Appendix C
TM #2A – Intake Hydrology and Hydraulics

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

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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

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. A predominant feature in the watershed is Englishman River Falls which is located about 10 km upstream from the estuary. A map of the watershed is shown in Figure 1.

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.

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.

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 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 (WSC 08HB002). A plot showing monthly average discharges for the pre-dam (before 1999) and post-dam (after 1999) is shown in Figure 4.

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. However, the influence of the dam appears to decrease by later summer or early fall especially in drier years.

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. Figure6 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 a low-flow rating curve. This low flow rating curve can be used to estimate water levels and water depths at the two intake locations for design of the intake pump station. The low flow rating curves for Sites 2 and 3 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.
[a] Maximum modeled average channel velocity within the river reach near the intake structure locations.

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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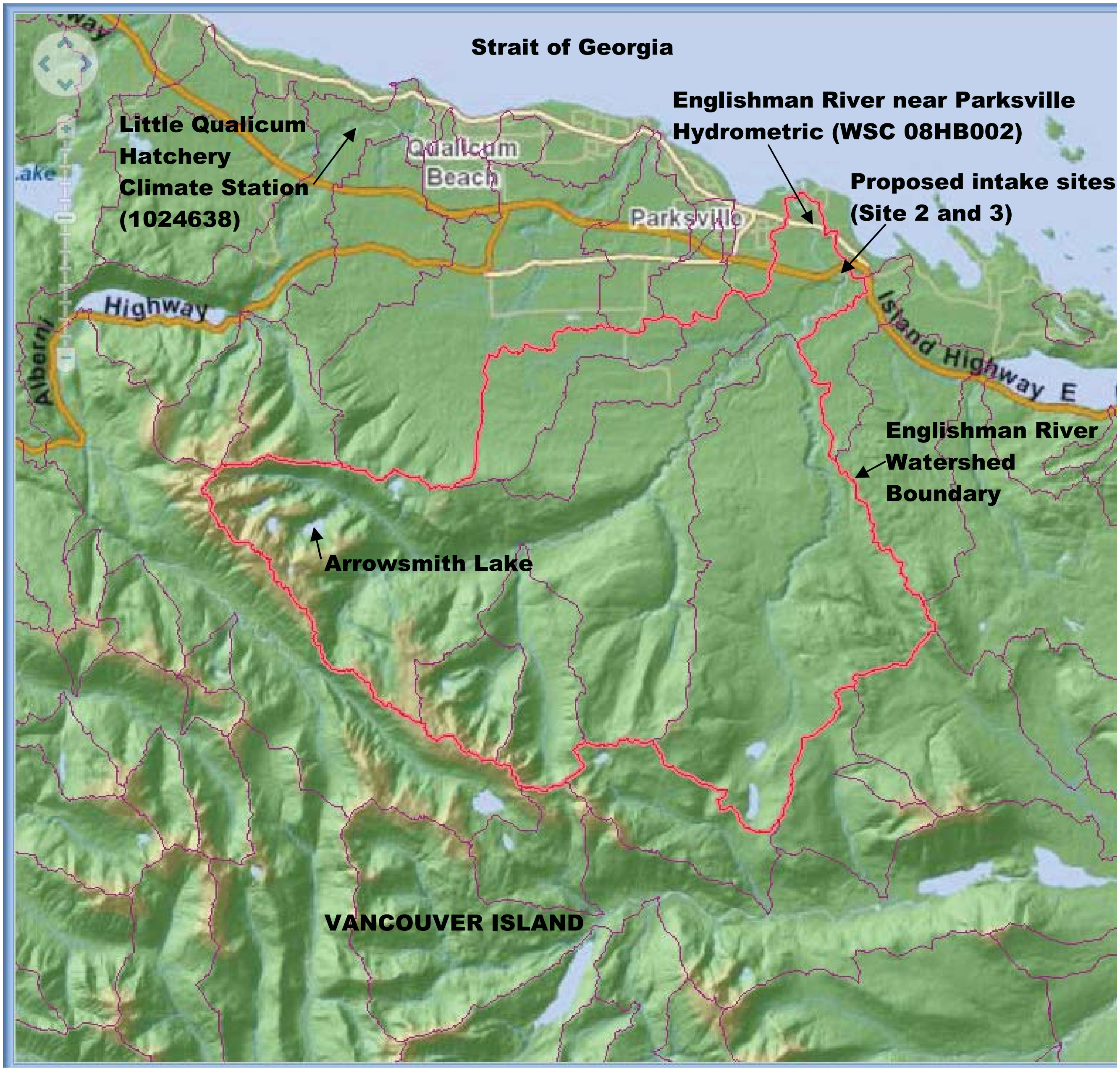
Wendy Yao, P.Eng.
Technical Review

Revision History

Revision #	Date	Status	Revision	Author
0	Sept. 27, 2013		Issued for review	CS
1	October 7, 2013		Issued as Final	CS



Scale: 1:150,000

Source: iMapBC

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associates limited
CONSULTING ENGINEERS

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

200 0 200 (m)

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

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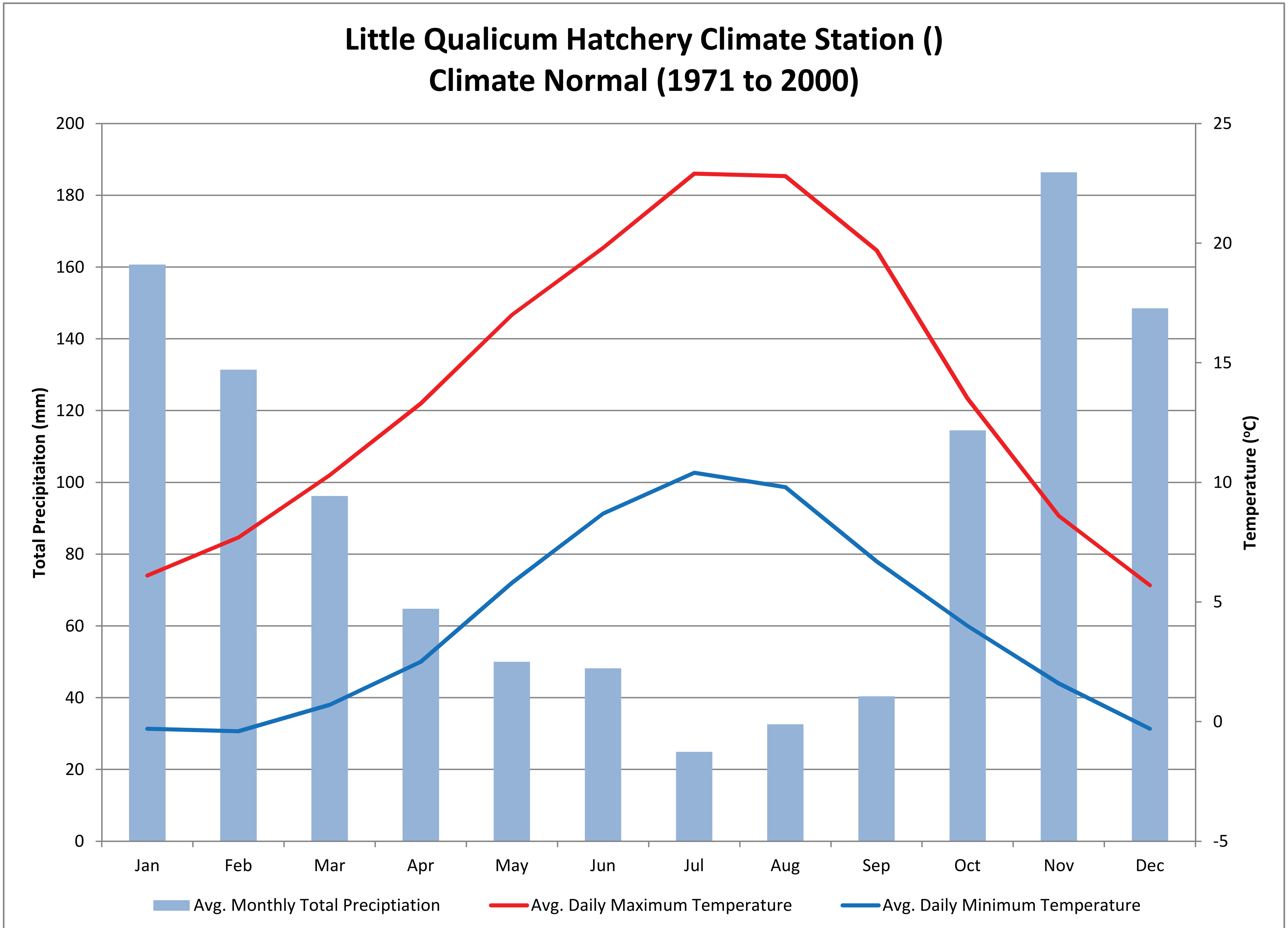
Englishman River
Proposed Intake Sites
Figure 2



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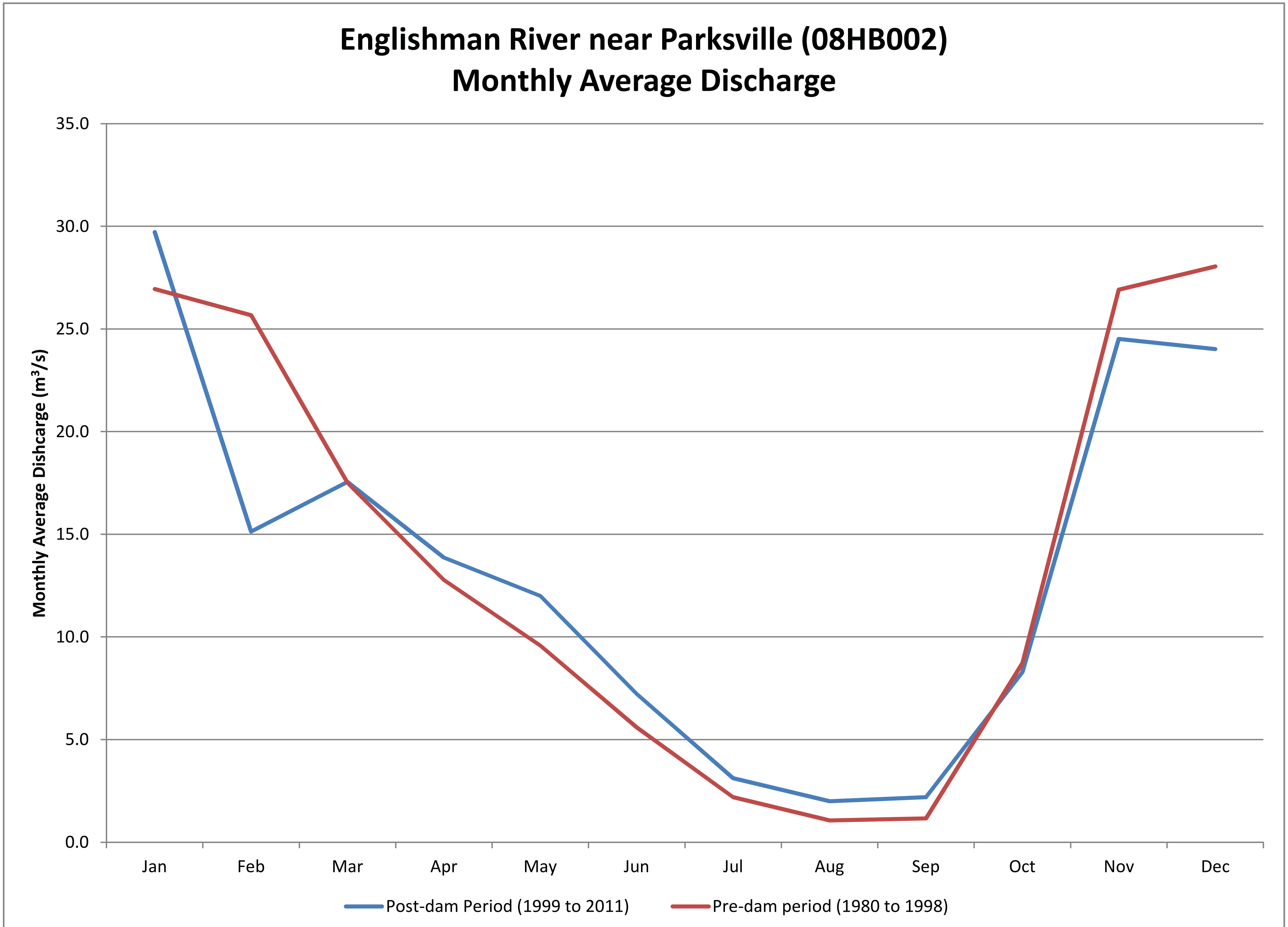
Englishman River - ERWS Water Intake Project
Little Qualicum Hatchery Climate Normal (1971 to 2000)
Figure 3



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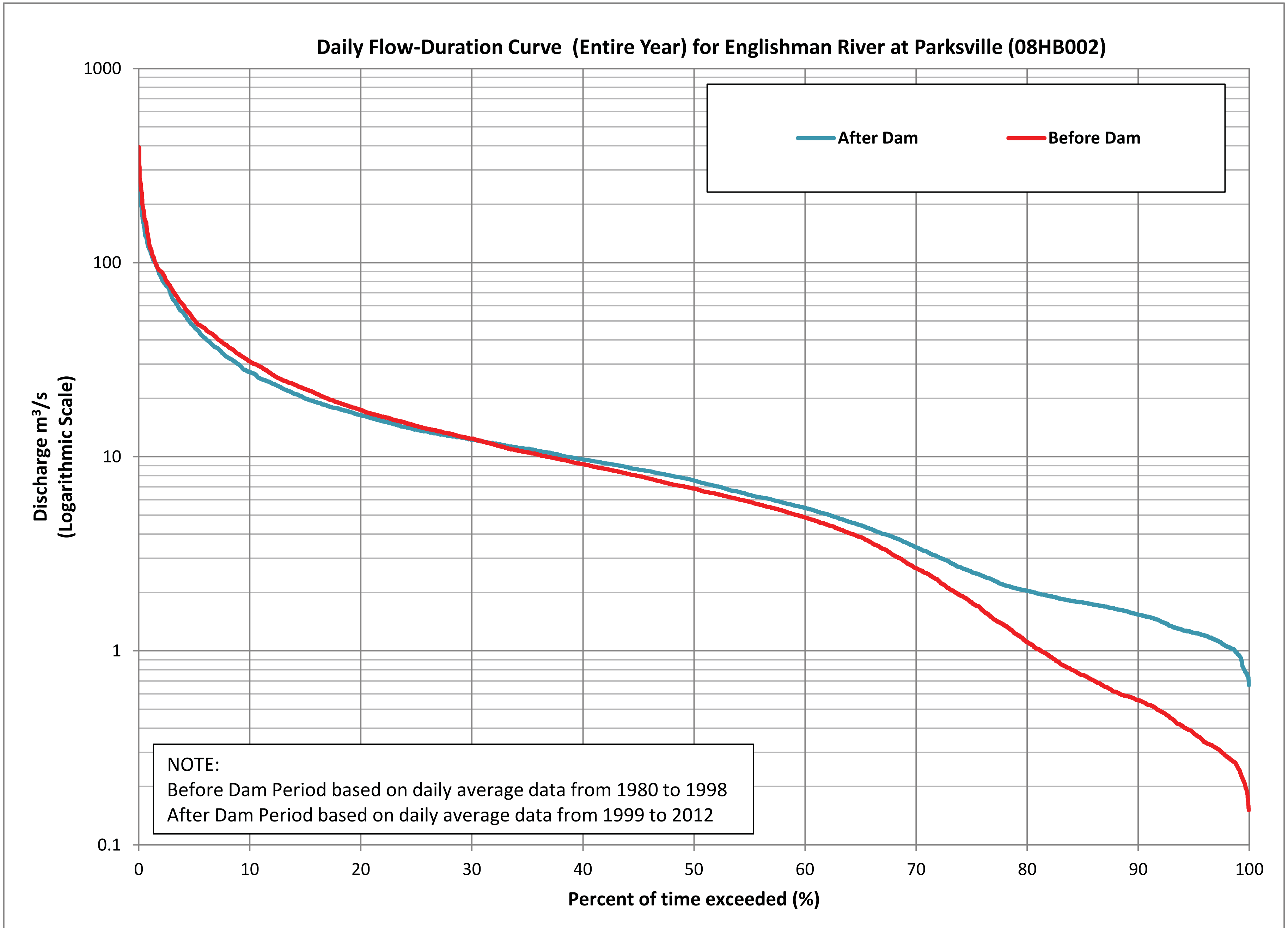
Englishman River - ERWS Water Intake Project
Average monthly dichargeFigure 4



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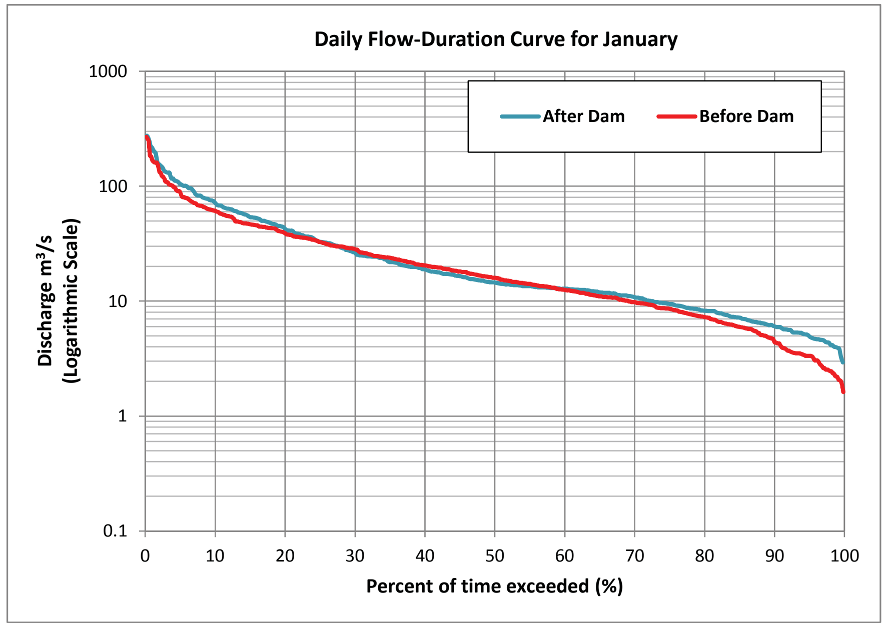
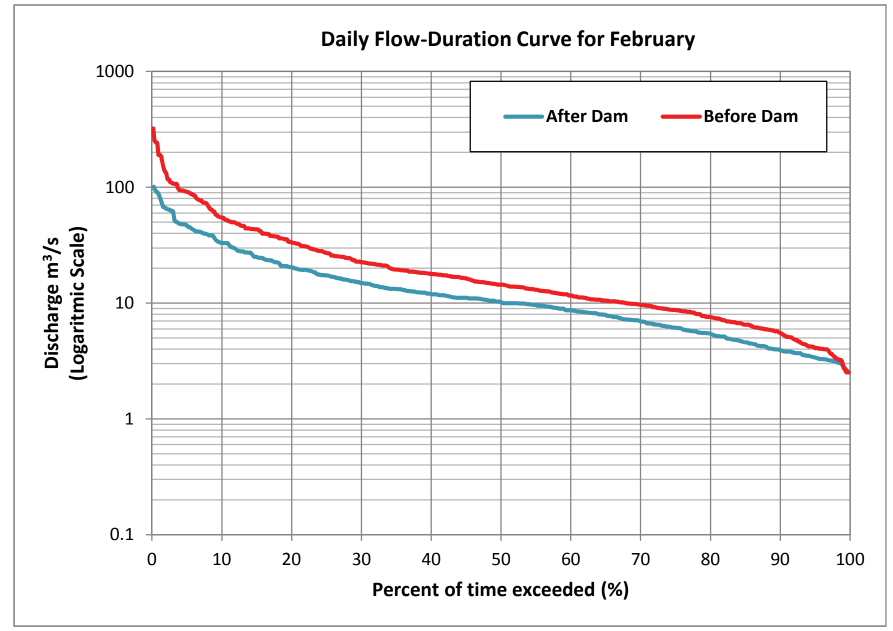
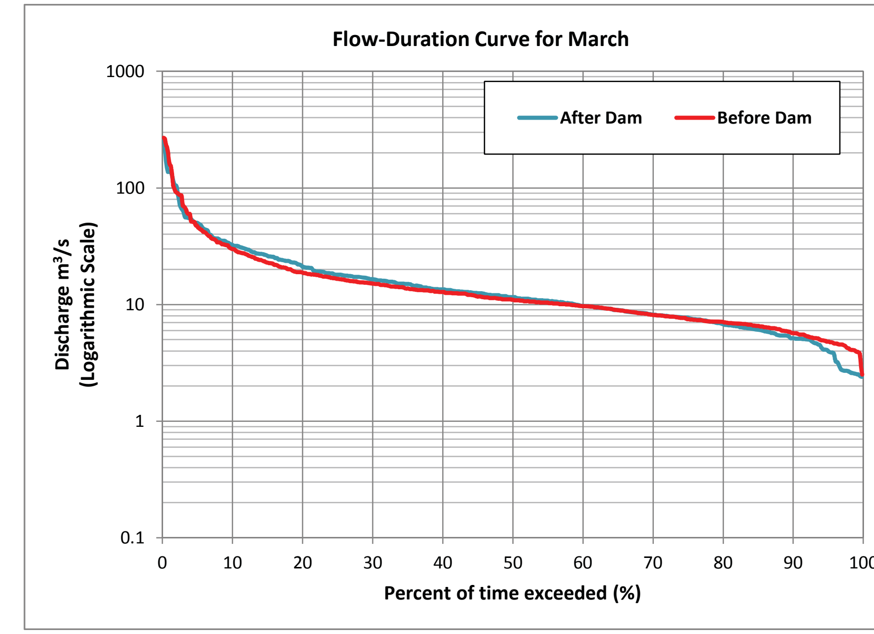
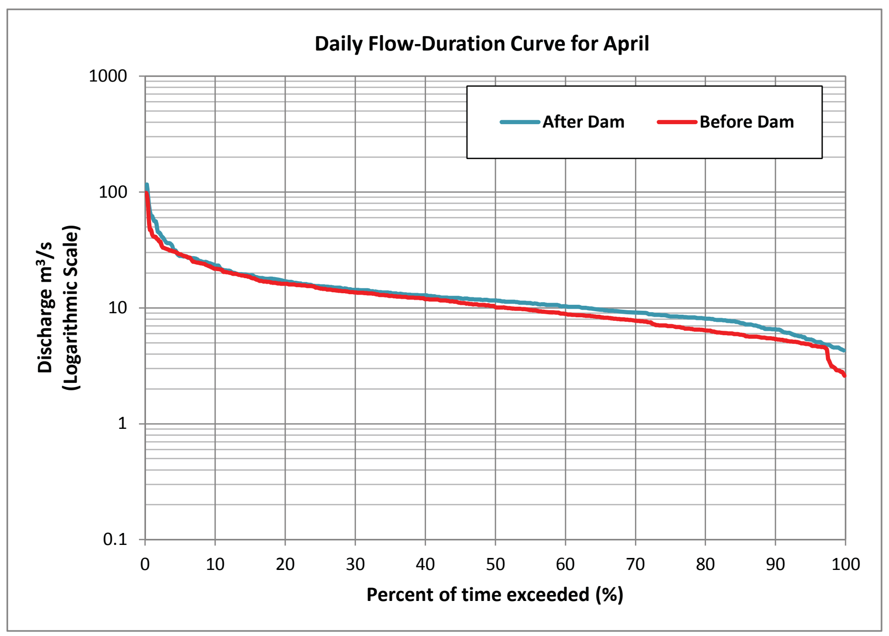
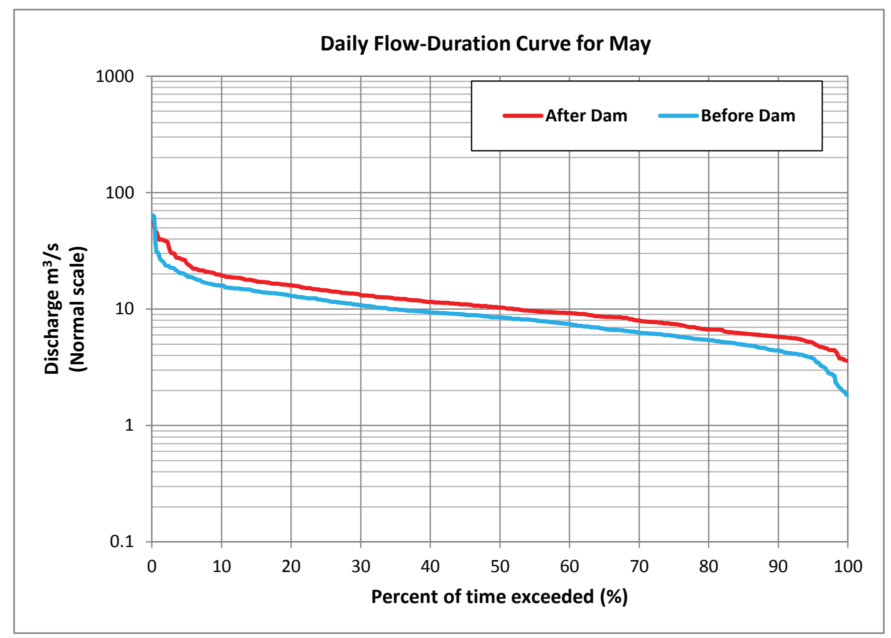
EWRS - Englishman River Intake
Englishman River Flow Duration Curve (Entire Year)
Figure 5a

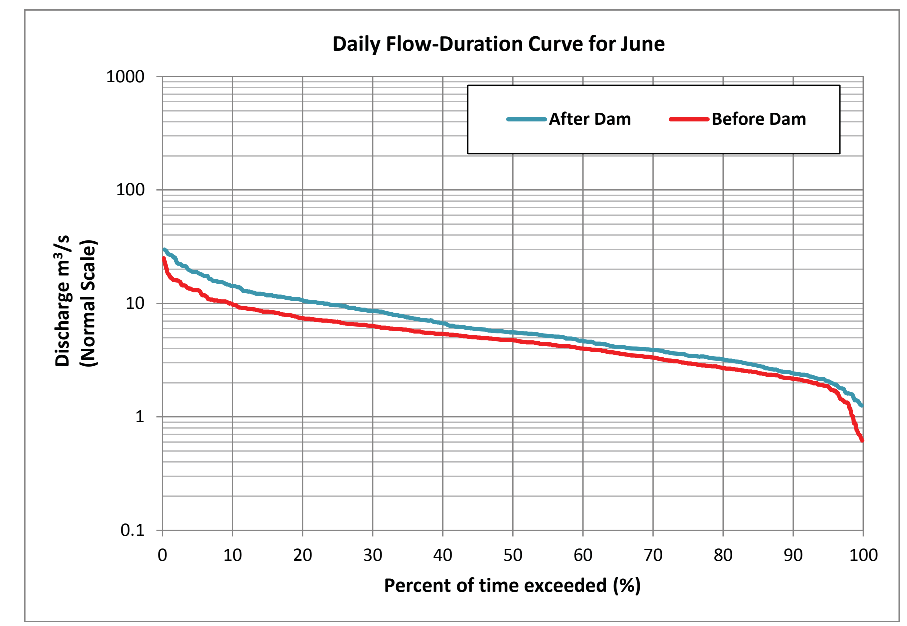




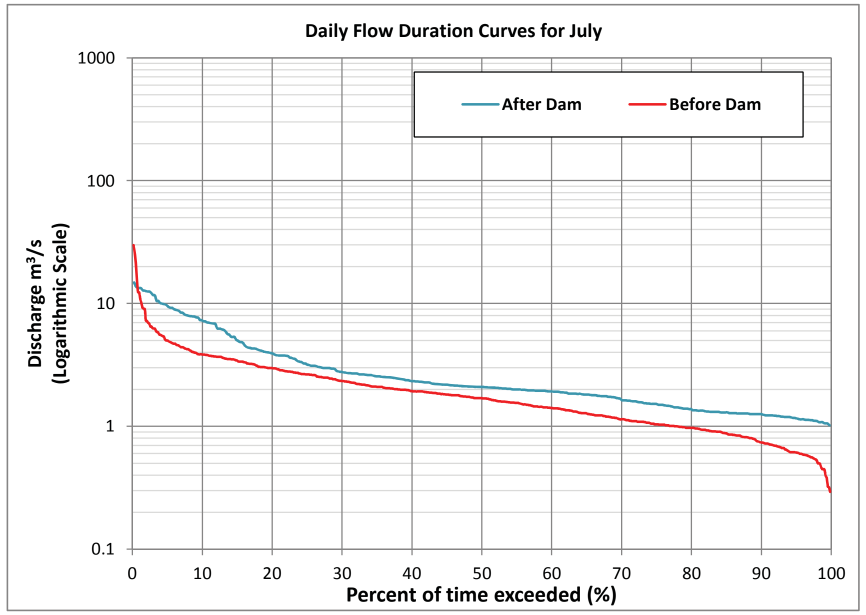


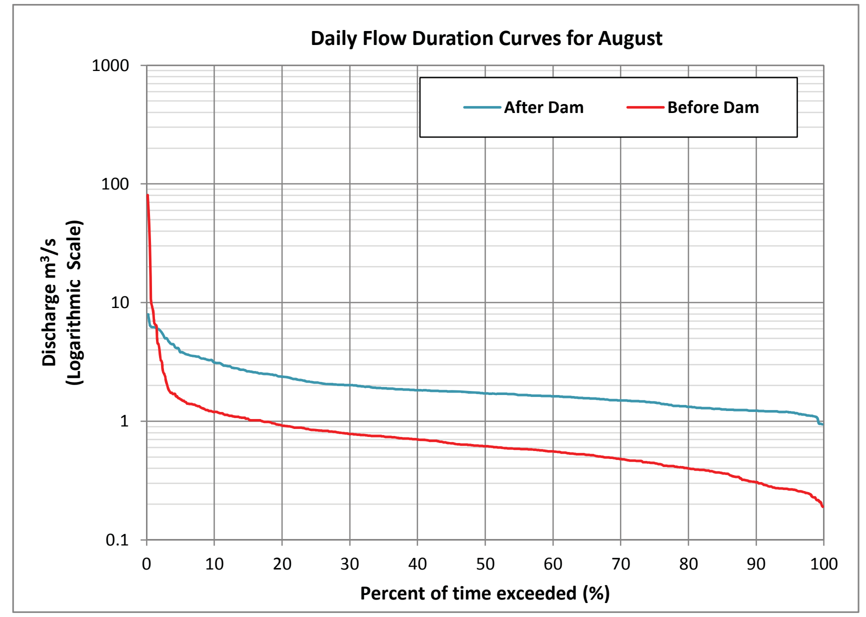


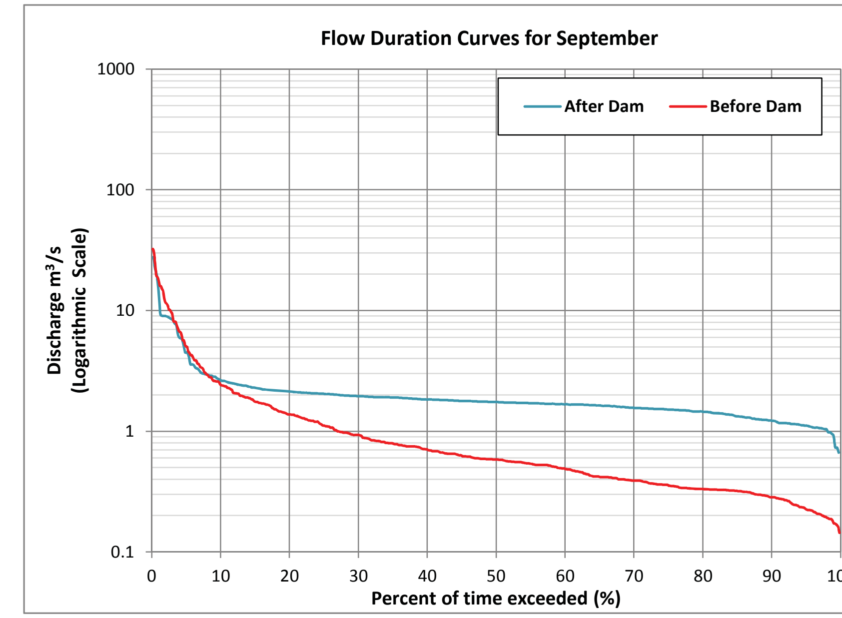


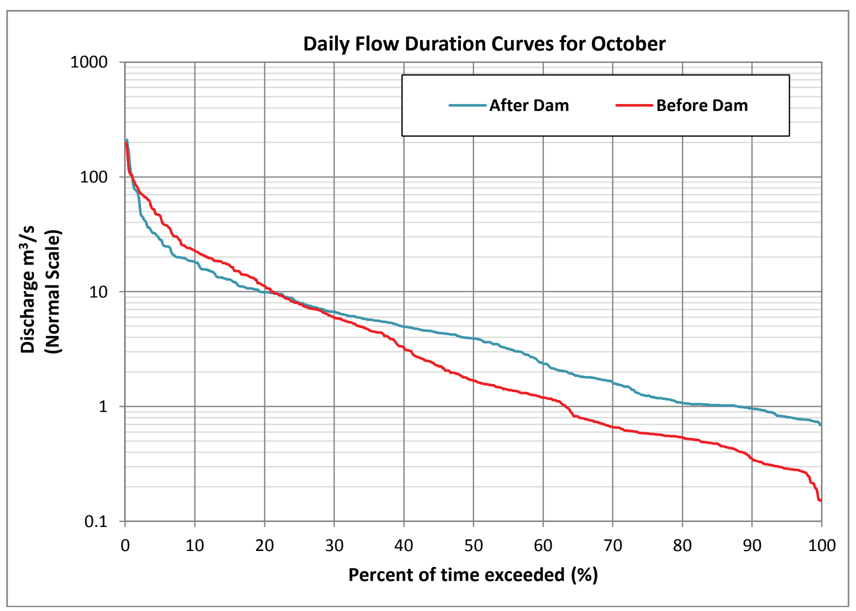


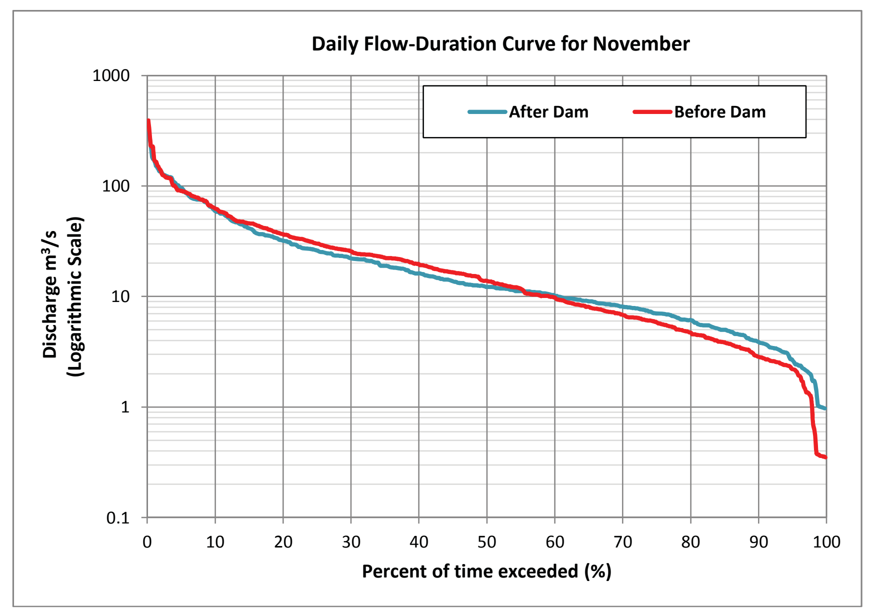
Note: Before Dam period based on 1980 to 1998 daily average flow data and After Dam period based on 1999 to 2012 daily average flow data

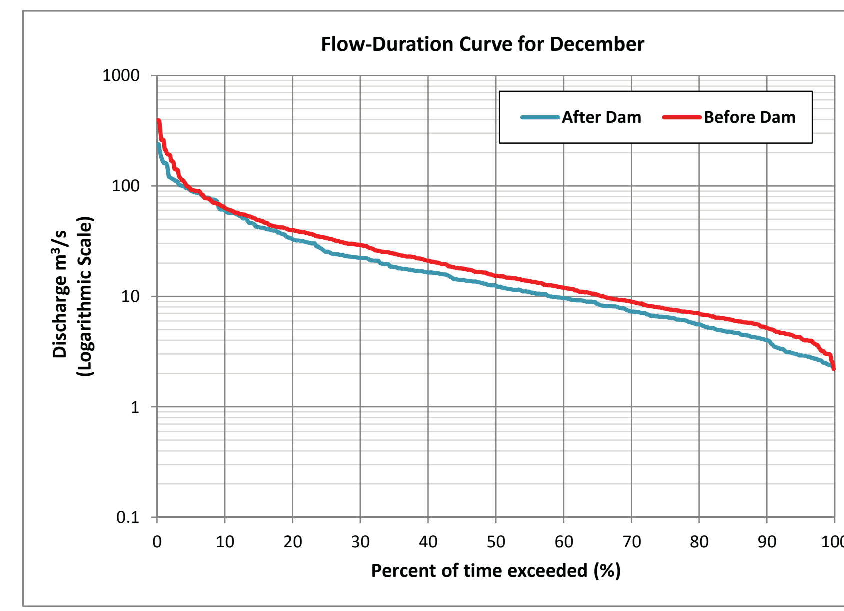




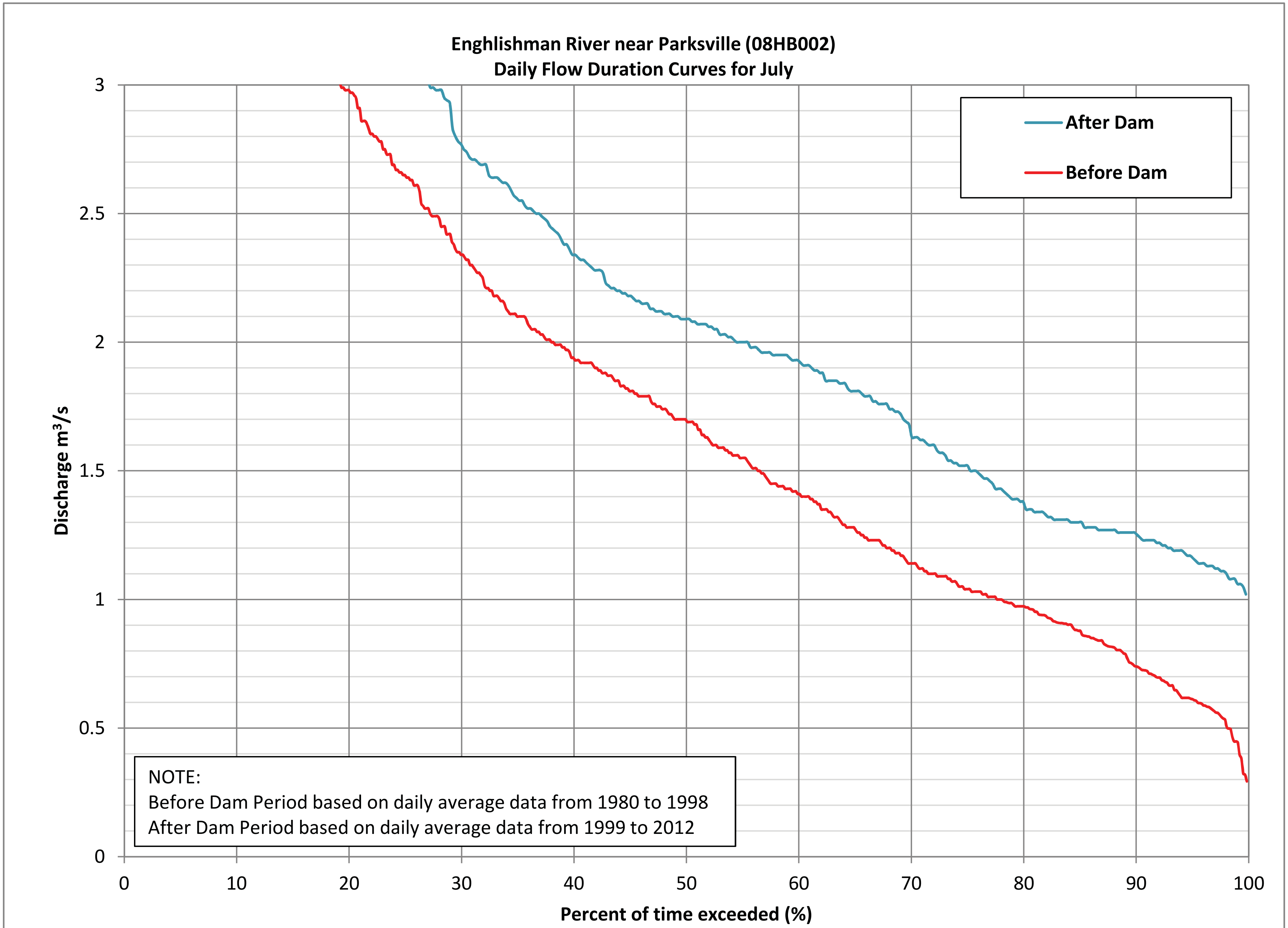








Note: Before Dam based on 1980 to 1998 daily average flow data and After Dam based on 1999 to 2012 daily average flow data



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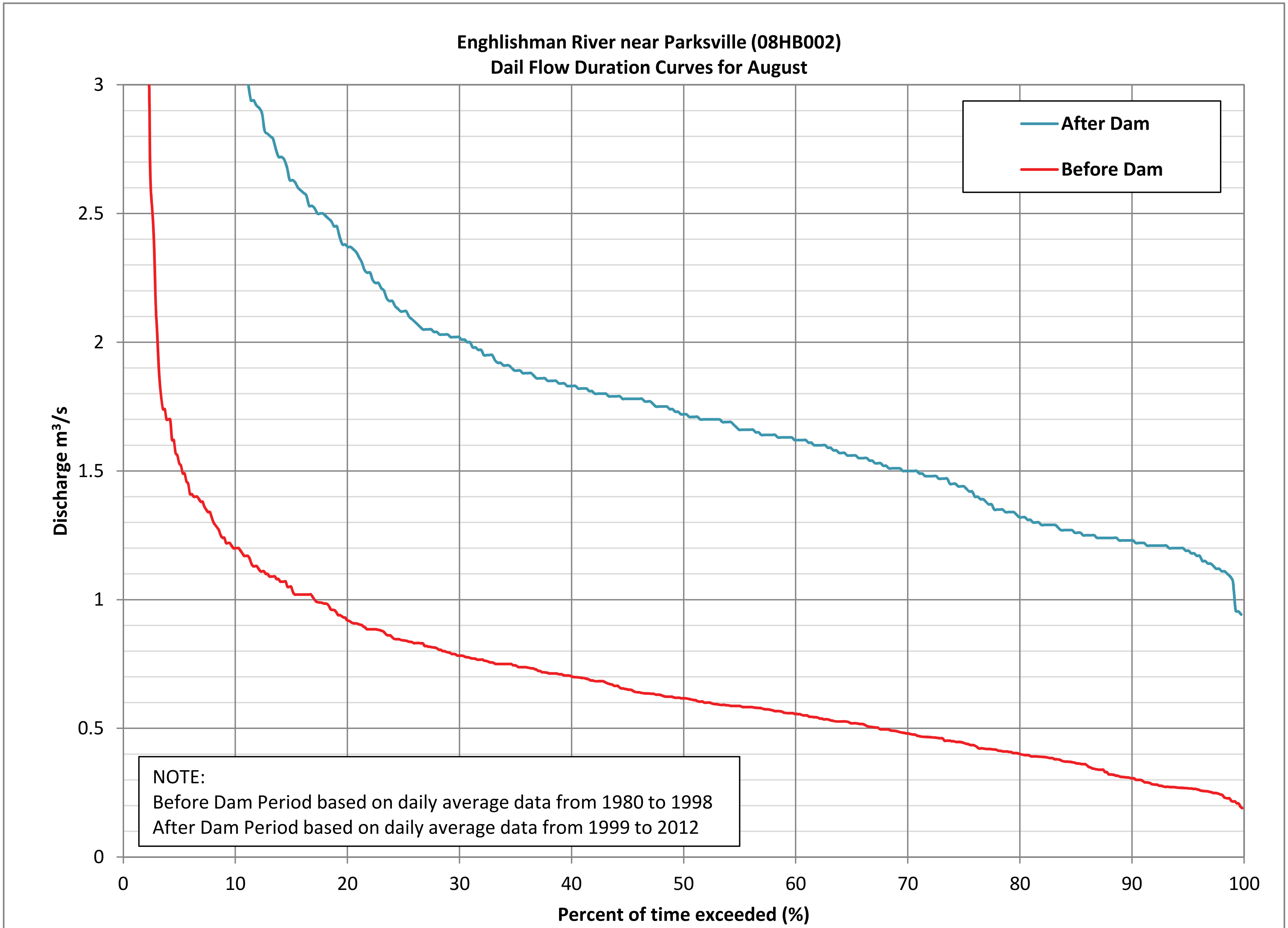
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5d



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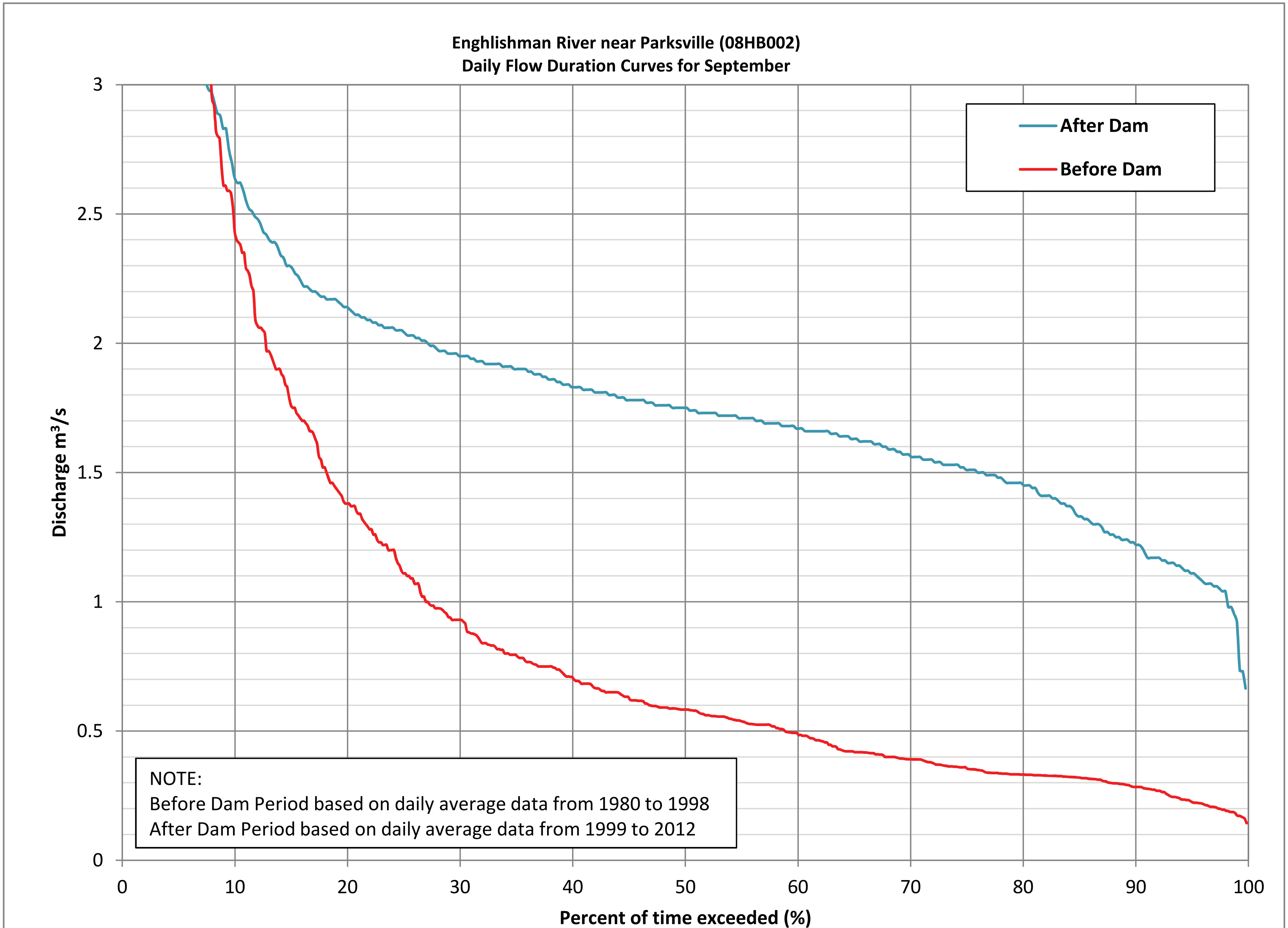
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5e



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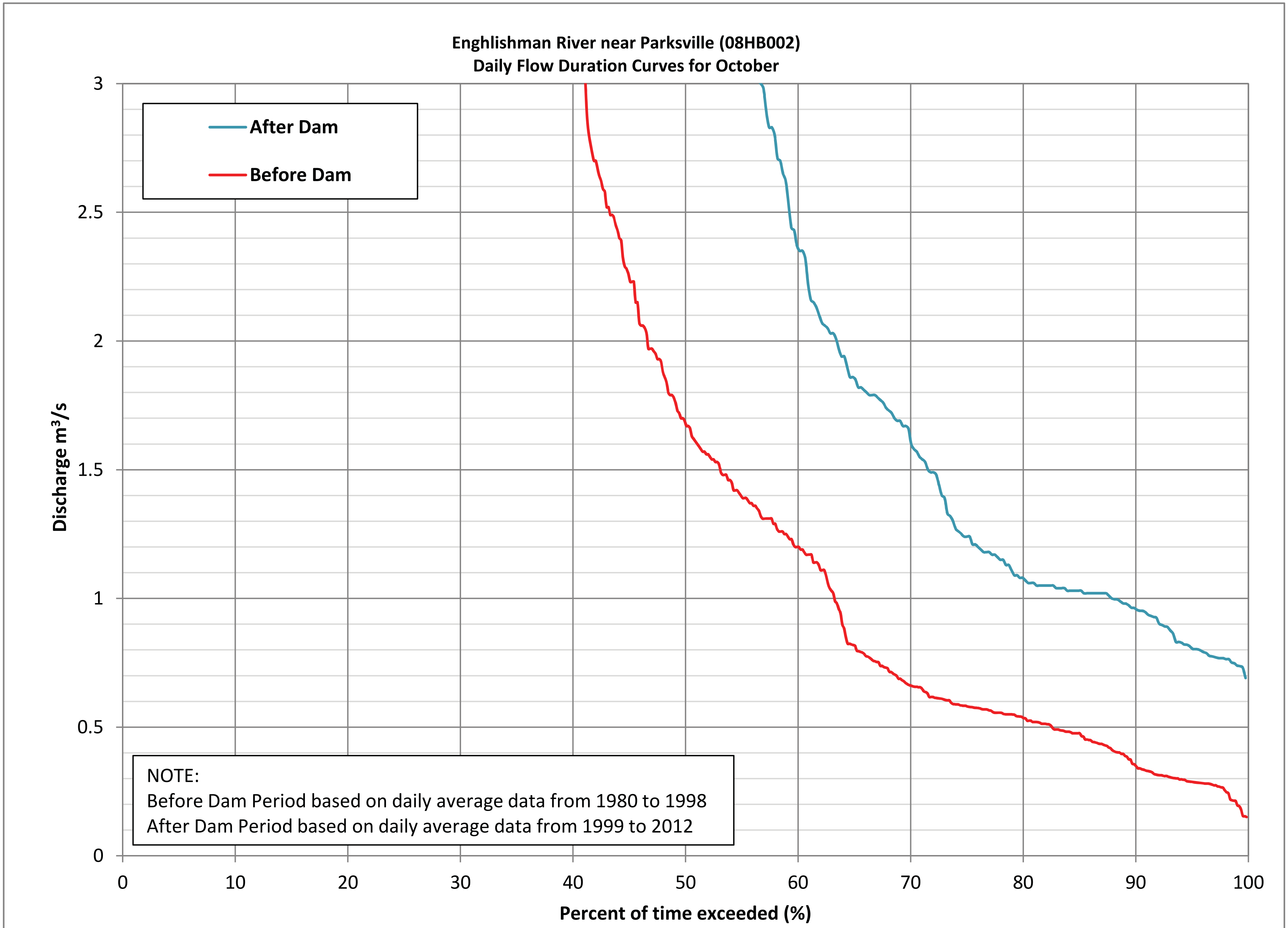
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5f



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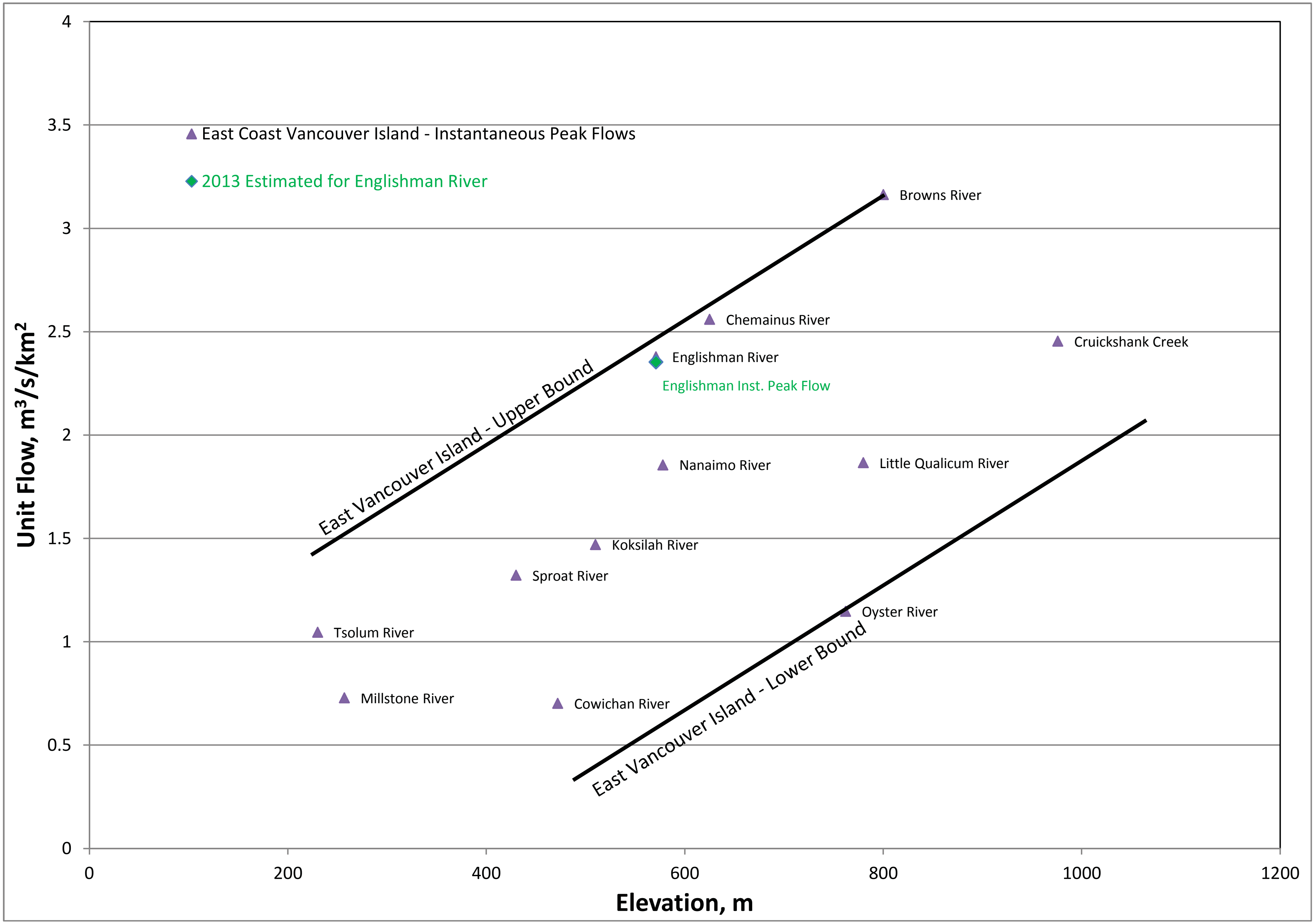
Englishman River - ERWS Water Intake Project
Daily Flow Duration Curves by Month
Figure 5g



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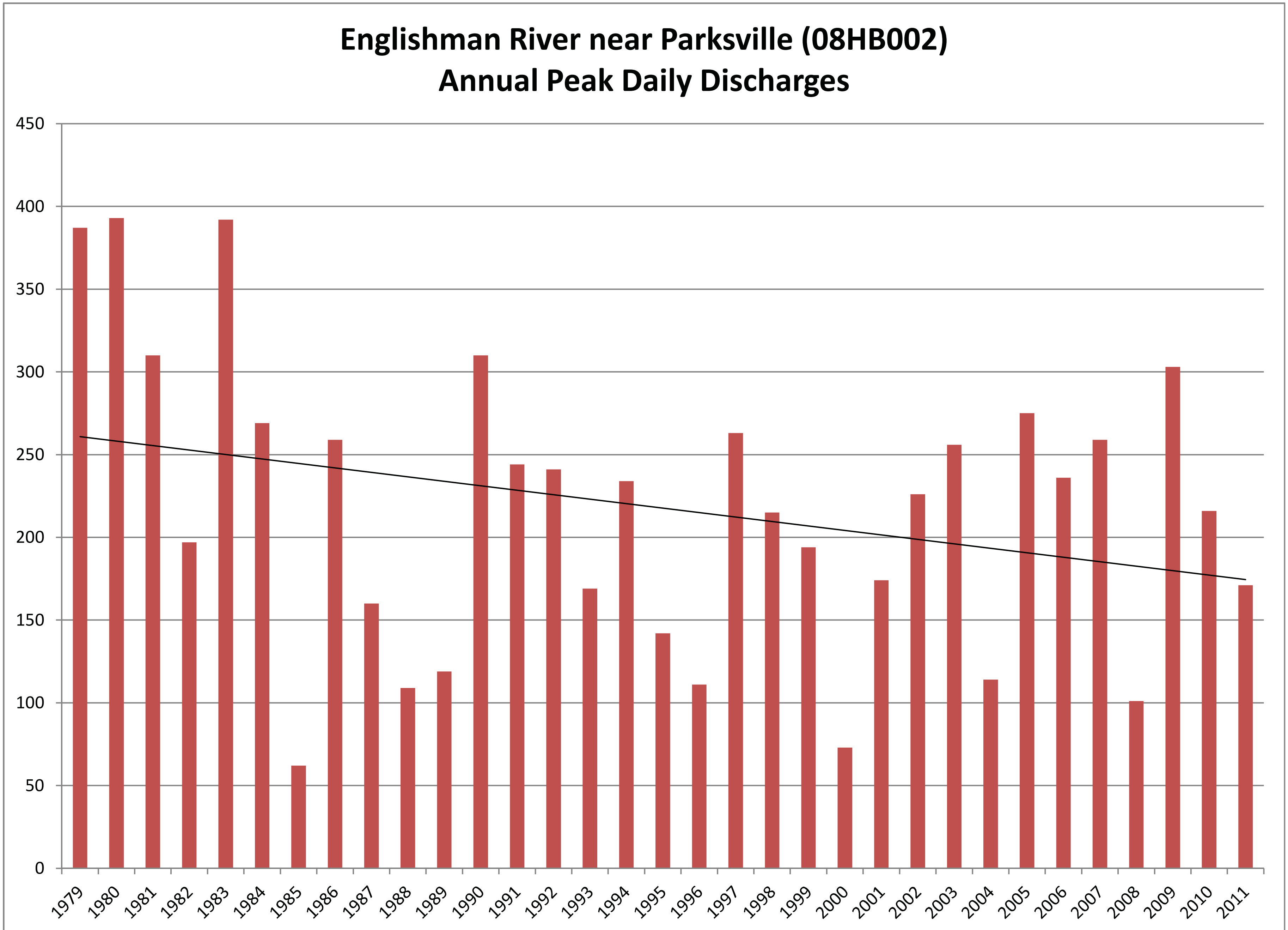
Englishman River - ERWS Water Intake Project

Regional Check of the 200-Year Design River Flood Flows

Figure 6



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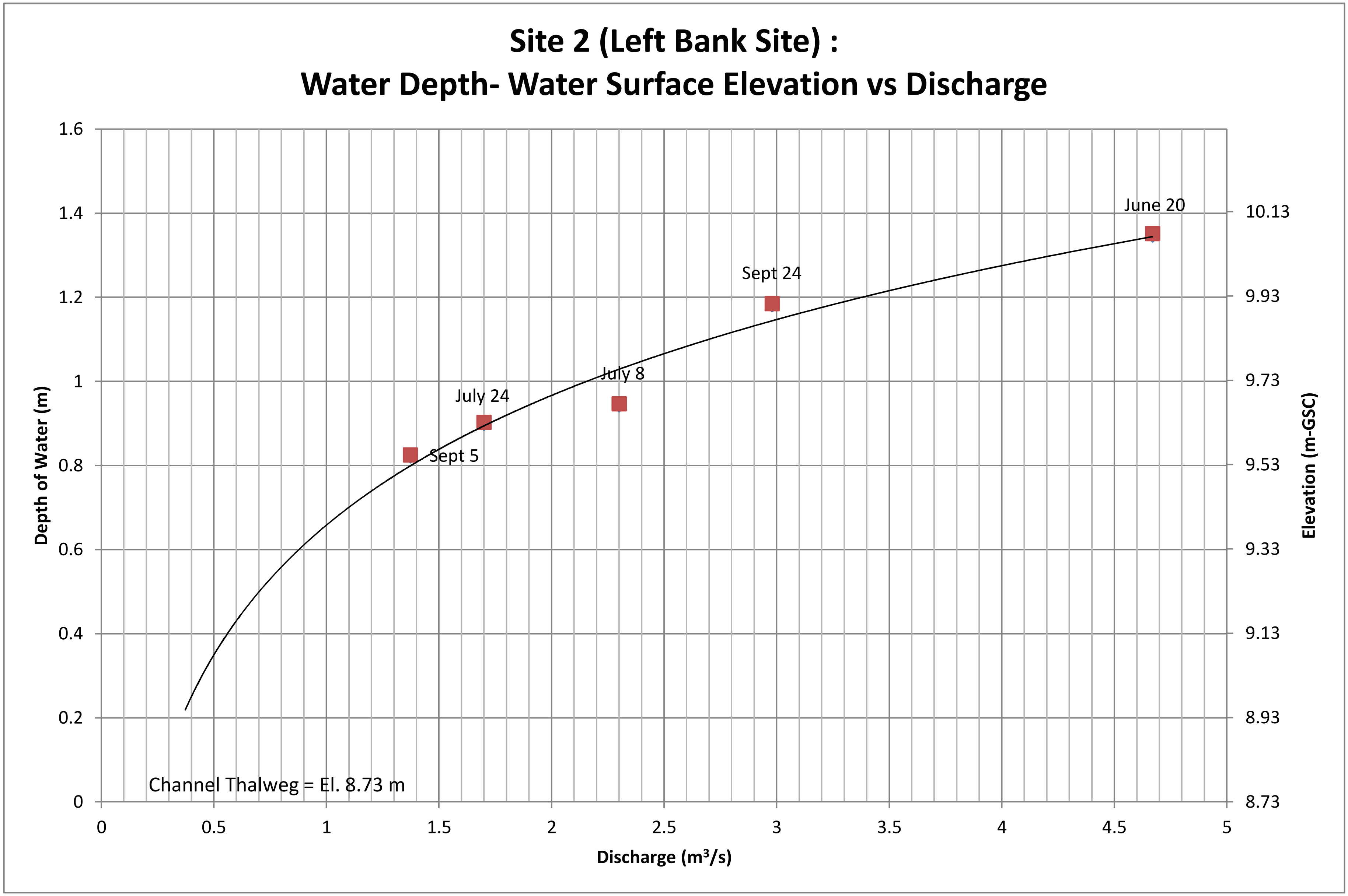
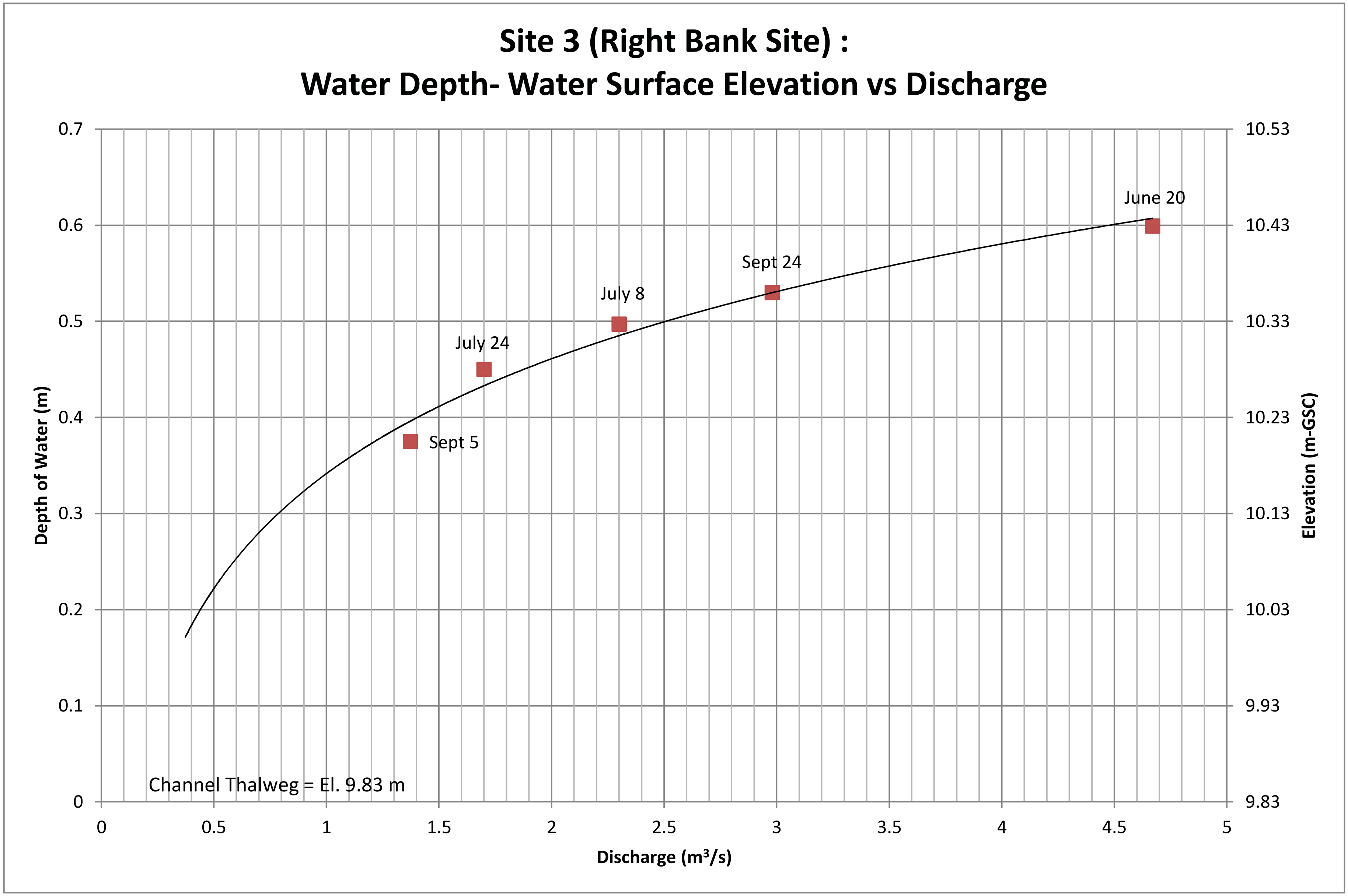
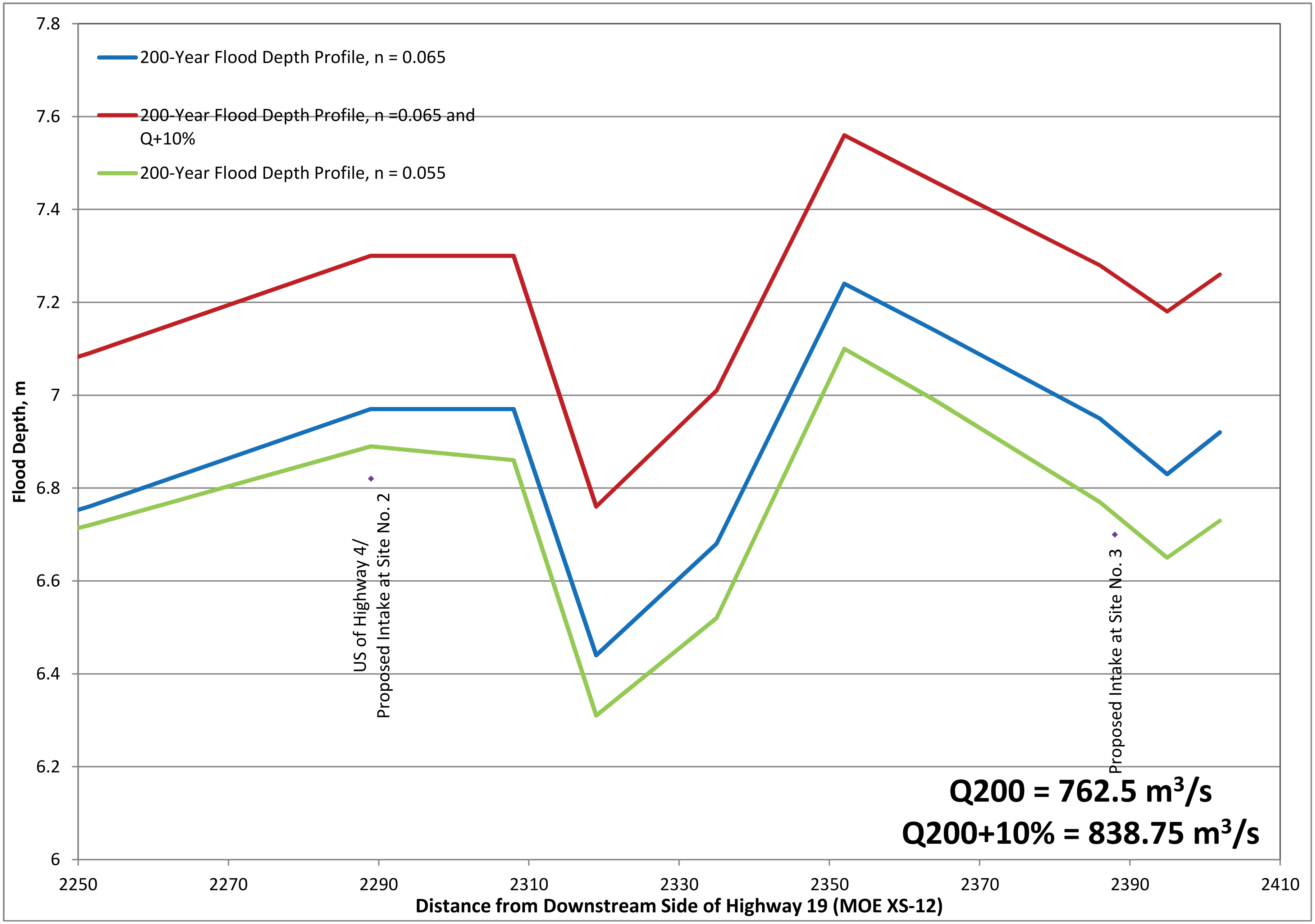
Englishman River Intake Project
Trend in Maximum Daily Peak Flow
Figure 7


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


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



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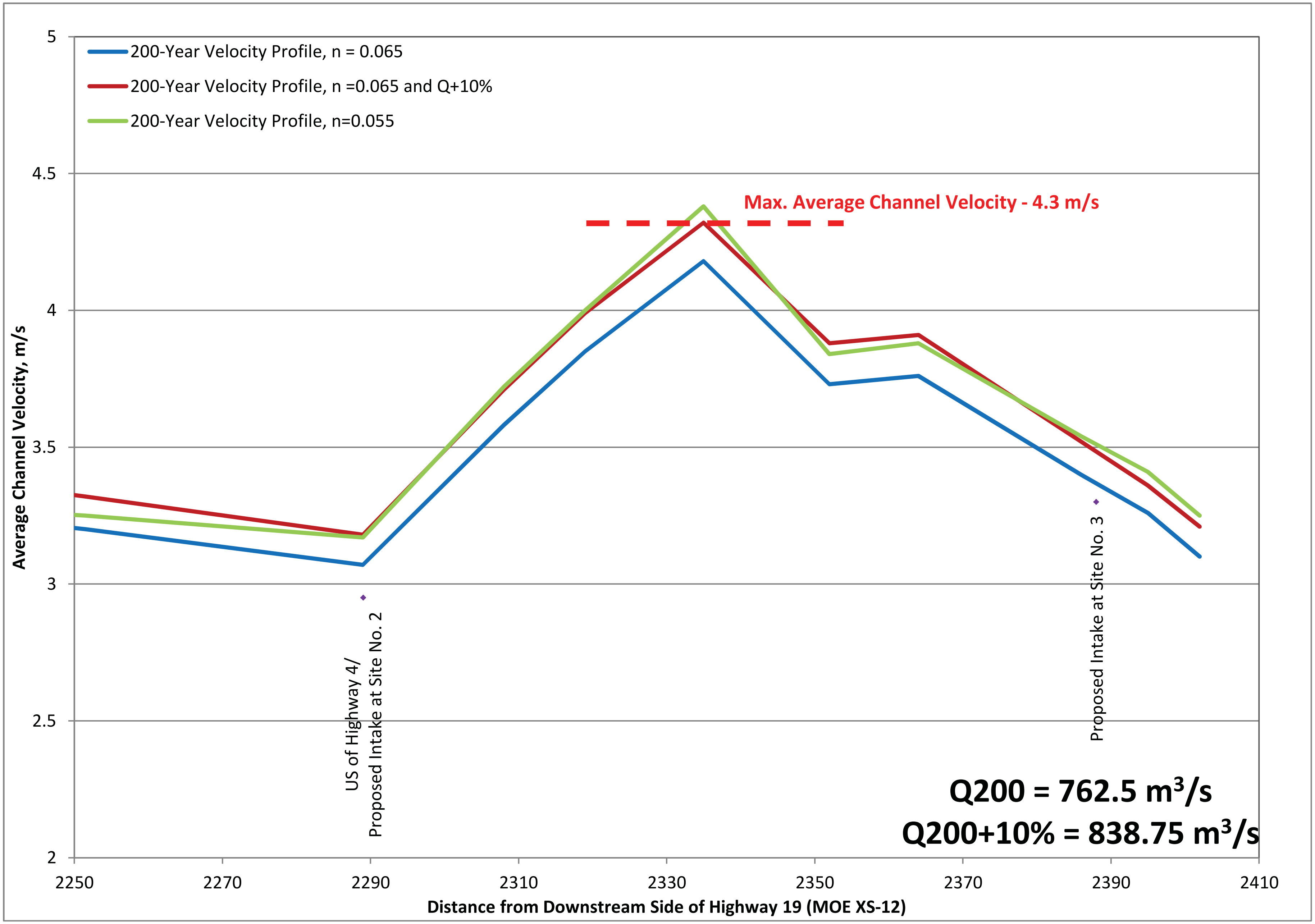
Englishman River - ERWS Water Intake Project
Simulated Flood Depth Profiles
Figure 9



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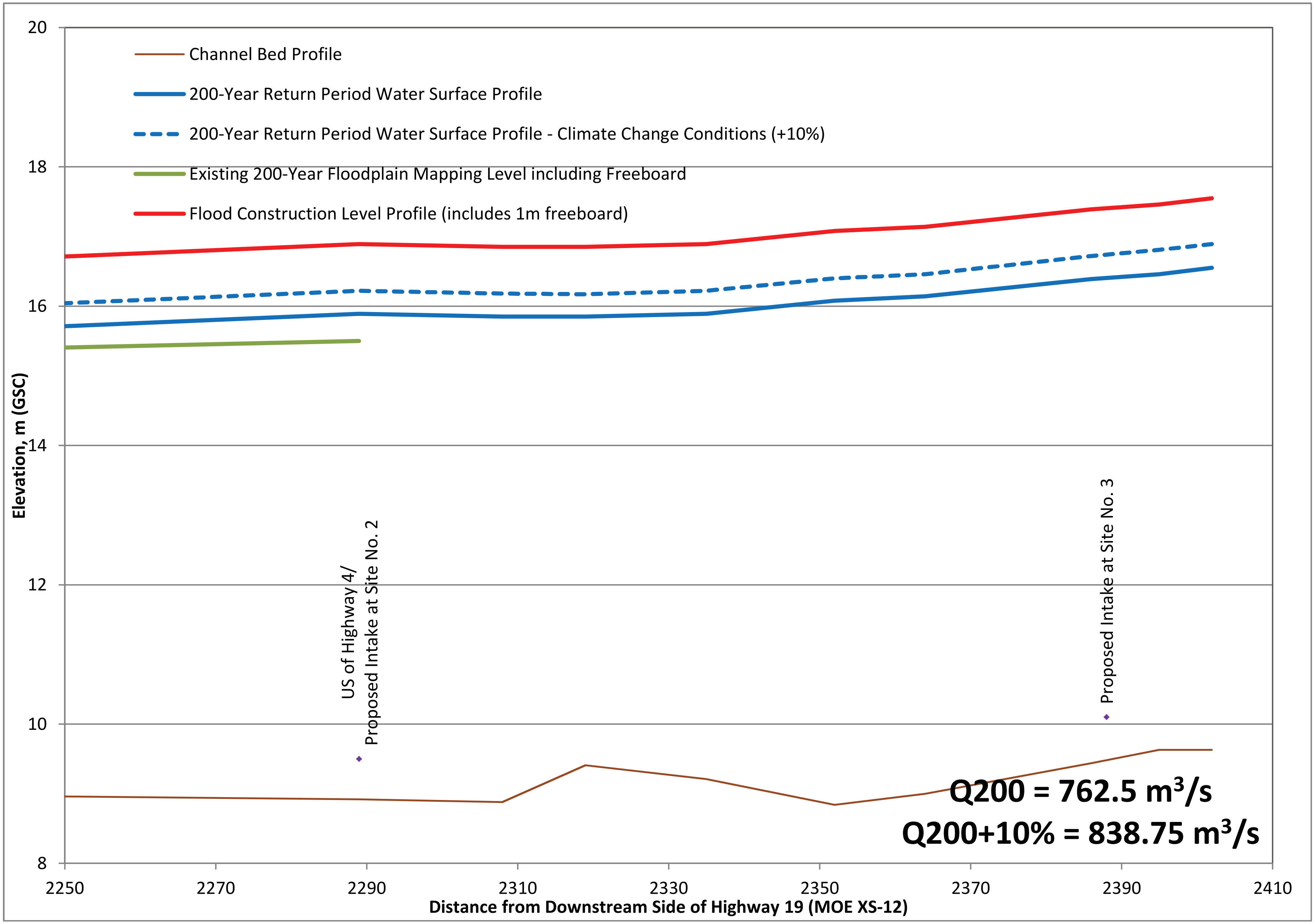
Englishman River - ERWS Water Intake Project
Simulated Flood Velocity Profiles
Figure 10



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Simulated Flood Level Profiles

Figure 11