FINAL REPORT
Okanagan Water Allocation Tool Plan

Prepared for:

Okanagan Basin Water Board
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May 1, 2014

Okanagan Basin Water Board
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Attention: Dr. Anna Warwick Sears, Executive Director

Re: **Final Report – Okanagan Water Allocation Tool Plan**

Western Water Associates Ltd. (WWAL) in collaboration with Polar Geoscience Ltd., and ESSA Technologies Ltd., is pleased to provide this final report for the Okanagan Water Allocation Tool (OWAT) Plan. This document outlines a suggested approach for proceeding with the development of the OWAT, and has incorporated comments on the draft report provided by the Technical Advisory Committee (TAC) and others following a workshop in Kelowna on March 11, 2014.

WESTERN WATER ASSOCIATES LTD.

Douglas Geller, M.Sc, P.Geo.
Principal Hydrogeologist

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List of Acronyms

AAFC – Agriculture and Agri-Food Canada

AWR – Agricultural Water Reserve

BC OGC – BC Oil and Gas Commission

BMID – Black Mountain Irrigation district

CFN – Critical Flow Needs

DHI – Danish Hydrologic Institute

ESSA – Essa Technologies Ltd.

EFN – Environmental Flow Needs

INF – Instream Flow Needs[1]

MFLNRO – BC Ministry of Forests Lands and Natural Resources

NEWT – Northeast Water Tool

OBHM – Okanagan Basin Hydrologic Model

OBWAM – Okanagan Basin Water Accounting Model

OBWB – Okanagan Basin Water Board

OHCM – Okanagan Hydrologic Connectivity Model

OkWaterDB – Okanagan Water Database

OWAT – Okanagan Water Allocation Tool

OWDM – Okanagan Water Demand Model

OWSDP = Okanagan Water Supply and Demand Project

Polar – Polar Geoscience Ltd.

RHF – RHF Systems Ltd.

SEI – Stockholm Environment Institute

SEKID = Southeast Kelowna Irrigation District

Summit = Summit Environmental Consultants Inc.

UNA – User Needs Assessment

USL = Urban Systems Ltd.

WEAP = Water Evaluation and Planning Tool

WWAL – Western Water Associates Ltd.

[1] Within the BC *Water Sustainability Act*, reference is made to Environmental Flow Needs (EFN) not Instream Flow Needs (IFN) to define water requirements for the proper functioning of the aquatic ecosystem of a stream. The latter term is used in this report in accordance with MFLNRO preference.

EXECUTIVE SUMMARY

The Okanagan Basin Water Board, in partnership with B.C. Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), commissioned this report to develop a plan for an Okanagan water allocation tool, known as the OWAT. The primary purpose of the tool is to support water licence decisions made by MFLNRO. Decisions regarding licence approval (with or without conditions) or licence refusal are currently made using guidelines and policies that were last updated in the 1990s. The pending new *Water Sustainability Act* legislation and continued the pressure on water resources in the valley fuel the need for a more sophisticated, scientifically based and transparent decision support tool.

The overall objective of this project was to review existing Okanagan data and models to determine how they can best be used to create an effective decision support tool for water licensing in the Okanagan, and to identify tasks required to develop the tool.

The project engaged key knowledge holders and end users and included the following steps:

- Review of existing Okanagan Basin studies, specifically, the hydrologic and water accounting models completed for the Water Supply and Demand Project, as well as a review of Environmental Flow Needs (a.k.a., In-stream Flow Needs or EFNs) information;
- Consultations with MFLNRO water allocation staff and other knowledge holders to advise on OWAT objectives and a framework;
- Preparation of a draft OWAT plan and vetting of the plan at a Kelowna workshop attended by knowledge holders and end-users; and
- Completing a final OWAT plan report documenting the process, information gaps and questions to be addressed and recommended approach for plan development.

The focus of this project was to evaluate the potential applicability of two platforms to house the OWAT: 1) the Northeast Water Tool (NEWT) adapted to the Okanagan; and 2) the Okanagan Water Evaluation and Planning (WEAP) platform, which served as the framework for the existing Okanagan Hydrologic Connectivity Model (OHCM).

Outcomes of Consultations and Existing Model / Information Review

MFLNRO staff provided current licence evaluation criteria that have been in use for a number of years. These criteria use different risk of water shortage tolerances based on types of uses (e.g., domestic, small or large waterworks, or irrigation). The evaluation criteria require varying degrees of spatial and temporal data, in the extreme case, daily streamflows for intakes on tributaries. One issue with existing licences was that there is currently no central database that associates water licences and points-of-diversion with estimates and/or records of water use; moreover, the provincial E-licence database does not report all licence conditions so work is needed to converge the various databases (both electronic and hard copy) into a comprehensive format to support new licence decisions.

The reports, models and model platforms reviewed for this study included component technical studies and databases for Okanagan water supply and demand, including the MikeSHE hydrology model, the Okanagan Water Demand Model, the OHCM, EFN calculation methods, the NEWT user interface and a similar interface being developed for Northwest B.C. (NWWT). The capabilities of the various technical approaches, models and model platforms were evaluated against OWAT objectives and the user needs expressed by MFLNRO staff.

The outcome of this review is that none of the existing models, in current form, can be used as water licence decision making tools without significant technical expertise, but that both WEAP and NEWT platforms have considerable potential for use in the Okanagan. Also, as conditions change and new licences are issued, it will be necessary to have a convenient system to update data and risk model scenarios. Similarly, while there are a number of potentially applicable approaches to determining EFNs, there is no consistent methodology for the Okanagan. Examples do exist from prior water use plans (WUPs) in the Mission and Trout Creek watersheds that could potentially be applied in other local drainages. It was a consensus of the group that where EFNs are established as a component of existing supply, they must be operationally attainable given the existing state of water management in the basin.

Recommended OWAT Plan Approach

Any modeling approach will have its own advantages, constraints and disadvantages, and this held true in our evaluation of the WEAP and NEWT/NWWT platforms as possible stand-alone tools developed for the OWAT. Based on discussions held during the project, including a March 2014 workshop in Kelowna, a consensus emerged favouring a hybrid approach incorporating a new hydrologic supply and demand model using the WEAP platform, coupled with a NEWT-like user interface. However, MFLNRO is apparently considering developing a NEWT-like water allocation tool for the entire Thompson – Okanagan region, which includes but extends considerably beyond the boundaries of the Okanagan Basin.

Should two tools covering portions of the same area be developed (OWAT for the Okanagan, and a NEWT-like tool for Thompson-Okanagan) it would be better if one approach can complement the other, and the appropriate decision support tool could be chosen based on the location and the available data. Covering the same spatial domain with two models raises issues such as how to resolve inconsistencies (if both were used). A strong consensus was that having a similar user interface as the NEWT and the NWWT for the Okanagan would help foster consistency across the province. To take advantage of the detailed hydrologic and water supply information that is available, development of a new tool using a new WEAP-based model and a NEWT-based user interface is recommended for the Okanagan basin. OWAT development must continue to involve end users and key stakeholders and prior to implementation should be pilot tested on typical licence application scenarios (e.g. intake on stream, lake intake, storage, etc.), as requested by Ministry staff.

Summary of Key Gaps and Questions to be Addressed

Based on the outcomes of this project and the consultations (which should continue in the next phase with key stakeholders and end-users), we identified a number of issues that need further deliberation and questions that must be answered. The table below summarizes the major gaps and questions (not necessarily in priority order) that must be answered as the OWAT project moves forward toward the development and implementation stage. Detailed discussion of each of the major issues, and other lesser but still important ones, may be found within the main body of the report.

Type of Gap, Issue or Question	Issue Summary	Comments / Recommendations
Environmental Flow Needs (EFNs)	No agreement on methodologies to apply in Okanagan	Conduct specific studies in targeted watersheds and seek consensus on how to assign and prioritize EFNs throughout basin
Water allocation guidelines vs. ability of models to generate sufficiently detailed flow data	OWAT may not be capable of supplying the spatial or temporal resolution to inform guideline criteria	Consider modifying criteria to fit limitations of models / data or increase data collection and resolution of models. A consensus on how to address this issue is considered critical.
Model uncertainty analysis	There has been relatively little independent uncertainty analysis on the models and data that would be used by WEAP.	Consider conducting supply and demand uncertainty analysis for incorporation into OWAT
How to address pending groundwater licencing in OWAT	Groundwater supply, and groundwater use, are poorly understood relative to surface water. Existing models represent groundwater in a highly simplified manner, and are likely insufficient to inform license evaluation decisions involving wells.	Decide on a possible phased approach to incorporating groundwater in OWAT beginning with a linkage analysis and populating a database with existing licenced supply (assuming existing supplies are grandparented). Increase the level of detail / sophistication in priority basins.
Need for a comprehensive and updatable water licence database	Not all information on licences are available electronically and there is no linkage between licences, points-of-diversion, and modeled, actual or reported use. This issue will compound once groundwater is included.	Make the investment to reconcile all existing licence data into a robust and comprehensive licence database.
OWAT end-users and potential public interface.	Confirm primary or only end-users are MFLNRO water allocation staff Decision needed on public interface	Decision on public interface could be driven by costs (public interface will increase OWAT development costs). Could be phased in later.
State of the basin analysis with regard to licensing	No basin-wide summary of allocation status (over-allocated, fully allocated, water potentially available) exists that also considers EFNs or groundwater.	Conduct state of the basin analysis as part of OWAT development and implementation.

1. INTRODUCTION

Western Water Associates Ltd. (WWAL), in collaboration with Polar Geoscience Ltd. (Polar), and Essa Technologies Ltd., (ESSA) is pleased to provide this report for the Okanagan Water Allocation Tool (OWAT) Plan. This project is being directed by the Okanagan Basin Water Board (OBWB), in coordination with BC Ministry of Forests Lands and Natural Resource Operations (MFLNRO). The OWAT Plan is a suggested framework for moving forward with the development of a decision support tool for water licensing and allocation in the Okanagan. A draft report outlining the plan was circulated to a Technical Advisory Committee and other interested parties in late February 2014 and a workshop held in Kelowna on March 11, 2014. Comments received during and following this workshop have been incorporated into this document.

Since approximately 2004, there has been significant progress in advancing the state of knowledge relating to water resources in the Okanagan Basin, primarily as a direct result of initiatives directed by the OBWB, such as the Okanagan Water Supply and Demand Project (OWSDP), and academic and government research. Background information regarding the history of the OWSDP and reports for the components of the OWSDP can be referenced on the OBWB website: http://www.obwb.ca/wsd/. The previous work has collectively and significantly increased the availability of Okanagan Basin water data, and, therefore, provides a strong foundation for proceeding with focused development of a science-based tool to assist in water licensing decisions in the Okanagan (i.e., the OWAT).

2. PROJECT OBJECTIVE AND SCOPE

The overall objective of this project is to review existing Okanagan data and models to examine how they can best be used in an effective decision support tool for water licensing in the Okanagan, and to identify tasks required to proceed with development of the tool.

This first phase of the OWAT project focuses on drafting a plan for a decision support tool to assist in regulatory water licensing and allocation decisions in the Okanagan. Water licensing and allocation can be considered as specific aspects within the broader context of water resources management. Water resources management includes licensing and allocation, but also includes responding to real-time conditions, reservoir management, flood management, drought response planning, specification of water restrictions or reserves, optimizing economic, social, recreational and environmental factors, land use planning, water supply and demand forecasting, water use planning, source water assessment/protection, public education, and scientific study.

Key points about this project are summarized below:

- The OWAT is intended to be a licensing decision support tool and not necessarily a water resource management tool. The focused scope on licensing and allocation decisions (in this phase) has been adopted to facilitate timely implementation and effectiveness.

- In keeping with the emphasis on licensing, the OWAT Plan focuses on accurate and appropriate representation and accounting of water supply (natural and regulated streamflow), water demand, and environmental flow needs (EFNs).
- Although the current focus is on water licensing decision support, we anticipate that the OWAT could potentially be used in some capacity, or could be further developed, to assist with other water management decisions.

This first phase of the OWAT project involved the following general components, which are described further in Section 3.2:

1. Definition of the needs and goals of the OWAT and identification of outstanding questions with respect to defining needs and goals.
2. Review of existing Okanagan models and data and identification of data gaps in the context of the defined OWAT needs/goals. A comprehensive scientific review of existing models/data, and a review of other potential models to generate data were not within the scope of this project.
3. Preliminary review and specific assessment of two potential OWAT platforms (identified below). Identification and review of other potential user platforms was not part of the scope of this project.
4. Development of the OWAT Plan based on the above tasks.

With respect to the review of potential platforms, we are aware of a number of potentially applicable water allocation systems and tools that are in use worldwide. However, as discussed and agreed to with the OBWB, this project specifically considered two general options:

1. Use of the Water Evaluation and Planning (WEAP) platform, which was used to develop the Okanagan Hydrologic Connectivity Model (OHCM).
2. Use of a platform similar to the Northeast Water Tool (NEWT)[2] and Northwest Water Tool (NWWT), which have been jointly developed by the BC Oil and Gas Commission (BC OGC) and the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO).

3. PROJECT METHODOLOGY

This section briefly introduces the project team and the approach used to compile the information necessary to draft a plan for development of the OWAT.

3.1 Project Team

The project team and their respective roles in this project are indicated below.

- Dr. Anna Warwick Sears, Executive Director, Okanagan Basin Water Board - Project Director and Advisor

- Doug Geller, M.Sc., P.Geo. of Western Water Associates Ltd. – Project Manager

[2] Online at: http://geoweb.bcogc.ca/apps/newt/newt.html

- Laurie Welch, Ph.D., P.Geo., Western Water Associates Ltd. – Technical Lead in Groundwater Resources

- Lars Uunila, M.Sc., P.Geo., P.H., Polar Geoscience Ltd. – Technical Lead Hydrology / Surface Water Resources

- Clint Alexander, MRM, ESSA Technologies Ltd. - Senior Decision Support System Advisor

- Frank Poulsen, MSc. P.Eng, ESSA Technologies Ltd. – Technical Lead, Environmental Flow Needs

3.2 Methodology

The original methodology was presented in a proposal from WWAL to the OBWB on December 2, 2013, and also in the document "Okanagan Water Allocation Tool Planning Proposal, Stage 1 Project Overview, Developing a Plan to Build a Decision Support Tool for Water Allocation in the Okanagan" dated December 13, 2013. While key components of the original work plan were included in this study, based on revised study objectives some of the scope was modified. The following text outlines the steps actually taken.

1. Definition of the needs and goals of the OWAT and identification of questions with respect to defining the OWAT needs/goals: The team identified OWAT needs and goals based on interviews and discussions with potential users of OWAT and/or those with significant knowledge of Okanagan's water resources (see Section 3.3 for a list of individuals consulted with during the project). Discussions during the interview process were focused on the following topics:

- Types of water licensing decisions to be addressed,
- Representation of supply and demand components of the water budget,
- Representation of instream flow needs,
- Criteria for licence evaluation, including future scenarios,
- Spatial and temporal scale of the OWAT ,
- Accuracy and validity,
- Specific Okanagan conditions that need to be represented,
- Adaptability to new information,
- Requirements for understanding OWAT underpinnings and limitations, and
- General user interface needs.

2. Review of existing Okanagan models and data in the context of the defined OWAT needs/goals: We reviewed Okanagan models and data (Section 3.4) with respect to their ability to meet the needs and goals of the OWAT. We then identified relevant data gaps associated with the models.

3. Preliminary review and assessment of potential user platforms: We considered two potential avenues for the development of OWAT user platforms (i.e. WEAP and NEWT). We reviewed these platforms for potential applicability in meeting the needs of intended users, as well as their limitations.

4. Development of an OWAT Plan based on the above tasks: The OWAT Plan (presented in this report) outlines suggested tasks for moving forward with OWAT development, and incorporates comments received during and after the March 11, 2014 workshop.

5. Workshop to discuss the Draft OWAT Plan: The goal of the March 2014 workshop was to discuss the Draft OWAT Plan, refine the components of the plan, and identify any remaining concerns or missing components.

6. Draft and Final Reports for the OWAT Plan: Based on discussions during and following the workshop, the OWAT Plan was revised accordingly to incorporate feedback and input.

3.3 Consultation

This phase of the project involved phone conversations, in-person meetings, a March 2014 workshop to discuss the initial draft report, and follow-up correspondence with identified key knowledge holders. Cthe following people:

- Brian Symonds, BC Ministry of Forests, Lands and Natural Resource Operations (BC MFLNRO)
- Conrad Pryce, Mr. Mike Epp, and Mr. Ray Reilly, BC MFLNRO water licensing staff
- Skye Thomson, Hydrogeologist with BC MFLNRO
- Tara White, Fisheries Biologist, BC MFLNRO
- Denise Neilson, Climate scientist, Agriculture and Agri-Food Canada (AAFC)
- Brian Guy and Drew Lejbak, Summit Environmental Consultants Inc. (Summit)
- Ron Fretwell, RHF Systems Ltd. (RHF)
- Don Dobson, Urban Systems Ltd. (USL)
- Bob Hrasko, Black Mountain Irrigation District (BMID)
- Toby Pike, Southeast Kelowna Irrigation District (SEKID)
- Allan Chapman, BC Oil and Gas Commission (BC OGC)
- Ben Kerr, Foundry Spatial Ltd.
- Pat Delaney, Danish Hydrologic Institute (DHI)

3.4 Review of Existing Models, Reports and Information Sources

The following documents and models provided information to support the preparation of the OWAT Plan. Additional descriptions of specific Okanagan Models are provided in Section 5, and references are provided in Section 10.

1. **Okanagan Water Supply and Demand Project (OWSDP)** – Suite of technical reports for surface water, groundwater, water use, lake evaporation, and instream flow needs. Phase 1 involved largely a User Needs Assessment and scoping study, while the majority of the technical work was performed in Phase 2. Some follow-up work has been part of Phase 3 of the Project. A summary report developed at the end of Phase 2 was prepared by Summit (2010).
2. **The User Needs Assessment (UNA):** The UNA brought together stakeholders, scientists, and agency staff to share information, techniques and aspirations and inform the work plan for the Okanagan Water Supply and Demand Project (ESSA, 2007).
3. **Okanagan Water Database (OkWaterDB):** This database, managed by the OBWB, is the repository for much of the water data compiled or developed during the OWSDP. The database is structured according to the key components of the Okanagan's water balance (refer to Appendix B in Summit (2010) .
4. **Okanagan Basin Hydrology Model (OBHM):** A distributed hydrologic model developed using the MIKE SHE platform. This grid-based model generates predictions of water balance components such as evapotranspiration, overland flow, interflow (near surface groundwater flow), and deeper groundwater recharge. This model is the basis for estimates of the "current" and projected natural water supply throughout the Okanagan Basin (DHI, 2010).
5. **Okanagan Water Demand Model (OWDM):** Developed primarily by the BC Ministry of Agriculture and Agriculture and Agri-Food Canada, this model estimates agricultural and non-agricultural water demands in response to current and future climates and population growth scenarios (BC MAG and AAFC, 2010).
6. **Okanagan Basin Water Accounting Model (OBWAM):** This model is also based on the MIKE SHE platform but combines the naturalized streamflow results of the OBHM with output from the OWDM to account for the effects of water extractions from groundwater and surface water resources was well as reservoir operation (DHI, 2010).
7. **Okanagan Hydrologic Connectivity Model (OHCM):** The OHCM was developed for the entire Okanagan Basin to provide a means for relatively rapid simulation and scenario evaluation. It is based on the WEAP platform and uses data generated from the OBHM and the OWDM (Summit, 2013a).
8. **Okanagan Hydrologic Connectivity Model: Trout Creek Watershed Groundwater Integration.** A pilot study to develop an appropriate method for including groundwater in the OHCM (Summit, 2013b).
9. **Northeast Water Tool (NEWT) and Northwest Water Tool (NWWT):** Customized water supply and licensing tools developed by the BC Oil and Gas Commission in partnership with FLNRO and Geoscience BC to support the decisions regarding water allocation in Northern BC. The tools includes an online viewer which incorporates near real-time water licence information along with independently derived water supply estimates (BC OGC, 2013). Expansion of the tool to other parts of BC is envisioned by the developers.
10. **A Desk-top Method for Establishing Environmental Flows in Alberta Rivers and Streams.** Alberta Environment and Alberta Sustainable Resource Development (Locke and Paul, 2011).

4. CONSULTATION OUTCOMES

To help further focus the approach needed to develop the OWAT Plan the study team consulted with a number of selected persons and agencies with knowledge and experience in water allocation and resource management in the Okanagan and elsewhere in the Province of B.C. (Section 3.3). Consultation included: phone and in-person interviews, a March 11, 2014 Kelowna workshop, and follow-up correspondence.

4.1 General Needs of Provincial Regulators

Adjudicating water licence applications in the Okanagan is a complex process that may become even more complex when the new *Water Sustainability Act* and regulations come into effect. As indicated previously, the OWAT is primarily intended to be used by MFLNRO staff to support sound, scientifically defensible decisions with respect to water licensing. According to MFLNRO, water allocation personnel are often required to make decisions with respect to: 1) issuing licences, 2) refusing licences, or 3) issuing licences with conditions. In order to properly adjudicate water licence applications, the following information is usually required:

1. Accurate water supply information for the source.
2. Accurate water demand information from the source, including existing water licences that may or may not actually be diverting water.
3. Any water restrictions on the source.
4. The influence of any groundwater extractions on the source.
5. The appropriate EFNs for the source.
6. Any requirement for an agricultural water reserve (AWR) on the source.
7. Estimate of the unrecorded water on the source after consideration of existing licenced demands, EFNs, AWR, etc.

Often this information is identified during a desktop analysis using available data on water supply and demand as well as an assessment of environmental flow needs. Water supply data are often estimated from available hydrometric data, provincial GIS data, and previous technical reports on file (sometimes dating back several decades), which vary in level of detail across the Okanagan depending on the needs of the study at the time it was completed, and site measurements and observations. Water demand estimates are based on an analysis of existing water licences, typically using the provincial E-licence database. There is no single method used to determine environmental flow needs (EFNs), and thus there is variability in the approaches and methods used. The desktop analysis may be augmented with a site reconnaissance.

MFLNRO water licensing staff in the Okanagan have indicated that they are interested to use the supply and demand data produced during the OWSDP. The OWSDP data, however, are in a format that is not easily accessible or usable in the licence decision making process. Therefore, one need of MFLNRO regulators is a tool that will allow them to easily access and use up-to-date information (e.g. OWSDP data) to assist with licensing decisions. There is also an important need to define EFNs (or procedures for determining such quantities) that are ecologically sustainable and appropriate for the Okanagan.

MFLNRO has also indicated that should the OWAT be developed, it would not necessarily be used to support decision making in isolation, but rather in conjunction with other procedures such as site reconnaissance and other desktop methods discussed above.

4.2 Specific OWAT Needs and Goals

In addition to the general need of regulators described above, based on the consultation process with potential users of an OWAT and those with an interest in or knowledge of the Okanagan's water resources and/or management, a number of needs were identified, which translate to potential OWAT goals. Although opinions varied, a general consensus emerged that the OWAT tool should possess the following general traits:

1. **Account for conditions specific to the Okanagan:**
    - At a minimum the following should be explicitly accounted for:
        - a) natural water supply,
        - b) the variable influence of regulation (i.e. storage and release of water) at both upland and valley bottom reservoirs,
        - c) water extractions from surface water sources[3],
        - d) groundwater extraction[4], and
        - e) environmental flow needs (EFNs).
    - The tool should account for the different conditions and allocation decisions[5] associated with:
        - Tributary streams (e.g. Mission, Vernon, Trout Creeks, and others),
        - Mainstem lakes (Ellison [Duck], Kalamalka/Wood, Swan, Okanagan, Skaha, Vaseux, and Osoyoos Lakes), and
        - Okanagan River.
    - The tool should account for EFNs that are not only ecologically responsible but also operationally attainable (by the water suppliers who manage upland reservoirs and stream intakes).
2. **Use best available information:**
    - Supporting models should be well calibrated or validated using actual measurements where possible.
3. **Leverage existing models where possible:**
    - Use of existing models (e.g. OBHM, OWDM, OBWAM, OHCM) to reduce costs and time for tool development.
4. **Accommodate updates when necessary:**
    - To ensure the continued use of the tool, it should be regularly updated, for example, in response to:

[3] Since actual records of water extraction from surface water sources are relatively limited in the Okanagan, various techniques for estimation are required.
[4] This includes major groundwater extractions as well as multiple small (e.g. domestic) groundwater extractions.
[5] Streams and lakes may require data at different temporal resolutions. E.g. while monthly data may sufficiently characterize lake variations, this may be too coarse for streamflow characterization with respect to water licence adjudication.

- changing climate, population, and/or land use/water use patterns,
- availability of new information,
- the issuing or modification of licences, and/or
- policy changes, such as new risk thresholds.

5. **Be well-documented to facilitate training and communication:**
   - To facilitate training and promote effective communication among water managers and the public, the tool must be clearly documented and be based on good science.
6. **Be easy to use:**
   - Once developed, the tool application should require only relatively modest training and be accessible to water allocation staff and other interested users.
7. **Provide results at a sufficient resolution to support allocation decisions:**
   - The tool should enable assessment of various allocation decisions such as those for surface water extraction and/or reservoir storage development.
   - At a minimum, the spatial resolution should include:
     - Outlets of upland reservoirs,
     - Major stream confluences, and
     - All points-of-diversion or (i.e. intakes)[6].
   - The tool should have the ability to evaluate conditions (i.e., water supply, demand, and licences) upstream and downstream of points-of-interest.
8. **Clearly report the level of uncertainty or reliability in the results:**
   - Water supply and demand varies widely throughout the Okanagan and from year to year. Such variability as well as uncertainty in any estimates should be should be clearly accounted for and reported with results.

4.3 Key Unknowns / Questions

While the consultation process indicated specific OWAT needs identified above, it also highlighted the need for further discussion regarding some aspects of water allocation in the Okanagan. Some of the questions are technical or administrative, while others involve higher level policy decisions. A summary of these questions, which were discussed at the March 11, 2014 workshop, are outlined below:

1. *What level of risk of water shortage should be adopted when adjudicating a licence application?*
   Currently, the approach that MFLNRO uses to adjudicate water licences is outlined in "Guideline #8: Water Allocation Guidelines" (Province of BC, 1996). According to this document, the acceptable risk of water shortage depends on the purpose of the application. Guidelines are provided for five (5) categories of use as outlined in Table 4.1. Note that the method used to evaluate irrigation licences is significantly different than the other uses.

[6] Locations of groundwater extraction may also be required.

Table 4.1 Summary of provincial guidelines for acceptable risk levels when assessing water availability for various purposes

	Acceptable water shortage		Water supply assessment criteria[1]	
Purpose	**Duration**	**Return Period**	**Duration of average low flow**	**Return Period**
Domestic	15 days	1 in 5 years	30 days	1 in 5 years
Waterworks (small)	15 days	1 in 5 years	30 days	1 in 5 years
Waterworks (medium)	3.5 days	1 in 10 years	7 days	1 in 10 years
Waterworks (large)	3.5 days	1 in 25 years	7 days	1 in 25 years

Irrigation	Suggested rule: Maximum Soil Water Deficit (MSWD) may exceed the safe limit by 50%, which approximates the maximum shortfall a crop can tolerate without permanent damage.
	Methodology[2]: 1. Calculate the MSWD (using reference tables/maps). 2. Multiply MSWD by 0.50 to obtain the allowable shortage of water. 3. Determine the peak evapotranspiration (ET) rate (using reference tables/maps). 4. Determine shortage duration by dividing the allowable shortage (step 2) by the peak ET rate (step 3). 5. Determine sensitivity value for crop (reference table) and multiply this value by the shortage duration (step 4). 6. Determine the appropriate return period for the crop: 1 in 5 year return period applies to *forage* and *grain*. 1 in 10 year return period applies to *berries, grapes, tree fruits, vegetables*, and *potatoes/peas*.

Notes:
1. The duration of the average low flow is double the acceptable duration of demand based on the assumption that during a 7-day (or 30-day) period, the flow will be less than the average for half of the period. E.g., an acceptable shortage of 3.5 days (or 15 days) in duration requires the use of the 7-day (or 30 day) average low flow in the supply analysis (Province of BC, 1996).
2. Refer to Province of BC (1996) for details.

It should be recognized that the water supply assessment criteria assume information is available to support the calculation of the 7-day, 30-day, or another duration average low flow. For irrigation purposes, the flow duration to evaluate is variable and is based on crop and soil conditions. With available daily streamflow records, calculation of these statistics is relatively straightforward. With respect to the 7-day average low flow statistic, for example, moving averages of seven (7) consecutive daily streamflows are calculated and the lowest value for each year is determined. Based on the annual minima calculated in this manner, a low-flow frequency analysis is then performed and the value representing the return period of interest is estimated. The availability of daily streamflows upon which to base the 7-day moving average (or 30-day moving average) is key to determine this statistic accurately. Note that a 7-day moving average using a daily time-step is not the same as weekly values. Similarly, a 30-day moving average is not the same as monthly values.

If there is a desire to meet the current provincial guidelines within OWAT, it is likely that OWAT would need to report output at a daily time-step, from which the required statistics above can be calculated. This relatively fine temporal resolution is anticipated to present significant challenges for model development and should be further evaluated and discussed.

Not only are there anticipated technical issues managing large datasets (including multiple scenarios), but also there is the issue whether the current models and data are reliable and accurate at such fine temporal resolution (i.e. daily). As part of this discussion, it is recommended that the specific criteria used to evaluate not only water supply but also water demand (e.g. licensed quantity, estimated demand[7]) be further discussed. The discussion should also include the merits of using daily vs. weekly vs. monthly vs. annual data as well as measures of central tendency (mean, median) vs. extremes.

2. *What is the most suitable spatial resolution for the OWAT?*
   According to the BC Watershed Atlas, the Okanagan has some 12,700 catchments. By comparison, in the OWSDP, 81 points-of-interest were adopted. Further deliberation is required to determine the optimal level of resolution for the OWAT. This can be achieved through continued involvement of the end users as the tool development proceeds.

3. *What is the most suitable temporal resolution for the OWAT?*
   The required temporal resolution may vary based on user needs. It could range from a daily time-step (when assessing short-term low flow events, i.e. 7-day low flows) to monthly or seasonal (when assessing lakes and reservoirs). It is also important to keep in mind the temporal resolution that can be supported by available models and data. Based on our consultation, the decision on OWAT temporal resolution will require further deliberation.

4. *Should water licensing decisions be based on current conditions or future scenarios (involving climate change, land use change and population growth)?*
   Based on our consultation, the OWAT would ideally have the ability to query different scenarios. However, according to MFLNRO, the main priority of the OWAT is to characterize "current" conditions as determined from recent historical data (e.g. last 20-30 years). The characterization of "current" normal and drought conditions are included. Projected climate change and other land use and population changes would prove useful, but are of secondary importance.

5. *What are the criteria for assessing requests for expansion of reservoir capacity?*

6. *Should surface water be allocated based on the ability of an existing reservoir to supply the proposed extraction while maintaining EFN, or based on other criteria?*

7. *What are the allocation implications of upland storage increases?*

8. *What factors should be considered for developing EFNs for the Okanagan?*

[7] It is recognized that the quantity allocated under water licences is often used as a surrogate for water demand. However, since many types of water licences are defined at coarse temporal scales (e.g. annual, seasonal), a challenge when assessing supply and demand at finer scales (e.g. monthy, weekly, daily) is to disaggregate the licensed quantity accordingly. Regardless of how this is accomplished, some bias and uncertainty is introduced. This topic requires further deliberation.

9. *When and where should EFNs take priority over licensed extractions?*
   According to MFLNRO, during the licence adjudication phase, EFNs would be considered as a component of demand and new licences would not be issued if the existing demand exceeds supply. Critical Flow Needs (CFNs), which may be used to regulate water demands during extreme water shortages would be dealt with through other processes, and therefore outside the scope of OWAT.

10. *Should the OWAT be used for decisions regarding any water licence or only "large" licence applications?*
    According to MFLNRO, this answer will depend on the time and effort required.

5. OKANAGAN MODELS, DATA, AND DATA GAPS

This section provides an overview of the key models and data sources developed as part of the OWSDP, which can provide water supply and demand information for evaluating water licence applications. Data gaps that could affect development of the OWAT are identified.

5.1 MIKE SHE and the Okanagan Basin Models

The MIKE SHE model is a distributed hydrologic model that was developed by Danish Hydrologic Institute. MIKE SHE underpins the Okanagan Basin Hydrologic Model (OBHM) and the subsequent Okanagan Basin Water Accounting Model (OBWAM) (DHI, 2010). The MIKE SHE-based models are currently managed by RHF Systems Ltd. on behalf of the OBWB. The models were developed using gridded climate data at a 500 m resolution, along with a large suite of estimated surface and subsurface parameters. Although output is technically available for sub-daily time-steps, weekly output was generated and reported for the OBHM and OBWAM.

Okanagan Basin Hydrologic Model (OBHM)

This model was developed for the baseline period 1996-2006 in order to generate weekly naturalized streamflow estimates at 81 nodes (or points of interest – POIs). The model numerically simulates the physical processes of evapotranspiration, overland flow, precipitation infiltration, and partitions infiltration into components of interflow, baseflow, and deeper groundwater. The OBHM therefore generates *naturalized* gridded estimates of overland flow, interflow, and baseflow, which can be then assigned to specific stream reaches. Scripts have been developed to assign MIKE SHE output to specific points of interest, which have been used for example in the Okanagan Hydrologic Connectivity Model (Section 5.2).

The OBHM was calibrated using desktop estimates of naturalized streamflow developed through previous work of the OWSDP, as well as overall water budgets, snow water equivalent data, and Okanagan Lake data (DHI, 2010). An uncertainty analysis suggested a considerable range of uncertainty from <10% to over 50% depending on the specific POI. During model calibration, groundwater parameters were adjusted to match the baseflow component of desktop naturalized streamflow estimates. While groundwater is accounted for, it was not explicitly represented for in the model.

Okanagan Basin Water Accounting Model (OBWAM)

Once the OBHM was fully developed and calibrated, the model was enhanced to run future water supply and demand/use scenarios for development of the Okanagan Basin Water Accounting Model (OBWAM) (DHI, 2010). The OBWAM simulated scenarios to evaluate potential impacts of climate change, land use changes, population growth and water efficiency programs. Projected water use under future scenarios were determined using the Okanagan Water Demand Model (Section 5.4). The OBWAM was calibrated to observed lake levels and discharges along the mainstem system at seven (7) hydrometric stations (i.e. stream gauges). Calibration was generally successful in obtaining a good fit to most data, but some calibration difficulties were documented. Calibration procedures involved adjustments to gridded topography at mainstem lakes, temperature and snowmelt parameters, and mainstem lake regulation. Multiple factors contribute to model uncertainty. These include uncertainty due to model data error and naturalized streamflow input uncertainty. The limited uncertainty analysis indicated overall model uncertainty was highly variable and ranged from <10% to >50%, depending on the point of interest (total of 81 POI).

OBHM/OBWAM Data and OWAT Data Needs

The following are key points with regards to potentially using OBHM and OBWAM data in developing the OWAT:

1. As developed, OBHM/OBWAM requires several days of processing time to run through a 30-year scenario, thus the generation of new datasets (e.g., for different time periods or different scenarios) demands careful planning in order to optimize resources.
2. There are significant complexities in completing simulations and managing data output (however, the OBWB is currently working with DHI to resolve some of the output management issues).
3. Models use a 500 m grid resolution, which although satisfactory in many areas, is relatively coarse for accurate evaluation of inflows to reservoirs in small catchments or smaller catchment streamflow.
4. A thorough sensitivity and uncertainty analysis has not been conducted for the models (due to project constraints at the time of OBWAM development).
5. Uncertainty in the data produced by the MIKE SHE-based models could be due to a number of factors including:
    a. Groundwater flow was not physically-modeled, but represented using a reservoir approximation approach.
    b. Groundwater extractions in the OBWAM were accounted for implicitly by calibration of the baseflow contributions to the tributaries, rather than modeled explicitly.
    c. Upland reservoirs (in the OBWAM) were operated in the model based on "broad" assumptions and simplifications, not necessarily as practiced. Also as noted above, reservoirs capturing runoff from small catchments may not be well represented given the grid resolution used.

   d. Significant difficulties were encountered with respect to representing the regulation of main-stem lakes.
6. The models have not been verified to demonstrate their predictive capability at the tributary level. The models have been *calibrated* to match specific data as indicated above. Model *verification*, however, would be required to demonstrate the model's ability to generate accurate predictions over time periods other than that used for calibration, or when there are changes in the system (e.g, if reservoir storage or operation changes, does the model still generate accurate predictions of gauged streamflow?).

5.2 Okanagan Hydrologic Connectivity Model (OHCM)

The Okanagan Hydrologic Connectivity Model (OHCM) (Summit, 2013a) was developed to illustrate how water management actions are interconnected within the Okanagan Basin and to help the OBWB and major water purveyors examine water supply/demand scenarios. The OHCM uses the Water Evaluation and Planning (WEAP) modeling platform (developed by Stockholm Environmental Institute - SEI). WEAP is not a physically-based numerical model, but an accounting model that arithmetically determines water inputs and outputs though an iterative procedure that allows for relatively efficient simulations of complex water management scenarios. The OHCM represents both natural and human influences on the Basin's surface water resources including rivers and creeks, reservoirs, inter-basin transfers, water users, return flows, and IFNs.

The OHCM was developed for the same 11 year period (1996-2006) covered by the OWSDP. It is important to recognize that the OHCM does not operate independently but rather uses water supply estimates from the MIKE SHE-based OBHM and OBWAM (Section 5.1). Furthermore, it relies on estimates of water demand from the Okanagan Water Demand Model (OWDM) or alternatively licensed quantities. Locations of major licensed surface water extractions are embedded in the OHCM. Twenty-one (21) major water users were represented in twelve (12) selected tributary catchments (Mission, Kelowna, Trout, Powers, Trepanier, Lambly, Ellis, Penticton, Peachland, Eneas, Irish, and Vernon Creeks). Smaller individual licences are cumulatively accounted for within each major catchment. For demonstration purposes, the model assumes EFN estimates as the 25th percentile of natural flows. Some reservoir operation rules were incorporated into the OHCM; however, the model was not constructed to represent specified reservoir operating rules. Instead, reservoir operation reflects downstream demand. Since the OHCM focused on examining water licence priorities, each water licence holder was assigned a priority according to the date on which their licence was granted. Furthermore, priorities were assigned for instream flows as well as reservoir filling (i.e. in some scenarios these were given priority, in others they were not). As a result of varying priority settings in the model, different output is available. The OHCM generates weekly "net" streamflow values and shows time periods when streamflows may not be adequate to meet demand and EFNs.

The OHCM was tested by comparing net streamflows (calculated by the OHCM) against streamflows modeled by the OBWAM (Section 5.1) at the mouths of major stream catchments, and comparison to actual and OBWAM-modeled lake levels.

The OHCM as developed does not reflect groundwater supply or use. A pilot study for the Trout Creek watershed (Summit, 2013b) considered the potential to use the WEAP platform to represent groundwater extractions within the OHCM (see Section 5.3).

Considerations regarding the OHCM and its data outputs with respect to the OWAT needs and goals include:

- It is not a physically based model.
- It relies on input of data from the OBHM, which has inherent uncertainties and limitations discussed above.
- The OHCM incorporates EFN estimates (25th percentile of natural flows) as a surrogate for more rigorous estimates of EFNs.
- The OHCM has not been fully developed to reflect details of water supply and use across the Okanagan. The model represents twelve (12) major stream catchments within the Okanagan and only major water users are represented in detail.
- The OHCM cannot physically model nor represent hydrogeological or hydrological implications of groundwater extractions. It is principally a water accounting model, so to incorporate these processes, they would need to be assessed in some manner prior to incorporation into WEAP.
- The model must be modified to provide data to meet the OWAT goals, because the OHCM was developed for a specific purpose with specific rules, priorities, and assumptions.
- The OHCM was verified to the results of the OWAM for each respective tributary; and, the OWAM and the OBHM were verified to actual gauged records and (where records not available) naturalized streamflow estimates during Phase 2 of the OWSDP. Thus, OHCM results should be considered as equivalent to the accuracy of the OWAM and OBHM results.

5.3 OWSDP Groundwater Study and OHCM GW Integration Pilot Study

OWSDP Groundwater Objectives 2 and 3 Basin Study (Golder and Summit, 2009)

The purpose of this groundwater study was to provide an overview of the groundwater component of flow within the Basin for the OBWAM, and was designed to be applied on a Basin scale. The report does provide an analysis of individual aquifers within the Basin, but does not provide detailed groundwater characteristics for aquifers at a local scale.

The general methodology of the groundwater study involved a review of available data to map upland bedrock aquifers and valley unconsolidated aquifers. Available data were also reviewed to estimate general aquifer dimensions and bulk hydrogeological properties. The water balance analysis was then completed for the unconsolidated valley aquifer system using a Groundwater Balance Analysis spreadsheet tool (GWBAT) to assist in broadly estimating long term water balances (inputs and outputs) for the identified aquifers.

Bedrock aquifers were accounted for in the study in a highly simplified manner. This was accomplished by using climate and other data to assign a steady-state aquifer recharge rate, which was then translated into the GWBAT analysis as a discharge rate where bedrock aquifers discharged either to down-gradient unconsolidated aquifers or to a mainstem lake or river.

Considerations regarding the OWSDP Groundwater study with respect to providing data to meet the needs and goals of the OWAT include:

- The groundwater study provided preliminary estimates to quantify groundwater supply at the individual mapped aquifer scale (i.e. basic groundwater balance or discharge estimates), but not the information necessary to support a potential future licensing decision, such as whether or not well interference could occur or if abstraction (pumping) would intercept surface water flow.
- The parameters in the GWBAT spreadsheet (e.g., aquifer hydrogeologic properties, stream losses, aquifer to aquifer transfers, and inputs from adjacent bedrock highlands) were assigned in many instances with limited information, such as interpretation of well drillers reports but without actual aquifer hydraulic data. Thus the unconsolidated aquifer water balances produced by the study have a high level of uncertainty.
- Locations and characteristics of groundwater/surface water interactions were not specifically established or verified (in fact, further assessment of groundwater -surface water interaction, and increased groundwater monitoring were key recommendations of the study).

OHCM Trout Creek Watershed Groundwater (GW) Integration Pilot Study (Summit, 2013b)

This pilot study was completed to investigate the potential to integrate groundwater into the existing OHCM, using the Trout Creek watershed. It reviewed potential methods to integrate groundwater into the OHCM using the WEAP framework. The integration required conceptualized aquifer to aquifer linkages and aquifer to surface water linkages for areas of groundwater use, as well as estimates of aquifer hydrogeological characteristics. The simulations suggested the WEAP model may be useful to broadly represent groundwater extraction influences on streamflow based on the conceptualized locations of aquifer – stream linkages. There were challenges with the ability of the WEAP platform to assess aquifer storage changes over time and the potential for well interference.

While no specific data were generated as a result of this work, it provided an important assessment of the potential challenges of representing groundwater in a water accounting model such as WEAP, and an indication of the level of detail (spatial scale) with which a WEAP-based model can estimate how groundwater extraction influences streamflow. The work highlighted that identifying locations and characterizations of aquifer-surface water linkages are a primary data gap for moving forward with groundwater integration into WEAP for water budget accounting.

5.4 Okanagan Water Demand Model and Water Use Data

The Okanagan Water Demand Model (OWDM) was developed by the Ministry of Agriculture and Lands (MAL) and Agriculture and Agri-Foods Canada (AAFC) with assistance from Environment Canada. The model is centered around the Agriculture (Irrigation) Water Demand Model (van der Gulik et al., 2010) which is based on a GIS database containing detailed information on crop type, irrigation system type, soil texture and gridded climatic data. These data were ground-truthed through a comprehensive land use inventory using resources from local government, water purveyors and locals with knowledge of agriculture in the Okanagan Valley. The model estimates crop water demand for individual polygons that represent unique combinations of crop type, irrigation type, soil and climate. These polygons are summed to determine the demand for each land parcel or cadastre. The cadastre water demands are then summed to obtain total demand for a watershed, sub-basin, water purveyor or local government.

As part of the OWSDP all other forms of water use within the Okanagan Basin were incorporated into the demand model (e.g. irrigation of domestic properties, irrigation of green spaces, irrigation of golf courses, and indoor water use for domestic, industrial, commercial, and institutional purposes). Given the limited availability of water use records in the Okanagan, the information provided by the OWDM was a key input for the Okanagan Water Accounting Model.

With regards to a future OWAT, the OWDM would likely be indispensable in providing a thorough picture of water demands in the Okanagan. However, further verification and calibration is desirable to improve reliability particularly with respect to non-irrigation water use. This may be possible given additional water use records may be available, for example through the BC Water Use Reporting Centre. In addition, given that the OWDM is based on land use information, as this changes updates to the land use inventory will be required.

5.5 Environmental Flow Needs[8] Assessment

An Environmental Flow Needs Assessment was completed by part of the OWSDP (ESSA 2009). The assessment involved the development of EFN thresholds for the entire Okanagan basin divided into 38 Okanagan tributary streams using a combination of two peer reviewed methods: 1) the Hatfield and Bruce (2000) meta-analysis approach (based on 127 physical habitat simulation studies in western North America), and 2) the BC Phase II Instream Flow Guidelines (Hatfield et al. 2003). Details of these methods can be found in ESSA/Solander (2009). ESSA/Solander used these methods in conjunction with naturalized flows generated by the OBHM to define recommendations for each week in a calendar year: 1) optimal flows for different salmonid species and lifestages, 2) flows that minimize risk to fish and

[8] The term Environmental Flow Needs (EFN) is used herein for consistency with the BC Water Sustainability Act. For the purposes of this report, it is considered analogous with Instream Flow Needs (IFN).

other biota, and 3) watershed conservation flows (in high flow months) that promote broader ecological functions.

Considerations regarding the OWSDP Instream Flow Needs Assessment with respect to the OWAT needs and goals include:

- Are BCIFN flows the most appropriate method for the Okanagan?
- How to integrate BCIFN flows with the OWAT?
- Is the spatial resolution appropriate for the OWAT?
- The BCIFN flows are not achievable in drier years. Which methods should be used to establish targets for dry water years?
- Support a research project that explicitly considers water temperature requirements and impacts on recommended flow thresholds.
- Assess stakeholder risk tolerance to fish harm.

5.6 Okanagan Water Database (OkWaterDB)

This database, managed by the OBWB and RHF Systems, is the repository for much of the water data compiled or developed during the OWSDP. The database is structured on the key components of the Okanagan's water balance (refer to Appendix B in Summit (2010)). Much of the data are time-series output from the various supply and demand models developed as part of the OWSDP, however there is considerable input data (e.g. climate data) as well as metadata. In its current form, the database is a repository of uploads from study partners and consultants. A recent review of the database returns some 120 distinct data uploads or instances (Table 5.1). Currently, there is no ability to download data online (Fretwell, pers. comm, 2014) so data requests must be made to OBWB. Given the volume of data (multiple model runs from a number of models), navigating through the database is generally challenging and time consuming. In an effort to present a small subset of this information graphically, the OkWaterDB has a map-based graphic viewer. However, the viewer facilitates only relatively rudimentary water supply and demand queries, and as a result does not present sufficiently detailed information to support water licence decision making.

With respect to the OWAT, the database represents time-series output from various model runs. The applicability of this data for water allocation purposes is directly related to the assumptions made in the specific model, the model calibration/verification, and the scenarios (e.g. climate, land use, population) modeled. Prior to using any specific dataset it is important that a data inventory be conducted, which would result in a consolidated listing of the volume of data within the Okanagan Water Database. Once this inventory is complete, the data should be critically reviewed with respect to the goals (i.e. desired resolution and accuracy) of the OWAT.

Table 5.1 List of datasets contained within the Okanagan Water Database

179 WUAM pilot: various terms (ESSA Part I)
234 WUAM pilot: natural streamflows (ESSA Part II)
236 Okanagan Lake Evaporation - KELOWNA - ETR - 1996-2006
237 Okanagan Lake Evaporation - SUMMERLAND - ETR - 1996-2006
238 Okanagan Lake Evaporation - PENTICTON - ETR - 1996-2006
239 Okanagan Lake Evaporation - AVERAGE - ETR - 1996-2006
246 Core Maps - Okanagan Supply and Demand Study
247 Lake Evaporation for Four Lakes: Osoyoos, Vaseux, Skaha and Kalamalka-Wood Lake
255 GW Pilot Study
259 WUAM pilot: terms 1 and 7 (ESSA Part III)
271 Osoyoos Lake Precipitation 1996 - 2006
273 Okanagan Lakes (other than Osoyoos Lake) Precipitation 1996 - 2006
275 Revised Final WMUS study data
277 Instream Flow Needs: Sockeye: FWMT (Okanagan River)
278 Final Okanagan Basin Naturalized Flows
279 Aquifer water useage summary
282 Instream FN: Trout Crk Agreement - dry years (8.5xCamp to 10xCamp)
283 Instream FN: Trout Crk Agreement - dry years (6.5xCamp to 9.5xCamp)
284 Instream FN: Trout Crk Agreement - average/wet years (10xCamp)
285 Instream FN: Trout Crk Agreement - average/wet years (9xCamp)
286 Instream FN: Mission Crk draft Water Use Agreement
289 Instream FN: max diversion flows tributary streams (BCIFN)
297 Instream FN: optimal fish Q - Chinook - rearing (lower 50% PI)
298 Instream FN: optimal fish Q - Chinook - rearing (mean)
299 Instream FN: optimal fish Q - Chinook - rearing (upper 50% PI)
300 Instream FN: optimal fish Q - Chinook - spawning (lower 50% PI)
301 Instream FN: optimal fish Q - Chinook - spawning (mean)
302 Instream FN: optimal fish Q - Chinook - spawning (upper 50% PI)
303 Instream FN: optimal fish Q - coho - rearing (lower 50% PI)
304 Instream FN: optimal fish Q - coho - reaing (mean)
305 Instream FN: optimal fish Q - coho - rearing (upper 50% PI)
306 Instream FN: optimal fish Q - coho - spawning (lower 50% PI)
307 Instream FN: optimal fish Q - coho - spawning (mean)
308 Instream FN: optimal fish Q - coho - spawning (upper 50% PI)
309 Instream FN: optimal fish Q - kokanee - spawning (lower 50% PI)
310 Instream FN: optimal fish Q - kokanee - spawning (mean)
311 Instream FN: optimal fish Q - kokanee - spawning (upper 50% PI)
312 Instream FN: optimal fish Q - rainbow trout - rearing (lower 50% PI)
313 Instream FN: optimal fish Q - rainbow trout - rearing (mean)
314 Instream FN: optimal fish Q - rainbow trout - rearing (upper 50% PI)
315 Instream FN: optimal fish Q - rainbow trout - spawning (lower 50% PI)
316 Instream FN: optimal fish Q - rainbow trout - spawning (mean)
317 Instream FN: optimal fish Q - rainbow trout - spawning (upper 50% PI)
318 Instream FN: optimal fish Q - sockeye - spawning (lower 50% PI)
319 Instream FN: optimal fish Q - sockeye - spawning (mean)
320 Instream FN: optimal fish Q - sockeye - spawning (upper 50% PI)
321 Instream FN: optimal fish Q - steelhead - rearing (lower 50% PI)
322 Instream FN: optimal fish Q - steelhead - rearing (mean)
323 Instream FN: optimal fish Q - steelhead - rearing (upper 50% PI)
324 Instream FN: optimal fish Q - steelhead - spawning (lower 50% PI)
325 Instream FN: optimal fish Q - steelhead - spawning (mean)
326 Instream FN: optimal fish Q - steelhead - spawning (upper 50% PI)
327 Instream FN: conservation flows tributary streams (BCIFN derived)
328 Instream FN: min flow thresholds tributary streams (BCIFN)
329 Final Unconsolidated Aquifer Properties
332 Groundwater Balance Analytical Tool (GWBAT) Spreadsheets (Aquifers 201 to 241)
333 Groundwater Balance Analytical Tool (GWBAT) Spreadsheets (Aquifers 242 to 279)
335 Metadata for Groundwater Objectives 2 and 3, Part I
336 Metadata for Groundwater Objectives 2 and 3, Part II
337 Metadata for Groundwater Objectives 2 and 3, Part III
338 Metadata for Groundwater Objectives 2 and 3, Part IV
339 Regulated Flows for Selected Nodes
342 Main valley-bottom lake level elevations
349 Groundwater Objectives 2 and 3
350 Updated Water Management and Use Terms

358 Okanagan Valley Water Extraction 1996-2006
372 Okanagan Valley Water Use 1996-2006
459 Scenario 99 Demand - calibration period using bias-corrected cgcm2.a2 precipitation and temperature
460 Scenario 25 Demand (T1C1M1E3A3P3: 2011-2040 - effect of climate change alone); bias-corrected precipitation and temperature
461 Scenario 1 Demand (T1C1M1E1A1P1: 2011-2040 - current trends continued); bias corrected climate data
462 Scenario 3 Demand (T1C1M1E1A2P1: 2011-2040 - current trends except expanded agriculture); bias-corrected climate data
463 Scenario 4 Demand (T1C1M1E1A2P2: 2011-2040 - current trends except rapid population growth and expanded agriculture); bias-corrected climate data
464 Scenario 2 Demand (T1C1M1E1A1P2: 2011-2040 - current trends, except rapid population growth); bias-corrected climate data
465 Scenario 5 Demand (T1C1M1E2A1P1: 2011-2040 - efficient water use, otherwise current trends continued); bias-corrected climate data
466 Scenario 6 Demand (T1C1M1E2A1P2: 2011-2040 - efficient water use, rapid population growth, otherwise current trends); bias-corrected climate data
471 Scenario 7 Demand (T1C1M1E2A2P1: 2011-2040 - efficient water use, expanded agriculture, otherwise current trends); bias-corrected climate data
477 Scenario 8 Demand (T1C1M1E2A2P2: 2011-2040 - efficient water use, rapid population growth, expanded agriculture, expected climate and pattern of MPB); bias-corrected climate data
487 Water balance terms for Scenario1
488 Water balance terms for Scenario2
489 Water balance terms for Scenario3
490 Water balance terms for Scenario4
491 Water balance terms for Scenario5
492 Water balance terms for Scenario6
493 Water balance terms for Scenario7
494 Water balance terms for Scenario8
495 Water balance terms for Scenario17
496 Water balance terms for Scenario18
497 Water balance terms for Scenario19
498 Water balance terms for Scenario20
499 Water balance terms for Scenario25
500 Water balance terms for Scenario26
501 Water balance terms for Scenario27
506 Water balance natural flow terms for calibration period GCM bias corrected
507 Water balance natural flow terms for scenario1
508 Water balance natural flow terms for scenario2
509 Water balance natural flow terms for scenario3
510 Water balance natural flow terms for scenario4
511 Water balance natural flow terms for scenario5
513 Water balance natural flow terms for scenario7
514 Water balance natural flow terms for scenario8
519 Water balance natural flow terms for scenario25
520 Water balance natural flow terms for scenario26
522 Scenario 27 Demand (T2C1M2E3A3P3: 3 driest years 2011-2100 - 3 successive drought years starting 2011); bias-corrected climate data
523 Scenario 26 Demand (T3C1M1E3A3P3: 2041-2070 - effect of climate change alone); bias-corrected climate data
524 Scenario 17 Demand (T2C1M1E1A1P1: 3 driest years 2011-2100 - 3 successive drought years - current trends continued); bias-corrected climate data
525 Scenario 18 Demand (T2C1M1E1A1P2: 3 driest years 2011-2100 - 3 successive drought years - current trends, except rapid population growth); bias-corrected climate data
526 Scenario 19 Demand (T2C1M1E1A2P1: 3 driest years 2011-2100 - 3 successive drought years - current trends except expanded agriculture); bias-corrected climate data
527 Scenario 20 Demand (T2C1M1E1A2P2: 3 driest years 2011-2100 - 3 successive drought years - current trends except rapid population growth and expanded agriculture); bias-corrected climate data
528 Water balance terms for scenario17_corrected
529 Water balance terms for scenario18_corrected
530 Water balance terms for scenario19_corrected
531 Water balance terms for scenario20_corrected
532 Water balance terms for scenario27_corrected
534 Water balance terms for calibration period_Qout_corrected (1996 - 2006)
539 test of new OBWB server
540 Remote test of upload to new server - outside of RDCO
541 Copy of Scenario 25 Demand (T1C1M1E3A3P3: 2011-2040 - effect of climate change alone); bias-corrected precipitation and temperature Metadata Only
542 Copy of Scenario 19 Demand (T2C1M1E1A2P1: 3 driest years 2011-2100 - 3 successive drought years - current trends except expanded agriculture); bias-corrected climate data Metadata Only
544 Phase 3 Scenario 28 Water Balance Terms

6. SUMMARY OF PRIMARY CONSTRAINTS, CHALLENGES AND QUESTIONS TO BE RESOLVED

Based on the review of existing models and data (Section 5) and discussions during the consultation process (Section 0), the following challenges or unresolved questions were identified with respect to meeting the OWAT needs/goals.

1. Although progress has been made toward developing operationally attainable environmental flow needs (EFNs) in select watersheds through the water use planning process (e.g. Mission Creek, Trout Creek), EFNs have not been universally established in the Okanagan. Agreement is required regarding methodologies for establishing EFNs for the purposes of water allocation in the Okanagan Basin. Until specific studies are done, such as those conducted for Mission and Trout Creeks, consensus is needed on how to assign, and prioritize, EFNs in the basin.
2. Although provincial water allocation guidelines are available (Province of BC, 1996), a number of questions need to be addressed regarding the procedures and criteria for adjudicating water licence applications, and specifically how OWAT would fit into these. For example, will OWAT be relied upon as a source of relatively high level water supply and water licensing information (e.g. similar to that of North East Water Tool [Section 7.2]), or be expected to provide the detailed statistics required to adjudicate water licences according to current provincial guidelines? Such questions must be answered prior to moving forward with the OWAT.
3. The water supply data developed by the OBHM is based on a large suite of assumptions and was calibrated or verified with relatively limited information. It may be warranted to evaluate the uncertainty of these data and/or consideration of updates to reflect new data available, if it is to form the basis for water allocation decisions. Uncertainty analysis would need to address supply and demand uncertainty separately.
4. In anticipation of groundwater licensing under the new Water Sustainability Act, challenges associated with incorporating groundwater into the OWAT include:
    - While the groundwater component of the OWSDP compiled basic information regarding aquifers, it remains that knowledge of aquifer characteristics, groundwater flow systems and existing groundwater supply and demand lags behind surface water hydrology knowledge in the Okanagan.
    - Given that existing models represent groundwater in a highly simplified manner, OWAT development must consider the issues that are likely to arise when adjudicating groundwater licences, such as well interference and stream capture. Such issues cannot be addressed with existing models, and so will require either site specific studies; and, in the absence of studies, procedures that will enable decisions to be made when data are lacking.
    - Many of the anticipated scientific issues relating to groundwater will likely need to be addressed outside of OWAT through the implementation of regulations requiring technical studies in support of new groundwater licences. The groundwater supply information coming out of the grandparenting of existing wells (type of use, flow rate, duration, etc) is an example of information that is not yet available that would form part of the database that would populate the OWAT.

- o Groundwater has not been explicitly accounted for in OBHM, OBWAM, or OHCM at least partly due to the lack of groundwater information. In anticipation that water allocation decisions will ultimately need to include groundwater, an appropriate and cost-effective way to represent groundwater in the models should be assessed. An initial step involving a linkage analysis is a possible first step (see Section 8).
- o Based on the above, a decision on how to incorporate groundwater into OWAT is needed. One possibility is to use a piloted approach by selecting a relatively small number of watersheds in which the tool would represent groundwater.

5. There is currently no central database that associates water licences (and points-of-diversion) with estimates of water demand and/or meter records documenting actual water use. Such a database would represent the convergence of at least the existing Provincial water licensing database, the OWDM (and its supporting GIS data), and the BC Water Use Reporting Centre. Developing a comprehensive database such as this would be technically challenging, however, given that some work has already been done on this topic (e.g. in developing the OHCM) it should be feasible and would prove highly valuable. The challenge not only lies in the sheer number of water users and licences in the Okanagan but also the several complexities stemming from the water licensing system. For example, decisions or assumptions must be made on how to reconcile estimated demand with licences and meter records where multiple licences, point-of-diversion, or users are involved (e.g. a large water utility). In addition, assumptions and/or rules will need to be developed in cases where reconciliation involves information with different time scales (e.g. annual, seasonal, monthly, weekly, daily). It will be important that assumptions be minimized in order to minimize uncertainty and the introduction of bias.
6. The provincial E-licence database does not report all conditions on a licence, such as seasonal restrictions. Therefore, it is difficult to capture all pertinent information without referencing hardcopy files – a time-consuming process when evaluating a large area such as the Okanagan.
7. The current OHCM has been developed based on a suite of rules and priority ratings which may require changes/adjustment depending on MFLNRO licence evaluation procedures and criteria.
8. For a couple of the Okanagan water suppliers, water is imported from watersheds outside of the Okanagan Basin. Within the OBHM and OWAM, the geographic extent of the model domain did not include any areas outside of the Okanagan Basin. As a result, the natural source of imported water is not currently estimated using existing models. It is therefore recommended that the OBHM and OWAM be updated to include the watershed areas outside of the Okanagan Basin. These watershed areas are as follows:
   - o Duteau Creek (Shuswap River Watershed) – Greater Vernon Water;
   - o Fortune Creek (Shuswap River Watershed) – City of Armstrong;
   - o Stirling Diversion (West Kettle River Watershed) – South East Kelowna Irrigation District; and
   - o Alocin Diversion (Nicola River Watershed) – District of West Kelowna.
9. Before proceeding further with OWAT there must be a clear decision by the MFLNRO as to what form the tool should take. During the consultation process, a number of options were identified as described below:
   - o Development of a model/tool internally by Corporate Services, the NEWT/NWWT approach, and/or the OWAT.

- While not affirmed, the consensus appears that a two-tiered approach is desired. This would comprise a higher level NEWT/NWWT approach (Section 7.2) used for the Thompson Okanagan Region[9], while a WEAP-based model (Section 7.1) could be developed for the Okanagan[10][11]. In this way, one approach could complement the other and could be incorporated into an updated water allocation procedure where the appropriate version of the decision support tool would be chosen based on the data available.
- Having two models cover the same spatial domain may raise a number of issues such as how to resolve potential inconsistencies and how to avoid confusing end users.

10. Consensus should be sought for who the ultimate end-users are. We recognize that the OWAT is to be developed primarily for MFLNRO staff; but should it also to be designed for the public? Regardless, the end-users (including but not limited to qualified staff from MFLNRO) should be involved in the development process from beginning to end. This should include product testing with real scenarios and feedback to model/tool developers with the user interface component developed as early in the process as possible.
11. The issue of model/tool ownership, royalties, updates, maintenance and security requires further deliberation and is more appropriately resolved in the next phase of OWAT development.
12. With the development of OWAT, it will be desirable to assess the allocation status (i.e., fully allocated, potentially over-allocated, or not yet fully allocated) of the Okanagan's watersheds. Such an assessment would require specification of EFNs and establishment of licence evaluation criteria. (A similar exercise should be planned for the valley's major aquifer systems, listed in Table 10 of the Golder-Summit (2009) Objectives 2 and 3 groundwater study.)

[9] A NEWT/NWWT-like product is slated to begin development in summer 2014 for Thompson-Okanagan Region (Kerr, pers. comm., 2014).
[10] NEWT/NWWT is designed as a public interface tool which is usable by provincial agencies. It is our understanding that the OWAT's is primarily intended to be a tool for water allocation staff to adjudicate licence applications.
[11] It is recognized that the Okanagan generally has more detailed water supply and demand information as a result of the OWSDP.

7. EVALUATION OF POTENTIAL OWAT PLATFORMS

The structure of the OWAT will be built upon underlying platforms that allow the user to extract and/or analyze water supply and demand data for licence evaluation. As indicated in Section 2, two potential OWAT platforms were selected by OBWB for review by this project with respect to meeting the objectives of the OWAT.

1. Water Evaluation and Planning Tool (WEAP), developed by Stockholm Environment Institute (SEI), and
2. Northeast Water Tool (NEWT) (and Northwest Water Tool (NWWT)), developed by the BC Oil and Gas Commission (BC OGC) and its partners MFLRNO and Geoscience BC.

Each of these platforms has different capabilities and potential uses for the development of the OWAT and they are described in the following sections (Sections 7.1 and 7.2). Based on the review, Section 7.3 provides recommendations regarding the approach for using these platforms in developing the OWAT.

7.1 WEAP Platform

WEAP is a water accounting platform capable of simulating different scenarios and providing data output to assist in water licence decision making. As described above, the OHCM was developed using the WEAP platform to represent many of the unique and complex aspects of water systems in the Okanagan. Assuming input data are available (e.g. output for a specific scenario from the OBHM and OWDM) and formatted correctly, the OHCM can be run in a timely manner and can provide results, for example, to directly evaluate the influence of existing and proposed extractions on streamflow, to determine if instream flows could be met, or to assess whether sufficient upland storage exists to support a new (downstream) water licence application. It is unlikely that the OHCM in its present form would meet the specific needs and goals of OWAT (see Sections 4.1and 4.2) given the scope and focus of the OHCM. However, the WEAP platform provides a viable means of accounting for water supply and demand as required by the OWAT.

Advantages of the WEAP platform include:

1. Relatively complex water systems (such as the Okanagan) can be represented.
2. Model simulations are relatively fast (time frame of seconds to minutes).
3. Although technical knowledge is required to operate WEAP, it is far simpler than for example, distributed process-based hydrologic models (e.g. MIKE SHE).
4. WEAP is well-suited for simulating upland reservoir operation and therefore has potential for use in assessing licence applications for reservoir storage increases as well as the ability of a reservoir to supply a new downstream surface water licence.
5. Water use priorities and constraints or rules can be embedded in the model and modified as required (e.g. instream flow needs).
6. Various input data can be used, however as with all models, data must formatted correctly.

Potential challenges of the WEAP platform:

1. As a water accounting model, WEAP is dependent upon input data to characterize the pattern of water supply and demand. For the OHCM, these data are provided by the OBHM (for water supply) and the OWDM (for water demand) or provincial water licence database. This dependence means that as new scenarios are developed, the three models would need to be run.
2. Data output tends to be complex and large datasets are generated. Although WEAP contains a data viewer, it may not provide results in a desirable format. Scripts would be required to convert the output data into a user-friendly form needed by MFLNRO staff to adjudicate water licence applications. Furthermore, there is potential to develop a customized user-interface similar to the NEWT/NWWT (Section 7.2) which is discussed below. Such an interface would not interact directly with the core models, but rather provide a means to query the output data of various selected model runs.
3. Use of the core model(s) if desired would require training of MFLNRO staff.
4. If water use data are embedded within the model structure, WEAP would need to be updated as each new licence or groups of licences are approved.
5. WEAP cannot physically model nor represent hydrogeological or hydrological implications of groundwater extractions. It is principally a water accounting model, so these processes would need to be assessed in some manner prior to incorporation into WEAP.

7.2 Northeast Water Tool (NEWT) Based Platform[12]

The Northeast Water Tool (NEWT) was developed for use in northeast BC by the BC Oil and Gas Commission (BC OGC) in partnership with MFLNRO and Geoscience BC (**http://www.bcogc.ca/public-zone/northeast-water-tool-newt**). The framework of NEWT has also been used in the development of a similar tool for Northwest BC (i.e. NWWT). Therefore, if it is adoption of this model for the Okanagan would foster consistency across the province.

NEWT is an interactive GIS-based user interface developed for northeast BC that was built to support regulatory decisions and dissemination to surface water supply and licence information to the public. The NEWT interface generates specifically designed output for queries at requested points of interest, where the output is linked to underlying databases of water supply (i.e. annual and monthly streamflow), water licences, and EFNs. The output allows users to evaluate surface water availability for specific sub-basins within a watershed, in light of existing licences and EFNs, with consideration of cumulative effects within defined "water management basins." It is important to recognize that the supply information reflects long-term normals or typical conditions and not low-flow or drought conditions, which often are a key factor in water supply and demand issues.

While the tool and underlying data comprising NEWT are specifically developed for Northeast BC, the NEWT framework has potential applicability in other areas of the province, particularly in ungauged or

[12] The Northwest Water Tool (NWWT) has been subsequently developed. However, the study team has not had the opportunity to review this model, which we understand is similar to NEWT.

poorly gauged basins. It is our understanding that a NEWT-like tool is slated for development by the MFLNRO in the Thompson-Okanagan Region in summer 2014 (Kerr, pers. comm., 2014).

According to Chapman et al. (2012) and Kerr (pers. comm. 2014), NEWT was developed to specifically estimate normal annual and monthly flows and EFNs, which provide a basic reference against which existing and proposed water licences can be compared. An annual water balance model using a conservation of mass approach was initially developed using gridded precipitation, temperature, and evapotranspiration (ET) data as well as land cover/vegetation mapping, and hydrometric data. This model was calibrated by using the continuity equation *Annual Runoff (Q) = Annual Precipitation (P) – Annual Evapotranspiration (ET)*, and by monitoring regional data inputs and results. The authors indicate that exploratory spatial data analysis (involving expert knowledge) was a large component of this work so that the hydrology of the region is reflected as effectively as possible given the data constraints. Normal monthly runoff was estimated based on a multivariate regression technique[13] to distribute the modeled annual runoff to individual months. Although the study team did not have the opportunity to evaluate the model in detail, we did discuss it with the NEWT developers to gain better understanding of the model, and we also examined the online user interface. We summarize the key results of our review below.

Advantages of a NEWT-like user platform include:

1. Given the development of NEWT and NWWT, development of a similar product in the Thompson-Okanagan would promote consistency within MFLNRO.
2. The user-interface is relatively simple to use, attractive and facilitates queries for specific points (or catchments) of interest. The reported output is obtained quickly and well laid out and informative.
3. For consistency across government agencies and others, the tool is based on defined catchments in the BC Watershed Atlas. This appears to provide a reasonable level of spatial resolution in most circumstances.
4. The tool is linked to underlying database(s) for water supply, water licence information, and EFNs, which can be updated as needed to reflect new information. The ability to update the tool is particularly important with respect to the water licence information, which may change often.
5. The current methodology for developing the water supply database involves significant expert knowledge and review, similar to the approach used in the in Phase 2 Surface Water Hydrology and Hydrologic Modeling Study "State of the Basin" Report (Summit, 2009). This is often important in data-poor locations or where hydrologic conditions vary rapidly (and are not necessarily captured in the hydrologic record).
6. The underlying databases can be developed using different methodologies if desired. This includes the use of model output such as is available for the Okanagan.

[13] Input parameters included: grid cell elevation, UTM northing, UTM easting, monthly mean temperature and monthly mean precipitation.

Potential Challenges:

1. NEWT was developed based on data from relatively undeveloped (or natural) catchments with limited regulation. Based on our discussion with the tool developers, it remains unclear how well the model would represent the complex patterns of water imports, diversion, and reservoir storage and release, which are widespread in the Okanagan. Flow regulation applies not only to many upland reservoirs, but also valley bottom lake/reservoirs. Although scheduled or typical reservoir storage and release patterns could be included within water supply model (Kerr pers. comm., 2014), such information may only suffice when characterizing normal conditons. It may not be representative of individual years (e.g. drought) when flow regulation deviates from the normal schedule. An appropriate framework should also reconcile surface water licences (i.e. water demands) to upland reservoir storage, and account for the timing of reservoir filling and releases with respect to downstream demands. Further deliberation on MFLNRO licence evaluation requirements is required to shed further light on this issue.
2. Given the potential challenge associated with Point #1, a NEWT-like too by itself may not be appropriate to assess water licence applications in regulated Okanagan watersheds, or for example to assess applications for reservoir storage increases in a way that would enable decisions to made.
3. Although not necessarily unique to NEWT, any output generated by a NEWT-like tool would need to be specifically designed for the Okanagan to reflect the licence evaluation criteria and the needs of regulators. It has yet to be confirmed whether MFLNRO would be willing to accept an OWAT that provides only normal annual, monthly (or even weekly) water supply information (i.e. current output from NEWT) or whether more detailed information is required to support statistics as defined in the current water allocation guidelines (Province of BC, 1996).
4. Depending on the needs of the MFLNRO for adjudicating water licence applications, underlying databases may need to be developed based on the data and models available in the Okanagan. Furthermore, these models may need to be expanded or refined (to address new points-of-interest).
5. Based on our consultation, there is some desire in the MFLNRO to have two models available for water licensing purposes. One model could cover the Thompson-Okanagan Region using an underlying methodology similar to NEWT and NWWT. The other could cover the Okanagan basin only, and would be based on the relatively more detailed data and models specifically developed there. Ideally, these would be integrated or nested within a common user interface, with the NEWT/NWWT interface being one logical choice. The integration of the two methodologies will be required, as will be reconciliation of the results so that the end-users have confidence in the tool.
6. Depending on the needs of MFLNRO, the temporal scale of NEWT may require modification. It is understood that a NEWT-like product is being developed in Alberta using a weekly time-step, so that may be feasible. A NEWT-like tool may however be difficult to develop if a daily time-step is required. Further deliberation on licence evaluation criteria is required.

7.3 Recommendations Regarding OWAT Framework

Based on the discussions presented above in Sections 7.1 and 7.2, the following recommendations are made with respect to the OWAT framework:

1. Specific tasks to develop the OWAT will depend, in part, on the desired user platform(s) and interface, with the most appropriate framework being dependent on OWAT objectives and licence evaluation criteria. Therefore, it is recommended that the objectives and criteria be firmly established at the outset.
2. Based on our review and the consultation process, a hybrid approach to developing a decision support tool for water allocation purposes is recommended. In such an approach, a higher resolution WEAP-based model for the Okanagan would be nested within the provincial NEWT/NWWT framework, which we understand is slated for development in the Thompson-Okanagan Region in summer 2014. Importantly, the user interface, which likely would use NEWT/NWWT as a template, should be developed to seamlessly integrate the datasets developed by the two models and allow the user to draw upon the best available information when using the tool.
3. In terms of development, the proposed hybrid approach would build upon the NEWT/NWWT framework, and would likely start with development of the user interface as dictated principally by the MFLNRO requirements (e.g. data requirements). It is envisioned that two parallel modeling paths would then be followed, which would closely interact[14]. The first path would follow the general methodology used by NEWT/NWWT based on annual water balance calculations and statistical regression approaches for the Thompson-Okanagan Region. The water supply estimates provided would include normal streamflows (e.g. annual, monthly, and/or weekly) over some long-term (e.g. 30 year) period. The second path would develop a new WEAP-based model of the Okanagan using updated model output[15] from the Okanagan Basin Hydrology Model (OBHM). There will be option to evaluate water supply against only water licences or against estimated demand (using results of the Okanagan Water Demand Model (OWDM)). The WEAP-based model will also develop water supply output for the chosen normal period thus enabling an important verification step required to evaluate the two approaches. Based on MFLNRO requirements, the WEAP-based model may also be used to model future scenarios (e.g. including climate change, land use change, and/or population change), which are beyond the abilities of the NEWT/NWWT tool.
4. Water diversions, reservoir regulation, and extractions in the Okanagan Basin are ubiquitous and indeed a defining feature of its hydrology. Representing such conditions has been challenging in several of the previous models developed during the OWSDP. This will likely continue to be the case as such human-influences on the hydrology are far more complex than simple rule curves or schedules. As a result, careful attention should be paid on how upland reservoirs and valley bottom reservoirs are represented, regardless of the model platform used.
5. In order to meet specific requirements of the MFLNRO, the WEAP-based approach noted above will require updated input datasets from supporting models such as the OBHM (i.e. water

[14] Interaction and communication between modelers is paramount to ensure they are working with consistent datasets, etc.
[15] The spatial domain of the model would be expanded to include those areas that supply water to but are physically outside the Okanagan Basin.

supply data) and the OWDM (i.e. water demand data). Given that the use of models involved in the hybrid approach noted above will require significant technical ability, it is expected that the core model components would be managed and maintained by experienced or well-trained personnel. The user interface however should be designed for MFLNRO staff who may or may not be technically inclined. A decision whether this should be extended to the public (as it is for NEWT) is required.

8. OWAT PLAN RECOMMENDATIONS

The following subsections outline the main work plan elements comprising the development of the OWAT (i.e., the OWAT Plan). Figure 8.1 is a flow chart that illustrates the suggested steps for development of the OWAT. This diagram was first vetted at the March 11, 2014 workshop. Many of the proposed tasks are linked or dependent on other tasks and linkages are noted by reference to section numbers. The organizational chart in Figure 8.2 indicates the main tasks and demonstrates how they are interdependent with respect to the conceptual project timeline. The subsections to follow discuss each of these elements in more detail. Once the work plan elements are finalized, these sections can be re-cast in a form consistent with a formal Terms of Reference for procuring technical and professional support for tool development.

Figure 8.1 OWAT Development Process Flow Chart

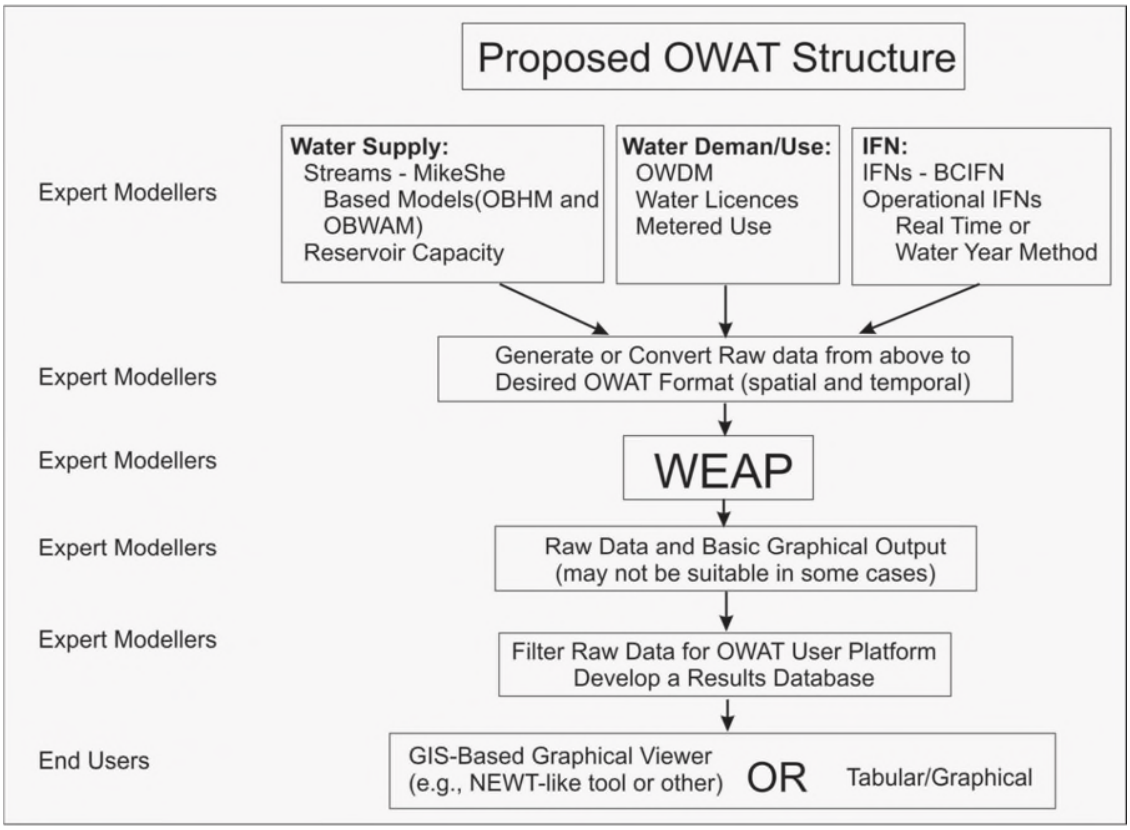
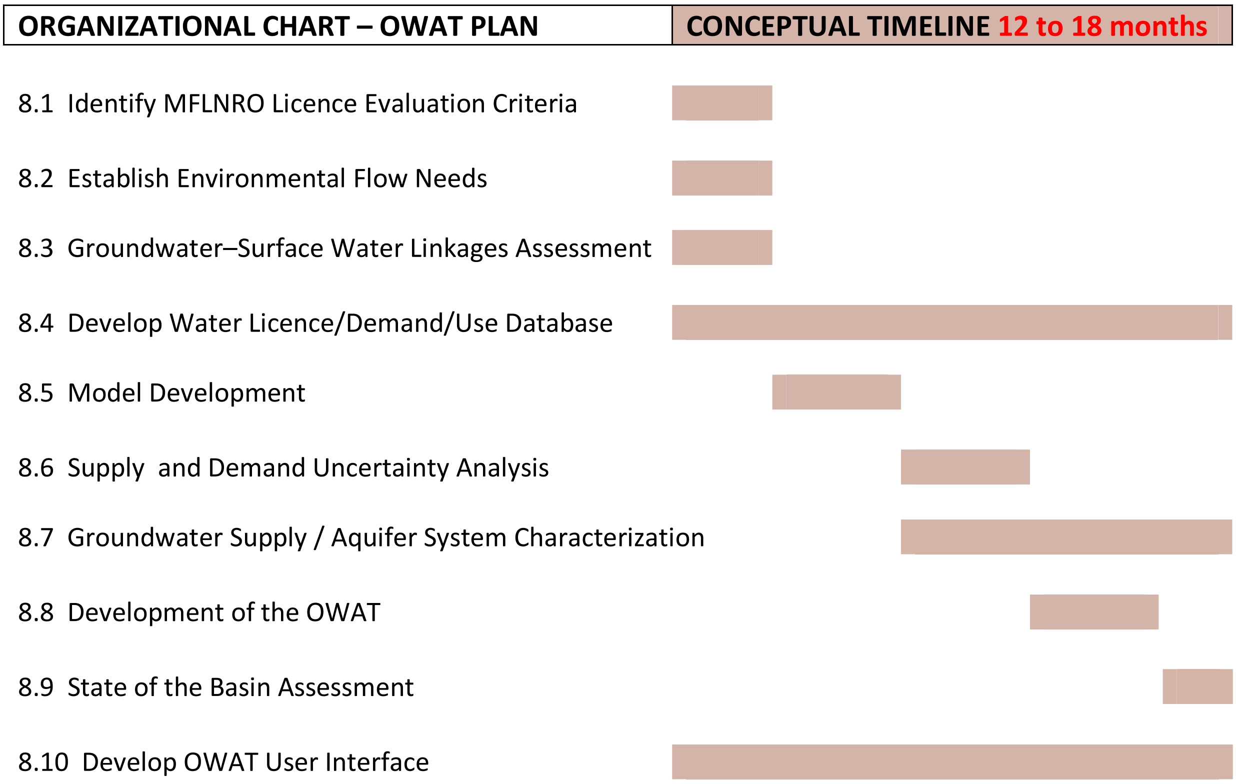


Figure 8.2 OWAT Plan Organizational Chart and Conceptual Timeline



8.1 Identify MFLNRO Licence Evaluation Criteria

One of the first tasks that should be completed prior to proceeding with OWAT development is the clear identification of MLFNRO licence evaluation criteria for the Okanagan. Although much is documented in Province of B.C. (1996), more discussion is required to determine how OWAT would fit in with the process of adjudicating water licence applications. If relatively high level information on normal annual or monthly streamflow is desired, a methodology similar to the NEWT/NWWT may be adequate. If more detailed data on streamflows is required in order to develop statistics to support the use of current provincial water allocation guidelines, then use of the Okanagan models may be required. The requirements of MFLNRO will also determine whether the Okanagan models will require refinement (e.g. for different points of interest or different time scales) and/or modification (e.g. to include areas where water is imported from). In addition, MFLNRO requirements will affect whether future scenarios (e.g. based on projected climate, land use, population) should be modeled.

8.2 Establish Environmental Flow Needs (EFNs)

Establishing appropriate EFNs is a key task required to proceed with the development of the OWAT. There are many different approaches to establishing EFNs for water allocation purposes and it is our understanding that MFLNRO intends to release an updated policy document and draft guidelines in Spring 2014. Table 8.1 summarizes five (5) different potential EFN approaches that could be adopted; details for each approach are presented in Appendix A. Recommendations regarding appropriate method(s) for the Okanagan, based on this review as well as discussions with MFLNRO, are discussed in Section 8.2.2. Based on our discussion with MFLNRO, it was noted that EFNs need to be operationally achievable, and thus, we identify potential methods for developing Operational IFNs (OIFN) in Section 8.2.1.

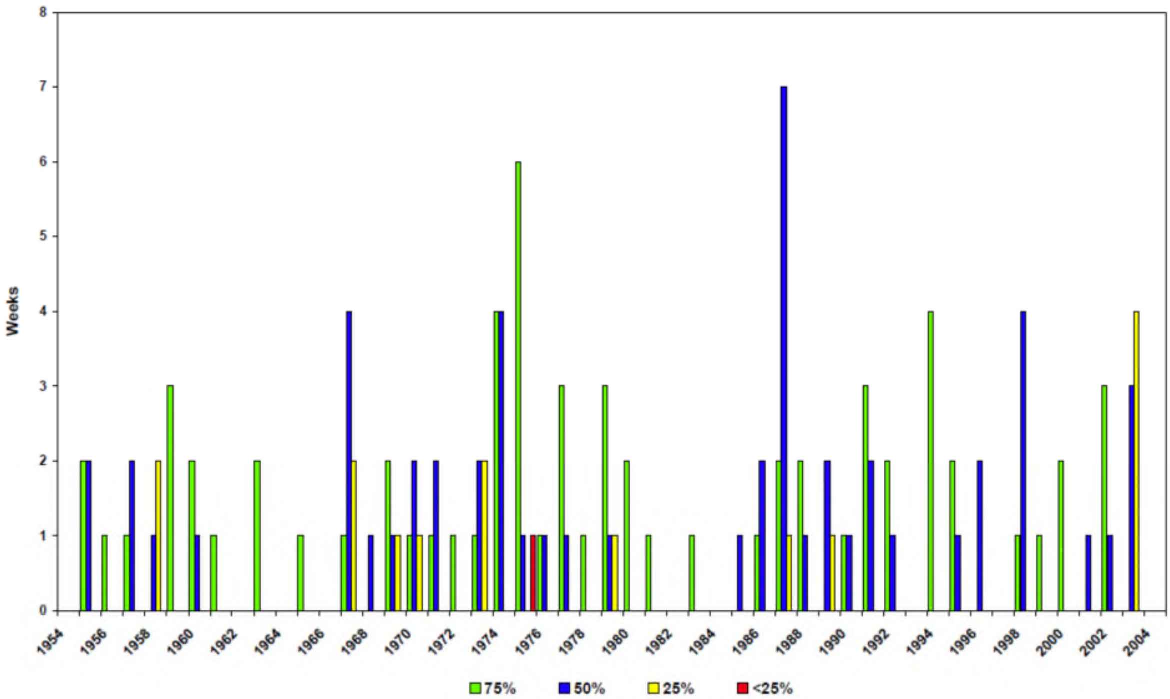
Table 8.1: Overview of potential methods for quantifying EFNs

IFN Approach	Brief description	Advantages	Disadvantages
Modified Tenant methods	Based on monthly rules for %MAD	Easy to implement Requires no field work Based on a single hydrologic statistic (MAD) that is easy to obtain Often applied in BC and Okanagan	Requires high degree of professional judgment; lacks biological validation Mean flow (unlike median) is influenced by extreme flow events, especially high flows; and changes as the climate changes Does not consider duration of flows under threshold
BCIFN method	Based on percentiles between 20th and 90th based on formula	Already established for entire Okanagan basin Requires no field work Uses percentiles instead of means	Requires natural flow record, preferably for 20+ years Does not consider duration of flows under threshold
Alberta Desktop method	Based on a 15 per cent instantaneous reduction from natural flow or the 80 per cent exceedance natural flow	Frequently applied in Alberta and North-East BC for water allocation Already integrated with NEWT &considers variations between water year Uses percentiles instead of means	The approach is generally applied in unregulated rivers. Requires natural flow record Does not consider duration of flows under threshold
UCUT approach	Based on the natural flow paradigm, applies Uniform Continuous Under Threshold (UCUT) analysis to develop flows and durations	Only approach that considers duration of flows under threshold Explicitly considers variations between water year Impact on fish can be estimated from stress days Allows water managers to manage flows below thresholds for short durations	Not frequently applied in BC (mostly used in Eastern US) Requires natural flow record
Functional flows approach	Develops recommended flows based on biological metrics from flow relationships established through fieldwork	A preferred approach for complex water management systems in the Okanagan Based on local conditions and biological metrics Allows water managers to estimate risks from flows below targets; and to evaluate trade-offs between EFN and other water uses	Requires field-work Analysis intensive (may require modeling) Not appropriate for all watersheds

8.2.1 Operational EFNs – Review of Potential Methods

This section outlines three (3) different methods ("Real-time OEFN", "Water-year type OEFN" and "Fish harm flows") for establishing Operational EFNs (OEFNs) that are operationally achievable in drier years. Most EFN methods are based on average conditions, which mean they are not necessarily operationally achievable in drier years. For example, in the Mission Creek WUP (Water Management Consultants 2010), EFN targets were developed based on a modified-Tenant approach as a % of MAD for different month. They found that target levels could normally only be achieved in wet years (Figure 8.1). Even with OEFNs, however, reduced withdrawals may still be required during drier years. Both approaches described below can be based on any of the EFN methods introduced in the previous section.

Figure 8.3 Operational EFNs



Real-time OEFN

If there are any gauged, unregulated tributaries in the watershed, it may be possible to establish real-time EFN that are automatically adjusted based on water year type. An example is the Trout Creek WUP (NHC 2005), where naturalized flows for Trout Creek were estimated from Camp Creek, a relatively unaltered tributary with a real-time gauge. Original EFN targets were established for the watershed using a modified-Tenant method, and an analysis of EFN, naturalized flows for Trout Creek and mean flow for the Camp Creek tributary was performed to calculate a multiplier for Camp Creek flows that would be equivalent to the EFN in average water years. For Trout Creek, real-time EFNs are determined as 10:1 multiplier of Camp Creek flows. The Trout Creek WUP also prescribes reduced withdrawals under drought conditions to achieve the real-time EFN.

Advantages:

- Operationally achievable in drier water year types.

Potential Limitations:

- Requires a real-time gauges in a relative unregulated tributary.

Water-year type OEFN

Since most EFN approaches only provide a target for mean water year conditions, which is often used for water allocation decisions, more detailed EFN can be developed for individual water year types. An example is the Integrated Assessment Plan for the Trinity River Restoration Program (ESSA 2009), which prescribes different release patterns for different water year types. Different geomorphic processes and thermal regimes are addressed in different water-years, similar to pre-dam conditions.

Water-year class	Acre-feet	Peak flow (cfs)
Critically dry	369,000	1,500
Dry	453,000	4,500
Normal	636,000	6,000
Wet	701,000	8,500
Extremely wet	815,000	11,000

Water-year type specific EFNs can be developed based on all the EFN approaches introduced in Section 0 by relating average conditions to equivalent conditions in drier or wetter years.

Advantages:

- Operationally achievable in drier water year types

Potential Limitations:

- Less detailed than real-time OEFNs

Fish harm flows

MFLNRO have used a functional flows approach in some watersheds to developed flow thresholds below which fish harm is known to happen (White, pers. comm. 2014). Flow relationship for wetted width and pool depth can be used to determine thresholds below which pools become shallow and isolated, which can lead to high fish mortality, particularly when associated with high water temperatures. Flows resulting in severely reduced wetted widths are also limiting food production because the stream is disconnected from the riparian zone. The flow thresholds are validated in the field by monitoring fish die-off in very dry years. The fish harm flows should only be considered in very dry years because they only protect fish survival and higher flows are required in normal and wet years to sustain a healthy fish population.

8.2.2 Priority Watersheds and Recommendations for Establishing EFNs

In a study by Matthews and Bull (2003), 21 watersheds in the Okanagan are identified as highest priority based upon:

- whether they support (or could support) wild, indigenous fish stocks;
- whether their production potential is considered significant (based on the size of the watershed and the judgment of agency biologists as to the extent of water flows and the amount of usable habitat); and
- the degree to which the watershed has been impacted by habitat alterations.

Out of these 21 watershed, 15 have had EFN determined using the BCIFN method as part of the 2009 Instream Flow Needs Assessment and the remaining 6 watersheds are part of larger watersheds used in the 2009 study. Two out of the priority watershed have existing Water Use Plans (Mission and Trout Creek), and one is currently developed a Water Use Plan (Vernon Creek).

MFLNRO currently uses three different methods for establishing EFNs: The modified-Tennant approach (including the Tessman modification), the BCIFN method and the functional flows approach depending on data availability. Their preference is to establish local flow-habitat relationships and only apply the modified-Tennant approach in absence of more detailed information (White, pers. comm. 2014).

Based on the above review of potential methods for establishing EFN's and comments from MFLNRO, we recommend using the BCIFN flows already developed for the Okanagan Basin, and utilize these quantities and available data to develop operationally achievable EFN's for all 21 priority watersheds that don't currently have a Water Use Plan. We acknowledge that the BCIFN approach yields more conservative conservation flows than the modified-Tennant approach, but in agreement with MFLNRO, we would only recommend using the modified-Tennant approach in absence of more detailed information. The Alberta desktop method is developed specifically for unregulated rivers and as such is not well suited to the highly regulated watersheds in the Okanagan. We would recommend developing EFNs based on functional flows (i.e., Operational EFN) where feasible, as have already been done in Mission Creek, Trout Creek and Middle Vernon Creek.

We recommend developing OEFN for all watershed based on the Real-Time OEFN approach where data allows it (i.e. a real-time gauge on a mostly unregulated tributary) and water-year type OEFNs elsewhere (see previous section for discussion of OEFN approaches). Fish harm flows OEFN should be priority for sensitive watersheds when water-year type OEFNs have been established for all watersheds.

The priority watersheds are summarized in Table 8.2

Table 8.2: Overview of potential methods for priority watershed EFNs.

Watershed	EFN	OEFN	WUP
Bx Creek	No[1]	Water Year Type [3]	
Coldstream Creek	No[1]	Water Year Type [3]	
Equesis Creek	BCIFN	Water Year Type [3]	
Hydraulic Creek	No[1]	Water Year Type [3]	
Inkaneep Creek	BCIFN	Water Year Type [3]	
KLO Creek	No[1]	Water Year Type [3]	
Lambly Creek	BCIFN	Water Year Type [3]	
Mill (Kelowna) Creek	BCIFN	Water Year Type [3]	
Mission Creek	BCIFN/Modified-Tenant	Real-time IFN	Completed
Naswito Creek	BCIFN	Water Year Type [3]	
Oyama Creek	No[1]	Water Year Type [3]	
Peachland Creek	BCIFN	Water Year Type [3]	
Penticton Creek	BCIFN	Water Year Type [3]	
Powers Creek	BCIFN	Water Year Type [3]	
Shingle Creek	No[1]	Water Year Type [3]	
Shorts Creek	BCIFN	Water Year Type [3]	
Trepanier Creek	BCIFN	Water Year Type [3]	Completed[2]
Trout Creek	BCIFN/Modified-Tenant	Real-time EFN	Completed
Vaseux (McIntyre) Creek	BCIFN	Water Year Type [3]	
Vernon Creek	BCIFN/Modified-Tenant	In progress	In progress
Whiteman Creek	BCIFN	Water Year Type [3]	

[1] EFN established for this watershed as part of a larger watershed in the Instream Flow Needs Assessment study.

[2] Trepanier Creek has an Operational strategy.

[3] Water Year Type is proposed here unless gauge is identified that would provide appropriate data for real-time method.

8.3 Groundwater - Surface Water Linkages Assessment

Though not currently licensed, as already noted in Section 7 above, groundwater extractions may require licences and/or assessment as a result of pending legislation, and thus it is recommended that at a minimum, large groundwater extractions be incorporated into the WEAP-based portion of the decision support tool. Groundwater extractions have the potential to influence surface water bodies at some location and at some time, whether they draw water from the surface water body into the aquifer, or intercept groundwater flow that would otherwise discharge to the surface water body. Therefore, incorporating groundwater linkages into WEAP requires some scientific basis for assigning linkage locations. A groundwater – surface water linkages assessment, described below, is recommended to provide a basis for assigning such linkages.

This task will involve a hydrogeological assessment to map groundwater-surface water linkage zones for individual groundwater aquifers in the Okanagan, focusing on priority aquifers (see Section 8.7). Proposed and existing groundwater extractions locations could then be reviewed in the context of the mapped groundwater – surface water linkage zones to link the extraction to a specified water body (a tributary stream or the mainstem lake/river). The approach to this would likely need to include a piloted assessment in a priority basin.

Following the initial linkages assessment, further work would need to be done outside of the models, as mentioned above in Section 6. This would include but not be limited to assessing existing grandparented supply and demand, and characterizing selected aquifer systems (and their associated connected surface water bodies) using models and other techniques in order to estimate whether there is additional water to licence. In this way, the OWAT database could begin to be populated with groundwater data. See also Steps 7 and 8 in Section 8.5 below.

8.4 Reconciliation of Water Licences and Estimated Water Demand

One of the important products of the OWSDP is the Okanagan Water Demand Model (OWDM), which provides state-of-the-science estimates of water demand throughout the developed portion of the Okanagan Basin. In lieu of actual water use records, which are slowly being developed as water metering increases, the OWDM, which is driven by climate, soil, crops, land use, irrigation practices, population and other factors, provides one of the most comprehensive perspectives on water use patterns in the Okanagan. In this task, we recommend that a database is developed to clearly document the water licences (and their points-of-diversion) in the Okanagan with their associated water demand estimates and, if available, water use records. It is our understanding that some of this work has been done during development of the OWDM, however the accuracy and completeness is unknown. Reference to MFLNRO Water Allocation files may also be worthwhile in those cases where there is significant discrepancy in order to identify the original rationale for the allocated quantities. The database should be developed with foresight to facilitate integration with the OWAT.

Sub-tasks required to develop a water licence/demand/use database include:

- Review the OWAT goals with respect to the representation of water use and consider MFLNRO licence evaluation criteria.
- Review the form of the OWAT in developing the database to facilitate future integration.
- Review available Okanagan water licence/demand/use data to consider how the data could be incorporated into a water use database.

The Water Use Database should incorporate data from the following sources or other relevant sources:

- Okanagan Water Management and Use, OWSDP, Appendix C.
- BC Water Use Reporting Centre http://bcwaterusereporting.ca/Login.aspx
- BC Ministry of Environment, Water Licences Electronic Database http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input (and scanned actual licences as necessary).

- Okanagan Water Demand Model Summary, OWSDP, Appendix I1.
- Irrigation Water Demand Model – Technical Description, OWSDP, Appendix I2.
- Residential, Commercial, Industrial , and Institutional Actual Water Use in Vernon and Kelowna, OWSDP, Appendix I3
- Okanagan Valley Water Demand Data, Scenario Modelling, OWSDP, Appendix O.

The development of the Water Use Database should consider the following potential complexities of water licences in BC.

- Issue of beneficial use and double licensing of the same allocation amount.
- Multiple points of diversion for a single licence.
- Seasonal influences when not specified on a licence. Most licences are issued as a bulk volume over a significant period of the year or all year. Assumptions may be necessary regarding how the water usage is distributed over the prescribed period in order to reconcile licenced amounts with actual water use. The influence of these assumptions on any discrepancies between licenced amounts, calculated water demand, and actual use should be evaluated as part of this task.
- The Provincial electronic licence database may not represent the full conditions within a paper licence. Reference to MFLNRO files may be necessary.
- Linking of licences to BC Watershed Atlas watershed codes (may be an important link depending on the form of the OWAT).

8.5 Model Development

In order to meet the objectives of the OWAT, a hybrid approach is recommended whereby a WEAP-based model is nested within a NEWT/NWWT-type framework. The NEWT/NWWT-type framework would be developed for the broad Thompson-Okanagan Region while the WEAP-based model would apply specifically to the Okanagan[16]. It is our understanding that the MFLNRO is initiating the NEWT/NWWT-type model for the Thompson-Okanagan in summer 2014. Therefore, it is crucial that the modeling approaches be well coordinated in order to avoid duplication of effort and ensure consistency. It is envisioned that the NEWT/NWWT framework for the Okanagan will be similar to that already developed; however, as indicated above careful attention to the effects of flow regulation will be required as it varies significantly and strongly affect the timing and magnitude of flows.

The WEAP-based model will be similar to the OHCM but be modified according to the requirements of the MFLNRO. Nevertheless, based on our review of the OHCM in the context of the OWAT objectives, the following points should be considered:

1. Investigate the viability and pros/cons of developing separate modules for individual watersheds/basins. Modularization of WEAP would reduce model complexity and output

[16] Also to be included are those areas from which water is imported to the Okanagan Basin.

generation. The advantages and limitations of using WEAP modules for individual basins should be documented (e.g., can inter-watershed transfers be appropriately represented, if necessary?).

2. In its current form, the OHCM has been developed somewhat differently for the 12 target watersheds (Mission, Kelowna, Trout, Powers, Trepanier, Lambly, Ellis, Penticton, Peachland, Eneas, Irish, and Vernon Creeks) than for the remaining watersheds in the Okanagan. For example, the target watersheds are more completely represented in WEAP with naturalized streamflow inputs, reservoir operation rules, and water purveyor/demand data. Whereas, streamflow data in the remaining watersheds is net streamflow output (already accounting for water use/demand) from the OBWAM and water use or streamflow regulation is not specifically represented. To provide consistency across the Basin, it may be necessary to re-develop the WEAP model for the other watersheds.
3. In its current form, the OHCM accounts individually for major water purveyors, and smaller water use licences are collectively represented at one stream location (rather than individual locations). Depending on the requirements of OWAT for considering different licence applications, the OHCM may need to be redeveloped to represent both large and smaller water licence holders at their specific points of diversion. Storage licences should also be included within the model.
4. The input water use/demand data for the OHCM may require modification depending on MFLNRO licence evaluation criteria related to appropriate water use/demand rates.
5. Clearly identify licences based on MFLNRO licence number. The current OHCM uses unique codes that are referenced to the licence number, but this requires the additional step of referencing a look-up table. If feasible, this step should be removed.
6. Modify input data to the OHCM with updated EFNs.
7. Add major groundwater extractions by linking directly to the most hydrogeologically appropriate surface water body. Groundwater can be incorporated into the OHCM via direct connection with surface water (i.e., treat as surface water extractions). This method of representing groundwater extraction is a conservative approach to assess potential ecological influences of groundwater use, where groundwater extractions are inferred to either intercept groundwater that would otherwise discharge to a water body or draw water from the water body. The potential influences of groundwater extractions on streamflow can be approximated based on extraction rates and inferred locations of aquifer linkages to surface water bodies. Focused groundwater investigations (Section 8.7) would be required to assess other potential sustainability issues associated with groundwater extraction such as well interference and aquifer storage depletion, and results of such studies could be incorporated into the OHCM once they are complete.
8. Add deep groundwater data from MIKE SHE and route these to the mainstem lake system. This modification will allow for the potential to link groundwater withdrawals directly to the lake where such a linkage is appropriate (e.g., confined aquifer systems in alluvial fans that are inferred to extend to the lake).
9. The OHCM will need to be re-developed with new or modified points of interest (e.g., downstream of each reservoir).
10. The priority rules that are embedded within the OHCM may require review to ensure that they reflect the goals of the OWAT and the licence evaluation criteria. For example, if EFN's are

always considered as the top priority, the rules embedded in the OHCM may require adjustment if they currently prioritize reservoir filling.

11. The OHCM is currently run using water supply input from the MIKE SHE-based OBHM and water demand data from the OWDM, and therefore adopts any uncertainty and limitations with respect to these models. The uncertainty of input data should be determined and documented.
12. In addition to model uncertainty assessments for the underlying water supply and demand models, verification of the WEAP-based model results should involve validation by referencing gauged streamflow records where possible.
13. Since upland reservoir management and releases greatly influence streamflows within Okanagan watersheds, inclusion of upland minimum flow releases, management targets, and drought management plans should be considered when developing the WEAP-based model. Upland reservoir model calibration/verification could be considered through comparison of available reservoir water level or spillway records.

In summary, the methodology and assumptions used in the OHCM are not necessarily in line with the OWAT objectives and therefore the OHCM in its current form cannot be directly applied for water allocation decision making purposes. Assumptions directly affect model results and it is important from water allocation purposes that the impact of human decisions and/or bias (i.e. assumptions) are well understood and minimized to the greatest extent possible. It is envisioned that rather than modifying the OHCM, a new WEAP-based model would be developed for the Okanagan, and the output from this be used within a NEWT/NWWT-based framework.

8.6 Supply and Demand Uncertainty Analysis

Although water supply and demand data in the Okanagan have been rigorously and scientifically developed using physically based models, some degree of uncertainty is associated with the output generated by any model. As indicated previously, models have not been comprehensively evaluated for uncertainty. An uncertainty study should be conducted for the streamflow data generated by MIKE SHE as well as the data generated by WEAP. Uncertainty pertains to both overestimates and underestimates of available water and while it may not necessarily be incorporated as decision making criteria, it should be estimated and documented so that regulators are aware of the limitations of the OWAT.

Based on the uncertainty analysis, clear documentation of uncertainty should be developed for use by regulators for consideration in water licensing decisions. Recommendations could be made to reduce the uncertainty in the calculations via, for example, monitoring, gauging, data collection, and so on.

8.7 Groundwater Aquifer System Characterization

In order to more accurately assess surface water – groundwater interactions (than proposed in Section 7), and to assess other factors related to groundwater sustainability such as the potential for aquifer storage depletion and well interference, comprehensive aquifer characterization and assessment would be required for priority watersheds and associated aquifer systems. Such studies would involve compiling geological data and well information followed by quantitative analysis. Numerical modeling has been used in some regions (e.g., Australia) to quantify allocation limits for aquifers and provide a quantitative basis to assess groundwater/surface water interactions. Simpler water balance methods have also been used, for example, estimating the natural flow through an aquifer (or the natural recharge rate) and then making available for licensing a fixed percentage of that natural flow; and, a tiered approach to hydrogeologic investigation depending on how close to the threshold licensed use becomes over time.

Groundwater investigations involving fieldwork and data collection are expensive and time-consuming. Therefore, establishment and agreement on priority aquifer areas is needed. In addition to further classification/characterization of aquifers, groundwater allocation policies will likely be needed for some watersheds that will in turn govern the level of hydrogeological information required to support a licence application. For example, a proposed shallow irrigation well extraction near a stream could be treated as a surface water extraction with a time-lag effect on stream capture, based on factors such as the allocation status of the watershed and the expected degree of groundwater-surface water interaction. An approach like this could be piloted in a priority basin, or even applied in a hypothetical scenario in the early stages of OWAT development.

The Provincial Observation Well Network Review, conducted in 2009, (Kohut, et al., 2009) identified priority aquifers for establishing observation wells in BC based on a set of evaluation criteria that included specific aquifer characteristics, vulnerability, sustainability issues, ecological concerns and other factors. These priority aquifers, together with other potential areas that are already monitored but could be under stress could be considered for possible incorporation in the OWAT. In response to the B.C. Office of the Auditor General, the Ministry of Environment (2012) published a list of 20 priority areas across the province for Aquifer Characterization including three in the Okanagan. Characterization involves a more detailed investigation of groundwater resources than the standard Aquifer Classification program. Table 8.3 lists the monitoring priority areas as well as the three priority areas identified in the MoE (2012) report on Aquifer Characterization.

Table 8.3: Recommended priorities for monitoring and/or characterization

Key Area - Monitoring	Priority Unconsolidated BC Aquifers	Priority Bedrock BC Aquifers
North Okanagan	102, 103, 111, 316, 317, 319, 346, 347, 349, 352, 353, 354, 849	104, 107, 110, 350, 351
Kelowna	464, 463, 344, 345	304, 473, 861, 863
Summerland	299, 860	298, 300
Skaha Lake	261, 264	260, 263
Osoyoos	193, 194, 254, 255, 257	808
Key Area - Characterization	**Priority Unconsolidated and Bedrock Aquifers**	
Priority #7 – Greater Kelowna	462, 463, 464, 465, 467	
Priority # 8 – South Okanagan	193, 194, 195, 254, 255, 256, 257	
Priority # 20 – North Okanagan, Spallumcheen to Enderby (extends N. of OK Basin boundary)	111, 348, 353, 354, 356, 849	

See BC Aquifer Classification Database for additional aquifer information:
https://a100.gov.bc.ca/pub/wells/public/common/aquifer_report.jsp

Aquifer characterization and assessment studies can take many forms and different methods or models may be used to assess conditions depending on the available data and specific aquifer characteristics. We also note that these types of detailed studies are generally longer term – taking a year or more to complete. Therefore, it is likely that aquifer characterization data would be integrated into the OWAT after initial development. It is recommended that work for aquifer characterization studies be completed based on prior development of a detailed and area-specific work plan, developed by the persons who will complete the work.

8.8 OWAT Development

At this stage of OWAT development, EFN's will have been established, MFLNRO licence evaluation criteria will have been clearly defined, new NEWT/NWWT and WEAP-based models will have been developed along with an uncertainty analysis, and decisions made about how to incorporate groundwater. The OWAT can now be fully developed. OWAT development would include full documentation of procedures for using the OWAT results to support water licensing decisions, as well as comprehensive and clear reporting of the underlying models, data, data limitations, and uncertainty. In addition, at this point the OWAT would be tested with support from the MFLNRO using real-world scenarios if possible to ensure that the tool meets OWAT goals.

We note that the OWAT will likely need ongoing updates to add any newly approved water licences. In addition, tasks associated with the development of the water demand/use database and groundwater aquifer characterization studies may still be in progress at this stage. The development of the OWAT will, therefore, also include documentation of a plan for monitoring of the OWAT, upkeep, and updates with new data.

8.9 State of the Basin Assessment for Allocation Status

Once the OWAT is developed, calibrated and verified, it could begin to be used to assess the state of the basin with respect to available water for allocation. This task would assist in identifying which watersheds or streams are approaching or already are fully allocated. While this was done to some extent in Summit (2013), new model runs would be required based on newly established EFNs and well defined licence evaluation criteria.

A similar approach would be used with groundwater resources. With respect to aquifers, additional specific aquifer studies (Section 8.8) would be required in some of the identified priority areas to specify allocation limits or allocation status for specific aquifers. Key factors to assess the aquifer status would be the degree of surface water groundwater interconnection, the degree of existing stress on surface water, and the existing and anticipated intensity of groundwater extractions.

8.10 Develop User Interface

Although listed last, the task of developing the user interface runs throughout the duration of the project, although in the early stages it would not be fully operational. In fact, user interface is one of the earliest tasks to address as soon as licence evaluation criteria are confirmed. Specific components of this task would involve extracting specifically required output from the NEWT/NWWT and WEAP-based models into a user friendly interface specifically designed to assist with water licensing decisions based on established MFLNRO licence evaluation criteria. The user interface would also need to incorporate the state of the basin assessment results (e.g., which watersheds or streams are already fully allocated), and the results of the uncertainty analysis. An important feature of the interface is to determine and provide guidance on which dataset(s) should be used for a particular query (e.g. NEWT/NWWT-based or WEAP-based).

The development of the user interface would require:

- Interviews with end users.
- Identification of specific characteristics required for the interface (e.g., flexibility needs, GIS-based, output format for queries).
- Development of computing scripts/codes to extract and analyze WEAP-based model output.
- Development of mock-ups for the interface design.
- Testing of interface, involving end-users at appropriate junctures.
- Documentation of clear procedures for working with the interface including any procedures required for monitoring and updates.

With respect to the user interface, if a map-based interface is desired, the logical option is to consider using NEWT/NWWT as a template, recognizing that changes in code will be required.

9. LIMITATIONS

Our standard limitations are included at the end of this report.

10. REFERENCES

BC Ministry of Agriculture and Lands and Agriculture and Agri-Food Canada (BC MAL and AAFC) 2010. Okanagan Water Demand Model (OWDM) Summary Report, Appendix 11, OWSDP. (cited as"van der Gulik et al 2010")

B.C. Ministry of Environment 2012. List of British Columbia's 20 Priority Areas for Aquifer Characterization.

Capra, H., P. Breil, and Y. Souchon. 1995. A new tool to interpret magnitude and duration of fish habitat variations. Regulated Rivers: Research and Management 10: 281-289.

Chapman, A., B. Kerr, and D. Wilford. 2012. Hydrological Modelling and Decision-Support Tool Development for Water Allocation, Northeastern British Columbia. In: Geoscience BC Summary of Activities 2011, Geoscience BC, Report 2012-1, p. 81-86.

Danish Hydrologic Institute Water & Environment (DHI), 2010. Okanagan Basin Water Accounting Model Final Report. Prepared for Okanagan Basin Water Board, May 2010.

ESSA Technologies Ltd. (ESSA) 2007. Okanagan Basin Water Supply and Demand Study II: User Needs Assessment Final Report. Prepared for Okanagan Basin Water Board, July 2007.

ESSA Technologies Ltd. (ESSA) and Solander Ecological Research 2009. Instream Flow Needs Analysis for the Okanagan Water Supply & Demand Project. Prepared for the Okanagan Basin Water Board, November 2009.

Golder Associates Ltd. And Summit Environmental Consultants Ltd. (Golder and Summit). 2009. Phase 2 Okanagan Water Supply and Demand Project, Groundwater Objectives 2 and 3 Basin Study. Prepared for the Okanagan Basin Water Board, July 2009.

Hatfield, T. and J, Bruce. 2000. Predicting salmonid habitat-flow relationships for streams from western North America. North American Journal of Fisheries Management 20:1005-1015.

Hatfield, T., A. Lewis, D. Ohlson, and M. Bradford. 2003. Development of instream flow thresholds as guidelines for reviewing proposed water uses. B.C. Ministry of Sustainable Resource Management and B.C. Ministry of Water, Land and Air Protection. Victoria, BC.

Kerr, Ben. 2014. Personal communication with L. Uunila of Polar Geoscience Ltd. Foundry Spatial Ltd.

Kohut, A., Hodge, W., and Azar, J., 2009. Provincial Observation Well Network Review, British Columbia, Volume I of II, prepared for Water Stewardship Division, BC Ministry of Environment. August 2009. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=20489

Locke, A. and Paul, A. 2011. A Desk-top Method for Establishing Environmental Flows in Alberta Rivers and Streams. Prepared for Alberta Environment and Alberta Sustainable Resource Development, April 2011.

Matthews, S. and C.J. Bull. 2003. Selection of focal watersheds for the protection and restoration of fish stocks and fish habitat in the Okanagan Region. Ministry of Land, Air and Water Protection, Victoria, B.C. and Glenfir Resources, Penticton, B.C.

Northwest Hydraulic Consultants (NHC). 2001. Hydrology, Water Use and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Northwest Hydraulic Consultants (NHC). 2005. Trout Creek Water Use Plan Fisheries Report.

Province of BC. 1996. "Guideline #8: Water Allocation Guidelines", In Revision 4 of the Policy & Procedures Manual (January 8, 1996), Section 2, Subsection .03.01.05, Subject: Water Allocation, Water Licence Applications, Field Inspection. Ministry of Environment, Lands and Parks, Water Programs Policy & Procedures.

Summit Environmental Consultants Ltd. (Summit). 2009. Phase 2 Okanagan Water Supply and Demand Project, Surface Water Hydrology and Hydrologic Modelling Study "State of the Basin" Report. Prepared for Okanagan Basin Water Board, September 2009.

Summit Environmental Consultants Inc. (Summit). 2010. Okanagan Water Supply and Demand Project: Phase 2 Summary Report. Prepared for the Okanagan Basin Water Board, July 2010.

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

Summit Environmental Consultants Ltd. (Summit). 2013a. Okanagan Hydrologic Connectivity Model Summary Report. Prepared for the Okanagan Basin Water Board. May 2013.

Summit Environmental Consultants Inc. (Summit). 2013b. Okanagan Hydrologic Connectivity Model: Trout Creek Watershed Groundwater Integration. Report prepared for the Okanagan Basin Water Board. March 2013.

Water Management Consultants. 2010. Mission creek water use plan. Prepared for Mission Creek Watershed Partnership, March 2010.

APPENDIX A - POTENTIAL METHODS FOR QUANTIFYING EFNS[17]

Modified Tenant methods

Methods based on Tennant's approach provide criteria usually expressed as a percent of mean annual discharge (MAD). The methods are rules based, typically summarized in a table with different %MAD prescriptions under different circumstances. Rules based methods are attractive because they are easy to implement due to the relatively low cost and effort required, but they do have limitations.

In BC, the most frequently applied method based on Tennant's approach is the BC Modified Tenant (Ptolemy and Lewis 2002) summarized in table 1 below. In the Okanagan region, a localized set of rules (NHC 2001) summarize in Table 1 are more often applied, e.g. in the Trout Creek and Mission Creek WUP. MFLNRO often apply the Tessman modification (White, pers. comm. 2014), which incorporates consideration of natural variations in flow on a monthly basis.

Table 1 Summary of Tennant's Approach

BIOLOGICAL OR PHYSICAL REQUIREMENT	PERCENT MEAN ANNUAL DISCHARGE	DURATION PER ANNUM
Short-term Biological Maintenance	10	days
Juvenile summer-fall rearing	20	months
Over-wintering	20	months
Riffle Optimization	20	months
Incubation	20	months
BIOLOGICAL OR PHYSICAL REQUIREMENT	**PERCENT MEAN ANNUAL DISCHARGE**	**DURATION PER ANNUM**
Kokanee spawning	20	days-weeks
Smolt Emigration	50	weeks
Gamefish Passage at Partial Barriers	50 to 100	days
Large Fish Spawning/Migration	148*MAD^-0.36	days-weeks
Off-channel Connectivity/Riparian Function	100	weeks
Channel Geomorphology/Sediment Flushing	>400	1 to 2 days

TABLE 1c BC Modified Tennant Method

Note: zero deviations from standards suggest no HADD will occur

Source: Ptolemy and Lewis, 2002

[17] For the purposes of this report the term Environmental Flow Needs (EFNs) is synonymous with Instream Flow Needs (IFNs). For consistency with the BC Water Sustainability Act, the term EFN is recommended.

	Conservation Flow (as % of Natural Mean Annual Flow)			
Month	Kokanee	Rainbow	Stream Ecosystem	Nature of Life-History Demands
Jan	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
Feb	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
Mar	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
Apr	20%	46%	100%	Incubation & Emergence (KO) / Adult & Parr Migration (RB)
May[a]	>50%	100%	200%	Emergence (KO) / Spawning & Adult Migration (RB) / Flushing [a]
Jun	-	100%	100%	Spawning, Adult Emigration & Egg Incubation (RB)
Jul	-	40%	40%	Spawning, Adult Emigration & Egg Incubation (RB)
Aug	-	30%	30%	Juvenile Rearing / Temperature Moderation (RB)
Sep	20%	25%	25%	Adult Migration & Spawning (KO) / Juvenile Rearing (RB)
Oct	20%	20%	20%	Adult Migration & Spawning (KO) / Juvenile Rearing (RB)
Nov	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
Dec	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)

[a] For channel maintenance over the longer term, a maximum instantaneous flow of 500% of MAD with a 1:2 year frequency is recommended. The above conservation flows are required to maintain aquatic life

The role of the criteria and relationship to MAD are sometimes not clear. MAD is a useful index of stream size. Percentages of MAD have been shown to be useful descriptors of flow requirements across streams of different scales at a regional level. For example, twenty percent MAD is a benchmark flow for riffle health. Below 20% MAD the ecological function of riffles begins to degrade. However, it is natural in many streams for the flow to decrease below 20% MAD. The ecosystems within these streams are naturally adapted to those conditions; diverting water from the stream at that time may further stress its health and result in lower productivity. Therefore the criterion of 20% MAD is used as an indicator that direct withdrawals of water from the stream should be avoided as stream health can be radically degraded due to riffle dewatering. One result of riffle dewatering is reduced flow to pools, leading to reduced fish production.

Advantages:

- Easy to implement
- Requires no field work
- Based on a single hydrologic statistic (MAD) that is easy to obtain
- Often applied in BC and Okanagan

Potential Limitations:

- Requires high degree of professional judgment
- Lack of biological validation
- Mean flow (unlike median) is influenced by extreme flow events, especially high flows; and changes as the climate changes
- Does not consider duration of flows under threshold

<u>BCIFN method</u>

The BCIFN method developed by Hatfield et al. (2003) for fish-bearing streams calculates recommended minimum instream flow thresholds based on daily stream discharge data over a 20+ year period of record. Thresholds are determined on a monthly basis and water diversions/allocations are restricted to periods when stream flows are greater than the corresponding thresholds. A maximum diversion rate (i.e., infrastructure limit) is defined as equivalent to the 80th percentile flow over the period of record is in effect at all times. During times when flows exceed the sum of the minimum flow threshold and the maximum diversion rate, diversions are restricted to the maximum diversion rate. This approach generally generates more conservative IFN thresholds than the modified-Tennant methods (Ptolemy, pers. comm. 2014)

The BCIFN method for fish-bearing streams calculates the median of all daily flows for each calendar month (grouping all years together) and the monthly medians are then ordered from lowest to highest. The minimum instream flow threshold for the lowest median flow month is set to the 90th percentile of the mean daily flows for that month. Conversely, the minimum flow threshold for the highest median flow month is set to the 20th percentile of the mean daily flows for that month. The flow threshold for each of the other 10 months is also calculated as a percentile of mean daily flows in the respective month, but the percentile varies between 20th and 90th according to the following formula:

$$90 - \left[\left(\frac{median_i - median_{\min}}{median_{\max} - median_{\min}} \right) \times (90 - 20) \right]$$

Where: $median_i$ is the median of mean daily flows for month i,

$median_{min}$ is the month of lowest median flows, and

$median_{max}$ is the month of highest median flows.

Figure 1 shows an example for Pennask Creek taken from Hatfield et al. 2003.

Figure 1 BCIFN Example

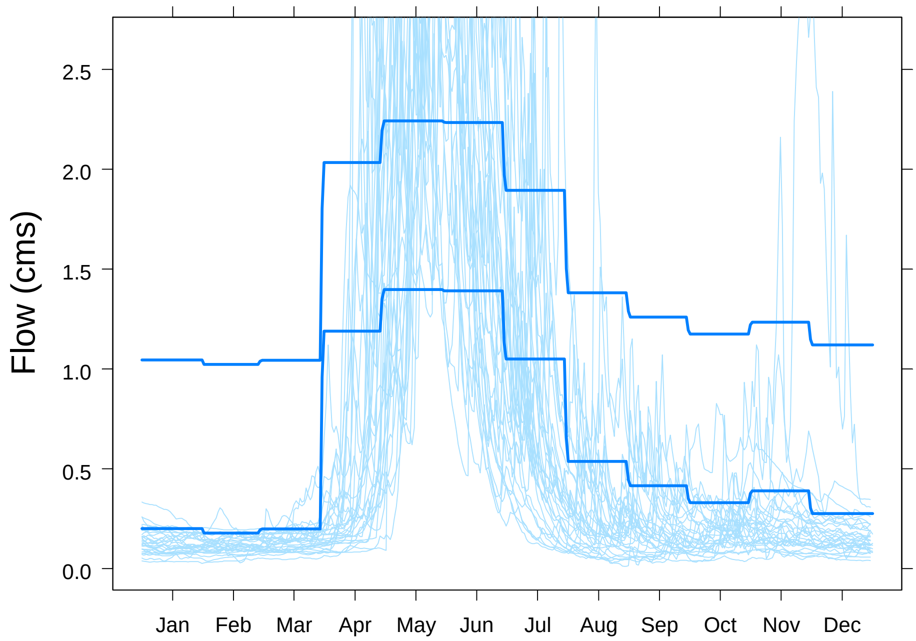


Figure Z: Natural mean daily flows (light blue) for Pennask Creek, with flow time series superimposed for each year on record. The dark blue lines show the minimum and maximum diversion thresholds as calculated using the proposed guideline for fish-bearing streams. Flows occurring between these two thresholds are available for diversion.

Advantages:

- Requires no field work
- Uses percentiles instead of means

Potential Limitations:

- Requires natural flow record, preferably for 20+ years
- Does not consider duration of flows under threshold

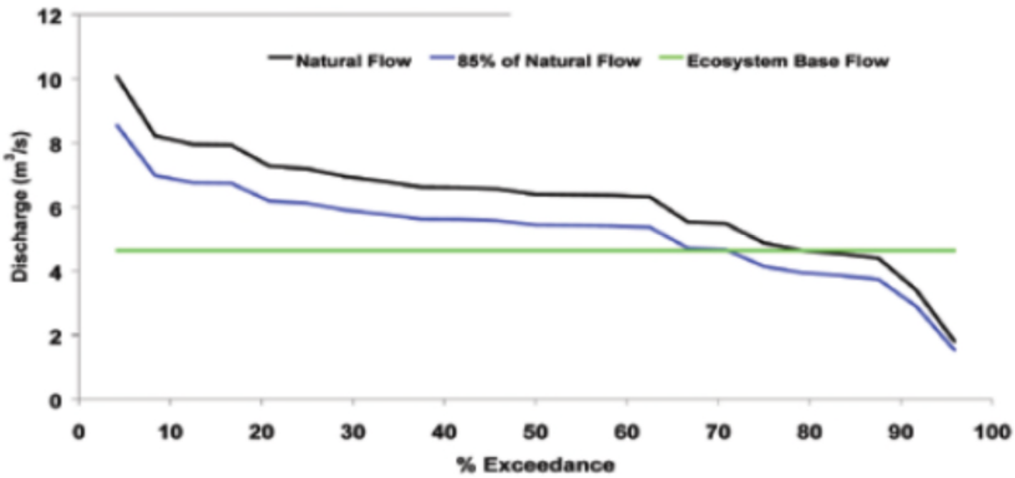
Alberta Desktop method

The Alberta Desktop method was developed in 2011 for Alberta Environment (Locke and Paul 2011). The method is based upon the results of numerous site-specific studies carried out in Alberta and an extensive review of instream flow studies and riverine ecology. The calculation has been simplified so that it only requires hydrology data. The Alberta Desktop method is calculating IFN based on flow-duration curves based on weekly or monthly time step.

The formula for the IFN method is the greater of either:

- A 15 per cent instantaneous reduction from natural flow or,
- The lesser of either the natural flow or the 80 per cent exceedance natural flow based on a weekly or monthly (depending on the availability of hydrology data) time step

Figure 2 Alberta Desktop Method Illustration



A comparison by Locke and Paul (2001) showed that the Alberta Desktop method provided more conservative IFN targets for most months when applied to Trout Creek. In all months except April, June and August, the flows established by the modified-Tennant approach are below the Ecosystem Base Flow component (80% exceedance) of the Alberta Desktop method (higher % exceedance yields lower flows).

Trout Creek conservation flows at point of diversion expressed as a naturalized monthly exceedance value.

Month	Conservation Flow			
	% MAD	CF	% Exceedance	Criteria
January	20	0.54	84	Over-wintering
February	20	0.54	85	Over-wintering
March	20	0.54	90	Over-wintering
April	100	2.7	64	Rainbow trout -passage/spawning
May	200	5.4	90	Channel maintenance
June	100	2.7	77	Riparian
July	30	1.08	83	Resident Rainbow trout rearing
August	23	0.81	65	Rearing
September	25	0.675	81	Kokanee passage/spawning
October	20	0.54	84	Rearing
November	20	0.54	88	Over-wintering
December	20	.54	84	Over-wintering
Average	**Median**		**84**	

Note: MAD = Mean Annual Discharge, CF = Conservation Flow
(Source: R. Ptolemy, British Columbia Ministry of Environment, Victoria).

The approach is used within NEWT to develop potential maximum allocation for each month by applying the IFN target to average flows with a monthly allowable allocation = 15% of average naturalized runoff.

Advantages:

- Frequently applied in Alberta and North-East BC for water allocation
- Already integrated with NEWT
- Considers variations between water year
- Uses percentiles instead of means

Potential Limitations:

- The approach is generally applied in unregulated rivers.
- Requires natural flow record
- Does not consider duration of flows under threshold

UCUT approach

Based on the natural flow paradigm, Uniform Continuous Under Threshold (UCUT) curves (Capra et al. 1995) are used to define a variable range of defensible lower flow IFN thresholds of concern based on the magnitude, frequency and duration of an individual stream's historical natural flow patterns. The UCUT approach generates intra-annual rules that identify the magnitude and the duration of low flow events common within an average year as well as the frequency of occurrence of uncommonly low flow events. Two duration types are also defined for uncommon events: persistent low flows that can happen

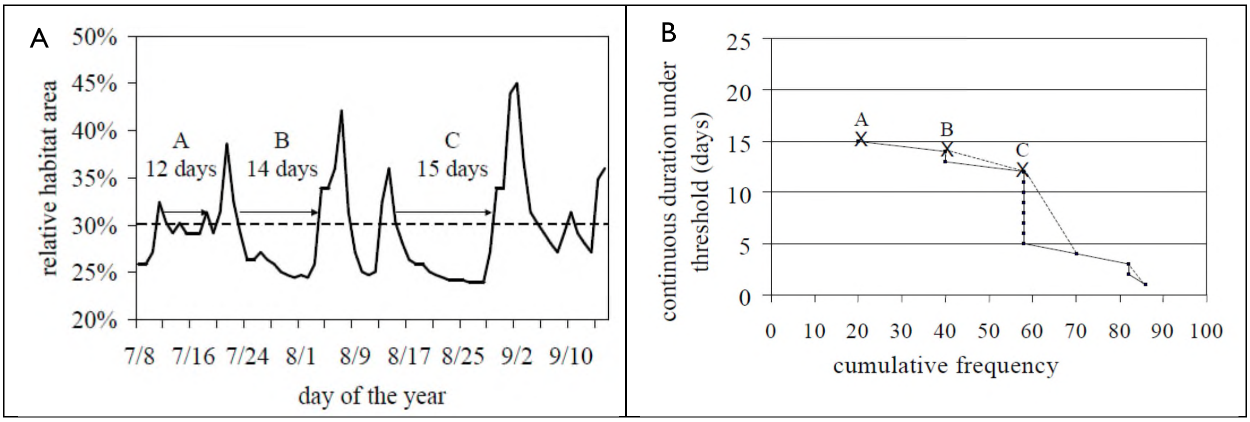
2 or 3 years in a row and catastrophic low flows that generally occur only on the decadal scale. Using this technique, it is possible to identify both the magnitude of key flow thresholds across fishery life cycles, and the number of days that flows can remain below these thresholds before they become a cause of increasing concern (an example of UCUT-defined risk zones that are based on both flow magnitude (cfs) and duration (days) is shown in Table 2).

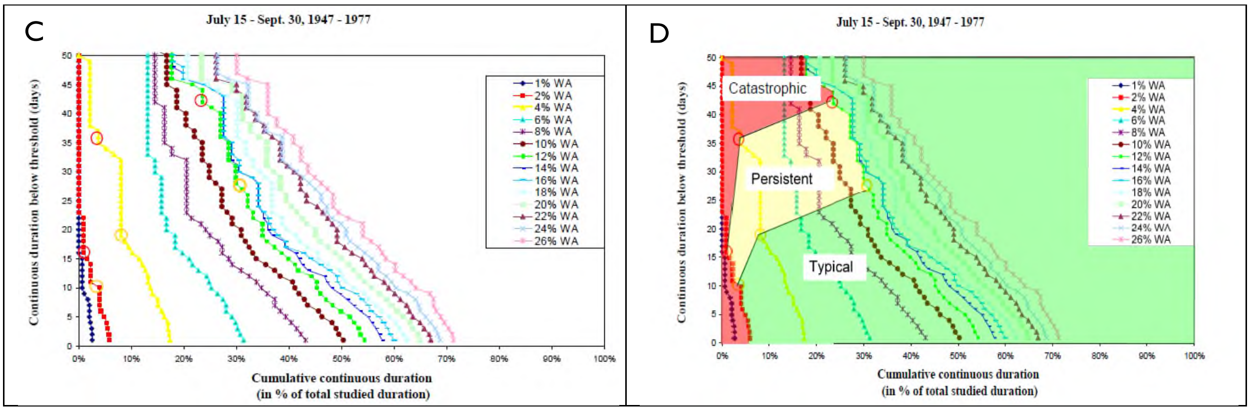
Table 2 UCUT Risk Matrix

Flow Event	Flow threshold (cms)	Persistent duration (days)	Catastrophic Duration (days)
Typical	0.8	**9**	**13**
Critical	0.5	**6**	**9**
Rare	0.4	**3**	**5**

The (UCUT) methodology integrates the duration during which the flow (or habitat area) is below a threshold in a given time series (Figure 3, Panel A). A cumulative frequency curve is developed for each specific threshold (Figure 3, Panel B) and multiple curves are developed for a series of thresholds, typically at regular intervals (Figure 3, Panel C). Finally, IFN thresholds are established based on inflection points which indicate a significant change in frequency (Figure 3, Panel D).

Figure 3 UCUT Curves





On gauged stream systems it is possible to track the duration that flows remain below different defined risk thresholds and monitor stream status over time, i.e., number of "stress days" experienced by the system. This approach is used currently for tracking the real-time flow status of rivers in Connecticut's Pomperaug watershed (http://pomperaug.org/, Figure 4) where flow duration below the varied UCUT-defined thresholds are used to define a green, yellow, red warning system that triggers voluntary or compulsory water conservation measures based on the level of perceived system stress.

Figure 4 Pomperaug Watershed Continuous Flow Thresholds

Three Rivers ACT Summary*

As Of: 09/02/2007 For the BioPeriod: Rearing & Growth

	Pomperaug		Nonnewaug		Weekeepeemee	
As Of:	09/02/07	ACT Status	09/02/07	ACT Status	09/02/07	ACT Status
Flow (cfs):	12	Days Duration	1.7	Days Duration	0.96	Days Duration
Rare Event						
Flow Threshold (cfs)	11	0	5	11	7	15
Persistent Days Duration	9		8		7	
Catastrophic Days Duaration	12		13		15	
Critical Event						
Flow Threshold (cfs)	20	9	6	11	9	22
Persistent Days Duration	15		10		15	
Catastrophic Days Duaration	23		17		24	
Common Event						
Flow Threshold (cfs)	89	44	26	44	27	44
Persistent Days Duration	27		27		27	
Catastrophic Days Duaration	43		43		43	

ACT Status Color Code Legend

- (green) = Discharge Flow either above the "Flow Threshold" or below but within the timeframe of Persistent Days Duration
- (yellow) = Discharge Flow below the "Flow Threshold" for Persistent Days Duration or more. Preparatory management actions required.
- (red) = Discharge Flow below the "Flow Threshold" for Catastrophic Days Duration or more. Mandatory management measures in effect

* Based on the 2005 UMass MesoHABSIM study ACTogram (Assessment of Continuous Thresholds) images for the assessment and mangement of flows.

The traditional methods for defining minimum flows in BC share a possibly dangerous weakness, in that they consider only low flow magnitude and not low flow duration. For example, an unusually extended low flow event could cause serious impacts to fish and their habitats even if above a single set low flow magnitude threshold for the duration. Traditional IFN methods would be unable to identify this risk.

Advantages:

- Only approach that integrates duration
- Explicitly considers variations between water year
- Impact on fish can be estimated from stress days
- Allows water managers to manage flows below thresholds for short durations

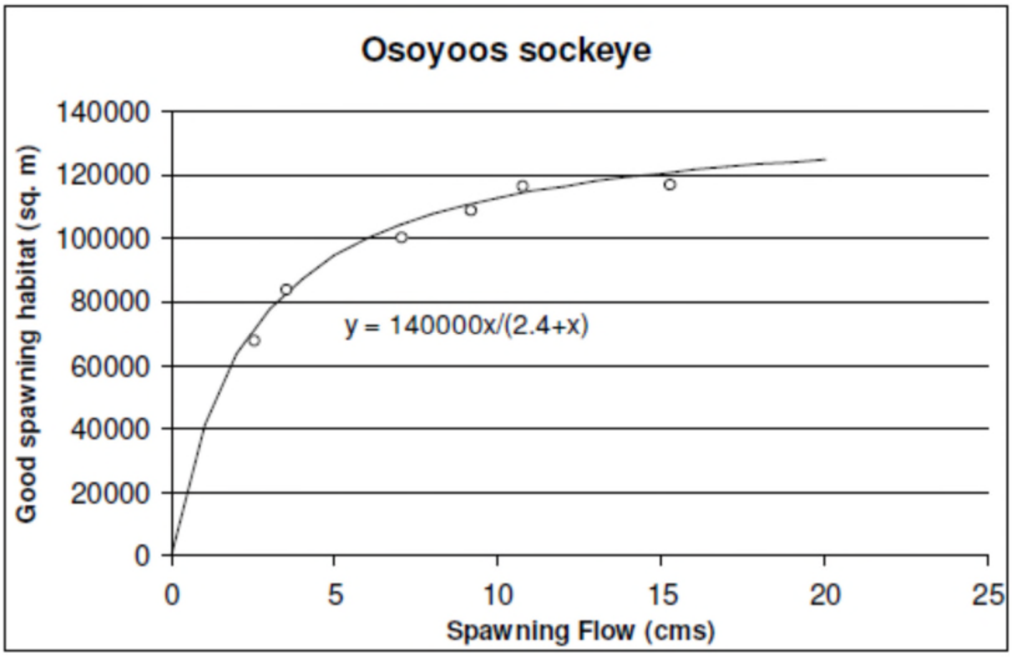
Potential Limitations:

- Not frequently applied in BC (mostly used in Eastern US)
- Requires natural flow record

Functional flows approach

The functional flows approach is significantly different from the other presented IFN approaches because a) the recommended flows are based on biological metrics and b) the approach requires fieldwork. The fieldwork is required to develop local relationships between flows and biological metrics. Frequently developed relationships are habitat curves for spawning and rearing and mortalities due to dewatering and scour. An example of a spawning habitat as a function of flows is shown in figure 5.

Figure 5 Example of Functional Flow Analysis

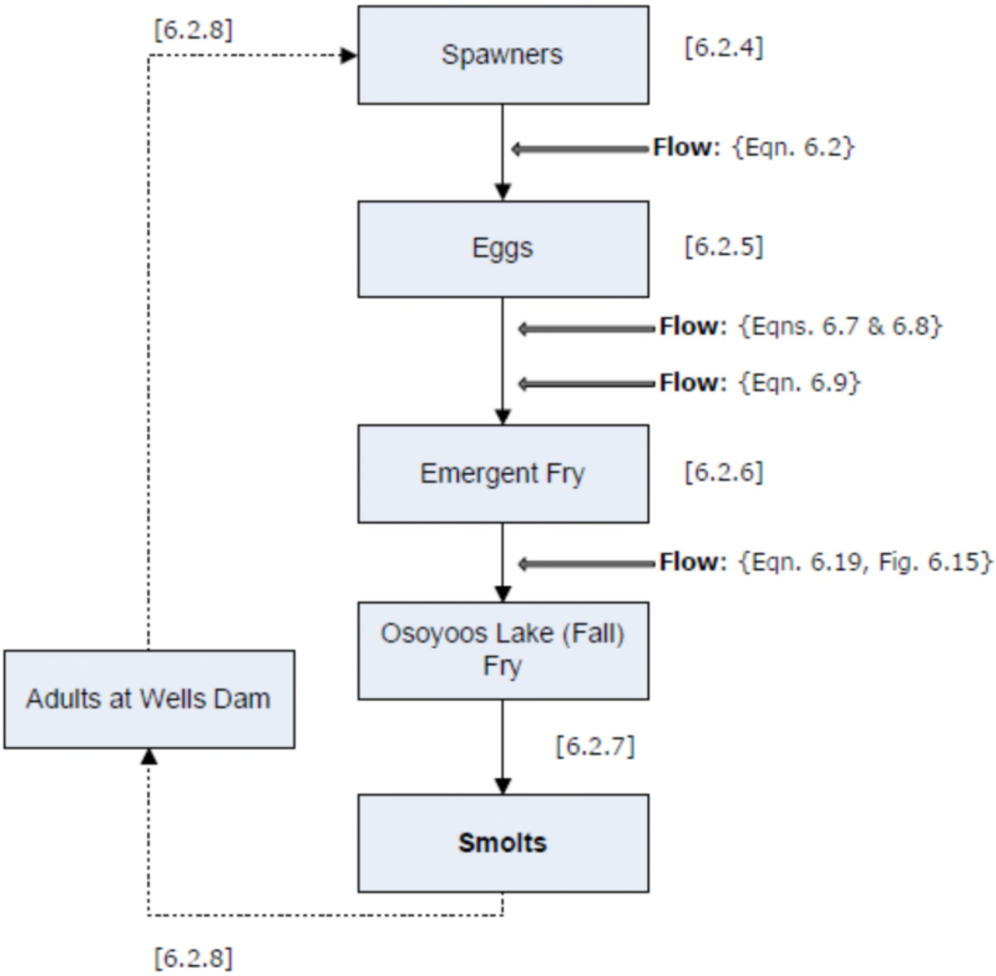


The IFN targets are typically developed by first establishing maximum acceptable mortality and minimum habitat criteria (Figure 6) for the watershed, and then using the flow relationship to calculate the equivalent flow target.

Performance Measure	Green	Yellow	Red
Sockeye egg and alevin incubation survival (egg to fry survival rate)	> 18%	10 to 18%	< 10%
Emergent sockeye fry survival in Osoyoos Lake to fall fry	> 65%	45 to 65%	< 45%

For example, the Fish/Water Management Tool (FWMT) developed functional relationships for Sockeye spawning habitat, egg desiccation, alevin stranding and Redd scour mortality (Figure 7) to manage flows downstream of Okanagan Lake (Alexander and Hyatt 2013). Similar flow relationships were developed for other management objectives such as Kokanee, Rocky Mountain Ridged Mussel and socio-economic objectives including avoiding flooding.

Figure 6 Fish Water Management Tool



The functional flows approach was recommended by the Canadian Okanagan Basin Technical Working Group (COBTWG) as the preferred method to meet sockeye ecosystem restoration objectives for managing the highly complex Okanagan water management system (resulting in the development of the FWMT).

Advantages:

- Recognized as the preferred approach for complex water management systems in the Okanagan
- Based on local conditions and biological metrics
- Allows water managers to estimate risks from flows below targets, including large impacts from small flow changes.
- Allow managers evaluate trade-offs between IFN and other water uses

Potential Limitations:

- Requires field-work
- Analysis intensive (may require modeling)
- Not appropriate for all watersheds

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