek Near The Mouth - 05AA027.tif	Grassy Mountain Project	Date: August 2016 — Approved: SJ — Figure: **30**

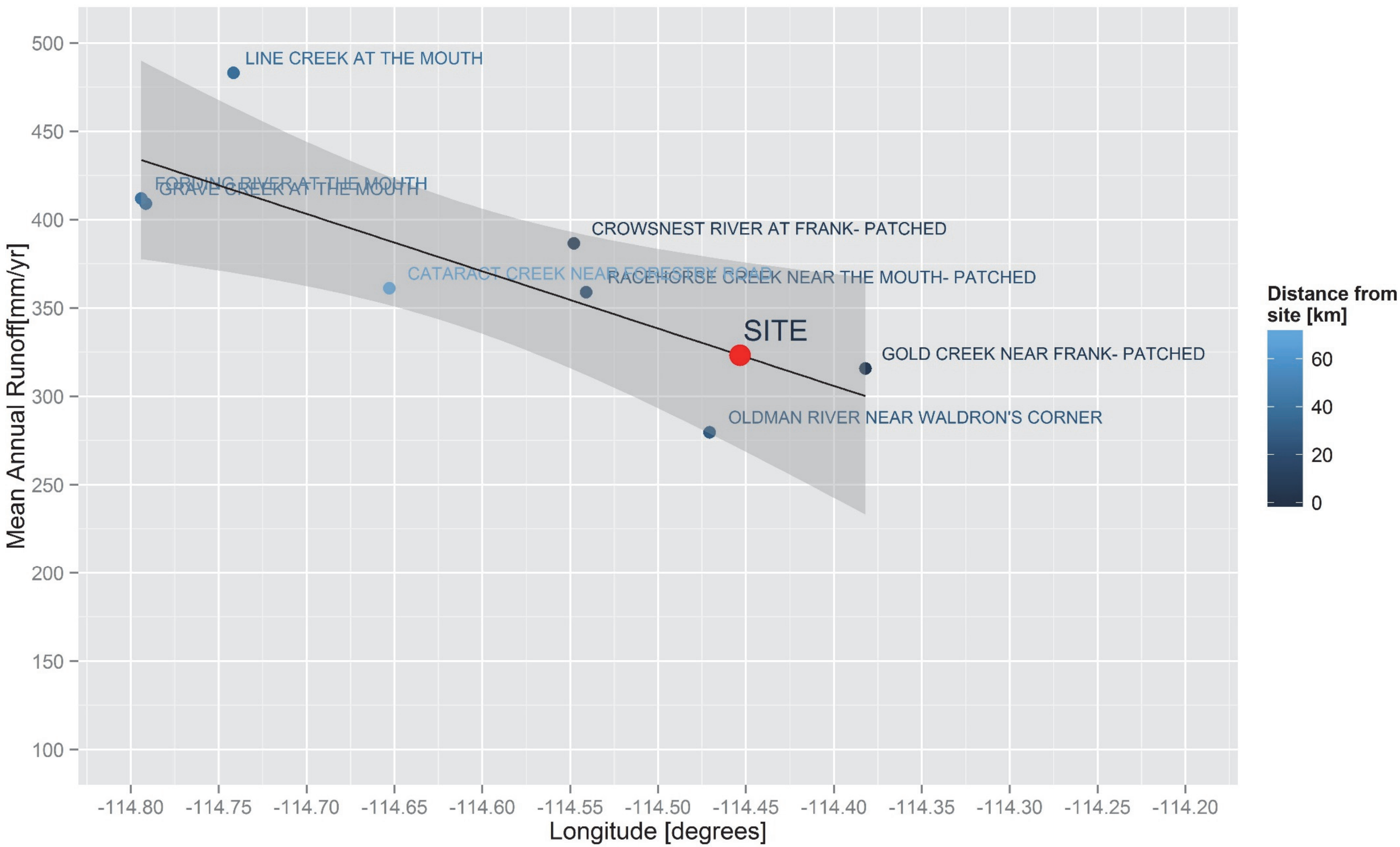




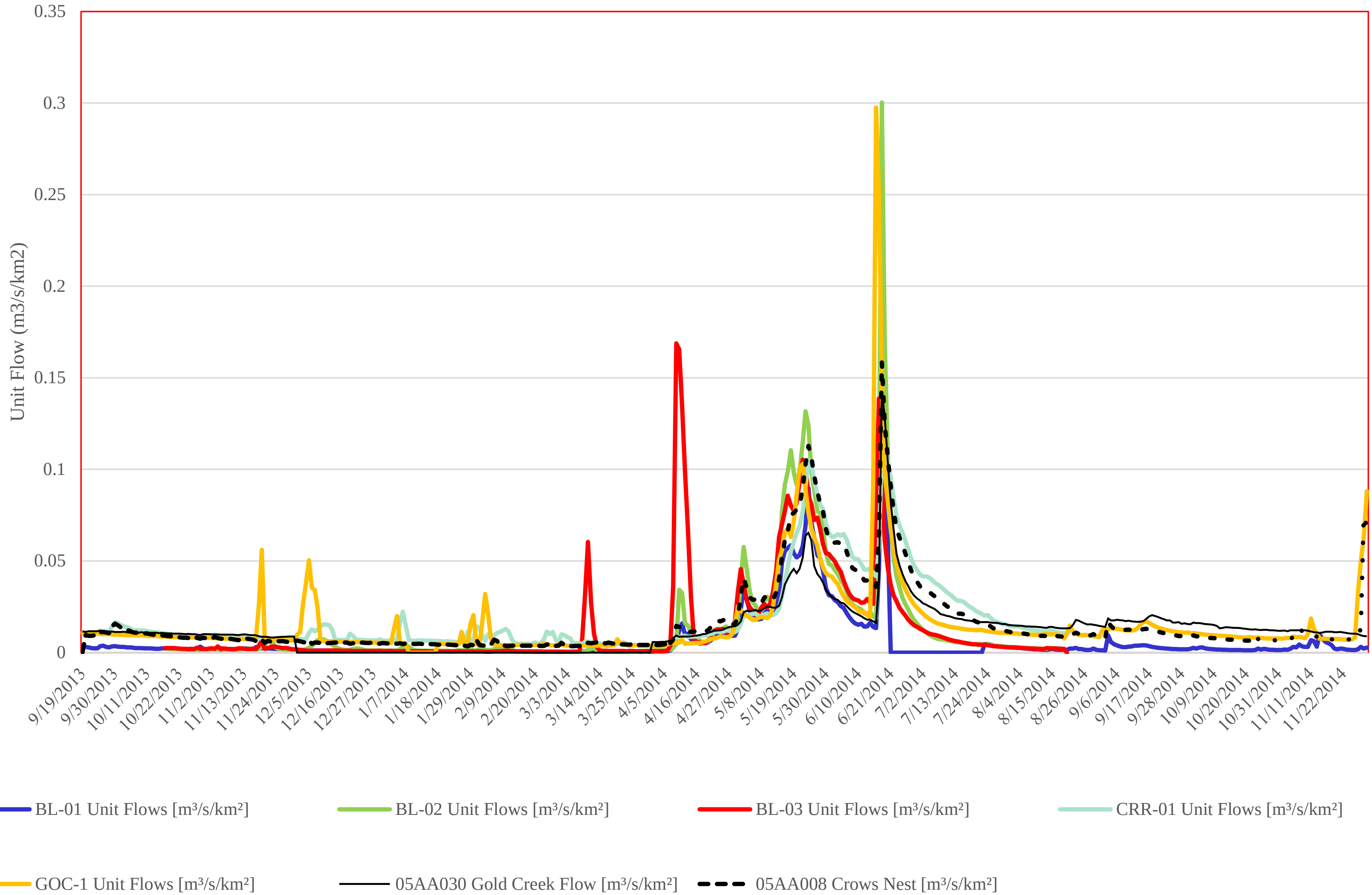




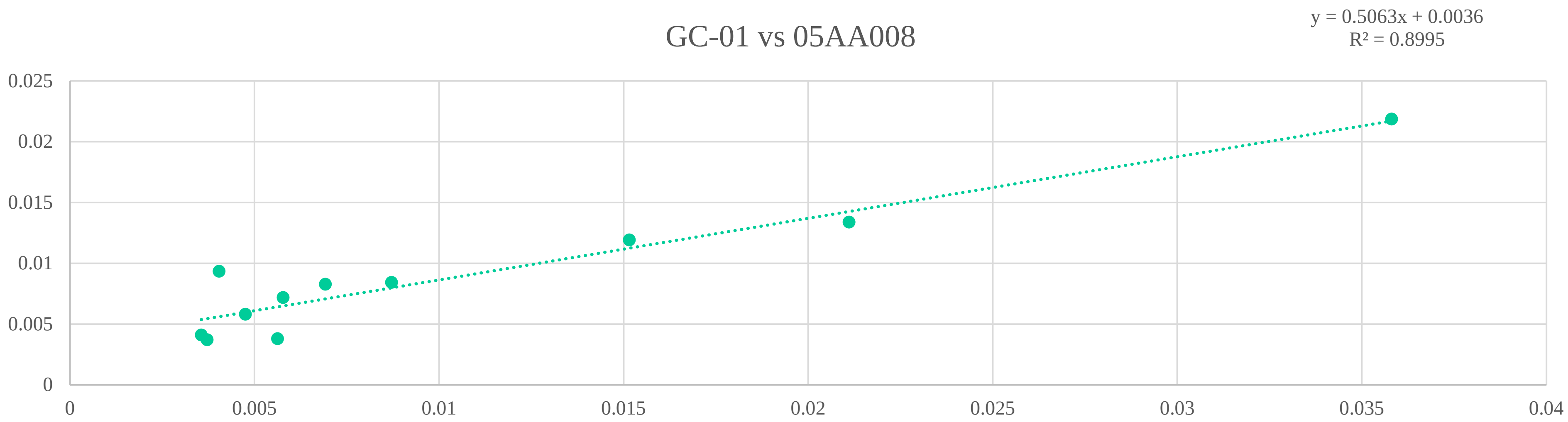
srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Flow Records for Oldman River Near Waldron's Corner Regional Station
Job No: 1CM029.011 Filename: Oldman River Near Waldron's Corner - 05AA023.tif	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **31**

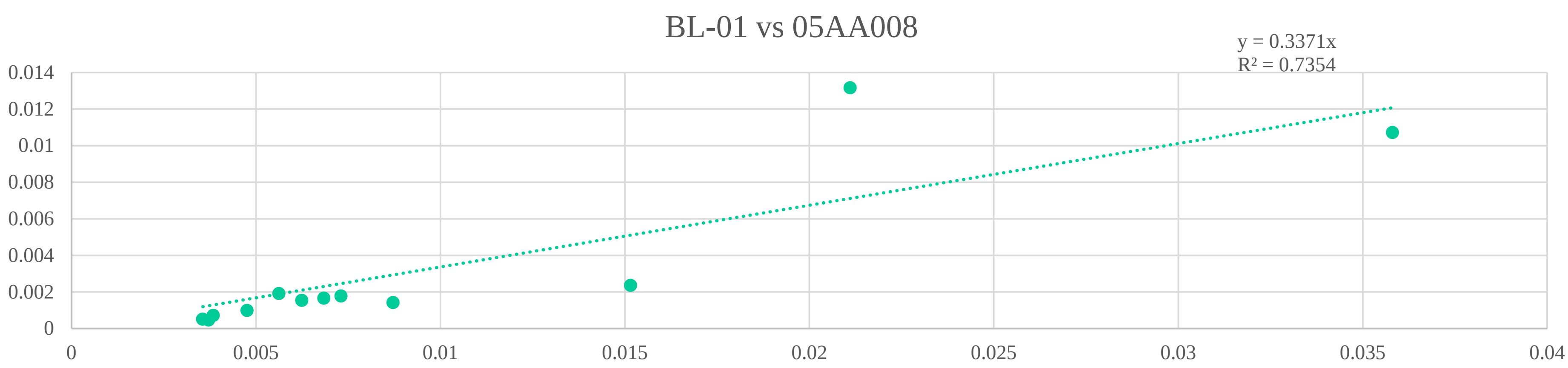


srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Mean Annual Runoff Regional Analysis
Job No: 1CM029.007 Filename: GrassyMountainUpdate_Rev7-CrownestPatched-VM.xlsm	Grassy Mountain Project	Date: Nov 2015 / Approved: JFD / Figure: **32**

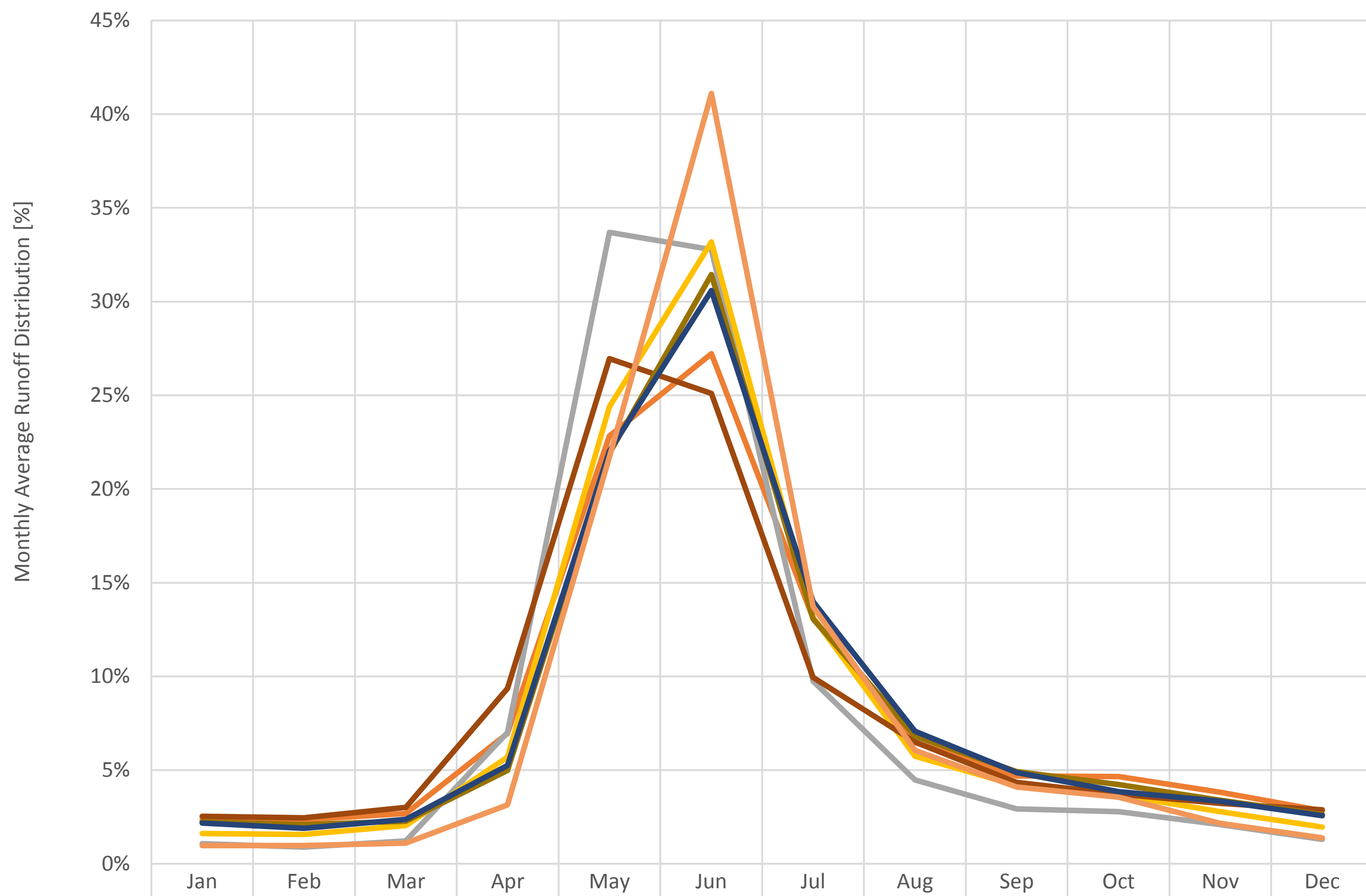


srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Local Gauge Comparison**		
Job No: 1CM029.011 Filename: Regional_Local_Comparison_v2_FS.xlsx	Grassy Mountain Project	Date: August 2016	Approved: SJ	Figure: **33**





srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment		
		Mean Annual Runoff Regional Analysis		
Job No: 1CM029.011 Filename: BaseflowRelation_v1.xls	Grassy Mountain Project	Date: August 2016	Approved: SJ	Figure: **34**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CROWSNEST RIVER AT FRANK- PATCHED	2%	2%	3%	7%	23%	27%	13%	6%	5%	5%	4%	3%
RACEHORSE CREEK NEAR THE MOUTH- PATCHED	1%	1%	1%	7%	34%	33%	10%	4%	3%	3%	2%	1%
OLDMAN RIVER NEAR WALDRON'S CORNER	2%	2%	2%	6%	24%	33%	13%	6%	4%	4%	3%	2%
GRAVE CREEK AT THE MOUTH	3%	2%	3%	9%	27%	25%	10%	6%	4%	4%	3%	3%
LINE CREEK AT THE MOUTH	2%	2%	2%	5%	22%	31%	13%	7%	5%	4%	3%	3%
FORDING RIVER AT THE MOUTH	2%	2%	2%	5%	22%	31%	14%	7%	5%	4%	3%	3%
CATARACT CREEK NEAR FORESTRY ROAD	1%	1%	1%	3%	22%	41%	14%	6%	4%	4%	2%	1%

srk consulting

MILLENNIUM EMS Solutions Ltd.

Hydrology Impact Assessment

Regional Average Monthly Runoff Distribution

Job No: 1CM029.011

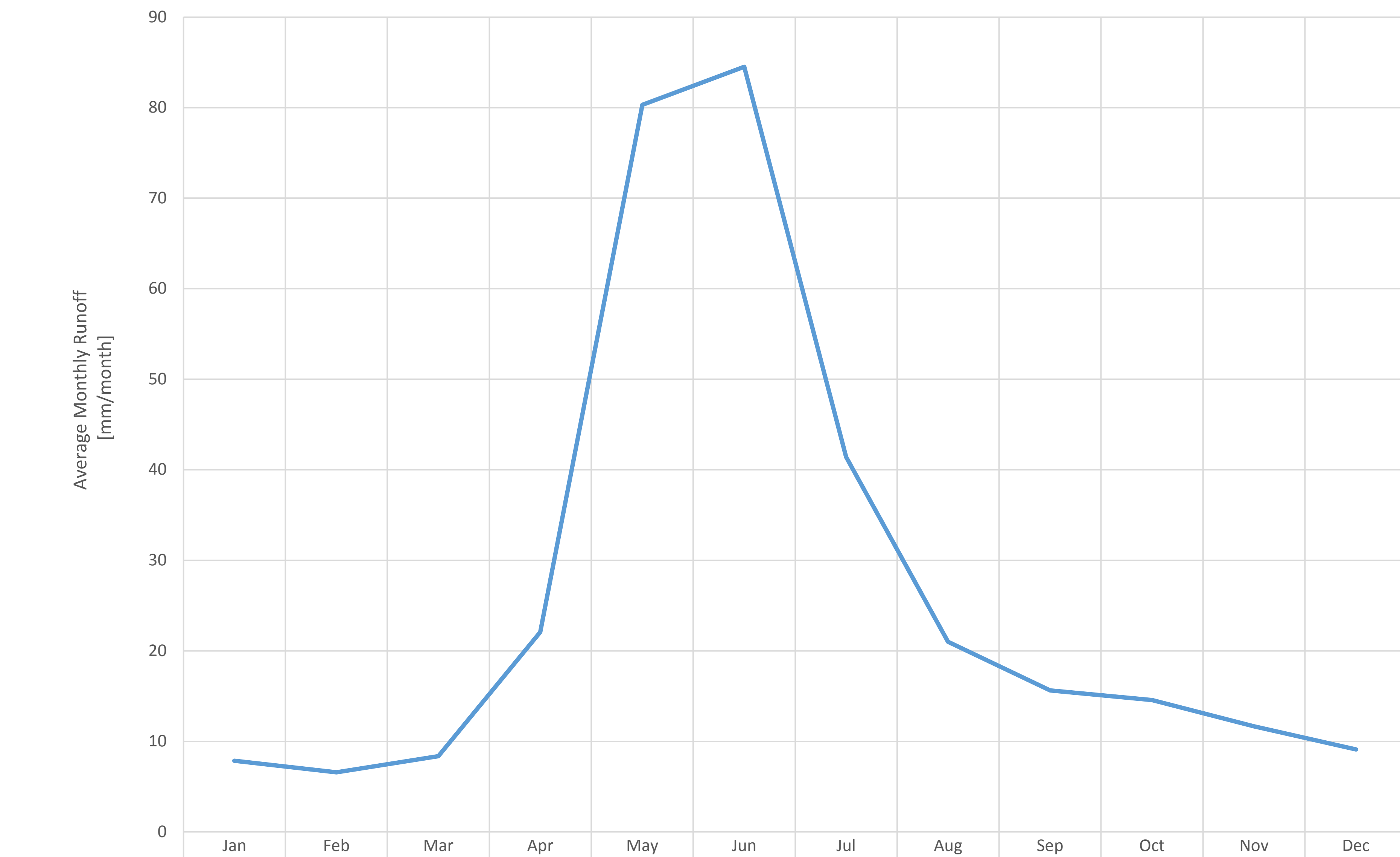
Filename: GrassyMountainUpdate_Rev7-CrownestPatched-VM.xlsm

Grassy Mountain Project

Date: August 2016

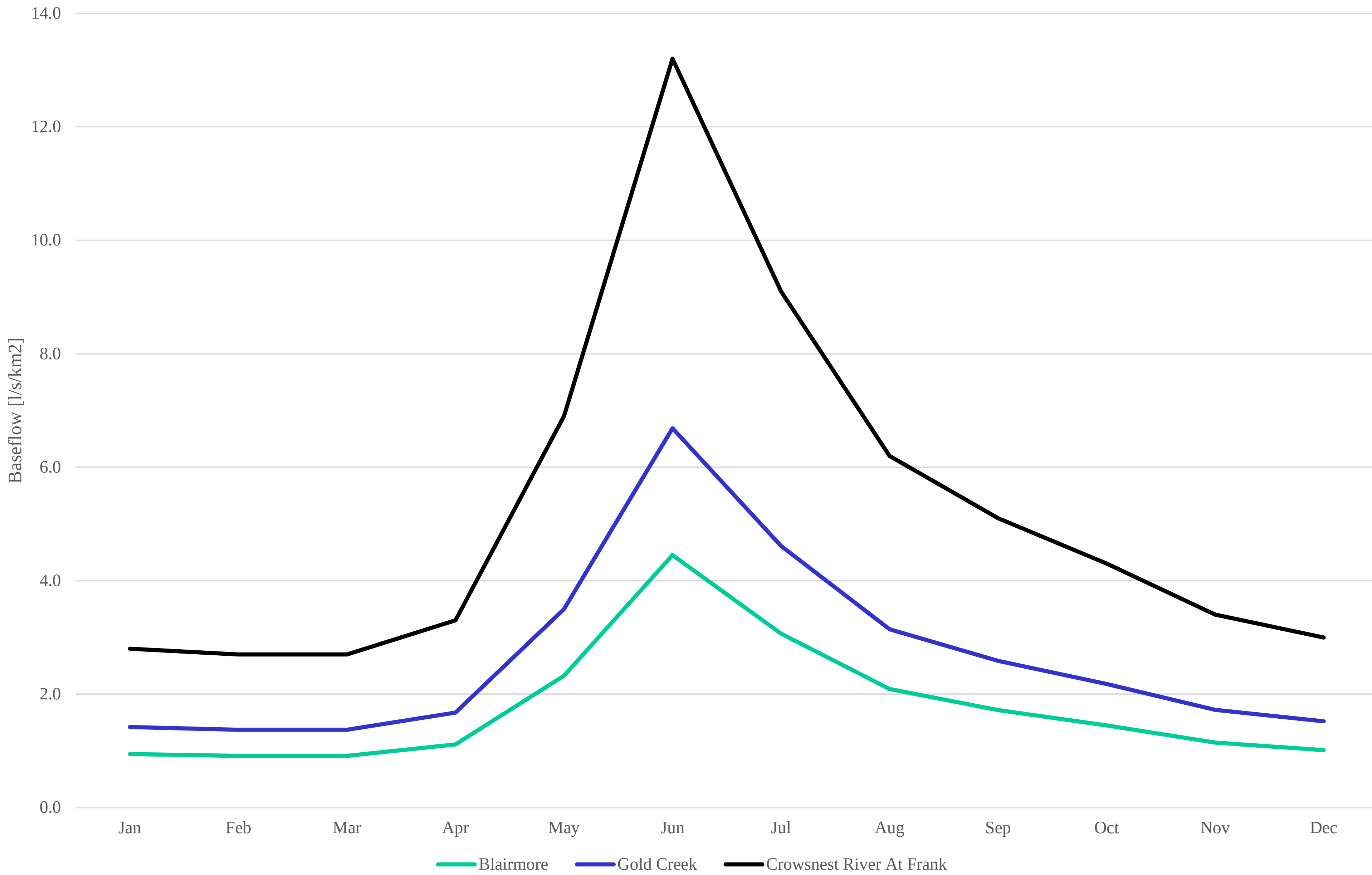
Approved: SJ

Figure: **35**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grassy Mountain	8	7	8	22	80	85	41	21	16	15	12	9

srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Mean Monthly Runoff Distribution at the Grassy Mountain Project**
Job No: 1CM029.011 Filename: GrassyMountainUpdate_Rev7-CrownestPatched-VM.xlsm	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **36**



srk consulting

MILLENNIUM
EMS Solutions Ltd.

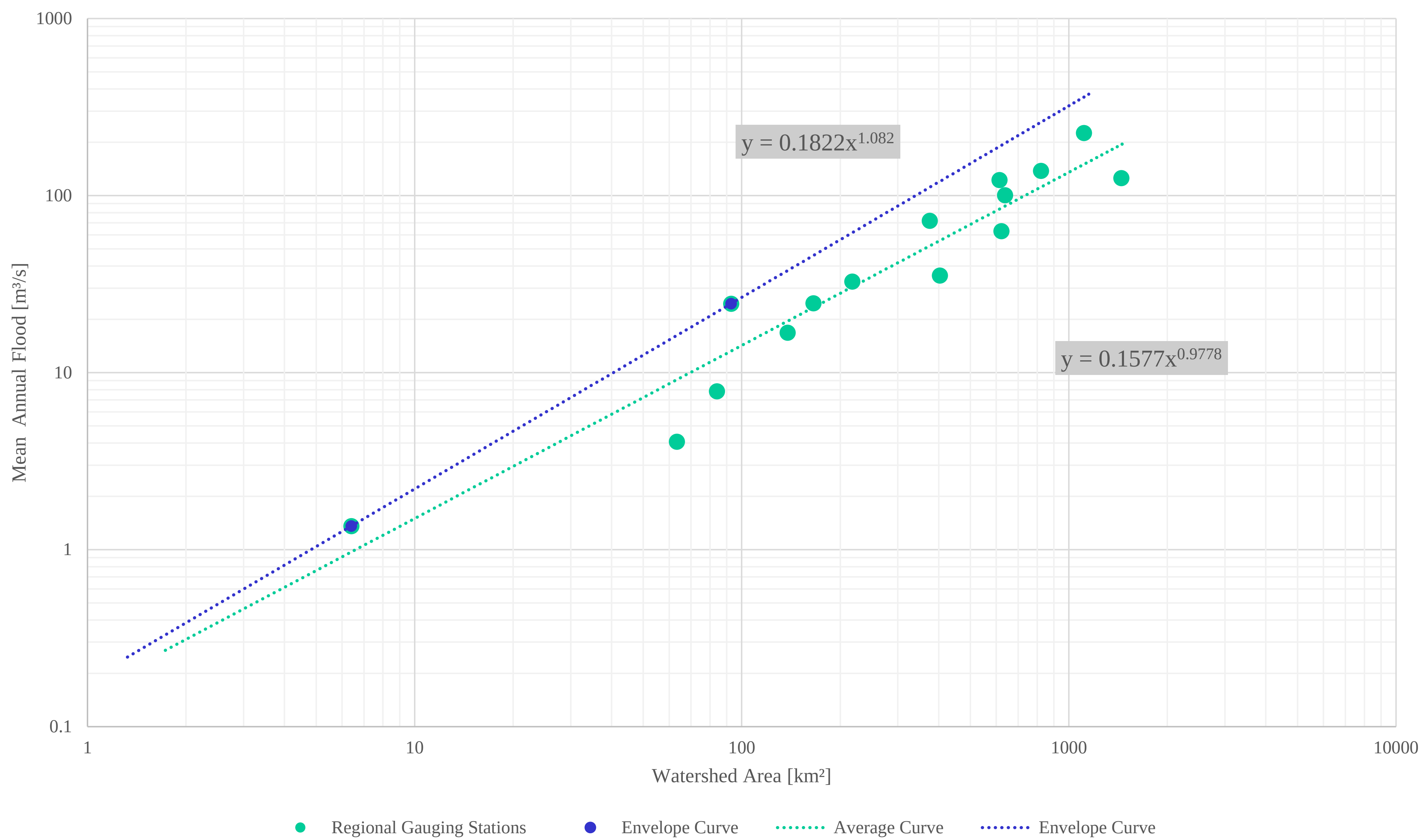
Hydrology Impact Assessment

Base Flow Estimations

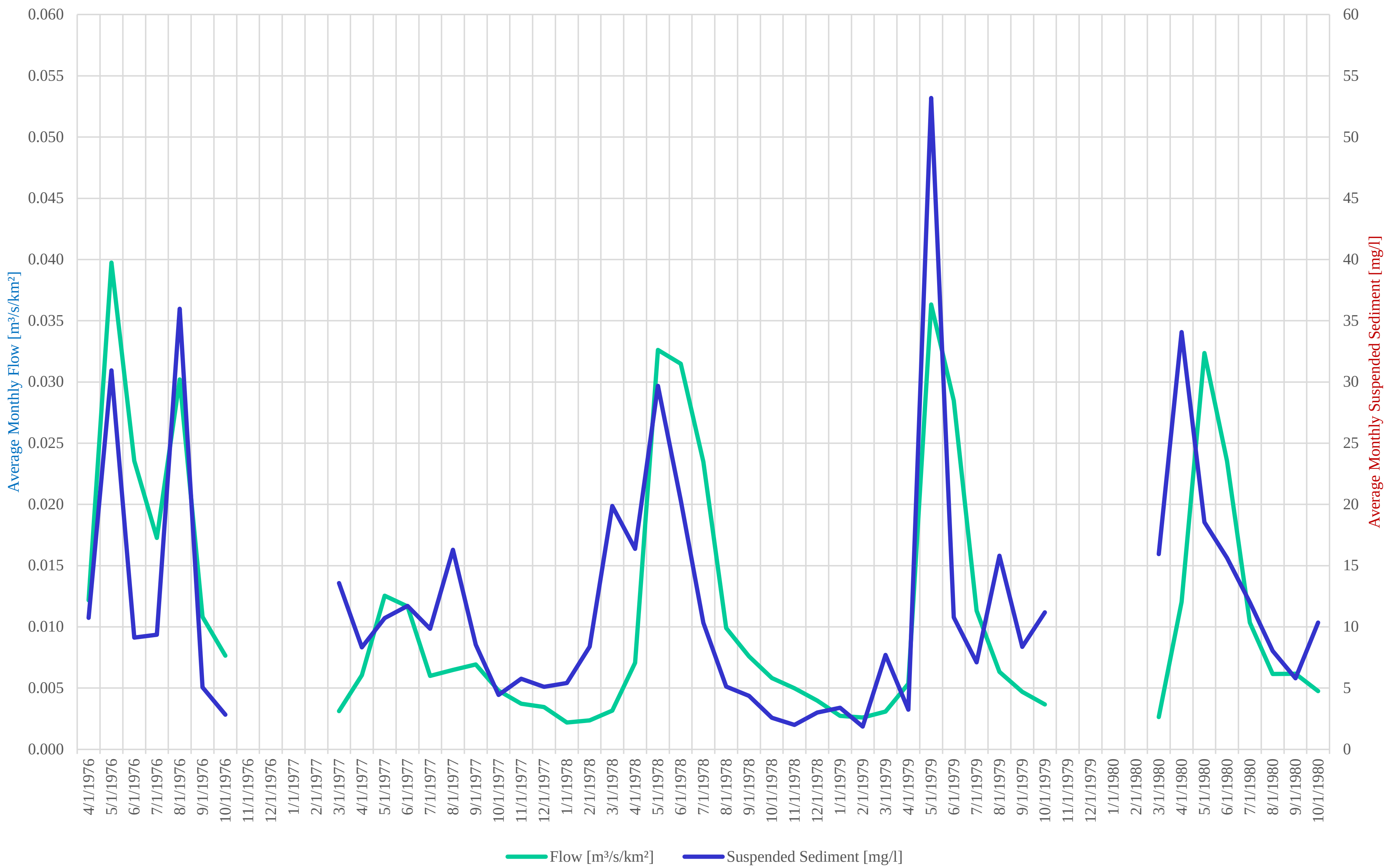
Job No: 1CM029.011
Filename: RunoffDistribution_v1_FS.xls

Grassy Mountain Project

Date: August 2016
Approved: SJ
Figure: **37**

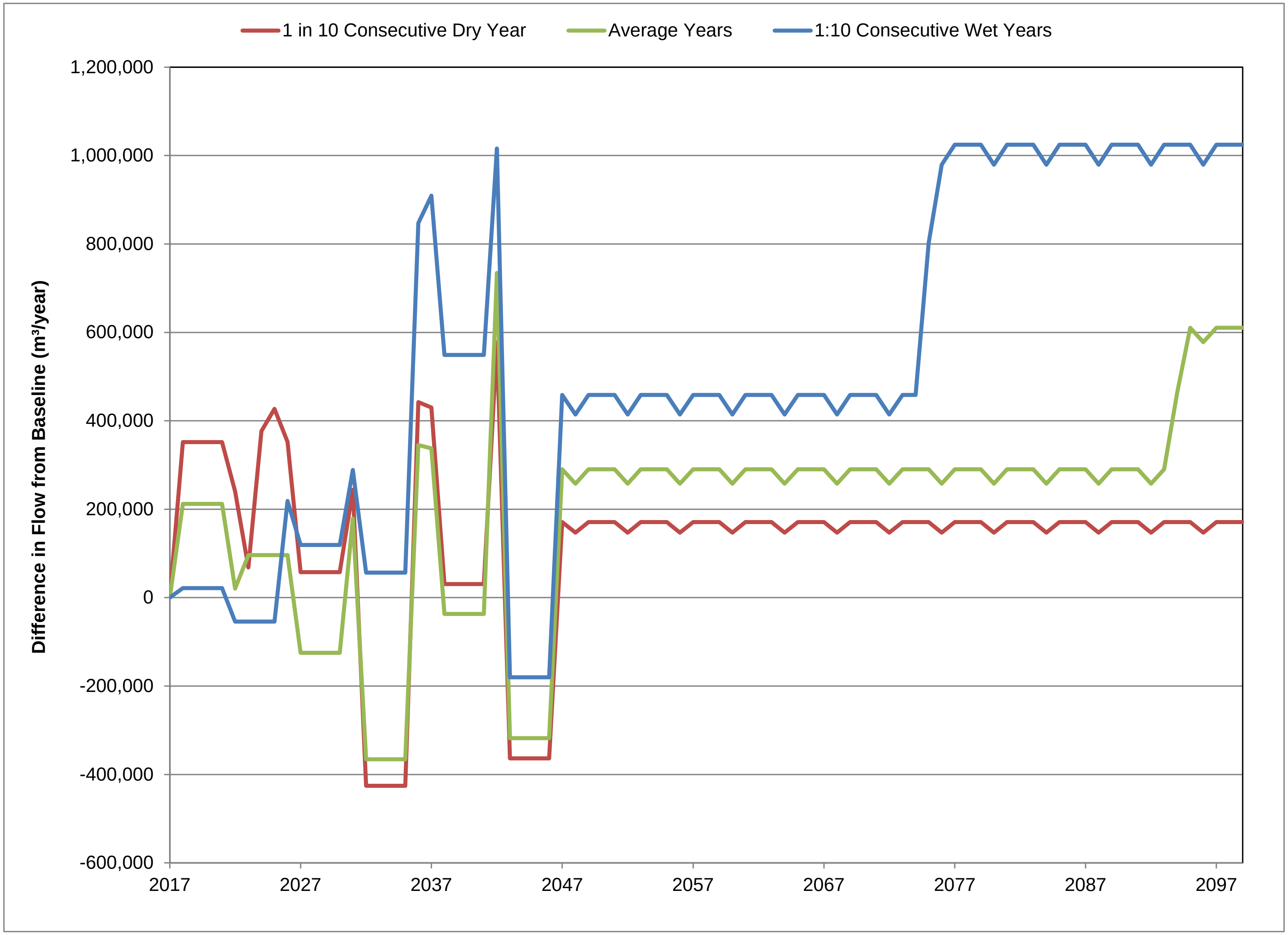


srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Mean Annual Flood Based on the Index Flood Method**
Job No: 1CM029.007 Filename: GrassyMountainUpdate_Rev7-CrownestPatched-VM.xlsm	Grassy Mountain Project	Date: Nov 2015 · Approved: JFD · Figure: **38**

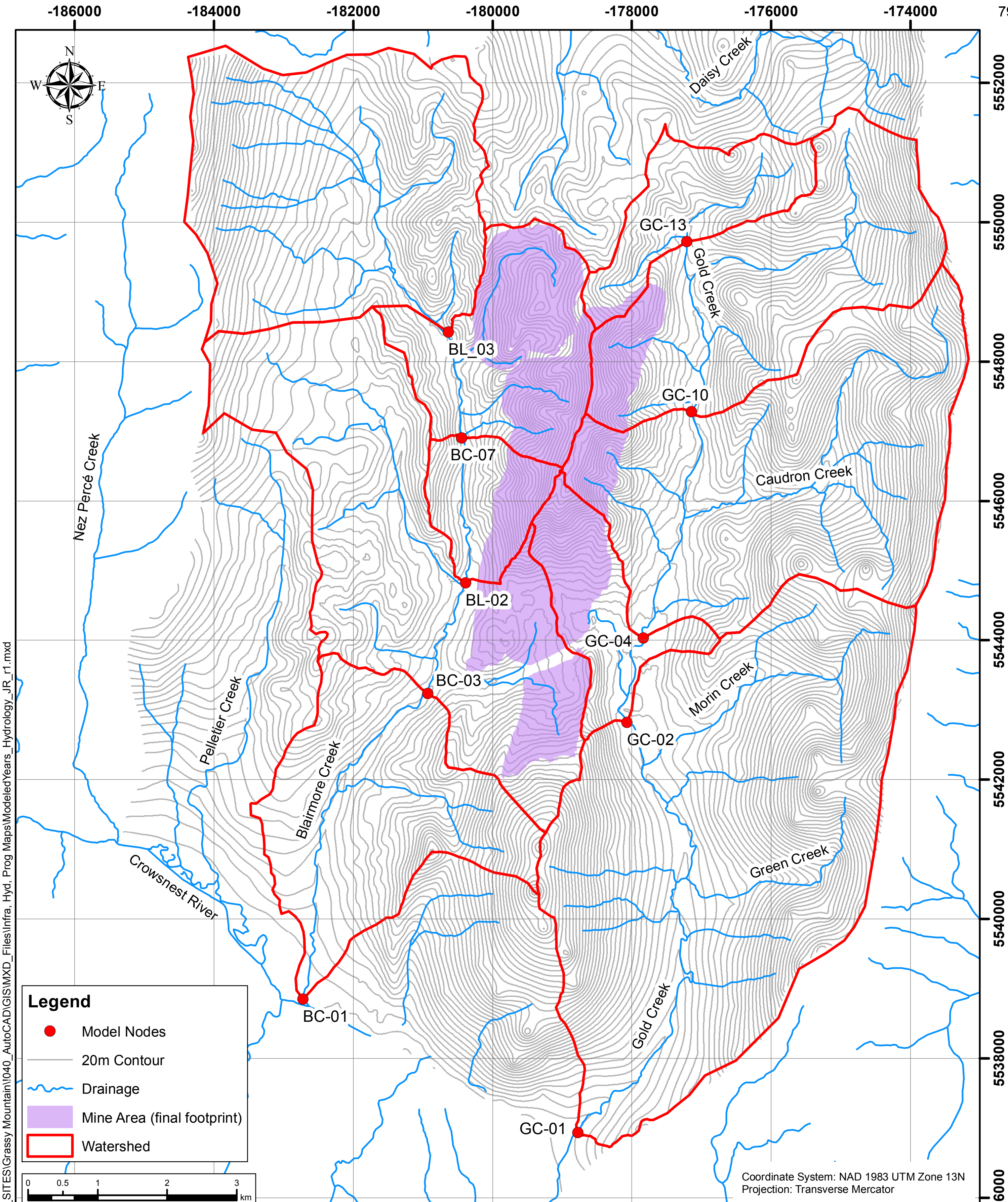


srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Average Monthly Flows and Suspended Solid at Crowsnest River at Frank**
Job No: 1CM029.011 Filename: SuspendedSediment_Rev1_VM.xlsx	Grassy Mountain Project	Date: August 2016 | Approved: SJ | Figure: **39**

srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Linear Relationship Between Average Monthly Flows and Average Monthly Suspended Sediment at Crowsnest River at Frank
Job No: 1CM029.011 Filename: SuspendedSediment_Rev1_VM.xlsx	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **40**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Estimated Change to Annual Discharge Volumes for Blairmore and Gold Creeks (Combined Change)**
Job No: 1CM029.011 Filename: Figure_41_to_47_SRJ_20160808	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **41**



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srk consulting | RIVERSDALE RESOURCES | Water Quality Prediction Model

Grassy Mountain Coal Project Site Map and Watershed Delineation

Job No: 1CM029.011

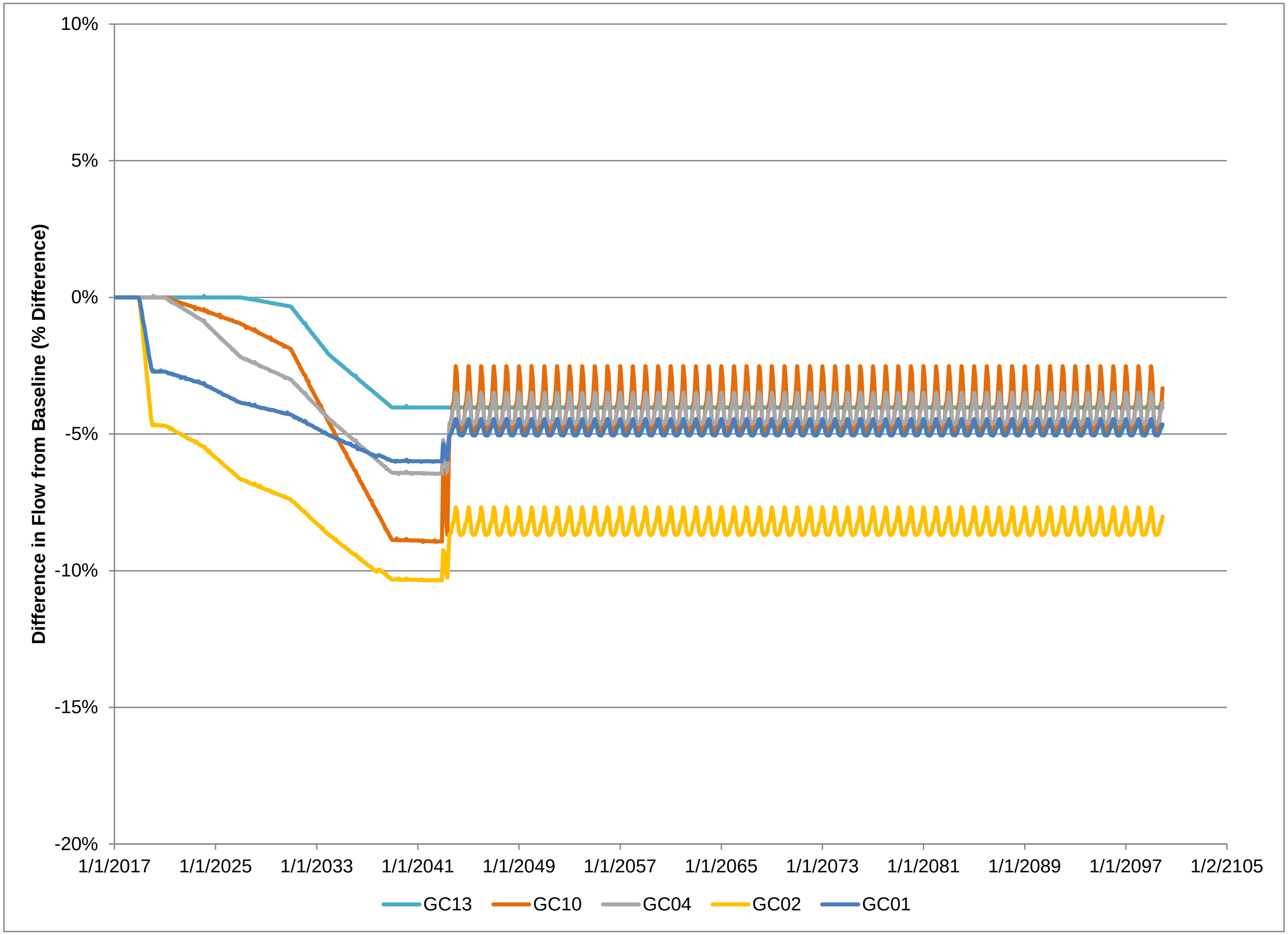
Filename: ModeledYears_Hydrology_JR_r1

Grassy Mountain Coal Project

Date: July 29, 2016

Approved: MC

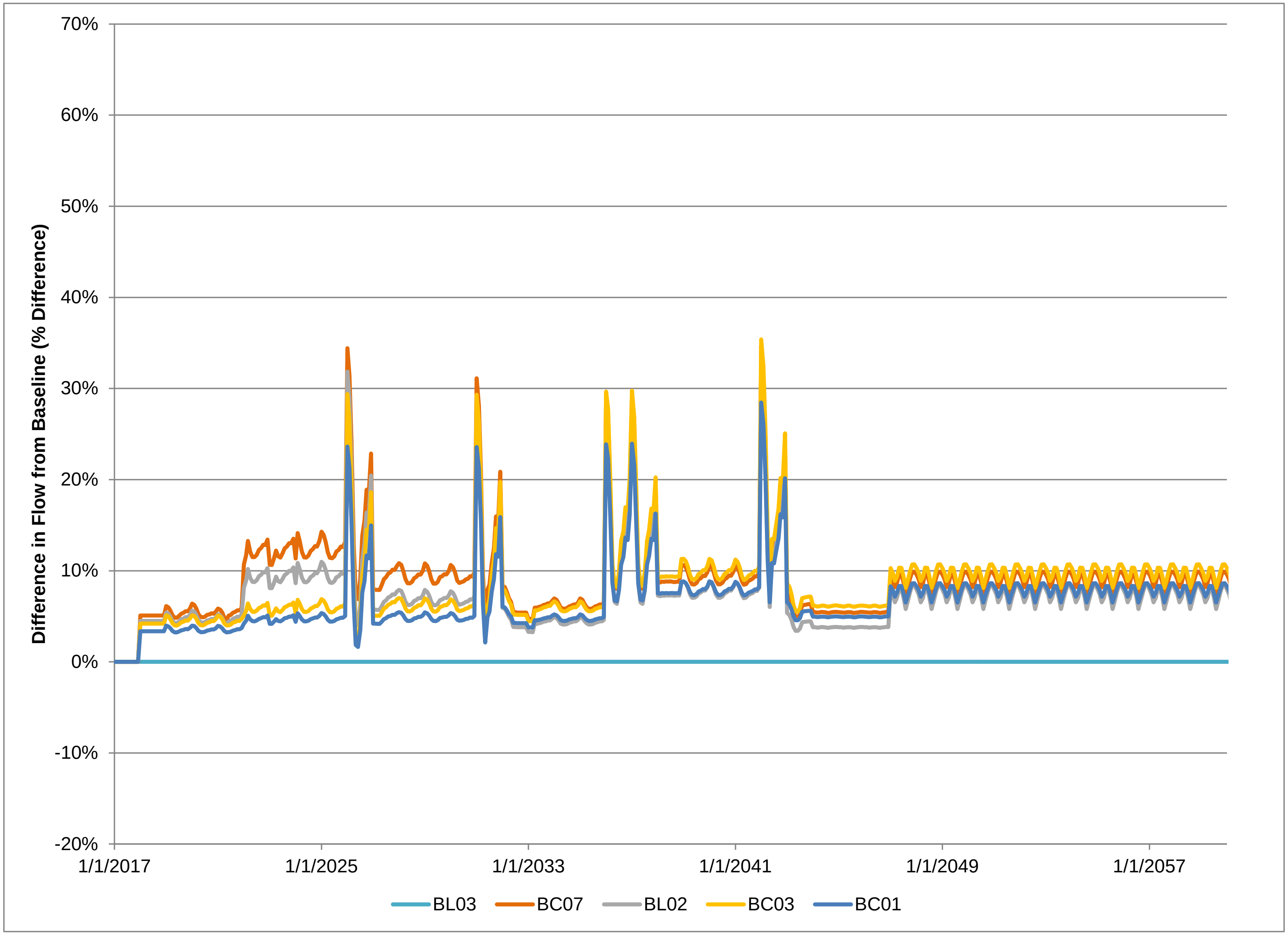
Figure: 42



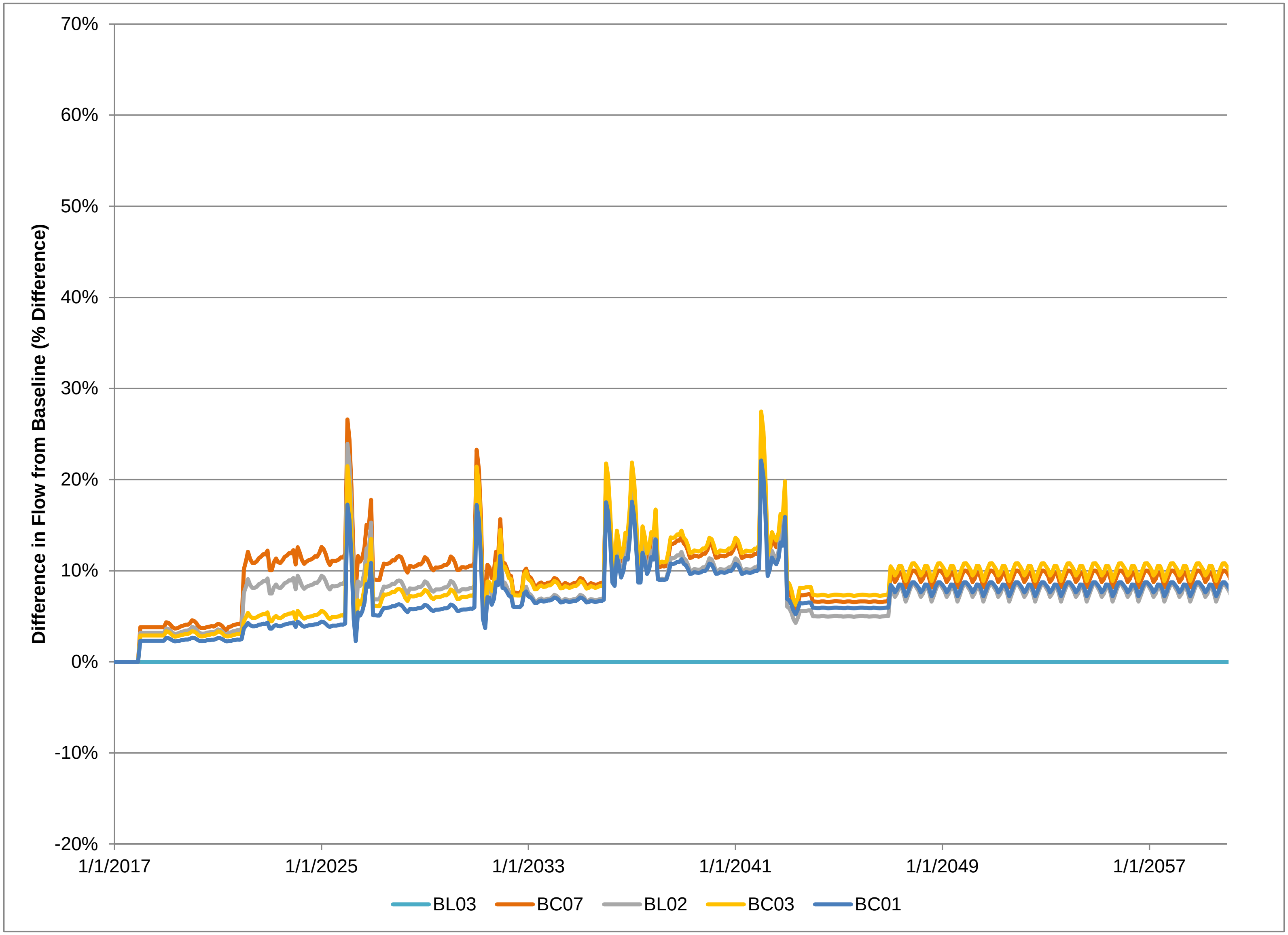
srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Estimated Flow Changes in Gold Creek w.r.t. Baseline Flow**
Job No: 1CM029.011 Filename: Figure_41_to_47_SRJ_20160808	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **43**

srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Estimated Flow Changes in Gold Creek w.r.t. Baseline Flow, 1 in 10 Dry Years (All Years)**
Job No: 1CM029.011 Filename: Figure_41_to_47_SRJ_20160808	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **44**

srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Estimated Flow Changes in Gold Creek w.r.t. Baseline Flow, 1 in 10 Wet Years (All Years)**
Job No: 1CM029.011 Filename: Figure_41_to_47_SRJ_20160808	Grassy Mountain Project	Date: August 2016 | Approved: SJ | Figure: **45**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment **Estimated Flow Changes in Blairmore Creek w.r.t. Baseline Flow, Average Flow Conditions**
Job No: 1CM029.011 Filename: Figure_41_to_47_SRJ_20160808	Grassy Mountain Project	Date: August 2016 / Approved: SJ / Figure: **46**



srk consulting

MILLENNIUM EMS Solutions Ltd.

Hydrology Impact Assessment

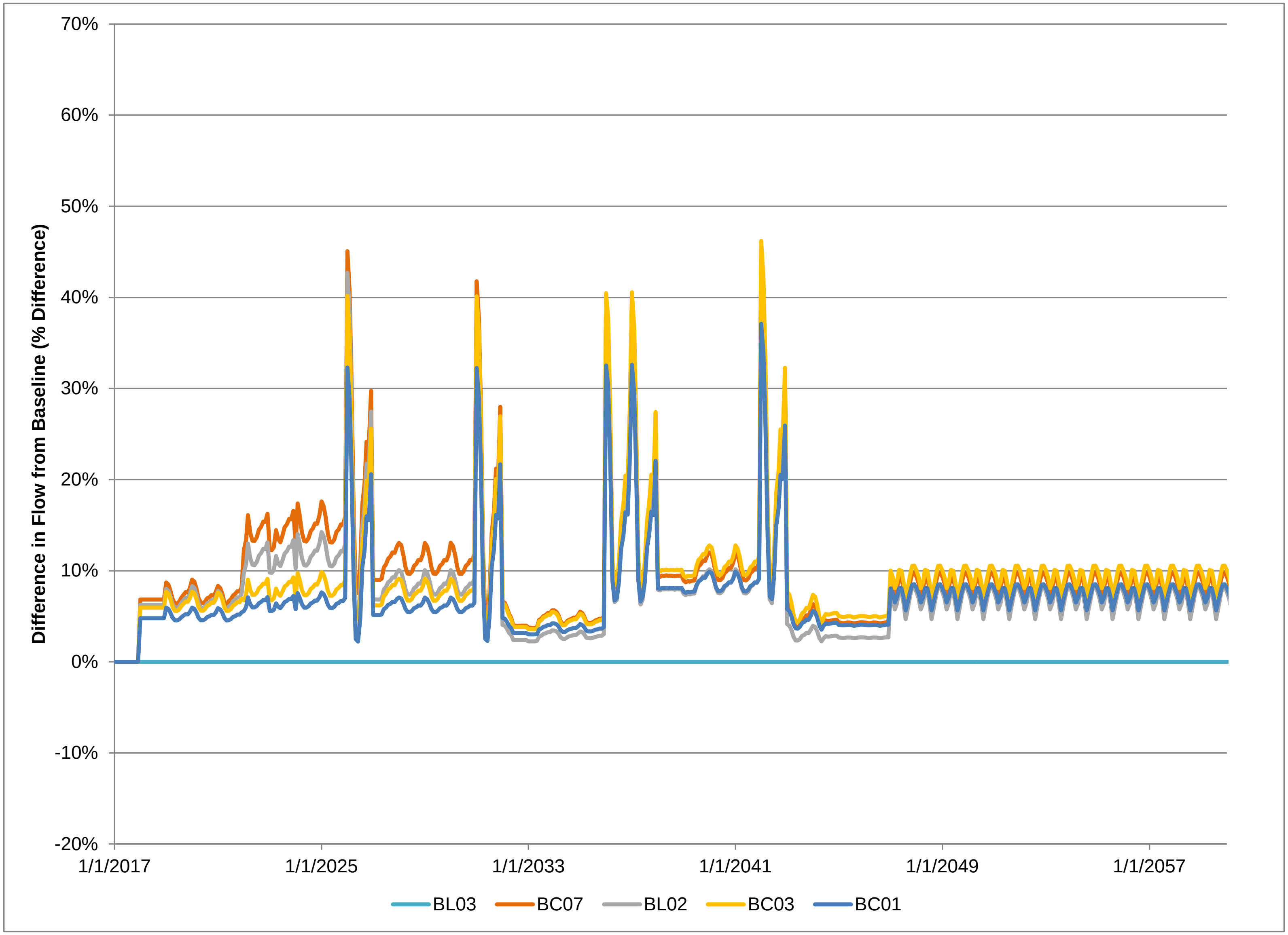
Estimated Flow Changes in Blairmore Creek w.r.t. Baseline Flow, 1 in 10 Dry Years (All Years)

Job No: 1CM029.011

Filename: Figure_41_to_47_SRJ_20160808

Grassy Mountain Project

Date:	Approved:	Figure:
August 2016	SJ	**47**



srk consulting	MILLENNIUM EMS Solutions Ltd.	Hydrology Impact Assessment
		Estimated Flow Changes in Blairmore Creek w.r.t. Baseline Flow, 1 in 10 Wet Years (All Years)
Job No: 1CM029.011 Filename: Figure_41_to_47_SRJ_20160808	Grassy Mountain Project	Date: August 2016 · Approved: SJ · Figure: **48**