TM #2A – Intake Hydrology and Hydraulics (REVISED FINAL)

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KWL PROJECT NUMBER: 0468.010

Introduction

The following technical memorandum (TM #2A) forms part of the technical deliverables for the design of the water supply intake for the proposed Englishman River Water Intake and Treatment Plant Project. The purpose of the memo is to outline the design criteria relating to river hydrology and hydraulics at the water supply intake site. The memo includes:

1. A brief overview of the Englishman River watershed and potential intake site locations
2. A summary of Englishman River hydrology and monthly flow duration curves
3. Calculation of design flood discharges
4. A summary of modelled flood levels and velocities at the intake site locations
5. Low flow water level rating curves and channel cross sections at the intake sites

Englishman River Raw Water Intake

As part of Englishman River Water Service (ERWS) water supply and treatment project, a new raw water intake is proposed on the Englishman River. The proposed raw water intake will replace the existing infiltration gallery intake located downstream of the Old Island Highway (HWY 19A) bridge. The purpose of the raw water intake and treatment plant is to provide municipal water supply to the City of Parksville and Nanoose Bay Water Service Area operated by the Regional District of Nanaimo. The total population of the area to be serviced by the ERWS intake was 17,550 in 2013 with population forecast to increase to 24,290 by 2035. Maximum current water demand (2013) is about 22.9 MLD and is forecast to increase to approximately 27.8 MLD by 2035. The proposed intake will support the majority of these demands supplemented by existing groundwater wells operated by the City of Parksville. Future municipal water demands may also be supported by a proposed aquifer storage and recovery (ASR) system, if groundwater studies being carried out at the time of writing prove to be feasible. ASR could provide the benefit of capturing and storing water during winter high flow period for use in the summer low flow period, thus reducing summer withdrawals from Englishman River. Further details on water demands can be found in Technical Memorandum #4A.

The water licence issued for the intake (C129710 dated January 17, 2013) permits a maximum withdrawal rate of 48 MLD, which was based on water demand forecasts to the 2050s. However, given the uncertainty in water demand forecasts and the potential for ASR to supplement future water demand, the ERWS has decided to install pumping capacity at the intake to withdraw up to 28.8 MLD (0.333 m^3/s) at the current time. This maximum rate is based on nominal maximum daily average of 24 MLD (0.278 m^3/s) with an allowance for +/-20% instantaneous peak flow variation to account for fluctuations in flow rate as a result of the water treatment plant process and as an added factor of safety for peak day demands. For the assessment of river hydraulics at the intake site, we have assumed 28.8 MLD as the maximum design withdrawal at the intake site.

Site Location

The Englishman River is located on the east coast of Vancouver Island near the City of Parksville,BC. The watershed has a total area of 324 km^2 and rises from sea level at the estuary on Georgia Strait up to El. 1820 at Mount Arrowsmith. The mainstem of the river is approximately 40 km long. Several small lakes are located within the watershed including Arrowsmith Lake, Hidden Lake, Fishtail Lake, Rowbotham Lake, Healy Lake, Shelton Lake, and Rhododendron Lake. Land use in the watershed is predominantly private forest land managed by Island Timberlands and Timberwest, with rural agricultural and suburban development in at lower elevations. Soils within the watershed range from thin soils over bedrock on steeper mountain slopes in the headwaters of the watershed to thicker fluvio-glacial sediments where the river crosses the Nanaimo lowlands. Figure 1 shows map of the watershed.

The proposed water supply intake locations are located upstream of the Island Highway (HWY 19) bridge about 4 km upstream from the river mouth. The reach upstream of the highway bridge was identified as the most preferable location for the proposed intake as part of the initial feasibility study prepared by Associated Engineering, dated April 2011. Two potential intake sites have been identified in the reach, one located on the left bank (looking downstream) immediately upstream of the highway bridge (Site 2) and one located on the right bank about 100 m upstream of the bridge. Site 2 is located on the outside of the river bend at a bedrock controlled pool. Site 3 is located opposite a bedrock outcrop in the centre of the channel which focuses the river thalweg to the right bank in this location. A plan showing the locations of the two sites is shown in Figure 2. Photographs of Site 3 are shown in Appendix A.

Hydrology and hydraulic analysis for both sites 2 and 3 have been completed as part of the study. However, site 3 is the preferred intake location as it is located on the same side of the river as the treatment plant site. A comparison of the two proposed intake sites and rational for selection of site 3 is included in Technical Memorandum #2.

Climate and Hydrology

The Englishman River watershed is located within the mild coastal climate zone of the east coast of Vancouver Island with warm dry summers and mild wet winters. Typically more than 75% of the total annual precipitation falls during the six month period between October and March. Average total annual precipitation (1971 to 2000 normal period) at Little Qualicum River Hatchery, located about 20 km to the east of Parksville, is 1098.5 mm. Total precipitation at higher elevations in the watershed is estimated to be more than double that recorded at low elevations. A plot of the average monthly temperatures and precipitation recorded at Little Qualicum Hatchery is shown in Figure 3.

Snowpack accumulates within the higher elevation areas within the watershed. No snow course data is available within the watershed. However, a snow course is located at Mount Cockeley about 5 km north of the watershed at El. 1267 m. The average April 1st snow water equivalent measured at Mt. Cockley is 862 mm.

The hydrology of the Englishman River is predominantly rainfall driven with higher discharges through the fall and winter period with lower discharges in the spring and summer. Most of the highest recorded flows occur between October and February with smaller peak flows in the spring resulting from snowmelt from the upper watershed.

Through the summer, discharge in the Englishman River is augmented by flow releases from the Arrowsmith Lake reservoir located near the headwaters of the watershed. The Arrowsmith Dam was constructed in 1999/2000 and provides approximately 9 million m^3 of storage capacity to support summer river flow for water supply and to support minimum instream flows for fish habitat protection.

The Water Survey of Canada records Englishman River discharge at a hydrometric station located at the Old Island Highway Bridge (Hwy 19A) about 2 km downstream of the intake site locations (Englishman River near Parksville - WSC 08HB002). This data has been used to prepare hydrographs and flow duration curves for the pre-dam (prior to 1999) and post-dam (after 2000) conditions as described below.

Daily Average Hydrographs

Hydrographs using daily average data recorded at the Englishman River near Parksville gauge have been prepared to show seasonal variation in discharge and the impact that Arrowsmith Lake dam has had on summer flows. Hydrographs for the median daily flows and the daily 90% exceedance flows are shown in Figures 4a and 4b, respectively. In addition to the recorded historical flows, the hydrographs also show forecast post project flows under anticipated future withdrawal conditions. The post project flows downstream of the proposed intake have been calculated by subtracting estimated maximum future daily withdrawal from the median and future withdrawals under stage 4 watering restrictions from the 90% exceedance flows based on recorded data. Future daily withdrawals are based on a synthetic daily withdrawal hydrograph based on recorded withdrawals at the existing intake scaled to match the maximum daily withdrawal (24 MLD). The maximum daily withdrawal hydrograph for maximum withdrawal rate and under Stage 4 watering restrictions also shown in Figures 4a and 4b, respectively.

Flow Duration Curves

In order to assess available water supply at the intake sites, flow duration curves using daily average data from the Englishman River near Parksville hydrometric gauge (WSC 08HB002) have been prepared for the pre-dam and post-dam periods. Both flow durations curves plotted on logarithmic scale to show the full range of flows over the entire year as well as for each month are shown in Figures 5a to 5c. More detailed plots for the summer low flow months showing only the flow range from 0 m^3/s to 3 m^3/s from July to October are shown in Figures 5d to 5g. The flow duration curves clearly show the increase in summer flows as a result of releases from Arrowsmith dam in the summer period.

The maximum potential for reducing flow downstream of the proposed intake are also shown on the summer (July to Oct) flow duration curves as the minimum potential post-project flow. These curves were calculated by subtracting the maximum withdrawal capacity (28.8 MLD or 0.333 m^3/s) from the flow duration curves based on daily average flow records for the post-dam period. The minimum post-project curve should be considered as envelope curves, indicating the minimum potential downstream flow at any given level of flow exceedance (ie: comparing the pre-project flow duration curve to the minimum post project flow duration curve along the vertical axis). As the maximum withdrawal of 28.8 MLD will not be continuously sustained, the curves should not be used to compare change in flow exceedance at a given river flow rate (ie: comparing pre-project flow duration curve to minimum post project flow duration curve along the horizontal axis).

Design Flood Discharges

Design flood discharges at the intake sites for the 2-year, 10-year, 50-year, 100-year and 200-year return periods have been estimated at the proposed intake site using annual maximum data series from the Englishman River near Parksville gauge (WSC 08HB002). It has been assumed that the flows at the gauge are approximately the same as the flows at the intake site because there are no major tributaries or other inflows between the intake sites and the gauge.

The maximum annual series from the Englishman River gauge includes 23 annual peak instantaneous flow values between 1986 and 2010 and 35 annual maximum daily flow values between 1915 and 2011. As the recorded maximum daily data covers a longer period than the recorded peak instantaneous flows, a flood frequency analysis using the maximum daily flow data provides a more representative data set for flood frequency analysis. The HYFRAN flood frequency program was used to determine best fit for the General Extreme Value (GEV), Log Normal 3 Parameter and Log Pearson Type 3 extreme value distributions. The average of the three distributions was used in estimating peak daily design flows.

The instantaneous flows were then estimated using the average ratio of annual peak instantaneous to peak daily flow ratio for the 23 year period of overlapping record. The average ratio was calculated to be 1.57.

The results of flood frequency analysis of the data from the Englishman River gauge is shown in Table 1.

TABLE 1
Englishman River Design Flood Discharge Estimates (No Climate Change Allowance)

Design Return Period (years)	Englishman River near Parksville (1979 to 2011)	
	Peak Daily Discharge (m3/s)	Peak Instantaneous Discharge (m3/s)
2	203	319
10	334	524
50	423	664
100	456	715
200	486	763

[a] Daily flood frequency analysis based on the average best fit of General Extreme Value (GEV), Log Normal 3 Parameter and Log Pearson Type 3 distributions to the maximum annual discharge series. Instantaneous peak flows based on average daily to insntaneous peak flow ratio of 1.57 using data from overlapping period of record from 1986 to 2010.

The design flood flows were also compared with the other regional flood frequency estimates. Figure 6 shows the comparison of the estimated 200-year return period unit flood discharge for the Englishman River of 2.35 $m^3/s/km^2$ with the peak instantaneous unit discharge from other stations on the east coast of Vancouver Island summarized in the BC Streamflow Inventory (Coulson, 1998). The comparison indicates that the estimated maximum daily and peak instantaneous 200-year flood flows fall within the regional range of estimates.

Climate Change

Climate models are forecasting changes in future average precipitation for the east coast of Vancouver Island generally with increased winter precipitation and lower summer precipitation. However, the model results have significant uncertainty around changes in extreme events. In order to assess potential influence of climate change on extreme events in the Englishman River, a trend analysis of the annual maximum series has been carried out. Interestingly, the historical trend analysis indicates that since 1979 peak flows on the Englishman River show a decreasing trend of about 27 m^3/s/decade or about 12% of the mean annual flood per decade (see Figure 7). However, significant care must be taken in using trends based on short term historical records to forecast future changes in flood hydrology due to the impact that cyclical climate patterns such as El-Nino Southern Oscillation and the Pacific Decadal Oscillation have on extreme precipitation and flood events.

The recently released Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC Guidelines prepared by Association of Professional Engineers and Geoscientists of BC (APEGBC, 2012) indicates that for watersheds showing no trend or a decreasing trend in peak floods a factor of 10% should be added to the peak design flows to account for future changes in climate. Based on this recommendation, a sensitivity analysis has been carried out to review the influence of changing flow by 10% on water levels and flow velocities. This is described in more detail in the following section.

River Hydraulics

In order to establish design water levels for the proposed intakes, both low flow and high flow water levels have been estimated. The low flow design water levels have been estimated through field measurement during the period from May 2013 to September 2013 and the high flow water levels are based on results of computer hydraulic modelling.

Low Flow Water Levels

A series of water level and discharge measurements have been taken at each of the potential intake site locations to establish low-flow rating curves. These rating curves can be used to estimate water levels and water depths at the two intake locations for design of the proposed intake and pump station. The Aquatic Effects Assessment Report prepared by LGL, indicates that the minimum instream flow downstream of the intake site to limit negative impacts to fish species is 0.9 m^3/s. The low flow rating curves for Sites 2 and 3 showing water depth at the minimum instream flow are shown in Figures 8a and Figure 8b, respectively.

High Flow Design Water Levels and Flow Velocities

Peak design water levels and flow velocities for the intake structure design have been estimated using hydraulic analysis using HEC-RAS computer hydraulic model. The model covers the Englishman River between the Old Island Highway (Hwy 19A) and the proposed intake locations upstream of the Inland Island Highway (Hwy 19). The cross-sections surveyed by the Ministry of Environment in 1984 for the river channel between Highway 19 and approximately 150 m downstream of railroad (MOE XS-12 to 21) were adopted to use in this study. Channel geometry for reach upstream of the Island Highway Bridge (HWY19) is based on topographic survey completed by KWL on August 13, 2013. There are three bridges, the Island Highway (Hwy 19), the Old Island Highway (Hwy 19A) and the E&N railway, in the modeled channel section. However as all of them are well above the channel and the 200-year flood levels; therefore, the have not been included in the hydraulic model.

No high flow and river level data is available near the intake locations to calibrate the models. Therefore, typical channel roughness values have been used based on experience from previous studies on similar rivers and typical textbook values for boulder/cobble bed rivers. To account for the uncertainty in the Manning's n roughness values, a range of n = 0.055 to n = 0.065 has been used in the modelling with the upper limit used to establish peak design water levels and the lower range used to establish peak average channel velocities (see Figures 9 and 10).

Profiles of the design 200-year water levels, velocities and water depths at the intake sites are shown in Figures 9 to 11, respectively. The design 200-year return period water levels are about 0.7 m higher than the modelled water levels established for the 1984 floodplain mapping. It is most likely that this is a result of increased estimate for the peak 200-year return period flow based on the past 19 years of additional data. The difference may also be the result of changes to the elevation datum since preparation of the 1984 mapping, a field survey check of the monument used to establish floodplain mapping levels has not yet been completed. The monument is to be checked as part of the final site survey prior to finalization of design parameters.

To account for uncertainty in flood frequency analysis results, on-going changes in channel geometry, floating debris and impacts on flood magnitudes from climate change, a freeboard of 1 m above the modeled design 200-year water is recommended to establish minimum flood construction level for the pump station building. Sensitivity analysis results show that increases in modeled water levels as a result of changes in channel roughness and 10% increase in peak design flow are well within the recommended 1 m freeboard allowance (see Figure 11). The minimum recommended flood construction levels and design velocities for riprap bank protection are outlined in Table 2.

TABLE 2
Englishman River Intake – River Design Parameters

Design Parameter	Site 2 (Left Bank)	Site 3 (Right Bank)
Low-flow water level (at 1.2 m^3/s)	9.47 m-GSC	10.20 m-GSC
200-year Return Period Water Level	15.89 m-GSC	16.39 m-GSC
200-year Return Period Average Channel Velocity	4.3 m/s	4.3 m/s
Flood Construction Level[a]	16.9 m-GSC	17.4 m-GSC

[a] Flood Construction Level includes 1 m freeboard allowance for uncertainty in flood frequency analysis, future changes in channel geometry, floating debris and potential impacts of climate change on peak flood flows.

Submission

If you have any questions regarding the hydrological or river hydraulic analysis carried out for the Englishman River Intake design, please contact the undersigned at (250) 595-4223.

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Reviewed by:
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Wendy Yao, P.Eng.
Technical Review

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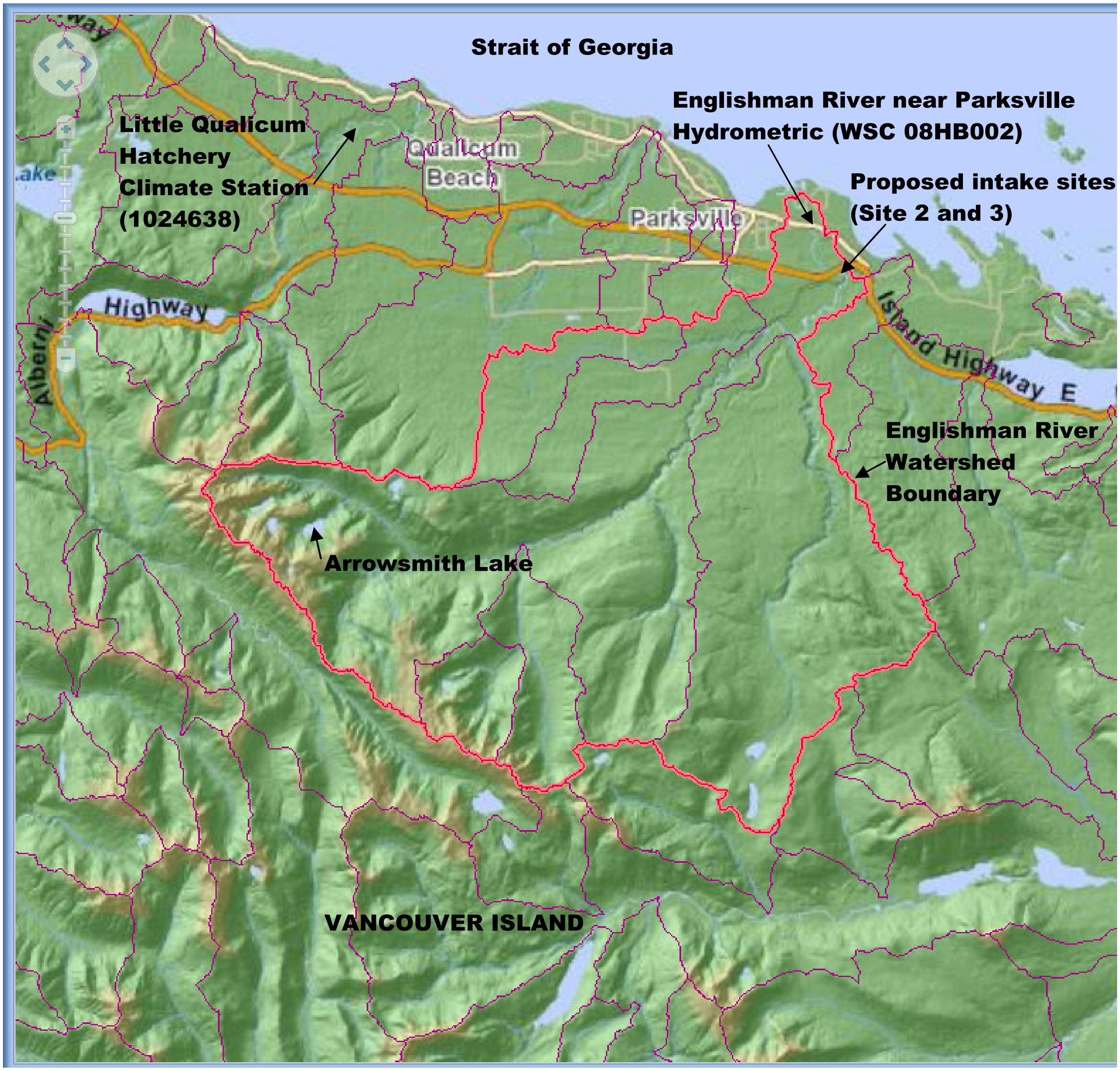
Revision History

Revision #	Date	Status	Revision	Author
2	October 20, 2014		Issued as Revised Final for revised DFO Submssion	CS
1	October 7, 2013		Issued as Final	CS
0	Sept. 27, 2013		Issued for review	CS



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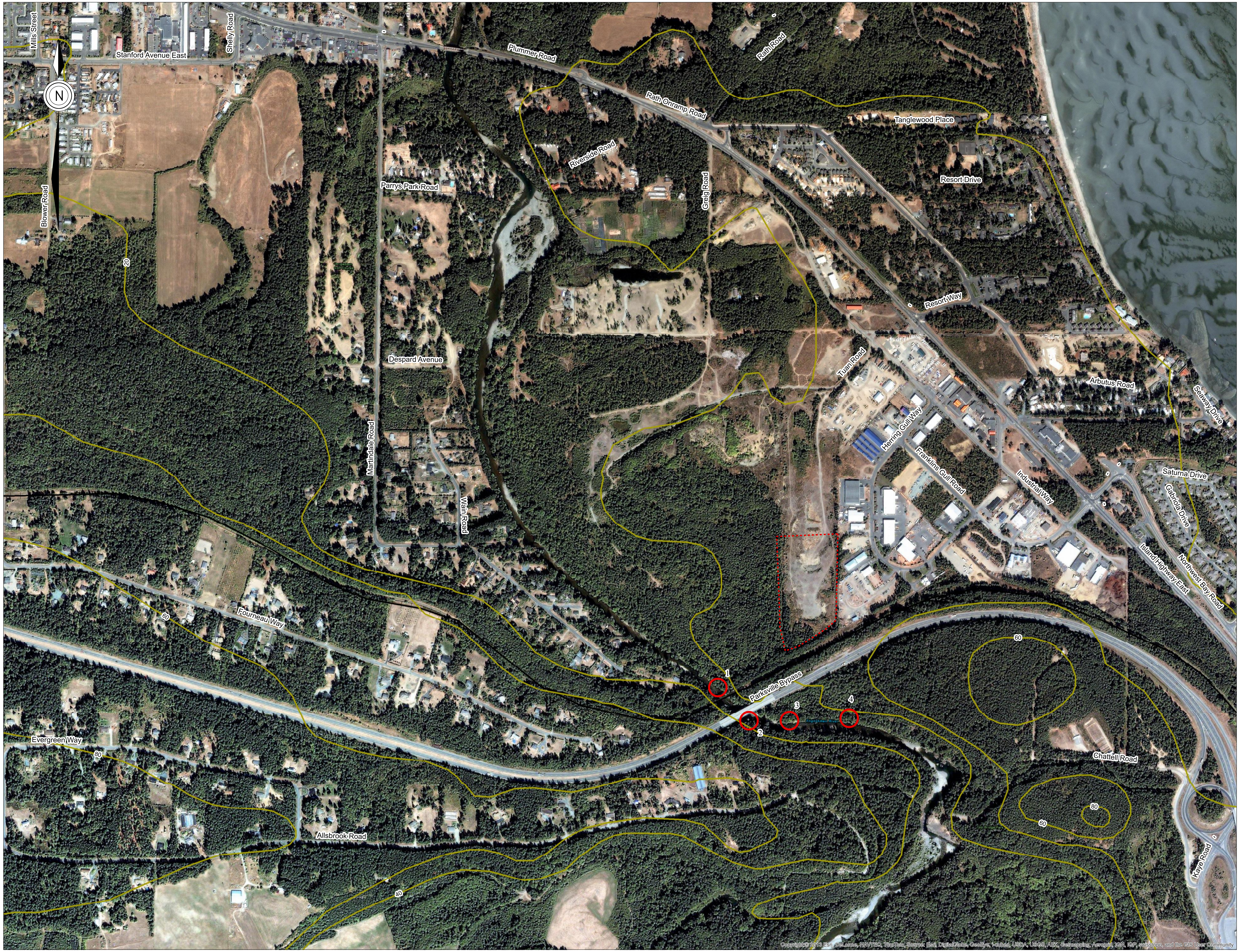
Englishman River Water Service

Project No.	Date
0468.010	Sep. 2013

Englishman River Water Intake/Treatment Plant

Englishman River Watershed Map

Figure 1



ERWS Intake Treatment and Supply

Legend

- Contour
- Railway
- Proposed Intake Sites
- Treatment Plant Site

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Reference: Orthophoto from Bing aerial image map.

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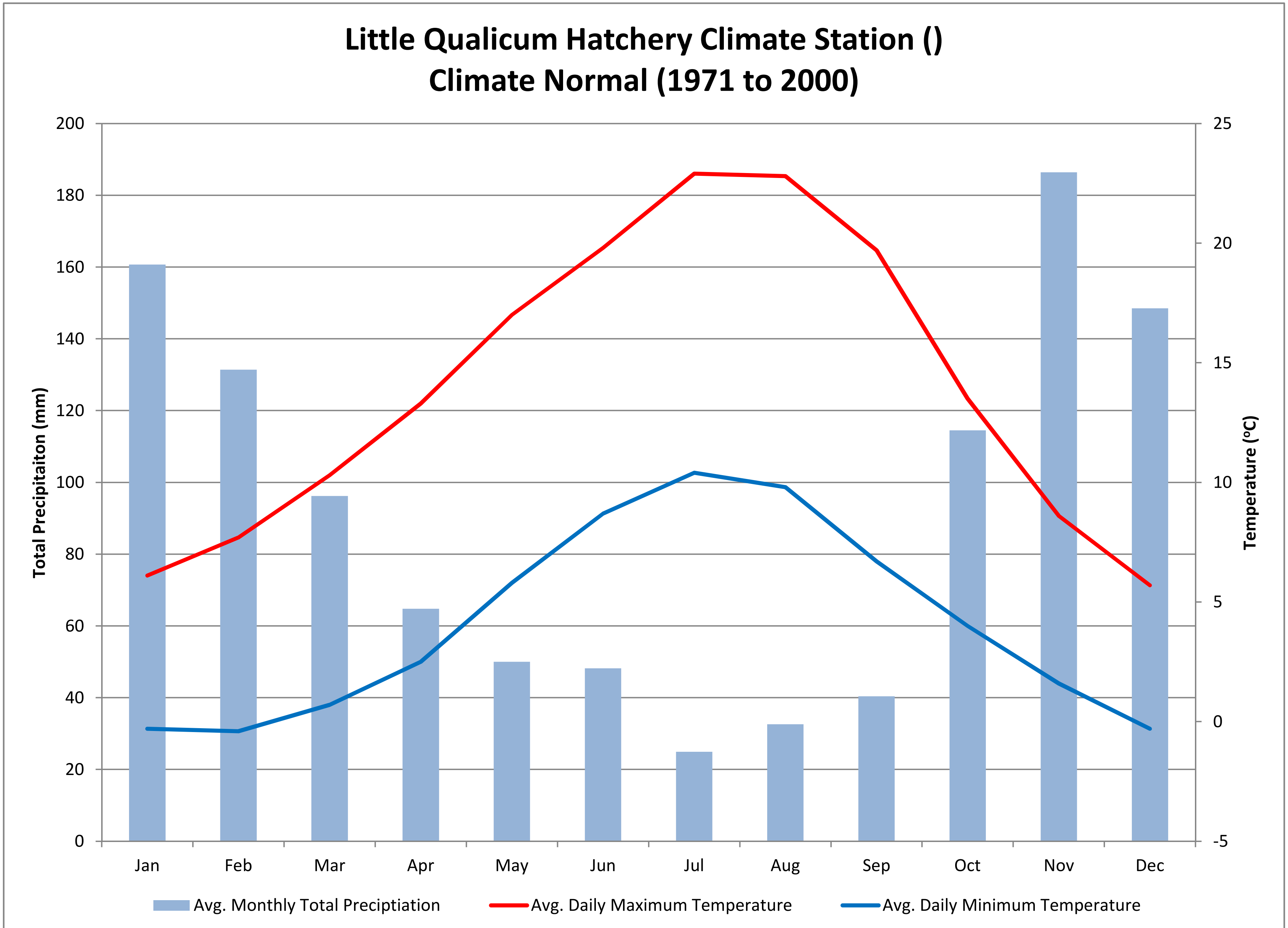
Project No.	Date	Drawn By
468-010	June 2013	PAC

Englishman River Proposed Intake Sites Figure 2



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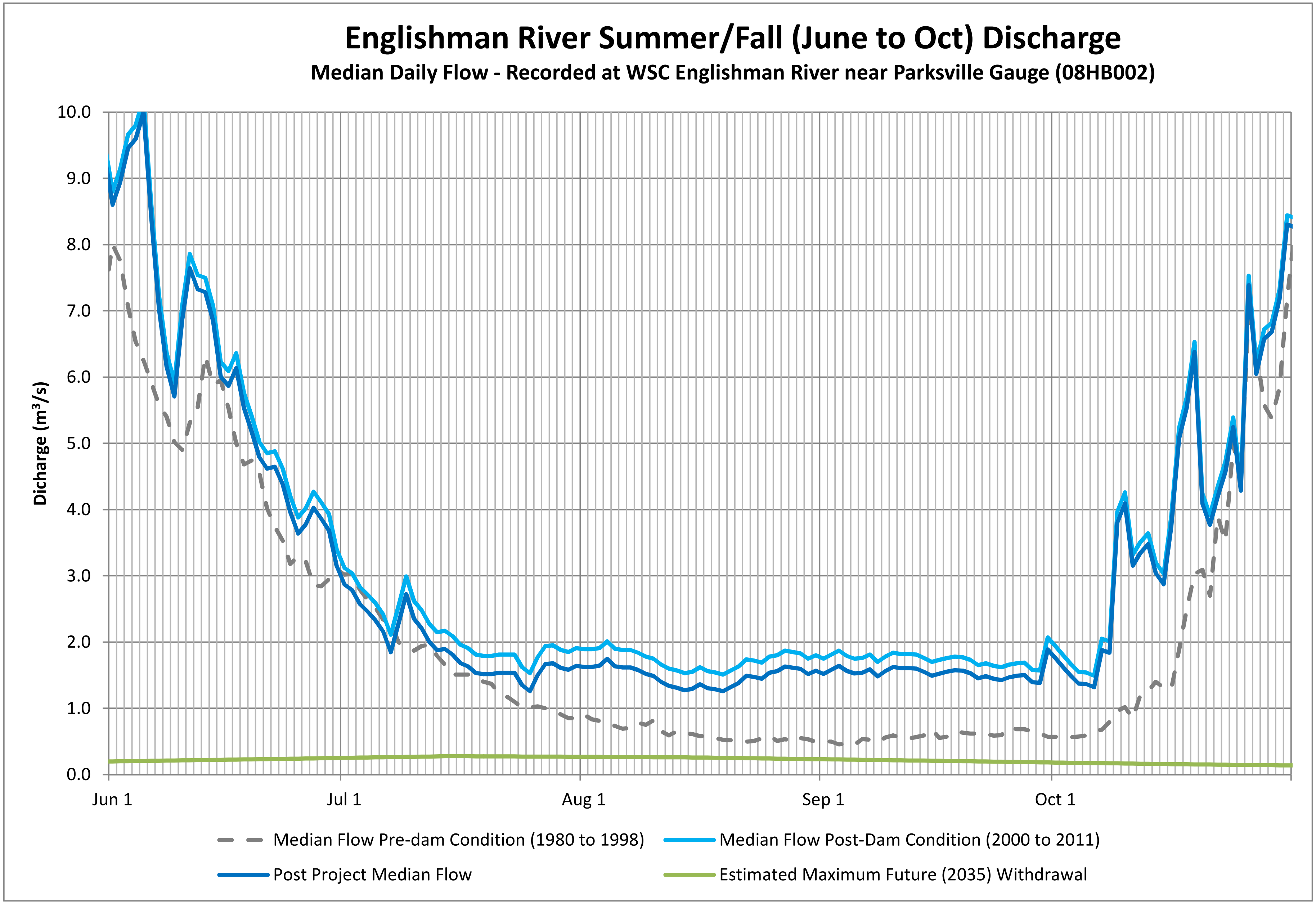
Englishman River - ERWS Water Intake Project
Little Qualicum Hatchery Climate Normal (1971 to 2000)
Figure 3



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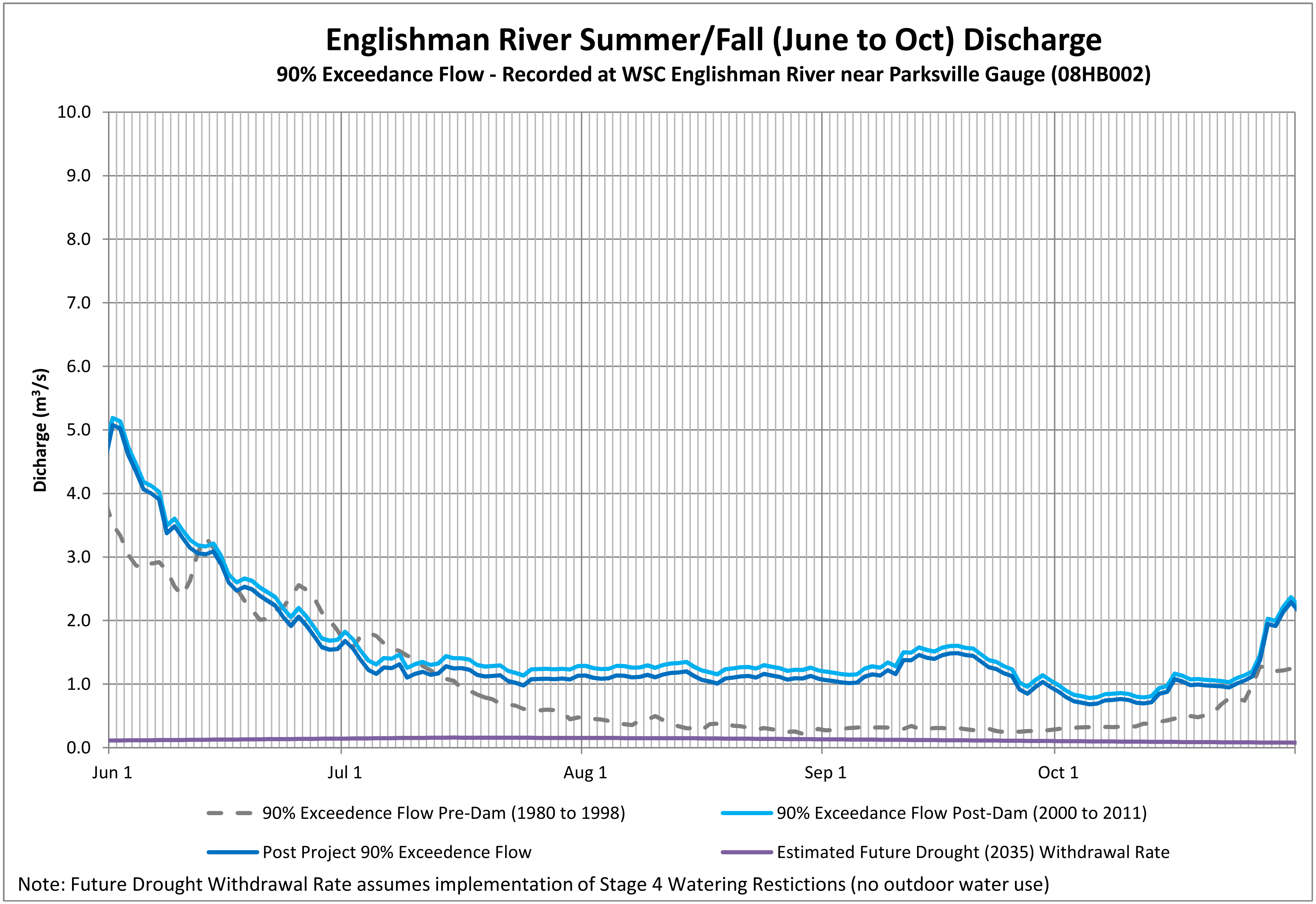
EWRS - Englishman River Intake
Median Daily Flow Hydrograph
Figure 4a



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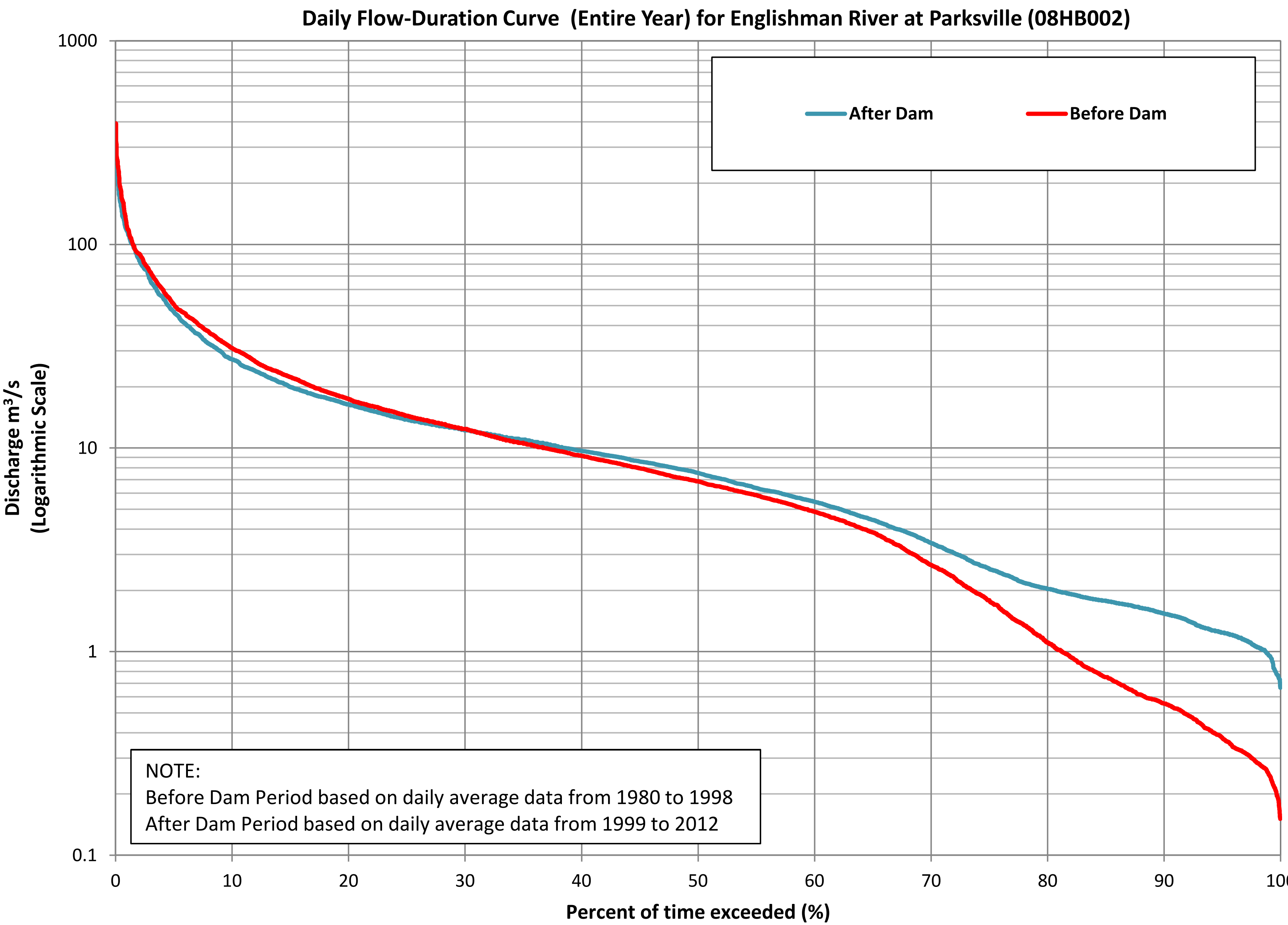
ERWS - Englishman River Intake
90% Exceedance Flow Hydrograph
Figure 4b



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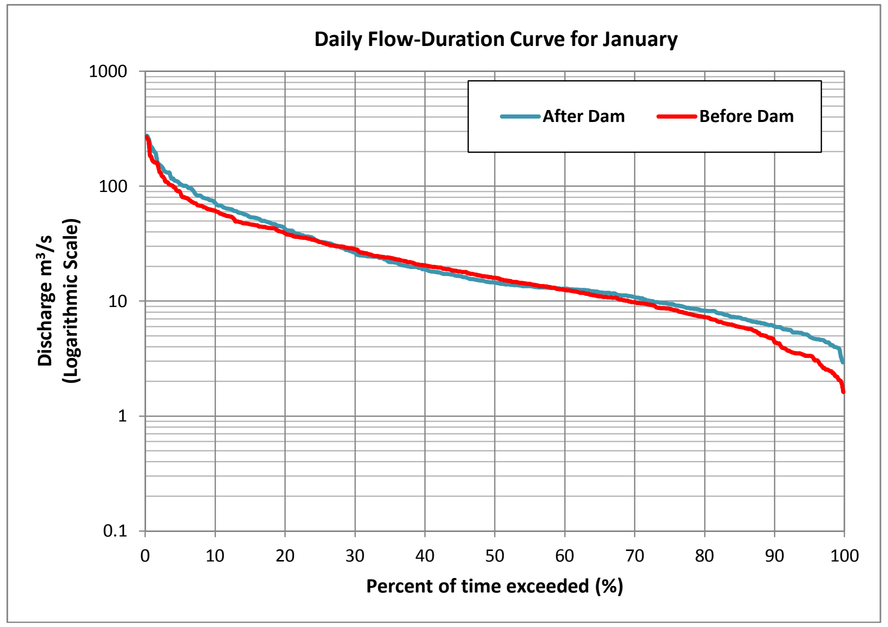
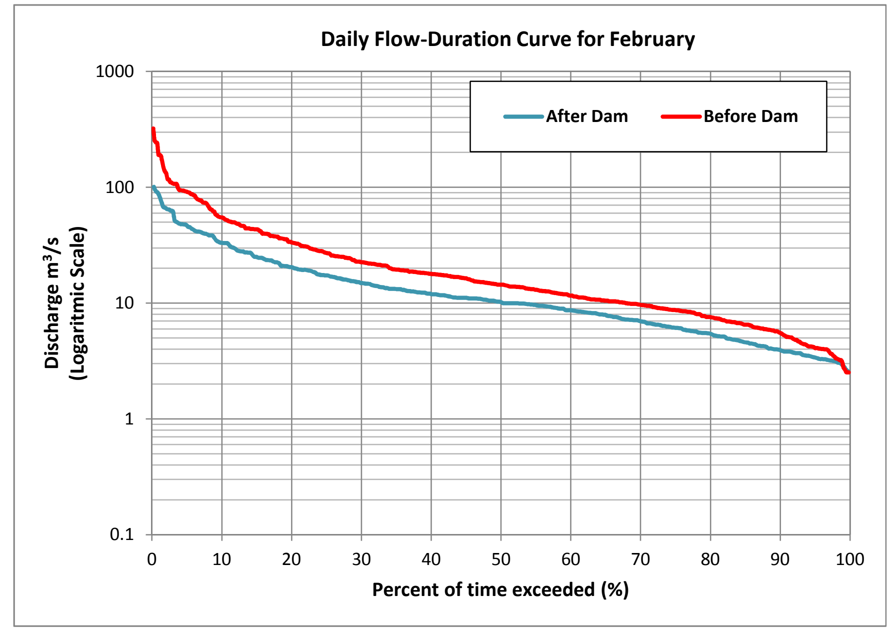
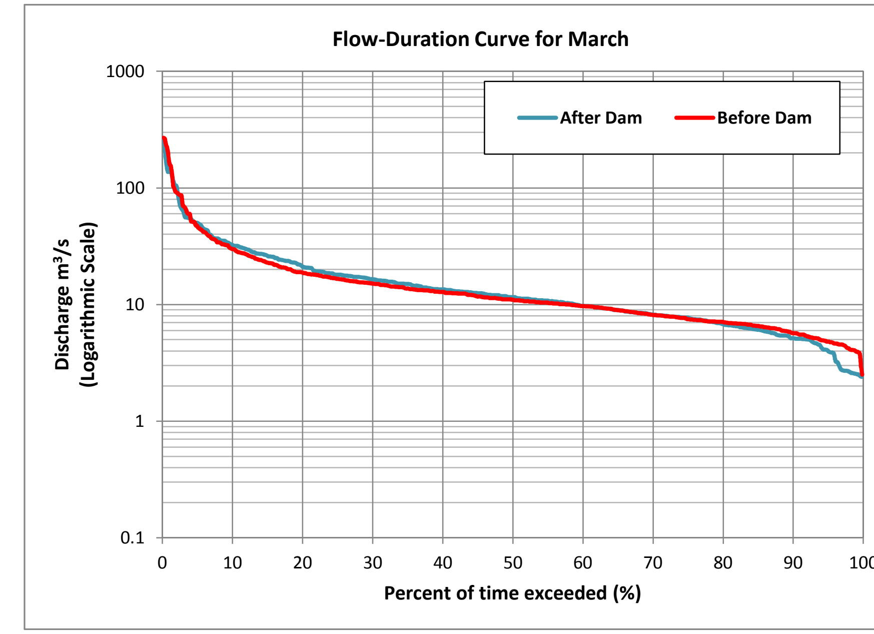
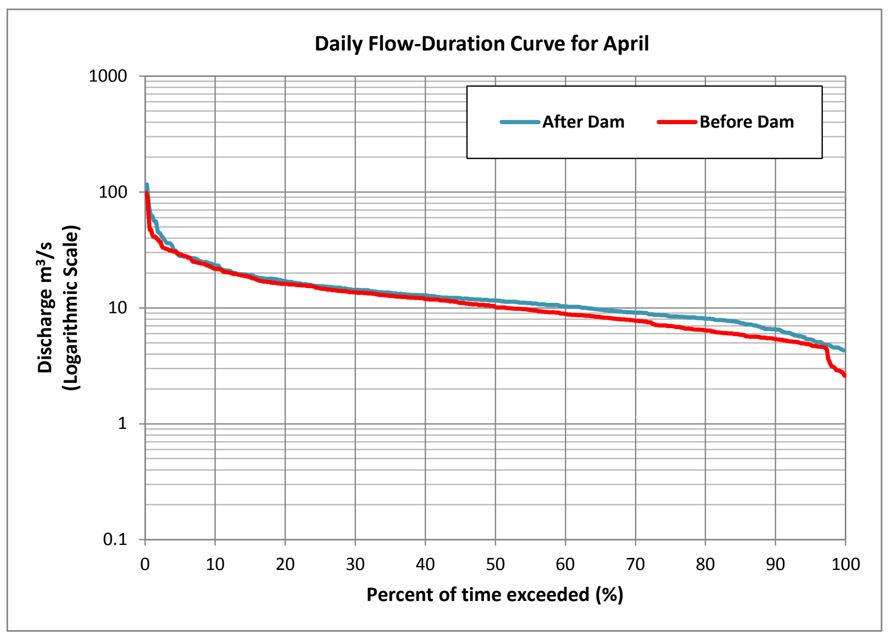
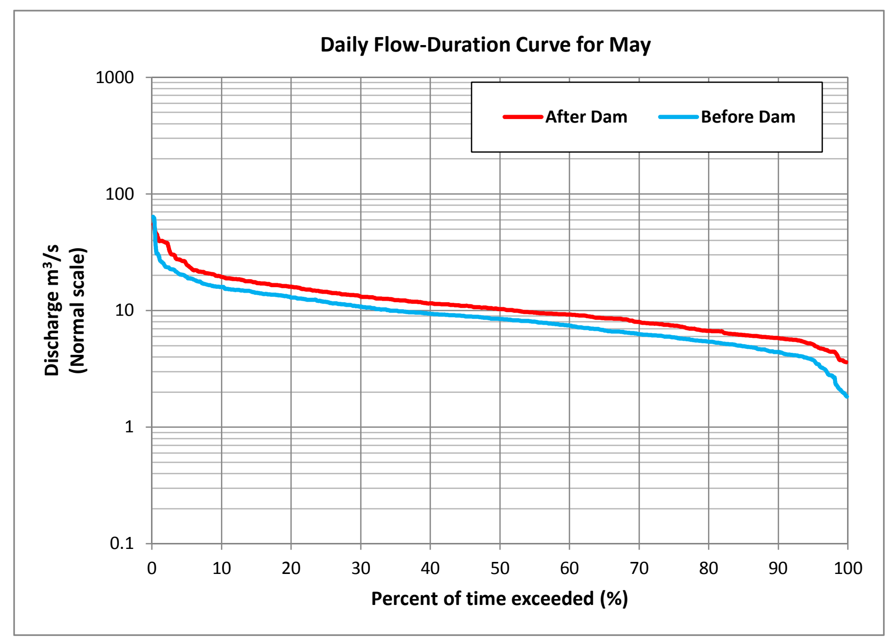
EWRS - Englishman River Intake
Englishman River Flow Duration Curve (Entire Year)
Figure 5a

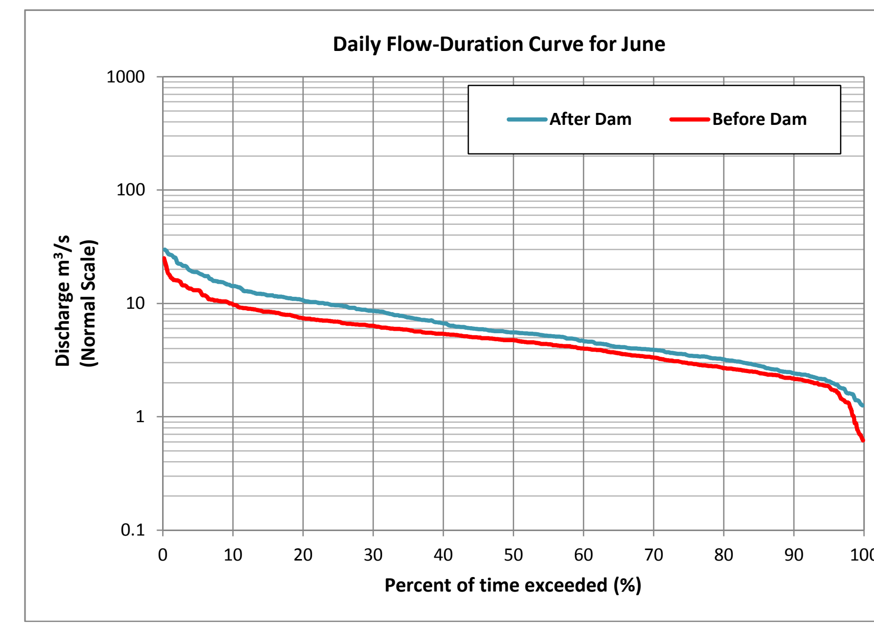




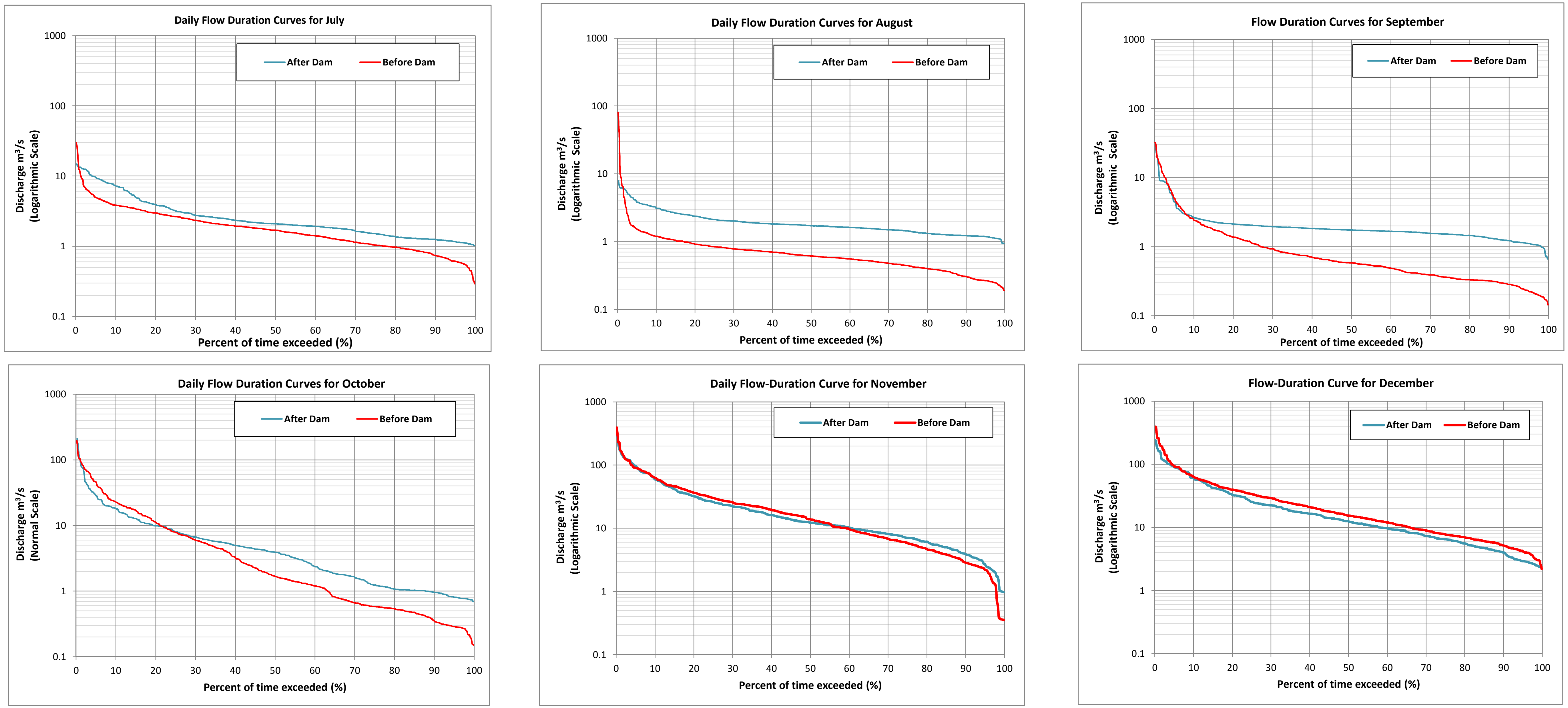




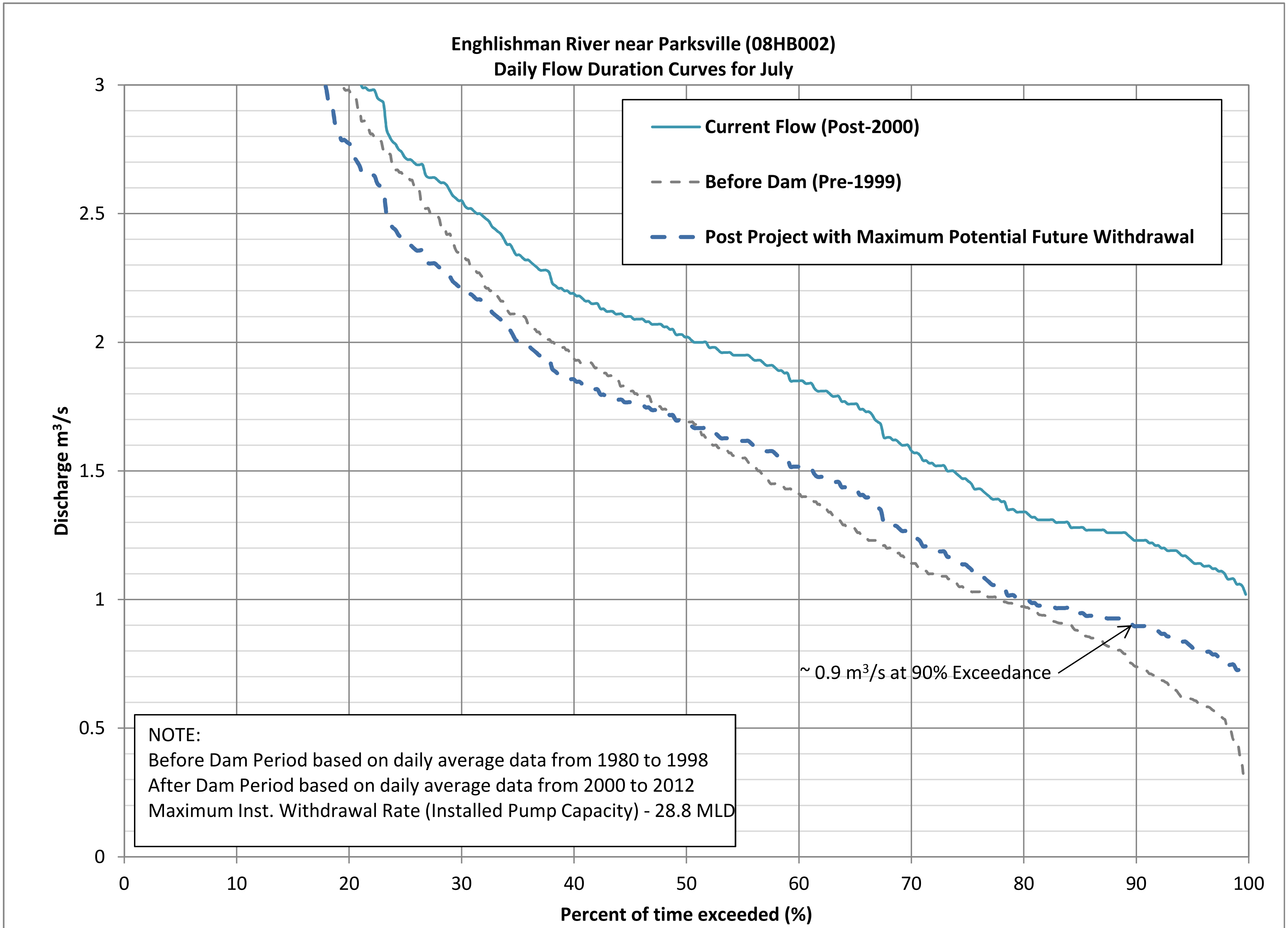




Note: Before Dam period based on 1980 to 1998 daily average flow data and After Dam period based on 1999 to 2012 daily average flow data



Note: Before Dam based on 1980 to 1998 daily average flow data and After Dam based on 1999 to 2012 daily average flow data



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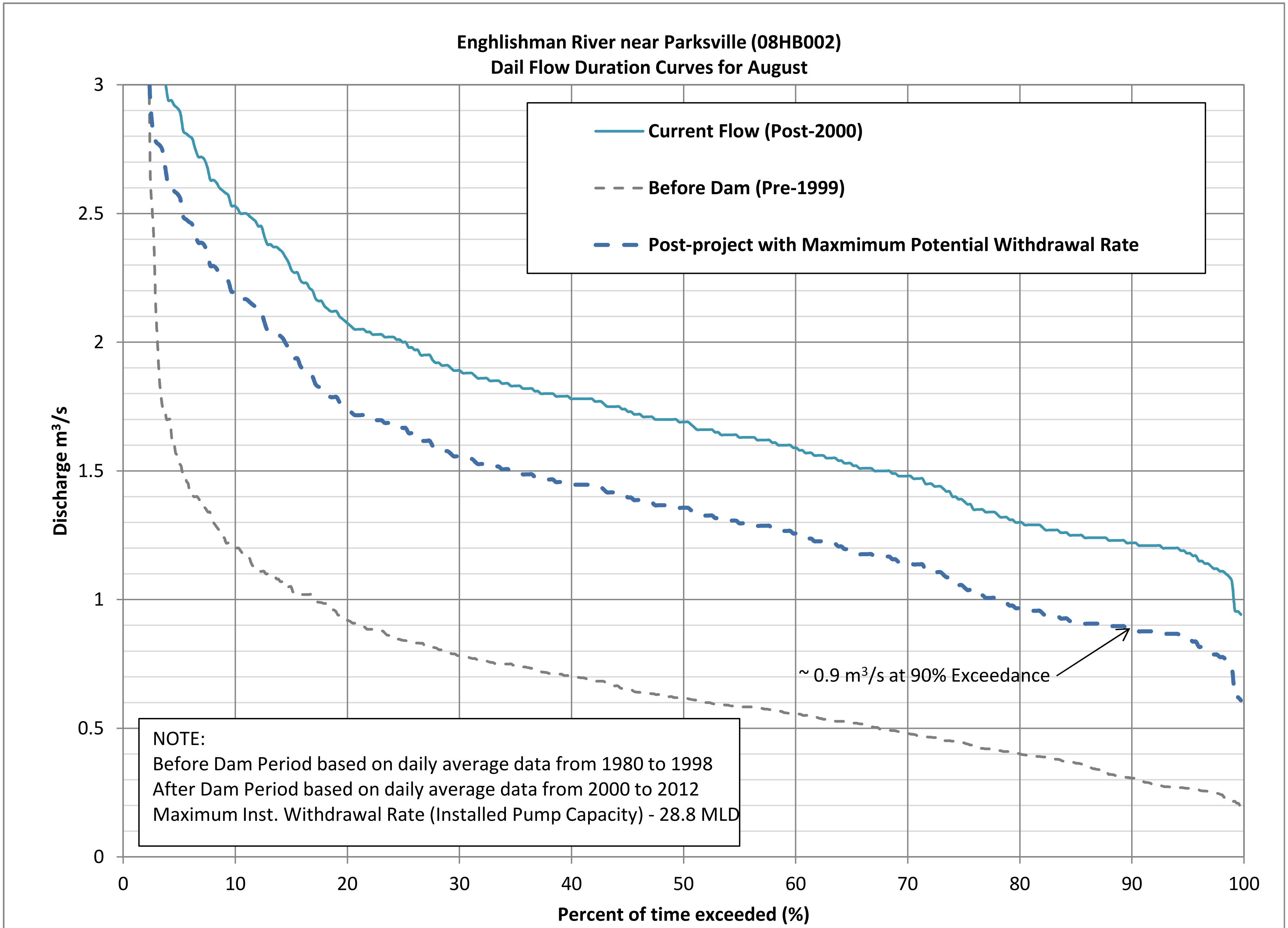
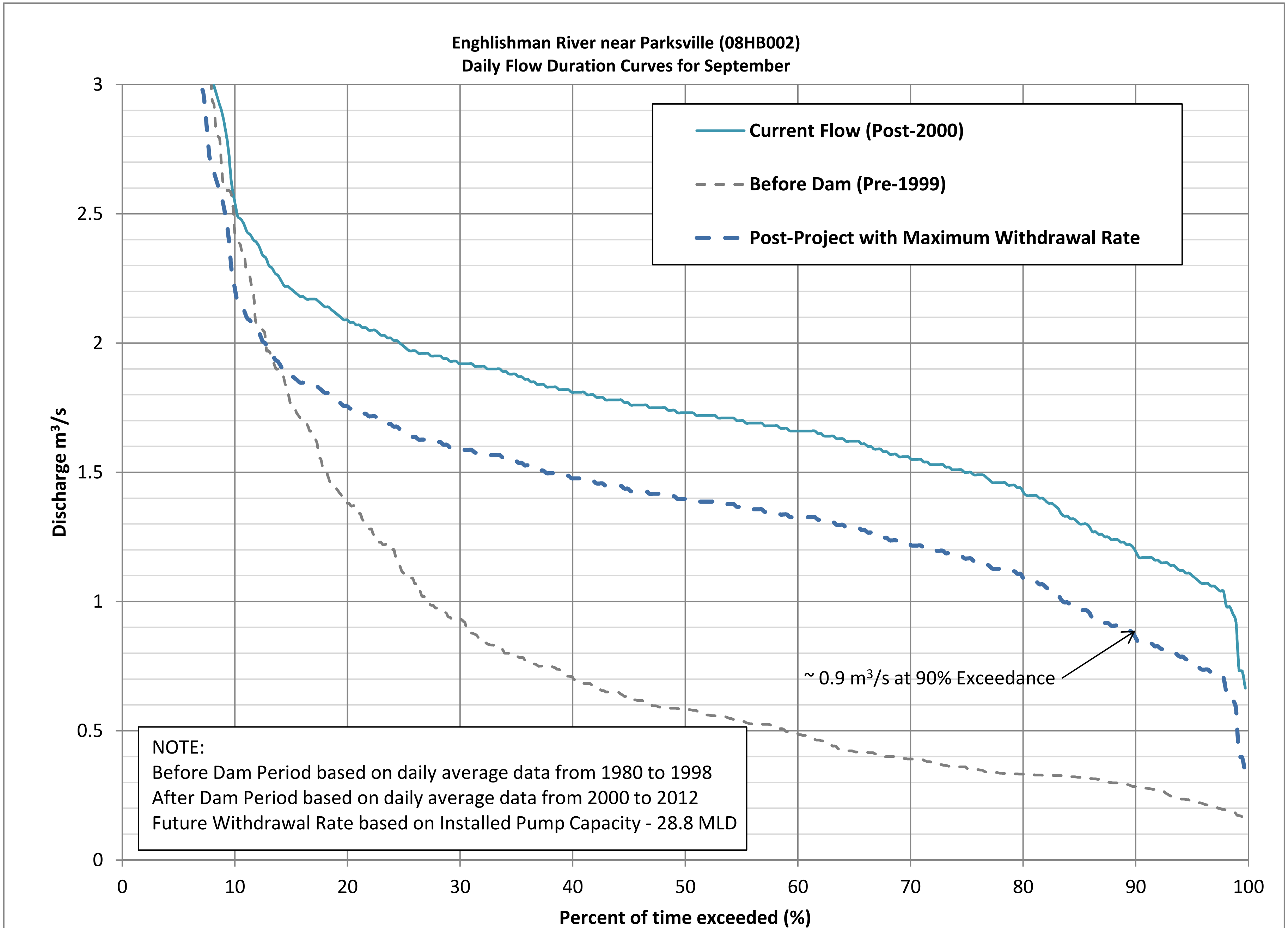
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5d


Enghlishman River near Parksville (08HB002)
Dail Flow Duration Curves for August
Current Flow (Post-2000)
Before Dam (Pre-1999)
Post-project with Maxmimum Potential Withdrawal Rate
Discharge m³/s
Percent of time exceeded (%)
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
90
100
~ 0.9 m³/s at 90% Exceedance
NOTE:
Before Dam Period based on daily average data from 1980 to 1998
After Dam Period based on daily average data from 2000 to 2012
Maximum Inst. Withdrawal Rate (Installed Pump Capacity) - 28.8 MLD



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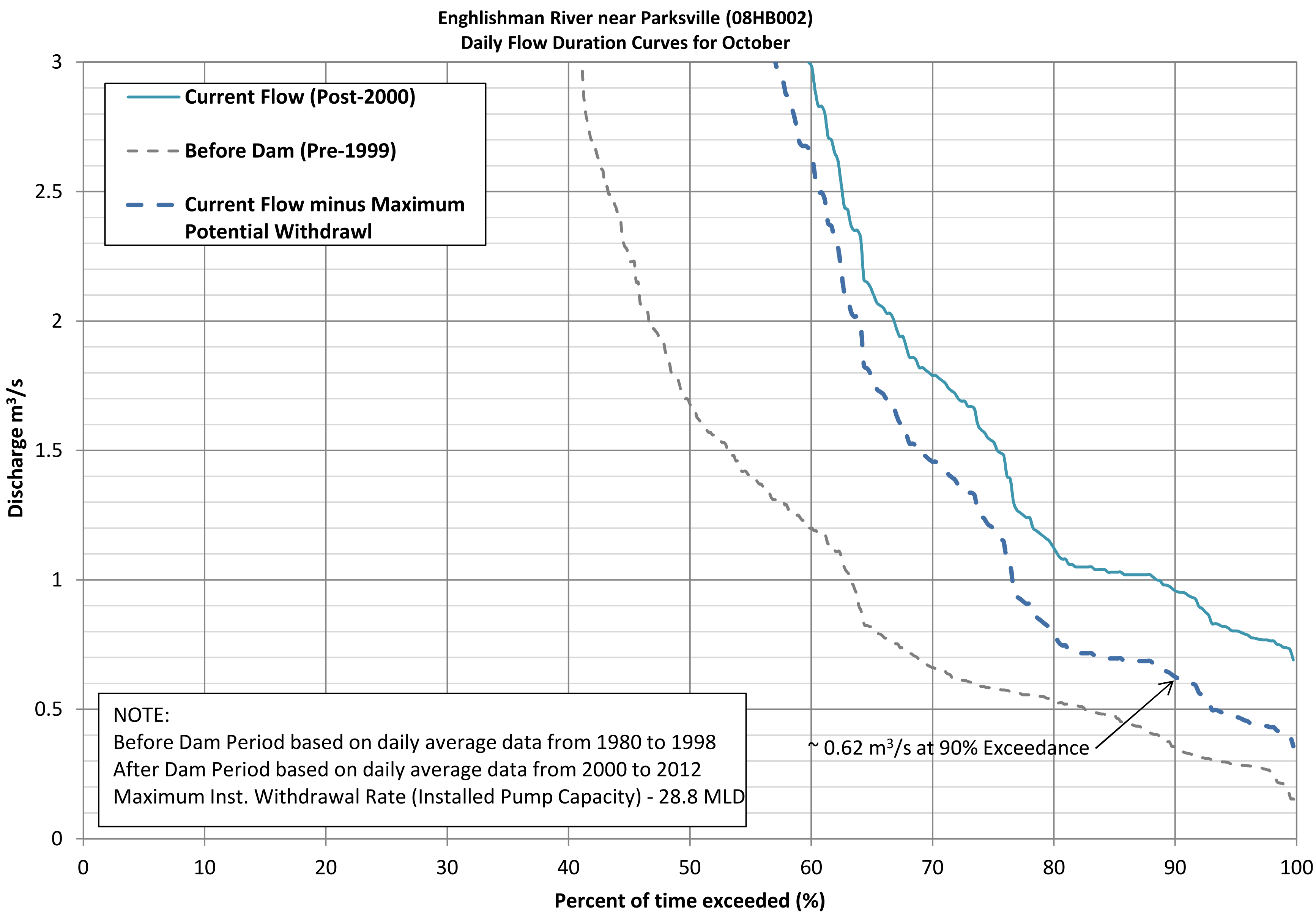
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5f



Note: Maximum Potential Withdrawal indicates future worst case , future water demands to be limited by means of outdoor watering restrinctions during drought conditions and future river flows to be managed using proposed operating rules (see Technical Memo 2B).

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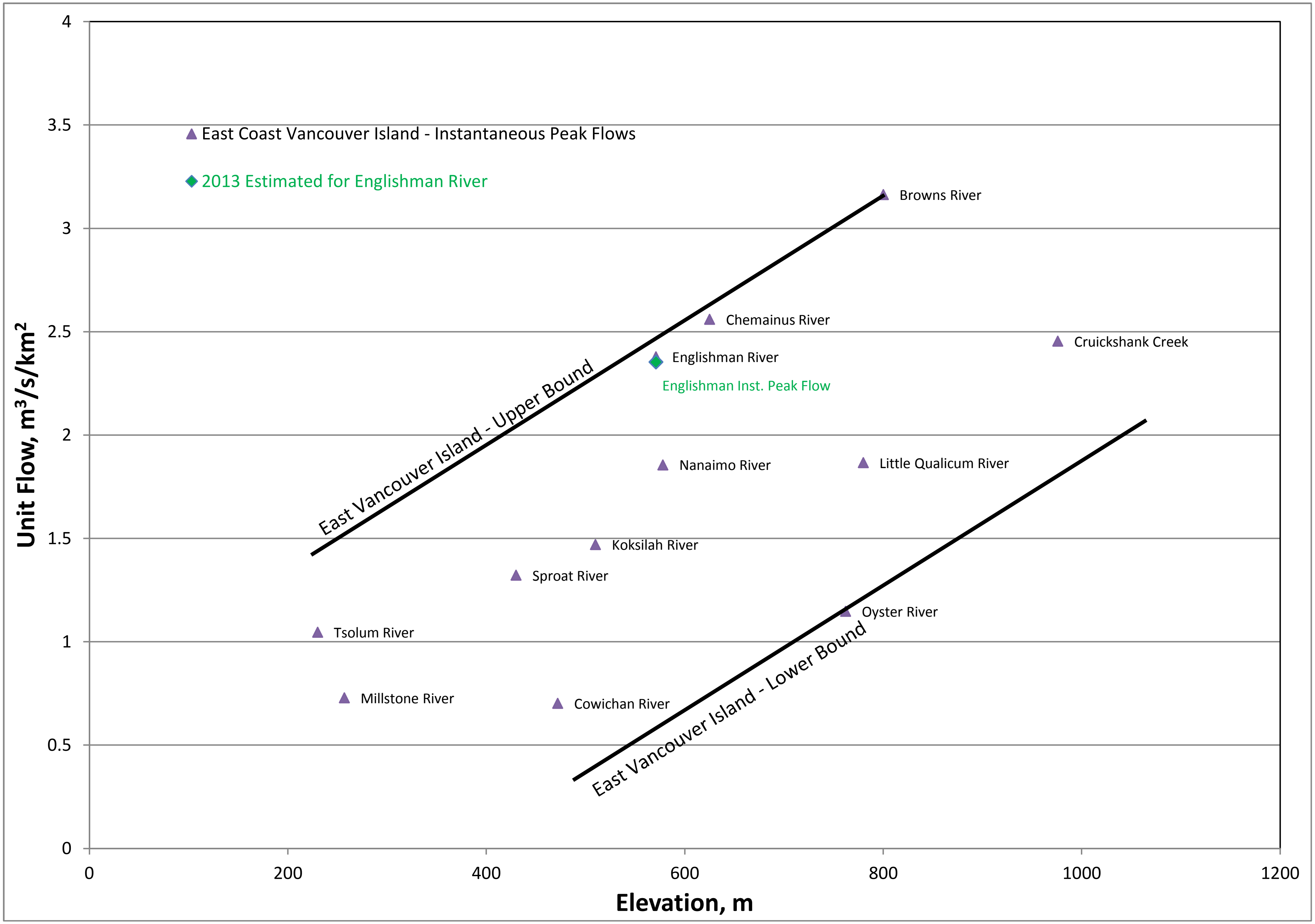
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5g



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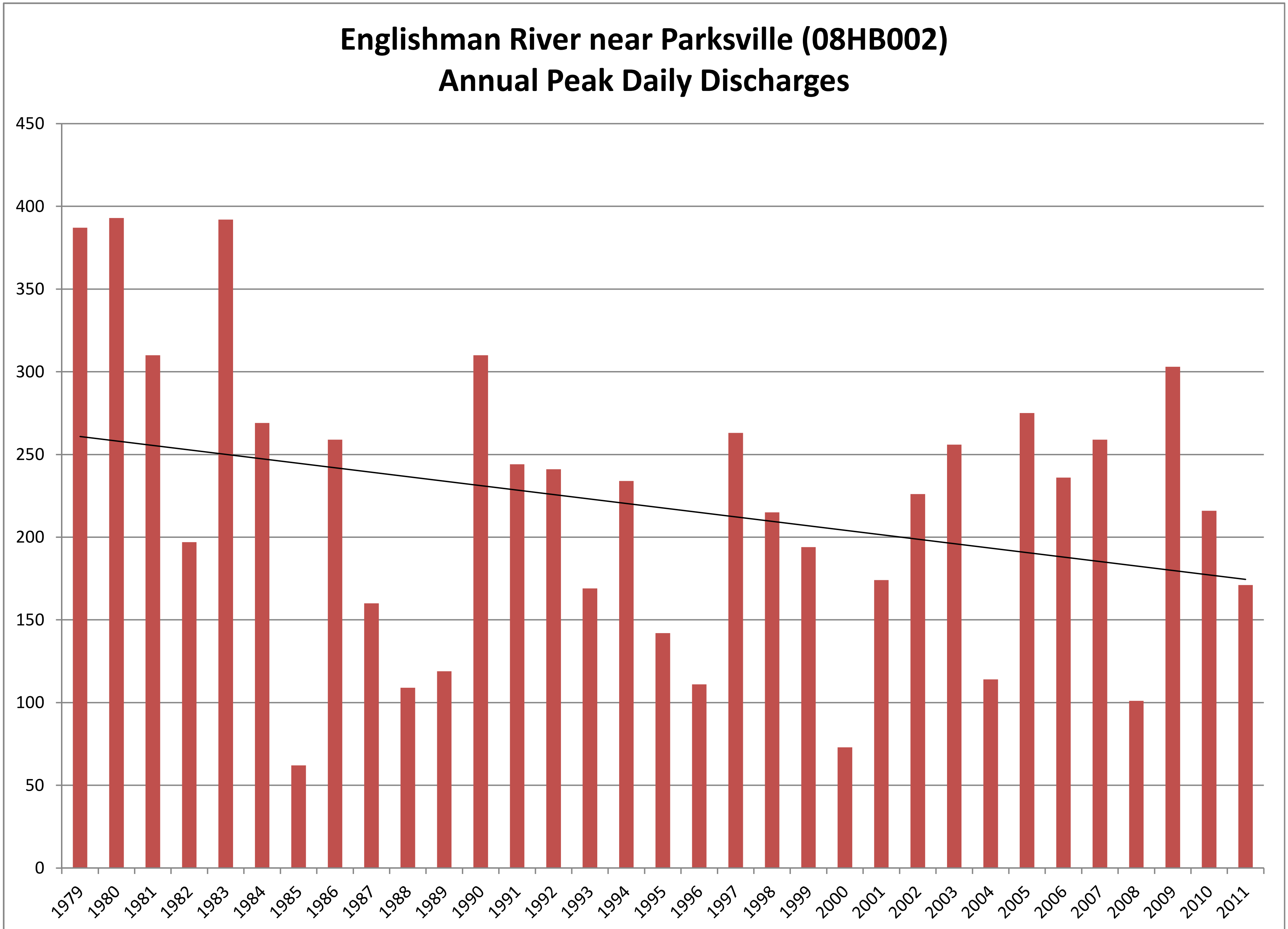
Englishman River - ERWS Water Intake Project
Regional Check of the 200-Year Design River Flood Flows
Figure 6



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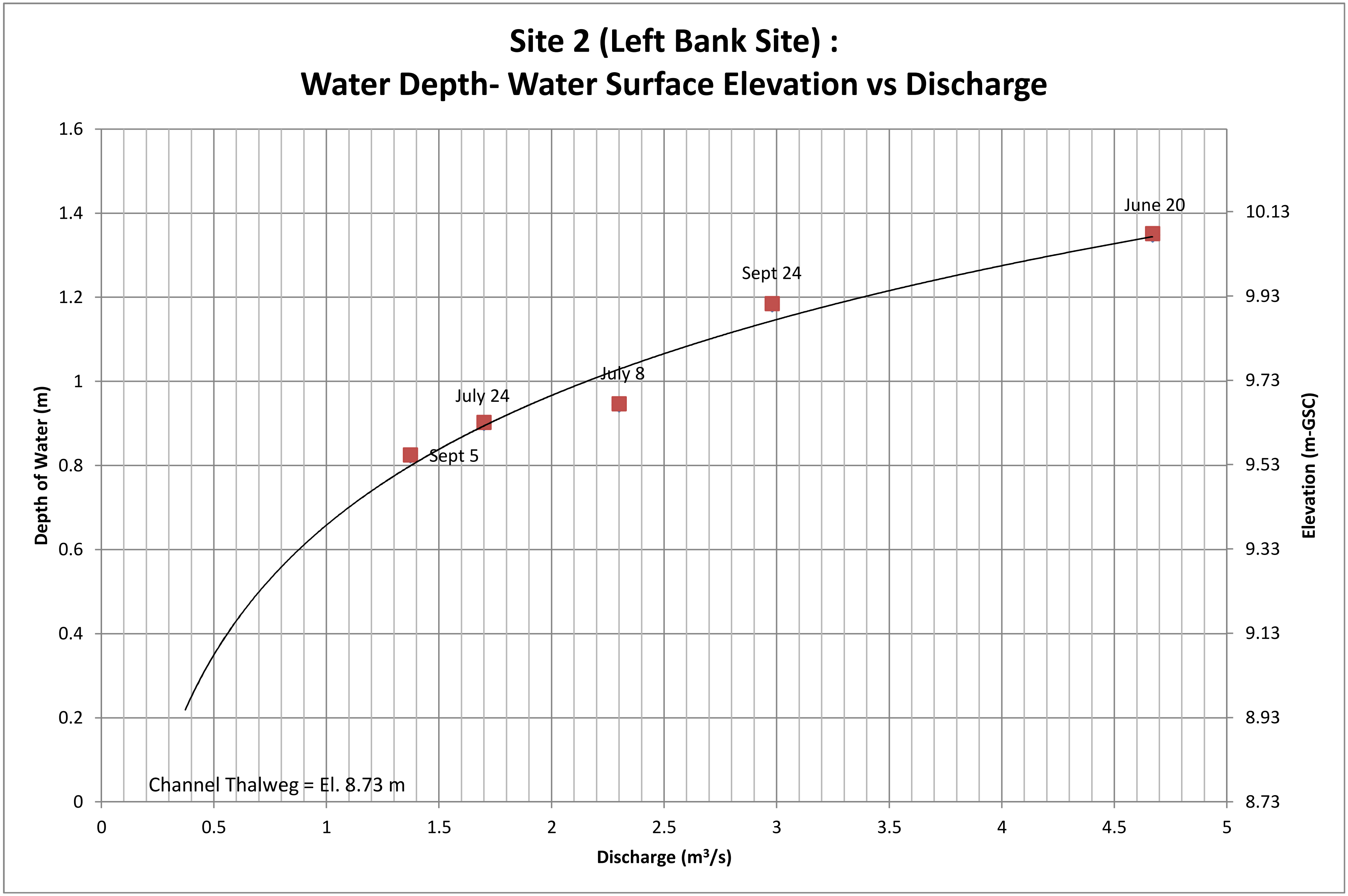
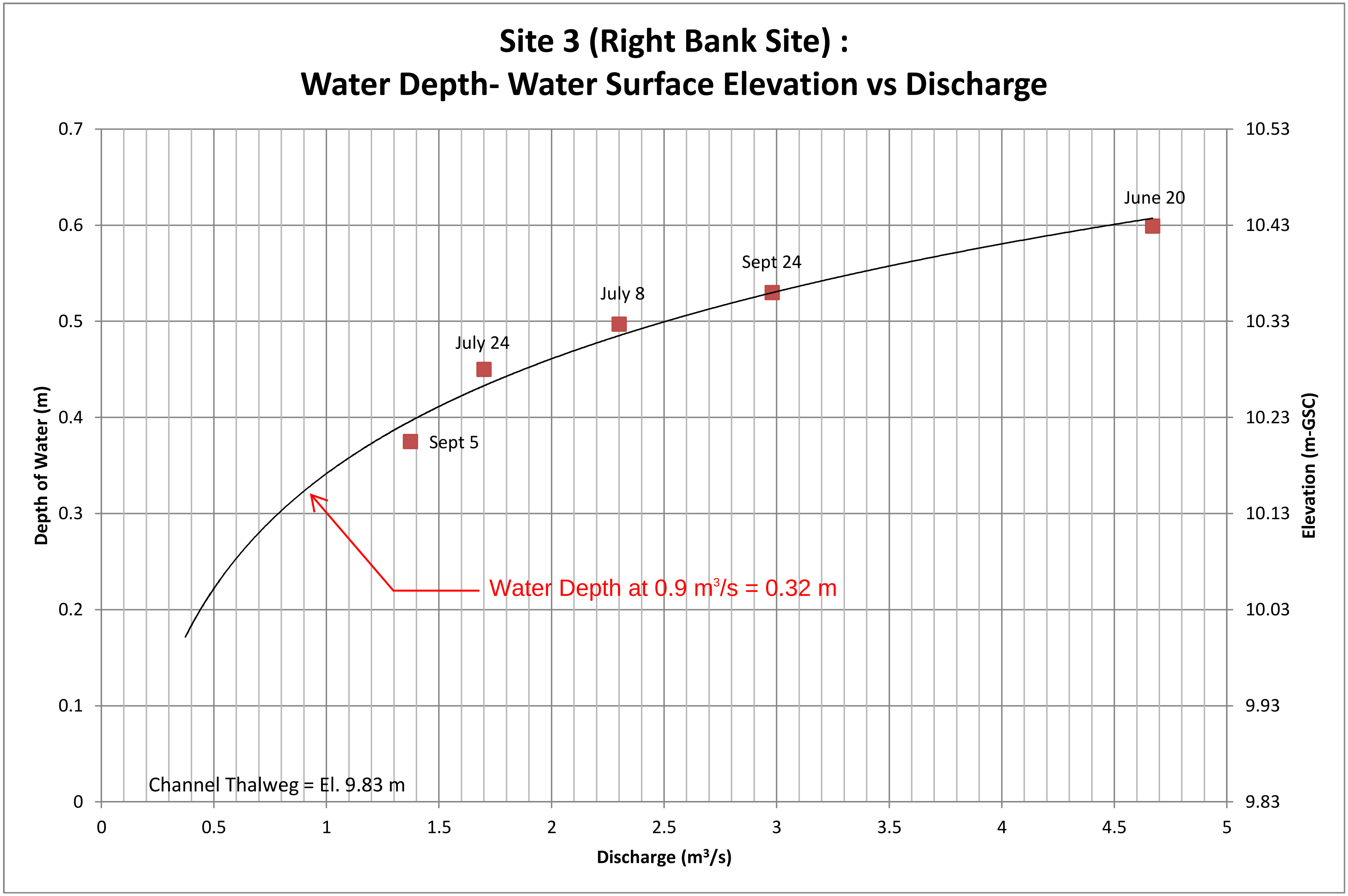
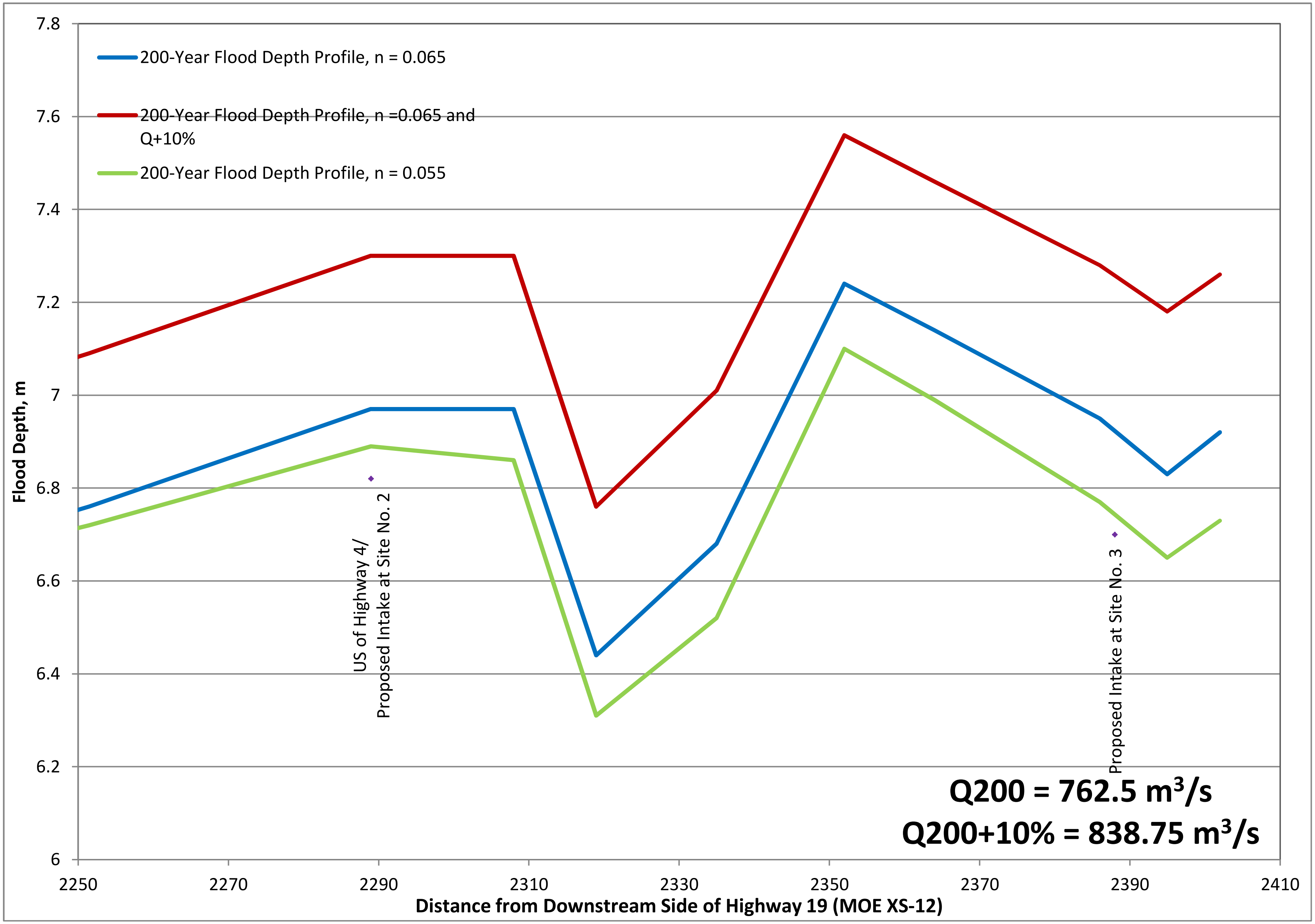
Englishman River Intake Project
Trend in Maximum Daily Peak Flow
Figure 7


Site 2 (Left Bank Site) :
Water Depth- Water Surface Elevation vs Discharge
Depth of Water (m)
Elevation (m-GSC)
Discharge (m³/s)
June 20
Sept 24
July 8
July 24
Sept 5
Channel Thalweg = El. 8.73 m
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10.13
9.93
9.73
9.53
9.33
9.13
8.93
8.73
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Site 3 (Right Bank Site) :
Water Depth- Water Surface Elevation vs Discharge
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Depth of Water (m)
10.53
10.43
10.33
10.23
10.13
10.03
9.93
9.83
Elevation (m-GSC)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Discharge (m³/s)
June 20
Sept 24
July 8
July 24
Sept 5
Water Depth at 0.9 m³/s = 0.32 m
Channel Thalweg = El. 9.83 m



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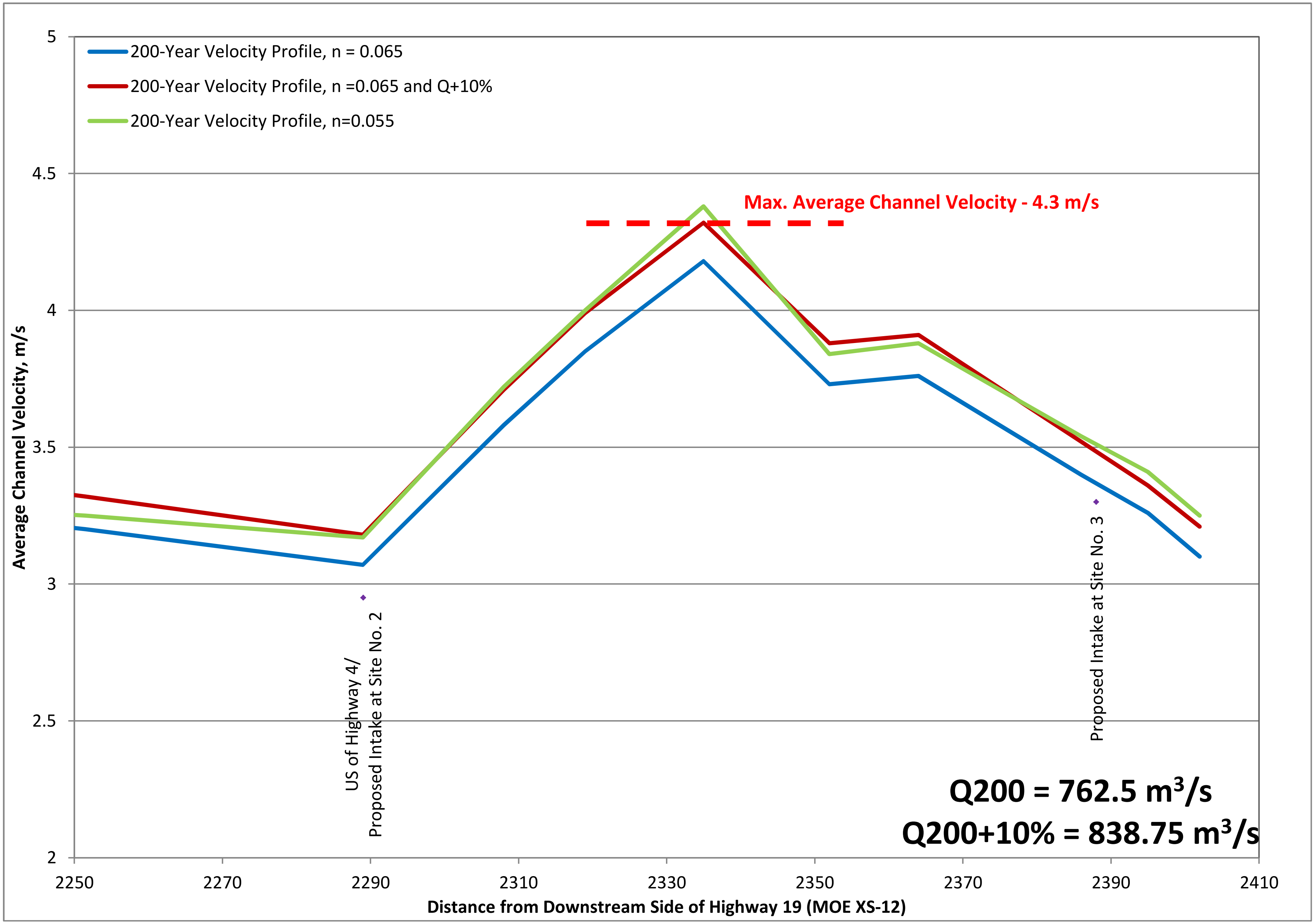
Simulated Flood Depth Profiles

Figure 9



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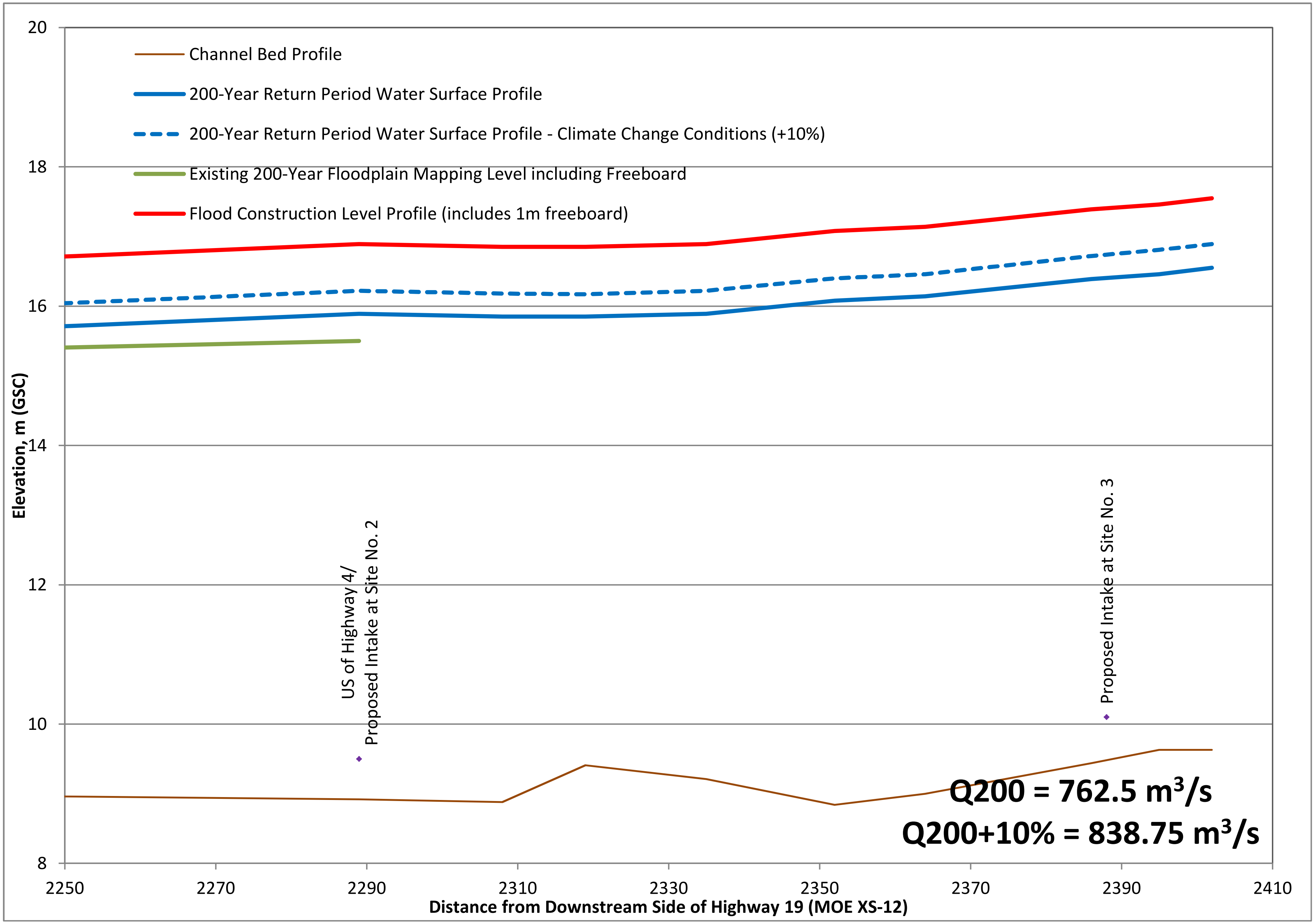
Simulated Flood Velocity Profiles
Figure 10



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Simulated Flood Level Profiles

Figure 11

Appendix A - Photographs

Photo 1: Site 3 – Looking U/S April 17 2013
~ 7.5 cms

Photo 2: Site 3 – Looking D/S April 17 2013
~ 7.5 cms

Photo 3: Site 3 – Looking U/S June 20 2013
4.7 cms

Photo 4: Site 3 looking D/S June 20 2013
4.7 cms

Photo 5: Site 3 – July 8 2013 Looking US
2.3 cms

Photo 6: Site 3 – July 8 2013 Looking DS
2.3 cms

Note: Flows based on field measurements except April 17 which is based on real-time data from WSC gauge.