Date:	March 21, 2016	**File:**	2015-8164
To:	Thompson Okanagan Regional Drought Response Team		
From:	Brian T. Guy, Ph.D., P.Geo.		
Project:	2015 drought response		
Subject:	Bessette, Duteau, and Creighton Creek watersheds: summary of water use, fisheries, and streamflow		

FINAL MEMO

This memo summarizes key information for the Bessette, Duteau, and Creighton Creek watersheds needed to support consideration of an order to restrict irrigation water withdrawals from surface water sources. Details of the methods, calculations, assumptions, and results supporting this summary document are provided in two attached documents (Associated 2016a; 2016b). Much of the information summarized in this memo is portrayed on Figures 1, 2, 3, and 4.

This is the final version of a draft memo provided to the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) on September 25, 2015. The technical information contained in the draft memo was used by FLNRO to support drought response initiatives up to end-September 2015. The format and content of the draft memo reflect FLNRO requirements at the time. The citation for the draft report is as follows:

- *Summit Environmental Consultants Inc. 2015. Bessette and Duteau Creek Watersheds: Summary of Water Use, Fisheries, and Streamflow. Prepared for the B.C. Ministry of Forests, Lands, and Natural Resource Operations, September 2015.*

Summit Environmental Consultants Inc. rebranded to Associated Environmental Consultants Inc. (Associated) in November 2015. As a result, this final memo is provided on Associated letterhead.

After end-September 2015 (i.e. after the draft memo had been used for operational purposes), FLNRO and the Okanagan Nation Alliance (ONA) reviewed and provided comments on it. All comments have been considered in preparation of this final memo. The largest change from the draft memo was the division of Bessette Creek watershed into the following sub-watersheds:

- Duteau Creek;
- Bessette Creek above Duteau Creek confluence;
- Creighton Creek; and
- Bessette Creek below Duteau Creek confluence.

This watershed division was requested by FLNRO and ONA (pers. comm., 2015)[1] and is reflected throughout this final memo. Outside of this change, none of the changes between the draft and final memos would have materially altered the decisions made by FLNRO that were based on the draft memo.

[1] B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) and Okanagan Nation Alliance (ONA). 2015. Personal Communications between Elinor McGrath (ONA), Richard McCleary (FLNRO), and Associated Environmental Consultants Inc. on December 8, 2015.

The critical flow thresholds included in this memo were recommended by FLNRO and represent the best information that was readily available to FLNRO during the summer of 2015. These values are subject to change based on additional information specific to the stream and each fish population and life history stage.

1 Overview of fisheries information for the Bessette, Duteau, and Creighton Creek watersheds

Bessette Creek Watershed

A summary of fish and fish habitat information for the Bessette Creek watershed is as follows:

- Eleven species of fish have been observed in Bessette Creek:
  - Chinook Salmon
  - Coho Salmon
  - Kokanee Salmon
  - Sockeye Salmon
  - Rainbow Trout
  - Sculpin spp.
  - Dace spp.
  - Sucker spp.
  - Mountain Whitefish
  - Redside Shiner
  - Northern Pikeminnow
- Since 2006, Denison Lakes have been stocked annually with between 300 and 1,000 Rainbow Trout.
- The watershed is of special conservation concern for Coho and Chinook Salmon.
- From a fishery value and water use perspective, the watershed remains one of DFO's and FLNRO's highest priorities within the Shuswap River watershed.
- The watershed is within the Okanagan and Secwepemc traditional territories and provides an important part of their First Nation culture.
- Rainbow Trout have been documented to spawn in Bessette Creek and Vance Creek (a tributary), and Kokanee Salmon spawning has been noted in a 6 km reach of Bessette Creek upstream from its confluence with the Shuswap River.
- Coho and Chinook Salmon have been observed by the ONA (during spawner surveys) to spawn within Bessette Creek from the mouth to the confluence of Blue Springs Creek. In addition, suitable Coho Salmon spawning and rearing habitat has also been identified for an additional 5 km upstream of the Blue Springs Creek confluence (FLNRO and ONA, pers. comm., 2015).
- It is not unusual during drought years for streamflows and temperature related fish-kill events to occur in Bessette Creek (upstream of Lumby), Creighton Creek and Duteau Creek. Fish kill events in Creighton Creek have served as an early indicator that problems may be developing in other streams in the region. Prudent and proactive water management by all licensees is important for preventing these events (Watts and Harding [DFO], pers. comm., 2015, as cited by FLNRO and ONA, pers. comm., 2015).

Duteau Creek Watershed

A summary of fish and fish habitat information for the Duteau Creek watershed is as follows:

- Nine species of fish have been observed in Duteau Creek:
  - Chinook Salmon
  - Coho Salmon
  - Sucker spp.
  - Mountain Whitefish

  - Sockeye Salmon
  - Rainbow Trout
  - Dace spp.
  - Brook Trout
  - Sculpin spp.
- The watershed is within the Okanagan and Secwepemc traditional territories and provides an important part of their First Nation culture.
- Within Duteau Creek, salmon have been identified to have access up to 10.8 km from the mouth to the Greater Vernon Water (GVW) Headgates Dam.
- Rainbow Trout spawning has been documented in the outflow from Aberdeen reservoir, and between Haddo Lake and Grizzly Swamp Dam. In addition, Heart Creek has been documented as a primary spawning and rearing location for Aberdeen reservoir Rainbow Trout, particularly at the confluence. Mabel Lake adfluvial rainbow trout access Duteau Creek upstream to the GVW Headgates Dam (FLNRO and ONA, pers. comm., 2015).
- Prime spawning and rearing habitat for Coho Salmon has been noted in Duteau Creek, from the confluence with Harris Creek, to approximately 10 km upstream. This stream is also used for Chinook spawning and rearing (FLNRO and ONA, pers. comm., 2015).
- In 1988, Vernon Irrigation District (VID) (now GVW) shut off downstream streamflows at the Headgates water intake, resulting in the dewatering of portions of Duteau Creek and a fish kill. Following this event, an order was issued to VID by Fisheries and Oceans Canada (DFO) to release a minimum of 0.141 m^3/s downstream from the Headgates water intake to ensure sufficient flow for salmon spawning in Duteau Creek. Subsequent to this, an agreement was established between GVW and DFO which outlined fish flow releases at the Headgates water intake based on time of year.
- On July 29, 2015, at 12:15 pm flows in Duteau Creek were measured at 0.062 m^3/s at Whitevale Road. Flows downstream from the irrigation pumphouse located 100 m downstream were further reduced to approximately 0.040 m^3/s. Fish mortalities were expected but not directly observed. At approximately 1:00 pm flows suddenly recovered to the range of target fish flow release levels. GVW was contacted and corrected the operating procedure to prevent further occurrences (FLNRO and ONA, pers. comm., 2015).

Creighton Creek Watershed

A summary of fish and fish habitat information for the Creighton Creek watershed is as follows:

- Nine species of fish have been observed in Creighton Creek:
  - Chinook Salmon
  - Coho Salmon
  - Sockeye Salmon
  - Rainbow Trout
  - Dace spp.
  - Sucker spp.
  - Mountain Whitefish
  - Brook Trout
  - Sculpin spp.
- The watershed is of special conservation concern for Coho and Chinook Salmon (FLNRO and ONA, pers. comm., 2015).
- The watershed is within the Okanagan and Secwepemc traditional territories and provides an important part of their First Nation culture.

- Important Coho Salmon spawning grounds have been identified and spawning salmon have been observed within the lower reaches of Creighton Creek from the mouth to above 401 Creighton Valley Road (MOE 2015a; FLNRO and ONA, pers. comm., 2015).
- Low summer streamflows resulting from high water demand and irrigation have frequently been documented in Creighton Creek, limiting rearing and spawning potential for salmonids.
- No drought-related fish kills have been reported for the Creighton Creek watershed.

2 Current situation

FLNRO identified the hydrometric stations on Bessette Creek near Lumby (WSC 08LC005), Bessette Creek above Beaverjack Creek (08LC039), and Duteau Creek near Lavington (WSC 08LC006) as the ones being used for analysis of streamflow and fish-at-risk. Real-time data is not available for two of these stations since they have been discontinued; however, FLNRO collected field discharge measurements at Bessette Creek near Lumby and Duteau Creek near Lavington, as well as at the mouth of Creighton Creek[2] in July, August, and September 2015 in support of the 2015 drought response effort. Real-time data is available for Bessette Creek above Beaverjack Creek (08LC039), while FLNRO operated their own hydrometric station at Duteau Creek near Lavington in 2015[3]. Based on the latest flow measurements obtained by FLNRO (mid-September 2015) in both Bessette and Duteau Creeks, streamflows were close to, or above the median recorded flows (Figures 1 and 2). The measurements collected at Creighton Creek could not be compared to historic recorded flows, since a hydrometric station (WSC or other) has not been located here in the past.

3 Why the current situation is a problem for fish

- Of the salmon species, Chinook Salmon typically spawn first and are therefore most likely to have spawning affected during the irrigation period. The spawning window for Chinook Salmon in Bessette Creek begins in early September and extends until the middle of October. Spawners may enter the creek as early as the beginning of August. In Duteau Creek, the spawning window for Chinook Salmon begins September 1 and extends until September 30. However, Coho Salmon typically spawn later in the season (mid-October to late November or even into December in both watersheds).
- Critical flow thresholds for Chinook Salmon rearing and spawning for Bessette and Creighton Creeks are shown in Figure 1 and Figure 2.
- For Duteau Creek (Figure 2), the critical flow thresholds were assumed to equal the fish flows releases from the Headgates Dam water intake for the period of April 1 – August 31 (rearing) and September 1 – September 30 (spawning). This approach assumes that the GVW and DFO agreed upon fish flow releases consider all fish species and meet the needs of the critical life stages for each of the focal species.

[2] Field discharge measurements were collected at the location identified as habitat transect 'Creighton Lower (CRE 2)' in Trout Creek Hydrology & Soils (2014).

[3] FLNRO identified that the station operated in 2015 was located near the Whitevale Road crossing of Duteau Creek, which is assumed to be at the same location as the discontinued WSC station 08LC006.

- Based on the discharge measurements collected by FLNRO in September 2015, the following observations are made:
    - Streamflow in Bessette Creek (at WSC 08LC005) was last measured on September 18, 2015. At the time, streamflow was above the critical flow threshold for Chinook Salmon rearing, but below the critical flow threshold for Chinook Salmon spawning;
    - Streamflow in Bessette Creek (at WSC 08LC039) was last measured on September 14, 2015. At the time, streamflow was above the critical flow threshold for both Chinook Salmon rearing and spawning;
    - Streamflow in Duteau Creek (at WSC 08LC006) was last measured on September 14, 2015. At the time, streamflow was above the GVW and DFO agreed upon fish flow releases from the Headgates Dam water intake; and
    - Streamflow in Creighton Creek at the mouth was last measured on September 2, 2015. At the time, streamflow was above the critical flow threshold for Chinook Salmon rearing, but below the critical flow threshold for Chinook Salmon spawning.
- Predicted streamflows for Bessette Creek (Figure 3), based on the 52nd percentile flows (at WSC 08LC005) and the 48th percentile flows (at 08LC039), suggest the following:
    - Streamflows will likely increase throughout the remainder of September 2015.
    - Streamflows are likely to remain above the instream flow target for Chinook Salmon rearing until the end of September 2015. At WSC 08LC039 (i.e. Bessette Creek below Duteau confluence), streamflows are expected to remain close to, or above the critical flow threshold for Chinook Salmon spawning for the remainder of the irrigation season, regardless of whether or not water restrictions are enforced. At WSC 08LC005 (i.e. Bessette Creek above Duteau confluence), streamflows are expected to remain below the critical flow threshold for Chinook Salmon spawning, regardless of water restrictions.
- Within Duteau Creek, assuming that GVW continues to release the agreed upon flows from the Headgates Dam water intake (at a minimum) for the remainder of the irrigation season, it is expected that streamflows will remain at or above the critical flow thresholds (Figure 4).
    - However, it is recommended that the operational flow release program at the Headgates Dam water intake be confirmed with GVW to confirm the agreed upon flow releases. It is currently unclear how the flow releases relate to critical life stage requirements within the creek; therefore, a further understanding should be gained regarding how the agreed upon flow releases at the water intake meet the needs of all (or selected) fish-at-risk downstream from the water intake and specifically at Duteau Creek near Lavington (i.e. at WSC 08LC006).
- It is not possible to provide future streamflow estimates for the location at which 2015 field measurements were taken within Creighton Creek. However, Figure 4 shows that if water restrictions were enforced prior to September 2, 2015, streamflows in Creighton Creek at the mouth would have exceeded the critical flow threshold for Chinook Salmon rearing, and been close to, or above the threshold for Chinook Salmon spawning. However, flows measured on September 2, 2015 within Creighton Creek exceeded the critical flow threshold for Chinook Salmon rearing, regardless of irrigation water use.

4 Is water use contributing to the current problem?

In an average year, irrigation from surface water sources removes the following estimated water quantities from each of the sub-watersheds:

- Duteau Creek: 0.502 m^3/s in July, 0.405 m^3/s in August, and 0.214 m^3/s in September;
- Bessette Creek above Duteau confluence: 0.201 m^3/s in July, 0.162 m^3/s in August, and 0.086 m^3/s in September;
- Creighton Creek: 0.156 m^3/s in July, 0.126 m^3/s in August, and 0.067 m^3/s in September; and
- Bessette Creek below Duteau confluence: 0.490 m^3/s in July, 0.396 m^3/s in August, and 0.209 m^3/s in September.

Accordingly, irrigation withdrawals from surface water sources are causing flow reductions in Bessette, Duteau, and Creighton Creeks.

5 Benefits of restricting irrigation from surface water sources

- If restrictions were placed on irrigation from surface sources, the following predictions are made:
    - Bessette Creek above Duteau confluence: Streamflows will likely remain below the critical flow threshold for Chinook Salmon spawning, but above the flow target for Chinook Salmon rearing.
    - Bessette Creek below Duteau confluence: If water use restrictions are implemented throughout the entirety of Bessette Creek, Duteau Creek, and Creighton Creek, streamflows will likely be substantially increased. However, it does not appear that water use restrictions are required to maintain flows above the critical flow thresholds for both Chinook Salmon rearing and spawning at Bessette Creek above Beaverjack Creek (i.e. at WSC station 08LB039).
    - Duteau Creek: Assuming that GVW continues to maintain their flow releases from the Headgates Dam water intake, streamflows are expected to remain at or above the critical flow thresholds (at a minimum). However, to properly comment on Duteau Creek streamflows and critical flow thresholds, it is recommended that the flow release rates and timing be confirmed with GVW and an understanding be gained on how the flow releases meet the needs of fish-at-risk downstream.
    - Creighton Creek: Due to the absence of historic streamflow records at the mouth of Creighton Creek, it is not possible to provide a conclusion on the impact of future irrigation water use restrictions for Creighton Creek at this time. However, if streamflows remain at the level observed on September 2, 2015, for the remainder of the irrigation season, streamflows will exceed the critical flow thresholds for Chinook Salmon rearing, regardless of whether or not water restrictions are applied. If water restrictions are applied, it is anticipated that streamflows would exceed the critical flow thresholds for Chinook Salmon spawning.
- For all creeks, the implementation of water restrictions would likely result in a small reduction in water temperatures and small improvements in the existing fish habitat (e.g. deeper pools, higher velocity riffles).

6 Final considerations

The calculations and estimates provided in this memo are based on several assumptions as outlined herein. Key assumptions for Bessette Creek watershed include that streamflows during the remainder of the irrigation season follow the trend of the 52nd percentile; the lands irrigated, crop types, and irrigation water sources identified by the Ministry of Agriculture in 2014 are consistent with current land practices; that irrigation demands will occur at average rates, and will follow the pattern of a typical year, for the remainder of the 2015 irrigation season; and that all irrigators are currently irrigating and will continue to do so through the end of the 2015 irrigation season. For Duteau Creek watershed, it was assumed that fisheries flow releases at the GVW's Headgates water intake were constant and sufficient to meet focal species critical life stages.

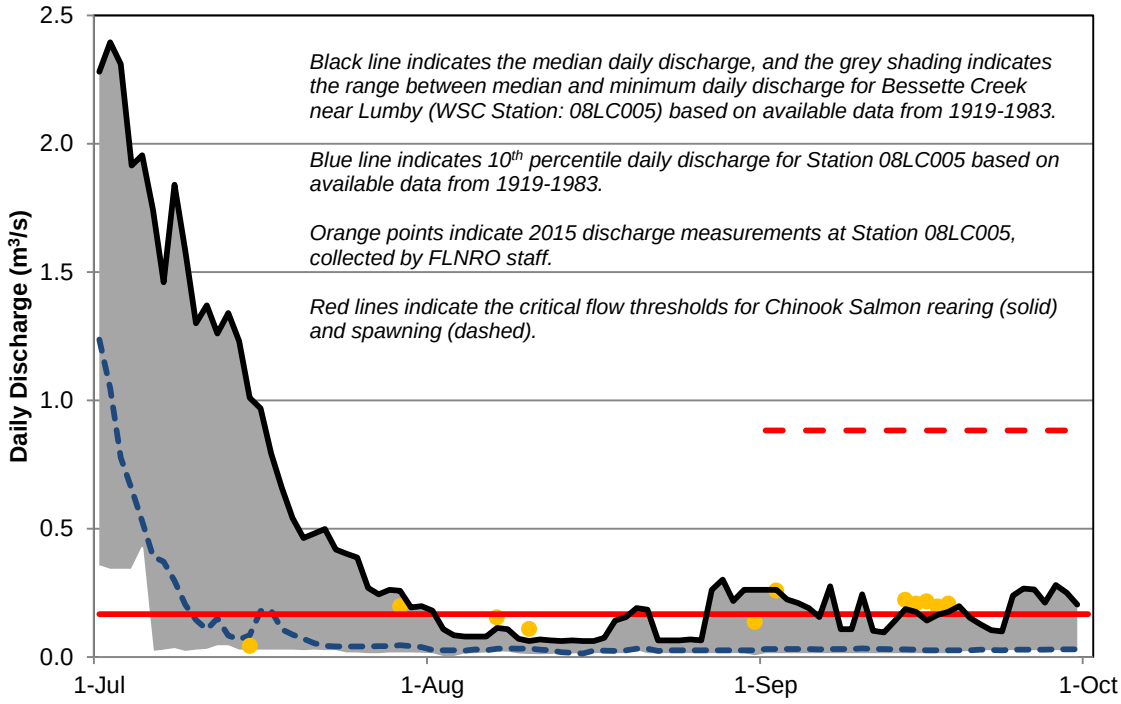
It is recommended that before seeking to restrict water use, FLNRO continues to obtain site-specific field-based information to determine or confirm current conditions in the affected areas.

Acknowledgements
Funding for this project was provided by FLNRO to identify science-based options for responding to a Level 4 drought emergency in 2015 that impacted streamflow in many watersheds that support important fish populations in the Thompson-Okanagan Region. Additional funding for the Bessette Creek watershed was provided through the Habitat Conservation Trust Fund – Thompson Shuswap Okanagan Instream Conservation Flows Project.

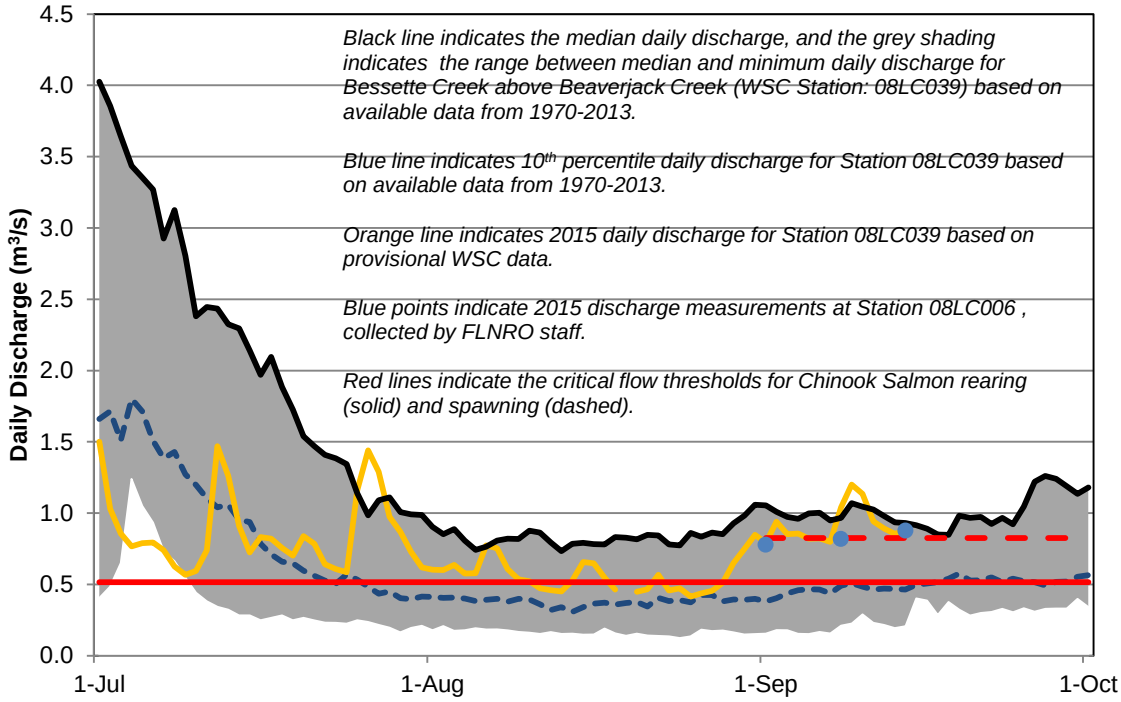
The terms of reference for the irrigation water demand component of the project were developed collaboratively by FLNRO (Richard McCleary), Ministry of Agriculture (Andrew Petersen and Geoff Hughes-Games) and Associated Environment Consultants Inc. (Brian Guy, Hugh Hamilton, and Drew Lejbak).

Attachments:

- Figure 1: Current year and historical flow comparison for select Water Survey of Canada (WSC) stations within the Bessette Creek watershed
- Figure 2: Current year and historical flow comparison for select Water Survey of Canada (WSC) stations within Duteau and Creighton Creek watersheds
- Figure 3: Measured and estimated streamflows for Bessette Creek near Lumby (WSC 08LC005), July 1 to September 30, 2015
- Figure 4: 2015 flow estimates for select Water Survey of Canada (WSC) stations within Duteau and Creighton Creek watersheds
- Associated 2016a: letter to Thompson-Okanagan Regional Drought Response Team dated March 21, 2016 re: Irrigation Water Demands – Bessette, Duteau, and Creighton Creek Watersheds.
- Associated 2016b: letter to Thompson-Okanagan Regional Drought Response Team dated March 21, 2016 re: Overview of Fish Populations at Risk: Bessette, Duteau, and Creighton Creek Watersheds.



A) Current year and historical flow comparisons for Bessette Creek near Lumby (WSC Station: 08LC005).



B) Current year and historical flow comparisons for Bessette Creek above Beaverjack Creek (WSC Station: 08LC039).

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DATE: **FEBRUARY 2016**

DRAWN BY: **LB**

Figure 1 – Current year and historical flow comparisons for select Water Survey of Canada (WSC) stations within the Bessette Creek watershed.

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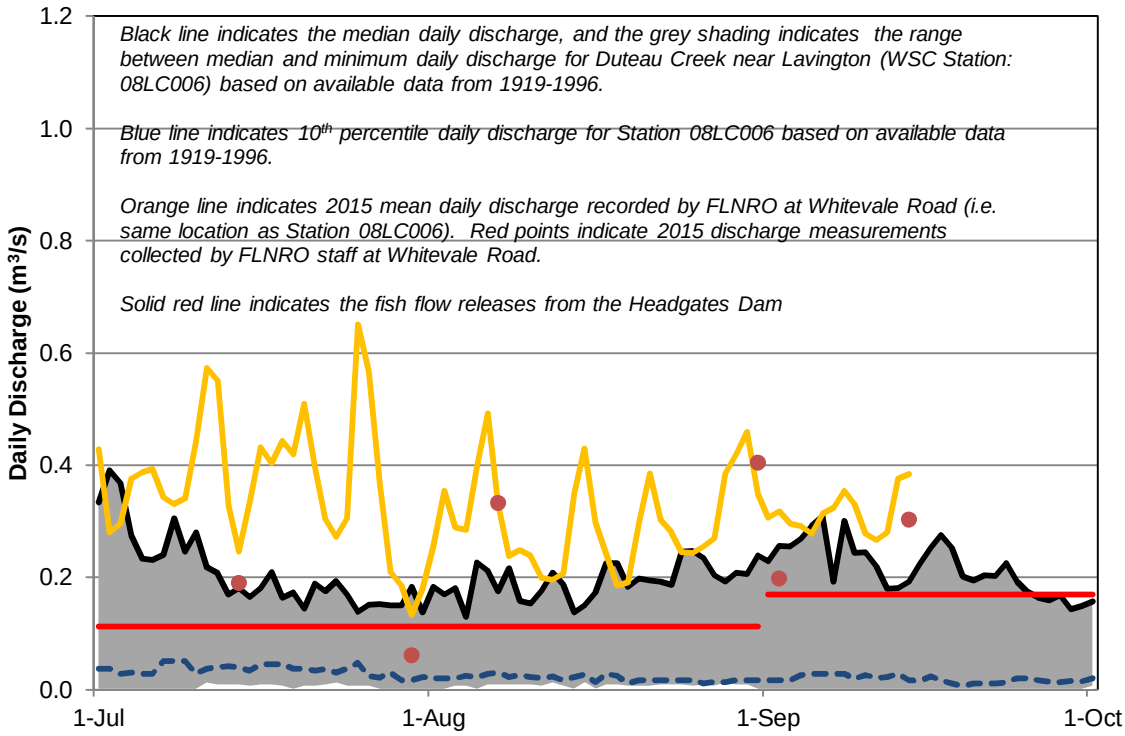
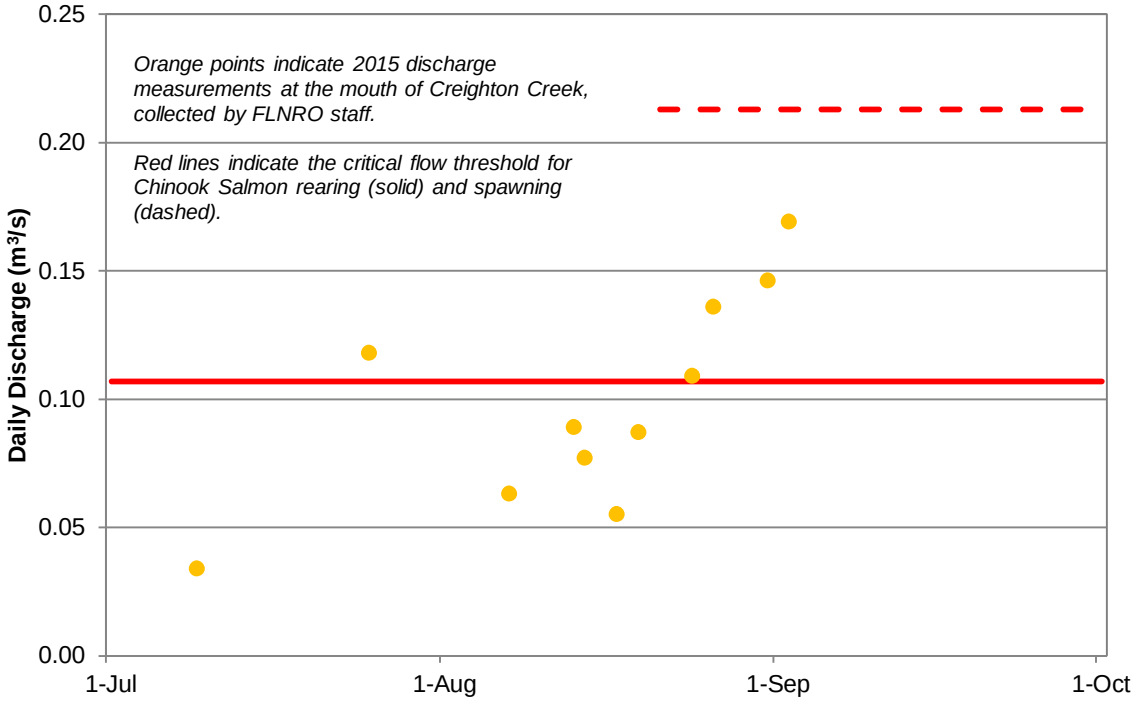
Ministry of Forests, Lands, and Natural Resource Operations



A) Current year and historical flow comparisons for Duteau Creek near Lavington (WSC Station: 08LC006).



B) Current year flow measurements for Creighton Creek at the mouth.

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Figure 2 – Current year and historical flow comparisons for select Water Survey of Canada (WSC) stations within Duteau and Creighton Creek watersheds.

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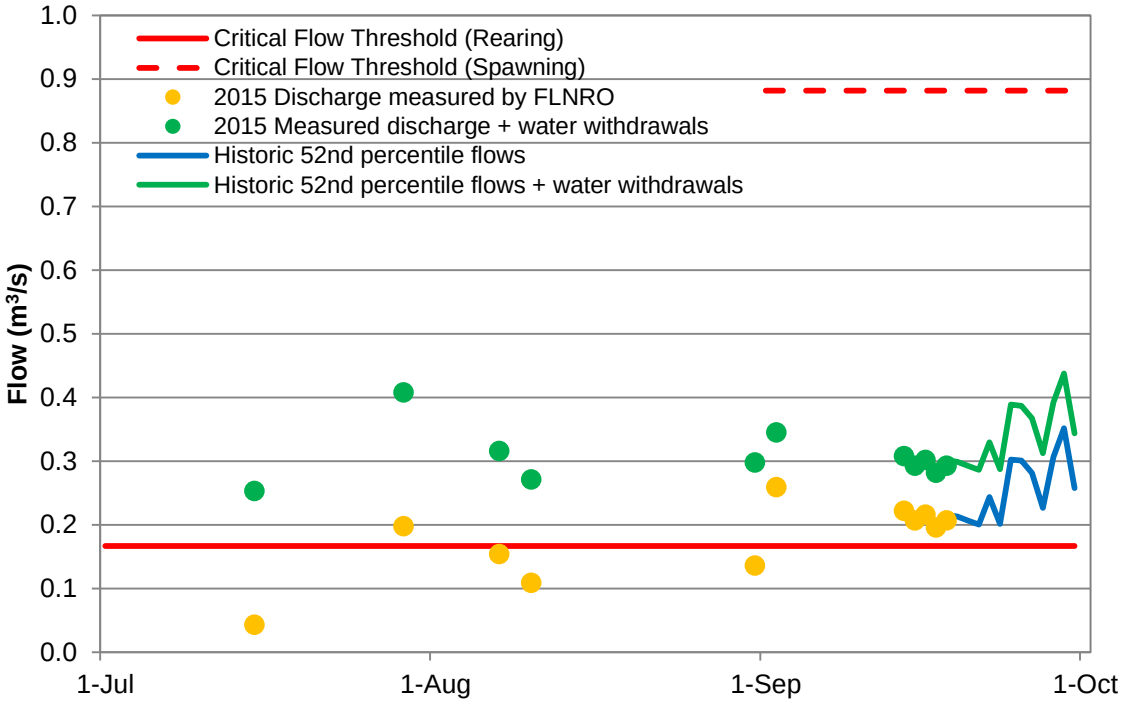
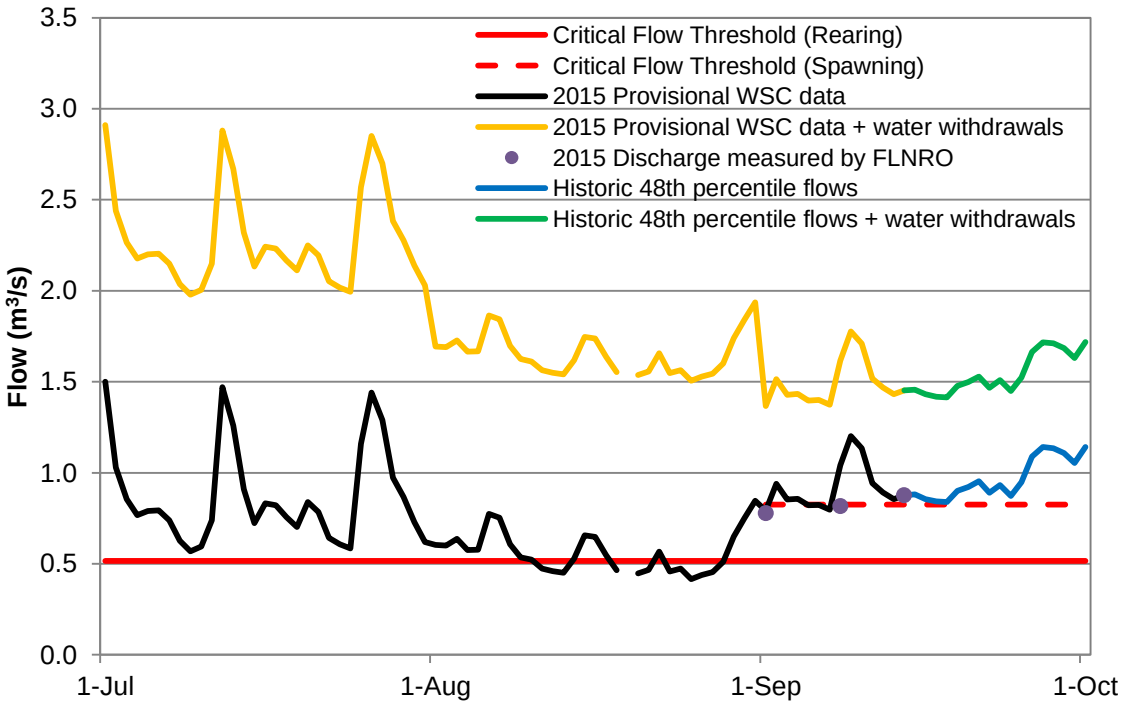


A) Measured and estimated streamflows for Bessette Creek near Lumby (WSC Station: 08LC005), July 1 to September 30, 2015.



B) Measured and estimated streamflows for Bessette Creek above Beaverjack Creek (WSC Station: 08LC039), July 1 to October 1, 2015.

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Figure 3 – 2015 flow estimates for select Water Survey of Canada (WSC) stations within the Bessette Creek watershed.

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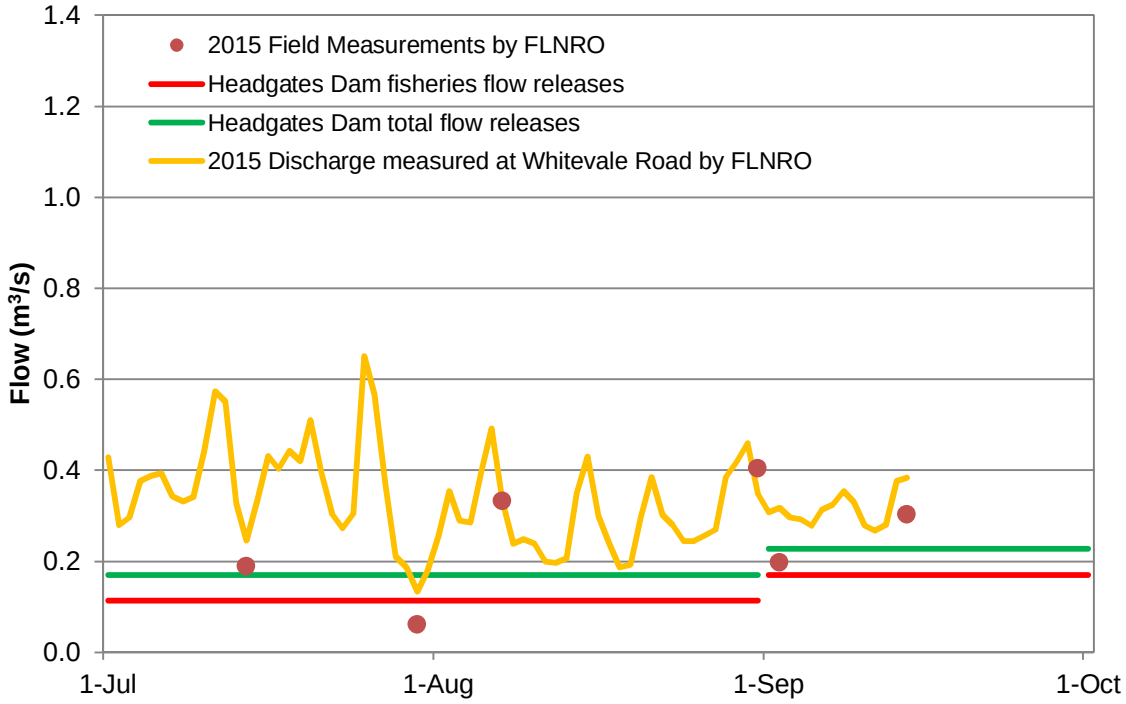
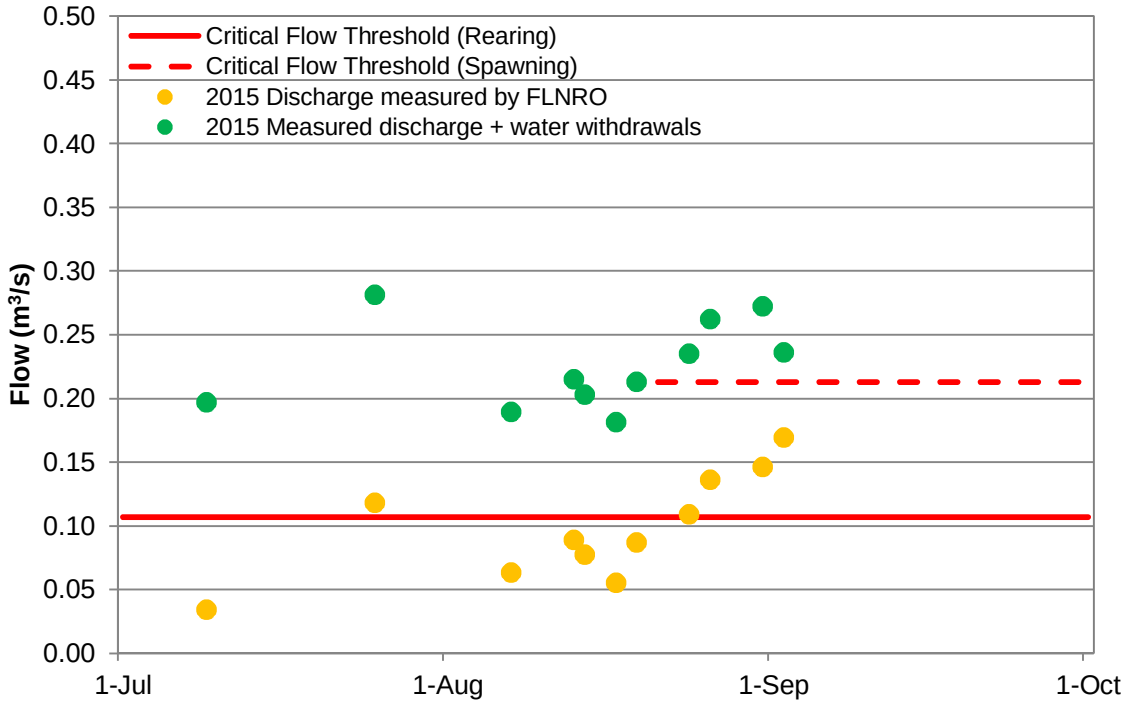


A) Measured streamflows for Duteau Creek near Lavington (WSC Station: 08LC006) and minimum future flow releases from the GVW Headgates water intake, July 1 to October 1, 2015.



B) Measured streamflows for Creighton Creek at the mouth.

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Figure 3-2 – 2015 flow estimates for Duteau and Creighton Creek watersheds.

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Prepared for: **Ministry of Forests, Lands and Natural Resource Operations**

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Thompson-Okanagan Regional Drought Response Team
B.C. Ministry of Forests, Lands, and Natural Resource Operations
Thompson-Okanagan Region
1259 Dalhousie Drive
Kamloops, B.C., V2C 5Z5

Re: IRRIGATION WATER DEMANDS - BESSETTE, DUTEAU, AND CREIGHTON CREEK WATERSHEDS

Dear Thompson-Okanagan Regional Drought Response Team:

In support of B.C. Ministry of Forests, Lands, and Natural Resource Operations' 2015 water management initiatives, this letter provides water demand information for Bessette, Duteau, and Creighton Creek watersheds.

This is the final version of a draft report provided to the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) on August 23, 2015. The technical information contained in the draft report was used by FLNRO to support drought response initiatives up to end-September 2015. The format and content of the draft report reflect FLNRO requirements at the time. The citation for the draft report is as follows:

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Summit Environmental Consultants Inc. rebranded to Associated Environmental Consultants Inc. (Associated) in November 2015. As a result, this final report is provided on Associated letterhead.

After end-September 2015 (i.e. after the draft report had been used for operational purposes), FLNRO and the Okanagan Nation Alliance (ONA) reviewed and provided comments on it. All comments have been considered in preparation of this final report. The largest change from the draft report was that Bessette Creek was considered as one watershed in the draft report, but it has now been divided into the following sub-watersheds:

- Duteau Creek;
- Bessette Creek above Duteau Creek confluence;
- Creighton Creek; and
- Bessette Creek below Duteau Creek confluence.

This watershed division updated was requested by FLNRO and ONA (pers. comm., 2015)[1] and is reflected throughout this final report.

[1] B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) and Okanagan Nation Alliance (ONA). 2015. Personal Communications between Elinor McGrath (ONA), Richard McCleary (FLNRO), and Associated Environmental Consultants Inc. on December 8, 2015.

Finally, the Ministry of Agriculture has not developed an Agriculture Water Demand Model (AWDM) for the Bessette, Duteau, and Creighton Creek watersheds. As a result, irrigation water demands estimated herein were calculated following the approach outlined in Section 2. In the future, if an AWDM is developed for these watersheds, it is recommended that similar future work make use of the AWDM.

1 OBJECTIVES

The objectives of the work were as follows:

- Obtain and review relevant existing information on water use within the Bessette, Duteau, and Creighton Creek watersheds, and determine the extent to which existing information is sufficient for the purposes of this assignment;
- Identify areas (map polygons) of irrigated land and calculate the area under irrigation, categorized by crop where feasible;
- Estimate the actual water demand from the irrigated area for the remainder of the 2015 irrigation season and for the 1981-2010 normal period (if available); and
- If possible, estimate the fraction of the total irrigation water demand supplied from surface water and the total supplied from groundwater.

The following sub-watersheds with the Bessette Creek watershed were identified by FLNRO and ONA (pers. comm., 2015) to support water management initiatives:

- Duteau Creek;
- Bessette Creek above Duteau Creek confluence[2];
- Creighton Creek; and
- Bessette Creek below Duteau Creek confluence.

The boundaries of the four sub-watersheds are outlined in Figure 1-1 (attached). Registered irrigation groundwater wells and water licences for irrigation purposes available from provincial databases are also shown on Figure 1-1.

2 METHODS

2.1 GENERAL STEPS

We undertook the following steps in completing this assignment:

Literature review:

- Conducted a literature review to identify previous water demand information, augmented with telephone discussions with Ministry of Agriculture staff.

Determination of Irrigated Area:

- Obtained Agricultural Land Use Inventory (ALUI) and accompanying GIS files from the Ministry of Agriculture (MOA) that included, for each agricultural polygon, the crop type, irrigation type, source of irrigation water (i.e. surface or groundwater), and whether the agricultural lands are currently under irrigation. Further details on the use of this data are provided in Section 2.

[2] In some literature, this sub-watershed is sub-divided into Harris and Nicklen Creeks.

- Mapped locations of points of diversion associated with irrigation water licences in the watersheds, and mapped water wells used for irrigation.

Estimation of Irrigation Water Demand:

- Computed evapotranspiration for a reference crop (ET_o) (i.e. grass) and for other crop types within each watershed on a daily basis for the irrigation season (i.e. April – September) for the most recent normal period (1981-2010), and for 2015 (to July 31st) using standard methods based on UN Food and Agriculture Organization (FAO) guidelines. This method is consistent with the computation procedure used by the MOA Agriculture Water Demand Models.
- Estimated the daily irrigation demand for the irrigation season based on the crop evapotranspiration (ET_c) estimates for the range of crop and irrigation types in the irrigated areas for the normal period (1981-2010) and for 2015 (to July 31st). Further details on the estimation method are provided in Section 2.3.

Groundwater vs Surface Water:

- Based on the ALUI dataset, estimated the relative irrigation demand supplied by surface water and groundwater for agricultural areas within each watershed.

2.2 AGRICULTURE LAND USE INFORMATION

The Agriculture Land Use Inventory (ALUI) for the Bessette, Duteau, and Creighton Creek watersheds was obtained from the Ministry of Agriculture (MOA). The land use information is housed in a GIS database that contains cadastre information (showing the boundaries of land ownership), primary and secondary crop types, and irrigation system type. Also, for each delineated area, the MOA has linked irrigation to a specific water source type (i.e. surface water or groundwater). The information was assembled from background information as well as high resolution orthophotos and GIS, which was based on surveys completed in 2014.

This GIS database provides the best information on current agricultural land practices within Bessette, Duteau, and Creighton Creek watersheds and it was therefore used as a primary data source to support the estimation of irrigation water demands.

2.3 IRRIGATION WATER DEMANDS

The estimation of irrigation water demands for the Bessette, Duteau, and Creighton Creek watersheds followed the methods outlined by van der Gulik et al. (2013)[3] and the Farmwest website. The estimates were based on the standard reference crop (grass) and climate data from the Environment Canada Vernon North station. Because the focus of the present assignment is estimation of irrigation demand in August and September 2015, it was assumed that irrigation water demand is equivalent to the Irrigation Requirement (IR) (as defined by van der Gulik et al. [2013]), based on the crop evapotranspiration (ET_c). This approach does not consider precipitation because after accounting for the reduction to "Effective Precipitation"[4], there is normally negligible rainfall left in August and September to offset the irrigation demand. This is consistent with Farmwest.

[3] van der Gulik, T., Neilsen, D., Fretwell, R., Petersen, A., and S. Tam. 2013. 2013. Agriculture Water Demand Model – Report for the North Thompson. May 2013.

[4] Effective precipitation (EP) is estimated by MOA as: EP = (Daily P – 5) x 0.75.

ET_c is estimated as follows:

$$ET_c = ET_o \times K_c \quad \textbf{Eq.1}$$

where:

ET_c = crop evapotranspiration for a specific crop type (mm);
ET_o = reference evapotranspiration for a grass crop (mm); and
K_c = crop coefficient from standard B.C. Ministry of Agriculture, Food, and Fisheries (MAFF) (2001)[5] tables.

The ET_c was then adjusted to account for irrigation efficiency, yielding the Irrigation Requirement (IR), i.e. the irrigation water demand:

$$IR = ET_c \div I_e \quad \textbf{Eq. 2}$$

where:

I_e = irrigation efficiency factor obtained from tables published by the Ministry of Agriculture (2005a[6]; 2005b[7]).

The estimation process was as follows:

- Calculation of ET_o and ET_c followed the guidelines for computing crop water requirements (MAFF 2001). Air temperature and precipitation for each sub-watershed was assumed to be represented by the meteorological data collected at the Vernon North climate station[8] (Station No. 1128583; Elevation = 512 m) (Figure 1-1);
- Within all sub-watersheds, forage (hay) is the dominant crop type (Section 3.2). Therefore, the crop distribution was considered 100% hay and the K_c value used for hay was 1.0 throughout the growing season for all watersheds (MAFF 2001).
- The irrigation efficiency value (I_e) was the weighted average of the irrigation types[9] in the ALUI dataset, weighted by irrigated area. The irrigation efficiency value for each sub-watershed was as follows:
    - I_e = 0.64 for Duteau Creek watershed based on 'sprinkler', and 'gun' irrigation types serviced by surface water;
    - I_e = 0.69 for Bessette Creek above Duteau Creek confluence watershed based on 'sprinkler' and 'gun' irrigation types serviced by surface water;

[5] B.C. Ministry of Agriculture, Food, and Fisheries (MAFF). 2001. Crop Coefficients for Use in Irrigation Scheduling. Water Conservation Fact Sheet. Order No. 577.100-5.

[6] Ministry of Agriculture. 2005a. Determining Actual Annual Water Use of Sprinkler Irrigation Systems. Water Conservation Fact Sheet. Order No. 577.100-9.

[7] Ministry of Agriculture. 2005b. Determining Actual Annual Water Use of Trickle Irrigation Systems. Water Conservation Fact Sheet. Order No. 577.100-10.

[8] The 1981-2010 climate normals published by Environment Canada for the Vernon North climate station are based on data from 1990-2007.

[9] In the ALUI dataset there is no record of drip irrigation in use in the areas serviced by surface water in either watershed.

- I_e = 0.70 for Bessette Creek below Duteau Creek confluence watershed based on 'sprinkler' and 'gun' irrigation types serviced by surface water;
- I_e = 0.70 for Creighton Creek watershed based on 'sprinkler' and 'gun' irrigation types serviced by surface water.

The irrigation estimates generated for this report were based on simplifying assumptions of soils with a consistent texture, rooting depth, and a consistent soil moisture content at the end of July. This approach has been used in MOA's water demand modeling in situations where digital soil information is not available and, at the scale of the Bessette, Duteau, and Creighton Creek watersheds, is not expected to have a significant influence on the estimated August and September irrigation demand.

3 RESULTS

This section provides a summary of the lands under irrigation and the corresponding water demands within each of the sub-watersheds.

3.1 LITERATURE REVIEW

We reviewed available public databases (e.g. Ecological Reports Catalogue) and found relevant information on irrigation water demands for all sub-watersheds. This information is summarized below.

Bessette Creek Watershed
Anthony (1975)[10] identified that the entire Bessette Creek watershed (including Duteau and Creighton Creek watersheds) has a total of 78.2 km^2 of irrigated and potential irrigable land. Anthony (1975) also identified that at the time of reporting (in 1975), the major crop types were alfalfa and alfalfa-grass mixtures for hay and that 12.6 km^2 (16%) of lands within the watershed were being irrigated.

In addition, Golder (2012)[11] summarized the high volume water licences by purpose and by selected sub-watershed within Bessette Creek watershed (Table 3-1). Note that Table 3-1 is not an exhaustive summary of water licences for the entire Bessette Creek watershed. Golder (2012) also reported that for the entire Bessette Creek watershed, current water use equates to 18.5% of the mean annual discharge.

[10] Anthony, E. D. 1975. Report of the Bessette Creek Watershed. August 1975.

[11] Golder Associates Ltd. (Golder). 2012. Phase 1: Shuswap River Watershed Sustainability Plan – Technical Assessment of the Shuswap River Watershed. Prepared for the Regional District of North Okanagan, February 2012.

Table 3-1 Summary of high volume water licences by purpose for select sub-watersheds within the Bessette Creek watershed (from Golder [2012])

Sub-watershed	Irrigation (Private) (ML/yr)	Local Storage (Private)[1] (ML/yr)	Irrigation (Local Authority) (ML/yr)	Waterworks (Local Authority) (ML/yr)	Waterworks (Local Authority) Storage[1] (ML/yr)
Duteau Creek	659	-	21,995	4,210	32,885
Bessette Creek (above Lumby)[2]	979	822	9,868	-	-
Vance Creek	817	-	-	253	274
Creighton Creek	2,145	142	-	-	-
Bessette Creek (below Lumby)[2]	1,776	4	-	-	-
Total Watershed	6,376	968	31,863	4,463	33,159

Note:
1. Golder (2012) identified that 'local storage' refers to the relatively small volume of storage associated with an individual's irrigation license and 'waterworks storage' refers to the volume of storage associated with a water utility's license.
2. The naming convention used by Golder (2012) for these sub-watersheds is consistent with the Bessette Creek sub-watersheds (i.e. above and below Duteau Creek confluence) included in this report.

Trout Creek Hydrology & Soils (2014)[12] also reported that within the entire Bessette Creek watershed there are 109 private irrigation licences supported by 9 storage licences and there are 11 waterworks and irrigation local authority licences supported by 6 storage licences. Trout Creek Hydrology & Soils (2014) assumed that 90% of the licensed volume was being used by irrigation license. This estimate is similar to Minor (2005)[13], who noted that a select group of water users within the watershed reported using approximately 80% of their irrigation licensed volumes. A summary of mean monthly irrigation water use for July, August, and September reported by Trout Creek Hydrology & Soils (2014) for the selected sub-watersheds of Bessette Creek watershed is provided in Table 3-2.

[12] Trout Creek Hydrology & Soils. 2014. Environmental Flows and Hydrologic Assessment for the Bessette Creek Watershed – 2011 – 2013 Final Report. Prepared for the B.C. Ministry of Forests, Lands, and Natural Resource Operations, March 2014.

[13] Minor, T. 2005. Creighton Creek Stream Flow Recovery – Project Summary. Prepared for Whitevalley Community Resource Centre, March 2005.

Table 3-2 Summary of estimated water use for the selected sub-watersheds within the Bessette Creek watershed (from Trout Creek Hydrology & Soils [2014])

Sub-watershed	Estimated Mean Monthly Water Use (m^3/s)		
	July	August	September
Duteau Creek	0.066	0.066	0.026
Bessette Creek above Duteau Creek Confluence[1]	0.039	0.039	0.016
Creighton Creek	0.180	0.180	0.074
Bessette Creek below Duteau Creek Confluence[2]	0.197	0.197	0.085

Note:
1. This sub-watershed is assumed to represent the same area reported by Trout Creek Hydrology & Soils (2014) for Bessette above Lumby 08LC005.
2. This sub-watershed is assumed to represent the difference between the two areas (i.e. Lower Bessette 08LC039 and Bessette at Lumby 08LC005) reported by Trout Creek Hydrology & Soils (2014).

Bessette Creek above Duteau Creek Confluence

For the Bessette Creek above Duteau Creek confluence sub-watershed, Minor (2006)[14] reported that Harris and Nicklen Creek provide the available surface water flow for irrigation during the peak irrigation season. Minor (2006) also reported that GVW is licensed to divert water from McAuley Creek (a tributary of Harris Creek) to the Duteau Creek watershed (Figure 1-1). The diversion typically occurs during the spring, but can occur anytime depending on demand.

Minor (2006) documented a lack of continuous streamflow during July and August in the portion of Bessette Creek between the Horner and Whitevale Road bridges (approximately 3 km). This section of the creek has been identified as a deposition zone and as a result, the creek loses water to the bed naturally (Minor 2006). Water use by irrigators has been assessed throughout this portion of the creek and the results indicated that no irrigators were exceeding their licensed volumes (Minor 2006).

Other than the information reported by Minor (2006) and the water use estimates provided in Table 3-2, no other specific information was identified on water use for the agricultural lands within this portion of Bessette Creek watershed.

Bessette Creek below Duteau Creek Confluence

For the Bessette Creek below Duteau Creek confluence sub-watershed, Minor (2010)[15] reported that nine water licences were active on Bessette Creek between the Duteau Creek and Shuswap River confluences.

[14] Minor, T. 2006. Creighton Creek Streamflow Recovery Project – Phase II. Prepared for the Whitevalley Community Resource Centre Society.

[15] Minor, T. 2010. 2010 Low Flow Monitoring Project: Bessette Creek Walk. Prepared for Farmland-Riparian Interface Stewardship Program, November 2010.

Minor (2010) also reported that three licences were inactive and no evidence of use was found for nine other licensed locations. Minor (2010) reported that the nine active licensed locations were licensed for irrigation purposes for a total volume of 1,009 ML (based on a 90 day irrigation period), but actual water use estimates were not provided.

Other than the information reported by Minor (2010) and the water use estimates provided in Table 3-2, no other specific information on water use was identified for the agricultural lands within this portion of Bessette Creek watershed.

Creighton Creek Watershed

In 2004, a Creighton Creek Streamflow Recovery Project was initiated. The goal of the project was to reduce or eliminate the threat of dewatering and/or fish kills in the Bessette Creek watershed and specifically in Creighton Creek (Minor 2006). Minor (2005) indicated that there have been on-going disputes over water availability within the watershed. The water disputes were reported to be a result of insufficient streamflows and upstream water users diverting their licensed volumes ahead of more senior licensees downstream (Minor 2005).

Minor (2005) identified that for Creighton Creek watershed, a select group of water users reported using between 50% and 160% of their licensed volumes for irrigation purposes. Note that other than the water use estimates provided in Table 3-2, no other specific information on water use was identified for the agricultural lands within Creighton Creek watershed.

Duteau Creek Watershed

A wealth of information is available on Greater Vernon Water (GVW) and their use of Duteau Creek for domestic and irrigation purposes. Note that water use by GVW is supported by upland storage. Only a summary of GVW water use is provided below; since as directed by FLNRO (Richard McCleary, pers. comm., 2015)[16], water restrictions to agricultural users supported by storage are not a priority consideration of FLNRO at this time.

AECOM et al. (2013a)[17] reported that GVW relies on surface water from Duteau Creek watershed to supply a portion of its raw water supply. The Duteau Creek source for GVW is collected and drawn from the upland watershed and associated reservoirs (Aberdeen, Haddo, and Grizzly reservoirs) at the Headgates Intake (Figure 1-1). In addition, AECOM et al. (2013a) noted that GVW's Duteau Creek source is supplemented by the Gold-Paradise Diversion, which diverts water from the adjacent Harris Creek watershed into the Duteau Creek system (Figure 1-1).

AECOM et al. (2013b)[18] reported that GVW's Duteau Creek source supplies water for both domestic and agricultural purposes within their water distribution area. AECOM et al. (2013b) also reported that for 2011, the annual water demand from the Duteau Creek source was 9,670 ML and 12,600 ML for domestic and

[16] Richard McCleary. 2015. Regional Aquatic Ecologist, B.C. Ministry of Forests, Lands, and Natural Resource Operations. Personal communication with Brian Guy of Summit Environmental Consultants Inc., August 2015.

[17] AECOM, Associated Engineering (B.C.) Ltd., and Kerr Wood Leidal Associates Ltd. 2013a. Technical Memorandum No. 2 – Evaluation of Water Supply Sources. Prepared for the Regional District of North Okanagan, February 2013.

[18] AECOM, Associated Engineering (B.C.) Ltd., and Kerr Wood Leidal Associates Ltd. 2013b. Technical Memorandum No. 4 – Domestic Water System Analysis. Prepared for the Regional District of North Okanagan, February 2013.

agricultural purposes, respectively. Note that the majority of GVW's Duteau Creek water distribution area is outside of Duteau Creek watershed (Figure 3-1 – attached).

In addition to the information noted above, in 2004 the B.C. Ministry of Environment initiated the Okanagan Water Supply and Demand Project (OWSDP). The OWSDP was a multi-phase work program focused on improving the state of knowledge of the water resources of the Okanagan Basin (Summit 2010)[19]. Included in Phase 2 of the OWSDP was the development of the Okanagan Water Demand Model (OWDM). The OWDM was developed to provide current and future estimates of agricultural and indoor and outdoor water demands in the Okanagan Basin (van der Gulik et al. 2010)[20]. Accordingly, the model provides estimates of water demand for individual crops on a parcel of land; or for an entire watershed, or local government jurisdiction, or water supplier area (e.g. irrigation district) by summing the demands within those areas (van der Gulik *et al*. 2010). The water demands are also linked to extractions from water sources (e.g. streams, lakes, and aquifers) for specific mapped "water use areas".

One of the water use areas included in the OWDM is the GVW water use area that is supplied by Duteau Creek. The GVW's Duteau Creek distribution area (for active users, broken down by water use purpose) is illustrated in Figure 3-1. The total agricultural lands irrigated by the GVW are 15.3 km^2 and the specific crop type distribution for those lands is summarized in Table 3-2.

Table 3-2 Summary of irrigated lands and irrigated crop types serviced by Greater Vernon Water's Duteau Creek source

Location	Irrigated Lands[1,2] (km^2)					
	Total	Forage Crops	Field Crops	Vegetable Crops	Fruit Crops	Other
Greater Vernon Water's Duteau Creek Water Distribution Area	17.1	9.7	2.3	0.1	3.2	1.8

Note:
1. This represents the land irrigated by GVW from their Duteau Creek water source based on agricultural land use information from MOA collected in 2007.
2. Forage crops are identified as 'Alfalfa' and 'Grass'; field crops include 'Corn', 'Turf Farm', and 'Nursery'; vegetable crops include 'Vegetables' and 'Ginseng'; fruit crops include 'Apple', 'Apricot', 'Berry', 'Cherry', 'Grape', 'Peach', 'Pear', 'Plum', 'Raspberry'; and other includes 'Interior Greenhouse' and a portion of lands for which the crop type is unknown within the OWDM dataset.

Water use data from the OWDM for GVW's Duteau Creek water source area for 1981-2010 was not available at the time of this report; however, Summit (2012)[21] summarized 1996-2006 water use information from the OWDM for GVW's Duteau Creek distribution area. A summary of the mean monthly water use by

[19] Summit Environmental Consultants Inc. 2010. Okanagan Water Supply and Demand Project: Phase 2 Summary Report. Prepared for Okanagan Basin Water Board. July 2010.

[20] van der Gulik, T., Neilsen, D., and Fretwell, R. 2010. Agriculture Water Demand Model: Report for the Okanagan Basin. B.C. Ministry of Agriculture and Agriculture and Agri-Foods Canada.

[21] Summit Environmental Consultants Inc. (Summit). 2012. Okanagan Hydrologic Connectivity Model: Summary Report. Prepared for the Okanagan Basin Water Board, March 2012.

GVW (which includes the irrigation season) reported by Summit (2012) for 1996-2006 is provided in Table 3-3.

Table 3-3 Estimated 1996-2006 Duteau Creek water use by Greater Vernon Water for all water use purposes (from Summit [2012])

Period[1]	Mean Monthly Surface Water Use from Duteau Creek by GVW[2] (m^3/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average 1996-2006	0.017	0.018	0.087	0.210	0.638	1.09	1.52	1.39	0.712	0.059	0.017	0.017

Note:
1. The 1996-2006 period included in Summit (2012) was the baseline scenario developed for the OWSDP.
2. Summit (2012) reported water use information on a weekly time-step. The weekly values were converted to monthly estimates assuming an average water use value for each day of the respective week.

3.2 SIZE OF IRRIGATED LAND AND CROP TYPES

Using the agricultural land use information outlined in Section 2, the total area of agricultural land and lands irrigated within all four sub-watersheds is provided in Table 3-4 and illustrated in Figure 1-1. Note that Table 3-4 does not include the lands irrigated by GVW outside of the Bessette and Duteau Creek watersheds, only the lands within the watershed downstream of the GVW water intake. The total lands irrigated by GVW and crop types are provided in Table 3-2.

The estimated area of irrigated land from the ALUI dataset is larger than the estimate from the 2011 Census of Agriculture for the census geographic sub-division (i.e. Regional District of North Okanagan Area D) that includes all four sub-watersheds (Table 3-4). Note that the North Okanagan Area D sub-division also includes Trinity Creek watershed; therefore, the two are not directly comparable. The 2011 census data is based on actual reports from farmers within the North Okanagan Area D. It is unknown whether all farmers have reported within the sub-watersheds; therefore, it was judged that the ALUI dataset is a more accurate of representation of current conditions.

A summary of the primary crop types for the irrigated areas within the four sub-watersheds is provided in Table 3-4. The crop type distribution is consistent between the ALUI dataset and the 2011 census, where forage crops represent more than 90% of the crop types.

Table 3-4 Summary of irrigated lands and irrigated crop types for the selected sub-watersheds within the Bessette Creek watershed

Sub-watershed	Irrigated Lands[1,2] (km²)					
	Total	Forage Crops	Field Crops	Vegetable Crops	Fruit Crops	Other
Ministry of Agriculture Land Use Inventory[3]						
Duteau Creek[4]	6.1	5.6	0.0	0.0	0.0	0.5
Bessette Creek above Duteau Creek Confluence	4.5	4.4	0.0	0.0	0.0	0.1
Creighton Creek	2.5	2.4	0.0	<0.1	0.0	<0.1
Bessette Creek below Duteau Creek Confluence	13.7	13.5	0.2	<0.1	0.0	0.0
2011 Census of Agriculture[5]						
Area D	19.1	16.8	2.0	0.1	<0.1	0.2

Note:
1. This represents land irrigated by surface water and groundwater.
2. Forage crops are identified as 'Forage, Pasture'; field crops include 'Cereal and oilseeds', 'Nursery and Tree plantations', and 'Specialty, Turf, Nut Trees'; vegetable crops include 'Vegetables'; and other includes 'Other' within the preliminary ALUI dataset.
3. Based on agricultural land use information from MOA collected in 2014 and only includes lands identified to fall within the respective sub-watershed boundary (Figure 1-1) and/or portions of land outside a sub-watershed, but considered to be supplied by water from that respective sub-watershed.
4. The irrigated lands for Duteau Creek watershed include lands identified by MOA to be serviced by a surface water licence and/or groundwater. Lands identified by MOA to be serviced by a water purveyor or irrigation district are not included as they are considered to be part of the GVW water distribution area.
5. 2011 census data based on 88 farms reporting in North Okanagan Area D.

3.3 IRRIGATION WATER DEMAND

To provide an understanding of how the 2015 irrigation season (to July 31st) compares to normal conditions (1981-2010) within the four sub-watersheds, the cumulative crop evapotranspiration was calculated for the Vernon area (Figure 3-2). This includes irrigation sourced by all water sources. Note that in comparison to normal conditions, the cumulative crop evapotranspiration for 2015 (on July 31st) was approximately 27 mm higher than normal for the Vernon area.

The estimated mean monthly irrigation water demand supplied by surface water alone for the irrigation season under normal conditions is provided for each of the sub-watersheds in Table 3-5, and digitally in Attachment 1. Note that for Duteau Creek watershed, Table 3-5 does not include the water demand supplied to the agricultural lands outside of the watershed by GVW (i.e. Figure 3-1 and Table 3-3).

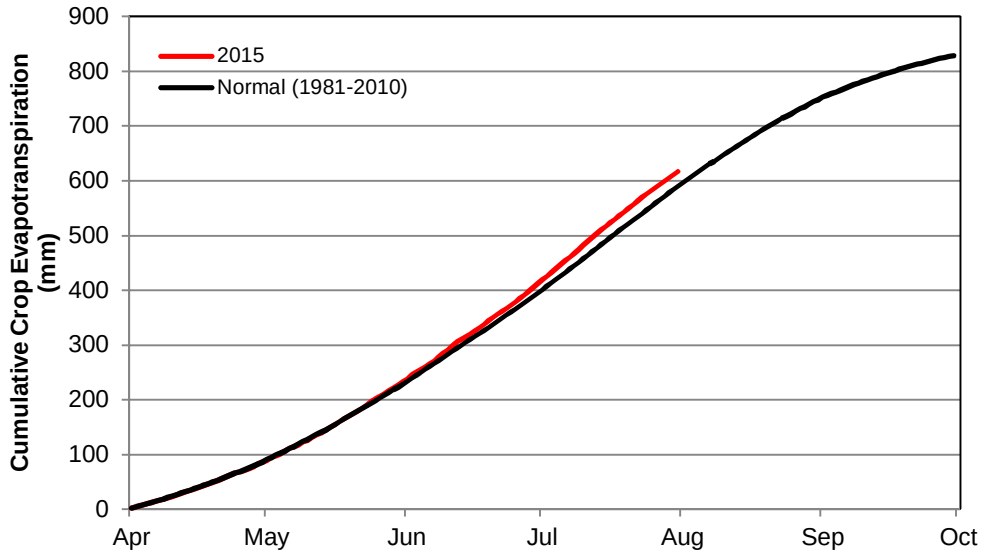

Figure 3-2 Cumulative crop evapotranspiration for a reference crop (grass) within the Vernon area

Table 3-5 Mean monthly normal and 2015 irrigation water demand supplied by surface water for the selected sub-watersheds within the Bessette Creek watershed

Sub-watershed[1]	Period	Mean Monthly Irrigation Water Demand (m^3/s)					
		April	May	June	July	August	September
Duteau Creek[2]	2015	0.227	0.375	0.474	0.524	n/a	n/a
	Normal Period	0.230	0.364	0.442	0.502	0.405	0.214
Bessette Creek above Duteau Creek Confluence	2015	0.091	0.150	0.190	0.210	n/a	n/a
	Normal Period	0.092	0.146	0.177	0.201	0.162	0.086
Creighton Creek	2015	0.071	0.117	0.148	0.163	n/a	n/a
	Normal Period	0.072	0.113	0.138	0.156	0.126	0.067
Bessette Creek below Duteau Creek Confluence	2015	0.222	0.366	0.463	0.511	n/a	n/a
	Normal Period	0.224	0.355	0.432	0.490	0.396	0.209

Note:
1. Sub-watersheds are updated in this final report as per outlined on page 1 of this document.
2. Lands within the watershed boundary identified by MOA to be serviced by a water purveyor or irrigation district are not included as they are considered to be part of the GVW water distribution area.

The mean monthly estimates of irrigation water demand are provided in cubic metres per second (m^3/s) (in Table 3-5) to allow for direct comparison to streamflow data. Irrigation water demands supplied by groundwater are available, but are not reported here because restrictions on groundwater use are not presently being considered in this scope of work.

FLNRO (Richard McCleary, pers. comm., 2015) recommended that August and September 2015 irrigation demand should be estimated based on average data from the 1981-2010 normal period. Accordingly, the columns with the normal irrigation demand for August and September in Table 3-5 provide estimates of the amount of irrigation water that is expected to be withdrawn from surface water sources over the remainder of the 2015 irrigation season.

The irrigation water demand results provided in Table 3-5 are larger for all sub-watersheds, except Creighton Creek, in comparison to the estimates completed by Trout Creek Hydrology & Soils (2014) (Table 3-2). The reason for the difference between the two estimates is unknown. The method used herein is based on ALUI dataset used by MOA, while Trout Creek Hydrology & Soils (2014) based their estimates on water licences and an assumed percentage of licensed usage. Due to this discrepancy, it is recommended that FLNRO consider both irrigation water demand estimates when assessing the expected amount of surface water withdrawals for the remainder of the 2015 irrigation season.

3.4 PORTION OF LAND IRRIGATED BY GROUNDWATER AND SURFACE WATER

The individual breakdown of the irrigated land by water supply source from the ALUI dataset within the four sub-watersheds is provided in Table 3-6.

Table 3-6 Summary of irrigated lands by surface water and groundwater for the selected sub-watersheds within the Bessette Creek watershed

Sub-watershed	Total Irrigated Area[1] (km^2)	Irrigated Area Supplied by Groundwater (km^2)	Irrigated Area supplied by Surface Water (km^2)
Duteau Creek[2]	6.1	1.7 (28%)	4.4 (72%)
Bessette Creek above Duteau Creek Confluence	4.5	2.6 (58%)	1.9 (42%)
Creighton Creek	2.5	1.0 (40%)	1.5 (60%)
Bessette Creek below Duteau Creek Confluence	13.7	9.0 (66%)	4.7 (34%)

Note:
1. Based on agricultural land use information from MOA collected in 2014 and only includes lands identified to fall within the respective sub-watershed boundary (Figure 1-1) and/or portions of land outside a sub-watershed, but considered to be supplied by water from that respective sub-watershed.
2. This does not include lands identified by MOA to be serviced by a water purveyor or irrigation district within the watershed boundary as they are considered to be part of the GVW water distribution area.

4 ACKLOWEDGEMENTS

Funding for this project was provided by FLNRO to identify science-based options for responding to a Level 4 drought emergency in 2015 that impacted streamflow in many watersheds that support important fish populations in the Thompson-Okanagan Region. The terms of reference for the irrigation water demand component of the project were developed collaboratively by FLNRO (Richard McCleary), Ministry of Agriculture (Andrew Petersen and Geoff Hughes-Games) and Associated Environmental Consultants Inc. (Brian Guy, Hugh Hamilton, and Drew Lejbak).

5 CLOSURE

We trust that this report provides you with the information that you require at this time. Please contact us if you have any questions or comments.

Yours truly,
Associated Environmental Consultants Inc.

Drew Lejbak, M.Sc., GIT
Hydrologist

Brian T. Guy, Ph.D., P.Geo.
National Practice Leader – Environmental Sciences

DL

Attachment 1 – Bessette-Duteau Water Demand Estimates_2015 and Normal.xlsx

N

Bessette Creek below Duteau Creek Confluence

Vance Creek

08LC039

Vernon North Climate Station (1128583) ~18km

Bessette Creek

08LC005

08LC006

GVW Headgates Intake

08LC033

Creighton Creek

Duteau Creek

Harris Creek

Aberdeen Reservoir

Haddo Reservoir

Grizzly Reservoir

Duteau Creek

Gold-Paradise Diversion

Bessette Creek above Duteau Creek Confluence

Water Survey of Canada Hydrometric Station
Environment Canada Climate Station
Irrigation Groundwater wells
Irrigation Water Licence POD
Agricultural Lands (groundwater source)
Agricultural Lands (surface water source)
Land Currently Under Irrigation (Based on 2014 survey)
Selected Watershed Boundaries

Kilometers
0 1 2 3 4 5

duteau bessette.mxd / 1/26/2016 / 3:04:01 PM

Associated Environmental

PROJECT NO.: 2015-8164.000.000
DATE: February 2016
DRAWN BY: DA

FIGURE 1-1:IRRIGATED LANDS WITHIN THE BESSETTE AND DUTEAU CREEK WATERSHEDS

BC Ministry of FLNRO

Watershed Irrigation Water Demand

N

Vance Creek

Bessette Cr

GVW Headgates Intake

Duteau Creek

Aberdeen Reservoir

Haddo Reservoir

Grizzly Reservoir

Duteau Creek

Gold-Paradise Diversion

Private Agricultural Lands not serviced by GVW

Irrigated Land Supplied by GVW - Duteau source

- Agricultural Use
- Domestic Use
- Recreational Use

Selected Watershed Boundaries

Kilometers

0 1 2 3 4 5

duteau bessette figure 3-1.mxd / 1/26/2016 / 12:19:25 PM

Associated Environmental

PROJECT NO.: 2015-8164.000.000

DATE: February 2016

DRAWN BY: DA

FIGURE 3-1: GREATER VERNON WATER DUTEAU CREEK SOURCE WATER DISTRIBUTION AREA BY WATER USE PURPOSE

BC Ministry of FLNRO

Watershed Irrigation Water Demand

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March 21, 2016
File: 2015-8164.010.000

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Re: OVERVIEW OF FISH POPULATIONS AT RISK: BESSETTE, DUTEAU, AND CREIGHTON CREEK WATERSHEDS

Dear Thompson-Okanagan Regional Drought Response Team:

In relation to the potential application of water use restrictions to protect fish stocks, the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) retained Associated Environmental Consultants Inc. (Associated) to provide an overview of the fish habitat and fish populations at risk due to current streamflow conditions within the Bessette, Duteau, and Creighton Creek watersheds (Figure 1-1). This letter is organized into four sub-sections:

1. System History
2. Current Streamflow Conditions
3. Problems for Fish related to Current Streamflows
4. Benefits of Water Restrictions to Fish

The assessment was completed through a desktop review of available information, including historical reports from the Ecological Reports Catalogue, iMAP BC and the B.C. Habitat Wizard, Fish Inventory Data Queries, Fish Inventory Projects Query, Water Survey of Canada, NuSEDS, and Freshwater Fisheries Society of BC stocking reports.

This is the final version of a draft report provided to FLNRO on September 25, 2015. The technical information contained in the draft report was used by FLNRO to support drought response initiatives up to end-September 2015. The format and content of the draft report reflect FLNRO requirements at the time. The citation for the draft report is as follows:

- *Summit Environmental Consultants Inc. 2015. Overview of Fish Populations at Risk: Bessette and Duteau Creek Watersheds. Prepared for the B.C. Ministry of Forests, Lands, and Natural Resource Operations, September 2015.*

Summit Environmental Consultants Inc. rebranded to Associated Environmental Consultants Inc. (Associated) in November 2015. As a result, this final report is provided on Associated Letterhead.

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Bessette Creek below Duteau Creek Confluence

08LC039

Shuswap Falls - Wilsey Dam

Documented Coho spawning habitat

08LC005

08LC006

GVW Headgates Intake

08LC033

Creighton Creek

Bessette Creek above Duteau Creek Confluence

Duteau Creek

Water Survey of Canada Hydrometric Station

Coho/Chinook/Kokanee Salmon Spawning Habitat

Coho/Chinook Salmon Spawning and Rearing Habitat

Agricultural Lands (groundwater source)

Agricultural Lands (surface water source)

Land Currently Under Irrigation (Based on 2014 survey)

Watershed Boundary

Kilometers

0 1 2 3 4 5

duteau bessette fish.mxd / 1/26/2016 / 3:04:14 PM

Associated Environmental

PROJECT NO.: 2015-8164.010.000

DATE: February 2016

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FIGURE 1-1: BESSETTE AND DUTEAU CREEK WATERSHEDS AND SELECTED FISH HABITAT INFORMATION

BC Ministry of FLNRO

Assessment of Fish at Risk in 2015

After end-September 2015 (i.e. after the draft report had been used for operational purposes), FLNRO and the Okanagan Nation Alliance (ONA) reviewed and provided comments on it. All comments have been considered in preparation of this final report. The largest change from the draft report was that Bessette Creek was considered as one watershed in the draft report, but it has now been divided into the following sub-watersheds:

- Duteau Creek;
- Bessette Creek above Duteau Creek confluence;
- Creighton Creek; and
- Bessette Creek below Duteau Creek confluence.

This watershed division was requested by FLNRO and ONA (pers. comm., 2015) and is reflected throughout this final report. Outside of this change, none of the changes between the draft and final reports would have materially altered the decisions made by FLNRO that were based on the draft report.

The critical flow thresholds included in this report were recommended by FLNRO and represent the best information that was readily available to FLNRO during the summer of 2015. These values are subject to change based on additional information specific to the stream and each fish population and life history stage.

1 SYSTEM HISTORY

The Bessette Creek watershed covers approximately 796 km^2 and is a major tributary to the Shuswap River. Bessette Creek flows in a northerly direction through a primarily agriculturally dominated valley prior to flowing eastwards to its confluence with the Shuswap River about 1.6 km downstream of Shuswap Falls at BC Hydro's Wilsey Dam (Swain 1991). Other major watercourses in the watershed include Duteau, Harris, and Vance Creeks and minor tributaries Spider, Creighton, and Lawson Creeks (Figure 1-1). These creeks generally flow through forested mountain areas with the exception of Lawson Creek, which flows through agricultural and industrial areas (Figure 1-1).

The Duteau Creek watershed covers approximately 216 km^2 and comprises a portion of the headwaters of Bessette Creek watershed (Figure 1-1). The Duteau Creek watershed is one of two primary drinking water sources for Greater Vernon Water (GVW) and contains a group of reservoirs, diversions, and control structures. The Duteau Creek watershed upstream of the GVW's Headgates Dam water intake includes three reservoirs (Aberdeen, Grizzly, and Haddo) and the Gold-Paradise Diversion, which diverts water from the Harris Creek watershed (Figure 1-1).

The Creighton Creek watershed covers approximately 103 km^2 and comprises a portion of the headwaters of Bessette Creek Watershed, similar to Duteau. Much of the Creighton Creek watershed is valley bottom running through agriculture dominated fields of alfalfa and corn.

The Bessette Creek watershed discussed herein is considered to include all the lands contributing to Bessette Creek minus Duteau and Creighton Creek watersheds (i.e. it includes Bessette Creek above Duteau confluence and Bessette Creek below Duteau confluence). The boundaries of the Bessette, Duteau, and Creighton Creek watersheds are outlined in Figure 1-1. These watersheds are situated within the Okanagan and Secwepemc traditional territories, and thus are an important part of their culture (UBC 1994).

The following sections provide a summary of fish species (current and historic) within each watershed, critical habitat locations, and life stage timing.

1.1 FISH SPECIES

The **Bessette Creek watershed** is a highly valuable fisheries resource, providing habitat for a variety of fish species including salmonids, and has been identified by DFO as a watershed of special conservation concern for Coho and Chinook Salmon (Golder 2012; FLNRO and ONA, pers. comm., 2015). Eleven species of fish have been documented in the Bessette Creek watershed (Table 1-1) (MOE 2015a/b/c; Golder 2012). Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), Kokanee Salmon (*O. nerka*), and Rainbow Trout (*O. mykiss*) have been identified as the focal species within the Bessette Creek watershed (Trout Creek Hydrology & Soils 2014). Similar fish presence has been documented within the tributaries of Vance, Harris, and Creighton Creeks (MOE 2015a). There is no documented fish presence in Spider Creek.

The **Duteau Creek watershed** supports a variety of commercially and culturally valuable fish species. Nine species of fish have been documented in the Duteau Creek watershed (Table 1-1) (MOE 2015a/b/c). Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), Kokanee Salmon (*O. nerka*), and Rainbow Trout (*O. mykiss*) have been identified as the focal species within the Duteau Creek watershed (Trout Creek Hydrology & Soils 2014). Rainbow Trout have also been documented in all three reservoirs (Aberdeen, Grizzly, and Haddo) (MOE 2015a/b) and in Heart Creek, but not in Paradise or McAulay (Gold) Creeks (which contribute to the Gold-Paradise Diversion). Lastly, Fisheries and Oceans Canada (DFO) have released hatchery raised Coho Salmon fry into Duteau Creek between 1998 and 2013 (FLNRO and ONA, pers. comm., 2015)

The **Creighton Creek watershed** supports a variety of commercially and culturally valuable fish species as well. Nine species of fish have been documented in the Creighton Creek watershed (Table 1-1) (MOE 2015a/b/c; Golder 2012). Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), and Rainbow Trout (*O. mykiss*) have been identified within the Creighton Creek watershed (Secwepemc Fisheries Commission 2010). Northern Pikeminnow (*P. oregonensis*) is also documented in Creighton Creek (MOE 2015a).

Table 1-1 Fish Observations in the Bessette, Duteau, and Creighton Creek watersheds

Common Fish Name	Status
Bessette Creek[1]	
Chinook Salmon	Native
Coho Salmon	Native, endangered[2]
Kokanee (land-locked Sockeye Salmon)	Native
Sockeye Salmon	Native
Rainbow Trout	Native, stocked in lakes
Dace spp.	Native
Sucker spp.	Native
Mountain Whitefish	Native
Redside Shiner	Native
Northern Pikeminnow	Native
Sculpin spp.	Native
Duteau Creek	
Chinook Salmon	Native
Coho Salmon	Native, endangered[2]
Sockeye Salmon	Native
Rainbow Trout	Native
Dace spp.	Native
Sucker spp.	Native
Mountain Whitefish	Native
Brook Trout	Introduced
Sculpin spp.	Native
Creighton Creek	
Chinook Salmon	Native
Coho Salmon	Native, endangered[2]
Sockeye Salmon	Native

Common Fish Name	Status
Rainbow Trout	Native
Dace spp.	Native
Sucker spp.	Native
Mountain Whitefish	Native
Brook Trout	Introduced
Sculpin spp.	Native

Note:
1. Bessette Creek watershed refers to all areas within the watershed minus Duteau and Creighton Creek watersheds (i.e. Bessette Creek above Duteau confluence and Bessette Creek below Duteau confluence.)
2. Following COSEWIC, Coho Salmon are identified as endangered. Species defined as endangered are facing imminent extirpation or extinction.

Since 2006, Denison Lakes within the Bessette Creek watershed have been stocked annually with between 300 and 1,000 Rainbow Trout by the Freshwater Fisheries Society of B.C. (2015).

Golder (2012) also reported that Bessette Creek watershed remains as one of DFO's and FLNRO's highest priorities within the Shuswap River watershed for fish and fish habitat from a fishery value and water use perspective. The average annual salmon escapements (i.e. numbers of salmon entering a stream to spawn) are provided in Table 1-2.

Table 1-2 Average annual salmon escapements in the Bessette Creek watershed (from NuSEDS 2015)

Watercourse	Average Annual Salmon Escapements[1]		
	Chinook	Coho	Sockeye
Bessette Creek Watershed			
Bessette Creek[2]	129 (1976-2013)	59 (1976-2013)	239 (2005-2013)
Harris Creek	8 (1997-2013)	111 (1976-2013)	-
Duteau Creek Watershed			
Duteau Creek	32 (1997-2013)	310 (1976-2013)	-
Creighton Creek Watershed			
Creighton Creek	1 (2004-2013)	68 (1976-2013)	-

Note:
1. Years in brackets indicate the range of years the species was identified.
2. Bessette Creek includes the portion of the Bessette Creek watershed minus Harris, Creighton, and Duteau creek watersheds (i.e. Bessette Creek above Duteau confluence and Bessette Creek below Duteau confluence.)

1.2 FISH HABITAT

A general summary of fish habitat within Bessette, Duteau, and Creighton Creek watersheds is provided in this section:

Bessette Creek

- Swain (1991) identified that some reaches of Bessette Creek and tributaries remain in a fairly natural state, but several headwater tributaries have been dammed, and many sections have undergone channelization, bank stabilization and shade tree removal.
- The watershed provides highly valuable spawning habitat for a variety of salmonids. Kokanee Salmon spawning grounds have been documented in a 6 km reach of Bessette Creek upstream from its confluence with the Shuswap River (Figure 1-1). The location of spawning and rearing habitat for Coho and Chinook Salmon was also documented by Anthony (1975) and is included in Figure 1-1.
- Rainbow Trout have been known to spawn in Bessette Creek and provide most of the Rainbow Trout stocked in Mabel Lake (located downstream, northeast of Lumby, B.C.) (Swain 1991).

Rainbow Trout have also been identified to spawn in Vance Creek near the confluence with Bessette Creek (MOE 2015a).

- Coho and Chinook Salmon have been observed by the ONA (during spawner surveys) to spawn within Bessette Creek from the mouth to the confluence of Blue Springs Creek (Figure 1-1). In addition, suitable Coho Salmon spawning and rearing habitat has also been identified for an additional 5 km upstream of the Blue Springs Creek confluence (FLNRO and ONA, pers. comm., 2015).

Duteau Creek

- Rainbow Trout spawning has been documented in the outflow from Aberdeen reservoir, and between Haddo reservoir and Grizzly Swamp Dam (MOE 2015a). In addition, Heart Creek has been documented as a primary spawning and rearing location for Aberdeen reservoir Rainbow Trout, particularly at the confluence (MOE 2015a).
- Coho Salmon have been found to use Duteau Creek from the confluence with Harris Creek, to approximately 10 km upstream (Figure 1-1) (Swain 1991). Coho Salmon have also been documented spawning up to Whitevale Road (Figure 1-1), although the high percentage of fine grained bed material present was identified as a limitation for spawning in the lower reaches (Summit 2000).
- DFO (2006) identified that salmon have access up to 10.8 km from the mouth on Duteau Creek.
- Spawning and rearing habitat for Coho and Chinook Salmon was documented by Anthony (1975) and is included in Figure 1-1.
- Mabel Lake adfluvial rainbow trout access Duteau Creek upstream to the GVW Headgates Dam (FLNRO and ONA, pers. comm., 2015). .
- This stream is also used for Chinook spawning and rearing (FLNRO and ONA, pers. comm., 2015).

Creighton Creek

- Low summer streamflows resulting from a high water demand and irrigation have frequently been documented in Creighton Creek, limiting rearing and spawning potential for salmonids (MOE 2015a). Nevertheless, important Coho Salmon spawning grounds have been identified and spawning salmon have been observed within the lower reaches of Creighton Creek from the mouth to above 401 Creighton Valley Road (Figure 1-1) (MOE 2015a; FLNRO and ONA, pers. comm., 2015).
- This watershed is of special concern for Coho and Chinook Salmon (FLNRO and ONA, pers. comm., 2015).

1.3 LIFE STAGES AND TIMING

Trout Creek Hydrology & Soils (2014) identified that the focal species within these watersheds were Chinook, Coho, and Kokanee Salmon and Rainbow Trout; and that the critical life stages for each species were adult migration and spawning and juvenile rearing. Trout Creek Hydrology & Soils (2014) summarized critical times for each life stage and/or activity within the watersheds (Table 1-3).

Table 1-3 Life history timing of focal species within the Bessette, Duteau, and Creighton Creek watersheds (from Trout Creek Hydrology & Soils [2014])

Species	Activity[1]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Bessette Creek Watershed													
Chinook Salmon	Smolt/Fry movement			xxx	**xxxx**	**xxxx**	xxxx	xxxx	xxxx	xxxx	xxxx		
	Migration							xxxx	xxxx	xx			
	Spawning									**xxxx**	**xx**		
	Incubation	xxxx	xxxx	xxxx	xxxx					xxxx	xxxx	xxxx	xxxx
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Over-wintering	xxxx	xxxx	xxx								xxxx	xxxx
Coho Salmon	Adult Migration									xxx	xx**xx**	**xxx**x	xxxx
	Spawning	xx									xx	**xxxx**	**x**xxx
	Incubation	xxxx	xxxx	xxxx	xxxx							xxxx	xxxx
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Smolt migration				xx	**xxxx**	**x**xxx	xxxx					
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Rainbow Trout	Adult passage into mainstem and tributaries				xxx**x**	**xxxx**	x						
	Spawning				xx	**xxxx**	xx						
	Incubation				x	xxxx	**xxxx**	**xxxx**					
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx

Species	Activity[1]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Kokanee Salmon	Adult passage into mainstem and tributaries									xxx	xx		
	Spawning									xx	**xx**		
	Incubation	xxxx	xxxx	xxxx	xxxx							xxxx	xxxx
Duteau Creek Watershed													
Chinook Salmon	Smolt/Fry movement	xxxx	xxxx	xxx	**xxxx**	**xxxx**	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
	Migration							xxxx	xxxx	xx			
	Spawning									**xxxx**	xx		
	Incubation	xxxx	xxxx	xxxx	xxxx					xxxx	xxxx	xxxx	xxxx
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Coho Salmon	Adult Migration									xxx	xx**xx**	**xxx**x	xxxx
	Spawning	xx									xx	**xxxx**	**x**xxx
	Incubation	xxxx	xxxx	xxxx	xxxx						xx	xxxx	xxxx
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Smolt migration				xx	**xxxx**	**x**xxx	xxxx					
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Rainbow Trout	Adult passage into mainstem and tributaries				xxx**x**	**xxxx**	x						
	Spawning				xx	**xxxx**	xx						
	Incubation				x	xxxx	**xxxx**	**xxxx**					
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx

Species	Activity[1]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Creighton Creek Watershed													
Chinook Salmon	Smolt/Fry movement	xxxx	xxxx	xxx	**xxxx**	**xxxx**	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
	Migration							xxxx	xxxx	xx			
	Spawning									**xxxx**	xx		
	Incubation	xxxx	xxxx	xxxx	xxxx					xxxx	xxxx	xxxx	xxxx
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Coho Salmon	Adult Migration									xxx	xx**xx**	**xxx**x	xxxx
	Spawning	xx									xx	**xxxx**	**x**xxx
	Incubation	xxxx	xxxx	xxxx	xxxx						xx	xxxx	xxxx
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Smolt migration				xx	**xxxx**	**x**xxx	xxxx					
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Rainbow Trout	Adult passage into mainstem and tributaries				xxx**x**	**xxxx**	x						
	Spawning				xx	**xxxx**	xx						
	Incubation				x	xxxx	**xxxx**	**xxxx**					
	Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
	Over-wintering	xxxx	xxxx	xx								xxxx	xxxx

Note:
1. The "X" and location within the column represents the corresponding week within each month for the respective critical life history. The bolded values indicate the key weeks that are more important than others for each respective life stage or activity.

The following is an overview of the life stages of the key species within the Bessette, Duteau, and Creighton Creek watersheds as reported by Trout Creek Hydrology & Soils (2014):

- Rainbow Trout spawning occurs from April to mid-June, with rearing throughout the summer and fall. Juveniles and resident Rainbow Trout also overwinter within all watersheds. In addition to the

resident Rainbow Trout, some fish may rear instream for several years before migrating to Mabel Lake (FLNRO and ONA, pers. comm., 2015).

- Chinook Salmon migration can start in July, with spawning occurring from late August to October depending on streamflows and water temperatures. Rearing occurs from spring to fall, while juveniles have been documented to over-winter.
- Coho Salmon migration can start in October, with spawning occurring into the winter. Rearing occurs from spring to fall, while juveniles have been documented to over-winter.
- Kokanee Salmon migration begins in early September, with spawning occurring until mid-October. Kokanee Salmon fry migrate downstream to Mable Lake in the spring; therefore, are not present in the summer.

2 CURRENT STREAMFLOW CONDITIONS

Current and historic water levels and discharges recorded by the Water Survey of Canada (WSC) are available at the following locations (Figure 1-1):

Bessette Creek Watershed

- Bessette Creek above Beaverjack Creek (WSC 08LC039; Period of Record: 1970-present);
- Bessette Creek above Lumby Lagoon Outfall (WSC 08LC042; Period of Record: 1973-present);
- Bessette Creek near Lumby (WSC 08LC005; Period of Record: 1919-1983);
- Vance Creek below Deafies Creek (WSC 08LC040; Period of Record: 1970-present);
- Paradise Creek near Lumby (WSC 08LC015; Period of Record: 1921-1921);
- Nicklen Creek near Lumby (Upper Station) (WSC 08LC010; Period of Record: 1921-1921);
- McAuley Creek near Lumby (WSC Station 08LC009; Period of Record: 1920-1920); and
- Nicklen Creek near Lumby (Lower Station) (WSC 08LC008; Period of Record: 1920-1920).

Duteau Creek Watershed

- Duteau Creek near Lavington (WSC 08LC006; Period of Record: 1919-1996);
- Duteau Creek at outlet of Haddo Lake (WSC 08LC014; Period of Record: 1921-1979);
- Grizzly Swamp near Haddo Lake (WSC 08LC047; Period of Record: 1978-1986);
- Haddo Lake at the outlet (WSC 08LC044; Period of Record: 1968-1986);
- Aberdeen Lake at the outlet (WSC 08LC043; Period of Record: 1968-1986);
- Dermont Creek near Lavington (WSC 08LC017; Period of Record: 1921-1921); and
- Vernon Irrigation District diversion near Lavington (WSC 08LC007; Period of Record: 1919-1966).

Creighton Creek Watershed

- Creighton Creek near Creighton Valley (WSC 08LC046; Period of Record: 1977-1977); and
- Creighton Creek near Lumby (WSC 08LC033; Period of Record: 1959-1966).

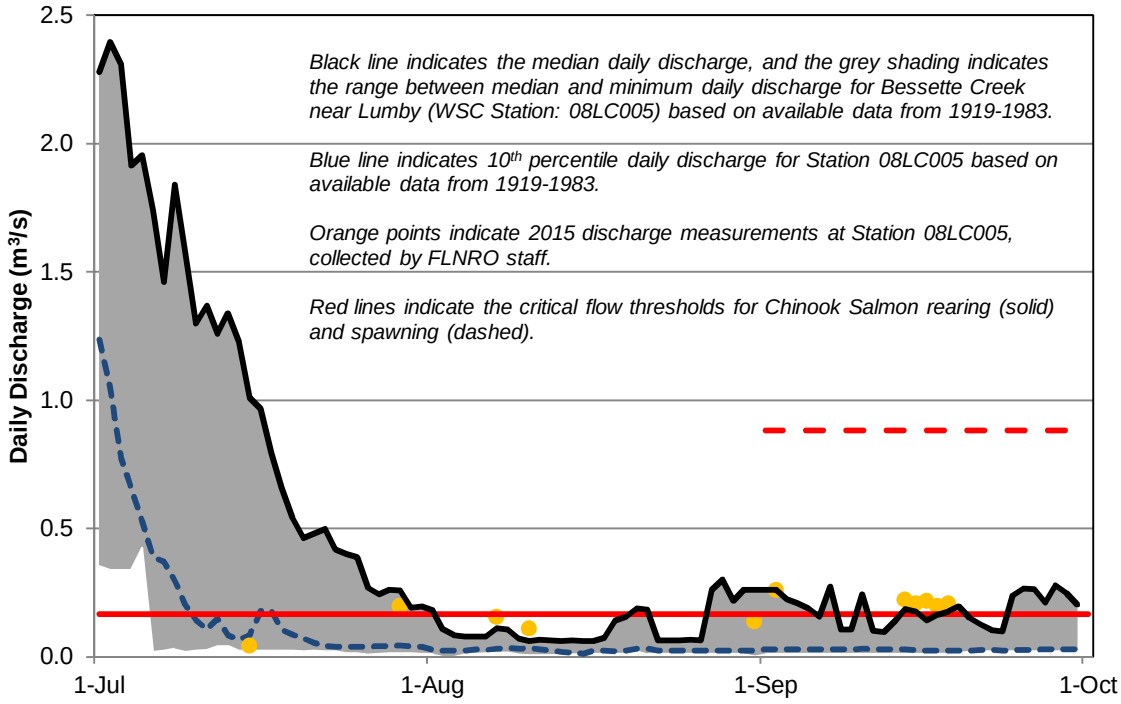
FLNRO identified the hydrometric stations on Bessette Creek near Lumby (WSC 08LC005), Bessette Creek above Beaverjack Creek (08LC039), and Duteau Creek near Lavington (WSC 08LC006) as the ones being used for analysis of streamflow and fish-at-risk. Real-time data is not available for two of these stations since they have been discontinued; however, FLNRO collected field discharge measurements at Bessette Creek near Lumby and Duteau Creek near Lavington, as well as at the mouth of Creighton Creek[1] in July, August, and September 2015 in support of the 2015 drought response effort. Real-time data is available for Bessette Creek above Beaverjack Creek (08LC039), while FLNRO operated their own hydrometric station at Duteau Creek near Lavington in 2015[2].

Figures 2-1 and 2-2 provide a comparison of the 2015 field and recorded measurements to historic streamflows for Bessette and Duteau Creek watersheds. The historic streamflows shown in the figures are the median, 10th percentile, and the minimum recorded for each day of this time period[3]. Note that historic streamflows are not available for the location at which 2015 field measurements were collected on Creighton Creek (i.e. at the mouth). Accordingly, only 2015 field measurements are provided for Creighton Creek (Figure 2-2b). Based on the latest flow measurements obtained by FLNRO (mid-September 2015) in both Bessette and Duteau Creeks, streamflows were close to, or above the median recorded flows. The critical flow thresholds included within Figures 2-1 and 2-2 are further described in Section 3.2.

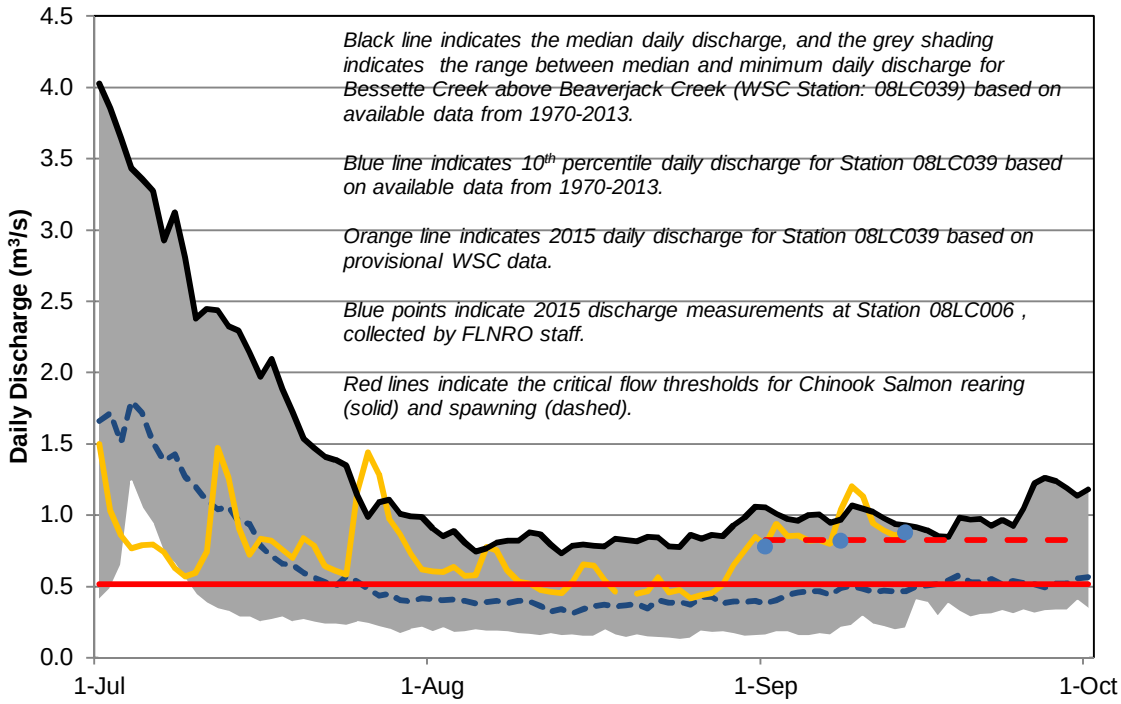
[1] Field discharge measurements were collected at the location identified as habitat transect 'Creighton Lower (CRE 2)' in Trout Creek Hydrology & Soils (2014).

[2] FLNRO noted that the station operated in 2015 was located near the Whitevale Road crossing of Duteau Creek, which is assumed to be at the same location as the discontinued WSC station 08LC006.

[3] The median value represents the 50th percentile or the middle value for the period of record. The 10th percentile represents the lower 10% value and the minimum is the lowest value on record.



A) Current year and historical flow comparisons for Bessette Creek near Lumby (WSC Station: 08LC005).



B) Current year and historical flow comparisons for Bessette Creek above Beaverjack Creek (WSC Station: 08LC039).

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DATE: **FEBRUARY 2016**

Figure 2-1 – Current year and historical flow comparisons for select Water Survey of Canada (WSC) stations within the Bessette Creek watershed.

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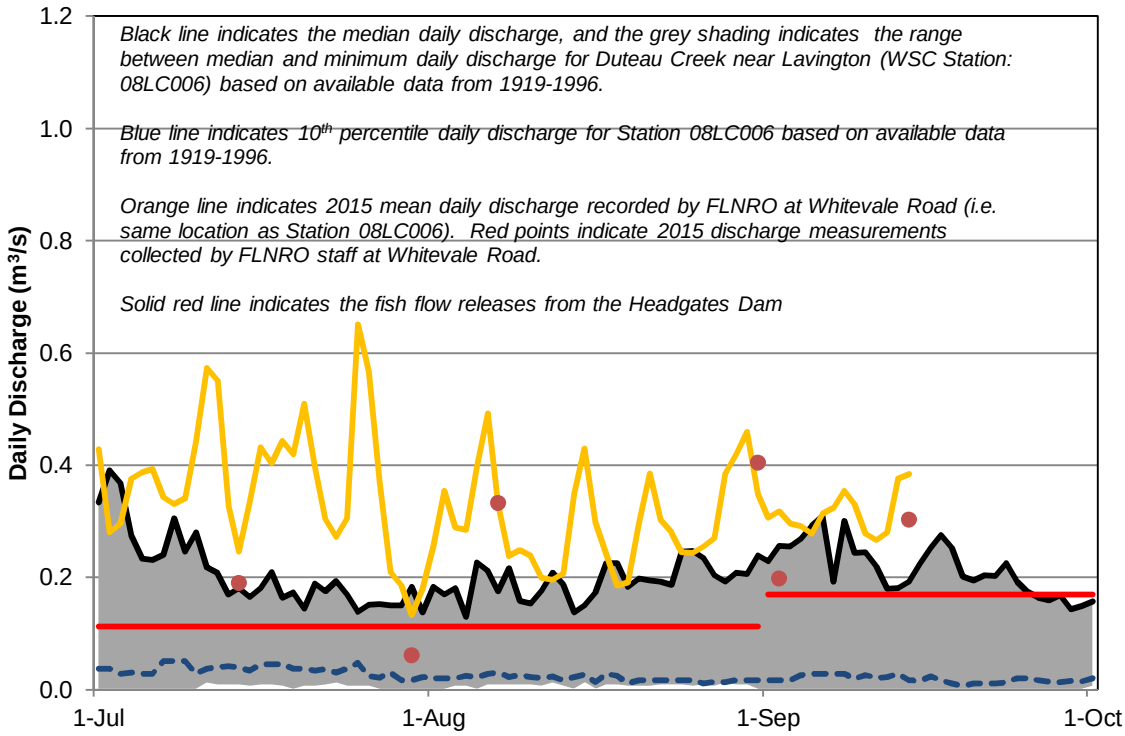
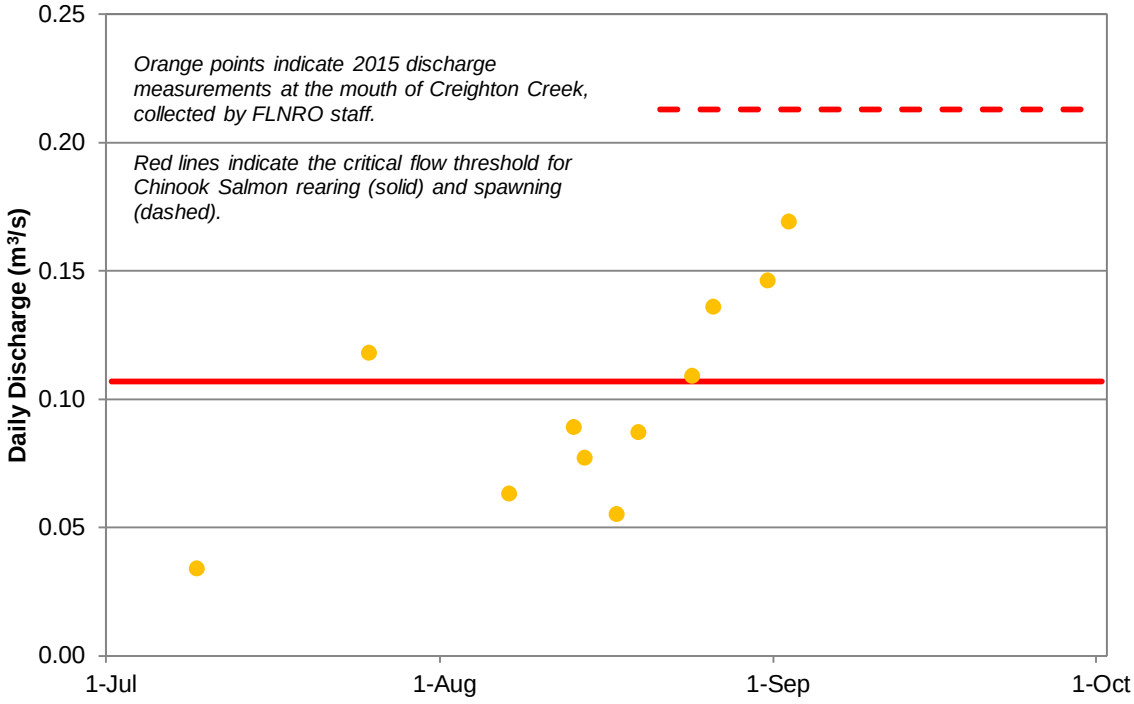
Prepared for: **Ministry of Forests, Lands, and Natural Resource Operations**



A) Current year and historical flow comparisons for Duteau Creek near Lavington (WSC Station: 08LC006).



B) Current year flow measurements for Creighton Creek at the mouth.

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Figure 2-2 – Current year and historical flow comparisons for select Water Survey of Canada (WSC) stations within Duteau and Creighton Creek watersheds.

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Prepared for: **Ministry of Forests, Lands and Natural Resource Operations**

3 PROBLEMS FOR FISH RELATED TO CURRENT STREAMFLOWS

3.1 FISH KILLS

It is not unusual during drought years for streamflows and temperature related fish-kill events to occur in Bessette Creek (upstream of Lumby), Creighton Creek, and Duteau Creek. Fish kill events in Creighton Creek have served as an early indicator that problems may be developing in other streams in the region. Prudent and proactive water management by all licensees is important for preventing these events (Watts and Harding (DFO), pers. comm., 2015, as cited by FLNRO and ONA, pers. comm., 2015).

For Duteau Creek watershed, in May 1988 the Vernon Irrigation District (VID) shut off downstream streamflows at the Headgates Dam water intake, which resulted in the dewatering of portions of Duteau Creek and a fish kill (DFO 1988). After this event, Fisheries and Oceans Canada (DFO) issued an order to VID to release a minimum of 0.141 m^3/s to Duteau Creek at the Headgates Dam water intake to ensure sufficient flow for salmon spawning in Duteau Creek (DFO 1988). Subsequent to this, an agreement was established between GVW and DFO (date unknown), which outlined fish flow releases at the Headgates Dam water intake based on time of year (Section 3.2).

On July 29, 2015, at 12:15 pm flows in Duteau Creek were measured at 0.062 m^3/s at Whitevale Road. Flows downstream from the irrigation pumphouse located 100 m downstream were further reduced to approximately 0.040 m^3/s. Fish mortalities were expected but not directly observed. At approximately 1:00 pm flows suddenly recovered to the range of target fish flow release levels. GVW was contacted and corrected the operating procedure to prevent further occurrences (FLNRO and ONA, pers. comm., 2015).

3.2 CRITICAL LOW FLOWS

Critical low flows (0.025 m^3/s) in Bessette Creek were documented in September 1987 by the B.C. Conservation Foundation (BCCF) between the upper Whitevale Road Bridge and the mouth of Duteau Creek. Following this, BCCF (1987) noted that the low flows resulted in exceptionally poor rearing habitat and questionable water quality and suggested that a streamflow of 0.083 m^3/s (at Horner Road Bridge) be considered the minimum required to maintain rearing habitat throughout the reach.

GVW and DFO have an agreement for fish flow releases at the Headgates Dam water intake (Trout Creek Hydrology & Soils 2014). The agreed fish flow releases are as follows:

- 0.057 m^3/s (6% long-term mean annual discharge [LTMAD] at WSC Station 08LC006) (January 1 to March 31);
- 0.113 m^3/s (11% LTMAD at WSC Station 08LC006) (April 1 to August 31);
- 0.170 m^3/s (17% LTMAD at WSC Station 08LC006) (September 1 to September 30); and
- 0.142 m^3/s (14% LTMAD at WSC Station 08LC006) (October 1 to December 31).

Finally, for Bessette and Creighton Creeks, Trout Creek Hydrology & Soils (2014) suggested instream flow targets as the percent of the LTMAD (under naturalized conditions [i.e. accounting for water use]) at selected locations throughout the watershed. A summary of the suggested LTMAD percentages by species and life stage/activity are provided in Table 3-1. Note that the percentages included in Table 3-1 represent the low weighted usable width flow values from habitat suitability index curves. These instream flow targets were recommended to be used herein by Epp (pers. comm., 2015) and are considered critical flow thresholds for the purpose of this assessment.

Table 3-1 Summary of instream flow targets by fish species and life stage or activity (from Trout Creek Hydrology & Soils [2014])

Life Stage / Activity	Instream Flow Targets by Fish Species (% of the Long-Term Mean Annual Discharge)[1]				
	Rainbow Trout	Kokanee Salmon	Coho Salmon	Chinook Salmon	Washington State Stream Chinook Salmon[2]
Bessette Creek above Duteau Creek confluence[3]					
Rearing	12.5	-	-	8.5	-
Spawning	50	15	55	100	45
Riffle Passage	25	7	25	55	25
Bessette Creek below Duteau Creek confluence[4]					
Rearing	15	-	-	12.5	-
Spawning	25	10	25	45	20
Riffle Passage	17.5	7.5	17.5	37.5	17.5
Creighton Creek[5]					
Rearing	30	-	-	25	-
Spawning	80	30	175	250	50
Riffle Passage	62.5	23.5	62.5	112.5	62.5

Note:

1. Herein, 'Low (50%) Weighted Usable Width Flow' target values were recommended to be selected by Epp (pers. comm., 2015), as defined in Trout Creek Hydrology & Soils (2014). These values are considered the critical flow thresholds for assessment purposes herein.
2. Trout Creek Hydrology & Soils (2014) provided additional habitat suitability index curves for spawning thresholds for stream Chinook Salmon from Washington State. Since Chinook Salmon in Bessette Creek are small bodied, stream type Chinook, Washington State habitat sustainability index value for Chinook Salmon spawning was selected for this analysis.
3. Based on information collected at monitoring transect "BES 2 2012" located at or near WSC 08LC005. No values reported for Kokanee or Coho Salmon rearing.
4. Based on information collected at monitoring transect "BES 3" located at or near WSC 08LC039. No values reported for Kokanee or Coho Salmon rearing.
5. Based on information collected at monitoring transect "CRE 2" located downstream of WSC 08LC033. No values reported for Kokanee or Coho Salmon rearing.

Chinook Salmon thresholds are considered by FLNRO to be the critical management thresholds for the present work. Accordingly, the critical flow thresholds for Chinook Salmon rearing and spawning in Bessette and Creighton Creeks are provided in Table 3-2.

For Duteau Creek, the critical flow thresholds were assumed to equal the fish flow releases from the Headgates Dam water intake for the period April 1 – August 31 (rearing) and September 1 – September 30 (spawning) (Table 3-2). This approach assumes that the GVW and DFO agreed upon fish flow releases consider all fish species and meet the needs of the critical life stages for each of the focal species.

Table 3-2 Summary of instream flow targets and critical flow thresholds, and current streamflow conditions within all sub-basins

Watershed and Location	Long-Term Mean Annual Discharge[1] (LTMAD) (m^3/s)	Critical Flow Threshold[2,3]		Measured September 2015 Streamflow in Bessette, Duteau, and Creighton Creeks[4]	
		Rearing (m^3/s)	Spawning (m^3/s)	(m^3/s)	% of LTMAD
Bessette Creek at WSC 08LC005 (i.e. Bessette Creek above Duteau confluence)	1.96	0.167	0.882	0.207	11%
Bessette Creek at WSC 08LC039 (i.e. Bessette Creek below Duteau confluence)	4.13	0.516	0.826	0.877	21%
Duteau Creek at WSC 08LC006	1.03	0.113	0.170	0.303	29%
Creighton Creek at the mouth[5]	0.426	0.107	0.213	0.169	40%

Note:
1. The long-term mean annual discharge (LTMAD) represents naturalized flows (i.e. accounting for water use) as reported by Trout Creek Hydrology & Soils (2014).
2. Threshold values for Bessette and Creighton Creeks were calculated following the percent of the LTMAD identified in Table 3-1. Note that for Chinook spawning, the Washington State habitat suitability index values were selected for this analysis.
3. Threshold values for Duteau Creek were assumed to equal the agreed upon fish flows releases from the Headgates Dam water intake for the period April 1 – August 31 (rearing) and September 1 – September 30 (spawning).
4. Discharge measurements collected by FLNRO staff on Duteau Creek (September 14, 2015), Bessette Creek at WSC 08LC005 (September 18, 2015), Bessette Creek at WSC 08LC039 (September 14, 2015), and Creighton Creek (September 2, 2015).
5. The LTMAD presented for Creighton Creek is for "CRE 2" as reported by Trout Creek Hydrology & Soils (2014), downstream of WSC 08LC033.

The critical flow thresholds for the Bessette, Duteau, and Creighton Creek assessment locations are included in Figures 2-1 and 2-2. Based on the discharge measurements collected by FLNRO in September 2015 (Table 3-2), the following observations are made:

- Streamflow in Bessette Creek (at WSC 08LC005) was last measured on September 18, 2015. At the time, streamflow was above the critical flow thresholds for Chinook Salmon rearing, but below the critical flow thresholds for Chinook Salmon spawning;
- Streamflow in Bessette Creek (at WSC 08LC039) was last measured on September 14, 2015. At the time, streamflow was above the critical flow thresholds for both Chinook Salmon rearing and spawning;
- Streamflow in Duteau Creek (at WSC 08LC006) was last measured on September 14, 2015. At the time, streamflow was above the GVW and DFO agreed upon fish flow releases from the Headgates Dam; and
- Streamflow in Creighton Creek at the mouth was last measured on September 2, 2015. At the time, streamflow was above the critical flow threshold for Chinook Salmon rearing, but below the critical flow threshold for Chinook Salmon spawning.

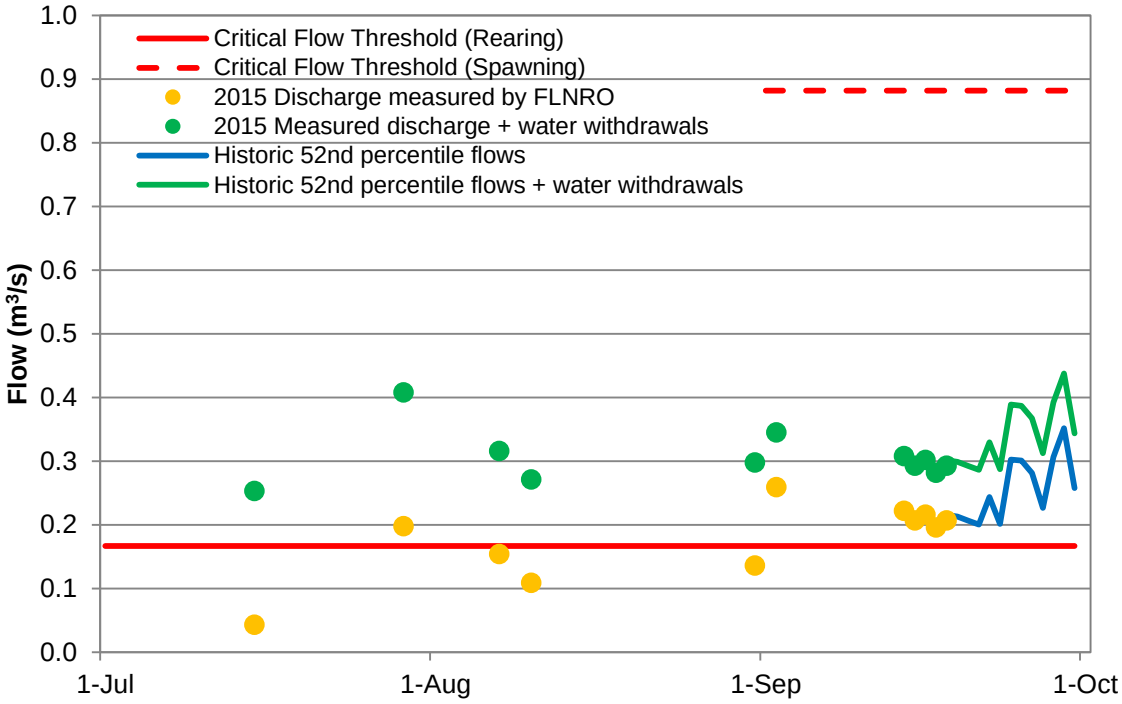
3.3 LIKELY 2015 AND FUTURE STREAMFLOWS

Real-time hydrometric information is available for Bessette Creek (at WSC 08LC039). However, without active real-time hydrometric monitoring at the other locations where the 2015 measurements were conducted, current streamflows are not available. The field measurements performed by FLNRO in September 2015 result in the following observations:

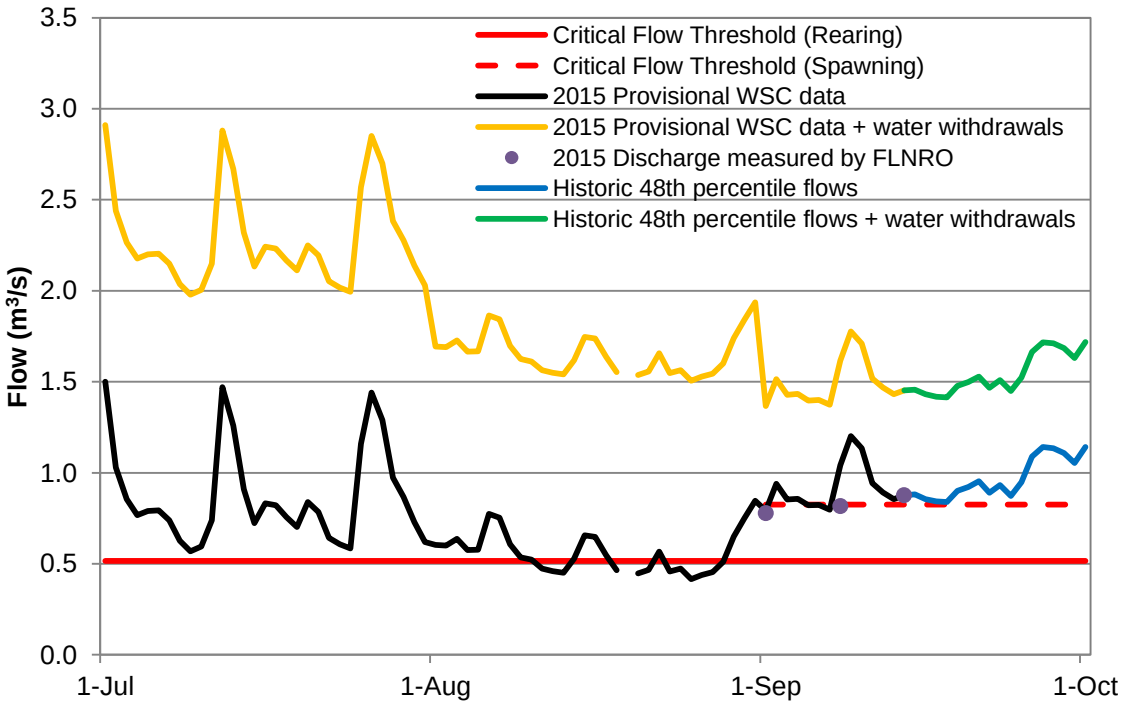
- Streamflows in Bessette Creek (at WSC Station 08LC005) were at the 52nd percentile of recorded streamflows;
- Streamflows in Bessette Creek (at WSC Station 08LC039) were at the 48th percentile of recorded streamflows; and
- Streamflows in Duteau Creek were nearly double the median recorded streamflows.

Since 2015 field measurements were conducted at the mouth of Creighton Creek, approximately 10 km downstream of the WSC Station 08LC033, there is no historic streamflow record for this location. Accordingly, it is not possible to provide a comparison between 2015 flow conditions and historical flows for Creighton Creek at this time.

Figure 3-1 and 3-2 include the critical flow thresholds, and the estimated streamflows that would exist if the water being withdrawn from the creeks for irrigation instead remained in the creeks. This information is taken from the irrigation water demand analysis provided by Associated (2016). Figure 3-1 demonstrates the following for the Bessette Creek watershed:



A) Measured and estimated streamflows for Bessette Creek near Lumby (WSC Station: 08LC005), July 1 to September 30, 2015.



B) Measured and estimated streamflows for Bessette Creek above Beaverjack Creek (WSC Station: 08LC039), July 1 to October 1, 2015.

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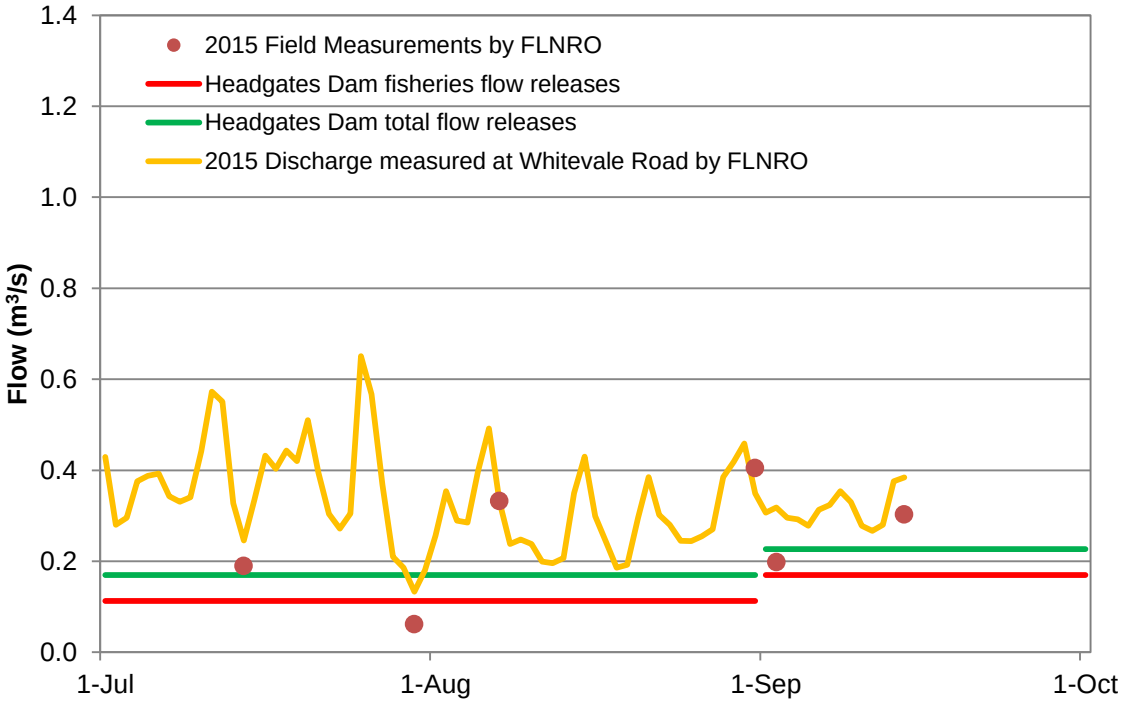
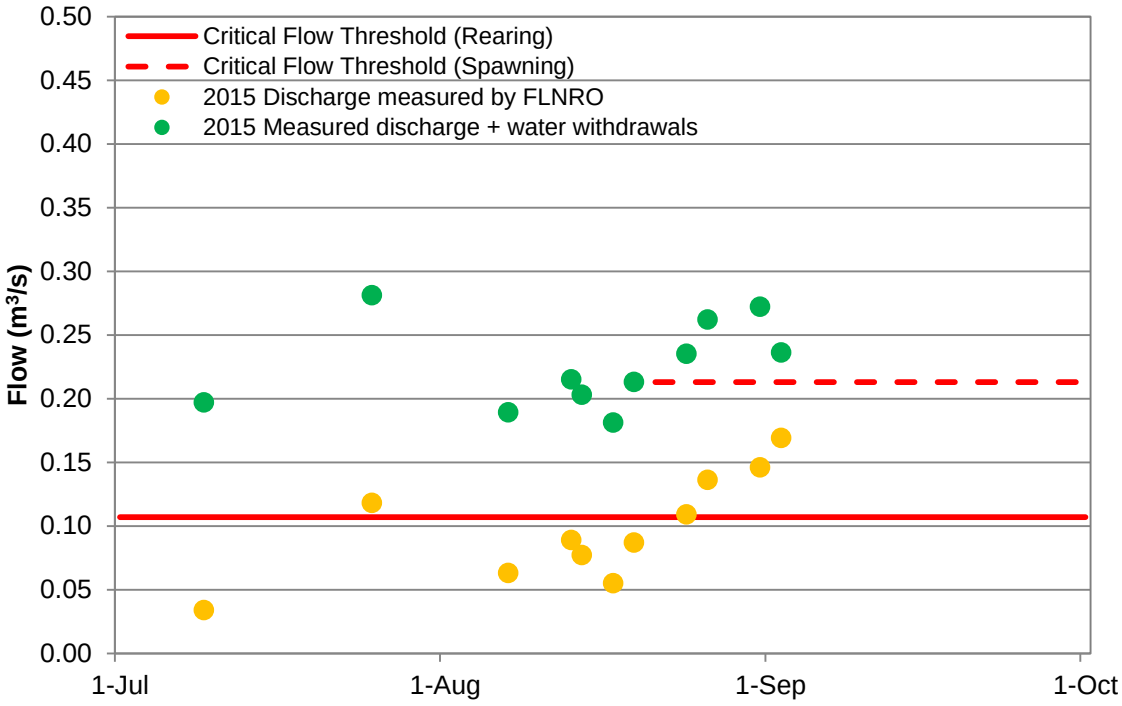
Figure 3-1 – 2015 flow estimates for select Water Survey of Canada (WSC) stations within the Bessette Creek watershed.

Prepared for: **Ministry of Forests, Lands and Natural Resource Operations**



A) Measured streamflows for Duteau Creek near Lavington (WSC Station: 08LC006) and minimum future flow releases from the GVW Headgates water intake, July 1 to October 1, 2015.



B) Measured streamflows for Creighton Creek at the mouth.

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Figure 3-2 – 2015 flow estimates for Duteau and Creighton Creek watersheds.

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Prepared for: **Ministry of Forests, Lands and Natural Resource Operations**

- Bessette Creek near Lumby: Assuming that streamflows at WSC Station 08LC005 continue at the level observed on September 18, 2015, the 52nd percentile of recorded streamflows provides a reasonable basis for estimating future streamflows (Figure 3-1a). Streamflows will likely increase throughout the remainder of September 2015. Streamflows are expected to remain above the critical flow threshold for Chinook Salmon rearing until the end of September 2015, but below the Chinook Salmon spawning threshold, regardless of whether or not water restrictions are enforced.

- Bessette Creek above Beaverjack Creek: Assuming that streamflows at WSC Station 08LC039 continue at the level observed on September 14, 2015, the 48th percentile of recorded streamflows provides a reasonable basis for estimating future streamflows (Figure 3-1b). Streamflows are likely to increase throughout the remainder of September 2015 and remain above the critical flow threshold for Chinook Salmon rearing. Streamflows are also expected to remain close to, but above the critical flow threshold for Chinook Salmon spawning, regardless of whether or not water restrictions are enforced. Note that the water demands included for Bessette Creek above Beaverjack Creek (i.e. at WSC Station 08LC039) represent the water demand for all sub-basins (i.e. the entire watershed area upstream of WSC Station 08LC039).

Figure 3-2 demonstrates the following for the Duteau and Creighton Creek watersheds:

- Duteau Creek near Lavington: Understanding that Duteau Creek is regulated by the GVW Headgates Dam and based on available information, estimated streamflows for the remainder of the irrigation season were assumed equal to the flow release targets at the Headgates Dam at a minimum. Accordingly, flow releases (including fish flows and an additional 0.057 m^3/s identified by Trout Creek Hydrology & Soils [2014] for priority water licences) were judged to provide the best approximation of future minimum streamflows. The expected releases from the GVW Headgates Dam for Duteau Creek and the estimated streamflows that likely would have occurred if the water being withdrawn from Duteau Creek for irrigation instead remained in the creek are plotted in Figure 3-2a.

  Streamflow measured in Duteau Creek on September 14, 2015, was above the Headgates Dam fisheries and total flow release targets for September. Assuming that GVW continues to release the required fisheries and total flows from the Headgates Dam (at a minimum) for the remainder of the irrigation season, it is expected that streamflows will remain at or above the critical flow thresholds. However, it is recommended that the operational flow release program at the Headgates Dam be confirmed with GVW to confirm the agreed upon flow releases. In addition, it is currently unknown how the flow releases relate to critical life stage requirements within the creek; therefore, a further understanding should be gained regarding how the agreed upon flow releases at the water intake meet the needs of all (or selected) fish-at-risk downstream from the water intake and specifically at Duteau Creek near Lavington (i.e. at WSC 08LC006).

- Creighton Creek at the mouth: Since 2015 field measurements were conducted at the mouth of Creighton Creek, approximately 10 km downstream of the WSC Station 08LC033, there is no historic streamflow record for this location. Accordingly, it is not possible to provide estimated future flows for Creighton Creek at this time. However, Figure 3-1b shows that streamflows are expected to have exceeded the critical flow threshold for Chinook Salmon spawning until September 2, 2015, if restrictions were placed on surface water use for irrigation.

4 BENEFITS OF WATER RESTRICTIONS TO FISH

For all watersheds, the implementation of water restrictions would likely result in reduced water temperatures and improvements in the existing fish habitat (e.g. deeper pools, higher velocity riffles).

Based on Figure 3-1 and the assumed future scenarios, the following conclusions are drawn:

- Bessette Creek: Implementing water use restrictions on irrigation in Bessette Creek downstream of the confluence with Duteau Creek will likely not increase streamflows to above the critical threshold for Chinook Salmon spawning, which may present a problem for the Chinook Salmon attempting to migrate upstream. However, flows are expected to remain above the critical threshold for Chinook Salmon rearing.

  Implementing water use restrictions throughout the entirety of Bessette, Duteau, and Creighton Creeks will likely result in substantially increased streamflows. However, it does not appear that water use restrictions are required to maintain flows above the critical flow thresholds for Chinook Salmon rearing and spawning at Bessette Creek above Beaverjack Creek (i.e. at WSC station 08LB039).

Based on Figure 3-2 and the assumed future scenarios, the following conclusions are drawn:

- Duteau Creek: Assuming that GVW continues to maintain their total and fisheries flow releases from the Headgates Dam, streamflows are expected to remain at or above the critical flow thresholds (at a minimum). However, to properly comment on Duteau Creek streamflows and critical flow thresholds, it is recommended that the flow release rates and timing be confirmed with GVW and an understanding be gained on how the flow releases meet the needs of fish-at-risk downstream and specifically at Duteau Creek near Lavington (i.e. at WSC 08LC006).

  Since a large portion of the irrigated lands are located downstream of the FLNRO monitoring location (i.e. Whitevale Road), it is difficult to comment on the effect of restrictions to irrigation water use on streamflows observed at this location. In addition, Trout Creek Hydrology & Soils (2014) suggest that Duteau Creek is likely being recharged by groundwater in its lower reaches; however, the use of groundwater for irrigation was not considered herein because restrictions on groundwater use are not presently being considered.

- Creighton Creek: Due to the absence of historic streamflow records at the mouth of Creighton Creek, it is not possible to provide a conclusion on the impact of future irrigation water use restrictions for Creighton Creek at this time. However, if streamflows remain at the level observed on September 2, 2015, for the remainder of the irrigation season, streamflows will exceed the critical flow thresholds for Chinook Salmon rearing, regardless of whether or not water restrictions are enforced. If water restrictions are enforced, it is anticipated that streamflows would exceed the critical threshold for Chinook Salmon spawning.

5 ACKNOWLEDGEMENTS

Funding for this project was provided by FLNRO to identify science-based options for responding to a Level 4 drought emergency in 2015 that impacted streamflow in many watersheds that support important fish populations in the Thompson-Okanagan Region. Additional funding for the Bessette Creek watershed was provided through the Habitat Conservation Trust Fund – Thompson Shuswap Okanagan Instream Flow Conservation Flows Project.

6 CLOSURE

The calculations and estimates provided in this memo are based on several assumptions as outlined herein. Key assumptions for Bessette Creek watershed include that streamflows during the remainder of the irrigation season follow the trend of the 52nd percentile at WSC Station 08LC005 and the 48th percentile at WSC 08LC039; the lands irrigated, crop types, and irrigation water sources identified by the Ministry of Agriculture in 2014 are consistent with current land practices; that irrigation demands will occur at average rates, and will follow the pattern of a typical year, for the remainder of the 2015 irrigation season; and that all irrigators are currently irrigating and will continue to do so through the end of the 2015 irrigation season. For Duteau Creek watershed, it was assumed that fisheries flow releases at the GVW's Headgates Dam were constant and sufficient to meet focal species critical life stages.

It is recommended that before seeking to restrict water use, FLNRO obtains site-specific field-based information to determine or confirm current conditions in the affected areas.

Associated Environmental

March 21, 2016
Thompson-Okanagan Regional Drought Response Team
B.C. Ministry of Forests, Lands, and Natural Resource Operations
- 26 -

We trust that this meets your requirements at this time. If you have any questions or require additional information, please do not hesitate to contact me.

Yours truly,
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REFERENCES

Anthony, E. D. 1975. Final Draft on Report of the Bessette Creek Watershed Committee. August 1975.

Associated Environmental Consultants Inc. (Associated). 2016. Irrigation Water Demands – Bessette, Duteau, and Creighton Creek Watersheds. Prepared for the B.C. Ministry of Forests, Lands, and Natural Resource Operations, February 2016.

B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) and Okanagan Nation Alliance (ONA). 2015. Personal Communications between Eleanor McGrath (ONA), Richard McCleary (FLNRO), and Associated Environmental Consultants Inc. on December 8, 2015.

British Columbia Conservation Foundation (BCCF). 1987. Stream Report: Bessette Creek. http://a100.gov.bc.ca/appsdata/acat/documents/r44440/streamrept_1424470653739_4467091277.pdf

British Columbia Ministry of Environment (MOE). 2015a. Fish Inventory Data Queries (FIDQ). http://www.env.gov.bc.ca/fish/fidq/ (accessed 18 Aug 2015)

British Columbia Ministry of Environment (MOE). 2015b. Habitat Wizard database. www.env.gov.bc.ca/habwiz (accessed 18 Aug 2015).

British Columbia Ministry of Environment (MOE). 2015c. iMAPBC 2.0. http://www.data.gov.bc.ca/dbc/geographic/view_and_analyze/imapbc/index.page (accessed 18 Aug 2015)

British Columbia Ministry of Environment (MOE). 2015d. B.C. Species and Ecosystem Explorer. http://www.env.gov.bc.ca/atrisk/toolintro.html (accessed Aug 19 2015).

Epp, P. 2015. Hydrologist, Trout Creek Hydrology & Soils. Personal email communication with Drew Lejbak of Associated Environmental Consultants Inc., September 2015.

Fisheries and Oceans Canada (DFO). 1988. Duteau Creek Fisheries Flow Releases. Letter to the Vernon Irrigation District. http://a100.gov.bc.ca/appsdata/acat/documents/r44597/Flow_1425495109853_5494347805.pdf

Fisheries and Oceans Canada (DFO). 2006. Conservation Strategy for Coho Salmon (Oncorhynchus kisutch), Interior Fraser River Populations. October 2006.

Freshwater Fisheries Society of B.C. (FFSBC). 2015. Fish Stocking Reports. http://www.gofishbc.com/fish-stocking-reports.aspx (accessed 18 Aug 2015)

Golder Associates Ltd. (Golder). 2012. Phase I – Shuswap River Watershed Sustainability Plan: Technical Assessment of the Shuswap River Watershed. Prepared for the Regional District of North Okanagan, February 2012.

Government of Canada. 2015. New Salmon Escapement Database System (NuSEDS). http://open.canada.ca/data/en/dataset/c48669a3-045b-400d-b730-48aafe8c5ee6 (accessed 18 Aug 2015).

McPhail, J.D. 2007. The Freshwater Fishes of British Columbia. The University of Alberta Press. Edmonton.

Secwepemc Fisheries Commission. 2010. Lower Creighton Creek Restoration Project (BCRP Project 09.SHU.01). Report Prepared for BC Hydro, Whitevalley Community Resourse Centre, and Splats'in First Nation. May 2010.

Summit Environmental Consultants Inc. (Summit). 2000. Final Report - Coho Salmon Enumeration 1999 – Bessette Creek, Harris Creek, Creighton Creek, Ireland Creek, Six-Mile Creek, Bolean Creek, Salmon River. Prepared for Okanagan Nation Fisheries Commission. February 2000.

Swain, L. G. 1991. Shuswap-Mabel Area. Bessette Creek Water Quality Assessment and Objectives. Technical Appendix. Ministry of Environment, Province of British Columbia. http://www.env.gov.bc.ca/wat/wq/objectives/bessette/Bessettetech.pdf

Trout Creek Hydrology & Soils. 2014. Environmental Flows and Hydrologic Assessment for the Bessette Creek Watershed. Prepared for the B.C. Ministry of Forests, Lands, and Natural Resource Operations, March 2014.

University of British Columbia (UBC). 1994. First Nations of British Columbia. https://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-BC/STAGING/texte-text/fnmp_1100100021018_eng.pdf