Okanagan Basin Water Supply & Demand Study II:
User Needs Assessment

Final Report

Prepared for

Okanagan Basin Water Board
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Executive Summary and Recommendations

ESSA Technologies Ltd (ESSA) is pleased to submit this report which clarifies and prioritizes user needs and technical requirements for the Phase 2 Okanagan Basin Water Supply & Demand study. This report documents findings from a User Needs Assessment (UNA), one of the first formal tasks undertaken as part of the Phase 2 study. The objectives of the UNA were to:

(i) prioritize questions on current and future water supply/demand and clarify the priority outputs and their acceptable resolution,

(ii) provide recommendations for Phase 2 deliverables and potential deliverables for future phases, and

(iii) in so doing identify the required attributes of Phase 2 data sources and models to satisfy these requirements.

As illustrated in the body of this report, the UNA achieved a high degree of success in meeting these three objectives. One reason for this success was the decision to conduct two UNA workshops, one with a primarily technical audience, and a follow-on workshop with Okanagan Water Stewardship Council (OWSC) members that represented a broader base of interested stakeholders. Both audiences were led through a series of presentations and questions to: (1) critically review and "sign-off" on a conceptual and quantitative model, (2) define priority outputs and form of deliverables, (3) define the spatial and temporal resolution for the study, and (4) identify climate futures and adaptation options that should be explored in the Phase 2 study or beyond.

It was readily apparent that the focus of these two audiences was very different. Technical specialists focused on the water budget equation and discussion of outputs. In contrast, OWSC members emphasized the importance of clearly presenting information and messages so that decision makers and politicians throughout the Okanagan would be able to readily disseminate Phase 2 information and make more informed decisions. Feedback on the OWSC UNA workshop revealed that there was some frustration created by sticking to (essentially) the same process as that used during the first UNA workshop. However, it is hoped that following the same process has helped these two audiences establish a common understanding of assumptions for the study. Given the early stage of the project, the UNA was intentionally structured to improve clarity and understanding over key *technical* details (water budget equation, temporal/spatial resolution, etc.). This will help position study teams to realize the 'big picture' goal of providing **high quality, reliable water supply and demand data at the basin wide scale**. Ultimately, this technical foundation must be agreed upon as it will define what is possible in terms of future communication plans and educational opportunities for lay audiences.

As expected prior to the workshop, the UNA process made limited progress in identifying future water supply/demand scenarios to pursue in the Phase 2 project. The main reasons were that participants at the OWSC workshop felt that: (a) they were not choosing from a full range of options, (b) the outcomes of choosing a given option was not known in advance, (c) identifying possible options would be perceived as 'recommending' that option, or (d) climate change scenarios and adaptations were simply viewed as beyond the scope of the Phase 2 study. Other participants believed that this created an awkward catch-22: "*You want us to tell you how a potential adaptation option performs, but you won't share your ideas on the options you think are worth exploring that are in need of further evaluation so we can provide the additional insight on outcomes*?" In practice, this simply highlights the political nature of these issues and their sensitivity. From an analyst's point of view, at some point someone inevitably must 'seed the dialogue' with some facts by initiating exploration of potential actions. This is different from recommending the option—it is not within the analysts grasp to control perception. **Given the sensitivities around the issue of climate futures and adaptation strategies, it is recommended that a separate plan be developed and executed to gather and clearly lay out this information.** If it is already known by Phase 2 project leaders that this component is not within scope/budget of the Phase 2 project, this fact should be made more transparent.

With regards to lay audiences, decision makers and politicians, considerable effort was expended prior to and during the second UNA workshop to identify a summary output approach that would be clear and practical for this audience. **Participants of both workshops unanimously supported the use of 'traffic light' or 'hazard coded' map based output displays to quickly communicate the status of water availability**. This output approach is described in detail in section 4.2.

Some participants were concerned that discussions of water budget equations and adaptation options implied that the study was moving away from sustainable water management, toward hard engineering solutions. This is a misunderstanding. It is important to recognize that the act of using an equation in itself does not require the Okanagan's water supply to be managed simply by diverting water from elsewhere, drawing down Okanagan Lake, or adding more storage. The water budget equation merely organizes what we know and do not know about water supply and demand, and links sub-basins together. Done right, water budget equations organize information, including seasonal variation and other forms of uncertainty, and identify gaps. With any equation value judgements must then be applied at the point a specific decision is to be made. For instance, the hazard map output approach makes this linkage very explicit, forcing the two spheres of 'hard data' and 'risk attitudes' to come together thereby bringing value judgements out into the open.

A mild tension that emerged during the UNA workshops was that some participants disagreed about the right balance of "depth" vs. "breadth" to pursue in the study. All agreed that reliable basin wide water supply and demand data was the most important deliverable. However, some participants stated that too much effort was being spent discussing the water budget equation and other technical details—the scientific underpinnings that will determine the project's credibility. Others suggested that products were needed quickly even if they were only approximately accurate. Further extending this apparent contradiction in expectations, others expressed that they wanted high quality reliable data, with known error bounds, and that this should be readily possible within the resources of the Phase 2 study. Hence, there are differing expectations and understandings of what the Phase 2 project can and should accomplish. In reality, it will not be practical to be highly rigorous and precise in the first pass whilst attempting to gather and link water supply and demand data over a basin wide scale. Therefore, to position the Phase 2 study to address these differing expectations, **it is critical that the data management and modelling framework used be easy to update, so that analyses can be repeated and data improved over time**. A related recommendation is to **conduct pilot tests for a limited number of sub-basins to refine methodologies before taking on the entire basin**. This will further clarify what is and is not possible with current data, techniques and funding, and hopefully identify one or more new solutions.

The UNA process identified 13 functional requirements for Okanagan water budget modelling (OkWBM) products (Table 8). The following table summarizes the major recommendations emerging from the UNA, mapping to each the requirements that are served:

Table E1. Major recommendations emerging from the UNA

Recommendations	Requirements achieved	
	Numbers	***Narrative***
1. Finalize and adopt the water budget equations presented in section 2.3 and use them as the organizing framework for the Phase 2 study. - Ensure that the equations used are linked at the basin-wide scale, and explicitly account for north-south water routing between sub-basins.	11, 12, 2, 4	The most important and desired deliverable from the project is reliable data linked at the basin wide scale. The completeness, clarity and consistency of water budget term definitions and the granularity of linked water supply and demand data are critical. "Granularity" in this context means that water budget terms are not subsequently re-defined, 're-lumped' or grouped inconsistently over space or time in ways that invalidate or confound water budget interpretation.
2. Separate the functions of "data management" from "modelling" in project planning and implementation, and move immediately to design & build a custom relational database. - Do not proceed with collecting data prior to having this data model designed and in place, as it should inform what data is collected and in what precise format.	4, 2, 3, 1, 9, 7, 8, (12 & 6 if need custom water budget engine)	This project's needs are custom. The water budget equation and scope are custom. Output requirements are highly custom. It is already known that several different models, data sources and techniques will be required to populate the water budget equation. Ungoverned, this data will come in different formats, different spatial and temporal resolutions, and data owners will bring forward their own specialized "dialects" for how they like to define terms and aggregate related components. Hence, it is a major accounting enterprise to get all this data to "talk to one another" and maintain "apples and apples." The most practical way to link all of these techniques and systems together is relational data management. Without a professionally designed data model and data import templates, analysts will inevitably end up "re-inventing the wheel" and "rediscovering processes". An ad hoc approach will lead to extra costs and errors. It is exceedingly unlikely that with these custom requirements any existing single system will be capable of managing all forms of water supply/demand data. More optimistically, if an existing water budget framework is found (e.g., to enable routing), a considerable amount of data re-formatting / transformations would be required to supply data in the format it expects. This will create a need for a large number of "one-off" queries, scripts, etc. to get data into the correct format. This task itself would justify creation of a relational database to efficiently enable this type of process. If an existing water budget model is *not* found, then an "engine" could simply be added on top of the relational water budget database to address routing and other requirements. Another distinct advantage of a custom relational database is that in Phase 2 or the future a reporting module could be added to deliver the various custom reports identified in this report. Because this study involves many interested users, a well designed, flexible data model will enable new reports or types of outputs to be quickly generated (e.g., when obtain new question or perspective). Over time, these reports could also be "web enabled" to make information available to a wide audience. Furthermore, a relational database will enable analyses to be efficiently repeated, as new and better data becomes available. Given expected gaps and the evolving state of water

Recommendations	Requirements achieved	
	Numbers	***Narrative***
		supply/demand data, facilitating updates is a critical service aided by a relational database. Note: other modelling and analyses can proceed in parallel outside this database, using it as an information source (input vehicle), and as a results repository (high-graded outputs). It should not be viewed as duplicating functions. Modern databases (rather than non-relational storage designs, flat files, etc.) enable interoperability with other systems (e.g., through web services, if desired).
3. Identify strategies to meet the requirements of exceedance plots and the map-based, hazard outputs identified in this report. - These maps should be dynamic, running forward in time on a decadal or other appropriate increment.	10, 7, 13	The most effective form of output is exceedance plots, tied to hazard maps. People were unanimously in support of 'traffic light' or 'hazard coded' map based output that quickly communicates the status of water availability. This type of output, rather than numbers emerging in raw form from the water budget equation, is much more useful to decision makers and other lay audiences. This output yields information that decision makers, not just technical experts can understand and use. It is simple enough to form a focal point for building social consensus. Different value judgements about desired/acceptable conditions can be readily expressed/built-into the approach. There is a major education goal associated with these maps: a given sub-basin node might be 'green', but this does not necessarily mean that there will be additional water to allocate at that location. Doing so may negatively impact downstream sub-basin(s) – i.e., turn them 'red' even while the upstream sub-basin suggests there is surplus water availability. Unlike other types of outputs, these maps move water managers to a basin-wide perspective, rather than a "my backyard only" view of water allocation decision making.
4. Using the finalized water budget equation from recommendation #1 along with the requirements described in this report, move to model evaluation and selection. Determine if a custom water budget engine is needed for this study. - This project requires two kinds of models: (a) a hydrologic model and (b) a water budget model (to link components and route water from location x to y). - An existing hydrologic model will likely be required, and should not be re-invented. - However, existing water budget models may or	12, 6, 11	Some of the constituent terms of the water budget equation will need to be provided by models. It may turn out that a custom model engine may need to be developed if an existing water budget model (like WUAM) is found to not meet the requirements identified in this report. Note: even if an existing water budget model is deemed suitable, it will not duplicate the services provided by building the custom relational database recommended in #2. This is because many requirements of this study are custom, they are many, and as such any single existing system will not be able to adequately meet enough of them (without major compromises on requirements or deliverables).

Recommendations	Requirements achieved	
	Numbers	*Narrative*
may not be suitable, depending on their ability to match the requirements identified in this report. These requirements should be used to guide water budget model selection.		
5. It is recommended that alternative approaches be evaluated on how best to determine confidence limits or distributions for any given estimate of $Q_{net\ i,t}$ (e.g., bootstrap approaches, Taylor series approximations).	5	Further thinking on how to account for uncertainty in individual estimates is required. There are several different ideas, some that focus only on providing "1 in 10 year" frequency information. Others wanted proper confidence limits, or Bootstrap estimates of uncertainty. During pilot applications some worked through examples comparing these and other alternatives should be provided. Note: if recommendation #3 is achieved, this issue may be implicitly resolved.
6. Develop a simplified but credible condensed description of the studies' underlying equations, datasets and models for use with non-technical audiences.	8	Work is needed to develop a communications plan that focuses on lay audiences. This includes simplifying the water budget equation for public consumption and other materials that describe the studies scientific underpinnings and uncertainties. A project plan that achieves recommendation #3 would go a long way toward enabling wide dissemination of study results.

Phase 2 of the Okanagan Basin Water Supply & Demand study provides a very rare opportunity to improve the basin-wide scientific basis for water management decision making in the valley. Equally rare is the opportunity to bring together numerous stakeholders, leading scientists and agency staff to share information, techniques and clarify aspirations. One challenge for the study is to efficiently manage the enormous amount of data that is necessary and develop a means of making different kinds of models "talk to each other" given that information will be available in different formats, different spatial resolutions and in different "dialects". A related challenge is ensuring more practical access to, clear dissemination of, and incorporation of this data and knowledge into routine water supply and demand decision-making by numerous water authorities, as well as the public consciousness. Given these and other challenges, combined with the high expectations facing the study, it is critical to understand exactly where you want to get to, what the desired end products are ("must have" vs. "nice to have") prior to starting the work. By using this report as a reference during detailed project planning, the Phase 2 proponents will be well placed to meet the needs and expectations of both technical and non-technical users.

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1. Introduction

1.1 Background

In response to increasing concern over the sustainability of water use and water management in the Okanagan Basin, in 2004 the Province of B.C. initiated a study to determine the current supply of and demand for water in the basin. Phase 1 of the study was completed in May 2005 by Summit Environmental Consultants Ltd. with participation of a wide range of stakeholders. The Phase 1 work identified and catalogued relevant sources of data on current supply and demand, identified data gaps, and developed a strategy for Phase 2. Phase 1 included a workshop with representatives from federal, provincial, and local government, as well as First Nations and user groups, to discuss the information review and the Phase 2 strategy.

The Okanagan Basin Water Board (OBWB) and the Province, in partnership with Environment Canada, Agriculture Canada and First Nations, have recently initiated Phase 2. The goals of the Phase 2 project are as follows:

1. Determine the **current** supply of and demand for water throughout the Okanagan Basin;
2. **Develop or select a model or linked suite of models** that routes water from tributaries into main valley lakes and downstream into Osoyoos Lake that can be used to examine water management alternatives; and
3. Identify potential **future** changes in both supply and demand and run the model for a range of realistic future scenarios.

In a project of this scale it is critical to know exactly where you want to get to, what the desired end products and goals of a project are prior to starting the work (“must have” vs. “nice to have”). Before initiating specific analyses or choosing specific models, the overall objectives, desired outputs, and kinds of “Okanagan basin futures” must be generally agreed upon by the Technical Working Group and stakeholders. While the Phase 1 project identified many potential objectives, performance measures and kinds of analyses that could be performed, it remains unclear what the priorities are and what is technically feasible and affordable.

To clarify priorities, one of the first formal tasks undertaken in Phase 2 is the User Needs Assessment (UNA). The purposes of the UNA are to:

1. prioritize questions on current and future water supply/demand and **clarify the priority outputs and their acceptable resolution**;
2. provide **recommendations for** Phase 2 **deliverables** and potential deliverables for future phases; and
3. in so doing **identify the required attributes of** Phase 2 **data sources and models to satisfy these requirements**.

1.2 UNA workshops

To achieve these purposes, two UNA workshops were held in March and April 2007. Workshop 1 was held in Kelowna on March 7th, 2007 with members of the Technical Working Group. A summary report on workshop 1 was delivered to the Okanagan Basin Water Board in March (Alexander and Robson 2007a). Participants of the second UNA workshop were given a copy of this report (as a "mini-backgrounder") prior to the second UNA.

The second UNA workshop was held in Kelowna on April 12th, 2007 and was principally attended by Okanagan Water Stewardship Council members that represent water stakeholders with a broad interest base, who are expected to be among the end users of the Okanagan Water Model. A summary report on this workshop was delivered to the Okanagan Basin Water Board in April (Alexander and Robson 2007b).[1]

At the workshops, British Columbia Ministry of Environment (BC MoE) representative Wenda Mason emphasized the high profile of and uncertainty surrounding future water licensing decisions. Many streams in the Okanagan are now fully allocated, and yet the population and economic output of the valley is projected to increase considerably over the next 20 years and beyond. In this context, it is essential to find out whether or not there is more water to allocate, and what the most promising strategies are for balancing demands with ecological needs and quality of life metrics. Some of the goals of particular interest to BC MoE expected to be informed from the Okanagan water budget modelling are to:

1. identify which streams are fully allocated;
2. identify which streams are not fully allocated, and thus can be further allocated; and
3. take supply, demand and climate change into account.

Wenda Mason noted that BC MoE are aware of the many other benefits and uses of the Phase 2 study. Given the potential breadth of the study, from BC MoE's perspective, it is essential that the scope and focus be maintained in Phase 2, so that a product is created within a reasonable time and within a reasonable budget.

Keeping this in mind, for purposes of looking ahead to future phases of the project, the participants were asked to think about other uses of Okanagan water budget modelling (hereafter OkWBM) products. The participants were encouraged to identify information and needs for future phases of the study, so that short-term priorities do not limit or cut-off opportunities in future phases (thereby increasing the overall multi-phase project cost).

1.3 UNA "roadmap"

Workshop facilitator Clint Alexander created a "roadmap" for the UNA workshops set in the context of the overall Phase 2 project (Figure 1). The topics and issues inherent in Figure 1 and their sequence are the focus of this report.

[1] Lists of the participants who attended the workshops are provided in Appendix A of this document.

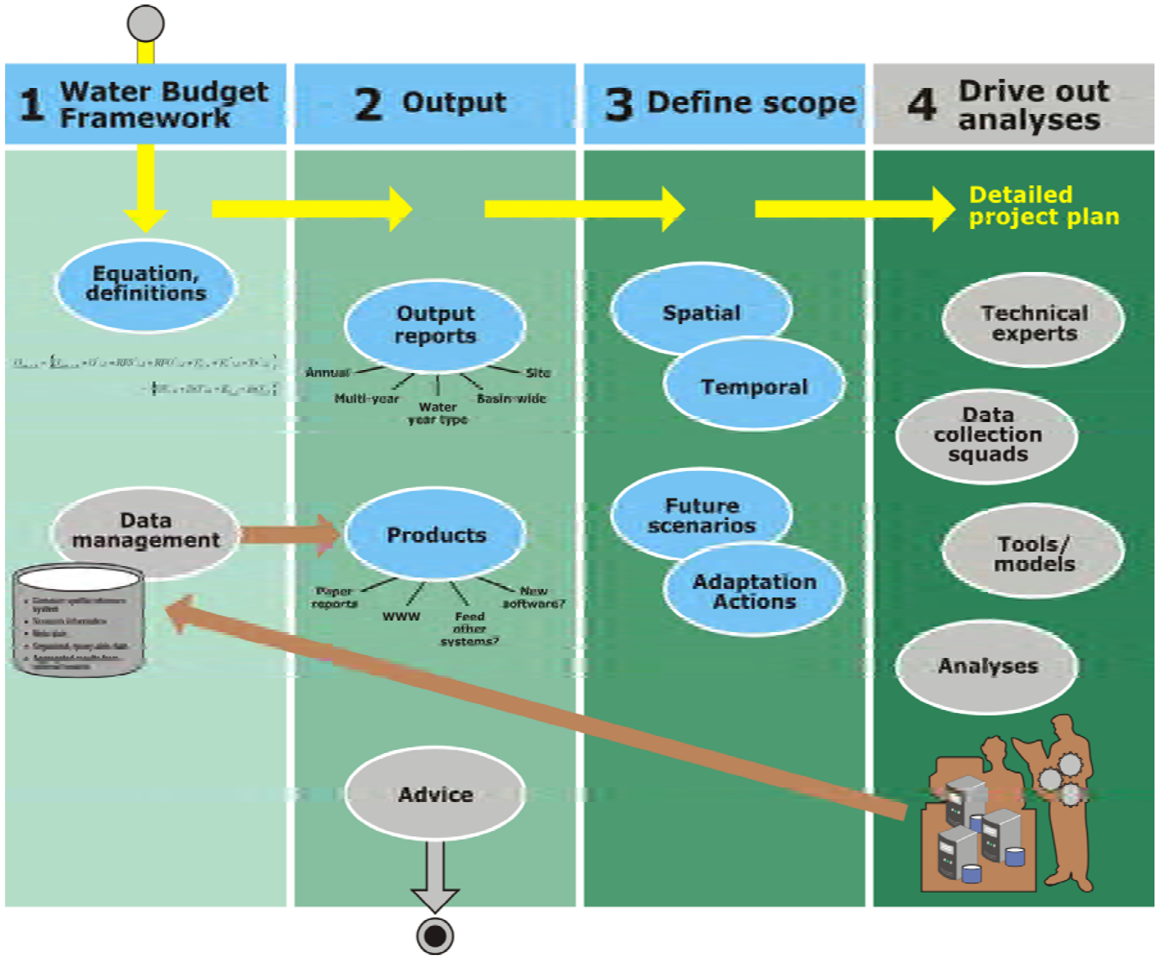

Figure 1: UNA workshop "roadmap". Items in blue under steps 1, 2 and 3 show the 'in scope' items to be addressed by the user needs assessment workshops. Items in grey under step 4 and at the bottom of steps 1 and 2 are Phase 2 project needs beyond the scope of workshop discussions.

2. Overall Conceptual and Quantitative Model

2.1 Background

The overall conceptual model for the Phase 2 study is shown in Figure 2. This conceptual model centers on the notion of a "water buffer" or surplus water availability in the outer ring, with a variety of ecological and human consumptive uses at the core. The water buffer is influenced by three major factors: (i) year to year and seasonal variability; (ii) growth in human consumptive needs; and (iii) climate change. The relative importance of each of these factors varies within a watershed. Ecological and other non-consumptive needs (e.g., recreation) also vary seasonally and from place to place. Hence, even under current conditions, the "water buffer" or surplus water availability is **not** a static volume. Add to this the uncertainty over increases in demand due to population growth and reductions in water supplies due to climate change, and the challenges of making sound water allocation decisions are evident.

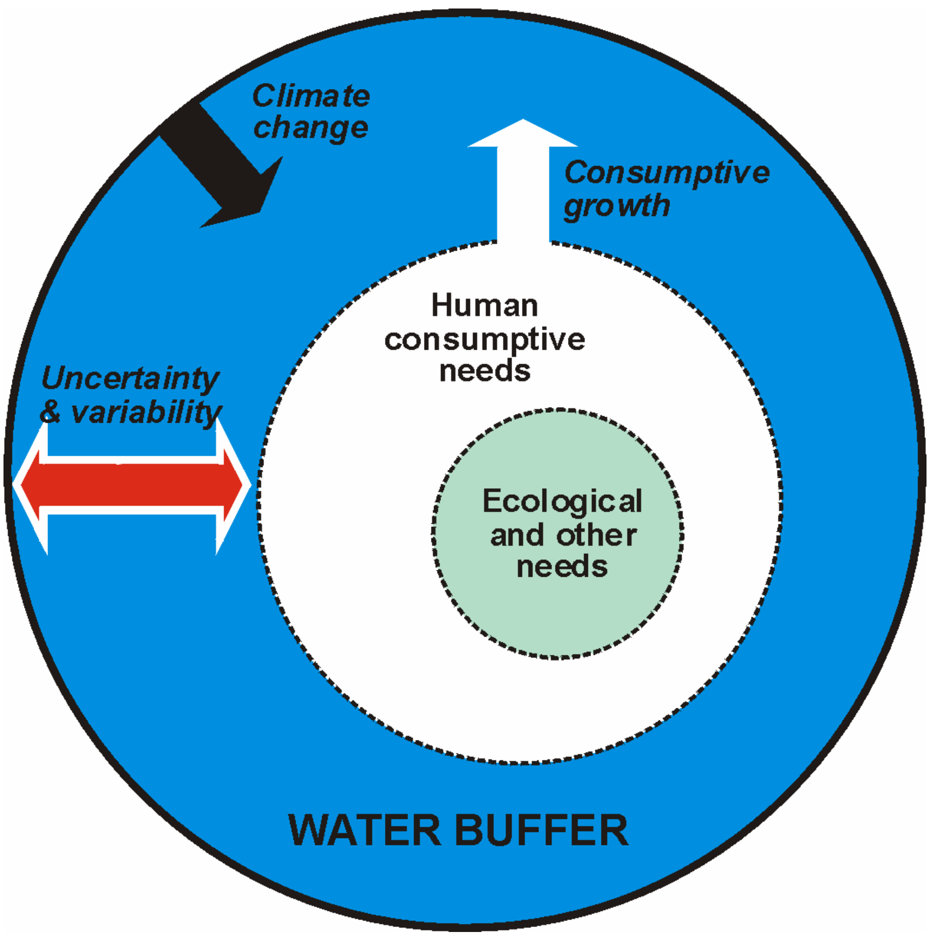

Figure 2: Conceptual water budget framework. *Adapted* from a presentation given by Dr. Atef Kassem, Environment Canada, October 2006.

2.2 Discussion focus

Participants of both workshops were introduced to the quantitative version of Figure 2 in the form of a water budget equation.[2] A water budget equation is the mathematical basis of any water supply and demand study. These equations can be written in different forms, aggregated in different ways, but are straightforward to understand **once each of the terms is clearly defined**. Having introduced the equation and its terms plus these big picture questions, both workshop groups were asked: *what do people think of representing the overall problem in one equation?*

The discussion of the water budget equation garnered considerable focus at both UNA workshops. Technical minded participants were keen to delve into the details, and raised several important points, including identifying changes and enhancements to earlier versions of the equation. Portions of the less technical audience at the April 12, 2007 workshop were frustrated by the time spent discussing the equation, and suggested it was not the best use of time. While this later view is somewhat at odds with **the clear and persistent request for the study to provide accurate and reliable data**, it points out the two distinct audiences that contributed ideas to user needs.

Those who were engaged in the discussions over the water budget equation focused on understanding the definitions of the equations component terms. Understanding what sub-details and specific physical processes were included in which terms, and what the relationships between them was and was not. It was emphasized that care is needed to understand the equation and its definitions and not double count (or fail to include) supply/demand elements. It was also pointed out that **the equation must account for north-south or sub-basin to sub-basin routing of flows**.

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from the two workshop discussions are presented in Table 1.

Table 1. Equation discussion points of general agreement & recommendations, and points of departure or issues requiring further discussion.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	Participants agreed to move forward using the revised equation in Alexander and Robson (2007a).	No significant points of departure.
Workshop 2	Drop ω (element 13) from the equation, but build in +/- error into Qnet (element 1). The equation is too complicated for a lay audience. We need a simplified way to present the equation, progressively revealing the details. Also we need a schematic map based presentation that more clearly shows where water is coming from and going to. (This point includes illustrating how the equation does and will sum to zero.) Equation is generally fine, as long as the terms are carefully defined. Nodes must join together properly to form a routing model for the entire basin – otherwise, we cannot show north-south impacts of different water use scenarios. There is nothing *missing* from the equation.	InQ – whether it should be on the right or the left (vote among participants: 11 on right, 4 on left).

[2] See Alexander and Robson (2007a) for the version provided prior to and during the workshop.

2.3 Recommendations

Without an organizing framework for collecting water supply and demand data, it will be impossible to move forward and intelligently address the “big picture questions” that all participants are keen to tackle. In this context, settling on an appropriate set of water budget terms and equations is a critical first step that should receive “sign-off” before moving to formal data design, data collection, model evaluation or analysis.

An important aspect of the UNA was to identify all key water balance terms for the Okanagan Basin. The *precise* form of the equation(s) is expected to be finalized after this report inside the individual technical work scopes for subsequent project components (e.g., water management and use, surface hydrology, groundwater, water balance modeling). Once finalized however, the definitions of water budget terms and equations are an item that should be ‘locked in’ and not subject to the whims of data collection, synthesis and analysis personnel.

In consideration of and response to workshop feedback, a ‘near final’ version of the water budget equation is provided below at two levels of detail:

- **Detailed** equation form, including definition of individual terms (Eqn. 1, Eqn. 2 through Eqn. 5), and
- **Schematic overlay format** showing where these equation terms *conceptually* fit on the landscape (Figure 3).

These equations are merely expanded versions of classic hydrological equation: $Inflow = Outflow + \Delta Storage$. In other words, by grouping the appropriate terms on each side of the ‘equal’ sign, the equation will balance to 0. Further refinements of these equations are the domain of the project’s Technical Working Group members, and are beyond the scope of the UNA.

$$Q_{net\ i,t} = \left\{ Q_{surf\ \ i,t} + G_{i,t} + RFS^{*}_{\ i,t} + RFG^{*}_{\ i,t} + P_{l\ i,t} + R^{*}_{\ i,t} + Tr^{*}_{\ i,t} \right\}$$

$$- \left\{ DS^{*}_{\ i,t} + DG^{*}_{\ i,t} + E_{l\ i,t} + InQ^{*}_{\ i,t} \right\} + \sum_{i=first}^{i=n} Q_{net\ UPSTREAM\ ,t}$$

1. *Net amount of water available for all purposes, incld. lake storage mgmt.*
2. *Natural* surface water component of supply
3. *Natural* groundwater component of supply
4. Surface component of return flow
5. Groundwater component of return flow
6. Direct precipitation on large lake surfaces (Okanagan, Kal/Woods, Skaha, Vaseaux & Osoyoos)
7. Upland reservoir component of inflow
8. Water transferred from other basins (optional)
9. Volume removed by demands on all surface sources (agricultural and residential/industrial)
10. Volume removed by demands on all groundwater sources (agricultural and residential/industrial)
11. Lake surface evaporation (Okanagan, Kal/Woods, Skaha, Vaseaux & Osoyoos)
12. In-stream flow needs for fish, ecological needs and other non-consumptive purposes (incld. aesthetic)
13. Net amount of water received (>=0) from all upstream contributing sources [i.e., model requires routing]

Eqn. 1: Recommended Okanagan basin water budget equation – overall supply and demand framework.

Note: definitions for these 13 terms are provided below.

Equations by landform or node type

The overall equation (Eqn. 1) is valid for: (i) a tributary point of interest; (ii) a mainstem river point of interest; (iii) a valley bottom lake; and (iv) a residual land area sub-basin. Each of these four types of sub-basins will be defined and used in the Phase 2 study. These distinctions are important because certain terms in the master equation may drop out depending on the landform or node type.

1. ***Upland tributaries (no contributing flow from upstream nodes)***

- $P_{l\ i,t} = 0$; $E_{l\ i,t} = 0$.
- $\sum_{i=first}^{i=n} Q_{net\ UPSTREAM\ ,t} = 0$.

$$Q_{net\ i,t} = \left\{ Q_{surf\ \ i,t} + G_{i,t} + RFS^{*}_{\ i,t} + RFG^{*}_{\ i,t} + R^{*}_{\ i,t} + Tr^{*}_{\ i,t} \right\} - \left\{ DS^{*}_{\ i,t} + DG^{*}_{\ i,t} + InQ^{*}_{\ i,t} \right\}$$

Eqn. 2: Water budget equation for an upland tributary with no contributing flow from upstream sources.

2. ***Mainstem rivers (receiving flow from upstream nodes)***

- $P_{l\,i,t}=0$; $E_{l\,i,t}=0$.
- $\sum_{i=first}^{i=n} Q_{net\,UPSTREAM,t} \geq 0$.

$$Q_{net\ i,t} = \left\{Q_{surf\ \ i,t} + G_{i,t} + RFS^{*}{}_{i,t} + RFG^{*}{}_{i,t} + R^{*}{}_{i,t} + Tr^{*}{}_{i,t}\right\} - \left\{DS^{*}{}_{i,t} + DG^{*}{}_{i,t} + InQ^{*}{}_{i,t}\right\} + \sum_{i=first}^{i=n} Q_{net\ UPSTREAM\ ,t}$$

Eqn. 3: Water budget equation for a mainstem river with contributing flow from upstream sources.

3. ***Main valley bottom lakes - Okanagan, Kalamalka/Wood, Skaha, Vaseaux and Osoyoos (receive contributing flow from upstream nodes)***

- $R_{i,t}=0$.

$$Q_{net\ i,t} = \left\{Q_{surf\ \ i,t} + G_{i,t} + RFS^{*}{}_{i,t} + RFG^{*}{}_{i,t} + P_{l\ i,t} + Tr^{*}{}_{i,t}\right\} - \left\{DS^{*}{}_{i,t} + DG^{*}{}_{i,t} + E_{l\,i,t} + InQ^{*}{}_{i,t}\right\} + \sum_{i=first}^{i=n} Q_{net\ UPSTREAM\ ,t}$$

Eqn. 4: Water budget equation for a valley bottom lake with contributing flow from upstream sources.

$Q_{net\,i,t}$ is available to generate lake outflow, to increase or decrease the lake level, or to meet new demands not accounted for in the equation. That is, it should be recognized during *interpretation* that a portion of $Q_{net\,i,t}$ will be needed to meet lake elevation targets, which depending on the lake, its starting lake elevation and time of year, creates or embeds an implicit $\Delta S_{i,t}$ term. As the purpose of OkWBM products is for planning rather than operational decision-making, a recommended simplifying assumption is to *exclude* explicit tracking of lake storage requirements. Likewise, the $R_{i,t}$ term does not apply to main valley bottom lake nodes (its effects are embedded within the $\sum_{i=first}^{i=n} Q_{net\,UPSTREAM,t}$ term).

4. ***Residual areas (no contributing flow from upstream nodes)***

- $P_{l\,i,t}=0$; $E_{l\,i,t}=0$.
- $\sum_{i=first}^{i=n} Q_{net\,UPSTREAM,t}=0$.
- $Q_{surf\ i,t}$ may be close to 0.
- $InQ^{*}{}_{i,t}$ may be 0.

$$Q_{net\ i,t} = \left\{Q_{surf\ \ i,t} + G_{i,t} + RFS^{*}{}_{i,t} + RFG^{*}{}_{i,t} + R^{*}{}_{i,t}\right\} - \left\{DS^{*}{}_{i,t} + DG^{*}{}_{i,t} + InQ^{*}{}_{i,t}\right\}$$

Eqn. 5: Water budget equation for a residual area with no contributing flow from upstream sources.

Where:

*** = a component that can be moderately to highly influenced by human decisions (and values).**

$Q_{net\ i,t}$ = **net amount of water available** (surplus/deficit)$^{\Psi}$ **for all conceivable purposes** – except in-stream flow requirements – to point of interest *i*, during time *t*, for a given aggregate scenario *X* (e.g., current supply/demand or future condition *X*).

$^{\Psi}$ e.g., water available for meeting any number of purposes, such as meeting downstream needs (in the case of a tributary sub-basin) or increasing lake levels or contributing to lake outflow (in the case of a mainstem lake sub-basin). **That is to say, all of $Q_{net\ i,t}$ is not necessarily *available* for licensing or other human use, especially in the case of valley bottom lake nodes.**

- It is important to interpret this value in the context of all terms in the water budget equation, as well as the 'kind' of point of interest location '*i*' is part of, i.e.,
  - a mainstem river or tributary point of interest,
  - a mainstem lake defined as a sub-basin or
  - a residual land area sub-basin.
- In the case of mainstem lakes, $Q_{net\ i,t}$ includes the notion of meeting lake level storage change needs (i.e., implicitly includes a $\Delta S_{\ i,t}$ term).

Supply terms:

$Q_{surf\ i,t}$ = the natural **surface water component** of total stream inflow from all watershed sub-basins contributing to point of interest *i*, during time *t* from rainfall, snow-melt, less **evapotranspiration**, including accounting for soil moisture effects, **<u>etc.</u>**

- For clarity: this is the natural surface water component of the stream hydrograph. It does not include inputs (or losses) from (to) groundwater;

$G_{i,t}$ = the natural **groundwater component** of total stream inflow to point of interest *i*, during time *t*. *This value may be positive or negative*. This is the groundwater component that would occur in the absence of human extraction and water uses.

- For clarity: this is the natural groundwater discharge component of the stream hydrograph. Withdrawals from wells and return flows from irrigation and distribution system losses are accounted for separately in other terms of this water budget equation;

$RFS^{*}{}_{i,t}$ = the **surface component of return flow** from all sources (municipal, agricultural, etc.) to point of interest *i*, during time *t*

- e.g., municipal wastewater return flow is an $RFS^{*}{}_{i,t}$ term

$RFG^{*}_{i,t}$ = the **groundwater component of return flow** from all sources (municipal, agricultural, etc.) to point of interest *i*, during time *t*

- e.g., distribution system leakage and agricultural over-irrigation are $RFG^{*}_{i,t}$ terms
- Ensure water re-use is accounted for where necessary;

$P_{l\,i,t}$ = the **direct precipitation on large lake surfaces** at point of interest *i*, during time *t. Used for sub-basins in which lake surface is a significant proportion of the total sub-basin area* (lake surface area × precip. depth = volume)

- = 0 unless the sub-basin is dominated by one or more lakes/reservoirs;

$R^{*}_{i,t}$ = the **upstream reservoir component of total inflow** contributing to point of interest *i*, during time *t*. *This value may be positive* (reservoir release, draw-down) *or negative* (reservoir filling, storage gain). This term does **not** address storage changes in the five major valley bottom lakes. Rather, it is reserved to account for the effects of regulated *upland* reservoirs.

- Depending on the configuration of the reservoir, this term may be tightly linked with **human control**;

$Tr^{*}_{i,t}$ = the amount of **water transferred/received from other basins** to point of interest *i*, during time *t.* (Be careful not to double count in terms $DS^{*}_{i,t}$ or $RFS^{*}_{i,t}$)

- This can occur from one *watershed* to another (e.g., Shuswap) or intra-basin from one sub-basin to another sub-basin, depending on "the plumbing".

$\sum_{i=first}^{i=n} Q_{net\,UPSTREAM,t}$ = **net amount of water received (>=0) from all upstream contributing sources** to point of interest *i*, during time *t*.

- In order to account for north-south water flows and linkages amongst sub-basins – a high-priority requirement identified by users is explicit accounting of water routing and transit times in OkWBM;
- = 0 for tributaries and residual areas.

Demand & use terms:

$DS^{*}_{i,t}$ = the **total volume of water removed from all surface sources** at point of interest *i*, during time *t.*

- There are *many* components and assumptions that affect this term. We intentionally lump domestic, agricultural, industrial etc. use (i.e., before return flows) for elegance/simplicity/ease
- **Note: actual use is distinguished from licensed withdrawals which is further distinguished from how other estimates of how water should be used (e.g., based on other model results)**
- this term is under **human control**;

$DG^{*}_{i,t}$ = the **total volume of water withdrawn from groundwater** at point of interest *i*, during time *t.*

- As for $DS^{*}_{i,t}$, we lump all uses (i.e., before return flows)
- As this represents groundwater wells & 'tapped' aquifers, water arising from this term will be under **human control**
- **Note**: in some sub-basins, it may be necessary to add an explicit groundwater aquifer tracking component, to ensure that the calculated ground-water extraction does not

exceed the available groundwater supply. This is an important technical question that depends on the level of groundwater-surface water accounting sought by the study.

$E_{l\ i,t}$ = for significant valley bottom lakes (Okanagan, Kalamalka/Woods, Skaha and Osoyoos), the **lake surface evaporation** lost at point of interest *i*, during time *t* (lake surface area × evaporation depth = volume).

$InQ^{*}_{i,t}$ = if applicable at point of interest *i*, the **in-stream flow needs** during time *t*, for environmental (aquatic organisms & ecological services), cultural, aesthetic, recreational and *all* other misc. non-consumptive needs not directly related to/linked with $DS^{*}_{i,d}$

- **Note**: mainstem Okanagan River in-stream flow needs (through to Osoyoos Lake) are very well understood/documented via the Okanagan Fish/Water Management Tool
- They are less well understood/documented for most upland tributaries.

Values for each of these terms are expressed in units of volume (m^3 or millions m^3).

Uncertainty / Error

During both UNA workshops, several participants emphasized the importance of accounting for uncertainty and error in the various water budget equation terms. Others felt that error analysis would use up too much of the project's resources. All participants recognized that each variable in Eqn. 1 will have an associated error (at a particular point of interest and week of the year). It is recommended that alternative approaches be evaluated for how best to determine confidence limits or distributions for any given estimate of $Q_{net\ i,t}$ (e.g., bootstrap approaches, Taylor series approximations). These findings should be used to inform whether it is feasible to explicitly address uncertainty in the Phase 2 study.

Note: this is a different issue than (the important requirement) to calibrate models so as to achieve water balance. The latter is an issue of *accuracy* or *reliability*, whereas the former is one of *precision*.

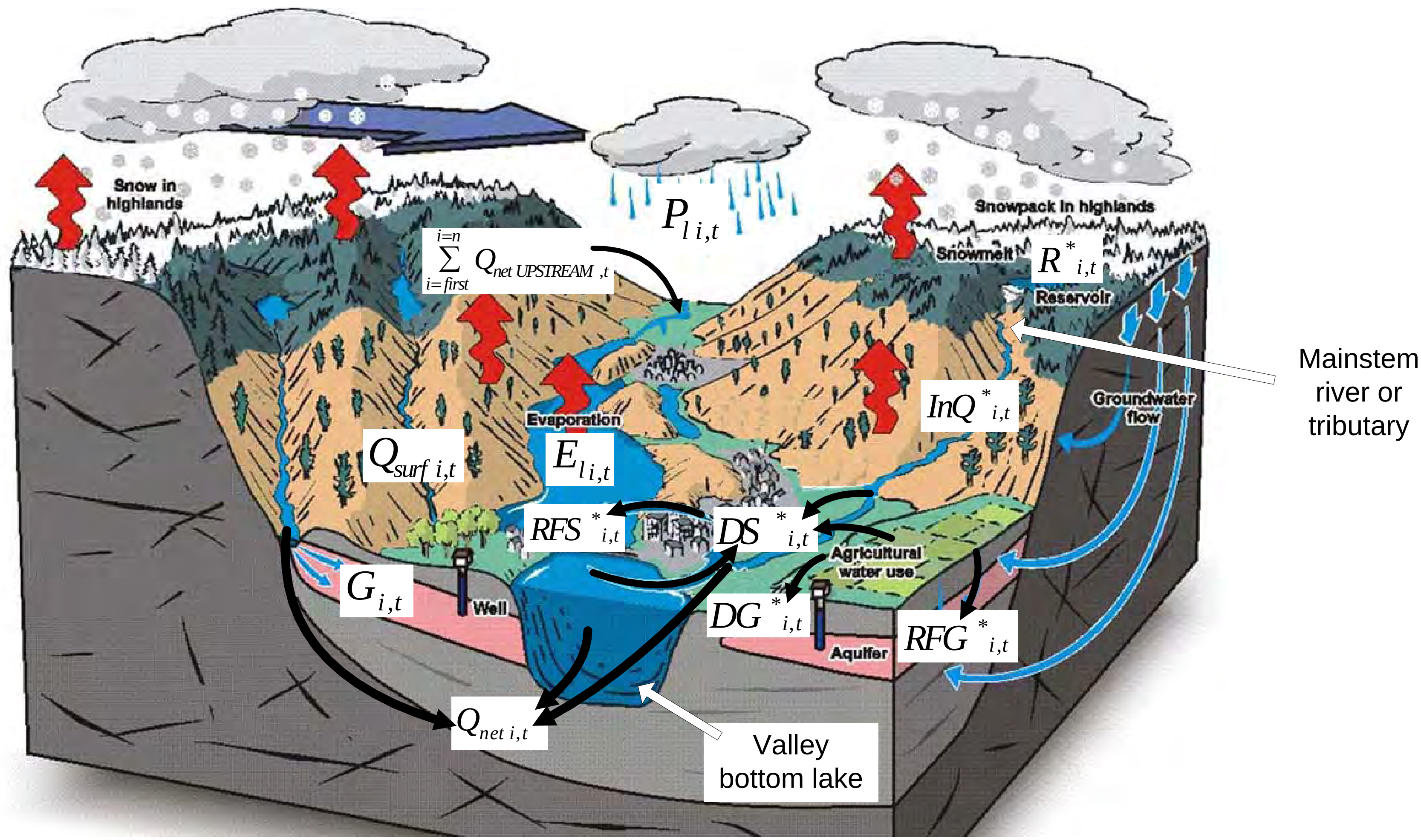

Figure 3: Water budget equation terms and general relation to physical elements on the landscape.

3. Who are the Users?

3.1 Who are the users? Who is the target audience?

Most "user" needs assessments begin with definition of *who* the individuals are that are expected to benefit from some proposed type of tool or technology. A "user group" can be defined as a set of people who share common concerns and interests in a topic and as a result, may have common requirements for tools and information. The key point for the Phase 2 UNA, is to focus on the end-users, whether people or organizations, that will benefit directly from the project and use the information it generates to make more informed decisions.

The two UNA workshops involved a representative sample of two groups: (i) the technical specialists who understand or may even perform pre-requisite water supply/demand analyses; and (ii) decision makers and the broader public interested in the findings of the study.

Discussion focus

It was readily apparent that there are many potential sets of audiences, most of whom are *not* technical experts. Many people who will use the studies' information do not necessarily live and breathe hydrology, modelling or water demand studies. Wenda Mason pointed out that the project's "audience" is different from its "users": the **audience** has to find the results credible yet easy to grasp, while **end-users** work directly with OkWBM technology and products. The requirements of both groups need to be considered in the Phase 2 study. A strategy for managing non-technical and technical needs is to orient the project's output presentation towards decision-makers and the public while focusing the project's internal configuration (equations, scope, models, etc.) towards the technical specialists.

Table 2. Broad list of potential audience and users developed by workshop participants. Workshop 1 and 2 results are separated for comparison.

	General, non-technical "audience":	Technical "end-users":
Workshop 1	Provincial decision makers regarding infrastructure grants Regional District planners developing community and water use plans Educators Local and provincial politicians (to answer the question, "How do we make broader decisions to achieve sustainable water management?") Property developers Planners developing water use plans Local government finance decision makers First Nations Boaters Farmers British Columbia Agriculture Council (BCAC) BC Fruit Growers Association (BCFGA) Federal and Provincial fisheries management staff Residents (changes to lifestyle as water availability change) Broader public	BC MoE water allocation Flood control planners Existing and emerging academic research teams (e.g., Groundwater Assessment in the Okanagan Basin (GAOB)) Environmental stewardship groups Ministry of Forests Water suppliers with extra capacity River Forecast Centre Water boards Fisheries and Oceans Canada and provincial fisheries specialists International Joint Commission (IJC) National Agri-Environmental Standards Initiative (NAESI) National Land and Water Information Service (NLWIS) UBC-Okanagan, spOke Okanagan Basin Water Board
Workshop 2	Tourist operators Chamber of Commerce	Ministry of Agriculture Environment Canada Agriculture and Agrifood Canada

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from the workshop discussions are presented in Table 3.

Table 3. End users and target audience: points of general agreement & recommendations, and points of departure or issues requiring further discussion. Workshop 1 and 2 results are separated for comparison.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	1. There are hundreds of interested individuals in OkWBM products, from many agencies, with a wide range of backgrounds and points of view. 2. The Technical Working Group should focus on delivering **reliable data and accounting for uncertainties at the watershed scale** by integrating available datasets, tools and models in a way which supports the organizing water budget framework (Eqn. 1). Once this is achieved, it will be relatively easy to respond to different user requests. 3. Technically, design a data management and delivery approach for "2" that is centered on the idea of a 'report' which can be customized and tailored for different audiences, and source data linked to other systems.	No significant points of departure.
Workshop 2	General agreement with Workshop 1 points.	No significant points of departure.

3.2 User experience levels

Discussion focus

Given the broad range of users there will be a wide diversity of experience levels. Several felt it would be risky to allow a general user to "run" the model themselves, given the number of assumptions that need to be aligned and vetted. Participants recognized this, and identified two 'use-cases' for distinguishing end-user actions:

1. individuals who import datasets to the model, configure a water budget scenario, and/or "run" the OkWBM; vs.
2. individuals who query pre-defined 'reports' and 'metadata' from OkWBM's underlying database.

Another important area of discussion relates to communication strategy. A simplified but credible condensed description of the studies' underlying equations, datasets and models will be needed when presenting model results to non-technical audiences.

3.3 Recommendations

The recommendations that emerged from the workshop discussions of users are presented in Table 4.

Table 4. End-user recommendations.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	The group agreed that because it will take a lot of resources to make the OkWBM easy enough to operate by a general user, there will have to be controls put in place with respect to who inputs and receives information. This could be achieved in two ways: 1. designing the system to grant differential rights based on user profile (e.g., “power” users vs. “public”); and/or 2. establishing a *Gatekeeper* or system administrator to oversee who belongs to each profile, respond to requests for certain kinds of information, and decide on what model scenarios and runs are input into the system.	No significant points of departure.
Workshop 2	Would like the model to be able to be used by all types of users. Implicit support for a reduced-rights user profile system for the model so that both technical and non-technical people could readily use it. In terms of communicating underlying scientific basis, a simplified form of the water budget equation is needed for a lay audience. Issues of optics are important. Some people will rush to judgement and latch onto numbers (without taking the time, or knowing how to interpret them). The Phase 2+ communication plan should include educational events around any emergent water budget model, to reduce the risk of misuse and abuse of information. With any model, even intuitive traffic-light systems, there is a learning and education process involved with interpreting outcomes. (However, as with anything involving political agendas, this cannot be completely eliminated).	No significant points of departure.

4. Primary Outputs and Forms of Deliverables

The participants were asked to distinguish between outputs and deliverables (Figure 4). **Outputs** are *what* you are giving to the users—the specific performance measures, types of reports and displays. **Deliverables** are *how* or *in what format* you are giving it to them (e.g., paper reports, web sites, databases, desktop software, GIS maps, etc.).

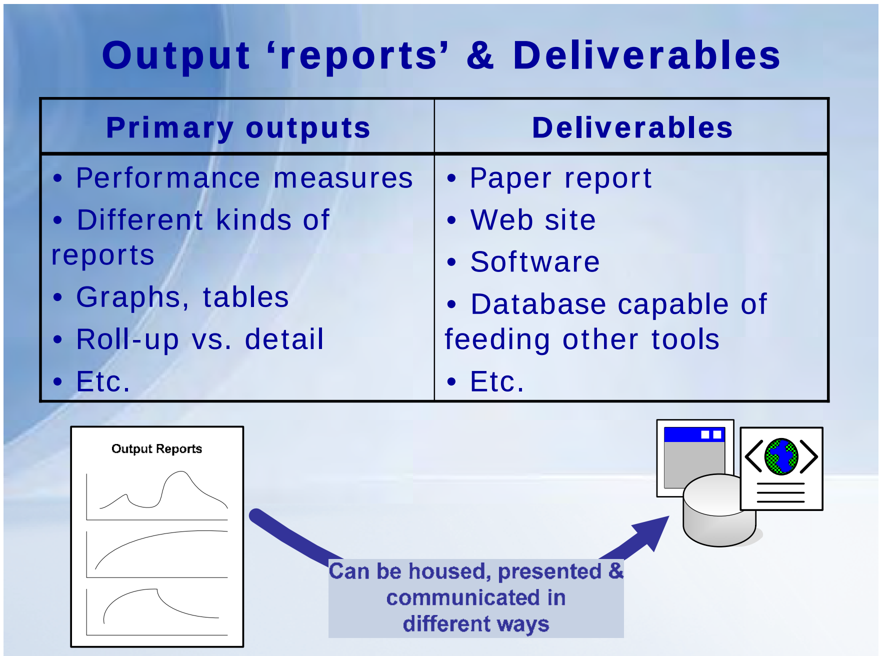

Figure 4: Slide used at the March 7th 2007 workshop to initiate a group discussion on outputs and deliverables.

4.1 What information might users need & what form? Primary Outputs?

Discussion focus

At workshop 1, the lead facilitator presented approximately ten different graphical output examples to seed discussions. These examples, and brief discussion surrounding them, were meant to draw out the major challenges associated with addressing:

- multiple objectives;
- choice of performance measures;
- scenario vs. scenario comparison (trade-offs);
- variation (within year and across multiple years);
- uncertainty (probability weighted outcomes or “what if”);
- risk attitudes, value judgments / quickly gauging acceptability; and
- scale (sub-basin, basin-wide).

Following Clint Alexander's presentation, a 15 minute "silent generation" task was again used to elicit feedback from the entire group. Two parting questions were given to the participants:

(A) What problems do users want to solve?

(B) Think of "use cases" for how end-users would best interact with products of this study?

- e.g., issue a license, y/n
- evaluate alternative demand mgmt. options
- evaluate pros/cons of additional storage
- educate public

Participant responses to the question of what problems they wish to solve were grouped into five categories (Table 5).

Table 5: Sampling of workshop 1 participant responses to: *(i)* what information do users need and *(ii)* what problems do users want to solve? Workshop 2 participants reviewed this list and in the case of item 3 (future scenarios), added to and prioritized the items (documented later, under Water Futures).

1. Current supply / demand	2. Issuing new / restricting existing licenses	3. Future scenarios & planning	4. How to account for uncertainty	5. Provide data to other systems
Need to understand where we currently are in terms of water supply and demand at different locations. Then if a decision is made to allocate water for a given purpose at a given location, what will this mean?	Should you give a licensing condition that says you can only use water during this time of year. You might want to limit the license, and go back and cancel that allocation in the future. But right now the licenses don't do that. What information can we assemble to credibly define these types of constraints? Licensing: Query of stream summary data at any location (conserve. flow; average monthly flows; licensed flow; flow actually used by licensees.) Query drought/flood frequencies at locations along creek. License/demand queries. Can BC MoE Water Stewardship Division issue more licenses? If yes, where? How does licensing match supply in dry areas? "Guarantee" accuracy of license allocations. This needs to be a tool which can inform decision makers who are responsible for allocating water regarding the *terms* (restrictions, limit license, can cancel in the future) of those allocations and policy makers regarding trade-offs between different sectors and community regions in the valley both now and in the future. Policy makers need the supporting science to make a decision to cut off future licensing in a watershed or the basin as a whole. To do this they need to understand where the demand and limiting constraints are (spatial and temporal).	Generate reports that compares scenarios for each parameter in water balance formula, by sub-basin. What is the range of water availability at a specific site, projected into the future with climate change scenarios? Paint picture of future to direct residential development to sustainability. Evaluate alternative water management options for reservoirs and Okanagan Lake. Water use plans by sub-basin. Drought plans by sub-basin (phase 3). How to plan for future residential growth. If lots of people, and if it's high density, lots of people can move in. but if it's urban sprawl, then no, can't move in. Indicator of what happens in the valley is can people afford to move here. But the economic equation will be worse. Money is the thing that limits population growth.	How to account for uncertainty: 1) Determine what components of the water balance are most sensitive to the conditions imposed by a given scenario (could be spatially or schematically presented). 2) Forecast verification statistics. 3) Changes in land use patters, consumptive use, diversions spatially through the basin. Seasonal and year to year variability must be implemented and easily communicated. Estimates of reliability of data.	Make it easy to feed other models (e.g., AgWD, OK-QUEST, spOke web portal, etc.)

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from the workshop discussions are presented in Table 6.

Table 6. Points of general agreement & recommendations, and points of departure related to problems users wish to solve and what primary outputs should look like. Workshop 1 and 2 results are separated for comparison.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	"Stop light" approach – highly intuitive.	No significant points of departure
	Generate a report for net amount of water available for each sub-basin; and ability to output any variable in Eqn. 1 for each time period for each sub-basin in tabular and graphical forms	
	Graphical summary outputs are desired (spatially referenced data).	
	Important to show actual demand/use vs. current licensing;	
	Need to show: a) uncertainty; b) spatial variation within the watershed; c) compare availability of water with licenses and their constraints;	
	Plots that communicate and demonstrate the risk of inadequate supply	
	"State of the watershed" report (where are we currently at)?	
	Return periods for various variables in Eqn. 1.	
	Exceedance plots in combination with hazard thresholds and mapping	
Workshop 2	Exceedance and map-based graphical summary outputs are very useful.	The participants were split on the merits of putting out "quick and dirty" estimates. Many felt this would hurt the project's credibility.
	Need to show the public and decision makers that sub-basin nodes aren't really separate – decisions in one sub-basin can affect other (downstream) sub-basins.	
	Nothing missing from Workshop 1 results of "Primary outputs and form of deliverables" and "Primary outputs: problems to solve." (Table 5)	
	Need better information so that we can know whether the decisions made are good.	

4.2 Most effective form of output: exceedance plots and hazard maps

Participants at both workshops were particularly supportive of the notion of using exceedance plots in combination with hazard mapping. The basic premise is illustrated in Figure 5 and Figure 6. These plots are very useful because:

- they absorb and integrate seasonal and inter-annual variability in water supply and demand; and
- they can be created for any variable or combination of variables in Eqn. 1.

For non-technical audiences, adding "traffic lights" to these plots removes the need to think in terms of probabilities, making them straightforward and intuitive. The value of traffic lights takes on further meaning after overlaying various contemplated options (Figure 7) and value judgements in the form of thresholds. Many other questions could be structured using this framework beyond licensing and allocation, depending on the variables plotted on the y-axis and the type of overarching scenario assumptions used. By "interrogating" these plots, one can easily move to a map based approach, and much more rapidly communicate the condition of water supplies throughout the Okanagan watershed (Figure 8). *This type of output, rather than numbers emerging in raw form from the water budget equation, is much more useful to decision makers and other lay audiences*.

Given the UNA workshop 1 support for this approach, Clint Alexander gave a step-wise presentation of a "vision" for the water budget model that used exceedance plots and basin-wide hazard mapping as its summary presentation back-bone. Following this presentation, participants at workshop 2 made the following general observations and statements:

- About the red, green and yellow. We are not necessarily in a three mode world. We could have more than 3 states (e.g., because some sub-basins are already over allocated).
- These maps are excellent, but should be implemented as a running animation. E.g., run them on a loop from year *i* to year *i* + 10. It is **critical** to demonstrate and educate consumers of this information that status and risks are not fixed, and that the sub-basin linkages have upstream (north) to downstream (south) consequences amongst different water use scenarios.
- There is a major education goal associated with these maps: a given sub-basin node might be green, but this does not necessarily mean that there will be additional water to allocate at that location because doing so may negatively impact downstream sub-basin(s) (turn them red even while the upstream sub-basin remains green). The potential for having upstream sub-basins remaining green while allocating additional water needs to take into account whether there are downstream consequences for other communities in the watershed. The purpose here is to move to a basin-wide perspective, rather than a "my backyard only" view of water allocation.
- A comment was made about the assumptions associated with use of exceedance plots. The relevant considerations in application of the exceedance plots are:
  1. The sample size (*n*) of time series observations must be large (*n* >> 100). This implies the availability of a time series of weekly or monthly water budget equation observations spanning 8-10 or more continuous years (e.g., 8 years x 52 weeks = *n* = 416). In contrast, a time series of length 34 years would be required if using a monthly resolution. Sensitivity analyses would be required to determine how stable percentage points are in relation to sample size.
  2. Serial correlation between observations (wet periods and dry periods, etc.) within a year are to be expected with this kind of data. Therefore, these exceedance plots are only meaningful if used with the appropriate *temporal stratification*, i.e., grouping months of the year, not plotting entire year's together. In practice, the study will likely be focusing on low flow portions of the year, or other portions of the year with low $Q_{net\ i,t}$ values.
  3. Water supply/demand data will be non-stationary. That is, *there is an inherent "scenario" and time context to any exceedance plot*. The exceedance curve for the present day will be different from the one present 20 or 50 years from now (etc.) or the one today with a different water use context. This is not a problem for the exceedance plots themselves, so long as *consumers of the information realize that the plots are dynamic and moving* and can depend on human value decisions associated with water use. Hence, these plots should **not** be used to extrapolate outcomes into the future. Rather, a fresh/new plot must be generated based on the predicted future state found using the underlying water budget model. This requirement ties back to the need to implement these plots as a running animation rather than as static images.
  4. The component of the results that must withstand scientific scrutiny are the data themselves, and how they were generated, what assumptions and uncertainties have been accounted for, etc. So long as the assumptions in this list have been addressed, the exceedance plots *themselves* are **not** the focal point of scientific scrutiny. Long-term data of high quality is always a goal that should be striven for.

5. The hazard thresholds used are independent of the exact shape of the exceedance relation. Hazard thresholds (percentage points between 0 and 100) are merely **value judgements** based on risk attitudes. Regardless of the shape of the exceedance relation, any one person can always state their comfort with meeting a certain water demand. E.g., "I want to meet water demand *x* at least 80% or more of the time". This statement involves no inference or other statistical link with the shape of the exceedance curve itself. Obviously, precise percentage point values will differ between individuals and because of this these plots provide an excellent context for discussing different value and risk attitudes.

6. Exceedance graphs make no assumptions about the underlying distributional properties of the data. They are simply **empirical cumulative probability distributions**—*any* underlying data distribution is addressed by this graphical presentation technique.

   - Exceedance plots simply order *n* observations (usually ascending).
   - The empirical "probability" assigned to each observation is 1/*n*. (Hence the significance of assumption "1").
   - The first "probability" value of exceedance is 1 (if ordered ascending, starting with the smallest value. I.e., based on this dataset, our smallest value is *v*, and because there are no smaller values than it observed historically, we assume that we will observe values larger than it 99.9999% of the time). Hence, we are simply reading off a line, using a scale/distribution free technique.
   - As a frequency tool based on observational data, we in fact are not dealing with *true* probabilities. This is a fine point for frequentist and Bayesian philosophers. The true probability depends on other factors that will not have been seen by the observer, so the true probabilities, factoring in other prior information, will be different. This difference becomes negligible as *n* approaches infinity—a theoretical consideration.

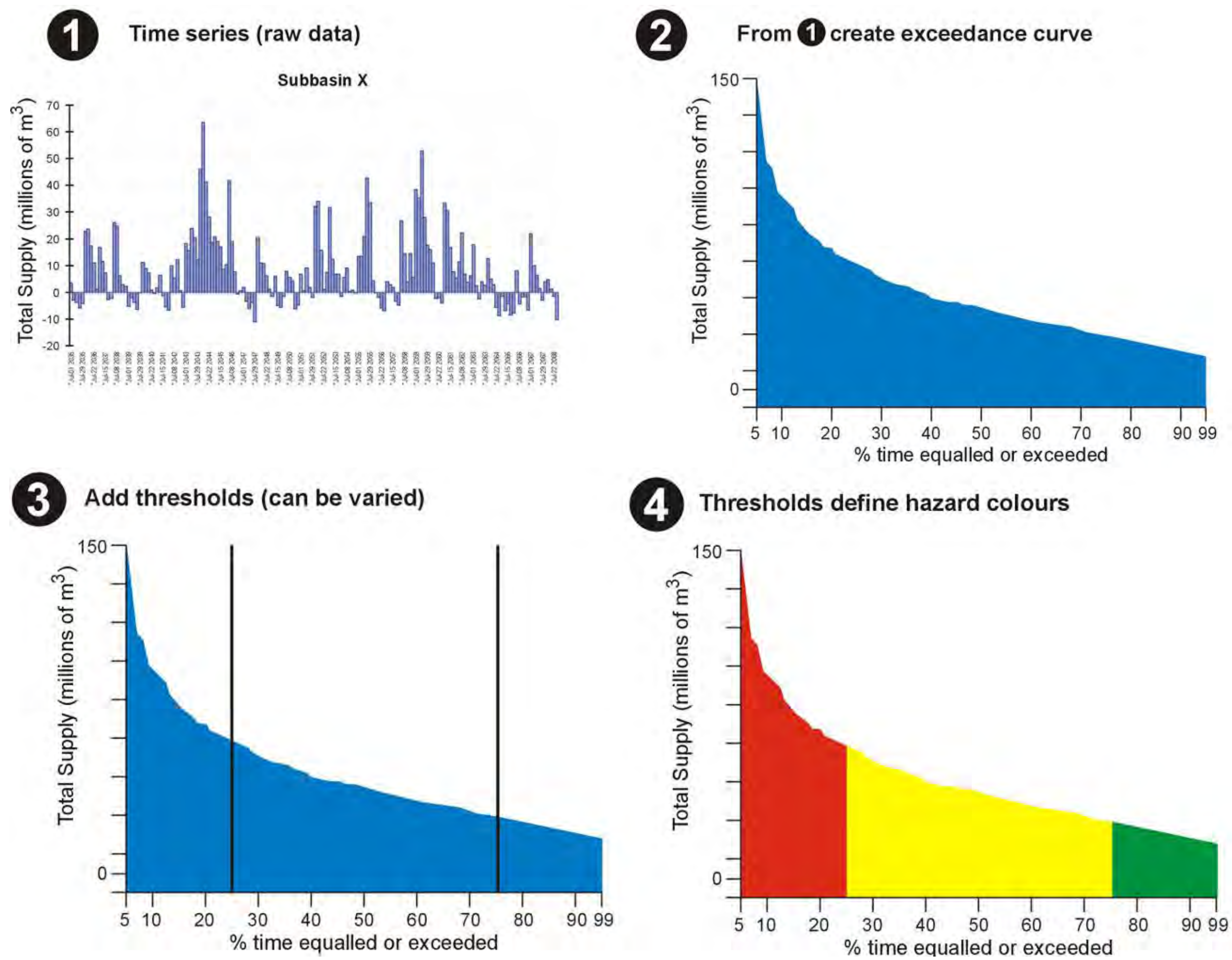

Figure 5: Exceedance plots can be generated for any time-series of total water availability (or other variable in the water budget equation) for a given sub-basin. These plots integrate seasonal and inter-annual variability in water supply and demand. Managers then must decide on thresholds of acceptability for water availability based on exceedance probabilities. For *example*, graph "#3" indicates rates of total water availability above 75% are considered "good" or "acceptable" whereas rates between 25% and 75% are "marginal" or "worrisome" and values below 25% are "unacceptable". This is made even clearer by employing a "traffic light" hazard assessment (graph "#4").

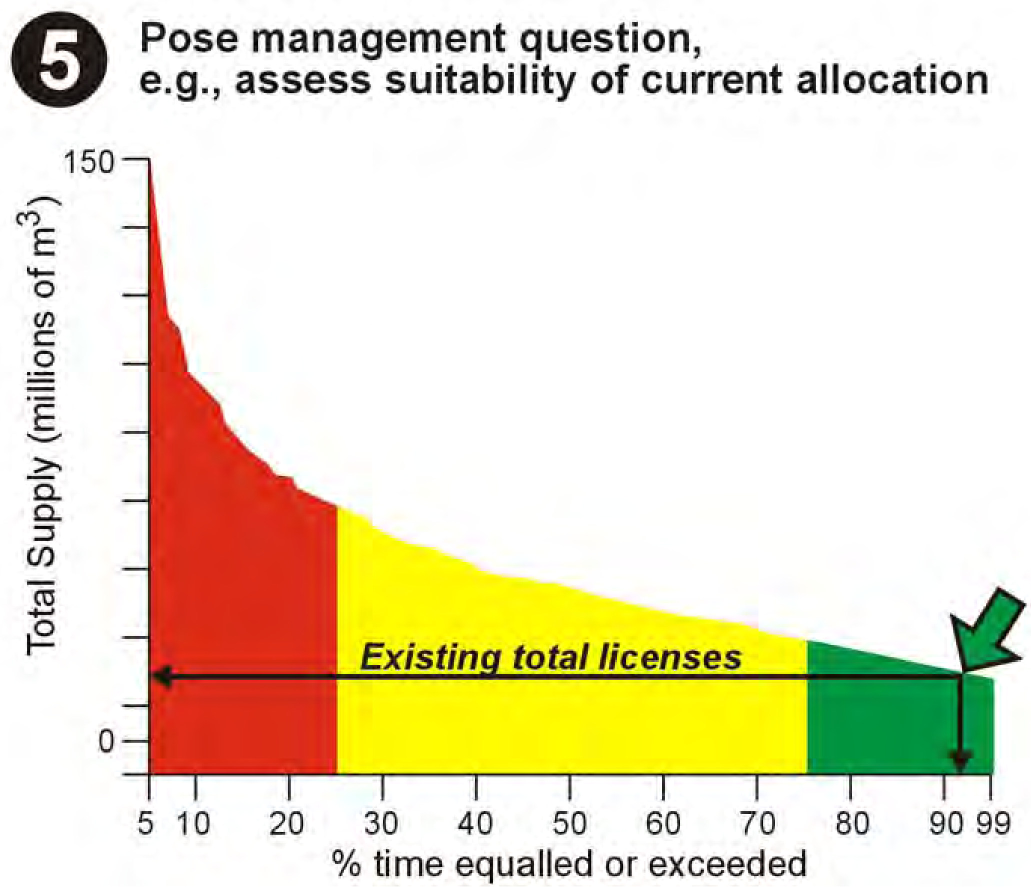

Figure 6: Following from Figure 5, the next step is to pose management questions using these plots, for *example*, assessing the suitability of current allocation levels or licenses. This can be done for both current and future water supply/demand scenarios, as well as for assessing *actual use*. To read these plots, start at the y-axis, which shows the volume of the supply that is licensed (black arrow), then follow this line across to the intersection point of the exceedance curve (green arrow), and follow this point down to the x-axis, which gives the percentage of time this volume is equalled or exceeded. In this example, the total licenses in this hypothetical sub-basin are in the "green" range, being met more than 90% of the time.

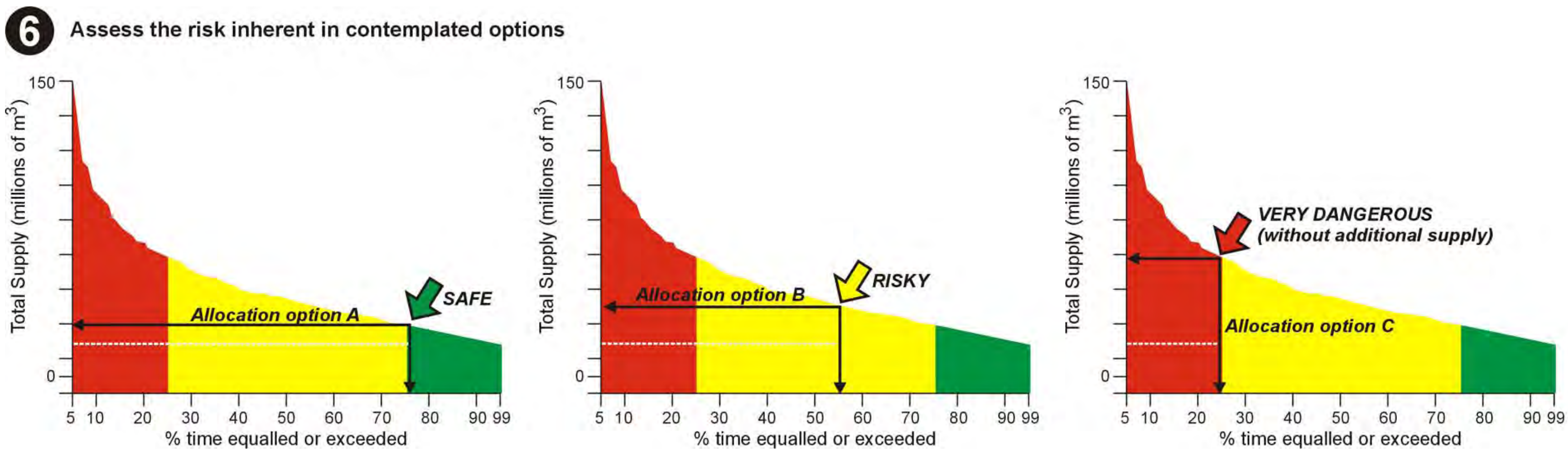

Figure 7: Following from Figure 5 and Figure 6, different options can be compared for their ability to reliably meet different levels of water demand. The best options are those that fall in the "green" range. Understanding this "traffic light" foundation, one can then move to a more graphical and intuitive display – Figure 8.

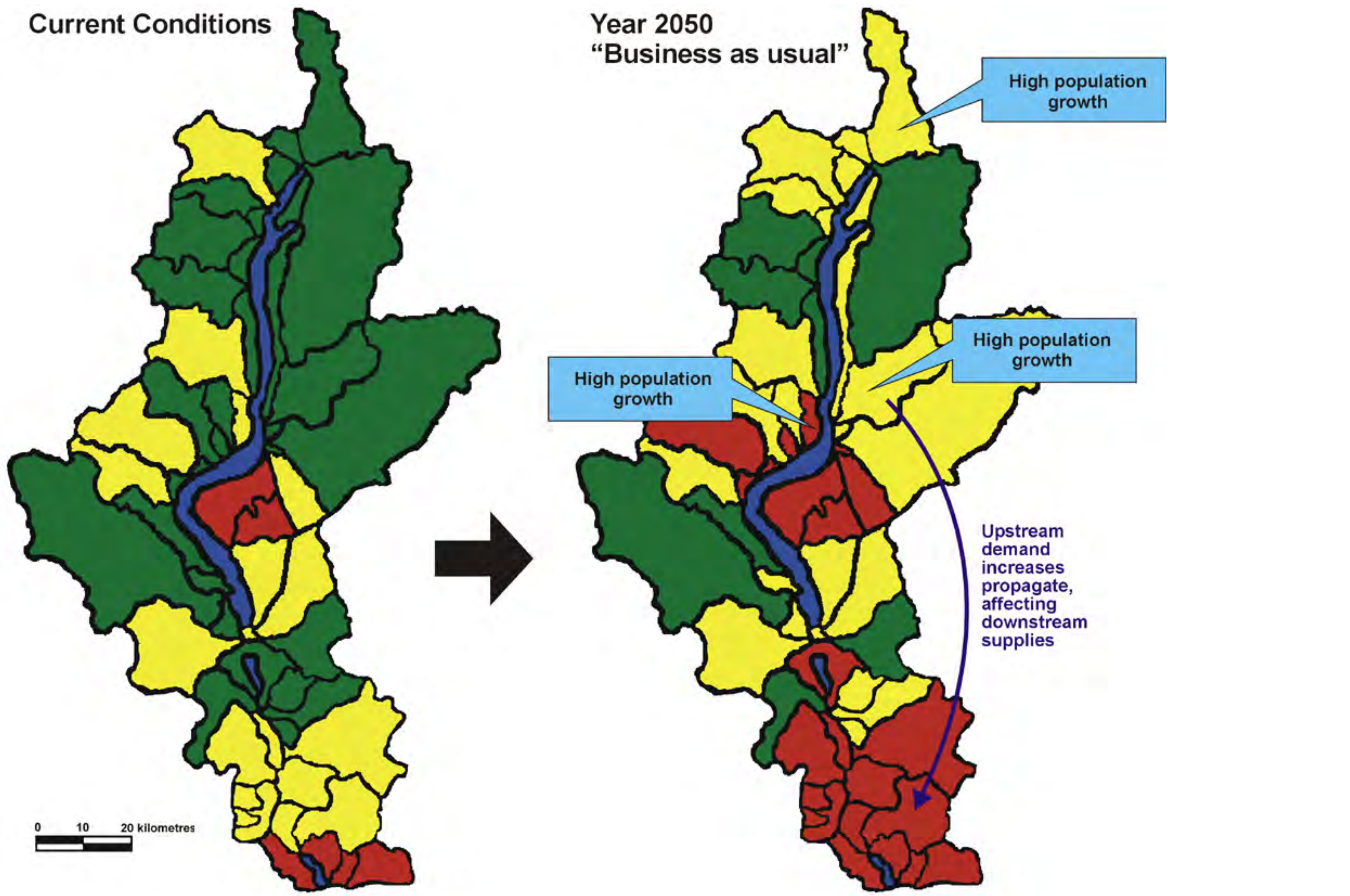

Figure 8: Hypothetical watershed sub-basin maps comparing different scenarios of water supply and demand, linked to “traffic light” exceedance plots (Figure 7). *In this example* yellow sub-basin water demands are met between 25%–75% of the time. Red sub-basin water demands are met less than 25% of the time. Green sub-basin water demands are met more than 75% of the time. **Using these maps, managers could rapidly assess how decisions in one sub-basin change water availability within that location, as well as downstream sub-basins. Implemented as part of a graphical user interface, this display could be used to navigate to other summary and detail reports by scenario and sub-basin.**

4.3 Most effective form of deliverable: reliable, organized & accessible data for the water budget equation, linked at the basin wide scale.

Discussion focus

Clint Alexander reminded participants that **deliverables** are how or in what format you provide outputs to the project's end-users. This can generally be divided into two formats: (a) one-time analyses and paper reports with limited dissemination; or (b) dynamic decision support tools capable of broad dissemination.

One participant pointed out that groundwater consultants have done hundreds of studies, but their data often sits in poorly organized electronic files, that are not available or practical to work with. For this person, something that streamlines the funneling of data though the water budget equation and makes it widely available is a key deliverable. Another participant agreed with this comment, adding that in general, not enough processes are in place to reliably capture and use data. They re-iterated that a lot of data is taken in but then lost. Another participant noted: "if we assemble good, reliable basin-wide data, others will conform to use it later on."

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from the workshop discussions are presented in Table 7.

Table 7. Most effective form of deliverable? Points of general agreement & recommendations, and points of departure or issues requiring further discussion. Workshop 1 and 2 results are separated for comparison.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	Good, reliable data (organized around Eqn. 1) at the basin wide scale. The decision support tool should also be made widely accessible, and useable. The Technical Working Group should move to data design as soon as possible, so that this data can be collected in a manner that meets functional the projects functional requirements.	Will this decision support tool be "built from the ground up" or will an existing "off the shelf" tool be chosen and the studies' requirements adapted to suit it? If the answer to "1" is build a custom OkWBM, what are the priorities and logical components and phases? What will it cost?
Workshop 2	Good, reliable data is key.	No significant points of departure.

4.4 Functional requirements for technical components

Having completed discussions on information users need, problems users want to solve, preferred outputs and deliverables and spatial and temporal resolution (next section), a number of functional requirements emerged (Table 8).

Table 8. Major functional requirements identified for technical components of the study. Grey-shaded requirements (5 & 6) were identified to be of relatively lower priority by workshop 2 participants.

1. All component datasets implicit in Eqn. 1 should be **spatially referenced** (according to 79+ sub basins), including specifying necessary routing and travel time information. Likewise, all component datasets should be **temporally referenced**, allowing for a weekly or monthly resolution.
2. The system must **define a process for ensuring consistency in data, and govern the process of receiving and importing constituent datasets**, including the enabling of receiving future data updates. This will require: (a) relational database technology; (b) data templates; and (c) manual or automated import tools and validation logic.
3. **Maintain a meaningful set of "meta-data"** on each imported dataset, to enable assessments of reliability and understand the limitations and intended uses of imported data
4. Possess a data design, logic or code **capable of identifying and linking "apples and apples" datasets together** to generate estimates of the net amount of water available for alternative aggregate scenarios;
5. Possess a data design and internal logic that **can accept alternative states of nature on constituent terms in the water budget**, either as simple "what-if" cases or as probability weighted alternatives **in order to account for uncertainty**.
6. **A model engine that can be "run" to answer simple "what if" management questions.**
7. The tool must **provide reports** spatially and over time, graphically and in tabular format at both the detail and summary level.
8. **Employ technologies that make this data widely accessible**, including being highly interoperable with other systems.
9. **The data management approach and model is readily updateable** as new information becomes available.
10. **The most effective form of <u>output</u> is exceedance plots, tied to hazard maps.**
11. **The most effective <u>deliverable</u> is reliable, organized & accessible data for the water budget equation.**
12. **Sub-basin nodes must be linked to allow routing water from north-south** so basin-wide impacts of different water use scenarios can be identified in their proper context.
13. **To adequately capture risk information, a minimum temporal horizon of 8 years is needed when using weekly data, or 30 years if using monthly data.** E.g., when we say "2020", what we really mean to say is a continuous set of years, 2016-2024 (if using weekly data) or 2005 to 2035 (if using monthly data), not one year. **Without providing a time series of data that produce n (>>100) observations, exceedance plots cannot be created.**

The points of general agreement and points of departure or issues requiring further discussion that emerged from these discussions are presented in Table 9.

Table 9. Points of general agreement, and points of departure or issues requiring further discussion on functional requirements. Workshop 1 and 2 results are separated for comparison.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	8 functional requirements.	What are the priorities are among the 8 functional requirements (at left)? Requirement #5 is important, but how will uncertain states of nature be formally built into the study? Finalizing these priorities and moving towards a more detailed design in relation to these functional requirements is necessary to understand scope and cost implications. Are any existing databases and models available capable of implementing Eqn. 1 while meeting the 8 functional requirements? Alternatively, how far would Eqn. 1 and related requirements and resolution need to be 'bent' in order to work with some pre-existing system? Would such 'bending' create more problems than it would solve?
Workshop 2	Of the first 8 functional requirements, 5 and 6 are of lower priority in the Phase 2 project.	No significant points of departure. However, some participants, under the discussion of the water budget equation, emphasized the importance of accounting for uncertainty and error in the various terms. *It is unclear how this reconciles with assigning requirement 5 as lower priority*.

4.5 Recommendations

This project's technical needs are highly customized. Based on this and the information above, it is strongly recommended that "data management" be clearly separated from "modelling and analysis". Specifically, the water budget equation and its scope are custom. Further, participants identified that many different models, data sources and techniques will be required to populate this equation. The only practical way to link all of these techniques and systems together **and** meet the project's requirements will be through development and use of relational data management. Likewise, the process of collecting data will require standardization around a database that ensures water budget elements can be meaningfully linked. In this context, professional relational database design is a proven, highly efficient form for organizing data and enforcing the necessary standards.

It is important to note that other modelling and analyses can proceed in parallel outside this database, using it as an information source (input vehicle), and as a results repository (high-graded outputs). Designed in a modular fashion with automated import/export features, this database can also provide the foundation for meeting other needs in the future. Given the custom nature of this project, it is very unlikely that any existing database or water budget model will be identified that can meet this project's technical requirements. While existing models and tools do exist (and need to be selected) to provide data for various water budget equation terms, none of these tools will be able to link all the components together or meet the majority of the specific technical requirements identified in this report, such as provision of reports or hazard maps, simplifying future updates, or ensuring interoperability with other systems.

It is further recommended that project staff not proceed with collecting data before having this data model designed and in place, as it will best direct the specific formats in which data (and meta-data) need to be collected and stored. Rushing forward with data collection will increase errors and inevitably lead to missed requirements. These errors are very time consuming to correct after the fact.

5. Spatial and Temporal Resolution

5.1 Spatial resolution

Discussion focus

The Phase 1 final report (Summit 2005, Table 6.1) proposed 79 points-of-interest. These 79 points-of-interest encompass about 100 km^2 each. The participants discussed whether to use these 79 points as the model's spatial resolution, or to focus on a different spatial scale. An alternative posed was 500 m^2, which would yield over 32,000 points-of-interest. Another alternative discussed was to build a "mainstem" model, aggregating all sources that contribute to Okanagan Lake together, and aggregate 2-4 mainstem Okanagan River sites down to Osoyoos Lake.

Another area of discussion was the question of whether or not the model should simulate water routing from sub-basin to sub-basin and down through the entire Okanagan basin. It was recognized that routing would be an implicit requirement of any spatial resolution chosen, but that the level of effort associated with it increases the finer the spatial (and temporal) resolution.

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from the workshop discussions are presented in Table 10.

Table 10. Spatial resolution. Points of general agreement & recommendations, and points of departure or issues requiring further discussion. Workshop 1 and 2 results are separated for comparison.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	Some sub-basins might have sufficient data to support a further subdivision into sub-basins. For example Mission Creek might have sufficient streamflow data to allow an intermediate point-of-interest on Mission Creek. It was agreed that this possibility will be explored, creating the notion of "79+" sub-basins 79+ sub-basin points-of-interest is a good compromise for spatial resolution While some of the external, driving models that feed the OkWBM may use a finer spatial resolution, their outputs will be aggregated to fit these 79+ sub-basins A set of focal sub-basins (<12) should be chosen from the list of 79+, and prioritized for purposes of pilot testing methodologies and learning before blanket application to all 79+ sub-basins.	No significant points of departure.
Workshop 2	79 points is good, but some will likely need to be aggregated in some cases due to data limitations. Routing is critically important to achieving basin-wide traffic light graphical animation discussed earlier.	No significant points of departure.

5.2 Temporal resolution

Discussion focus

Referring once more to Eqn. 1, participants were asked what temporal resolution works best for all terms in water budget equation. In particular, what temporal resolution would they like to see for $Q_{net\ i,t}$.

Notes from participants included:

- The agricultural water demand model must operate on a daily temporal resolution, because different crops have different growing seasons. However, we will convert its outputs to a weekly or monthly resolution for input into the overall water balance.
- Groundwater datasets are monthly at best, usually yearly (so would have to be disaggregated according to some rules, even if only ÷ 52 or ÷ 12).
- Streamflow data can be obtained from real-time loggers as fine as every 15 minutes.
- Some participants suggested they would like to use different time-steps at different times of year (e.g. for certain months of the year, a monthly time-step would be adequate, otherwise weekly).
- One person said: “we don’t need a daily answer”. In response another said, “most of the data is no where near daily”.
- Daily time-steps can add significant complexity to water routing requirements.
- Spring freshet lasts weeks not months.
- A number of participants said a weekly resolution is the best compromise, and most desired.

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from the workshop discussions are presented in Table 11.

Table 11. Temporal resolution and horizon points of general agreement & recommendations, and points of departure or issues requiring further discussion. Workshop 1 and 2 results are separated for comparison.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	Weekly temporal resolution was the preferred compromise. Monthly resolution during the dry, low flow months of the year would be adequate. The merits of a mixed time-step should be further explored, to determine whether it adds unwarranted technical complexity. It should also be understood that in order to generate exceedance results, any scenario must be run for a minimum length of time. E.g., a “2050” scenario would need to be run +/-10 years each side of this reference date.	No significant points of departure.
Workshop 2	When we say “2020”, what we really mean to say is a range of years, 2010-2030 or 2000 to 2040, not one year. Hence, there is a temporal horizon in addition to temporal resolution that needs to be identified. Without providing a time series of data that produce *n* (>>100) observations, exceedance plots cannot be created.	No significant points of departure.

5.3 Recommendations

79+ sub-basin points-of-interest is a good compromise for spatial resolution, and is recommended for the Phase 2 study. This may require some component water budget data to be aggregated up or down. However, a set of focal sub-basins (<12) should be chosen from the list of 79+, and prioritized for purposes of pilot testing methodologies and learning before blanket application to all 79+ sub-basins. Also, regardless of the spatial resolution chosen, routing is critically important to demonstrating the linked effects of water allocation decisions amongst sub-basins. Accounting for routing between sub-basins will be a critical feature used to determine success or failure of the project's water budget estimates.

To adequately capture risk information, a minimum temporal horizon of 8 years is needed when using weekly data, or 30 years if using monthly data. Without providing a *time series* of data that produce *n* (>>100) observations, exceedance plots cannot be created. Therefore, the detailed project plan should identify and explore options for providing time series datasets for each component term in the water budget equation. This may involve sampling from assumed distributions given point estimate information and assumptions about the underlying distributional form of the data, standard error estimates, etc.

6. Water Futures: Scenarios to Include in the Phase II Study

6.1 Background

The third major objective of the Phase 2 study is to **identify potential future changes in both supply and demand and run the model for a range of realistic future scenarios.** Development of future scenarios is a major endeavour, one that received only cursory treatment at the March 7, 2007 workshop. This element was therefore emphasized at the April 12 2007 workshop, though progress was limited.

To initiate the discussion at the workshop, Clint Alexander presented the slide shown in Figure 9.

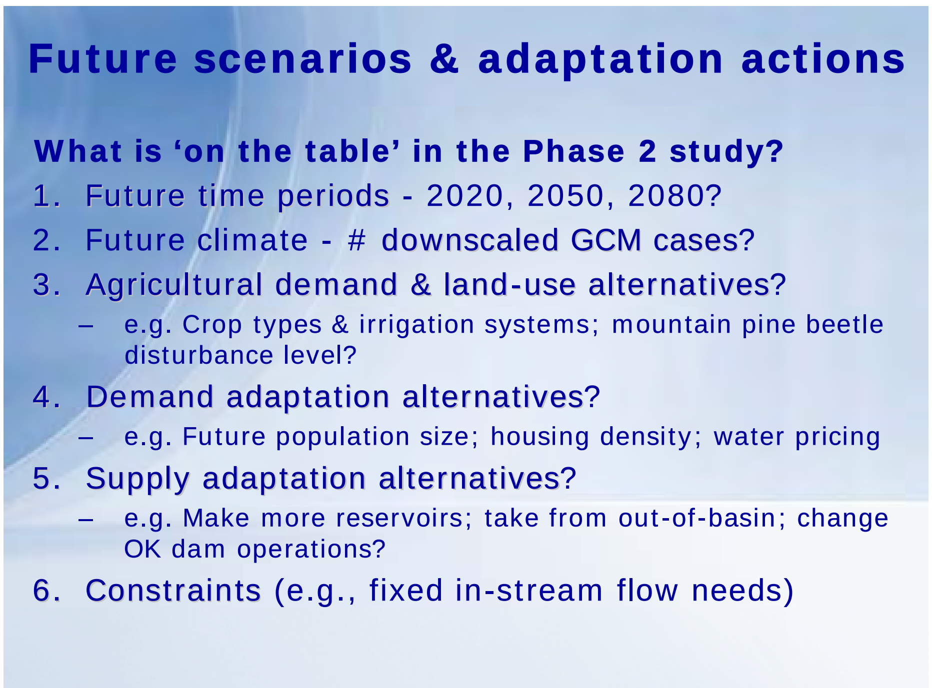

Figure 9: Intro slide for future scenarios and adaptation actions—topics and questions.

Participants were then asked: *"what kinds of scenarios & adaptation actions are 'on the table' in the Phase 2 study? Of most interest to this project's primary audience?"*

Discussion focus

At the first UNA workshop, a wide range of feedback was obtained on the subject of water futures and adaptation strategies (Table 12).

Table 12: Major categories and sub-sampling of responses from participants on the topic of Okanagan water futures and adaptation strategies.

Driving Factors				Adaptations			
Future climate	Population growth	Lake evaporation	Landscape disturbances	Residential demand	Agricultural demand	Increase supplies	Operations
Workshop 1							
Seasonal temperatures Precipitation Freezing levels Growing season length Evapotranspiration Which downscaled GCMs? They can vary considerably in terms of their projections. Dependent driving models must use the same downscaled GCM scenarios. * Climate data needs to be input into a hydrologic model that generates water flow. Climate data itself does not address the needs of the water budget equation. The level of effort involved with this modelling, should drive choices of downscaled GCM scenarios.	>700,000 by 2050? 2020 population? 2080 population?	Potentially enormous effect. How much? Need a low, medium, high scenario to scale outcomes	Pine beetle Pine beetle – a temporary effect? Actually significant *relative* to climate change itself? Forest fires An obvious future state would be to look at what would happen with conversion of large portions of the landscape to grasslands Start with climate, use a driving time-series of future climate to determine 'climax' (steady state) landscape. Pass this state to dependent models.	Increase housing densities Metering & water pricing, restrictions and other behavioural changes that improve water use efficiency Xeriscaping Improve water re-use efficiency	Crop types ("essential" vs. "non-essential" food products) & irrigation systems ALR conversion rates Fallow lands converted to residential land vs. being activated and farmed Assumptions about time-frame over which changes phased in (e.g., conversion to drip irrigation)	Lake pumping? Add small reservoirs in uplands Active groundwater injection and banking? Increase cross-basin diversions? 'Sink' intakes in Okanagan River Some felt supply side changes harder to game with because must run hydrologic models	Re-operate Okanagan Lake (more draw-down, change views on 'acceptable' fluctuations). 'How low can we go'? Optimize existing storage, thinking basin-wide Definitely include in-stream flow needs in operational assumptions wherever necessary
Workshop 2	Hydroelectric energy demands Geothermal water use			Changing outdoor residential water use			

The participants of the April 12 2007 UNA workshop were asked to consider the adaptations listed in Table 12 and indicate the adaptations they felt were missing and/or most important to include in the model.[3] Each participant was given eight "voting dots" to cast for adaptations that were listed on wall posters. Participants were free to weight each adaptation as heavily as they chose, using multiple votes on one choice if necessary. The results of this voting is presented in Table 13.

Table 13. Results of workshop 2 participant voting on adaptations to consider in the Okanagan water supply/demand study.

Adaptations	Votes
Residential demand	
Increase housing densities	15
Metering & water pricing, restrictions and other behavioural changes that improve water use efficiency	15
Xeriscaping	2
Improve water re-use efficiency	7
Agricultural demand	
Crop types ("essential" vs. "non-essential" food products) & irrigation systems	14
ALR conversion rates	0
Fallow lands converted to residential land vs. being activated and farmed	0
Assumptions about time-frame over which changes phased in (e.g., conversion to drip irrigation)	10
Increase supplies	
Lake pumping?	0
Add small reservoirs in uplands	15
Active groundwater injection and banking?	3
Increase cross-basin diversions?	1
'Sink' intakes in Okanagan River	0
Some felt supply side changes harder to game with because must run hydrologic models	0
Operations	
Re-operate Okanagan Lake (more draw-down, change views on 'acceptable' fluctuations). 'How low can we go'?	1
Optimize existing storage, thinking basin-wide	8
Better inclusion of in-stream flow needs (***not*** just restricted to fish) in operational assumptions wherever necessary	17

The points of general agreement and recommendations, and points of departure or issues requiring further discussion that emerged from this discussion are presented in Table 14.

[3] **It is important to emphasize that the discussion on adaptations was about whether or not they would be important to include in the model, not whether they would be effective or appropriate adaptations to pursue in public policy.**

Table 14. Water futures. Points of general agreement & recommendations, and points of departure or issues requiring further discussion from.

	Points of general agreement & recommendations	Points of departure or issues requiring further discussion
Workshop 1	No significant points of agreement.	There is a need for clarity on scope and priorities for the Phase 2 study
Workshop 2	Add items to the list of adaptations (see bottom of Table 12)	There was a lot of reluctance to pick specific adaptations. This was identified as a political problem. Running climate scenarios is not costly (once models are built), so why not do them? Have a range of scenarios? Are adaptations beyond the focus of this study? What exactly is in Phase 2 vs. Phase 3 – spell it out.

6.2 Recommendations

Limited progress was achieved by the UNA workshops on climate futures and adaptation options. The main reasons were that the group felt that:

- they were not choosing from a full range of options,
- the outcomes of choosing a given option wasn't known in advance,
- identifying possible options would be perceived as recommending that option, or
- climate change scenarios and adaptations were simply viewed as 'beyond the scope of the Phase 2 study'.

Others believed that this created an awkward catch-22: "*you want us to tell you how a potential adaptation option performs, but you won't share your ideas on the options you think are worth exploring that are in need of further evaluation so we can provide the additional insight on outcomes*?" In practice, this simply highlights the political nature of these decisions, and their sensitivity. From an analyst's point of view, at some point someone inevitably must 'seed the dialogue' with some facts by initiating exploration of potential actions. This **is** different from recommending the option—it is not within the analysts grasp to control perception.

Given the sensitivities around the issue of climate futures and adaptation strategies, it is recommended that a separate plan (potentially including surveys or other workshops) be developed and executed upon to gather this information.

Any future work to clarify water future scenarios in the Okanagan should build on the information given in Table 12 and Table 13.

References

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Appendix A: Workshop Participants

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