APPENDIX A

Study Methodology

APPENDIX A – STUDY METHODOLOGY

A.1 TASK 1: GIS ANALYSIS

To provide basic information for each sub-basin and residual area in the Basin, the following information was compiled using Geographic Information System (GIS) (ArcView) software:

- Drainage areas of sub-basins and residual areas;
- Minimum and maximum elevations of sub-basins and residual areas;
- Median elevations of sub-basins and residual areas;
- Location (i.e. latitude and longitude) of each node;
- Location (i.e. latitude and longitude) of all known hydrometric stations in the Basin, including those operated by Water Survey of Canada (WSC) and other parties;
- Area and median elevation of the drainage areas upstream of the hydrometric stations (if unavailable from other sources), and
- Boundaries of provincial hydrologic zones.

A.2 TASK 2: COMPILE AND SCREEN HYDROMETRIC DATA

All current and former hydrometric stations in the Okanagan Basin (see Section 4.0) were organized by node (Appendix B). This includes stations operated by the WSC and those operated independently. While the latter group of stations have relatively short records and the data was collected according to varying standards (depending on the operator's objectives), the station records nonetheless can provide useful insight into the hydrology of some streams. Independent hydrometric data was provided to the study team by Dobson Engineering Ltd. (on behalf of from several water purveyors), Mr. Phil Epp of the Ministry of Environment, and the Oceola Fish and Game Club (Appendix B).

The list of hydrometric stations was screened to determine which stations could potentially be useful for the study. Those stations particularly useful for the study had the following characteristics:

- They have records of *natural* streamflows,

- They have records of streamflow throughout the year,
- They contain at least some streamflow records during the 1996-2006 standard period, and
- The overall record of streamflows is generally greater than five (5) years.

While these characteristics are desirable, a relatively small number of stations in the Okanagan Basin have these characteristics. It was therefore necessary to include other stations lacking some of the desired characteristics in order to provide at least some basic insight to the hydrology in parts of the Basin. A total of 94 stations were identified as having some potentially useful information for the study (Appendix B). Of these, 35 were employed to development regional runoff relations (see Section A.3).

For those hydrometric stations identified as potentially useful for the study, the following steps were taken:

- Mean *daily discharge* data from all hydrometric stations in the Okanagan Basin were obtained from Environment Canada (2008a) and others (Section 4.0).
- Mean daily discharge data were reduced to mean *weekly discharge* and organized in a standard spreadsheet template.
- Mean *weekly unit discharge* ($L/s/km^2$) was calculated for each station by dividing mean weekly discharge by the drainage area upstream of the stream gauge. The calculation of unit discharge permits comparisons between streams with differing drainage areas. In effect, it indicates the amount (or rate) of water produced on a unit area (i.e. km^2) of the watershed.

A.3 TASK 3: DEVELOP UPDATED REGIONAL RUNOFF RELATIONS

In order to identify runoff patterns in the Basin, regional relations developed by Mr. Bill Obedkoff of MOE in 1998 were updated. These relations and describe how mean annual runoff varies with elevation and geographic location in Interior British Columbia (Obedkoff 1998). The updated relations were prepared in order to estimate the annual runoff *normalized* for the 1996-2006 period at any location in the Okanagan, based on the median

elevation and the drainage area upstream of the point-of-interest (determined by GIS). Since this information can support estimates of aquifer recharge it was made available in November 2008 to the consulting team investigating groundwater for the OWSDP. The annual runoff predicted by the updated regional relations describes the general pattern of runoff in the Basin and also provides a basis from which monthly and weekly runoff can be estimated with knowledge (or estimation) of the distribution of runoff at the location of interest. This is particularly useful in ungauged basins. The following summarizes the methods used to develop the updated regional runoff relations.

Based on a review of all available streamflow records (Section A.2), 35 hydrometric stations distributed throughout the Okanagan and nearby surrounding Basin areas were identified (Table A.1 and Map 1) as suitable to support the analyses. These stations have most if not all the desirable characteristics listed in Section A.2 and were considered representative of the annual runoff patterns.

For each station, mean annual discharge (in units of m^3/s) for each year of record were compiled and converted to *mean annual unit discharge, i.e. runoff* (in units of mm). In order to make comparisons for the 1996-2006 standard normal period, mean annual runoff data was normalized. While there are different approaches to adjust data of different periods so that they reflect a normal (or common) period, a relatively straightforward approach was adopted for this study. It involved scaling the mean annual runoff for the available period of record at each station by a factor that reflected how runoff over the specific period of record compared to the 1996-2006 period. This factor was based on averaging the patterns of runoff from 14 stations listed in Table A.1 that operated between 1996 and 2006 and have records of natural streamflows. Although the patterns of mean annual runoff vary slightly between the 14 stations, the overall average pattern was considered reasonably consistent in the region (Figure A.1). The normalized runoff for each of the 35 hydrometric stations is presented in Table A.1.

Table A.1 List of hydrometric stations used to develop updated regional runoff relations.

Provincial Hydrologic Zone (refer to Map 1)	**Station no.**	**Station name** (* indicates stations outside the Okanagan Basin)	**Natural** (bold) / **Regulated** (not bold)	**Years of record**	**Median Elevation (m)**	**Normal Annual Runoff 1996-2006 (mm)**
24/b	**08LG064**	**Beak Creek at the mouth***	**Natural**	**1983-2000**	**1450**	**177**
24/b	**08NM035**	**Bellevue Creek near Okanagan Mission**	**Natural**	**1911-1986**	**1540**	**164**
24/b	**08NM133**	**Bull Creek near Crump**	**Natural**	**1965-1986**	**1530**	**90**
24/b	**08NM134**	**Camp Creek at the mouth near Thirsk**	**Natural**	**1965-2007**	**1450**	**126**
24/b	**08NM137**	**Daves Creek near Rutland**	**Natural**	**1965-1986**	**1290**	**110**
24/b	**08NM242**	**Dennis Creek near 1780 m contour**	**Natural**	**1985-2007**	**1893**	**499**
24/b	**08NM173**	**Greata Creek near the mouth**	**Natural**	**1970-2007**	**1280**	**65**
24/b	**08NL050**	**Hedley Creek near the mouth***	**Natural**	**1973-2006**	**1680**	**197**
24/b	08NL045	Keremeos Creek below Willis Intake*	Regulated	1971-2006	1320	110
24/b	08LG049	Nicola River above Nicola Lake*	Regulated	1915-2007	1230	88
24/b	**08LG016**	**Pennask Creek near Quilchena***	**Natural**	**1920-2006**	**1680**	**290**
24/b	08NM037	Shatford Creek near Penticton	Regulated	1911-2007	1530	124
24/b	08NL022	Similkameen River near Nighthawk*	Regulated	1928-2006	1480	203
24/b	**08NM164**	**Testalinden Creek in canyon**	**Natural**	**1969-1986**	**1270**	**69**
24/b	**08NM240**	**Two-forty Creek near Penticton**	**Natural**	**1983-2007**	**1769**	**416**
24/b	**08NM241**	**Two-forty-one Creek near Penticton**	**Natural**	**1983-2007**	**1768**	**378**
24/b	**08NM015**	**Vaseux Creek above Dutton Creek**	**Natural**	**1919-1982**	**1591**	**179**
24/b	**08NM171**	**Vaseux Creek above Solco Creek**	**Natural**	**1970-2007**	**1680**	**265**
23/c	08NM020	BX Creek above Vernon intake	Regulated	1921-1999	1130	180
23/c	**08NM142**	**Coldstream Creek above municipal intake**	**Natural**	**1967-2007**	**1120**	**143**
23/c	08NM116	Mission Creek near East Kelowna	Regulated	1946-2007	1340	258
23/c	**08NM172**	**Pearson Creek near the mouth**	**Natural**	**1970-1987**	**1560**	**399**
23/c	**08NN019**	**Trappping Creek near the mouth***	**Natural**	**1965-2006**	**1350**	**338**
23/c	**08LC040**	**Vance Creek below Deafies Creek***	**Natural**	**1970-2006**	**1040**	**240**
23/c	**08NN022**	**West Kettle River below Carmi Creek***	**Natural**	**1973-1996**	**1380**	**285**
23/c	**08NN015**	**West Kettle River near McCulloch***	**Natural**	**1949-2006**	**1620**	**502**
15/e	**08NM146**	**Clark Creek near Winfield**	**Natural**	**1968-1982**	**1360**	**154**
15/e	**08NM177**	**Deep Creek at Young Road**	**Natural**	**1970-1975**	**770**	**37**
15/e	**08NM176**	**Ewer Creek near the mouth**	**Natural**	**1971-1986**	**1470**	**228**
15/e	08NM165	Lambly Creek above Terrace Creek	Regulated	1970-1995	1390	247
15/e	08LE020	Salmon River at Falkland*	Regulated	1911-2007	1190	102
15/e	08LE021	Salmon River at Salmon Arm*	Regulated	1911-2007	1130	124
15/e	**08LE075**	**Salmon River at Salmon Lake***	**Natural**	**1965-2002**	**1350**	**167**
15/e	08NM138	Terrace Creek near Kelowna	Regulated	1965-1992	1490	267
15/e	**08NM174**	**Whiteman Creek above Bouleau Creek**	**Natural**	**1971-2006**	**1450**	**204**

Following the approach of Obedkoff (1998), all normalized runoff data were first stratified by provincial hydrologic zone (see Map 1) and then plotted against median elevation of the drainage area on semi-log graph paper (Figure A.2). The best-fit relations for the three main provincial hydrologic zones in the Okanagan[1] were then fitted by eye using professional judgement since not all stations are given equal weighting. This is necessary since some stations have regulated streamflow, some have relatively short records, and some stations may be influenced to a greater extent by surface water-groundwater interactions (see Section 3.6).

A suite of parallel lines on semi-log graph paper (curvilinear on arithmetic paper) reflect the general pattern of increasing runoff with elevation and increasing runoff from the south to the north as one moves from hydrologic zone "24/b" to "15/e" to "23/c" (Obedkoff, 1998). In order to provide a practical tool for this and other OWSDP studies, the above-noted dataset was further stratified into 12 sub-regional "hydrologic groups" that reflect reasonably uniform runoff characteristics. These groups were identified based on the normalized runoff statistics, reported streamflow characteristics in the Okanagan, and professional experience. While there is a gradual transition of runoff characteristics from one group to the next, for this study the groups were defined along sub-basin or residual areas boundaries. Runoff relations for each "hydrologic group" are provided in Appendix B. Map 1 shows the locations of each group. For each group there is a best-fit relation to estimate the *expected value* of the normalized annual runoff as well as the likely upper and lower estimates of annual runoff. It is important to note that the upper and lower limits were estimated by eye and were not statistically derived. The ranges in estimates vary by group depending on the within-group runoff variation. Discussion of the pattern of regional runoff identified in the Basin is provided in Section 5.0 of the main report.

[1] A fourth provincial hydrologic zone is present at the extreme north end of the Okanagan Basin. However due to its small size this zone was not included.

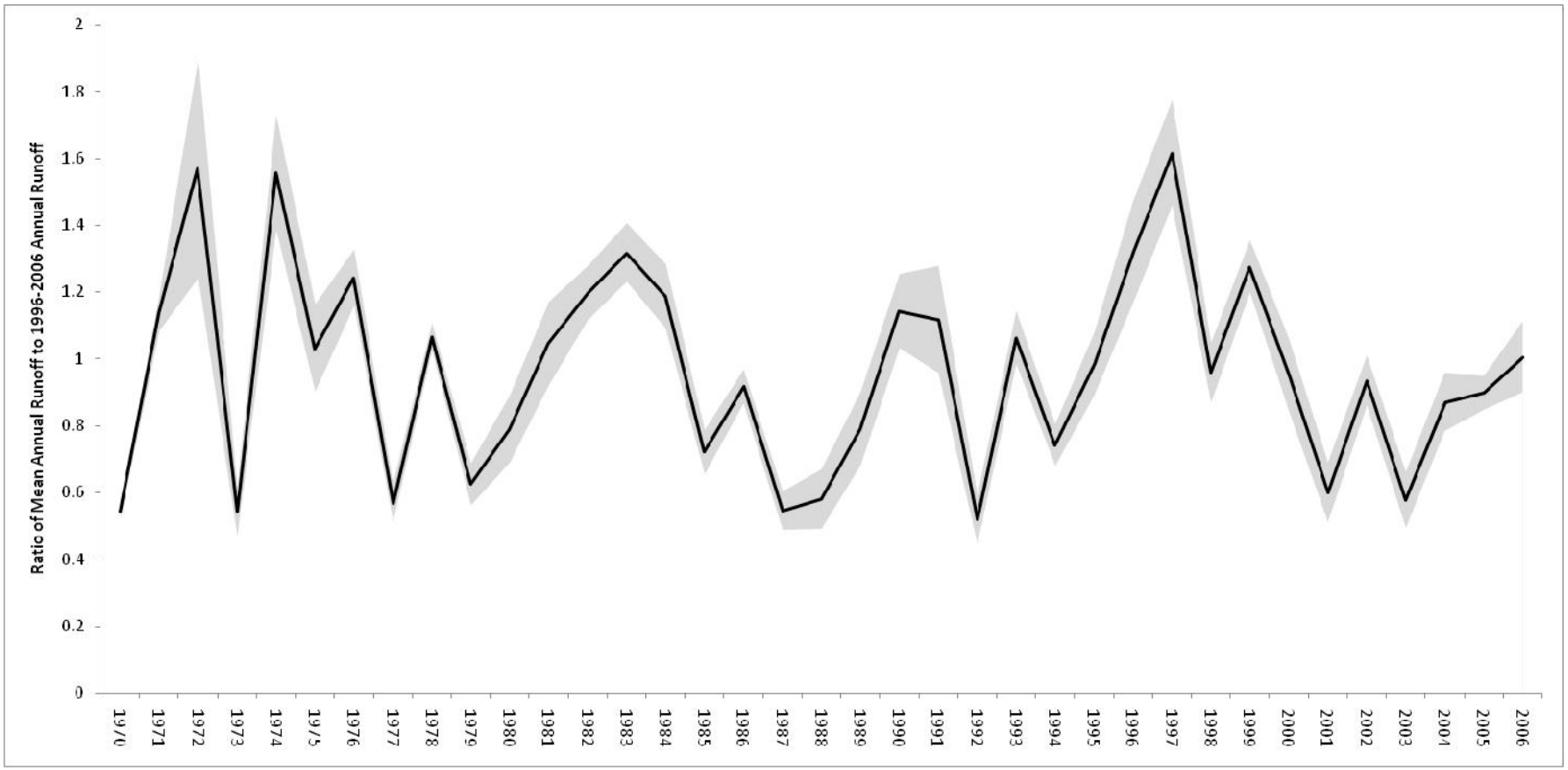


Figure A.1 Regional average ratio of mean annual runoff to 1996-2006 normal annual runoff (based on natural streamflow records from 14 hydrometric stations).

Note: Values above 1.0 indicate years when the Okanagan Basin overall experienced higher than normal runoff, while those below 1.0 indicate lower than normal runoff. Gray area indicates +/- 2 standard deviations about the mean.

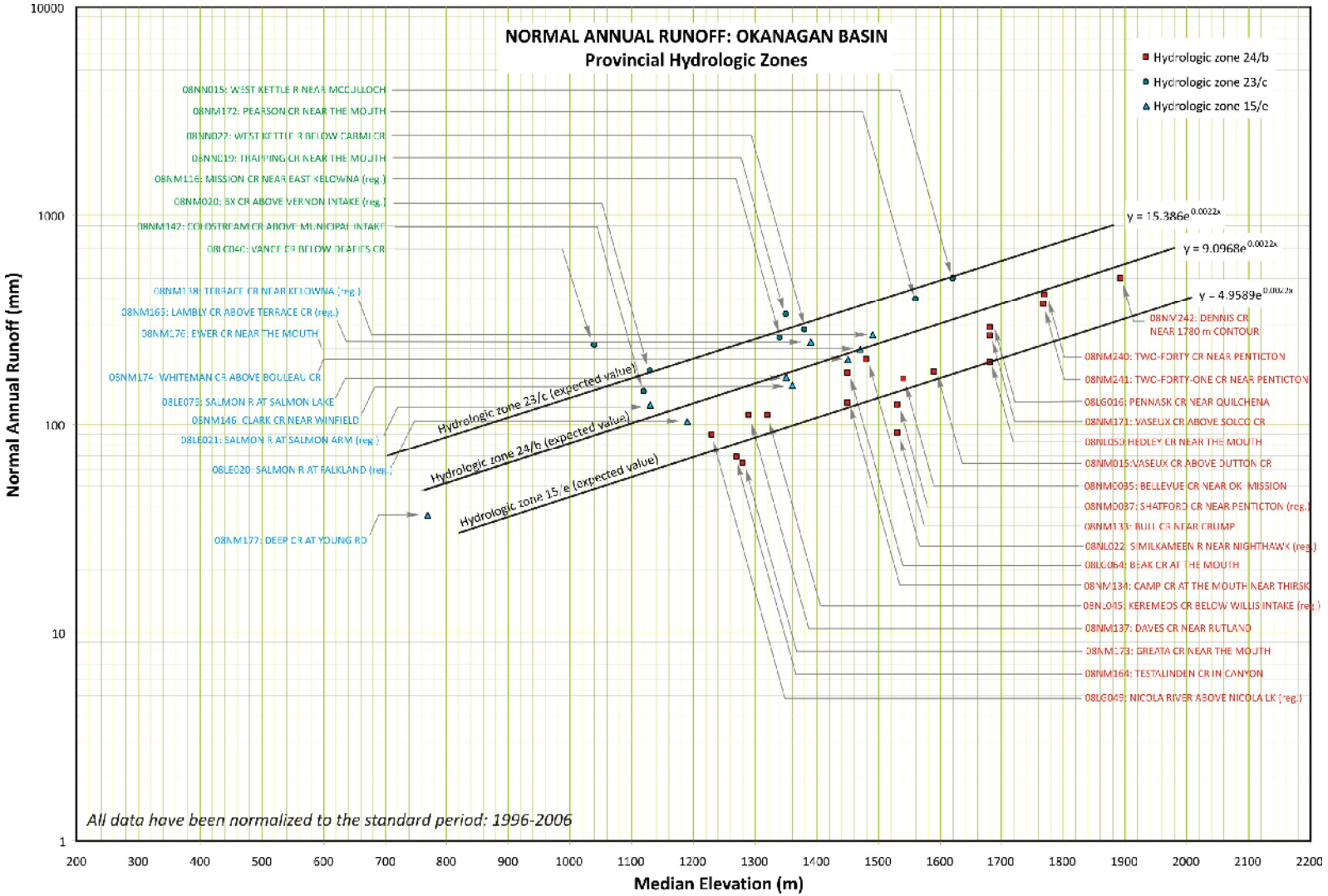


Figure A.2 Normal (1996-2006) annual runoff relations for the Okanagan Basin, stratified by provincial hydrologic zone.

A.4 TASK 4: ANALYSIS AND FILLING OF GAPS IN HYDROMETRIC RECORDS

Once all the potentially useful hydrometric data had been compiled (Appendix B), the next step involved systematically screening all the potentially useful information one sub-basin at a time. The purpose of the screening was to confirm the methods to be used for estimating natural streamflows at each of the nodes and to confirm the usefulness of the data available within each sub-basin. During this step, the smaller gaps in hydrometric records were filled. This typically involved identifying relations between the hydrometric records from the station having missing data and the hydrometric records at one or more nearby stations having records for the period of missing data.

A.5 TASK 5: REVIEW KEY REPORTS IN THE OKANAGAN INFORMATION DATABASE

The Okanagan Information database, developed in Phase 1 of the OWSDP and updated thereafter, was used to identify key reports that could be useful for developing and/or confirming estimates of natural streamflows. Included within the database are many stream-specific hydrology studies conducted by Ministry of Environment staff, professional consultants, and university researchers. The most relevant reports are listed in Appendix D. In several sub-basins, this information proved to be supplementary to actual hydrometric records; however, in other sub-basins, this information provided the only data available and was key in developing some streamflow estimates (Section 2.10).

A.6 TASK 6: REVIEW WATER MANAGEMENT AND USE REPORT

As indicated in Section 1.3.1, the process of streamflow naturalization involves the use of hydrometric records and estimates of water use and management (i.e. water storage, release, and diversions). This information was obtained from the Water Management and Use (WMU) Study (Dobson Engineering Ltd. 2008).

Streamflow naturalization was done for the three largest streams in the Okanagan: Vernon, Mission and Trout Creeks, using a detailed update of the water management and use data for

these sub-basins was completed after the 2008 Dobson Engineering study was published (see Section A.7). Naturalization was also completed for Trepanier Creek.

A.7 TASK 7: REFINE WATER MANAGEMENT AND USE DATA

A technical memorandum outlining the methods and assumptions used in the refinement of data presented in Dobson (2008) is provided in Appendix E. In summary, water balance parameters that directly influence streamflow naturalization were revised for Vernon Creek sub-basin (Nodes 1, 2, and 12), Mission Creek sub-basin (Node 22), and Trout Creek sub-basin (Node 42). The goal was to gain additional confidence in the following parameters over the 1996-2006 standard period:

- The weekly volume of water imported to the sub-basin (if any),
- The weekly volume of water captured into or released from storage in the sub-basin, and
- The weekly volume of water extracted from surface sources in the sub-basin.

Vernon, Mission, and Trout Creeks were chosen not only because they represent the three largest sub-basins in the Okanagan (providing 42% of the total average streamflow in the Basin), but also because Vernon and Mission Creeks have long (regulated) streamflow records that facilitate streamflow naturalization. While the (regulated) streamflow record for Trout Creek has considerably more gaps, it is nevertheless useful for developing naturalized streamflow estimates in conjunction with other methods such as regionalization. Although there are several other sub-basins where water use and management data could have been re-examined in order to facilitate streamflow naturalization, alternative techniques were available to reasonably estimate natural streamflows in those (smaller) sub-basins - although at the cost of slightly greater levels of uncertainty.

Following the revisions, it was evident that, in some cases, some original WMU data was reasonable, but for others the revised estimates differed considerably (Appendix E), and these differences would have significantly affected streamflow naturalization results. Revised data were uploaded to the Okanagan Water Database, and used for this study.

A.8 TASK 8: SUMMARIZE NATURAL STREAMFLOWS

Natural streamflow records provide a direct means to determine natural runoff patterns at the mouths of each of the streams of interest. A major challenge is that although 42 hydrometric stations with natural streamflow records have operated in the Okanagan Basin (Appendix B), only nine Water Survey of Canada stations and one independent station have records that fall within the 1996-2006 standard period (Table A.2). Furthermore, only one station (Vaseux Creek near the mouth) has natural streamflow records (albeit for a short period) in the 1996-2006 period near the mouth of a stream of interest (i.e. at a node).

Table 2.2 List of hydrometric stations with at least some records of natural streamflows in the 1996-2006 period.

Node	Sub-basin	WSC Station[1]	Year	Status	Drainage area (km^2)	Median elevation (m)
1	Vernon Creek	**08NM142, Coldstream Creek Above Municipal Intake**	1967-present	Active	58.5	1,120
14	Whiteman Creek	**08NM174, Whiteman's Creek Above Bouleau Creek**	1970-present	Active	109	1,450
22	Mission Creek	Pooley Creek above Pooley Ditch (South East Kelowna Irrigation District)	2007-2007	Active	-	-
32	Peachland Creek	**08NM173, Greata Creek near the Mouth**	1970-present	Active	41	1,280
42	Trout Creek	**08NM134, Camp Creek at Mouth near Thirsk**	1965-present	Active	34	1,450
46	Penticton Creek	08NM240, Two-Forty Creek near Penticton	1983-present	Active	5.0	1,769
		08NM241, Two-Forty-One Creek near Penticton	1983-present	Active	5.0	1,768
		08NM242, Dennis Creek near 1780 metre Contour	1985-present	Active	3.7	1,893
66	Vaseux Creek	**08NM171, Vaseux Creek Above Solco Creek**	1970-present	Active	117	1,680
		08NM246, Vaseux Creek near the Mouth[2]	2006-present	Active	296	1,535

Notes:
1) The five (5) stations shown in bold have the most useful natural streamflow records in the Okanagan Basin for assessing natural streamflow patterns and are considered the primary reference stations in the Basin.
2) This is the only station with natural streamflow records near the mouth of a stream of interest (i.e. node) in this study.

To support Part Two of this study, weekly streamflow data from the above-noted nine WSC stations were summarized in a standard spreadsheet template and forwarded to the study team calibrating the MIKE SHE hydrologic model. Once Part One is completed, natural streamflow estimates at all sub-basin and residual area nodes will be available for calibration and checking purposes.

As a result of the limited natural streamflow records near nodes, there were only three streams (Whiteman, Peachland and Vaseux Creeks) where the available records (within their respective sub-basins) could be used to directly estimate natural streamflows at the mouths of their respective streams (i.e. nodes). The process however involved extending the available data both spatially and temporally so that streamflows reflected conditions at the mouth during the complete 1996-2006 period. In general, the steps included:

- Calculating the unit discharges in L/s/km^2 (or runoff in mm) for each of the hydrometric stations with natural streamflow data (Section A.2);
- Identifying and applying the sub-regional relations between unit discharge or runoff and elevation in the Basin (Section A.3). In general, this involved determining the median elevation of the drainage areas at the hydrometric station and at the mouth of each stream. As runoff is directly related to median elevation (Section A.3), a reduction in elevation typically results in a reduction in unit runoff.
- In order to fill gaps in records and extrapolate records so that the complete 1996-2006 period was reflected, natural streamflow records from the five hydrometric stations shown in bold in Table A.2 were used as reference.

Specific methods of estimation for each stream are discussed further in Appendix J.

A.9 TASK 9: NATURALIZE REGULATED STREAMFLOW RECORDS

As indicated above, naturalization of gauging records involves obtaining and adjusting measurements of regulated flows by accounting for the effects of water storage and withdrawal. The resulting flows are therefore estimated, not measured, and are referred to as *naturalized* to avoid confusion with measured *natural* flows from non-regulated streams

(Section 2.8). Where records of *regulated* streamflows are available, the process of *naturalization* effectively removes the human effect from the streamflow record. In general, the process involves the following:

- Compiling weekly regulated streamflow records (i.e. those affected by human water use/regulation);
- Compiling weekly water use and management information; and
- Estimating naturalized streamflows by accounting for water held and released from storage, water extracted, and water returned to the stream upstream of each node.

While conceptually simple, there are several factors that complicate this task:

- The streamflow records are often incomplete, requiring considerable gap filling and/or record extension (similar to that described in Section A.8);
- The streamflow records are often upstream of the mouth and therefore do not necessarily reflect all significant water use in the sub-basin; and
- The confidence in the water use estimates can vary by location and over the standard period at a given tributary.

Originally, this study planned to use streamflow naturalization on up to seven streams in the Basin. However, given some uncertainty in the WMU database (Section A.6), revised water use and management estimates were developed only for the **Vernon, Mission and Trout Creek** sub-basins (Appendix F). These estimates in turn were the basis for streamflow naturalization in Vernon, Mission and Trout Creeks. Since there was also sufficient streamflow data and information available to estimate water use for Trepanier Creek, its streamflows were also naturalized.

The details of the methods used for each sub-basin are provided in Appendix J.

A.10 TASK 10: ESTIMATE NATURAL FLOWS IN REMAINING TRIBUTARIES AND RESIDUAL AREAS

In order to estimate natural streamflows and runoff in all remaining tributaries and residual areas, several methods were used depending on the nature of the available information. Since the streamflow estimates were to be used for calibration or checking of the MIKE SHE hydrologic model, it was important that the methods be documented and that the confidence in the results is made explicit (Sections A.13 and 6.0 of main report). As a general rule, estimates were to be as closely associated as possible with measured hydrometric data. Streamflows in nearby representative streams along with sub-regional runoff relations were therefore the primary references. Selection of the representative station(s) and development of streamflow estimates in ungauged basins and basins with records other than for the 1996-2006 period required considerable professional judgment. Where estimates were of lower confidence, higher levels of uncertainty were necessarily assigned to the data. The specific methods used for streamflow estimation in ungauged basins are provided in Appendix K.

A.11 TASK 11: INVESTIGATE SURFACE WATER - GROUNDWATER INTERACTION

Observations at several Okanagan locations suggest that surface-groundwater interactions may be significant, particularly where streams cross alluvial fans, which also represent alluvial aquifers. This topic was investigated to help aid in the estimation of flows at the mouths of streams that at least partially overlie alluvial aquifers. The investigation included a review of the literature and the WSC hydrometric network to identify if existing data upstream and downstream of alluvial aquifers could provide some insight. The review was documented in a technical memorandum prepared for the Working Group on November 6, 2008 (Polar Geoscience Ltd. 2008) and is summarized in Section 3.6. Since surface water – groundwater interaction is of direct relevance to the groundwater investigation, these findings were also forwarded to the groundwater study team.

A.12 TASK 12: ASSIGN DATA QUALITY RATINGS

In order to provide confidence to the overall study, it was paramount that data quality and uncertainty were tracked throughout Part One. To provide a consistent measure of uncertainty, the framework developed for the OWSDP and presented in Table A.3 was adopted. All weekly streamflow estimates were therefore assigned data error rating from 1 to 5 and a data quality rating from 1 to 5. A data error rating of 1 would reflect hydrometric data collected at a WSC station[2]. However, since not one node has a complete record of natural streamflows, some degree of extrapolation or gap filling was necessary for all nodes. Therefore, in no cases were data error ratings of 1 assigned to the data.

Table A.3 Data error and data quality rating framework used in the study.

Rating	Data Error
1	less than or equal to 10%
2	greater than 10% and less than or equal to 25%
3	greater than 25% and less than or equal to 50%
4	greater than 50% and less than or equal to 100%
5	greater than 100%

Rating	Data Quality
A	Entirely from measurements at the node
B	Combination of measurements at the node and modelling
C	Modelled, based on other areas of the Okanagan Basin
D	Modelled, but with limited or questionable data
E	Expert judgment

A.13 TASK 13: QUALITY ASSURANCE AND QUALITY CONTROL

During Part One, all efforts were made to minimize the potential for introducing errors to the estimates. This began by designating a technical leader responsible for conducting and overseeing all technical work in Part One, then designating a small team to ensure consistency. Specific tasks were designated to each team member, consistent with their

[2] Class "A" hydrometric data are considered accurate to +/-7%.

level of experience. Data error and quality was tracked throughout Part One. Furthermore, a series of checks of calculations were made.

The first check involved a systematic comparison of the preliminary natural / naturalized streamflow estimates with information reported in previous hydrologic studies and with available hydrometric records on the same stream (Appendix D). In order to minimize potential bias, the check was conducted by members of the team not directly involved in developing the preliminary estimates. In most cases only annual and monthly streamflow information was available, so all weekly streamflow records developed in this study were converted to monthly and annual values. Upon completing the review, differences and similarities were assessed, and adjustments were made to the preliminary estimates if they were necessary. In some cases, detailed studies revealed local information (e.g. the presence of zero flow conditions during some times of the year) that the study team had not previously known.

As a second check of the natural streamflow estimates, the annual water balance for the following five areas were calculated for 1996-2006:

- Area 1: Kalamalka/. Wood Lake (including all contributing area upstream of the outlet of Kalamalka Lake);
- Area 2: Okanagan Lake (including all contributing area upstream of the outlet of Okanagan Lake);
- Area 3: Skaha Lake (including all contributing area between the outlets of Okanagan Lake and Skaha Lake);
- Area 4: Okanagan River: Okanagan Falls to Oliver [including all contributing area to Okanagan River between the hydrometric stations at Okanagan Falls (08NM002) and near Oliver (08NM085)]; and
- Area 5: Okanagan River: Oliver to Oroville, WA [including all contributing area to Okanagan River between the hydrometric stations near Oliver (08NM085) and at Oroville, WA (08NM127).

The annual water balance for each of the above-noted areas takes the form:
Volume of water in – Volume of water out = Volumetric change in storage ... [Eq A.1]

Using the water balance parameters adopted by the OWSDP, the general annual water balance equation is as follows:

$[Q_{upstream} \bullet \Delta t + (QS + \sum DSN \bullet \Delta t) + PL + RFS + DL \bullet \Delta t + QT \bullet \Delta t] - [Q_{out} + EL + ES] = \Delta SL$... [Eq A.2]

where,

Δt = 1 year

$Q_{upstream} \bullet \Delta t$ = Incoming volumetric runoff in the Okanagan River (ML). This term is based directly on the Water Survey of Canada streamflow records on the Okanagan River (at Penticton, Okanagan Falls, and Oliver). The term does not apply to Area 1.

$(QS + \sum DSN) \bullet \Delta t$ = Natural volumetric runoff from all contributing areas (ML). This was calculated by summing the natural runoff estimates developed in Part One of this study.

PL = Volume of precipitation directly onto lake surfaces (ML). This term is based on the precipitation estimates developed by Duke et al. (2008a). Precipitation in mm was converted to volumes based on lake surface areas identified in this study (Appendix F).

RFS = Volume of surface return flows due to human activity (e.g. wastewater treatment plant outflows) (ML). This term was based on wastewater treatment

plant outflows presented by Dobson Engineering Ltd. (2008) for 2006. The year-to-year variation was assumed to mimic the variation in water use (*ES*).

DL • Δt = Volume of groundwater discharged as underflow to lakes (ML). This value is unknown and is a topic currently being investigated by the groundwater study for the OWSDP. It is important to note that the uncertainty in this term restricts the inferences that can be made using the annual water balance.

QT • Δt = Volume of water imported from outside natural contributing area (ML). This is based on information provided by Dobson Engineering Ltd. (2008) as well as several major water suppliers.

Q_{out} • Δt_t = Residual or outgoing volumetric runoff in mainstem river (ML). This term is based directly on the Water Survey of Canada streamflow records on Vernon Creek at the outlet of Kalamalka Lake and the Okanagan River (at Penticton, Okanagan Falls, Oliver, and Oroville, WA.).

EL = Volume of water lost to evaporation from lake surface (ML). This term is based on lake evaporation estimates developed by Schertzer and Taylor (2008) which are subject to revision since these estimates may underestimate actual values.

ES = Volume of water extracted from surface sources for human use (ML). This term is based on estimates of water use by Polar Geoscience Ltd. (2009) for Area 1 and Dobson Engineering Ltd. (2008) for Areas 2-5. While the study team is confident in the estimates for Area 1, there is some uncertainty in the estimates for Areas 2-5 (Section 2.6). Nevertheless, the estimates are likely reasonable for the purposes of the annual water balance check.

ΔSL = Volumetric change in lake storage (ML). This is based directly on the lake level records on Kalamalka Lake, Okanagan Lake, Skaha Lake, and Osoyoos Lake.

The conversion of lake level changes to volumetric changes was based on the lake storage tables developed during this study (Appendix G).

The results of the annual water balance checks are presented in Section 6.2 and Appendix L.

A.14 TASK 14: BASEFLOW SEPARATION

Following review of the natural streamflow estimates, weekly streamflow data for each of the nodes can be analyzed by baseflow separation, which involves analysis of the streamflow hydrograph and estimating the relative contributions of baseflow (the longer-term delayed flow from groundwater) and quickflow (the short-term response to rainfall and snowmelt events). The goal is to understand the magnitude and dynamics of groundwater discharge to the study streams. Several graphical methods and models are available to achieve baseflow separations (Brodie and Hostetler, undated).

As emphasized by Brodie and Hostetler (undated), the assumption that baseflow equals groundwater discharge is not always valid. Water can be released from streams over different time scales from different storage locations such as lakes, wetlands, snow or streambanks. Since the streamflow record represents the net water balance, baseflow is also influenced by any water losses from the stream such as direct evaporation, transpiration from riparian vegetation, or seepage into aquifers along specific reaches (Sections 2.11 and 3.6). While regulation and direct extractions from the stream are accounted for in the natural/naturalized streamflow data, there is a possibility that nearby groundwater pumping can affect baseflow. Therefore, careful consideration of the overall water balance for the stream is required in interpreting the baseflow component.

Upon review of baseflow separation methods, for consistency purposes, separations will be calculated using the MIKE SHE model in Part 2 of this study. MIKE SHE separates hydrographs into three separate groupings: overland flow, interflow (or quickflow), and baseflow (DHI 2008). MIKE SHE routes quickflow and baseflow via a linear reservoir

method, while overland flow is routed by the finite difference method (DHI 2008). By using MIKE SHE, the subjectivity of graphical techniques used for separations is removed; thereby, maintaining data control and increasing reproducibility.

Baseflow separations will occur when the MIKE SHE model is calibrated using the naturalized streamflow data presented in this report. Once calibrated, the MIKE SHE model will provide four separate outputs for each stream hydrograph: the calibrated naturalized streamflow (total flow) separated into overland flow, quickflow, and baseflow.

A.15 TASK 15: DATA SUMMARY AND REPORTING

All data developed during Part One was summarized in a standard MS Excel spreadsheet format, which was developed to simplify its use by the team members conducting Part Two. Each summary provides the basic physiographic information for each node and provides the mean weekly discharge (m^3/s) between January 1, 1996 and December 31, 2006 (and where possible also for January 1 to December 31, 1995). Data error and quality ratings are provided with all estimates. In addition, all data for 1996-2006 was converted to MS Access and uploaded to the OK Water Database.

Once Part Two of the study is complete, modeled streamflow data will be available. At that time, a final suite of streamflow estimates for each node will be developed by considering the uncertainty of the estimates from both Parts One and Two, and these final data will be uploaded to the Okanagan Water Database.

All relevant reports and sources of information identified during Part One that were not identified in the Okanagan Information Database are listed in Appendix H. Summaries of these references were uploaded to the Okanagan Information Database.

APPENDIX B

Nodes and Hydrometric Stations in the Okanagan Basin

Table B.1 Nodes and hydrometric stations in the Okanagan Basin.

Node Characteristics										Hydrometric Stations													
Node	**Sub-basin / Residual area description**	**Drainage Area (km²)**	**Median Elevation (m)**	**Minimum Elevation (m)**	**Maximum Elevation (m)**	**Location of node** (mouth of stream)		**Provincial Hydrologic Zones** (where sub-basin / residual area falls in more than one zone distribution within each zone in % is indicated)	**Hydrologic Group** (see text for discussion)	**Hydrometric Stations within sub-basin or residual area** (operated by Water Survey of Canada unless noted otherwise). Stations in **red** were used (along with others outside the Okanagan) in developing regional hydrologic relations (see text for discussion)	**Streamflow**	**River flow**	**Lake or Reservoir Level**	**Diversion / Canal**	**Natural** (green shade) / **Regulated** (blue shade)	**Years of Record**	**Station status**	**Drainage Area (km²)**	**Median Elevation (m)**	**Location of hydrometric station**		**Notes**	**Potentially useful for hydrology / modeling study** (see text for discussion)
						Lat.	**Long.**													**Lat.**	**Long.**		
1, 2, 12	Vernon Creek	Drainage area above Kalamalka and Wood Lakes = 537.3 km². Drainage area above outlet of Kalamalka Lake = 572.0 km². Drainage area of Vernon Creek at the mouth = 749.3 km².	Median elevation of drainage area above Kalamalka and Wood Lakes = 1041 m. Median elevation of drainage area above outlet of Kalamalka Lake = 998 m. Median elevation of Vernon Creek watershed above the mouth = 914 m	342 +/-	1655	50.25	-119.35	Drainage area above Kalamalka and Wood Lakes falls within zones 15 (60%) and 23 (40%). Drainage area above outlet of Kalamalka Lake falls within zones 15 (60%) and 23 (40%). Drainage area above Vernon Creek at the mouth falls within zones 14 (1%), 15 (34%), and 23 (65%).	1	**08NM146, Clark Creek near Winfield**	✓				**Natural**	**1968-1982**	**Discontinued**	**15.3**	**1360**	**50.05**	**-119.33**	**Continuous record**	**Yes**
										08NM142, Coldstream Creek Above Municipal Intake	✓				**Natural**	**1967-2006**	**Active**	**58.5**	**1120**	**50.26**	**-119.08**	**Continuous record**	**Yes**
										08NM235, Ribbleworth Creek near Oyama	✓				**Natural**	**1973-1979**	**Discontinued**	**12.5**	**971**	**50.08**	**-119.38**	**Continuous record 1975-1979**	**Yes**
										08NM020, BX Creek Above Vernon Intake	✓				**Regulated**	**1921-1999**	**Discontinued**	**55.7**	**1130**	**50.30**	**-119.21**	**Continuous record 1959-1999**	**Yes**
										08NM123, BX Creek Below Swan Lake Control Dam	✓				**Regulated**	**1910-1978**	**Discontinued**	**120**	**-**	**50.28**	**-119.28**	**Continuous record 1973-1978**	**Yes**
										08NM125, BX Creek Above Swan Lake Control Dam	✓				**Regulated**	**1959-1979**	**Discontinued**	**-**	**-**	**50.29**	**-119.26**	**Continuous record**	**Yes**
										08NM124, Coldstream Creek near Lavington	✓				**Regulated**	**1910-1979**	**Discontinued**	**61.9**	**-**	**50.25**	**-119.07**	**Continuous record 1969-1979**	**Yes**
										08NM154, Coldstream Creek at the Mouth	✓				**Regulated**	**1969-1970**	**Discontinued**	**-**	**-**	**50.23**	**-119.25**	**Continuous record**	**Yes**
										08NM179, Coldstream Creek Above Kalavista Diversion	✓				**Regulated**	**1970-1982**	**Discontinued**	**207**	**-**	**50.23**	**-119.26**	**Continuous record**	**Yes**
										08NM048, Oyama Creek Above Wood Lake Irrigation Intake	✓				**Regulated**	**1921-1987**	**Discontinued**	**-**	**-**	**50.12**	**-119.33**	**Continuous record 1973-1987**	**Yes**
										08NM021, Vernon Creek at Vernon	✓				**Regulated**	**1921-1960**	**Discontinued**	**593**	**-**	**50.26**	**-119.27**	**Continuous record**	**Yes**
										08NM022, Vernon Creek at Outlet of Swalwell Lake	✓				**Regulated**	**1921-1998**	**Discontinued**	**62.4**	**-**	**50.04**	**-119.24**	**Continuous record 1969-1998**	**Yes**
										08NM065, Vernon Creek at Outlet of Kalamalka Lake	✓				**Regulated**	**1927-2006**	**Active**	**572**	**997**	**50.24**	**119.27**	**Continuous record 1959-2006**	**Yes**
										08NM160, Vernon Creek near the Mouth	✓				**Regulated**	**1969-1999**	**Discontinued**	**751 (WSC), 744 (GIS)**	-	50.26	-119.31	Continuous record 1969-1982, seasonal record 1984-1999	Yes
										08NM181, Winfield Creek at inlet to Wood Lake	✓				**Regulated**	**1971-1973**	**Discontinued**	**-**	**-**	**50.05**	**-119.41**	**Continuous record 1969-1987**	**Yes**
										08NM143, Kalamalka Lake at Vernon Pumphouse			✓		**Regulated**	**1967-2006**	**Active**	**-**	**-**	**50.23**	**-119.27**	**Continuous record**	**Yes**
										08NM062, Swalwell Lake near Okanagan Center			✓		**Regulated**	**1926-1992**	**Discontinued**	**-**	**-**	**50.04**	**-119.24**		**Yes**
										Middle Vernon Creek at the Remiche Road Bridge Crossing (Oceola Fish and Game Club)	✓				Regulated	2004-2007	Discontinued	-	-	50.05	-119.41		No
										08NM008, Vernon Creek above diversions	✓				Regulated	1919	Discontinued	-	-	50.02	-119.40		No
										08NM009, Vernon Creek at Inlet to Wood Lake	✓				Regulated	1919-1987	Discontinued	151	-	50.05	-119.41		No
										08NM043, Vernon Creek near Okanagan Centre	✓				Regulated	1919-1963	Discontinued	90.1	-	50.01	-119.34	Seasonal record 1926-1930 and 1960-1963	No
										08NM162, Vernon Creek at inlet to Ellison Lake	✓				Regulated	1969-1974	Discontinued	-	-	50.01	-119.39		No
										08NM175, Vernon Creek Below Arda Dam	✓				Regulated	1972-1979	Discontinued	102	-	50.02	-119.32		No
										08NM182, Vernon Creek at outlet of Ellison Lake	✓				Regulated	1971-1974	Discontinued	-	-	50.02	-119.40		No
										Vernon Creek at Outflow Swalwell/Beaver Lake (Old WSC Location) (Oceola Fish and Game Club)	✓				Regulated	2004-2007	Discontinued	-	-	50.04	-119.26		No
										Vernon Creek downstream from old Hiram Walker Spillway (Oceola Fish and Game Club)	✓				Regulated	2004-2007	Discontinued	-	-	50.01	-119.39		No
										Vernon Creek downstream from DLC Intake (Oceola Fish and game Club)	✓				Regulated	2004-2007	Discontinued	-	-	50.01	-119.38		No
										08NM163, Crooked Lake at the Outlet			✓		Regulated	1970-1981	Discontinued	-	-	50.06	-119.20		No
										08NM067, Ellison Lake Near Winfield			✓		Regulated	1968-1980	Discontinued	-	-	49.98	-119.40		No
										Ellison/Duck Lake (Oceola Fish and Game Club)			✓		Regulated	2004-2007	Discontinued	-	-	50.00	-119.40		No
										08NM183, Kalamlaka Lake at Outlet of Oyama Canal			✓		Regulated	1971-1979	Discontinued	-	-	50.11	-119.38	Seasonal and continuous records	No
										08NM224, Oyama Lake at the Outlet			✓		Regulated	1961-1986	Discontinued	-	-	50.12	-119.28		No
										08NM066, Wood Lake at Inlet to Oyama Canal			✓		Regulated	1928-1973	Discontinued	-	-	50.11	-119.38	Continuous record 1964-1973	No
										08NM028, Oyama Creek Oyama Diversion				✓	Regulated	1920-1931	Discontinued	-	-	50.12	-119.33		No
										08NM236, Vernon Creek diversion to WOCID				✓	Regulated	1973-1978	Discontinued	-	-	50.02	-119.32		No
										08NM044, Vernon Creek Okanagan Centre Diversion				✓	Regulated	1919-1963	Discontinued	-	-	50.01	-119.34		No
3	Deep Creek	217.5	675	342 +/-	1645	50.35	-119.31	14 (83%), 15 (5%), 23 (12%)	2	**08NM177, Deep Creek at Young Road**	✓				**Natural**	**1970-1975**	**Discontinued**	**115**	**770**	**50.46**	**119.18**	**Continuous record**	**Yes**
										08NM119, Deep Creek at Armstrong	✓				**Regulated**	**1951-1982**	**Discontinued**	**135**		**50.45**	**-119.20**	**Continuous record 1974-1982**	**Yes**
										08NM153, Deep Creek at the Mouth	✓				**Regulated**	**1969-1975**	**Discontinued**	**306**		**50.35**	**-119.29**	**Continuous record**	**Yes**
										08NM075, Deep Creek near Vernon (Station No. 3)	✓				Regulated	1930-1967	Discontinued	207		50.36	-119.28		No
4	Residual Area W-1	19.0	586	342 +/-	1234	-	-	15	2														
5	Irish Creek	30.6	899	342 +/-	1425	50.35	-119.32	15	2	08NM052, Irish Creek near Vernon	✓				Natural	1922	Discontinued	-	-	50.36	-119.34	Record limited to a single year	No
6	Residual Area W-2	36.2	827	342 +/-	1353	-	-	15	2														
7	Residual Area E-1	38.2	556	342 +/-	837	-	-	15	2														
8	Equesis Creek	203.9	1173	342 +/-	1778	50.28	-119.40	15	3	**08NM176, Ewer Creek near the Mouth**	✓				**Natural**	**1971-1986**	**Discontinued**	**52.8**	**1470**	**50.37**	**-119.50**	**Continuous record 1972-1986**	**Yes**
										08NM161, Equesis Creek near the Mouth	✓				**Regulated**	**1969-1982**	**Discontinued**	**199**	**-**	**50.29**	**-119.41**	**Continuous record 1977-1982**	**Yes**
										08NM024, Equesis Creek near Vernon	✓				Regulated	1911-1926	Discontinued	179	-	50.31	-119.44		No
9	Residual Area W-3	2.7	394	342 +/-	537	-	-	15	2														
10	Nashwito Creek	86.8	1242	342 +/-	1835	50.27	-119.44	15	3	08NM047, Naswhito Creek near Ewing's Landing	✓				Natural	1912-1921	Discontinued	-	-	50.29	-119.46	-	No
11	Residual Area W-4	17.0	685	342 +/-	1175	-	-	15	2														
13	Residual Area E-2	124.4	550	342 +/-	1066	-	-	15 (90%), 24 (10%)	2	08NM152, Brandts Creek near the Mouth	✓				Regulated	1969-1975	Discontinued	-	-	49.89	-119.49		No
14	Whiteman Creek	204.3	1340	342 +/-	2039	50.23	-119.44	15	3	**08NM174, Whiteman's Creek Above Bouleau Creek**	✓				**Natural**	**1970-2006**	**Active**	**109**	**1450**	**50.21**	**-119.54**	**Continuous record 1971-2006. Drainage area is based on Obedkoff (1998); WSC reports a drainage area of 112 km².**	**Yes**
										08NM046, Whiteman Creek near Vernon	✓				Regulated	1920-1970	Discontinued	197	-	50.23	-119.45	Seasonal record; Median elevation assumed similar to Whiteman Creek at the mouth.	No
										08NM180, Whiteman Creek at the Mouth	✓				Regulated	1970-1972	Discontinued	197	-	50.23	-119.45	Drainage area assumed similar to station 08NM046. Median elevation assumed similar to Whiteman Creek at the mouth	No

Node Characteristics										Hydrometric Stations													
Node	**Sub-basin / Residual area description**	**Drainage Area (km²)**	**Median Elevation (m)**	**Minimum Elevation (m)**	**Maximum Elevation (m)**	**Location of node** (mouth of stream)		**Provincial Hydrologic Zones** (where sub-basin / residual area falls in more than one zone distribution within each zone in % is indicated)	**Hydrologic Group** (see text for discussion)	**Hydrometric Stations within sub-basin or residual area** (operated by Water Survey of Canada unless noted otherwise). Stations in **red** were used (along with others outside the Okanagan) in developing regional hydrologic relations (see text for discussion)	**Streamflow**	**River flow**	**Lake or Reservoir Level**	**Diversion / Canal**	**Natural** (green shade) / **Regulated** (blue shade)	**Years of Record**	**Station status**	**Drainage Area (km²)**	**Median Elevation (m)**	**Location of hydrometric station**		**Notes**	**Potentially useful for hydrology / modeling study** (see text for discussion)
						Lat.	**Long.**													**Lat.**	**Long.**		
15	Residual Area W-5	32.8	744	342 +/-	1587	-	-	15	2														
16	Shorts Creek	184.9	1350	342 +/-	1903	50.13	-119.49	15	4	**08NM151, Shorts Creek at the Mouth**	✓				**Regulated**	**1969-1982**	**Discontinued**	**185**	**-**	**50.13**	**-119.51**	**Continuous record**	**Yes**
17	Residual Area W-6	56.6	761	342 +/-	1326	-	-	15	2														
18	Lambly Creek	243.3	1281	342 +/-	1893	49.93	-119.51	15 (93%), 24 (7%)	4	**08NM139, Esperon Creek near Kelowna**	✓				**Regulated**	**1965-1981**	**Discontinued**	**13**	**-**	**50.07**	**-119.69**	**Continuous record 1967-1981**	**Yes**
										08NM003, Lambly Creek near the Mouth	✓				**Regulated**	**1910-1975**	**Discontinued**	**272**	**-**	**49.93**	**-119.51**	**Continuous record 1969-1974**	**Yes**
										08NM141, Lambly Creek below Terrace Creek	✓				**Regulated**	**1967-1971**	**Discontinued**	**-**	**-**	**49.98**	**-119.57**	**Continuous record**	**Yes**
										08NM165, Lambly Creek above Terrace Creek	✓				**Regulated**	**1970-1998**	**Discontinued**	**76.1**	**1390**	**49.99**	**-119.61**	**Continuous record**	**Yes**
										08NM166, Lambly Creek Below Bald Range Creek	✓				**Regulated**	**1970-1982**	**Discontinued**	**229**		**49.96**	**-119.56**	**Continuous record**	**Yes**
										08NM138, Terrace Creek near Kelowna	✓				**Regulated**	**1965-1992**	**Discontinued**	**31.3**	**1490**	**50.07**	**-119.67**	**Continuous record 1967-1992**	**Yes**
										08NM058, Lambly Creek near Kelowna	✓				Natural	1910-1927	Discontinued	-	-	49.96	-119.55	Continuous record	No
										North Lambly Creek below Tadpole Reservoir (Dobson)	✓				Regulated	2007	Active	-	-	50.04	-119.76		No
										Esperon Reservoir at the Outlet (Dobson)			✓		Regulated	2007	Active	-	-	50.08	-119.75		No
										Bighorn Reservoir at the Spillway (Dobson)			✓		Regulated	2007	Active	-	-	50.07	-119.67		No
19	Residual Area W-7	37.0	605	342 +/-	1409	-	-	15 (1%), 24 (99%)	5	08NM167, Lambly Creek Diversion to Rose Valley Lake				✓	Regulated	1970-1978	Discontinued	-	-	49.91	-119.56		No
										Lambly Creek Diversion to Rose Valley Lake (Dobson)_				✓	Regulated	2001-2007	Active	-	-	49.75	-119.56		No
20	Mill (Kelowna) Creek	222.8	983	342 +/-	1666	49.88	-119.50	15 (84%), 23 (7%), 24 (9%)	7	**08NM036, Scotty Creek near Rutland**	✓				**Natural**	**1911-1964**	**Discontinued**	**35**	**1165**	**49.93**	**119.37**	**Seasonal record**	**Yes**
										08NM145, Bulman Creek at the Mouth	✓				**Regulated**	**1968-2004**	**Discontinued**	**12.7**		**50.00**	**-119.25**	**Continuous record**	**Yes**
										08NM053, Kelowna Creek near Kelowna - Lower Station	✓				**Regulated**	**1922-1998**	**Discontinued**	**221**	**1013**	**49.90**	**119.42**	**Continuous record 1922-1998**	**Yes**
										08NM117, Kelowna Creek at Rutland Station	✓				**Regulated**	**1950-1975**	**Discontinued**	**162**	**-**	**49.92**	**-119.39**	**Continuous record 1970-1975**	**Yes**
										08NM026, Kelowna Creek near Rutland (Upper station)	✓				Regulated	1911-1922	Discontinued	-	-	49.99	-119.35		No
										08NM061, Kelowna Creek near Rutland	✓				Regulated	1924-1931	Discontinued	77.7	-	49.98	-119.35		No
										Mill Creek downstream of GEID Intake (Dobson)	✓				Regulated	2005-2007	Active	-	-	49.98	-119.35		No
										08NM234, Moore Lake Reservoir at the Dam			✓		Regulated	1973-1986	Discontinued	-	-	50.03	-119.22		No
										Mill Creek / Postill Reservoir Sluiceway (Dobson)			✓		Regulated	2005-2007	Active	-	-	50.00	-119.21		No
										Postill Reservoir at the Outlet (Dobson)			✓		Regulated	2005-2007	Active	-	-	50.00	-119.21		No
										James Reservoir at the Outlet (Dobson)			✓		Regulated	2007	Active	-	-	49.95	-119.25		No
21	Residual Area E-3	10.4	357	342 +/-	373	-	-	24	6														
22	Mission Creek	844.7	1345	342 +/-	2170	49.84	-119.49	15 (5%), 23 (76%), 24 (19%)	8	**08NM137, Daves Creek near Rutland**	✓				**Natural**	**1965-1986**	**Discontinued**	**31.1**	**1290**	**49.87**	**-119.27**	**Continuous record 1967-1986**	**Yes**
										08NM172, Pearson Creek near the Mouth	✓				**Natural**	**1970-1987**	**Discontinued**	**73.6**	**1560**	**49.89**	**-119.06**	**Continuous record**	**Yes**
										08NM225, Belgo Creek near the Mouth	✓				**Regulated**	**1976-1982**	**Discontinued**	**190**	**-**	**49.87**	**-119.15**	**Continuous record**	**Yes**
										08NM232, Belgo Creek Below Hilda Creek	✓				**Regulated**	**1976-2007**	**Active**	**70.7**	**1430**	**50.00**	**119.07**	**Continuous record 1978-2007**	**Yes**
										08NM011, Hydraulic Creek at Outlet of McCulloch Reservoir	✓				**Regulated**	**1919-1986**	**Discontinued**	**-**	**-**	**49.78**	**-119.18**	**Continuous record 1976-1980 an 1984-1986**	**Yes**
										08NM116, Mission Creek near East Kelowna	✓				**Regulated**	**1946-2007**	**Active**	**811**	**1340**	**49.88**	**-119.41**	**Continuous record 1967-2007**	**Yes**
										Mission Creek below BMID Intake (Dobson)	✓				**Regulated**	**2004-2007**	**Active**	**-**	**-**	**49.85**	**-119.28**		**Yes**
										Mission Creek upstream of Gordon Drive (MOE)	✓				**Regulated**	**2006-2007**	**Active**	**-**	**-**	**49.84**	**-119.48**		**Yes**
										Mission Creek upstream of E. Kelowna Rd. (MOE)	✓				**Regulated**	**2007**	**Active**	**-**	**-**	**49.86**	**-119.39**		**Yes**
										Stirling Creek Diversion to McCulloch Reservoir - Old WSC Location (Dobson)				✓	**Regulated**	**2004-2007**	**Active**	**-**	**-**	**49.73**	**-119.22**		**Yes**
										08NM018, Hilda Creek near Rutland	✓				Natural	1920	Discontinued	-	-	50.00	-119.07	Record limited to a single year	No
										08NM004, KLO Creek near Kelowna	✓				Natural	1919-1922	Discontinued	-	-	49.82	-119.36	Continuous record	No
										08NM210, Pooley Creek Above Pooley Ditch	✓				Natural	1973-1979	Discontinued	18.1	-	49.75	-119.34	Seasonal record	No
										Pooley Creek Above Pooley Ditch (Old WSC Location) (Dobson)	✓				Natural	2004-2007	Active	-	-	49.75	-119.34		No
										08NM017, Belgo Creek near Rutland	✓				Regulated	1920-1921	Discontinued	-	-	50.00	-119.08		No
										08NM010, Hydraulic Creek near the Mouth	✓				Regulated	1919-1982	Discontinued	89.6	-	49.84	-119.33	Continuous record 1976-1982	No
										Hydraulic Creek above Sterling Ditch (Dobson)	✓					2004-2007	Active		-	49.75	-119.22		No
										08NM129, Joe Rich Creek near Rutland	✓				Regulated	1964-1987	Discontinued	44.8	-	49.86	-119.13	Continuous record	No
										08NM226, KLO Creek at McCulloch Road	✓				Regulated	1976-1982	Discontinued		-	49.82	-119.36	Continuous record	No
										08NM229, Loch Katrine Creek at the Outlet of Graystoke Lake	✓				Regulated	1977-1998	Discontinued	16.1	-	49.98	-118.87	Continuous record	No
										08NM016, Mission Creek near Rutland	✓				Regulated	1919-1946	Discontinued	622	-	49.85	-119.34		No
										08NM233, Mission Creek Above Pearson Creek	✓				Regulated	1977-1982	Discontinued	233	-	49.89	-119.06		No
										08NM239, Mission Creek below BMID intake	✓				Regulated	1980	Discontinued	-	-	49.85	-119.28		No
										Pearson Creek at WSC (MOE)	✓				Regulated	2006-2007	Active	-	-	49.89	-119.06		No
										08NM216, Browne Lake Reservoir above the Dam			✓		Regulated	1973-1977	Discontinued	-	-	49.82	-119.19		No
										08NM215, Fish Lake at the Outlet			✓		Regulated	1973-1977	Discontinued	-	-	49.80	-119.19		No
										Fishhawk Reservoir at the Outlet (Dobson)			✓		Regulated	2007	Active	-	-	50.03	-118.86		No
										08NM230, Graystoke Lake at the Outlet			✓		Regulated	1977-1998	Discontinued	-	-	49.98	-118.87	Seasonal record	No
										Graystoke Reservoir at the Outlet (Dobson)			✓		Regulated	2007	Active	-	-	49.99	-118.87		No
										08NM231, Ideal Lake near the Outlet			✓		Regulated	1963-1980	Discontinued	-	-	50.01	-119.10		No
										Ideal Reservoir at the Outlet (Dobson)			✓		Regulated	2007	Active	-	-	50.01	-119.10		No
										08NM213, McCulloch Reservoir at McCulloch Dam			✓		Regulated	1973-1986	Discontinued	-	-	49.78	-119.18		No
										Loch Long Reservoir at the Outlet (Dobson)			✓		Regulated	2007	Active	-	-	49.97	-118.90		No
										08NM217, Long Meadow Lake Reservoir above the Dam			✓		Regulated	1973-1977	Discontinued	-	-	49.81	-119.17		No
										08NM019, BMID diversion near Kelowna				✓	Regulated	1920-1930	Discontinued	-	-	49.86	-119.30		No
										Canyon Creek Diversion to McCulloch Reservoir (Dobson)				✓	Regulated	2004-2007	Active	-	-	49.74	-119.27		No

Node Characteristics										Hydrometric Stations													
Node	**Sub-basin / Residual area description**	**Drainage Area (km²)**	**Median Elevation (m)**	**Minimum Elevation (m)**	**Maximum Elevation (m)**	**Location of node** (mouth of stream)		**Provincial Hydrologic Zones** (where sub-basin / residual area falls in more than one zone distribution within each zone in % is indicated)	**Hydrologic Group** (see text for discussion)	**Hydrometric Stations within sub-basin or residual area** (operated by Water Survey of Canada unless noted otherwise). Stations in **red** were used (along with others outside the Okanagan) in developing regional hydrologic relations (see text for discussion)	**Streamflow**	**River flow**	**Lake or Reservoir Level**	**Diversion / Canal**	**Natural** (green shade) / **Regulated** (blue shade)	**Years of Record**	**Station status**	**Drainage Area (km²)**	**Median Elevation (m)**	**Location of hydrometric station**		**Notes**	**Potentially useful for hydrology / modeling study** (see text for discussion)
						Lat.	**Long.**													**Lat.**	**Long.**		
										08NM039, Hydraulic Creek Diversion near Kelowna				✓	Regulated	1919-1968	Discontinued	-	-	49.83	-119.35		No
										08NM040, Hydraulic Creek Southeast Kelowna Diversion				✓	Regulated	1920-1930	Discontinued	-	-	49.83	-119.37		No
										08NM205, Hydraulic Creek diversion to SEKID				✓	Regulated	1976-1980	Discontinued	-	-	49.84	-119.34		No
										08NM060, KLO Diversion near Kelowna				✓	Regulated	1922-1968	Discontinued	-	-	49.84	-119.37		No
										08NM057, Mission Creek Rutland Diversion				✓	Regulated	1922-1930	Discontinued	-	-	49.88	-119.39		No
										08NM207, Myra Ditch Below KLO Creek				✓	Regulated	1973-1985	Discontinued	-	-	49.75	-119.27		No
										Myra Ditch below KLO Creek - Old WSC Location (Dobson)				✓	Regulated	-	-	-	-	49.75	-119.27		No
23	Residual Area E-4	6.9	446	342 +/-	739	-	-	24	6														
24	Bellevue Creek	92.9	1384	342 +/-	2166	49.82	-119.51	24	6	**08NM035, Bellevue Creek near Okanagan Mission**	✓				**Natural**	**1911-1986**	**Discontinued**	**73.3**	**1540**	**49.79**	**-119.46**	**Continuous record 1969-1986**	**Yes**
										08NM156, Bellevue Creek at the Mouth	✓				**Regulated**	**1969-1972**	**Discontinued**	**-**	**-**	**49.82**	**-119.49**	**Continuous record**	**Yes**
25	Residual Area E-5	155.3	888	342 +/-	1609	-	-	24	6														
26	McDougall Creek	53.0	1071	342 +/-	1563	49.82	-119.60	15 (11%), 24 (89%)	5	08NM014, McDougall Creek near Westbank	✓				Regulated	1920-1929	Discontinued	-	-	49.88	-119.59		No
27	Residual Area W-8	25.1	711	342 +/-	1456	-	-	24	5	08NM198, Westbank Creek at the Mouth	✓				Regulated	1972-1975	Discontinued	-	-	49.82	-119.62		No
28	Powers Creek	144.6	1242	342 +/-	1868	49.82	-119.62	15 (1%), 24 (99%)	4	**08NM033, Powers Creek Above Westbank Diversion**	✓				**Natural**	**1920-1974**	**Discontinued**	**128**	**1317**	**49.86**	**119.67**	**Seasonal record 1965-1974**	**Yes**
										Powers Creek at Bear Main (Dobson)	✓				**Natural**	**2007**	**Active**	**-**	**-**	**49.95**	**-119.75**		**Yes**
										Powers Creek upstream of Jackpine Creek (Dobson)	✓				**Natural**	**2007**	**Active**	**-**	**-**	**49.94**	**-119.73**		**Yes**
										08NM157, Powers Creek at the Mouth	✓				**Regulated**	**1969-1982**	**Discontinued**	**144**	**-**	**49.81**	**-119.63**	**Continuous record**	**Yes**
										Powers Creek at Gellatly Rd (MOE)	✓				**Regulated**	**2004-2006**	**Active**		**-**	**49.81**	**-119.63**		**Yes**
										08NM034, Powers Creek Westbank Diversion	✓				Regulated	1919-1931	Discontinued	-	-	49.85	-119.67	Seasonal record 1920-1931	No
										08NM059, Powers Creek Below Westbank Diversion	✓				Regulated	1912-1987	Discontinued	139	-	49.84	-119.65	Continuous record	No
										08NM136, Lambly Lake Diversion to Powers Creek				✓	Regulated	1965-1972	Discontinued	-	-	49.95	-119.71		No
29	Residual Area W-9	13.5	616	342 +/-	1012	-	-	24	5														
30	Trepanier Creek	257.9	1228	342 +/-	1911	49.78	-119.71	24	5	**08NM041, Trepanier Creek near Peachland**	✓				**Regulated**	**1919-2006**	**Active**	**179**	**1267**	**49.83**	**119.79**	**Continuous record 1973-1979 and 1983-2006**	**Yes**
										08NM155, Trepanier Creek at the Mouth	✓				**Regulated**	**1969-1981**	**Discontinued**	**254**	**-**	**49.79**	**-119.71**	**Continuous record**	**Yes**
										Trepanier Creek at Hwy 97 (MOE)	✓				**Regulated**	**2006-2007**	**Active**	**-**	**-**	**49.78**	**-119.71**		**Yes**
										Trepanier Creek downstream of Hwy 97C (MOE)	✓				**Regulated**	**2006-2007**	**Active**	**-**	**-**	**49.81**	**-119.74**		**Yes**
										Trepanier Creek upstream of Hwy 97C (MOE)	✓				**Regulated**	**2006-2008**	**Active**	**-**	**-**	**49.81**	**-119.75**		**Yes**
										08NM013, Jack Creek at the Mouth	✓				Regulated	1919	Discontinued	-	-	49.82	-119.75		No
31	Residual Area W-10	16.3	676	342 +/-	1072	-	-	24	5														
32	Peachland Creek	144.9	1209	342 +/-	1837	49.74	-119.76	24	5	**08NM173, Greata Creek near the Mouth**	✓				**Natural**	**1970-2006**	**Active**	**41**	**1280**	**49.79**	**-119.85**	**Continuous record**	**Yes**
										08NM159, Peachland Creek at the Mouth	✓				**Regulated**	**1969-1982**	**Discontinued**	**150**	**-**	**49.74**	**-119.76**	**Continuous record**	**Yes**
										08NM140, Peachland Creek Above Diversions	✓				**Regulated**	**1966-1982**	**Discontinued**	**122**	**-**	**49.75**	**-119.80**	**Continuous record 1973-1982**	**Yes**
										08NM029, Peachland Creek near Peachland	✓				Regulated	1919-1922	Discontinued	-	-	49.76	-119.81		No
										08NM201, Peachland Creek below diversion to Peachland Lake Reservoir	✓				Regulated	1973	Discontinued	-	-	49.84	-119.97		No
										08NM202, Peachland Lake Reservoir Outflow	✓				Regulated	1973-1982	Discontinued	80.3	-	49.83	-119.96		No
										08NM220, Peachland Lake near Peachland			✓		Regulated	1973-1984	Discontinued	-	-	49.83	-119.97		No
										08NM218, McDonald Creek Diversion to Peachland Creek				✓	Regulated	1973-1979	Discontinued	-	-	49.87	-119.99		No
										08NM030, Peachland Creek Municipal Irrigation Diversion				✓	Regulated	1919-1926	Discontinued	-	-	49.76	-119.82		No
										08NM219, Peachland Creek Diversion to Peachland Lake				✓	Regulated	1973-1979	Discontinued	-	-	49.84	-119.97		No
33	Residual Area W-11	23.0	590	342 +/-	1098	-	-	24	9														
34	Chute Creek	79.3	1354	342 +/-	2035	49.65	-119.63	24	6	08NM007, Chute Creek near Naramata	✓				Natural	1920-1922	Discontinued	-	-	49.68	-119.53		No
35	Residual Area E-6	19.3	814	342 +/-	1466	-	-	24	6														
36	Eneas Creek	91.4	935	342 +/-	1764	49.61	-119.65	24	9	**08NM228, Eneas Creek near Summerland**	✓				**Regulated**	**1974-1975**	**Discontinued**	**-**	**-**	**49.68**	**-119.77**	**Continuous record**	**Yes**
										08NM227, Garnet Lake near Summerland			✓		Regulated	1973-1981	Discontinued	-	-	49.69	-119.77		No
37	Residual Area W-12	26.4	628	342 +/-	1134	-	-	24	9														
38	Robinson Creek	20.0	1220	342 +/-	1694	49.61	-119.60	24	6														
39	Residual Area E-7	2.3	513	342 +/-	757	-	-	24	6														
40	Naramata Creek	41.1	1330	342 +/-	1906	49.60	-119.60	24	6														
41	Residual Area E-8	13.1	736	342 +/-	1238	-	-	24	6														
42	Trout Creek	768.3	1330	342 +/-	2019	49.56	-119.62	24	9	**08NM133, Bull Creek near Crump**	✓				**Natural**	**1965-1986**	**Discontinued**	**46.9**	**1530**	**49.62**	**-119.90**	**Continuous record 1969-1986**	**Yes**
										08NM134, Camp Creek at Mouth near Thirsk	✓				**Natural**	**1965-2007**	**Active**	**34**	**1450**	**49.72**	**-120.02**	**Continuous record**	**Yes**
										08NM158, Trout Creek at the Mouth	✓				**Regulated**	**1969-1982**	**Discontinued**	**764**	**-**	**-**	**-119.63**	**Continuous record**	**Yes**
										Trout Creek at Canyon Mouth - Old WSC Location (MOE)	✓				**Regulated**	**2004-2007**	**Active**	**-**	**-**	**49.57**	**-119.65**		**Yes**
										08NM023, Darke Creek northwest fork	✓				Natural	1921-1922	Discontinued	-	-	49.71	-119.87	Seasonal record	No
										08NM025, Darke Creek at Meadow Valley	✓				Regulated	1921-1922	Discontinued		-	49.67	-119.81		No
										08NM054, Trout Creek near Faulder	✓				Regulated	1921-1954	Discontinued	704	-	49.59	-119.75	Seasonal record	No
										08NM237, Trout Creek below Thirsk Lake	✓				Regulated	1936-1978	Discontinued	-	-	49.71	-120.05	-	No
										08NM042, Trout Creek near Summerland	✓				Regulated	1920-1928	Discontinued	-	-	49.57	-119.65		No
										08NM238, Thirsk Lake near the Outlet			✓		Regulated	1979-1987	Discontinued	-	-	49.73	-120.09		No
										08NM055, Trout Creek Summerland Diversion				✓	Regulated	1922-1931	Discontinued	-	-	49.60	-119.76	Seasonal record	No
43	Residual Area W-13	27.5	717	342 +/-	1384	-	-	24	9														
44	Turnbull Creek	22.3	1282	342 +/-	1864	49.56	-119.58	24	6														
45	Residual Area E-9	22.2	725	342 +/-	1484	-	-	24	6														

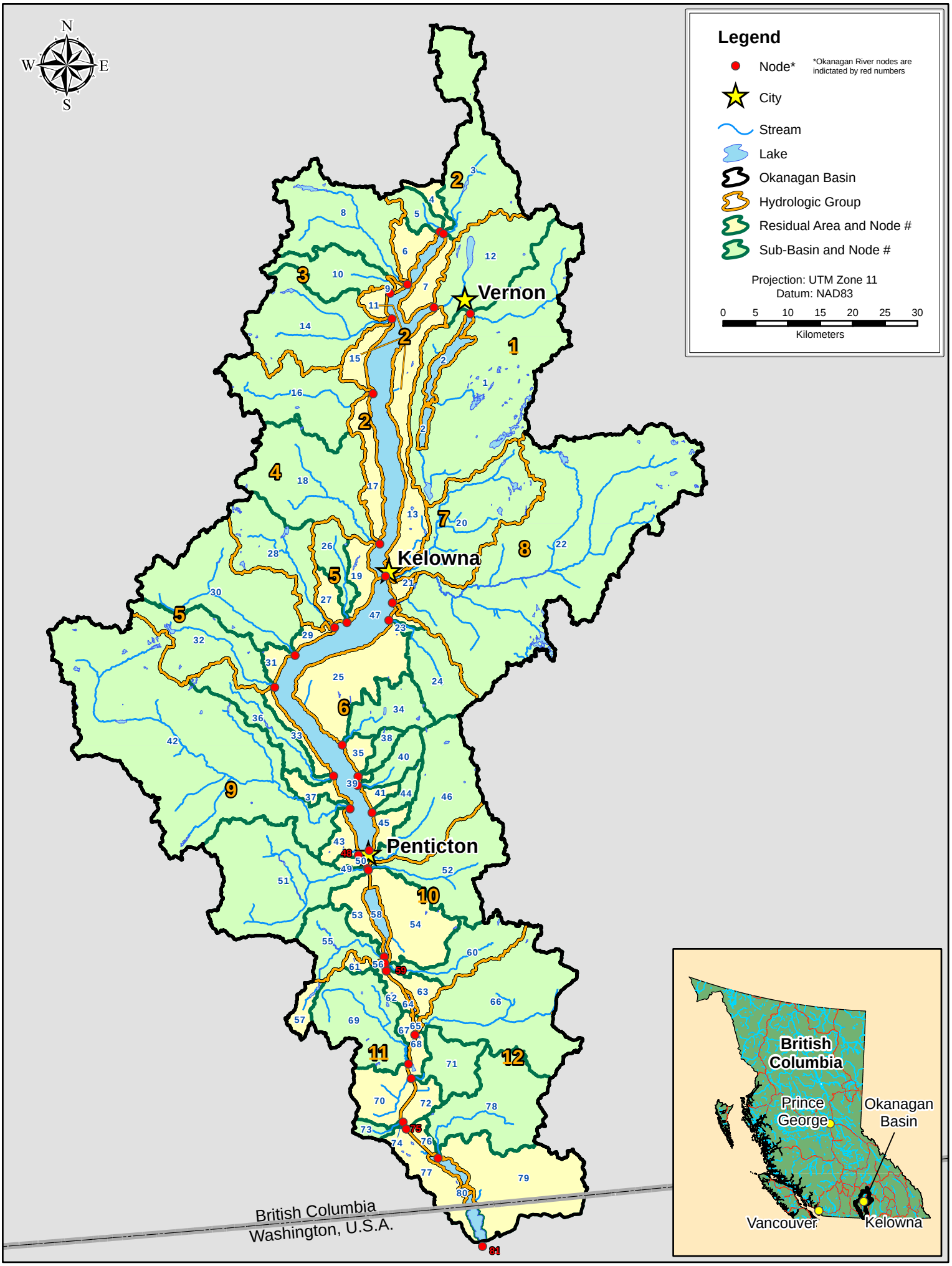
Node Characteristics										Hydrometric Stations													
Node	**Sub-basin / Residual area description**	**Drainage Area (km²)**	**Median Elevation (m)**	**Minimum Elevation (m)**	**Maximum Elevation (m)**	**Location of node** (mouth of stream)		**Provincial Hydrologic Zones** (where sub-basin / residual area falls in more than one zone distribution within each zone in % is indicated)	**Hydrologic Group** (see text for discussion)	**Hydrometric Stations within sub-basin or residual area** (operated by Water Survey of Canada unless noted otherwise). Stations in **red** were used (along with others outside the Okanagan) in developing regional hydrologic relations (see text for discussion)	**Streamflow**	**River flow**	**Lake or Reservoir Level**	**Diversion / Canal**	**Natural** (green shade) / **Regulated** (blue shade)	**Years of Record**	**Station status**	**Drainage Area (km²)**	**Median Elevation (m)**	**Location of hydrometric station**		**Notes**	**Potentially useful for hydrology / modeling study** (see text for discussion)
						Lat.	**Long.**													**Lat.**	**Long.**		
46	Penticton Creek	181.7	1492	342 +/-	2144	49.50	-119.59	24	6	**08NM240, Two-Forty Creek near Penticton**	✓				**Natural**	**1983-2006**	**Active**	**5.0**	**1769**	**49.65**	**119.40**	**Continuous record, established for the Upper Penticton Experimental Watershed (MOF)**	**Yes**
										08NM241, Two-Forty-One Creek near Penticton	✓				**Natural**	**1983-2006**	**Active**	**5.0**	**1768**	**49.65**	**119.39**	**Continuous record, established for the Upper Penticton Experimental Watershed (MOF)**	**Yes**
										08NM242, Dennis Creek near 1780 metre Contour	✓				**Natural**	**1985-2006**	**Active**	**3.7**	**1893**	**49.62**	**119.38**	**Continuous record, established for the Upper Penticton Experimental Watershed (MOF)**	**Yes**
										08NM118, Penticton Creek at the Mouth	✓				**Regulated**	**1950-1972**	**Discontinued**	**177**	**-**	**49.50**	**-119.58**	**Seasonal and continuous records**	**Yes**
										08NM168, Penticton Creek Above Dennis Creek	✓				**Regulated**	**1970-1999**	**Discontinued**	**35.5**	**-**	**49.62**	**-119.42**	**Continuous record**	**Yes**
										08NM170, Penticton Creek Below Harris Creek	✓				**Regulated**	**1970-1981**	**Discontinued**	**153**	**-**	**49.52**	**-119.52**	**Continuous record**	**Yes**
										Penticton Creek at Van Horne (Dobson)	✓				**Regulated**	**2007**	**Active**	**-**	**-**	**49.50**	**-119.59**		**Yes**
										08NM076, Penticton Creek Above Diversion	✓				Natural	1910-1941	Discontinued	-	-	49.49	-119.55	Seasonal record 1936-1941	No
										08NM031, Penticton Creek Below Diversion	✓				Regulated	1919-1921	Discontinued	-	-	49.49	-119.56		No
										08NM068, Nickel Plate Reservoir Outflow	✓				Regulated	1975-1976	Discontinued	-	-	49.61	-119.35		No
										08NM069, Read Creek near Penticton	✓				Regulated	1911-1930	Discontinued	-	-	49.59	-119.38		No
										08NM169, Greyback Lake at the Outlet			✓		Regulated	1970-1987	Discontinued	-	-	49.63	-119.42		No
										08NM032, Penticton Creek Main Diversion				✓	Regulated	1919-1966	Discontinued	-	-	49.49	-119.56	Seasonal record	No
										08NM063, Penticton Creek Lot 19 Diversion				✓	Regulated	1926-1954	Discontinued	-	-	49.51	-119.56	Seasonal record	No
47	Okanagan Lake	Drainage area above Okanagan Lake= 5610.4 km². Drainage area above outlet of Okanagan Lake = 5960.3 km²	Median elevation of drainage area above lake = 1,215 m. Median elevation above the outlet of Okanagan Lake= 1,174 m	Lake elevation = 342 +/-	Maximum elevation of drainage above Okanagan Lake = 2,170 m	49.50	-119.61	Drainage area above station falls within zones: 14 (3%), 15 (34%), 23 (18%) , 24 (45%)	n/a	**08NM083, Okanagan Lake at Kelowna**			✓		**Regulated**	**1943-2006**	**Active**	**Drainage area above Okanagan Lake= 5610.4 km². Drainage area above outlet of Okanagan Lake = 5960.3 km²**	**Median elevation of drainage area above lake = 1,215 m. Median elevation above the outlet of Okanagan Lake= 1,174 m**	**49.89**	**-119.50**	**Continuous record**	**Yes**
										08NM071, Okanagan Lake at Penticton			✓		**Regulated**	**1920-1974**	**Discontinued**			**49.50**	**-119.61**	**Continuous record**	**Yes**
48	Okanagan River at Penticton	5962.4 km²; (drainage area reported by WSC is 6090 km²)	Median elevation of drainage area above station = 1,174 m	337	2170	49.50	-119.62	Drainage area above station falls within zones: 14 (3%), 15 (35%), 23 (17%) , 24 (45%)	n/a	**08NM050, Okanagan River at Penticton**		✓			**Regulated**	**1910-2006**	**Active**	**5962.4 km²; (drainage area reported by WSC = 6090 km²)**	**Median elevation of drainage area above station = 1,174 m**	**49.50**	**-119.62**	**Continuous record 1921-2006**	**Yes**
49	Residual Area W-14	7.3	527	339	1021	-	-	24	9														
50	Residual Area E-10	3.1	355	339	370	-	-	24	6														
51	Shingle Creek	281.4	1273	339	2200	49.48	-119.60	24	9	**08NM038, Shingle Creek Above Kaleden Diversion**	✓				**Natural**	**1920-1977**	**Discontinued**	**44.8**	**1537**	**49.51**	**119.80**	**Seasonal record**	**Yes**
										08NM037, Shatford Creek near Penticton	✓				**Regulated**	**1911-2007**	**Active**	**101**	**1530**	**49.42**	**-119.79**	**Continuous record 1966-2007**	**Yes**
										08NM150, Shingle Creek at the Mouth	✓				**Regulated**	**1969-1982**	**Discontinued**	**308**	**-**	**49.48**	**-119.60**	**Continuous record 1969-1979**	**Yes**
										08NM070, Riddle Creek near West Summerland	✓				Natural	1930-1931	Discontinued	-	-	49.51	-119.79	Continuous record	No
52	Ellis Creek	160.6	1428	339	2019	49.48	-119.60	23 (6%), 24 (94%)	10	**08NM135, Ellis Creek at Penticton**	✓				**Regulated**	**1965-1979**	**Discontinued**	**-**	**-**	**49.48**	**-119.59**	**Continuous record**	**Yes**
										Ellis Creek near the Mouth (Dobson)	✓				**Regulated**	**2007**	**Active**	**-**	**-**	**49.48**	**-119.60**		**Yes**
										Ellis Creek at Atkinson St. (MOE)	✓				**Regulated**	**2006-2007**	**Active**	**-**	**-**	**49.48**	**-119.59**		**Yes**
										08NM074, Ellis Creek near Penticton	✓				Natural	1933-1955	Discontinued	-	-	49.47	-119.39		No
										08NM056, Ellis Creek South Main Diversion				✓	Regulated	1910-1966	Discontinued	-	-	49.48	-119.56		No
										08NM122, Ellis Creek North Main Diversion				✓	Regulated	1955-1957	Discontinued	-	-	49.48	-119.56		No
53	Residual Area W-15	40.9	715	337 +/-	1418	-	-	24	9														
54	Residual Area E-11	122.1	1019	337 +/-	1949	-	-	24	10	08NM005, McLean Creek near Okanagan Falls	✓				Natural	1921-1926	Discontinued	20.7	-	49.35	-119.52	Seasonal record	No
55	Marron River	82.4	877	337 +/-	1574	49.36	-119.58	24	9	08NM049, Horn Creek near Kaleden	✓				Regulated	1920	Discontinued	-	-	49.40	-119.65		No
56	Residual Area W-16	0.8	451	337 +/-	624	-	-	24	11														
57	Residual Area W-17	23.8	1200	793	1623	-	-	24	11														

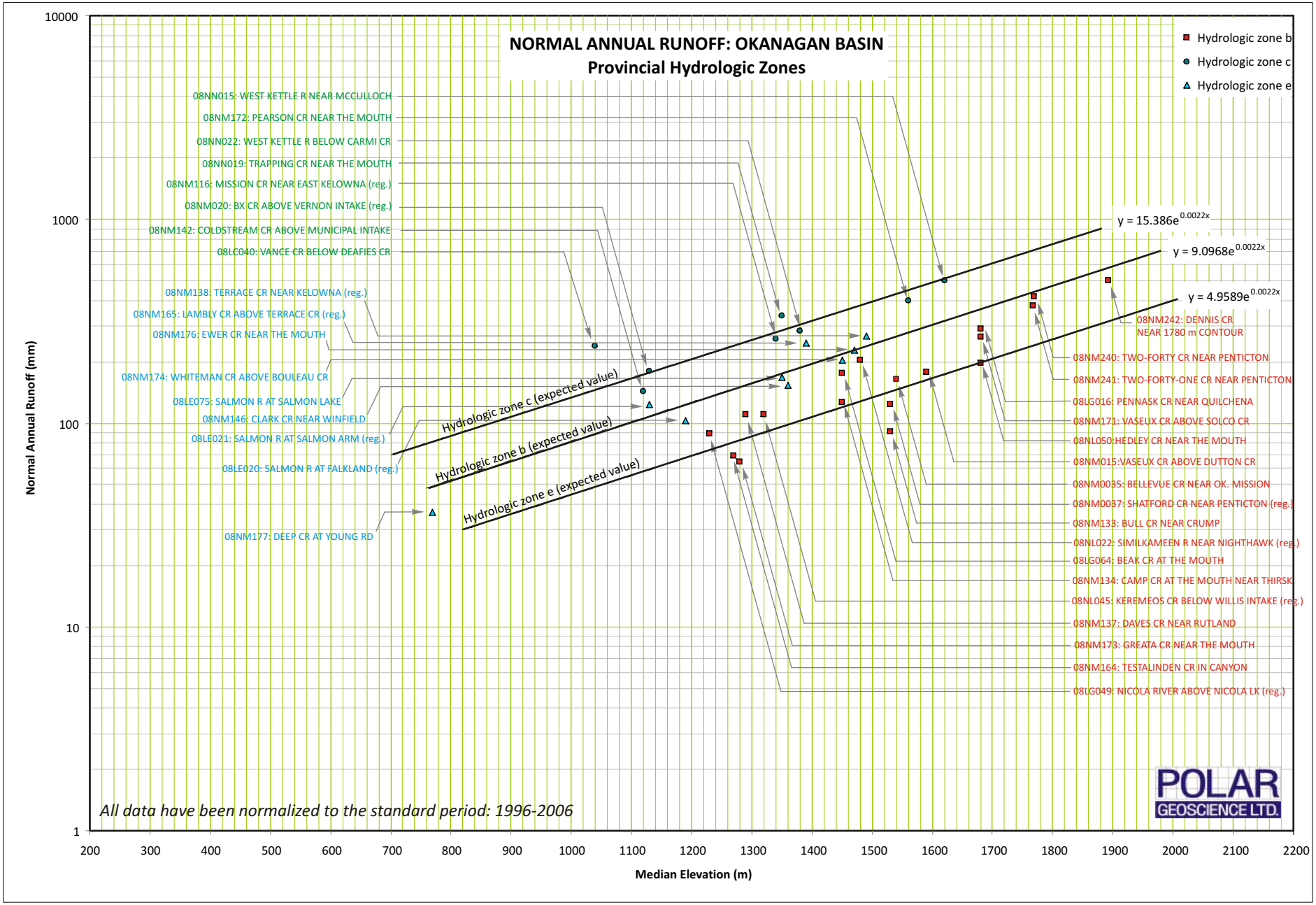
Node Characteristics										Hydrometric Stations													
Node	**Sub-basin / Residual area description**	**Drainage Area (km²)**	**Median Elevation (m)**	**Minimum Elevation (m)**	**Maximum Elevation (m)**	**Location of node** (mouth of stream)		**Provincial Hydrologic Zones** (where sub-basin / residual area falls in more than one zone distribution within each zone in % is indicated)	**Hydrologic Group** (see text for discussion)	**Hydrometric Stations within sub-basin or residual area** (operated by Water Survey of Canada unless noted otherwise). Stations in **red** were used (along with others outside the Okanagan) in developing regional hydrologic relations (see text for discussion)	**Streamflow**	**River flow**	**Lake or Reservoir Level**	**Diversion / Canal**	**Natural** (green shade) / **Regulated** (blue shade)	**Years of Record**	**Station status**	**Drainage Area (km²)**	**Median Elevation (m)**	**Location of hydrometric station**		**Notes**	**Potentially useful for hydrology / modeling study** (see text for discussion)
						Lat.	**Long.**													**Lat.**	**Long.**		
58	Skaha Lake	Drainage area above Skaha Lake= 6659 km². Drainage area above outlet of Skaha Lake = 6678.7 km²	Median elevation of drainage area above Skaha lake = 1177 m. Median elevation above Skaha lake at the mouth = 1175m	337 +/-	Maximum elevation of drainage area above lake =2199m	49.35	-119.58	Drainage area above lake falls within zones: 14 (3%), 15 (31%), 23 (15%), 24 (51%)	n/a	**08NM084, Skaha Lake at Okanagan Falls**			✓		**Regulated**	**1943-2006**	**Active**	**-**	**-**	**49.43**	**-119.57**	**Continuous record**	**Yes**
59	Okanagan River at Okanagan Falls	6,860	Median elevation of drainage area above station = 1175 m	337	2199	49.34	-119.58	Drainage area above station falls within zones: 14 (3%), 15 (31%), 23 (15%), 24 (51%)	n/a	**08NM002, Okanagan River at Okanagan Falls**		✓			**Regulated**	**1915-2006**	**Active**	**6860**	**-**	**49.34**	**-119.58**	**Continuous record**	**Yes**
60	Shuttleworth Creek	89.5	1379	334	1885	49.34	-119.58	24	n/a	**08NM149, Shuttleworth Creek at the Mouth**	✓				**Regulated**	**1969-1971, 2006**	**Active**	**89.5**	**1379**	**49.34**	**119.58**	**Continuous record; drainage area determined by GIS**	**Yes**
										08NM006, Shuttleworth Creek near Okanagan Falls	✓				Regulated	1921-1964	Discontinued	85.2	-	49.33	-119.52	Seasonal record	No
61	Residual Area W-18	9.3	778	558	1372	-	-	24	11	08NM147, Horn Creek near Olalla	✓				Natural	1968-1977	Discontinued	15	-	-	-119.75	Seasonal record	No
										08NM148, Twin Lakes near Olalla			✓		Regulated	1968-1977	Discontinued	-	-	49.32	-119.73		No
62	Residual Area W-19	15.5	587	324	946	-	-	24	11														
63	Residual Area E-12	27.9	640	324	1362	-	-	24	10														
64	Vaseux Lake	Drainage area above Vaseux Lake= 6821.0 km². Drainage area above outlet of Vaseux Lake = 6823.9 km²	Median elevation of drainage area above Vaseux Lake = 1175 m; Median elevation of drainage area above outlet of Vaseux Lake = 1175m	324	2199	49.27	-119.53	Drainage area above lake falls within zones: 14 (3%), 15 (30%), 23 (15%), 24 (52%)	n/a	**08NM243, Vaseux Lake near the Outlet**			✓		**Regulated**	**1991-2006**	**Active**	**-**	**-**	**49.27**	**-119.52**	**Continuous record**	**Yes**
65	Residual Area E-13	2.3	345	316	373			24	10	08NM114, Oliver Canal near Oliver				✓	Regulated	1934-1972	Discontinued	-	-	49.25	-119.53		No
66	Vaseux Creek	295.6	1535	317	2301	49.24	-119.53	23 (10%), 24 (90%)	12	**08NM171, Vaseux Creek Above Solco Creek**	✓				**Natural**	**1970-2006**	**Active**	**117**	**1680**	**49.25**	**-119.32**	**Continuous record 1964-1982**	**Yes**
										08NM246, Vaseux Creek near the Mouth	✓				**Natural**	**2006-2007**	**Active**	**295.5**	**1535**	**49.25**	**119.53**	**Continuous record, short period**	**Yes**
										08NM015, Vaseux Creek Above Dutton Creek	✓				**Natural**	**1919-1982**	**Discontinued**	**255**	**1591**	**49.26**	**119.47**		**Yes**
67	Residual Area W-20	11.5	496	297	914			24	11														
68	Residual Area E-14	15.8	403	294	852			24	12														
69	Park Rill	158.6	841	297	1595	49.20	-119.55	24	11	**08NM120, Park Rill near Oliver**	✓				**Regulated**	**1951-1970**	**Discontinued**	**160**	**-**	**49.24**	**-119.57**	**Seasonal record**	**Yes**
70	Residual Area W-21	70.3	725	284	1853	-	-	24	11	08NM199, Unnamed Ditch above Packing House Outfalls in Oliver				✓	Regulated	1972-1973	Discontinued	-	-	49.18	-119.55		No
										08NM178, Unnamed Ditch at Oliver				✓	Regulated	1970-1972	Discontinued	-	-	49.18	-119.55		No
71	Wolfcub Creek	71.2	979	297	1721	49.18	-119.55	24	12	08NM121, Wolfcub Creek near Oliver	✓				Regulated	1952	Discontinued	-	-	49.18	-119.53		No
72	Residual Area E-15	28.7	453	279	952			24	12														
73	Testalinden Creek	13.6	1195	285	1857	49.13	-119.57	24	11	**08NM164, Testalinden Creek in Canyon**	✓				**Natural**	**1969-1986**	**Discontinued**	**13**	**1270**	**49.12**	**-119.60**	**Continuous record 1969-1979, Seasonal 1980-1986**	**Yes**
										08NM130, Testalinden Creek near Oliver	✓				Regulated	1965-1968	Discontinued			49.12	-119.59	Continuous record	Yes
74	Residual Area W-22	0.37	291	282	371	-	-	24	11														
75	Okanagan River near Oliver	7,590.0	Median elevation of drainage area above station =1180 m	291	2296	49.16	-119.55	Drainage area above station falls within zones: 14 (2%), 15 (28%), 23 (14%), 24 (56%)	n/a	**08NM085, Okanagan River at Oliver**		✓			**Regulated**	**1944-2006**	**Active**	**7590**	**-**	**49.11**	**-119.57**	**Continuous record 1953-2006**	**Yes**
										08NM197, Okanagan River below the S.O.L.I.D Canal		✓			Regulated	1972	Discontinued	-	-	49.26	-119.53		No
										08NM001, Okanagan River near Fairview		✓			Natural	1914	Discontinued	-	-	49.14	-119.58	Record limited to a single year	No
76	Residual Area E-16	12.2	354	276	782	-	-	24	12														
77	Residual Area W-23	62.4	516	271	1206	-	-	24	11														

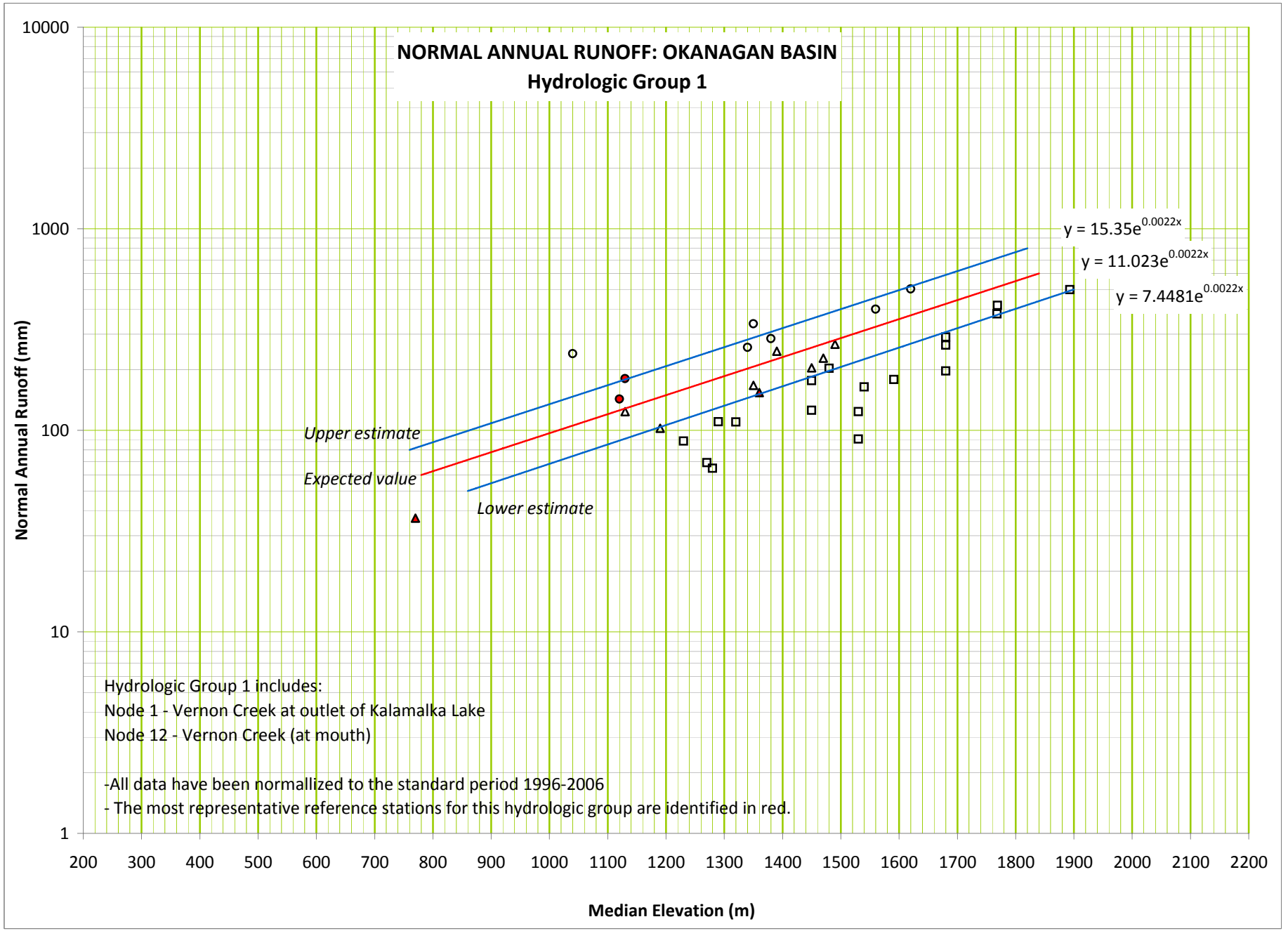
Node Characteristics										Hydrometric Stations													
Node	**Sub-basin / Residual area description**	**Drainage Area (km^2)**	**Median Elevation (m)**	**Minimum Elevation (m)**	**Maximum Elevation (m)**	**Location of node** (mouth of stream)		**Provincial Hydrologic Zones** (where sub-basin / residual area falls in more than one zone distribution within each zone in % is indicated)	**Hydrologic Group** (see text for discussion)	**Hydrometric Stations within sub-basin or residual area** (operated by Water Survey of Canada unless noted otherwise). Stations in **red** were used (along with others outside the Okanagan) in developing regional hydrologic relations (see text for discussion)	**Streamflow**	**River flow**	**Lake or Reservoir Level**	**Diversion / Canal**	**Natural** (green shade) / **Regulated** (blue shade)	**Years of Record**	**Station status**	**Drainage Area (km^2)**	**Median Elevation (m)**	**Location of hydrometric station**		**Notes**	**Potentially useful for hydrology / modeling study** (see text for discussion)
						Lat.	**Long.**													**Lat.**	**Long.**		
78	Inkaneep Creek	184.8	1227	276	2312	49.07	-119.51	24	12	**08NM200, Inkaneep Creek near the Mouth**	✓				**Regulated**	**2006-2007**	**Active**	**227**	**1227**	**49.25**	**119.53**	**Continuous record**	**Yes**
										08NM012, Inkaneep Creek near Oliver (Lower Station)	✓				Natural	1911-1950	Discontinued	164	-	49.12	-119.49	Seasonal record 1920-1929 and 1941-1950	No
										08NM082, Inkaneep Creek near Oliver (Upper Station)	✓				Natural	1941-1977	Discontinued	70.4	-	49.12	-119.36	Seasonal record 1941-1950	No
79	Residual Area E-17	160.4	1054	276	1676	-	-	23 (19%), 24 (81%)	12	08NM126, Haynes Creek near Osoyoos	✓				Natural	1912-1964	Discontinued	17.6	-	49.02	-119.39	Seasonal record 1959-1964	No
80	Osoyoos Lake	Drainage area above Osoyoos Lake = 8001.0 km^2. Drainage area above outlet of Osoyoos Lake = 8024.3 km^2	Median elevation of drainage area above Osoyoos Lake = 1169 m. Median elevation of drainage area above outlet of Osoyoos Lake = 1167 m.	270 +/-	Maximum elevation of drainage area above lake =2305m	48.95	-119.43	Drainage area above lake falls within zones: 14 (2%), 15 (26%), 23 (14%), 24 (58%)	n/a	**08NM073, Osoyoos Lake near Oroville**			✓		**Regulated**	**1929-2006**	**Active**	**-**	**-**	**48.96**	**-119.44**	**Continuous record 1930-2007**	**Yes**
										08NM113, Osoyoos Lake near Osoyoos			✓		**Regulated**	**1977-2004**	**Discontinued**	**-**	**-**	**49.03**	**-119.46**	**Continuous record**	**Yes**
81	Okanagan River at Oroville	8280 (WSC)	Median elevation of drainage area above station = 1167 m	270	2305	48.94	-119.43	Drainage area above lake falls within zones: 14 (2%), 15 (26%), 23 (14%), 24 (58%)	n/a	**08NM127, Okanogan River at Oroville**		✓			**Regulated**	**1942-2006**	**Active**	**8280**	Median elevation of drainage area above station = 1167 m	**48.93**	**-119.42**	**Continuous record**	**Yes**
										08NM131, Okanogan River at Bridge Street at Oroville		✓			Regulated	1939-1992	Discontinued	8110	-	48.94	-119.43		No
										08NM132, Okanogan River at Zosel Millpond at Oroville		✓			Regulated	1939-1986	Discontinued	8280	-	48.93	-119.42		No

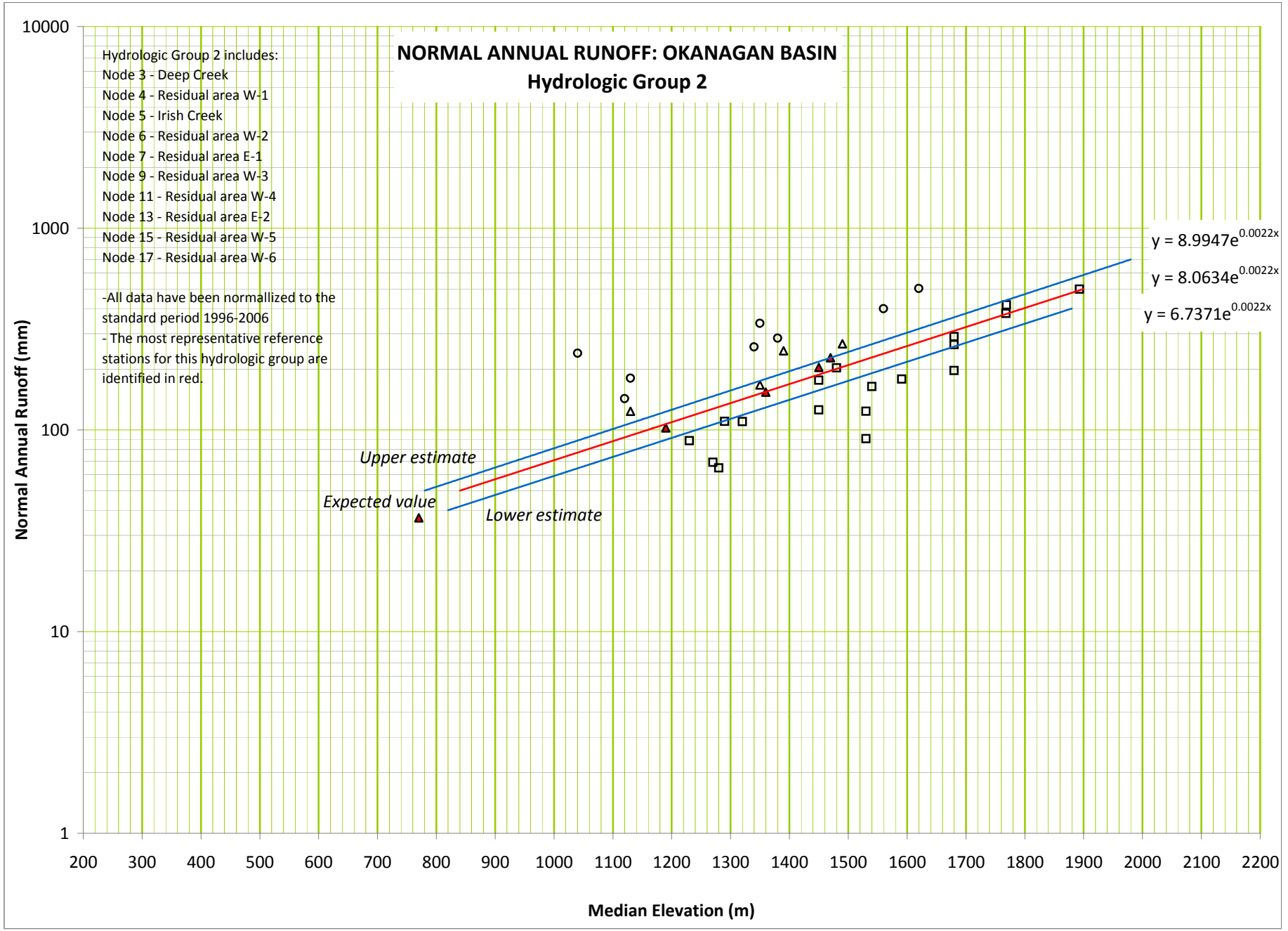
APPENDIX C

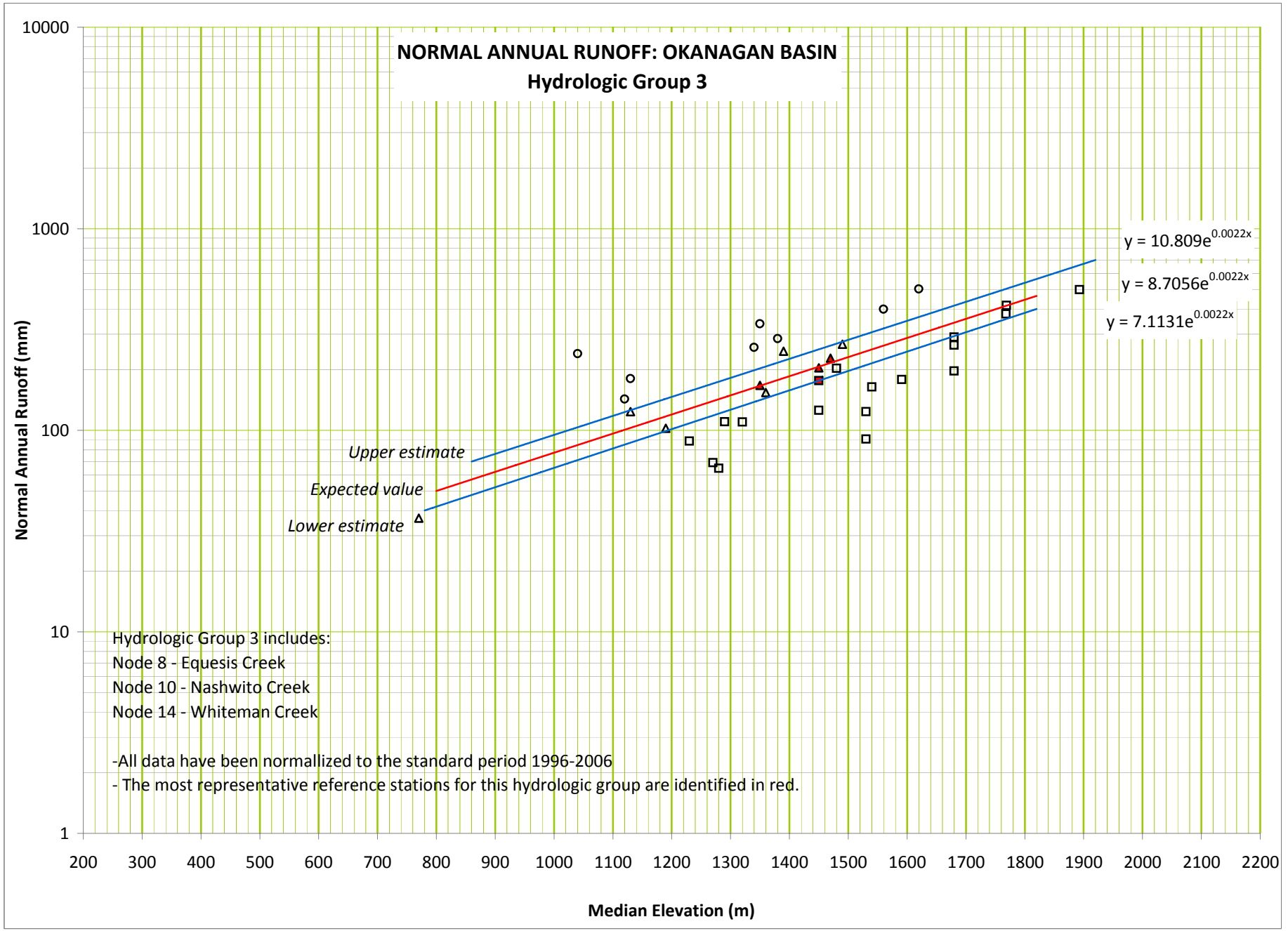
Regional Runoff Relations for the Okanagan Basin

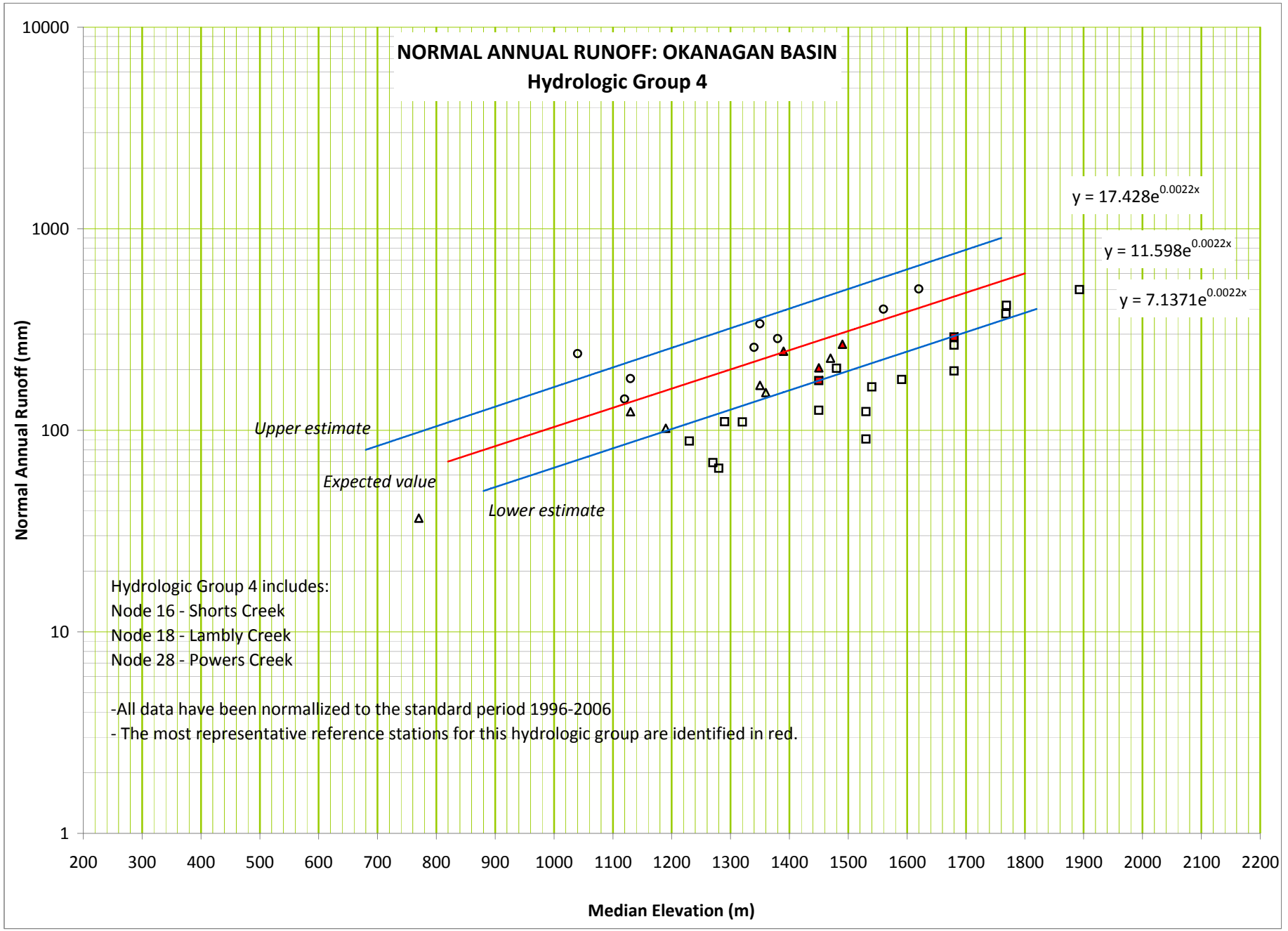

N
W
E
S
Legend
Node*
*Okanagan River nodes are indictated by red numbers
City
Stream
Lake
Okanagan Basin
Hydrologic Group
Residual Area and Node #
Sub-Basin and Node #
Projection: UTM Zone 11
Datum: NAD83
0 5 10 15 20 25 30
Kilometers
Vernon
Kelowna
Penticton
British Columbia
Washington, U.S.A.
British Columbia
Prince George
Okanagan Basin
Vancouver
Kelowna

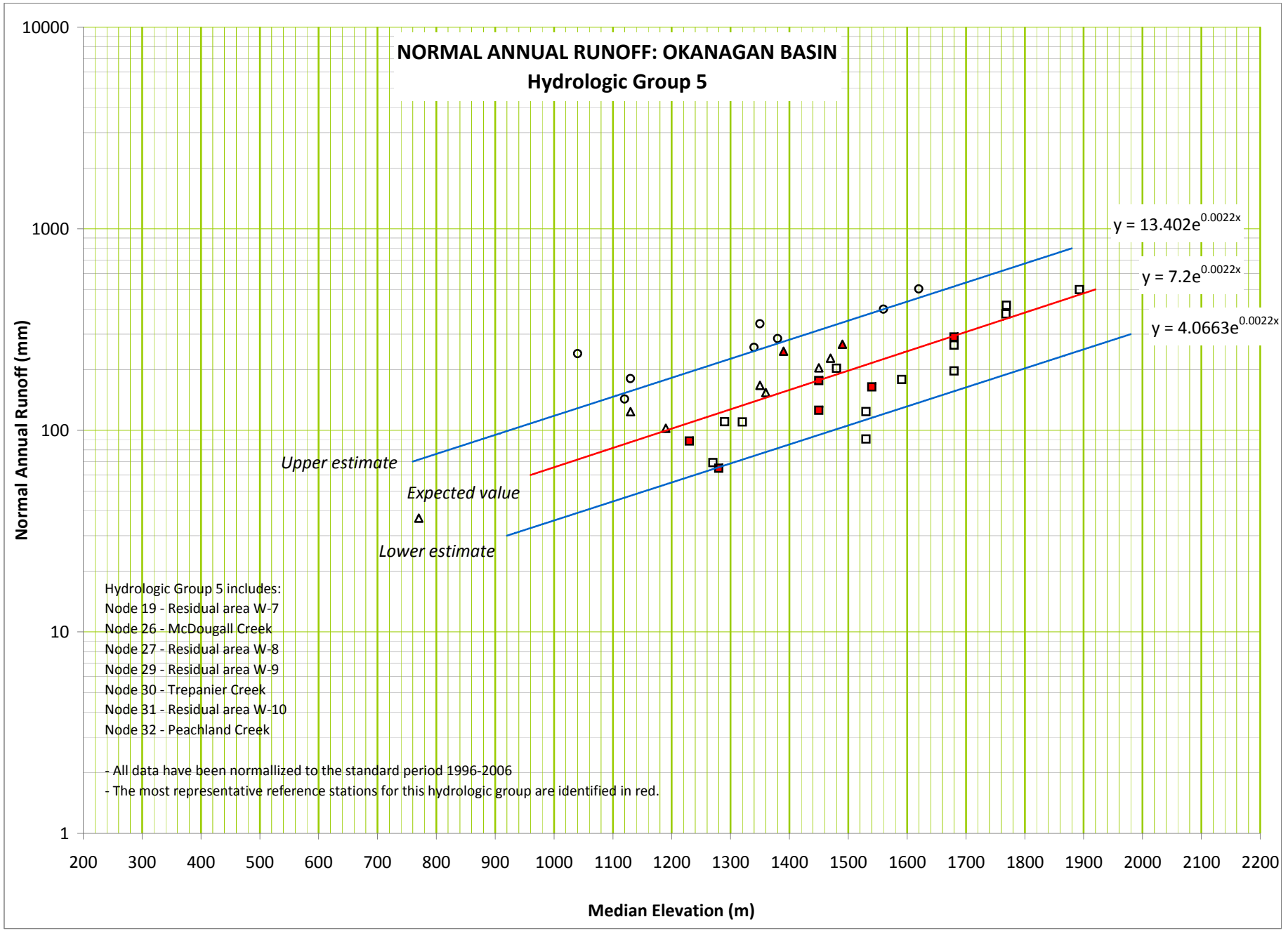

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Provincial Hydrologic Zones
Hydrologic zone b
Hydrologic zone c
Hydrologic zone e
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 15.386e^0.0022x
y = 9.0968e^0.0022x
y = 4.9589e^0.0022x
Hydrologic zone c (expected value)
Hydrologic zone b (expected value)
Hydrologic zone e (expected value)
08NN015: WEST KETTLE R NEAR MCCULLOCH
08NM172: PEARSON CR NEAR THE MOUTH
08NN022: WEST KETTLE R BELOW CARMI CR
08NN019: TRAPPING CR NEAR THE MOUTH
08NM116: MISSION CR NEAR EAST KELOWNA (reg.)
08NM020: BX CR ABOVE VERNON INTAKE (reg.)
08NM142: COLDSTREAM CR ABOVE MUNICIPAL INTAKE
08LC040: VANCE CR BELOW DEAFIES CR
08NM138: TERRACE CR NEAR KELOWNA (reg.)
08NM165: LAMBLY CR ABOVE TERRACE CR (reg.)
08NM176: EWER CR NEAR THE MOUTH
08NM174: WHITEMAN CR ABOVE BOULEAU CR
08LE075: SALMON R AT SALMON LAKE
08NM146: CLARK CR NEAR WINFIELD
08LE021: SALMON R AT SALMON ARM (reg.)
08LE020: SALMON R AT FALKLAND (reg.)
08NM177: DEEP CR AT YOUNG RD
08NM242: DENNIS CR NEAR 1780 m CONTOUR
08NM240: TWO-FORTY CR NEAR PENTICTON
08NM241: TWO-FORTY-ONE CR NEAR PENTICTON
08LG016: PENNASK CR NEAR QUILCHENA
08NM171: VASEUX CR ABOVE SOLCO CR
08NL050:HEDLEY CR NEAR THE MOUTH
08NM015:VASEUX CR ABOVE DUTTON CR
08NM0035: BELLEVUE CR NEAR OK. MISSION
08NM0037: SHATFORD CR NEAR PENTICTON (reg.)
08NM133: BULL CR NEAR CRUMP
08NL022: SIMILKAMEEN R NEAR NIGHTHAWK (reg.)
08LG064: BEAK CR AT THE MOUTH
08NM134: CAMP CR AT THE MOUTH NEAR THIRSK
08NL045: KEREMEOS CR BELOW WILLIS INTAKE (reg.)
08NM137: DAVES CR NEAR RUTLAND
08NM173: GREATA CR NEAR THE MOUTH
08NM164: TESTALINDEN CR IN CANYON
08LG049: NICOLA RIVER ABOVE NICOLA LK (reg.)
All data have been normalized to the standard period: 1996-2006
POLAR
GEOSCIENCE LTD.

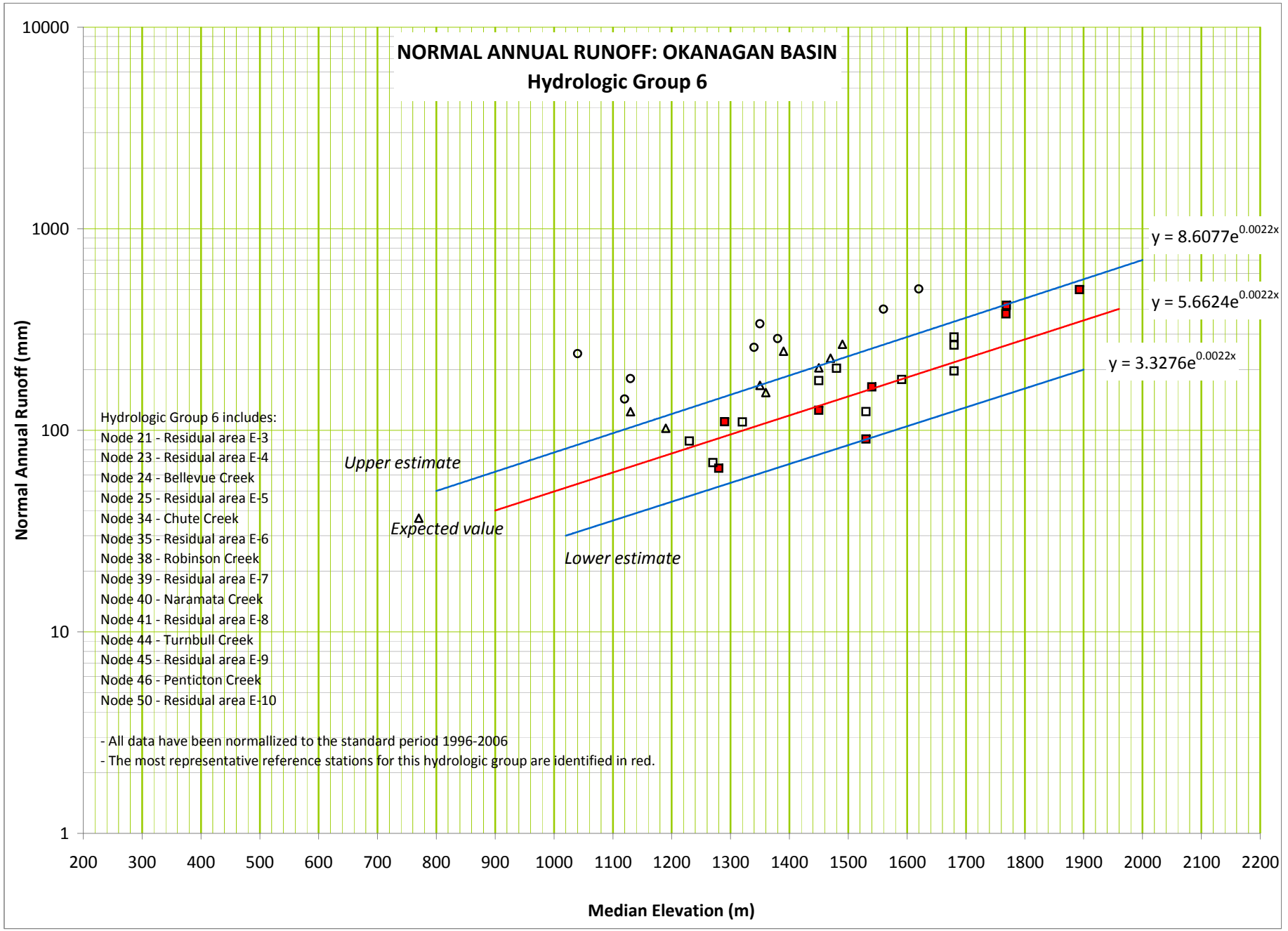

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 1
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 15.35e^0.0022x
y = 11.023e^0.0022x
y = 7.4481e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 1 includes:
Node 1 - Vernon Creek at outlet of Kalamalka Lake
Node 12 - Vernon Creek (at mouth)
-All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.

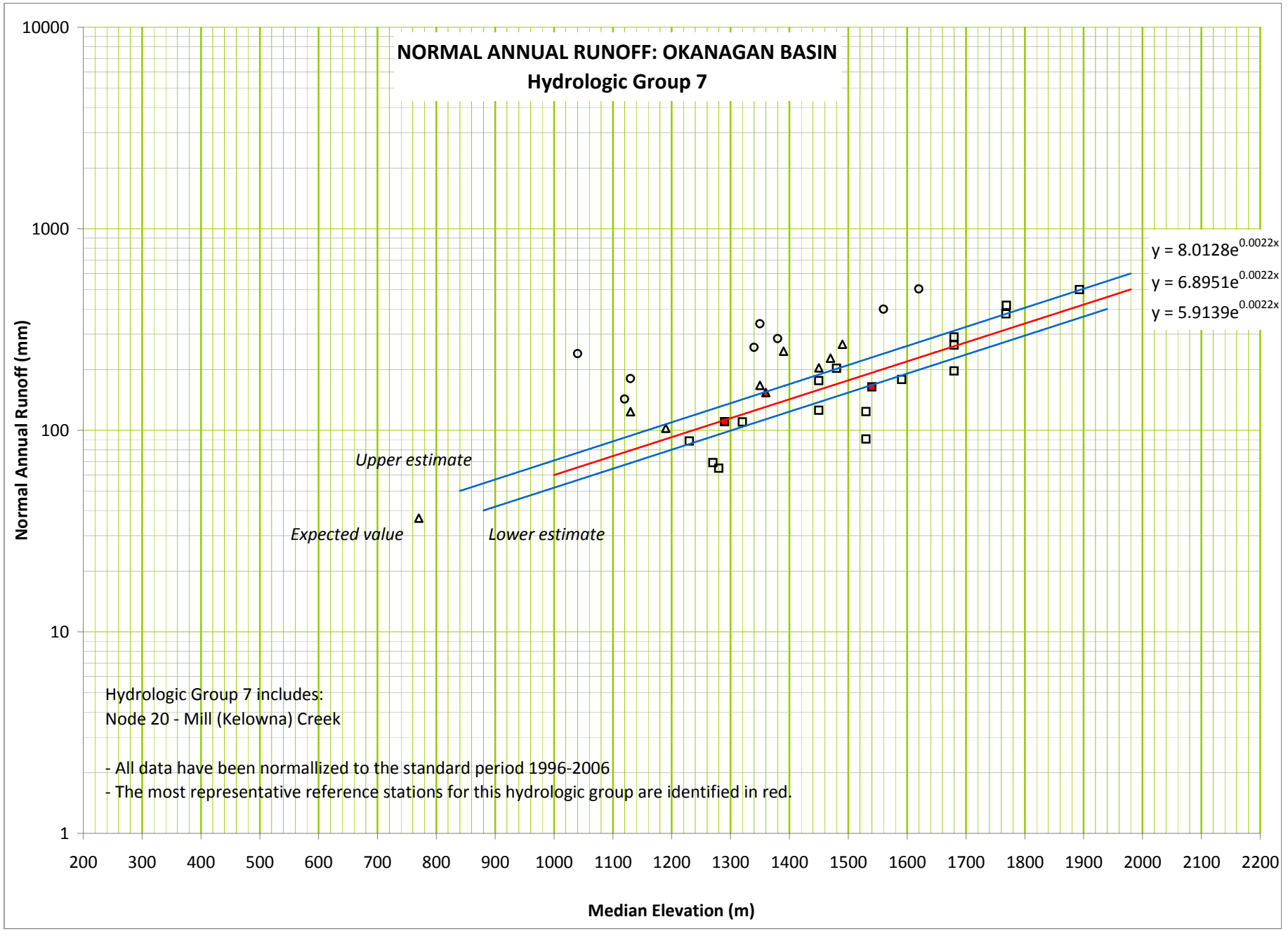

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 2
Hydrologic Group 2 includes:
Node 3 - Deep Creek
Node 4 - Residual area W-1
Node 5 - Irish Creek
Node 6 - Residual area W-2
Node 7 - Residual area E-1
Node 9 - Residual area W-3
Node 11 - Residual area W-4
Node 13 - Residual area E-2
Node 15 - Residual area W-5
Node 17 - Residual area W-6
-All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.
Upper estimate
Expected value
Lower estimate
y = 8.9947e^0.0022x
y = 8.0634e^0.0022x
y = 6.7371e^0.0022x
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

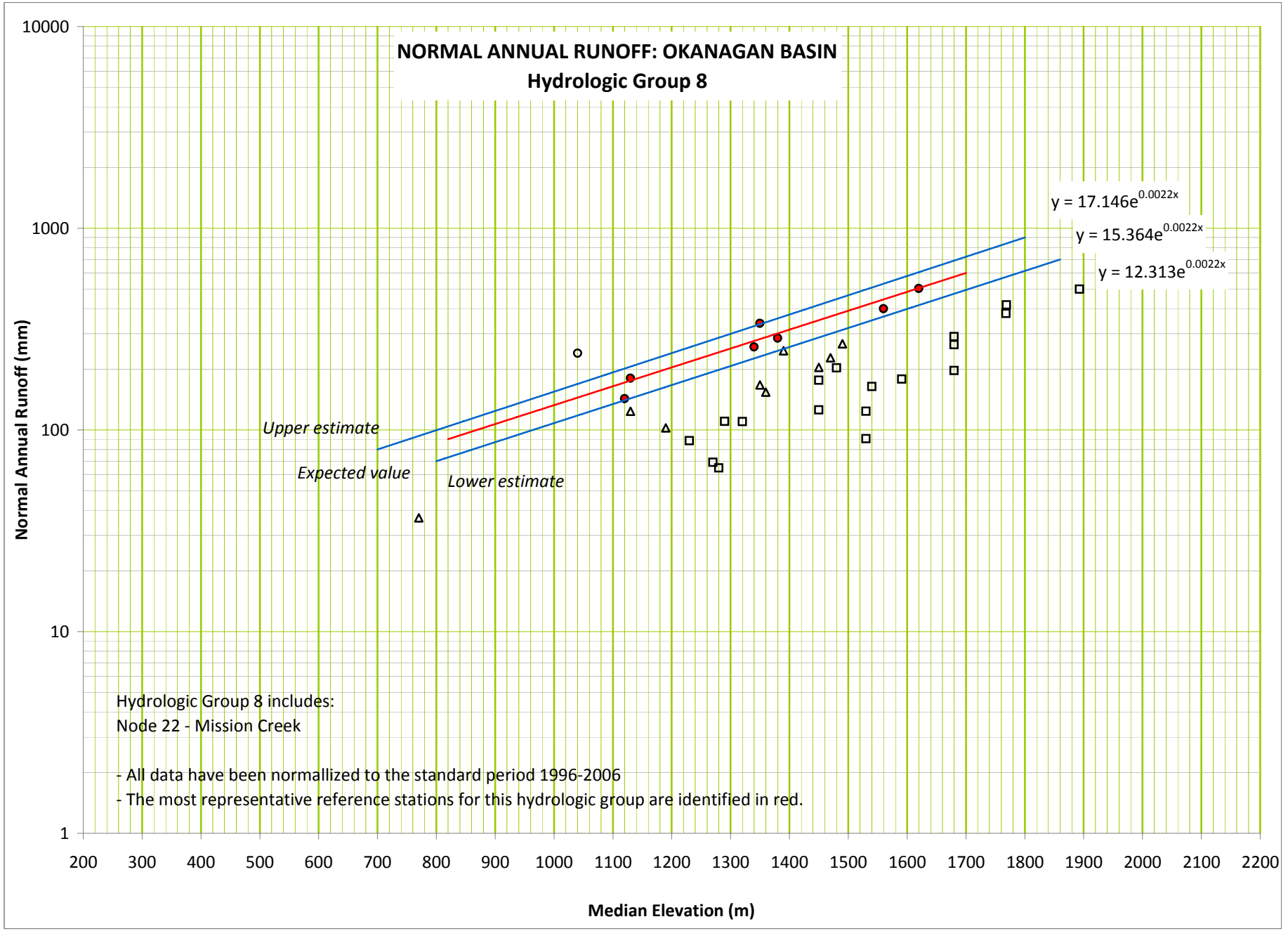

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 3
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 10.809e^0.0022x
y = 8.7056e^0.0022x
y = 7.1131e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 3 includes:
Node 8 - Equesis Creek
Node 10 - Nashwito Creek
Node 14 - Whiteman Creek
-All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.

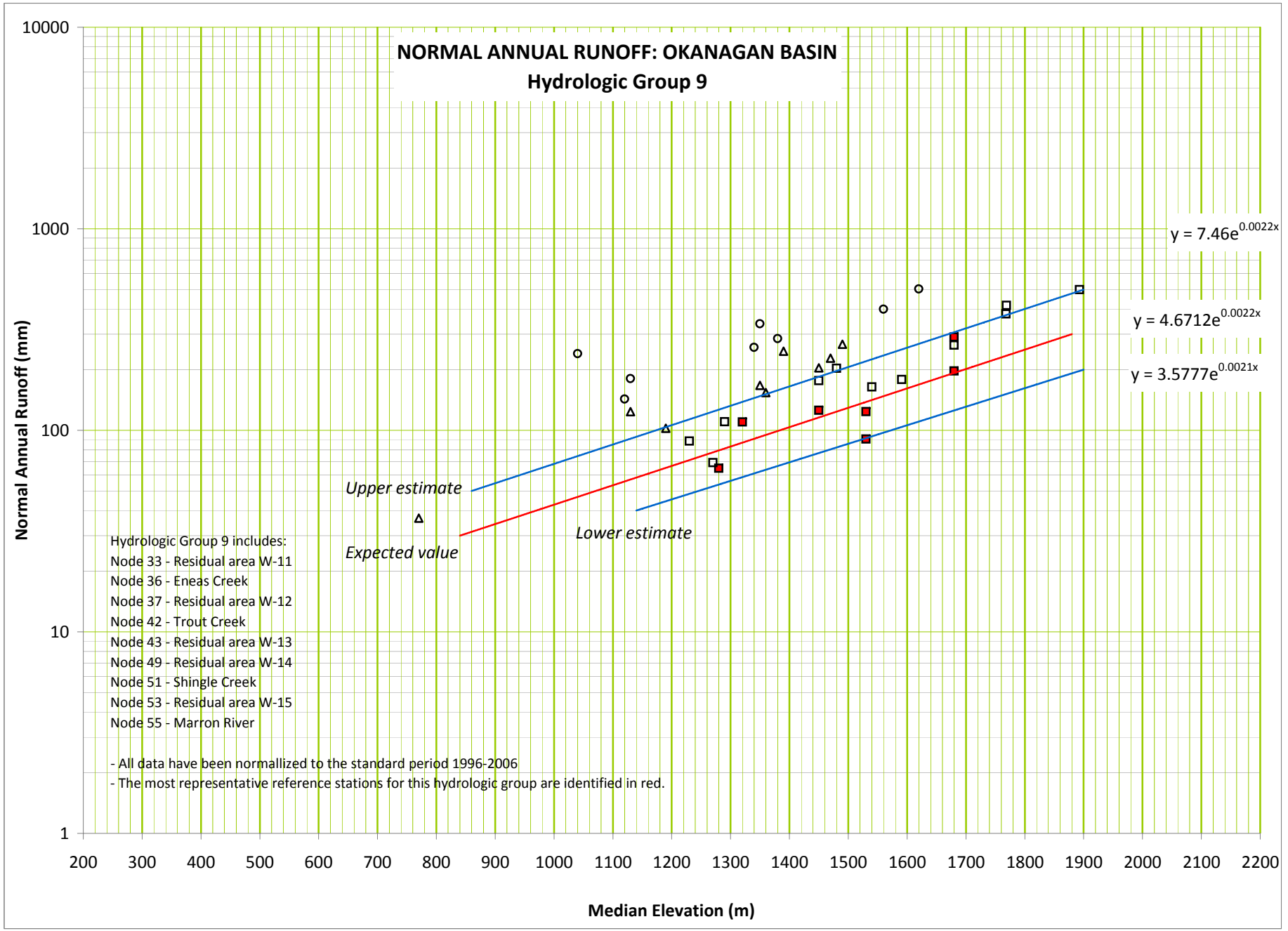

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 4
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 17.428e^0.0022x
y = 11.598e^0.0022x
y = 7.1371e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 4 includes:
Node 16 - Shorts Creek
Node 18 - Lambly Creek
Node 28 - Powers Creek
-All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.

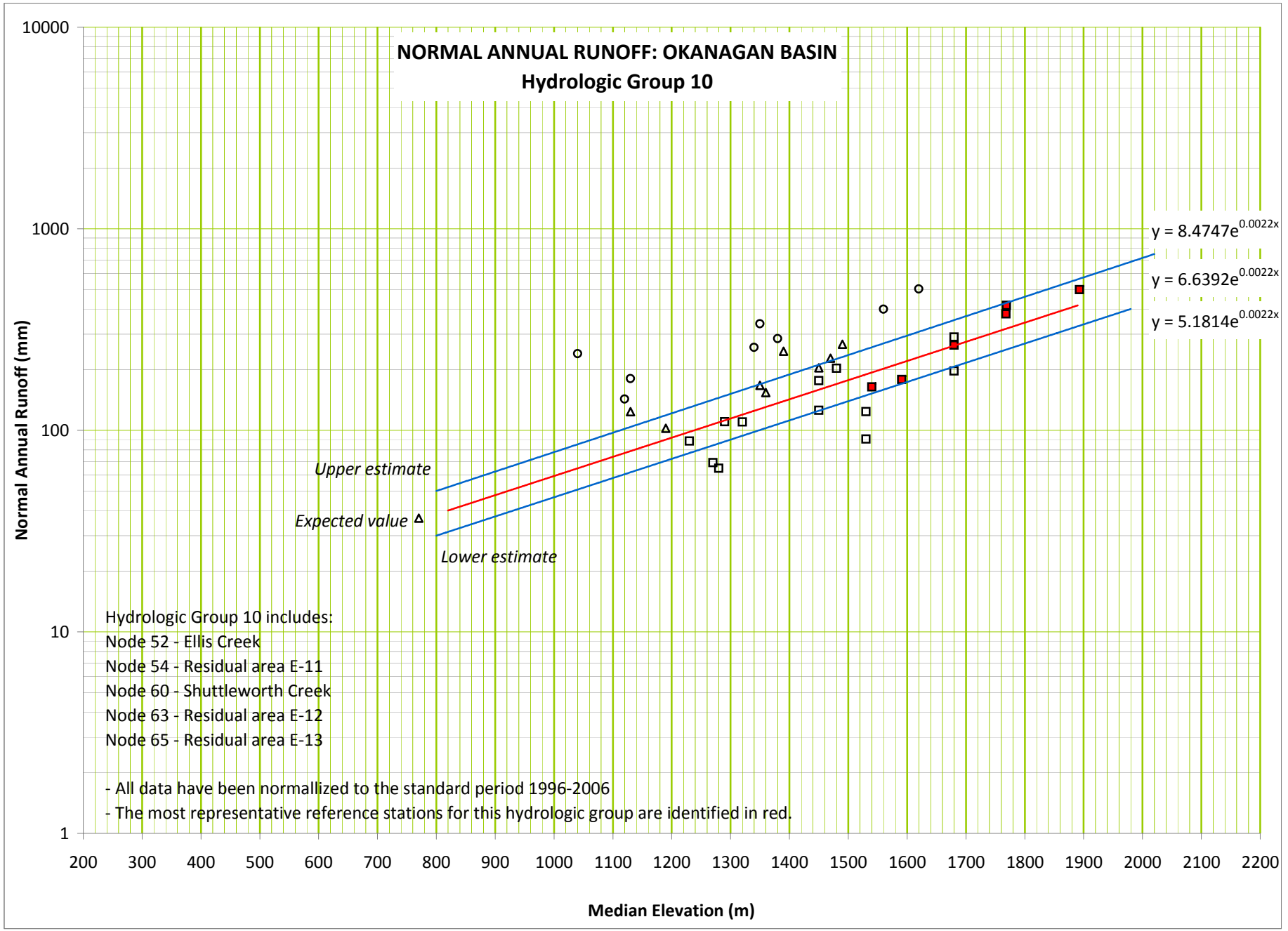

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 5
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 13.402e^0.0022x
y = 7.2e^0.0022x
y = 4.0663e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 5 includes:
Node 19 - Residual area W-7
Node 26 - McDougall Creek
Node 27 - Residual area W-8
Node 29 - Residual area W-9
Node 30 - Trepanier Creek
Node 31 - Residual area W-10
Node 32 - Peachland Creek
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.

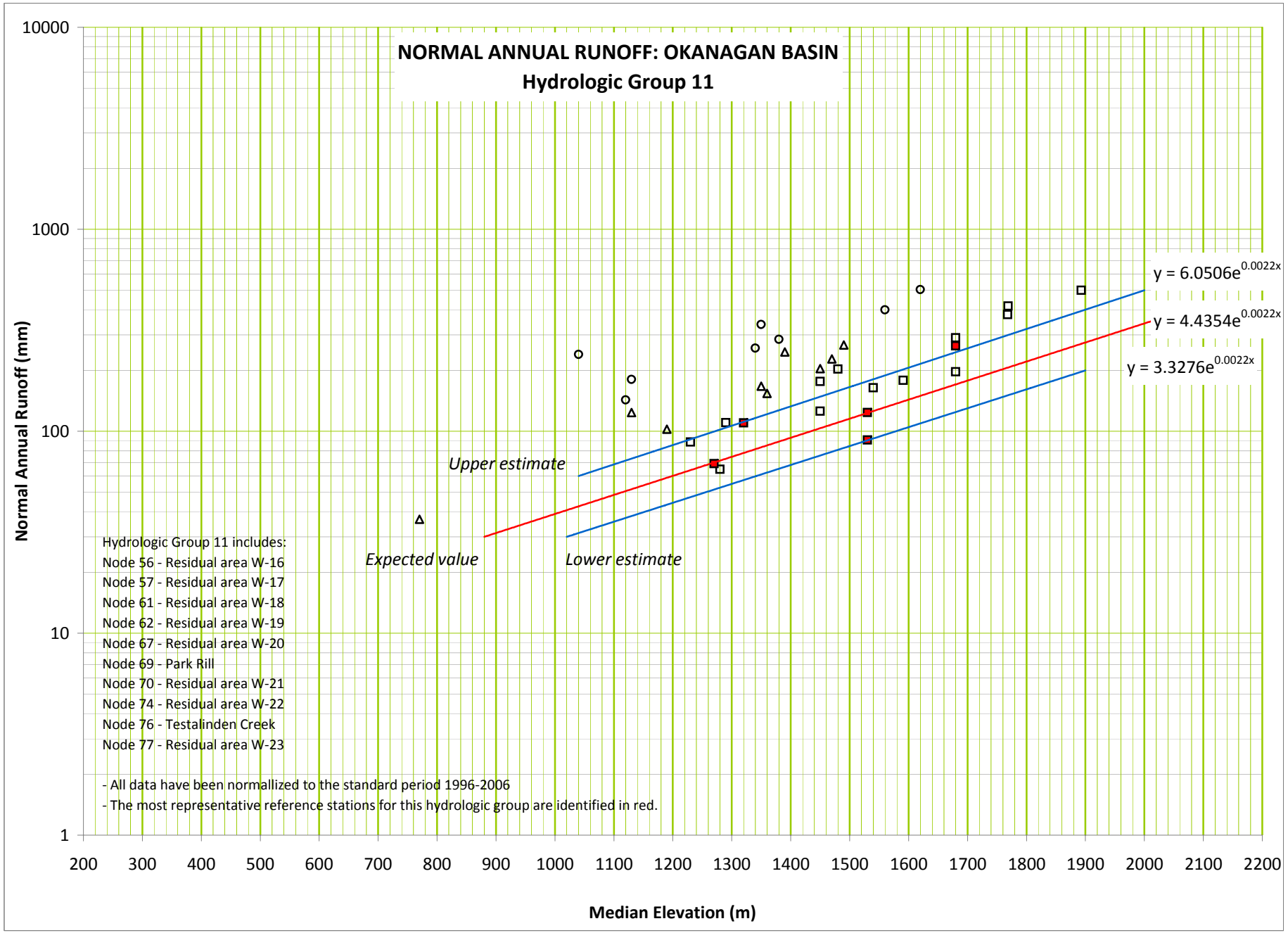

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 6
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 8.6077e^0.0022x
y = 5.6624e^0.0022x
y = 3.3276e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 6 includes:
Node 21 - Residual area E-3
Node 23 - Residual area E-4
Node 24 - Bellevue Creek
Node 25 - Residual area E-5
Node 34 - Chute Creek
Node 35 - Residual area E-6
Node 38 - Robinson Creek
Node 39 - Residual area E-7
Node 40 - Naramata Creek
Node 41 - Residual area E-8
Node 44 - Turnbull Creek
Node 45 - Residual area E-9
Node 46 - Penticton Creek
Node 50 - Residual area E-10
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.

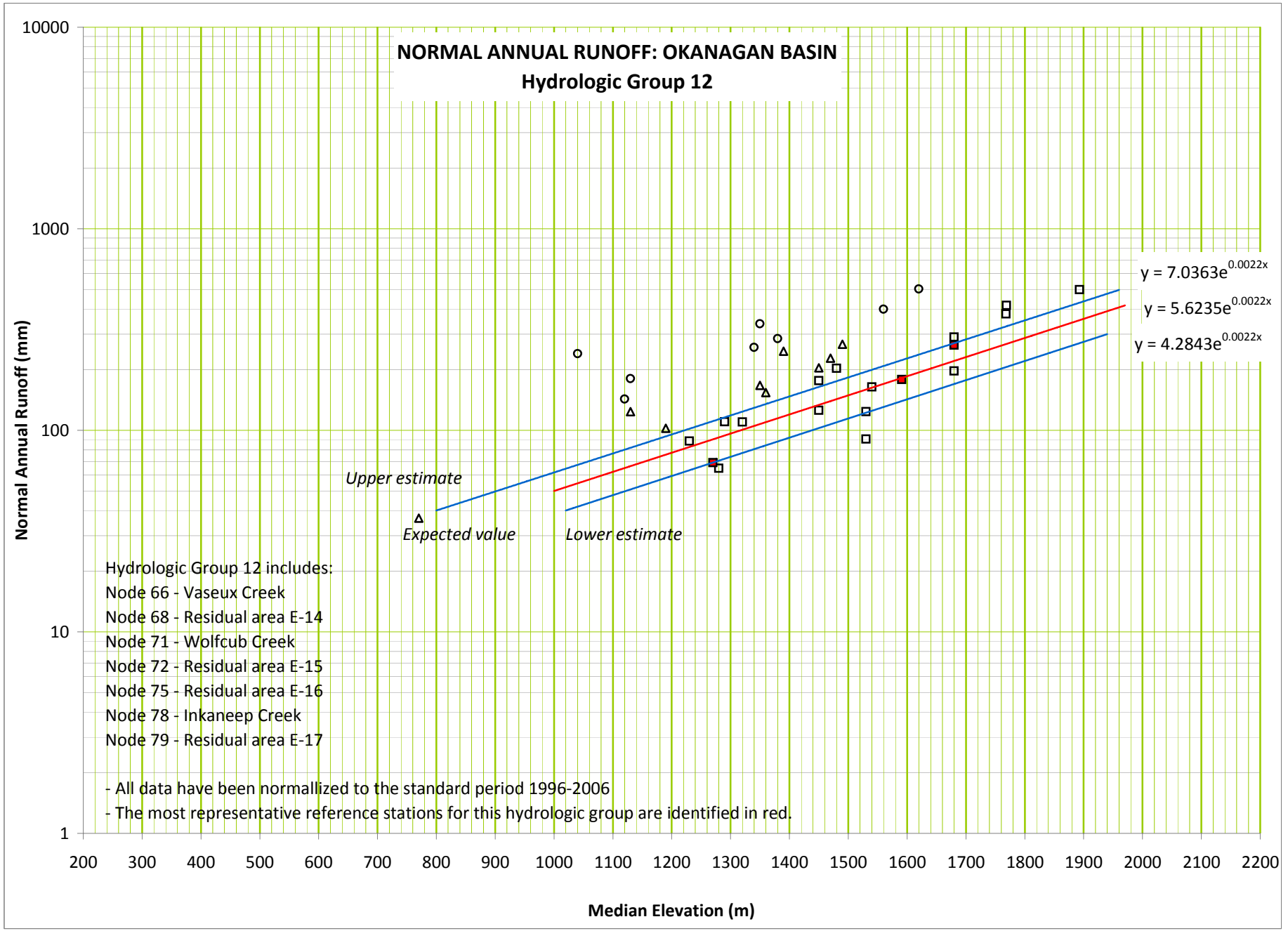

NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 7
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 8.0128e^0.0022x
y = 6.8951e^0.0022x
y = 5.9139e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 7 includes:
Node 20 - Mill (Kelowna) Creek
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.


NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 8
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 17.146e^0.0022x
y = 15.364e^0.0022x
y = 12.313e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 8 includes:
Node 22 - Mission Creek
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.


NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 9
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 7.46e^0.0022x
y = 4.6712e^0.0022x
y = 3.5777e^0.0021x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 9 includes:
Node 33 - Residual area W-11
Node 36 - Eneas Creek
Node 37 - Residual area W-12
Node 42 - Trout Creek
Node 43 - Residual area W-13
Node 49 - Residual area W-14
Node 51 - Shingle Creek
Node 53 - Residual area W-15
Node 55 - Marron River
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.


NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 10
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 8.4747e^0.0022x
y = 6.6392e^0.0022x
y = 5.1814e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 10 includes:
Node 52 - Ellis Creek
Node 54 - Residual area E-11
Node 60 - Shuttleworth Creek
Node 63 - Residual area E-12
Node 65 - Residual area E-13
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.


NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 11
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 6.0506e^0.0022x
y = 4.4354e^0.0022x
y = 3.3276e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 11 includes:
Node 56 - Residual area W-16
Node 57 - Residual area W-17
Node 61 - Residual area W-18
Node 62 - Residual area W-19
Node 67 - Residual area W-20
Node 69 - Park Rill
Node 70 - Residual area W-21
Node 74 - Residual area W-22
Node 76 - Testalinden Creek
Node 77 - Residual area W-23
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.


NORMAL ANNUAL RUNOFF: OKANAGAN BASIN
Hydrologic Group 12
Normal Annual Runoff (mm)
Median Elevation (m)
10000
1000
100
10
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
y = 7.0363e^0.0022x
y = 5.6235e^0.0022x
y = 4.2843e^0.0022x
Upper estimate
Expected value
Lower estimate
Hydrologic Group 12 includes:
Node 66 - Vaseux Creek
Node 68 - Residual area E-14
Node 71 - Wolfcub Creek
Node 72 - Residual area E-15
Node 75 - Residual area E-16
Node 78 - Inkaneep Creek
Node 79 - Residual area E-17
- All data have been normallized to the standard period 1996-2006
- The most representative reference stations for this hydrologic group are identified in red.

APPENDIX D

Key Hydrologic Studies Identified Using the Okanagan Information Database

Table D.1 Key hydrologic studies identified using the Okanagan Information Database that cover the Okanagan Basin.

Key Hydrologic Studies Identified using the Okanagan Information Database
Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. Ministry of Environment and Parks, Water Management Branch.
Canada-British Columbia Okanagan Basin Agreement. 1974. Main Report of the Consultative Board. Office of the Study Director, Penticton, B.C. March 1974.
Canada-British Columbia Okanagan Basin Agreement. 1974. Technical Supplement I: Water Quantity in the Okanagan Basin. Office of the Study Director, Penticton, B.C.
Canada-British Columbia Okanagan Basin Agreement. 1974. Technical Supplement III: Water Quantity Alternatives and Supporting Water Quantity Data. Office of the Study Director, Penticton, B.C.
Canadian Okanagan Basin Technical Working Group. 2004. Okanagan Fish/Water Management Tool. Online at http://www.essa.com/okfwm/
Cheng, J.D. 1979. Low Flow Characteristics of Tributary Streams in the Okanagan Basin.
Cohen, S. (ed.) and Kulkarni, T. (ed.). 2001. Water Management & Climate Change in the Okanagan Basin. Environment Canada & University of British Columbia.
Cohen, S., D. Nielsen, and R. Welbourn (editors). 2004. Expanding the dialogue on climate change & water management in the Okanagan Basin, British Columbia - Final Report. Environment Canada, Agriculture and Agri-Food Canada, and University of British Columbia.
Coulson, C.H. and Obedkoff, W. 1988. British Columbia Streamflow Inventory. B.C. Ministry of Environment, Lands and Parks. March, 1988.
Forest Research Extension Partnership (FORREX). 2003. Effects of Forest Management Activities on Streamflow in the Okanagan Basin, British Columbia: Outcomes of a Literature Review and a Workshop. FORREX, Kamloops, B.C. FORREX Series 9.
Letvak, D.B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley. B.C. Ministry of Environment. January, 1980.
Letvak, D.B. 1988. Runoff in Okanagan Valley 1983-87. Memorandum dated May 3, 1988. Ministry of Environment and Parks, Water Management Branch. File S2109, Study 272.
Merritt, W.S., Alila, Y., Barton, M., Taylor, B., Cohen, S. Unknown date. Exploring impacts of climate change on the hydrology of the Okanagan Basin. Unpublished.
Ministry of Environment (MOE), Okanagan Basin Implementation Board, 1982, Summary Report on the Okanagan Basin Implementation Agreement. September, 1982.
Obedkoff, W. 1971. Inventory of storage and diversion and their effect on flow records in the Okanagan River Basin. Canada-British Columbia Okanagan Basin Agreement, Water Quantity Studies. Task #36 - Estimation of Available Water Supply. Department
Obedkoff, W. 1973. Regionalization of Sub-Basin Hydrology. Preliminary Report No. 38. Prepared for the Okanagan Study Committee. March, 1973.

Table D.1 Cont'd.

Key Hydrologic Studies Identified using the Okanagan Information Database
Obedkoff, W. 1990. Okanagan Tributaries. Hydrology Section Report. May 1990.
Obedkoff, W. 1994. Okanagan Basin Water Supply. Ministry of Environment, Lands and Parks. March, 1994.
Reksten, D.E. 1973. Regionalization of Okanagan Sub-basin runoff from basin characteristics. Canada - British Columbia Okanagan Basin Agreement Water Quantity Studies. Task 53 - Regionalization of sub-basin hydrology. Department of Lands, Forests and Parks.
Summit Environmental Consultants Ltd. (Summit). 1999. Improved Seasonal Inflow Forecasting Models for Okanagan and Kalamalka Lakes. Prepared for the Ministry of Environment, Lands, and Parks. March, 1999.
Summit Environmental Consultants Ltd. (Summit). 2004. Okanagan Basin Study: Phase 1 - Information Review and Workshop (Proposal). Prepared for Land and Water British Columbia Inc. November, 2004.

Table D.2 List of relevant hydrologic studies identified using the Okanagan Information Database that focus on specific streams.

Node	Description	Potentially useful references for streamflow estimation
1	Vernon Creek at outlet of Kalamalka Lake	• Associated Engineering. 2004. Greater Vernon Water Master Water Plan - Addendum. Prepared for Greater Vernon Water. • Coulson, C.H. 1972. Report on Kalamalka-Wood Lake Basin Water Resource Management Study, Preliminary Report for Project 3 Annual Runoff Relationship. • District of Lake Country. 2005. Water supply and distribution system information provided to L. Uunila of Summit by Jack Allingham, Utility Manager. • Letvak, D.B. 1992. Kalamalka-Wood Lake Water Supply Hydrology. • McNeil, R.Y. 1991. Report on the Derivation of an Operating Rule Curve for Duteau Creek Reservoirs. • Reksten, D.E. 1971. 1971 Runoff Conditions in the Kalamalka-Wood Lake Drainage Basin. • Reksten, D.E. 1991. North Okanagan Low Flows (Vernon Cr, Deep Cr and Equesis Cr). B.C. Ministry of Environment, Water Management Branch, File S2108-3P, Study #350
3	Deep Creek	• Reksten, D.E. 1991. North Okanagan Low Flows (Vernon Cr, Deep Cr and Equesis Cr). B.C. Ministry of Environment, Water Management Branch, File S2108-3P, Study #350
8	Equesis Creek	• Letvak, D.B. 1994. Equesis Creek Water Supply Hydrology - 1994. • Reksten, D.E. 1991. North Okanagan Low Flows (Vernon Cr, Deep Cr and Equesis Cr). B.C. Ministry of Environment, Water Management Branch, File S2108-3P, Study #350
12	Vernon Creek (at mouth)	• Associated Engineering. 2004. Greater Vernon Water Master Water Plan - Addendum. Prepared for Greater Vernon Water.
18	Lambly Creek	• Dobson Engineering Ltd. (Dobson). 2001. Interior Watershed Assessment Update for the Lambly Creek Watershed. Prepared for Riverside Forest Products Ltd. And the Small Business Forest Enterprise Program (Penticton). December, 2001. • Dobson Engineering Ltd. (Dobson). 2002. Interior Watershed Assessment Update for the Lambly Creek Watershed. Prepared for Riverside Forest Products Ltd. February, 2002. • Letvak, D.B. 1989. Lambly Creek / Lakeview I.D. • Reksten, D.E. 1970. Preliminary Report on Lambly Creek Water Yield for Lakeview Irrigation District. Department of Lands, Forests, and Water Resources, Water Resources Service, File 0242512-15. • Summit Environmental Consultants Ltd (Summit). 2004. Trepanier Landscape Unit Water Management Plan, Volumes 1 and 2. Prepared for Regional District of Central Okanagan, Kelowna, B.C. and Ministry of Sustainable Resource Management, Kamloops, B.C. June 2004.
20	Kelowna (Mill) Creek	• Coulson, C.H. 1983. Memorandum re. Kelowna (Mill) Creek Flood Flows. • Reksten, D.E. 1973. Kelowna Creek Water Supply for Glenmore and Ellison Irrigation Districts.
22	Mission Creek	• Coulson, C.H. 1971. Review of Mission Creek Hydrology Study. • Hunter, H.I. 1971. Hydrology Study of Mission Creek Basin (South East Kelowna Irrigation District). Hydrology Division, File 0256957. • Lowen, D.A. and D.B. Letvak. 1981. Report on Groundwater - Surface Water Interrelationship Lower Mission Creek, B.C. • Obedkoff, W. 1978. Southeast Kelowna Irrigation District (S.E.K.I.D.) Watershed Hydrology. Memorandum to C.H. Coulson, Water Investigations Branch, March 1, 1978. • Reksten, D.E. 1972. Mission Creek Water Yield for Black Mountain Irrigation District. • Reksten, D.E. 1973. Update of Hydrology Studies for South East Kelowna Irrigation District ARDA Project. Water Investigation Branch, File 0256957. • Reksten, D.E. 1977. Mission Creek Folio Area.

Table D.2 Cont'd.

Node	Description	Potentially useful references for streamflow estimation
26	McDougall Creek	• Summit Environmental Consultants Ltd (Summit). 2004. Trepanier Landscape Unit Water Management Plan, Volumes 1 and 2. Prepared for Regional District of Central Okanagan, Kelowna, B.C. and Ministry of Sustainable Resource Management, Kamloops, B.C. June 2004.
28	Powers Creek	• Dobson Engineering Ltd. 2001. Stream Channel Monitoring Program for the Powers Creek Watershed (2000 Report - Year 1). Prepared for Riverside Forest Products Ltd. • Dobson Engineering Ltd. (Dobson). 2002. Interior Watershed Assessment Update for the Powers Creek Watershed. Prepared for Riverside Forest Products Ltd. February, 2002. • Summit Environmental Consultants Ltd (Summit). 2004. Trepanier Landscape Unit Water Management Plan, Volumes 1 and 2. Prepared for Regional District of Central Okanagan, Kelowna, B.C. and Ministry of Sustainable Resource Management, Kamloops, B.C. June 2004.
30	Trepanier Creek	• Cairns, R. 1992. Trepanier Creek Investigation Report. Ministry of Environment, Lands, and Parks. April, 1992. • Dobson Engineering Ltd. (Dobson). 1998. Watershed Assessment Report for the Trepanier Creek Watershed. Prepared for Gorman Brothers Lumber Ltd. November, 1998. • Hunter, H.I. 1978. Trepanier Creek Water Yield. Hydrology Division, Water Investigations Branch. June 16, 1978. • Reksten, D.E. 1973. Runoff Estimates for Trepanier Creek Watershed. • Summit Environmental Consultants Ltd (Summit). 2004. Trepanier Landscape Unit Water Management Plan, Volumes 1 and 2. Prepared for Regional District of Central Okanagan, Kelowna, B.C. and Ministry of Sustainable Resource Management, Kamloops, B.C. June 2004. • Trumbley Environmental Consulting Ltd. 1997. Peachland/Trepanier Creek Watershed Fisheries Habitat Assessment Procedure 1996. Prepared for District of Peachland, May 29, 1997. Project No. TO96129-WR
32	Peachland Creek	• Dobson Engineering Ltd. (Dobson). Interior Watershed Assessment for the Peachland Creek Watershed. Prepared for Riverside Forest Products Ltd. September, 1999. • Summit Environmental Consultants Ltd (Summit). 2004. Trepanier Landscape Unit Water Management Plan, Volumes 1 and 2. Prepared for Regional District of Central Okanagan, Kelowna, B.C. and Ministry of Sustainable Resource Management, Kamloops, B.C. June 2004. • Trumbley Environmental Consulting Ltd. 1997. Peachland/Trepanier Creek Watershed Fisheries Habitat Assessment Procedure 1996. Prepared for District of Peachland, May 29, 1997. Project No. TO96129-WR
36	Eneas Creek	• Reksten, D.E. 1973. Eneas Creek Flows.
40	Naramata Creek	• Obedkoff, W. 1982. Memorandum re. Naramata Irrigation District Study Tributary Annual Runoff Estimates. • Obedkoff, W. 1987. Naramata Creek Peak Flow Estimates. Memorandum dated September 16, 1987. Ministry of Environment and Parks, Water Management Branch. File S2106, Study 263.

Table D.2 Cont'd.

Node	Description	Potentially useful references for streamflow estimation
42	Trout Creek	• Associated Engineering. 1997. District of Summerland Water System Master Plan. Prepared for the District of Summerland, October 1997. • Cheng, J.D. 1981. Hydrologic Impact of Salvage Logging in the Trout Creek Watershed near Penticton, B.C. • Fitzpatrick, Joe. 2004. District of Summerland Water Coordination 2004 Report. Submitted to District of Summerland, November 26, 2004. • Letvak, D.B. 1989. Water Supply Analysis for Trout Creek and the District of Summerland. B.C. Ministry of Environment, Water Management Branch, File W3576. • Reksten, D.E. 1971. Available Hydrometeorological Data in the Trout Creek Watershed. • Reksten, D.E. 1972. Flood Flows in Trout Creek Basin. • Riordan, Sarah. 1986. The History of Summerland's Water System. Prepared for the Summerland Heritage Advisory Committee, August 1986. • Water Management Consultants. 2003. Trout Creek Hydrology and Operations Review (Draft). Prepared for District of Summerland, June 2003. • Weiss, E. 1981. Trout Creek Water Supply Study.
46	Penticton Creek	• City of Penticton. 2005. Water supply and distribution system information provided to L. Uunila of Summit by Brent Edge, Water Supervisor. • Schnorbus, M.A., R.D. Winkler, and Y. Alila. 2004. Modelling forest harvesting effects on maximum daily peak flow at Upper Penticton Creek. Ministry of Forests, Research Branch, Victoria, B.C. Extension Note 67. http://www.for.gov.bc.ca/hfd/pubs/docs • Thyer, M., J. Beckers, D. Spittlehouse, Y. Alila, and R. Winkler. 2004. Diagnosing a distributed hydrologic model for two high-elevation forested catchments based on detailed stand- and basin-scale data. Water Resources Research, Vol. 40, 1-20. • Winkler, R., D.L. Spittlehouse, B.A. Heise, T.R. Giles and Y. Alila. 2003. The Upper Penticton Creek Watershed Experiment: A Review at Year 20. Water Stewardship: How Are We Managing? Annual Conference of the Canadian Water Resources Association, Vancouver, BC.
66	Vaseux Creek	• Coulson, C.H. 1978. Vaseux Creek Water Supply for April 15 to June 15.
78	Inkaneep Creek	• Obedkoff, W. 1986. Inkaneep Creek Irrigation Study.

APPENDIX E

Technical Memorandum outling Revisions to Water Management and Use Data used in this study

POLAR GEOSCIENCE LTD.
Box 5721, 1005 Balsam Place, Squamish, BC, V8B 0C2

TECHNICAL MEMORANDUM

DATE	January 19, 2009
TO:	Brian Guy
CC:	
FROM:	Lars Uunila
RE:	Verification and revisions to selected water balance parameters for Vernon Creek (Nodes 1, 2, 12), Mission (Node 22), and Trout Creeks (Node 42)
FILE:	Polar No. 102001

Introduction

This memo summarizes the steps taken to verify and refine selected water use and management (water balance) parameters for the Vernon, Mission and Trout Creek sub-basins. The work was initiated on December 9, 2008 following concerns over the accuracy of selected database terms prepared by Dobson Engineering Ltd. (Dobson) during the Okanagan Basin Water Management and Use Study. A large part of this concern stems from inconsistencies between data summarized in the Final Water Management and Use Report (that was deemed satisfactory) and the accompanying database. Furthermore, based on a selected audit of water balance terms in the database developed by Dobson at several locations water use, water imports and exports could not be reconciled.

Since inaccuracies in the database could potentially cascade through several studies underway, interim measures to correct for such inaccuracies were urgently required. A general work plan was developed, which would cover two main aspects:

1. Part 1: Essential work necessary to provide satisfactory water use and management data required for streamflow naturalization; and
2. Part 2: Work necessary to verify water use linkages between sub-basins, source and end users (including water suppliers).

The scope of work summarized herein is limited to Part 1. Based on recent Working Group discussions (January 14, 2008), Part 2 may be incorporated directly into the Ministry of Agriculture's Irrigation demand model. This approach has potential to improve the ease of future scenario modeling.

Work Scope for Part 1

The main goal of Part 1 was to gain reasonable confidence in the following water use and management parameters that directly affect the accuracy of streamflow naturalization[1]:

[1] Streamflow naturalization is a process to estimate the natural streamflow based on a regulated streamflow record. It involves the removal of the effect of withdrawals, imports, and regulation of the water upstream of the point-of-interest.

- *Q_T (database term ID 15)* : volume of water imported from outside the contributing area of node *i* during time *t*,
- *Q_R (database term ID 12)*: the volume of water captured into (+) or released from (-) storage in node *i* during time *t*,
- *E_S (database term ID 16)*: volume of water extracted from surface sources in node *i* during time *t*.

Since alterations to the Water Management and Use database are time consuming, the scope of work was limited to the following three sub-basins:

- Vernon Creek (Nodes 1, 2, and 12),
- Mission Creek (Node 22), and
- Trout Creek (Node 42).

These three sub-basins were chosen not only because they represent the three largest sub-basins in the Okanagan, but also because Vernon and Mission Creeks have long (but regulated) streamflow records that facilitate streamflow naturalization. While the (regulated) streamflow records for Trout Creek have considerably more gaps they are nevertheless useful for developing naturalized streamflow estimates in conjunction with other estimation methods such as regionalization and various modeling techniques.

Although there are several other sub-basins where water use and management data could be re-examined in order to facilitate streamflow naturalization, alternative techniques are available to reasonably estimate natural streamflows in those (smaller) sub-basins - although at the cost of slightly greater levels of uncertainty.

Suggested Additional Water Balance Terms

As a refinement of the current water balance terms, we have identified additional terms to improve communication and facilitate reconciliation of water balance terms:

- ***Q_T_surf_imp***: volume of water imported to node *i* over time *t*, which directly enters the stream network;
- ***Q_T_surf_exp***: volume of water exported to node *i* over time *t*, which directly enters the stream network;
- ***Q_T_res_imp***: volume of water imported to node *i* over time *t* that enters a reservoir. This distinction is made to avoid the risk of "double counting" since this term represents water that will be reflected downstream by the term *Q_R*
- ***Q_T_res_exp***: volume of water exported to node *i* over time *t* that enters a reservoir. This distinction is made to avoid the risk of "double counting" since this term represents water that will be reflected by the term Q_R
- ***Q_T_dist_imp***: volume of water imported to node *i* over time *t*, which enters the distribution system (and not directly to the stream network). This distinction is made since this water does not directly report to nor influence streamflows in node *i*.
- ***Q_T_dist_exp***: volume of water exported to node *i* over time *t*, which enters the distribution system (and not directly to the stream network). This distinction is made since this water does not directly report to nor influence streamflows in node *i*.
- ***E_S_bulk***: total bulk volume of water extracted from node *i* during time *t* from surface water sources. This includes water extracted by all users including major water suppliers and independent water licensees. The term E_S_bulk is used since it is unknown if the ***E_S*** term presented by Dobson (2008) includes the independent water licensees or not.

Import and export terms for ***Q_T*** are used to clearly identify which node water is coming from and going to. So in every instance where water crosses a divide there are equal import and export terms on opposite sides of the divide. As a result of the above-noted changes, use of the original terms ***Q_T*** and ***E_S*** should be avoided. The term ***Q_R*** remains unchanged however.

Of the noted variations of the original term ***Q_T***, knowledge of ***Q_T_surf_imp*** and ***Q_T_surf_exp*** are the key ones for streamflow naturalization. In the three sub-basins investigated (Vernon, Mission, and Trout) however, there are no instances where these apply. Instances of ***Q_T_res_imp*** were identified in the Mission and Trout Creek sub-basins and ***Q_T_dist_imp*** and ***Q_T_dist_exp*** were identified in all three sub-basins. While important for water balance modeling, these last four parameters were not necessary for streamflow naturalization and were therefore not evaluated.

Verification and Refinement Methods
The following sections, organized by sub-basin and water balance parameter, summarize the methods and assumptions used to develop revised estimates for the selected sub-basins.

The work was led by Lars Uunila, P.Geo. of Polar Geoscience Ltd. (Polar) with technical assistance provided by Drew Lejbak, M.Sc. and Dan Austin, M.G.I.S. of Summit Environmental Consultants Ltd. (Summit), Antonio Faccini of AF Consulting Ltd. (AF), and Bob Hrasko, P.Eng. of Agua Consulting Ltd. (Agua). A kick off meeting was held at the Black Mountain Irrigation District office on December 15, 2008. At this meeting information was reviewed, and assignments were confirmed. As a result, Polar and Summit were principally responsible for Vernon and Trout Creek revisions while Agua and AF were responsible for Mission Creek revisions.

Vernon Creek (Nodes 1, 2, and 12)
E_S_bulk
There are two major water suppliers in the Vernon Creek sub-basin: Greater Vernon Water (GVW) and District of Lake Country (DLC). Establishing an accurate estimate of the bulk water use in the sub-basin involved re-examining existing data and obtaining some new data from these suppliers as well as considering the number of independent water users in the sub-basin. These are described below.

Greater Vernon Water (GVW)
Greater Vernon Water (GVW) sources water from:

- Duteau Creek (within the Shuswap River watershed),
- Kalamalka Lake,
- Deer Creek,
- Okanagan Lake, and
- Groundwater.

For the purposes of this assignment, estimates of Deer Creek and Kalamalka Lake bulk water use were the key objectives. Water from Duteau Creek is considered an import to the distribution system and therefore does not directly affect streamflows within the Vernon Creek sub-basin. Groundwater and Okanagan Lake water use are relatively small and also do not directly affect streamflows in the sub-basin.

Dobson (2008) reported estimates of annual and monthly bulk water use data for GVW; however, the methods used to distribute the annual values into monthly and weekly estimates were not

indicated. The following identifies the assumptions that were necessary to arrive at independent estimates required to verify the data reported by Dobson (2008):

1. Based on a review of data obtained independently from North Okanagan Water Authority (2002) and Clark (2008), the annual estimates of bulk water use presented in Appendix B of Dobson (2008) were assumed to be reasonable.
2. Renee Clark (GVW Senior Water Quality Technologist) provided actual water use data for Duteau and Deer Creeks for 1997-2003 – data that was not explicitly presented in Dobson (2008).
3. The annual ***E_S_bulk*** values were estimated as follows:
    a. The distribution of bulk water usage by source reported in 2007 by GVW (Clark 2008) was assumed constant (Duteau Creek = 62.6%; Kalamalka Lake = 31.7%; Deer Creek = 2.4%; BX Creek = n/a; Okanagan Lake = 0.2%; Groundwater = 3.1%).
    b. For 1997-2003, the actual Duteau Creek and Deer Creek water use data was subtracted from the total annual water use estimates from all sources. The remainder was split between the Kalamalka Lake source and groundwater (GW), based on the 2007 GVW distribution. As a result, the Kalamalka Lake source represents 91.1% of the remainder of the annual bulk water use, while groundwater represents 8.9%. Okanagan Lake water use was disregarded.
    c. For 1996 & 2004-2006, actual water use data was not available for any sources. As a result, for Duteau Creek and Deer Creek the 1997-2003 average annual bulk water use from these sources was calculated with respect to the total bulk water use (Duteau = 66.7%; Deer = 3.0%). These percentages were assumed representative of the missing years and were applied to the annual bulk volumes. The remainder of the annual bulk volume was split between the Kalamalka Lake intake and groundwater, as noted above.
4. The monthly ***E_S_bulk*** values were estimated as follows:
    a. For the Kalamalka Lake intake, the monthly water use distribution for the City of Vernon, reported in the GVW drought management plan (GVS 2002) was assumed representative.
    b. For Deer Creek, actual data was available for 1997-2003. For all other years, the average percentage of the 1997-2003 monthly distribution was assumed representative (May = 1.5%; June = 16.1%; July = 42.8%; August = 36.6%; September = 3.0%).
5. The weekly ***E_S_bulk*** values were estimated as follows:
    a. For the Kalamalka Lake intake, the weekly estimates assumed an even usage of water for each day of the month. A 5-week moving average was then applied to smooth the results.
    b. For Deer Creek, actual data was available for 1997-2003. For all other years, the weekly estimates assumed an even usage of water for each day of the month. A 5-week moving average was used to smooth the results.

District of Lake Country (DLC)

Dobson (2008) reported estimates of annual and monthly bulk water use data for DLC for 2002-2006, partial data for 1996-1998 & 2000-2001, and no data for 1999. The following identifies the assumptions that were necessary to arrive at independent estimates required to check the data reported by Dobson (2008):

1. Patti Hansen (DLC Water Quality Technician) provided actual water use data for the three major DLC water systems:
    a. Winfield Okanagan Center Water System (WOCWS);
    b. Oyama Water System (OWS); and
    c. Wood Lake Water System (WLWS)

2. The annual ***E_S_bulk*** values for DLC were estimated as follows:
    a. Actual annual bulk water use data was available for:
        i. WOCWS (1996-1998 & 2002-2006);
        ii. OWS (1999-2006); and
        iii. WLWS (1996-1998 & 2000-2006).
    b. For the DLC water systems missing annual bulk water use data, estimates were developed from the 2002-2006 distribution, as these were the only years with overlapping records by all three water systems. The 2002-2006 average water use percentage split between all DLC water systems was assumed the same each year (WOCWS = 58.5%; WLWS = 29.3%; OWS = 12.2%).
3. The monthly ***E_S_bulk*** values for DLC were developed from the average monthly distributions calculated from the actual DLC bulk water use data for each water system.
4. The weekly ***E_S_bulk*** values for DLC were estimated by assuming an even usage of water for each day of the month. A 5-week moving average was used to smooth the results.

Independent Water Licenses

In order to account for the number of water users that independently obtain water, we assumed that the volume of water licensed represented the volume of water used each year. No adjustment was made for water use in any given year, although it is likely that water use would be higher in the drier years and lesser in the wetter years. The assumption above is considered conservative and likely overestimates water use on average. The methods below were used to estimate the water use by the independent water licensees.

1. Independent water licences for the Vernon Creek watershed (minus the major water suppliers GVW and DLC) were grouped into three categories:
    a. Water licences on streams feeding Kalamalka and Wood Lakes (Node 1),
    b. Water licences on Kalamalka and Wood Lakes (Node 2); and
    c. Water licences on streams feeding Vernon Creek downstream of Kalamalka Lake (Node 12).
2. The annual ***E_S_bulk*** values for each group were assumed equal to the total licensed volume available for extraction.
3. The monthly ***E_S_bulk*** values for each group were estimated by distributing the annual volumes into monthly volumes according to the type of water licence. For agricultural, domestic and small waterworks, following distributions were assumed:

Month	**Agricultural water use (%)**	**Domestic (indoor and outdoor) water use (%)**	**Waterworks (%)**
January	0	3.6	3.0
February	0	3.6	2.8
March	0.5	3.9	3.0
April	4.0	5.9	4.0
May	13.7	11.4	9.0
June	15.0	12.1	15.0
July	24.6	17.6	20.0
August	25.0	17.8	24.0
September	13.4	11.2	9.0
October	3.8	5.7	4.0
November	0	3.6	3.2
December	0	3.6	3.0
Annual	**100**	**100**	**100**
Source:	Summit (2004)	Summit (2004)	Greater Vernon Water 2007 water use records (Hansen 2008)

For other water licences (e.g. enterprise, processing, stockwatering), water use was assumed constant throughout the year.

4. Weekly ***E_S_bulk*** values for each group were then estimated by developing a weekly distribution that was consistent with the monthly water use patterns.

Q_R (Upland reservoirs in Node 1)

No data is available on reservoir operations (e.g. reservoir levels, inflows or outflows) for 1996 to 2006 for the storage reservoirs in the Vernon Creek sub-basin (Node 1). The following identifies the steps taken and the necessary assumptions used to arrive at estimates of Q_R for Node 1.

1. All major reservoirs in the uplands were identified. This includes:
    a. Swalwell Lake (licensed storage 11925 ML),
    b. Crooked Lake (licensed storage 4932 ML),
    c. Oyama Lake (licensed storage 6150 ML),
    d. Dammer Lake (licensed storage 263 ML), and
    e. King Edward Lake (licensed storage 1356 ML).
2. Since we have no available information on actual storage volumes, we assumed live storage is equal to licensed storage. The total licensed storage for all reservoirs is 24,847 ML.
3. Water use from each system was estimated based on the bulk water use data provided by the major water suppliers (District of Lake Country and Greater Vernon Water). From this data, the distribution of water use on a weekly basis was determined for 1996-2006.
4. Natural inflows to reservoirs were estimated as follows:
    a. Reservoir level records for Swalwell Lake (08NM062) and Crooked Lake (08NM163) as well as outflows from Swalwell Lake (08NM022) were compiled. Data was only available for 1970-81 for all three gauges, so this was the period used for analysis.
    b. Gaps in reservoir level records were filled assuming a linear change between known lake levels.
    c. The average weekly outflows from Swalwell Lake for 1970-81 were calculated.
    d. The end of week lake levels on both Crooked and Swalwell Lakes were identified, and the change in storage was calculated for each reservoir assuming lake areas of 1.946 km^2 (Crooked) and 3.055 km^2 (Swalwell) by assuming vertical shorelines.
    e. Inflows were calculated by summing the outflows and total change in reservoir storage (i.e. both lakes).
    f. The 1970-81 inflows were compared with the 1970-81 streamflows for Coldstream Creek above the municipal intake (WSC 08NM142) – this is the nearest station with a natural record covering both 1970-81 and 1996-2006. Whiteman Creek was also considered, but its correlation was lower than Coldstream Creek. Weekly scaling factors were identified to predict 1996-2006 unit reservoir inflows based on Coldstream Creek streamflow records.
    g. Using GIS, the total drainage area (102.9 km^2) and the median elevation (1,420 m) were identified for all contributing areas above the upland storage reservoirs in the Vernon Creek basin. Based on regional hydrologic relations, the expected annual runoff for the total contributing area is estimated at 250 mm.
    h. Based on the records for Coldstream Creek, total weekly inflows (to all reservoirs) were estimated and values were adjusted to ensure average 1996-2006 runoff is consistent with the regionally-based runoff estimate of 250 mm.
    i. Inflow estimates were compared with estimates developed by Letvak (1977, 1987) to ensure they were reasonable.

5. In each year we assumed the total reservoir capacity is at 35% (16,151 ML) on November 30 (in Week 48). This is an assumption reported in the Water Management and Use Final Report. It represents the only assumed "fixed point" in the reservoir operations.
6. We assumed that filling of reservoirs occurs only between April 2 and July 1 (Weeks 14-26) based on the estimated natural inflows. Once total reservoir capacity is reached (24,847 ML), water is spilled. Spilled water is ignored in the analysis. In some years reservoirs are filled, and in some they are not – depending on the natural inflow for that year.
7. We assumed that the total volume of water captured during weeks 14 to 26 is released over weeks 14-52 of that year and weeks 1-13 of the following year based on the 1996-2006 weekly distribution of actual water use. This distribution is based on bulk water use data from District of Lake Country and Greater Vernon Water. Note that relatively small volumes were assumed to be released during winter and early spring. In reality, this water is likely supplied by natural inflows downstream of the reservoirs.
8. The parameter Q_R is calculated for each week (1996-2006) by subtracting the water released from the water captured each week. Positive values represent net reservoir filling; negative values represent reservoir releases. Note that we have adopted this convention to be consistent with the Dobson Engineering Ltd. database.

Q_R (Kalamalka/Wood Lake - Node 2)

In order to evaluate the regulation effect of Kalamalka/Wood Lake[2] on streamflows of Vernon Creek several steps were taken, as follows:

1. Daily streamflow records for 1996 to 2006 at Vernon Creek at the outlet of Kalamalka Lake (08NM065) were compiled. The net weekly outflow (ML) from Kalamalka Lake for 1996 to 2006 was calculated based on these records.
2. Daily water level records from Kalamalka Lake at Vernon Pumphouse (08NM143) were compiled and converted to geodetic elevations. Daily lake elevations were converted to weekly values for 1996 to 2006. The combined Kalamalka and Wood Lake storage volumes were estimated based on the lake elevations and lake rating curves developed by the GIS staff at Summit Environmental Consultants Ltd. Weekly net change in lake storage volume was calculated for 1996 to 2006.
3. Lake evaporation data for Kalamalka/Wood Lake were compiled from the Okanagan Water database (on December 9, 2008) and reduced to weekly values.
4. Net weekly inflows to Kalamalka/Wood Lake were calculated by summing the net outflow from Kalamalka/Wood Lake, the change in lake storage, and the evaporation over each week from 1996 to 2006.
5. Weekly bulk water extraction (***E_S_bulk***) for all streams draining into Kalamalka/Wood Lake and from the lakes directly were compiled for 1996 to 2006 (see above). These values includes bulk water use by Greater Vernon Water, District of Lake Country, and independent water licensees.
6. The reservoir component of streamflow from all upland reservoirs (***Q_R***) for all upland reservoirs that feed to Kalamalka/Wood Lake were compiled (see ***Q_R*** for Node 1 above).
7. Natural weekly inflows to Kalamalka/Wood Lake were calculated by summing the net inflow with the estimated bulk water extraction (***E_S_bulk***) and reservoir component of streamflows (***Q_R*** for Node 1).
8. Natural outflows from Kalamalka/Wood Lake were estimated by developing a water balance model for the lake. This model assumed an initial natural lake elevation of 391.0 m on January 1, 1996 and operated by summing gains (natural inflow) and losses (natural outflow and evaporation) from the lake at a weekly time step. Natural outflows were estimated using

[2] Kalamalka and Wood Lake were considered together as one reservoir for this analysis.

Haestad Flow Master hydraulic modeling software assuming a natural channel with a width of 4.0 m, slope of 0.01 and roughness value of 0.035. All assumed values were based on field observation and measurement made on December 18, 2008 by Lars Uunila, P.Geo.

9. The regulation effect of Kalamalka/Wood Lake on streamflows in Vernon Creek (***Q_R*** in Node 2) was determined on a weekly basis by subtracting the recorded (net or regulated) outflow from the estimated natural inflow. Positive values represent net reservoir filling; negative values represent reservoir releases. Note that we have adopted this convention to be consistent with the Dobson Engineering Ltd. database.

Q_R (Node 12)

There are no known reservoir operations in Node 12 that feed the stream network.

Mission Creek (Node 22)

E_S_bulk

Black Mountain Irrigation District and South East Kelowna Irrigation District

There are two major water suppliers in the Mission Creek sub-basin: Black Mountain Irrigation District (BMID) and South East Kelowna Irrigation District (SEKID). Establishing an accurate estimate of the bulk water use in the sub-basin involved re-examining existing data as well as meeting and calling representatives of BMID and SEKID to obtain independent records from those suppliers. In addition, independent water users with water licences were also considered. The steps taken are described below.

1. Surface water withdrawals by SEKID from the Mission Creek sub-basin were compiled from two sources: Summary Spreadsheet supplied by SEKID and Kelowna Joint Water Committee (KJWC) (2005). The spreadsheet had complete monthly data for 1996 to 2006.
2. Groundwater usage by SEKID on a monthly basis was compiled from two sources: Summary Spreadsheet supplied by SEKID and Kelowna Joint Water Committee (KJWC) (2005). The spreadsheet had incomplete data on groundwater pumpage. It only provided flows from 1 of 3 wells (O'Reilly Well) for years 2002 – 2006 on a monthly basis. The KJWC information was also incomplete providing annual flows from each of the 3 wells for years 1996 to 2004.
3. Surface water usage by BMID on an annual basis was compiled. Information sources included the KJWC (2005) and Agua Consulting (2007). Both sources provided information on annual basis and covered the period of 1996 to 2006.
4. Groundwater usage for BMID on an annual basis was compiled. Information sources included the KLWC (2005) and Agua Consulting (2007). Both sources provided information on an annual basis and covered the period of 1996 to 2006.
5. ***E_S_bulk*** data was compared between Dobson (2008) and the independent sources noted above. The differences were calculated as a percentage of the annual water use obtained from KJWC report, SEKID spreadsheet and BMID reports. The differences for BMID annual water use were typically lower than 5%, but in some years the differences were considerable: 2004 (10.3%), 1997 (19%). The difference in 2004 might be explained by the fact that monthly water use data for the last 4 months of the year were missing in the Dobson database. The 1997 data in Dobson (2008) was suspicious since it was exactly the same as data for year 2000. Differences for SEKID were lower with only 2005 data having an error in the range of 27%. However, Dobson did not present any surface water use data from SEKID for 1996 to 2002.
6. For BMID surface water withdrawals in the Mission Creek sub-basin, the Dobson data was considered reasonable, but was refined by estimating missing data for 2004 by averaging the monthly flows for years 1996, 1999 – 2003, and 2002 – 2006. The Dobson data for 1997 was discarded and replaced with the estimated annual values from Agua (2007). Monthly

estimates were developed for 1997 by assuming an average monthly distribution based on the available Dobson data.

7. For SEKID surface water withdrawals from the Mission Creek sub-basin, the incomplete Dobson data was discarded in favor of the complete dataset obtained from SEKID.

Independent Water Licenses

In order to account for the number of water users that independently obtain water we assumed that the volume of water licensed represented the volume of water used each year. No adjustment was made for water use in any given year, although it is likely that water use would be higher in the drier years and lesser in the wetter years. The assumption above is considered conservative and likely overestimates water use on average. The methods below were used to estimate the water use by the independent water licensees.

1. The annual ***E_S_bulk*** values were assumed equal to the total licensed volume available for extraction.
2. The monthly ***E_S_bulk*** values were estimated by distributing the annual volumes into monthly volumes according to the type of water licence. For agricultural, domestic and small waterworks, following distributions were assumed:

Month	**Agricultural water use (%)**	**Domestic (indoor and outdoor) water use (%)**	**Waterworks (%)**
January	0	3.6	3.0
February	0	3.6	2.8
March	0.5	3.9	3.0
April	4.0	5.9	4.0
May	13.7	11.4	9.0
June	15.0	12.1	15.0
July	24.6	17.6	20.0
August	25.0	17.8	24.0
September	13.4	11.2	9.0
October	3.8	5.7	4.0
November	0	3.6	3.2
December	0	3.6	3.0
Annual	**100**	**100**	**100**
Source:	Summit (2004)	Summit (2004)	Greater Vernon Water 2007 water use records (Hansen 2008)

For other water licences (e.g. enterprise, processing, stockwatering), water use was assumed constant throughout the year.

3. Weekly ***E_S_bulk*** values for each group were then estimated by developing a weekly distribution that was consistent with the monthly water use patterns.

Q_R

The following summarizes the steps taken to independently estimate ***Q_R*** for Mission Creek:

1. McCulloch Reservoir level data provided by SEKID was considered reliable, however due to substantial data gaps the BMID reservoir storage data, it could not be used without considerable analysis and gap filling, which was deemed too time consuming. We therefore assumed the McCulloch Reservoir operational patterns would be representative of the BMID reservoirs given their proximity, location and similar customer base.
2. SEKID supplied McCulloch Reservoir release data for 2002 to 2006 in a spreadsheet extracted from their SCADA system. This data provided instant flows released from

McCulloch Reservoir at 1 pm each day from January 10, 2001 to December 31, 2006. A few days of data were missing. Gaps were filled by interpolating and assuming a linear change over time and assuming the 1 pm release represented the average daily release.

3. The monthly change in McCulloch Reservoir storage volume between 2002 and 2006 was calculated based on available reservoir level records.
4. The McCulloch Reservoir filling/emptying pattern was applied to all BMID reservoirs in the Mission Creek sub-basin. It was assumed that the last reservoir level measurement of the year was constant to March 31 of the next year. Storage volume and storage volume changes for each month were calculated.
5. Based on some simplifications for a weekly time step and relatively small reservoirs, it was assumed that ***Q_R*** would be reflected by the change in reservoir storage volume. The value ***Q_R*** is defined as Outflow(natural) – Outflow(regulated). Given: Inflow(regulated) = Inflow(natural), and assuming Inflow(natural) = Outflow(natural), then Inflow(natural) = Inflow(regulated) = Outflow(natural). By definition: Change in storage = Inflow (regulated)-Outflow(regulated), so Change in storage = Outflow (natural) – Outflow (regulated) = ***Q_R***.
6. While monthly storage volumes at McCulloch reservoir were supplied by SEKID for years 1997 – 2006, 1996 data was missing. Data for 1996 was estimated assuming that storage variation changes as a function of water usage. In 1996 monthly surface water usage was known and it was found that the highest correlation was with year 2003 data. Using the monthly water usage data for years 1996 and 2003 and the storage volume variation for year 2003 and assuming a linear ratio, the 1996 volume storage change was estimated.
7. Monthly McCulloch Reservoir volume changes for 1996 to 2006 were disaggregated into weekly estimates.
8. Since there is no storage data at Brown, Fish and Long Meadows Lakes, the McCulloch Reservoir volume changes were increased by a correction factor of 5.7% to account for storage in Brown Lake, Fish Lake and Long Meadow Lakes. The 5.7% factor was obtained as the ratio of storage developed for Brown Lake, Fish Lake and Long Meadow Lakes divided by storage developed at McCulloch Reservoir. The source information for developed storage is the KJWC (2007).
9. The available BMID reservoir storage data was used to obtain storage volumes at weekly intervals. The available data provides the stored volume at the first day of the month and 15th day of each month. Adjustments were carried out on the BMID data to obtain 1996 to 2006 volumes at the weekly time step.
10. Q_R was calculated by totaling the estimated weekly volume of water stored and released from all BMID and SEKID reservoirs in the Mission Creek sub-basin.

Q_T_res_imp (Stirling Creek to Mission Creek)

One surface water import was identified in the Mission Creek sub-basin - the diversion of Stirling Creek (in the Kettle River watershed) to McCulloch Reservoir by Southeast Kelowna Irrigation District (SEKID). SEKID were contacted to obtain all information they could provide on this diversion. Since about October 2003, Dobson Engineering Ltd. has been responsible for gauging the flows in Stirling Creek, which are diverted into McCulloch Reservoir. However, only monthly data (for the summer period) were provided for 2004 to 2006. Estimates of monthly flows for 1996 to 2003 were made by identifying the patterns of runoff at Two-Forty One Creek near Penticton (08NM241) for 1996-2003 with respect to the 2004-2006 average runoff. Weekly values were estimated based on the monthly data assuming a linear change between one month and another. Zero imports were assumed during the winter months (November to April).

Trout Creek (Node 42)
E_S_bulk
District of Summerland

The District of Summerland is the principal water supplier in the Trout Creek sub-basin. Dobson (2008) reported actual annual and monthly bulk water use data for the District of Summerland. This data was checked against water use data in Agua Consulting Inc. (2008) and was found to be reasonably consistent. However, the weekly estimates of ***E_S_bulk*** provided in the database do not reconcile with the monthly and annual data in the report. We therefore assumed the monthly and annual data provided by Dobson (2008) was correct and used it to re-calculate the weekly water use estimates. Water use during a given month was assumed constant. However, to minimize sudden changes in the dataset from one month to another, a 5-week moving average was used to smooth the results.

Independent Water Licenses

In order to account for the number of water users that independently obtain water we assumed that the volume of water licensed represented the volume of water used each year. No adjustment was made for water use in any given year, although it is likely that water use would be higher in the drier years and lesser in the wetter years. The assumption above is considered conservative and likely overestimates water use on average. The methods below were used to estimate the water use by the independent water licensees.

4. The annual ***E_S_bulk*** values were assumed equal to the total licensed volume available for extraction.
5. The monthly ***E_S_bulk*** values were estimated by distributing the annual volumes into monthly volumes according to the type of water licence. For agricultural, domestic and small waterworks, following distributions were assumed:

Month	**Agricultural water use (%)**	**Domestic (indoor and outdoor) water use (%)**	**Waterworks (%)**
January	0	3.6	3.0
February	0	3.6	2.8
March	0.5	3.9	3.0
April	4.0	5.9	4.0
May	13.7	11.4	9.0
June	15.0	12.1	15.0
July	24.6	17.6	20.0
August	25.0	17.8	24.0
September	13.4	11.2	9.0
October	3.8	5.7	4.0
November	0	3.6	3.2
December	0	3.6	3.0
Annual	**100**	**100**	**100**
Source:	Summit (2004)	Summit (2004)	Greater Vernon Water 2007 water use records (Hansen 2008)

For other water licences (e.g. enterprise, processing, stockwatering), water use was assumed constant throughout the year.

6. Weekly ***E_S_bulk*** values for each group were then estimated by developing a weekly distribution that was consistent with the monthly water use patterns.

Q_R

Fortunately there is a reasonable record of reservoir storage volumes for the reservoirs operated by the District of Summerland. This record was provided in digital spreadsheet form by David Sellars of Water Management Consultants Ltd. The following identifies the steps taken and the necessary assumptions used to arrive at estimates of ***Q_R*** for Node 42.

1. The daily reservoir storage volume data for District of Summerland reservoirs were compiled. Data for 1996 to 2003 was available.
2. We confirmed that the reservoir data represents all the major reservoirs operated by the District of Summerland (i.e. Headwaters 1, Headwaters 2, Headwaters 3, Headwaters 4, Thirsk, Whitehead, Crescent, Isintok, and Tsuh). The Meadow Valley Irrigation District operates Darke Lake reservoir (fed partially by Munroe Lake outflows), however the only information known on the Darke Lake reservoir is its live storage of 743 ML (Letvak 1989). This represents about 6% of the total reservoir capacity of nine (9) District of Summerland reservoirs (about 11,500 ML).
3. Gaps in the daily reservoir storage volume record between 1996 and 2006 were filled by assuming linear change between one level and another. For larger gaps and for missing data in 2004-2006 the percentage of total storage on a given date was approximated using data obtained for McCulloch Reservoir operated by SEKID in the Mission Creek sub-basin. Some smoothing was necessary to ensure realistic water level changes over time.
4. Weekly changes in total reservoir volume (ML) were calculated for 1996 to 2006. These changes represent the reservoir component of streamflow (***Q_R***).
5. To account for Darke Creek reservoir operations, an additional 6% was added to all weekly filling or release data for Summerland.

Q_T_res_imp

Trout Creek Water Use Plan Consultative Committee (2005) indicate that Finley and Lapsley Creeks, which are located in the Eneas Creek sub-basin, are diverted into Darke Lake (reservoir) in the Trout Creek watershed. This is done to meet all water demands by the Meadow Valley Irrigation District, which has an intake located on Darke Creek.

Actual bulk diversion volumes were not available; however, Letvak (1989) indicated that 500 acre-feet from Lapsley Creek are licensed for diversion from Lapsley Creek (to Darke Lake in the Trout Creek sub-basin). This diversion was assumed to occur from April 1 to June 30 during freshet.

The annual diversion volume was distributed into weekly estimates based on the percentage distribution of the naturalized Eneas Creek hydrographs (weeks 14 – 26 only) for 1996-2006 prepared by Polar (2009).

Summary

In summary, water balance parameters that directly influence streamflow naturalization were revised for Vernon Creek (Nodes 1, 2, and 12), Mission Creek (Node 22), and Trout Creek (Node 42). In some cases the differences between the revised data and the original Dobson database (as of December 2008) were small, but in several cases the differences were considerable and could have resulting in significant errors. In some cases, the database values developed by Dobson (2008) were simply incorrect and have now been corrected. The revised data described herein will be uploaded to the Okanagan Water database and will reduce uncertainty in streamflow naturalization in the three largest sub-basins in the Okanagan.

Attachments

The following spreadsheet files provide the revised weekly time series data:

File	Sub-basin	Revised data
Revised WMU data Vernon Cr.xls	Vernon Creek (Nodes 1, 2, and 12)	E_S_bulk (Node 1) E_S_bulk (Node 2) E_S_bulk (Node 12) Q_R (Node 1) Q_R (Node 2) Q_R (Node 12)
Revised WMU data Mission Cr.xls	Mission Creek (Node 22)	E_S_bulk (Node 22) Q_R (Node 22) Q_T_res_imp (Node 22)
Revised WMU data Trout Cr.xls	Trout Creek (Node 42)	E_S_bulk (Node 42) Q_R (Node 42) Q_T_res_imp (Node 42)

With the assistance of ESSA Technologies, we intend to upload these data to the Okanagan Water database.

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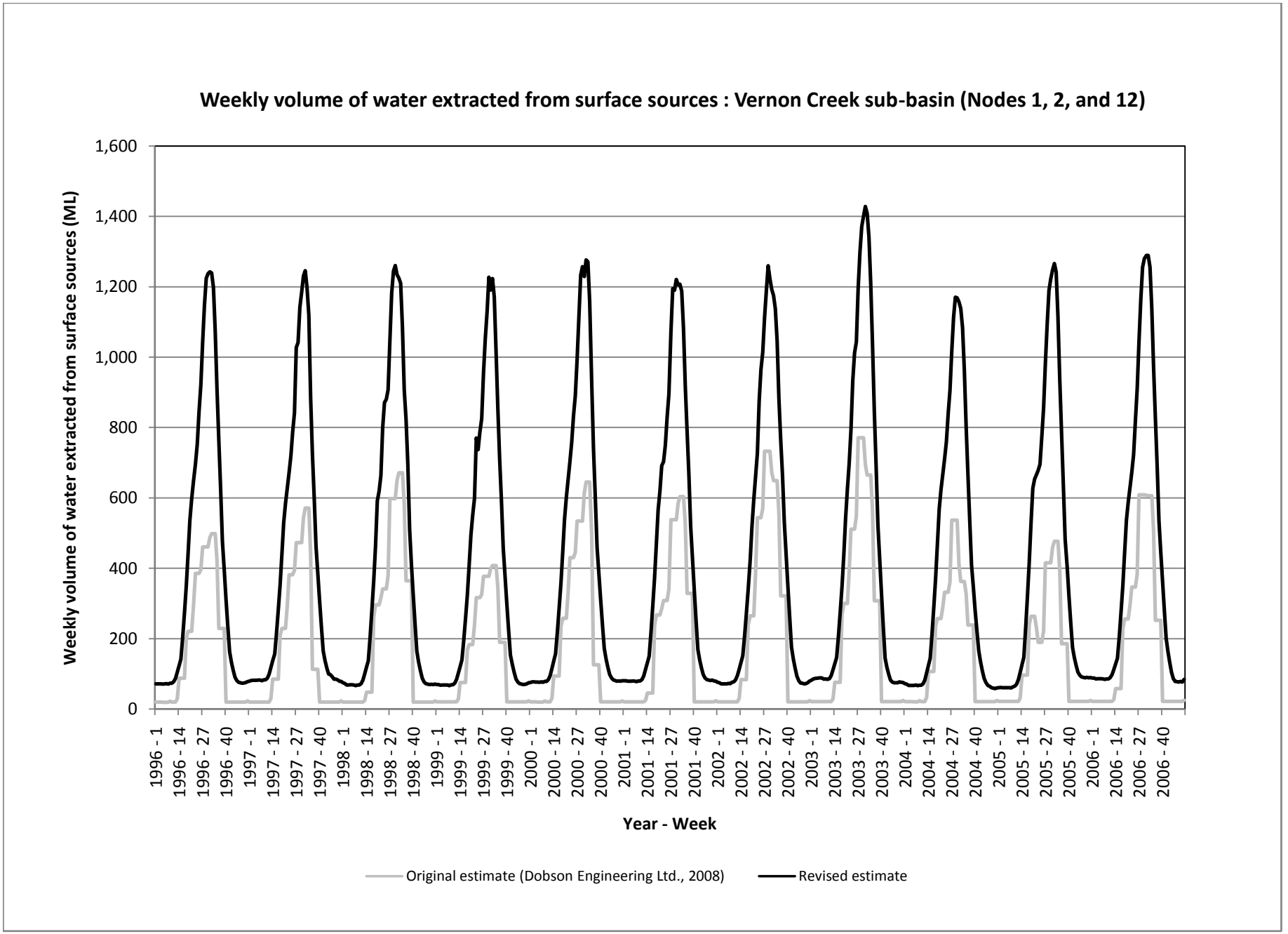
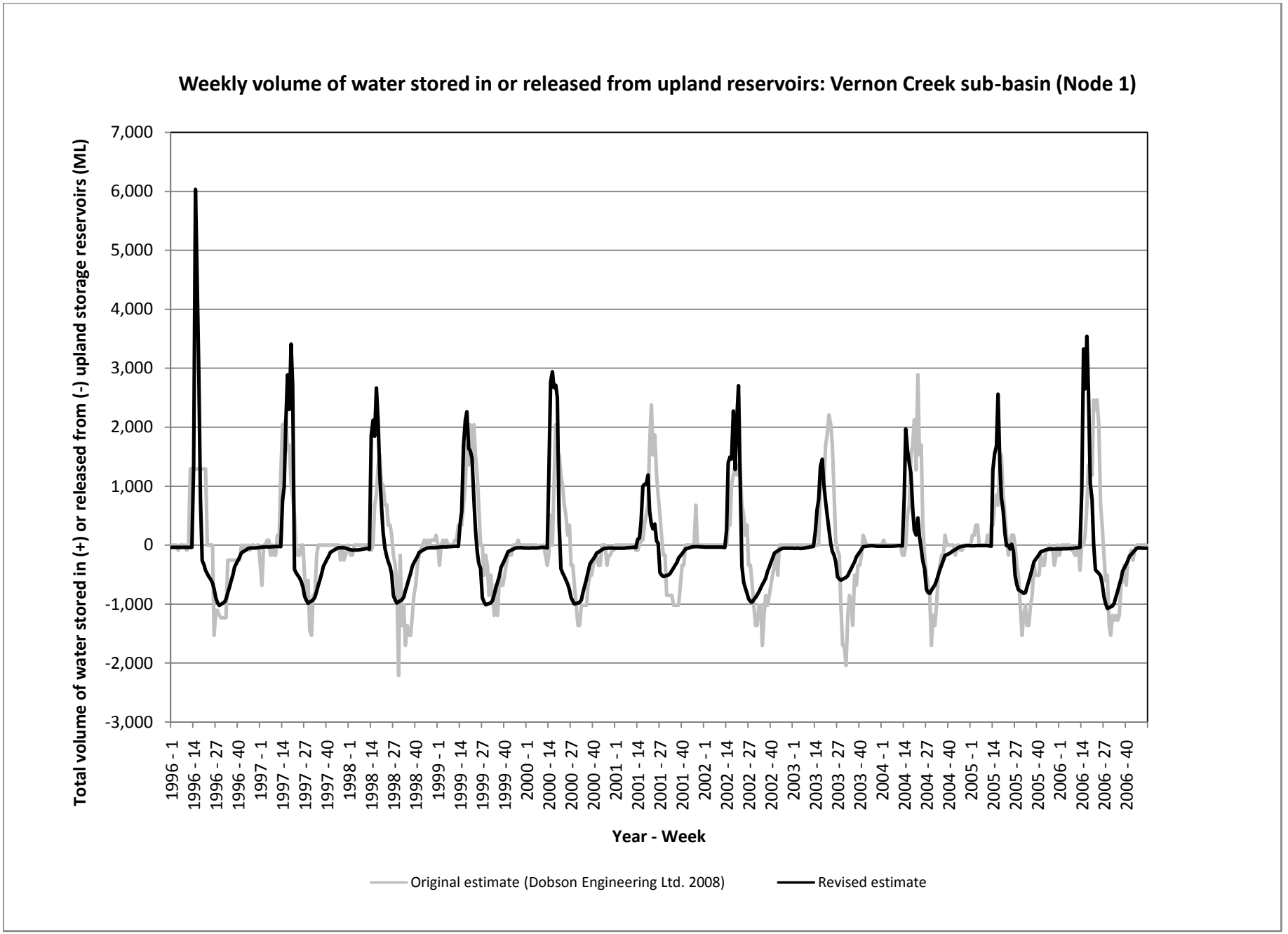
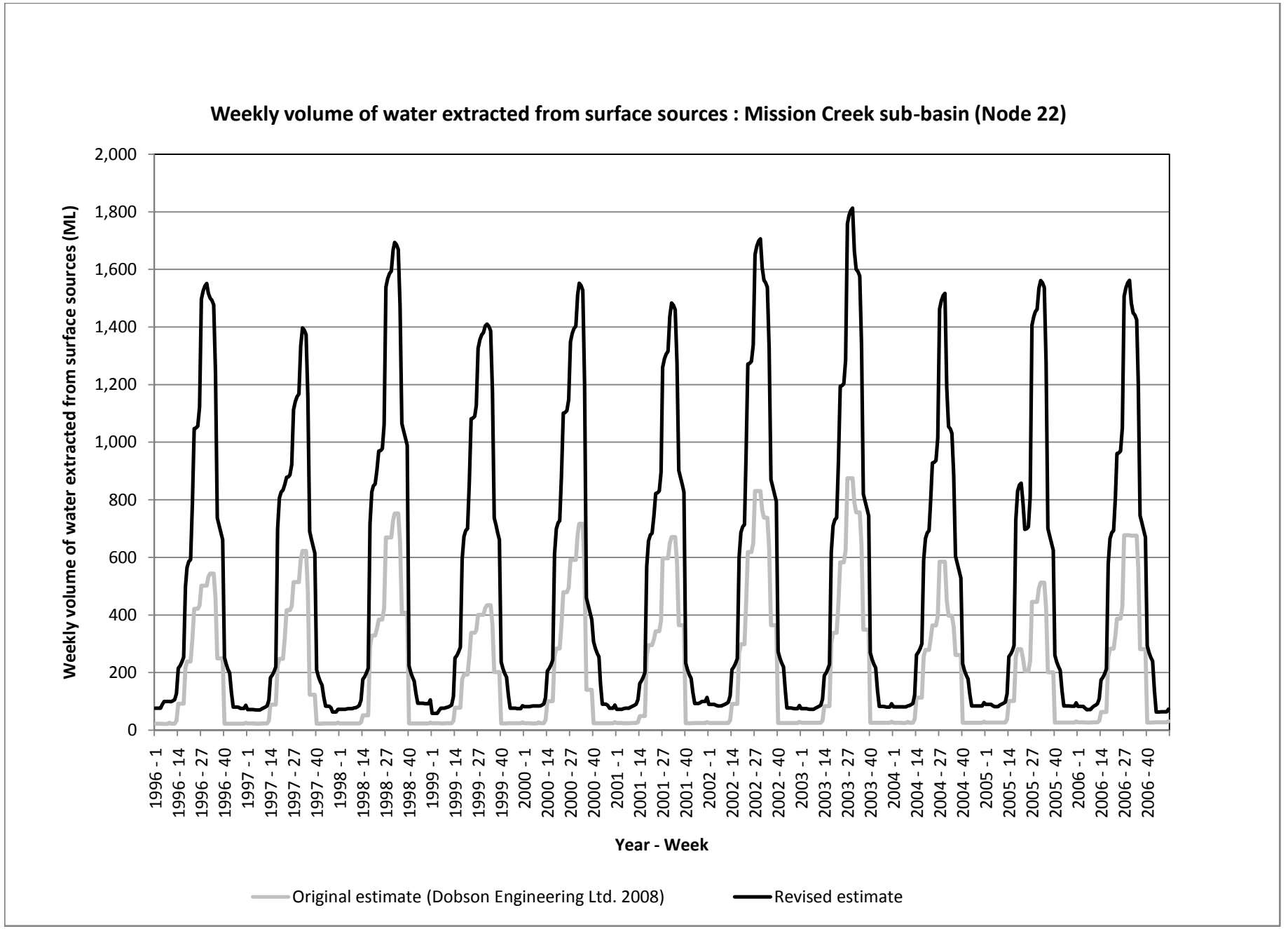
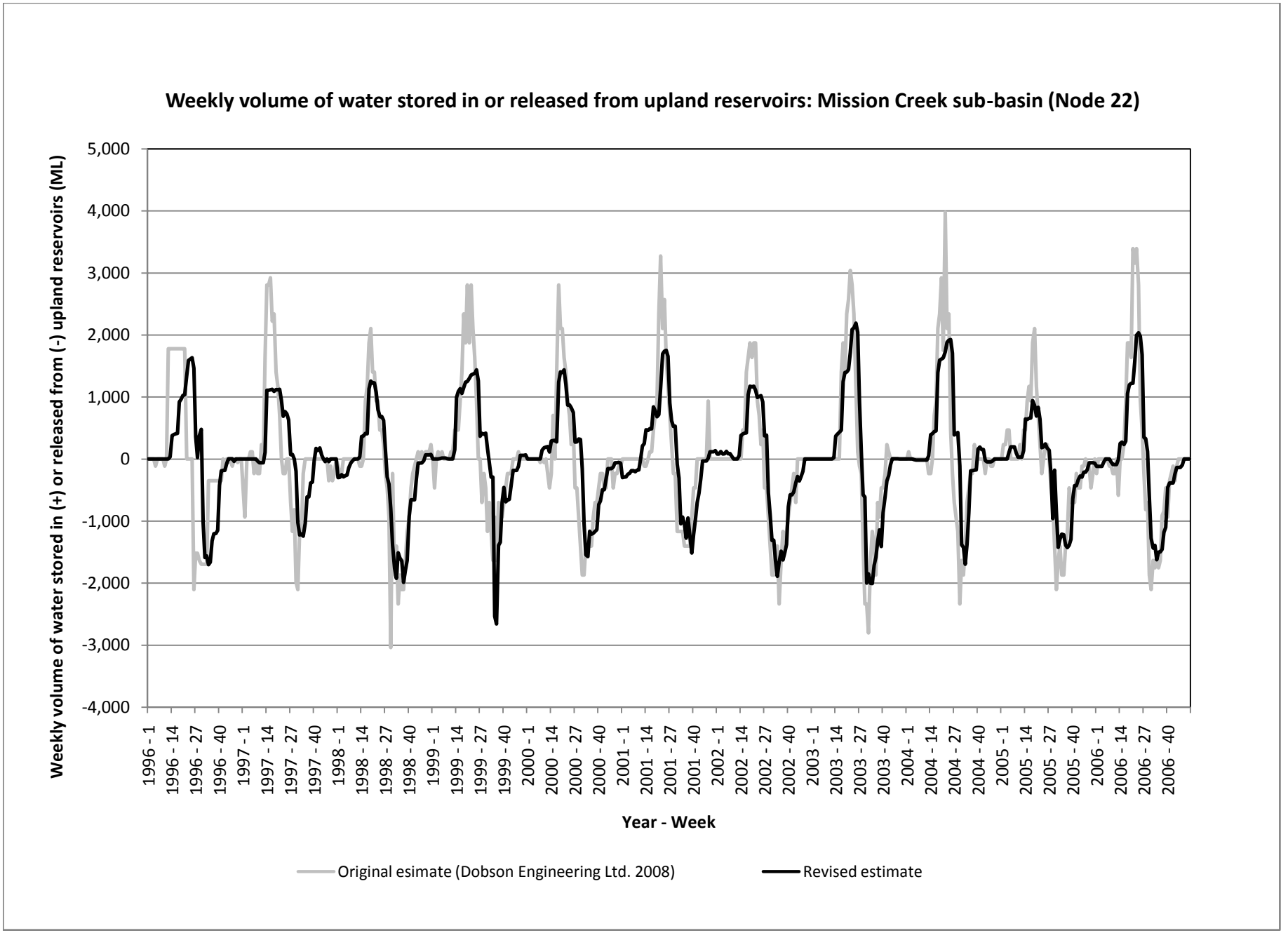
APPENDIX F

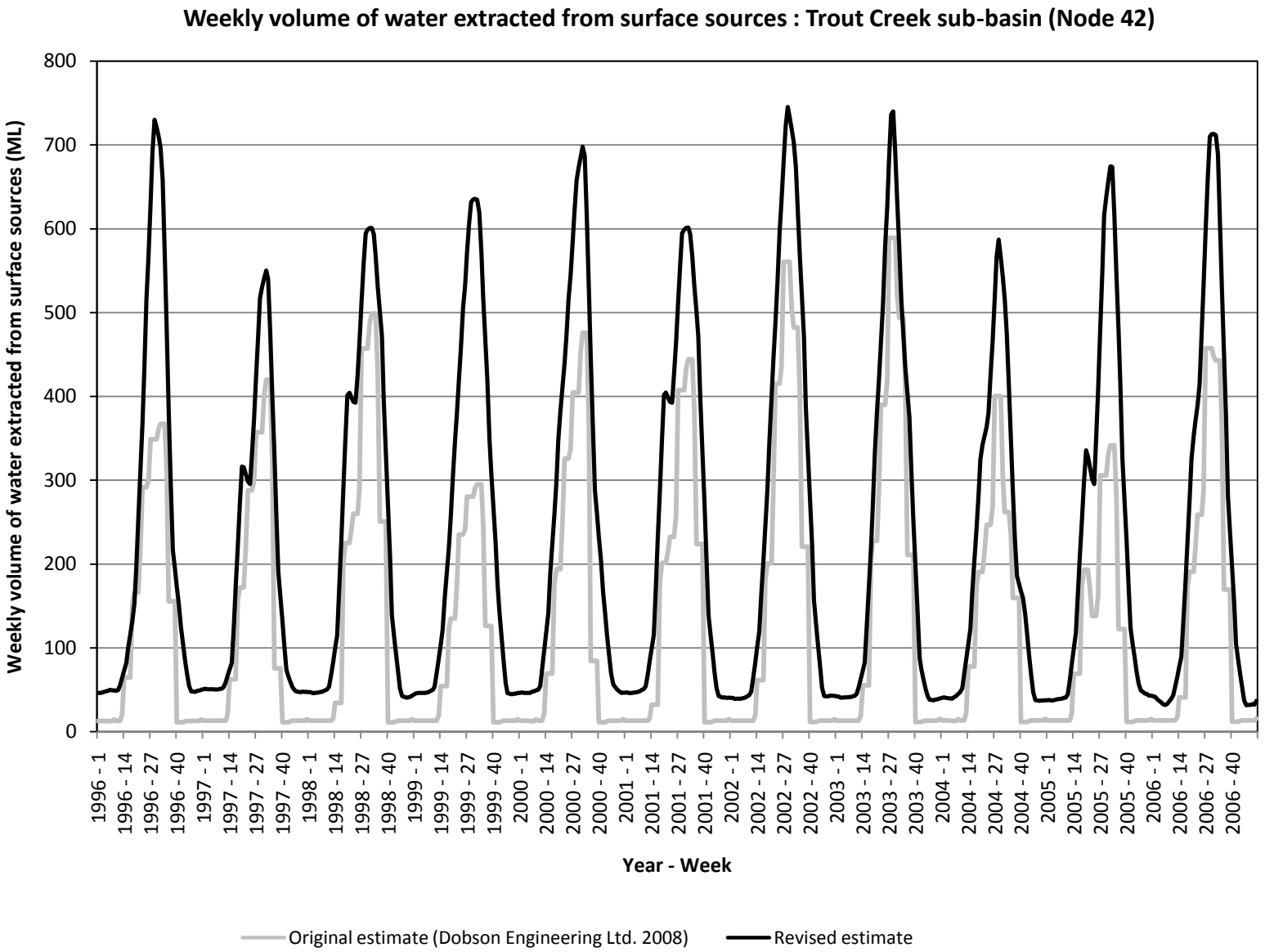
Revised Water Management and Use Data for Vernon, Mission and Trout Creeks

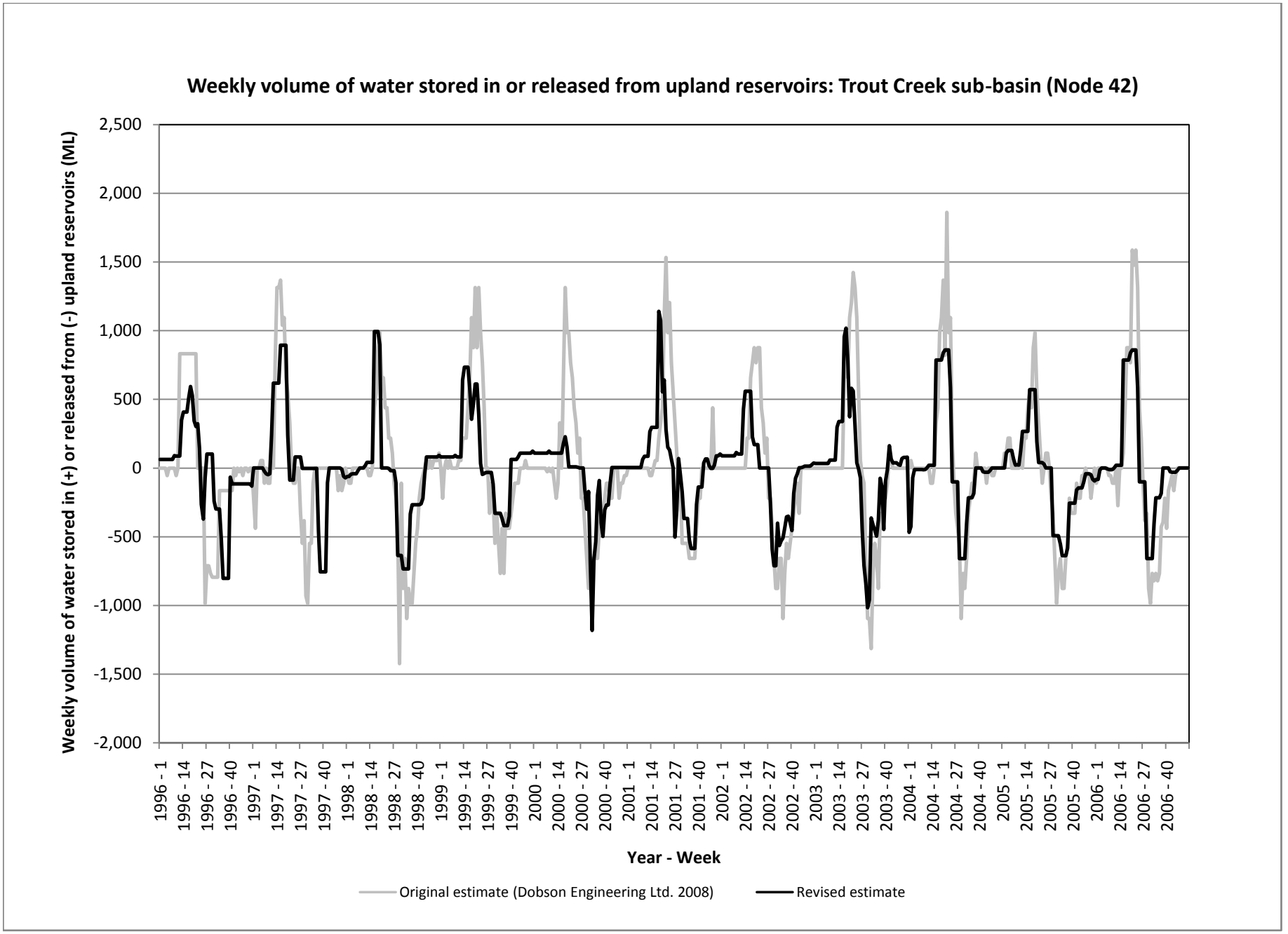

Weekly volume of water extracted from surface sources : Vernon Creek sub-basin (Nodes 1, 2, and 12)
Weekly volume of water extracted from surface sources (ML)
1,600
1,400
1,200
1,000
800
600
400
200
0
1996 - 1
1996 - 14
1996 - 27
1996 - 40
1997 - 1
1997 - 14
1997 - 27
1997 - 40
1998 - 1
1998 - 14
1998 - 27
1998 - 40
1999 - 1
1999 - 14
1999 - 27
1999 - 40
2000 - 1
2000 - 14
2000 - 27
2000 - 40
2001 - 1
2001 - 14
2001 - 27
2001 - 40
2002 - 1
2002 - 14
2002 - 27
2002 - 40
2003 - 1
2003 - 14
2003 - 27
2003 - 40
2004 - 1
2004 - 14
2004 - 27
2004 - 40
2005 - 1
2005 - 14
2005 - 27
2005 - 40
2006 - 1
2006 - 14
2006 - 27
2006 - 40
Year - Week
Original estimate (Dobson Engineering Ltd., 2008)
Revised estimate


Weekly volume of water stored in or released from upland reservoirs: Vernon Creek sub-basin (Node 1)
Total volume of water stored in (+) or released from (-) upland storage reservoirs (ML)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
-1,000
-2,000
-3,000
1996 - 1
1996 - 14
1996 - 27
1996 - 40
1997 - 1
1997 - 14
1997 - 27
1997 - 40
1998 - 1
1998 - 14
1998 - 27
1998 - 40
1999 - 1
1999 - 14
1999 - 27
1999 - 40
2000 - 1
2000 - 14
2000 - 27
2000 - 40
2001 - 1
2001 - 14
2001 - 27
2001 - 40
2002 - 1
2002 - 14
2002 - 27
2002 - 40
2003 - 1
2003 - 14
2003 - 27
2003 - 40
2004 - 1
2004 - 14
2004 - 27
2004 - 40
2005 - 1
2005 - 14
2005 - 27
2005 - 40
2006 - 1
2006 - 14
2006 - 27
2006 - 40
Year - Week
Original estimate (Dobson Engineering Ltd. 2008)
Revised estimate


Weekly volume of water extracted from surface sources : Mission Creek sub-basin (Node 22)
Weekly volume of water extracted from surface sources (ML)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1996 - 1
1996 - 14
1996 - 27
1996 - 40
1997 - 1
1997 - 14
1997 - 27
1997 - 40
1998 - 1
1998 - 14
1998 - 27
1998 - 40
1999 - 1
1999 - 14
1999 - 27
1999 - 40
2000 - 1
2000 - 14
2000 - 27
2000 - 40
2001 - 1
2001 - 14
2001 - 27
2001 - 40
2002 - 1
2002 - 14
2002 - 27
2002 - 40
2003 - 1
2003 - 14
2003 - 27
2003 - 40
2004 - 1
2004 - 14
2004 - 27
2004 - 40
2005 - 1
2005 - 14
2005 - 27
2005 - 40
2006 - 1
2006 - 14
2006 - 27
2006 - 40
Year - Week
Original estimate (Dobson Engineering Ltd. 2008)
Revised estimate


Weekly volume of water stored in or released from upland reservoirs: Mission Creek sub-basin (Node 22)
Weekly volume of water stored in (+) or released from (-) upland reservoirs (ML)
5,000
4,000
3,000
2,000
1,000
0
-1,000
-2,000
-3,000
-4,000
1996 - 1
1996 - 14
1996 - 27
1996 - 40
1997 - 1
1997 - 14
1997 - 27
1997 - 40
1998 - 1
1998 - 14
1998 - 27
1998 - 40
1999 - 1
1999 - 14
1999 - 27
1999 - 40
2000 - 1
2000 - 14
2000 - 27
2000 - 40
2001 - 1
2001 - 14
2001 - 27
2001 - 40
2002 - 1
2002 - 14
2002 - 27
2002 - 40
2003 - 1
2003 - 14
2003 - 27
2003 - 40
2004 - 1
2004 - 14
2004 - 27
2004 - 40
2005 - 1
2005 - 14
2005 - 27
2005 - 40
2006 - 1
2006 - 14
2006 - 27
2006 - 40
Year - Week
Original esimate (Dobson Engineering Ltd. 2008)
Revised estimate


Weekly volume of water extracted from surface sources : Trout Creek sub-basin (Node 42)
Weekly volume of water extracted from surface sources (ML)
800
700
600
500
400
300
200
100
0
1996 - 1
1996 - 14
1996 - 27
1996 - 40
1997 - 1
1997 - 14
1997 - 27
1997 - 40
1998 - 1
1998 - 14
1998 - 27
1998 - 40
1999 - 1
1999 - 14
1999 - 27
1999 - 40
2000 - 1
2000 - 14
2000 - 27
2000 - 40
2001 - 1
2001 - 14
2001 - 27
2001 - 40
2002 - 1
2002 - 14
2002 - 27
2002 - 40
2003 - 1
2003 - 14
2003 - 27
2003 - 40
2004 - 1
2004 - 14
2004 - 27
2004 - 40
2005 - 1
2005 - 14
2005 - 27
2005 - 40
2006 - 1
2006 - 14
2006 - 27
2006 - 40
Year - Week
Original estimate (Dobson Engineering Ltd. 2008)
Revised estimate


Weekly volume of water stored in or released from upland reservoirs: Trout Creek sub-basin (Node 42)
Weekly volume of water stored in (+) or released from (-) upland reservoirs (ML)
2,500
2,000
1,500
1,000
500
0
-500
-1,000
-1,500
-2,000
1996 - 1
1996 - 14
1996 - 27
1996 - 40
1997 - 1
1997 - 14
1997 - 27
1997 - 40
1998 - 1
1998 - 14
1998 - 27
1998 - 40
1999 - 1
1999 - 14
1999 - 27
1999 - 40
2000 - 1
2000 - 14
2000 - 27
2000 - 40
2001 - 1
2001 - 14
2001 - 27
2001 - 40
2002 - 1
2002 - 14
2002 - 27
2002 - 40
2003 - 1
2003 - 14
2003 - 27
2003 - 40
2004 - 1
2004 - 14
2004 - 27
2004 - 40
2005 - 1
2005 - 14
2005 - 27
2005 - 40
2006 - 1
2006 - 14
2006 - 27
2006 - 40
Year - Week
Original estimate (Dobson Engineering Ltd. 2008)
Revised estimate

APPENDIX G

Okanagan Mainstem Lake Storage Tables

Okanagan Mainstem Lake Storage Tables

Developed by Summit Environmental Consultants Ltd.

Wood Lake

Elevation (m)	Lake surface area (ha)	Volume (ML)
388.25	821.28	127,530
388.50	826.21	129,589
388.75	831.15	131,661
389.00	836.12	133,745
389.25	843.41	135,844
389.50	847.19	137,957
389.75	850.91	140,080
390.00	854.57	142,212
390.25	858.18	144,352
390.50	861.74	146,502
390.75	865.31	148,661
391.00	868.88	150,829
391.20	871.76	152,570
391.50	876.09	155,191
391.70	879.00	156,946
392.00	883.37	159,590
392.25	887.04	161,803
392.50	890.72	164,025
392.75	894.42	166,257
393.00	898.14	168,497
393.25	901.88	170,747
393.50	905.63	173,007
393.75	909.40	175,276
394.00	914.05	177,554
394.25	916.91	179,843
394.50	919.85	182,139

Notes:

1) Normal operating range = 391.2 m to 341.7 m

2) Calculations were restricted to the area above the Oyama Canal outlet.

3) Bathymetric data obtained from Canadian Hydrographic Service

Kalamalka Lake

Elevation (m)	Lake surface area (ha)	Volume (ML)
388.25	2,380.95	1,473,629
388.50	2,391.74	1,479,594
388.75	2,403.25	1,485,588
389.00	2,415.84	1,491,612
389.25	2,429.25	1,497,668
389.50	2,440.33	1,503,755
389.75	2,451.67	1,509,870
390.00	2,463.44	1,516,014
390.25	2,476.20	1,522,188
390.50	2,489.29	1,528,395
390.75	2,502.66	1,534,635
391.00	2,521.70	1,540,909
391.20	2,532.97	1,545,963
391.50	2,550.41	1,553,588
391.70	2,562.40	1,558,701
392.00	2,585.38	1,566,416
392.25	2,591.48	1,572,887
392.50	2,597.76	1,579,373
392.75	2,604.23	1,585,876
393.00	2,612.29	1,592,395
393.25	2,617.85	1,598,932
393.50	2,623.47	1,605,484
393.75	2,629.12	1,612,051
394.00	2,634.79	1,618,631
394.25	2,640.65	1,625,226
394.50	2,646.52	1,631,837

Notes:

1) Normal operating range = 391.2 m to 391.7 m

2) Calculations were restricted to the area above Kalamalka Lake outlet.

3) Bathymetric data obtained from Canadian Hydrographic Service

Okanagan Lake

Elevation (m)	Lake surface area (ha)	Volume (ML)
338.50	32,078.81	23,268,858
338.75	32,222.00	23,349,233
339.00	32,370.04	23,429,972
339.25	32,536.42	23,511,101
339.50	32,806.61	23,592,833
339.75	32,972.53	23,675,059
340.00	33,136.62	23,757,693
340.25	33,298.54	23,840,737
340.50	33,458.76	23,924,184
340.75	33,617.85	24,008,030
341.00	33,795.15	24,092,273
341.34	34,005.98	24,207,516
341.50	34,110.76	24,262,007
341.75	34,274.92	24,347,486
342.00	34,491.04	24,433,383
342.25	34,614.14	24,519,762
342.48	34,729.58	24,599,507
342.75	34,865.36	24,693,461
343.00	35,025.10	24,780,783
343.25	35,149.68	24,868,502
343.50	35,273.79	24,956,531
343.75	35,397.48	25,044,871
344.00	35,563.86	25,133,519
344.25	35,694.72	25,222,585
344.50	35,831.12	25,311,992
344.75	35,966.45	25,401,738
345.00	36,101.99	25,491,824
345.25	36,278.94	25,582,401
345.50	36,373.06	25,673,217

Notes:

1) Normal operating range = 341.44 m to 342.48 m

2) Calculations were restricted to the area above Okanagan Lake Outlet Dam.

3) Bathymetric data obtained from Canadian Hydrographic Service

Skaha Lake

Elevation (m)	Lake surface area (ha)	Volume (ML)
334.75	1,673.60	443,812
335.00	1,684.29	448,009
335.25	1,695.04	452,233
335.50	1,705.84	456,485
335.75	1,729.71	460,781
336.00	1,747.67	465,128
336.25	1,765.24	469,519
336.50	1,782.66	473,954
336.75	1,800.27	478,433
337.00	1,818.23	482,956
337.25	1,835.53	487,523
337.50	1,852.91	492,134
337.80	1,873.88	497,724
337.90	1,880.90	499,601
338.00	1,890.67	501,485
338.25	1,906.91	506,232
338.50	1,923.22	511,020
338.75	1,939.58	515,849
339.00	1,997.74	520,718
339.25	2,014.51	525,733
339.50	2,029.42	530,789
339.75	2,046.09	535,883
340.00	2,082.62	541,026
340.25	2,092.49	546,261
340.50	2,139.44	551,574
340.75	2,143.39	556,971

Notes:

1) Normal operating range = 337.80 m to 337.90 m

2) Calculations were restricted to the area above Skaha Lake Outlet Dam.

3) Bathymetric data obtained from Canadian Hydrographic Service

Vaseux Lake

Elevation (m)	Lake surface area (ha)	Volume (ML)
324.50	152.55	10,900
324.75	158.17	11,288
325.00	165.20	11,691
325.25	172.09	12,113
325.50	181.58	12,553
325.75	197.08	13,026
326.00	237.37	13,544
326.25	261.11	14,170
326.50	276.28	14,842
326.75	289.53	15,552
327.00	294.64	16,283
327.25	298.37	17,025
327.40	299.69	17,473
327.50	300.57	17,773
327.60	301.43	18,074
327.75	302.72	18,527
328.00	305.44	19,287
328.25	307.13	20,053
328.50	308.79	20,823
328.75	311.99	21,597
329.00	317.64	22,385
329.25	328.25	23,190
329.50	357.52	24,041
329.75	382.91	24,968
330.00	403.27	25,951
330.25	418.36	26,978
330.50	431.59	28,041

Notes:

1) Normal operating range = 327.40 m to 327.60 m

2) Calculations were restricted to the area above McIntyre Dam.

3) Bathymetric data obtained from Province of B.C.

Osoyoos Lake

Elevation (m)	Lake surface area (ha)	Volume (ML)
274.00	944.48	242,899
274.25	1,855.51	247,502
274.50	1,884.70	252,177
274.75	1,915.49	256,927
275.00	1,948.21	261,756
275.25	1,983.85	266,670
275.50	2,024.57	271,680
275.75	2,071.16	276,798
276.00	2,155.22	282,070
276.25	2,369.45	287,930
276.50	2,396.73	293,895
276.75	2,412.50	299,909
277.00	2,439.78	305,961
277.25	2,453.99	312,064
277.50	2,468.17	318,204
277.75	2,477.43	324,381
278.00	2,504.65	330,593
278.25	2,523.93	336,880
278.50	2,543.15	343,215
278.75	2,562.58	349,598
279.00	2,613.58	356,030
279.25	2,651.73	362,609
279.50	2,685.59	369,283
279.75	2,719.99	376,043
280.00	2,770.15	382,892
280.25	2,809.59	389,867
280.50	2,852.09	396,945
280.75	2,894.26	404,130

Notes:

1) Normal operating range = 277.06 m to 277.83 m

2) Calculations were restricted to the area above Zosel Dam.

3) Bathymetric data obtained from Province of B.C.

APPENDIX H

References Added to the Okanagan Information Database during this Study

Table H.1 Selected references added to the Okanagan Information Database during Part One of this study.

References Added to the Okanagan Information Database
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