Appendix 12-E

Hydrology Synthetic Flow Series – Additional Information

December 22, 2014

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Mr. Frank Wheatley
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Dear Frank,

Re: Hydrology Synthetic Flow Series – Additional Information

1 – INTRODUCTION

In November 2014, Yellowhead Mining Inc. (YMI) submitted an Application for an Environmental Assessment (EA) Certificate for the Harper Creek Project. Lorax Environmental Services Ltd. (Lorax) was then retained by the British Columbia Ministry of Energy and Mines (BC MEM) to provide screening review of several components of the Application (Lorax, 2014). The scope of Lorax's review included hydrology and water management. This letter aims to address the following comments provided by Lorax during the EA Screening period.

5.0 Hydrology and Water Management	5.2 Information Request	Please provide the R^2 values and derived equations for the EFP analysis.
		Please provide rationale for the assumed slope of the extrapolated lines in the EFP relationships (to highest recorded flows at the WSC Harper Creek stations). In some cases, the relationship appears to be extrapolated following the 1:1 line (*e.g.*, JONESUS – autumn), when the existing data suggest that the actual slope is lower. In other cases (*e.g.*, JONESUS – spring/summer; OP – autumn, HARPERUS – autumn), the slope indicated by the measured data appears to have been retained for the extrapolation.

2 – EMPIRICAL FREQUENCY PAIRING MODEL QUALITY

No goodness of fit statistics, such as the coefficient of determination, R^2, are provided for the empirical frequency pairing (EFP) correlations because the ranking process implicit in EFP invalidates such values. The quality of the modelling procedure can best be assessed by comparing watershed characteristics, concurrent hydrographs, chronologically pared data and measured and synthesized hydrographs. The derived equations are not presented as the methodology used in this analysis provided relationships between each concurrent measured data point in the ranked relationship, rather than a best fit relationship to the data.

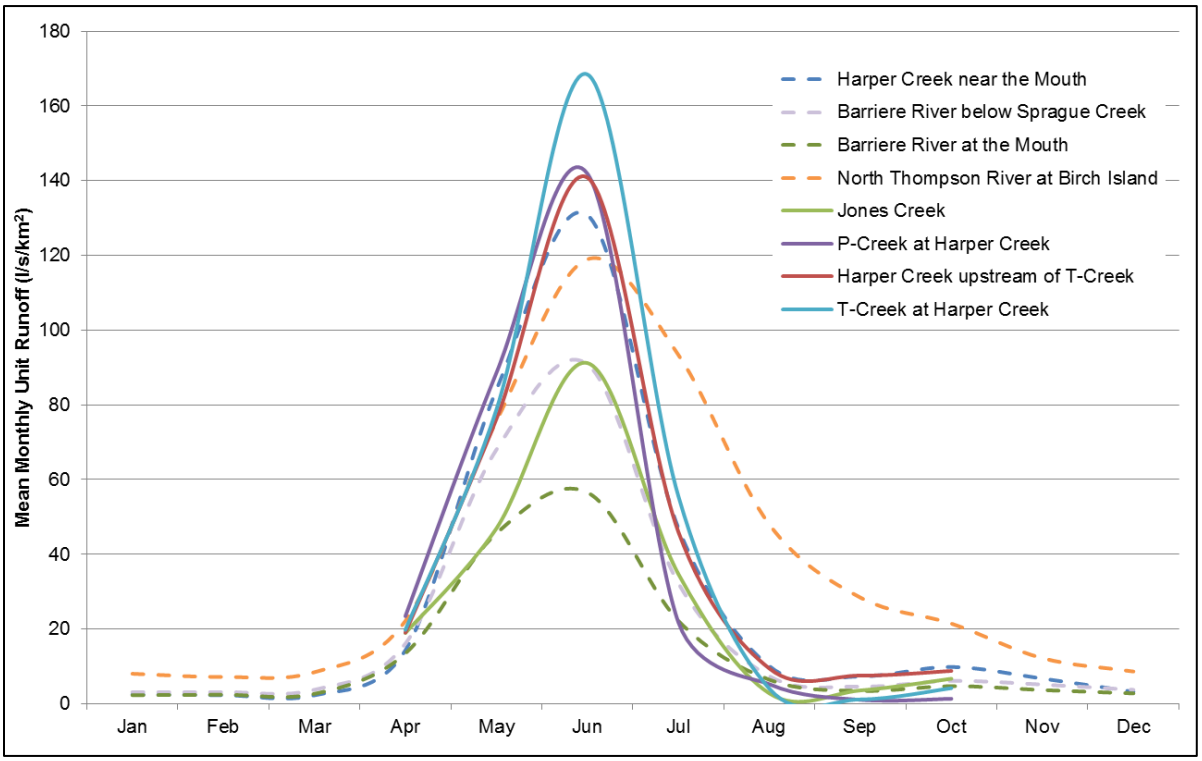
The first step in in a correlation analysis is to compile regional information and datasets to develop an understanding of the similarities and differences in hydrologic characteristics proximal to the site of interest. The second step is to select a regional station for correlation with the Project stream. The regional station must have a period of record concurrent with the Project streams. When developing synthetic streamflow data using a correlation methodology, be it EFP or chronological pairing (CP), the selection of the regional station "pair" is critical. These pairing methods are based on an assumption that the two watersheds exhibit similar runoff characteristics and have similar hydro-climatic influences (Butt 2013). The selection of Harper Creek at the Mouth WSC station as the regional pair for the EFP analysis for this Project was based on an examination of hydrograph patterns and watershed characteristics. Mean monthly unit runoff and watershed characteristics for four regional WSC stations and the four HCMC stations selected for long term streamflow development were compared to select an appropriate WSC station to use as a suitable pair. Maps and tables presenting details of

the WSC and HCMC stations can be found in the Surface Hydrology Baseline Report (KP, 2014). The unit hydrographs are presented in Figure 1 for the concurrent period of record 2011 to 2013.

Harper Creek at the Mouth has a more similar watershed size to the Project watersheds than the other three stations which are located on larger river systems. Harper Creek at the Mouth also includes much for the Project area within its watershed, as do the two Barriere River WSC Stations. The remaining Project area is included in the North Thomspon River at Birch Island watershed. Using a regional station with a shared watershed for three of the four HCMC stations would be expected to produce superior results as the runoff mechanisms and relationships from the Project watersheds are contained within the regional watershed. This is illustrated in the match of hydrograph shape shown in Figure 1. The rising and falling limb shows a similar shape and slope, although the peak unit runoff values vary. Similarly, unit runoff magnitudes match well during the summer low flows and during the fall.

The two Barriere River stations contain the Project area, but have much larger watersheds and slower, more muted runoff response to precipitation and snowmelt than the smaller Project watersheds. These watersheds also include substantial catchment outside of the Project area.

The station at North Thompson River at Birch Island has a different hydrograph shape from the Harper Creek and Barriere River stations and the Project stations. The North Thompson River at Birch Island sees much higher late summer flows than the Project area, due to significant glaciation in its headwaters to the north-west of the Project. Given that these conditions are not present in the Project watersheds, the North Thompson River at Birch Island would be a poor candidate for a regional representative station for correlation analysis.



NOTES:

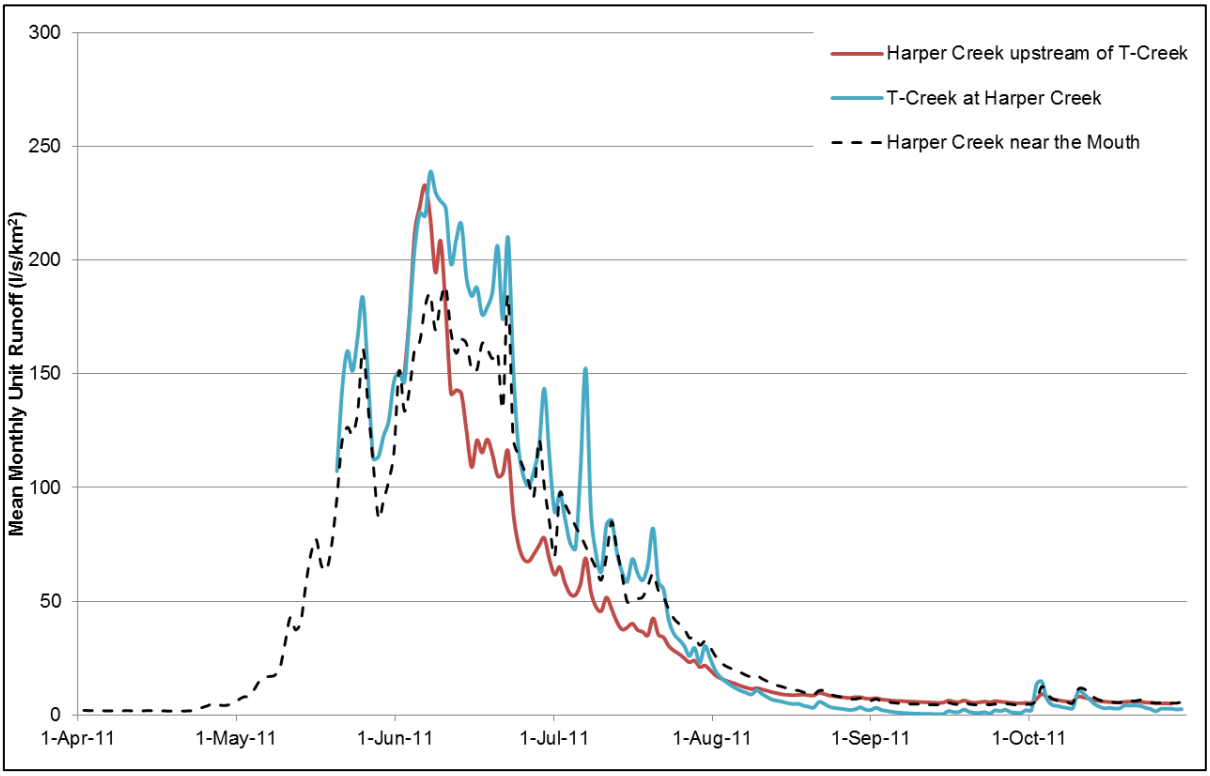
1. MEAN MONTHLY UNIT RUNOFF AVERAGED OVER 2011 TO 2013 WHERE SUFFICIENT DATA ARE AVAILABLE.

Figure 1 Mean Monthly WSC and HCMC Stations

Examination of concurrent daily flows at the regional stations further confirms the Harper Creek at the Mouth WSC Station as the most appropriate pair for the Project stations. At a daily resolution, the regional station

should show similar timing and response to precipitation and temperature conditions. Daily unit runoff at the Project stations and Harper Creek at the Mouth are shown on Figure 2 on a year-by-year basis. Overall, all stations show a similar timing response to hydrologic events and similar runoff patterns.

a)



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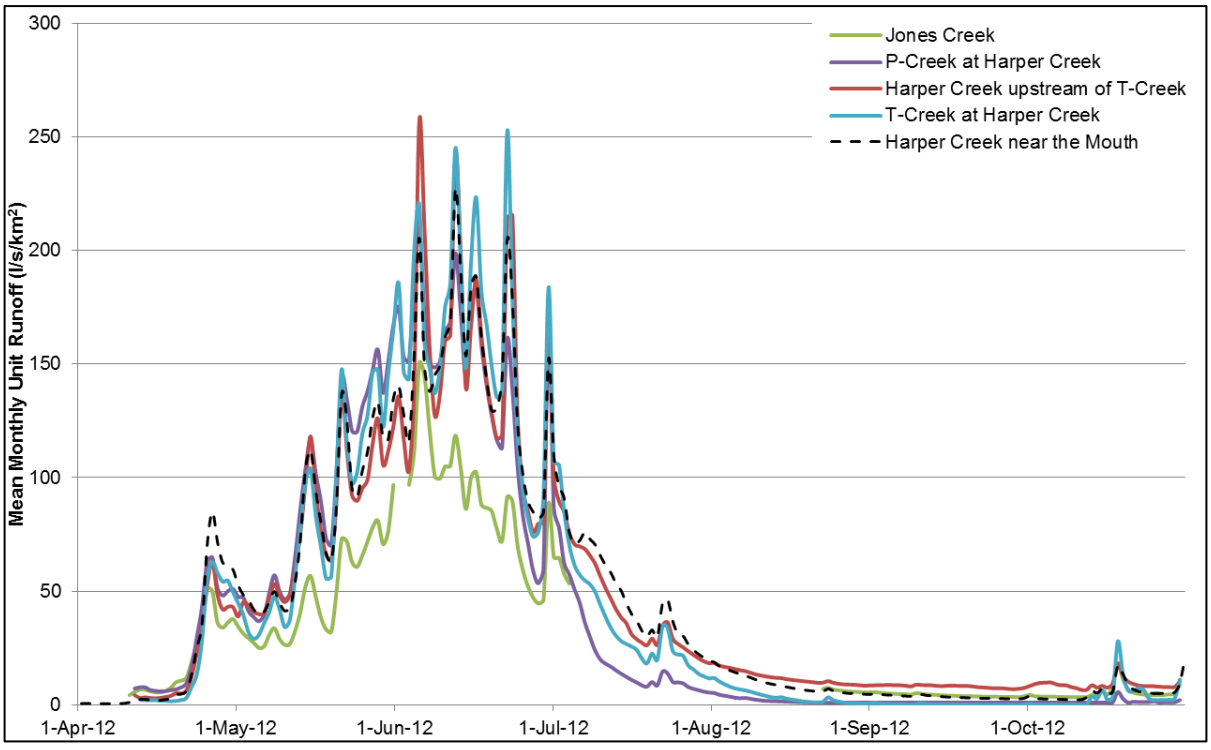

c)

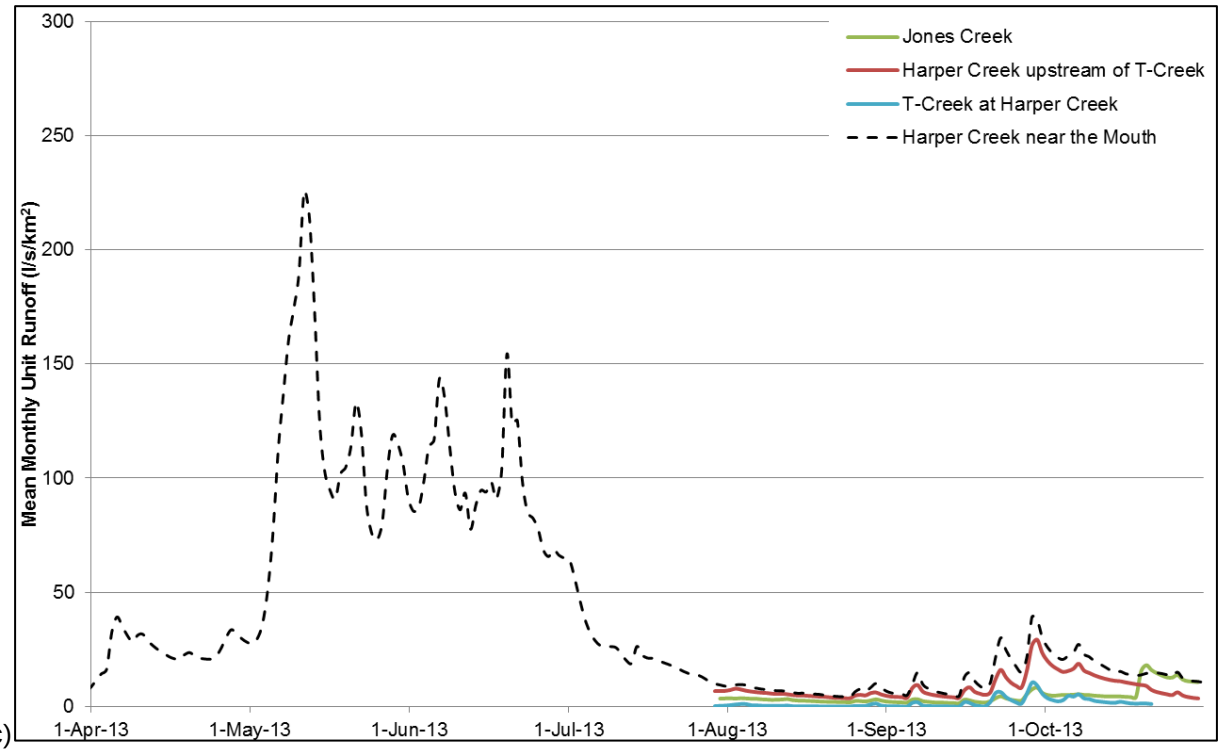

Figure 2 Unit Runoff at Harper Creek at the Mouth and HCMC Stations showing separate years, a) 2011, b) 2012 and c) 2013

The high degree of correlation between the HCMC stations and the WSC Harper Creek station is further indicated by the R^2 values ranging from 0.92 to 0.96 for CP data for the April-October period. CP plots are presented in Figures 3 to 6 for JONESUS, OP, HARPERUS, and TSFDS respectively. Review of these figures and R^2 values indicate that even without the seasonal segregation, discharge Harper Creek and the Mouth has a strong linear relationship with discharge at each of the HCMC stations. Despite the high degree of correlation of CP data, EFP was selected as a superior methodology for developing a synthetic dataset over CP. Removing the chronological restriction on the pairing model by allowing pairing to be based on frequency provides a superior fit to the flow duration relationship to the measured dataset for nival and pluvial hydrographs, particularly for shorter concurrent streamflow records (Butt, 2013). Given that EFP matches the flow duration relationships between the pairs better than CP, the results from the EFP analysis would be expected to be an improvement over those derived from these CP relationships.

Measure and synthetic concurrent hydrographs are shown in the Surface Hydrology Baseline report (KP, 2014) and despite the ranking process, the timing of flows are captured reasonably well.

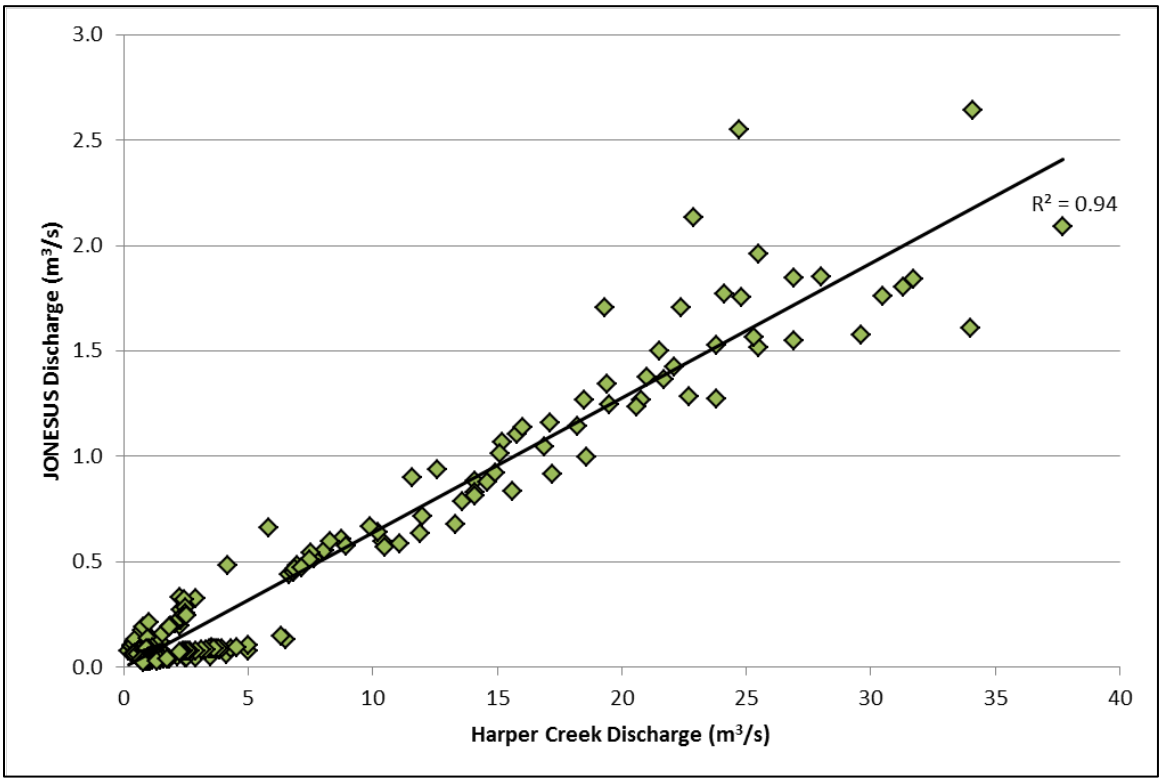

Figure 3 **Chronologically Paired Relationship for JONESUS and Harper Creek at the Mouth**

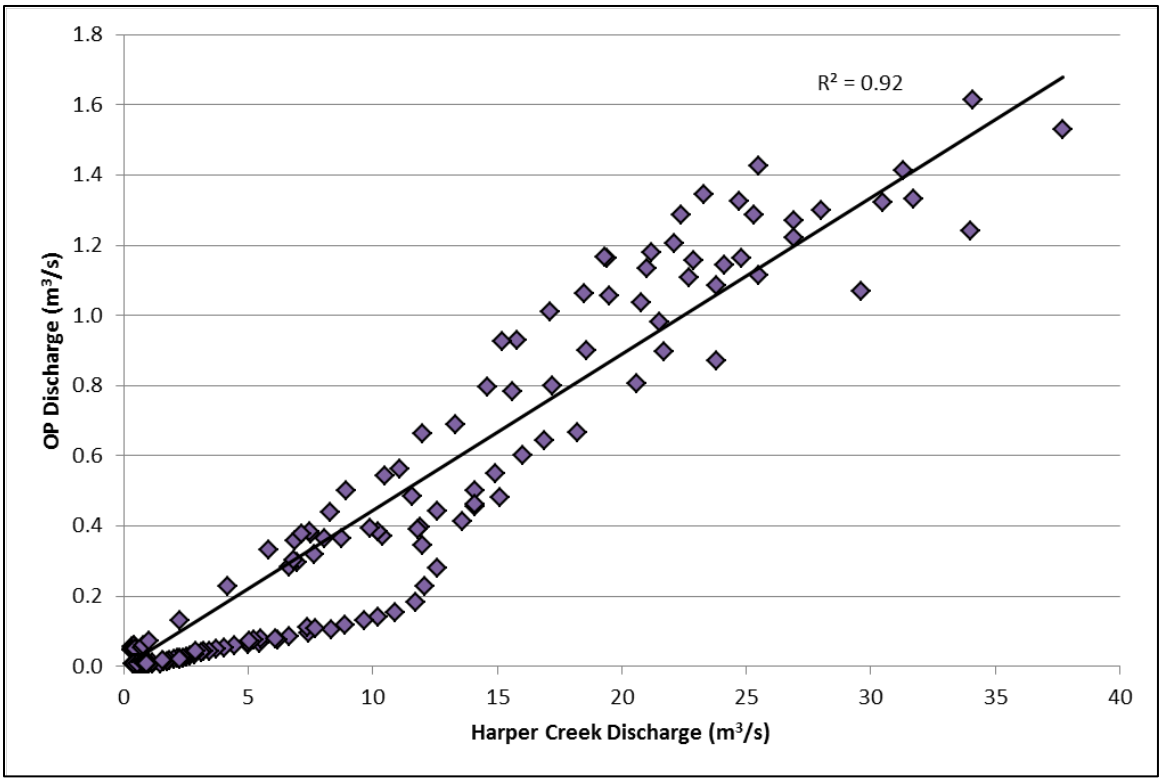

Figure 4 **Chronologically Paired Relationship for OP and Harper Creek at the Mouth**

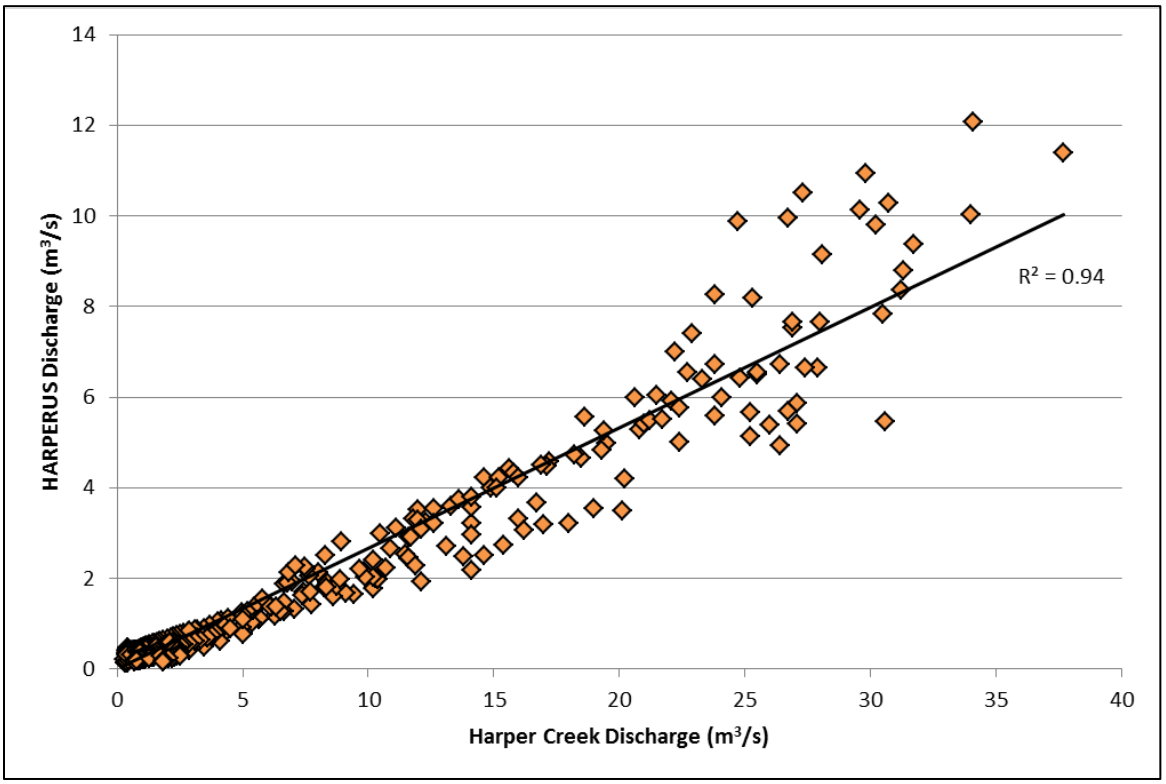

Figure 5 **Chronologically Paired Relationship for HARPERUS and Harper Creek at the Mouth**

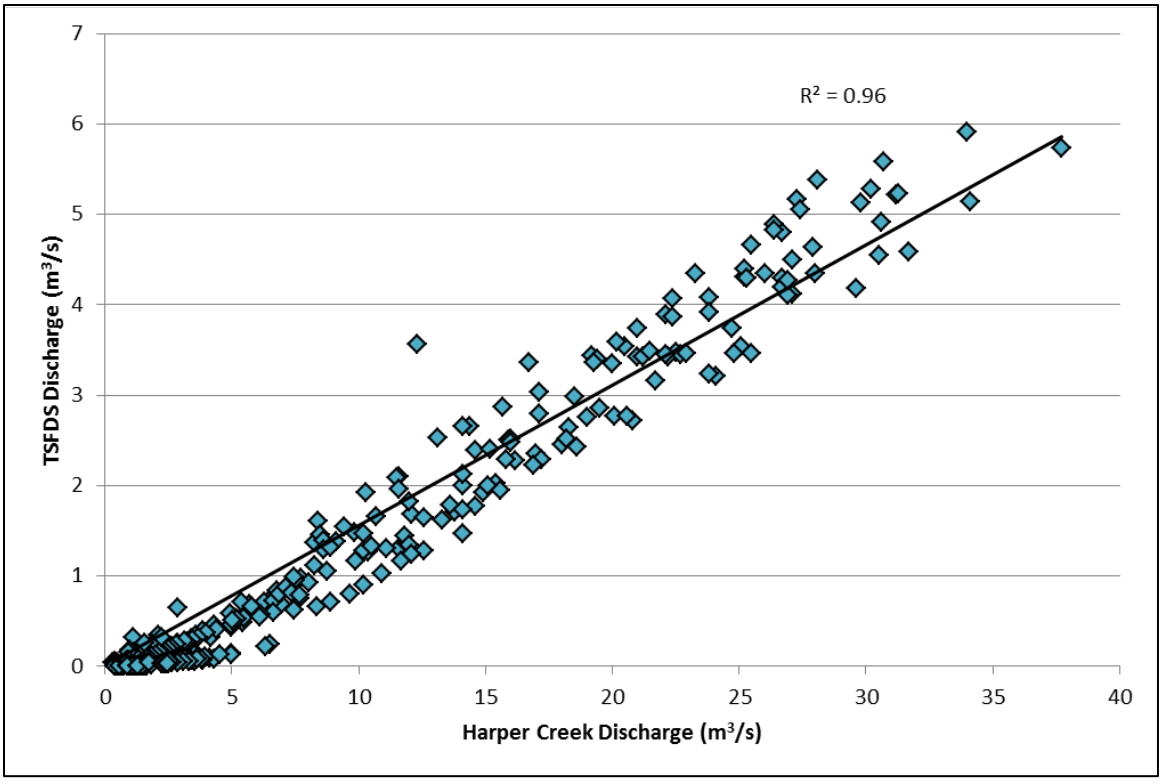

Figure 6 **Chronologically Paired Relationship for TSFDS and Harper Creek at the Mouth**

3 – EXTRAPOLATION OF EFP RELATIONSHIPS

When extrapolating EFP relationships beyond the concurrent measured data to cover the full range of points within the regional streamflow record, two approaches can be considered. One could continue the relationship suggested by the measured points if this relationship is physically defensible during higher flows or one could select a more physically likely relationship. As no data are available to predict this relationship, extrapolation from the last point parallel to the line of equal unit runoff (EUR) while maintaining the offset was considered reasonable where extrapolation of the measured points seem unreasonable. For this Project a mix of extrapolation techniques were used. Although the range of flow values in the extrapolation appears great, the extrapolation covers only a small proportion of the measured flows over the record from 1974 to 2010. Seasonal flow duration curves for Harper Creek at the Mouth are shown in Figure 7. For the Spring/Summer relationships, the relationships are extrapolated from flows around 35 m^3/s to 55 m^3/s, indicating that the extrapolation is applied approximately 2% of the time. For the Autumn regressions, the relationships are extrapolated from flows between 3 to 5 m^3/s to almost 25 m^3/s, indicating that the extrapolation is applied between 14% and 4% of the time. The extrapolation leads to uncertainty in the magnitude of extreme events in the synthetic flow series but due to the infrequent application of these extrapolations, typical flows are accurately represented. The results from the EFP modeling were used to calibrate the watershed model on a monthly timestep, so this extrapolation, regardless of approach, will have little impact of the mean monthly flows given the proportion of the flow duration curve it represents.

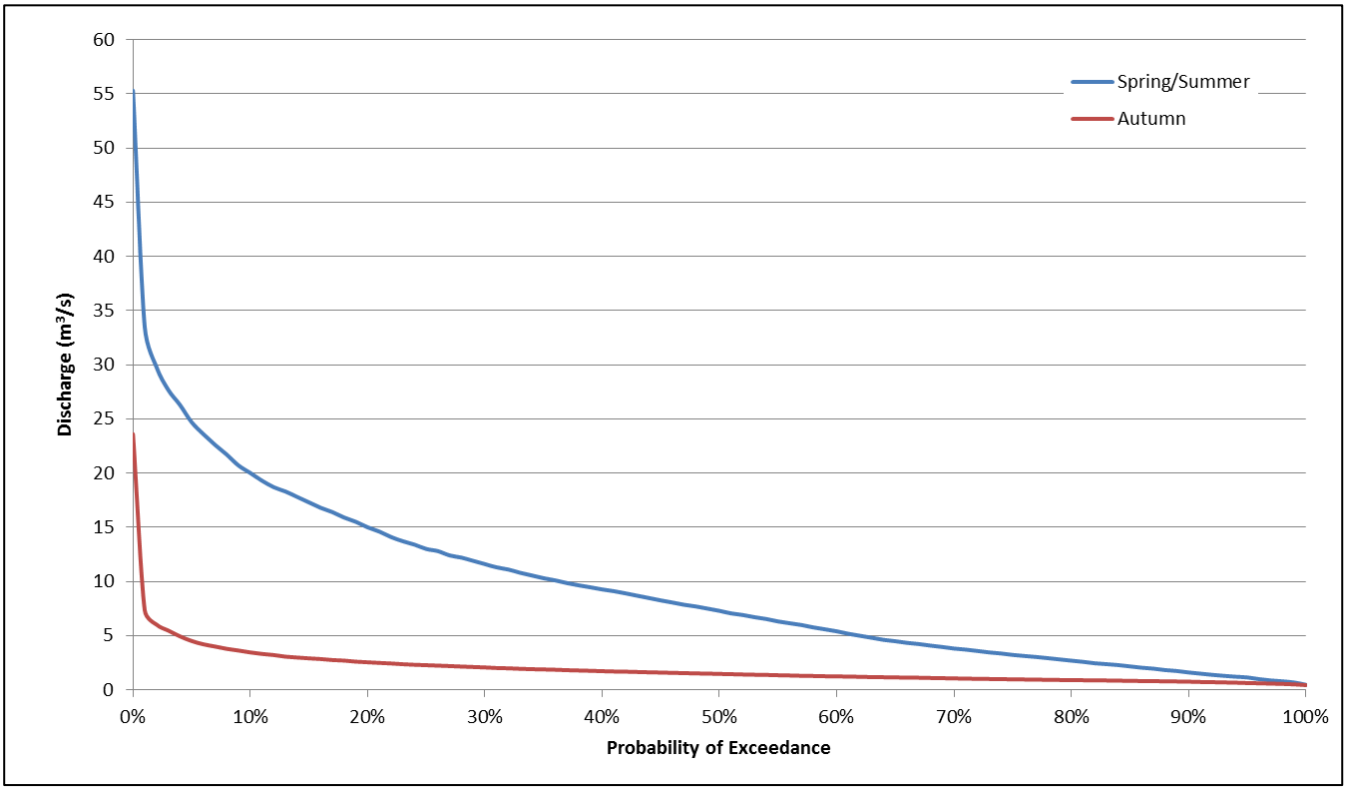

Figure 7 Flow Duration Curves for Harper Creek at the Mouth for Each Regression Period

We trust that this letter meets the current needs of the Project team. Please contact the undersigned with any questions or comments.

Yours truly,
KNIGHT PIESOLD LTD.

Signed:

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References

Butt, C., 2013. Evaluation of the Performance of Frequency and Chronological Pairing Techniques in Synthesizing Long-Term Streamflow. Master's Thesis, Department of Civil Engineering, Faculty of Applied Science, University of British Columbia, Vancouver, BC.

Knight Piésold Ltd. (KP), 2014. Harper Creek Project –Surface Hydrology Baseline. Ref. No. VA101-458/15-2, Rev. 0. Vancouver, BC

Lorax Environmental Services Ltd. (Lorax), 2014. Harper Creek Application Screening Comments, 28 November 2014. Lorax Environmental Services Ltd., Vancouver, BC.

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