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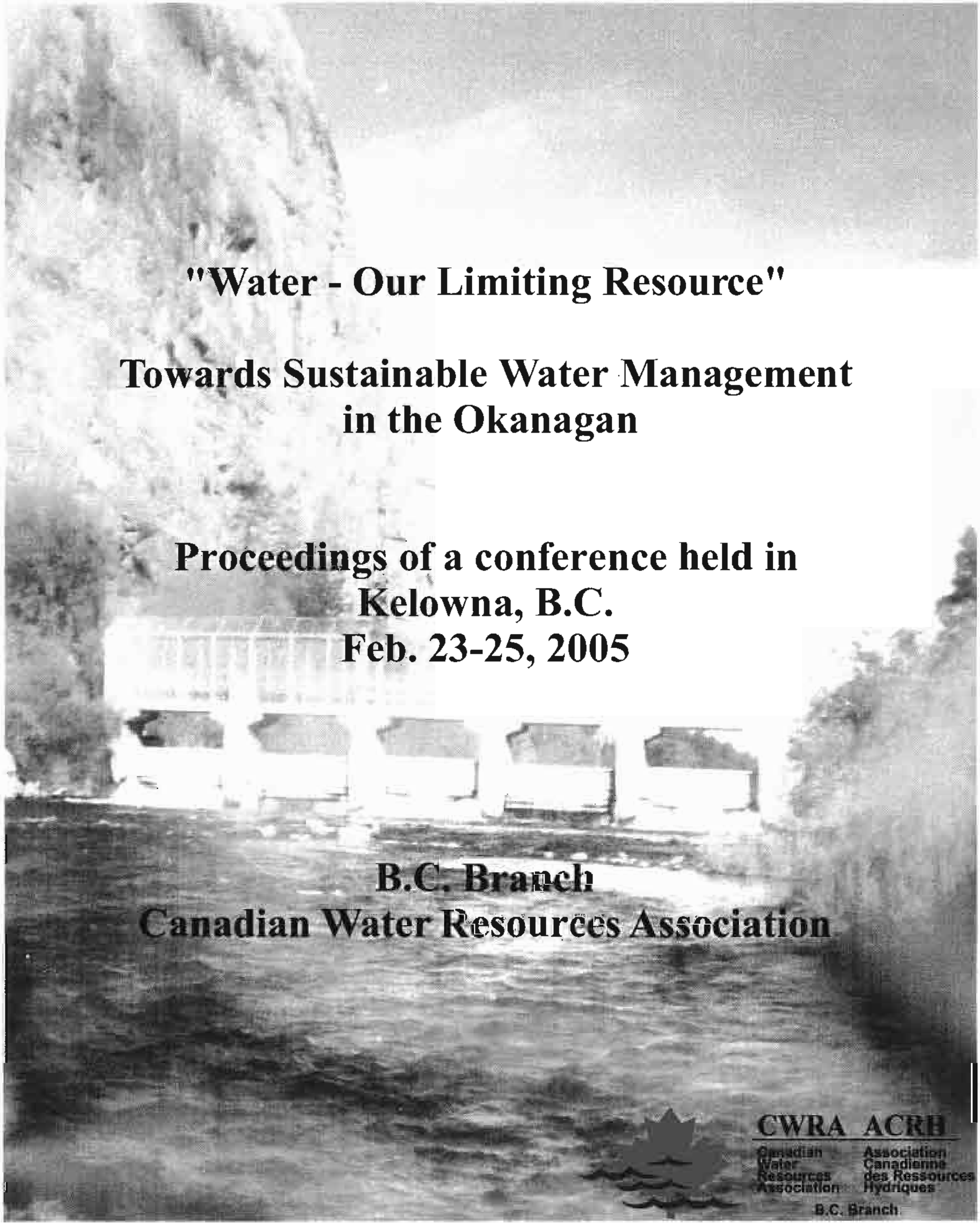

"Water - Our Limiting Resource"

Towards Sustainable Water Management in the Okanagan

Proceedings of a conference held in
Kelowna, B.C.
Feb. 23-25, 2005

B.C. Branch
Canadian Water Resources Association

CWRA ACRH
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Canadian Water Resources Association
British Columbia Branch
2005 Conference Proceedings

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Full conference proceedings on CD
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ISBN 1-896513-28-X

Acknowledgements

This conference has come about through the collective efforts of many individuals. The B.C. Branch of the Canadian Water Resources Association gratefully acknowledges the contributions of the following people and the support of their employers:

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Conference Proceedings have been produced with financial assistance from B.C. Ministry of Water, Land and Air Protection, Land and Water British Columbia Inc., Environment Canada and Okanagan University College.

About the Canadian Water Resources Association

Organization

The Canadian Water Resources Association is a national organization of individuals and groups interested in the management of Canada's water resources. The Association's objectives are to stimulate public awareness and understanding of Canada's water resources, encourage recognition of the high priority of water resources, and to participate with appropriate agencies in international water resources management activities. The Mission Statement is "Promoting Effective Water Management".

Membership

Membership is diverse and comprises water users, government officials at all levels, consultants, scientists, educators, and other interested parties from across Canada.

Publications

The quarterly *Canadian Water Resources Journal* is the primary publication of the Association. It is a well-established and reputable academic/professional journal in the water resources field, publishing academic/professional practice papers, conference papers, and book reviews. All papers published in the *Journal* are subject to an external peer review process.

The newsletter *Water News* provides regular contact with members, giving news and information on branch and membership activities, and disseminating water-resources related information of regional and national interest. In British Columbia, a provincial newsletter, *Runoff*, is published several times per year..

The CWRA also produces many special publications, such as these conference proceedings. Additional copies may be obtained through the CWRA Membership Services office.For information about CWRA Membership, please contact:

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Welcome

On behalf of the B.C. Branch of the Canadian Water Resources Association (CWRA), I would like to welcome you to the 2005 B.C. Branch conference. The aim of the CWRA is to promote wise water management, and the Okanagan in early 2005 presents an excellent opportunity to consider the principles of long-term, sustainable water management. Kelowna is an ideal location for the conference because of its central location in the Okanagan basin, and its rapid population and economic growth highlight the challenges that water managers will face in the future.

The Okanagan basin covers 7,970 km^2 in the arid southern interior of British Columbia. In the early 1970s, its water resources were the focus of a major study that culminated in a 1974 federal-provincial-local agreement on managing the water. Thirty years later, the population has grown at a faster rate than even the highest of the 1974 predictions. In addition, the climate has changed, which has affected water supplies, and these changes are predicted to continue over the next century. Groundwater is still a virtually unknown resource, and many government-led data inventory programs are being cut back. Technical studies have suggested that we are approaching a critical cross-roads, and that failure to grasp the implications and make the right choices in the next few years could result in significant harm to the environment and to our quality of life.

The situation presents us with both a challenge and an opportunity. This conference provides a vehicle to help us understand the state of the basin's water resources, see the challenges facing decision-makers, share experiences with respect to opportunities for success, and send a clear message to decision-makers at all levels of government that ordinary Canadians concerned with water management wish to help.

The papers in this volume showcase the wide range of water-related activities underway in the Okanagan; update our understanding of the state of the basin and of future pressures on the water resource; and explore the challenges and the opportunities for improving water management in the basin. With the help of the many volunteers, partners, sponsors, authors, and delegates, this conference and this volume can make a useful and lasting contribution to the goal of improving water management in the Okanagan.

Brian Guy
Conference Chairperson
February 2005

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Poster Presentations

Okanagan Lake Foreshore Inventory and Mapping

by

Brent Magnan[1], Todd Cashin[1]

[1]Regional District of Central Okanagan

Abstract

Beginning in 2001, The Regional District of Central Okanagan (RDCO) has been mapping stream corridors and their associated riparian areas using the Sensitive Habitat and Inventory (SHIM) methodology. In response to the continual increase in foreshore development along Okanagan Lake, the RDCO has expanded the methodology to include lake foreshore mapping. In the summer of 2004, the RDCO, in partnership with the Ministry of Water, Land and Air Protection, the City of Kelowna and the District of Lake Country conducted a detailed inventory of the foreshore of Central Okanagan Lake.

The project utilizes Global Positioning System (GPS) technology to categorize the foreshore according to near shore and upslope characteristics. The result is an easily accessible baseline inventory of foreshore morphology, land use, existing riparian condition and anthropogenic alterations which includes video of the foreshore in the entire study area. The results address the integrity of the foreshore condition suggesting it has been compromised by residential and urban development, as well as agriculture, industrial and commercial uses. Extensive alterations to the foreshore include lake infilling, beach grooming, shoreline armouring, riparian vegetation removal and shoreline development. This has lead to widespread degradation and fragmentation of foreshore habitats that are relied upon by a variety of aquatic and terrestrial species.

The information collected will be provided to local and senior government agencies to assist in the management of the foreshore (including upland) ecosystems. It will aid in developing land use policies, initiatives, regulations and standards, and to promote strong community stewardship and awareness. It will also serve as a benchmark for agencies by documenting land use changes, changes in riparian habitats, providing evidence for regulatory investigations, and assessing objectives set out in foreshore protection initiatives.

This paper represents the preliminary results of the project, with the final results to be made available in the spring of 2005.

1.0 INTRODUCTION

It is well recognized that foreshore ecosystems function upon intricate relationships; their ability to maintain function is often buffered by their relative stability and resiliency to disturbance (Smith, 1992). The lack of comprehensive information regarding these relationships continues to offer unvarying complexity to resource managers. These challenges are often compounded by management over multiple jurisdictions, inter-agency coordination, and the public expectation of a cooperative effort by all parties involved.

In 2004, The Regional District of Central Okanagan (RDCO) initiated the Okanagan Lake Foreshore Mapping Project in response to the continual increase in foreshore development along Okanagan Lake. This report details the preliminary findings of the project, which aims to help partnering agencies identify existing foreshore conditions, evaluate resource values, and explore conservation and restoration opportunities associated with lakeshore habitats. Targeting local, regional, provincial and federal government organizations, the project addresses development issues relating to foreshore sensitivity while providing agencies with an easily accessible baseline inventory of land use, existing riparian condition and anthropogenic alterations along Okanagan Lake. The project combines Geographic Information System (GIS) and digital video applications to produce an easily accessible database of shoreline information that will aid local governments in developing land use policies, regulations and standards along Okanagan Lake. It is intended to increase long-term environmental planning capabilities for the protection of aquatic habitat within existing and future local government land use planning programs. It will also serve as a benchmark for regulatory agencies by documenting foreshore alterations and providing evidence for regulatory investigations and assessing objectives set out in foreshore protection initiatives.

The final report is anticipated to be available in March 2005 through the Regional District of Central Okanagan Planning Services Department.

1.1 Background

The RDCO has been mapping sensitive aquatic habitats since 2001 using the Sensitive Habitat, Inventory and Mapping (SHIM) standards (Mason and Knight, 2001). The mapping has largely focused on stream and riparian corridors and been successful in accurately documenting sensitive habitats throughout the Central Okanagan. With the success of the SHIM project, the RDCO began applying SHIM methodologies to lakeshore habitats in an attempt to better manage foreshore habitats. Beginning in 2002, the RDCO was instrumental in developing foreshore inventory and mapping methodologies with the aid of Fisheries and Oceans Canada (DFO). In response to a need for detailed video of foreshore habitats, this methodology has been in development since the inception of the Osoyoos Lake foreshore mapping project, and under revision following similar projects on Christina and Kootenay Lakes.

1.2 Context

In light of changing roles and responsibilities of local governments, the RDCO Planning Services Department is turning its focus toward the development of policies, guidelines, education and other management tools to provide habitat and species protection in settlement areas. The project is intended to address objectives established by regional strategies on the basis of scientific evaluations and site-specific data compiled through the project. These include the Regional Growth Strategy (RGS), Okanagan Lake Action Plan (OLAP), Okanagan Shuswap Land Resource Management Plan (OSLRMP), as well as objectives established by Land Water British Columbia (LWBC) for environmental protection. The project is aligned with the objectives found in these strategies, which will guide the discussion and recommendation sections in this document.

1.3 Study Area

The study area includes 121 km of Okanagan Lake foreshore within the RDCO in the Southern Interior of British Columbia. The area encompasses both sides of Okanagan Lake from Okanagan Mountain Park (to the south) to the RDCO boundary (to the north) (see Figure 1). The study area includes the administrative boundaries of the District of Lake Country (Lake Country), the City of Kelowna (City), the RDCO Westside and North Westside OCP areas, and an additional 7.5 km section of shoreline on the South Slopes (between Okanagan Mountain Park and the City boundary). Data was also collected for Westbank First Nations lands Tsinstikeptum I.R. #9 and Tsinstikeptum I.R. #10, however not compiled as part of the results.

1.4 Objectives

The objectives of this project are:

- To provide an overview of foreshore habitat condition on Okanagan Lake within the Central Okanagan;
- To inventory land use, riparian condition, shoreline morphology, anthropogenic alterations and kokanee spawning suitability;
- To obtain digital video of the shoreline of Okanagan Lake that is spatially accurate, and easily accessible;
- To develop an easily accessible GIS database on the ecological integrity of Central Okanagan Lake foreshore;
- To prioritize preservation opportunities and;
- To make the information available to planners, politicians and other key development staff who review applications for land development approval.

2.0 METHODOLOGY

Project methodologies were compiled from several sources including current SHIM (Mason and Knight, 2001) and Reconnaissance (1:20 000) Fish and Fish Habitat Inventory Standards (Resources Inventory Committee, 1999). Development of the methodology was guided by a need to inventory a large study area with limited resources. The collection of detailed information (including video) over the study area strikes a balance between data accuracy, time, efficiency and cost. The results yield a low cost solution to inventorying lake shorelines with limited time. Deliberation between DFO, as well as partnering agencies has guided this process in determining the scope of information to be collected and its applicability to successful lakeshore management.

2.1 Pre-Field Assessment

Maps and orthophotos of the study area were acquired for photo interpretation and general background information. These were Terrain Resource Information Management (TRIM) map sheets and orthophotos 082E.072, 082E.073, 082E.082, 082E.083, 082E.093, 082L.003, 082L.013, and 082L.023. 1:5,000 scale TRIM maps were prepared to provide an overview of the Okanagan Lake foreshore, and delineate preliminary segment breaks. These maps included regional zoning, cadastral and stream information that would be utilized during the field component.

2.2 Field Assessment

2.2.1 Foreshore Data Collection

Differential GPS data was collected using a Trimble GeoXT hand held GPS receiver. The GPS receiver was configured according to standard SHIM methodology. Both position and attribute data were captured simultaneously via the data dictionary, which provides a structure for the data. Field cards that mimic the data dictionary were designed to facilitate data collection by several individuals at once during the field component. This increased the amount of data that could be collected, minimized collection time and enabled for a check / balance scenario within the database.

Three field technicians were used to collect the data. Their duties included operation of the GPS and completing the data dictionary; completing pre determined site cards (would be later input into the database); and collecting information describing foreshore modifications within the segment. As the crew boat traversed the shoreline, the team divided the foreshore into segments based on the boundaries of contiguous shoreline morphology and land use characteristics. For each segment, detailed information was recorded describing: existing foreshore type, land use, riparian condition, shoreline substrate composition, littoral zone, level of disturbance and modifications. In addition, information regarding kokanee spawning habitat was recorded based on substrate type and historic kokanee use. Minimum segment lengths were set to 100 m to ensure classification did not interfere with project efficiency. Optimal boat speed was 4 knots, as determined by time and video quality constraints, and study area size.

2.2.2 Foreshore Video and Photograph Data

Digital video of the entire foreshore was taken simultaneously to the data collection using a Cannon GL-1 video camera. The video technician captured images in Digital Video (DV) format (frame size 720x486). GPS positional data (latitude and longitude), time (GMT), date, heading (degrees) and speed (knots) from a Magellin handheld GPS were projected onto the video image using a Seaviewer Sea-Trak GPS overlay device. The resulting analogue image was recorded using a Sony TRV-900 video camera providing the basis for subsequent video management. The video was recorded at an optimal distance from shore (approximately 60 m) to achieve approximately 1 mature tree height within the view. Segment breaks were recorded based on time (PST) as well as field identifiers such as major changes in shore type, land use, modifications etc. These breaks correspond to segments identified within the database. Representative digital photographs were taken for each segment using a Kodak DC5000 digital camera.

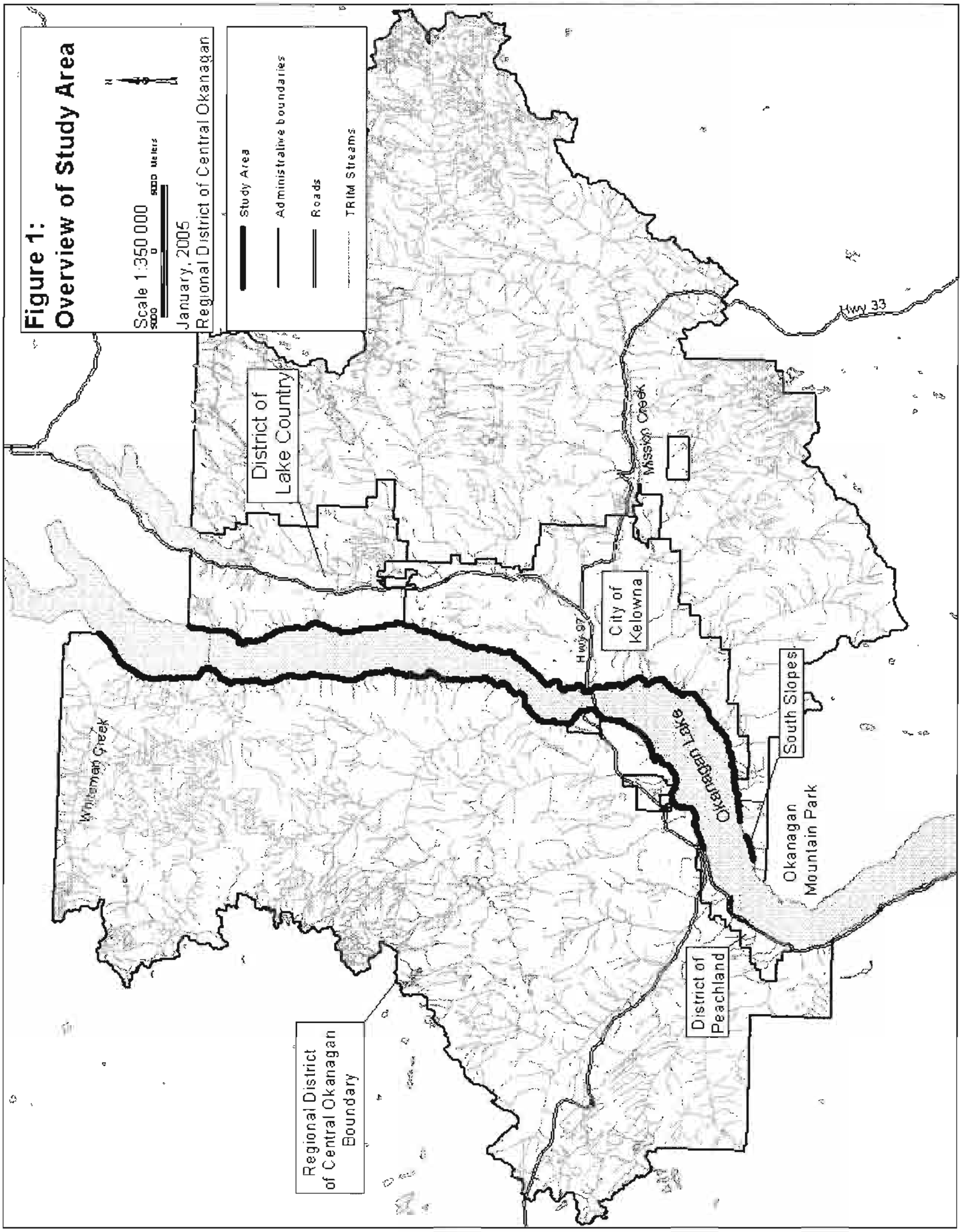
Figure 1:
Overview of Study Area
Scale 1:350 000
5000 0 5000 Meters
January, 2005
Regional District of Central Okanagan
Study Area
Administrative boundaries
Roads
TRIM Streams
District of Lake Country
City of Kelowna
Mission Creek
Hwy 33
Hwy 97
South Slopes
Okanagan Lake
Okanagan Mountain Park
District of Peachland
Regional District of Central Okanagan Boundary
Whiteman Creek

2.3 Data Management

Differential correction of the GPS data was performed upon completion of the field component (July 2004). The remainder of data management was performed in November 2004.

2.3.1 Trimble GPS Data

Raw GPS files were managed using Trimble Pathfinder Office software according to standard SHIM protocol (Mason and Knight, 2001). The raw GPS data was post processed using source data from SOPAC, Dominion Radio Astrophysical Observatory in Penticton, BC. The rover files were exported to shapefile format (.shp) useable in the ESRI GIS platform.

2.3.2 Arcview Data

Data management was performed using ArcView 3.2 via the SHIM ArcView extensions. Individual segments were extrapolated from the GPS data (boat centerline) and transferred onto the existing TRIM shoreline location with the aid of local cadastral and land use maps. The database was then populated with additional information collected on site cards during the field survey. In addition, land use information was referred to from local zoning bylaw maps to determine percent composition per segment.

2.3.3 Video Processing

17 raw digital video tapes were transferred and encoded into MPEG2 format (frame size 640 x 480). The video was broken into 165 files corresponding with the foreshore segments based on a predetermined naming scheme (i.e. OKLK_Seg165). The resulting files were transferred to DVD.

2.4 Quality Assurance / Quality Control

Quality assurance and quality control will be performed by an independent consulting team to ensure the accuracy of the database. Objectives of the QA/QC include:

- To ensure the database is consistent; attributes are classified accordingly and percent compositions are comparable within the dataset.
- To ensure the database is repeatable based on the methodology provided.

3.0 PRELIMINARY RESULTS

These results are considered preliminary until quality assurance and quality control objectives have been met. Summaries of Foreshore Impact Values (FIV) have been included for each area. The FIV is a qualitative measurement indicating the overall health of the foreshore (based on disturbance indicators). Each segment has been assessed and given a value describing the relative level of impact (low, moderate, high) that has occurred throughout the segment. It is based on attributes from the database such as % disturbed, riparian condition and modifications.

Field assessments were conducted on June 22nd, 23rd, 24th and 25th, 2004 aboard the *Nerka* (WLAP – Okanagan Lake Action Plan (OLAP) sampling boat). Conditions were calm and clear during the survey, with the exception of light northerly winds in the afternoons. Results of the inventory are summarized based on the five administrative areas that occur within the study area (Table 1). A total of 117297m of shoreline were compiled for results (does not include results from Tsinstikeptum I.R.#9 and I.R.#10).

Table 1: Summary information based on administrative boundaries within the study area.

Administrative Boundary	# Segments	Length of Shoreline (m)	% Natural	% Disturbed
RDCO Westside OCP Area	23	20363	30%	70%
RDCO North Westside OCP Area	52	38176	66%	34%
RDCO South Slopes	3	4908	86%	14%
District of Lake Country	31	17777	54%	46%
City of Kelowna	52	36073	39%	61%
TOTAL	161	117297	51%	49%

3.1 RDCO Westside OCP Area

A total of 23 segments comprised of six different shore types were found in the Westside OCP area. Out of a total 20363 m of shoreline assessed, 14283 m of shoreline were identified as disturbed (70%).

Foreshore type is dominated by gravel beach, sand beach and vegetated shore, corresponding with the major alluvial fans in the area (McDougall and Powers Creek) (Table 2). Representative photographs of foreshore types can be found in Appendix A. The low gradient alluvial fans are situated between cliff / bluff to the south and steep hillsides promoting low, rocky shores to the north. The majority of the cliff / bluff remains natural, while gravel and sand beach, and low rocky shore habitats are heavily disturbed. A summary of disturbance based on shore type can be found in Table 3.

Table 2: Shore type summary within RDCO Westside OCP area.

Shore Type	Length of Shoreline (m)	% Of Total
Cliff/Bluff	2219	11%
Gravel Beach	4823	24%
Sand Beach	5353	26%
Vegetated Shore	4928	24%
Low Rocky Shore	2155	11%
Wetland	885	4%
TOTAL	20363	100%

Foreshore land use is distributed among, commercial, rural, agriculture and park with higher percentage of the foreshore being used for urban residential (Table 4). Much of the alluvial fans have been used for residential development or agriculture in the past, although recent pressures on these areas include commercial resort development. Segments zoned residential show the highest amount of foreshore disturbance including docks, retaining walls, beach grooming and riparian clearing (Table 6). Rural lands are generally less disturbed (Table 5). FIV can be found in Table 7.

Table 3: Summary of shore type disturbance within RDCO Westside OCP Area.

Shore Type	Distribution	Length of Shoreline (m)	Total %
Cliff/Bluff	Natural	1616	73%
	Disturbed	603	27%
Gravel Beach	Natural	456	10%
	Disturbed	4367	90%

Sand Beach	Natural	383	7%
	Disturbed	4970	93%
Vegetated Shore	Natural	3031	62%
	Disturbed	1897	38%
Low Rocky Shore	Natural	243	11%
	Disturbed	1912	89%
Wetland	Natural	358	40%
	Disturbed	527	60%

Table 4: Land use summary within RDCO Westside OCP area.

Land Use	Length of Shoreline (m)	% Of Total
Urban Residential	7968	39%
Commercial	1691	8%
Rural	2979	15%
Agricultural	2446	12%
Park	4610	23%
Industrial	671	3%

Table 5: Summary of land use disturbance within RDCO Westside OCP area.

Land Use	Distribution	Length of Shoreline (m)	Total %
Urban Residential	Natural	732	9%
	Disturbed	7237	91%
Commercial	Natural	88	5%
	Disturbed	1603	95%
Rural	Natural	2055	69%
	Disturbed	924	31%
Agricultural	Natural	1117	46%
	Disturbed	1329	54%
Park	Natural	2025	44%
	Disturbed	2585	56%
Industrial	Natural	67	10%
	Disturbed	604	90%

Table 6: Summary of modifications within RDCO Westside OCP area.

Land Use	Docks	Average Docks / km	Retaining Walls
Urban Residential	204	25.6	145
Commercial	8	4.7	2
Rural	3	1.0	3
Agricultural	3	1.2	8
Park	2	0.4	8
Industrial	0	0.0	1

Table 7: Summary of foreshore impact values for RDCO Westside OCP area.

FIV	# Segments	Length of Shoreline (m)	% Of Total
Low	4	4562	22%
Moderate	5	3802	19%
High	14	12001	59%

3.2 RDCO North Westside OCP Area

A total of 52 segments were surveyed in the North Westside OCP area characterized by five different shore types. Out of a total 38176 m of shoreline assessed, 13004 m of shoreline were identified as disturbed (34%).

The North Westside OCP area is largely undeveloped, steep hillsides and rock bluffs extend into the lake promoting development in the flatter, more buildable sites such as the alluvial fans of Shorts and Whiteman Creek, and low gradient hillsides. Some residential development has occurred on bench lands atop steep bluffs, which provide building sites that have limited potential impact on the foreshore.

Shore type is evenly distributed between cliff/bluff, gravel beach and vegetated shoreline, with smaller amounts of low, rocky shore and sand beach (Table 8). A majority of the cliff/bluff and vegetated shores remain natural throughout this area. High levels of disturbance are evident on the gravel beach shore type (Table 9), which is largely associated with development of alluvial fans and small coves throughout the area.

Table 8: Shore type summary within RDCO North Westside OCP area.

Shore Type	Length of Shoreline (m)	% Of Total
Cliff/Bluff	9388	25%
Gravel Beach	11760	31%
Sand Beach	783	2%
Vegetated Shore	10810	28%
Low Rocky Shore	5435	14%
TOTAL	38176	100%

Table 9: Summary of shore type disturbance within RDCO North Westside OCP area.

Shore Type	Distribution	Length of Shoreline (m)	Total %
Cliff/Bluff	Natural	8156	87%
	Disturbed	1232	13%
Gravel Beach	Natural	4148	35%
	Disturbed	7612	65%
Sand Beach	Natural	459	59%
	Disturbed	324	41%
Vegetated Shore	Natural	8809	81%
	Disturbed	2000	19%
Low Rocky Shore	Natural	3598	66%
	Disturbed	1836	34%

Table 10 describes land use, which is primarily rural, and remains mostly natural. There are smaller amounts of residential and park throughout the area. Disturbance based on land use was found to occur primarily in land uses associated with urban residential, agricultural and institutional areas. A summary of land use disturbance is presented in Table 11.

Table 10: Land use summary within RDCO North Westside OCP area.

Land Use	Length of Shoreline (m)	% Of Total
Urban Residential	9821	26%
Commercial	4055	11%
Rural	13856	36%
Agricultural	493	1%
Park	9172	24%
Institutional	778	2%

Modifications such as docks, retaining walls and groynes are found primarily in residential areas, but are also apparent in land uses including rural, commercial and institutional (Table 12). A summary of FIV can be found in Table 13.

Table 11: Summary of land use disturbance within RDCO North Westside OCP area.

Land Use	Distribution	Length of Shoreline (m)	Total %
	Natural	1400	14%
Urban Residential	Disturbed	8421	86%
	Natural	2541	63%
Commercial	Disturbed	1514	37%
	Natural	11304	82%
Rural	Disturbed	2552	18%
	Natural	0	0%
Agricultural	Disturbed	493	100%
	Natural	8511	93%
Park	Disturbed	661	7%
	Natural	0	0%
Institutional	Disturbed	778	100%

Table 12: Summary of modifications for RDCO North Westside OCP area.

Land Use	Docks	Average Docks / km	Retaining Walls
Urban Residential	118	12.0	78
Commercial	19	4.7	5
Rural	124	9.0	85
Park	2	0.2	1
Institutional	6	7.7	3

Table 13: Summary of foreshore impact values for RDCO North Westside OCP area.

FIV	# Segments	Length of Shoreline (m)	% Of Total
Low	25	20649	54%
Moderate	16	9552	25%
High	11	7973	21%

3.3 RDCO – South Slopes (City of Kelowna to Okanagan Mountain Park)

Only 3 segments were surveyed in RDCO - South Slopes, however four different shore types were observed. Out of a total 4908 m of shoreline assessed, 676 m of shoreline were identified as disturbed (14%).

This area is characterized by rocky outcrops and cliff/bluff extending into the lake, with gravel beach and sand beach occurring in small coves and alluvial fans (Table 14). Shore types in this area remain primarily natural as access is limited and ownership of these lands is crown provincial or private, large holdings (Table 15). The majority of disturbance has occurred on gravel beaches (generally alluvial fans) where slopes are more suitable for building. This area was substantially affected by the Okanagan Mountain Park fire (2003).

Table 14: Shore type summary for RDCO – South Slopes.

Shore Type	Length of Shoreline (m)	% Of Total
Cliff/Bluff	3476	71%
Gravel Beach	788	16%
Sand Beach	209	4%
Low Rocky Shore	435	9%
TOTAL	4908	100%

Table 15: Summary of shore type disturbance for RDCO – South Slopes.

Shore Type	Distribution	Length of Shoreline (m)	Total %
Cliff/Bluff	Natural	3116	90%
	Disturbed	360	10%
Gravel Beach	Natural	518	66%
	Disturbed	270	34%
Sand Beach	Natural	209	100%
	Disturbed	0	0%
Low Rocky Shore	Natural	390	90%
	Disturbed	45	10%

The majority of the land use in this area is rural, with some agriculture occurring on flatter sites (Table 16). Disturbance based on land use is found primarily within the agricultural areas (Table 17) and few modifications exist in this area as most of the foreshore remains undeveloped (Table 18). A summary of FIV can be found in Table 19.

Table 16: Land use summary for RDCO – South Slopes.

Land Use	Length of Shoreline (m)	Total %
Rural	4345	89%
Agricultural	563	11%

Table 17: Summary of land use disturbance for RDCO – South Slopes.

Land Use	Distribution	Length of Shoreline (m)	Total %
Rural	Natural	3895	90%
	Disturbed	450	10%
Agricultural	Natural	338	60%
	Disturbed	225	40%

Table 18: Summary of modifications for RDCO – South Slopes.

Land Use	Docks	Average Docks / km	Retaining Walls
Rural	5	1.2	0
Agricultural	1	1.8	1

Table 19: Summary of foreshore impact values for RDCO – South Slopes.

FIV	# Segments	Length of Shoreline (m)	% Of Total
Low	3	4908	100%

3.4 District of Lake Country

31 segments were surveyed in Lake Country, represented by four different shore types. Out of a total 17777 m of shoreline assessed, 8198 m of shoreline were identified as disturbed (46%).

Shore types in Lake Country were found to be primarily gravel beach and vegetated shore, with smaller amounts of cliff/bluff and low, rocky shore (Table 20). A majority of the gravel beach habitat has been disturbed through rural development, while other shore types are disturbed to a much lesser extent (Table 21).

Table 20: Shore type summary within District of Lake Country.

Shore Type	Length of Shoreline (m)	Total %
Cliff/Bluff	2758	15%
Gravel Beach	9389	53%
Vegetated Shore	5258	30%
Low Rocky Shore	372	2%
TOTAL	17777	100%

Table 21: Summary of shore type disturbance within District of Lake Country.

Shore Type	Distribution	Length of Shoreline (m)	Total %
Cliff/Bluff	Natural	1968	71%
	Disturbed	790	29%
Gravel Beach	Natural	3881	41%
	Disturbed	5508	59%
Vegetated Shore	Natural	3484	66%
	Disturbed	1774	34%
Low Rocky Shore	Natural	246	66%
	Disturbed	126	34%

Land use within this area is primarily rural; other land uses are equally represented with the exception of park lands (Table 22). Almost 20% of the area is designated as parkland and conservation, which is provincial crown land and remains undisturbed. Disturbance in this area is largely associated with residential development and agriculture, however residential and rural land uses have the most modifications associated with them (Table 23). A summary of modifications can be found in Table 24. A summary of FIV can be found in Table 25.

Table 22: Land use summary within District of Lake Country.

Land Use	Length of Shoreline (m)	% Of Total
Urban Residential	3859	22%
Rural	7483	42%
Agricultural	2434	14%
Park	790	4%
Conservation	3211	18%

Table 23: Summary of land disturbance within District of Lake Country.

Land Use	Distribution	Length of Shoreline (m)	Total %
	Natural	503	13%
Urban Residential	Disturbed	3355	87%
	Natural	4823	64%
Rural	Disturbed	2660	36%
	Natural	499	21%
Agricultural	Disturbed	1935	79%
	Natural	543	69%
Park	Disturbed	247	31%
	Natural	3176	99%
Conservation	Disturbed	35	1%

Table 24: Summary of modifications for District of Lake Country.

Land Use	Docks	Average Docks / km	Retaining Walls
Urban Residential	66	17.1	52
Rural	113	15.1	47
Agricultural	4	1.6	0
Park	0	0.0	2
Conservation	18	5.6	0

Table 25: Summary of foreshore impact values for District of Lake Country.

FIV	# Segments	Length of Shoreline (m)	% Of Total
Low	13	7711	43%
Moderate	7	5053	29%
High	11	5013	28%

3.5 City of Kelowna

52 segments were surveyed in the City, represented by five different shore types. Out of a total 36073 m of shoreline assessed, 21822 m of shoreline were identified as disturbed (60%).

Foreshore within the City of Kelowna is primarily sand beach, coinciding with the large alluvial fan of Mission Creek (Table 26). This area is bordered by steep hillsides to the south, and cliff/bluffs to the north. A majority of this cliff/bluff remains undisturbed, as a majority of it falls within Knox Mountain Park. Areas comprised of sand beach are almost entirely disturbed, and as seen in other areas, they are easily developed due to gentle grades and easily moveable soils (Table 27).

Table 26: Shore type summary within City of Kelowna.

Shore Type	Length of Shoreline (m)	% Of Total
Cliff/Bluff	7867	22%
Gravel Beach	6162	17%
Sand Beach	13861	38%
Vegetated Shore	3102	9%
Low Rocky Shore	5081	14%
TOTAL	36073	100%

Table 27: Summary of shore type disturbance within City of Kelowna.

Shore Type	Distribution	Length of Shoreline (m)	Total %
Cliff/Bluff	Natural	5912	75%
	Disturbed	1955	25%
Gravel Beach	Natural	2957	48%
	Disturbed	3205	52%
Sand Beach	Natural	1166	8%
	Disturbed	12694	92%
Vegetated Shore	Natural	2112	68%
	Disturbed	990	32%
Low Rocky Shore	Natural	2103	41%
	Disturbed	2978	59%

The majority of the foreshore within the City of Kelowna is considered rural, with residential and park being evenly distributed to a lesser amount (Table 28). Disturbance within these land uses has primarily occurred in residential areas, however, land uses including commercial, industrial and institutional are completely disturbed (Table 29). Parklands within the area have been heavily disturbed. Shorelines are found to be heavily modified in residential and rural segments (Table 30). A summary of FIV can be found in Table 31.

Table 28: Land use summary within City of Kelowna.

Land Use	Length of Shoreline (m)	% Of Total

Urban Residential	9228	26%
Commercial	768	2%
Rural	16900	47%
Agricultural	819	2%
Park	7597	21%
Industrial	450	1%
Institutional	310	1%

Table 29: Summary of land use disturbance within City of Kelowna.

Land Use	Distribution	Length of Shoreline (m)	Total %
	Natural	1229	13%
Urban Residential	Disturbed	7999	87%
	Natural	0	0%
Commercial	Disturbed	768	100%
	Natural	9323	55%
Rural	Disturbed	7576	45%
	Natural	543	66%
Agricultural	Disturbed	276	34%
	Natural	2331	31%
Park	Disturbed	5266	69%
	Natural	0	0%
Industrial	Disturbed	450	100%
	Natural	0	0%
Institutional	Disturbed	310	100%

Table 30: Summary of modifications within the City of Kelowna.

Land Use	Docks	Average Docks / km	Retaining Walls
Urban Residential	188	20.4	121
Commercial	11	14.3	5
Rural	177	10.5	93
Agricultural	4	4.9	1
Park	8	1.0	16
Industrial	0	0.0	1
Institutional	4	12.9	3

Table 31: Summary of foreshore impact values for the City of Kelowna.

FIV	# Segments	Length of Shoreline (m)	% Of Total
Low	11	9861	27%

Moderate	7	5439	15%
High	34	20772	58%

4.0 DISCUSSION

The foreshore is an integral part of any lake system and is influenced, in part by upland processes. As the results suggest, the integrity of Okanagan Lake foreshore has been compromised by residential and urban development, as well as agriculture, industrial, institutional and commercial uses of upland areas. Of particular importance is that industrial and institutional land uses promote extremely high impact activities. In the RDCO North Westside, Westside, and the City of Kelowna OCP areas, percent disturbed values average over 90% in these land uses. A similar relationship is observed regarding commercial land uses, making it imperative that foreshore protection is addressed in land use policies.

Foreshore alterations have also lead to widespread degradation and fragmentation of foreshore habitats, modifying natural ecosystem processes, structure and functions (Battelle et. al. 2001). Historically, these alterations were a result of decision-making that lacked an adequate understanding of the long-term effects of such activities. Today, activities continue to degrade foreshore habitats including lake infilling, beach grooming, shoreline armouring, over water structures and riparian vegetation removal. These alterations are likely to result in shifts in species composition, viability, and productivity (Battelle et. al. 2001). Activities in both aquatic and terrestrial habitats along Okanagan Lake have lead to frustration over the management of the foreshore. Compounded by a wide variety of foreshore guidelines, and the lack of enforcement of regulations relating to foreshore development, conservation becomes increasingly difficult.

There are numerous reasons for widespread frustration; many of which can be attributed to the difficult task of coordinating a large-scale effort in managing resources over multiple jurisdictions and agencies. Lack of inter-agency cooperation and program integration, and limited funding resources complicate foreshore management issues. These challenges often lead to further frustration by landowners, developers and government staff alike, as clear and concise expectations are not easily presented. The most prominent challenge is found in the varying degree of scientific information and expertise that resides in agencies responsible for foreshore management. Where information does exist, it is often limited in scope, availability, and comprehensiveness (data gaps), making it exceedingly difficult for resource managers to make educated, informed decisions. Education has long been a priority in the mandates of resource managers, yet public awareness, understanding and involvement in foreshore protection issues is surprisingly low. A lack of incentives for foreshore protection, reduced staffing and funding levels for enforcing violations, and a lack of coordinated inter-governmental foreshore protection policies have allowed modifications and disturbance on Okanagan Lake to go largely unchecked. It has become exceedingly apparent that the need for a consolidated approach is utmost in our bid to preserve foreshore ecosystems.

In light of the degradation presented, significant natural areas remain within the Central Okanagan. These areas present a unique challenge to governing agencies responsible for balancing unprecedented growth with environmental protection. The cost of protection of such areas, in terms of biological and economic cost, is low compared to the cost of restoration (Battelle et. al. 2001). This is of importance because most foreshore restoration efforts on Okanagan Lake are recent and have not been monitored for long-term effectiveness. Challenges are especially formidable when dealing with foreshore protection issues in areas where long-term visions have not been established, such as those with no OCP to guide development.

A clear understanding of regional strategies may guide our decisions and promote a coordinated approach to foreshore management. The inventory presented in this report is consistent with the management initiatives set forth in a number of regional strategies (as described in the Context section). These strategies are key in establishing regional visions and common goals with consideration for provincial interests (RDCO, 2002). Action items from these documents include:

- Planning for development by knowing first what to protect and developing and using management tools to achieve the desired level of protection (RDCO Regional Growth Strategy);
- Managing water resources to ensure their long term health and sustainability (RDCO Regional Growth Strategy);
- Developing protection and restoration plans for shore spawning habitats and implementing effective shoreline protection preservation activities. (Okanagan Lake Action Plan);
- Inventorying the known salmon watersheds for locations of critical habitat (Okanagan Shuswap Land Resource Management Plan).

Using guidance from regional strategies and the information gained from this inventory, one can begin to identify and prioritize critical areas on Okanagan Lake. Subsequent efforts should concentrate on protecting these areas using tools available in a regional planning environment. These tools include regional policies, foreshore plans and foreshore development guidelines, which should be examined and updated to include science based policy direction for conservation planning. This direction should be intent on achieving a higher level of quality in development that preserves the integrity of the upland and maintains environmental attributes of the foreshore. Other tools include public education, which can be used to curtail the loss of critical habitat on private property, and expanding partnerships, therefore increasing local government's ability to adapt to increasing development pressure.

5.0 RECOMMENDATIONS

Decisions regarding the management of Okanagan Lake foreshore should be based on the best available science and should reflect policies set out in regional strategies and guidelines. The recommendations presented in this report are limited in extent; for detailed technical and strategic recommendations, please refer to the final report.

In order to conserve the ecological integrity of Okanagan Lake, and enhance the ecosystems that it supports, the following recommendations are put forth based on the results of this inventory:

1. Identify critical areas for protection, restoration, and enhancement.
    - Use data provided by WLAP to determine critical kokanee spawning habitat.
    - Complete inventory on the remainder of Okanagan Lake.
2. Develop a regional foreshore protection program that designates protection of critical areas in policies (i.e. Foreshore Development Guidelines, Foreshore Structure Bylaws).
    - The current foreshore plans within the Central Okanagan should be updated based on the results of this inventory and should consider the lakeshore development guidelines developed jointly by the Thompson Nicola Regional District (TNRD) and LWBC.
    - The program should address protection, acquisition, and incentive strategies for lands that would contribute to maintaining or restoring ecosystem processes and functions.
    - The program should develop and implement technical guidance for alternatives to traditional shoreline modifications (i.e. armouring).
    - The program should explore agreements with LWBC to ensure adequate control and protection of foreshore ecosystems.

- The program should explore a memorandum of understanding with all levels of government to clarify responsibilities and areas of jurisdiction regarding foreshore issues.

3. Prioritize conservation activities.
   - Conservation activities should be prioritized based on updates to regional and local plans such as OCP's and rural land use bylaws.
   - Considering that the shorelines of Lake Country and North Westside are the least developed, protection efforts should concentrate on these areas first.

4. Protect critical areas.
   - Protect fish spawning and adjacent upland areas (including *historic* kokanee spawning areas). Location of kokanee spawning habitat is not well defined and changes depending upon population size. Current spawning areas are deemed critical to the persistence of the population, historic spawning areas will be re-colonized as populations increase (A. Wilson, personal communication, December 12, 2004).
   - Protect upland ecosystems (adjacent to the foreshore) associated with the life cycle of threatened or endangered species.

5. Protect natural areas.
   - Protect existing undeveloped shoreline and upland areas along Okanagan Lake from development practices that would be detrimental to the foreshore ecosystem.
   - Protect natural foreshore substrates from the adverse effects of shoreline modifications such as beach grooming, filling, overwater structures, armoring, and dredging.
   - Local and regional governments should investigate lease agreements over the foreshore with the provincial government.

6. Address modifications.
   - Restore natural, physical, and biological processes lost as a result of shoreline modifications such as armouring, infilling, beach grooming etc. These efforts should concentrate on areas where development practices have reduced ecological processes and functions that support habitat quality.
   - Prevent further modifications to foreshore that reduce ecological processes.

7. Identify challenges and opportunities.
   - The feasibility of developing a formal set of digital foreshore mapping methodologies should be explored in conjunction with the Community Mapping Network.
   - Prioritize rehabilitation and restoration opportunities on Okanagan Lake.

8. Make data and habitat information available.
   - Provide foreshore inventory information to federal, provincial and local jurisdictions to aid in the production of regional foreshore BMPs.
   - Make the Okanagan Lake dataset available via the Internet through a continued partnership with the Community Mapping Network.

9. Monitor habitat losses and gains.

10. Measure success.
    - Results from monitoring program should be compared to original inventory data to determine compliance with BMP's and effectiveness of protection measures.

11. Re-evaluate.

6.0 CONCLUSION

The findings of this inventory are intended to aid in foreshore management activities on Okanagan Lake leading to improved ecosystem structure and function. It is recognized there are strengths and weaknesses to the methodologies used in this assessment and refinements are ongoing. The dissemination of this material will help promote a coordinated ecosystem based approach that is essential to successful foreshore management. In order to adequately address foreshore protection issues, it is important to examine the way residents and stewards view foreshore ecosystems (Batelle, 2001). The key to protection is our ability to recognize and acknowledge our influence on these systems, and the role they play in the health and vitality of Okanagan Lake. Preservation of these ecosystems is critical in maintaining the environmental, social and economic values that have long drawn people to the Okanagan region.

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Photo A: Foreshore type – Cliff/Bluff. Areas adjacent to steeper slopes, usually indicating a steep-sided lake basin or sudden drop off.

Photo B: Foreshore type - Gravel Beach. Often associated with low gradient foreshore or coves with pockets of riparian vegetation among steeper hillsides. Sometimes associated with alluvial fans.

Photo C: Foreshore type - Sand Beach. Often associated with alluvial fans or other shoreline deposition areas.

Photo D: Foreshore type - Vegetated Shoreline. Characteristic of undisturbed foreshore with narrow littoral width. Vegetation is commonly shrubs and small trees.

Photo E: Foreshore type – Low, Rocky Shore. Cobble, boulder or bedrock substrate, prevalent along the base of steeper shorelines.

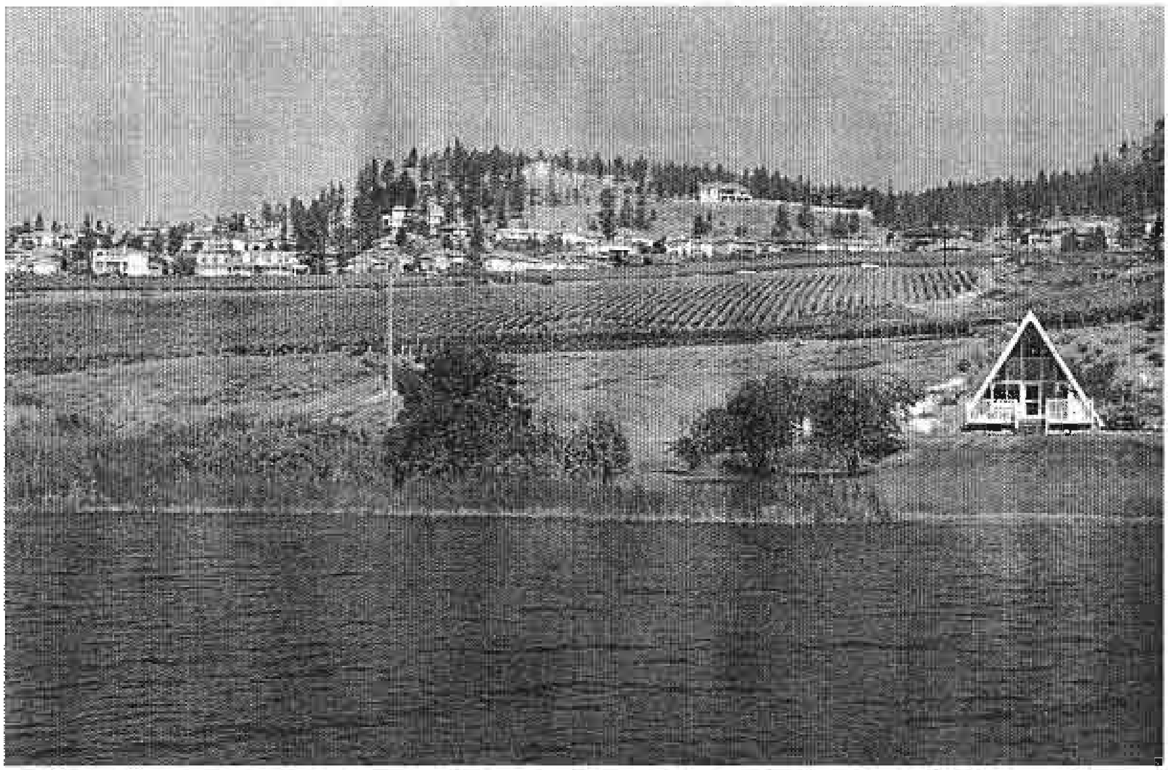

Photo F: Foreshore type – Wetland shore. Characteristic of wide littoral widths with fine substrates promoting abundant emergent vegetation such as sedges, reeds, cattails, etc.

Presentation # 1

Trepanier Landscape Unit Water Management Plan

by

Brian Guy, Ph.D., P.Geo.[1], Ron Smith, P. Eng.[2], and Leah Hartley, M.C.I.P.[3]

Abstract

The Trepanier Landscape Unit (TLU) water management plan was initiated by the B.C. Ministry of Sustainable Resource Management (MSRM) and the Regional District of Central Okanagan (RDCO) in 2003, and completed in 2004. The TLU covers 990 km^2, including five major watersheds on the west side of Okanagan Lake. The population has doubled in the past 20 years, and is expected to increase by 65% in the next 20 years. Water service delivery is managed by over 20 licensed water utilities. About 66% of the water used in the TLU comes from surface sources (upland reservoirs and streams), and the remainder is drawn from Okanagan Lake (30%) and groundwater (4%). The study included analysis of current water conditions in the TLU and of conditions expected in 2020 and 2050, based on trends in population and the predicted effects of climate change.

Water demand is projected to be 55% higher by 2020 and 128% higher by 2050 based on current water use rates. In addition, due to climate change, natural streamflows are expected to be an average of 15% smaller by 2020 and 35% smaller by 2050. The analyses conclude that expansion of water supply from streams, unless supported by storage, is not environmentally sustainable, nor does it permit population and economic growth to occur as planned. Failure to both reduce rates of water use and develop additional water sources by 2020 will either constrain economic growth or impair environmental resource values, or both. The problems are expected to be moderate by 2020 and severe by 2050. The plan makes several detailed recommendations for improved water management in the TLU, including expanded demand management, supply augmentation, improvements in water-related data, and creation of a leadership group that will champion the cause of improved water management and encourage adoption and implementation of the recommendations. The plan is summarized in this paper.

The water issues, conflicts, and future pressures that have been examined in detail in the TLU are known or expected to occur elsewhere in the Okanagan, although analyses and specific predictions at a similar level of detail have not been made elsewhere. The approach taken in the TLU water management plan is a useful model for other Okanagan tributary basins.

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2: B.C. Ministry of Sustainable Resource Management, Kamloops, B.C.
3: Regional District of Central Okanagan, Kelowna, B.C.

1.0 Introduction

This paper summarizes the results of a water management plan completed in the Trepanier Landscape Unit (TLU), an area on the west side of Okanagan Lake near Kelowna, in June 2004 by Summit Environmental Consultants Ltd. (Summit). A full report of the work is presented in Summit (2004a) and a stand-alone Executive Summary is presented in Summit (2004b). Copies of the plan are available on the Regional District of Central Okanagan (RDCO) website. This paper summarizes the work presented in these two reports, and extends the analysis slightly to consider the implications for the entire Okanagan Basin.

The TLU study was initiated by the B.C. Ministry of Sustainable Resource Management (MSRM) and the RDCO, and led by a Steering Committee comprised of MSRM, RDCO, Land and Water B.C. (LWBC) and the Ministry of Water, Land, and Air Protection (MWLAP). Technical advice was provided by a Technical Advisory Working Group (TAWG) comprised of water stakeholders in the study area with a mandate to manage water - such as water utilities, government agencies, and representatives of the forestry and mining sectors.

2.0 Objectives

The general objectives of the study were to engage stakeholders on a community watershed basis to encourage greater understanding of the relationship between water resource and land use planning, and to provide strategic direction to provincial and local agencies. Land use managers (RDCO, Westbank First Nation, and Peachland) will be able to incorporate recommendations into Official Community Plans and servicing policies that will in turn guide land use decisions. Provincial resource managers will be better able to implement the objectives and strategies of the Okanagan-Shuswap Land and Resource Management Plan in the TLU, and MSRM will be better able to identify water-related economic constraints and opportunities in the TLU.

Specific objectives included:

- analyse current land use, resource use, and population within the TLU;
- describe surface and groundwater resources, as well as fisheries and water quality;
- assess water use according to sector (agricultural, residential, commercial, and industrial), and according to source (tributaries, Okanagan Lake, and groundwater);
- determine water pricing and pricing strategies in use within the TLU;
- identify water issues and barriers to more effective water management in the TLU;
- assess specific impacts on the water resources of the TLU that are likely to result from population growth and climate change in the years 2020 and 2050; and
- provide recommendations for improved water management to mitigate or avoid future impacts.

3.0 Current conditions

3.1 Population and land use

The TLU covers 990 km^2 (Figure 1), including five major watersheds on the west side of Okanagan Lake (Lambly, McDougall, Powers, Trepanier, and Peachland Creeks). Land use includes forestry, mining, agriculture (range, vineyards, orchards, pasture, and crops), recreation, and urban (commercial, industrial, and residential). The bulk of the land base is managed by the provincial crown. Private lands include one municipality (Peachland), a First Nation community (Westbank I.R. #9 and I.R. #10), and the largest populated unincorporated area in B.C (Westbank and Lakeview). Commercial and industrial operations include a nursery, two wineries, retail malls, an industrial park, several aggregate operations, and many small businesses. There are 982 ha of intensive agriculture in the TLU, much of which is irrigated. The population has doubled in the past 20 years to 36,366, and is expected to increase to 59,937 (a 65% increase) by 2020.

3.2 Climate, surface water hydrology, and groundwater hydrology

The area is relatively dry, with annual precipitation (total of rain and snow) averaging about 600 mm. Flows in the creeks rise in the spring as the winter snowpack melts, then decrease over summer to reach low levels in late summer, and flows stay low through the fall and winter. Streamflows are highly variable from year to year – the driest year in an average five-year period has only two-thirds of the runoff of an average year.

Flows in all five principal streams in the TLU have been altered by human intervention – largely by the construction and operation of reservoirs and water intakes to regulate flow for water supply purposes. Estimates of "naturalized" flows (i.e. flows that would exist without human intervention) were estimated at 14 locations in the TLU (Figure 2). These locations were chosen strategically to represent the upper "plateau" portion of the TLU where the storage reservoirs are located, an intermediate "canyon" zone between the reservoirs and the intakes of the major water utilities, and a lower "valley bottom" zone, below these intakes. At present, average annual flows (actual flows, i.e. flows that reflect the effects of water management) at the mouths of the major creeks are 13% smaller than "naturalized" flows, due to water removals for offstream use, as shown in Table 1. However, water licences for offstream use that are already issued account for (on average) 28% of the naturalized flow in the TLU (Table 2), indicating that actual offstream removals are less than licences allow. The amount of offstream use that is supported by storage varies widely, as shown in Table 2.

There is very little information on groundwater conditions or use in the TLU. Six large aquifers have been identified by the Ministry of Water, Land and Air Protection, all located in the vicinity of Westbank. There are likely additional, smaller aquifers in the upland area of the TLU that have not yet been identified. Detailed assessments of aquifer size and extent, aquifer yield and aquifer use were not possible due to a lack of basic hydrogeological information. Maximum groundwater extraction rates in the TLU were estimated at 400 L/s (i.e. 0.4 m^3/s, or 12.6 million m^3 per year), which is approximately equal to the estimated average annual recharge rate from precipitation.

3.3 Water supply systems, water use, and water pricing

Water service delivery is managed by four major utilities (Westbank and Lakeview Irrigation Districts, Peachland, and Westbank First Nation), and more than 16 small utilities (most of which are shown in Figure 3). Water licences have been issued for the withdrawal of 53.674 million m^3 per year from 184 streams and waterbodies in the TLU (including Okanagan Lake).

About 66% of the water used in the TLU is obtained from surface streams, of which 90% is obtained from the five major tributary streams. In addition, approximately 30% of the total water used is pumped from Okanagan Lake, and only about 4% is obtained from groundwater wells (this water is not licensed). There are likely minor amounts of water withdrawn at unlicensed points-of-diversion from surface streams.

Actual annual offstream water use is estimated to be 24.554 million m^3 (i.e. about 46% of the licensed amount). Storage licences have been issued for 36.098 million m^3, of which 28.950 million m^3 is actually utilized. In three of the five principal streams (Lambly, McDougall, Trepanier), neither licensed offstream use nor actual offstream use is fully supported by storage, but in Peachland and Powers Creeks, both licensed and actual offstream use are fully supported by storage.

The distribution of water use in the TLU from all sources was estimated as follows: residential - 41%; agriculture (including golf courses) - 34%; commercial/industrial - 20%, and leakage - 5%. The year-round average residential water use rate in the TLU was calculated to be 789 litres per person per day, based on estimates of total residential water use and population served. This value is very high - more than double the Canadian average, and almost double the B.C. average (Brandes and Ferguson, 2003; Environment Canada, 2001). Prior to implementation of demand management measures, water use rates in Vernon and parts of Kelowna were similar to those in the TLU, however with metering and other conservation initiatives now in place, residential use rates have dropped by about 30% in these communities. These and other experiences (e.g. Earth Tech, 2003) suggest that effective water conservation measures could reduce water use in the TLU by 30% to 50%.

A variety of water pricing systems is in use in the TLU, but the flat rate system is by far the most common. Very few residential, commercial or agricultural users are connected to water meters. Without meters, volume-based billing cannot be applied, and economic tools to encourage conservation are unavailable.

Based on estimates of total residential water use and utility revenues from the residential sector, it is estimated that TLU residents pay only about \$0.25 per m^3 for water. This price is less than half the B.C. average (which is about \$0.63 per m^3) and much less than the Canadian average (which is about \$0.93 per m^3) (Environment Canada, 2001). Similarly, commercial, industrial, and agricultural water users in the TLU pay relatively low prices for water.

3.4 Water quality

Water quality generally meets water quality guidelines (or water quality objectives where they have been set), however all of the major streams that serve as sources of domestic and irrigation water occasionally have turbidity, coliform bacteria, and true colour concentrations that do not meet the B.C. water quality guidelines for raw water, and thus require treatment. The causes of the above-guideline concentrations of these variables include both natural factors and land use effects. However, during stakeholder consultations, few water quality issues were identified in relation to forest practices. Water quality concerns include existing development and the potential for increased development on upland reservoirs, cattle access to streams, and erosion along forest roads and trails from vehicular traffic. Boil water advisories have occasionally been implemented to address risks from bacteria. Discharge from the old Brenda Mine site is monitored for molybdenum, copper, and other parameters. By far the majority of sampling results are within guidelines/objectives, however, exceedances for molybdenum and copper have occurred on occasion in Trepanier and Peachland Creeks. Increases in the concentrations of some water quality variables occur as the streams flow through urbanized areas.

3.5 Fisheries resources

Streams in the TLU support a variety of fish species, including rainbow trout and kokanee salmon. Fish populations have faced pressures in recent decades due to flow withdrawals from tributaries and habitat impacts, particularly in the lower reaches of TLU creeks below the intakes of the major municipal water purveyors. Instream water uses (e.g. water required for fish) are in general not protected by water licences. Instead, efforts have been made to negotiate "conservation" flows in the major streams of the TLU. The conservation flows that have been proposed are based on a percentage of the mean annual discharge, with the percentage changing each month. In many stream reaches these flows will produce optimal flows for fish as opposed to minimum flows. In a year with average runoff, the proposed conservation flows are close to the naturalized flows during the low-flow months. In drier than average years, conservation flows exceed naturalized flows, suggesting that conservation flows may be set too high. However, even in an average runoff year, water withdrawals for offstream use leave insufficient water in the streams to satisfy conservation flows in some months.

3.6 Water management issues and barriers

The TAWG identified several water-related issues in the TLU, including unregulated groundwater use, over-licensed streams, reductions in flow affecting fish, urban development near streams, increasing competition for water, and water quality impacts associated with land use.

There are several provincial and federal Acts and regulations that govern water in B.C. In addition, the Okanagan-Shuswap LRMP and four Official Community Plans (OCPs) in the TLU provide a long list of goals, objectives, and policies for managing water. TAWG members reported that their rates of implementation of LRMP and OCP policies were relatively low. These agencies identified several challenges to water management in the TLU, including ineffective management tools, lack of data for decision-making, limited education on water values and use, organizational barriers, differing institutional priorities, and conflicting objectives.

Lack of data is a significant barrier to improved management - streamflow data is routinely collected on only two of the five major streams in the TLU; water licence information is maintained in a complex format that is difficult to use and the data are difficult to interpret; there is virtually no information on rates of groundwater supply or demand or on groundwater quality; and fish conservation flows in some streams may be set unrealistically high. These and other barriers will have to be overcome for water management to improve in the TLU. The recommendations presented in the plan are intended to help achieve that goal.

4.0 Future pressures on water

As noted above, RDCO predicts that the population of the TLU will increase from 36,366 in 2003 (based on 2001 data) to 59,937 by 2020. If the same growth rate continues beyond 2020, the TLU population will be 97,201 by 2050, and the economy will be correspondingly larger as well. Based on several simplifying assumptions (e.g. water use rates remain the same, the land base does not change), water use by all sectors (residential, commercial, industrial, agricultural) is expected to be 41% higher than 2003 levels by 2020 and 91% higher by 2050 due to population and economic growth , as shown in Table 3.

In addition, the climate is changing, which is expected to further increase the demand for water because the growing season will be longer, drier, and warmer. In total, water use in the TLU is expected to increase by 55% over 2003 levels by 2020 and by 128% by 2050 under the combined influences of population growth and climate change, as shown in Table 4.

These changes are summarized on Figure 4. The effects of increased water demands on the five major streams in the TLU (assuming that all of the increased demand is satisfied from surface streams) are shown on Figure 5. (The scenarios referred to on Figure 5 are described below.)

In addition to its effect on water demand, climate change will have a second effect on the TLU's streams – it will substantially reduce water supply. Predictions of three global circulation models

(GCMs) and the UBC watershed model indicate that natural streamflows will be about 15% smaller in 2020 and 35% smaller in 2050 than they are now, even if water use does not increase in future. These figures are based on averaged results from the three GCMs and from two potential future CO_2 emission scenarios, as outlined in Cohen et. al. (2004). These potential changes are summarized in Table 5.

Detailed analyses were done on the effects of population growth (increased water use) and climate change (increased water use and reduced streamflow) at 14 locations on the five major streams of the TLU. The output consisted of 56 graphs - one for each of 14 locations for each of the following four future scenarios:

- effects of population growth to 2020 (Scenario 1.1)
- effects of population growth to 2050 (Scenario 1.2)
- effects of population growth and climate change to 2020 (Scenario 2.1)
- effects of population growth and climate change to 2050 (Scenario 2.2)

The analysis relied on several key assumptions, including:

- all future water demand is satisfied from surface streams (not groundwater or Okanagan Lake);
- no changes occur in the seasonal patterns of water storage and release in the upper elevation reservoirs in response to future hydrologic and demand changes;
- indoor domestic water use rates remain the same in the future – only the outdoor component is assumed to increase as the climate warms;
- despite climate change, there are no future changes in the locations of agricultural activity, or crops grown;
- we have analysed only for "average" future years, not wetter or drier than average future years; and
- no intervention is made to prevent future water conflicts.

The effects of adoption of future conservation measures in reducing water use were also examined - specifically the effects of 10%, 20%, and 30% reductions in demand.

Detailed spreadsheets and analysis of the output are provided in Volume 2 of Summit (2004a). The analyses are summarized in Figures 6 through 10 - one figure for each of the five major creeks. These figures show the combined effects of expected future changes in both demand and supply, <u>and demonstrate clearly that present-day water resource issues and conflicts will be substantially intensified throughout the TLU in future</u>.

5.0 Conclusions

On the basis of the results summarized in Figures 4 through 10, the following conclusions were drawn:

1. If potential climate changes are ignored, streamflows in 2020 will be smaller than they are today due simply to population and economic growth, but the predicted flow reductions will be relatively small. Nevertheless, the flow allocation, fish habitat, and water quality issues that are experienced now will intensify. Conservation flows will not be met in Powers Creek. Streamflows in 2050 will decrease further, resulting in more substantial flow reductions and associated water quality and fisheries impacts, which will be concentrated in Lambly, McDougall, and Powers Creeks.

2. If climate change is accounted for, significant streamflow reductions (averaging 25%) are expected in all five major creeks by 2020 due to increased use and reduced supply. This will result in zero flow at some locations for parts of the year in an average year. An average year will be like a 5-year drought year today, and a 5-year drought year will be like a 20-year drought year today. Current licences will not be sufficient to satisfy demand on Powers Creek.
3. These impacts will be even more severe by 2050, when annual flows will be reduced by an average of 56%, resulting in conservation flows not being met at many locations, and zero flow in all creeks for parts of the year. An average year will be like a 20-year drought year today, and a 5-year drought year in 2050 will be like a 50-year drought year today. Current licences will not be sufficient to satisfy demand on Powers and Lambly Creeks.
4. Streamflow impacts will be much larger downstream of the intakes of the major water purveyors than further upstream.
5. If future demands are satisfied from sources other than tributary streams, the predicted impacts on the tributaries will be smaller than indicated here. For example, if groundwater were developed to its currently estimated capacity, increased use of tributaries and Okanagan Lake may be avoided until about 2020.
6. If the climate does not change, demand management alone to 2020 would allow future demand to be satisfied from tributaries alone, and permit population and economic growth to occur without streamflow reductions relative to 2003, and the associated water quality and fisheries impacts.
7. However, by 2050 (even without climate change), both demand management and alternate supplies will be needed to prevent streamflow reductions and associated environmental impacts.
8. If the climate does change as predicted, augmentation of the water supply will be needed (along with demand management) to prevent streamflow reductions and associated environmental impacts by 2020.

In summary, the results of the study indicate clearly that unless changes in the way water is used in the TLU occur, current plans for population and economic growth cannot be realized without incurring environmental harm. On the other hand, significant efficiencies in water use are possible, and along with development of alternate water sources, could allow growth to occur as planned.

6.0 Recommendations for improved water management

On the basis of the key findings and conclusions, the plan makes several recommendations for improved water management. The recommendations are consistent with the goals and policies for water management contained within the Okanagan-Shuswap LRMP and the four OCPs in the TLU. They are listed in approximate priority order.

6.1 Demand management

The following demand-side management approaches should be implemented before 2010:

- a minimum water use reduction target should be set;
- public education programs (to promote water conservation and to encourage changes such as xeriscaping and improvements in irrigation application techniques and irrigation scheduling);
- universal metering;
- financial incentives (use of a volume-based rate system and potentially other incentives);
- ensuring full cost-recovery pricing; and
- regulations (including requiring water conserving fixtures, and restrictions on water use in peak periods).

It is expected that 30% reductions in water demand, which would reduce residential per capita water use to the same levels as experienced in parts of Kelowna and Vernon, are attainable in the TLU with these basic approaches. As soon as metering is in place, additional measures (that depend on meters) should be implemented:

- utilities should implement a leak detection program;
- utilities should conduct water audits to determine locations and amounts of water use and leakage;
- improvements in irrigation application techniques should continue to be made; and
- a program of irrigation scheduling should be implemented.

Finally, the following measures that do not depend on meters should be implemented:

- promotion of land use changes - local governments should encourage developments with lower per capita water use such as multi-family residential vs. large single-family lots, and low impact development designs including xeriscaping and onsite retention and infiltration of stormwater runoff. The low density of development in the TLU, combined with substantial future development potential, provides opportunities for significantly affecting water use and quality through urban design;
- promotion of crops that require less irrigation, considering the economic implications within and beyond the TLU;
- implementation of recycling and reuse of wastewater by businesses and jurisdictions; and
- the potential for achieving water supply and distribution efficiencies through combining water systems should be investigated.

Some of the planning changes (such as changes in urban form) generate other secondary benefits, such as reduced vehicle use and road area, and more efficient servicing patterns (for water, power, sewer, drainage, and transportation). Low impact development techniques often accompany new urban forms, reducing runoff peaks and improving the quality of stormwater runoff.

Adoption of all of these conservation measures could result in total water savings near 50%.

6.2 Supply Side Augmentation

In order to prevent exacerbation of present-day water management issues and conflicts, development of additional water supplies will likely be necessary by 2020 if climate change is accounted for, and by 2050 if only projected population changes are considered. Since it is likely that the climate is changing, the plan recommends that all utilities that rely on surface water sources develop additional water supplies before 2020.

Supply-side management strategies recommended for the TLU include:

- operational improvements, including achieving operational efficiencies, leakage reduction in the primary conveyance systems, and reductions in system pressure;
- additions to or development of new upstream storage on the plateau;
- pumping from Okanagan Lake; and
- increased use of groundwater.

Reflecting further on the above recommendations, the plan indicates that there is likely some remaining opportunity to increase storage in upland areas, although an assessment of the potential for increases in storage was beyond the scope of the study. Each water utility should evaluate the extent to which additional storage can be developed in the areas under their management. In the short term, increased storage is likely to be the most cost-effective approach to increasing supply. In the longer term, however, tributary storage will become more difficult and more costly to develop, and there is a limit to the availability of water from this source.

The plan recommends that the province carefully consider any proposed sale of Crown land around upland lakes or storage reservoirs, because private shoreline ownership could constrain the development of increased storage.

Because of limits to the availability of new upland storage, the plan recommends that investigation and development of Okanagan Lake and groundwater become higher priorities than they have been in the past. However, current knowledge of groundwater is limited, so large-scale groundwater development should not occur before the resource has been properly evaluated. It is noteworthy that while the use of Okanagan Lake and groundwater to service future demands represents a medium to long-term solution, there is a limit to the use of these alternative supplies. Groundwater-surface water interactions could cause reductions in baseflows in surface streams if groundwater is overused. Also, water use from Okanagan Lake will eventually become significant enough to affect lake levels, which has negative implications for lake water quality and downstream flows. It is estimated that 2 to 4 cm of water is permanently lost from the lake each year due to consumptive water use in the TLU. This figure will rise with continued population and economic growth.

Increased use of tributary flow without upstream storage development, and inter-basin diversions into the TLU are two supply-side options that are not consistent with the goals and policies for water management contained in the Okanagan-Shuswap LRMP, and are not recommended for the TLU. Even though Table 2 indicates that Powers and Peachland Creeks may have sufficient storage to support current offstream use, the detailed scenario output summarized in the plan indicates that increased withdrawals without supporting storage are not recommended on these creeks.

Prior to embarking on supply augmentation programs, the plan recommends that each of the three major water utilities in the TLU that obtain water from surface sources conduct utility-specific analyses of future supply-side and demand-side management options (including analyses of costs and benefits), and determine which of the demand or supply options described in the plan are most appropriate for implementation.

The plan makes a further recommendation that RDCO assist the smaller water utilities with similar utility-specific analyses to determine the optimal adaptation approach in each case. Many of these smaller utilities obtain water directly from Okanagan Lake, so detailed analyses of alternative sources of supply are not likely necessary. However, analyses of demand reduction strategies will be relevant to these utilities.

6.3 Surface Water Allocation

If current licences for offstream use were fully utilized, water withdrawals from surface sources would exceed those in Scenario 2.2 (year 2050, assuming climate change takes place) by 10.2 million m^3 per year, or 18%. Therefore, the plan recommends that, despite the fact that there is room available within the scope of existing licences for additional withdrawals from the five major tributaries, no increases to offstream withdrawals should be made without an equivalent increase in upstream storage to support the withdrawal. This recommendation is consistent with current practice.

Future water licence applications for surface streams in the TLU should be accompanied by proof that all reasonable alternatives have been pursued for obtaining water from already licensed sources, and that demand management measures are incapable of meeting the water requirements of the applicant.

6.4 Protection of Water Quality

The plan recommends that appropriate effort be directed at protecting water quality on both Crown Land and private land by the appropriate agencies. On Crown Land, this may take the form of source assessments under the *Drinking Water Protection Act*, potentially followed by Drinking Water Protection Plans. On private land, this could take the form of measures to control development in order to minimize development impacts on hydrologic response and water quality. This recommendation is particularly salient, since the province is considering the sale of Crown land along the shorelines of upland lakes and reservoirs, which may result in increased development pressures.

6.5 Protection of Streamside Corridors

The plan recommends that the appropriate agencies ensure that sufficient protection is provided to streamside areas within the TLU to maintain the functioning of riparian and floodplain processes at adequate levels, and minimize the negative impacts to the aquatic ecosystem that will be associated with reduced future streamflows.

6.6 Recommendations to improve water information

Each of the above water management recommendations should be implemented without waiting for additional data or information. However, the study revealed several issues with respect to data and information in the TLU, and makes several recommendations to improve the quality and quantity of the data available in the TLU for making water management decisions. They are outlined below, organized approximately in order of priority. They are all important, and it is recommended that they all be implemented before 2010.

6.6.1 Water Licence Information System

A thorough examination of the Water Licence Information System is recommended in order to identify improvements for access and querying. A map and database (GIS) approach should be pursued, in which a user could easily identify existing water licences upstream of a particular location on a stream network. In order to facilitate analysis, metric units should be adopted. At a minimum, metric units should be provided along with traditionally used (non-metric) units.

The Provincial government should become more proactive in cancelling licences that are no longer in use, so that water managers will be able to more easily identify currently active instream and offstream licences.

6.6.2 Measurement of Water Use

The plan recommends that all water utilities in the TLU measure their rate of water withdrawal from primary sources (surface streams, Okanagan Lake, and groundwater), and further that the customers of each of the water utilities in the TLU be metered, whether the water source is tributaries, groundwater, or Okanagan Lake. Meters are most urgent where customers are supplied from tributary sources.

The plan also recommends that water utilities conduct an audit or survey of water withdrawal rates, and indoor and outdoor use among their residential and commercial customers after a one or two year period. Such information can guide conservation programs, water pricing decisions, and public education messages.

6.6.3 Groundwater

Improvements in groundwater management depend on obtaining improved groundwater inventory and use information, which should be done prior to significant new groundwater development. The recently (November 1, 2004) enacted amendments to the Water Act take the first steps towards regulating groundwater in B.C. The research and inventory work currently being led by the Ministry of Water, Land, and Air Protection in the Okanagan will provide additional information useful for understanding and managing the groundwater resources of the TLU.

Aquifer mapping, based on surficial geology mapping, anecdotal evidence and limited field mapping, should be considered for the upland areas of the TLU. Detailed hydrogeological data and information should be generated for the six identified aquifers so detailed assessments of aquifer yield and sustainability can be completed. Detailed aquifer vulnerability mapping that considers land use, zoning and levels and types of development should be considered for the six identified aquifers. Finally, the need for wellhead protection plans and groundwater protection areas should be assessed, based on the results of the updated vulnerability mapping and the monitoring program.

6.6.4 Streamflow Inventory

The plan recommends that hydrometric stations be re-established in all five major watersheds of the TLU, at least near the mouths of each stream, and also preferably above major intake locations and below major storage reservoirs. Flows in all significant municipal and irrigation diversions should be monitored - at least those of the Westbank and Lakeview Irrigation Districts and the District Municipality of Peachland. All data collection in the TLU should be managed by a single agency, which would disseminate the information to all stakeholders.

6.6.5 Water Quality

The plan makes several specific recommendations for protecting water quality in the TLU, including, but not limited to:

- updating the EMS database;
- continuing to monitor in all the water supply watersheds, at least at hydrometric stations and water intakes;
- expanding the list of monitoring parameters beyond the minimum requirements in the *Drinking Water Protection Act,* and customizing the sampling design for each stream;
- involving all stakeholders in study design; and
- exploring opportunities for cost sharing of the monitoring amongst all stakeholders.

6.6.6 Fish Conservation Flows

To improve the setting of conservation flows in TLU tributaries, the plan recommends that conservation flows should vary depending on the naturalized flows in any given year. During low-flow periods, conservation flows should be no greater than the total naturalized flows available. Sufficient information should be collected on habitat-flow relationships to enable explicit evaluation of the implications of managing flow on this basis.

6.6.7 Water Information Accessibility

The plan recommends that an Okanagan water information clearinghouse be developed, and that local and provincial agencies with water-related mandates in the TLU support such an initiative.

7.0 Next steps

The analyses conducted in support of the Trepanier Landscape Unit water management plan indicate very specifically where and by how much streamflows in the TLU will be affected in future. Recommendations have been made to mitigate these impacts, beginning with substantial reductions in water demand beginning before 2010, and including development of alternative water sources beginning before 2020. Failure to change rates of water use or seek alternative water sources will either constrain economic growth or impair environmental resource values, or both.

Recommended next steps are set out in the plan (Summit, 2004a), some of which have already been implemented. The recommended next steps outlined in the plan are as follows:

- creation of a leadership group that will champion the cause of improved water management and encourage adoption and implementation of these recommendations;
- holding stakeholder and public consultations to develop an implementation plan; and
- implementation of improved water management actions using a variety of existing mechanisms.

Led by RDCO, a leadership group that includes the major water purveyors in the TLU is being established and is working cooperatively to begin implementing the report's recommendations. Consultations with a wider group of stakeholders than was possible during the study are also underway. This process is intended to foster understanding of the key water issues, and encourage support for the plan's recommendations.

8.0 Relevance to the Okanagan Basin

This paper has summarized detailed analyses and recommendations prepared for an area covering about 12% of the entire Okanagan Basin, but which is representative of the entire basin in terms of governing natural processes (e.g. climate and hydrology) and water use patterns. The water issues, conflicts, and future pressures that have been examined in detail in the TLU are known to occur at other locations in the Okanagan. Experiences in many areas of the basin during summer 2003 suggest that water use conflicts will intensify in future. However, similar analyses of water quantity, quality and use have not been made for the entire Okanagan Basin since the early 1970's.

The technical approach taken in the TLU water management plan provides a useful model for other Okanagan tributary basins. In addition, the recommendation for a leadership group to champion improved water management in the TLU could have relevance to the entire basin. If the TLU is indeed representative of the Okanagan, a basin-wide approach to water management could provide benefits to communities throughout the basin.

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Table 1 Comparison of naturalized flow and net flow for the five major creeks of the TLU.

Creek	Naturalized flow (m^3/s)	Net flow (m^3/s)
Lambly	1.77	1.58
McDougall	0.119	0.084
Powers	0.920	0.849
Trepanier	1.09	1.03
Peachland	0.570	0.515

Table 2 Comparison of actual and licensed offstream water use (expressed as a percent of the naturalized flow) and of storage.

Creek	Licensed Offstream Use	Actual Offstream Use	Percentage of Liceused Offstream Use Supported by Storage
Lambly	23%	11%	37%
McDougall	30%	30%	43%
Powers	29%	18%	191%

Trepanier	13%	5%	19%
Peachland	43%	10%	115%

Table 3 Present and future TLU water use (in millions of m^3/year) assuming that climate change does not occur.

Land use	2003	2020	2050
Residential	10.2	16.8	27.3
Commercial / Industrial	4.9	7.8	9.1
Agricultural[1]	8.3	8.3	8.3
Distribution system losses	1.2	1.6	2.2
TOTAL	**24.6**	**34.5**	**46.9**

Note: 1. includes water used by golf courses.

Table 4 Present and future TLU water use (in millions of m^3/year) accounting for climate change.

Land use	2003	2020	2050
Residential	10.2	18.3	32.0
Commercial / Industrial	4.9	8.5	10.6
Agricultural[1]	8.3	9.6	10.8
Distribution system losses	1.2	1.8	2.7
TOTAL	**24.6**	**38.2**	**56.1**

Note: 1. includes water used by golf courses.

Table 5 Predicted reductions in annual flow caused by climate change.

Creek	2020	2050
Lambly	11%	30%
McDougall	11%	36%
Powers	17%	34%
Trepanier	20%	39%
Peachland	18%	34%
Average	**15%**	**35%**

Note: This table represents the changes that are likely to occur if the climate changed but future water usage remained the same as it is today. Percentage reductions are based on 2003 levels.

Figure 1 Boundaries of the Trepanier Landscape Unit.

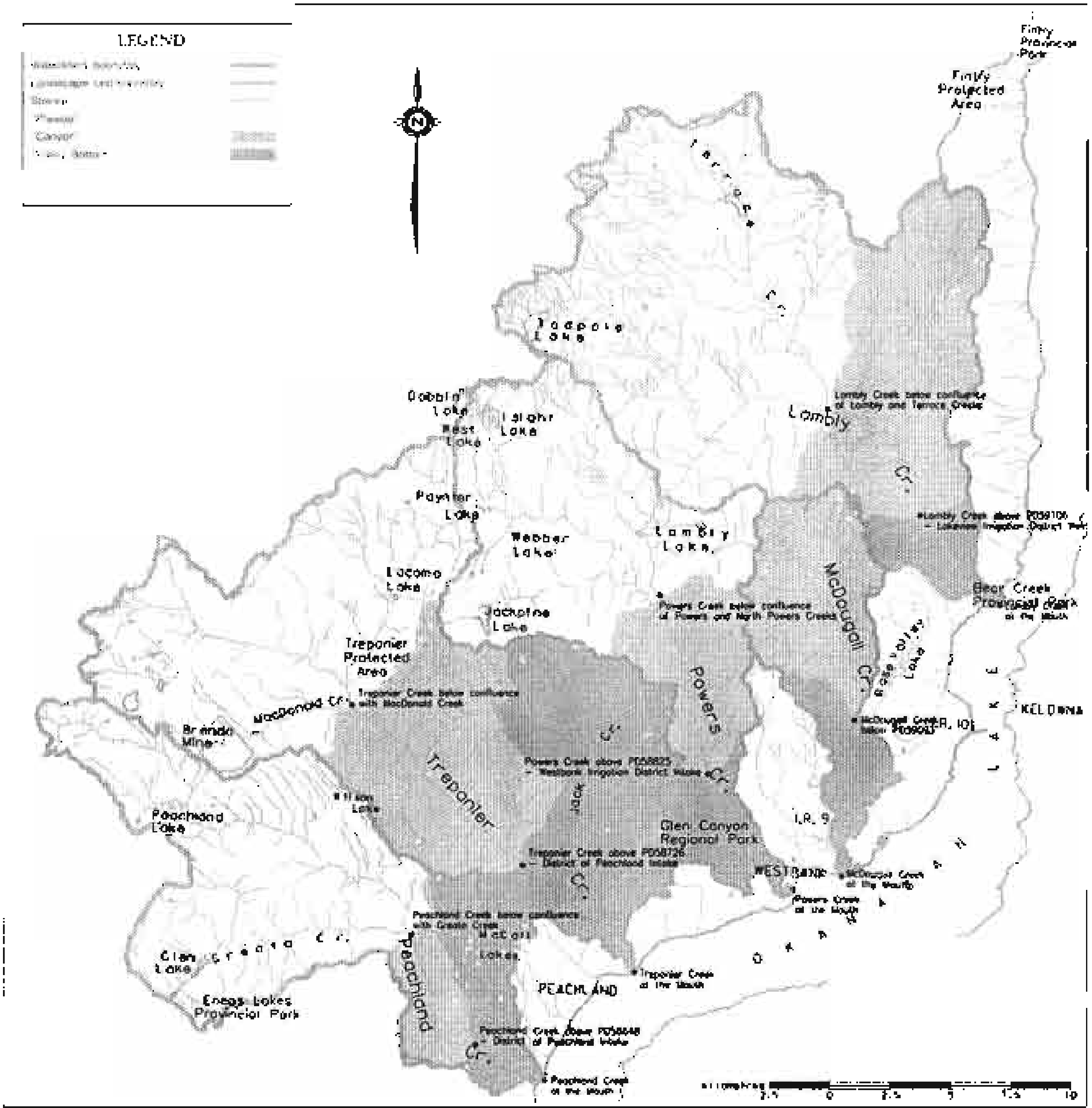

Figure 2 Map of the TLU indicating the 14 points-of-interest at which flows have been estimated.

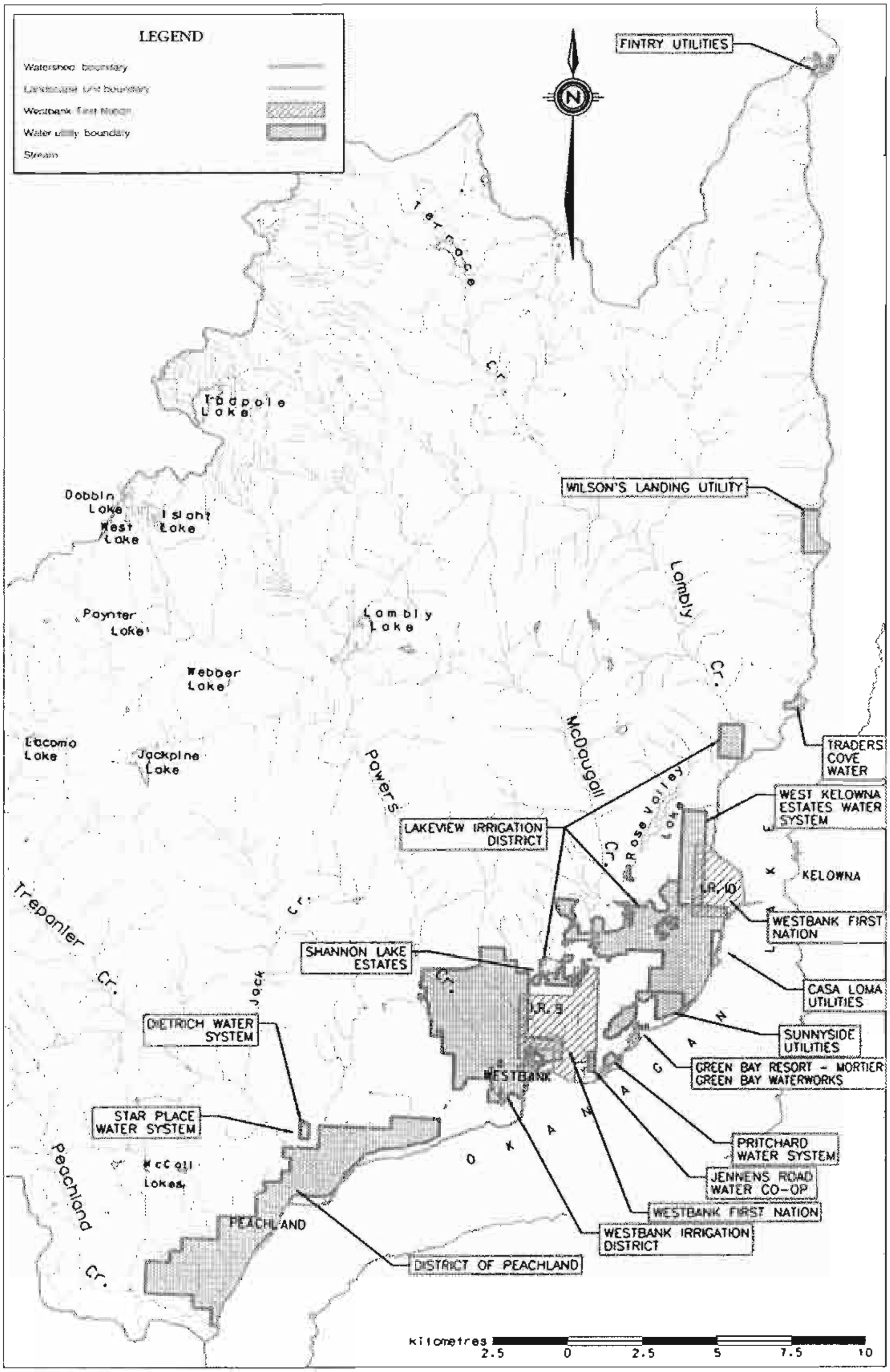

Figure 3 Distribution areas of the water utilities present in the TLU.

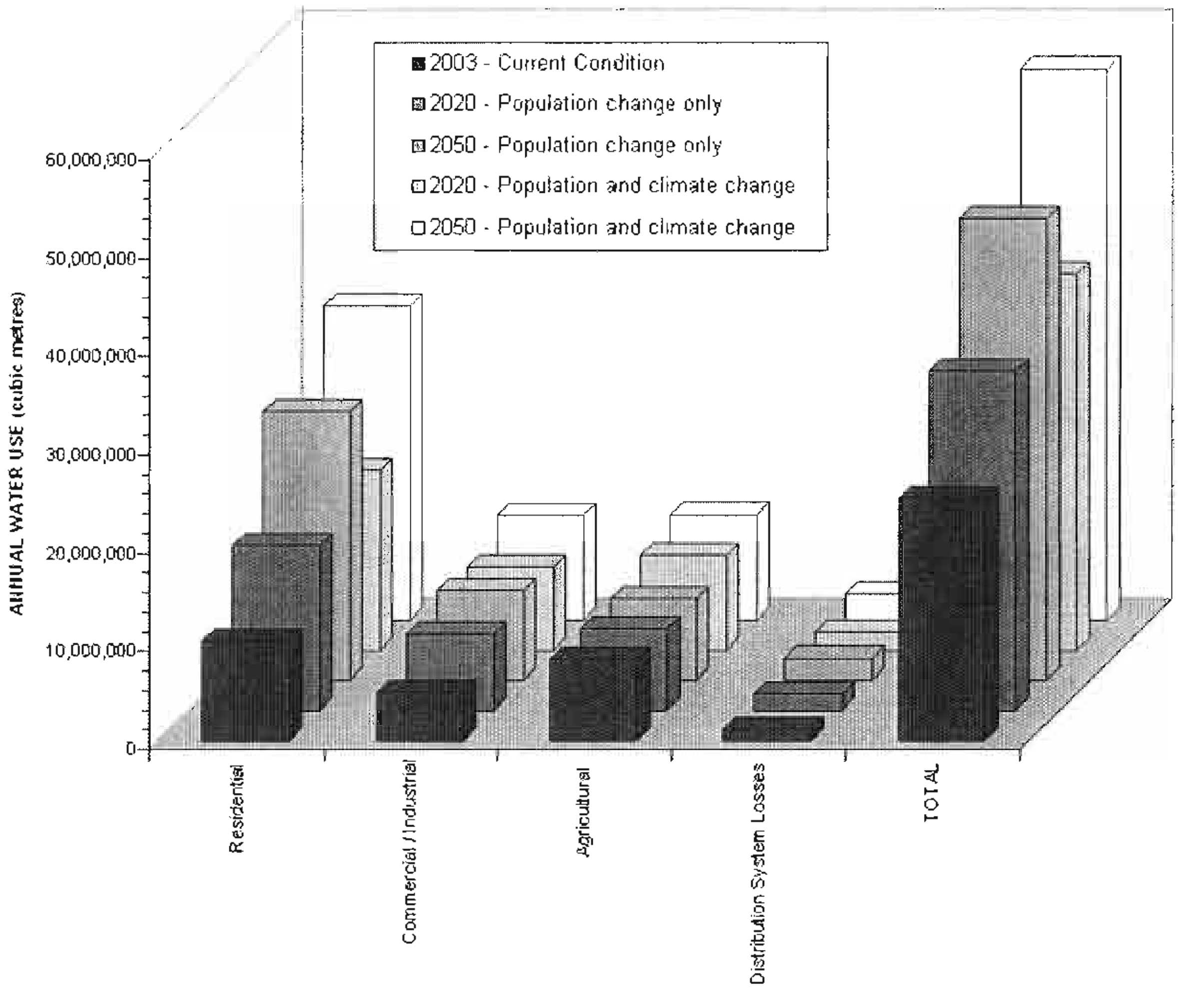

Figure 4 Estimated annual water use in the Trepanier Landscape Unit by land use.

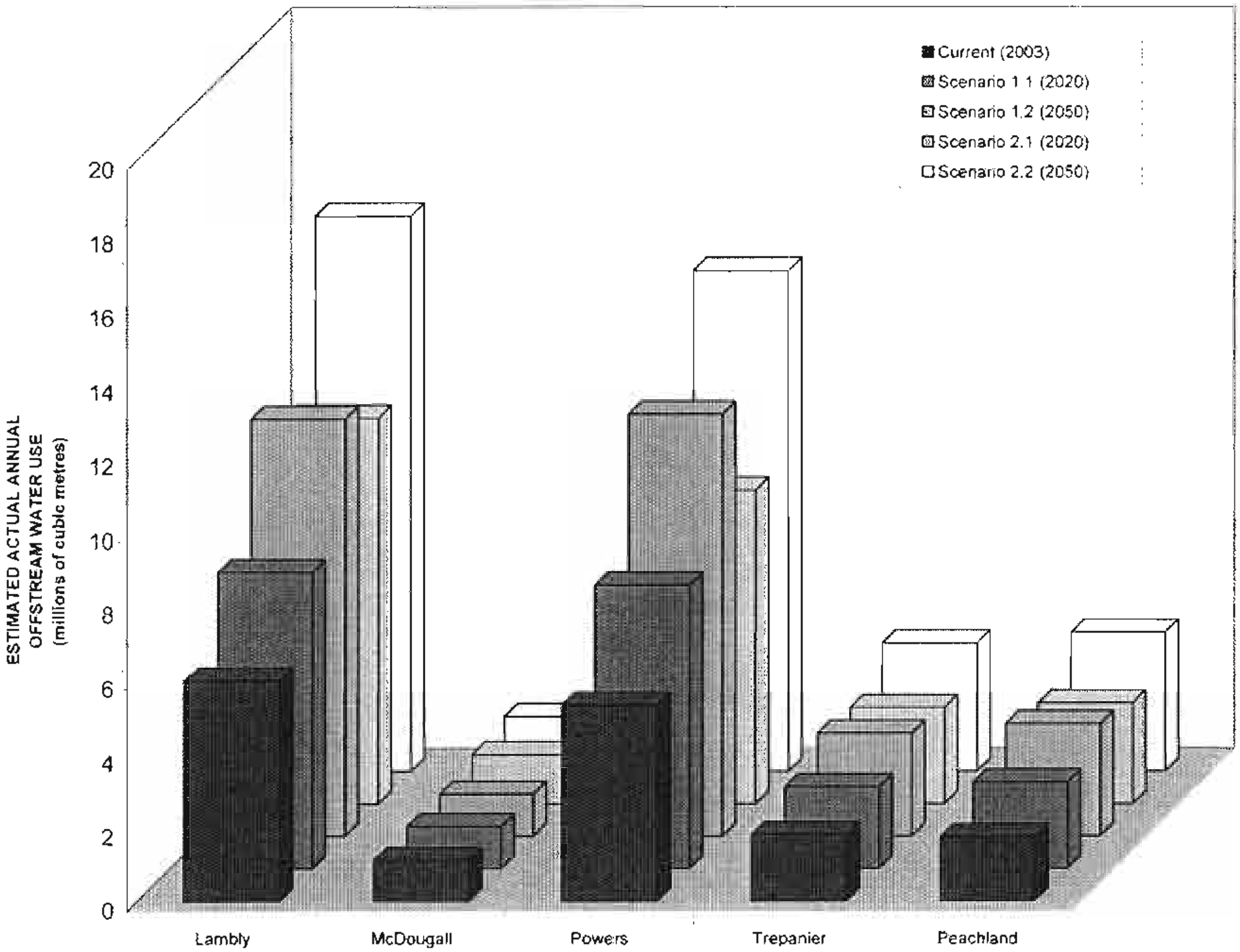

Figure 5 Estimated actual annual offstream water use at the mouths of the five principal streams in the TLU.

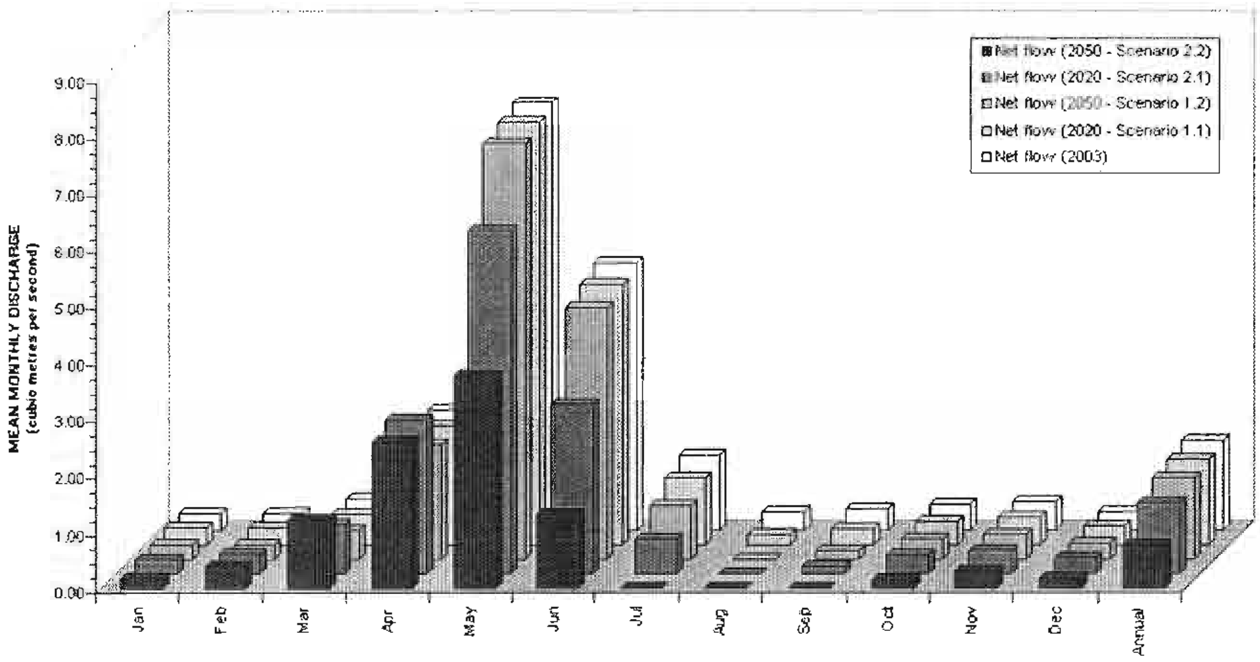

Figure 6 Net flows: Lambly Creek at the mouth.

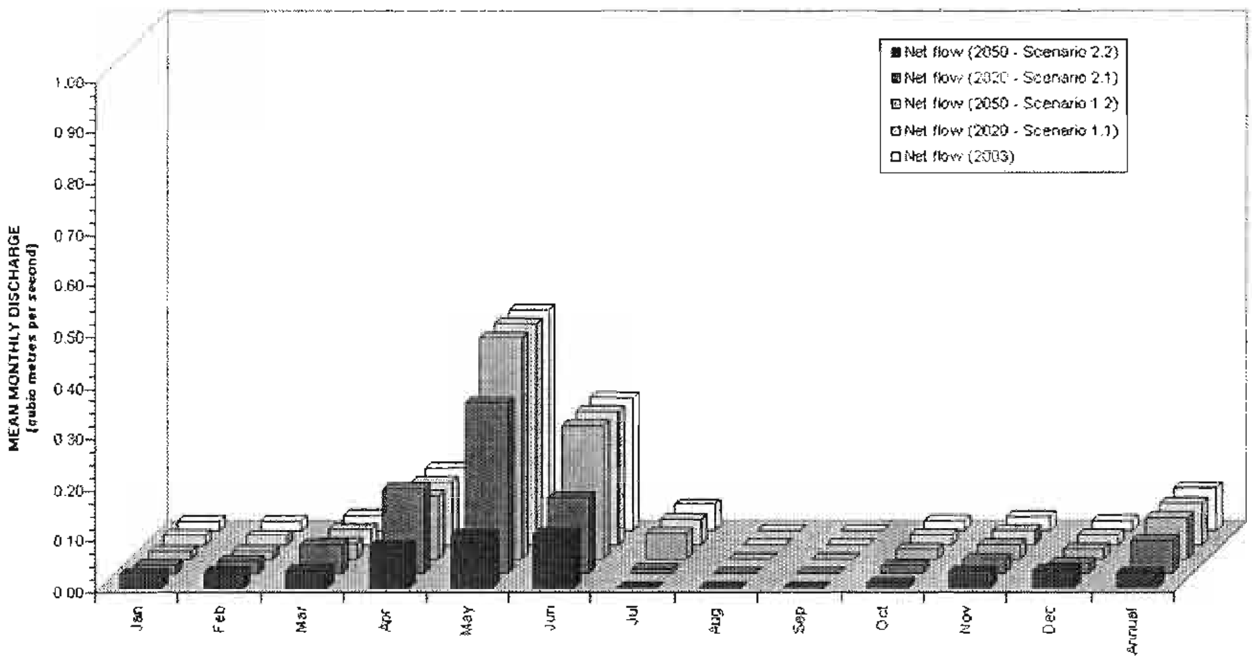

Figure 7 Net flows: McDougall Creek at the mouth.

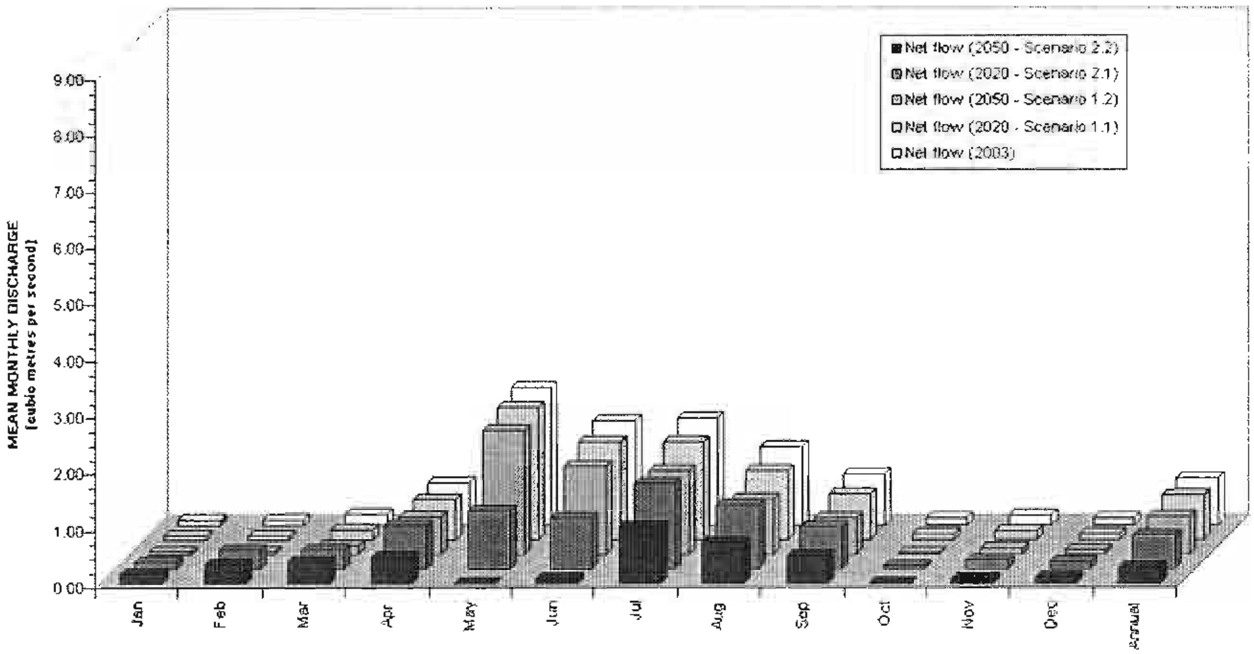

Figure 8 Net flows: Powers Creek at the mouth.

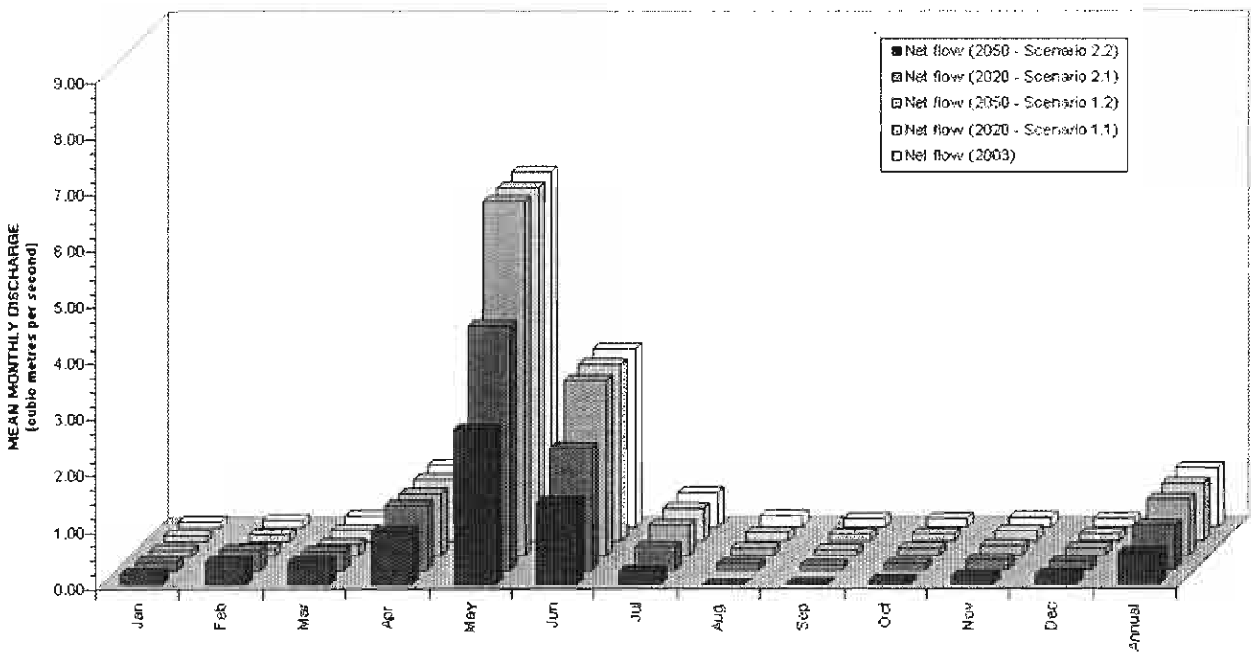

Figure 9 Net flows: Trepanier Creek at the mouth.

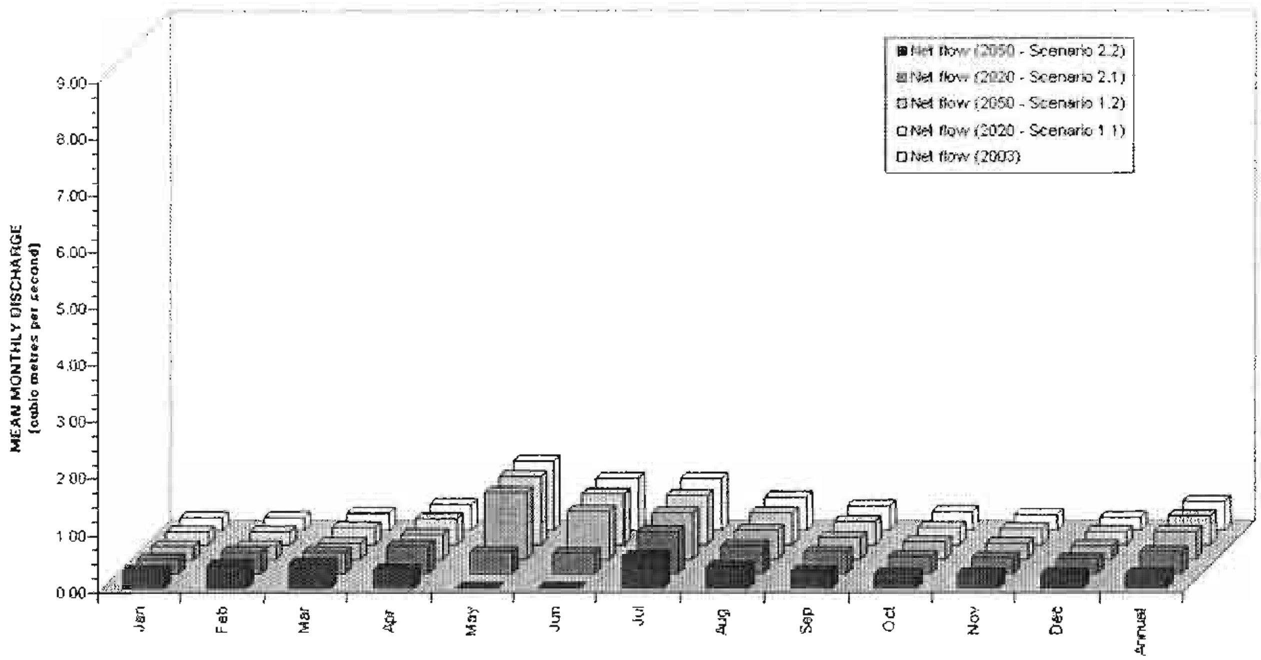

Figure 10 Net flows: Peachland Creek at the mouth.

POST-TASK DISCUSSION

· PETER (U of A) – DISCUSSION OF 1 MAJOR DROUGHT IN LAST CENTURY

The physical limnology of Okanagan Lake

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Abstract

The physical limnology of Okanagan Lake is described, using both a review of observational data, and data obtained from a three-dimensional numerical model. The observational data falls into two classes: forcing functions, such as wind, heating and cooling processes and river flows; and lake response data, primarily its temperature structure at varying times and locations. The numerical model uses a 500 m grid in the horizontal, is fully three-dimensional and includes the baroclinic effects arising from the lake's thermal stratification. The circulation is quantified by means of both the thermal structure and its time variations, as well as by vector fields of time-averaged currents. The response of the lake to specific factors, such as large wind events, is examined. Other aspects considered are near-surface phenomena, such wind-generated waves.

Okanagan Lake, Limnology, Numerical model, Water circulation, Thermal stratification

Introduction

Okanagan Lake is a long, narrow and deep lake located in the Okanagan Valley in south central British Columbia, with lake surface at an elevation of approximately 341.5 m GSC. The lake is about 120 km long, and its width ranges from 1.5 km to 5 km (Figure 1). The lake is divided into three main basins. A sill that rises to a depth of 45 m at Kelowna separates the southern basin from the central basin, and a second sill that rises to 15 m near Vernon separates the large central basin from a considerably smaller northern basin. The maximum depth in the southern basin is 200 m, in the central basin 230 m and in the smaller northern basin 55 m. The lake receives limited freshwater inflow and its turnover time, based on the ratio of lake volume to annual fresh outflow through Okanagan River at Penticton, is on the order of 50 years.

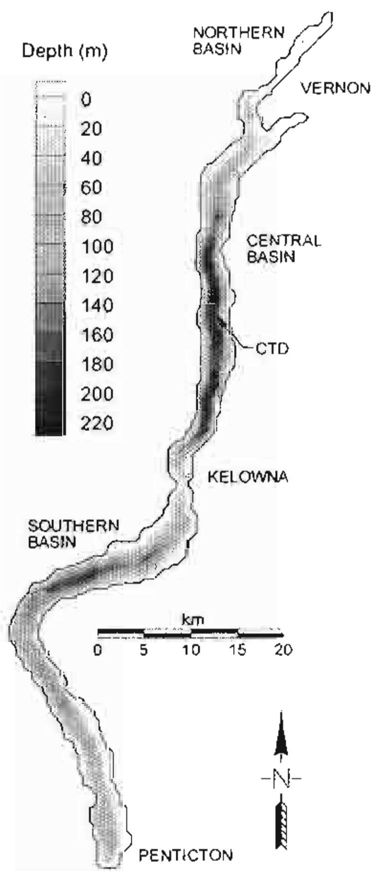


Figure 1. Okanagan Lake bathymetry.

The Okanagan Valley is a long north-south trench in the Interior Plateau of British Columbia that drains south to the Columbia River, with a basin area of approximately 8000 km^2. Elevation ranges from nearly 270 m GSC in the southern valley regions to over 2100 m GSC on the plateaus. The valley extends southward from the divide between the drainage basins of the Columbia and Fraser Rivers to the Columbia Plateau in Washington State. The main valley is occupied by Okanagan Lake as well as Skaha Lake and Osoyoos Lake to its south. A second valley to the east runs from Kelowna to Vernon, and contains Wood and Kalamalka Lakes. A smaller valley to the west runs from southwest of Peachland to the Oliver/Osoyoos area. The Okanagan system has no major tributaries; most of the streams that drain into Okanagan Lake are in narrow valleys with steep gradients, and have watershed divides that are extremely close to the main valley.

The Okanagan Valley is located in the Interior Dry Belt climatic region, in the rain shadow of the Coast Mountains. The basin has a semi-arid climate with annual average precipitation of roughly 350 mm, the majority of which falls as snow. The annual distribution of precipitation is bimodal with a winter peak associated with migrating Pacific storms, and a summertime convective precipitation maximum. A decline in mean temperature and a gradual increase in precipitation occurs moving south to north. Precipitation also increases with elevation. The region is characterized by relatively hot and dry summers and cool winters, so that the lake stratifies over the spring-summer period, and then becomes isothermal at the end of the fall period. The lake becomes vertically homogeneous in about November, and remains so until the early part of April, when surface warming starts the cycle again.

Hydrological and meteorological forcing

River flows

Okanagan Lake drains via the Okanagan River at its south end, near Penticton. The river is regulated to control lake water level. The average annual flow of the Okanagan River is 15.5 m^3/s. Given the lake's volume of about 24.35 km^3, the turnover time can then be crudely estimated as 49.8 years. However, the residence time of any particular parcel of water could be considerably longer or shorter, depending on the circulation as discussed in subsequent sections.

The Okanagan Lake watershed encompasses an area of 6,200 km^2 and is divided into seventeen sub-basins. The majority of the creeks drain very small watersheds. Mission Creek is by far the most significant tributary, contributing roughly one-third of the inflow. Many of the tributaries are subject to licensed water withdrawals for irrigation, public waterworks, and domestic water supplies. Annual flow patterns are influenced by snowmelt, with high flows in May-June (Figure 2). Water is stored in the lake during that period, in order to meet domestic and irrigation demands during the dry months of July to October.

Atmospheric heating and cooling

The local climate is characterized by hot summers and cool winters. Temperatures can reach extreme highs and lows (Table 1). Okanagan Lake is a typical monomictic temperate lake, undergoing an annual alternation of summer stratification and winter circulation. In summer, the surface of the lake can reach temperatures of over 26 °C. The greatest source of heat to lakes is direct absorption of solar radiation. Okanagan Lake receives over 2,000 hours of bright sunshine per year. In summer, surface layers are heated by direct insolation and the heat is distributed by wind. During cooler periods, heat is lost through thermal radiation, evaporation and ice formation.

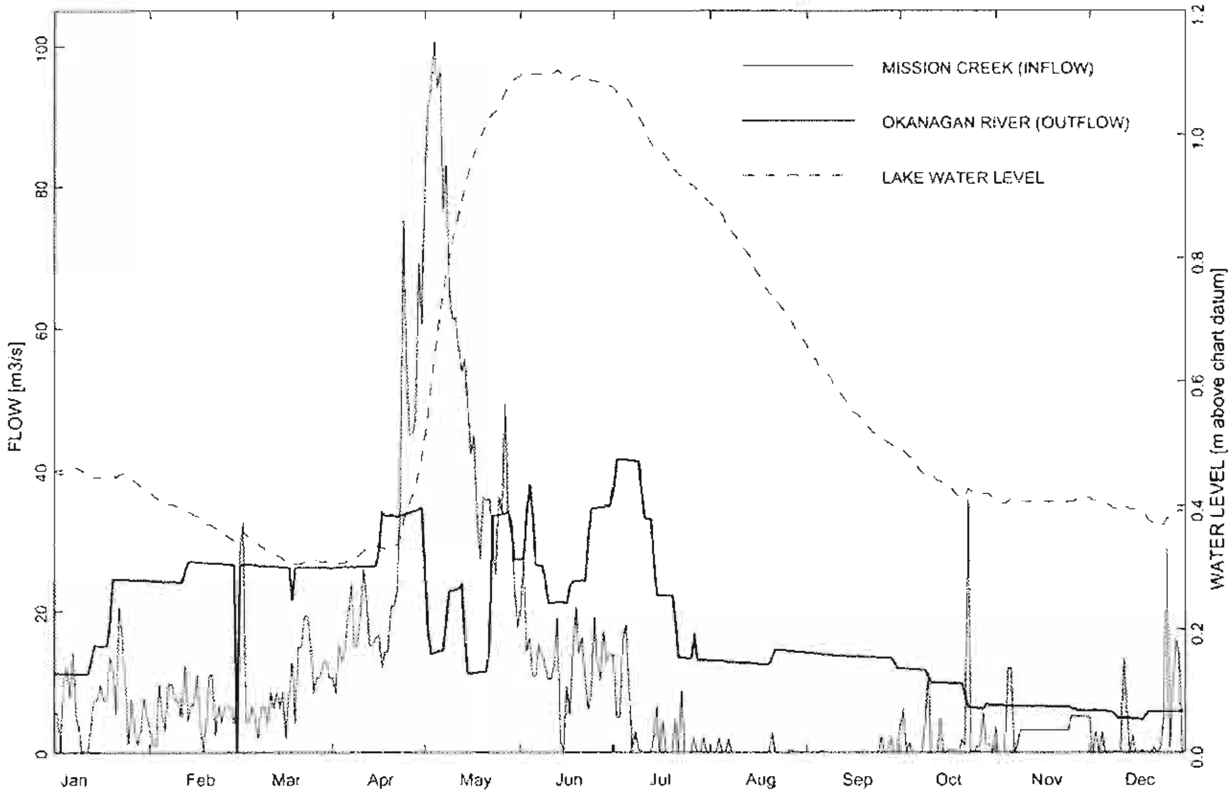


Figure 2. Flow in Mission Creek (inflow to lake), flow in Okanagan River (outflow from lake) and water level in Okanagan Lake, 1998. Okanagan River is regulated.

Table 1. Monthly temperatures 1960-2004

	Penticton Airport			Kelowna Airport		
Month	Minimum	Mean	Maximum	Minimum	Mean	Maximum
January	-22.2	-1.6	14.1	-31.7	-3.3	13.0
February	-20.1	0.8	15.9	-26.1	-0.8	14.5
March	-14.8	4.4	21.1	-19.4	3.7	21.1
April	-6.1	8.9	29.4	-8.3	8.7	28
May	-3.9	13.6	33.5	-3.9	13.5	33.5
June	0.0	17.8	36.7	0.0	17.5	36.8
July	2.8	20.8	39.0	2.8	20.4	38.7
August	3.2	20.2	38.3	1.1	19.5	38.9
September	-2.8	14.8	35.2	-5.6	13.9	35.0
October	-13.6	8.8	26.4	-15.5	7.3	25.8
November	-22.3	3.4	18.9	-28.4	1.6	20.6
December	-27.2	-0.7	14.1	-35.6	-2.4	13.9

Winds

Wind performs a very important role in lake stratification. If solar influx were the only phenomenon involved in heating, the vertical thermal structure would approximate the attenuation profile of solar radiation. Warmer, less dense and very stable water would overlie cooler, denser water. However, this is not observed; rather, a relatively uniformly mixed upper portion of the lake is isothermal, often well below the photic zone. Convection currents alone are insufficient to produce the thermal profile observed during thermal stratification. Direct absorption of solar radiation accounts for only about 10% of the observed heat distribution. Most of the heat distribution profile results from wind-induced mixing and circulation.

Long-term wind records are available from several AES stations around Okanagan Lake, including Penticton airport, Kelowna airport and Vernon. The prevailing winds at Penticton are primarily in the north-south direction (Figure 3), corresponding to the orientation of the lake valley. The largest storms are from the south and occur primarily in winter. The winds at Kelowna are much weaker than those at Penticton, and are calm during a greater percentage of the time. The Kelowna airport located in the next valley to the east of the lake valley, and is sheltered by topography. As such, it is not representative of the winds over the lake. The Vernon wind station is located at the head of Kalamalka Lake, in the same valley as Kelowna airport, and similarly is not a good indicator of the winds over the lake. Anecdotal evidence indicates that west winds blowing down the Peachland valley can split over the lake at Squally Point, creating northward winds to the north and southward winds to the south.

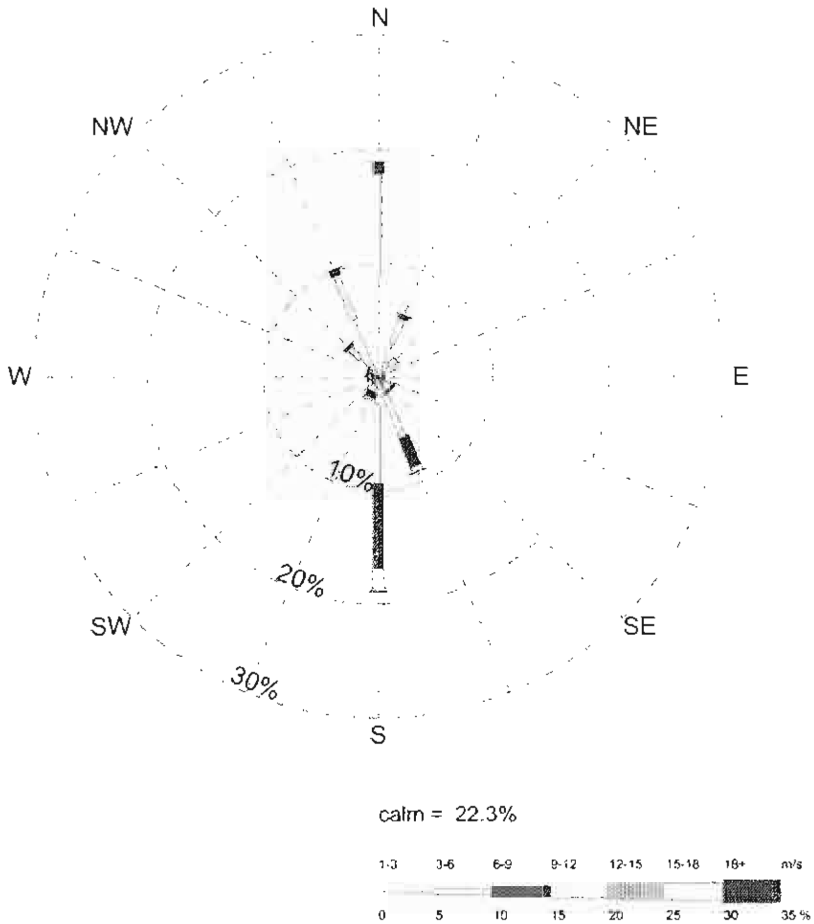


Figure 3. Wind rose for Penticton Airport, 1960-2004.

Wave climate

Although the wave climate is not usually considered in a description of physical limnology, waves are important for the role they play in the coastal geomorphology of the lake. While surface waves cause little displacement of deeper water masses, the shear due to the orbital motion caused by surface waves may increase the vertical eddy viscosity and diffusivity somewhat, and thus plays a role in temperature distribution and circulation. In a limnological sense, surface waves are important in near-shore areas where they can affect the coastal morphology if moveable sediments are present, and are also important in clearing out fine sediments that may be deposited on spawning beds, for instance. With respect to coastal morphological processes, two types of transport need to be considered. Longshore transport results from the stirring up of sediments in the upper beach zone by breaking waves. Once suspended, the sediment is moved parallel to the beach if the incident wave direction is not normal to the beach face. Waves approaching a beach at an angle move sediment by two mechanisms. First, the wave moves the sediment a short distance up the beach with the arrival of each wave and second, waves breaking at an angle create a longshore current that transports sediment along the beach. The direction of longshore transport is directly related to the direction of wave approach and the angle between the waves and the shoreline. Due to variability in the direction of wave approach and the orientation of beaches in any reach of the shoreline, reversals in the net littoral transport direction can be common, resulting in pockets or cells of erosion and accretion. Furthermore, in the nearshore area, wind-driven currents are present whenever wind-driven waves are present, and their interaction tends to increase sediment transport rates.

An example of the wave field around Kelowna is presented as an example of the variability that can develop in the near-shore region. The wave field is generated by a sequence of two numerical models. First, a large-scale model of the entire lake is used to determine wave properties (significant wave height, peak period and wave direction) on a relatively coarse grid, 500 m in this case. Next, a high resolution model is used to determine the effects of shallower depths on the wave field, right up to the shore line.

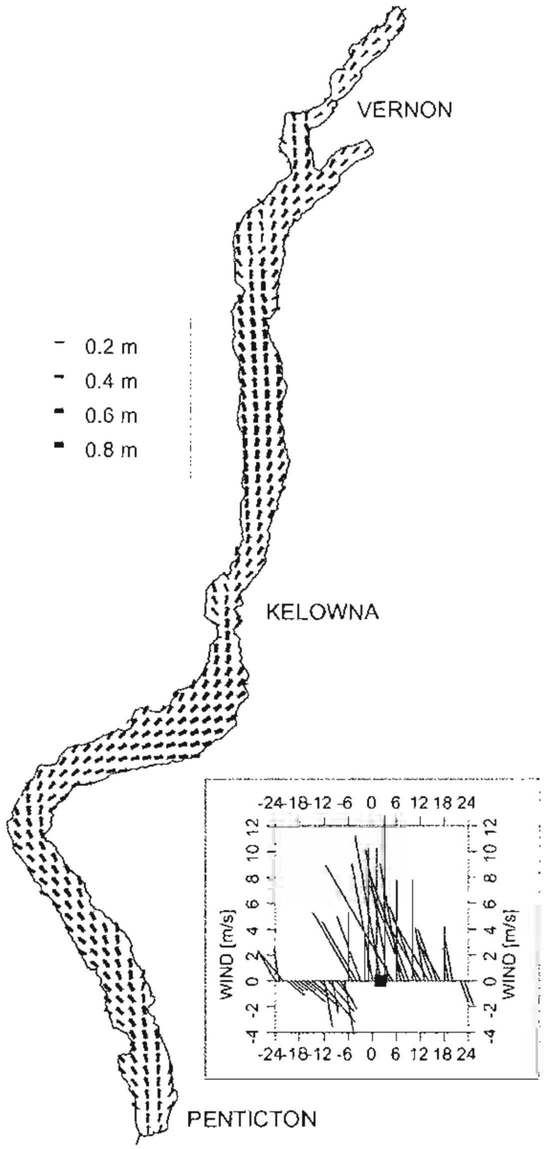


Figure 4. Wave field generated by Donelan model during strong wind from south, 2:00 May 27, 1998. Wave height is represented by vector thickness. Every second vector is shown on the 500 m grid.

The full-lake wave model (Donelan, 1979) is a parametric model, implying that extensive observational data is embedded in the model, simplifying greatly the calculations. The Donelan model provides values of wave height, wave period and wave direction at all grid points in the basin, typically for every hour of the simulation period. The model computes deep-water waves only; that is, the effects of shoaling and refraction are not incorporated. The model has been validated extensively against data from Lake Ontario and the Strait of Georgia, and performs well in enclosed basins such as Okanagan Lake.

The model requires a two-dimensional, time-dependent wind field as input. While wind stations are located at Penticton, Kelowna, and Vernon, only the winds at Penticton are considered representative of the winds over the lake, as discussed above. In order to represent the changes in wind direction over the lake as it funnels down the valley, the two-dimensional wind field for the Donelan simulation was created by rotating the Penticton wind according to the orientation of the valley at each grid cell in the model. The effects of fetch (distance from shore) and duration (length of time the wind has been blowing) on the wind-generated wave field are automatically incorporated in the model.

Figure 4 shows a typical wave field computed by the Donelan model. In general, wave heights are relatively uniform, but one can see sheltering effects, and the way in which the wave directions follow approximately, but not completely, the main channel orientations of the lake. A statistical analysis can be applied to the waves generated by the Donelan model for a long-term wind record to calculate wave heights for various return periods. Table 2 below summarizes the wave heights from the south and north in the central basin (at the location marked "CTD" in Figure 1), based on analysis of the Donelan model results from 1960 to 2004. Since winds from the south are stronger than winds from the north for a given return period, it follows that waves from the south are bigger than those from the north for any return period. However, it is interesting to note that for winds of roughly the same magnitude, the waves from the north are somewhat larger than waves from the south, due to the effects of fetch at the specific location chosen.

Table 2. Wind at Penticton and deepwater wave height in central basin for various return periods.

	Winds from the south		Winds from the north	
Return period (yr)	Wind (m/s)	Wave height (m)	Wind (m/s)	Wave height (m)
0.5	15.3	0.74	11.5	0.49
1	16.2	0.80	12.6	0.57
2	17.2	0.85	13.8	0.66
5	18.4	0.93	15.3	0.79
10	19.4	0.99	16.4	0.91
20	20.3	1.04	17.5	1.03
50	21.6	1.12	19.0	1.20
100	22.5	1.18	20.1	1.34
200	23.4	1.23	21.2	1.48

The wave field computed by the Donelan model can then be applied to a nested model of a small region, using the model SWAN (Holthuijsen et al., 2000). SWAN utilizes a finite difference scheme to compute random, short-crested wind-generated waves and allows for spectral wave input at specified boundaries. The model incorporates physical processes such as wave propagation, wave generation by wind, white-capping, shoaling, wave breaking, bottom friction, sub-sea obstacles, wave set-up and wave-wave interactions in its computations. It is thus well suited to computing the changes in the wave field as it propagates from the deep waters of Okanagan Lake towards the shore. In this example, the Kelowna waterfront is resolved with a grid spacing of 10 m. Figure 5 is a typical output product, showing how wave direction changes as the waves approach the shallower water at an angle, a process known as refraction. Over much of the area, waves are propagating within a breaker zone, so that in fact wave height is controlled by local water depth, independent of its deepwater value. The control is such that the peak to trough wave height cannot be greater than 70% of the local stillwater depth. Furthermore, this near-shore control allows smaller offshore waves generated during small storms to have an impact similar to that of larger waves.

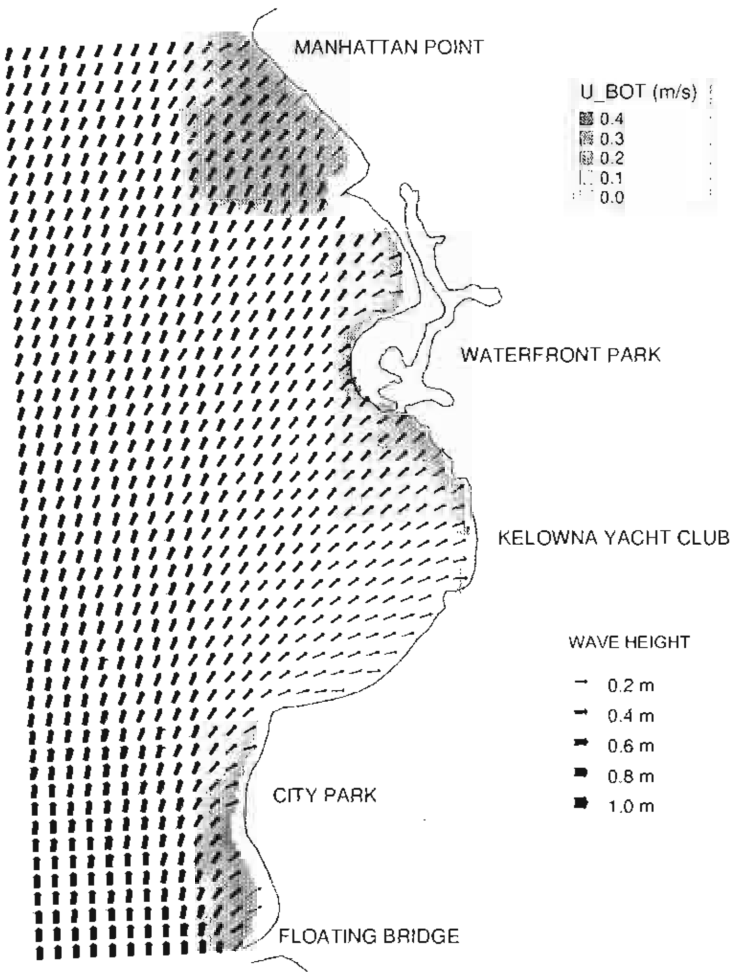


Figure 5. SWAN wave model output. Wave height (m) is shown by vector thickness. Every fourth vector is shown; grid size is 10 m. Orbital velocity (m/s) at the bottom of the water column is shown as greyscale shading. Boundary conditions are wind and waves from the south.

Waves cause water particles to move in an orbital motion, with velocities and orbit sizes decreasing with depth. Where the water is shallow enough, the orbital velocity is strong enough to lift sediments into suspension. This suspended sediment can then be carried by local currents, until it eventually settles. The SWAN model also outputs the orbital velocity near the lake bottom at each grid cell, shown in Figure 5.

Thermal stratification

Okanagan Lake is a typical temperate monomictic lake, that is, a lake that mixes once per year. The seasonal pattern of the thermal structure can be observed in Figure 6, which shows a series of profiles

at approximately monthly intervals. The profiles show data collected by a CTD (conductivity, temperature, depth) probe at the site marked on Figure 1.

One notes first the isothermal character in the winter, followed by the start of stratification as spring commences, both in terms of a warmer surface layer, and a deepening thermocline. During summer, the stratification intensifies, but the upper layer thickness remains relatively constant. The surface layer of nearly uniform, warm, circulating and fairly turbulent water, the epilimnion, overlies the hypolimnion, a colder, relatively undisturbed region.

As fall approaches, the temperature contrast between the surface waters and deeper waters decreases. Interestingly, the upper layer begins to deepen in the fall, as wind events become more intense, and as the stabilizing thermal stratification begins to break down. Ultimately, the lake returns to near-isothermal conditions in early winter, eventually reaching 4 °C, the temperature of maximum density. The loss of stratification means there is relatively little resistance to mixing, and wind energy on the

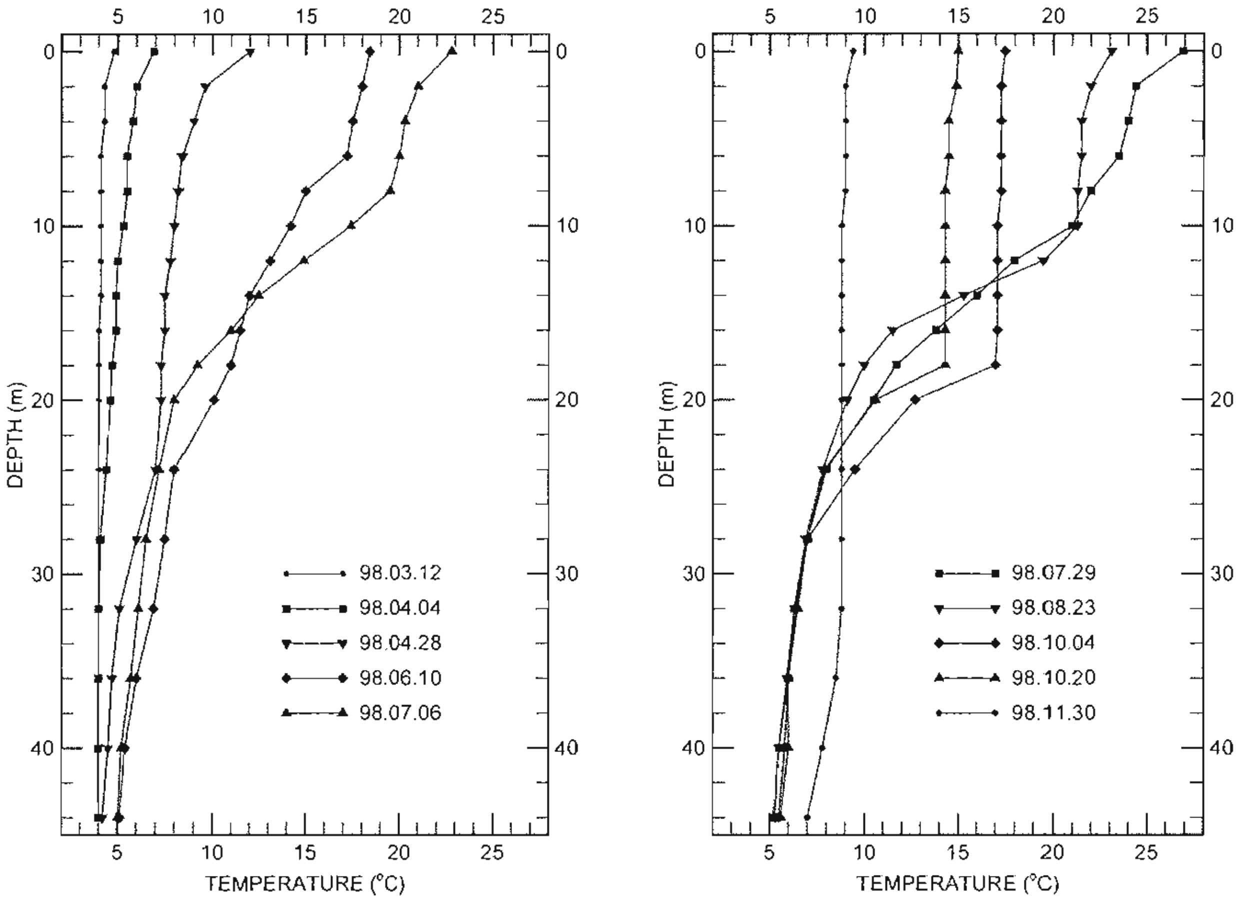


Figure 6. Observed temperature profiles in central basin. Left-hand panel: spring/summer lake warming. Right-hand panel: summer/fall lake cooling.

surface is adequate to circulate the entire water column.

The above annual sequence can also be viewed as a contour temperature field on a graph of depth versus time, Figure 7. The features noted in the individual profiles are apparent, in particular the development of the stratification which ultimately leads to a two-layer system, the persistence of this two-layer system over the summer months, and its decay in the fall. It is a significant feature that the isotherms deepen in the fall, indicating that the rate at which heat is mixed downward exceeds the rate at which cooling occurs at the surface.

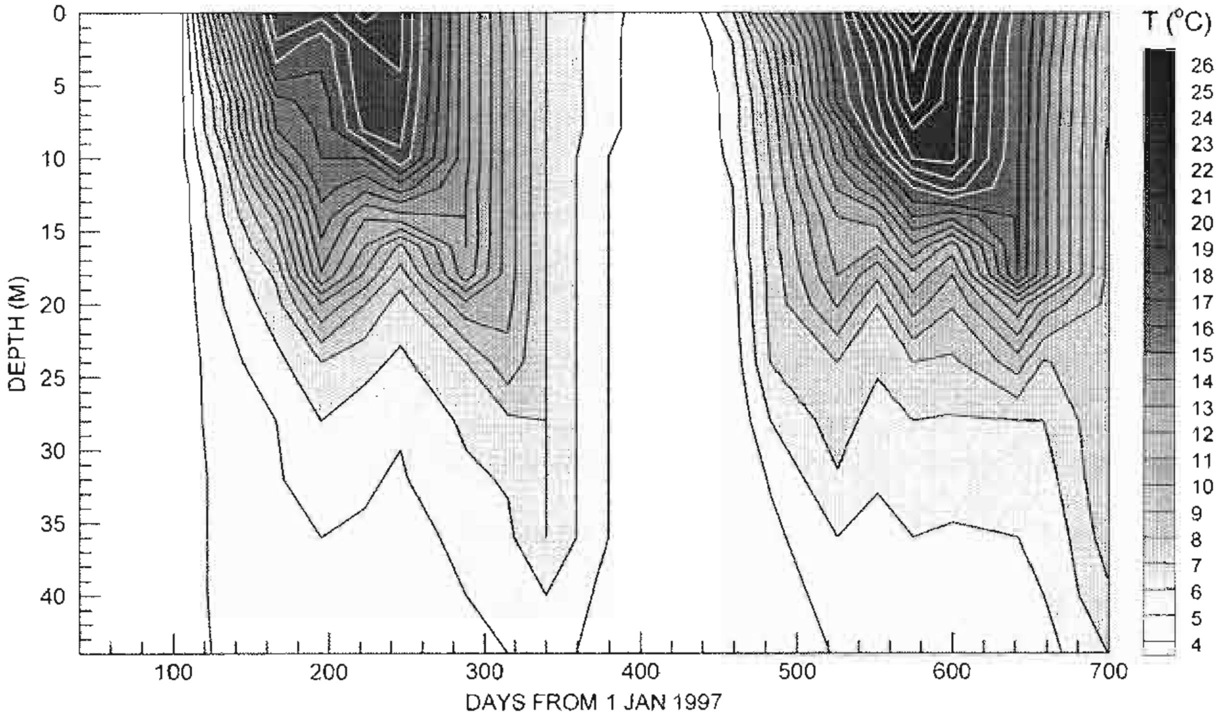


Figure 7. Temperature in central basin from Feb. 9, 1997 to Nov. 30, 1998. Contours were created by interpolating monthly profiles. The lake is stratified in summer and is isothermal in winter.

Three-dimensional lake modeling

While the observational data is instructive in terms of the thermal structure of the lake and its long-term variation, a greater understanding of the processes governing the short-term temperature variations and water movements can be gained by using a model to create a three-dimensional picture of the circulation in the lake. This implementation of Hay and Company's proprietary model H3D for Okanagan Lake was developed under contract from the City of Kelowna as part of an overall limnology study conducted in 2000 (Hay and Company, 2001). The model has been modified slightly since that study with the addition of river flows and in the model's treatment of fluctuating water levels. The simulation year 1998 is discussed herein, during which some significant meteorological events occurred.

Model description

The proprietary three-dimensional model H3D was used for the Okanagan Lake simulations. H3D is derived from GF8 (Stronach, Backhaus and Murty, 1993), developed for Fisheries and Oceans. H3D is a three-dimensional time-stepping numerical model that computes the three components of velocity (u,v,w) on a regular grid in three dimensions (x,y,z), as well as such fields as temperature, sediment and contaminant concentrations.

The spatial grid may be visualized as a number of interconnecting computational cells collectively representing the water body. Velocities are determined on the faces of each cell, and non-vector variables, such as temperature or sediment concentration, are situated in the centre of each cell. All cells have identical x and y dimensions, 500 m in this study.

In the vertical, the cells near the surface are closely spaced, with thickness of 2 m for depths less than 30 m. Layers become progressively thicker with depth, so that the bottommost cell extends from 200 m to 250 m, in the deepest part of the lake. The increased vertical resolution near the surface is needed because much of the variability (stratification, wind mixing, inputs from streams) is concentrated near the surface. The current implementation of the model uses a variable number of surface layers that appear and disappear as the lake level rises and falls.

Some specific aspects of the Okanagan Lake implementation are discussed below.

- Wind forcing causes currents within enclosed water bodies as well as water level differences. Consideration of wind forcing is also important since wind energy has a significant impact on vertical mixing. Wind stress acting at the water surface for the entire lake was based on data from the Penticton Airport station, with direction modified in each cell to be approximately parallel to the local axis of the lake.

- Other meteorological data, in addition to winds, is also required in order to compute heat flux into the water body. Data from Penticton Airport for wind speed, dry bulb air temperature, wet bulb air temperature and cloud cover, along with water surface temperature from the model, were used to compute the heat flux at the lake surface. In the summer, heat input leads to increased stratification. Near-surface effects, such as contaminant concentrations and water velocities, are generally more significant when the water body is stratified. In the winter, cooling can lead to static instabilities and overturning in lakes, as well as ice cover. Since the model was run over all seasons, the ability to simulate winter cooling is important.

- Turbulence modelling is important in determining the correct distribution of velocity and scalars such as contaminants. The diffusion coefficients for momentum and scalars at each computational cell depend on the level of turbulence at that point. H3D uses a shear-dependent turbulence formulation in the horizontal, and a shear- and stratification-dependent formulation in the vertical for momentum. These parameters have been shown to work well when simulating the annual cycle of temperature Okanagan Lake, and are consistent with current practice. For scalars, constant horizontal eddy diffusivity is used, and the vertical diffusivity is similar to the vertical eddy viscosity, but scaled by a fixed ratio.

- The model operates in a time-stepping mode over the period of simulation, with a timestep of 180 s. During each time step, values of velocity, temperature, and concentrations of scalars are updated in each cell. Typically, data were archived on a 12-hour basis, so that a manageable amount of data was generated for subsequent analysis.

Model calibration and validation

The most significant factor in lake dynamics is the manner in which the lake becomes stratified due to heat input over the course of the spring and summer, and then cools over the fall. As heat is added, it sets up stratification in the lake, which acts as a barrier to vertical mixing, so that additional heat mainly serves to increase the temperature of the surface layer and not deepen the layer. Additionally, the presence of the stratification leads to a two-layer system, in which the two layers, the surface layer (epilimnion) and the deep layer (hypolimnion), can have considerably different motions.

The goal in calibrating this model was to choose the various model parameters so that in conjunction with the known forcings of wind, cloud cover, air temperature and humidity, the annual cycle of temperatures in the lake was reproduced. If information on water currents were available, that data could have been also used for calibration. For this study, however, only temperature data were available. The correct reproduction of the temporal and spatial variability of the temperature field means that the model satisfies two important criteria:

1. The model can adequately simulate the behaviour of scalar fields considering the processes of advection and diffusion (in this study temperature is considered but essentially any conservative water quality parameter could be used);

2. The model sets up a realistic density field so that internal motions, often referred to as internal seiches, are reproducible. This second point is important, because it means that a temperature calibration actually addresses both the transport of scalars, as well as the dynamics of the lake.

The calibration focused on the reproduction of the temperature signal. Many runs using different model parameters were executed in order to determine the optimal settings. A good reproduction of the annual temperature cycle was achieved, as indicated in the Figure 8, which compares computed profiles with selected profiles in the central basin ("CTD" in Figure 1). Although there are some differences, the general ability to reproduce a wide range of profiles throughout the year is quite good. The only major shortcoming is a tendency for warmer water to penetrate too deeply in the fall months.

After calibration, the model was validated against thermistor string data collected near the Kelowna sill between April 25 and July 13, 1998, which captured the internal seiching of the lake. Most observed spikes in temperature were reasonably reproduced by the model. It was found that by increasing the drag coefficient, the amplitude of the modelled spikes could be increased, but at the cost of deterioration in the long-term calibration. Since the wind field was not well-resolved by the available observing stations, it was felt that it would not be useful to pursue further refinements to the model by means of changing drag coefficients until better wind data became available.

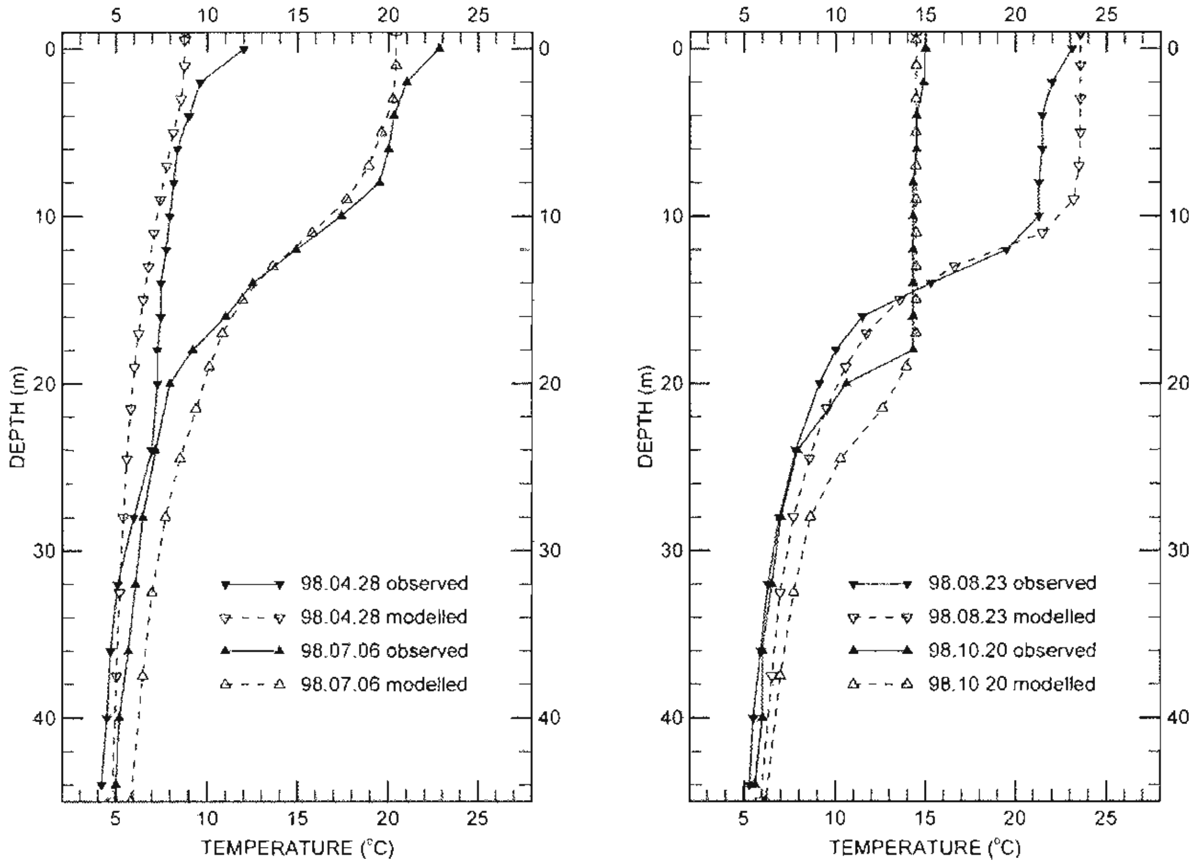


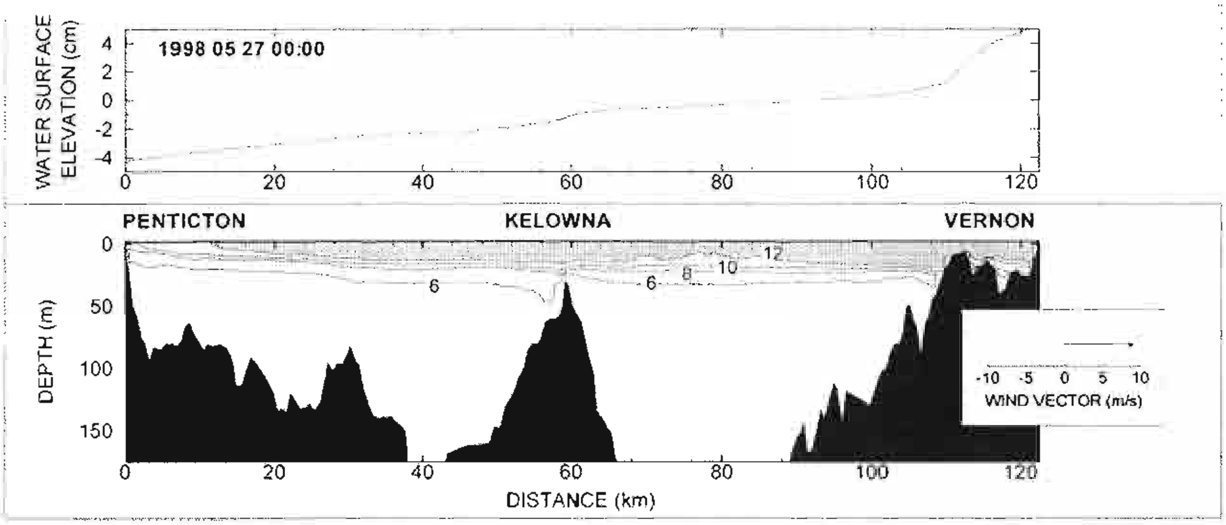
Figure 8. Model calibration – comparison between model results and selected profiles observed in central basin.

Model results – seiching and circulation

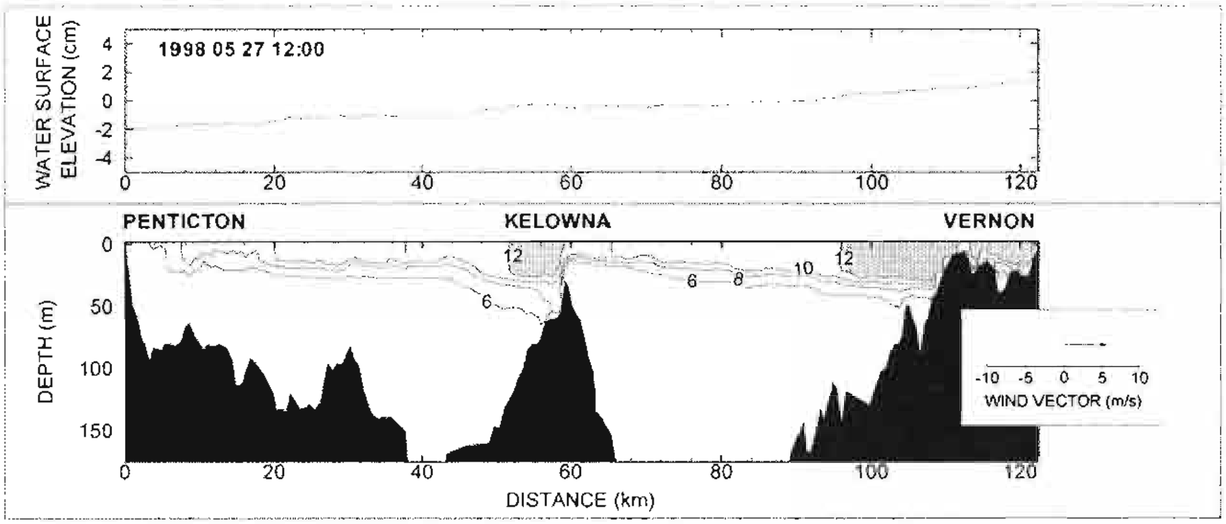
The model provided considerable information on the circulation in the lake, particularly with respect to water quality management issues. One element of the circulation of considerable general interest is the degree of internal seiching that occurs in the lake, and the strong impact that the sill near Kelowna has on this seiching. The seiching transports surface water quite deep, along with any potential pollutants or micro-organisms found in the surface water which could contaminate drinking water intakes, depending on their depth. For example, the original motivation for the Okanagan Lake model study was the 1996 cryptosporidium outbreak in Kelowna.

A numerical simulation of 1998 generated by the calibrated model illustrated several seiching events. An event starting May 27 is shown in Figure 9. The wind response consists of firstly a build-up of water at the north end of the lake as indicated by the water surface trace in the top panel. At the same time, the lake splits into two major basins, with the sill at Kelowna acting as a barrier. Once the wind dies down, the surface slope relaxes to a flat condition, as do the interface slopes. The process by which the interface relaxes, however, is a series of propagating waves, such that the vertical location of the interface fluctuates extensively with time, particularly in the vicinity of Kelowna. The sequence of panels in Figure 9 show one such wave propagating from north to south.

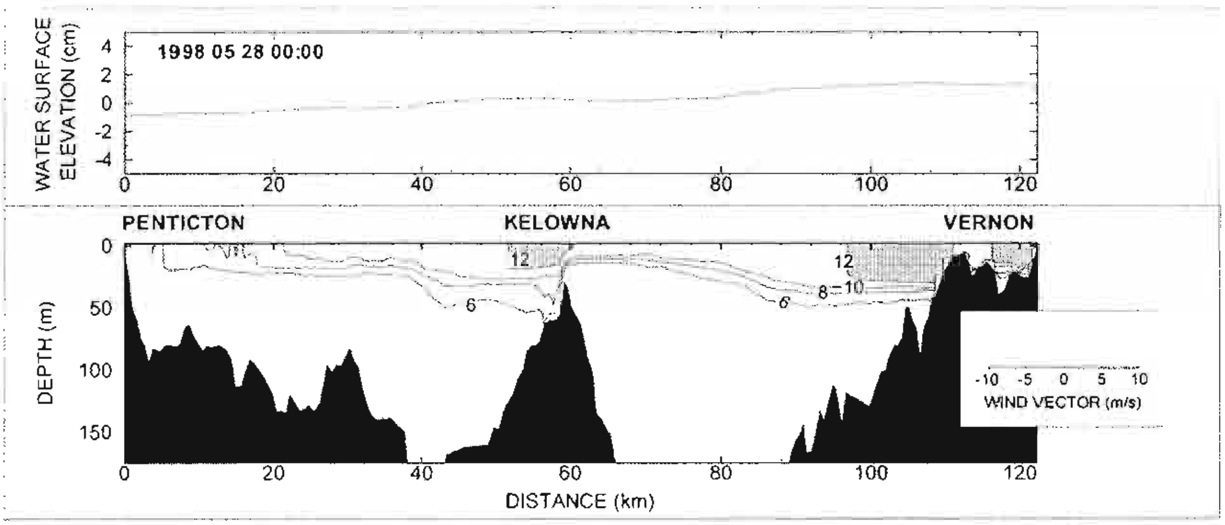
(a)


1998 05 27 00:00
WATER SURFACE ELEVATION (cm)
PENTICTON
KELOWNA
VERNON
DEPTH (m)
WIND VECTOR (m/s)
DISTANCE (km)

(b)


1998 05 27 12:00
WATER SURFACE ELEVATION (cm)
PENTICTON
KELOWNA
VERNON
DEPTH (m)
WIND VECTOR (m/s)
DISTANCE (km)

(c)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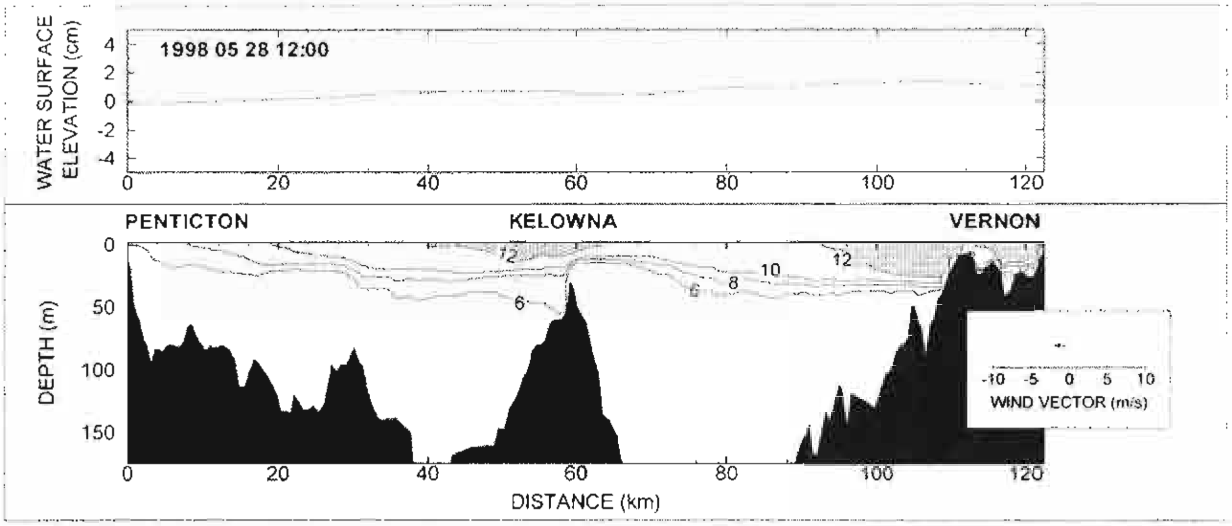
KELOWNA
VERNON
DEPTH (m)
WIND VECTOR (m/s)
DISTANCE (km)

(d)



(e)

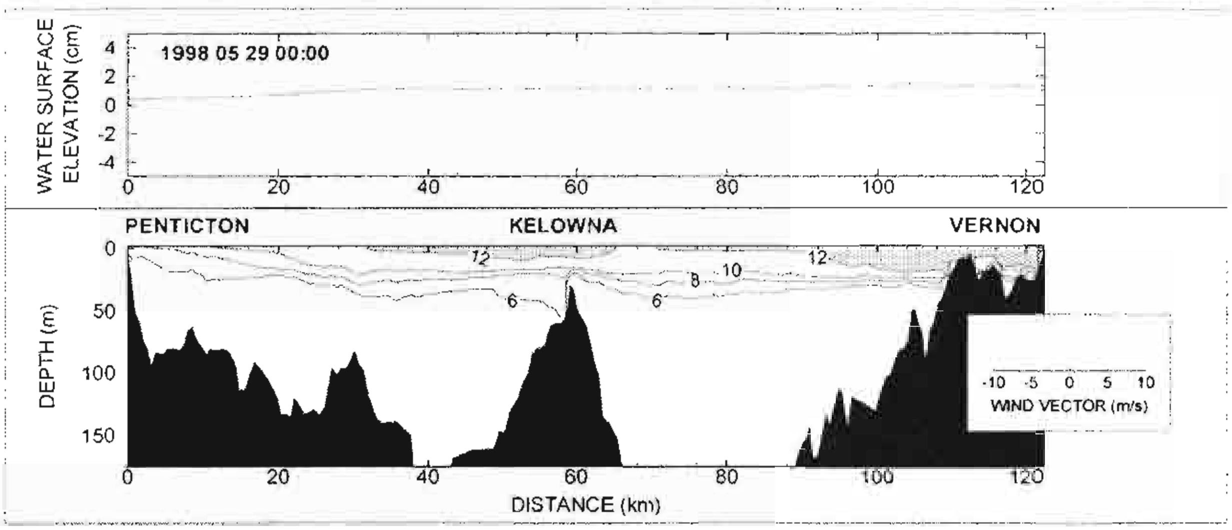


Figure 9. Water surface elevation (upper panel) and water temperature contours (lower panel) at 12-hour intervals during internal seiching following a wind event. The lake bottom is shaded black, and water above the 12 °C contour is shaded grey for reference. The aspect ratio on the water surface elevation has been exaggerated greatly and the wind vector is also shown at each time. (a) The isotherms are relatively flat at the start of the wind event. Wind setup has caused water to pile up at the northern end of the lake. (b) Wind continues to push warm water to the north. The sill at Kelowna has a strong influence on stratification by separating the southern and central basins. (c) Wind is calm and relaxation begins. (d) Warm water that was piled up at the north end of the lake flows south as the seiche propagates across both the central and southern basins. (e) The warm water continues to flow south, the 12 °C layer thins, and the seiche begins to interact with the sill at Kelowna. Note that the propagation of the internal wave from north to south is best seen by following the 6 °C contour in panels (c) through (e).

The seiching of the lake can also be visualized by examining the vertical velocities during the event. During the internal seiching, the interface sloshes back and forth in each basin, as if the lake were being tilted to the north and south. A snapshot of vertical velocities during the seiche shows the northern part of each basin experiencing downwelling while the southern portions of each basin undergo upwelling (Figure 10).

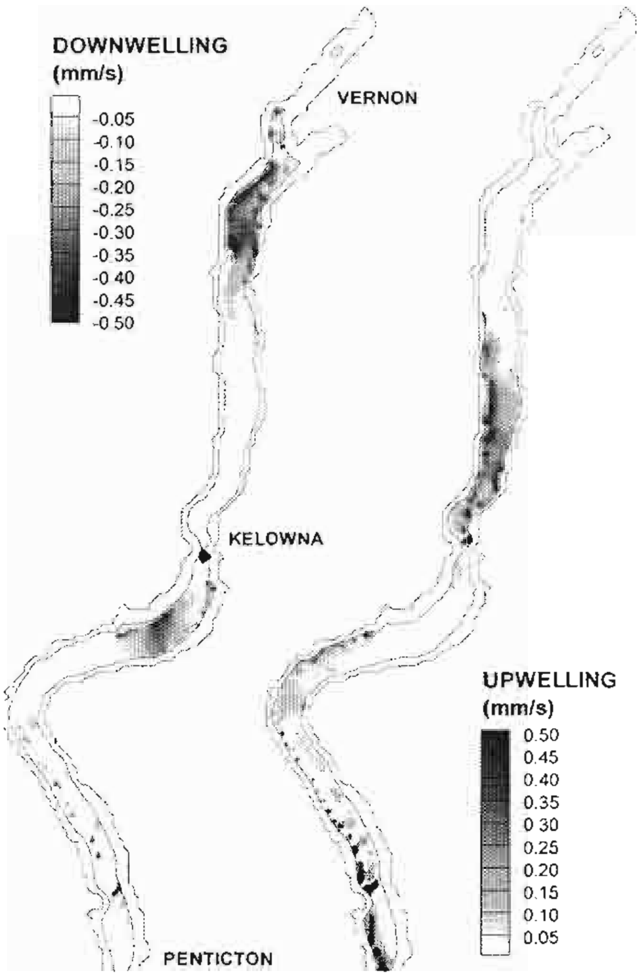


Figure 10. Vertical velocity in layer 14 of model (26 to 30 m depth), during seiche, 12:00 May 27, 1998. Downward and upward velocities are shown in separate panels for clarity.

The dramatic nature of the water movement during the seiche can be seen by examining the vertical excursion of various temperature contours (Figure 11). During the initial period of relatively calm winds, the isotherms move vertically on the order of one metre. After the wind event beginning May 24, and especially the major event after May 27, the isotherms experience significant vertical movement. This is due to the internal waves propagating back and forth in the basin, as seen in Figure 9. The surface water (12 °C) undergoes the biggest vertical movement, plunging up to 25 m in depth and resurfacing. The seiching mixes the heat from the surface into the water column so that the isotherms have descended more than 10 m over the course of roughly 10 days.

The model is also able to provide information about the horizontal patterns of water movement at different depths in the lake. Such data could be important for predicting movement of pollutants, for example. Figure 12 shows a typical velocity field computed by the model, for May 27, 1998, 12:00, for the surface layer and a mid-depth layer (40-50 m depth). The opposing flows are the result of different forces acting in the two layers. Wind stress acting directly on the near-surface waters causes a surface flow to the north. In turn, the northerly surface flow results in a surface slope acting in the opposite direction, driving flow in the deeper layer towards the south. The mass flow from the upper and lower layers are balanced such that there was no net transport across any vertical section except for a small amount required for surface setup.

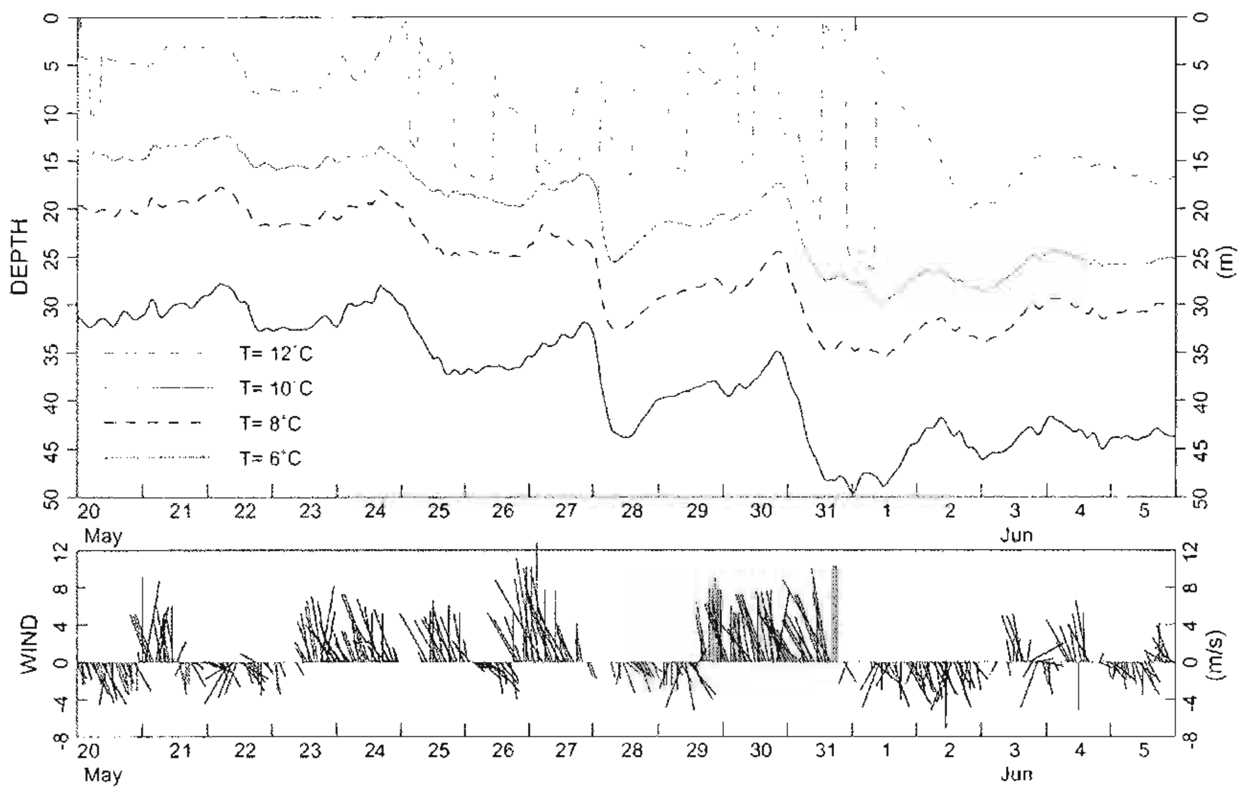


Figure 11. Temperature isotherms and wind at Penticton, May 20 to June 5, 1998, including seiching event of May 27 to 31. Temperature contours are taken from numerical model at centre of central basin. Note positive values on stick plot indicate winds from the south and negative values indicate winds from the north.

Conclusions

Lake Okanagan exhibits features of physical limnology that could be readily predicted by a brief examination of the basic parameters: lake geometry, seasonally-varying meteorological forcing, and river inflow and outflow. However, by conducting a more rigorous study of the lake, using various sophisticated numerical models, several unique and significant features have been identified.

A striking phenomenon in the lake is the degree and extent of internal seiching that occurs, likely related to the aspect ratio of the lake. For a given longitudinal wind stress, the external and internal setup can be quite large and consequently the internal oscillations, which occur when the wind dies down, are also of large amplitude. The flow in the hypolimnion and epilimnion can be in opposite directions.

Another often-neglected aspect of physical limnology is the wave field, and the influence it has on near-shore processes that control lake morphology and the distribution of fine sediments. An example for the Kelowna waterfront was presented, illustrating the spatial variability on an embayment, as well as the controlling effect of bathymetry on near-shore wave fields.

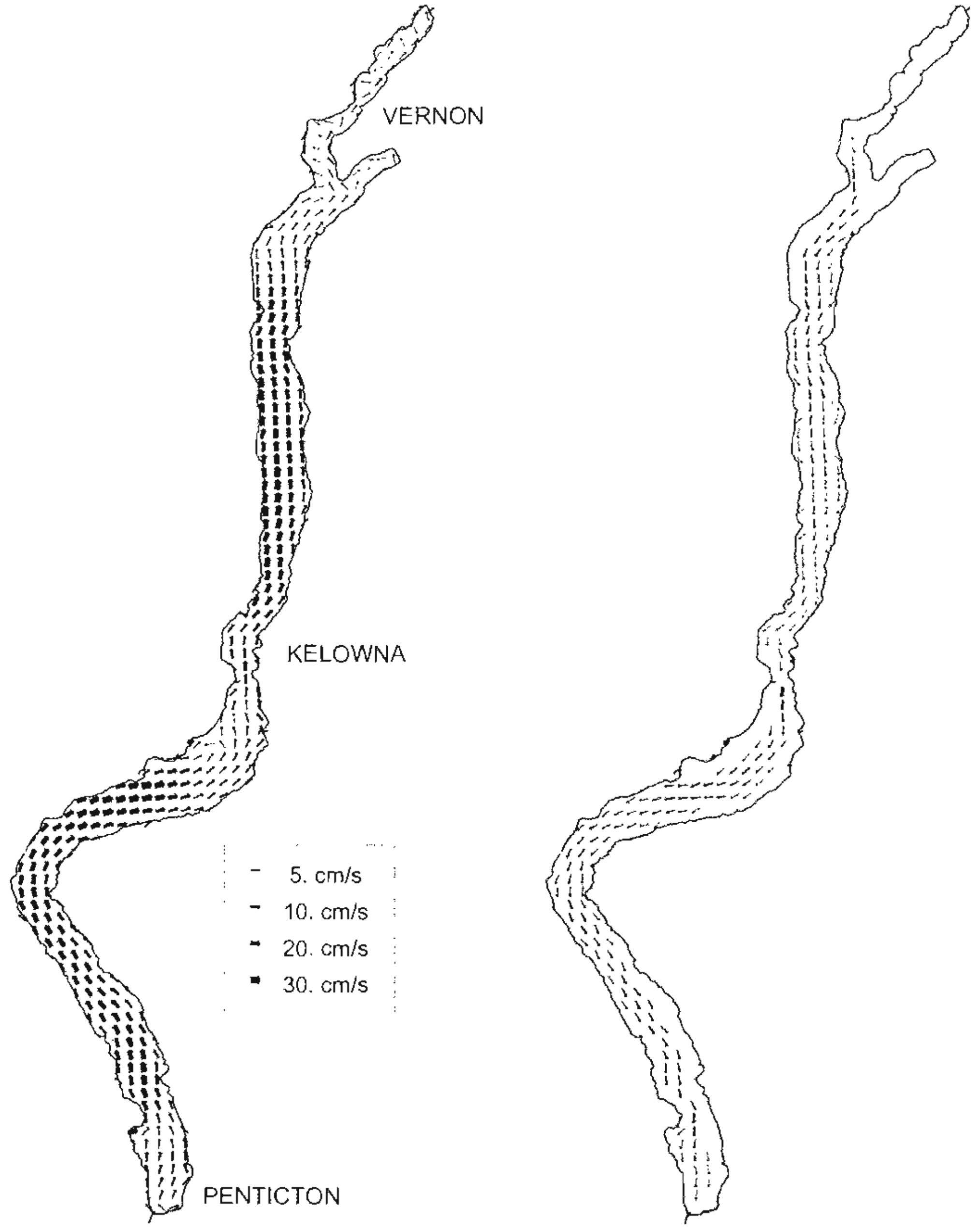


Figure 12. Currents in two layers of model, 12:00 May 27, 1998. Left-hand panel: surface layer (2 m thick). Right-hand panel: layer 17, 40 to 50 m depth. Note, in surface layer flow is to the north, while flow is to the south at 40-50 m depth.

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Presentation #2

In the hands of the community: the potential for community-based implementation of combined land use and water resource management plans in British Columbia.

by

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Abstract

There exists in British Columbia a plethora of planning specific to water, and as well there exists much for land use. However many plans do not explicitly seek to combine the two as part of a more integrated planning model.

The B.C. Ministry of Sustainable Resource Management (MSRM) and the Regional District of Central Okanagan (RDCO) have recently developed the Trepanier Landscape Unit water management plan. It has become the first of its kind in the water-scarce Okanagan (Summit 2004), recognizing the influence of land uses on water resources and acting to integrate land use planning with water management. However, many exciting and potentially important water and land use plans like this have failed to be brought to fruition. Failure to implement these plans has happened for a variety of often complex reasons.

This report will try to uncover the factors that can encourage successful implementation of integrated land use planning and water management. Research will be aimed at determining what measures are used for successful implementation through case studies and interviews. The involvement of the community will be a major part of this analysis as they are seen to be the ultimate stakeholder and are thus best suited to successfully champion the implementation and future management of this and other such plans.

Keywords: Watershed, Trepanier, Implementation, Community

Introduction:

In this time and space that we live in, water is possibly the most critical of resource concerns. Nothing other than the lack of oxygen has more potential to disrupt our daily lives if it were mismanaged than this precious liquid. In answer to this, many geographic locations have strived to manage their water resources in a sustainable fashion. Plans and policies governing water have been made, legislation come and gone, billions of dollars spent in the process. Few of these though, but increasingly more, have addressed the important link between land use and water. In British Columbia there is much planning specific to water, and as well there exists much for land use. However many of these plans do not explicitly seek to combine the two as part of a more integrated planning model.

The BC Ministry of Sustainable Resource Management (MSRM), Land and Water British Columbia Inc. (LWBC), and the Regional District of Central Okanagan (RDCO) have recently developed the Trepanier Landscape Unit (TLU) water management plan. It has become the first of its kind in the water-scarce Okanagan region of the province (Summit, 2004), recognizing the influence of land uses on water resources and acting to integrate land use planning with water management. However, many exciting and potentially important water and land use plans like this have failed to be brought to fruition. Failure to implement these plans has happened for a variety of often-complex reasons; all too often, these plans get shelved or come upon impassable obstacles.

This report will discuss the results of work in progress on my undergraduate honours paper for the Department of Geography at the University of Victoria. The honours paper will try to uncover the factors that can encourage successful implementation of integrated land use and water management plans. Research based on a review of case studies and completion of interviews will be aimed at determining what measures have led to successful implementation. The role of the community is expected to be a major part of this analysis as they are seen to be the ultimate stakeholder and may be best suited to successfully champion the implementation and future management of the TLU and other such plans.

To date, a 'first look' has been taken at academic literature and case studies to determine factors important to successful plan implementation, and at the TLU plan in light of this analysis to determine the potential for its successful implementation. Ultimately, this research hopes to contribute to successful implementation of integrated land use planning and water management.

Methodology:

This report seeks a better understanding of the link between land-use and water management planning, what measures are used for implementation and if possible, which have been most successful, as well as of the possibilities for community involvement. To do this, relevant literature will be examined particularly that related to Integrated Watershed Management Plans. Integrated Water Resource Management (IWRM) will be outlined as a major concept which, among other things, seeks to integrate and link land-use planning and water management. Much research has been completed on the subject, with a good account of key factors leading to its successes in water management; and these will be added to the overall analysis.

In addition to the literature review, case studies have been explored to determine and focus on real-world successes and failures of implementation. These case studies include work of the Ontario Conservation Authority in Canada, the Massachusetts Watershed Initiative in the United States, the Murray-Darling Basin Initiative in Australia, and a look at the Resource Management Act in New Zealand. Previous work in British Columbia recommending water management planning will also be discussed such as:

- *Stewardship of the Water of British Columbia* report (1993) which provides a 'vision' of the future which BC desired in relation to its water resources and the subsequent *Freshwater Strategy* (1999).

- The *Protecting Drinking Water Sources* report conducted by the Office of The Auditor General of British Columbia in 1999 focusing on the Provincial government and concluding that they were failing to protect drinking water sources.

- The *Living Rivers in a Living Land* concept for BC outlining the "Living Rivers" initiative by highlighting key concepts and demonstrating through case studies some critical lessons.

Other planning processes in BC to be acknowledged include Sustainable Resource Management Plans, Landscape Unit Plans, Water Use Plans and Drinking Water Protection Plans. Also, at a smaller scale, are Official Community Plans (OCPs) and Regional Growth Strategies under the Local Government Act

The Trepanier Landscape Unit water management plan will be examined in a 'first look' fashion in this paper with further analysis to take place in the expanded honours paper to come. It will be analyzed against findings from the literature review and case studies in order to judge if it contains key factors for successful implementation. Influential players in the development and maintenance of the plan will be interviewed regarding their thoughts to successful implementation of the plan and the role of the community and I also hope to discuss my work with conference participants. Recommendations will be made and will follow from the above examinations, analyses, and discussions.

Preliminary Findings:

Many commentators suggest the importance of the link between land use planning and water resources. "It has been recognized that the quality of receiving waters is affected by human activities in a watershed via point sources, such as wastewater treatment facilities, and non-point sources, such as runoff from urban area and farm land (Wang, 2001, 25)." Unfortunately, Wang points out "Although watersheds are increasingly viewed as appropriate natural spatial unit(s) for planning and for sustainable water resources management, watersheds have not received as much attention in land-use planning field(s) as that in the biological and environmental studies (2001,34)." Since often it is the actions on land that have the most impact on water, "it is necessary to look into water-quality management and land-use-planning and draw the connection between the two" (Wang, 2001, 33). As for the situation in BC, Creighton echoes Wang stating, "it is logical that an approach that integrates the two resources be adopted" since "many water issues are a result of land based activities" (1999).

What has become evident in my preliminary research, is that there exists a large disparity between plan objectives and implementation initiatives. One key to this may be that policy makers, managers, and planners, do not understand the large number of activities, competing interests, and diverse agencies involved in implementation (Pressman and Wildavsky cited. in Albert et al. 2003, 53)." Barrett and Fudge repeat the dissatisfaction suggesting that government, "whether national, regional, or local, appears to be adept at making statements of intention, but what happens on the ground often falls a long way short of the original aspirations (1981, 3)." "Concern with effectiveness is now being extended to include a closer look at what actually happens to policy 'in the hands' of implementers, that is, the process of implementation, the factors affecting those processes and their relationship to policy formulation and change (Barrett and Fudge, 1981, v)." For whatever reasons there may be, and there may be numerous, the issue of implementation is one that requires thorough examination as it is important to the success of planning efforts.

Without implementation, much of the time and resources devoted to planning and management would be a waste. Dzurik, in his influential text on water resource planning, mentions the unfortunate absence of this vital step, "Often in water resource planning, considerable effort goes into developing plans that are never adopted (1990, 92)." As such, it is thus a key topic within the context of this research and analysis of the TLU water management plan.

Implementation in BC:

The BC Auditor General's report on drinking water in the province concluded that implementation was one of the "essential elements that are lacking in almost all of the integrated management processes"(cited in Creighton, 1999). Further it said "very few mechanisms (are) presently in place for translating the findings of integrated planning processes into action"(cited in Creighton, 1999). As for the move toward IWRM, it has not been implemented successfully in the province due to social, institutional, and organizational barriers limiting its adoption (Creighton, 1999). Social barriers include perceptions that IWRM would involve a major shift in how people lived and also may point to a general misunderstanding of the water resources. Institutional and organizational barriers may relate to the fragmentation and complexities of water management in BC.

Trepanier Landscape Unit Water Management Plan:

The exact role and the importance of the TLU water management plan is recognized as we see the difficulties of implementing plans, of integrating resource management, and of linking land-use planning to water in the current management web that exists. To provide background, much of the information to follow has been sourced directly from the June 2004 Final Report for the plan.

The Trepanier Landscape Unit is located on the west side of the Okanagan Valley and covers an area of 990 km^2 including 5 individual watersheds. The Okanagan of the southern interior of British Columbia serves as a good study area due to its high growth rate and drought prone climate, and the TLU offers an especially prime example. Add to this the climate change scenarios presented by numerous models and the need for a comprehensive water management plan integrating land use planning is obvious. Developed by the B.C. Ministry of Sustainable Resource Management (MSRM), Land and Water British Columbia Inc. (LWBC), and the Regional District of Central Okanagan (RDCO), this plan is potentially a very important tool in managing the province's freshwater resources.

Included in the TLU are multiple communities as well as two Westbank First Nations reserves. The population of the area has doubled in the last 20 years and is expected to continue at a rapid pace; demonstrating an obvious and serious potential for growth related impacts on water resources. Land uses in the watersheds are extremely varied and often intense; management of these lands is mostly the responsibility of the province. Existing water management in the TLU involves a complex array of stakeholders (Figure 1) and government agencies.

Prior to this plan, there had been a variety of more narrow focusing plans and reports; such as water demand and availability studies, groundwater vulnerability mapping, watershed assessments, flow assessments, urban growth projections, and climate change research. Management issues have bee addressed through the Okanagan-Shuswap LRMP, however there has been nothing to date that has synthesized all pertinent information into one all-encompassing document. The TLU report hopes to provide key guidance in planning and management so that the link between land-use and water is properly incorporated into significant planning tools such as LRMPs, OCPs and Regional Growth Strategies.

Implementation history in the TLU:

As part of the plan development, members of the Technical Advisory Working Group (TWAG) were asked to report on implementation of 74 applicable policies laid out in the Okanagan-Shuswap LRMP and OCPs. As well, they were asked to comment on the effects of implementation on their respective agencies. It reports that two clear trends are apparent; that policy implementation rates are relatively low, and that there were very few negative effects of those 74 policies on the agencies. An average of 33 percent implementation has occurred and over 90 percent of the responses reported no possible negative effects which could result from policy implementation. This raises the obvious question, and lends to the focus of this research, why if implementation is not seen to have negative effects, has the rates of implementation been so low?

In an effort to examine the low implementation rates and answer this question, the TLU report also asked selected water managers about barriers to implementation. Their response was to highlight 5 such barriers:

1. Ineffective management tools (especially geared towards IWRM)

2. Lack of data (both timely and accurate)

3. Limited education on water value and use

4. Organizational barriers (lack of coordination and integration)

5. Differing institutional priorities and conflicting objectives

Summary of Current Findings regarding Implementation:

After conducting my literature review and case studies examination, a compilation of necessary factors for the successful implementation of water management plans has been attempted. The list of factors deemed important to successful implementation of these plans is shown in Appendix 1 and has been grouped into 4 themes:

- Administration and Funding
- Coordination and Integration
- Focus and Clarity
- Monitoring and Adaptation

TLU Analysis:

A 'first look' at the TLU has been attempted (Appendix 1) but it is not the intention of this paper to rate or discuss the effectiveness of each factor within the TLU plan, merely to show inclusion or absence. This occurs because of the nature of the plan which makes only recommendations of what needs to be done, not what will be done. In particular, I will analyze elements of the plan mentioned by the "Next Steps" section (242, 2004) of the TLU plan:

1. Establish a Water Management Advancement Team (WMAT) to champion the cause of improved water management and encourage adoption and implementation of recommendations presented in the report.

2. Hold stakeholder and public consultations to agree on goals, strategies, and action items resulting in the creation of an implementation plan.

3. Implement improved water management recommendations through adoption into OCPs and servicing bylaws, Water Use Plans, Drinking Water Protection Plans and other management objectives for watersheds set out in the Ministry of Forests Forest and Range Practices Act.

The expanded assessment of the full TLU water management plan (which contains key factors not mentioned in the "Next Steps" part of the plan) will be conducted at a later date (see honours research available May 2005).

From this introductory examination of the plan, it would appear that it has addressed, in some way, most of the necessary factors for successful implementation. It remains to be seen how effective the entire plan will be and if it will fully address concerns mentioned and the above "barriers" to implementation success. These issues will be investigated in depth and recommendations made on completion of all the research. Supplementary methods of determining TLU implementation success will be included in the final honours paper based on more in-depth comparison to case studies and recommendations made by key BC reports, both of which have been listed above. Also, the results of interviews undertaken as part of this research will be included in this analysis.

Conclusion:

The TLU water management plan is a very necessary endeavor that must be implemented in the face of previous management and planning initiatives that have not succeeded to their potential. It is hoped that this study of factors important in the implementation of successful integrated land use and water management plans will assist the TLU plan and others to succeed in the future.

Figure1. TLU Technical Advisory Working Group – Involved Stakeholders

Name	Job Title	Company
Brian Jamieson	Manager	Westbank Irrigation District
Ted Jeffery	Administrator	Lakeview Irrigation District
Joe Mocilac	Director of Operations	District of Peachland
Brian Symonds	Section Head, Floodplain Management Section	Ministry of Water, Land and Air Protection
Steve Matthews	Fisheries Section Head	Ministry of Water, Land and Air Protection
Don McKee	Hydrologist/Engineer	Land & Water B.C. Inc.
Hilary Hettinga	Director of Engineering Services	Regional District of Central Okanagan
Leah Hartley	Planner	Regional District of Central Okanagan
Dave Smith	Senior Habitat Biologist	Fisheries and Oceans Canada
Mike Adams	Drinking Water Officer	Interior Health Authority
Ron Smith	Regional Water Planner	Ministry of Sustainable Resource Management
Karen Rothe	Water Planning Team	Ministry of Sustainable Resource Management
Mike Doiron	Forestry Planner	Riverside Forest Products
Kerry Ronck	Project Forester	Gorman Bros. Lumber Ltd.
Michael Patterson	Regional Reclamation Manager	Noranda Mines (Brenda Mine)
Pauline Terbasket	Executive Director	Okanagan Nation Alliance
Rob Richardson	Director of Public Works	Westbank First Nation
Ted McRae	District Planning Officer	Ministry of Forests
Carl Withler	Resource Stewardship Agrologist	Ministry of Agriculture, Food & Fisheries, Interior Region

Appendix 1. Successful Factors in Implementing Integrated Land -Use and Water Management Plans

	Key Factor	TLU Water Management Plan	Comments
	Administration		
1	Strong commitment from implementing officials	✓	Recommends firm commitments to be gained
2	Supportive institutional structure	✓	Through creation of collaborative WMAT and consultations
3	Skilled implementers		
4	Agency power and decision making authority		
5	Supportive and clear mandates, legislations, and laws		
6	Accountability of implementers	✓	By assigning responsibilities (2) and mentioned in (3)
7	Regulatory measures for specifying desired action and enforcement		
	Funding		
8	Access to adequate financial and human	✓	Role of WMAT and resulting implementation plan

	resources		
9	Methods of acquiring resources built into agency design	✓	Role of WMAT and resulting implementation plan
	Coordination		
10	Seeks coordination with all interested groups	✓	Role of WMAT and consultations
11	Cooperative and collaborative planning process	✓	Role of WMAT and consultations
12	Multijurisdictional communication, outreach, and involvement	✓	Role of WMAT and consultations
13	Project leaders chosen	✓	WMAT
14	Stakeholder and technical consultation	✓	Role of WMAT and consultations
15	Stakeholder commitment	✓	WMAT and consultations
16	Stakeholder participation	✓	WMAT and consultations
17	Stakeholder partnerships	✓	WMAT
18	Multijurisdictional and collaborative stakeholder committee	✓	WMAT
19	Continuation of committee members from planning to implementation	✓	WMAT includes members of Steering Committee
20	Seeks consensus	✓	Seek "agreement on key goals for water management"
	Integration		
21	Pertinent information accessible and integrated into plan	✓	Role of WMAT
22	Learns from previous plans, monitoring programs, and consultation		
23	Uses best available science		
24	Uses best management practices		
25	Links land use management/planning to water resources	✓	Suggests adoption of recommendations into OCPs and bylaws
	Focus		
26	Relays need for management and/or plan actions		
27	Proper scale (watershed)	✓	Assumed of the Trepanier Landscape Unit
28	Focus on critical factors within scale	✓	Role of WMAT and consultations
29	Utilizes comprehensive information on critical factors	✓	Role of WMAT and consultations

30	Watershed assessment for broad understanding of system		
31	Design and adhere to business plan for implementing aetions	✓	Role of WMAT and consultations
32	Links strategic and operational management tasks	✓	Assigned responsibilities of implementation plan elements
	<u>Clarity</u>		
33	Plan is clear and defines purpose and goals	✓	Role of WMAT and consultations; implementation plan
34	List clear objectives	✓	Role of WMAT and consultations; implementation plan
35	Provides strategies/guidelines for implementing objectives	✓	Assigned responsibilities of implementatiou plan elements
36	Prioritizes objectives	✓	Recommended as part of implemeutation plan
37	Not undermined or weakened by conflicting policies or laws	✓	Suggests adoption into OCPs, bylaws, plans, and others
	<u>Monitoring and Adaptation</u>		
38	Monitoring programs	✓	Role of WMAT
39	Programs provide for evaluation		
40	Programs provide for result communication		
41	Measures for rewarding successes		
42	Measures for enforcement of negative results		
43	Adaptable over long term time frame		

* N/A designates that inclusion of this factor was not determined.
WMAT refers to Water Management Advancement Team as per TLU plan "Next Steps")

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Snow and snow surveys in the Okanagan basin

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Abstract

Snow surveys began in the Okanagan basin in 1934, in response to the extended drought that affected western Canada and the Unites States during the early 1930s. This paper describes the history of snow surveys in the Okanagan basin, from 1934 to the present; it describes the application of snow survey information to water supply modelling; and it documents spatial and temporal changes in patterns of snow accumulation over time. The paper presents detailed analysis of long-term snow data to document affects on snow accumulation and snow water availability associated with the Pacific Decadal Oscillation (PDO) and El Nino South Oscillation (ENSO).

Central Okanagan Post Fire Rehabilitation Project

by

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Abstract

In 2003 the Okanagan Mountain Fire burned 25,912 hectares. Deeper, Bertram, Lebanon and Varty Creek watersheds were all 100% burned, while Priest, KLO and Bellevue Creek watersheds were 50%, 41% and 40% burned, respectively.

The intensity of the fire has created or may create several problems:

- Elevated levels of suspended sediment and bedload transport in each of the burned watersheds impairing water quality as well as risk of damaging Okanagan Lake kokanee foreshore spawning habitat.
- Increased erosion due to loss of the protective forest floor layer and the creation of hydrophobic soil conditions.
- Risk of detrimental effects to water quality and licensed water users, especially during heavy rainfall and spring freshet.
- Loss of riparian and wetland habitat which is vital to aquatic life and is utilized by 85% of wildlife, including species at risk.

Hazard and geotechnical assessment work was performed for the City of Kelowna by Dobson Engineering Ltd. in 2003, in which severe impacts were noted. The City of Kelowna's Environmental Division has a comprehensive Watershed Stewardship Program. Therefore, in 2004, the watershed efforts focused its restoration and enhancement in the Okanagan Mountain Fire (subsequently referred to as the Fire) affected areas. The City of Kelowna hired Interior Reforestation Company Ltd., an environmental consultant, to develop prescriptions for high priority sites, as well as implement the prescriptions with the assistance of the City's Watershed Summer Crew. At four high priority sites, hillslope stability was addressed utilized log contours, ditching and planting and instream structures were placed.

The City of Kelowna will continue to restore and enhance the post fire watersheds in 2005. Work will include completing restoration at the four high priority sites in the Bertram, Lebanon and Bellevue Creek watersheds, accelerating rehabilitation of six key wetland features in the Bellevue Creek watershed and planting 42,000 trees and shrubs throughout the burn areas. This vegetation will help slow water transport, improve water quality, provide bank and hillslope stability and provide important habitat for wildlife and aquatic life.

1.0 City Watershed Stewardship Program

Water is a precious and limited resource in the Central Okanagan, where the average precipitation is approximately 32 centimeters per year, and summertime temperatures typically exceed 35 degrees Celsius (McKay, pers. comm., 2005). Additionally, the population of Kelowna is currently 105,000 people; however it is projected to be 153,000 by 2020 (Stephen, pers. comm., 2005). Therefore, the City recognizes that water resources are vital in our region.

Many of the twenty-seven creeks in the Kelowna area, like those throughout North America, have been impacted by humans. Urban expansion, agriculture, industry, forestry and fire have caused increased erosion and pollution, altered drainage patterns and reduced riparian vegetation. This has resulted in loss of property, flooding and drainage problems for Kelowna residents. Methods previously used to overcome these problems addressed short-term human needs, but failed to consider the ecological function of water systems and healthy watersheds. In many cases, drainage and protection of property had been dealt with using vertical rock or concrete walls or even piped networks, which diminishes valuable habitat for both aquatic and terrestrial life and natural infiltration patterns. These practices reduce watershed function and decrease the health of our local creeks.

In 1996, The City of Kelowna's Environmental Division introduced the Watershed Stewardship Program to help mitigate anthropogenic impacts to local creeks. The program includes three components:
1) Education
2) Stewardship
3) Restoration and Enhancement.
These three components have been successfully used for several years and were applied towards the Fire rehabilitation areas in 2004.

1.1 Education:
"The first step toward protecting streams and wetlands is education" (Fisheries and Oceans Canada). Education helps encourage the community to become stewards of the land and to change people's understanding, behaviors and actions towards environmental sustainability, water conservation and healthy watersheds. The City's Environmental Division has implemented several programs such as student education, public events, and targeted community educational campaigns to improve watershed health and water conservation.
Student education is a significant portion of the City's education component, reaching an average of 3,500 students each school year. Students not only become stewards of their environment, but they also educate their parents and influence changes in their household's behavior. Student education is done through a variety of methods including classroom presentations, outdoor education, school assemblies, the Kokanee in the Classroom Program and the Environmental Mind Grind trivia contest. In 2004, fire related education was incorporated into student education.
Community education is undertaken by the City through targeted educational campaigns such as the *Living by Water Dessert Evening* for streamside landowners, *Caring for the Streamside Workshop* for arborists, landscapers and pest control companies and *Promoting Healthy Waterfront Properties Workshop* for realtors. Additionally, the City facilitates annual public events such as Family Environment Day, Mayor's Environmental Expo and BC Rivers and Fisheries Awareness Day. Further, in 2004, staff helped educate landowners regarding Best Management Practices for post Fire rehabilitation, including streamside properties.

The City of Kelowna water utility also works towards water conservation and watershed protection through a "source to tap" water management approach. The City of Kelowna has recognized the need to promote water conservation and decrease water demand. These issues began to be addressed in 1996 with the installation of water meters and the introduction of the Water Smart Program.

In 2003, the City water utility pumped 15,888,794 cubic meters of water from Okanagan Lake, the source water for the City's water utility. Kelowna's residential water consumption rate is one of the highest in North America. In 1999, Canadians used an average of 343 litres of water per person per day. In Kelowna, the 1998 average was over 570 litres per day. By 2003 it had dropped slightly to 525 litres per person per day (City of Kelowna, 2004) .

One of the main issues in Kelowna is the irrigation of lawns during the summer which increases peak demand; when water use is at its highest. In Kelowna, peak demand typically occurs for the last two weeks in July and the first week of August. Subsequently, the Water Smart Program has focused its education efforts on reducing peak demand.

1.2 Stewardship:

The City of Kelowna facilitates the stewardship component to encourage citizens of Kelowna to become active in their watersheds by restoring or enhancing one of our 27 streams or numerous wetlands. This includes short term projects such as painting storm drains through the Yellow Fish Road Program or the removal of garbage or invasive weeds along riparian areas. For those groups and organizations interested in a long-term partnership, they can take part in the Adopt A Stream Program. This program involves helping keep Kelowna's creeks healthy by removing garbage and invasive weeds and painting storm drains over a minimum two year period. Currently 20 organizations have adopted 7 kilometers of streams and 14,000 square meters of wetland. To date, almost 8,000 hours of volunteer time have been donated to the City of Kelowna's Watershed Stewardship Program which equates to $80,000 in volunteer labour. This stewardship component will be expanded into the Fire affected areas in 2005.

1.3 Restoration and Enhancement:

The City of Kelowna's Environmental Division has facilitated creek restoration and enhancement projects since 1997. The Environmental Division has facilitated 5,400 meters of stream restoration or enhancement and the planting of over 6,500 plants. The projects focus on restoration and enhancement practices that are environmentally sound, cost-effective and provide multiple benefits. The program utilizes partnerships with landowners, government agencies and volunteers to ensure community support and project success. The City looks to a variety of sources to help fund restoration and enhancement initiatives and the City's Watershed Summer Crew has been active in the implementation of the restoration projects. Objectives of the restoration and enhancement component include:

- To improve water quality by repairing streambank erosion, and enhancing riparian areas to filter, trap and break down pollutants from nearby runoff.
- To restore and enhance instream and streamside habitat for both aquatic and terrestrial life.
- To educate the public, private landowners and developers on the importance of healthy watersheds and encourage these groups to become stewards of our creeks.

Water quality and quantity is improved by enhancing and restoring riparian areas. Riparian vegetation is extremely important as it provides shade, lowers water temperatures, filters pollutants and increases aquatic and terrestrial habitat.

City restoration and enhancement projects to date include the following:

- **1997, Mill Creek Tree Revetment**. The City's first eco-sensitive, biotechnical restoration project was the installation of two tree revetments at a local turf farm. These structures were installed to control erosion and improve water quality. Additionally, installation of fences restricted livestock access to the creek, and planting native species helped enhance the riparian zone.
- *1998, Mill Creek Erosion Control Blankets.* ***This project focused on stabilizing streambanks using erosion control blankets. Fencing and intensive riparian planting comprised the remainder of this project.***
- **1999 and 2000, Mill Creek Habitat Recruitment Structures and Instream Complexing**. A variety of techniques were utilized to overcome extensive erosion, lack of instream habitat and a degraded riparian area at the previous Central Park Golf Course.
- **1999 and 2002, Park Naturalization Program**. Riparian zone enhancement occurred in two manicured City parks along Mill Creek. The project focused on educating the public on the importance of a healthy riparian zone versus a manicured streamside and encouraged private landowners to incorporate similar landscaping as a benefit to the creek and themselves.
- **2001, Spawning Channel Construction, Instream Complexing, Replanting**. A variety of bioengineering techniques were utilized at four project sites along Mill and Bellevue Creeks.
- **2001 and 2002, Mill Creek Urban Instream Enhancement Project**. Enhancement techniques, such as spawning gravel placement, rock weirs and riparian planting, were implemented at thirty sites along Mill Creek, focusing on improving fish habitat and water quality in urban areas.
- **2003, Thompson Creek Instream Restoration and Enhancement Project**. This project included gravel addition for kokanee spawning, stone line creation for instream pool habitat and replanting for riparian enhancement.
- **2004, Central Okanagan Post Fire Rehabilitation Project**. Four high priority sites were identified and enhancement began using erosion control techniques along the hillslopes as well as instream.

2.0 Okanagan Mountain Fire, 2003

> *"The summer of 2003 was the worst ever for forest fires in British Columbia. Abnormally hot, dry weather resulted in over 2,500 wildfire starts over a vast area, mostly in the Interior of the province." Interface fires were at an all-time high. These interface fires destroyed over 334 homes and many businesses, and forced the evacuation of over 45,000 people (Filmon, 2003).*

In August and early September 2003, the Okanagan Mountain Fire burned 25,912 hectares on the south slopes within and surrounding Kelowna (Dobson 2003). This Fire, which reached a Rank Six Firestorm where flames were moving 100-feet per minute and jumping from the crown of one tree to the next, caused the evacuation of 30,000 people from their homes. Forestry firefighters, city firefighters, army and navy forces and reserves all joined together to fight this massive Fire (see Photo 1, Appendix 1).

In the end, there was a direct loss of 238 homes to the Fire. Of the watersheds impacted by the Fire, the Deeper, Bertram, Lebanon and Varty Creek watersheds were 100% burned, while the Priest, KLO, and Bellevue Creek watersheds were 50%, 41% and 40% burned, respectively (Dobson Engineering, 2003) (see Photos 2 to 4, Appendix 1).

2.1 Environmental Impacts:

Fire impacts hydrology, terrain stability and erosion potential in watersheds and thus can create supplementary hazards with risks to people, property, infrastructure and the natural environment. Slope and hydrologic hazards that can be attributed to a wildfire include the following:

- Shallow translational landslides
- Increased erosion of surface soils
- Increased sedimentation of creeks, leading to poor water quality
- Changes in the frequency and magnitude of runoff and peak flows due to the loss of forest cover and rainfall on water repellent soils
- Debris flows and floods (Dobson Engineering, 2003).

Due to the possibility of these hazards, the City of Kelowna hired Dobson Engineering Ltd. to assess slope hazards and hydrologic conditions of the areas impacted by the Fire. It was determined that surface erosion, from increased water flows and lack of vegetative cover, has resulted in increased sediment loads to creeks, impairing creek habitat and both creek and lake water quality (Dobson Engineering, 2003).

2.2 Habitat Loss:

The loss of trees, shrubs and grasses was an immediate impact of the Fire. The Fire and associated suppression activities also significantly impacted the plant and animal communities, altering several rare and fragile ecosystems that had been previously identified in the Central Okanagan Sensitive Ecosystem Inventory (Iverson and Cadrin, 2003).

2.3 Hydrophobic Soils:

Due to the intense heat of the fire and the amount of understory and litter burned, the Fire created hydrophobic soils in the burned watersheds. These hydrophobic soils repel water, reducing the amount of water infiltrating the soil. This decreased soil infiltration results in increased erosion and sediment into the streams, consequently increasing turbidity and decreasing water quality. As a result, assessments that were completed by Dobson Engineering indicated that the main concern was the potential impacts from flooding related to intense rainfall on hydrophobic soils. Impacts from hydrophobic soils can be widespread across the areas burned by the Fire during spring runoff and during storm events for three to five years, the estimated time for breakdown of the hydrophobic conditions in burned soils. This breakdown can be reduced to 2 years by introducing an aggressive grass seeding program (Dobson Engineering, 2003).

The assessments also confirmed that the terrain stability hazards resulting from the Fire are typically low and localized. Shallow translational landslides into streams may be frequent where side slopes are greater than 50%. Due to the low gradient of the streams (less than 20%), the debris flow hazard is also low. However, due to the complete destruction of forest vegetation and the creation of hydrophobic soil conditions, the elevated risk of flooding was indicated as high should an intense rainfall event occur. On October 22nd, this intense rainfall event occurred, when a localized extreme storm event that deposited between 12 to 20 mm of rainfall in a 20 to 45 minute period. Flooding and debris flows were triggered causing significant erosion. One of the significant outcomes was an instream debris flow on Rembler Creek depositing debris up to 200 metres downstream (Dobson Engineering, 2003). Additionally, City records show the turbidity levels of the raw water at the Cedar Creek intake rose to at least 20 NTU's (Nephelometric Turbidity Units) for 8 minutes, and then 10-19 NTU's for 2.5 hours. At this intake which is situated 267m from shore and at a depth of 20 m, the typical range of turbidity is between 0.1 to 0.5 NTU's. Therefore, this storm event showed the impact on water quality (Toma, pers. comm., 2005).

2.4 City Culvert Improvements:

Flows from Fire affected areas were also analyzed to determine the flow increase the City could expect due to the hydrophobic condition. There is a 1:10 chance that a 1 in 25 year rainfall event will occur in the next three years, so the City chose that level of protection for the design criteria. The City's Subdivision Bylaw requires protection of roads at creek crossings to a 1 in 200 year level. It was determined that a 1 in 25 year rainfall event on hydrophobic soils will produce about four times as much flow as a 1 in 200 year rainfall event produced before the fire. As a result, culvert capacities were upgraded where necessary to accommodate the flows from the 1 in 25 year rainfall event on hydrophobic soils (McKay, pers. comm., 2005).

2.5 Provincial Grass Seeding Program:

The Ministry of Forests facilitated the grass seeding program in late 2003 for private and public properties that were affected by the Fire. The program utilized aerial seeding and targeted areas with steep slopes where vegetative cover was removed by the Fire. The amount of aerial seeding that occurred covered 7,840 hectares (Okanagan Mountain Park was not seeded). The seeding program helped establish ground cover and was the first stage of revegetation and erosion control. The erosion control grass mix also provided forage for wildlife and helped condition soils for future rehabilitation. The aerial seeding program was deemed successful due to the vigorous grass growth in the spring of 2004 (see Photo 5, Appendix 1). However, this growth of grass may cause a problem for replanting in these areas due to competition with the seedlings (Interior Reforestation, 2004) and there is potential for grass fires to occur.

2.6 City Owned Land:

The City of Kelowna's Parks Department has also been active on City owned land in the burned watersheds. They have completed hazardous tree assessments, removed hazards and hazardous trees, grass seeded burned areas and replanted native species in several parks and along road right of ways.

3.0 Central Okanagan Post Fire Rehabilitation Project

3.1 Importance of Riparian Areas:

Riparian and wetland ecosystems provide terrestrial and aquatic life with water, cover, breeding habitat and food. In general, streams and stream corridors provide habitat for more than 85% of our wildlife species. The wide diversity of plants, invertebrate organisms, and structural complexity of these ecosystems provide habitat niches. Riparian areas are also important for trapping sediment and maintaining water quality. Dense root growth of vegetation in riparian ecosystems helps slow water transport, improves infiltration and provides bank and hillslope stability. Some of the gully riparian ecosystems in the burned watersheds have limited continuous surface flow, however, they all flow to Okanagan Lake and they have the potential to possess productive vegetation with cooler microclimates that provide significant cover and food. Within the study area, streams with steep-sided canyons form natural wildlife corridors in the Central Okanagan (Iverson and Cadrin, 2003).

All of the streams in the burned watersheds are tributaries to Okanagan Lake. A variety of fish species including kokanee and rainbow trout utilize stream and lake habitats that were impacted by the Fire. The foreshore of Okanagan Lake, particularly near the mouth of Bertram Creek, is a popular location for the fall shore-spawning kokanee.

3.2 Project Objectives:

Beginning in 2004, the Environmental Division began the Central Okanagan Post Fire Rehabilitation Project to address the impacts of the Fire and accelerate natural rehabilitation of the area. The City of Kelowna hired Interior Reforestation to mitigate the long-term loss of sensitive and other important ecosystems that were impacted. This multi-year rehabilitation program includes:

1) assessing sensitive and other important ecosystems
2) identifying areas prone to further degradation or prolonged natural recovery
3) determining feasible treatments
4) prioritizing sequence of treatments
5) developing and implementing rehabilitation prescriptions
6) monitoring treatment effectiveness and completing required maintenance (Interior Reforestation, 2004)

The treatment objectives for the project include the following:

- control surface runoff and minimize sediment transport to creeks and Okanagan Lake to protect downstream fish habitat
- protect infrastructure
- accelerate tree and shrub establishment to reduce sediment transport and potential slope failures
- increase deciduous tree cover and shrub diversity in riparian ecosystems
- develop wildlife connectivity corridors

3.3 Completed Works :

In 2004, Interior Reforestation implemented initial prescriptions at four high risk locations which would benefit from immediate rehabilitation. Locations were chosen based on a review of existing literature, discussions with various stakeholders and field assessments. Sites 1-4 were located in Bertram Creek, Lebanon Creek, Cedar Creek and Bellevue Creek (refer to Appendix 2 for site map and Appendix 3 for site specifics). Implementation was completed by Interior Reforestation and the City of Kelowna's Watershed Summer Crew (see Photo 6, Appendix 1). Due to the lack of forest vegetation and hydrophobic soils, erosion control was a priority for these sites. Therefore, prescriptions focused primarily on utilizing hillslope and rehabilitation techniques to stabilize soils as well as instream structures to trap sediment (Interior Reforestation, 2004).

3.4 Partnerships:

Partnerships with the Central Okanagan Regional District and various landowners were important prior to restoration and enhancement occurring. Three of the four high priority sites were on private land, therefore, access agreements were necessary for these properties prior to work taking place. The landowners were cooperative and all provided in-kind contributions towards the projects. For example, two landowners completed hazardous tree assessment and removal and Scouts Canada, an additional landowner, provided excavator time for the placement of instream structures.

3.5 Enhancement Techniques:

Techniques that were completed included contour logging, which involves the placement of felled or fire-burned trees running adjacent to the contours of the hillslope (see Photo 7, Appendix 1). This helps to lessen the impacts of mudflows and erosion caused by increased surface runoff. Instream structures such as root wad revetments were installed to reduce surface erosion to creeks, protect creeks from scour and provide locations for sediment trapping. Instream log weirs were installed to increase morphologic and hydrologic diversity. Live staking and native species were planted to help stabilize soils, capture fines, filter sediment and accelerate revegetation. In 2004, these restoration techniques occurred along 800 meters on Lebanon and Cedar Creek, 300 meters on Bellevue Creek and 350 meters on Bertram Creek (Interior Reforestation, 2004).

4.0 Enhancement In Post Fire Watersheds, 2005

The City of Kelowna recognizes the importance of continued effort in the fire affected areas. If action is not taken, Fire damaged areas could experience reduced success of environmental recovery and result in water quality impairment.

4.1 Wetland Prescriptions:

Interior Reforestation developed an additional six wetland prescriptions for 2005 which focus on sensitive ecosystems sites that would benefit from enhancement. Within the dry climates of the Interior Douglas fir (IDFxh1) and Ponderosa pine (PPxh1) biogeoclimatic subzones, small ponds, marshes and even human created wetlands are focal points for wildlife because of their infrequent occurrence in this dry landscape. The Sensitive Ecosystem Inventory states that the fringe riparian and upland plant communities associated with wetlands in the Central Okanagan support a disproportionately high level of biological diversity, including wildlife species, relative to the small area that they occupy (Iverson and Cadrin, 2003). Therefore, wetlands and associated upland connectivity corridors were the focus in the 2005 prescriptions (Interior Reforestation, 2004).

4.2 Restoration Objectives

The restoration objectives in 2005 for rehabilitating riparian and terrestrial communities are:

- Overcoming grass competition and re-establishing a riparian zone
- Accelerating recovery of six key wetland features
- Completing restoration works at high priority sites where rehabilitation was initiated in 2004
- Planting 42,000 trees and shrubs

The new plantings will stabilize hillslopes and to promote the re-establishment of sensitive wetland and riparian sites. The area has had some initial growth of grasses and shrubs; however, due to the lack of coniferous seed source and competition from agronomic grasses, this grass-shrubland phase may continue without the replanting of conifers. Of these plants, approximately 30,000 are conifer species including Ponderosa pine, Interior Douglas fir and Western red cedar. The remaining 12,000 native deciduous species include Paper birch, Red osier dogwood, Saskatoon and Prairie rose.

4.3 Stewardship in the Fire Areas:

To promote stewardship, members from the community will be involved in the replanting of some of these native species. School District #23 will incorporate the replanting in the spring of 2005. School District #23 is engaging in a district wide *Helping Hand: A Joint Reforestation Program* on May 5th where 25,000 students, parents and staff will simultaneously plant 130,000 trees at approximately 25 locations in Kelowna and the Regional District. Some of the students will be involved in planting in the areas affected by the Okanagan Mountain Fire (School District #23, 2004).

Scouts Canada will also be involved through the collection of willow and cottonwood stakes this winter and the planting of these stakes and the replanting of the seedlings in the spring of 2005.

The remaining seedlings will be planted by a team of professional tree planters in the spring of 2005. As the Environmental Division focuses on replanting 42,000 trees and shrubs, Parks will be replanting approximately 30,000 coniferous species and private landowners will also be replanting native species, all of which will contribute to healthier watersheds.

5.0 Project Monitoring

Site monitoring will be implemented for all works completed. The City has an on-going monitoring program which uses the methodology established in the "Stream Restoration Site Assessment Procedure for Southern Interior Streams". The City has been monitoring all projects completed to date using this methodology and projects are monitored at years 1, 3, 5, 10 and 20.

Planting maps will help form the basis for formal monitoring over time. A series of permanent survival plots will be established as per Ministry of Forests standards. Plots will be placed in representative areas to ensure that most species can be monitored for a 3 year establishment period. Each wetland will have at least one photo monitoring point established. These photo monitoring points will provide visual backup to survival data and will show habitat and successional changes over time.

6.0 Future Direction

The City has allocated an annual budget of $20,000 for 2005 through to 2007 for Fire rehabilitation efforts. The City has also applied for funding from the Habitat Conservation Trust Fund to supplement the amount of works completed in this large area.

Interior Reforestation has developed a multiple attribute evaluation framework for the City to prioritize future rehabilitation sites. This framework provides both a means of pre-screening potential projects, as well as re-evaluating their status as ecological succession progresses.

The City of Kelowna recognizes the importance of continued effort in the areas affected by the Okanagan Mountain Fire. The Environmental Division's Watershed Stewardship Program will continue education, stewardship and restoration and enhancement to increase the health of our watersheds for humans, aquatic and terrestrial life (see Photo 8, Appendix 1).

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8.0 Appendices

8.1 Photos of Fire Areas:

Photo 1. Okanagan Mountain Fire, Aug. 2003. Photo 2. Typical burn area, October 2003.

Photo 3. Creek channel in high intensity burn area. Photo 4. Burned wetland.

Photo 5. Successful grass seeding, summer 2004. Photo 6. Summer Watershed Crew working on Site 1 (Bertram Cr.)

Program #3

The Changing Climate Of The Okanagan Basin

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Abstract

Local climate stations and snow courses in the Okanagan Basin have been analyzed for seasonal and annual trends, and to determine the influence of El Nino and the Pacific Decadal Oscillation (PDO) on climate variability. Significant warming, particularly during winter and spring, has been observed at two long term stations (Summerland CDA and Vernon Coldstream Ranch). The warming has been accompanied by a longer growing season and earlier snow melt along the valley bottom. Daily minimum temperatures have increased at a faster rate than daily maximum temperatures. Spring and summer precipitation have been increasing during the last few decades, which are likely contributing to recent increases in lake inflow. The percentage of precipitation falling as snow (the "snow fraction") has been decreasing at low elevation valley stations, but not at higher elevations. There has also been a noticeable decline in snow packs below 1400 metres over the past two decades. A marked decline in snow water equivalent (SWE) is associated with a step change in climate that occurred in 1976 and has been linked to a phase shift in the PDO. The warming trend is projected to persist into the future with the continued rise in global concentrations of greenhouse gases. The results of Global Climate Models point to warmer, wetter winters, and hotter, drier summers in southern British Columbia over the 21st Century. These changes will affect the accumulation of snow and the timing of runoff, which in turn will affect water availability. Hotter, drier summers will lengthen the growing season and increase evaporative demand, thereby increasing the demands on irrigation. Despite domestic and international efforts to curb greenhouse gas emissions, it is inevitable that the global climate will continue to warm for many decades to come before possibly reaching a new equilibrium. Managing the Okanagan basin's water resources in the 21st Century will require consideration of these changing climatic conditions.

KEYWORDS: Climate, Climate change, Water resources, Okanagan, Agriculture

Introduction

The dry and reliably sunny summer Okanagan climate is a key reason that tourism and agriculture are the mainstays of the valley economy. Irrigation and domestic water supplies in many parts of the Okanagan Basin are dependent on water stored in high elevation reservoirs throughout the valley. Each spring, runoff from the previous winter's snow pack recharges these reservoirs, ensuring an adequate supply of water throughout the growing season. The future economic success of the Okanagan Basin is therefore closely tied to the continuation of suitable climatic conditions.

But what if these ideal climate conditions were to change because of global warming? This is a question that a project team recently attempted to answer through a two-year study funded by the Climate Change Action Fund. Researchers from the Pacific Agricultural Research Center in Summerland teamed up with colleagues from Environment Canada and the University of British Columbia to examine the potential impacts of climate change on water management in the Okanagan (Cohen et al, 2004). An assessment of climate trends and variations for the Okanagan Basin conducted during that study are summarized herein.

Trends in Snow Water Equivalent

In most areas of the Okanagan, water supplies are entirely dependent on annual runoff from the accumulation of snow in the surrounding mountains. The provincial government routinely carries out snow surveys to measure the snow water equivalent (SWE) of the snow pack at regular intervals throughout the winter. In recent decades, there has been a worrisome decline in April 1 SWE, normally a time of year when the snow pack reaches its maximum depth. Trends in SWE were calculated for 13 stations in the Thompson and Okanagan Basins and about half display statistically significant downward trends. Reductions in SWE in excess of 100 mm were found at some stations over a 54 year period. Most of the snow courses showing significant negative trends are at lower elevations (below 1,400 metres) as these sites are more prone to the effects of warming. The largest declines in snow pack have occurred since 1977 when a step-change in climate took place associated with a change in the phase of the Pacific Decadal Oscillation (Mantua et al, 1997; Trenberth and Hurrell, 1994; Trenberth, 1990). The declining trend in SWE is shown in a standardized SWE Index based on a composite of all 13 regional stations in **Figure 1.**

Long-term declines in the snow pack are associated with rising temperatures resulting in a lower snow fraction and the earlier onset of snowmelt. Snow fraction refers to the relative proportion of snow in total winter precipitation, which includes both rain and snow. Under a warmer climate, this balance shifts in favour of rain while the snow fraction is reduced. This is clearly seen at several climate stations located in the valley, but it is not evident at higher elevations which remain below freezing throughout the winter. This difference is illustrated in a comparison of trends in the snow fraction at Penticton Airport (344 metres) and McCulloch (1250 metres) in **Figure 2**.

As the climate has warmed, the onset of snow melt has also advanced. The date on which the daily average temperature makes the transition each year from sub-zero to above freezing at McCulloch was plotted in an annual time series. The trend from 1950 to 1994 as shown in **Figure 3** illustrates the sensitivity of the region's water supplies to a warming trend. Over this period, this transition date advanced 11 days, signalling a large shift in the timing of snow melt.

Trends in Temperature and Precipitation

Temperature records for daily minimum and daily maximum temperatures were examined for two long-term stations: Summerland CDA and Vernon Coldstream Ranch. Warming is significant at both sites for winter and spring for both daily minimum and daily maximum temperatures. Trends in daily minimum temperatures are larger than those for the daily maximums. At Summerland, for example, daily maximum temperatures during winter rose 2.4° C per century, while daily minimums in winter were higher by 3.6° C. Warming during the other three seasons was generally between one and two degrees per century. Seasonal temperature trends for daily minimum and maximum temperatures for Summerland CDA are shown in **Figures 4 and 5**, respectively.

Precipitation records from six different sites were examined for trend analysis: Kelowna Airport (429 m), Penticton Airport (344 m), Summerland CDA (454 m), Joe Rich Creek (875 m), McCulloch (1250 m) and Vernon Coldstream Ranch (482 m). Statistically significant trends were found at virtually all sites for spring and summer precipitation, but not for autumn or winter. Seasonal precipitation trends calculated for a composite of four valley stations are shown in **Figure 6**.

Natural Climatic Variability

Can the climatic trends observed at Okanagan stations during the 20th Century be attributed to global warming? The answer is not straight forward. There is little doubt that the earth's climate is changing, and according to the Intergovernmental Panel on Climate Change, most of the warming of the past 50 years may be attributed to human activities (IPCC, 2001). However, the climate has its own natural rhythm which explains at least some of the variability in temperature and precipitation on inter-annual and inter-decadal time scales. For reasons that are not well understood, the periodic warming and cooling of the tropical Pacific Ocean that we know as El Niño/Southern Oscillation (ENSO) exerts an influence on the position of the storm track and circulation patterns over North America (Wallace and Gutzler, 1989). During El Niño, the Aleutian Low (a semi-permanent low pressure centre in the North Pacific) deepens resulting in a more southerly flow of mild Pacific air, higher freezing levels, and a reduction in the snow fraction. Temperatures throughout western Canada are reliably higher during El Niño winters, and are typically lower during the opposite phase, La Niña (Shabbar and Khandekar, 1996).

On longer time scales, the Pacific Decadal Oscillation (PDO) has a similar influence on the climate as El Niño (Mantua et al, 1997; Trenberth and Hurrell, 1994; Trenberth, 1990). However, in contrast to El Niño, which occurs in the tropical Pacific, the action centre of the PDO is in the North Pacific, and it persists in one phase or the other for many years running. A change in phase of the PDO in 1976 is well documented, and coincides with the beginning of the long term decline in low elevation snow packs in southern British Columbia (Moore, 1996; Moore and McKendry, 1996).

Future Climate Change

Notwithstanding these natural variations attributed to ENSO and the PDO, there remains a long-term trend in the climate that can best be explained by a more widespread global climate change phenomenon attributed to the accumulation of greenhouse gases in the atmosphere. A particularly troubling aspect of this trend is the accelerated pace of warming that is predicted to occur over the 21st Century. The results of Global Climate Models point to warmer, wetter winters, and hotter, drier summers in southern British Columbia over the next 100 years (Taylor and Barton, 2004). These changes will dramatically affect the accumulation of snow and the timing of runoff, which in turn will affect water availability (Merritt and Alila, 2004). Hotter, drier summers will lengthen the growing season and increase evaporative demand, thereby increasing demands on irrigation (Neilsen, et al, 2004).

Despite domestic and international efforts to curb greenhouse gas emissions, it is inevitable that the global climate will continue to warm for many decades before possibly reaching a new equilibrium. Managing the Okanagan basin's water resources in the 21st Century will therefore require consideration of these changing climatic conditions.

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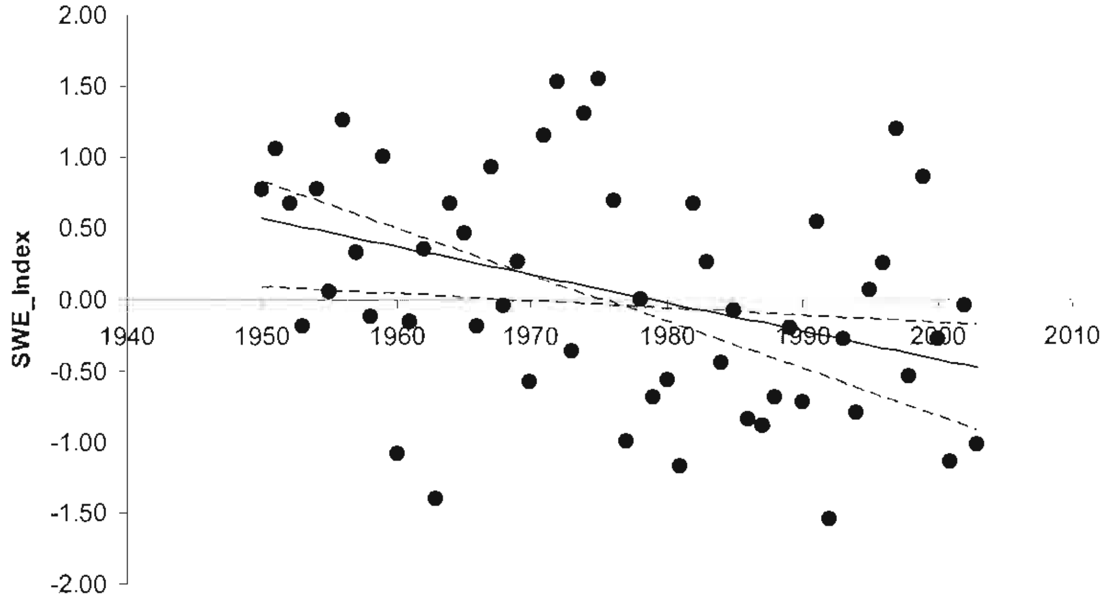


Figure 1 Trend in the standardized April 1 Snow-Water Equivalent for 13 stations in the Okanagan and Thompson Basins. The negative trend is statistically significant, and is strongly influenced by the period since 1977.

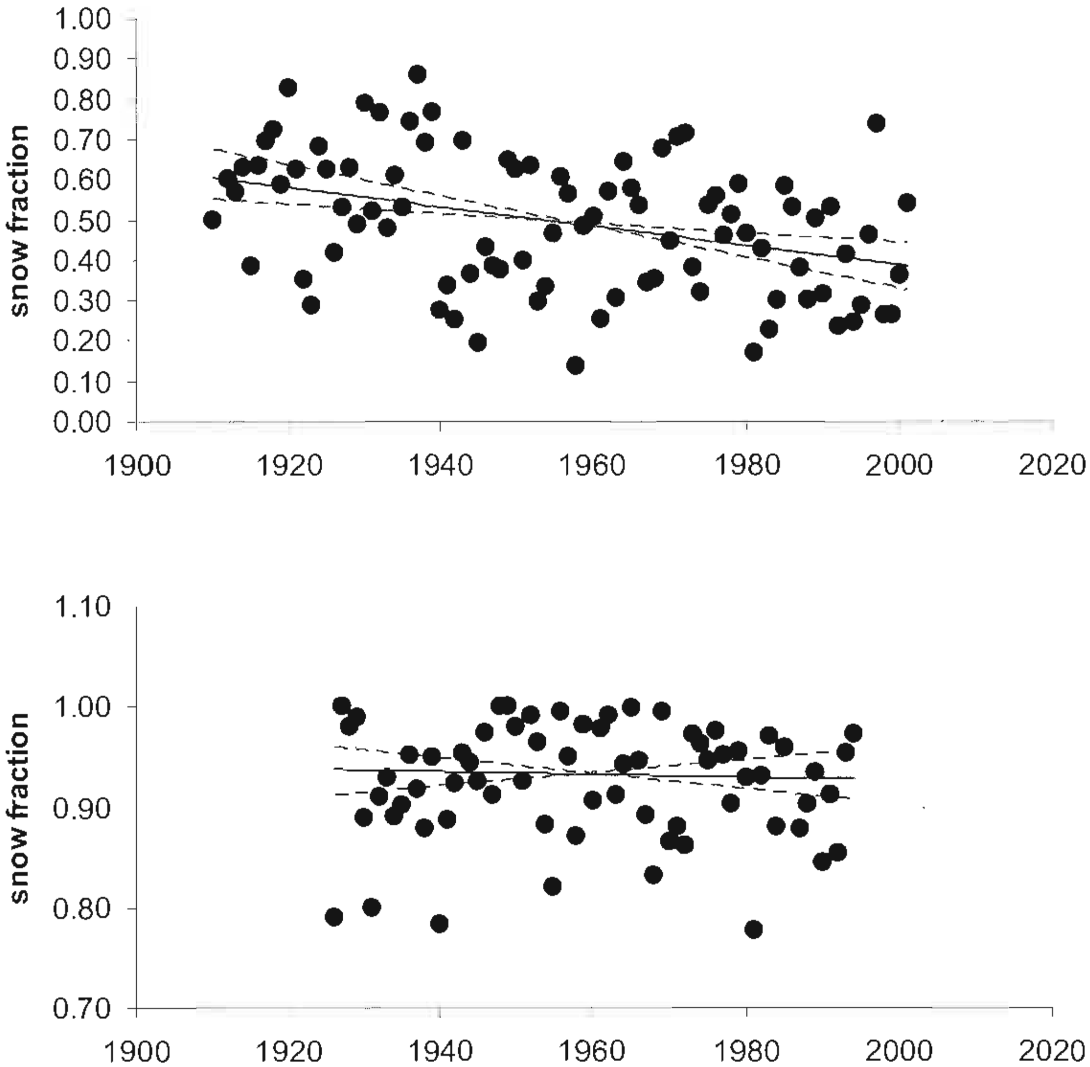


Figure 2 A comparison of trends in snow fraction at Penticton Airport (top), a low elevation station (344 m) and McCulloch (bottom), a higher elevation climate site (1250 m). The trend is statistically significant at Penticton Airport but not McCulloch.

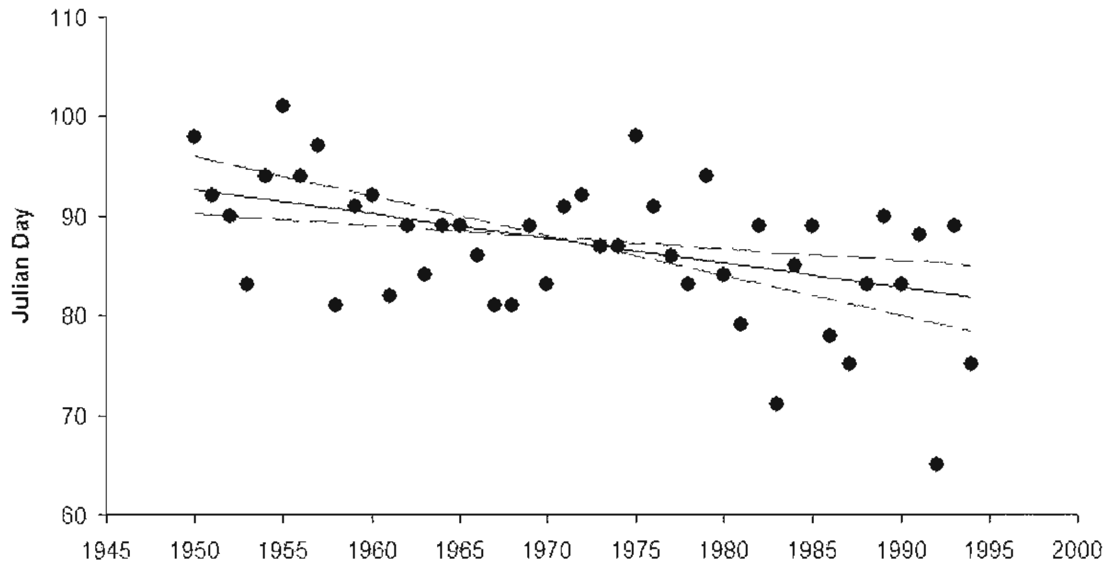


Figure 3 Trend in the date of onset of snowmelt at McCulloch (1250 m).

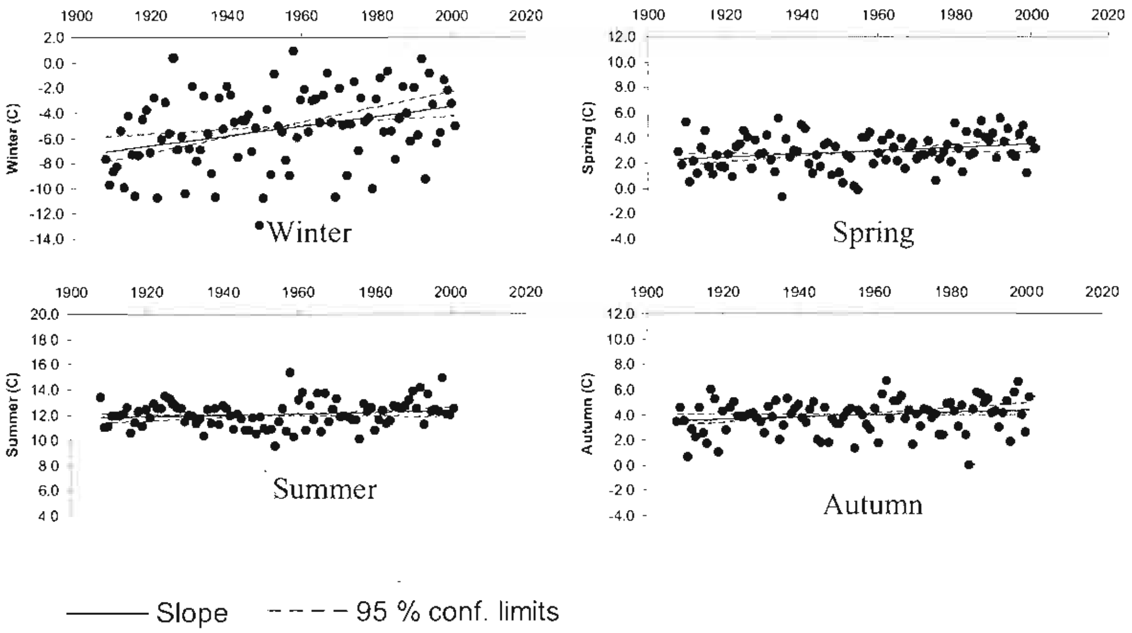


Figure 4 Seasonal trends in the annual mean daily minimum temperatures for Summerland CDA. Units are degrees C. Trends are statistically significant (p<.05) for winter and spring.

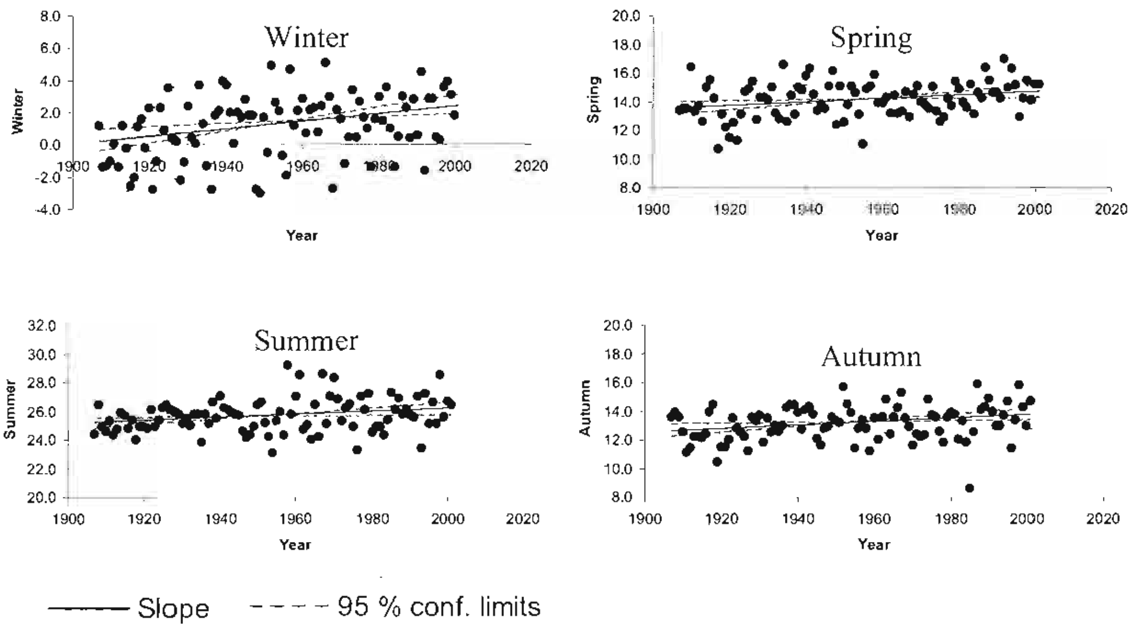


Figure 5 As in Figure 4 except daily maximum temperatures. Units are degrees C. Trends are statistically significant (p<.05) for all seasons.

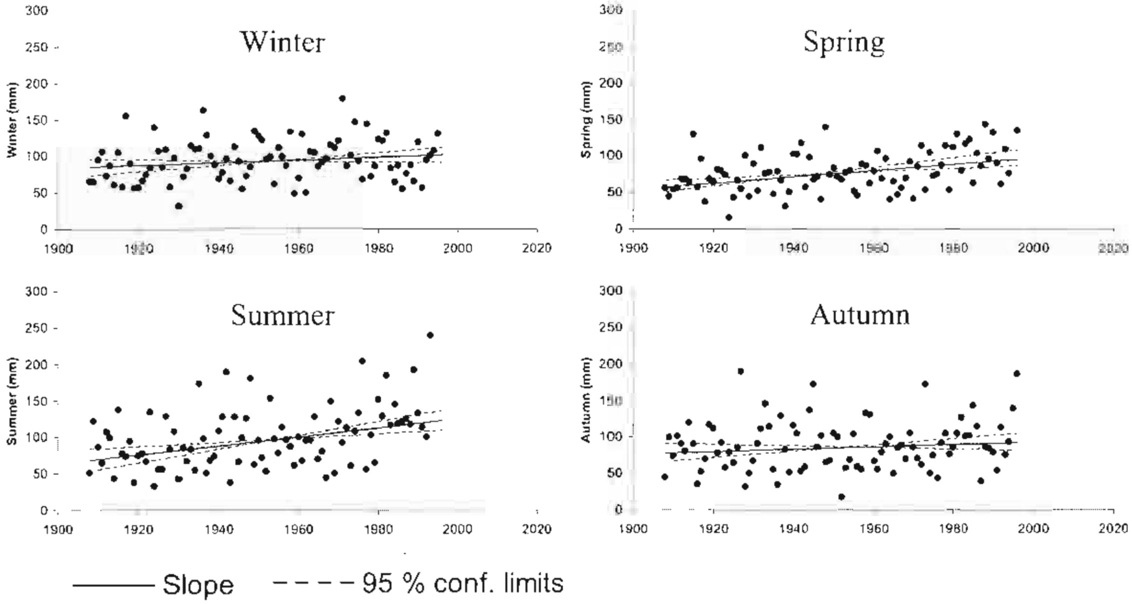
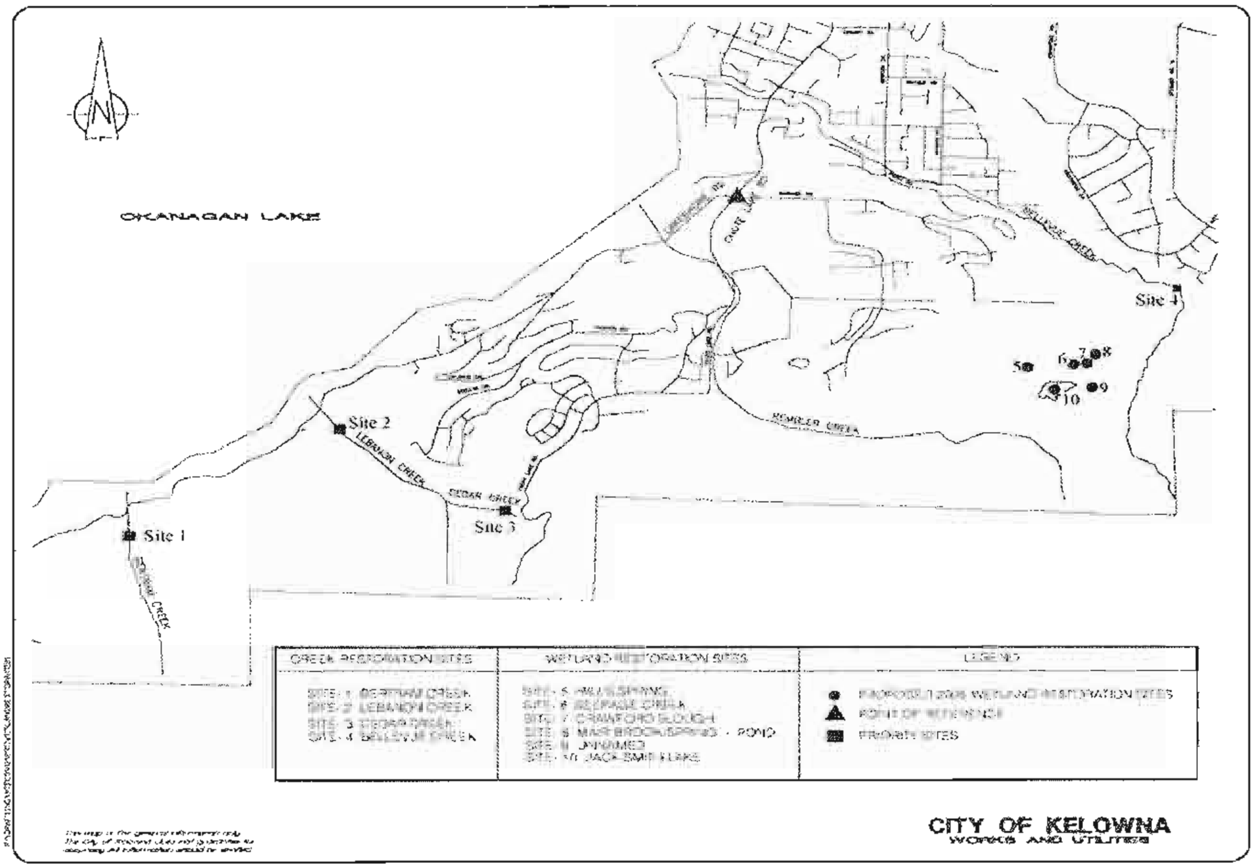


Figure 6 Seasonal trends in total precipitation based on the average of four valley stations. Units are millimeters. Spring and summer show statistically significant trends (p<.05).

2 Site Map:



8.3 Site Specifics:

- Site 1 is a riparian ecosystem located at Bertram Creek at 5681 Lakeshore Road, approximately 175 metres upstream from Okanagan Lake.
- Site 2 is a riparian ecosystem located at Lebanon Creek at 5325 Lakeshore Road, approximately 125 metres upstream from Okanagan Lake.
- Site 3 is a riparian ecosystem located at Cedar Creek, a tributary to Lebanon Creek, at 5635 Chute Lake Road and 5555 Chute Lake Road, approximately 1300 metres upstream from Okanagan Lake.
- Site 4 is a riparian ecosystem located at Bellevue Creek at 1856 Canyon Falls Court (Crawford Falls Park)
- Site 5 is a wetland ecosystem located at 1290 Ivens Road. This wetland is referred to as Hill's Spring and has a total wetted area of 0.2 hectares.
- Site 6 and 7 are a wetland complex located at 1320 Ivens Road. These wetlands are referred to as Seepage Creek and Crawford Slough and have a total wetted area of 0.33 hectares.
- Site 8 is a wetland ecosystem also located at 1320 Ivens Roads. This wetland is referred to as Mair Brook / Spring and Pond and has a total wetted area of 0.16 hectares.
- Site 9 is located at 1485 Ivens Road. This wetland is an unnamed wetland with a total wetted area of less than 0.1 hectare.
- Site 10 is a wetland / lake ecosystem located at 1290 and 1485 Ivens Road. This area is referred to as Jack Smith Lake and has a total wetted area of 2.5 hectares.

The experimental reintroduction of sockeye into Skaha Lake, British Columbia

by
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Prepared for the Okanagan Nation Fisheries Commission[1]

Abstract

Okanagan River sockeye salmon, which spawn near the town of Oliver, British Columbia, are blocked from further upstream migration by a series of water control and diversion dams, beginning with McIntyre Dam, immediately south of Vaseux Lake. The population has been generally declining in number over the past 50 years and the Okanagan Nation Alliance has been the principal advocate of a program to restore their numbers and range by reintroducing them into upstream waters where they may once have occurred in substantial numbers.

Because the proposed reintroduction into upstream waters has implications for other fish species, particularly kokanee, the Okanagan Nation Alliance, in association with Fisheries and Oceans Canada and BC Ministry of Water Land and Air Protection, undertook a three-year investigation to identify risks from the reintroduction and in 2004 began an experimental reintroduction to Skaha Lake to evaluate the risks prior to considering a full-scale reintroduction of sockeye into Skaha Lake and other parts of their former range in the Okanagan Basin. Funding for the work completed to date has been provided by Bonneville Power Administration, the Confederated Tribes of the Colville Reservation, Grant County Public Utility District, and the Canadian entities listed above.

This paper will describe the 3-year evaluation (2000-2003) looking into the risks and benefits anticipated upon reintroducing sockeye into Skaha Lake, B.C.

INTRODUCTION

The Columbia River sockeye salmon population, of which the Okanagan stock is a part, may have numbered in excess of 4 million fish around the end of the 20^{th} century (Fryer 1995). Since then it has been decimated by a combination of man-made and natural events such that the commercial catch, probably once well over one million fish, has been reduced to a few thousands in recent decades. Only the Okanagan stock and the Wenatchee stock in Washington State remain from the many sockeye stocks which propagated in the Columbia River Basin in early times.

LIFE STANZAS AND HAZARDS

The Okanagan population spawns in October, primarily in a 6 km stretch of the Okanagan River north of the town of Oliver, British Columbia (Fig 1), and about 900 km from the estuary. The vulnerable fry emerge in early spring and move downstream about 20km to Osoyoos Lake where they feed and grow exclusively in the northernmost lake basin until the following spring when as smolts they resume their journey south to the Columbia R. and thence to the sea. Mature fish usually return to the Columbia R. in their fourth year of age - after a little more than 24 months at sea.

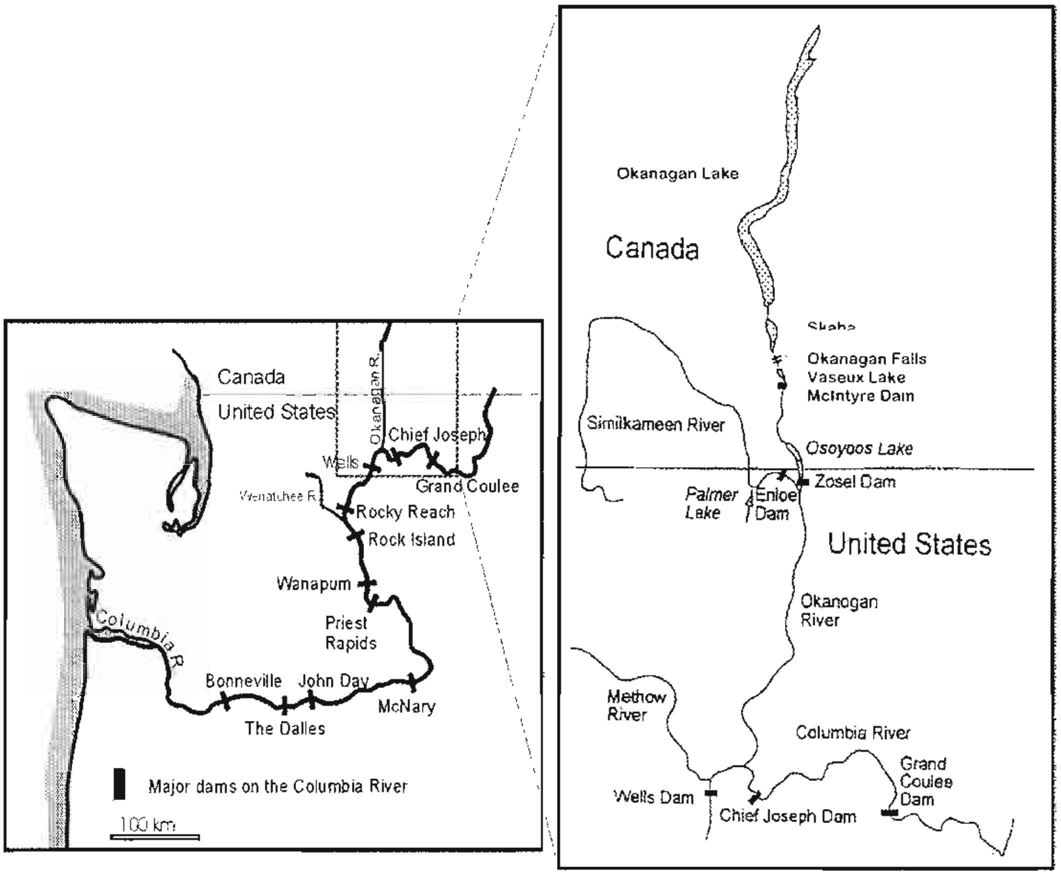

Figure 1. Columbia River and Okanagan River Drainages

Okanagan sockeye face a plethora of life threatening hazards. Returning adults proceeding upstream from the Columbia R. estuary must run the gauntlet of commercial, personal use and sport fisheries and pass through a series of 9 huge hydroelectric dams and the reservoirs above them, even before they reach the mouth of the Okanogan R.[2] Losses have been estimated as high as 5-10% per dam (Fryer, 1995). The Wells Dam is the last the fish encounter before entering the Okanogan R, and it is the principal site of annual escapement counts. (Fig. 2 presents Wells Dam escapement data 1971-2001 as presented by Hyatt et al. MS 2002).

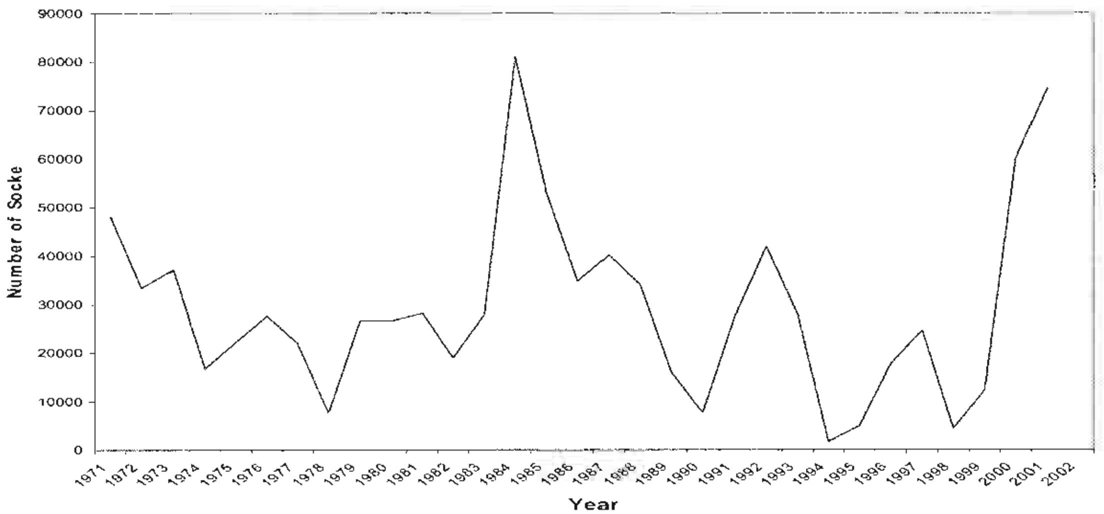

Figure 2. Counts of Okanagan sockeye salmon at Wells Dam, 1970-2001

Within the home river, a combination of competing water uses and channel modifications have had further significant impact on the stock. Much of the original fish habitat has gone or been radically altered and huge sections have been channelized. Three complete barriers to sockeye migration between Okanagan and Osoyoos lakes persist today and a series of 17 vertical drop structures for flow control were added in the 1950s. McIntyre dam below Vaseux L. delimits upstream migration of sockeye and is a major factor in projected management decisions.

Returning adults school at the mouth of Okanogan R. while water temperatures cool to acceptable levels for entry and spawning. Once on the spawning grounds the salmon must find suitable beds and eggs must remain well protected and safe from freezing or displacement by freshets until the young emerge and compete vigorously for food. At this stage, and during their seaward migration as smolts – usually at one year of age, they are at high risk from predators both indigenous and exotic. As smolts, many are destroyed or injured at dams on their way seaward. Fryer (1995) considered low smolt – adult returns (commonly abbreviated to SARs) as the primary reason for the low population of Columbia River sockeye salmon, and summed up this daunting array of hazards by

"...it is amazing that these fish manage to survive at all".

Against this worrisome background the Okanagan Nation Alliance Fisheries Department (ONAFD) in Westbank, British Columbia, the Colville Confederated Tribes (CCT) in

[2] Okanagan R. in British Columbia is the Okanogan R. in Washington State.

Washington State, and other groups and individuals have energetically sought reintroduction of the sockeye run to the Upper Okanagan R. basin, where it is believed to have flourished until the early 1900's[3].

The presence in the lakes of kokanee, sometimes termed the "landlocked" sockeye, is further indication that the anadromous form once populated Okanagan, Skaha and likely other lakes of the upper drainage where generations of their (presumed) offspring remain to the present. While kokanee abundance has declined in Okanagan and Skaha lakes in recent years there was an encouraging increase again in 2002 and 2003(S. Matthews pers. comm.).

DEVELOPING A PLAN

The International Pacific Salmon Fisheries Commission established an investigative body - the Okanagan Basin Technical Working Group, (OBTWG) and in 1997 a workshop comprised of their members, representatives of the ONAFD and a number of invited experts was convened by the ONAFD at Westbank. Pertinent historical data (e.g. findings of Mullan (1986), and Fryer (1995)) and technical information collected in ongoing investigations of the British Columbia Ministry of Water Land and Air Protection and its precursors; Fisheries and Oceans Canada, (Pacific Biological Station) and others; were included in the record of the 1997 meeting and collectively these provided a strong base for further investigative planning.

Workshop participants outlined areas of investigation they considered essential before any reintroduction should proceed. In particular they noted that the critical and only rearing area in Osoyoos L. was threatened by deteriorating water quality, and that an alternative or supplementary rearing area should be urgently sought.

The huge Okanagan L. appeared attractive as such a rearing area. However in view of its size, its poor stock information base and associated risks, workshop members proposed a temporizing step which was to first reintroduce fish into Skaha L. In a "Skaha first", approach, much information of value to an eventual introduction to Okanagan L. could be gathered before the stock was committed to it, and given its smaller size, Skaha would probably be more amenable to a project reversal if that was necessary. The project was termed "An Adaptive Management Experiment", reflecting the research component and the belief that if serious difficulties arose the project could be aborted.

INVESTIGATIONS TOWARD A REINTRODUCTION INTO SKAHA LAKE

Required research was grouped to six program objectives, which provide the framework for most of the investigations to date.[4] Particulars of these, and an outline of some major achievements after 3 years of investigations follow.

[3] While the strength of Okanagan sockeye runs, as well as those of chinook, coho and possibly other salmon species, entering the river in the early 1900's is poorly documented, Elder accounts (Tradiational Ecological Knowledge), newspaper articles, photographs and other publications of the time suggest that the combined numbers probably sustained significant native fisheries.

[4] A more detailed description can be found in Annual Reports 2000 to 2003, of the ONFC, in Peters and Marmorek (2003), and in Parnell et al (2003.)

Objective 1: Risk of Disease

To address concerns over possible transmission of disease from introduced to resident fishes disease experts in Provincial and Federal laboratories cooperated in the analyses of sockeye and other fish specimens collected by ONFC personnel in two river regions, i.e. above and below the McIntyre Dam barrier and tested for the presence of five potentially troublesome disease agents in several thousand specimens collected in years 2000, 2001 and 2002 and concluded:

> "There is no evidence that the fish populations above and below McIntyre Dam differ with respect to pathogens of concern. Nor is there any indication that Okanagan and Skaha lakes pose an extraordinary risk of causing disease in fish" (ONFC 2002).

This conclusion lessened concerns over the possibility of the disease spreading, but it was recommended that the barrier dam be left in place until final conclusions were reached[5].

Objective 2: Risk from Exotic fishes and Mysis relicta introductions

It was recognized that successful reintroduction of sockeye to upstream areas could be complicated by concurrent or later incursion of unwanted exotic species. Initially these were thought to be: *bluegill sunfish, black crappie, largemouth bass, tench, and walleye.*

Upstream extension could occur when particularly McIntyre Dam, but also Okanagan Falls Dam was removed, as the exotic species might then migrate to production areas above and prey on sockeye, kokanee or trout eggs or their young, or compete successfully for limited common food resources. There are a number of known predators - e.g. *smallmouth bass, rainbow trout, northern pike minnow*, already well established above McIntyre, but the concern has been largely limited to possible new arrivals.

To improve understanding of the likely kind and severity of hazards from various exotic species to valued salmonids – particularly kokanee and rainbow trout –ONAFD staff undertook three years of extensive riverine sampling between Okanagan and Osoyoos lakes as well as within them, utilizing six kinds of fishing gear and pre-established sites and schedules. Detailed records of catch per unit of effort (CPUE), specimen sizes and stomach analyses were published in ONAFD Annual Reports along with many descriptive photographs of sampling sites and representative fish habitats (Alexis et al. 2003). Throughout these was a clear concern for the welfare of resident fish species.

Results suggested that only the voracious walleye should still be of serious concern and then only if they should move upstream beyond their present range in the Columbia and Lower Okanogan rivers.

Studies by Williams & Brown (1982), as discussed by Vedan (ms 2003), suggest that unsuitable rearing habitat and bright light in the flat Okanagan R. valley may be at least a partial deterrent

[5] The parasite *Parvicapsula* was discovered in Okanagan sockeye from below McIntyre Dam, and while at time of writing the implications of this discovery are uncertain, if the organism does not already occur above the dam, the possibility of it spreading to there could be a serious concern. Further research is on-going.

to upstream walleye movement there. It was concluded that if walleye reached Okanagan Valley lakes they would likely thrive and affect salmon unfavourably. (Alexis et al, 2003). Effort is needed to ensure that walleye do not reach Osoyoos L.

Mysis relicta

The ½ inch long opossum shrimp, Mysis relicta is now ubiquitous in most of the larger Okanagan Valley lakes. Introduced to Okanagan L. in 1966 as a food source for kokanee, it has expanded its range, and because its own planktonic food preferences mirror those of young salmonids, it may affect food availability for the latter in Osoyoos and Skaha lakes and elsewhere. Because food supplies of sockeye juveniles in Osoyoos L. and kokanee in Skaha L. could be threatened by further proliferation of mysis, concerted sampling and research continues. A small commercial fishery for mysis exists on Okanagan L.

Objective 3: Habitat Inventory

Spawning Areas and Enhancement Opportunities

There was concern that spawning and incubation areas might be in short supply. However, Mullan, (1986), as reported by Bull (1999) estimated the carrying capacity of the primary spawning beds north of Oliver at 35,000-50,000 fish, depending upon water levels. This would be ample for escapements of the size recorded over the past 30 years. but in view of expected demands of the reintroduced fish and extensive changes made to the river, it was deemed important to reassess the quantity, quality and carrying capacity of remaining spawning grounds, and continue assessments of lake rearing conditions.

Apparently adult sockeye entering the current Skaha L. environs would have few spawning options there. Bull (2001) reported a dearth of opportunity for lakeshore or tributary spawning, and no apparent deep-water possibilities. Apparently, like the present kokanee population, sockeye rearing in Skaha L. and returning as adults will need to spawn in the river, and almost certainly above, rather than below the lake. Inspection and measurement of the channelized river and flow conditions showed that several spawning beds could be developed with space for about 4,000 pairs of sockeye and 3,700 pairs of kokanee (Long & Newbury 2002). In summary it appears that existing Okanagan River spawning areas could be significantly augmented if required

Rearing areas: Limnology and the Osoyoos Lake Zone of Tolerance

Lake rearing conditions were recognized a critical element in the proposed reintroduction and fortunately limnological investigations on larger Okanagan Valley lakes have been carried out by both Federal and Provincial agencies and by several Universities for many years and a considerable body of valuable information exists.

Recent data presented by Wright & Lawrence (2003) show a juvenile rearing capacity in Skaha L. equal to about 80-90% of that currently found in Osoyoos L, and when "zones of tolerance" were plotted (areas where maximum seasonal water temperatures and minimum oxygen levels are tolerable for young sockeye -- P. Rankin to H. Wright, pers. comm.), it appeared that juveniles would not likely have been restricted by those factors in Skaha L. in either 2001 or 2002. On the other hand in Osoyoos L. only the north basin (water mass north of Osoyoos, B.C.)

had suitable rearing area in August and September, and in September that was restricted to a narrow horizontal band only about 2 – 3 m. deep.

Objective 4: Develop a Life Cycle Model

Salmon stock performance is influenced by a great number of widely distributed variables that makes forecasting abundance and behaviour very troublesome. For instance, smolt to adult survival rates (SAR) among Okanagan sockeye are estimated to have varied from 0.6% to 6.6% in the few years for which there are data within the period 1965 - 1976 (Mullan 1986), cited in Fryer (1995).

Okanagan R. sockeye data sets are notoriously incomplete. However modeling can be a useful tool for exploring population dynamics and ESSA Technologies was tasked with developing a life cycle model. Interacting closely with workshop participants over several years, they completed a number of very informative analyses (Peters and Marmorek 2003; Pinkham and Peters 2003). The results of these analyses are referred to in Objectives 5 and 6.

Objective 5: Development of an experimental design

Using the three years of field sampling and the life cycle model an experimental design was debated. It was thought that a successful reintroduction process should the following criteria:

a) provide a satisfactory level of learning,
b) conserve existing stocks of both sockeye and kokanee; and
c) eventually produce a population with a large enough surplus to once again support a substantial fishery, notably for ceremonial purposes.

Three viable options were identified for reintroducing sockeye into Skaha L:

1. Remove barriers (McIntyre and Okanagan Falls dams) to migration between Osoyoos and Skaha lakes – thus allowing migrants to move into Skaha unimpeded.
2. Trap migrants (probably below McIntyre Dam), transport to Skaha and release, allowing them to find their own spawning areas.
3. Trap migrants, extract and fertilize eggs, incubate in a local (and disease free) hatchery and release fry into Skaha.

Option three was thought to best satisfy the three criteria. It was particularly strong from a learning perspective; it would enable precisely the required numbers of fry to be introduced into the lake; and by marking the fry investigators could accurately measure their survival to later life stages. Option 3 also has conservation value in that a comparatively small number of pre-spawners would need to be sacrificed. In options 1 and 2 the need to take larger numbers of spawners affected the stock unfavourably.[6] Any possible deleterious interaction, (e.g. strong competition between returning sockeye and resident kokanee for spawning space) would be avoided.

In reintroduction options one and two, there would also be doubt as to how fish produced in Skaha L. would be distributed at return, as they would not be distinguishable from spawners that

[6] Under option one, 385 spawners would be required for an introduction of 200 fry/ha, given normal fertilization and hatchery survival rates, whereas 3,454 would be required under option 2. (Some reduction in numbers might be achieved by reducing the number of males needed for fertilization)

reared in Osoyoos Lake. In any choice of reintroduction, wherein barriers remained to prevent complete homing, the fish would most likely spawn with the main population near McIntyre Dam. That could result in an unwanted level of competition both on the spawning grounds and later among juveniles in the Osoyoos L. rearing area.

In one series of analyses, the three reintroduction options discussed were modeled and results supported the view that reintroduction option No. 3, wherein fry would be incubated in a hatchery then released to the lake, would best satisfy the specified criteria. This analysis also suggested that introductions of 200 sockeye fry/ha would have relatively little effect on overall sockeye adult and fry performance, or on numbers of either kokanee, or mysids, though in common with several other analyses in the modeling series, stock strength was seen to decline rapidly in the final few years of each run. When this analysis was repeated, with removal of 50% of the mysis population each year both kokanee and salmon populations benefited.

Objective 6: Finalization of a plan for reintroduction of sockeye salmon into Skaha Lake and associated monitoring programs

The agencies now participating in the reintroduction project are providing vital expertise and information, and their continued participation is critical to project success. While reproduction and the early stages of Okanagan sockeye production capacity (spawner to smolt) occurs in Canada, most of the fresh water migration (smolt to adult return) occurs in the United States. Clearly agencies of both countries will need to be involved to ensure that rearing facilities are sufficient and protected, and that commercial, personal use and sport fisheries are well regulated as the run recuperates. Initiatives to improve adult and juvenile passage through the Columbia River dams should continue, and it will be helpful for investigators to know their nature and degree of success.

CONCLUSION

Progress toward meeting the six program objectives has been effective and has not revealed factors that should preclude a successful reintroduction to Skaha Lake.

Serious disease transfer now seems unlikely; concerns over possible exotic fish introductions are largely focused on walleye; spawning areas appear adequate for present population strengths; a life cycle model has been shown as a promising tool and several options for a successful introduction of sockeye into Skaha L. have been evaluated and prioritized. These are substantial and encouraging accomplishments, and they provide a strong rationale for recommending the reintroduction. At the same time some significant concerns persist and these will need to be explored farther as work progresses.

Investigators need to learn as soon as possible how adult spawners will distribute themselves in the river between McIntyre and Okanagan Falls; how effective their spawning there will be; and how serious a problem Vaseux Lake will be for juveniles passing through it. Concern over low SAR's is pervasive, and if SAR's cannot be improved, for instance by affording greater protection at dams, a much larger number of juveniles may be required to bolster the stock. Additionally the very thin layer of Osoyoos L. waters, which at present seems capable of supporting juveniles in the summer months could become further restricted. Finally the burgeoning mysis population seems a serious threat to both anadromous sockeye and kokanee.

Reductions in external and Lower Columbia R fisheries pressure may be needed to help ameliorate these problems.

The persistent stock decline is worrisome: In 30 years of data from Wells Dam (data courtesy of Hyatt et al. 2001) the sum of 15 consecutive escapements, from 1971 – 1986, were 1.3 times the sum of the following 15 consecutive escapements from 1987 – 2001. Peters et al (1998) suggested that without some form of intervention to improve survival rates the stock could go to extinction.

One cannot foresee with any degree of assurance how many years the run can persist unaided. It is clear however that unless the run is kept reasonably robust there will be few options for intervention of any kind. A thoughtful lean toward conservation appears justified to ensure that this highly valued resource survives.

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Presentation #4

Changes in crop water demand in response to climate change and some associated risks in water supply for agriculture in the Okanagan Basin

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Abstract
Agriculture accounts for 75% of consumptive water use in the Okanagan Basin and crop production is entirely dependent on irrigation. In order to examine the effects of long term climate change and variability on daily water demand for agriculture, a GIS based model was developed that estimates water demand based on crop type and spatial distribution, evapotranspiration and canopy development calculations and 1x1 km gridded climate datasets. Average annual crop water demand was determined from 1961-90 climate data and for three future time periods (2020s, 2050s and 2080s) using six climate model scenarios. A 20-40% increase in demand was projected by the 2080s. Licensed allocations would be able to meet this increased demand, but supply may be limiting as comparisons of basin wide demand and unregulated inflow into Okanagan Lake (UBC watershed model) indicated that scenarios projecting increased demand also projected decreased supply. Major risks to agriculture and basin water supply are associated with the occurrence of droughts and low flows. In 2003, the Trout Creek watershed experienced a combination of low flow and high demand which may be a foretaste of the future. In a case study, annual water supply and agricultural crop water demand in Trout Creek/Municipality of Summerland were modeled using the six future climate scenarios. Supply and demand were compared to critical thresholds based on flow, and current allocations associated with the maintenance of fish flows. Risk of exceeding both thresholds was assessed for each 30 year data set and scenario. Comparing the periods 1961-1990 and 2071-2100, risk of low flow increased from 1 year in 30 to 1 year in 3 and risks of high demand increased from 0 to 100%. The most extreme scenarios called for combinations of low flow and high demand 1 year in 6 by mid-century and 1 year in 2 by the end of the century. Adaptation options will require changes in both demand and supply management.

Keywords: agriculture, climate change, crop water demand, Okanagan, risks, water supply

Introduction

The Okanagan sub-basin is subject to some of the potential pressures identified for the whole Columbia River system in response to climate change (Mote et al., 2003; Barnett et al., 2004), in particular, the conflict over allocation of water resources for in-stream use by fish and wildlife and consumptive use by agriculture. The Okanagan watershed in British Columbia, is a snowmelt watershed which is highly subscribed to supply water for high-value crops. In 2002, a study was initiated to develop integrated climate change and water resource scenarios for the Canadian component of the Okanagan Basin as a basis for understanding some of the challenges facing both suppliers and consumers of water, currently, and in the future (Cohen et al., 2004). This paper reports on the development of a crop water demand model and some related water supply scenarios.

Agriculture accounts for 75% of consumptive water use in the Okanagan Basin and crop production is entirely dependent on irrigation. Currently, the climate of the region supports primarily perennial crops (high value tree fruits and wine grapes, with the balance in pasture and forage) and a small acreage of annual crops (potatoes, vegetables) planted in suitable micro-climates. Timely availability of water is imperative to economic production of high-value crops both to assure quality and to protect investment in perennial plant material. In some crops, for example wine grapes, planned water deficits are used to enhance quality attributes (Behboudian et al., 1998; Dry et al., 2001) while conserving water. Consequently, potential limitations and adaptation to the availability of irrigation water under current and future climates are important considerations for agriculture

Changes in average climate will determine, in the long run, which crop production systems are viable in a region. However, extreme climate events present a greater challenge to agriculture, to communities and to their ability to cope (IPCC, 2001). One of the major risks facing Okanagan agriculture is the occurrence and frequency of drought. In production systems that are entirely dependent on irrigation, drought can be defined as the inability to provide an adequate water supply to maintain an economic return. There are two components to drought in this case; high demand and low supply. Forecasting when droughts may occur is not feasible. It is, however, possible to examine the historical record and determine how frequently periods of high water demand and low supply have occurred, and under climate change scenarios, to determine the likelihood of such combinations in the future.

The objectives of the current study were to estimate the change in regional, crop water demand in the Okanagan Basin and, utilizing a case study approach, the inter-annual variability in water demand for a large agricultural water purveyor. Both sets of crop water demand conditions were compared to hydrologic model outputs developed in a companion study (Merritt and Alila, 2004). Both approaches have the limitation that the inter-annual variability in climate data from 1961-1990 is imposed on future climates and it is possible that this variation will not remain constant over time.

Methods and Model Development

Climate change scenarios

Global Climate Models (GCMs) simulate global climate by linking atmospheric and ocean circulation processes and their responses to changes in atmospheric greenhouse gas concentrations. Despite their increasing sophistication, GCMs are still limited in the detail with which they simulate climate and may produce a range of results dependent on the model constraints and the sets of conditions for which a model experiment is run. One of the major sources of uncertainty in GCMs is the magnitude of future greenhouse gas emissions. A set of emissions scenarios has been developed based on global population projections, economic growth and technological change (Nakicenovic et al, 2000). In order to account for uncertainty associated with GCM output, a range of GCMs and emissions scenarios were used in the current study (Taylor and Barton, 2004), as recommended in the IPCC Third Assessment Report (IPCC, 2001). These included a Canadian model (CGCM2), an Australian model (CSIROMk2) and a British model (HadCM3) with two emissions scenarios (SRES) for each model: A2 - high emissions with regional economic development and a continuously increasing population and B2 – lower emissions with local solutions to environmentally sustainable development and a moderate rate of population increase.

Output from GCM experiments is in gridded data sets with a grid size of several hundred km. In constructing regional climate scenarios, it is common practice to take into account data from several surrounding grid cells. However, this may be misleading if neighbouring grid cells contain very different terrain – as in the case of the Okanagan Basin, where adjacent cells contain either ocean or prairie (pers. comm., E. Barrow, senior CCIS principal investigator). Consequently, single grid cell data were used, which was feasible as the Okanagan Basin was contained within a single cell for each GCM.

Downscaling

Recently, there has been considerable discussion regarding the effect of this very broad output scale of climate change scenario data on the modelling of regional impacts on agriculture and hydrology (e.g. Mearns, 2003). At present, there is no suitable regional climate model available for southern British Columbia to allow dynamical downscaling from a suite of GCMs and SRES scenarios to a finer spatial scale (typically ~45km x 45km). Construction of annual variation in future climate has been attempted through the use of weather generator models (Semenov and Barrow, 1997) and statistical downscaling modelling (SDSM) (Wilby et al., 2002) but techniques were not available to extend such model output to the spatially distributed climate data based on multiple climate stations and topography that was used in the current study. Instead, a much simpler approach, the 'delta' method, was selected in which daily or monthly station data are perturbed by future changes in the 30 year averages of monthly mean, maximum or minimum temperature and precipitation derived from GCMs. Despite the many limitations of this method, not the least of which is the inability to account for changes in the variability of climate data over time (Daly et al., 2002) , there are tangible benefits, including the availability of a range of GCM and SRES scenario outputs, which satisfies the need to account for uncertainties associated with GCMs (IPCC, 2001). Other benefits include the relative ease of computation for gridded climate data sets and comparability with other studies which have used the delta method (Lettenmeier et al., 1999, Morrison et al., 2002). In order to maintain consistency amongst all components of the study, the 'delta' method of perturbing 1961-90 normals station data with average monthly changes from GCM output was also used to determine climate change scenarios for crop water demand modeling.

Spatial climate distribution

In highly complex terrain, temperature and precipitation can vary over short distances and these differences may not be captured by widely-spaced weather stations. A range of statistical techniques has been developed to spatially interpolate weather station data with respect to latitude, longitude and elevation. One such approach is to combine statistical interpolation techniques with expert information about local climate regimes. PRISM (parameter-elevation regressions on independent slopes) is an expert system which generates gridded datasets by interpolating among weather station datasets, and also includes 'facets' which are map elements defined by topography and terrain with known climate anomalies (Daly et al., 1994, 2002). The definition of facets is based on expert knowledge. PRISM datasets based on 30 year normals of monthly precipitation and temperature are available for British Columbia and were adapted for use in the current project. In a previous study (Neilsen et al., 2001), it was noted that the spatial downscaling of temperature data based on the original 4x4 km grid-cell output from PRISM, likely underestimated temperatures in crop use polygons because of the large elevation changes within the 4km x 4 km grid cells. This was based on observed differences between PRISM estimates and weather station temperatures. In consultation with Chris Daly (pers. comm., 2003), the 4km x 4 km gridded data set was further downscaled to a 1km x 1 km grid by calculating local average lapse rates based on existing grid cell temperature and elevation data. Data from the 24 nearest neighbour cells were pooled to calculate lapse rates and assign temperature values for each 1km x 1 km grid.

Temporal interpolation of climate data

A second transformation of scenario data involved the derivation of daily minimum and maximum temperature values during the growing season from PRISM monthly climate data (Tmax, Tmin). Daily mean temperature estimates were required to calculate growing degree day accumulations and daily maximum temperature was required to calculate potential evapotranspiration. Each monthly average was assigned to the middle of the month. For climate change scenarios, monthly data were perturbed by deviations (bias) in monthly maximum and minimum temperatures derived from GCM output (Figure 1). In order to ensure a smooth transition between months, a smoothing algorithm was defined, which redistributes the discontinuities between perturbation factors and monthly temperatures throughout the month according to the method of Morrison et al. (2002). Details of how smoothing was achieved for both the basin-wide study and the Trout Creek/Municipality of Summerland case study are given in Neilsen et al. (2004a). The end result was a 30-year climate record was synthesized for each PRISM grid cell for both 1961-90 and for periods centred on the 2020s, 2050s and 2080s.

Land Use

The relatively temporally stable but spatially complex land use patterns of orchards and vineyards utilized in our study were constructed from several cycles of land use survey over the last decade and are felt to adequately reflect current conditions. Within the Okanagan Basin, irrigated croplands comprise only a portion of the total agricultural land base which also includes large areas of non-irrigated range land. For this study, a map and related database of irrigated crop land was compiled from a number of sources and incorporated into a GIS using ArcInfo™. Information on vineyards is from Bowen et al. (2005), tree fruits from Okanagan Valley Tree Fruit Authority (1995), other croplands from BC Ministry of Sustainable Resource Management (2001) and pasture lands from the Canada Land Inventory (1966) updated from current cadastral survey data to eliminate urbanized areas. Location data for vineyards and tree fruits was relatively detailed. In areas dominated by pasture and cropland (i.e. in the North Okanagan), land use boundaries were ground truthed and re-drawn as necessary. In order to better examine the interaction of land use, crop water demand and licensed water allocations, boundaries of water purveyor districts were digitised and added as a layer within the GIS climate change application.

Crop water demand

The calculation of crop water demand requires some estimate of evaporative demand determined by weather conditions, and plant response determined by growth stage and water availability. For annual crops, demand is often simulated by growth models and evapotranspiration (ET) data. For perennial crops, the annual development of the canopy determines the response to evaporative demand. In irrigated crops, soil moisture is likely not a limitation to growth and water demand for irrigation can be estimated by applying a canopy development factor to measured or estimated ET (Doorenbos and Pruitt, 1978). For irrigation scheduling, ET can be estimated from weather station data, or measurements of evaporation from an evaporation pan or atmometer.

Limitations in the climate data (only rainfall and temperature data were available from PRISM) meant that simple relationships were required to estimate potential ET. Algorithms to estimate daily potential evapotranspiration (PET) during the growing season (approximately April 1 to Nov 1) were developed from comparing daily maximum temperature (Tmax), extraterrestrial radiation (Ra) at the Summerland CDA Environment Canada weather station against ET estimates from two methods currently used for irrigation scheduling: (eq. 1) using 1998 data from an electronic atmometer (Etgage Company. Loveland CO.) and (eq. 2) using 1994-98 Penman-Monteith calculations from weather data. A PET value was calculated for each PRISM cell as:

$$PET_1 = -3.26 + 0.210\,Tmax + 0.058Ra \quad (R^2 = 0.58) \qquad (Eq.1)$$

$$PET_2 = -0.495 + 0.011Tmax + 0.051Ra \quad (R^2 = 0.86) \qquad (Eq. 2)$$

The solar energy (MJ m^{-2}) reaching the top of the atmosphere (Ra) was calculated from day of the year and latitude (Allen et al., 1998). Estimates from Eq.1 compared well with Penman-Monteith calculations for 1994-1998 ($R^2 = 0.8145$), but tended to underestimate ET_o at low evaporative demand and overestimate ET_o at high evaporative demand . Estimates from Eq.2 compared well ($R^2 = 0.93$) with Penman Monteith calculations for an independent data set (Summerland CDA 2002 weather data), but always over estimated ET_o. Therefore, crop water demand estimates for climate change scenerios were based on Eq. 1 (Neilsen et al., 2004a). Equation 2 is currently undergoing further testing.

PET was modified by crop coefficients dependent on canopy development. Maximum mid-season crop coefficients (based on Penman-Monteith ET_o) range from 0.9-0.95 for apricot, peach, pear and plum and from 0.95 - 1.0 for apple and cherry under clean cultivated conditions (Fereres and Goldhammer, 1990). These may be expected to be 20-30% higher under a cover crop (Doorenbos and Pruitt, 1977). Changes in projected temperature from 1961-2100 required a crop coefficient curve which could be adapted to a longer growing season. For the purpose of the current climate change study, seasonal crop coefficient curves for tree fruit and grapes (Figure 2) were derived from generalised curves based on those published by Doorenbos and Pruitt (1977). Water use for pasture, forages and other field crops was not modified by seasonal crop coefficients and was thus characterised directly by calculated PET values.

A second factor in estimating irrigation demand is the length of the growing season. The timing of bud break in deciduous trees is a complex issue, and is related not only to genetic factors and increases in photoperiod and air temperature in the spring, but also to the magnitude and duration of cold temperatures experienced in the winter. For the current study, we examined the relationships between degree day accumulations and bloom date for a number of tree species, in a complete and well recorded set of unpublished data collected for phenological studies between 1937 and 1964 at the Pacific Agri-Food Research Centre in Summerland. Regression analysis was used to derive a set of equations for all tree fruit species based on the start of growing degree day base 10 °C (GDD10) accumulation and date of apple bloom, and the relationships derived for apple and other species (Neilsen et al, 2004a). The start of the growing season in grapes has similarly been related to the start of GDD10 accumulation (Association of British Columbia Grape Growers. 1984) and for pasture and perennial forages the start of the growing season to the start of growing degree days base 5 °C (GDD5) accumulation. The end of the growing season was determined as the end of accumulation of GDD5.

Rainfall was not included in estimates of crop water demand. Rainfall events are sparse and contribute little plant available water, the latter defined as rainfall >5mm (Van der Gulik, 1999). Within the growing season (March – October), the number of days per month with precipitation above 5 mm ranged from 1.1 to 3.9 from the south to the north of the basin (Neilsen et al., 2004a).

ARC Macro Language programming within ArcInfo™ was used to assemble PRISM gridded climate scenario output data and intersect it with the agricultural land use coverage. This procedure created a database that described climatic conditions, over the year, for each unique land unit (polygon). The centroids of latitude and longitude for each polygon were added to the database in order to calculate solar radiation. Visual Basic programming was used with MS Access™ to perform daily time-step calculations of crop water demand and for query and summary of annual, monthly or daily values of PET, growing degree days base 5 °C and 10°C and volume of water demand.

Water supply

Estimates of water supply derived from the UBC watershed model (Quick, 1995) parameterized for the Okanagan Basin were used for supply/demand comparisons. Details of the analytical methods, assumptions and limitations of the watershed modeling exercise are given in Merritt and Alila, (2004). There were insufficient data for a whole basin water budget to be constructed, thus comparisons were made between modeled basin wide crop water demand estimates and modeled Okanagan Lake inflow, and in a case study of the Trout Creek watershed, estimated supply was compared with crop water demand within the Municipality of Summerland under the range of climate change scenarios described previously.

Results and Discussion

<u>Crop water demand model testing</u>

To assess the validity of the model for basin-wide demand, estimates of crop water requirements derived for 1961-90 normals climate data were compared with annual irrigation requirements determined previously for the Okanagan basin (Van der Gulik, 1989, 1999). The modeled values increased from north to south and related well to expected values (Table 1).

Average values for historic climate data (1961-90), indicated modelled crop water (irrigation) demand for the Okanagan Basin to be around 200 $m^3 \times 10^6$.

Model validity for inter-annual demand projections in the Municipality of Summerland/Trout Creek case-study was assessed by comparing historic modeled demand to measured irrigation from 1977 to 2003 (Figure 3). Modeled demand did not reflect measured consumption before 1992 very well. There are several possible explanations for this. Firstly, there has been a downward trend in irrigation consumption from 1977 to the present largely due to changes in irrigation technology from, chronologically, less efficient movable irrigation pipes and overhead sprinklers to under tree sprinklers to micro irrigation systems. There has also been some reduction in irrigated land during this period. In addition, Summerland agricultural activity is dominated by apple growing and there was a large change in production practices for apple after 1992 in response to orchard renewal programs sponsored by the Okanagan Valley Tree Fruit Authority. At that time, more extensive orchard systems with widely spaced trees were replaced by high density plantings. This type of orchard structure is more suitable for efficient micro-irrigation systems. In a survey undertaken 2000-2001, around 30% of apple orchards in the South Okanagan used micro-irrigation systems (unpublished data, Sterile Insect Release Program). Modeled demand, after 1992, showed a much closer fit to consumption (Figure 3). The decline in measured consumption 2003 relative to 2002 was likely the result of imposed restrictions (i.e. Municipality of Summerland stage three drought restrictions), early irrigation shutoff and a concerted community effort to conserve water after August 1st of that year.

Basin-wide estimates

Crop water demand scenarios were created for the whole basin. Estimated demand for 1961-90 was around 200×10^6 m^3. All models showed an increase in annual crop water demand over the next 100 years up to a maximum of 324×10^6 m^3 (Figure 4). The magnitude of the change varied over time and between GCMs and emission scenarios, ranging from 12-61%. The greatest increases occurred under the HadCM3 model, and the least under the CGCM2 model scenarios with the CSIROMk2 being intermediate. This is consistent with the range of summer temperatures estimated from the three models as the crop water demand model is dependent on the effects of temperature on both PET and growing season length. Under the high emissions scenario (A2) there was little difference between scenarios which demonstrated a 12% increase between historic (1960-91) and 2020s crop water demand and a 24% and 40-48% increase for 2050s and 2080s respectively. For the HadCM3 model, demand increased by 20% in the 2020s, 38% in the 2050s and 61% in the 2080s. These high estimates of demand with the HadCM3 scenarios are likely unrealistic as temperature increases as high as 11°C were projected in the 2080s (Figure 1). Under low emission scenarios (B2), modelled crop water demand was similar to the A2 scenarios for the 2020s and 2050s time-slices, but lower by the end of the century (Figure 4). The lack of difference between high and low emissions scenarios in the earlier part of the century is the effect of different emissions scenarios for CO_2 and SO_2. Under A2 scenarios, the warming expected under high CO_2 emissions is offset by the cooling caused by the accompanying high SO_2 emissions (Albritton et al., 2001). Under B2 scenarios, lower CO_2 and SO_2 are projected to lead to a larger near-term warming.

Model output for the length of the growing season indicated an increase from an average of 194 days for 1961-90 to a maximum of 258 by the 2080s (Figure 5). Differences among scenarios were less than for total crop water demand (Figure 4). Changes in the length of the growing season and hence in the requirements for water supply, will put added strain on the ability of water purveyors to meet demand, over and above the effects of increased mid-season peak evaporative demand.

Basin supply

The Land and Water BC water licence database was queried for water licences for irrigation purposes in the Okanagan Basin. There are 1201 water licensees of which 10 are large, 7 medium and 34 small publicly owned water purveyors, as well as 3 large and 1147 small, private ones. The three major sources of water are the Okanagan river and lake-system main stem, tributary streams and groundwater. The majority of water supply for irrigation comes from headwaters diversions and high elevation in-stream storage basins. The remainder is pumped from lakes and streams and groundwater. Approximately 75% of irrigation water is supplied by the former method and 25% by the latter (Agrodev, 1994). Modelled demand for the 1961-90 period (200 x 10^6 m^3), was less than the current total licensed allocation for irrigation (323.7 x 10^6 m^3) estimated from the Land and Water BC water licence database. The demand for agricultural water use projected over this century under climate change scenarios (Figure 6) ranged from 225-324 x 10^6 m^3, indicating that unless increased demand is accompanied by increased supply in response to changing climates, further availability of water allocation for agriculture will be unlikely.

An estimate of how climate change scenarios might affect basin water supply can be derived from current and modelled Okanagan Lake inflows (Merritt and Alila, 2004). As a caveat, it should be noted that this is not a quantitative measure of total basin supply and thus cannot be used to calculate a water balance. Average net annual inflow into Okanagan Lake is estimated at 450 - 500 x 10^6 m^3 (B. Symonds, BC Ministry of Water, Land and Air Protection, pers. comm., 2004). Average inflow (UBC watershed model) with no restrictions, withdrawals or surface evaporation for the 1961-90 period, was 840.3 x 10^6 m^3 and this remained constant or declined slightly for 2020 scenarios (86 – 105%), and decreased for 2050s scenarios to between 80%- 93% of current inflow and for 2080s scenarios to around 69-84% of current inflow. A comparison of modelled crop water demand and Okanagan Lake inflows indicated that climate scenarios, which lead to increased demand for irrigation water also lead to decreased supply, exacerbating the vulnerability of all water users.

<u>Summerland/Trout Creek Case study</u>

Community vulnerability to the effects of drought is determined by limitations in the water supply system, both in terms of water withdrawal rights and the ability to store water. Communities in which agriculture is the dominant economic activity may be inherently more vulnerable to drought than those with a more diverse tax and income base. Jones (2000), examined the risk of climate change to agricultural viability in an irrigated production system in S. Australia. Risk was determined as the probability of exceeding known water supply thresholds. In the current study, risk thresholds associated with licensed limits on demand and hydrological limits on supply are defined and compared with projected demand and supply.

Future water demand

Crop water demands were estimated in response to climate change scenarios based on daily temperature records from Summerland CDA/CS which have been perturbed by average increases generated from 30 year GCM output. In this exercise, land use remained constant. The model output for crop water demand was compared with an irrigation demand threshold of

10×10^6 m^3, based on peak measured consumption since 1990 (Figure 6). In all scenarios demand increased over time compared with historic demand (1961-90). Demand for 1991-2003, based on observed climate data, was as high as that projected for CGCM2 and CSIROMk2 for the 2020s. Patterns of variability from year to year were similar, but not identical for modeled crop water demand derived from historical data and GCM scenarios. This is expected given that each year is perturbed by a constant value within a given scenario time-slice. The number of years when the demand threshold might be exceeded, increased over time, to around 18/30 years by the 2080s for CGCM2-A2 s, 28/30 for CSIROMk2-A2 and 30/30 for HadCM3-A2 scenarios. For the lower emissions scenarios (B2), differences in response compared with the high emissions scenarios (A2) only became evident by the end of the century.

Future water supply

From historical patterns, average unrestricted flow in Trout Creek has previously been estimated as 2.65m^3/sec. (Northwest Hydraulic Consultants, 2001). Modeled unrestricted flow at the mouth of Trout Creek, using the UBC watershed model, averaged 2.83 m^3/sec for the period 1961-90. Similar, unrestricted flows were projected for the 2020s in CGCM2 scenarios and the HadCM3-A2 scenario, but were slightly higher in the HadCM3-B2 scenario and were lower in CSIROmk2 scenarios (Neilsen et al. 2004b). Reductions in flow were projected for the 2050s and 2080s in all model scenarios.

A drought threshold of 30.3×10^6 m^3 (36% of average annual flow) has been proposed for Trout Creek (Associated Engineering, 1997). Total annual unrestricted flow volumes were calculated for each of the GCM scenarios and compared to modeled unrestricted flows (1961-90) (Figure 6). Between 1961-1990, there was only one occurrence of modeled, unrestricted flow lower than the drought threshold. For high emissions (A2) scenarios, the frequency of drought increased to ~6.8% of years by the 2020s; 17-24% depending on GCM by the 2050s and 31-44% by the 2080s. The CSIROMk2 model provided the driest A2 scenarios whereas CGCM2-A2 and HadCM3-A2 were relatively similar. For low emissions (B2) scenarios, CGCM2 and HadCM3 produced fewer extreme events than A2 scenarios. In contrast, the CSIROMk2-B2 scenarios produced more drought years in the 2020s and similar event frequencies in the 2050s and 2080s, when compared to A2 scenarios. The effects of low supply are likely to be exacerbated if coupled with high demand.

These 'worst case' scenarios are identified in Figure 7, where the irrigation demand threshold is defined by the 'peak' demand value of 10.1×10^6 m^3 and the supply limit by the drought threshold of 30.3×10^6 m^3. The lowest risk of not being able to meet demand occurs in the lower right hand quadrant of the diagrams. The majority of points fell within this quadrant for historic, 2020s and 2050s scenarios, but, with exception of CGCM2-B2, the majority of points fell outside of this quadrant for the 2080s data. The highest risk is associated with points found in the upper left hand quadrant of the diagrams (Figure 7). There were no instances of high risk in the historic (1961-90) data. High emissions (A2) scenarios resulted in a greater frequency of high risk outcomes for HadCM3 in the 2050s (1 year in 6) and for all GCMs by the 2080s (1 year in 4 to 1 year in 2). Incidence of 'high risk' response for low emissions scenarios was less than under high emissions.

The increased demand and low supply scenarios outlined above suggest that the existing infrastructure will be inadequate, even if conservation measures could save 30-40% of water used. The ability of the water system to supply demand in the future will be dependent on the availability of effective water storage which is presently around 9.1×10^6 m^3. Recent data suggest that years of high demand and early snow melt result in early use of stored water and potential water shortages. Between1974-2003, early use of stored water (before July 1st) occurred 6 times, five of them since 1992 (Neilsen et al., 2004b).

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Table 1. Estimates of crop water use for 1961-90 normals data and recommended irrigation requirements

[z] Derived from BCMAFF Sprinkler and Trickle Irrigation manuals

Region	Representative water purveyor	[z]Irrigation Requirements (mm)	Estimated crop water demand (mm)
N. Okanagan	Greater Vernon Water Utility	559	648
Central Okanagan	S. E. Kelowna Irrig. District	660	653
S. Central Okanagan	Municipality of Summerland	686	725
S. Okanagan	Oliver	864	839

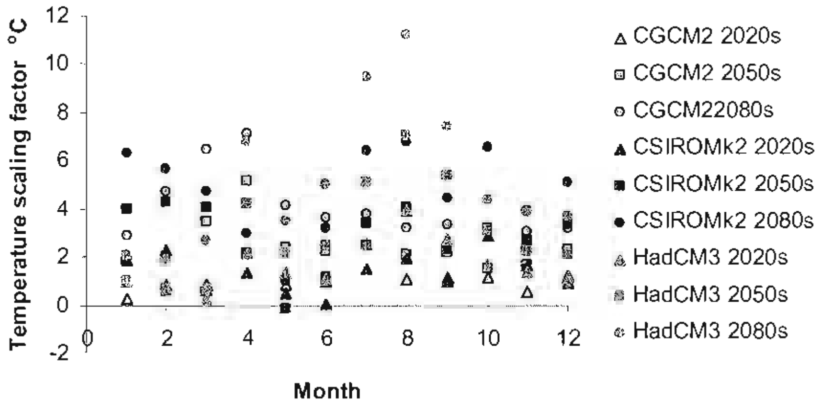

Figure 6. Monthly temperature bias factors generated from GCM A2 (high emissions) scenarios for three

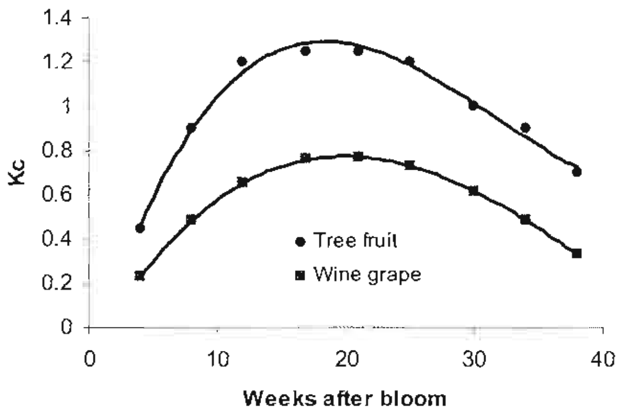

Figure 2. Generalised crop coefficient curves for tree fruit and grape

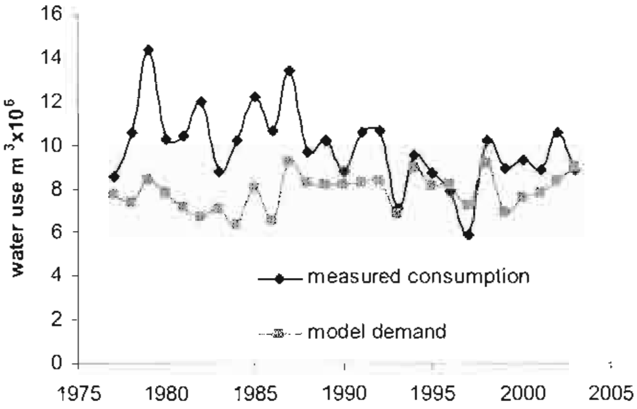

Figure 3. Comparison of measured consumption and modeled crop water demand for the Municipality of Summerland 1977-2003

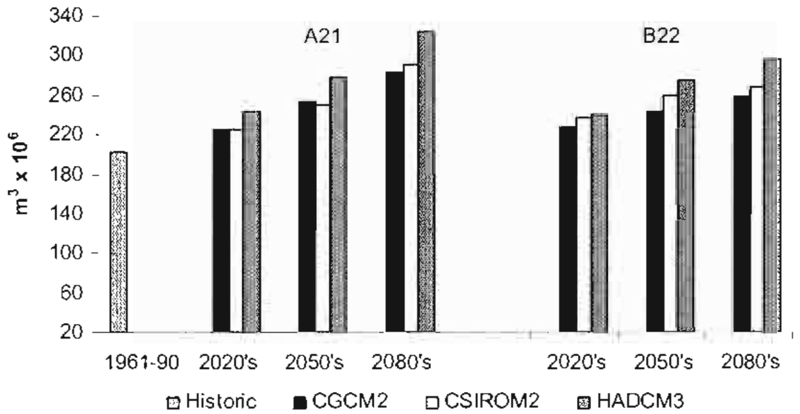

Figure 4. Estimated average annual crop water demand for the Okanagan Basin under historic conditions and six climate scenarios at three time slices.

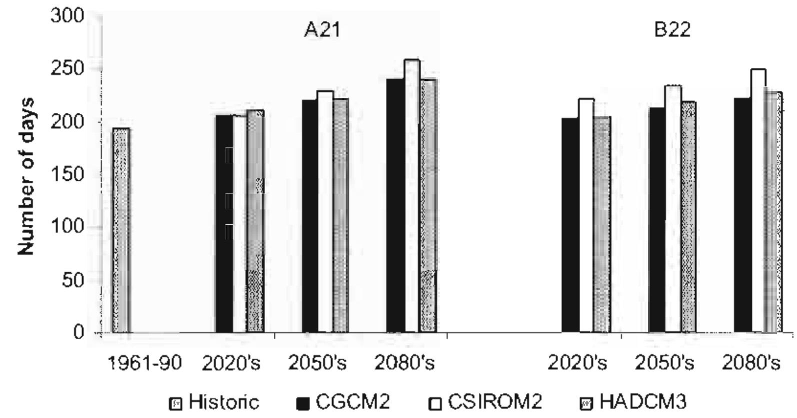

Figure 5. Estimated change in the length of the growing season for the Okanagan Basin under historic conditions and six climate scenarios at three time slices

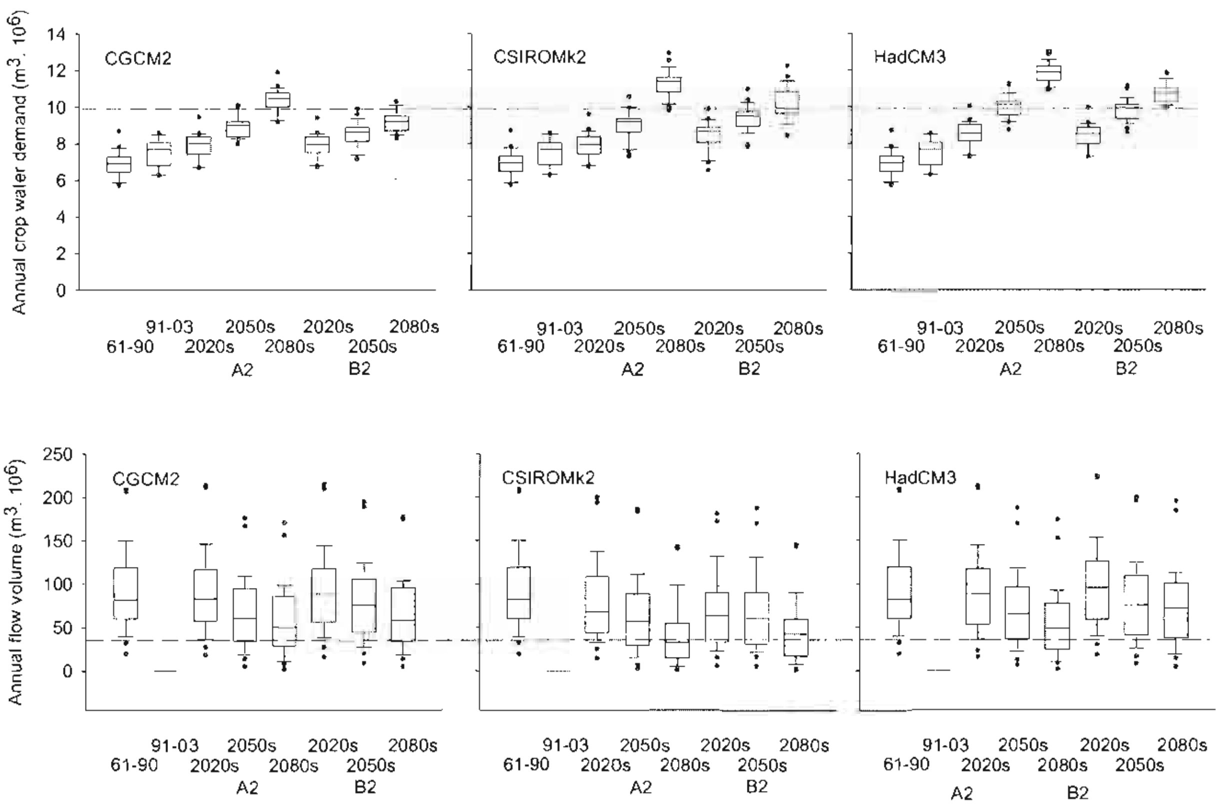

Figure 6. Magnitude and variability of modeled crop water demand (top row) and total annual flow in Trout Creek (bottom row) in response to climate change scenarios. Dashed line in top row is a maximum demand threshold imposed to protect in-stream flow requirements. Dashed line in bottom row is defined drought for Trout

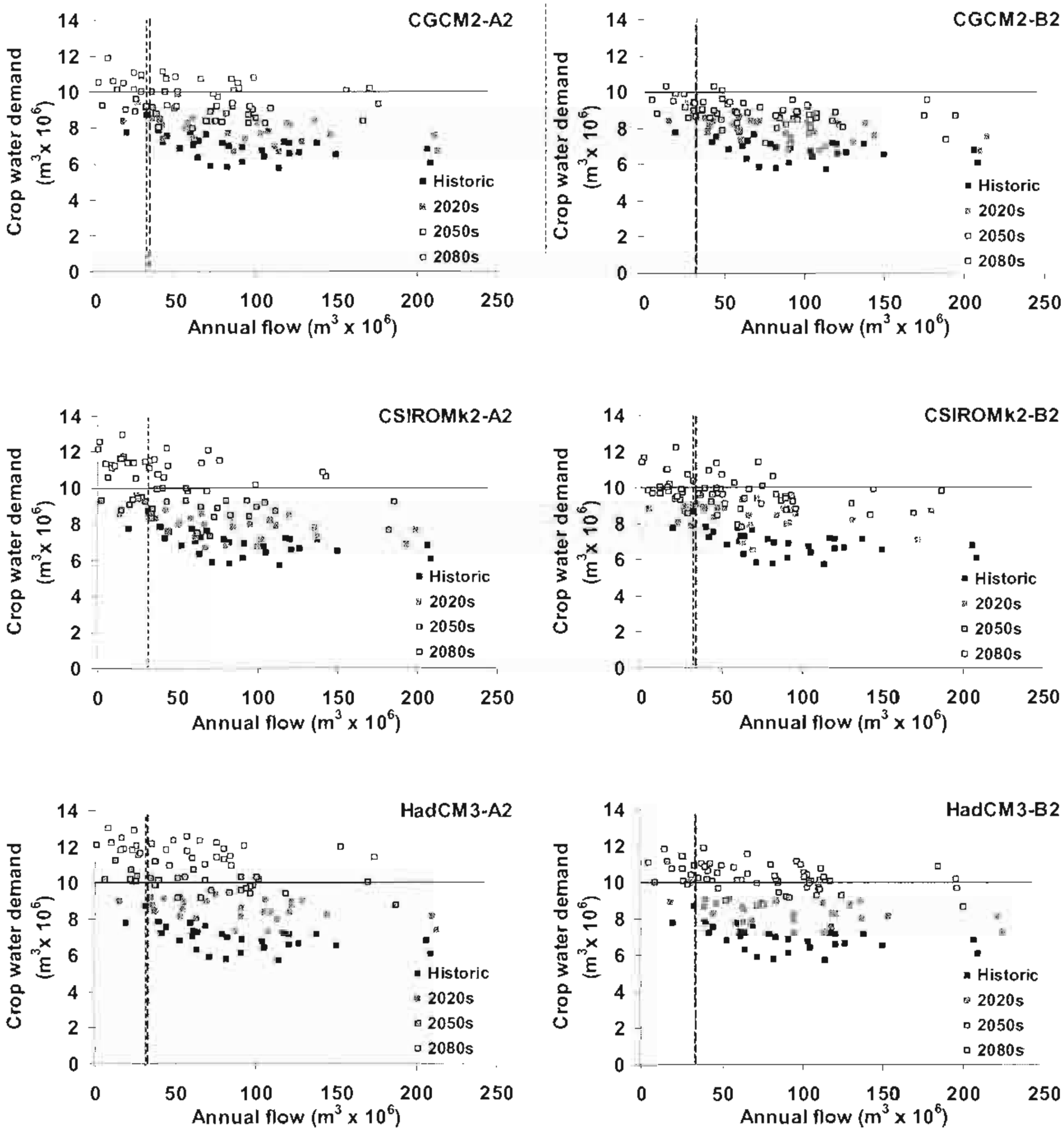

Figure 7. Relationship between total annual flow in Trout Creek and crop water demand in Summerland modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to climate change scenarios. Vertical dashed line is the drought threshold. Solid horizontal line is the maximnm annual demand.

The Okanagan Fish-Water Management (OKFWM) Tool: Balancing Water Objectives in Real-Time

by

Clint Alexander[1]

Abstract

Natural variation, scientific complexity, competing objectives and multi-agency communication barriers are challenges faced by managers who must decide how to allocate limited and variable water supplies. In the case of Okanagan Lake (British Columbia), water levels are managed to provide a balance between flooding, fisheries, urban/agricultural withdrawals and other interests. In 2001, the Okanagan Basin Technical Working Group (OBTWG) identified development of an Internet-accessible software application (OKFWM) as the central tool for improved flow release practices at Okanagan Lake Dam which better account for fish population requirements alongside traditional socioeconomic objectives. The OKFWM system provides a multi-user decision making framework based on five coupled state-of-the-science biophysical models (hydrology, socioeconomic water management rules, water temperature, kokanee and sockeye) that address lake and down-river considerations at a variety of sites. These submodels leverage web service automation for daily real-time updates on lake elevations, water temperatures and discharge in addition to manual information updates obtained from historical and ongoing field monitoring programs. OKFWM operates in two modes: (a) retrospective (or training) mode using historical data sets and (b) a prospective in-season management mode using real-time data to assist weekly water release decisions. In 2004, a comprehensive 25 year retrospective analysis was performed for the 1974 to 2003 period that included training of "apprentice" fish/water managers supported by senior managers. Results showed average sockeye smolt production gains from Osoyoos Lake of 384,000 – a 55% improvement – without adversely impacting flooding and economic interests. The process of developing the tool has produced significant advances in fish/water management in the basin. Given OKFWM's ease of use and demonstrated potential, water and fisheries managers representing private industry, First Nations, federal and provincial interests have enthusiastically adopted the tool. Further background on the motivation for and value of the tool are provided below.

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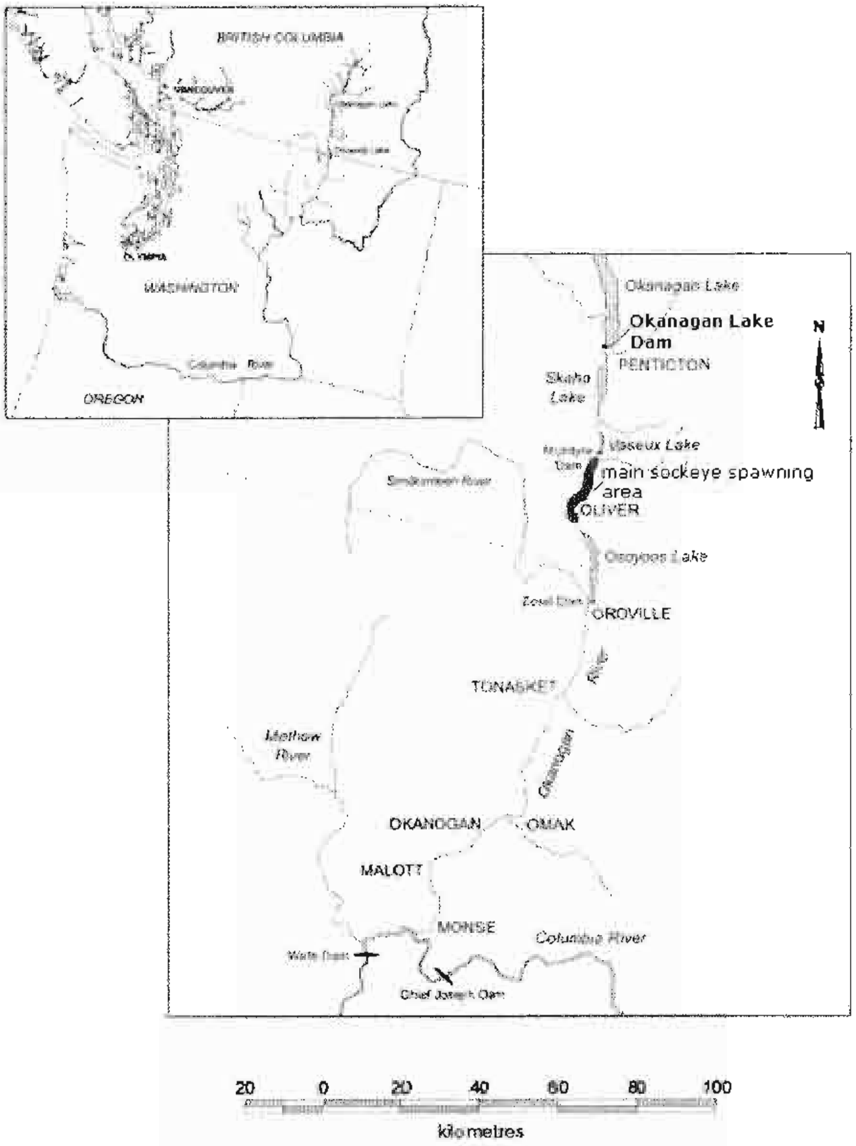
Problem Background

The abundance of Okanagan River (Fig. 1) sockeye salmon have declined precipitously since the 1950s and annual returns are frequently insufficient to support even modest levels of harvest by aboriginal peoples (Fig. 2). Similarly, until the recent dramatic decline in the 1980s, "landlocked" kokanee in Okanagan Lake had supported a sport fishery (Ashley and Shepherd 1995) valued at more than a million dollars annually (Fig. 3). Given their biological, social, economic and cultural significance, Okanagan Lake kokanee and Okanagan River sockeye salmon are the subjects of several significant stock and habitat restoration initiatives, including the Okanagan Fish/Water Management (OKFWM)



Model.

Figure 1. Southern Okanagan basin showing portion of Okanagan Lake, Okanagan Lake Dam at Penticton, the primary terminal spawning area for Okanagan River sockeye salmon (shaded region) and Osoyoos Lake, the rearing habitat for Okanagan sockeye.

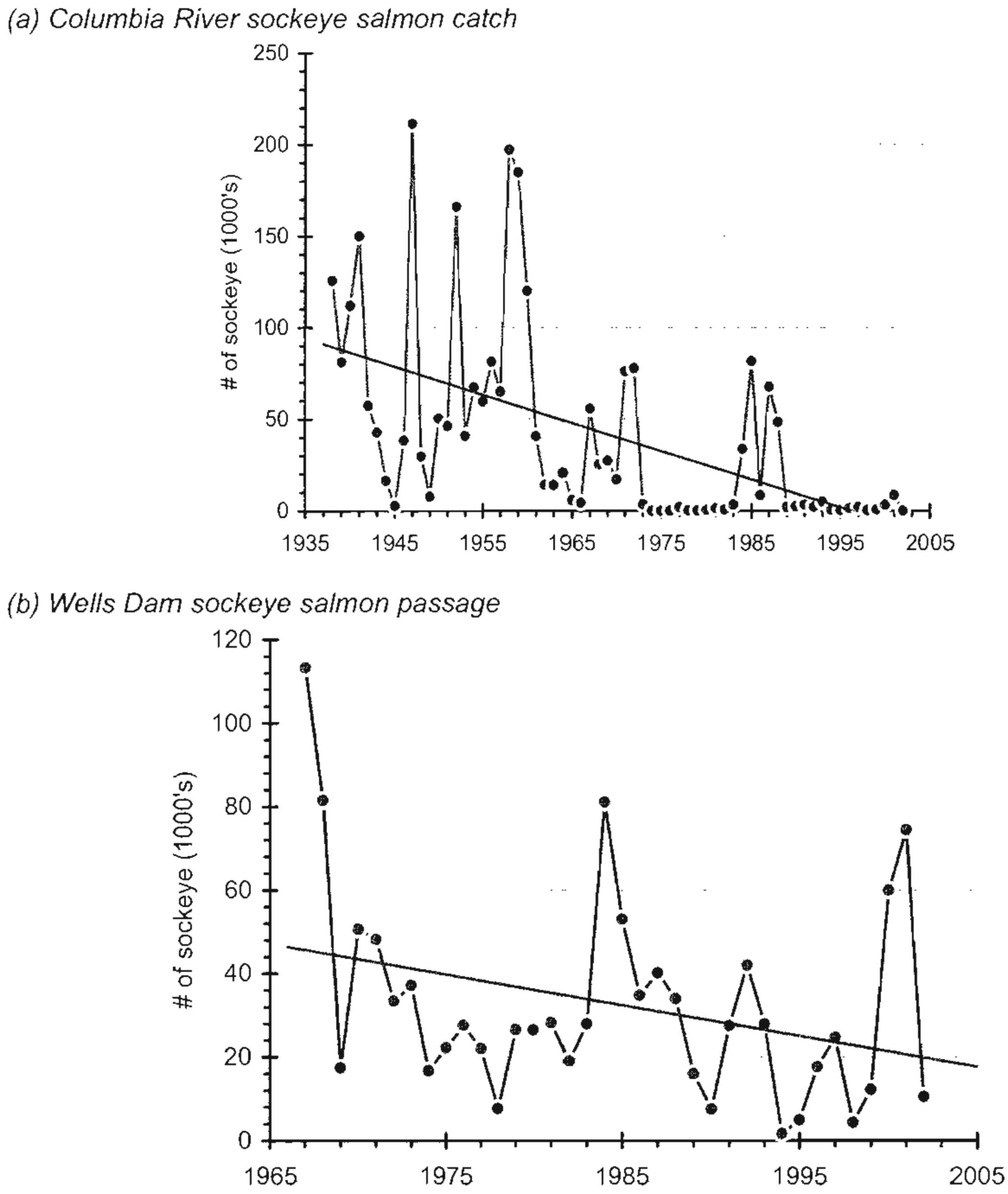


Figure 2. (a) Columbia River sockeye salmon catch and (b) Okanagan River sockeye salmon abundance as indexed by passage at Wells Dam, Columbia River (Hyatt and Rankin 1999).

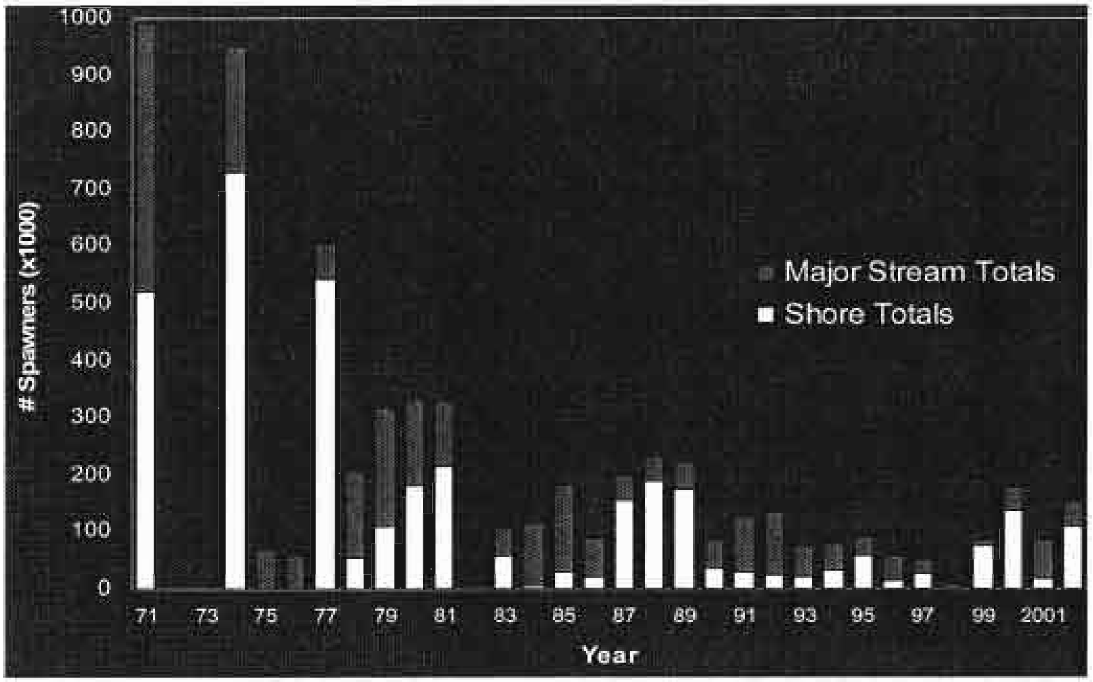


Figure 3. Okanagan Lake kokanee spawning abundance indices. *Source*: Ministry of Water, Land and Air Protection, 102 Industrial Place, Penticton BC, V2A 7C8.

In addition to rules for flood control and water supply management, the Okanagan Basin Implementation Agreement (OBIA) of the early 1970s recognized that water management decisions influence fish survival. Consequently, specific provisions of the OBIA focus on the maintenance of seasonal lake and river discharge levels to protect the productive capacity of various life history stages of sockeye and kokanee salmon throughout the system. A review by Bull (1999) illustrated that water management decisions frequently depart from compliance with OBIA targets. Furthermore, recent data from sockeye and kokanee field investigations and discussions with expert sockeye and kokanee biologists suggest the 1974 OBIA targets themselves can be improved to provide additional protection. The study by Bull (1999), sockeye egg scour and egg desiccation mortality investigations by Hyatt *et al* (2001) and subsequent expert workshops with fisheries biologists and hydrologists in 2001 and 2002 suggested significant fisheries survival gains were possible from improved in-stream flow management. Realizing these gains would require taking into account new scientific understanding, field data and better integration of information sources when making water release decisions at Okanagan Lake dam, the OBTWG pursued development of the OKFWM system.

What is *OKFWM*?

The OKFWM tool is an internet-accessible, multi-user decision support model for the Okanagan basin (Fig. 4). Specifically designed for "front-line" water and fisheries managers, the user interface and output for the system provide an intuitive decision-making framework for choosing weekly water releases at Okanagan Lake dam. Using the same external monthly inflow forecasts provided to the Okanagan Basin water managers by Environment Canada's River Forecast Centre, these release decisions are then passed to the tools five coupled biophysical models (Fig.

5) to generate critical performance measures at a variety of lake and down-river sites. In addition to holding parameters and lookup information for the tools biophysical models, the database for the system is automatically updated each day with the actual recorded data for Okanagan Lake elevation, water temperatures and Okanagan River discharge at several sites. This real-time information feeds into the hydrology and fisheries components of the model to "self-correct" inflow forecasts and adjust forecasts for accumulated thermal units (ATUs) which determine the windows of vulnerability for developing sockeye and kokanee eggs (see ESSA and Summit 2003 for details).

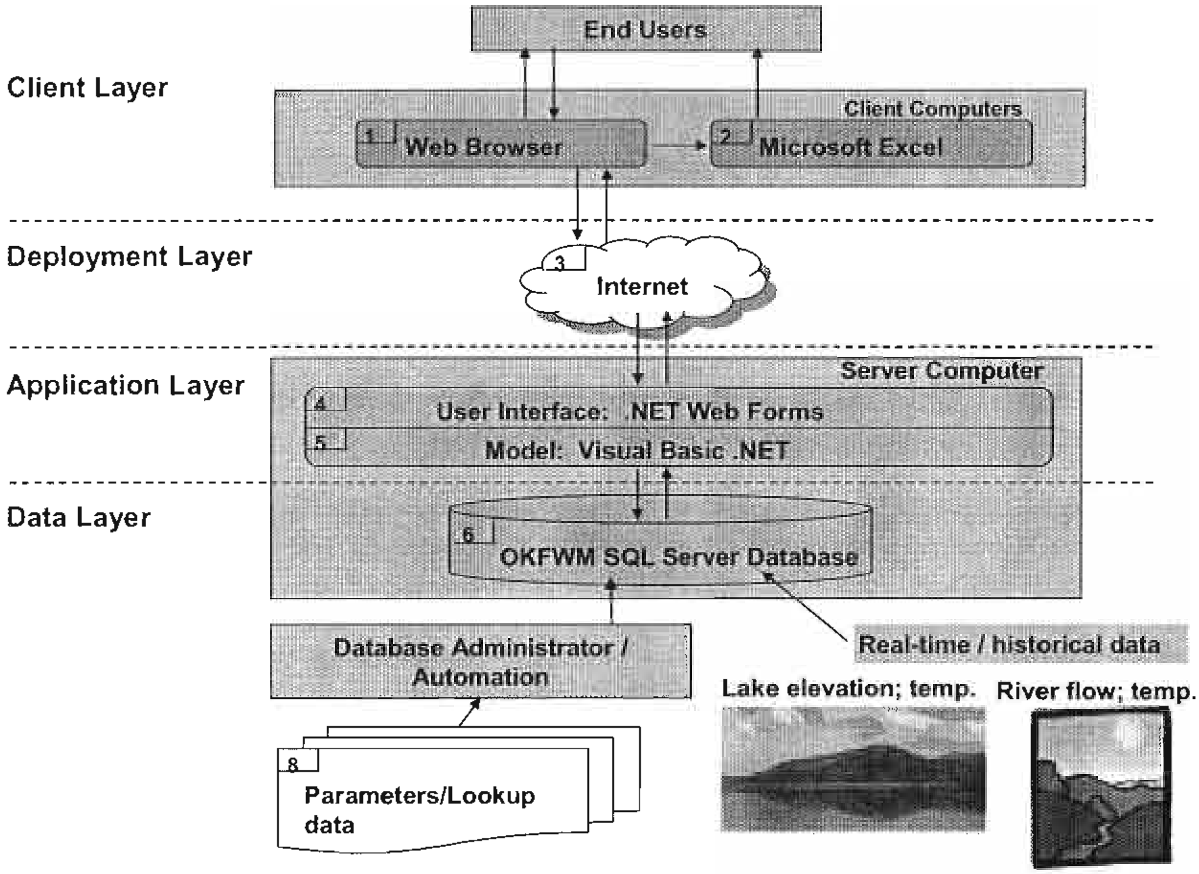


Figure 4. OKFWM system architecture. The system is built on the Microsoft .NET Framework, utilising ASP.NET for the web browser user interface (1, 4), VB.NET for application (submodel) logic (5) and Microsoft Excel for downloadable output reports (2). All data is housed in a single SQL Server 2000 relational database (6). A .NET Web service developed by Environment Canada supplies the real time data to the OKFWM database. This data is further processed into daily average, minimum and maximum values by OKFWM.

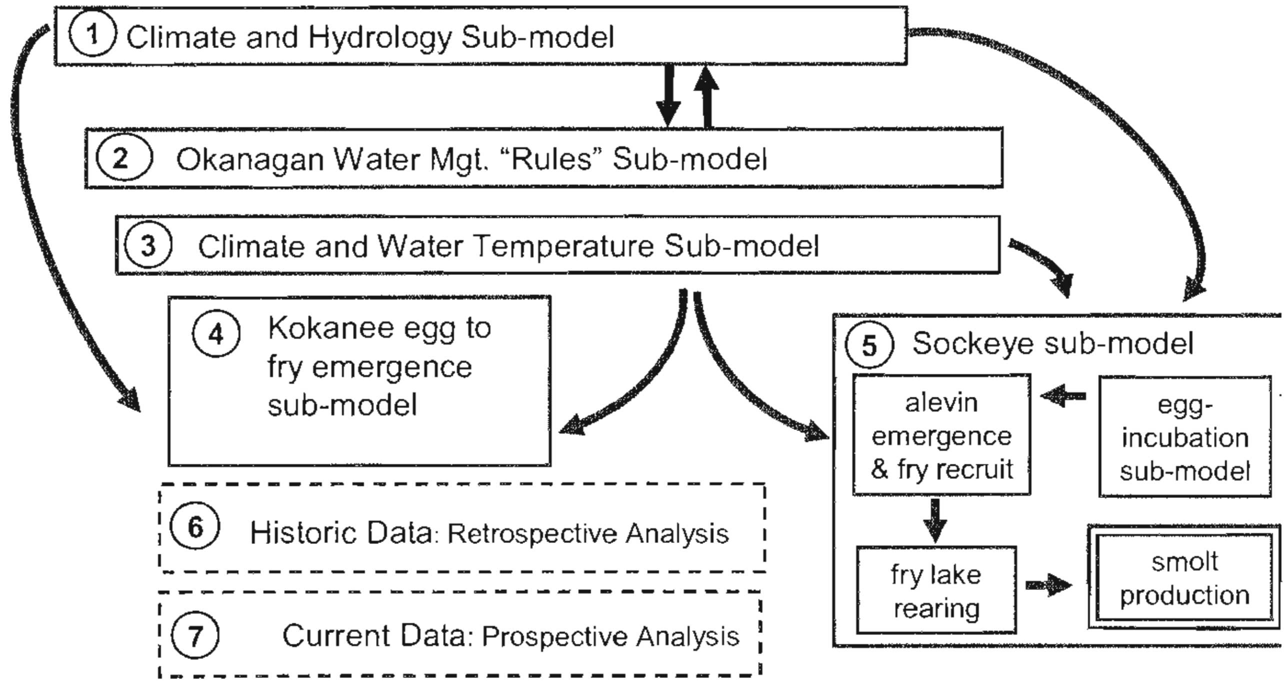


Figure 5. The OKFWM model is a coupled set of 5 biophysical models of key relationships (among climate/hydrology, water, fish & property) used to predict the consequences of water management decisions for fish and other water users. OKFWM may be used to explore water management decision impacts in-season or in a retrospective-model looking back where the true daily historic inflows are known. The details of these submodels are documented in ESSA and Summit (2003).

While driven by data and founded on linked state-of-the-science biophysical models, **a noteworthy feature of OKFWM is the simplicity/approachability of the user interface and its output reports** (Fig. 6). More details on the functions of the user interface components are given in Alexander et al. (2004a).

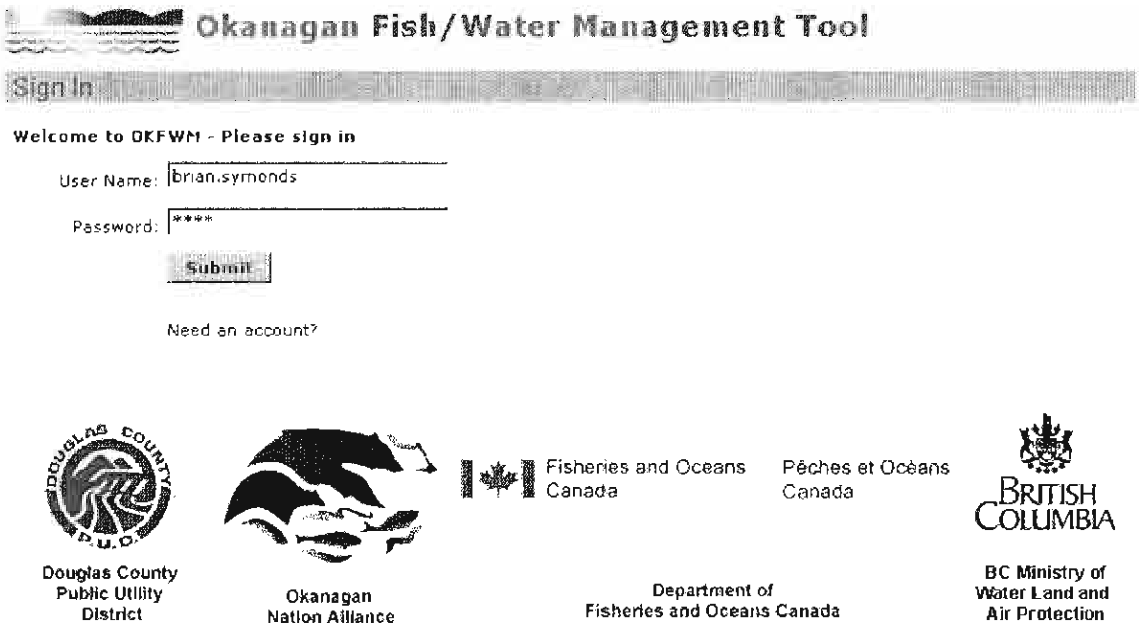


Figure 6-a. OKFWM login screen.

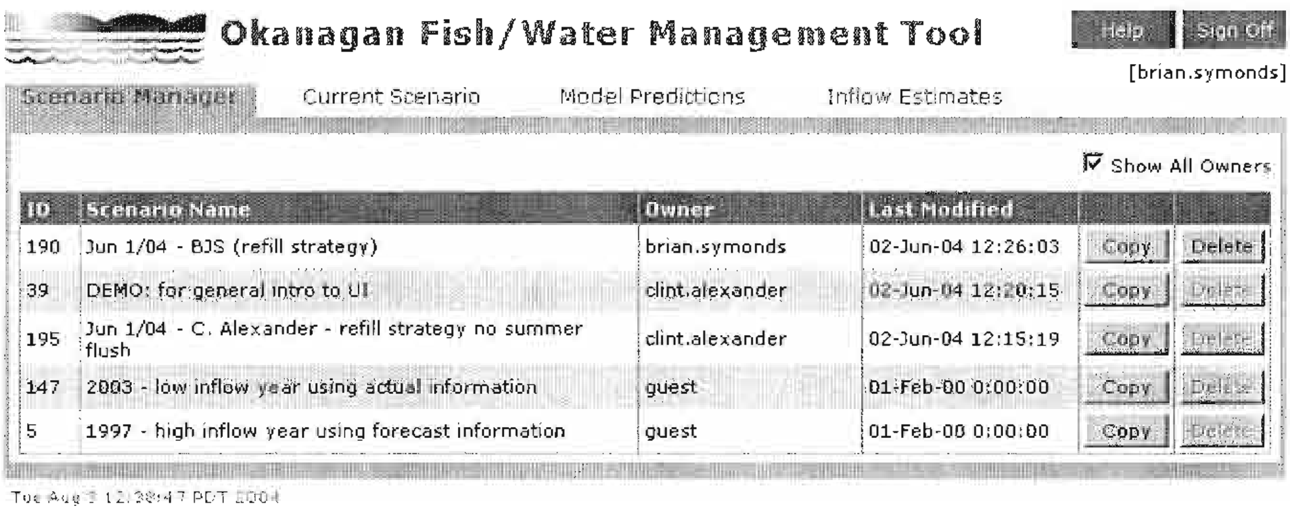


Figure 6-b. OKFWM Scenario Manager tab. The user interface is divided into 4 tabs ('Scenario Manager', 'Current Scenario', 'Model Predictions' and 'Inflow Estimates'). The Scenario Manager shows all the scenarios for the currently logged-in user and all of the shared scenarios in the database. This screen is used to find, copy or delete scenarios. Only scenarios that owners/creators have *elected* to share are visible. Scenario names are given as hyperlinks that once clicked, advance to the appropriate scenario under the 'Current scenario' tab.

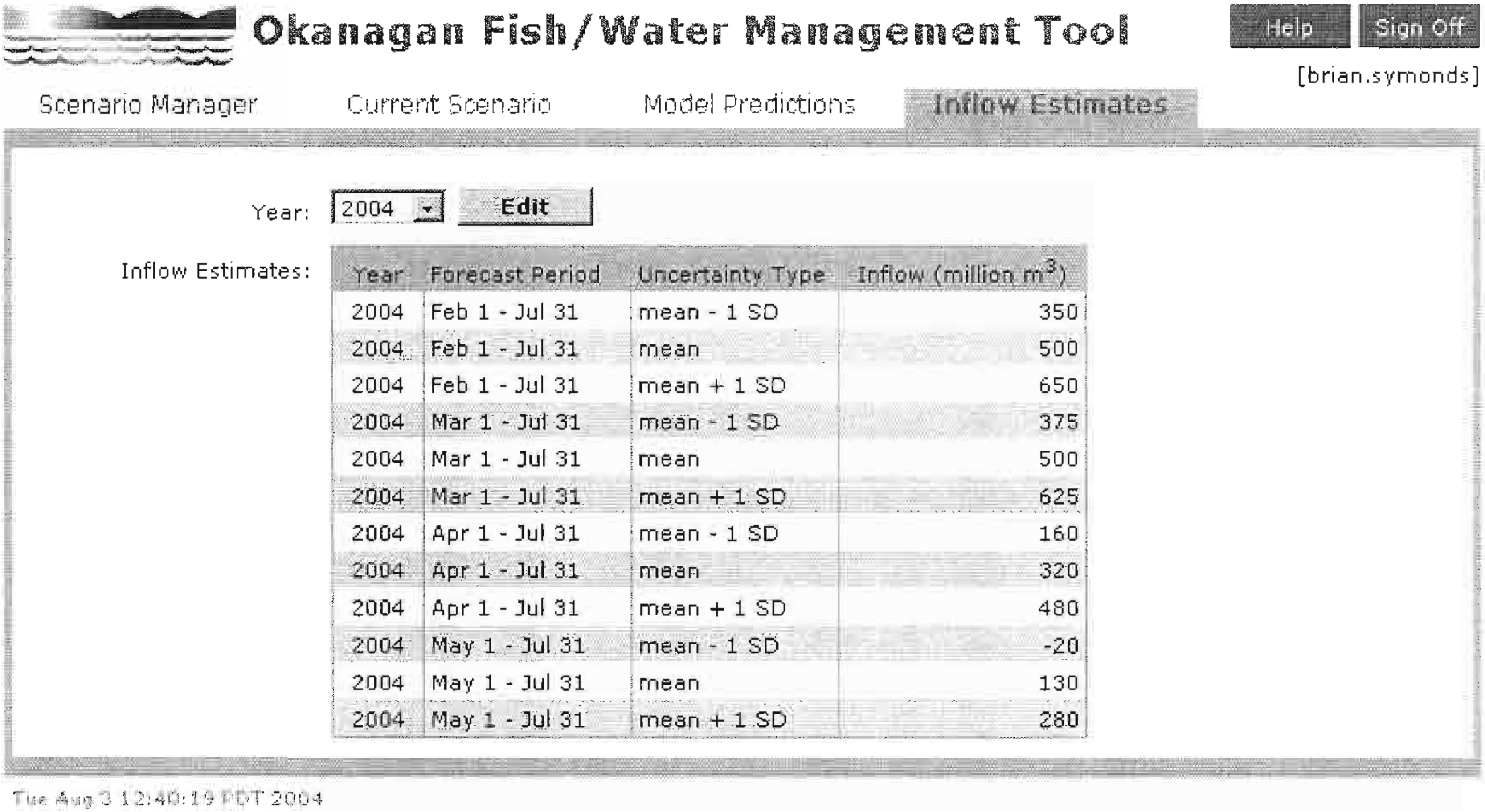


Figure 6-c. OKFWM Inflow Estimates tab. This is where external inflow forecasts provided by Environment Canada River Forecast Centre are entered. Uncertainty in net inflow forecasts is captured as low (mean -1 SD) and high (mean + 1 SD) forecasts. SD = standard deviation.

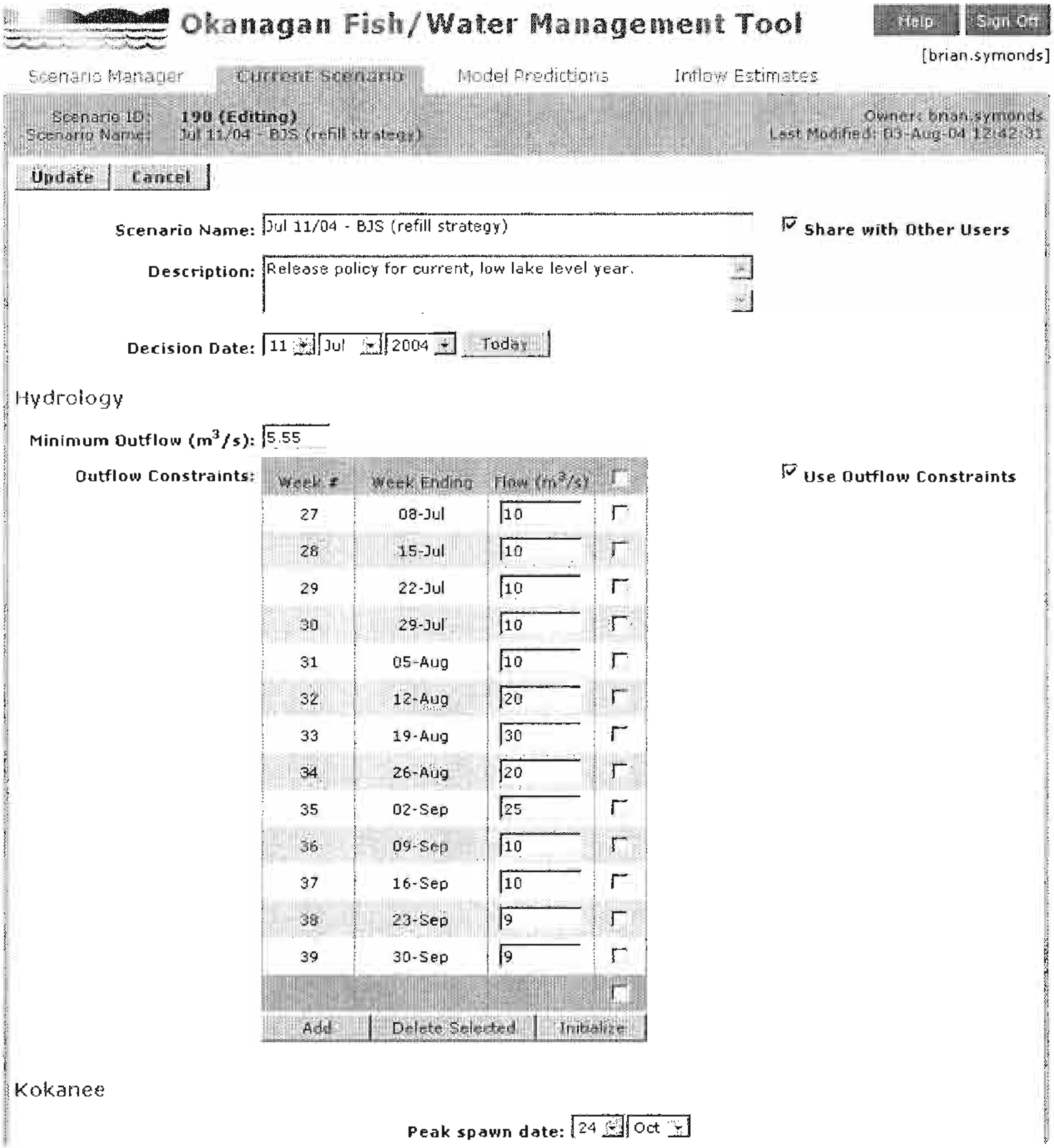


Figure 6-d (part 1 of 2). OKFWM Current scenario screen. This is the main tab used to modify a water management scenario. The main features include the Decision Date (the date after which forecast data are to be used) and Okanagan Lake dam outflow constraints, as well as other submodel assumptions.

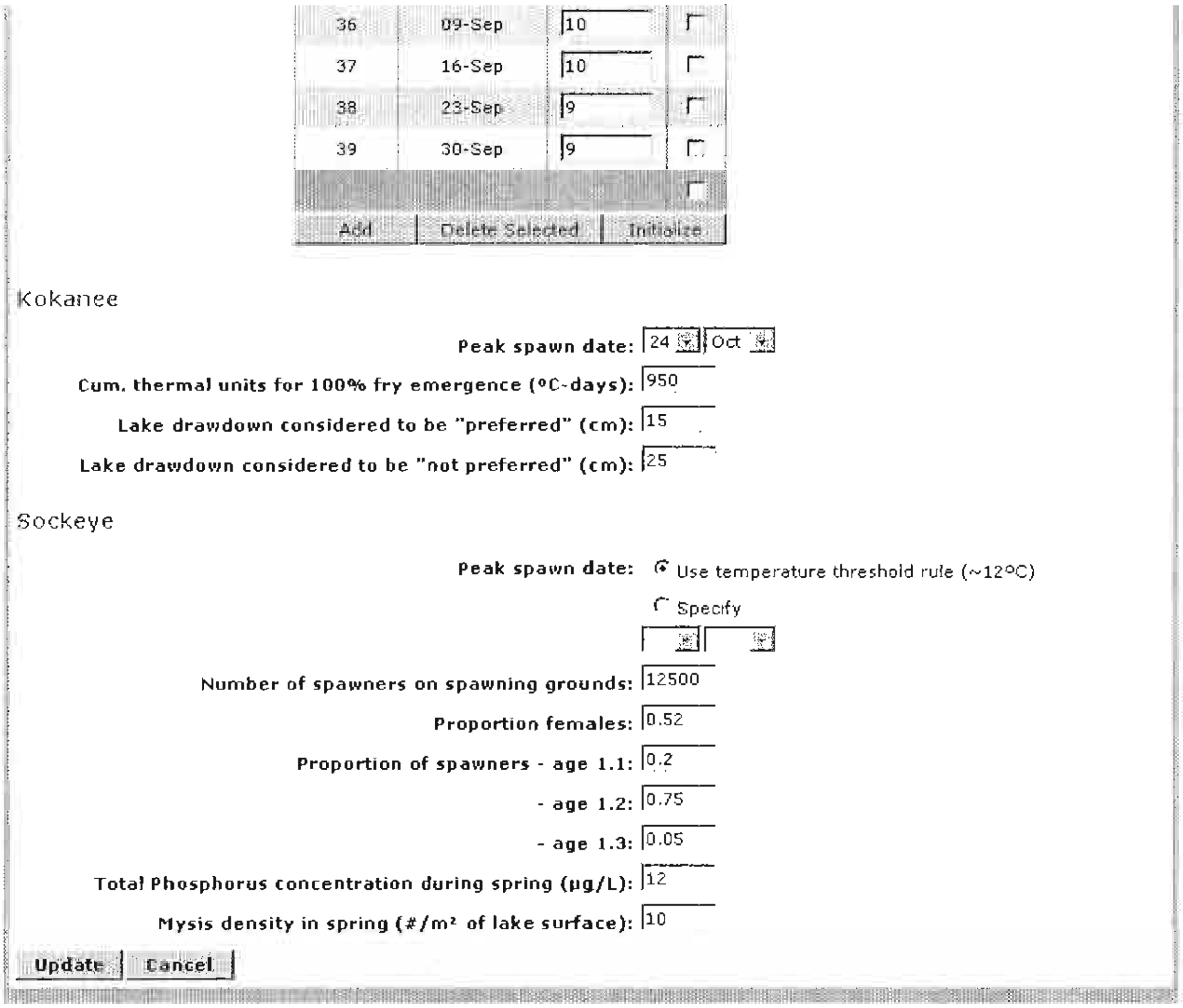


Figure 6-d (part 2 of 2). OKFWM Current Scenario screen. *Note*: a large number of model parameters exist in the OKFWM database, but are not exposed to users.

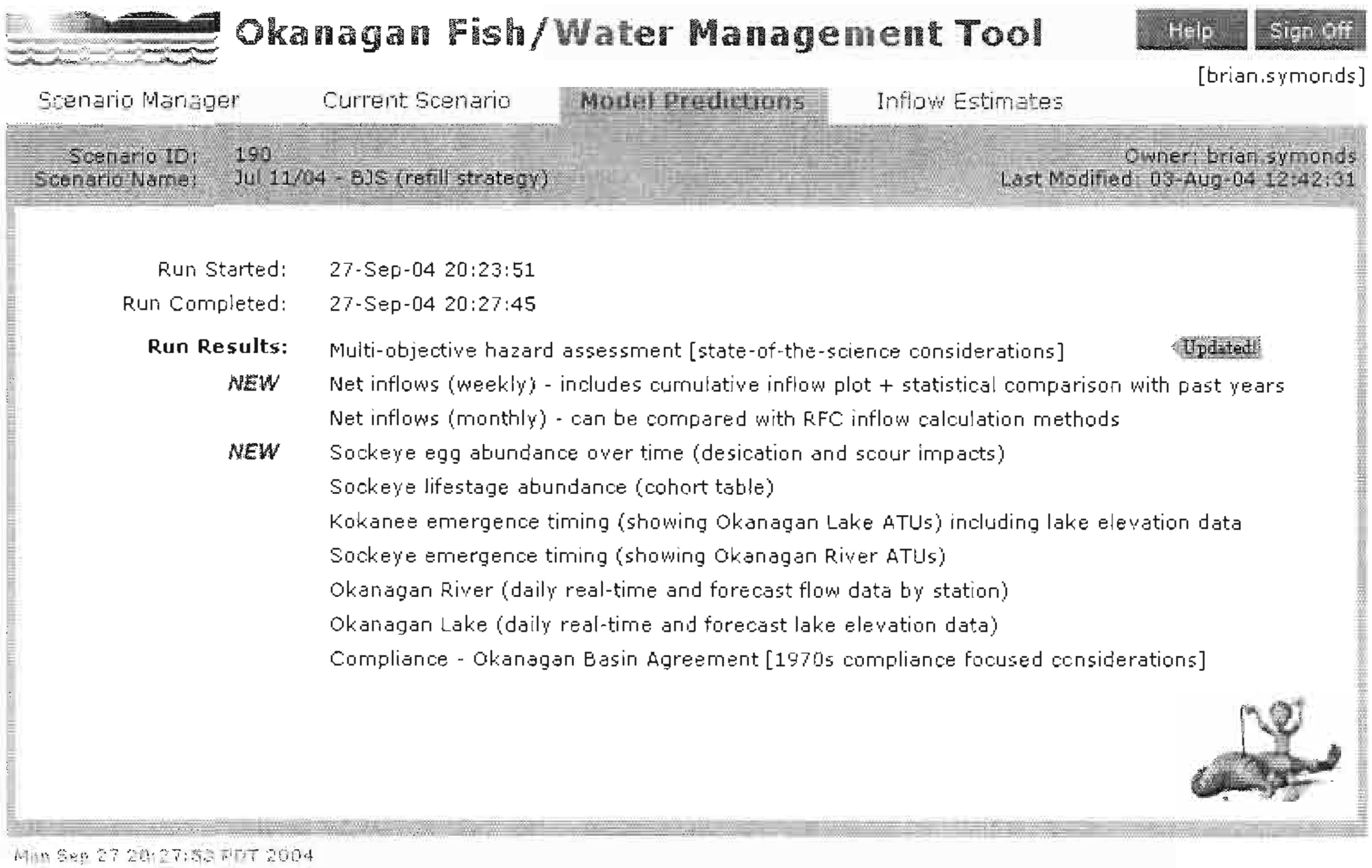


Figure 6-e. OKFWM Model Predictions tab. This shows the list of output reports for a model run that are downloadable in Microsoft Excel. The next image (Figure 6-f) shows a portion of the 'Multi-objective hazard assessment' report.

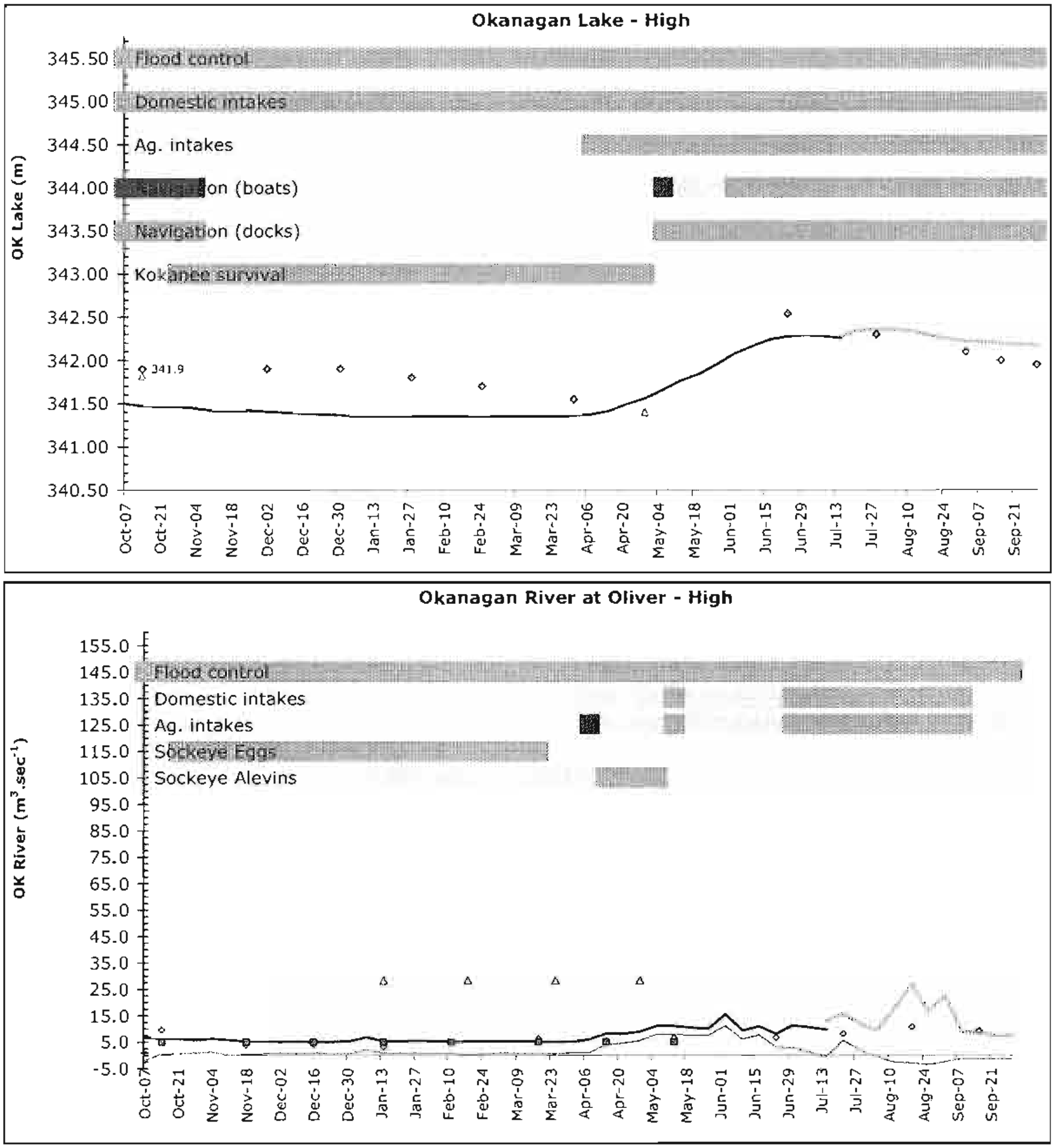


Figure 6-f. OKFWM multi-objective hazard assessment report (example). Only 2 of the 5 locations at which the model produces outputs are shown. Top graph shows Okanagan Lake water elevation and the six primary management objectives of concern: (1) lakeshore flooding, (2) non-agricultural water intakes (for domestic water supply), (3) agricultural intakes, (4) navigation of boats (e.g., in/out of marinas), (5) navigation at docks/boat launches, (6) kokanee egg survival (related to lake drawdown, egg dewatering). Green ( ) = good/desired; Yellow ( ) = undesired/potential losses; Red ( ) = highly undesired/significant losses. The horizontal width of the bars reflects the time-frame over which each objective applies. Bottom graph shows Okanagan River discharge at Oliver, where five management objectives of concern include: (1) river margin/floodplain flooding, (2) non-agricultural water intakes (for domestic water supply), (3) agricultural intakes, (4) sockeye egg survival (de-watering and scour mortality), and (5) sockeye alevin survival (de-watering and scour mortality).

So what?

To quantify the potential benefits of routine application of OKFWM for in-season management, a formal retrospective analysis was conducted to identify the potential sockeye production benefits while concurrently balancing flood control and water supply objectives. The research question posed in this analysis was: *if you had used OKFWM between 1974 and 2003, what water release decisions would have been made and how might this have changed the abundance of sockeye smolts leaving Osoyoos Lake?* To answer this question, we completed the following steps: (1) training of "apprentice" fish/water managers to use the OKFWM system[7]; (2) re-creation of the weekly/daily water management decisions made between 1974 and 2003; (3) generation of baseline sockeye smolt production expectation (via running OKFWM using the actual historical daily water release decisions made in each of the 25 years); and (4) comparing modelled sockeye smolt production in "2" and "3." Details of these steps and study findings are provided in Alexander et al. (2004b).

Results of our analysis suggested routine use of OKFWM by fish and water managers may yield an average sockeye smolt production gain from Osoyoos Lake of 384,000 – a 55% improvement – without adversely impacting flooding and economic interests. These smolt production benefits varied by water year type, with higher benefits generally occurring in average and wet years (Table 1).

Table 1. Summary of 2003/2004 retrospective analysis results grouped by water year type.

	n	$OKFWM_{smolts}$	$Actual_{smolts}$	$OKFWM_{smolts}$ - $Actual_{smolts}$	**Average Improvement**	**Median Improvement**
avg	7	1,534,848	978,364	556,485	57%	82%
dry	9	856,076	618,853	237,223	38%	4.1%
wet	9	961,745	563,409	398,336	71%	70%
	25					

A more informative way of presenting these results is as a function of net inflow given its driving influence (Fig. 7).

[7] Throughout this period, Brian Symonds of the Ministry of Water Land and Air Protection participated closely in the retrospective training and review. At the time of his close participation, Mr. Symonds had 14 years of experience with water management in the Okanagan basin.

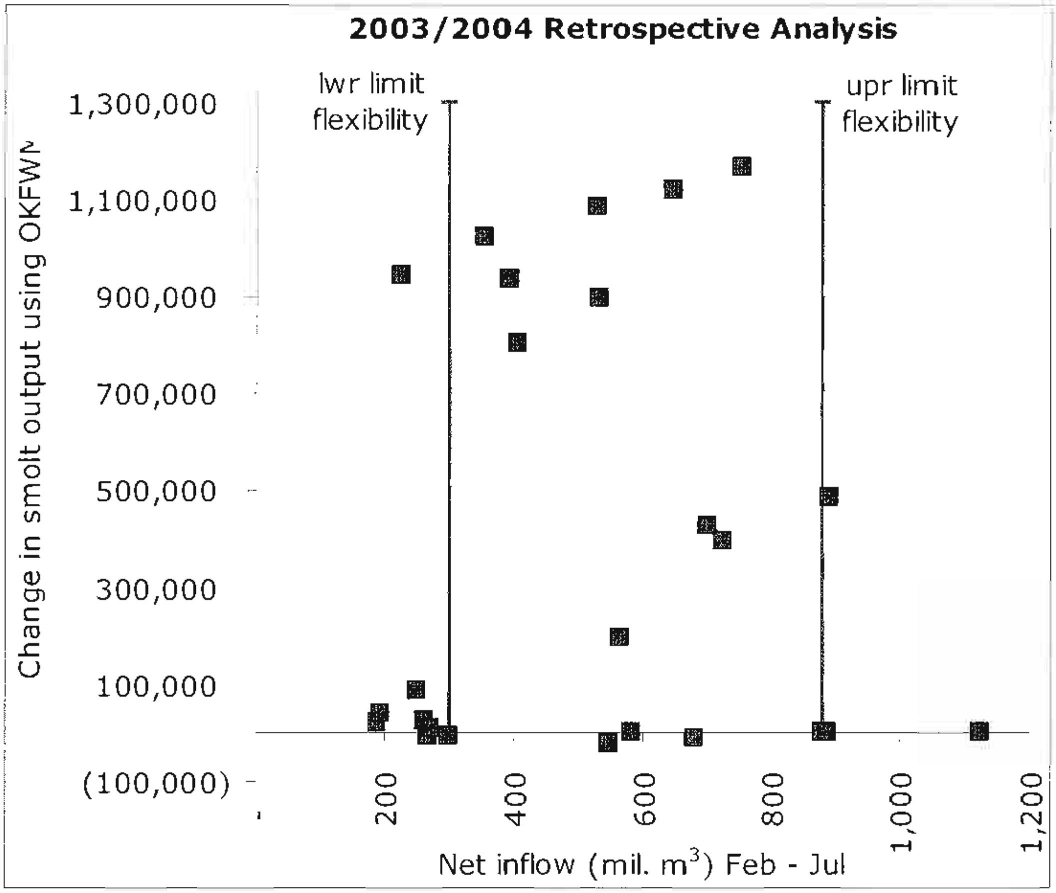


Figure 7. Change in sockeye smolt production owing to routine use of OKFWM between 1974 and 2003 as a function of water supply year (net inflow in millions of cubic meters between February 1st and July 31st). Beyond certain thresholds of inflow, some years are too dry or too wet to permit enough flexibility to realise smolt production gains (without seriously impacting other important objectives). Lwr = lower; Upr = upper.

Discussion

These encouraging results owe to an improvement in: (a) understanding of fundamental ecological processes controlling juvenile sockeye production, (b) the application of real-time data and biophysical models to dynamically predict the interaction of physical and biological variables plus enhance inflow and temperature forecasts, and (c) a heightened awareness of trade-offs. All of these features are seamlessly captured within the OKFWM tool.

The potential benefits of OKFWM's improved information capture and understanding should not be expected to occur in every year. As shown in Figure 7, when February 1st to July 31st net inflows fall below 300 million m^3 or approach 850 million m^3, flow management considerations may no longer be tipped in favour of improving juvenile fish survival. In the case of dry years, in-river egg desiccation mortality and especially density-independent temperature/oxygen squeeze mortality in Osoyoos Lake (Kim Hyatt, *personal communication*) dramatically limited smolt production. In these extreme dry years, supplying the water necessary to mitigate these effects would draw Okanagan Lake down well below tolerable levels. However, for below average water years (~ 310 million m^3 to 420 million m^3), pulse flows during July and August in the neighbourhood of 128 million m^3 or more were able to alleviate temperature/oxygen squeeze mortality and accounted for the large hypothesised improvements in those years[8].

When approaching 850 million m^3 in net inflow (between February 1 to July 31), water managers no longer have the flexibility to hold off large releases during the egg incubation period, and must release large quantities of water (often upwards of 45 $m^3.s^{-1}$ to 60 $m^3.s^{-1}$) starting as early as March, thereby unavoidably inducing high rates of egg and alevin scour. Further, in these high inflow years the large inertia in lake elevation response to outflow owing to Okanagan Lake Dam's limited release capacity and the rate differential between freshet inflows and outflows (e.g., > 250 $m^3.s^{-1}$ entering lake, ~ 60 $m^3.s^{-1}$ to 70 $m^3.s^{-1}$ release from lake) means that water managers who wait until mid-April or May to start ramping up releases to draw down Okanagan Lake will run out of time and experience *massive* lake and river flooding.

One "fish-friendly" tactical variation for a high inflow year is to 'get ahead' of the spring run-off, and draw down the lake in late winter (or sooner). This provides additional flexibility to hold off large releases until sockeye eggs have completed their incubation and emerged from the spawning gravels. However, "knowing" whether a year will be wet enough to warrant such an action in January or February is a highly uncertain science (R^2 on the River Forecast Centre's first net inflow forecast in February is ~0.24). Moreover, if adopted after kokanee spawning, this approach would generate large in lake de-watering mortality of shore spawned kokanee eggs if the draw-down realised was beyond 20 cm (Andrusak and Matthews, as cited in ESSA and Summit 2003). Thus, while the 'getting ahead' strategy is worth consideration, the best option from a kokanee and sockeye perspective may be to hold onto the water until late in the emergence period, then maximize releases (i.e., > 50 $m^3.s^{-1}$ at Okanagan Lake Dam, Penticton). The advisability of this 'hold-and-flush' approach depends on how wet the late spring is likely to be. If the magnitude of net inflow in May through July is manageable or happens to be less than expected or its distribution more diffuse (and downstream tributary inflows are below average) the water manager can avert both sockeye scour, kokanee dewatering *and* lake/down-river flooding.

Overall, results of our analysis suggest the 'hold-and-flush' strategy is a good one *if* the net February 1 to July 31 inflows are in the 550 million m^3 to 775 million m^3 range (because at this magnitude of inflow, "letting it rip" will not entail approaching/exceeding Okanagan Lake Dam's design outflow capacity of 60 $m^3.s^{-1}$). However, a 'hold-and-flush' approach was clearly shown to be foolhardy if net inflows exceeded the 825 million m^3 to 850 million m^3 level. Essentially, if faced with 850+ million m^3 of water, the outlet works at Okanagan Lake Dam at Penticton, in-channel structures in Okanagan River and its overall down-river configuration cannot cope with the magnitude of releases that would be needed to move this volume of water out of Okanagan Lake post-sockeye incubation, sometime in mid-April or early May.

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[8] It should be noted that the magnitude of summer pulse flows necessary to undo temperature/oxygen squeeze mortality and its mechanism was a key uncertainty in this analysis (relevant to dry year results only).

In summary, these retrospective results, in combination with the dramatic improvement in information acquisition and ability to trade-off amongst objectives provide ample evidence to proceed with routine in-season implementation of OKFWM.

Lessons and Recommendations

In the broader context of sustainable water management in the presence of climate change and increasing population demands this work offers several important lessons:

1. Improvements in water management (i.e., those that best balances *multiple* social *and* ecological objectives) are not possible without first-class, sustained collaboration of the type exhibited by the OBTWG and their partners for over a 6 year period. To be effective, this must include more routine and close connections between and among technical opinion makers and decision-making bodies through use of organizational arrangements like technical working groups and steering committees with dedicated and knowledgeable leadership. This collaboration must extend beyond traditional water district or other government boundaries to ensure physical watershed boundaries are taken into account when making decisions related to water supply and demand. Any structure which favors isolationist or piece-meal decision-making (e.g., knowledge silos) will not have the requisite membership and expertise to learn how to identify truly new and better optimums.
2. OKFWM is a flagship example of the value of information capture and consolidation across disciplines using a decision support system. The value of these tools are realized in two ways: (a) they create an interdisciplinary advance in knowledge during the process of design and development and (b) better handle complex arithmetic to identify a more suitable balance amongst objectives during routine implementation. Ignorance of data gaps, inconsistencies, failure to recognize uncertainty or over-weighting of easy-to-collect data are foregone conclusions in settings where there is no *coordinated and ongoing* information management strategy built into the routine cost of doing business. To be effective, this type of information management strategy must span the watershed and be accessible to all interested parties. The exact nature of the information system will depend on user requirements it is to serve, but may be a simple database, a web portal, a GIS system, a simulation model or some combination of these technologies. If well designed within an inclusive process, integrated decision support systems clarify trade-offs and simplify decision-making; they can be excellent tools to help foster an increase in mutual understanding needed for "1" to succeed.
3. View Okanagan water management planning as an "Alternative Futures" exercise, recognizing that decisions taken today impact the basin's socioeconomic and ecological trajectory and influence future management flexibility. More frequently review the list of specific *decisions* that water managers need to make on daily, weekly, monthly, annual and decadal time scales and ensure that the processes for informing these decisions adequately take into account future uncertainties such as population demand and supply owing to factors like climate change. In addition, we strongly recommend the use of formal decision analysis to better account for these uncertainties.

4. Following from "3", perform a "Desired Future Audit" every 4 to 6 years (or as significant new information accumulates). For instance, are things like irrigated highway medians consistent with water conservation needs? What is the low hanging fruit in terms of water demand and supply management? Are the social burdens and benefits of water conservation in the Okanagan basin fairly distributed? And ultimately, what must we do more of today to achieve our desired future? Who will be held accountable to do it?

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Trends In Water Demand & Consumption In The Glenmore-Ellison Improvement District

by
Greg Henderson[1] and Amanda Bridge[1]

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Abstract

The Glenmore-Ellison Improvement District (GEID) is a water purveyor in Kelowna, British Columbia that operates a Level 4 Water System and services nearly 11,000 people. The district draws the majority of its water from surface water brought down from mountain reservoirs and creeks, but also uses a considerable amount of groundwater.

The GEID has recently experienced a shift from servicing predominantly agricultural properties, to servicing an ever-increasing portion of urban development. This change in land use is causing a noticeable change in water consumption patterns, and is influencing the short and long term planning of the GEID. Total annual consumption is rising at faster than historic rates (almost 30% over the last ten years), attributable mainly to increased domestic growth. However, per connection domestic water use is trending to decrease over the last ten years, which we suspect is due mainly to higher density housing, smaller lot sizes and therefore less outdoor irrigation. Urbanization is also tending to increase the per hectare water consumption, in comparison to per hectare water consumption on agricultural land.

In order to keep up with growth, the Glenmore-Ellison Improvement District is continuously updating its 10-year Capital Works Plan to review water supply, infrastructure, and fiscal readiness in order to address long term needs and to make cost-effective choices. Recommendations are offered that may be helpful to other water purveyors and to elevate the awareness of the true economic value of water.

1.0. INTRODUCTION / BACKGROUND

The Glenmore-Ellison Improvement District (GEID) is one of five main water purveyors in Kelowna, British Columbia (see Figure 1 for a map of the purveyors' areas). It services an area of approximately 30 km^2 and nearly 11,000 people. The GEID supplies water to approximately 4332 domestic connections and 1494 hectares of agricultural land. The District obtains most of its water from the Kelowna Creek Watershed, which includes Postill Lake, Bulman Lake, and South Lake, and supplements it with water drawn from four main wells.

The Glenmore-Ellison Improvement District began in 1990 and was formed from two separate entities, the Glenmore and the Ellison Irrigation Districts. Ditches and flumes, built in the early 20th century, carried the precious water from reservoirs down the mountain to the crops and orchards growing in the extremely dry Glenmore and Ellison valleys below. In the late 1960's, the Glenmore Irrigation District overhauled the water distribution system into a pressurized, underground piping system. Chlorine disinfection was added in the 1970's to provide consumers with safer drinking water and to prevent crown root rot in fruit trees. In 1990, the Glenmore and the Ellison Irrigation Districts amalgamated to form the Glenmore-Ellison Improvement District that operates today.

Throughout its history, the Glenmore-Ellison Improvement District has been almost entirely dominated by agricultural properties. However, in recent years, the GEID has experienced a substantial building boom in the residential and commercial development areas. Strata's, subdivisions, and mini-malls are now occupying areas once used for agricultural purposes. This paper provides a retrospective look at historic water use in the GEID, trends that have emerged in recent years, and summarizes with some of the management implications and associated adaptations that will be needed to meet forecasted water supply and quality demand.

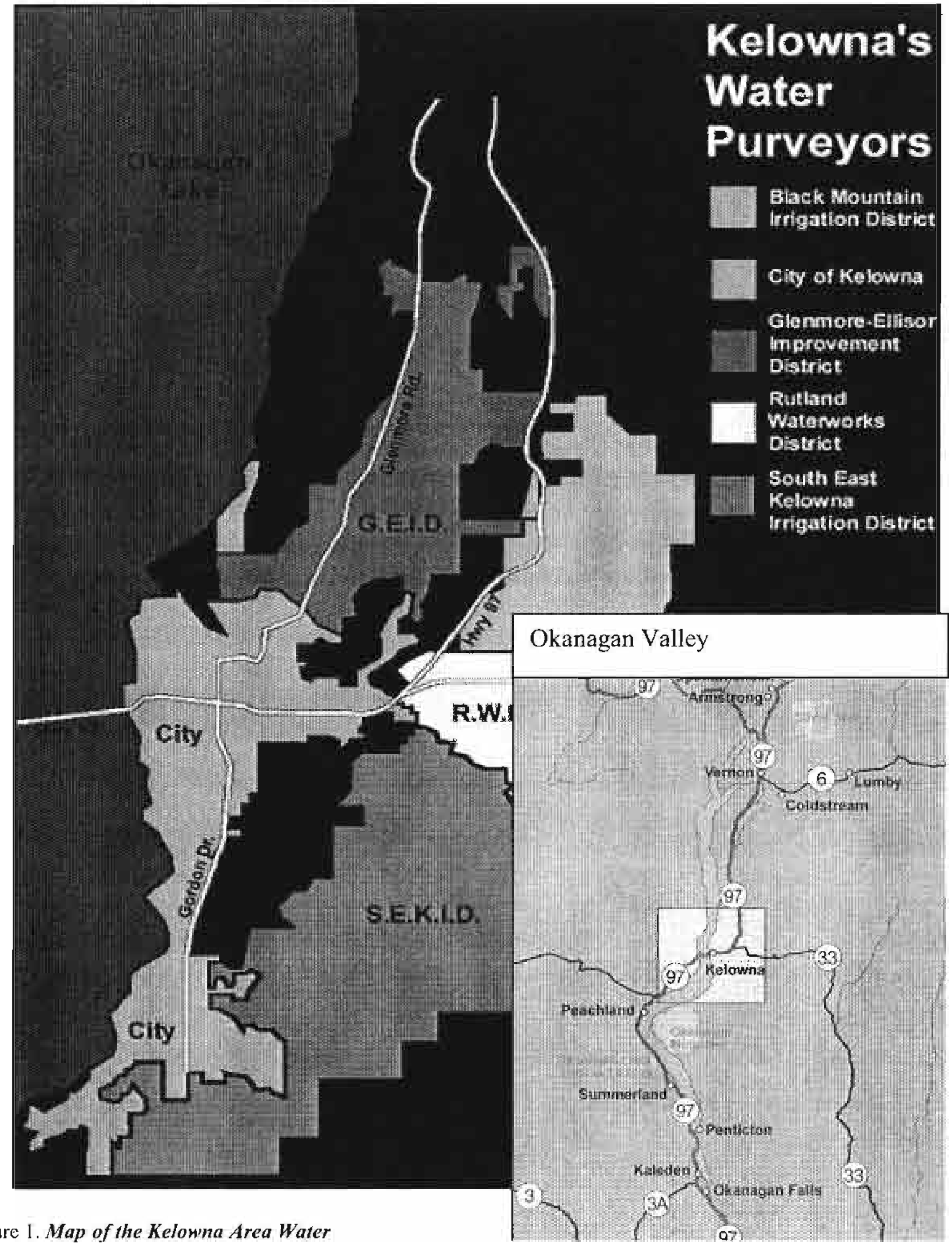

Figure 1. ***Map of the Kelowna Area Water Purveyors showing GEID's service area Note: The Ellison system is not shown on this map (Inset – Map of the Okanagan Valley)***

2.0. WATER USE

Annual water demand has more than doubled in the Glenmore-Ellison Improvement District since 1969 (Figure 2). Water consumption in 2003 was 6091 ML (megalitres). In the last ten years alone, consumption has increased by 1824 ML, or 30%.

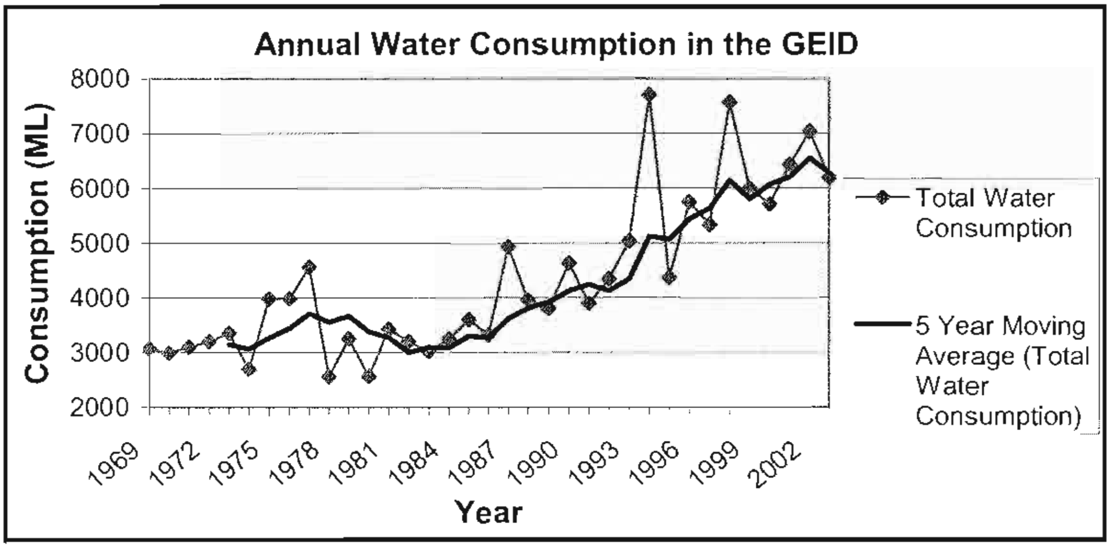

Figure 2. ***Historic water consumption values for the GEID. Although there are annual fluctuations, the 5-year average trendline depicts a steady increase in water demand through time.***

Figure 3 illustrates 2003 water consumption when segregated into the primary land-use types that occupy the Glenmore-Ellison Improvement District. Grade A land, or land used for agricultural purposes, currently consumes approximately sixty-nine percent of total water demand. The next largest users are the large single family (SF) residential lots (lots less than one acre) who account for fourteen percent, followed by the two golf courses with a total of six percent.

For GEID's operations, 'domestic' irrigation includes residential watering, commercial and institutional buildings, and stratas, while agriculture includes agricultural irrigation and water used by golf courses. Figure 3 separates 'golf courses' to illustrate the amount of water used by these facilities. [9]

[9] In generating data for this document, domestic and agricultural consumption values from 1998 to 2002 have been estimated using total annual consumption, number of domestic connections and agricultural acreage, water metering data, and SCADA information (a computer system for gathering and analyzing real time data). Domestic and agricultural consumption estimates previous to 1998 was calculated using the City of Kelowna's estimate of a 60/40 ratio (60% Agricultural consumption to 40% domestic consumption), suggesting that one acre of agricultural land developed into housing, would have a decrease in consumption of 20%.

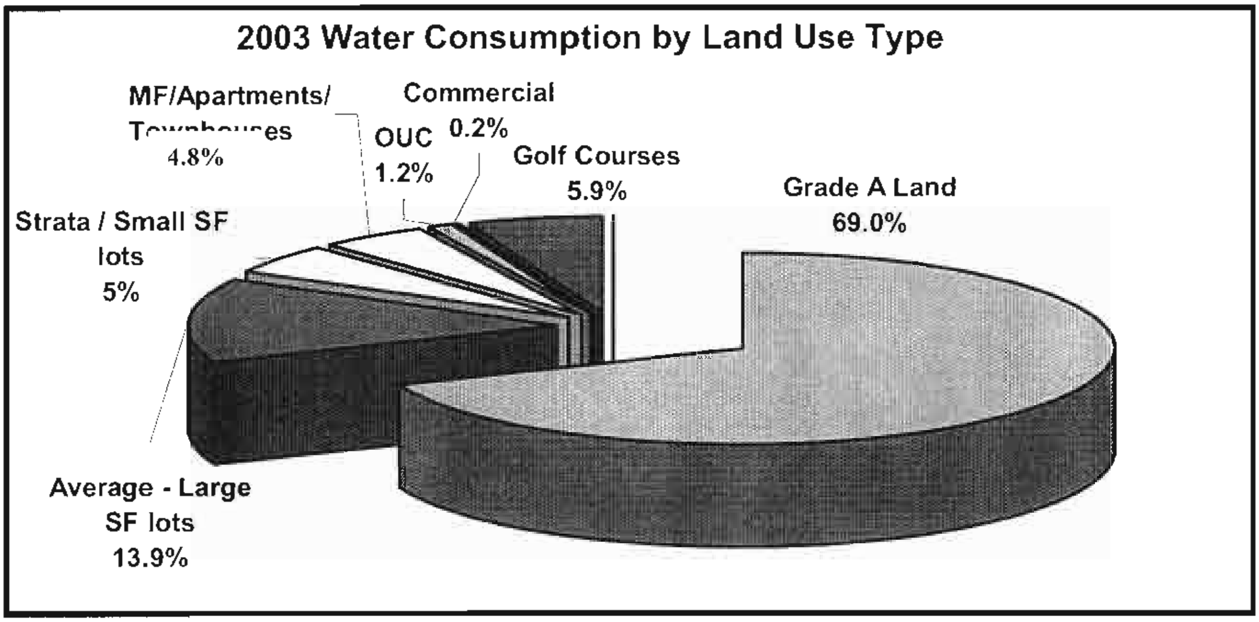

Figure 3. ***2003 breakdown of land use type in the Glenmore-Ellison Improvement District and the subsequent water consumption for each. Note how the agricultural (A-Grade) properties are the largest water consumers. (Data obtain from the 2004 Capital Update Plan (Agua Consulting Inc. 2004))***

Agricultural water use is positively related (R^2= 0.49) to annual evapotranspiration demand, as seen in Figure 4. Evapotranspiration is approximately the water used by a plant and indexes a combination of climate factors such as rain, temperature, humidity and wind. High water use years occur when summer weather conditions are dry and hot, and evapotranspiration is high, such as 1998 and 2003. Evapotranspiration is lowest in wetter or cooler summers, such as 1995, reducing water demand.

Annual domestic water consumption patterns follow a similar positive trend with evapotranspiration, likely related to increased outdoor irrigation during periods of warm weather, but the relationship is not as strong (R^2=0.28, data not shown) in comparison to agricultural water use. Overall, annual domestic water consumption appears less variable to annual climatic changes than for consumption rates on agricultural land.

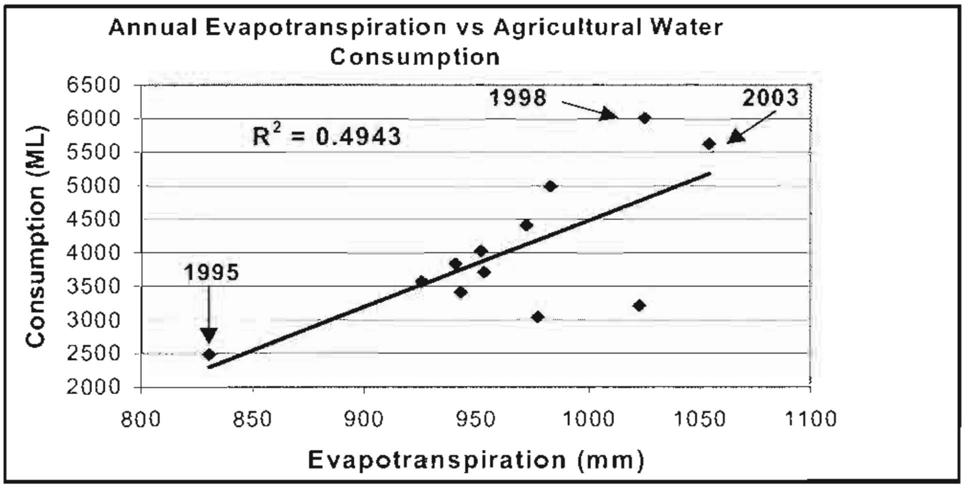

Figure 4. ***Correlation between the historical evapotranspiration data and the GEID's water consumption values for agricultural properties. The diamond points on the graph represent each year from 1991 to 2003. (Evapotranspiration data found online at www.farmwest.com and is for the Kelowna Airport area).***

The Glenmore-Ellison Improvement District draws water from two main sources, the Kelowna Creek watershed and groundwater. Surface water supplies the bulk of annual demand to GEID's customers, but Figure 5 shows an increasing reliance on groundwater. This is due partly to supplement supply, lessen the stress on storage in creeks and reservoirs, and also partly to dilute the surface water in times of lower water quality. In the last seven years, the GEID has drawn, on average, approximately 23% percent of its source water from wells, however, in 2003, a particularly hot, dry year, groundwater amounted to over 33% of the total source water.

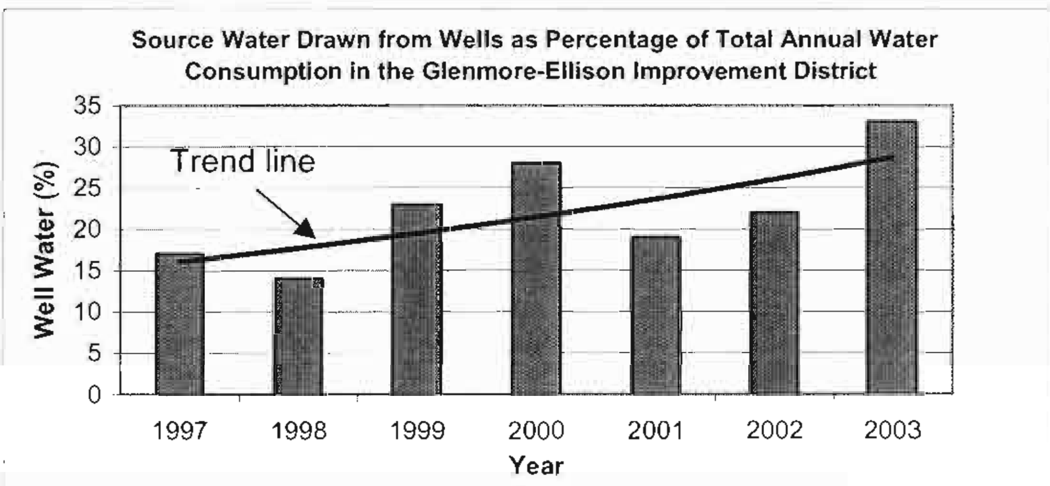

Figure 5. ***This figure illustrates the increasing groundwater dependence in the GEID.***

The ratio of agricultural to domestic water consumption widens in hotter summers (e.g. 1998) and narrows in cooler summers (e.g. 1995) (Figure 6). However, although the amount of irrigated hectares has remained relatively constant over the last ten years, the number of domestic connections has increased dramatically (Figure 7). Between 2003 and 2004, new domestic connections increased by over 7%, whereas the previous four years had an average yearly increase of only approximately 2.5%. The highest yearly increase occurred in 1991 at 26%. Although not evident in Figure 6, the split between domestic and agricultural peak day water use is approximately equal in some areas of the District (2004 internal data).

With increasing domestic connections, it may be expected to visualize a decline in agricultural hectares over time in Figure 6. However, this is not occurring because the GEID is continually expanding its land base through boundary inclusions and some of this acquired land is classified as agricultural. Also, many of the new developments are being built on land converted from D-grade, or land without water rights.

3.0 LAND USE CHANGE

The landscape of the Glenmore-Ellison Improvement District, especially the Glenmore area, is quickly changing from green hay fields and rows of fruit trees, to residential subdivisions, businesses, and major strata developments. As an example, a single home with a barn and several outlying buildings would be situated between several acres of productive soil that was used for growing hay or fruit trees. Today, that same property could now contain dozens of homes with limited green space.

This conversion of land use has caused some noticeable changes in the water consumption of the District. Figure 8 illustrates the small, but interesting decline in water consumption per unit of domestic connections over the last ten years. It is suspected that the higher density housing is reducing the overall water consumption per domestic connection because of lower outdoor irrigation over smaller lawn and garden areas. In addition, this may also be caused by greater water conservation efforts (sprinkling regulations, increased awareness through education and media) and an increased awareness or nervousness founded by the last couple of 'drought' years.

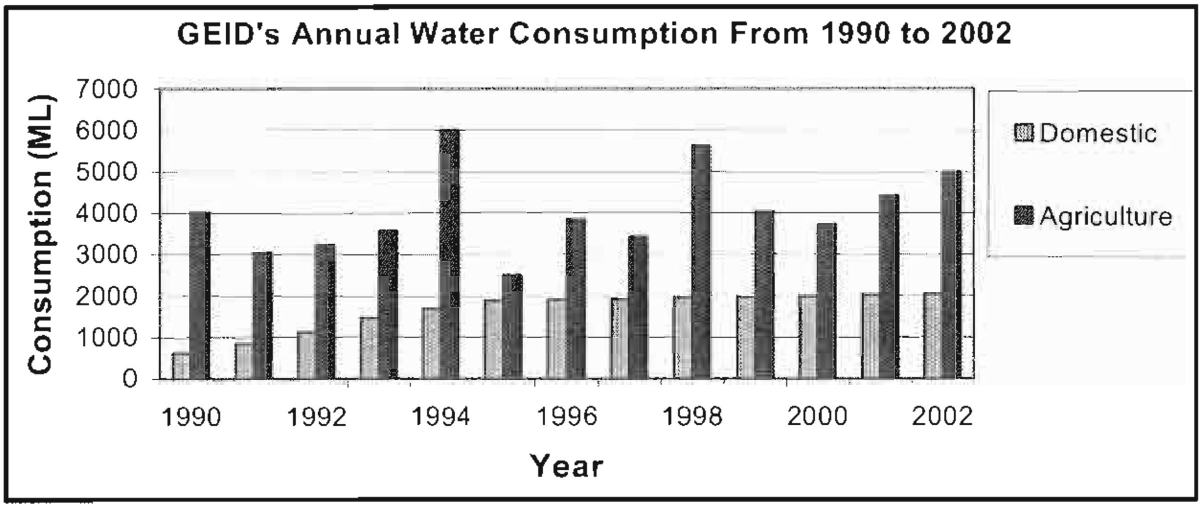

Figure 6. ***Comparison of annual water consumption for the domestic and agricultural properties in the Glenmore-Ellison Improvement District. For this graph, domestic consumption includes all water used by stratas, single family homes, multi-family homes, commercial ventures, and institutional buildings, while the agriculture values include agricultural irrigation and water used by golf courses.***

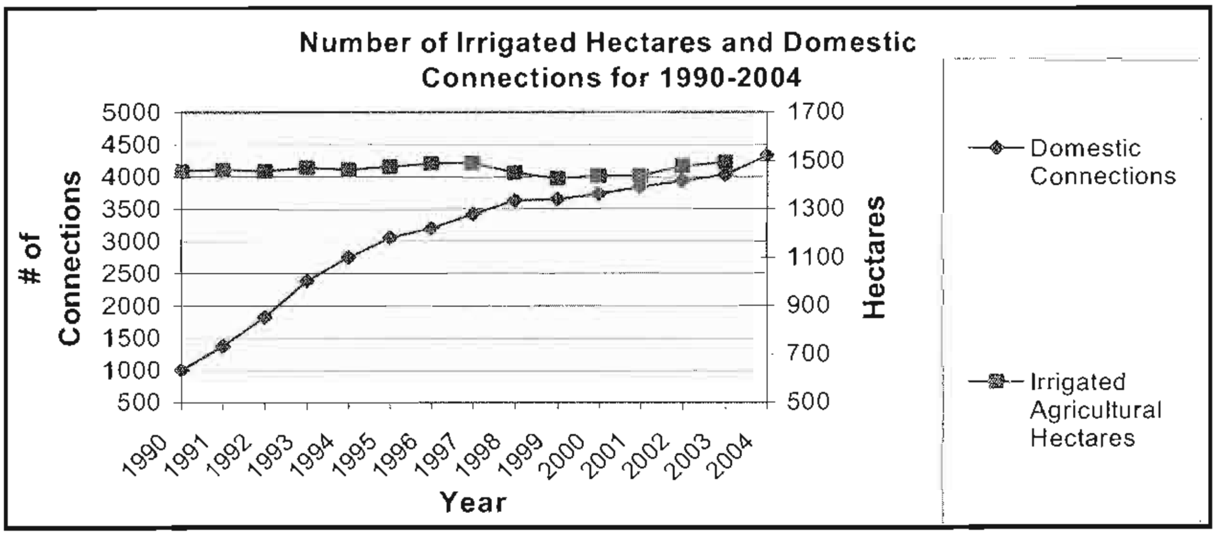

Figure 7. ***Number of domestic connections and hectares of irrigated agricultural land serviced by the Glenmore-Ellison Improvement District***

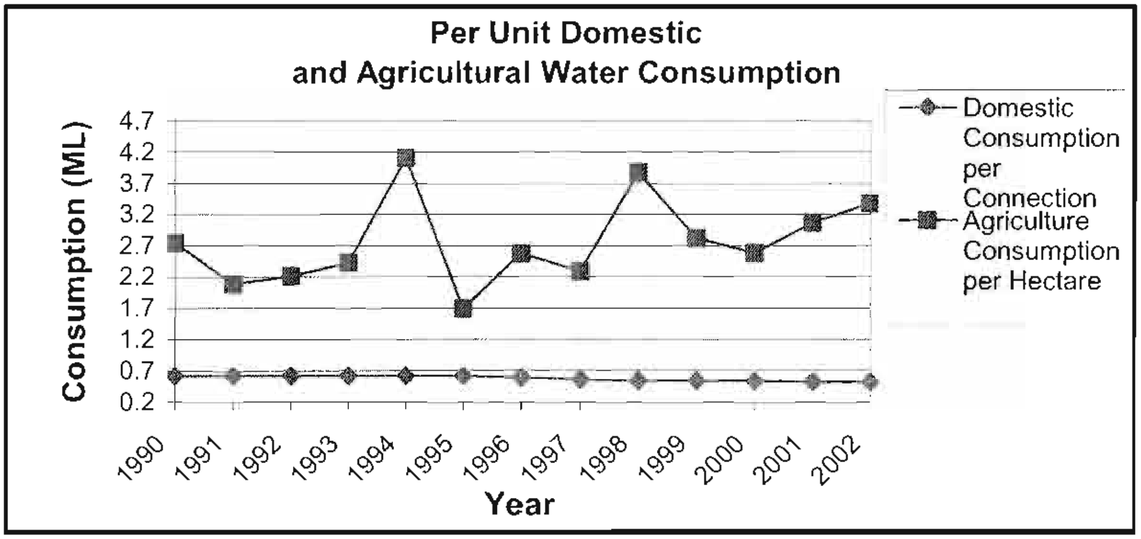

Figure 8. ***Comparison of the water consumption between domestic and agricultural land use. The domestic consumption is measured per connection and the agricultural consumption is measured per hectare of irrigated land.***

Another effect is the higher per hectare water consumption at urban strata developments in comparison to agriculture (Table 1). Although available data is limited, converting agricultural land to urban strata may result in an average of tripling water consumption on a per hectare basis. Water use by stratas is extremely variable around the average values shown in Table 1, however, and should be used with caution. Factors such as number of units, ornamental water works and outdoor irrigation all play a role at municipal developments.

Table 1. ***Average annual per hectare water consumption (ML) at agriculture land and stratas.***

Year	Agriculture	Stratas
2000	**2.6**	**8.8**
2001	**3.1**	**10.1**

4.0 CONCLUSIONS AND IMPLICATIONS

The historic analysis of water consumption trends show that domestic water demand is increasing in relation to agricultural irrigation, and that urban areas are becoming 'more urban' by virtue of increased housing density.

The much publicized climate change studies warn of longer, hotter summers, with less snowfall in the mild winter months. If realized, this will increase the amount, and affect the timing, of water needed by water purveyors such as GEID and their customers.

The increase in annual water demand from municipal development is expected to continue into the foreseeable future. The increase in water demand, and the shift in emphasis to increased domestic water delivery, has necessitated an intensive review of GEID's water sources, infrastructure, and fiscal readiness to meet expected water needs in the short and long term. This has resulted in a series of adaptations, guided in part by an updated Capital Works Plan (2004), and discussed in the following section.

5.0 ADAPTATIONS

The Glenmore-Ellison Improvement District has initiated a variety of demand and supply management strategies in response to anticipated growth. These include a water conservation program to reduce water consumption, metering, accelerated implementation of water source alternatives, projected rate increases, and exploring new water treatment and distribution technologies.

5.1 Conservation Measures

In 2003, the GEID began a water conservation program to reduce water consumption in the residential and agricultural areas of the district. This program incorporated the implementation of new irrigation regulations, patrolling neighborhoods and properties, monitoring irrigation practices, sending out educational information, and enforcing district regulations and bylaws. Domestic irrigation regulations are based on an odd/even weekday-sprinkling regime corresponding with street addresses, with particular times allotted for irrigating. Residents were fined a $100 shut-off/turn on fee for a third non-compliance of District bylaws. The drought summer of 2003 saw some residents forced to make decisions regarding overwatering or to face monetary penalties.

A focus of the 2004 water conservation season was directed to the main commercial or strata water users, as identified through our metering information. We found that the top ten water users accounted for 70 to 80% of the total annual commercial and strata water consumption. Here, the effort was to encourage voluntary water efficiency and reduction strategies, specific to their site.

The domestic water conservation program appears to be working. Our data suggests a trend to decreased water consumption during the daily peak demand, however we have not yet formally calculated the reduction.

Conservation efforts at agricultural properties have focused on improved irrigation efficiencies, primarily to reduce leakage, blatant overwatering, and to improve application efficiency. This has been carried out by site visits and notifications of non-compliance. Currently, the GEID is seeking new financing mechanisms to support a more science-based approach to agriculture water conservation.

5.2 Metering

The Glenmore-Ellison Improvement District is currently investigating the option of implementing full residential and agricultural metering programs. A pilot residential metering project has been initiated, and is expected to expand to a full metering program within the next five years. Houses have been randomly selected to participate in the pilot project over a cross-section of lot sizes and geographical areas.

The GEID is optimistic that metering programs will aid in the reduction of water consumption throughout all areas of the District with an overall target of 20% decrease in annual water consumption. Currently, all commercial and strata developments are metered, and all new homes being built in the District are required to install a meter. With the information obtained from the water-metering program, we will be better able to make suggestions to individual residents, orchardists, and farmers concerning their domestic water use and irrigation practices. Importantly, we hope to develop financial incentive and disincentive tools to promote demand management.

5.3 Alternative Water Sources

The GEID, especially after the droughts of 2002 and 2003, have initiated a search for alternate surface water sources to supplement its current water supply and to reduce dependence on groundwater. Recently, the GEID acquired McKinley Waterworks, a small water system used for servicing about 250 residents in the McKinley Landing area. The GEID hopes to eventually draw water from Okanagan Lake in the McKinley Landing area to supplement the Kelowna Creek source. This will provide the District with a fairly sustainable source of higher quality water. The GEID is also drilling a new well to meet demand during the transition phase to Okanagan Lake.

5.4 Projected rate increases

The GEID is planning a series of rate increases over the next several years to help the GEID fund necessary infrastructure upgrades, conservation efforts and to offset the increasing cost of construction materials and labour. Our 2004 Capital Plan suggests that toll rates should increase by 2.5% per year for the next ten years to balance anticipated expenditures.

The majority of the costs incurred during infrastructure construction or upgrading are paid using the GEID's capital expenditure fund. This capital expenditure charge is charged on a per unit basis for all new development in the District and on a per hectare basis for additional agricultural hectares.

5.5 New Treatment and Distribution Technologies

The Glenmore-Ellison Improvement District is researching new water treatment and distribution technologies. Recent announcements by the Interior Health Authority have added challenges to meeting Provincial goals of water quality, particularly reducing turbidity in source water. This will require funding to upgrade current facilities, and in the long term, and may require a water treatment plant.

As the District expands with municipal development, the GEID will continue expanding the water distribution system and its infrastructure with developer-funded capital expenditure funds. This includes all major pipelines, pump stations, reservoirs, and chlorination stations.

Providing fire flow pressure to municipal areas is the greatest concern when expanding the urban pipeline infrastructure, and is a major difference to supplying irrigation water to agriculture lands. The GEID uses a ten to twenty year forward looking Capital Works Plan to ensure system requirements meet water supply, and quality demands. The Plan helps forecast engineering and economic adjustments well in advance of the actual need.

6.0 RECOMMENDATIONS

We have found time series analysis using water meter data and simple graphical tools very useful for detecting water consumption trends by land use type, and we recommend this to other water purveyors for their planning purposes.

We recommend a building of the true economic value of water, particularly in water scarce areas such as the Okanagan Valley, by increasing the conservation ethic, and developing financial incentive and disincentive tools to promote demand management.

ACKNOWLEDGEMENTS

The authors would like to thank all of the staff at the Glenmore-Ellison Improvement District for their assistance in the preparation of this document and for review comments. We would also like to thank Bob Hrasko of Agua Consulting Inc. for his extensive work on the 2004 GEID Capital Plan Update, and to the GEID Board of Trustees for permission to present this material.

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Significant Advances in Information Technology and Water Supply and Demand Management at Greater Vernon Services

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Abstract

Greater Vernon Water (GVW) is responsible for the provision of potable and irrigation water to the Vernon, Coldstream and North Okanagan Water Authority (NOWA) communities. The GVW has reviewed and developed a comprehensive strategy to optimize their extensive system of irrigation and domestic water pipeline infrastructure. The GVW has commenced separating the network into two major systems: the first providing treated water for domestic consumption and the second supplying an independent irrigation system.

To support the design of a separated water supply network, the original Vernon, Coldstream and NOWA systems data was combined into a single highly accurate geographic information system supported network.

Utilizing highly sophisticated hydraulic supply and demand system computer modelling software, and integrating the actual water meter reading history where available, an accurate water model has been created for the supply area.

GVW is set-up to use this supply and demand management modelling decision support system to generate alternative supply strategies for their supply area. By analyzing and implementing water demand reduction strategies based on financial tariff strategies, all of which will be modelled, GVW will be able to minimize the amount of water required and optimize the amount of capital infrastructure needed to be constructed in the decade ahead.

The water demand strategies are designed to have the effect of reducing the amount of water used by domestic consumers. This case study of the GVW's initiative will illustrate a new governance model to provide proactive management to reduce the demand in the North Okanagan for water and to optimize the limited water resources of the Okanagan Basin. The lessons learnt could easily be applied to develop specific short-term and long-term solutions to water management in all parts of the Okanagan.

Information Technology and Water Demand Management at Greater Vernon Services, Water Department: The integration of Water Modelling with Geographic Information Systems as tools to support the development of sophisticated and effective Water Demand Management Strategies.

I. Introduction

The Greater Vernon area has experienced significant growth since the 1970s, particularly in the suburban areas. Concerns about water quality and supply led the existing water utilities in the area to explore a regional water management strategy in the 1990s, culminating in the formation of a single utility.
Greater Vernon Services Water Department was established in the beginning of 2003. This new organization was created through the amalgamation of the three previously existing water utilities of the City of Vernon, the District of Coldstream and the North Okanagan Water Authority (NOWA). The supply area of the combined network covers approximately 21,000 ha comprises of more than 640km of pipe network and supplies water to approximately 45,000 people and 4,500 ha of irrigation. Water is supplied by two main water sources, Kalamalka Lake and Duteau Creek.

Greater Vernon Services (GVS) is an independent sub-regional organization under the Regional District of North Okanagan. Its services consist of Water, Economic Development, and Parks, Recreation and Culture. It is directed by a board of elected officials from the City of Vernon, District of Coldstream, Electoral Areas B and C. A representative from the agricultural community also sits on the board for water issues.

Since its inception, GVS has made use of Information Technology to provide support for operational and management decisions. From the outset, it should be pointed out that the focus has been to establish sophisticated support tools in advance of specific programs. GVS does not claim to have the most comprehensive DSM program in the Okanagan at this early stage.

GVS also acknowledges the support of the City of Vernon, District of Coldstream and Regional District of North Okanagan, without which the advances made to date would not be possible. These organizations have made significant improvements to each of their data sets.

II. Water Supply and Demand Management Strategy

Network Separation

A brief background is required to better understand the complexity of the GVS water system. Many water systems in the Okanagan originated as irrigation systems; the former NOWA portion of the GVS system is an example. Over the years domestic customers were systematically added to the system until it became a complex integrated system supplying water from two main surface sources (and four wells) to irrigation and domestic customers. Approximately 60% of the annual volume of water supplied to the entire GVS system is for irrigation.

The Greater Vernon Master Water Plan prescribes a staged separation of the combined domestic/irrigation system in addition to the construction of two water treatment plants. The final configuration will include two systems, a treated domestic system and an untreated irrigation system. Both Kalamalka Lake and Duteau Creek will be domestic water sources, and Duteau Creek will be a significant irrigation source. The separation program will proceed over the next 10 years.

The population of Greater Vernon is expected to reach 121,000 by 2041, essentially tripling the demand for domestic water. Irrigation demand is expected to remain relatively static during the same period. Water licenses currently held on Kalamalka Lake and Duteau Creek support this growth scenario, but the Duteau Creek source, in particular, is susceptible to periods of low precipitation. There is clearly a need to accurately measure demands in order to successfully implement a DSM program and ensure water for future growth.

Metering Strategy

Each of the three previous utilities practised their own water demand management strategies, including metering and incentives. Approximately 75% of domestic customers and all Industrial-Commercial-Institutional (ICI) customers are metered. GVS has embarked on a program to meter all outstanding domestic customers by March 2005. Irrigation customers are not currently metered, but a voluntary program is being initiated in 2005.

Metering of all customers has been an important step for the new utility, as actual use and unaccounted for water will be more accurately tracked. Meter data is a critical input to GVS's support tools. Metering also has a direct impact on water use, with a reduction of approximately 25% among domestic customers under a program implemented by the City of Vernon in the 1990s.

Information Technology

Since GVS was a newly created organization, it was possible to implement state-of-the-art information technology from the outset. The first steps taken prior to implementation were:

a. A status quo report reviewing the completeness of existing data sets and software available from the previous water utilities;
b. Series of workshops with major role players conducted to examine the existing systems and data quality and identify focus areas for attention;
c. Following the workshop, a number of high priority decision support systems were identified as follows:
    - Hydraulic modelling
    - Demand management
    - Financial management

    Other additional operational needs were identified as:

    - Map books
    - Web based viewers

Implementation started with a data capturing and verification phase. The primary goal was to capture data sets that were required for the decision support and operational functions identified as priorities during the workshop phase. This helped GVS to focus their efforts and to set realistic and achievable goals.

Capturing of the Water Network

The initial water network data sets were obtained from the three previous utilities. The networks were independently captured in different data formats and at various levels of accuracy and completeness.

GVS has specific requirements regarding the format in which the network data needs to be captured and subsequently cleaned to the required standard. The original systems were combined into a single, highly accurate, Geographic Information System (GIS) supported network.

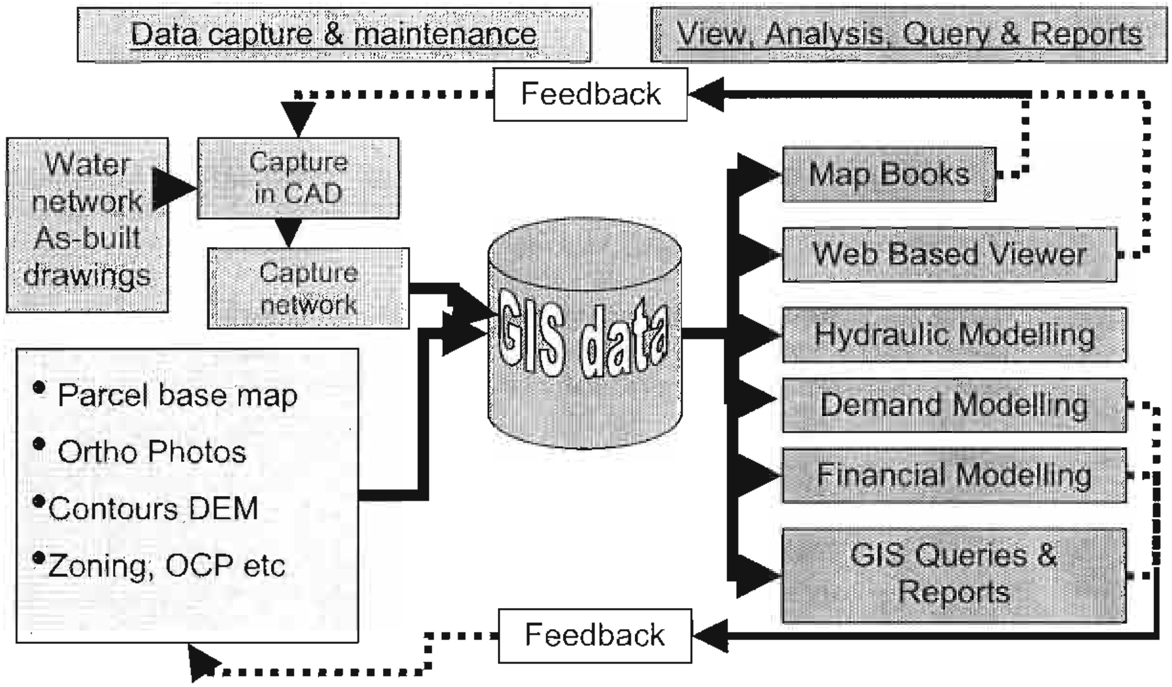
Using this detailed data set for modelling purposes, is a different approach to that typically used by local authorities. A scaled down or "stick" hydraulic model is more commonly used. However, GVS has specific reasons for using the more accurate GIS data set:

- To minimize the duplication of data sets: Since only one data set is maintained, rather than two different data sets (one for GIS and one for the hydraulic model), the network data maintenance time and cost is substantially less.
- A GIS accurate data set is required for demand and financial modelling since the network nodes are spatially linked to individual land parcels maintained on the GIS
- The same data set is also used for operational applications like the production of map books and a web based viewer.

In addition, data capturing utilities available within the GVS's hydraulic modelling software were used to capture the network. It was therefore possible to verify and "clean" the network to the format required for modelling purposes prior to converting the data to GIS. This again, is a different approach to the typical data capturing procedure at local authorities - usually networks are captured in CAD, converted to GIS and finally "skeletonized" for hydraulic modelling purposes.

The GVS data flow process is shown in the diagram below.

GVS GIS Data Flow



Capturing and Updating Water Demand

Effective DSM is only possible through metering of individual land parcels. GVS's water demand calculations are therefore parcel based and the water consumption obtained from Utility Billing system is (where available) linked to individual land parcels on the GIS. In the GVS system more than 75% of all customers already are metered and the aim is to meter the remainder in the near future.

Since all customers are not metered at this stage, three customer types were identified from a water demand perspective and treated separately in the model building process:

- Metered customers: the customer actual quarterly metered data was used as a basis for calculating the peak flow at the corresponding node in the hydraulic model.
- Irrigation customers: the irrigation allocation for each property was used as an estimate of the actual peak flow.
- Flat rate non-irrigation customers: the estimated demand for these customers was adjusted subjectively given the knowledge of the City guidelines, the metered customers' demands and the bulk meter data (SCADA system).

For the metered customers, the peak flow is based on actual metered readings, but for the remaining flat rate and irrigation customers, a computerised mathematical transformation was performed to estimate demands and then incorporate these customers' demands in the demand-to-model cross-reference procedure, discussed shortly, with the metered customers' demands.

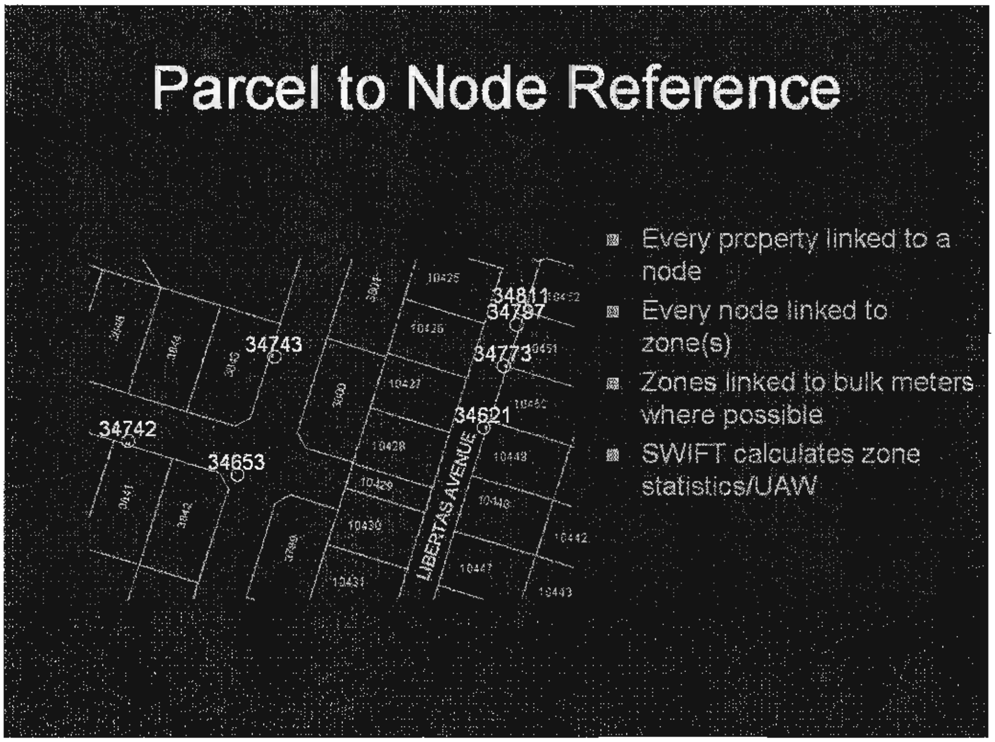
When populating the model, the actual quarterly water meter readings for each individual customer obtained from the applicable Utility Billing Systems are used as a basis to estimate the demand at each node in the hydraulic model of the water system. The four quarters' data preceding the date of extraction from the treasury system are used to calculate the average annual demand for each customer by means of software tools.

Hydraulic Model and Cross Referencing to Demand Model

In addition to building a GIS-based model of the demands, and a hydraulic model, it was necessary to estimate the peak flow at each node in the model and link the information to the central database warehouse. The peak flow, in turn, is dependent on the water actually used by customers and the usage patterns.

The peak flow pattern could be obtained from measured bulk meter readings (SCADA data). Different peak patterns could be identified for each of the three systems, namely the City of Vernon, Coldstream and Upland system. The peaks for the different systems were found to occur on approximately the same day, but as expected, the irrigation pattern was noted to be relatively flat when compared to the domestic systems.

A cross-reference is made between each customer and each node in the water model to geographically allocate the customers to the nearest nodes.



This approach is more accurate but less conservative than using the City guidelines to estimate water demands. For example, the initial demand analysis shows that typical metered residential customers in the City of Vernon use about 850 litres of water per day (per customer connection), while the City guideline suggests a value of 700 litres per capita – or 2100 litres per customer connection for a household size of 3 persons. The significant difference can probably be ascribed to very conservative City guidelines and factors such as metering and billing that have been implemented since the guidelines were compiled.

This suggests that policy makers are using potentially very conservative water usage assumptions. Metering and new sophisticated modelling tools provide more reliable water consumption estimates to increase development with existing available water resources in the Okanagan water basin.

Good actual metered data makes it is possible to have a sophisticated support tool providing a quarterly updated model of the water demand water network. This more accurate demand information can also impact on reducing major capital investment in expensive water infrastructure.

In GVS the integration of data with the more sophisticated IT systems (such as utility billing, hydraulic and demand modelling and GIS) now makes it possible to implement these sophisticated water demand management tools.

A further complicating feature of the GVS model and cross reference process is the fact that different water system operates with two major sources of different quality and little interconnection – this situation will be maintained until treatment is improved on both the Kalamalka and Duteau. At present the Kalamalka Lake source aesthetically preferable to the Duteau Creek source. The latter source is preferred for large irrigation customers, however, such a customer might be located geographically closer to a pipe that is part of the Kalamalka Lake supply. In addition to using the automated cross-reference procedure such issues are individually addressed, which is a dynamic and time consuming process. Utilizing highly sophisticated hydraulic supply and demand system computer modelling software, and integrating the actual water meter reading history where available, an accurate water model has been created for the supply area.

III. Conclusion

GVS is set up to use this supply and demand management modelling decision support system to generate alternative supply strategies for their supply area. An accurate representation of demands provides a starting point from which to measure the success of specific conservation programs. By analyzing and implementing water demand reduction strategies based on financial tariff strategies, all of which will be modelled, GVS will be able to minimize the amount of water required and optimize the amount of capital infrastructure needed to be constructed in the decade ahead.

The water demand strategies are designed to have the effect of reducing the amount of water used by consumers and reducing peak flows. This case study of the GVS's initiative illustrates a tool to facilitate an effective Demand-side Management program to reduce the unit water demand within the service area and to optimize the limited water resources. The lessons learnt could be applied to develop short-term and long-term solutions to water management in all parts of the Okanagan.

Application of the Water Use Plan Approach to Resolve Water Management Issues on Trout Creek in Summerland

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Abstract

The Summerland water supply for both the town and the surrounding irrigation area is provided by reservoirs in the upper Trout Creek watershed. The rate of reservoir drawdown in July and early August of 2003 created concerns regarding the adequacy of the supply to be able to provide both the community water supply and fish habitat flows in lower Trout Creek.

In the spring of 2004, the District of Summerland initiated a Water Use Plan process to address water use issues on Trout Creek. The process has a relatively formal structure which clarifies roles and responsibilities and provides a framework for defining the scope of the stakeholder discussions. An Interim Agreement was developed for Trout Creek reservoir operations based on alternative operating scenarios using a hydrological model of the Trout Creek watershed and a systems model of the reservoir operations. The implementation of the Interim Agreement in 2004 was very successful as it provided certainty to the reservoir operators, security for fish flows and targets for the community to achieve water usage reductions. This was the first time the Water Use Plan approach has been applied on reservoir systems other than those operated by BC Hydro.

In the light of the success of the program on Trout Creek, it is recommended that the Water Use Plan approach be used for other water supply systems in the Okanagan Basin to improve management and allocation of water resources and encourage water supply systems to be operated in a more sustainable manner

Summerland, Water Use Plan, hydrological model, reservoir systems model

Introduction

The District of Summerland supplies water to domestic, commercial and agricultural users. There are approximately 4,100 single family, 269 commercial and 1,151 irrigation connections. The Trout Creek watershed supplies about 90% of the District's water supply. There are eight reservoirs in the headwaters of the Trout Creek watershed, which are currently operated by the District to provide flow regulation. The reservoirs that are currently operated are Thirsk, Crescent, Whitehead, Isintok and the four headwaters reservoirs. Water is released from the reservoirs as required to provide sufficient flow at the diversion structure on Trout Creek.

The rate of reservoir drawdown in July and early August of 2003 created concerns regarding the adequacy of the supply to be able to provide both the community water supply and fish habitat flows in lower Trout Creek. Both irrigation and residential water use was cut back and fish flow releases to lower Trout Creek were reduced.

Following the drought of 2003, the District of Summerland initiated a Water Use Plan process modelled on the successful program originally developed by BC Hydro and participating provincial government agencies. The Water Use Plan Guidelines (1998) provide a step-by-step framework for undertaking Water Use Plans. For the Trout Creek Water Use Plan the participating stakeholders are the District of Summerland, Agricultural Water Users, the Ministry of Water, Land and Air Protection, the Ministry of Agriculture Food and Fisheries, Fisheries and Oceans Canada and the Penticton Indian Band.

The Water Use Plan Process as a Framework for Decision-Making

The Water Use Plan (WUP) Process has been demonstrated to be successful in providing an effective framework for improved management of water resources particularly where there are reservoirs in the supply system. Over the past five years, draft Water Use Plans have been prepared for 18 BC Hydro facilities and another six are expected to be completed this year.

The Water Use Plan process was originally developed to assist the resolution of conflicts between BC Hydro water use and fish habitat needs. Several years of costly litigation had demonstrated that a better way had to be found to manage water resources in the Province. The goal of the WUP process is to achieve consensus on a set of operating rules that satisfies the full range of water use interests at stake.

The structured framework of the Water Use Plan approach provides clarity to the decision-making process particularly regarding the roles and responsibilities of the stakeholders. The licensee, in this case the District of Summerland, leads the process, which ensures that any proposed changes to operations are voluntarily entered into by the licensee. The participating regulatory agencies maintain their role of monitoring licensee performance in accordance with the Water Use Plan.

The key principles of Water Use Planning include:

- Recognition that tradeoffs (choices) have occurred and will occur.

- Operating alternatives are examined on the basis of existing infrastructure. The potential for new dams and reservoirs is not part of the Water Use Plan process. The intention is to better manage the existing water resource within the constraints of the supply system in place.

- No changes will occur to existing legal and constitutional rights and responsibilities. The purpose of the program is to clarify obligations in detailed operating plans while maintaining the regulatory powers of the federal *Fisheries Act* and the provincial *Water Act*.

- The process is collaborative, cooperative and inclusive. The program brings together a wide variety of people to be part of decision-making.

Water Use Plans are developed within the context of the *Water Act*. The Act governs the construction, operation and maintenance of works to ensure the beneficial use of the water resource and must consider the rights of the licensee as well as the public interest.

The outcome of the planning process may be to recommend a voluntary change to operations resulting in a diminishment of water rights.

The Guidelines state that if there are financial impacts on the licensee, from reduction in water rights, compensation for losses will be an important consideration in plan implementation.

The guidelines call for consultation to be flexible to meet local circumstances and needs. Participants in the WUP process have the responsibility to:

- Articulate their interests in water management;

- Listen to and learn about other water use interests;

- Develop an information base for discussion;

- Explore the implications of a range of operating alternatives;

- Seek compromises across water uses;

- Each process will strive for consensus.

The process should foster an atmosphere of shared resource stewardship among the interested parties. This leads to a better understanding and support for resource management decisions.

Once the revised operating regime is agreed to by the consultative committee of stakeholders the licensee drafts the plan which is reviewed by the Water Comptroller and then becomes part of the water licence.
Preparation of a Water Use Plan requires a detailed understanding of the hydrology of the supply system and a model of the reservoir operations so that alternative operating rules can be examined.

Hydrology

The hydrology of Trout Creek has been studied by the Provincial Government; Reksten, 1973; Weiss, 1981 and Letvak, 1989. The Letvak report essentially updated the previous two studies.

The Letvak report estimated the mean annual runoff in Trout Creek watershed to be 80.8 $m^3 \times 10^6$ based on observed flow data for the period 1970 to 1982, data from the Summerland diversion and an estimate of the Brenda Mines diversion. The runoff model developed by Letvak estimated the mean annual natural runoff to be 62.3 $m^3 \times 10^6$.

The Letvak report used a mean monthly distribution for monthly runoff. This is a significant limitation on the analysis as the distribution of runoff varies from year to year.

Northwest Hydraulic Consultants (2001) carried out an assessment of the hydrology of the Okanagan Lake Basin as part of a fish flow assessment. The mean annual natural runoff for Trout Creek watershed for an area of 759 km^2 was estimated to be 110 mm. This corresponds to a mean annual flow of 2.65 m^3/s or 83.9 $m^3 \times 10^6$ per year.

Watershed Model Inflows

The modelling strategy used for this study was to first develop a watershed model for the unregulated recorded flows on Camp Creek, a subcatchment of the Trout Creek watershed. Once the model was calibrated for Camp Creek, it was expanded to natural flows for the entire Trout Creek watershed making adjustments for elevation differences and catchment areas.

The model used for this study was the WMC Watershed Model, which was originally developed for simulating runoff in semi-arid climates. The Trout Creek watershed was divided into subcatchments to facilitate calibration to monitoring locations and provide inflows to the reservoirs.

Meadow Valley Irrigation District operates Darke Lake. Finley Creek and Lapsley Creek are diverted into Darke Lake. To account for the Meadow Valley operations it would be necessary to model the operations of this system. According to local information, there is very little flow in Darke Creek downstream of the Meadow Valley system. Therefore, the subcatchment of Darke Creek was excluded from the total Trout Creek watershed for the purposes of the current analysis.

The total watershed area of Trout Creek was determined from a GIS analysis to be 759 km^2. Excluding Darke Creek, the watershed area of Trout Creek is 682 km^2. The watershed area at the Summerland intake is 637 km^2.

Temperature and precipitation data was available for a number of nearby sites including Summerland, Penticton, Osprey Lake and Brenda Mines. The last two stations although not active, provide an assessment of the impact of elevation and location within the catchment. Snow course data was available from Summerland (near Headwaters Lake), Isintok Lake and Trout Creek.

The temperature and precipitation data for Summerland is relatively continuous for the period 1916 to present with the few missing data points infilled with data for Penticton. Based on the available information, a correlation was derived for the upper reaches of the catchment and the Summerland data.

The distribution of precipitation to snow and rainfall assumed that all precipitation fell as rain if the average monthly temperature was greater than 2°C and all as snow if the average monthly temperature was below -2°C. In between the ratio of precipitation as snow was varied linearly with the temperature between -2°C and 2°C.

Calculations were carried out in 300 m bands beginning at below 600 m and going up to above 1800 m. The linear variation was calculated from data for Summerland and the midpoint of each elevation band.

Sublimation is complex and requires tabulation of a number of variables for a rigorous determination. In this analysis, we have assumed that maximum sublimation is 0.3 mm/day. This was modified where necessary to meet site water balance requirements. Sublimation was allowed in the months November through April. Although sublimation rates may be high during snowmelt, the sublimation is often offset by night-time condensation into the snowpack. Sublimation therefore was not considered for May.

Snowpack was calculated based on the calculated precipitation and temperature distributions as described above. However, winter precipitation measurements are difficult to measure reliably. For this reason, the winter snowpack was adjusted using the measured snowpack on April 1 at the Summerland site (Headwater Lakes). The calculated snowpacks for each elevation band were multiplied by a snowpack factor and the ratio of the measured and calculated snowpack at the Summerland station. The snowpack factor allows for input of a correction factor to account for the relationship between the point measurement and the whole basin.

Snowmelt is responsible for much of the available water in this region. Although snowmelt can be estimated, the required meteorological parameters are not available for this site. The snowmelt was estimated using a temperature index method.

Evapotranspiration was calculated with a methodology described by Thornthwaite (1948). First, the potential evapotranspiration (PET) was estimated based on the average monthly temperature and modified by the site latitude and the number of days in the month. The monthly water balance was calculated assuming the soil profile could retain some moisture from month to month. A maximum soil moisture retention was defined. The balance considered losses and gains to soil moisture, rainfall and snowmelt, evapotranspiration and surplus water (available for infiltration and runoff). Evapotranspiration was limited by the soil moisture condition. Below the soil moisture capacity of the soil, the PET was reduced linearly with soil moisture. This calculation was completed for each elevation band.

During snowmelt, the ground may be frozen, preventing contribution of snowmelt to soil moisture, and thereby contributing more water to runoff. This is particularly noticeable in low snowpack years. This was addressed by preventing any contribution to soil moisture below a set temperature and ramping up linearly the water available to soil moisture to a second temperature. Open water was assumed to evaporate at the full PET.

Infiltration was modelled at an adjustable rate that is dependent on surface conditions, soil permeability and available storage capacity. The infiltration rate was adjusted using two parameters, one a function of the quantity of water available for runoff and infiltration and the second a function of the subcatchment area. The infiltration was accumulated within the groundwater compartment and released at a rate determined by the product of the volume of water in storage and a discharge factor. In this way, month-to-month storage was allowed within each subcatchment, allowing an increasing discharge rate with increasing storage.

Water is infiltrated into storage in each subcatchment. The water is discharged from storage as a product of a discharge factor and the total storage. Lower discharge factors result in larger accumulated storage with the same recharge. The effect of decreasing the factor is to cause a more uniform discharge rate.

Camp Creek flows have been measured since 1965. The model parameters were adjusted to achieve a best fit to measured flows in Camp Creek. The results for 1996 to 2003 are illustrated on Figure 1.

The infiltration and groundwater storage discharge factors were adjusted for the upper reservoirs to match measured reservoir level increases over recent winters. The calibration was achieved primarily by adjusting the allowed infiltration rate and the groundwater discharge factor.

The model was calibrated by varying calibration parameters to achieve a best fit to Camp Creek flows and minor modifications to match base flows into the upper reservoirs. The mean annual runoff for the period from 1938 to 2002 determined from the model was 2.89 m^3/s for a catchment area of 682 km^2 (excluding Darke Creek). This corresponds to an annual runoff of 134 mm, about 20% higher than the estimate by Northwest Hydraulics (2001).

Based on the above calibration, an output of natural monthly flows was generated for each of the eight subcatchments that contribute to Trout Creek flows. These flows were used in a reservoir routing model to simulate operation of the water supply system.

Water Usage

The flow into the Summerland distribution system is measured with a flow meter at the chlorination house immediately downstream of the balancing reservoir. The water is used for agricultural irrigation, residential indoor and outdoor consumption, urban commercial use and unaccounted for losses. The trend in residential/urban consumption is increasing probably due to urban development and residential construction. There is a notable decline in irrigation consumption.

According to Neilsen *et al.* (2004) the decline in irrigation consumption is likely due to improvements in irrigation technology and more intensive agriculture. About one-third of the growers in the Summerland area are now using micro-irrigation techniques, which are better suited to intensification of production. Despite higher temperatures over the past 10 years, irrigation demands have dropped because of improved management practices which were introduced to increase fruit tree production.

For the model, the residential indoor component (includes urban commercial) was estimated by examining the Summerland winter demand. The winter demand for 2001/2002 used in this analysis was 1.24 million Imperial gallons perday (5,600 m^3/day).

Based on studies reported by Water Management Consultants (2001) for the Vancouver area, the residential outdoor demand was estimated as a multiple of the indoor demand on a month-by-month basis. However, the evapotranspiration values for turf grass supplied by the BC Ministry of Agriculture (2002) are 75% higher in Summerland than in Vancouver. In addition, studies completed by Water Management Consultants (2001) noted that when lawn sprinkling was banned in Surrey in 1997, the residential outdoor use declined by 50%, indicating that lawn watering in Surrey in the summer accounted for 50% of the summer residential outdoor use. To account for the drier climate, the residential outdoor demand was therefore increased by a factor 1.375. The outdoor demand was also increased in early spring, to account for increased water use measured in Summerland at that time.

The monthly total water usage in 2002 was available from Summerland meter records. The irrigation usage for that year was calculated by subtracting the residential indoor and outdoor water used derived as noted above from the total water used per month. The water usage values for 2002 are presented on Figure 2.

Modelling of Reservoir Operations

The reservoir operation model was set up within a spreadsheet format, with inflows generated into each of the subcatchments input from the hydrology model. The model was operated over the period from 1937 to 2002, the period when both local climate and snowpack data were available. The headwaters reservoirs were combined into one operating reservoir.

The reservoirs are not normally drawn down completely to the intake levels because of likely water quality degradation, particularly silt from eroding deposits in the floor of the reservoir. The standard currently in use by the Greater Vancouver Water District is to set the minimum reservoir levels 2 m above the intake. In the model, reservoirs were operated to allow live storage between a specified level above the intake (up to 2 m above the intake) to the spillway crest. All additional water was spilled downstream.

The model operates by accumulating inflows and discharges over quarter-month periods. Quarter-month time steps were required for effective modelling of the relatively small reservoirs. Based on the volume of water in the reservoir in the preceding month, the reservoir area was determined and the evaporation losses calculated. Seepage losses were neglected, as seepage would continue downstream towards the intake from most reservoirs.

The reservoir operating rules incorporated in the model were based on the rules set out in Associated Engineering (1997) modified to account for current operation practices.

Water spilled from Crescent Lake or released from Crescent Lake was routed to Headwaters Lakes. Release from Crescent Lake was required in the model as soon as Headwaters Lakes fell below full volume. Water spilled from Headwaters Lakes or released from Headwaters Lakes was routed to Thirsk Lake. The first release from Headwaters Lakes effectively removed water from storage in Crescent Lake and the inflows in the same time period. The second release from Headwaters Lakes removed the water that could be refilled relatively reliably. The third release was the remaining live storage.

Water spilled from Whitehead Lake or released from Whitehead Lake was routed to Thirsk Lake. The first release from Whitehead Lake was water that would be refilled relatively reliably. The final release from Whitehead Lake was the remaining live storage.

Water spilled or released from Thirsk Reservoir was routed to the intake. When 80% of the storage was depleted, makeup releases were requested in a specified order from the upstream reservoirs and Isintok Reservoir. Releases from upstream were routed through Thirsk Reservoir whereas Isintok Reservoir releases reported to the intake.

Comparison with Operation Data

For the period 1993 to 2003, there is a record of reservoir levels, and therefore knowledge of the total volume of water in storage. Figure 3 is a presentation of measured and calculated total volume of water in storage, assuming that fish flow releases as specified in 1997 were met. The agreement between the modelled reservoir operations and observed data provides a verification of both the watershed model and the reservoir operation model.

Summerland Design Drought

The Trout Creek water supply system was designed based on a design drought of three consecutive years with flows 36% of average (Associated Engineering, 1997). It is likely that this condition was experienced in the 1930s. A separate reservoir operation model was set up to simulate this design condition. Three consecutive drought years have not occurred in the 66-year period of simulated runoff though, with the potential for climate change, this design condition was considered in the scenario simulations.

<u>Interim Agreement</u>

The Trout Creek Water Use Plan Consultative Committee met three times in the spring of 2004 to develop an Interim Agreement for reservoir operations in the 2004 irrigation season.

The steps that were taken in developing the proposed Interim Agreement for operation of the Trout Creek water supply system were as follows:

- Each stakeholder on the Trout Creek Water Use Plan Consultative Committee presented their specific objectives in terms of their water requirements.

- It was demonstrated by modelling the Trout Creek water supply over a 67-year period, that it was not feasible to meet the objectives of all stakeholders in full.

- Compromises were made until a feasible operating regime was developed. This is the basis of the Interim Agreement.

Trout Creek Operation

The fish flow releases are based on a multiplier of the real-time Camp Creek flows available on the web from Environment Canada. Camp Creek is an unregulated tributary watershed of Trout Creek and provides an index of natural flow variations in Trout Creek. The general recession trend is used to determine Camp Creek flows; spikes caused by rainfall events are not included in the calculation. The fish flow multiplier is reduced when storage values in the reservoirs are at lower levels.

The basis of the Interim Agreement is that Stage 1 usage reduction targets (based on 2002 water usage) will be in effect throughout the summer. Stage 2 and Stage 3 will come into effect depending on the date and the trigger graph shown in Figure 4. The plan for usage reductions and fish flow releases is based on modelling of the watershed and supply system over the 67-year period. The modelling indicates that if this operation graph is used, the system would have avoided dropping into Stage 4 and Stage 5 at any time in the 67 year period. The usage reductions corresponding to each stage are as shown in Table 1. The irrigation water usage is based on actual 2002 usage.

The recorded total reservoir storage in 2003 is also shown on Figure 4 indicating that the usage reductions and fish flow releases would have corresponded to Stage 3 during August and early September of 2003.

Table 1: Water usage reductions for each reduction stage.

	Reduction Stage					
	1	2	3	4	5	
June	6	6	6	4	0	Fish flow x Camp
	90	85	80	70	0	Irrigation factor %
July	8	8	6	4	0	Fish flow x Camp
	90	85	80	70	0	Irrigation factor %
Aug	8	8	6	4	0	Fish flow x Camp
	90	85	80	70	0	Irrigation factor %
Sept	10	10	10	4	0	Fish flow x Camp
	90	85	80	70	0	Irrigation factor %
Oct	10	10	10	4	0	Fish flow x Camp
	50	50	50	50	0	Irrigation factor %

Operations in 2004

The Interim Agreement was implemented in 2004. The actual consumption in 2004 was tracked and compared with 2002 consumption to determine whether targets were being met and whether additional measures would be required. Consumption in 2004 was well within the usage reduction targets.

To investigate the usage reductions achieved by the District of Summerland an analysis of crop water demands was carried out based on a detailed irrigation survey carried out for Summerland by Fitzpatrick (2004). The analysis results, shown in Figure 5, indicate that in 2002, the irrigation usage was more than the calculated water demand for all months except October. In June and July 2003, the usage was also greater than the calculated demand. However, in August, September and October of 2003, the recorded water usage was less than the calculated demand demonstrating the efforts made by the community to reduce consumption during the drought year. With an Interim Agreement in place and, with irrigation scheduling implemented throughout the community, the actual usage in 2004 was less than the calculated demand for all months except August. The Trout Creek Water Use Plan Consultative Committee is now working towards a Final Agreement for Trout Creek reservoir operations.

Conclusion

An Interim Agreement was developed for Trout Creek reservoir operations based on alternative operating scenarios using a hydrological model of the Trout Creek watershed and a systems model of the reservoir operations. The implementation of the Interim Agreement in 2004 was very successful as it provided certainty to the reservoir operators, security for fish flows and targets for the community to achieve water usage reductions. This was the first time the Water Use Plan approach has been applied on reservoir systems other than those operated by BC Hydro.

In the light of the success of the program on Trout Creek, it is recommended that the Water Use Plan approach be used for other water supply systems in the Okanagan Basin to improve management and allocation of water resources and encourage water supply systems to be operated in a more sustainable manner.

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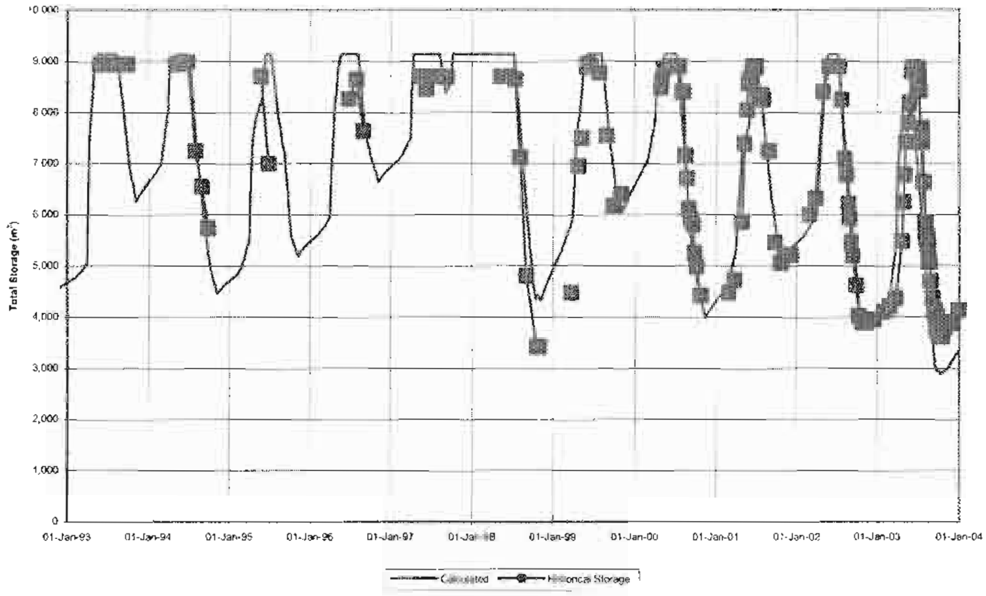

Figure 3: Calculated and observed total storage volume

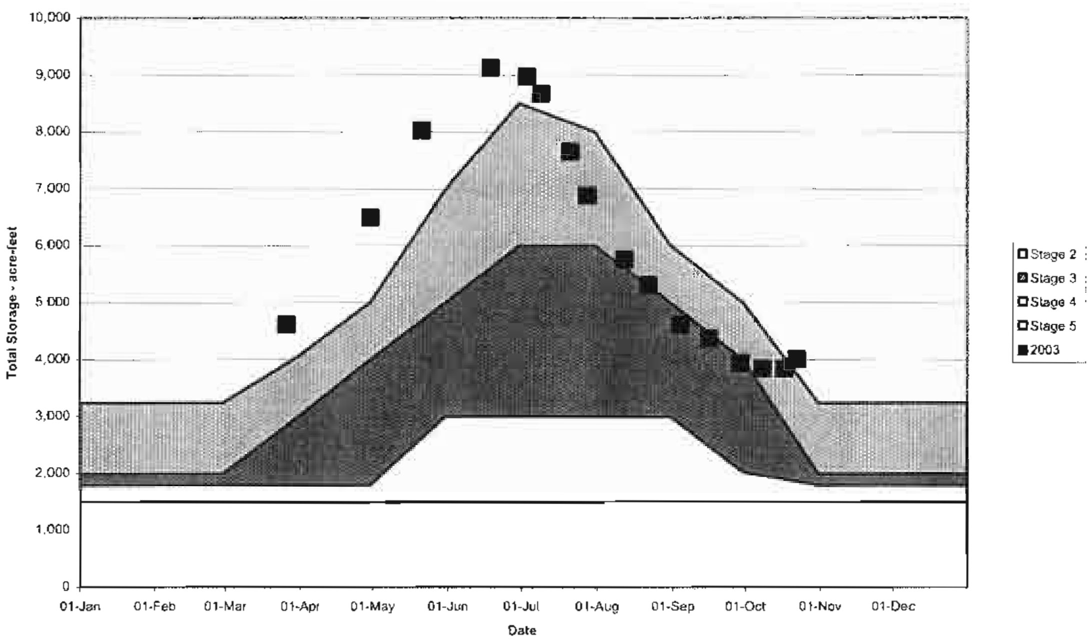

Figure 4: Trigger levels for water usage reductions

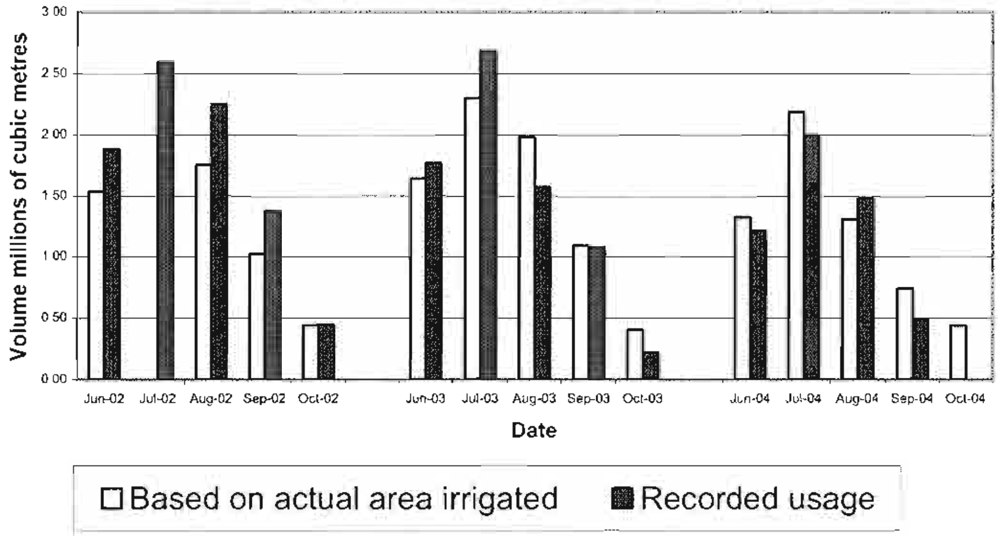

Figure 5: Summerland agricultural water demand 2002-2004

Group Model Building Of An Integrated Water Management Decision Support Tool

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Abstract:

At the present time, an average water year in the Okanagan will supply enough water to satisfy all current water demands. However, future projections on the state of the system that account for population growth and climatic changes to temperature and precipitation show that the region's water resources will be more highly stressed in the future. In order to more fully estimate water resource vulnerability and create a common resource for water users, information from a variety of sources must be collected and coordinated. Some of the information is already available. However, often data is frequently examined in isolation of its context, as is the case for sector-specific models (ie, agricultural, hydrologic, population, aquatic ecosystems, climate change). An integrated analysis is needed to be able to evaluate strategies for future water management. In order to provide support to those involved in planning and managing the Okanagan's water resources, our study team will guide local water professionals in a group model building process that will work to integrate all relevant information. Invited participants will include water managers, planners, decision-makers, and special interest groups. The project team and additional researchers will provide information and data to support the process. Participants will guide development of the model through defining areas of investigation and through sharing their own knowledge of the system. The model platform will be a user-friendly system dynamics software (STELLA™) that permits the inclusion of both quantitative and qualitative information. Active participation will foster shared learning and increase understanding of system behaviour. This process will create a decision support tool for the management and long-term planning of Okanagan water resources.

Keywords: Decision support; Group model building; Participatory process; Adaptation

Background
The Okanagan Basin is a semi-arid region, one of the driest areas in Canada. Currently, under normal water years, all water demands can be satisfied. However, recent droughts and fires in the summer of 2003, as well as dry conditions in 2004 demonstrated that the system is currently vulnerable to conditions of reduced supply and increased demand. Furthermore, changing conditions may apply additional stresses on water resources. Rapid population growth, particularly in the Central Region, is increasing residential water demand. Recent research for the project *Expanding the Dialogue on Climate Change and Water Management* (see Cohen et al. and Neilsen, both this volume) illustrated how climate change impacts may both reduce water supply and increase water demand. This work showed that in the future, instances of water demand not being met by the available supply occur with increasing frequently. Since this is an undesirable but not pre-defined future, alternate futures can be sought. We may have little control over the weather in next several decades, but we can control management practices. With this in mind, the research team guided local and regional stakeholders in an exploration of select adaptation options. Adaptation options were evaluated qualitatively, in terms of social, political, financial and environmental feasibility. General estimates of cost and effectiveness were also developed for the strategies.

This work was an important first step, but more information is still needed for water planners and managers to be able to make decisions about adaptation measures. To fill this gap, a more integrated assessment of the whole water system with a more rigorous evaluation of adaptation measures will be conducted in the current project, *Participatory Integrated Assessment of Water Management and Climate Change in the Okanagan Basin.* The approach taken will be a group model building process, involving the basin's water professionals. This paper describes the plans for this process that will take place over the next year, starting in February 2005.

Methodology
One fundamental objective of the series of projects in the Okanagan led by Dr. Cohen is to bridge the gap between research activities and the needs of policy makers. The work described here is intended to help water professionals in the region integrate climate change issues into their planning activities. The process will create pictures of what the future may bring, and provide a tool for testing alternative adaptation strategies. At the end of the process, the participating water professionals should feel comfortable with either implementing anticipatory adaptation measures, or resolving to informed inaction.

The proposed group model building process draws from the research fields of Integrated Assessment, Participatory Planning, and System Dynamics.

Current social and scientific philosophies associated with Integrated Assessment place value on the benefits available from the proposed group model building approach. The post-modern and social-constructivism movements recognize that "science" is not the means to an absolute truth, and that doing more science does not always result in reducing uncertainty. These movements also recognize that science is not purely objective, but is subject to the values of society and the research community. Because of this, research activities should not be directed exclusively by trained experts, but must include the value judgements of all relevant stakeholders.

Participatory model building is an example of a Participatory Planning method that engages stakeholders in a structured learning process. It is founded in the belief that within people's mental models are vast quantities of knowledge, significantly more than what is available in written forms; however, mental models contain numerous unstated assumptions, gaps and inconsistencies. The process of sharing these mental models identifies points of agreement and points of conflict. The rigor of a formal modelling exercise encourages participants to make their assumptions explicit, and to challenge and clarify unclear or conflicting beliefs.

Participatory model building can employ a variety of modelling approaches, but one that is a natural match is System Dynamics. System Dynamics and Integrated Assessment both share the philosophy of holism. Holism emphasizes connectedness, relationships, and context as the keys to understanding. This is in direct contrast to the reductionist paradigm that predominated for the last several centuries. Reductionism studies a system by dissecting each part, and examining it in isolation from its environment. In concert with the holistic philosophy, the process of creating a System Dynamics model emphasizes structure more than behaviour. Generally system structure is more transparent than resulting behaviour, so System Dynamics modeling draws on the strengths of human knowledge while compensating for weaknesses (Forrester 1987).

The group model building process follows previous work by Vennix (1996) and van den Belt (2004), who have applied the technique to institutional and environmental policy applications. The model will be created in STELLA™ software that uses a graphical, object-oriented language. This language is easy to understand, even by a non-technical audience, so participants will be able to examine and understand the completed model. STELLA™ also contains a user-interface level. This level can be designed as a flight simulator, with input controls and output graphs and tables.

Model Building Workshops

The process will be conducted through a series of workshops in the Okanagan region. The first workshop took place on February 22nd. Five subsequent events will be held every four to eight weeks thereafter. At these workshops, participants will decide on model format and structure, providing information to the project team, who will construct the computer version of the model and add relevant data between sessions. Researchers will be a resource outside of the workshops and will support the modelling process by providing details, expert opinions, and data.

Participation

One of the benefits of a group model building process is that participants have the opportunity to share and reconcile their understanding of the system's behaviour. Frequently, stakeholders that play an active role in a system have deep understanding of certain aspects, but lack knowledge of the big picture. The group model building process allows these separate pieces to be put together, and results in wider understanding by all participants. An example of this in the Okanagan water resource system is that a community in the upper part of the basin may lack knowledge of how their water use impacts communities in the lower part of the basin. Coming together to create a system-wide model would foster new understanding for both parties about the whole system.

The benefits of sharing mental models increase as participant diversification increases. Ideally, a group modeling process will contain representatives of all interests related to the central issue. Furthermore, participants will be those that have expertise, decision-making authority, and vested interest in the subject matter.

The project team wants to include a wide variety interests, but we also want to keep the group size manageable for ease of workshop activities and communication between meetings. A smaller group helps increase individual participation and discussion and may encourage greater participant commitment through the process. To meet these goals, about 20-30 professionals will be invited to represent their organization or interest area. Those selected will be responsible for communicating with their organization or interested parties. Participants will be invited from Federal and Provincial agencies, the First Nations community, the Okanagan Basin Water Board, Regional Districts, agricultural organizations, and local water purveyors. Effort will be made to ensure a variety of interests are represented (examples: agriculture, flood control, and fisheries) so that all critical issues can be included in the model. Participants at the workshops will actively engage in model building exercises. Researchers with expertise in specific subject areas (examples: groundwater, crop water demand, land use) will serve as "resource people," providing data and expert knowledge to the formal modelling work that will take place between workshops.

Workshop 1 (February 2005):
The objectives of the first workshop were to familiarize participants with system dynamics principles, demonstrating their advantage in problem exploration, and to begin defining the problem that will be addressed through the modelling process. Participants were introduced to system dynamics principles through an interactive learning activity in which participants played different roles in a "human simulation." Afterward, the facilitators led a group brainstorming session to develop a list of questions and issues that the model could address.

It is important to note that in this investigation, there is not a specific problem that we are trying to solve; instead, our starting point is to increase understanding of plausible future conditions, and to investigate options ("adaptation strategies") for managing the resource effectively under current and future conditions. Therefore, the model will reflect the broad nature of the investigation, and will be a general scoping model rather than a detailed operational model.

Workshop 2:
Model development will begin in workshop 2. The first steps will be to determine key state variables that are useful in addressing the questions raised in the first session. Once these variables are identified, they can be modeled by considering what changes their state. What makes the state increase or decrease? These are the first steps of causal mapping. For example, the water level of Okanagan Lake may be chosen as a state variable. What increases the lake level? (examples: precipitation, upstream dam releases) What decreases the lake level? (examples: releases downstream for fish, water withdrawals, evaporation).

An important issue that will be discussed in these early stages is the appropriate spatial and time scales and resolution that the model will focus on. Good modelling practice is to only make the model as complex as is needed or useful to address question effectively. If additional detail does not add useful information, then there is no reason to include it. At this point, a best guess can be made, keeping in mind that revisions can be made in the future. The investigation questions should determine appropriate scales. An example of how the questions can determine time scale resolution follows: If the questions are aimed at exploring the long term effects of a reduction of annual average precipitation on lake levels, then an annual time step may be sufficient. If the questions are aimed at exploring the effect of the earlier spring freshet on the tributary water supplies, then monthly or weekly time steps will be needed.

Spatial scales resolution will also have to be selected based on the questions of investigation. Based on the questions and discussion, the participants may decide that simply modelling the Okanagan mainstem (valley floor lakes) will be sufficient. If it is important to capture the differences in the north, central and south regions, then they may decide that the land area should be divided into three parts. However, if participants would like to investigate options for managing the upstream tributaries, then it may be necessary to model one or more representative sub-watersheds, nested into the main model.

Workshops 3 – 5:
The next three workshops will contain an iterative process. Participants qualitatively map out parts of the system. Then the project team recreates these maps into a formal model and adds appropriate data. Each newly formalized piece will be reviewed at the next workshop. Simulated behaviour from the modelled system provides an opportunity for validation to check assumptions, and deciding if the characterization is complete and accurate, or if variables are missing or misrepresented.

Once a base model is established, time will be spent determining the effect of adaptation strategies. How effective will they be? Will there be any side effects (example: Would lake pumping create an image of an unlimited resource, thereby reducing incentive to conserve?). These strategies will also be included in the formal model.

Workshop 6:
The final session will focus running simulations to test the model and create future scenarios with and without combinations of adaptation strategies. STELLA™ models support a user-interface level, separate from the modelling level. This is where flight simulator-type controls are placed. This layer will contain options for selecting the climate scenario and adaptation options. Other variations on future conditions may also be included, such as variable rates of population growth and land use changes. This level will also display model output, in the form of graphs or tables, so that simulations can be conducted exclusively on this level without the visual complexity of the underlying model structure.

Post-workshop Model Use:
When the model is completed, the project team will discuss with the participants what opportunities there may be to bring the model to a wider audience. Sharing the model with others, providing them the opportunity to explore the model structure and behaviour would help communicate the lessons and insights that will have emerged.

Conclusion

Making decisions today to manage resources in the future is not simple task. Managing resources on a daily basis has its challenges, but making decisions to manage future resources requires making educated projections in spite of inherent uncertainties. Complex systems cannot be fully understood if they are broken down into separate parts; they must be investigated through integrated methods. The participatory process, group model building is capable of effectively investigating complex systems by integrating a wide breadth of topics into a single model. The Okanagan Basin is an ideal candidate for a group model building process at this time. The recent water crises on top of rapid population growth raised concerns for the regions' water professionals. The work of researchers in previous phase of the *Climate Change & Water Management* project in the Okanagan (see Cohen et al, this volume) provide information on plausible future climates, along with their impacts on hydrology and crop water demand. These, combined with ongoing evaluations of water demand in the residential sector are alluding to more frequent crises where water demands will not be satisfied. This is the right time to step back and look at the big picture – to combine all of these effects into a single assessment, where interactions can be captured. This will provide a platform to explore the socio-economic responses; to consider how market changes may impact behaviour and offset negative impacts and to evaluate the effectiveness of strategies that water managers can take to reduce the risk of failure of the region's water resources.

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South East Kelowna Irrigation District:

Agricultural Water Conservation Program Review

by
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Abstract

In 1994 the South East Kelowna Irrigation District (SEKID) implemented a progressive and often controversial demand management program directed at the agricultural community it serves. This paper looks at the evolution of that program over the past ten years and provides insight to the challenges inherent in managing agricultural water use. Phase 1 of the program used an educational approach for water conservation resulting in a 10% reduction in drought year demand. Phase 2 of the program implemented a conservation strategy using water allotments and a metered rate penalty for excess water use. This resulted in a further 22% reduction in demand under drought year conditions, significantly reducing water use while maintaining adequate supply for agricultural use. Under average demand conditions water use was reduced 27.4% below the 29 year average annual consumption rate.

Introduction

The South East Kelowna Irrigation District (SEKID) encompasses twenty-two percent of the area of the City of Kelowna. It is mainly rural agricultural with about 1,900 domestic connections and over four hundred irrigation connections. The annual average water consumption (1994 – 2003) is 11,713 da m^3 (9,500 acre-feet), of which about 85% is used for agricultural purposes. The district watershed is $65km^2$ ($25mi^2$) in area and is supplied by runoff from the annual snow pack.

In 1994 the Board of Trustees of the South East Kelowna Irrigation District implemented a metering program for all irrigation connections in the district. A number of factors contributed to the board's decision to proceed with metering. In addition to the capital and operating cost savings of water conservation, also considered were limited and expensive options to increase the water supply to the district, the unknown implications of climate change, the availability of senior government grants for the metering program and favorable results from a pilot metering program that had been initiated in 1990.

From the beginning the program was highly controversial. The agricultural community believed water meters would result in higher water costs. To allay these fears the trustees made the commitment to the landowners that no metered rate for water would be implemented for a minimum of five years. The meters would be used as a tool to measure, learn and educate landowners about agricultural water use.

The educational approach used in Phase 1 of the program proved to be effective for the majority of landowners with metered irrigation connections. Efforts to collect, analyze and provide water use information and advice to landowners about water use contributed to a ten percent savings in the overall annual water demand of the district (Pike, 1998).

A small percentage of agricultural landowners continued to use a disproportionate amount of water, however, and Phase 2 of the program involves the implementation of water allotments. This allotment system is intended to provide adequate water for irrigation while eliminating excessive water waste and abuse. It has evolved to incorporate a punitive metered rate for water use in excess of the allotment and this has greatly increased the effectiveness of agricultural metering as a conservation and water supply management tool.

This report provides a summary of the metering program to date, including the financial implications of the metering program and looks at the effectiveness of education and metered rate penalties in agricultural water conservation.

Metering Program - Phase 1 Summary

Funding assistance for the metering program was received from the Canada-BC Green Plan for Agriculture. Technical assistance in irrigation scheduling, field day seminars and data collection and management was received from the staff at the B.C. Ministry of Agriculture, Food and Fisheries (MAFF). The Green Plan involved a five year cooperative commitment between staff from senior levels of government and SEKID. Program costs cited relate to the five year period of the formal Green Plan program from 1994 to 1998. A detailed report on the Green Plan project entitled *South East Kelowna Irrigation District Demand Management Project* was prepared by MAFF in 2000 and can be obtained from MAFF or the SEKID office.

Implementation

Over 400 irrigation meters were installed in 1994 and 1995 within the South East Kelowna Irrigation District's distribution area on properties with separate irrigation services. The total cost of installation including materials, equipment and labour amounted to $606,000.

Irrigation Scheduling

Considerable effort was put into educating growers to use irrigation water efficiently. Each property in the district that was metered was also provided with a set of two tensiometers. These devices indicate soil moisture and help to determine when to irrigate. For many growers in the district irrigation scheduling was a function of convenience or scheduling labour and not a water use efficiency process – the tensiometers were provided as a tool to monitor soil moisture levels to match actual crop requirements. Several field days were held over the course of the program to promote the use of tensiometers and other irrigation scheduling techniques.

Additionally, eight growers in the district participated in a pilot project managed by MAFF designed to track water requirement versus water use. This program showed there was considerable opportunity for water savings during the spring and fall (Van der Gulik, 2000). Irrigation systems are designed to provide for water requirements during the peak season and many systems are operated at full capacity regardless of seasonal demand. This, of course, results in over-watering.

The total costs of materials, equipment and labour for the irrigation scheduling amounted to $118,500.

Data Management

The basic data management aspect of the program involved reading meters and tracking water use. This information was collected monthly and determined the irrigation water demand of the district.

Concurrent with this was an initiative to determine the actual water use requirement of the district. This was done by collecting data from each property on crop, irrigated area, soil type and irrigation system. Climate information was collected from a weather station at the district yard.

From this information the estimated water requirement of the irrigated acreage in the district could be calculated for a given period of time.

Monthly water use reports were generated using the information described above. Each property in the district was provided with a report indicating water use, estimated water use requirement and average water use of the comparable peer group. In most cases water use was higher than the calculated requirement, but in some cases water use was lower. These detailed water use reports were provided monthly each year through to the end of the irrigation season in 2000.

The cost of collecting and analyzing data and sending out water use reports was $60,000.

Cost Summary

The project cost summary for the period 1994 to 1998 was as follows:

1.	Meter Installation	$606,000
2.	Irrigation scheduling	118,500
3.	Data management	60,000
	Total:	$784,000

Results

A new drought year requirement

Phase 1 of the metering program provided the district with the unique opportunity to do a detailed review and analysis of the water demand of the district. The year 1998 was the highest demand year in recent memory with a net moisture deficit for the May 1 to October 15 irrigation period of 777.8mm (30.62 inches) (Farmwest, 2004). These high demand conditions provided the opportunity to update the drought year water requirement of the district.

The original distribution system was designed in the late 1960's to deliver 7.62 da m^3/ha of land (2.50 acre-feet/acre) (Doughty-Davies, 1970). The 1998 analysis showed the actual demand figure was 6.86 da m^3/ha (2.25 acre-feet/acre) (Pike, 1998) – a savings of 10% from original design demand. The metering program was likely responsible for a large portion of this water savings. Advances in irrigation system efficiency, high density orchard plantings and other horticultural practices also have contributed to greater water use efficiency.

The surplus water supply resulting from this 10% savings is shown in the supply/demand calculation presented in Table 1.

Table 1: Water Supply and Demand 1970/1998

	Original drought year demand, 1970		New drought year demand, 1998	
Supply and demand budget:	7.62 da m^3/ha	2.50 acre-feet/acre	6.86 da m^3/ ha	2.25 acre-feet/acre
Dependable water supply (MOE, 1979)	16,428	13,324	16,428	13,324
Drought year requirement for 2,153 ha (5,322 acres)	16,405	13,305	14,769	11,975
Surplus/(deficit) da m^3 (acre-feet)	23	19	1,659	1,349

Under the old demand figure the district had a surplus of 23 da m^3 (19 acre-feet) of water, which would be adequate to provide water for an additional 3.07 ha (7.6 acres) of land at 7.62 da m^3/ha

(2.5 acre-feet/acre). Under the new demand figure the district had a surplus of 1,659 da m^3 (1,349 acre-feet) of water, which is adequate to supply water to an additional 242 ha (600 acres) of land at 6.86 da m^3/ha (2.25 acre-feet/acre).

Cost benefit analysis

Phase 1 of the program resulted in a net financial gain for the district based on the value of the water surplus identified.

As referenced above, one hectare of land has a drought year water requirement of 6.86 da m^3 (2.25 acre-feet/acre) of water. In 1998 water rights for one hectare of land could be purchased from the district for $4,942 ($2,000 per acre). The water surplus created through metering and other water use efficiencies is adequate to supply 242 hectares (600 acres) of land and the total revenue potential from the sale of these water rights amounts to $1,200,000. The total cost of the metering program amounted to $784,000. The benefit to cost ratio through Phase 1 of the program can be calculated as follows:

Description	Amount
Program Benefit (value of water rights freed up)	$1,200,000
Program Cost	$784,000
Benefit/Cost Ratio	1.53

This calculation does not consider the savings associated with the lower capital and operating costs inherent with greater water use efficiencies.

Metering Program Phase 2

The formal Canada-BC Green Plan agreement concluded in 2000. In addition to saving water, the meters provided many side benefits. These included the ability to detect leaks in private irrigation systems, to insure individuals stay within the flow allotment for their property and to fairly allocate water during shortages, insuring equitable distribution of the resource.

There was general agreement among board members that the benefits of water conservation combined with these additional benefits made it worthwhile to continue with the program. The wisdom of this decision became apparent the following 2001 irrigation season, which provided the district with a new approach to the program. It was at this stage that the main focus of the metering program evolved from an educational to a regulatory approach to water conservation.

Metered Irrigation Service Allotments

2001

Allotment with disconnection for excess water use

The snow pack, stream flows and groundwater levels in the spring of 2001 were at or below record levels. It was soon apparent the district could be facing water shortages for the coming season. In April the board implemented water restrictions on all irrigation and domestic connections in the district. Domestic connections had sprinkling restrictions imposed and irrigation connections were provided with an allotment of 5.49 da m^3/ha (1.8 acre-feet/acre), which was 80% of the estimated drought year requirement of 6.86 da m^3/ha (2.25 acre-feet /acre).

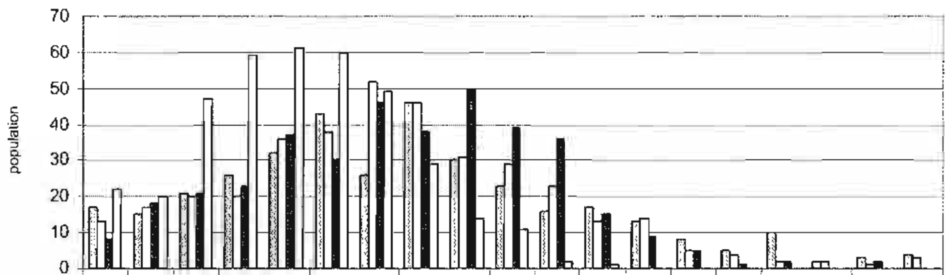
Notices of the restrictions were mailed to all agricultural landowners in the district and the spring newsletter featured extensive coverage of the issue. Landowners were also advised that failure to remain within the allotment would result in disconnection. In June of 2001 the district's main reservoir did not fill for the first time in over thirty years. The district wells were operated to supplement the surface water supply.

Results

Fortunately, 2001 proved to be a low demand year for irrigation with timely rainfall over the early summer and fall months. The net moisture deficit in the region for the period May 1, 2001 to October 15, 2001 was 720.7mm (28.37 inches) (Farmwest.com, 2004). By early August surface water reservoir supplies had returned to normal levels and the water allotment restrictions on irrigation services were lifted.

The distribution of annual water use as a percentage of the allotment used for the years 2001 to 2004 is presented in Chart 1.

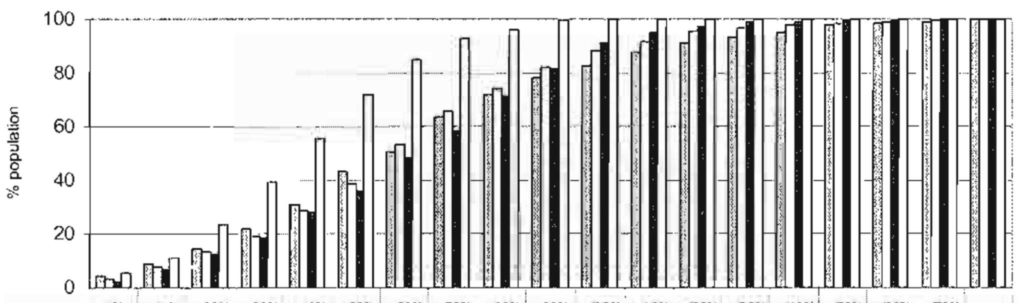
Chart 1: Percent of allotment used by population 2001 - 2004



	> 0% ≤ 10%	> 10% ≤ 20%	> 20% ≤ 30%	> 30% ≤ 40%	> 40% ≤ 50%	> 50% ≤ 60%	> 60% ≤ 70%	> 70% ≤ 80%	> 80% ≤ 90%	> 90% ≤ 100%	> 100% ≤ 110%	> 110% ≤ 120%	> 120% ≤ 130%	> 130% ≤ 140%	> 140% ≤ 150%	> 150% ≤ 160%	> 160% ≤ 170%	> 170% ≤ 180%	> 180%
□ 2001	17	15	21	26	32	43	26	46	30	23	16	17	13	8	5	10	2	3	4
□ 2002	13	17	20	20	36	38	52	46	31	29	23	13	14	5	4	2	2	1	3
■ 2003	8	18	21	23	37	30	46	38	50	39	36	15	9	5	1	2	0	2	0
□ 2004	22	20	47	59	61	60	49	29	14	11	2	1							

The annual percent of allotment used by percent of population for the years 2001 to 2004 is presented in Chart 2. At the end of the irrigation season in 2001 78.15% of metered irrigation services were within the water allotment for the property. This was somewhat surprising given that the allotment was only 80% of the drought year requirement, the water restrictions had been lifted in early August and the last half of the irrigation season saw relatively high demand.

Chart 2: Percent of allotment used by percent of population, 2001 - 2004



	> 0% ≤ 10%	> 10% ≤ 20%	> 20% ≤ 30%	> 30% ≤ 40%	> 40% ≤ 50%	> 50% ≤ 60%	> 60% ≤ 70%	> 70% ≤ 80%	> 80% ≤ 90%	> 90% ≤ 100%	> 100% ≤ 110%	> 110% ≤ 120%	> 120% ≤ 130%	> 130% ≤ 140%	> 140% ≤ 150%	> 150% ≤ 160%	> 160% ≤ 170%	> 170% ≤ 180%	> 180%
2001	4.76	8.96	14.85	22.13	31.09	43.14	50.42	63.31	71.71	78.15	82.63	87.39	91.04	93.28	94.68	97.48	98.04	98.88	100.00
2002	3.52	8.13	13.55	18.97	28.73	39.02	53.12	65.58	73.98	81.84	88.06	91.60	95.39	96.75	97.83	98.37	98.92	99.19	100.00
2003	2.11	6.84	12.37	18.42	28.16	36.05	48.16	58.16	71.32	81.58	91.05	95.00	97.37	98.68	98.95	99.47	99.47	100.00	100.00
2004	5.87	11.20	23.73	39.47	55.73	71.73	84.80	92.53	96.27	99.20	99.73	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

% allotment used

2002

Allotment with $100 penalty for excess water use

The fall and winter of 2001/2002 provided sufficient snow pack to replenish surface water supplies and the board determined the normal drought year requirement of 6.86 da m^3/ha (2.25 acre-feet/acre) of water rights would be a suitable allotment for the coming year. Notices of the restrictions were again mailed to each landowner and the spring newsletter featured similar coverage to the previous year. Landowners were also advised that to exceed the allotment was a violation of district bylaws and to do so could result in disconnection of service and a $100 fine.

Results

The net moisture deficit in the region for the period for the May 1 to October 15 2002 was 733.5mm (28.88 inches) (Farmwest.com, 2004). The water use percentage by allotment and population for 2002 is presented in Chart 2. At the end of the season 81.84% of services remained within the allotment. Sixty-seven landowners exceeded their allotment and were fined $100.

The fairness of applying a standard rate penalty came under scrutiny because it applies the same penalty regardless of whether the excess use is one or one million gallons. In light of this inequity, the board requested staff provide options for applying a metered rate for water use in excess of the allotment.

2003

Allotment with inclining block rate for excess water use

The staff recommendation to the board for a rate structure to promote agricultural water conservation was based on the assumption that the drought year requirement of the district would be an adequate supply for agricultural use under drought conditions. The metered rate would be used to determine the penalty charged for water use in excess of the allotment and was meant to deter waste.

Fundamental to this approach is the recognition that the agricultural sector requires the allotted volume of water under drought conditions for irrigation. There would be no metered charge for the initial allotment and a metered rate would only be calculated and charged for properties exceeding the allotment.

The inclined block rate was chosen because the incremental increase in each block rate provided the flexibility to develop an effective rate structure suited to the application. A rate structure was needed that would recognize that a uniform allotment is difficult to apply fairly over diverse demand (soil) conditions. The rate structure must also provide a strong deterrent against excessive water use.

The 6.86 da m^3/ha (2.25 acre-feet /acre) allotment is a weighted average drought year requirement covering a variety of soil types spread out over the 3,642 ha (9,000 acre) distribution area of the district. During drought years the actual water requirement of the highest demand soils in the district would exceed the weighted average drought year requirement. The inclined block rate was developed to recognize that some land should slightly exceed the allotment in a drought year and the penalty for doing so would be minimal. For example, excess water use within ten percent of the allotment would be charged a nominal rate and the penalty would increase incrementally with each ten percent block in recognition that increasing water use above that level is increasingly wasteful.

Rate options

The development of rate options for the Board of Trustees to consider was arbitrary (Pike, 2003). The options provided would generally be considered low for non-agricultural water use. The rates were intended as a deterrent and were not required as a source of revenue for the utility. Significantly, the board also maintained the discretion to discontinue water service to any lands in excess of the allotment. Table 2 provides the three rate options originally provided to the board. The board chose Option 3 and these rates were brought into effect with the passage of Bylaw No. 579, the *Irrigation Water Distribution and Regulation Bylaw, 2003*.

All landowners were advised of the new metered rate penalty through the district newsletter and special mailings. Those properties that had been over their allotment in 2002 were also mailed a notice of the penalty amount that would apply under the new rate structure if the same volume of water was used in 2003.

Table 2: Metered rate options

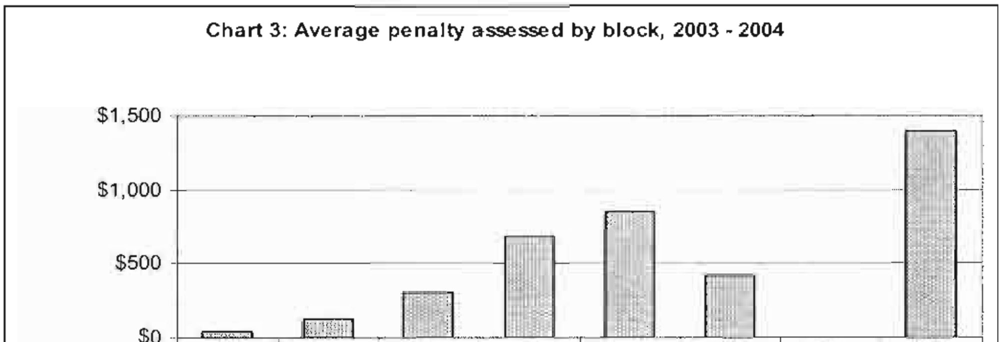
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Option 1 (rate per 1,000 USG)	\$0.01	\$0.02	\$0.03	\$0.04	\$0.05	\$0.06	\$0.07	\$0.08	\$0.09	\$0.10
Option 2 (rate per 1,000 USG)	\$0.10	\$0.12	\$0.14	\$0.16	\$0.18	\$0.20	\$0.22	\$0.24	\$0.26	\$0.28
Option 3 (rate per 1,000 USG)	\$0.10	\$0.13	\$0.16	\$0.20	\$0.25	\$0.31	\$0.38	\$0.46	\$0.55	\$0.65

Results

Snow packs, stream flows and groundwater levels were much lower than average over the winter of 2002/2003. Consequently, the district's main storage reservoir failed to fill for the second time in over thirty years. This low supply situation was followed by the fourth driest summer in the southern interior of B.C. since 1948 (Dobson, 2004).

The net moisture deficit in the region for the period May 1 to October 15, 2003 was 783.7mm (30.85 inches) (Farmwest.com, 2004). Water use as a percentage of allotment and population for 2003 is presented in Chart 2. At the end of the 2003 season 81.58% of properties remained within the allotment for the property.

Chart 3 provides a breakdown of the average penalty assessed to the 70 properties that exceeded the allotment in 2003. Over half of these properties (36) were within 10% of the allotment. The average penalty for this group amounted to $40. At the other extreme, two properties used between 70% and 80% over the allotment and the average penalty amounted to almost $1,400.



	100-110%	110-120%	120-130%	130-140%	140-150%	150-160%	160-170%	170-180%
Avg. Penalty	$40	$122	$307	$682	$851	$419		$1,398

The average annual water use for the nine years 1995 – 2003 is 11,659 da m^3 (9,456 acre-feet). The total water used for 2003 was 11,975 da m^3 (9,712 acre-feet), about 2.7% above average. By way of comparison, the water use for 1998 totaled 14,229 da m^3 (11,540 acre-feet), which is 22% above the nine year average. Both years were similar in terms of demand, with the irrigation period May 1 to October 15 showing a net moisture deficit of 777.8mm (30.62 inches) in 1998 and 783.7mm (30.85 inches) in 2003 (Farmwest, 2004). The main storage reservoir in 2003 was at 36.9% of capacity at the beginning of the year and at 41.5% at the end of the year. This indicates the district would be able to sustain water supplies through similar drought years in succession.

2004

Allotment with inclining block rate for excess water use

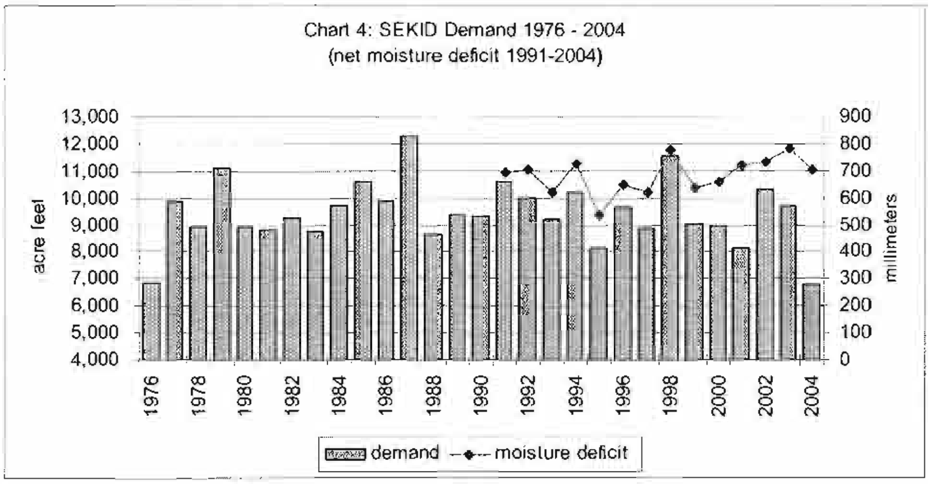
Given the effectiveness of the conservation strategy for the previous year, the decision was made to again implement water allotments with an inclined block rate for excess water use for the 2004 irrigation season. The snow pack over the 2003/2004 winter was adequate to replenish the surface water supply and the board determined the normal drought year requirement of 6.86 da m^3/ha (2.25 acre-feet/acre) of water rights would be a suitable allotment for the year.

All properties with metered irrigation services were notified by mail of the annual allotment in April and four water use reports updating water use information were provided over the course of the irrigation season.

Results

The net moisture deficit in the region for the period May 1 to October 15, 2004 was 701.7mm (27.62 inches) (Farmwest.com, 2004). Water use as a percentage of allotment and population for 2004 is presented in Chart 2. At the end of the 2004 season 99.20% of properties remained within the allotment for the property. McCulloch Reservoir ended the year at 64% of capacity.

Chart 4 provides a summary of district demand from 1976 to 2004 (Mould, 1997; SEKID.ca, 2004) and the net moisture deficit for the May 1 to October 15 irrigation period for the years 1991 to 2004 (Farmwest.com, 2004).



The water rights assessment area of the district has increased from 1,755 ha (4,337 acres) in 1974, to 2,291 ha (5,661 acres) in 2004, a 30.5% increase in water rights area over the past 30 years. The average net moisture deficit for the past fourteen years is 683.1 mm. The 2004 figure of 701.7 mm is higher than average, indicating irrigation demand for the year was above average for the period.

The total water use for 2004 was 8,380 da m^3 (6,792AF). This is the lowest level of annual water use in at least the past 29 years. The average annual use for this period is 11,550 da m^3 (9,364 acre-feet). Water use for 2004 was 27.4% below the 29 year average.

Discussion

The allotment system with an inclining block rate under Phase 2 of the program allocates water according to need. Careful consideration has been given to determining what the demand requirements are for agriculture under drought conditions. Once this demand plan is established, each property is provided with an allotment of water to meet these conditions. The punitive metered rate and trustee discretion to discontinue service for exceeding the allotment are effective deterrents to water waste and promote efficient use and conservation of a limited water supply. The demand plan must be flexible enough to allow for changes in water use requirements over time.

A comparison of the effectiveness of the educational approach of Phase 1 and the regulatory approach of Phase 2 of the program shows significantly greater water savings under drought year conditions were realized under Phase 2.

The allotment system is an effective method for managing agricultural water demand from several perspectives. The allotment provides an adequate volume of water for agricultural use under drought year conditions and the inclined block rate for water use in excess of the allotment deters significant excess water use, without severely penalizing those who exceed their allotment by a minor amount. The system is designed to eliminate water waste, not beneficial use.

Clearly the regulatory approach of Phase 2 was more effective in conserving water than the educational method used in Phase 1. It is doubtful, however, that Phase 2 of the program could have been as successful had it not followed the educational efforts of Phase 1. The drought conditions of 2003 created very high demand conditions and the regulations required that users stay within the drought year allotment. The ability of landowners to comply with the regulations can, in part, be attributed to knowledge gained through Phase 1 of the program.

The 2004 water use indicates the allotment system with an inclining block rate is also an effective conservation strategy under non-drought conditions. 2004 water use under above-average demand conditions was 27.4% below the twenty-nine year average. This is an impressive reduction and indicates the allotment system motivates users to regulate water use to match actual demand, regardless of what those demand conditions are.

This is significant because it indicates the program is capable of being an effective demand management tool under diverse conditions. The water resouree is managed so that the needs of the user are provided for and waste is eliminated. This reduces overall use of the resource.

Building a consensus within the region on agricultural water management is a significant challenge. Each water system presents a unique geopolitical entity with its own adaptive capacity for water conservation. Political will, capital costs, droughts, regulation and other influences allow (or prevent) adaptation to occur (Shepherd, 2004). An agricultural conservation program premised on delivering the required demand and only penalizing waste is, presumably, more acceptable to the agriculture industry than a program that charges by the volume of water used.

This approach establishes a demand plan based on a detailed analysis of the water demands of the service area. Greater control over demand provides greater certainty for management of supply. This allows rate structures to be established that meet the financial goals of the utility independently from water use. This provides revenue certainty regardless of consumption.

Significantly, this approach of analyzing water needs and eliminating waste could be applied to other water use sectors. The allocation of water resources then becomes a function of assessing demand and developing public policy for water allocation to reflect community and regional values. This method can recognize and allow for values that are not easily measured in economic terms and may be an alternative to using systems that provide access to the resource based on highest dollar value and ability to pay.

Recommendations

There has been considerable discussion recently about the formation of a basin- wide body in the Okanagan to deal with regional water management issues. Some of the following recommendations contemplate this may happen and are provided as suggestions on how local water management might be enhanced by basin-wide initiatives. Other recommendations are specific to developing local agricultural water conservation programs.

1. During the 1974 Okanagan Basin Study a number of citizen task forces were established to develop a consensus on the preferred life-style for the valley community. (These task forces unanimously supported a scenario that promoted a lower pace of economic growth, protection of agricultural lands and maintenance of the environment).

   It is recommended that a basin-wide body repeat that process and use the information obtained to develop and update public policy on regional water management. Once this has been done, a framework for regional water supply and demand management objectives can be established and used in support of local initiatives.

2. Demand management programs can only be fully developed and assessed in context with supply. Water licensing administration and hydrometric data collection are provincial responsibilities that have in recent years been subject to increasing restraint. To assess the long term effects of climate change and the increasing demands of growth on regional water supplies, accurate water supply information is needed. This is critical for reconciling regional water licenses with supply and assessing supply capacity.

It is recommended a basin-wide body add its voice to the call for provincial authorities to fulfill their water management mandate and provide adequate resources for doing so.

3. As surface water supply sources become fully subscribed in the region, groundwater resources will come under increasing development pressure. As with surface water, demand management programs for groundwater require accurate supply information. The concern for groundwater supply assessment is the same as for surface water supplies with the notable exception that groundwater is not licensed and not subject to volume restrictions.

   It is recommended that sufficient resources be devoted to assess regional groundwater supplies and that groundwater extraction be regulated to insure the sustainable capacity is not exceeded.

4. While local water suppliers in the Okanagan Basin currently have the authority to implement demand management programs, a variety of factors are preventing them from doing so. These include the lack of political will, the perception of ample supply (i.e.: Lake Okanagan), lack of funding for conservation programs and the lack of a cohesive regional policy on water management (why should one community conserve if the next is not).

   A basin-wide body would be able to provide coordination and support to local authorities in a number of these areas. This could include establishing regional water use policy, guidelines and planning (sec 1.), providing information, workshops and extension services to aid in program development and financial assistance to get programs started.

   In the long term, a basin-wide incentive system could be developed that rewarded efficient water use through short term (annual) supply credits that could be traded for beneficial use elsewhere in the basin.

5. Our experience with the agricultural metering program was that education alone as a means of conserving water had a limited effect. Substantial water use reductions were only gained after regulations mandating water conservation were put into effect (Most agree water conservation is a good thing yet, in the absence of regulation, few actually follow through in practice – there is a disconnection between attitude and practice).

   It is recommended that water suppliers considering agricultural conservation programs include both education and regulation as components of the program. Education in water conservation then becomes a means to assist users in complying with water use regulation.

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Risk-Based Wellhead Protection Planning

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Abstract

Wellhead Protection Plans (WHPPs) are established to identify, forestall, manage, mitigate, monitor and communicate issues of quality and quantity in water supplying wells for human, animal or process use. Standard WHPPs rely on groundwater travel times within a capture zone (e.g., 1, 2, 5-year time zones) for planning and action. The inference is that these estimated travel times represent meaningful threshold response times. However, real-world response times to well threats form a continuum from emergency response (minutes) to long-term education (years). Also, standard approaches are not explicitly risk-based and offer no clear process to rank risk priorities (e.g., correct level of response, appropriate monitoring effort, or level of risk communication) or to reorder priorities as new risks appear. Alternatively, WHPPs can be established within a risk framework using *risk assessment* (hazard and risk identification), *risk management* (mitigation, risk transfer, preventive action, land-use planning, monitoring, contingency planning) and *risk communication* (education, training). Basic risk concepts are presented. Well threats within a capture zone can be represented as *risk scenarios,* which are collectively ranked and plotted on a *Risk Matrix* – a plot of exposure (frequency or speed of transport to a well) versus hazard (severity or toxicity). Groundwater travel time and aquifer vulnerability are shown to be expressions of exposure, but not inherent expressions of risk. Hazard severity, exposure speed and risk level categories can be specifically determined to suit the type and sensitivity of receptors as well as the risk tolerance of the water purveyor. Risk scenarios can be tracked on databases or GIS, and shown on a colour-coded *Risk Map*. *Risk Management Plans* can be preplanned for all identified and anticipated risk levels. An example of a risk-based WHPP is presented. We conclude that WHPPs are a complex interplay of technical hydrogeology, municipal management, land-use planning and user education, requiring both stakeholder and professional input, and are best managed using a risk-based approach. *Risk communication* is essential throughout the process.

1.0 Introduction

1.1 Statement of Problem

Wellhead Protection Plans (WHPPs) are established to identify, manage, monitor and communicate issues of quality and quantity in water supplying wells used by humans, domestic animals, crops or for process uses. Water well owners need a pragmatic approach for managing wellhead risks that can be affordably developed and maintained. Standard WHPP approaches rely on groundwater travel times within a capture zone as a basis for management, planning and contingency action. However, a travel time based approach does not provide an intuitive framework for ranking risk priorities or determining correct levels of risk response or communication. Typical travel time increments (e.g., 1, 2, 5 years) are inferred to correspond with meaningful thresholds for response action or monitoring. However, actual response times to well threats form a *continuum* - from emergency response (in minutes) to long-term education, training programs and public education (months to years).

1.2 Alternative risk-based approach

Alternatively, WHPPs can be established within a *risk framework* using *risk assessment* (hazard and risk identification), *risk management* (mitigation, risk transfer, preventive action, monitoring and contingency planning) and *risk communication* (education and training). Specific well threats or *risk scenarios* can be identified, prioritized and reordered as they are addressed or as new risks appear. Importantly, a risk-based approach can be readily adapted to existing management frameworks, so there is no need for wholesale redevelopment of a useful existing system. The risk-based method here offers a rational, defensible framework for deciding appropriate action in response to a real or perceived threats to a well, the level and type of that response, and appropriate risk communication throughout the process. The approach includes simplifying conservative assumptions and is aimed at providing an internal management tool that, once set up by the owner's risk management team, is easily maintained, with minimized on-going requirements from outside technical experts.

1.3 Previous work on risk-based WHPPs

Previous studies have involved risk concepts for wellhead protection. The U.S. Environmental Protection Agency published several documents on the wellhead protection process incorporating qualitative and relative risks (e.g., US EPA, 1991; US EPA, 1993). The British Columbia provincial government adapted the US EPA approach in a six step approach (Wei et al., 2000). Quantitative, stochastic risk assessment has been applied to WHPP (Chin and Chittaluru, 1994), although this requires detailed site-specific information often unavailable or unaffordable for most well managers. EPRI (2000) presents a specialized tool (Health Standard Exceedance Index) for determining the severity of hazards in groundwater approaching wells. This type of tool may be useful as a refinement to the hazard evaluation in the examples presented here. In addition, the analysis and uncertainties of capture zones and travel times have been addressed by several authors (Bair et al., 1991; Evers and Lerner, 1998; Feyen et al., 2001; Guadagnini and Franzetti, 1999).

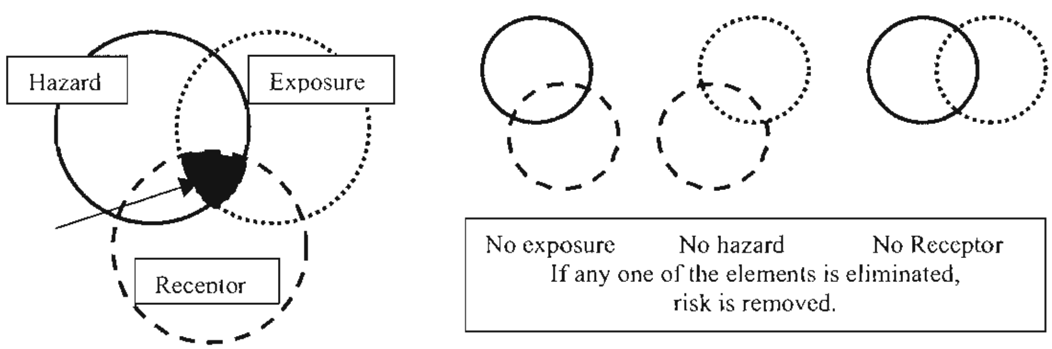
2.0 Risk Fundamentals

2.1 Essential Risk Elements

Risk can be defined as a measure of the likelihood for an adverse effect on a receptor due to exposure to a hazard. Here, receptors are taken to be any combination of human, animal, plant or process equipment users of well water. The three key elements of risk (receptor, hazard and exposure) must all combine to generate a risk (Figure 1a). In theory, risk can never be absolutely eliminated (i.e., "zero risk") since there always remains a possibility of combining the risk elements. However, in practical terms, risks can be effectively removed or reduced to acceptable levels if any of the three elements are eliminated or blocked (Figure 1b, 1c or 1d).

Figure 1 – Fundamental concepts of risk and risk management

a) b) c) d)



Exposure can be expressed in terms of the frequency or likelihood of receptors coming in contact with a hazard, which in this case is water from a well. Hazards can be expressed in terms of severity (or contaminant toxicity). To be pragmatic and conservative, we evaluate risks for the highest concentration of a given hazard that would confront receptors at the wellhead. Therefore a surrogate measure of exposure likelihood is the speed of water migration along the pathway from a hazard source to the well. If the speed is rapid, there is limited time for intervention and a higher likelihood of exposure. Both exposure and hazard can be described in qualitative terms such as Low, Medium, High or Very High, with specific and meaningful definitions developed to suit the risk management group.

2.2 Relationships of Hazard, Exposure and Risk

A hazard is a *potential* threat to a receptor and only evolves into a risk if a receptor is exposed to it. A banana peel on its own is a hazard (Figure 2a) but poses a risk when a person (receptor) slips on it (exposure) and falls (Figure 2b). Likewise, a gasoline spill does not pose a wellhead risk when it occurs outside its capture zone (Figure 3a), but does within the zone (Figure 3b).

Figure 2 – Relationship of Hazard and Risk

a) Hazard b) Risk

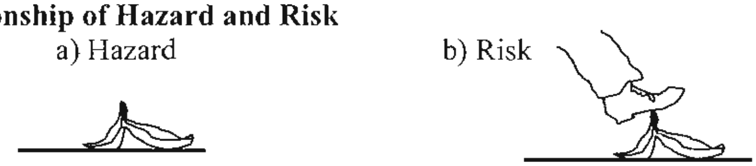
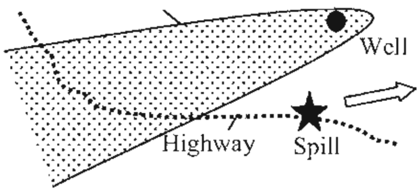
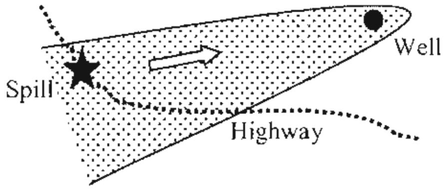


Figure 3 – Importance of Exposure in establishing Risk

a) Spill outside capture zone: no wellhead risk b) Spill in capture zone: wellhead risk

Capture zone





Aquifer vulnerability can be considered as the ease by which a contaminant could enter an aquifer. Typically an unconfined aquifer with shallow water table is considered more highly vulnerable than a deep confined aquifer. Similarly, groundwater *travel time zones* are a measure of speed of transport along a pathway between a point in the capture zone and a receptor (well user). However, in a risk sense, aquifer vulnerability and groundwater travel times are simply measures of the likelihood of exposure of a receptor to potential contaminants in well water. Importantly, neither a vulnerable aquifer nor a short groundwater travel time inherently signify higher *risk*, as the risk will appear only with a combination of exposure and hazard.

2.3 Risk Framework, Risk Assessment and Risk Management

A *Risk framework* as defined here is the approach and context a risk management team

Risk Stage	Step	Content
I Risk Framework	1	- Decide risk approach (qualitative or quantitative) - Identify Responsible Party - Form Risk Management Team - Rate risk perception (tolerance) - Determine position to accept/reduce/transfer risk
II Risk Assessment	2	- Define capture zone (professional judgement, analytical or numerical methods)
	3	- Identify receptors - Identify risk scenarios (hazards & exposure) - Define exposure likelihood and hazard consequence categories - Evaluate and rank risks in Risk Database - Plot risks on Risk Matrix and Risk Map
III **Risk** Management	4	- Establish roles and resources - Establish responsibilities and liabilities - Establish risk communication strategy - Establish risk reduction strategy
	5	- Develop risk reduction plan for each risk level - Implement risk reduction plan for desired risk levels - Undertake risk monitoring - Undertake preventive actions
	6	- Audit (check progress of risk reduction) - Update/revise risk database - Report (risk management team to Responsible Party using Risk Map) - On-going risk communication and education

takes in addressing well risks. This includes defining their risk tolerance (risk-averse or risk-tolerant) and to what extent the responsible party wants to accept, reduce or transfer risk. Risk identification can be qualitative, as presented here, or quantitative, based on probabilistic mathematical analysis. Due to the limited site information and resources, most risk-based WHPPs are likely to be qualititative. *Risk assessment* is the process of evaluating the consequences of hazard severity and likelihood of exposure, then evaluating, ranking and mapping the identified risk scenarios. *Risk management* is the process of mitigation, risk transfer, preventive action (e.g., through land-use planning), monitoring and contingency actions in response to identified risks.

Risk communication relates to the interpretation and flow of information between the risk management team and other parties (such as well users, media or the public) and is integral to the WHPP process.

3.0 Risk-Based Wellhead Protection Methodology

3.1 Overview of Methodology

The methodology presented here consists of three stages (Table 1). The internal steps shown could be grouped or further subdivided to suit the risk management team.

Table 1 – Summary of Risk-based Wellhead Protection Methodology

3.2 Illustrative Examples

To explain the proposed risk-based wellhead protection methodology, we present two hypothetical cases. Case 1 considers a privately-owned irrigation well. Case 2 considers a municipal well supplying drinking water for humans and livestock. These cases are used to present a range of receptors, contaminant types (point and non-point sources), and differing risk management teams, risk tolerance and risk management steps.

Five realistic hazard scenarios are imposed identically in both cases. These are 1) fertilizer applied in orchard 3 km upgradient of well, 2) road salt depot at 0.8 year travel time upgradient of well, 3) gasoline tanker spill 50 m from well, 4) gasoline tanker spill 500 m from well, and 5) sanitary sewer main break 200 m upgradient of well. These were chosen to represent a range of inorganic, synthetic organic and biological contaminant groups. As shown below, the risk posed by a given hazard depends on the receptors exposed to it. Recognizing that contaminant concentrations vary with time as a contaminant plume arrives at a well, for simplicity we considered only that consequences of maximum hazard severity for water arriving at a wellhead. As mentioned above, more sophisticated tools for evaluating well water health hazards are available and could be applied. Analogously, the greatest likelihood for exposure (minimum travel time between source and well) is considered. All of the key elements of a risk-based WHPP are developed for both cases below, showing the utility and adaptability of risk approach.

3.2.1 Risk Framework (Stage I)

Table 2 shows the elements of a Risk Framework and plausible information for Cases 1 and 2. The risk framework ranges from simple (Case 1) to complex (Case 2). As a minimum, the risk management team should include the *responsible party* (or representative), a provincial health or environment representative and a technical expert (e.g., in-house or outsourced hydrogeologist). The method shown here can accommodate changes in risk tolerance over time. If the City Council became more risk-tolerant in Case 2, the methodology would allow risks to be readily re-evaluated and re-ranked to fit the revised risk tolerance, without recreating the entire WHPP.

Table 2 – Stage I - Risk Framework for Example Cases

Content	Case 1 – Private Irrigation Well	Case 2 – Municipal Multi-use Well
Risk approach	Qualitative	Qualitative
Responsible Party	Well Owner	City engineer
Risk Management	Well owner, provincial health	City engineer, City manager, Farmer's Co-op Chair,

Team	official, consultant (3 total with funding from minor grant money through municipal green funding)	provincial health official, Citizens for Clean Groundwater (lobby group), Waste manager for Regional District, neighbor landowner, University professor, consultant (9 total, with town staff time, vehicles, media/PR staff available to assist; funding from municipal budget and federal funding)
Risk tolerance	Risk-tolerant	Risk-averse (current City Council)
Position to accept/ reduce/ transfer risk	Seek to accept or reduce at lowest cost	Seek to reduce with large emergency fund or transfer (insurance, contracts) to the maximum

3.2.2 Risk Assessment (Stage II)

Table 3 shows the key elements of a Risk Assessment and plausible results for Cases 1 and 2. The well capture zone is defined by judgement, analytical calculation or numerical modeling, depending on the risk tolerance of the risk management team, and requires technical expertise from a hydrogeologist. A risk-tolerant group might abide professional judgement, while a risk-averse group may require the rigor of a numerical model. We do not consider that fixed radius approaches (arbitrary or calculated) allow meaningful determination of exposure or risk level because they can include areas to manage which are outside of the actual capture zone contributing to a well.

Table 3 – Stage II - Risk Assessment for Example Cases

Content	Case 1 – Private Irrigation Well	Case 2 – Municipal Multi-use Well
Define capture zone	Calculated or defined by judgement (consultant)	Numerical modelling (consultant with input from City engineer & staff)
Base map for Risk Map	Figure 5a	Figure 5b
Identify receptors	Crops only (vineyard)	Humans; livestock
Identify risk scenarios	The same hazard scenarios are used for both cases (all within capture zone): 1. Fertilizer in orchard 3 km upgradient of well 2. Road salt depot at 0.8 year travel time upgradient of well 3. Gasoline tanker spill 50 m from well 4. Gasoline tanker spill 500 m from well 5. Sanitary sewer main break 200 m from well	
Exposure likelihood/ Hazard consequence categories	Table 4a	Table 4b
Evaluate & rank risks	Table 5a (Risk Database, Case 1)	Table 5b (Risk Database, Case 2)
Plot Risk Matrix & Risk Map	Figure 4a (Risk Matrix, Case 1) Figure 5a (Risk Map, Case 1)	Figure 4b (Risk Matrix, Case 2) Figure 5b (Risk Map, Case 2)

Receptors can be a single group (crop in Case 1) or combination (humans and livestock in Case 2). Risks are evaluated and can be shown for all receptors. The *Risk Database* is an organized archive to track the classifications, rankings and notes relating to hazard scenarios, exposure likelihood, hazard consequences and evaluated risks for each scenario by the risk management team. Each scenario can be updated, re-ranked and re-plotted as changes occur or new scenarios are recognized by the risk management team. An adaptable Risk Database is one of the key attributes of this risk-based methodology.

Table 4a and 4b show the exposure likelihood and hazard consequence categories defined by the hypothetical risk management teams for Case 1 and 2, respectively. The number of categories is at the discretion of the risk management team but, practically, three is a minimum and five is a maximum. Exposure likelihoods for the different categories are artifacts of the differing risk tolerance for Cases 1 and 2. For example, Case 1 shows a one year travel time as only a medium exposure likelihood, while for Case 2, the risk-averse team chooses 1 year as their cutoff for very high exposure likelihood. Different or more sophisticated health/toxicity criteria could be used for hazard consequences. Secondary effects of contaminated water, such as degradation of stream water quality from discharged well water, are beyond the scope considered here.

Table 4a – Categories of Exposure and Hazard for Case 1 – Private Irrigation Well

	Criteria
Exposure likelihood	
Low	Groundwater travel time over one year
Medium	Groundwater travel time 6 months to one year
High	Groundwater travel time less than 6 months
Hazard consequence	
Low	Crop yields marginally diminished, plants stressed but recoverable
Medium	Crop yields strongly diminished, plants stressed, some die
High	Crop failure likely, many plants die

Table 4b – Categories of Exposure and Hazard for Case 2 - Municipal Multi-use Well

	Criteria
Exposure likelihood	
Low	Groundwater travel time over 4 years
Medium	Groundwater travel time 2 to 4 years
High	Groundwater travel time greater than 1 but less than 2 years
Very High	Groundwater travel time 1 year or less
Hazard consequence	
Low	Human: Exceeds aesthetic objectives in Drinking Water guidelines (staining, taste) Livestock: Some aversion to water, animals distressed
Medium	Human: Short-term health condition, discomfort, illness (Lost time: days) Livestock: Illness or disease (full recovery probable); minor loss in commercial value
High	Human: Chronic health hazard, long-term disease or illness (Lost time: weeks-months) Livestock: Illness or disease (recovery in long term); major loss in commercial value
Very High	Human: Acute health hazard, disease or illness (permanent disability or fatalities) Livestock: Fatalities (major loss of herd)

A Risk Database could consist of a simple spreadsheet (Case 1) or be embedded (with the Risk Map) in an elaborate Graphical Information System (Case 2). An electronic (or web-based) format is favoured since it facilitates adding, removing and resorting risk scenarios. Tables 5a and 5b show risk evaluations for Case 1 and 2, respectively. Each table can be considered as an extract from a risk database.

Table 5a – Risk Evaluation for Case 1 – Private Irrigation Well

Scenario	Exposure likelihood	Hazard consequence	**Risk rank****
1 Fertilizer in orchard 3 km	Low	Low	**Low**
2 Salt depot 0.8 yr travel time	Medium	Medium	**Medium**
3 Gas tanker 50 m	High	High*	**High**
4 Gas tanker 500 m	Low	High*	**Medium**
5 Sanitary sewer break 200 m	Low	Low	**Low**

Note: *assumes no degradation in transit to well (conservative). Alternatively, retardation along a flow path could be calculated or modeled with sufficient resources, site information and necessity. ** Refer to Figure 4a

Table 5b – Risk Evaluation for Case 2 - Municipal Multi-use Well

(H = Human, L = Livestock)

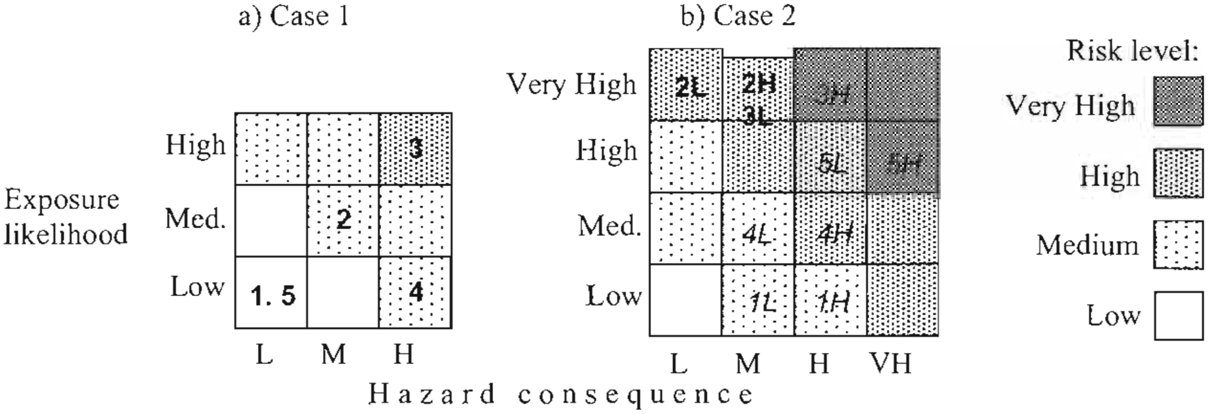
Scenario	Exposure likelihood	Hazard (H) consequence	**Risk (H) Rank****	Hazard (L) consequence	**Risk (L) Rank****
1 Fertilizer in orchard 3 km	Low	High	**Medium**	Medium	**Medium**
2 Salt depot 0.8 yr travel time	Very High	Medium	**High**	Low	**High**

3 Gas tanker 50 m	Very High	High*	**Very High**	Medium	**High**
4 Gas tanker 500 m	Medium	High*	**High**	Medium	**Medium**
5 Sanitary sewer break 200 m	High	Very High	**Very High**	High	**High**

Note: *assumes no degradation in transit to well (conservative). Alternatively, retardation along a flow path could be calculated or modeled with sufficient resources, site information and necessity. ** Refer to Figure 4b.

Figure 4a shows a 3x3 Risk Matrix for Case 1 and Figure 4b shows a 4x4 Risk Matrix for Case 2. The five example risk scenarios are plotted on Figure 4a and 4b (according to their risk rank in Tables 5a and 5b, respectively). Note that Figure 4a conveys a risk-tolerant approach (emphasis on Low and Medium risk fields) which might reflect the entrepreneurial outlook of private farmer, while Figure 4b conveys a risk-averse approach (emphasis on Very High and High risk fields) which might reflect a conservative public health approach of a municipal water supply manager.

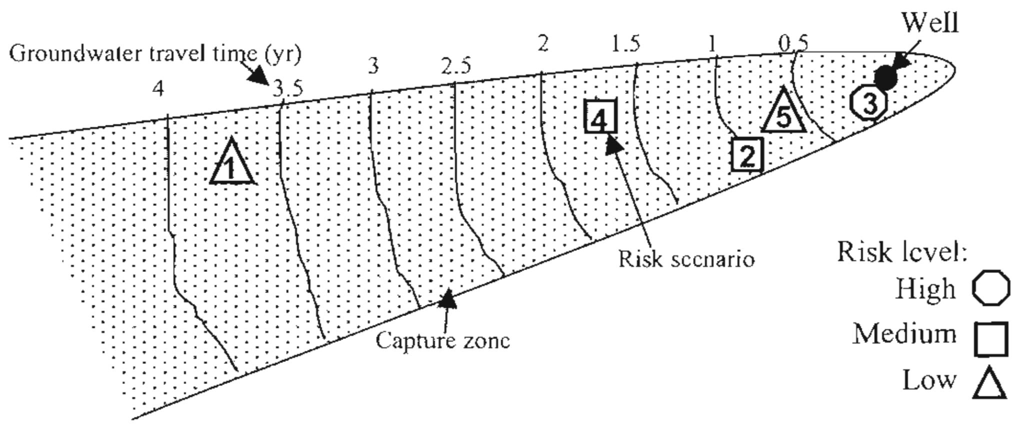
Figure 4 – Risk Matrices with Risk Scenarios for Cases 1 and 2



In Case 1 (Figure 4a), the five scenarios plotted (for crop receptors only) comprise one high, two medium and two low risks. In contrast for Case 2 (Figure 4b), the same scenarios (five for human and five for livestock receptors) constitute two very high, five high, three medium and no low risks. The risk results are different due to the differing receptor groups, risk-tolerance, and exposure likelihood and hazard consequence definitions for the two cases.

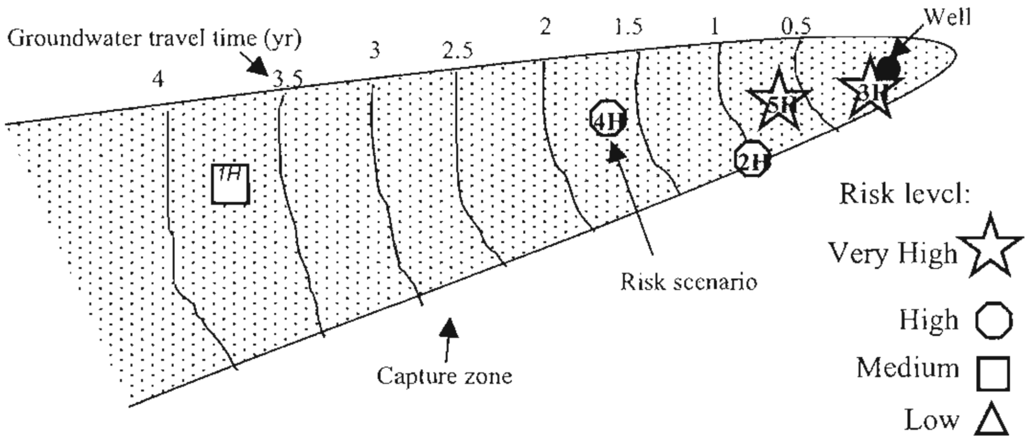
The risk results are on a *Risk Map* (Figures 5a and 5b) for Cases 1 and 2, respectively.

Figure 5a – Risk Map showing geographic distribution of risk scenarios for Case 1



The numbered risk scenarios (1-5) can be easily distinguished by symbol shape and number, making explanation to non-technical viewers and management tracking straightforward. Note that *risk is not necessarily related to travel time*, as shown for example by scenario 5 which is closer to the well than scenario 2 but with lower risk level. Scenarios with the same risk level (e.g., 2 and 4, at medium risk) can lie at different distances from the well.

Figure 5b – Risk Map showing geographic distribution of human risk scenarios for Case 2



For simplicity, only human risk scenarios (1H-5H) are plotted on Figure 5b. On Figure 5b, the very high risks (3H and 5H) are closest to the well, with lesser risks farther away. The differing risk assessment results are readily apparent by comparing Figure 5a and 5b, for the same five hazard scenarios. Any number of risk scenarios could be plotted on a Risk Map, with the symbols changing as risks are managed to lower levels, new ones added, or deleted as risks are managed below a threshold of concern set by the risk management team.

3.3 Risk Management (Stage III)

Risk Management begins with clarification of responsibilities, liabilities and resources in implementing risk management actions. Commitments to monitoring, auditing, risk reappraisal and stakeholder education are also considered. A risk reduction strategy entails devising a preplanned level of effort for various levels of risk. The approach might be to address only High or Very High risks due to resource constraints. The level of effort might range from immediate emergency response with mutual aid (fire dept, police, government authorities) for Very High risk, ranging down to simple long-term monitoring for Low risk.

Risk communication is essential throughout the entire WHPP process. A risk communication strategy entails the collection, selection and release of information tailored to the level of risk. The strategy identifies who speaks for the team (normally the chair) and the frequency of communication proportional to risk level (e.g., daily for Very High risk, or annually for Low risk). Involvement by a public relations firm may be elected for highly sensitive risk scenarios.

Preventive actions are taken to avoid repetitive problems. For example, this may entail changes in the storage, handling or distribution of chemicals, land use controls, legal/contractual agreements with land owners and public education.

The Risk Database should be reviewed and reappraised periodically by internal or external audit. From a management perspective, this could include regular review of the status of risk reduction and preventive actions for the top ten risks. The Risk Map forms a concise and convenient basis for the risk management team, Council or Board to view the status of risk management. Auditing frequency can also vary with risk level (e.g., weekly for Very High risk; annually for Low risk). Reporting is important to document progress, improve public perception, reduce potential legal issues and possibly reduce insurance costs. Reports may take the form of a section in an annual report, an entry on a web site or a community newsletter.

Table 6 presents plausible risk management actions for Cases 1 and 2.

Table 6 – Summary of Risk Management (Stage 3) Elements for Cases 1 and 2

Risk Management Element	Case 1 – Irrigation Well	Case 2 – Municipal Multi-Use Well
Roles, Responsibilities & Resources	Team: well owner (responsible party), Ministry of Health rep & consultant; owner is legally responsible and speaks for Team; owner is volunteer with minor grant through municipal green funding	Team: Town manager, town engineer, delegates from farmer's co-op, Ministry of Health representative and local groundwater lobby group, Waste Manager for Regional District, landowner (neighbor to well), University professor, consultant; town staff time and vehicles, media staff, University laboratories funded by major municipal infrastructure grant
Risk Reduction Strategy	Respond only to medium or high risks; High risk: immediate notify/seek help from municipality, regional district, emergency services (Fire Dept); invoke emergency water supply (own or Farmer's Coop); seek funding assistance from Provincial or Federal gov. for remediation & monitoring; no outside PR; Medium risk: Seek advice from municipal or regional district engineer; hire consultant for mitigation/monitoring; Low Risk: no remedial action; minimal monitoring	Respond to all risk levels; Very High Risk: immediately invoke Emergency Response Plan with coordinated mutual aid from other municipalities, province and federal agencies; use emergency fund to pay for contingencies; hire consultant for rapid engineered response and initiate appropriate monitoring; initiate risk communication plan; High Risk: rapid engineered response with consultant bired within days to follow emergency services in cleanup and monitoring; municipal engineer dedicated as point of contact for consultant; initiate risk communication plan; Medium Risk: standard engineered response with consultant (through proposals) hired within weeks for characterization & monitoring along with in-house resources; issue one press release; Low Risk: monitor with in-house resources, no media release
Risk Communication Strategy	Owner is sole spokesman; no press releases	Town engineer is sole spokesperson; internal briefings: Very High Risk: daily; High risk: weekly; Medium-Low Risk: monthly. Press releases: Very High Risk: daily; High risk: weekly-monthly; Medium Risk: one time; Low Risk: none.
Preventive Action	Informal, in-house changes in procedures; education & training for staff at next low-cost opportunity	Land use (zoning) changes; environmental bond required for certain commercial/industrial uses; contractual liability for polluters; certification requirements enforced (lawsuits as required); public education; warning signage; changes in type and level of municipal insurance
Auditing	Informal,internal; owner monitors and briefs staff	Monthly review of top ten risks using Risk Map; Annual external audit by consultant; root cause analysis; lessons learned review
Reporting	Informal, internal; minntes at monthly staff meeting	Formal internal and external reports; monthly review by risk team of "top ten" risk scenarios, with Chair enabled to trigger an Emergency Response Plan;

	section in Annual Report; newspaper article by risk team chair

4.0 Costs

Costs for a WHPP vary widely depending on the user (receptor) group, location of the well in relation to the complexity of the surrounding hydrogeology and potential sources of well stressors, significance attached to well protection (i.e., risk tolerance) by the well owner, duration of preventive action, auditing and followup monitoring undertaken, and other factors. A simple WHPP may cost on the order of $10,000 to $30,000, while complex WHPPs may be several times this amount. However, in light of higher public scrutiny of the integrity of water supplies, changing regulatory environment and the potential legal implications faced by water supply managers, the cost of *not* implementing a WHPP would undoubtedly be much higher. Williams and Fenske (2004) show that the avoided cost to benefit ratio for WHPPs is on average 8:1.

5.0 Conclusions

WHPPs involve a complex interplay of technical hydrogeology, well management, municipal land-use planning and user education, requiring both stakeholder and professional input. In our opinion, realistic capture zones must be used, either developed from professional judgement, analytical calculations or numerical modeling. Fixed radius approaches are essentially cost-saving shortcuts which can mislead users and do not add value to a risk-based approach.

We suggest that WHPPs are best developed using a risk-based approach, which allows managers to focus on salient risks, are flexible and easily updated, and are adaptable to all levels of risk tolerance and management sophistication. Technical expertise is required, especially in the risk assessment stage.

WHPPs should be considered as a dynamic and on-going process to understand and protect groundwater resources, prioritize and manage responsibilities and liabilities, and guide decision-making strategies. WHPPs offer sound planning and economical benefits, with the cost of preparing and maintaining a plan being far less than the costs of remediating or replacing a contaminated groundwater supply.

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The Race for Water: Reflections on the 1974 Okanagan Basin Study

by

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Abstract

The key recommendation of the 1974 Okanagan Basin Study was that the three regional districts be merged into a single regional government with boundaries defined by the Okanagan watershed. The recommendation was never implemented, limiting the scope for basin-wide coordinated management of the Okanagan's water resources. This outcome is not surprising when one considers the distribution of population growth in the valley and the scarcity of water. This paper describes some trends and projections for the valley and highlights how insecure and relatively untradable water rights serve to impede cooperation. Experiences with decentralized, participatory watershed management and with marketable water rights are discussed. It is recommended that water rights be reformed in British Columbia to enhance security and facilitate market trading, and that the Okanagan Basin Water Board be vested with the authority over an Okanagan Basin water market.

Introduction

In the Okanagan Basin, water has been a critical resource since European settlers first arrived, and likely before that (Wilson, 1996). In 1969, the Federal and Provincial governments signed the Okanagan Basin Agreement. From this agreement flowed a substantial research project, culminating in a series of reports and a ``Comprehensive Framework Plan." The leading recommendation in this plan was:

> That the boundaries of the present Regional Districts of North Okanagan, Central Okanagan and Okanagan-Similkameen be redrawn to create a single Okanagan Basin Regional District having boundaries coincident with those of the watershed, to be responsible for those water resource management functions that pertain to the Valley as a whole and in particular the implementation of those recommendations in this report that are Valley-wide in scope, especially waste treatment, the orderly development of shoreline recreation facilities, and flood-plain zoning. (Marr and Prince, 1974, page 13)

This recommendation was at best only partially acted upon, largely due to the inability of the three regional districts to agree to surrender powers. A couple of excerpts from the minutes of the Okanagan Basin Water Board (OBWB) highlight the issues.

> ... Vernon, for a number of years, has said that all their resources are committed to their master water plan and they will not support Water Board initiatives that they feel duplicate their own efforts. They want to see bottom line benefits to the City of any

> Water Board efforts but will not contribute to any analysis that might reveal those benefits (OBWB, 2003a, page 3).
>
> Mayor Harvey [of Vernon indicated] ... councils' satisfaction with weed control and sewer grants but their opposition to any expansion of the Boards' role (OBWB, 2003b, page 3).
>
> Director Novakowski questioned a role for the Water Board in providing leadership as the Province has the power and authority in water related matters (OBWB, 2003b, page 2).

The inability of the three regional districts to negotiate their merger, and the unwillingness of the provincial government to force the matter, leaves us where we are today. However, with a little reflection, it is not too difficult to see why the regional districts were not eager to commit to such an institutional change. Economic and demographic changes were rebalancing the relative power of the three regional districts, in favor of the Central Okanagan Regional District. This change would be seen as a threat by the other districts, a threat felt most strongly by the City of Vernon, making them less likely to cooperate. Overcoming these conflicts is easier if the involved parties are confident that changes will not leave them worse off. The current water and property rights regimes in British Columbia offers no such security. It is recommended that water rights be reformed to eliminate the requirement of beneficial use and simplify the division, renting and trading of water licenses. Such reforms should reduce the incentive to 'race' for water, increasing the likelihood that water will be used efficiently.

The Okanagan Basin

Water is scarce in the Okanagan. On the valley floor, average annual precipitation is in the neighborhood of 300 mm. For the basin as a whole, average precipitation is approximately 600 mm annually (Neilsen et al., 2001). Given the rapid population growth, and the fact that most available water has already been allocated to some use, conflicts over water are likely to intensify.

The shifting balance of power stands out when population trends and forecasts are considered. Using statistics provided by the B.C. government (Service BC, 2004), Figure 1 plots population trends and forecasts for the regional districts and main urban centers of the Okanagan Basin. Several points are highlighted by these figures. One is the historic and expected growth rates. The basin population appears on track to exceed the medium estimate in the original Okanagan Basin study. When broken down by regional district, one sees that in the first decade of the 21st century, the population of the Central Okanagan Regional District (CORD) has become the majority for all three. If one considers only the three main urban centers, then Kelowna clearly dominates, and has done so since the 1970s. Matters are even more biased if one recognizes that some parts of the current North Okanagan Regional District (NORD) lie outside the Okanagan Basin, and the only issue linking the Similkameen valley portion of the Regional District of Okanagan-Similkameen (RDOS) to the rest of the basin is flooding of Osoyoos Lake. The relative dominance of the CORD is therefore likely even greater than the Regional District population comparisons alone indicate.

The increase in population goes hand in hand with an increase in the demand for water. Figure 2 shows the total number of water licenses by type of use for the Okanagan basin as a whole. Although accurate measures of water use by private users is scarce, water licenses are here taken to be a rough measure. Towards the beginning of the 20th century, agriculture was the dominant water user. This is consistent with the history of irrigation in the Okanagan (Wilson, 1996). More recently, most of the growth has been in licenses for non-agricultural uses, reflecting both population growth and the limited scope for additional irrigation.

The growth of water licenses would not be an issue if there was adequate water. However, water has been allocated to the point that restrictions are being put on many water sources, limiting further extractions. Figure 3 shows the cumulative number of restrictions issued by date and regional district. It is apparent that the number of restrictions issued began its rapid growth while the Okanagan Basin study was taking place. The figure also shows that the largest number of restrictions were then being issued in the CORD. This suggests that the CORD was nearing the limits of its water supply more rapidly than the other regions. Along with this, the population in the CORD was growing to the point that it would represent a majority in any basin level Regional District. It would not be unreasonable to believe that the predominant focus of any basin level Regional District would be supplying water to the Kelowna area. This, of course, would make the other regional districts reluctant to loose control over water they see as needed for their own development.

The growth of water restrictions and continued growth in urban demand suggests that before long the main water allocation issue will be how to move it between use categories. To an extent this is already taking place, as many irrigation districts also supply water to suburban communities. This is the same issue being faced in the Western United States, which Shupe et al. (1989) term the 'Era of Reallocation.' The question is no longer how to find more water, but how to move water to its most valuable use. Such reallocation of water has the potential to redistribute incomes. It will not be welcome unless redistribution concerns are addressed in such a way that all benefit. In what follows experience with water management and reallocation in other places will be discussed, and some recommendations made.

Water Allocation and Management

From an economic perspective, the objective of resource management is to maximize the aggregate gain that the resource can produce. Watersheds provide natural geographical management units, which, in terms of water resources, are relatively isolated. This has lead to a progressive evolution of water management towards the river basin level (Teclaff, 1996). Several studies have shown that coordinated river basin management can increase overall economic gains (Rosegrant et al., 2000; Chakravorty and Umetsu, 2003; Wichelns et al., 2003). However, basin level management often means reallocating water in ways that may not maximize the gains of individual water users. At the international level, this makes the negotiation of river management agreements difficult (Rogers, 1969; Linnerooth-Bayer and Murcott, 1996; Dinar and Alemu, 2000; Janmaat and Ruijs, 2004b,a). Intra-nationally, governments have the authority to impose regulatory regimes. Beyond directly controlling use, there have been two decentralization thrusts recently, participatory 'consensus building' voluntary initiatives, and an increased role for water markets.

Water Rights

Regardless of how water is allocated, some system of rights determines who has priority in use. Most water rights systems fall into one of two broadly defined categories riparian or prior appropriation. Under a riparian rights system, water belongs to those adjacent to a stream, river, or lake. In its simplest 'rule of capture' form, generally the *de-facto* institution, users can take whatever they want. Often groundwater, including that in British Columbia, is still managed this way. Riparian rights are usually not efficient (Deshparde and Supe, 1989; Sharma and Acharya, 1989; Tsur and Dinar, 1995; Janmaat, 2001, 2004a,c). With rule of capture, consumers use water until the cost of acquiring an extra unit - pumping, etc. - becomes equal to the net productive value that water generates. The impact on other users, now and in the future, is ignored. Where legally defined, riparian rights systems often include restrictions to ensure that downstream users receive a basic level of supply. This somewhat increases both efficiency and equity. In most cases, the *de-jure* riparian systems do not permit large transfers or sales of water or water rights.

Prior appropriation systems replace the sequence in space of riparian rights with a sequence in time. They are often described as 'first in time, first in right.' They developed as an adaptation to the need for water in the arid regions of North America, where parcels of land were often far from a water source. This is the system governing surface water in British Columbia (Shepherd et al., 2003b). Legally, they facilitate diversions, and often sanction expropriation for the purpose of building diversion works. The inefficiency of this system is well known (Burness and Quirk, 1979; Zilberman and Lipper, 1999). When there is a shortfall, those with the more senior right are able to draw their allotment before the next senior right. This tends to lead to a lower level of return per unit water for senior rights holders compared to junior rights holders. This inefficiency is made worse when beneficial use is required - as in British Columbia - as this means that if senior users do not use their allotment, they may loose their rights.

The perverse incentives created by the doctrine of prior appropriation are very pronounced in the Colorado River basin. The Colorado River flows through or along seven different states, originating in Colorado and Wyoming, and defining the border between Arizona and California before flowing into Mexico. For many years, the riparian states have been battling over rights to the Colorado, with Arizona once calling up the National Guard to stop a project felt to disproportionately benefit California (Sheridan, 1998). US Court decisions have tended to favor California, as they were first to use the water. This has lead to a race for water among the riparian states to fully utilize their allocation, for fear that if they do not, it will be lost to other states (Miller, 2001). In California itself, along the Sacramento River, farmers grow rice in flooded paddy fields. At the same time, California cities are facing high costs for securing additional water supplies (Schiller and Fowler, 1999). This situation is sustained by the beneficial use requirement, which implies that if water users cease to use their allotment, it is lost. Using a theoretical model, (Janmaat, 2004b) demonstrates that if land owners cannot secure water rights until they can use the water, land development will be accelerated. Since surface water in B.C. is allocated using a prior appropriation system, the same incentives for inefficient use exist here.

Participatory or Community Based Management

For at least a decade, participatory or community based management of resources has been seen as a solution to environmental and development problems. This move has conveniently coincided with political pressures to down-size and privatize. The benefits of decentralized resource management are seen to come from two sources. Local management is more effective because locals are better able to identify their problems and the best solutions. Local level management also enhances legitimacy and thereby participation and acceptance of management programs. Thus, participatory management is expected to both reduce costs and enhance outcomes. However, without clearly defined, enforceable water rights, the *de-facto* 'rule of capture' system predominates. This grants an advantage to those in a position to seize the water, guaranteeing that they will capture a large share of the benefits.

Fisheries resources share aspects of the problems involved in water resources, particularly when water rights take the prior appropriation form. With prior appropriation and beneficial use, water only has value once one can capture it by using it, much like an open access resource. It has long been recognized that in the absence of regulation, fisheries are an open access resource (Gordon, 1954; Scott, 1955). Selfish choices by resource users then precipitate a ``tragedy of the commons (Hardin, 1968)," whereby the resource is over-utilized and aggregate wellbeing is reduced. Most analysts have concluded that some form of government intervention is necessary for efficient management (Scott, 1979; Townsend, 1990; Squires et al., 1995), with a broad consensus favoring individual tradable quotas. Recently, some researchers have reassessed the evidence on fisheries, and found that common property fisheries need not suffer the tragedy of the commons (Hanna, 1990; Feeny et al., 1996; Hanna, 1997). These researchers have found fisheries where local communities have established systems of rules and incentives which guide individuals to choices consistent with the interests of the community as a whole. However, whether fisheries are regulated by communities or governments, clear and enforceable rules must be in place to prevent open access problems. Some form of clear and secure property rights is necessary.

Watershed level participatory schemes have become very popular in developing country projects. Kolavalli and Kerr (2002) compare a number of watershed development projects with a high degree of community participation. Those with long term participation by non-governmental organizations (NGOs) tend to be successful at both environmental improvement and poverty reduction. However, when efforts at building community level cooperative institutions are insufficient, success is less likely. Also, the evidence suggests that successful projects had unique favorable attributes, making replication difficult. Many of the projects were ongoing, leaving it unclear whether they would continue without external funding. Further, in many projects, community elites were able to capture control, and thereby a disproportionate share of the benefits. In a comparison of water supply systems in India, Asthana (2003) finds that centrally controlled systems tend to be more efficient than locally controlled systems. This is attributed to scale effects - small systems cannot secure the expertise needed to manage the system - and 'corruption.' By corruption, the author refers to the fact that when control is devolved to the local level, locally powerful interests are better able to capture control of the project, leading to its implementation in a way that benefits their interests. A literature review by Mansuri and Rao (2004) also find that community based projects tend to produce better project outcomes, but elite capture leads to poor success in helping the poor. They also find that community heterogeneity seems to reduce project performance.

In the Indian state of Andhra Pradesh, the state government has mandated that farmers form water user associations (WUAs), which have responsibility for distributing water, maintaining irrigation works, and collecting user fees. Reddy and Reddy (2002) compare two villages in Andhra Pradesh, one which has had an informal water management institution in place for a couple of decades, while the other recently adopted a formal arrangement as mandated. The formal institution has not had much effect in the village where there was no informal arrangement. Interestingly, the village with the informal 'participatory' or 'organic' arrangement used economic incentives - fines, etc. - more so than the formal institution did. The use of economic incentives evolved 'organically' to solve the water allocation problem.

Participatory watershed management is also popular in North America. Beierle and Konisky (2000) survey a number of case studies of environmental planning processes in the Great Lakes region. Success was said to occur when participant values were incorporated into the plan, when conflict was reduced, and when trust in public agencies was increased. In general, the participatory process was seen as being valuable. However, in many cases studied participation was not representative, with those most likely at odds absent or leaving early. It was also found that where planning activities incorporated multiple jurisdictions, success was less likely.

Woolley et al. (2002) survey members of watershed organizations in California. Participant's stated values were in agreement, but there was little consensus on desired watershed projects. Many of the recently formed groups, often formed with government support, have as their objective avoiding stricter regulation. These groups tend to include the widest range of interests. It is particularly interesting that these groups also tend to be more involved in political activism and lobbying than they are in actions to protect the environment. It seems that the 'crisis' that promoted the formation of these groups was not environmental, but the threat of government regulation. Leach et al. (2002) surveyed a set of stakeholder partnerships in California and Washington states. They only included groups where there were conflicting interests - resource users and environmentalists. The resource users' motivations for participation tended to be defensive; they were present in part to protect their property and financial interests. Success was measured based on the opinions of those surveyed. Longer lived organizations were more likely to have succeeded in some measure. However, some participants felt that there had been failures in key areas, such as property rights. Partnerships were most successful on less controversial projects. An important component in making these partnerships work was success at securing external funds. These funds meant that the partnership did not itself have to figure out who would have to pay for any activities engaged in.

Lubell (2004) investigated the relationship between the presence of collaborative institutions and the levels of consensus and cooperation. Consensus was measured by surveying people's perception of agreement about various issues relevant to the watershed, while cooperation measured people's self-reported engagement in activities considered 'cooperative'. Overall it was found that collaborative institutions resulted in higher levels of consensus, but no significant difference in the amount of cooperation. In fact, engagement in collaborative activities may be a way to forestall actions. As long as the parties continue talking, there remains a chance for consensus. Irvin and Stansbury (2004) argue that many advocates of participatory decision-making fail to consider the costs, such as delay. There are benefits, including educating citizens, determining what is politically feasible, convincing citizens of the appropriateness of particular solutions, etc. However, there are also costs and risks. Costs include the time and resources consumed by the consultation process. Risks include being unable to move forward, entrenching existing views, increasing alienation when outcomes have been predetermined, domination of the process by elites, and use of the process as a means of delaying reforms. The authors feel that participatory decision making can be a valuable tool in the right situations, but that the situation needs to be carefully analyzed before a participatory process is chosen.

Is a participatory, consensus based watershed management approach appropriate for the Okanagan Basin? The Okanagan basin is large, making it costly to conduct meetings and other consultations that involve representation from the entire basin. Interests are heterogeneous. There are rapidly growing urban centers, agricultural producers facing urban encroachment and increasing regulatory burdens, agricultural communities facing slower growth and in some cases decline, aboriginal communities seeking economic development, and a forestry industry whose actions at upper elevations affect lower elevation water quality and availability. Further, the size of the basin, the multiplicity of uses, the presence of rare and endangered species and habitats, and the prospect of climate change makes efficient water management in the basin a complex issue. Finally, it is unclear how much external funding can be relied upon to implement basin-wide management plans. The research on participatory and community based resource management suggests that the Okanagan Basin is unlikely to gain much from such approaches. At best, participatory processes will eliminate politically infeasible options. At worst, it will be a means for delaying critical decisions and reforms.

Market Based Allocation

Within the economics literature, it is argued that resource use will be inefficient whenever property rights fail to be excludable, enforceable, and tradable. Property rights are excludable when all the benefits and costs related to the use of an owned resource accrue to the resource owner. If the rights are enforceable, the owner can be secure that the legal system will respect and uphold their rights. Finally, with tradable rights, an owner profits either by using the resource or by selling it to someone else. When these 'efficient' property rights are in place, resources will end up flowing to their most profitable use and no un-compensated external effects will occur.

With respect to water resources, there are often problems with excludability, enforceability and tradability. Excludability problems arise naturally when water quality is concerned. Prior appropriation water rights together with beneficial use requirements generate an additional excludability problem by making the supply of water rights like an open access resource. Enforceability is limited when government retains the right to make arbitrarily changes. Finally, the absence of tradability prevents water from moving to its most valuable use. Economists have long argued that secure, enforceable, and easily tradable water rights are important for increasing water use efficiency, with recent evidence generally being supportive.

A simple two agent water pollution externality is the basic example in most environmental economics texts. A polluting firm exists upstream of another firm - a resort or fishery - that depends on high quality water. Coase (1969) argued that in this situation, if the rights to the river are clear, the upstream and downstream firms can negotiate to an efficient level of pollution. When negotiation is difficult, when there are many involved parties or other complexities, then emissions taxes or tradable emissions permits can attain an efficient pollution level. In a river basin, the pattern of taxes can be quite complex (Janmaat, 2004d). However, they are no more complex than any other management regime, and can achieve desired goals at lower cost than most other approaches.

Water markets facilitate the movement of water to its highest value uses. Howe et al. (1986) discuss the efficiency of current water allocation methods and the gains from market based reforms. They suggest that a desirable water allocation mechanism achieves flexibility, security, marginal cost pricing, predictability, equity, and incorporation of externalities. It is argued that water markets can achieve these objectives at least as well as any alternative. In developing countries, formal water rights often do not exist. Rosegrant and Binswanger (1994) argue that it is more important to establish formal water rights than to worry about equity. *De-facto* rights exist, regardless of the *de-jure* status of water rights. These rights are highly inequitable. Formal water markets will enable water to be allocated to its most valuable use, increasing the overall gains. Taxes and transfers can then be used to reduce inequities. Tsur and Dinar (1995) show that many current water pricing systems are inefficient. They also demonstrate that pricing reform will have little impact on equity. Income distribution is generally much more dependent on factors such as land quality, size of farm, access to markets, etc., than to water access.

Water markets have been implemented in a few of countries. Tradable water rights have existed in Chile for a couple of decades. Hearne and Easter (1996) study the impact of water markets in Chile. They find that there are substantial efficiency gains. Gains accrue to both sellers and buyers, with buyers capturing a larger share of the gains. Although there were some transfers between agricultural and non-agricultural users, these have tended to be limited. Romano and Leporati (2002) also study the impact of water markets in Chile. They find similar results. However, when the gains are examined in relation to farm size and income distribution, they find that gains accrue disproportionately to large farmers. There are many small farmers lacking the means to effectively utilize their water. This results in a market where buyers have an advantage, explaining the result.

More recently, water market reforms have occurred in Australia. By examining the trading history, Crase et al. (2000) observe a large number short term trades, but few transfers of long term entitlements. This is felt to be in part due to risk concerns and large transaction costs, and is thought to limit efficiency gains. Bjornlund and McKay (2002) find that the distribution of gains in Australia are much like those in Chile, with gains being predominantly captured by larger farmers.

The development of water markets in the United States has been relatively limited. A pseudo-market that has developed uses water banking (Isreal and Lund, 1995; Miller, 1996). Water banking facilitates water trades without violating beneficial use requirements, as use is only postponed. Holders of water rights 'bank' their entitlement with a central authority, which then can sell the banked water to other users. Howitt (1994) examined the impacts of California's 1991 emergency water bank. The bank substantially increased the efficiency of water use in the drought regions of California. However, some communities suffered as land was fallowed and local food processing requirements fell. A similar scheme in Idaho was found to produce lesser gains the greater the severity of water scarcity (Miller, 1996). This is attributed to a legal regime that less effectively protects water rights.

Water markets increase the efficiency of water use by making the price of water reflect is value. The importance of making the price water users in the Okanagan pay reflect the true value of water is well recognized (Associated Engineering, 2002; Shepherd et al., 2003b; OBWB, 2003b; Huby, 2004; Mattison, 2004) and some reforms are taking place (Shepherd et al., 2003a; BMID, 2004). Unfortunately, pricing reform alone will harm water users who have become accustomed to particular use patterns. These users will almost certainly oppose pricing reform unless it does not apply to them. In contrast, water markets enable existing users to sell their current entitlement and profit. Where water rights have been reformed to allow an increased role for markets, overall benefits from water use have increased. The Okanagan Basin is near full allocation of available water resources, moving it into an era of reallocation. With secure, tradable water rights, current rights holders will be protected from arbitrary removal of those rights. This will ensure that no current rights holder will loose as a result of reallocation. A basin level management authority - such as a reconstituted Okanagan Water Board - with taxation and rights purchasing authority can then indirectly manage water resources.

Water markets also provide a degree of flexibility not normally found in other institutional arrangements. Zilberman and Lipper (1999) show that water markets ensure that water is allocated to its most valuable use, even when supply is uncertain. Janmaat (2004c) shows that even when there are spatial variations in supply, water markets increase efficiency. There is already evidence of climate change in the Okanagan, and little to suggest that the apparent trends will not continue (Neilsen et al., 2001; Cohen and Neale, 2003). Tradable water rights provide the least costly means of adapting to changing water supplies and demands.

Recommendations

Management of the Okanagan Basin as a whole, with respect to water resources, is recognized as the best way to manage the basin for aggregate benefits. However, differences between the regions within the basin mean that most communities are suspicious of coordinated actions (WRG, 2003). Amalgamation of the NORD, CORD, and RDOS is virtually inconceivable, and surrendering planning authority to a central body is also unlikely. However, reforming the legal status and administration of water rights in the Okanagan Basin can alleviate concerns about adverse impacts and provide a mechanism for more effective management. If the current pattern of water rights is accepted, and rights holders given greater scope to trade their rights, no current user need loose from the reforms.

Revision of the British Columbia Water Act

The B.C. Water Act defines the water rights regime in British Columbia. In its present form, this act encourages wasteful use because of its beneficial use requirement. This requirement should be removed, together with the hierarchy of use. The connection between a license and a land title should also be removed. It is recommended that water users hold 'water quota,' which are permits to use a specific volume of water from a specific source. The current water license system would be abandoned. The remaining terms of the act should be changed to simplify trading an individuals water quota, and to ensure that the terms governing quota cannot be changed without appropriate compensation to the allocation holder. Finally, to facilitate basin level management, the act should include provisions for delegating the issuance of water quota and management of water using activities to properly constituted Water Boards. The resulting system would be similar to the individual transferable quota system being introduced in many fisheries. Supply variations can be accommodated by retaining the current seniority system, adopting a proportionate reduction system such as used in some fisheries, or interventions similar to the 'irrigation reduction auction' piloted in Georgia (Cummings et al., 2002).

Creation of Water Boards

A properly constituted water board would be responsible for the management of water use activities within a watershed or basin. Its mission would entail several objectives, in line with the multiple ecosystem and economic functions served by water within a watershed. These objectives would include protection of ecosystem resources, particularly fragile and endangered habitats. It would also include protection of fishery resources, the control of pollution, and the promotion of both the economically and technically efficient use of basin water resources. In line with its objectives, the board would have representation from federal fisheries officials, federal and provincial environment ministries, as well as local officials.

The water board will have a restricted set of policy tools at its disposal. It will not be able to overturn community planning decisions or otherwise directly influence land use. It will be able to charge a tax on water users, assess emissions charges against polluters, and levy fines against water users who violate the terms of their allocations. It will also have full authority to issue and sell all new water quotas in the basin, and the authority to purchase and retire existing quotas. New quotas must be sold through a public process open to all bidders, and purchases must also occur through a public offer to purchase, unless there are too few quota holders in the target area. Re-purchase offers will necessarily be restricted to particular water bodies or water courses when the objective is enhancing water flows there.

Reform of the Okanagan Basin Water Board

The Okanagan Basin Water Board would be reconstituted as a Water Board under the reformed B.C. Water Act. It would thereby have the powers described above. Local community autonomy will be respected, while the new OBWB will have the ability to raise necessary funds, and the ability to control the distribution of water allocations.

Conclusions

The principle recommendation of the Okanagan Basin Study was that a single management authority be created to manage water resources in the Okanagan Basin. This recommendation was never implemented, a consequence of the inability of the three jurisdictions involved to agree on how to implement this merger. Population trends in the Okanagan basin, together with other experiences in 'participatory' management show that this outcome was not surprising. Overlapping jurisdictions and conflicting interests, and the opportunity for regulatory changes to affect the distribution of benefits makes voluntary agreement on efficient management unlikely.

A critical feature preventing reforms is the expectation or risk that regulatory changes can accomplish large benefit transfers. Establishing secure and transferable water rights can reduce this problem. With clearly established rights, regulatory takings cannot occur, so that any changes in water allocation must be beneficial for all involved in the change. With such rights in place, basin-wide management requires different tools. Rather than mandating particular water uses, the planning authority will have to rely on taxes, levies, and outright purchases of water rights to accomplish its management goals.

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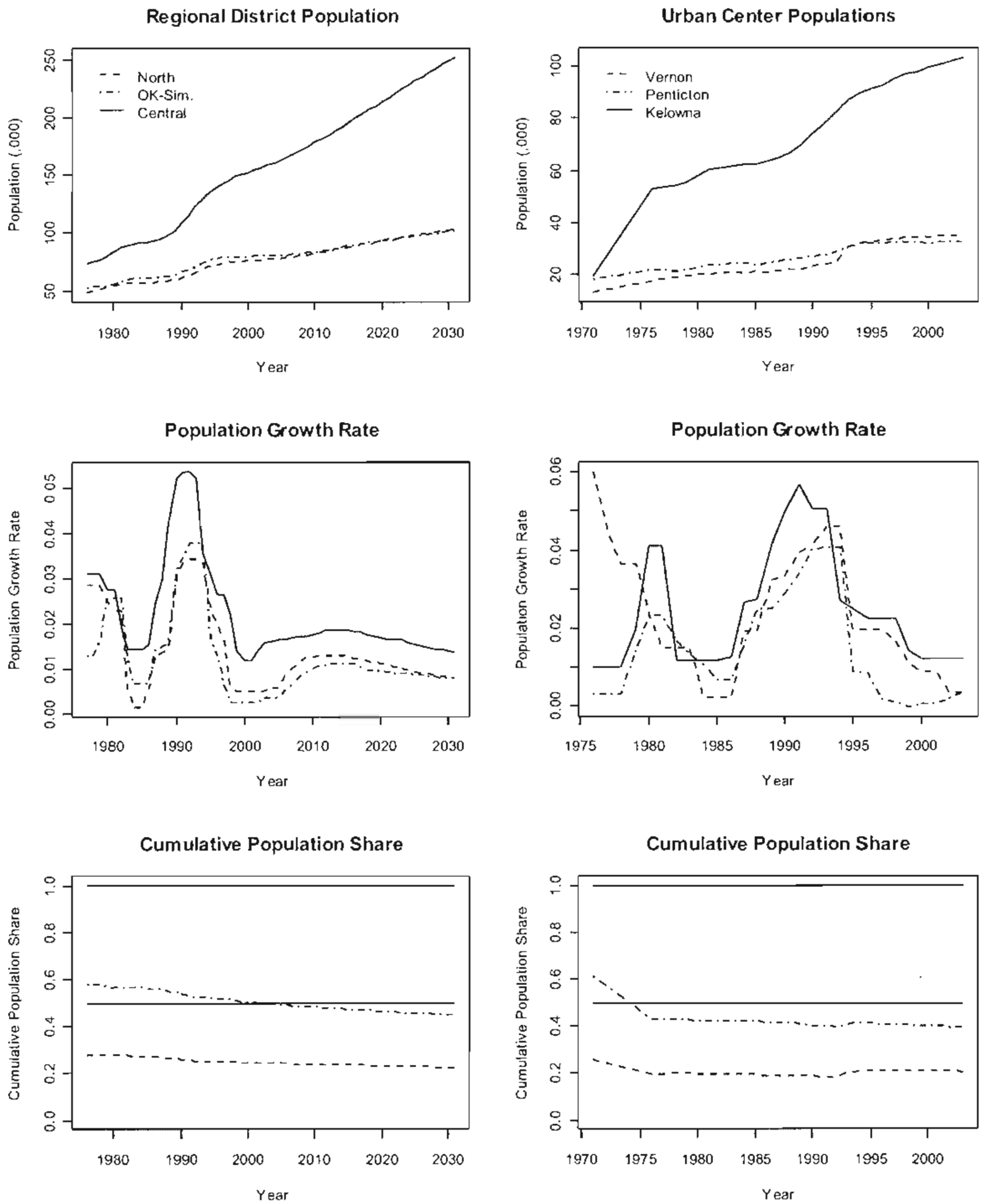


Figure 1: Regional district and urban center populations, growth rates, and cumulative shares. Growth rates are calculated as $(Pop_{t+1} - Pop_t)/Pop_t$. Cumulative shares are the NORD and NORD plus RDOS shares of the total for all three districts, and the Vernon and Vernon plus Penticton shares of the total. (Source: Service BC, 2004)

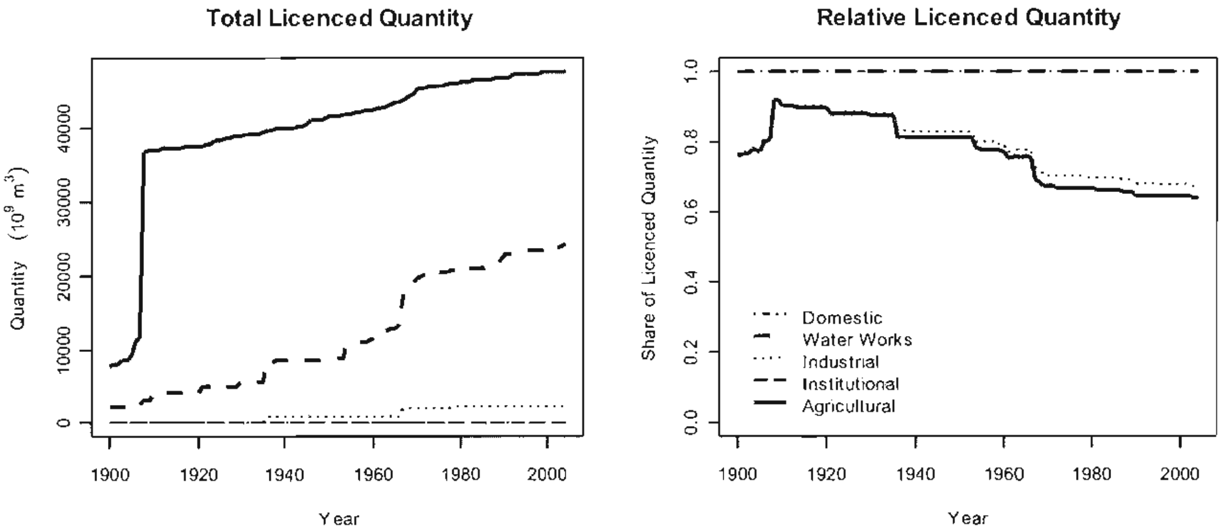


Figure 2: Consumptive water licenses by purpose and seniority. Quantities are cumulative totals of all licenses issued prior to and including the indicated year. Relative quantities are accumulated in the order shown in the legend. (Source: LWBC, 2004a)

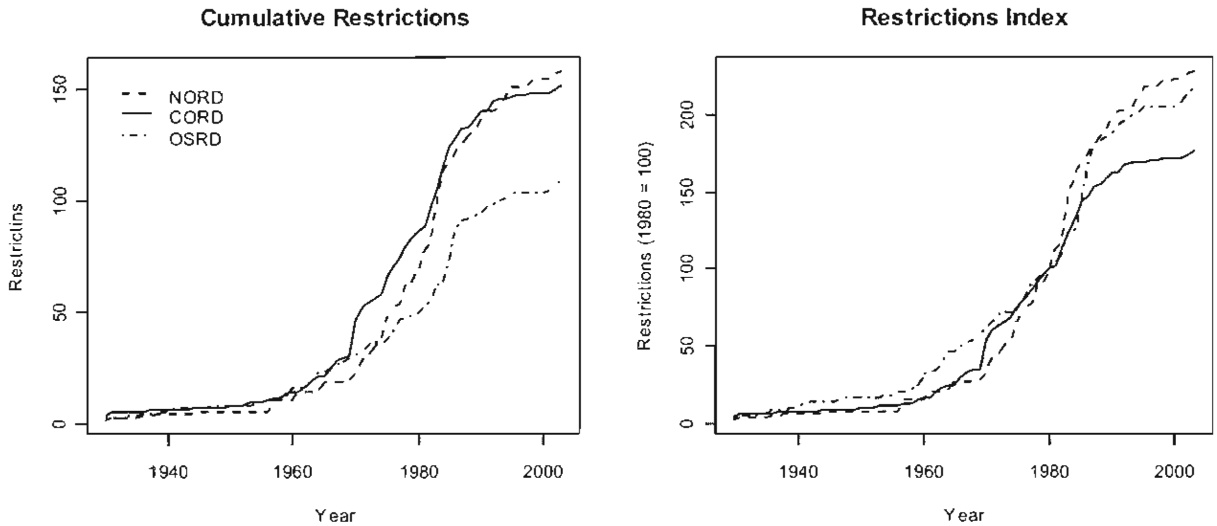
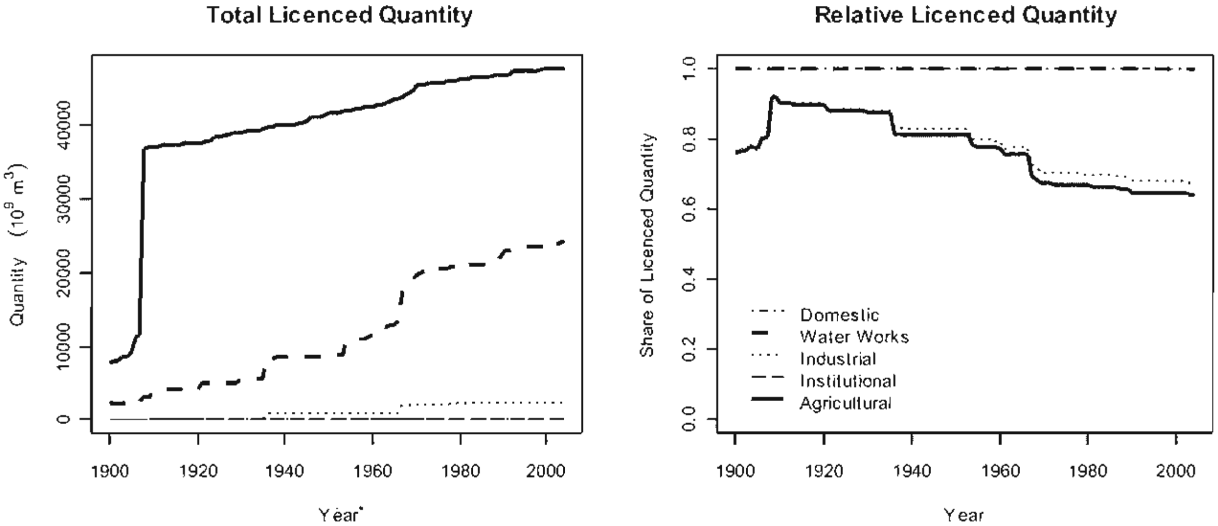


Figure 3: Number of restrictions on licensing by regional district. Cumulative restrictionsare the total number of restrictions issued up to and including the marked date. The restrictions index is set to 100 for 1980. (Source: LWBC, 2004b)



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Simulated Streamflow Response to Large-scale Forest Harvesting in Upper Penticton Creek, British Columbia

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Abstract

In the Okanagan region of British Columbia (BC) streamflow originates mainly from snowmelt in forested headwater basins. These same basins also act as an important source for timber resources. Taking advantage of the detailed hydro-meteorological data collected at the Upper Penticton Creek (UPC) watershed experiment site, a numerical hydrology model was calibrated and validated to a small 470 ha basin located in the headwaters of Penticton Creek in terrain and vegetation cover typical of the Okanagan Highlands. The present work reports on the use of this model, the Distributed Hydrology-Soil-Vegetation Model (DHSVM), to investigate the sensitivity of this basin to large-scale forest harvesting. Using a hypothetical scenario of clearcut harvesting 100% of the forested area, an ensemble of 100 annual simulations was used to asses the immediate impact of large-scale clearcut harvesting upon the distribution of annual yield, monthly yield, and annual peak hourly discharge. The sample distribution of annual yield is predicted to have significantly (α = 0.05) larger values following harvesting, with the median difference between the Control (no harvesting) and Treatment (100% harvesting) scenarios estimated at 1.15 x 10^6 m^3 (a 50% relative increase over the Control median value). Distributions of monthly yield also have significantly increased values during April through November, with the largest median difference (1.82 x 10^6 m^3) occurring during the freshet in May and the largest relative increase (361%) occurring in the September recession period. Annual peak hourly discharge is also significantly increased following harvesting with a median difference of 0.54 m^3/s (a 44% relative increase). When compared using event frequency, peak annual discharge is increased from 44 to 84% for return periods between 1.003 and 100 years. Changes in annual and monthly yield generally reflect reduced evapotranspiration and increased snow water equivalent whereas changes in peak annual discharge are a function of increased melt rates and enhanced runoff synchronization during the freshet period.

Key Words: Forest harvesting, Streamflow, Upper Penticton Creek, numerical modeling, DHSVM

Introduction

Streamflow in the Okanagan basin originates mainly from snowpacks in high-elevation forested headwater catchments. If these same headwater areas become the subject of forest harvesting activities the quantity and timing of streamflow could be affected, which is of obvious concern to downstream users. The removal of the forest canopy directly alters evapotranspiration, snow accumulation, snow melt, and soil moisture dynamics, thus potentially altering the magnitude and timing of runoff and streamflow. On occasion, a substantial proportion of the annual cut in the Okanagan region is used in the clearcut logging of stands infested with mountain pine beetle and during these activities harvest blocks can be in excess of 500 ha.

What little is known regarding large-scale forest removal impacts upon streamflow regime in the dry interior of southern British Columbia (BC) has been derived mainly from paired-basin studies. For instance, *Cheng* [1980] investigated the aftermath of a severe fire that burned 1088 ha (60% by area) of Palmer Creek, near Salmon Arm, BC. This fire resulted in higher and earlier annual peak flows, increases in April – August water yield and monthly water yield during the late summer and early fall [*Cheng* 1980]. *Cheng* [1989] assessed the impact of clearcutting 30% (1017 ha) of Camp Creek, located on the west side of the Okanagan basin. Streamflow changes included increased annual yield, increased monthly yield in nearly all months, and increased and earlier annual peak flow [*Cheng*, 1989]. Although some of the results of *Cheng* [1980] and *Cheng* [1989] are reported as being statistically significant, the fact that both studies suffer from short pre- and post-harvest calibration periods introduces high variability in the regression analysis used and makes it difficult to apply results to other watersheds.

This paper describes the use of numerical simulation to conduct an exploratory analysis of the impact of forest harvesting upon annual yield, monthly yield, and peak annual discharge in a small headwater catchment in the Okanagan basin. The emphasis is on the extreme case of forest harvesting, whereby the complete forest cover of a 470 ha study basin is removed. Given the past use of aggressive rates of cut to control mountain pine beetle outbreaks, we believe such an analysis has reasonable cause. We forgo the traditional approach of comparing paired events by regression analysis, but opt instead to compare the entire sample distribution of various streamflow metrics. We believe that such a comparison, when possible, gives a more complete picture of streamflow adjustment following forest harvesting. In this case, such a comparison is made possible via the use of a computer model to generate large stationary samples of various streamflow variables for a given land-use state. This study forms part of an ongoing effort to use data collected at the Upper Penticton Creek (UPC) watershed experiment to derive a greater understanding of how land-use activities may affect watershed processes in the south-central interior [*Winkler et al.*, 2003]. Additionally, this study is part of a larger project aimed at using numerical simulation to examine the impacts of forest harvesting throughout the different physiographic regions of BC [*Alila and Beckers*, 2001]

Study Area and Data

The study area is located in the Okanagan Highlands roughly 25-km northeast of Penticton in south-central British Columbia (Figure 7). The study focuses on 240 Creek, which forms the control basin in the UPC paired-basin experiment, which includes two additional treatment basins, the adjacent 241 Creek and Dennis Creek (not shown). All three basins drain into Greyback Lake, which supplies water, via Penticton Creek, to the city of Penticton. Physiographic characteristics of 240 Creek are summarized in Table 1.

Mean summer (June – August) and winter (November – March) air temperatures are 11 and –5^{0}C, respectively, and average 2^{0}C over the year. Mean annual precipitation is 750 mm, of which roughly half falls as snow and permanent snowcover generally lasts from late October until early June. The melting of this snowpack dominates the annual hydrograph, which typically peaks in late spring to early summer. Summer and fall streamflow are sustained by baseflow and rainfall that falls fairly uniformly throughout May and October.

The study area occupies the dry, cold subzone of the Engelmann Spruce – Subalpine Fir (ESSFdc) biogeoclimatic zone [*BC Ministry of Forests*, 2003]. The basin has a relatively open forest canopy containing predominantly mature lodgepole pine (*Pinus contorta* Dougl.) with small amounts of Engelmann spruce (*Picea Engelmannii* Parry) and sub-alpine fir (*Abies lasiocarpa* (Hook.) Nutt). The bedrock of the Okanagan Highlands consists of unfractured intrusive granodiorite and metamorphic granitic orthogneiss [*Hudson and Golding*, 1997]. The soil, derived from glacial till and local bedrock, is predominantly a sandy loam and loamy sand with high coarse fragment content, ranges in depth from 0.1 to 2.0 m, and is generally well drained [*Hope*, 2001]. The geology of 240 Creek is assumed to give a tight water balance, ensuring that the majority of net precipitation (precipitation less abstractions) exits each basin as streamflow. The vegetation and terrain of the study area is typical of the Okanagan Highlands.

Method

Numerical simulation with the Distributed Hydrology-Soil-Vegetation Model (DHSVM) [*Wigmosta et al.*, 1994] was used to assess the response of 240 Creek to forest removal. A 100-member ensemble of year-long simulations was run for two scenarios, one with the original forest cover intact (Control scenario) and one with 100% of the forest cover removed as a clearcut (Treatment scenario). The spatial distribution of the original forest cover is shown in Figure 8, with stand characteristics given in Table 2. The Treatment scenario assumes no remaining understory vegetation following harvesting and does not account for the effects of soil compaction or roads. Each simulation ensemble can be considered to produce 100 possible annual streamflow series representing conditions immediately after harvesting.

Simulations were run at an hourly time step, which is considered the best representation of the diurnal fluctuations and rapid streamflow response characteristic of the study area, and are based on a water year of 1 October to 30 September. For practical purposes, the simulation ensembles for each scenario were run as a continuous 100-year simulation, starting 1 October, Simulation Year (SY) 00 to 30 September, SY100. The period 1 January SY00 to 30 September SY00 was used to 'warm-up' the model to a realistic initial state for 1 October SY00. The warm-up period for each scenario commenced with identical initial conditions on 1 January SY00, whereas for each scenario, initial conditions for year *n* (00:00 hours on 1 October) were based on the simulated basin state at the end of year *n*-1 (23:00 hours on 30 September). This approach allowed for initial conditions for year *n* to vary between scenarios as a function of forest cover. Each 100-year simulation was forced with the same 100-year time series of hourly meteorology.

DHSVM is a physically-based distributed parameter model that explicitly estimates the spatial distribution of water and energy fluxes by subdividing the model into small computational grid elements. The location and spatial resolution (30-m in the current application) of the model grids is based on the structure of an underlying digital elevation model (DEM). DHSVM consists of a two-layer forest canopy model for precipitation interception and evapotranspiration, separate energy balance models for canopy and ground snow accumulation and ablation, a multi-layer soil moisture and subsurface flow model, and surface and channel flow routing models. Energy and water fluxes are balanced individually for each grid cell for each time step and residual water is exchanged between neighbouring cells, resulting in a three-dimensional redistribution of surface and subsurface water across the watershed. A complete description of model structure and governing equations is given by *Wigmosta et al.*, [2002]. Modification, calibration and validation of DHSVM utilized direct observations of streamflow, climate, forest and open radiation balance, snow accumulation and melt, rainfall interception, and tree transpiration collected at both 240 and 241 Creeks. The reader is referred to *Thyer et al.* [2004] for a complete description.

DHSVM simulations were forced with hourly time series of precipitation, air temperature, relative humidity, wind speed, solar beam and diffuse radiation, longwave radiation, and temperature lapse rate at a single location corresponding to station P1 (Figure 1). Extrapolation of the meteorological data to the model grid cells was accomplished by assuming that meteorology is spatially uniformly distributed over the study basin. Solar radiation and temperature for each grid cell are adjusted to account explicitly for the effects of topography (terrain shading and skyview) and elevation, respectively. Based on precipitation and snow course measurements, the precipitation gradient within 240 Creek is taken as zero. The 100-year meteorology time series used to force all simulations was constructed by stochastically extending data collected at the P1 and PB climate stations during the period 1 August 1997 to December 2001 as per the method of *Schnorbus and Alila* [2004].

The effect of forest harvesting was quantitatively assessed by comparing the sample distributions of annual (Q_a) and monthly (Q_m) discharge volume (given in m^3) and annual maximum hourly peak discharge (Q_p) (given in m^3/s) simulated using the Control and Treatment scenarios. The assessment of harvest impacts was based on comparisons of the simulated sample distributions using the Wilcoxon Rank Sum (WRS) test, assuming the Control and Treatment samples are independent groups [*Hirsch and Helsel, 2002*]. The WRS tests whether one distribution tends to produce larger or smaller values than the second group by comparing the null hypothesis:

H_0: Prob $[Q_x^C > Q_x^T] = 0.5$

to the alternate hypothesis

H_1: Prob $[Q_x^C > Q_x^T] \neq 0.5$ (two-sided test in which Q_x^C might be larger or smaller than Q_x^T)

where Q_x represents some streamflow variable (annual yield, monthly yield, or peak discharge) and, henceforth, the superscripts C and T represent the Control and Treatment distributions, respectively. As the WRS test is non-parametric, no assumptions are required concerning how the data are distributed for either scenario. Rejection of H_0 at the 5% level of significance is taken as evidence that forest harvesting has altered the distribution of the given streamflow metric (Treatment values are either higher or lower). Assuming that the Control and Treatment distributions are statistically different, one means of measuring the sign and magnitude of the change in Q_x is by comparing medians of the Control and Treatment distributions. An unbiased estimator of the difference in the medians is the Hodgeson-Lehmann estimator, $\hat{\Delta}$, which is the median of all possible pairwise differences between control and treatment values [*Hirsch and Helsel*, 2002], where

$$\hat{\Delta}_x = median\left[Q_x^C(i) - Q_x^T(j)\right] \quad for\ i = 1,...,n \quad and \quad j = 1,...,m \qquad (1)$$

where n and m are the sample sizes for Q_x^C and Q_x^T, respectively (both equal to 100 in the current application). The $\hat{\Delta}_x$ is more efficient than, and not exactly equal to, taking the difference between the sample medians. A positive $\hat{\Delta}_x$ infers that Q_x^T tends to be larger than Q_x^C and a negative $\hat{\Delta}_x$ infers that Q_x^T tends to be smaller than Q_x^C. Changes in Q_x on a relative basis were also assessed using $\hat{\Delta}_x / Q_x^C$. Possible changes in the variability of Q_x were assessed by comparing the inter-quartile range (IQR) for the Control and Treatment distributions. The IQR is defined as the 75th minus the 25th percentile (and thus contains 50% of the sample data) and is a resistant measure of data spread for highly skewed distributions (which occurs frequently for hydrologic data) and/or if outliers are present. Therefore, changes in the variability of Q_x were estimated as $\Delta IQR_x = IQR_x^T - IQR_x^C$

Potential adjustment of the peak flow regime to forest harvesting was further quantified via flood frequency analysis of the generated annual maximum hourly discharge series (Q_p). The three-parameter generalized extreme value (GEV) distribution was fit to the Control and Treatment peak discharge samples, respectively, using the method of L-moments [*Stedinger et al.*, 1993]. Peak discharge quantiles, Q_T, corresponding to return periods of T = 1.003, 1.05, 1.25, 2, 5, 10, 20, 50, and 100 years (corresponding to exceedance probabilities of 0.997, 0.95, 0.80, 0.50, 0.20, 0.10, 0.02 and 0.01, respectively) were estimated using the fitted GEV parameters and compared between scenarios. The hypothesis of increased Q_T following forest harvesting was tested by comparing the Q_T^T to the approximate one-sided upper confidence limit on Q_T^C, given as

$$Q^C_{T,1-\alpha} = \hat{Q}^C_T + z_{1-\alpha}\sqrt{Var\left(\hat{Q}^C_T\right)} \qquad (2)$$

where $\hat{Q}^C_T$ is the control quantile estimator (estimated using the fitted GEV parameters), which is assumed to be asymptotically normally distributed with variance $Var\left(\hat{Q}^C_T\right)$, α is the significance level, and $z_{1-\alpha}$ is the standard normal quantile [*Stedinger et al.*, 1993]. A value of Q^T_T greater than $Q^C_{T,1-\alpha}$ is taken as evidence that forest harvesting has increased the discharge magnitude corresponding to a return period of T. The $Var\left(\hat{Q}^C_T\right)$ was estimated using Monte-Carlo simulation.

Results and Discussion

Presentation of the results begins with a general comparison using the median annual hydrograph for both scenarios in Figure 9. The median hydrographs are based on daily average specific discharge and were constructed for each scenario by taking the median of the 100 specific discharge values simulated for each of the 365 days of the year. The comparison of the median hydrographs reveals that in general discharge can be expected to increase throughout most of the year, with the largest increases occurring during the rising limb and peak of the snowmelt freshet and during the low flow period of the summer and fall. The simulations further suggest that the annual maximum peak discharge event, which occurs during the spring freshet, tends to increase and advance in time following forest harvesting. However, a shift in the freshet hydrograph to an earlier and sharper rise causes a reduction in discharge during the falling limb. Discharge during the winter is slightly reduced.

The response of the sample distributions of Q_a, Q_m, and Q_p are summarized in Table 3 and compared graphically using box plots in Figures 4, 5, and 6, respectively. Annual discharge volume, Q_a, can be expected to increase following 100% removal of the forest cover in 240 Creek (Figure 10 and Table 3), a change which is highly statistically significant with $p < 0.001$. Additionally, the inter-quartile range (i.e. difference between the 25[th] and 75[th] percentile, a measure of variability) is also increased slightly following harvesting. For Qa harvesting gives $\hat{\Delta}_a = 1.15 \times 10^6$ m^3, which gives $\hat{\Delta}_a / Q^C_a = 0.50$. Increases in Q_m during the freshet and summer/fall periods are clearly evident and slight decreases in the winter are also apparent (Figure 11 and Table 3). In addition following harvesting, Q_m also tends to display higher variance for most months. Results of the WRS test indicates that significant increases in Q_m occur in months April through November, whereas Q_m is significantly reduced in February. The largest absolute increase occurs in May ($\hat{\Delta}_m = 0.18 \times 10^6$ m^3), the month of highest discharge, whereas the largest relative increase occurs in the low flow month of September ($\hat{\Delta}_m / Q^C_m = 3.61$). The median and variability of Q_p are also increased following harvesting (Figure 12 and Table 3). The result of the WRS test implies that Q^T_p tends to be larger than Q_p^C, a result which is highly statistically significant ($p < 0.001$), with $\hat{\Delta}_p = 0.54$ m^3/s and $\hat{\Delta}_p / Q_p^C = 0.44$. Treatment also increases the skew of Q_p.

Results of the flood frequency analysis of Q_p is summarized in Table 4 and compared graphically using a probability plot in Figure 13. The figure was constructed by plotting the ordered $Q_p(i)$, where $Q_p(1) > Q_p(2) > \ldots > Q_p(N)$, versus the empirical return period estimated as $1/q(i)$, where $q(i)$ is the Cunnane plotting position formula $(i - 0.4)/(N + 0.2)$ [*Stedinger et al.*, 1993]. Absolute increases in the discharge quantiles, Q_T, tend to increase with increasing T, however, the largest relative increase of 67% occurs at the smallest return period of T = 1.003 years and tends to stabilize at approximately 45% for $T > 2$ years (which is nearly equivalent to $\hat{\Delta}_p / Q_p^C$ of 44%). Increases in Q_T are statistically significant ($\alpha = 0.05$) at all return periods.

Annual and seasonal water yields from snow-dominated basins respond to changes over time in the relative importance of various components of the basin water balance, particularly precipitation, snowpack storage, and evapotranspiration (ET) [*Kattelman*, 1991]. Based on the average response over the 100-member ensemble, water balance accumulation (given as volume per unit area in units of m) from 1 October to 30 September for the Control scenario is represented in Figure 14a. Note that as individual water balance components in Figure 8a represents the average annual response over 100 simulations, the components as graphed do not necessarily balance to zero. During 1 October to the occurrence of peak snow water equivalent (SWE), snow accumulation is closely correlated with precipitation rate, the ET rate (from snowpack evaporation/sublimation) is nearly double the melt rate, and streamflow is mainly the residual of rainfall (not shown) minus ET. The low streamflow during this period is the consequence of roughly 65% (as of 1 April) of total precipitation being stored in the snowpack. During the freshet period, which extends through April, May and June, melt accumulates far more rapidly than ET and streamflow is derived mainly from snowmelt. Discharge volume during the months of April, May and June, which is derived mainly from snowmelt, accounts for 7, 46, and 13%, respectively, of annual discharge. Once melt has ceased in the summer and fall, streamflow decreases and is most closely correlated with the rate of ET, the rate of which progressively increases to the end of the year, and only 12% of annual discharge is accumulated during the months of July through October. For the year as a whole, total streamflow (0.496 m) represents roughly 75% of annual precipitation (0.735 m), with the difference accounted for by annual ET (0.224 m). For the year as a whole snow melt (0.278 m) and ET account for 56% and 45%, respectively of annual streamflow.

Changes in seasonal and annual discharge following forest harvesting arise from changes in the relative magnitudes of the various water balance components in the basin [*Jones*, 2002]. Following the removal of all forest cover (including understory vegetation) from 240 Creek, the simulations suggest that annual average ET component will all but disappear, with a negligible amount at year-end attributable to direct evaporation from the soil (not visible in Figure 14b). The near complete disappearance of ET during the winter for the treatment scenario implies that ET during this time from the control scenario derives mainly from evaporation and sublimation of snow intercepted by the forest canopy, which is in general agreement with the literature [e.g. *Lundberg and Halldin*, 2001]. The disappearance of the ET loss results in increased SWE of 18%, a result which falls at the low end of previous results observed for southeastern BC [i.e. *Toews and Gluns*, 1986], but agrees well with the range of values observed recently by *Winkler* [2001] for forest stands in the UPC study area. Higher snowmelt rates generate increased streamflow accumulation (44% as of 1 April) during the winter months, however, this increase is small in absolute terms (0.04 m) and streamflow is still relatively low due to the large proportion of precipitation stored in the snowpack (76% as of 1 April). Although the freshet begins at the same time for both scenarios, the rates of snowmelt and streamflow are higher and snowmelt ends sooner after harvesting This results in the shift in the median annual hydrograph (Figure 9) and the months April and May now account for 9% and 36%, respectively of annual discharge. Increased melt rates following forest harvesting are well documented [*Toews and Gluns*, 1986; *Winkler*, 2001] and arise mainly from increased turbulent fluxes in the winter and increased net radiation during the spring [*Male and Granger*, 1981; *Adams et al.*, 1998; *Koivusalo and Kokkonen*, 2002]. During the summer and fall period streamflow is increased by an amount roughly equivalent to the reduction in ET loss and the summer period now accounts for 28% of annual discharge. For the treatment scenario annual discharge now roughly equals annual precipitation, with the increase in streamflow equivalent to the reduction in annual ET loss. These results clearly highlight the importance of ET in controlling streamflow during summer/fall seasons and on an annual basis [*Troendle and Reuss*, 1997].

The process of peak annual discharge occurs on a much smaller temporal scale. As a result, the magnitude and timing of peak annual discharge in snow-dominated basins is mainly dependent upon the weather conditions during the spring, more specifically on the energy available for melt and the synchronization of runoff from different contributing areas of the basin [*Kattelman*, 1991]. The timing and duration of snowmelt varies spatially, depending upon forest cover, aspect, elevation, and weather [*Tarboton et al.*, 2000]. The timing of annual peak discharge typically coincides with the occurrence of peak soil moisture [*Grant et al.*, 2004], the distribution of which determines the size and extent of the runoff contributing area and the extent of runoff synchronization. Therefore, changes in Q_p following harvesting are attributable to higher melt rates and/or enhanced runoff synchronization deriving from increased antecedent soil moisture [*Schnorbus and Alila*, 2004b].

Conclusion

Numerical simulation was used to assess the hydrological impact of the complete removal of forest cover in a 470-ha basin located in the Okanagan Highlands of south-central BC. The justification for examining such a severe harvest scenario, or treatment, is based on the likelihood of seeing aggressive cut rates to control future severe insect outbreaks. Changes to annual yield, monthly yield, and annual hourly peak discharge were analyzed by statistically comparing the sample distributions (N = 100) generated for the Control (no harvesting) and Treatment scenarios. The results of the Wilcoxon rank sum test indicate that annual yield is significantly increased following harvesting, as are monthly yields for April through November. The largest absolute increase in monthly yield occurs in the main freshet month of May whereas the largest relative increase occurs in September. Simulations suggest that following treatment, although the majority of annual yield will still occur during the spring freshet, runoff during the summer and fall will be proportionately larger. The variability of annual and monthly yield (particularly April, May and June) can also be expected to increase following treatment. These increases in variability tend to complicate the planning process and, therefore, may be of greater concern regarding resource management than simple changes in the distribution median.

The magnitude of annual hourly peak discharge is also significantly increased following harvesting. Additionally, as per annual and monthly yield, the variability and skew of annual peak discharge is also increased due to treatment. The use of flood frequency analysis on the Control and Treatment peak discharge distributions indicates that peak discharge quantiles can be expected to increase by 44 to 84% for return periods in the range of 1.003 to 100 years. The non-uniform changes in discharge quantiles with return period results from changes in both the location (median) and shape (variance and skew) of the peak discharge distribution.

Acknowledgements

Data collection and analysis at Upper Penticton Creek has been was funded by various programs and agencies including Forest Renewal BC, Forest Innovation Investment and the BC Ministry of Forests. The authors acknowledge the ongoing commitment of the Kamloops Forest Region and Weyerhaueser Company Ltd. to research at UPC. We thank all those involved in data collection and UPC and in particular thank Rita Winkler and Dave Spittlehouse of the BC Ministry of Forests for their continued interest and support.

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Table 1. Physiographic Characteristics of 240 Creek[1].

Descriptor	Value
Drainage Area, A_d (ha)	470
Forested Area, A_f (ha)	437
Minimum Elevation, Z_n (m)	1609
Maximum Elevation, Z_m (m)	2036
Relief, Z_m - Z_n (m)	427
Mean Elevation (m)	1782
Mean Aspect (degrees clockwise from North)	153
Mean Slope (%)	24.3
Total Channel Length, L_c (km)	6.2
Drainage Density, L_c/A_d (km/km^2)	1.3

[1] Data derived from 30-m digital elevation model

Table 2. Structural Properties of Vegetation Classes

Class	Overstory Description	Dominant Height (m)	Canopy Closure (0.0 – 1.0)	LAI[1] (m^2/m^2)	Understory Present
1	Rock	N/A	N/A	N/A	No
2	Lodgepole Pine	20	0.2	2.0	No
3	Lodgepole Pine	25	0.4	3.4	Yes
4	Lodgepole Pine	19	0.5	4.0	No
5	Lodgepole Pine	25	0.5	4.0	Yes
6	Subalpine Fir	21	0.3	3.1	No
7	Subalpine Fir	26	0.4	3.8	No
8	Engelmann Spruce	23	0.2	2.4	No
9	Engelmann Spruce	28	0.4	3.8	Yes
10	Clearcut	N/A	N/A	N/A	No

[1] Leaf area index

Source: Thyer *et al.*, 2004

Table 3. Control and Treatment Sample Distributions.

Variable		Median[1] Control	Median[1] Treatment	$\hat{\Delta}_x$ [1]	$\hat{\Delta}_x / Q_x^C$	IQR_x^C [1]	ΔIQR_x [1]	WRS Significance[2]
Q_a		3.427	2.279	1.146	0.50	0.530	0.103	< 0.001
Q_m	Jan	0.043	0.037	-0.005	-0.12	0.030	-0.006	NS
	Feb	0.026	0.022	-0.003	-0.11	0.014	-0.003	< 0.05
	Mar	0.025	0.022	-0.002	-0.08	0.018	-0.001	NS
	Apr	0.178	0.353	0.145	0.81	0.247	0.285	< 0.001
	May	1.003	1.212	0.182	0.18	0.379	0.212	< 0.01
	Jun	0.286	0.431	0.116	0.40	0.262	-0.035	< 0.001
	Jul	0.113	0.281	0.155	1.36	0.096	0.116	< 0.001
	Aug	0.051	0.195	0.116	2.29	0.048	0.069	< 0.001
	Sep	0.043	0.209	0.155	3.61	0.034	0.105	< 0.001
	Oct	0.075	0.236	0.145	1.92	0.098	0.000	< 0.001
	Nov	0.095	0.133	0.040	0.42	0.064	0.004	< 0.001
	Dec	0.068	0.067	-0.000	-0.01	0.047	-0.005	NS
Q_p		1.220	1.700	0.540	0.44	0.440	0.240	< 0.001

[1] Units are ($\times 10^6$) m^3 for Q_a and Q_m and m^3/s for Q_p

[2] Significance of Wilcoxon Rank Sum Test given as probability that H0 is true; NS = not significant (i.e. $p > 0.05$).

Table 4. Peak Flow Frequency of Control and Treatment Annual Maximum Hourly Discharge

T (yrs)	Q_T^C (m^3/s)	Q_T^T (m^3/s)	ΔQ_T [a] (-)
1.003	0.39	0.72	0.84
1.05	0.68	1.06	0.55
1.25	0.93	1.37	0.47
2	1.21	1.74	0.44
5	1.51	2.19	0.45
10	1.66	2.45	0.47
20	1.79	2.68	0.49
50	1.93	2.95	0.53
100	2.01	3.13	0.55

[a] All values significant at $\alpha = 0.05$.

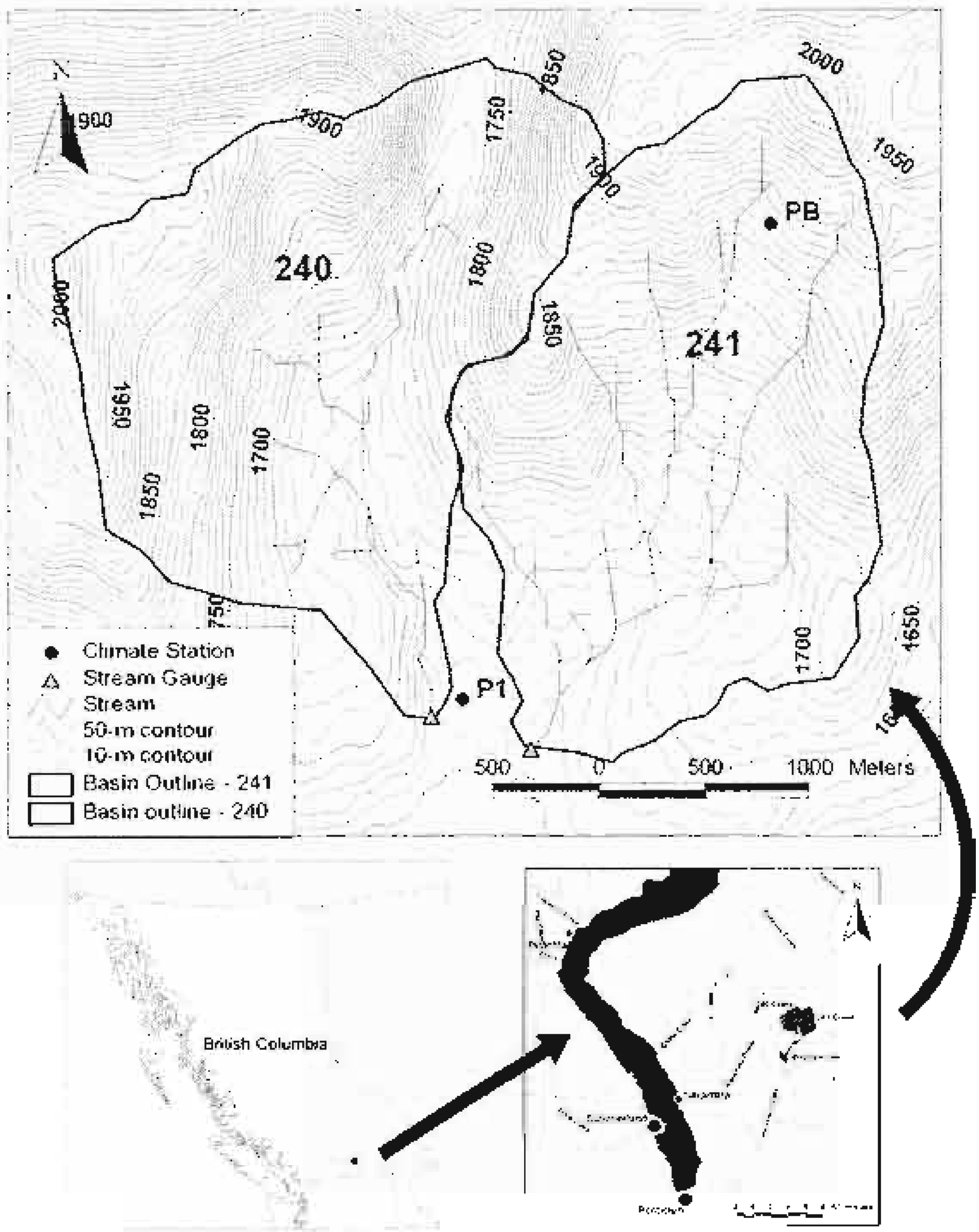

Figure 7. Location of 240 Creek and neighboring 241 Creek in south-central British Columbia.

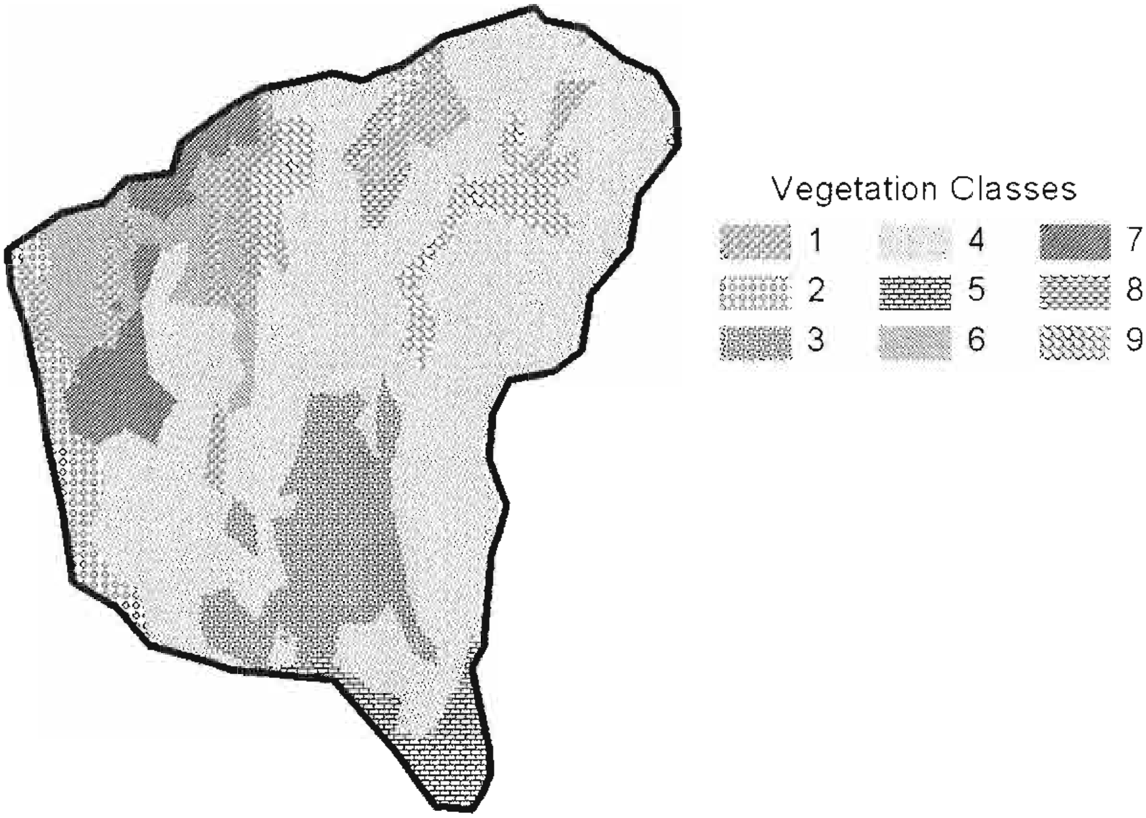

Figure 8. Spatial distribution of vegetation classes for Control scenario. Vegetation classes are described in Table 2.

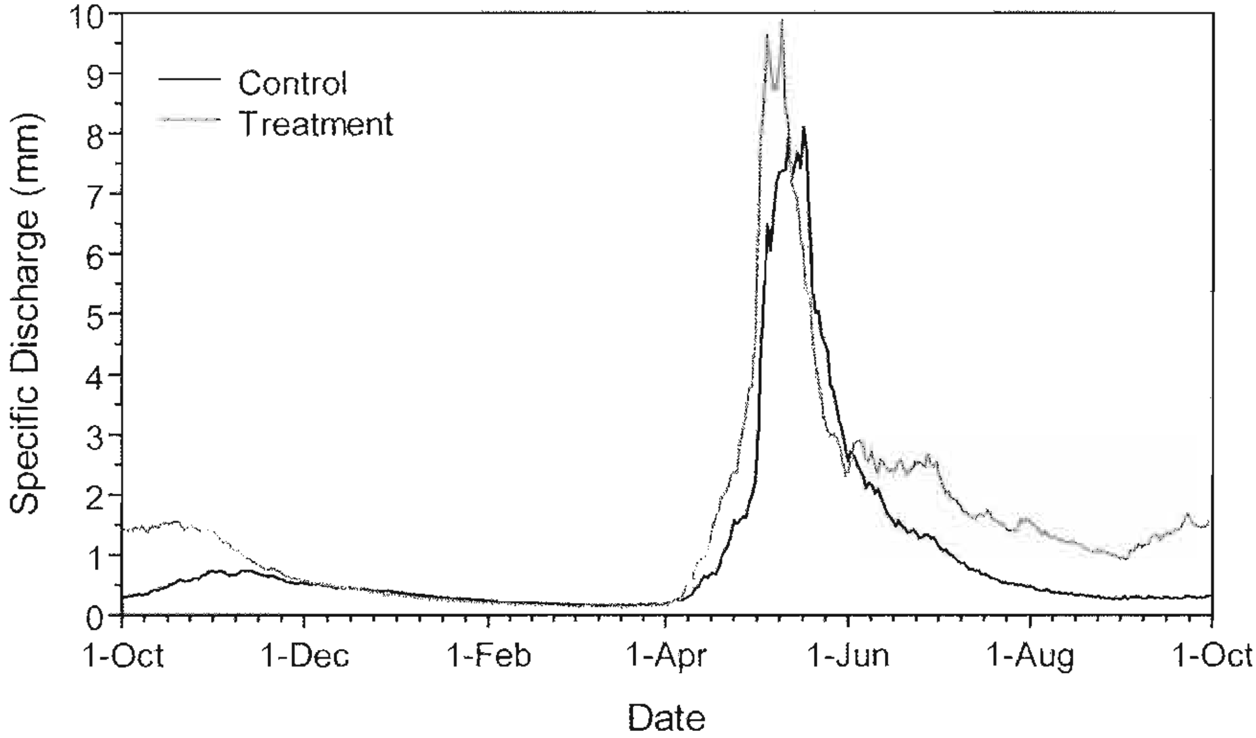

Figure 9. Median annual hydrograph (daily average discharge) comparing Control and Treatment discharge.

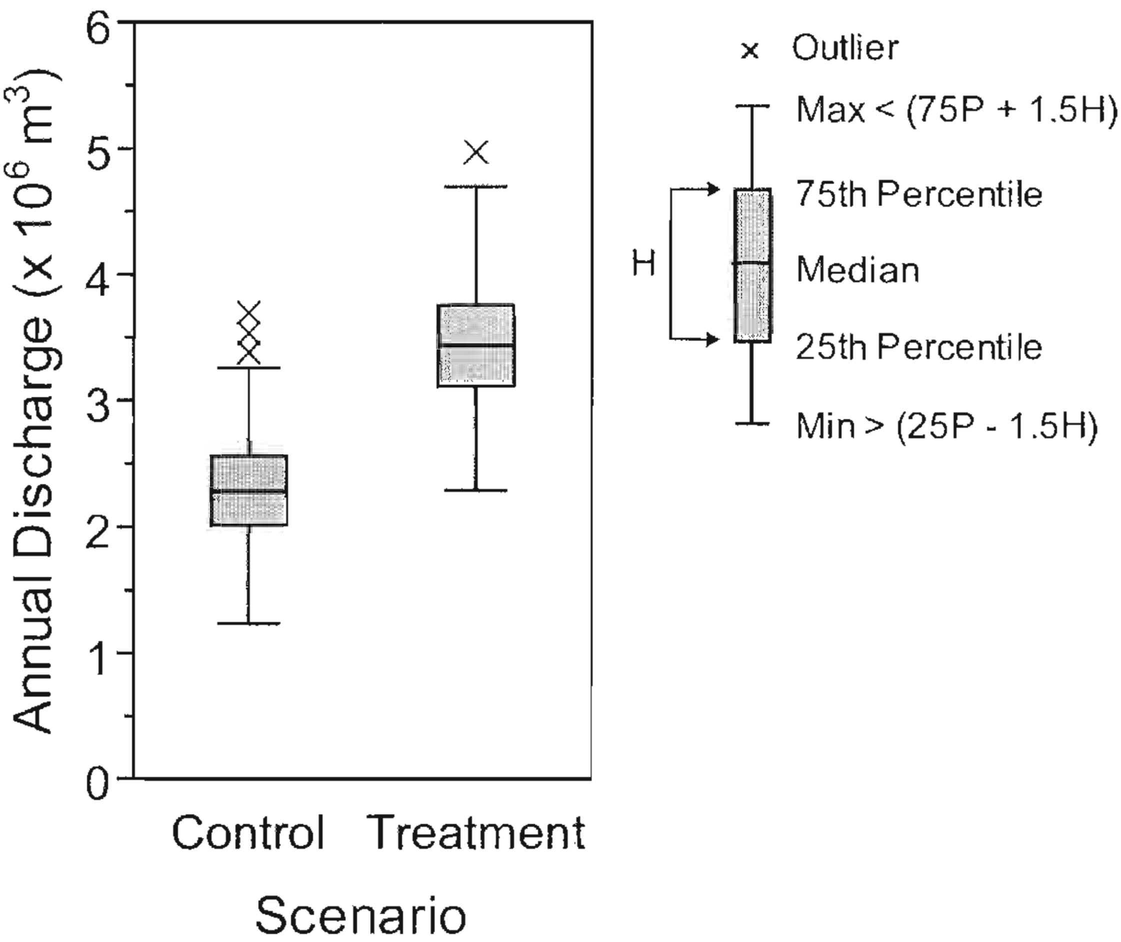

Figure 10. Box plots comparing simulated sample distributions of annual discharge volume.

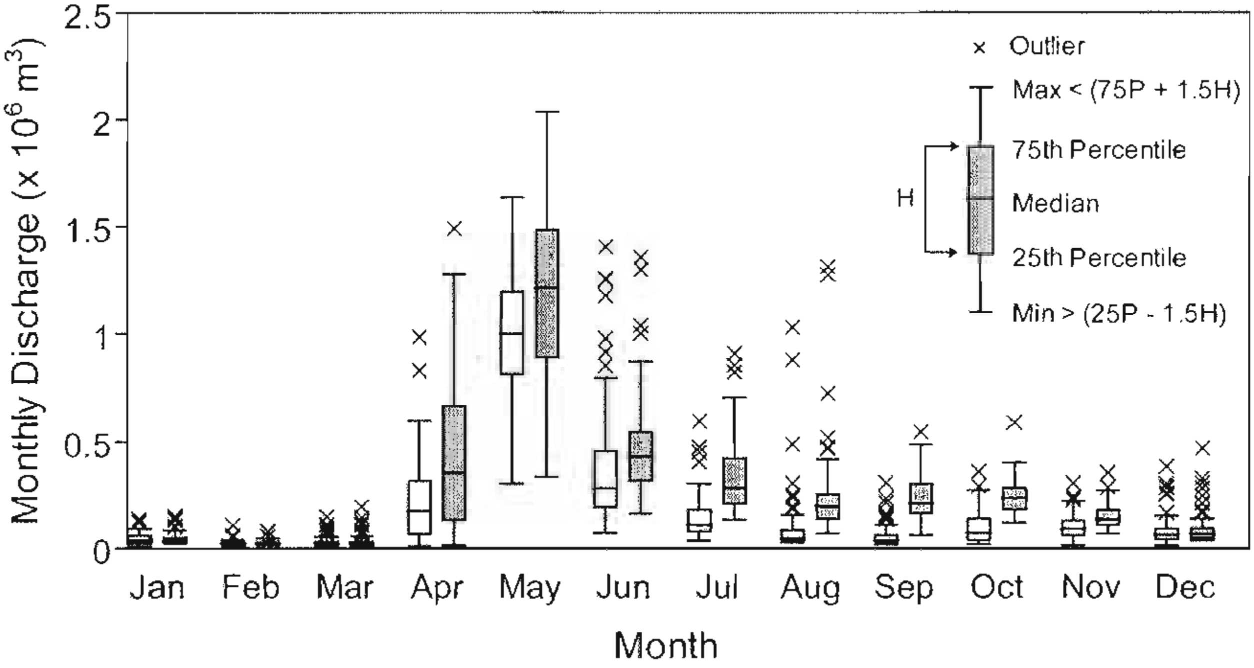

Figure 11. Box plots comparing simulated monthly specific discharge for Control (white boxes) and Treatment (grey boxes) scenarios.

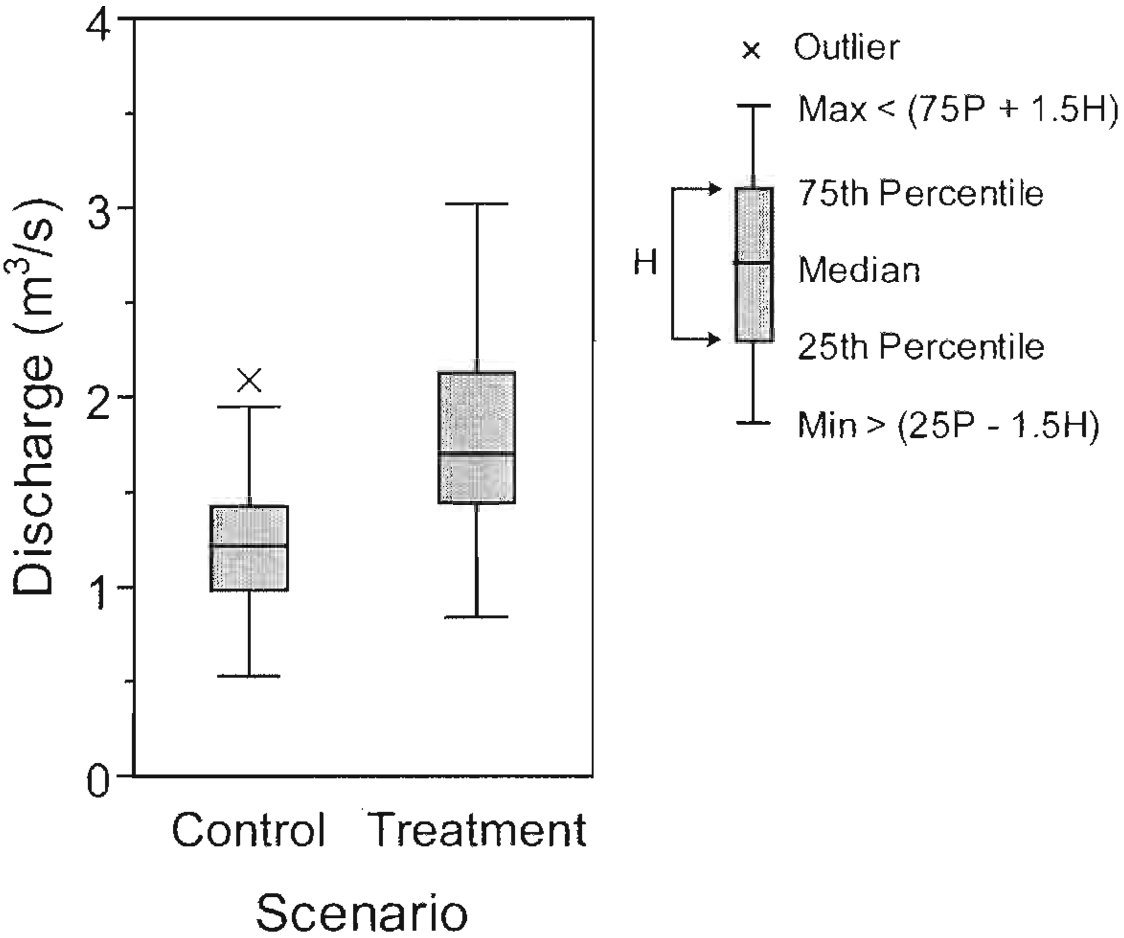

Figure 12. Box plots comparing simulated sample distributions of annual peak discharge.

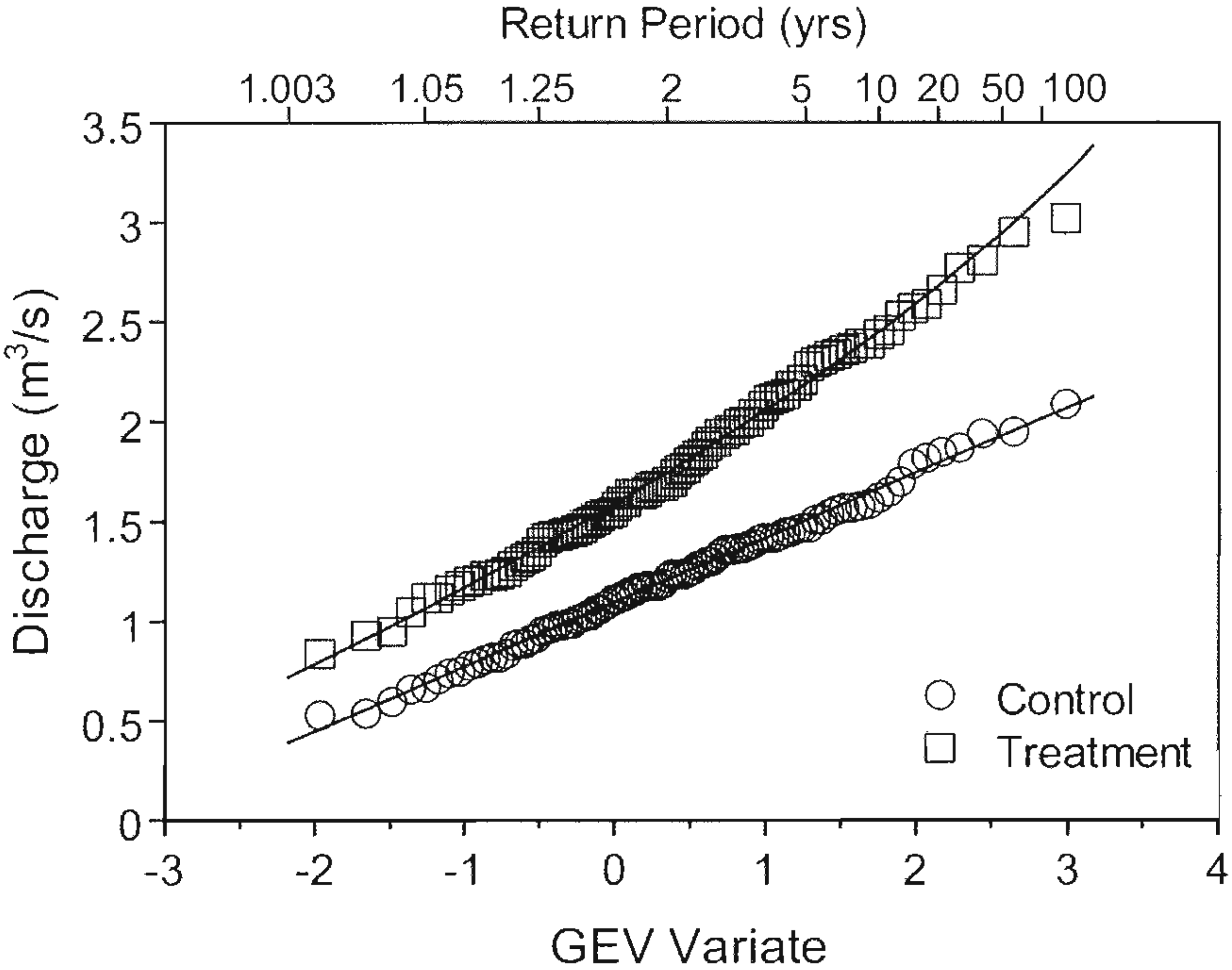

Figure 13. Probability plot of Control versus Treatment annual peak hourly discharge showing the sample discharge values (points) and corresponding fitted GEV distribution (lines). Discharge values are plotted versus the GEV variates of the Control distribution.

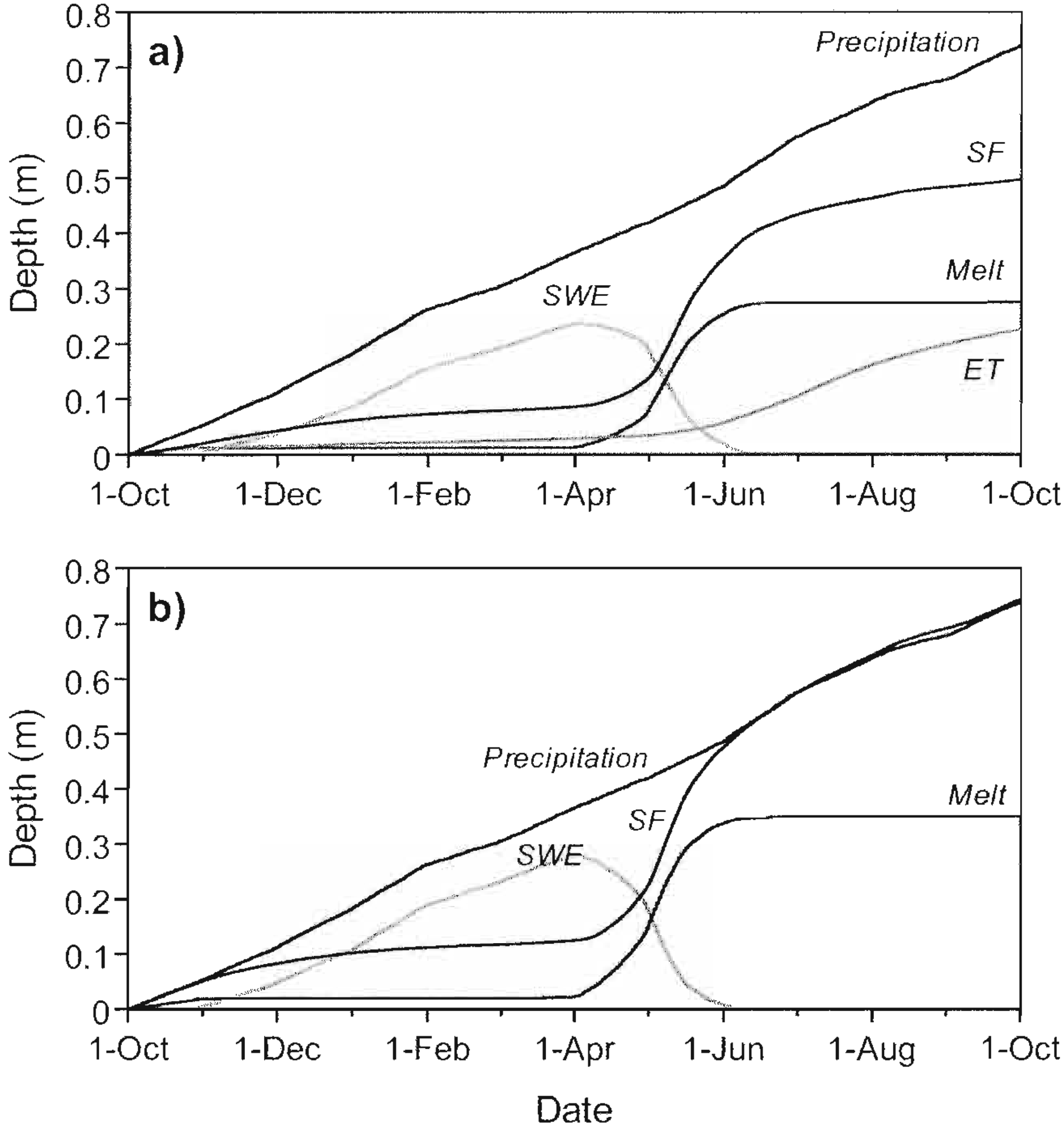

Figure 14. Ensemble-average water year accumulation of water balance components (given volume per unit area) for the a) Control and b) Treatment scenarios.

Assessment of water quality trends, and revised water quality objectives for Okanagan Lake

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Abstract

Nutrient reduction efforts to prevent eutrophication of the Okanagan lakes has taken decades to produce measurable improvements in water quality of Skaha and Osoyoos lakes. These trends are not evident in Okanagan Lake except in areas near outfalls, despite concerted efforts to reduce point source phosphorus loading from municipal sewage treatment plants discharging to Okanagan Lake. Point source load reductions of 95% for phosphorus and 40% for nitrogen load followed implementation of tertiary and spray irrigation disposal strategies. Non-point source control of nutrients has been implemented through various best management plans (BMP's) strategies but the net effect of these efforts is uncertain. In spite of Okanagan Lake's large volume, and long residence time, recent analysis has shown Okanagan Lake water quality responds relatively rapidly after periods of higher annual run-off. Two recent multi-year periods of higher run-off to Okanagan Lake are closely associated with higher phosphorus and nitrate concentrations, and reduced water clarity. Non-point source nutrient loading and natural run-off variation are important influences on the lake ecosystem. Further study is needed to better apportion non-point sources of nutrients and effectively manage nutrients within the Okanagan basin. On the basis of the trend data, the 1985 water quality objective for spring phosphorus in Okanagan Lake has been revised. Other chemical, physical and biological objectives are proposed to protect drinking water, fisheries, and recreational water uses, and to guide nutrient management efforts in the basin.

Introduction to the Okanagan Basin

The Okanagan River basin drains through a chain of lakes (Ellison, Wood, Kalamalka, Okanagan, Skaha, Vaseux, Osoyoos) in the southern interior of BC before crossing the US- Canada boarder and flowing on to the Columbia River (Figure 1). Okanagan Lake, the largest lake within the basin, is the most important and valuable lake in the basin and perhaps in British Columbia. The lake serves as the economic and cultural backbone of the Okanagan Valley. Without the presence of the lake, the communities and the economy would be so different it would be difficult to imagine. The lake is the focus of life in the valley, a source of recreation and drinking water for an ever-growing population as well a habitat for a wide range of organisms. Changes in the lake have the potential of affecting a wide range of economic and aesthetic values and the general social fabric and structure of the communities that border the lake. Water resources of the basin, both quantity and quality, have frequently presented management challenges in this semi-arid and rapidly urbanizing landscape. From the time of one of the first water quality studies in the Okanagan (Rawson, 1939) to the present time, the human population of the Okanagan Basin has tripled every thirty to forty years and now is approximately 300,000. As population in the valley increased, so did the volume of wastewater collection and discharge to surface waters. By 1970 the valley population had reached 100,000 and algal blooms occurred twice a year on Skaha Lake (Fleming and Stockner, 1975) due to the discharge of secondary treated effluent from Penticton. Deteriorating water quality was also a concern at Wood Lake, and where Vernon effluent entered

Vernon Arm of Okanagan Lake (Nordin *et al* . 1990). Public concern for water resources of Okanagan, Skaha and Osoyoos lakes led to comprehensive assessment of water resources under the Okanagan Basin Study (OBS) (Stockner and Northcote, 1974) and the Kalamalka Wood Study (Anon. 1974).

Okanagan Lake is divided into three basins and is a relatively deep lake with a maximum depth of 230 m in the north basin. The lake has relatively low biological productivity (oligotrophic); however, the two shallower reaches (Vernon Arm and Armstrong Arm) have poorer water circulation resulting in higher nutrient levels and greater plankton abundance.

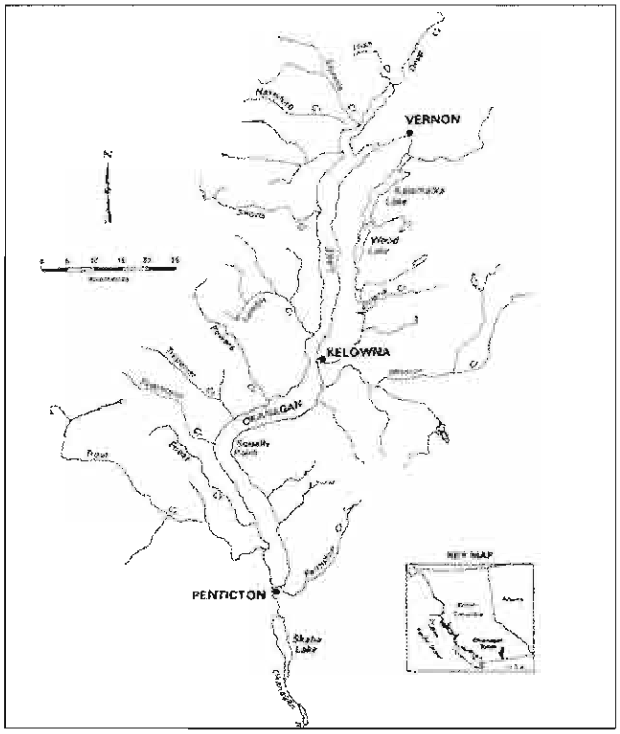

Figure 1: Okanagan Lake and tributaries (Andrusak et al., 2001)

The total inflows to Okanagan Lake since 1950 range from a low flow of 130 Mm^3 in 1970. (this was the OBS sampling period) to a high flow of 1,401 Mm^3 in 1997 (Symonds, pers. com.). In an average year the lake level would rise by 2.5 metres but add only 3.3% to the volume of water in Okanagan Lake. Evaporation from the lake surface removes almost a metre of water in an average year. Only 12% of the precipitation falling on the catchnment/watershed reaches the lake with 85% being lost to evaporation and evapotranspiration (Hall *et al.* 2001). About 2% of the lake volume flows out from the lake. The main inflow from the watershed tributary creeks to the lake takes place generally in May and June. The year-to-year variation is high with extremes in runoff covering a range of more than an order of magnitude. In addition, there is some evidence that the timing of flows may change, and water availability will decrease with global warming (Leith and Whitfield 1998).

Waste Management Efforts in the Okanagan Basin

The Okanagan Basin Study (OBS) identified point and non-point source control of phosphorus (P) as essential to preventing nuisance algal blooms and controlling the rate of eutrophication of surface waters in the Okanagan basin (Haughton et.al. 1974). The point sources of phosphorus in 1970 included the municipal effluent discharges from Armstrong, Vernon, Kelowna, Westbank, Penticton and Oliver, as well as industrial discharges from a trade waste treatment plant in Kelowna and the Summerland Fish Hatchery.

Being more amenable to control strategies, point source control of P has been implemented progressively over the past three decades with the initial goal of 90% P removal. Subsequent monitoring during the Okanagan Basin Implementation Agreement (OBIA) documented water quality improvements in Vernon Arm following diversion of City of Vernon's effluent to spray irrigation disposal in 1977 (Truscott and Kelso, 1979; Bryan, 1987; Jensen, 1981). Improvements were also observed along the City of Kelowna foreshore of Okanagan Lake following conversion of the Kelowna sewage treatment plant (STP) to the Bardenpho tertiary process in 1983 (Bryan, 1990; Nordin et al , 1990). Over the past three decades the volume of effluent discharged to Okanagan Lake has increased from approximately $8Mm^3/yr$ to $16Mm^3/yr$. Considerable investment has been made to reduce inputs of phosphorus from STPs to Okanagan Lake. A reduction of approximately 95% of the point source phosphorus load has been achieved (44 tonnes in 1970; 2.1 tonnes in 2001). Okanagan Lake continues to receive point source municipal effluent from Kelowna, Westbank, and Summerland. All three are tertiary treated effluents using the biological nutrient removal process. In recent years the combined effluent volume is approximately 10% of historic low inflows to Okanagan Lake (130M m3 in 1970). Reductions in point source nitrogen loading have been much more modest over the three decades and are estimated to be approximately 60% of the 1970 load.

Various regulations and guidance pertaining to timber harvest (Forest Practices Code-1996 , Forest and Range Practices Act-2004, Agriculture Waste Control Regulation-1992, and partial implementation of best management practices for sectors such as stormwater control are thought to have also reduced nutrient loading to Okanagan Lake. However, the nutrient removal efficiencies for these non-point sources (NPS) are much less than for point sources. Total phosphorus loading to Okanagan Lake is estimated to have decreased by 30% since 1970 with present relative contributions being 60-74% being from natural processes plus timber harvest activities, 26-40% from NPS (agriculture, septic tanks and stormwater), and 1.8-3% from STPs (Hall *et al.* 2001). Better NPS phosphorus and nitrogen loading estimates are recommended to guide further lake management planning.

In the first decade (1974-1984) following implementation of these point source P reductions, the monitoring of Skaha Lake immediately downstream of Penticton, and Osoyoos Lake further downstream, did not show reduced phosphorus levels. A lack of response was rationalized to be confounded by inaccuracies in nutrient loading estimates, changes in NPS loading over the study period, and hydrologic fluctuations (Nordin *et al.* ,1990; Fleming and Stockner, 1975). Although water quality improvements in area proximate to outfalls were detected, P levels in the main body of Okanagan Lake were found to be increasing. For these and other reasons, in 1985, the provincial government declared the Okanagan an environmentally sensitive area and renewed waste management planning efforts under the Okanagan Water Quality Control Program (OKWATER) to reduce phosphorus by 95% from sewage discharges. At the same time, water quality objectives for phosphorus were set for the Okanagan lakes to determine the success of the phosphorus management actions (Anon. 1985).

Water Quality Objectives as a Management Tool

Water quality objectives are based on an evaluation of historical norms for a particular water body as well as consideration of the BC approved and working guidelines and national water quality guidelines (CCME 1987, MWLAP 1998a,b). Water quality objectives are safe limits of the physical, chemical, or biological characteristics of water, biota (plant and animal life) or sediment which would protect water quality, taking into consideration local water quality variation, water uses, water movement, waste discharges and socio-economic factors.

Objectives guide the evaluation of water quality, the issuing of permits, licenses and orders, and the management of fisheries, and the province's land base. They also provide a reference against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies or enhanced protection measures should be initiated.

There are several advantages to using water quality objectives (as opposed to loadings) as a means of water quality protection. The setting of water quality objectives by specifying concentrations in the water is the approach favoured by the Canadian federal government (CCME,1987)) and the British Columbia provincial government (MWLAP 1998a, 1998b) as opposed to using loadings (the preferred approach of the US Federal Government) as a means of protecting water. Concentrations are considerably easier to measure than loadings. Loading estimates during the OBS and subsequent studies have considerable uncertainties associated with them, which does not make them an easy or accurate tool for evaluating lake status or defining water protection goals. Also, the linkage between loading and lake response is not always clear and can be influenced by a number of factors including hydrology, climate and food chain response. While loading estimates are difficult to quantify, some efforts in this regard are warranted if nutrient management resources are limited. Strategies which target non-point source sectors where multiple benefits of stream ecosystem protection, erosion control, and hydrograph normalization are recommended.

The 1985 report (Anon. 1985) proposed water quality objectives for phosphorus only. Recent assessment of Okanagan Lake data has enabled a review of the 1985 spring phosphorus objective as well as propose a broader suite of aquatic measures to guide the management of Okanagan Lake water quality in the future. The are an number of reasons for a new suite of objectives. Considerable data collection has occurred since 1985, including the seasonal data gathered by the Okanagan Lake Action Plan project (1996 to present) which has focused on kokanee (*Oncorhynchus nerka)* population recovery. This new data shows the 1985 TP objective did not provide a conservative management target and would allow deterioration of water clarity. Continued pressures on the lake to satisfy many water quality needs such as fisheries, drinking water and recreation require current and comprehensive management tools. Approximately 105,000 people rely on Okanagan Lake for at least a portion of their water supply and fisheries management concerns need to be recognized. Finally, to aid communication of water quality information to managers and the public, a water quality index is needed for Okanagan Lake. The index better communicates water quality status by incorporating magnitude and frequency of deviation of a measure from the desired objective. The calculation of a water quality index using one objective is not ideal and it has been suggested that at least six objectives are needed to calculate a meaningful index (Swain, pers. comm.). The Province of BC has used water quality objectives attainment and reports of water quality in index format to convey similar information (Swain, 1995; Rocchini, 1997).

Given the wide range of Okanagan Lake water usage, the objectives were set to protect the most sensitive designated water use at a specific location. Designated water uses for Okanagan Lake include: public water supply, and food processing, aquatic life and wildlife, agriculture (livestock watering and irrigation), recreation, aesthetics, and industrial water supplies.

Water Quality Trends in Okanagan Lake

Since 1985, considerable monitoring of lake quality has been carried out by the Ministry of Water Land and Air Protection to describe long term trends and point source impacts (Bryan,1990; Jensen, 2002; Andrusak *et al.* 2002).

Despite a phosphorus reduction of approximately 42,000 kg/yr from municipal sources to Okanagan Lake, spring phosphorus in Okanagan Lake, as demonstrated by data for the southern basin, near Summerland, shows little or no decrease, with some recent spring TP values higher than those recorded for the past 25 years (Figure 2). This is in contrast to the significant reduction in spring P in Skaha and Osoyoos Lakes were the water clarity has also increased (Jensen, 2002).

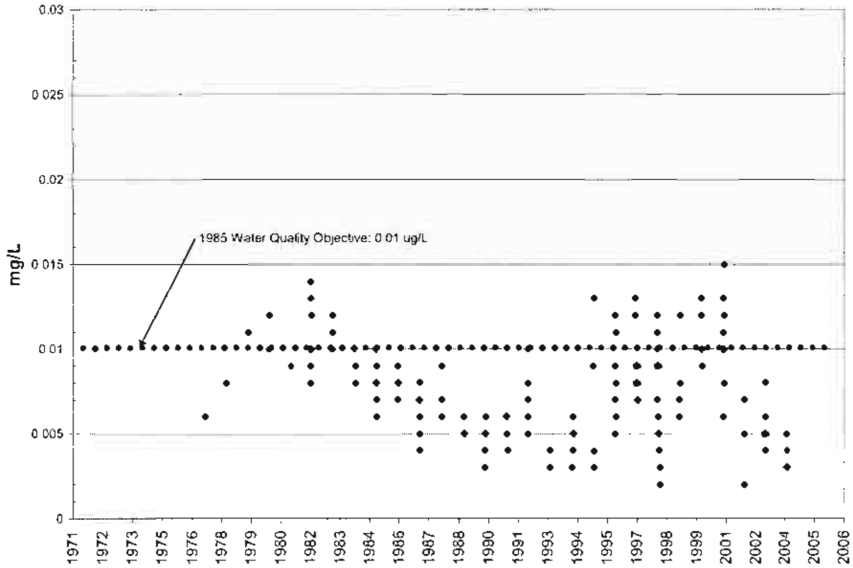

Figure 2: Spring Total Phosphorus (mg/L) in Okanagan Lake 1977 to 2004.

Between 1996 and 2001, Okanagan Lake spring TP has been near or above the water quality objective of 0.01 mg/L. On many spring dates between 1996 and 2001, one or more individual sites exceeded the objective (*http://wlapwww.gov.bc.ca/wat/wq/attain/ambient00-01.pdf*).

Water Quality Assessment

Water quality of Okanagan Lake was recently assessed (Nordin, 2005) with the purpose of proposing a new suite of water quality objectives to guide resource management. The parameters assessed included water clarity (Secchi disk), dissolved oxygen content, phosphorus and nitrogen concentrations, N:P ratio, chlorophyll *a*, phytoplankton, zooplankton, trace contaminants in biota, and bacterial indicators. Of general interest is that Okanagan Lake is becoming steadily more saline. Chloride inputs from wastewater, road salt application, leaching of soils by irrigation etc. have doubled chloride levels in Okanagan Lake (1.5 to 3 mg/L) over the past 30 years (Bryan, 1990, Nordin, 2005).

Phytoplankton biomass, measured as chlorophyll *a*, appears to influence the water clarity of Okanagan Lake. This is consistent with observations made in the literature. Whereas, the spring time water clarity of the lake has not changed appreciably from 1980 to 2005, the fall Secchi data showed a decrease in water clarity during periods of higher run off in certain years. Seasonal data sets are limited but comparison of the OBS (1971) , OBIA (1976-79 and OLAP (1996-2004) shows a consistent decrease (1970- 9.0m; 1976-78- 7.6m; 2001- 6.5m) over the period of study.

Although dissolved oxygen content is not a concern in the main lake, deep water oxygen depletion is a concern in Armstrong Arm of the lake; averaging 1.6 mg/L at the 45 metre depth in September over the past five years. This dissolved oxygen depletion is expected to improve from point and non-point source nutrient reduction efforts.

Phosphorus data collected in February or March over a 25-year period showed little change in the total phosphorus concentration other than response to annual inflow of water into the lake. The 25-year WLAP data set for total phosphorus (TP) in Okanagan Lake south of the bridge averaged out at 0.007 mg/L (7 ug/L) and north of the bridge 0.008 mg/L (8 ug/L). Vernon Arm now has essentially the same concentration of TP as the main body of the lake. The TP concentration was substantially lower in year 2003 (0.012 mg/L) (12 ug/L) as compared to the year 1985 concentration of 0.025 mg/L (25 ug/L).

The long-term spring monitoring indicates an increase in nitrate concentration in Okanagan Lake (0.0015 mg/L/yr) with significant increases during and following periods of higher run-off. A similar trend was observed for adjacent Kalamalka Lake but not in nearby Mabel, Sugar, or Christina lakes where the watersheds are less affected by urbanization and agriculture. However, there was no evidence that the concentration of total nitrogen (and total phosphorus) has changed significantly over the past 30 years. The correspondence of long term cycles in spring nitrate, fall phosphorus to hydrologic variation, as shown by inflow to Okanagan Lake, are illustrated in Figure 3. Increases in shore spawning kokanee populations (and stream spawners, which are not show here) correspond to periods of higher run-off and nutrient concentrations in Okanagan Lake, with a lag period of 2-4 years.

Total N: Total P (N:P) ratio is a key factor in understanding the aquatic food chain response to nutrient limitation. The present spring N: P ratio of about 28:1 is reasonably balanced and would not encourage the proliferation of cyanobacteria. Although there is a clear phosphorus limitation in spring and early summer and likely co-limitation of N and P in summer and fall, there is no evidence that the concentration of total N and P have changed significantly over the past 30 years, but does vary considerably between wet and dry hydrologic periods.

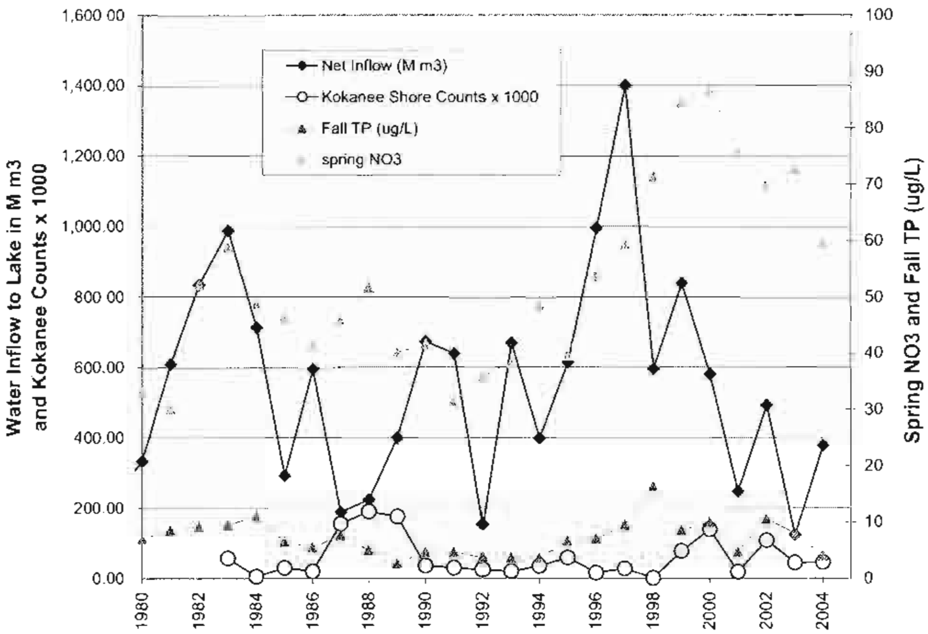

Figure 3: Okanagan Lake trends in spring nitrate, fall total phosphorus, water inflow and shore spawning kokanee counts.

Water Quality Objectives

On the basis of the review of historic data, consideration of water uses and expectations, a new suite of water quality objectives has been proposed for Okanagan Lake and its basins (Table 1). The objectives are based on the B.C. approved water quality guidelines, the Canadian Water Quality Guidelines developed by the Canadian Council of Ministers of the Environment, designated water uses, and ambient water quality characteristics.

The major water uses considered for the purpose of setting water quality objectives in this report are: recreation and aesthetics, drinking water, and aquatic life. Inclusion of all these uses was necessary for long-term management and protection of Okanagan Lake.

Monitoring Recommendations

A monitoring program is recommended by Nordin (2005) for water quality objectives including analysis at four stations and multiple depths for: nutrients, general anions and cations and metals, Secchi disk, phytoplankton chlorophyll a, zooplankton , dissolved oxygen, and trace contaminants in *Mysis* and rainbow trout. Fecal coliforms and *E. coli* sampling recommended in areas with water intakes and potential sources, especially near stream inflows.

There are lingering concerns over biological pathogens, viruses, bacteria, protozoa, and biochemical active constituents like pharmaceuticals and hormone mimics that could be discharged to the lake from sewage treatment plant outfalls. Monitoring for contaminants should be the responsibility of the discharger to ensure discharges are not having a negative effect. Given the large reliance on Okanagan Lake for drinking water, combined with the increasing discharge of treated effluent, and uncertainty of the effects of personal care products on ecological processes, further research is recommended in this area (Nordin, 2005).

Concerns have been raised regarding the limited resources presently allocated to monitoring Okanagan Lake. The need for local government involvement in a broad management role in Okanagan water issues has been advocated (Nordin, 2005). As presented here, there presently exist specific issue monitoring and management programs with respect to fisheries and waste management efforts. However, there are numerous other agencies or institutions that could play important roles in developing a broader base of water resource knowledge to protect all water uses of Okanagan Lake into the future.

Table 1: Summary of Recommended Water Quality Objectives for Okanagan Lake

Parameter	North Basin	Central Basin	South Basin	Armstrong Arm
Secchi disc transparency (growing season average)	6 m	6 m	7 m	5 m
Dissolved oxygen (minimum in bottom waters)	not determined	not determined	not determined	5 mg/L
Total phosphorus (maximum at spring overturn)	8 µg/L	8 µg/L	7 µg/L	10 µg/L
Chlorophyll-a (maximum seasonal average)	4.5 µg/L	4.5 µg/L	4 µg/L	5 µg/L
Total nitrogen (maximum)	230 µg/L	230 µg/L	230 µg/L	250 µg/L
N:P ratio (spring weight ratio)	>25:1	>25:1	>25:1	>25:1
Phytoplankton structure (heteroeystous cynobacteria by numbers)	<5%	<5%	<5%	<5%
Phytoplankton growing season average biomass	<0.75 g/m^3	<0.75 g/m^3	<0.75 g/m^3	<0.75 g/m^3
Zooplankton designated species mix minimum biomass	50 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$
Zooplankton structure (minimum of cladocera by numbers)	5%	5%	5%	5%
Contaminants in fish tissue and *Mysis* tissue	Below human consumption and wildlife protection guidelines	Below human consumption and wildlife protection guidelines	Below human consumption and wildlife protection guidelines	Below human consumption and wildlife protection guidelines
Fecal Coliforms[1] (water intake sites with disinfection only)	<10 /100 mL	<10/100 mL	<10 /100 mL	<10 /100 mL
Fecal Coliforms[1] (recreational sites)	<200 /100 mL	<200 /100 mL	<200 /100 mL	<200 /100 mL
E. coli[1] (water intake sites with disinfection only)	<10 /100 mL	<10 /100 mL	<10 s/100 mL	<10 /100 mL
E. coli[1] (recreational sites)	77 /100 mL	77 /100 mL	77 /100 mL	77 /100 mL

[1]- Geometric mean in colonies per 100 ml

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Summerland Water Intake Feasibility Study

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Abstract

The District of Summerland is considering the installation of a water intake in Okanagan Lake to reduce its reliance on Trout Creek source and to provide improved water quality. Currently two nearby inflows, the Summerland wastewater treatment plant and Trout Creek, present potential risk to the proposed water intake. A three-dimensional hydrodynamic numerical model is used to simulate the movement of water and tracers from each of the above noted inflows in Okanagan Lake to assist in assessing the viability of the proposed intake location. The model is constructed in a double-nested configuration consisting of a 500-m grid model of the entire Okanagan Lake and a 100-m grid model for the southern end of the lake. The 500-m grid model provides boundary conditions for the embedded fine-grid model. Both models incorporate Trout Creek, the Summerland wastewater treatment plant flow, and the proposed water intake, as well as other naturally occurring features and forcing in the lake. Simulations were carried and the 95-percentile contaminant concentration in each cell was determined and contoured to assist with the selection of the optimal depth for the water intake.

Keywords: Okanagan Lake, Water quality, Water intake, Numerical model

1 Introduction

The District of Summerland presently withdraws its domestic water from Trout Creek. The District is in the process of evaluating sites for the location of a new water intake on Lake Okanagan to reduce its reliance on Trout Creek and to provide improved water quality. The proposed intake location is south of Gartrell Point at the Wharf Street Boat Launch as shown in Figure 1. Currently there are two sources of potential risk in proximity to the proposed intake, Trout Creek, located 500 metres to the south, and the Summerland Wastewater Treatment Plant (SWTP) located approximately 1,500 m to the south. The treatment plant discharges sewage through a multi-port diffuser at a depth of 40 m. A key issue for consideration is the depth of the water intake and the possible benefits of extending the water intake to a deeper location. Hay & Company Consultants was retained to evaluate the impact of the SWTP effluent and Trout Creek on the proposed water intake location and provide information to assist with the selection of an optimal depth for the water intake.

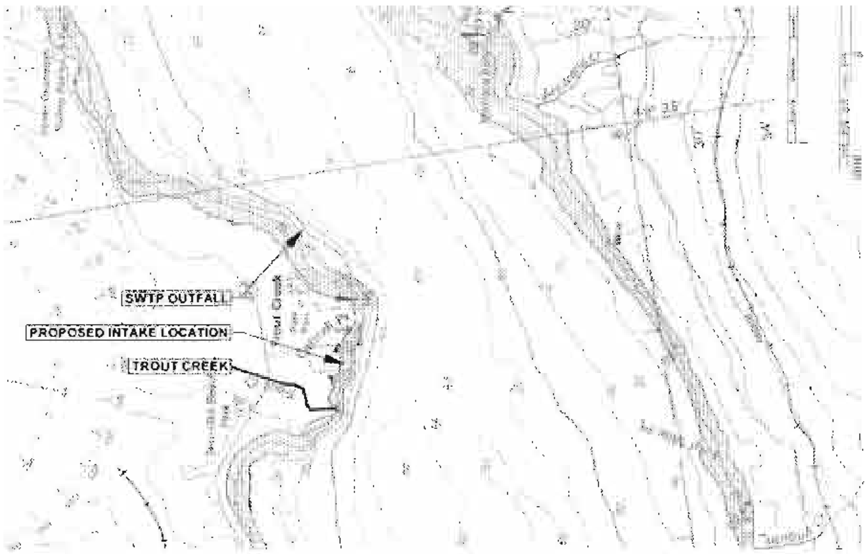

Figure 1. Proposed Water Intake Site

2 Methodology

The centrepiece of the methodology that Hay & Company used to assess the viability of the proposed intake location is an in-house three-dimensional hydrodynamic model, H3D. The general methodology used for this study is given below:

- Set up the model with respect to the grid, bottom topography, model boundaries and model input data in the form of initial conditions and boundary conditions which force the model to respond to real conditions.
- Assemble forcing data such as over-water wind conditions, radiation and cloud cover, air temperature and freshwater inflow.
- Calibrate the model to a set of field measured data.
- Validate the model to a completely independent set of field measured data.
- Conduct model runs in support of the study investigations.

2.1 Hydrodynamic Model

The numerical model used in this study is the three-dimensional hydrodynamic model H3D developed by Hay & Company. The model is described in Stronach *et al.*, (1993). It was implemented for Okanagan Lake in 2000, as part of a limnology study funded by the City of Kelowna. It includes comprehensive horizontal and vertical turbulence terms, a transport/diffusion algorithm for scalar fields such as effluents and flood/dry capability for the foreshore banks.

H3D computes the three components of velocity (u, v, w) on a regular grid in three dimensions (x, y, z) as well as such fields as temperature and contaminant concentration.

The spatial grid can be visualized as a number of interconnecting computational cells, which collectively represent the body of water. Velocities are determined on the faces of the cells, and non-vector variables, such as temperature or contaminant concentration, are situated in the centre of the cells. All cells have the same horizontal dimensions. In the vertical direction, the cells are generally thinner near the surface, and thicker at depth. The differences in horizontal and vertical geometry are required because of the large aspect ratio characterizing the lake, and because much of the variability (stratification, wind mixing, inputs from streams and land drainage) is concentrated near the surface, which requires a finer vertical resolution.

H3D is typically driven by the following forcing mechanisms:

- Wind stress acting at the water surface: Wind forcing causes surface currents and return currents in enclosed water bodies, water level differences, and enhanced vertical mixing.
- River and land drainage inflows: These bring mass and momentum into the water body, as well as contaminants.
- Heat fluxes across the water surface: In most applications, data is limited for calculating heat fluxes. Reasonable estimates can be made from wind speed, air/water temperature, and cloud cover or insolation. In summer, heat input leads to greater stratification, so that near-surface effects, such as contaminant concentrations and water velocities, are generally stronger than in the absence of stratification. In winter, the water cooling can lead to static instabilities and overturning in lakes, as well as ice cover. For Okanagan Lake, the following data are available from the Penticton airport:

    - Air temperature, dry bulb and dew point
    - Cloud cover, opacity, amount, height, and type
    - Wind, speed and direction
    - Relative humidity and
    - Pan evaporation

Turbulence modelling is important in determining the correct distribution of velocity and scalars (contaminants) that can be both passive, conservative and non-conservative, and settling. The diffusion coefficients for momentum and scalars at each computational cell are dependent on the level of turbulence at that point. H3D uses a shear-dependent turbulence formulation in the horizontal direction, and a shear and stratification dependent formulation in the vertical direction. For scalars, a constant horizontal eddy diffusivity was used, and the vertical diffusivity was similar to the vertical eddy viscosity, but scaled by a fixed ratio. These parameters have been shown to simulate closely the annual cycle of salinity and temperature in the Strait of Georgia, and are consistent with current practice.

Water column stratification is reproduced in the model through the transport and dispersion of salinity and temperature. In the case of a lake, only temperature is important and the temperature field is determined through heat flux balance at each grid point. Stratification and the formation of a thermocline depend on the heat balance internally and the energy flux at the water surface. Internal waves due to perturbations in the baroclinic pressure field are set up in a stratified water body and can also affect the stratification.

The model operates in a time-stepping mode over the period of simulation. During each time step, values of velocity, temperature and contaminants are updated in each cell. Data were archived on an hourly basis for subsequent analysis.

2.1.1 Model Implementation

Two implementations of H3D were used for the study: a 500-m grid model of the entire lake and a 100-m grid high resolution model of the area comprising the southern region of the lake about 25 km in extent. The model grids for the 500-m model and the 100-m model are shown in Figures 2. The 500-m grid model captured the significant processes of the development of thermal stratification over the course of the year, and the response, in terms of enhanced currents and vertical mixing, to wind-driven events. It, however, was not able to resolve the complexities of localized interactions between contaminant source and water intake in the near-shore part of the study area, for which a 100-m grid model was used. The time-varying boundary conditions at the north end of the 100-m grid model were established using output from the coarse grid model.

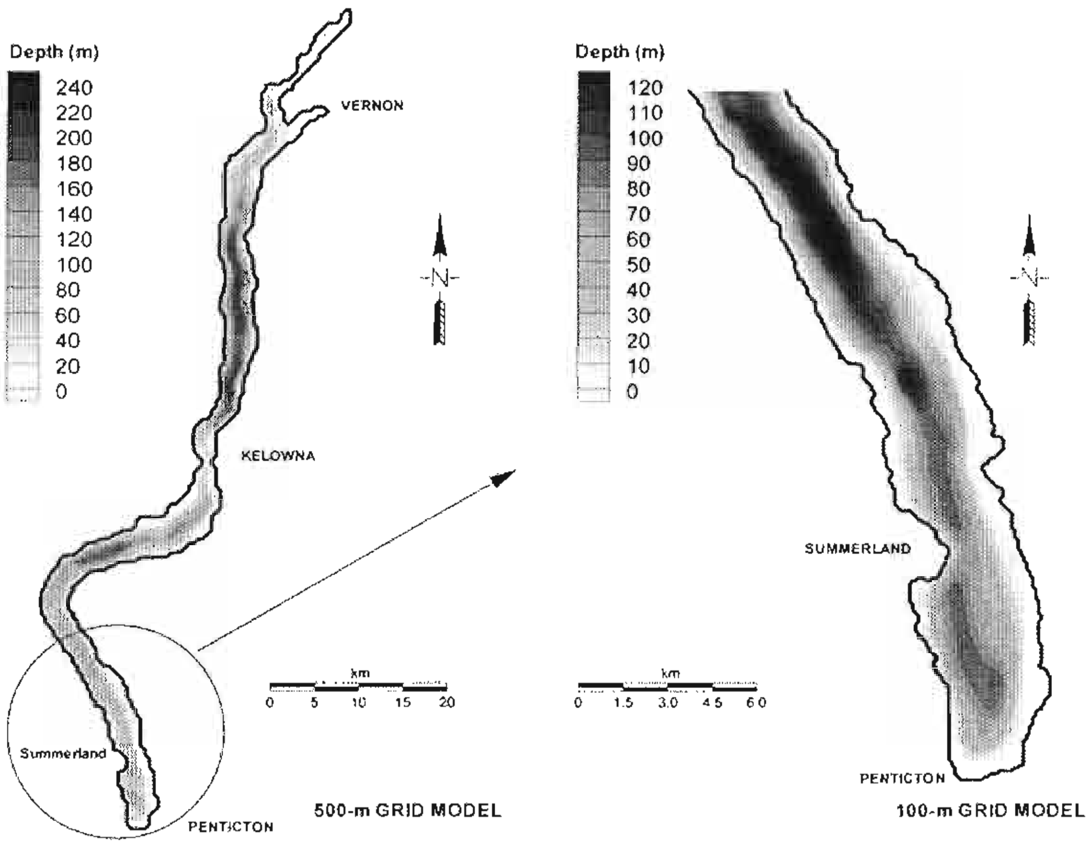

Figure 2. 500-m and 100-m model grid

The vertical resolution was chosen so that the layers are sufficiently close together near the surface to resolve the thermal structure. The model includes a penetrative convection mechanism, i.e. whenever a cell becomes denser than the cell immediately below it, through surface cooling at night for instance, the two cells are assumed to mix instantaneously, thus removing the static instability. This procedure will lead to vertical mixing of contaminants.

2.1.2 Model Calibration

The most significant factor in lake dynamics is the manner in which the lake becomes stratified due to heat input over the course of the spring and summer. As heat is added, it sets up stratification in the lake, which acts as a barrier to vertical mixing so that additional heat serves to increase the temperature of the surface layer and not to deepen the layer. Additionally, the presence of the stratification leads to a two-layer system. The surface layer and the deep layer can have considerably different motions.

The goal in calibrating the model is to choose the various model parameters (i.e. drag coefficient, horizontal eddy viscosity) such that in conjunction with the known forcing of wind, cloud cover, air temperature and humidity, the annual cycle of temperature in the lake is reproduced. The correct reproduction of the temporal and spatial variability of the temperature field indicates that the model satisfies two important criteria:

1. The model can adequately simulate the behaviour of scalar fields considering the processes of advection and diffusion.
2. The model sets up a realistic density field so that internal motions, often referred to as internal seiches, are reproducible. This is important because it means that a temperature calibration not only addresses the transport of scalars but the dynamics of the lake as well.

Figure 3 shows a time-series of observed lake temperature profiles at the Okanagan Centre location, based on 1998 Ministry of Environment data compared to those produced by the calibrated model. Although there are some differences, the general ability to reproduce a wide range of profiles throughout the year is quite good. The only major shortcoming is a tendency of warmer water to penetrate too deeply in the fall months.

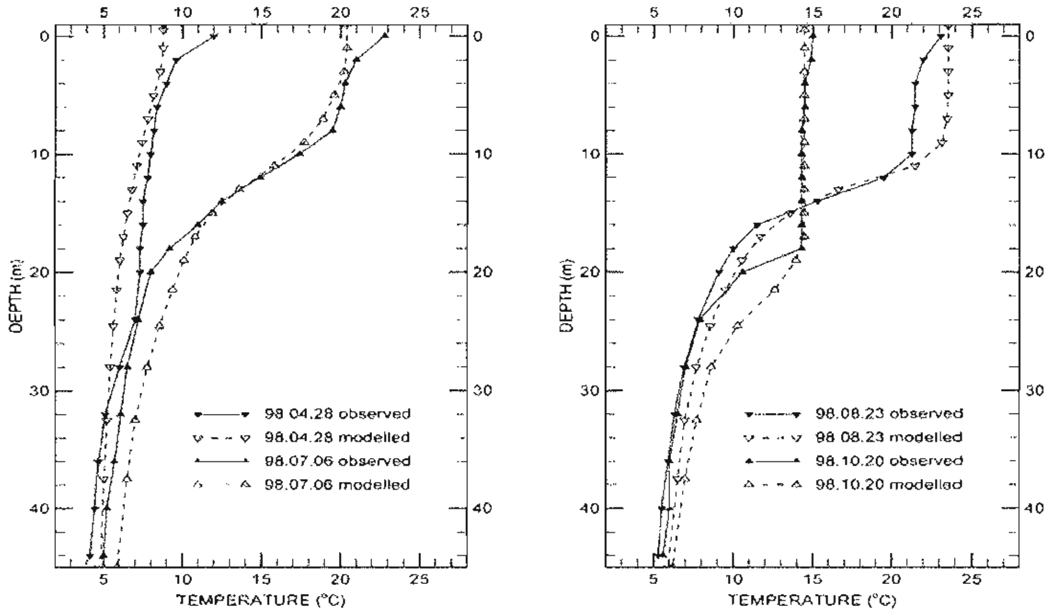

Figure 3. Comparison between model results and selected profiles observed in central basin.

2.1.3 Model Validation

Confidence in the model is enhanced by validating the model to a separate, independent data set. It is generally accepted that a calibrated model, which is verified against an independent data set, can be confidently used to predict conditions where data do not exist or where the data is hypothetical. A field program was undertaken by Hay & Company between April and July 2000 in which two thermistor strings were deployed in Lake Okanagan, one on each side of the Okanagan Bridge. The 500-m grid model was validated against the thermistor string data collected between these periods. In general, the model was able to reasonably reproduce the temperature fluctuations, which had periods of five days, and amplitudes of two to three degree Celsius.

2.2 Transport of Outfall Effluent

Modelling the transport of outfall effluent was carried out in the 100-m grid model, coupled with the Fortran version of the numerical model PLUMES (Baumgartner *et al*, 1993). PLUMES is a numerical dilution model for outfall discharge into marine and freshwater environments. The model, developed and distributed by the US Environmental Protection Agency, is the commonly accepted standard for determining environmental impacts from effluent discharge through an outfall. The PLUMES code was integrated into H3D such that all of the simulated time-varying properties of velocity and density can have the appropriate influence, and the far-field behaviour can be simulated in a realistic manner. The H3D PLUMES subroutine was verified against the stand-alone version, and found to agree closely.

To demonstrate the maximum impact of the SWTP effluent on the quality of water withdrawn from the intake, the design peak hourly SWTP flow of 10 ML/day or 0.116 m^3/s was chosen for the simulation. The effluent density of SWTP is assumed to be similar to that of the Westside Regional Wastewater Treatment Plant.

It should be noted that a specific contaminant was not modelled. Rather, the fate of the entire effluent stream was determined. Thus, the concentration of a particular contaminant, at any location in the lake and at any time during the simulation, is the numerical product of:

1. The concentration of the effluent stream, determined by H3D, and
2. The concentration of that particular contaminant in the initial effluent stream.

The initial concentration for the SWTP effluent is set as 1.0. The actual concentration of any contaminant can be estimated from the model results by multiplying the model prediction by the actual concentration in the input stream. The contaminant concentration is assumed to be conservative and does not decay with time for this study.

2.3 Transport of Creek Flow

Trout Creek flow and temperature time-series were constructed from available HYDAT data (HYDAT 1999). The 1982 Trout Creek flow was selected for the simulation as its hydrograph resembled the typical flow condition for an average year. Due to sparse creek temperature data available for 1982, 1998 Trout Creek temperature was used. The time-series of flow as well as river temperature are plotted in Figure 4. Mission Creek temperature data were used in place of any missing Trout Creek temperature data. River temperatures over the same measurement period in Mission Creek and Trout Creek indicate that the temperature in these two creeks are similar and follow the same trend.

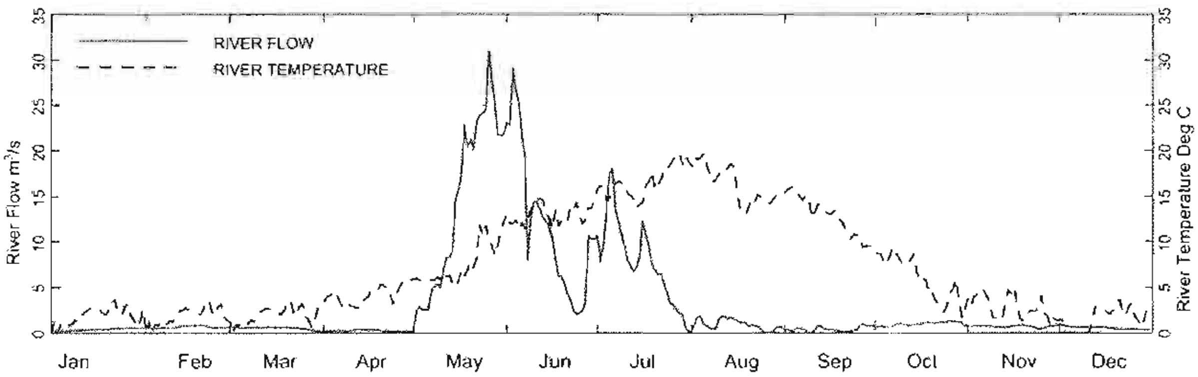

Figure 4. Modelled Trout Creek Flow and Temperature

In a similar manner to the outfalls, a specific contaminant was not simulated for the creek flow. Rather, the fate of the entire creek flow was modelled by introducing a hypothetical contaminant of concentration 1.0 into the creek flow. Thus, if the concentration of creek water at a particular location is 0.001, or 1 ppt, then the water in that part of the lake is a mixture of 999 parts of lake water, i.e. water which was in the lake itself prior to the start of the simulation, and 1 part of creek water, which was carried into the lake during the course of the simulation. Note that the same modelling procedure was used for the simulated outfall effluent. Thus, the flux due to creek sources, as it appears in the modelling presented here, is considerably higher than the flux from the outfalls, because the creeks have a much higher flow rate. For a simulation of a specific contaminant, these concentrations would be further adjusted by the actual initial concentration of that contaminant.

3 Discussion

Once the lake modelling system has been calibrated and validated, it becomes a powerful tool for the investigation of numerous hydraulic phenomena, such as the movement of creek water or treated effluent in the vicinity of a proposed water intake.

3.1 Model Simulation

A key transport mechanism of scalars in Lake Okanagan is wind-generated internal seiches. To gain further insight into the dynamics of this mechanism, a strong, steady northerly wind event occurring at the end of May 1998 is examined. Figure 5 shows the time-series of the wind vectors of this event.

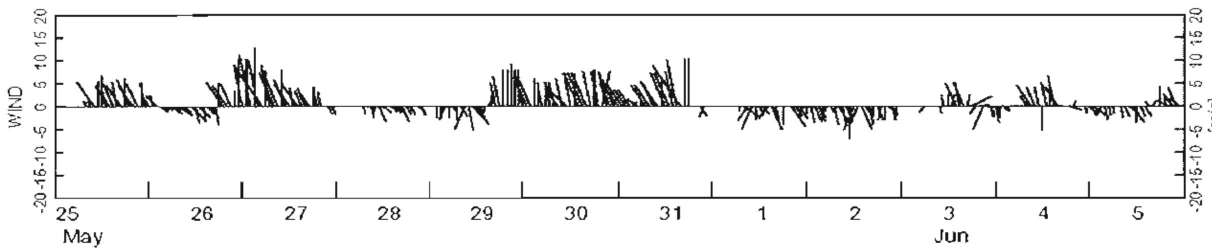

Figure 5. Time-series of wind vectors

Figure 6 shows the flow velocity field of the surface layer and at a depth of 28 m on May 31, 12:00, 48 hours into the wind event. The wind stress acting directly on the near-surface water caused a surface flow to the north. In turn, the northerly surface flow resulted in a surface slope acting in the opposite direction, driving flow in the deeper layer toward the south. The mass flow from the upper and lower layers were balanced such that there was no net transport across any vertical section except for a small amount required for surface set-up. This can be better visualized by taking a cross-section along the deepest depth of the model grid as shown in the top panel of Figure 7.

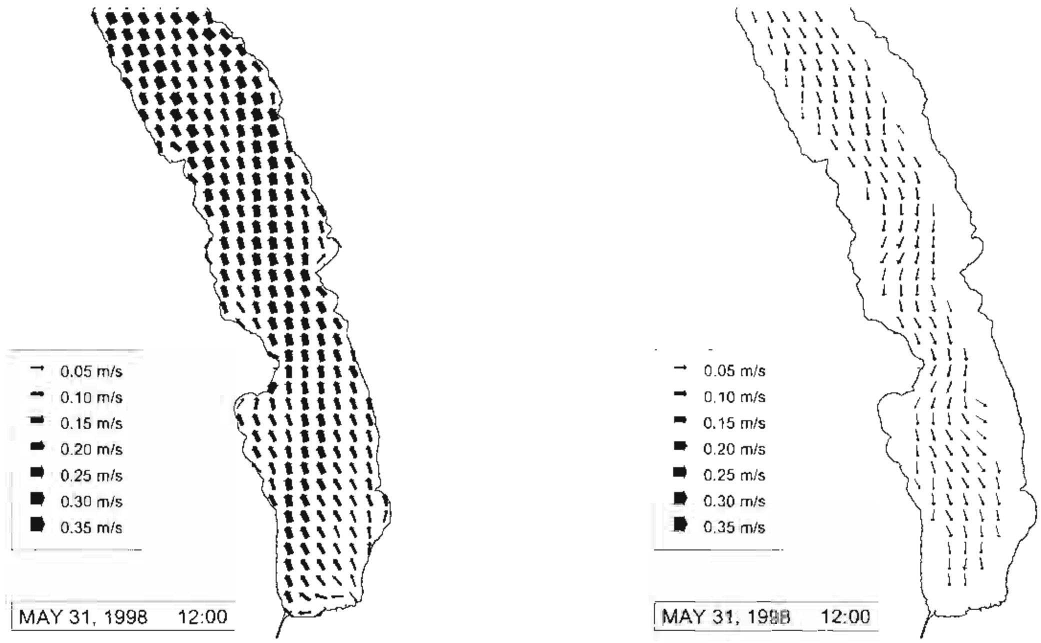

Figure 6. Velocity Flow Field on May 31, 1998 12:00. Left hand panel: at surface layer. Right hand panel: at a depth of 28 m.

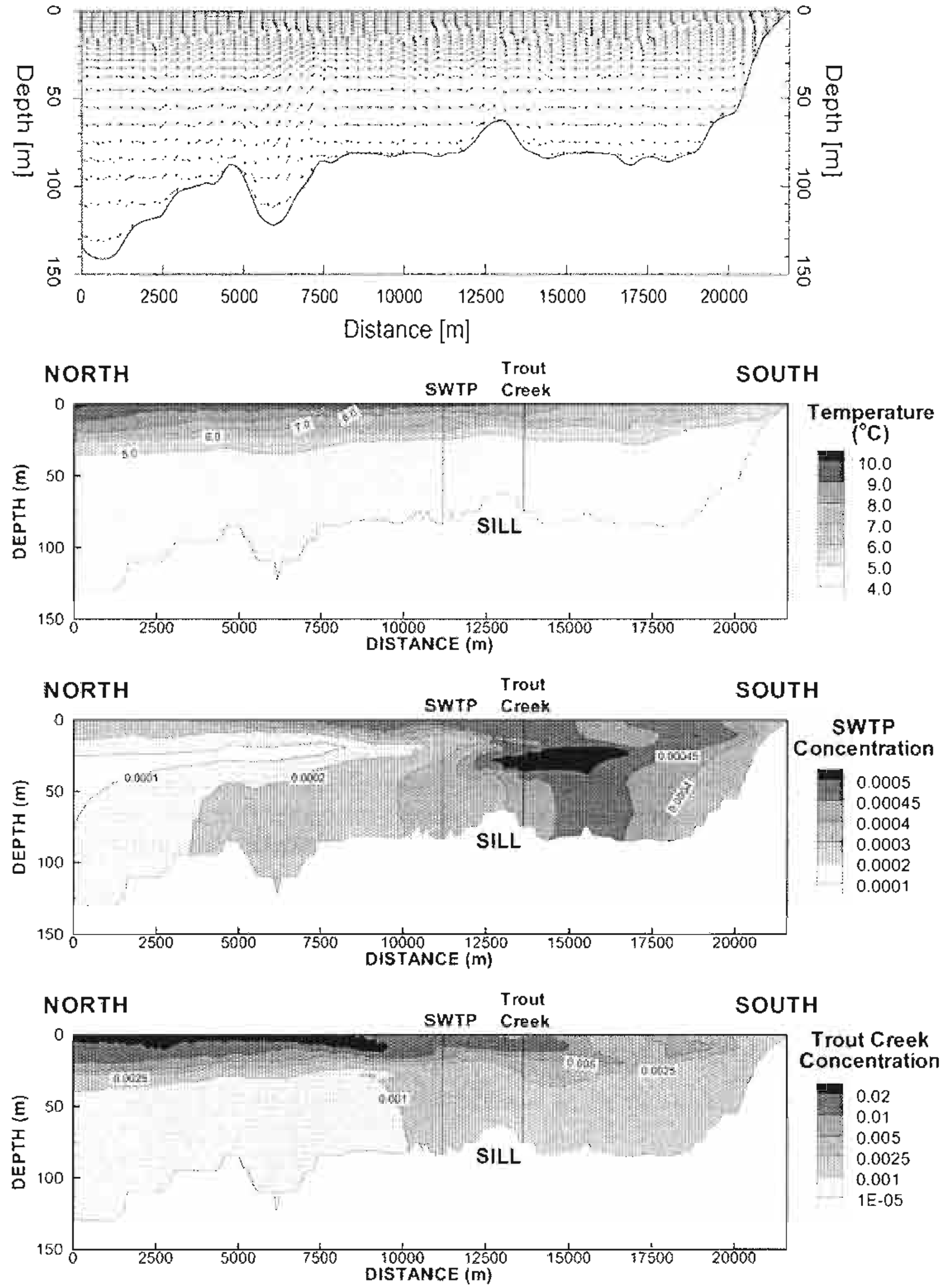

Figure 7. Cross sections of flow velocity, temperature, SWTP and Trout Creek concentration distribution on May 31, 12:00

Also shown in Figure 7 are cross-sections of temperature, SWTP concentration and Trout Creek concentration. Surface water piled up at the northern end of the lake, causing it to be warmer over a considerably greater depth than in the south. At the south end, the lake was cooled because surface water was driven to the north, and deeper water was upwelling along the south coast of the lake. The difference between the surface temperature at the north and south end of the model was 5°C.

The SWTP discharges effluent at a depth of 37.5 m and has a trapping depth typically below 20 m depending on the temperature profile in the water column. The third panel in Figure 7 shows that the upwelling of deeper water in the south not only induced a more uniformly distributed density in the water column but also carried a considerable amount of effluent southward.

The presence of the strong wind coincided with high creek flow and induced a more complex and energetic flow pattern. The creek water, upon being discharged to the lake, was mixed well to a depth of 30 m due to the strong wind stress. One notes the presence of a sill, which has an elevation 20 m higher than its neighbouring area. In addition to the rise in vertical elevation, the width of the lake contracts by 1500 m at this site. This configuration resulted in a complex distribution of scalars. It can be seen on the bottom panel of Figure 7, that there is a distinct difference between the Trout Creek concentration distribution north and south of the sill. South of the sill, the distribution was better mixed vertically as the result of the upwelling of deeper water. To the north, where the presence of upwelling was absent, a more stratified distribution of concentration is observed above 30 m.

After the wind stops, the thermocline oscillates about its equilibrium position, which results in internal seiching of the lake. Figure 8 shows the flow velocity field of the surface layer (0-2m) and at a depth of 28 m on June 4, 18:00, 96 hours after the strong wind event. The lake experienced light northerly wind at this time. The wind stress acting directly on the near-surface water caused a surface flow to the north and the deeper flow is seiched toward the south. The corresponding flow velocity vector cross-section plot is shown in the top panel of Figure 9. The wind stress on this day was significant less than that on May 31 and only affected the flow field directly to a depth of 10 m, about half the depth by that of May 31. The feature of the sill and internal seiching resulted in a unique four-layer flow north of the sill and a three-layer flow south of the sill.

Figure 8. Velocity Flow Field on June 4, 1998 18:00. Left hand panel: at surface layer. Right hand panel: at depth of 28 m.

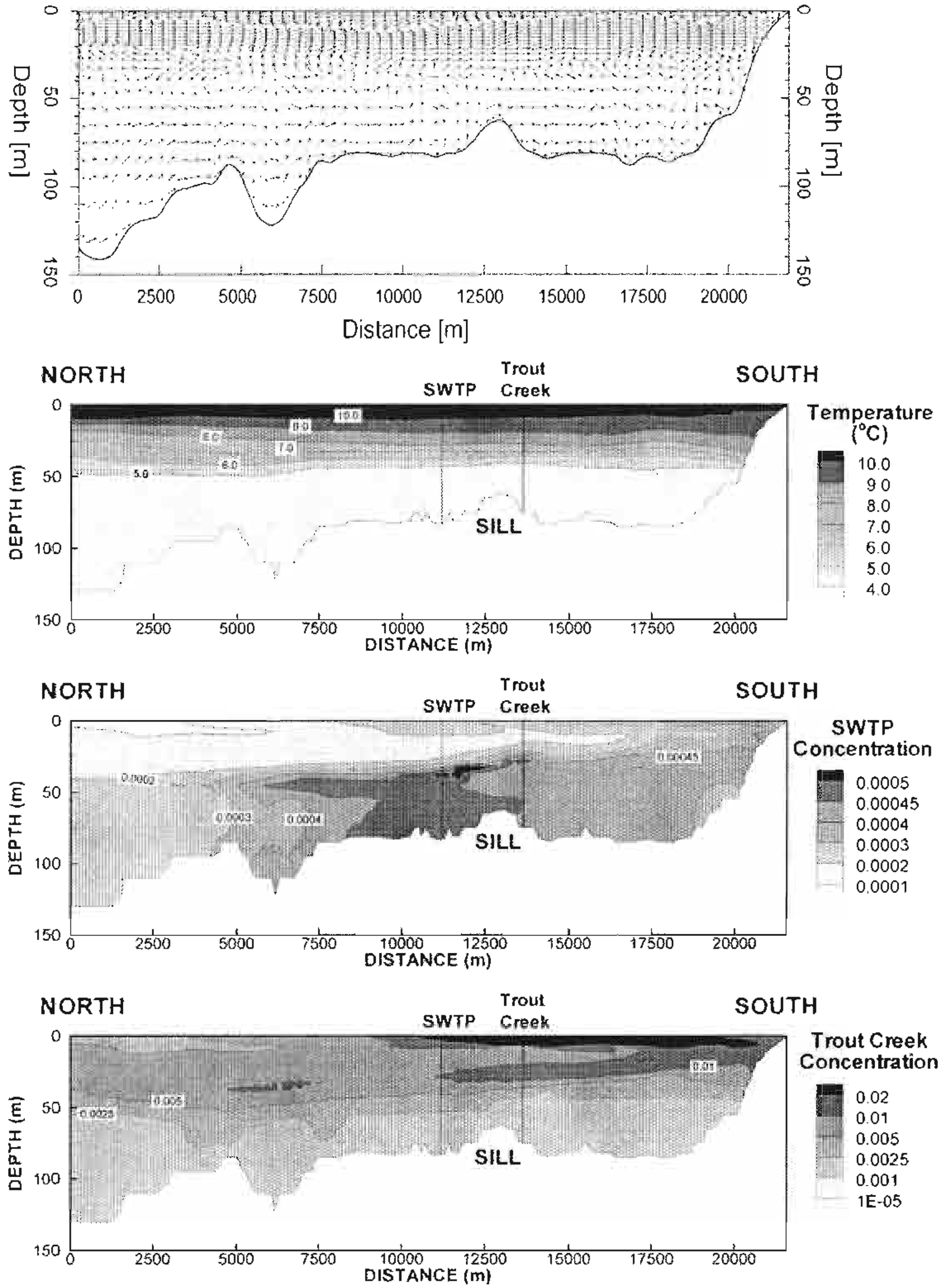

Figure 9. Cross sections of flow velocity, temperature, SWTP and Trout Creek concentration distribution on June 4, 18:00

Also shown in Figure 9 are cross-sections of temperature, SWTP concentration and Trout Creek concentration. The surface slope was relatively small along the section and temperature was uniformly distributed horizontally. There was little difference between the surface temperatures at the two ends of the model.

Without the upwelling of deeper water in the south and as the temperature profile stabilized, a significant amount of SWTP effluent was located at depths of 35 m or greater. The complex flow pattern introduced by the lake geometry and seiches resulted in the net transport of Trout Creek water southward in the surface layers and downwelling at the south. The volume of creek water downwelled at the south is negligible compared to that in the basin. Hence, it did not affect the distribution pattern of SWTP effluent.

3.2 Application of Results

An example of the use of the model is discussed below. A lake model simulation was carried out from February to October 1998 to evaluate the impact of the SWTP effluent and Trout Creek flow on the proposed water intake location. As a conservative means of interpreting the model runs, the 95-percentile concentration in each cell, over the simulation period, was determined, and contours of that variable were plotted. For instance the 0.01 concentration contour would indicate that the concentration was greater than 0.01 during 5% of the time and less than 0.01 95% of the time. Alternatively, the dilution was greater than 100:1 for 95% of the time, and less than 100:1 for 5% of the time. Figure 10 shows an example of the 95-percentile output. One notes quite clearly that the deeper the layer, the smaller the impact of SWTP effluent.

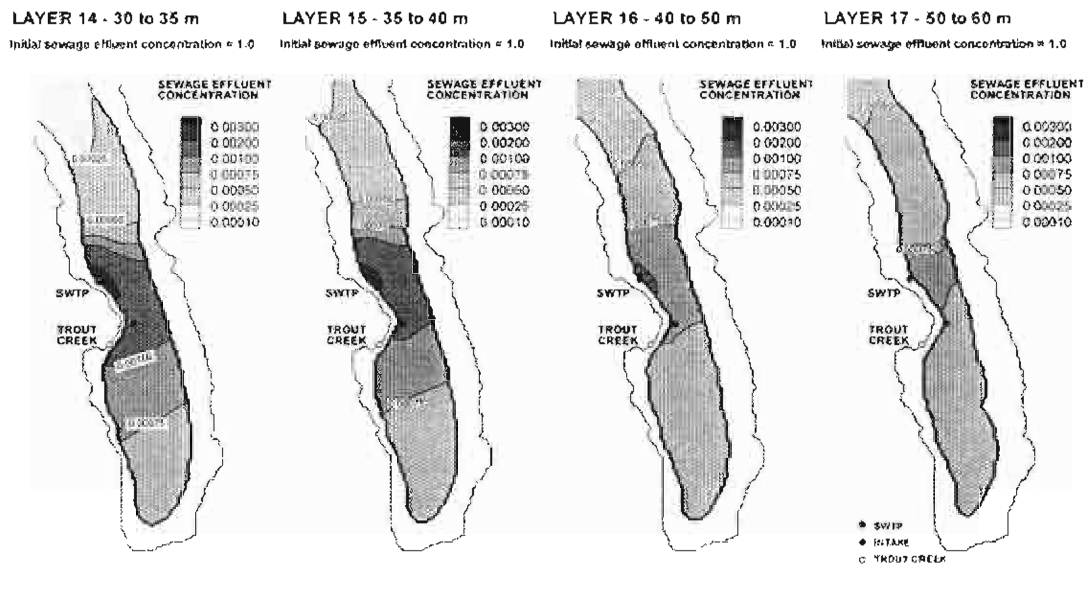

Figure 10. 95-percentile SWTP effluent concentration map

4 Conclusion and Recommendations

A three-dimensional model of Lake Okanagan was shown to accurately physical phenomena so that engineering and planning decisions can be based on it with confidence. To assist in assessing the viability of the proposed water intake site, two H3D models (500-m grid and 100-m grid) were used to model the movement of water and contaminants in Lake Okanagan. The 95-percentile scalar concentration in each cell, over the simulation period, was determined and contoured to assist in interpreting the model results. The data and drawings generated from the model allow engineers and planners to select the optimal depth for the water intake.

In addition to the Summerland water intake feasibility study, the H3D lake model has previously been used to conduct a study into the influence of Lake Okanagan limnology on the water quality entering City of Kelowna's domestic water supply. It is likely that there will be other water quality issues with respect to Lake Okanagan, and that the H3D lake model would be a useful tool for these management purposes. A major difficulty with the application of H3D was the lack of representative meteorological data. It is recommended that with a view to future requirements, a meteorological station on the lake be established and data collection and archiving be undertaken.

5 Acknowledgments

This study was supported by funding from the District of Summerland. We also thank Morrow Environmental Consultants for whom Hay & Company were subconsultants on this project. The writers would wish to extend grateful thanks to the City of Kelowna, who funded the original study of the Okanagan Lake model.

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Okanagan Basin Study –Thirty Years Later

by
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Paper not received in time for publication

Summary of Okan. Basin

120 yr. [illegible] 30% [illegible] 5% [illegible] | water yield inc.

Any different issues now than in 1974?
- No

* What are the current issues?
- Sustainable water supply
- A Basin management plan
- Current water yield data
- Current water demand data
- Water conservation strategies

- We still haven't implemented the 1974 plan fully

Full consideration to effects of [illegible] - forestry

S. of Penticton - not sig. in yield at harvest[illegible]

N. of Penticton - Before 1979 no inc. in yield
After 1979 - inc. 3-4%

- with sustainable [illegible] of 0.5% [illegible]

- Focus of forest harvesting [illegible]

- Groundwater contribution [illegible] not sig.

OB Study
Recommendations
1 - not implem.
2 - implem. in 1976
3 implem.
4 not
5 impl.
6 impl.
7 not
8 impl.
9 impl.
10 impl.
11 impl.

1982 implementation report

Pop. growth [illegible] ([illegible])
155,000 ([illegible])

Tourism 45[illegible] (1970)
1.0[illegible] (1990)

"[illegible]" .. 2.7 m (1970)
7.3 mill. (1990)

Water use [illegible] reduced since 1970 due to improvements in irrigation practices
→ this capacity [illegible] to continue to [illegible]

→ 25 new recommendations

- new Kal/Wood Lake system operating plan
- wharves
- pump drainage [illegible] water [illegible] Wood Lake [illegible]
- amended recommendations made in 1974

Water Availability and Use In the Okanagan Basin

by
Kevin M. Dickenson, P. Eng.[1]
[1]Land and Water British Columbia Inc.
Kamloops

Introduction

The Okanagan Basin, in the southern interior region of British Columbia, has a semi-arid climate. Located in the rain shadow of the Cascade Mountains, the Basin has a mean annual precipitation of only approximately 55 cm, making the area a favourite retirement and vacation destination, an attractive place to live, and an optimal location for many types of agriculture, such as hay production, fruit, vegetables, and vineyards. As a result, the region has experienced unprecedented growth in the past 30 years, far exceeding even the most optimistic projections.

This growth, and the resulting demand it has put on the water resource for domestic, industrial and agricultural use, has necessitated several formal agreements and various studies over the years to examine the hydrology, water supply and water use in the Okanagan Basin. The joint federal-provincial Okanagan Basin Study, completed in 1974, was a comprehensive look at water management. The results of this study formed a framework for a water management plan that has influenced the allocation decisions made in the years that followed. A subsequent study, by the Water Management Division of BC Environment, was completed in 1994 and looked at Okanagan Lake to determine what volume of water was still available for licensing. The results of this study served to inform water managers and decision-makers of the Basin's capacity for additional allocation. At the same time, other agreements were reached based on the transboundary flows of the Basin, which included the British Columbia Washington State Osoyoos agreement.

Now, in early 2005, it is apparent that further work needs to be done. Growth in the region is continuing at a rapid pace, and the drought conditions experienced in 2003 and the first part of 2004 have raised the profile of water supply issues. Climate change models indicate that the hydrology of the area will be affected in the near future, with earlier runoffs, lower precipitation, and longer growing seasons. There is a concern that water supply is quickly becoming the limiting factor to growth in the Okanagan. In response to this, Land and Water British Columbia Inc. has initiated a two part study of water supply and demand in the Okanagan.

To understand the need for the current initiatives and water allocation status in the Okanagan Basin, and the future direction that water management may take, it is important to examine the history of water availability and use in the Basin. Therefore, this paper will provide a discussion of the key findings of the 1974 and 1994 reports, the status of water allocation over the past 30 years, the Canada-US Osoyoos Agreement, and the current initiative of Land and Water British Columbia Inc.

Okanagan Basin Study – 1974

The Okanagan Basin Study was initiated in 1970 and completed in 1974 by the Canada – British Columbia Consultative Board. The study was undertaken in accordance with the 1969 Canada – British Columbia Okanagan Basin Agreement and examined water resource management in the Okanagan Basin. The overall objective of the study was to create a framework plan for the development and management of water resources in the basin for the next 50 years. All aspects of water resource management were included in the study, such as water quantity, water quality, waste treatment, fisheries, recreation, forestry and other land uses.

The study provided 45 recommendations relating to governance, implementation, water storage, flood management, water quality and other key areas that, if implemented, would comprise a comprehensive water management plan. In February 1976, the Governments of Canada and British Columbia entered into the Okanagan Basin Implementation Agreement. This agreement was aimed at implementing the recommendations of the study. The original term of the Agreement was five years, but was subsequently extended to September 1982, at which time a review was initiated.

The review included further recommendations for the ongoing management of water and water-related resources in the Okanagan Basin. A significant outcome of this review was the establishment of the Okanagan Basin Water Board, which was granted authority to carry out a coordinating role within the basin. The original recommendation of the 1974 study called for one regional district, instead of three. However, two alternatives to a single regional district were also suggested, including the establishment of a Water Board. At the time, functions such as waste treatment, the orderly development of shoreline recreation facilities, and flood plain zoning were considered valley-wide in scope.

The most direct recommendation relating to water allocation was specific to Mission, Equesis and Trepanier Creeks. The report recommended that these three creeks be managed for fisheries and irrigation purposes, allowing other major creeks to be developed primarily for domestic and agricultural water use. Other recommendations that were provided concerning water quantity included the management of Okanagan Lake and the development of storage on some of the major tributaries for both consumptive and fisheries needs.

Water Allocation (1974 – 1994)

The following is a brief summary of the licensing and overall status of some of the more significant sources in the Okanagan Basin for the period between the Okanagan Basin Study of 1974 and the Okanagan Basin Water Supply study of 1994.

Trout Creek:

Trout Creek is considered a valuable fishery resource and by 1971, was already listed as "fully recorded except for domestic purposes". This stream notation continues to restrict licensing on the source to allow only the issuance of licences for domestic use, at rates of 500 gallons per day each, unless the licence is backed by storage. The major licensee on Trout Creek is the Municipality of Summerland, who also have the last significant licence issued on the source. This licence was issued during this restricted time period, and is for 2500 acre-feet for irrigation purposes and is backed by storage, with a 1988 priority. During the period from 1974 to 1994, there were 27 licences totalling 2659 acre-feet issued on Trout Creek. This value does not include three storage licences totalling 2070 acre-feet.

Peachland Creek (also known as Deep Creek):

The last significant licence on Peachland Creek was issued in 1967 to the Municipality of Peachland for 146,000,000 gallons per year for waterworks purposes. In 1976, an application for a water licence was refused, resulting in a stream notation of "Refused – no water". A stream notation of this type acts as a red flag and may result in the refusal of subsequent applications where no storage exists to back up the licence. During the period from 1974 to 1994, there were 2 licences totalling 3 acre-feet issued on Peachland Creek.

Trepanier Creek

The major licensee on Trepanier Creek is also the Municipality of Peachland. The last significant licence issued on this source was in 1987, for 30 acre-feet for irrigation purposes. In 1992, Trepanier Creek was listed as "fully recorded from July until September except for domestic purposes, unless supported by storage". During the period from 1974 to 1994 there were 39 licences totalling 322 acre-feet issued on Trepanier Creek. This does not include five storage licences totalling 267 acre-feet.

Powers Creek

In 1979, Powers Creek was noted as "fully recorded after June 30" of each year, unless storage is provided. The major licensee is the Westbank Irrigation District. During the period from 1974 to 1994 there were five licences totalling 3119 acre-feet issued on Powers Creek. This does not include 3195 acre-feet for storage purposes and 2172 acre-feet for conservation purposes.

Mission Creek

The last significant licence was issued in 1970 to the Black Mountain Irrigation District. It authorizes the diversion of 575 acre-feet of water for irrigation purposes, and is backed by storage. By 1974 Mission Creek was already noted as "fully recorded", with various notations dating as far back as 1964. A reserve was placed on Mission Creek and its tributaries "To Investigate Best Uses For Source" in 1979. This reserve, under Section 44 of the *Water Act*, prohibits any further licensing but exempts licences issued for domestic and land improvement purposes. In addition to the Black Mountain Irrigation District, the South East Kelowna Irrigation District also has major licences in the watershed. During the period from 1974 to 1994 there were 47 licences issued totalling 46 acre-feet on Mission Creek. This does not include 214 acre-feet for storage, 2171 acre-feet for land improvement, and 180 acre-feet for conservation purposes.

Lambly Creek (also known as Bear Creek):

The last significant licence was issued in 1978 to the Lakeview Irrigation District for 365,000,000 gallons per year for waterworks purpose. It also includes 1500 acre-feet of storage. The stream notation reads "fully recorded for all purposes unless supported by storage", although a date is not associated with that conclusion. During the period from 1974 to 1994 there were 17 licences totalling 5 731 acre-feet issued on Lambly Creek. This does not include 5870 acre-feet for storage purpose.

Okanagan Basin Water Supply Study (1994)

The need to conduct a water supply study arose based on the allocation status of some of the major tributaries in the Basin and the concerns for water availability that were expressed by the Okanagan Basin Water Board in early 1991. The study, completed by the Water Management Division, Hydrology Branch, of BC Environment, was focused strictly on determining the water supply potential of the Okanagan River Basin under the current water-use development conditions and the Okanagan Lake operational procedures. Initiated in 1992, the study used both the data originally used for the 1974 Okanagan Basin Study, as well as the 20 years of new data available. A computer model was used to simulate monthly operation of Okanagan Lake during average and drought years to determine water supply potential utilizing Okanagan Lake inflows, reservoir releases and local net inflows between Penticton and Oliver.

Using the data available at that time, and making many assumptions regarding various parameters that would have an effect on the model's output, it was concluded that if the most severe drought conditions on record (1929-1931) occurred under the 1994 water use and reservoir operation conditions, 63,000 dam^3 (or approximately 51,000 acre-feet) of water were available, on an annual basis, for future licensing. Under those conditions, it would take three years of average net inflows for Okanagan Lake following the three years of drought to again reach a normal operating level. Therefore, it was recommended that no more than 63,000 dam^3 of water be licensed in the Okanagan River basin until more operational experience was gained with future drought conditions. However, due to the complex nature of water licences for the various consumptive and non-consumptive uses, it is difficult to ascertain whether this volume has been fully allocated to date.

Water Allocation (Current State)

Currently, there are 301 restrictions on sources in the Okanagan Basin. From a cost perspective, utilizing tributaries for water supply is preferable as it minimizes pumping costs. However, since many of these sources have reached, or are approaching a fully allocated status, and most of the cost-effective storage sites have already been developed, Okanagan Lake is being explored as a viable alternative. The Okanagan Suswap LRMP encourages diversions for consumptive use from mainstem lakes and rivers rather than upland tributaries. In the past two years, 71 licences totalling 12,184 acre-feet of water have been issued on Okanagan Lake.

Water allocation decisions continue to be made on an application-specific basis, based on historical streamflow data and existing licensed withdrawals. In addition, various supply and demand studies have also generally been based on water volumes licensed under the *Water Act*. In many cases, such as major water purveyors, the licensee is required to submit actual use records to Land and Water British Columbia Inc. However, in cases such as individual licences for irrigation or industrial use, no monitoring of actual use is undertaken and in these circumstances, actual use may vary from licensed right by a considerable amount.

Licences issued under the *Water Act* are assigned a priority date that is used for regulation purposes. In times when the water supplies of a source are insufficient to meet all licenced demands that exist, the Act allows for regulation to take place. The licensees with the most recently issued water licences must stop diverting water first. This regulation can be problematic if the most recent licences are for small volumes for domestic purposes. The impact of "shutting off" those licences has an immediate significant impact on people, and a minimal positive impact on the resource. This type of scenario can also have a significant negative impact on some licensees if they are required to stop diverting water for certain types of agriculture. For example, if vineyards and orchards lack water too early in the fall, not only is that season's harvest affected, but the vines or trees can be lost.

Drought conditions during the summers of 2003 and, to a lesser extent, 2004, caused by low snowpacks, below average rainfall, and higher than normal temperatures have highlighted water management challenges in the basin and caused major conflict between licensees, and between in-stream and off-stream demands. Climate change scenarios indicate that this situation could occur more frequently in the future due to the potential for earlier runoff, higher temperatures, longer growing seasons, and other factors. Long term impacts associated with climate change could affect allocation decisions that were made in the past based on historical data.

British Columbia Washington State Agreement on Osoyoos Lake

Osoyoos Lake is fed by the Okanagan River, which discharges from Okanagan Lake and flows south through Skaha Lake and Vaseux Lake towards the Canada – U.S. border. The border cuts across Osoyoos Lake, with approximately two-thirds of the lake area being in Canada. The Okanogan River discharges from the south end of the lake and eventually enters the Columbia River. The Zosel Dam is located at the south end of Osoyoos Lake and regulates the lake levels.

The Boundary Water Treaty of 1909 provides for the formation of an International Joint Commission (IJC), made up of three representatives from each country to act as referees in any dispute over boundary waters. As Zosel Dam impacts water levels in Osoyoos Lake on both sides of the international boundary, the construction and maintenance of the dam falls under Article IV of the Treaty.

The Zosel Dam was originally built in 1927 and operated solely to provide a millpond for the delivery of logs to the Zosel sawmill in Oroville, Washington. The IJC was not involved with the dam until the 1940's in response to complaints about high Osoyoos Lake levels in Washington State. In 1946 the IJC issued its first Order of Approval with respect to Zosel Dam requiring the owner to increase the discharge capacity of the dam.

By the late 1970's the deteriorated condition of the dam led to discussions between British Columbia and Washington State on an agreement to rebuild the structure. It was recognized that such an agreement would require the two sides to agree on how the new structure would be operated, although the IJC's jurisdiction would remain unchanged and be concerned only with lake levels and the discharge capacity of the works. This resulted in the issuance of a new Order of Approval in 1982 regarding the construction, operation and maintenance of a replacement structure. The Order also led to the establishment of the International Osoyoos Lake Board of Control to ensure compliance with the Order. A Supplementary Order of Approval was issued in 1985 amending conditions of the 1982

Order respecting the construction of the replacement Zosel Dam. The dam reconstruction was completed in 1987.

Outside of the Orders of the IJC, the provincial and state governments have developed the "British Columbia Washington State Cooperation Plan for Osoyoos Lake Levels and Trans-Border Flows" (1980). The Plan outlines a non-binding agreement on minimum flows that British Columbia will, as far as possible, release at the border under various conditions. It was British Columbia's goal that there be no interference in the Province's management of upstream storages and dams. Although both governments recognized that the sharing of international waters imposed a responsibility for mutual trust, harmony and understanding the Plan explicitly states that "Nothing in this Cooperation Plan shall be construed to usurp the water management rights expressly vested either in the Province of British Columbia or the State of Washington." Therefore, British Columbia is not bound by the minimum flows detailed in the agreement.

Current Initiative

The results of the numerous studies that have looked at specific aspects of water availability in the Basin have greatly contributed to the knowledge of water supply and demand in the area and influenced allocation decisions over the past three decades. In addition, several other initiatives are currently in progress by a number of government, academia, and non-governmental organizations, including a long-term groundwater assessment study, and the previously mentioned research on the impacts of climate change in the Basin. The conclusions of the numerous studies and of the many organizations involved in water management issues in the Okanagan is that there is a need to gain a better understanding of the water resources in the Basin in order to establish a more coordinated, effective, and sustainable approach to water management in the area.

Due to the rapid rate of growth, increasing demand for water, and recent drought conditions, an immediate need exists to clearly define the state of the water resource in the Okanagan Basin and to provide that information to managers and stakeholders to ensure that informed decisions can be made about the future of water management in the Basin. As part of this process, Land and Water British Columbia, Inc. in collaboration with other provincial ministries, Environment Canada, and the Okanagan Basin Water Board, have initiated a two-phase water supply and demand analysis of the Basin. The scope of the study will include Okanagan Lake and its main tributaries and the mainstem to Oroville, U.S.A.

Summit Environmental Consultants Ltd. has been contracted to complete Phase 1 of the study by April 2005. This phase involves an evaluation of the existing data records and models, including the hydrological data, climate trends, population growth trends, future projections, and any other relevant data that would be used to complete a supply and demand analysis of the Okanagan Basin. The evaluation will assess the quality of the data available, determine if data gaps exist and how these may or may not affect the accuracy of a supply and demand analysis and the management decisions that rely on this information. These findings will then be presented at a workshop with selected key stakeholders to inform them of available information and to discuss the direction, goals, and limitations of Phase 2 of the study in which the water supply and demand analysis will be completed. By directly involving local stakeholders, the results of the study are intended to be relevant and useful for all those managing water and land use in future years.

The supply and demand analysis will be completed in Phase 2 based on the information gathered and reviewed in Phase 1. Supplementary field data will be collected only if necessary. The goal is to provide a best estimate of the current and future available water supply and demand in the Okanagan Basin, taking into consideration the influence of growth, climate and other relevant factors. Recommendations will also indicate future data collection needs that could fill knowledge gaps and improve the accuracy of water supply and demand estimates. The results will provide a better understanding of the existing and future water resources of the Okanagan Basin. This information will enable water managers and planners to build a more integrated water management plan for the Basin.

Conclusions and Recommendations

As a result of the water short climate in the Okanagan Basin, many studies have been conducted on water supplies in past years. Growth in the region has far exceeded even the most optimistic projections of the first study, completed in 1974. Work done by the Hydrology Branch of BC Environment in 1994 indicated that up to 63,000 dam^3 of additional water could be licensed in the basin before another assessment was completed. Unfortunately, it is unclear how much total additional licensing has been approved since that time. In addition, other factors such as climate change and evolving agricultural practices cast further doubt on the current state of water supply in the basin.

The first phase of a two part study to examine water supply in the Basin is now underway. The information brought together by this first phase will be assessed to determine the parameters, criteria, and knowledge gaps that the second phase needs to address.

The relationship between licensed right and actual use varies greatly between individual licences. Long term water management in the basin needs to begin to look at quantifying actual use, even if only on a restricted scale such as a pilot study.

Conflict over water use continues to be a problem, and drought conditions over the past two summers have accentuated the issues. Development in the Basin has begun to be affected by available water supply, Planning for future growth needs to take into account water management and use to ensure continued ecological and economic health in the Okanagan.

The widespread use of water conservation measures throughout the Basin, for all types of water use, will become increasingly important in the near future as additional sources become fully allocated.

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Groundwater Assessment in the Okanagan Basin

by
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Abstract

The Okanagan Basin is an important groundwater region of the province. Sixty-five (10%) of the province's aquifers occur in the Okanagan Basin, including five (24%) of the province's twenty-one IA (heavily used, highly vulnerable) aquifers. In order to better manage this important resource, more detailed information with respect to an aquifer's characteristics (e.g., groundwater flow directions, flow rates and sustainable capacities, inter-connection with surface water bodies, location of sensitive recharge areas, factors governing ambient groundwater quality, etc.) is needed. This information will assist in determining impacts of water use and/or human activities and will provide a greater understanding of potential impacts from climate change.

A major federal-provincial groundwater assessment of the Okanagan Basin was initiated in 2003 and work has begun to collect and collate groundwater data and information. The major research themes for this regional assessment include aquifer characterization, estimating water budgets, gaining a better understanding of groundwater/surface water interactions, water quality, and climate change. In addition to providing scientific assessments of the quality and quantity of the Okanagan Basin's groundwater resource, this project will communicate the scientific findings to the public, land use and resource decision makers and industry through community outreach activities.

Introduction

Groundwater is an integral component of the hydrological cycle and plays an important role in the health of our streams, wetlands, lakes and associated ecosystems. It is estimated that between 25-28% of the population in British Columbia relies on groundwater as a drinking water supply. Industry utilizes approximately 55% of the groundwater extracted in the province, agriculture uses 20%, municipal use reaches 18% and rural domestic use amounts to 7%.

Groundwater use in British Columbia is expected to continue to grow given that, in general, groundwater supplies are often of better quality, more accessible and are less expensive to develop than surface water supplies. As the demand for water grows, and as climate change impacts natural hydrologic regimes, it is anticipated that groundwater will be relied upon to meet this increased demand.

The Okanagan Basin is an important groundwater region of the province. Sixty-five (10%) of the province's mapped aquifers occur in the Okanagan Basin, including five (24%) of the province's twenty-one IA (heavily used, highly vulnerable) aquifers. In order to better manage this important resource, more detailed information with respect to an aquifer's characteristics (e.g., groundwater flow directions, flow rates and sustainable capacities, interaction with surface water bodies, location of sensitive recharge areas, factors governing ambient groundwater quality, etc.) is needed. This information will assist in determining impacts of water use and/or human activities and will provide a greater understanding of potential impacts from climate change.

Partnership Initiative

The Groundwater Assessment in the Okanagan Basin (GAOB) project is a major partnership initiative to assess and characterize groundwater resources in the Okanagan. A Steering Committee for the project, which began in the fall of 2003, includes representatives from the Geological Survey of Canada, the Okanagan Basin Water Board and the Ministry of Water, Land and Air Protection. The Steering Committee's responsibility is to oversee the research priorities and directions for the GAOB project. In addition to the Steering Committee, there is a Working Group to oversee the research priorities and directions for the GAOB project and to communicate the research and science outputs from the project to key stakeholders and the public. Membership of the Working Group includes representatives from the following organizations:

- Okanagan Basin Water Board (OBWB)
- Geological Survey of Canada (GSC)
- Interior Health Authority (IHA)
- BC Ministry of Water, Land and Air Protection (MWLAP)
- Agriculture Canada (AC)
- Natural Resources Canada's Sustainable Development Through Knowledge Integration Program (Pathways Project)
- Canadian Centre of Excellence for Water (CCEW)
- Simon Fraser University (SFU)
- Okanagan University College (OUC)
- BC Groundwater Association (BCGWA)

Community Consultations

A workshop was held in Kelowna in November 2003 to initiate the joint project to study the groundwater resources in the Okanagan watershed. There were over 50 attendees at the workshop and the participants ranged from water purveyors and drillers to local, provincial and federal government representatives. One of the main purposes of the workshop was to solicit input from attendees and identify their needs with respect to the groundwater resource in the region so that these needs could be incorporated into the project design.

The issues identified in this sessions fall into three categories: science, management and community outreach. The science questions centre on groundwater sustainability and vulnerability and the identification of recharge areas. Control of groundwater withdrawals, water conflicts and conjunctive water use were some of the management issues raised. Enhanced awareness of groundwater and groundwater protection plans were two of the community outreach issues identified. In addition to highlighting key groundwater issues, the workshop was beneficial in establishing connections to stakeholder groups in the basin and available information resources for the project.

Key project activities

In June 2004, the GAOB Working Group and invited participants travelled the Okanagan Basin from Osoyoos to Armstrong, stopping at different places where there were known water supply or quality concerns, provincial monitoring locations, geological and hydrogeological places of significance, and areas where there are surface / groundwater concerns. The Working Group also met with local water stewardship groups and other provincial and local government staff along the route (Figure 1).

Figure 1. Field trip participants identify and discuss groundwater supply and quality issues (June 2004).

The major research themes for this regional groundwater assessment include characterizing aquifers, estimating water budgets, gaining a better understanding of groundwater/surface water interactions, water quality, and climate change. In addition to providing scientific assessments of the quality and quantity of the Okanagan Basin's groundwater resource, this project will communicate the scientific findings to the public, land use and resource decision makers and industry through community outreach activities.

Over the past 6 months there have been a variety of projects initiated as set out in the GAOB 2004/2005 workplan including:

WELL pilot project	The provincial WELL database will be updated in the Okanagan Basin – at the present time there are 1400 well records in various stages of being processed which includes locating and digitizing the well's location. This pilot project will assist in establishing a process to address the backlog of well records to be processed.
Drinking Water Supply Cross-Referencing Pilot project	This Interior Health Authority (IHA), Ministry of Health Services and Ministry of Water, Land and Air Protection partnership project will result in key data and information being collected on all the drinking water supplies in the IHA's Okanagan Service area. This includes accurately georeferencing points of extraction as well as important sub-facilities and monitoring locations for both surface and groundwater drinking water supplies. The data and information collected from this pilot project will be entered into a data management system developed by the Drinking Water Information Management Project (DWIMP) team at the Ministry of Health Services. This pilot project will assist in developing a process to inventory drinking water systems on a provincial basis.
Collection of well records and reports	A student from the Okanagan University College was hired to collect well records for those wells not currently entered into the provincial WELL database as well as any consultant or engineering report that provides information and data on the groundwater resources in the Okanagan Basin. A Consent to Use form was developed and is being used to acquire consent from the owner of the report/data for use in the study.
Analysis of Okanagan Basin pumping test data	A student from the University of Victoria has been hired to complete analysis work on pumping test data collected through the above mentioned project as well as from Ministry files and libraries to determine hydraulic properties and boundary conditions of the various aquifers in the Okanagan Basin.
Slug testing of provincial observation wells	A student from Simon Fraser University completed the slug testing of 14 different provincial observation wells in the Okanagan Basin in the summer of 2004. Analysis will include assessing the use of different methods to estimate hydraulic conductivity values and analysis of climate data.
Map Compilation	Surficial and bedrock geology maps for the northern part of the basin are being compiled and digitized by the Geological Survey of Canada to provide a regional framework for aquifer characterization and groundwater modeling studies.
Waterscape Poster	Development of an educational poster to reflect key water resource issues in the Okanagan region. An interactive poster design process provides a venue for communities to share

information and knowledge on key water resource issues in the region. The final poster product can help promote understanding and wise use of water among residents and visitors.

Aquifer characterization

A numerical groundwater modeling project to look at climate change impacts in the study area from Skaha Lake to the top of Osoyoos Lake area has been initiated by a graduate student from Simon Fraser University and will be ongoing over the next year.

Okanagan Valley Dissolved Oxygen and Nitrate Study

Led by Dr. Jim Hendry from the Canadian Centre of Excellence for Water, this research project is located in the Osoyoos Lake area. Geochemical and isotopic techniques will be used to characterize regional impacts to groundwater and surface water as a result of agricultural activity and regional mapping of nitrogen species will be conducted. The data from the study will support a hydrogeologic model designed to provide insight into the time required for BMPs to influence groundwater and surface water quality. This study will also provide baseline data on the impact of global warming.

Consultations with local governments

Members from the GAOB team met with representatives from various local governments in December 2004 and in January 2005. These meetings discussed the objectives of GAOB and local priority issues. Areas of collaboration between the project and local governments are being determined.

Partnership agreement

An agreement between the Earth Sciences Sector of NRCan and the Ministry of Water, Land and Air Protection is in progress to formalize a working arrangement for regional groundwater characterization and assessment work in British Columbia.

It is anticipated that the outputs from current and future GAOB associated projects will provide information and data on the following:

- a quantitative and qualitative assessment of the groundwater resource in the Okanagan Basin including a regional water budget;
- hydraulic properties and estimations of vulnerability of key aquifers in the Okanagan Basin;
- an increased understanding of groundwater/surface water interactions in key locations in the Okanagan Basin;
- the development of an interactive GIS database and numerical models for key Okanagan Basin aquifers and groundwater characteristics as part of the national and provincial databases;
- greater understanding of the potential impacts of climate change on the groundwater resource in the Okanagan Basin;
- outreach activities for increasing groundwater awareness of the groundwater resource; and

- development of a process to incorporate the science-based results into sustainable water management practices for communities in the Okanagan Basin.

Science-Policy Linkages

While the concepts of sustainability and smart growth resonate with many, it is not always clear how best to incorporate these strategies and the underlying base of scientific information into the context of ongoing planning, decision making and policy development. 'Place-based planning' is an emerging field of research and practice that supports interactive exploration of choices and consequences through the integration of expert and local knowledge, 'what-if' scenario modelling and landscape visualization. The integration of place-based community design and collaborative decision making offer a means of engaging citizens, planners and government agencies in an ongoing dialogue about policy options (choices and consequences), thereby helping to narrow the gap between intent and action.

It is the cumulative impact of individual and collective decisions made at the community and regional district level that have the most significant impact on the protection and management of groundwater resources. And, it is at this level of policy development and decision-making where the outputs of academic, private sector and federal-provincial groundwater studies (information knowledge and expertise) are most relevant, yet often least accessible.

Bridging the gap between groundwater science and water resource management is a key objective of GAOB. This objective is underscored by a partnership with the 'Pathways' project, an initiative of the Earth Sciences Sector of Natural Resources Canada, that aims to promote, facilitate and evaluate the use of public geoscience knowledge and decision support tools in the context of participatory place-based planning (Figure 2).

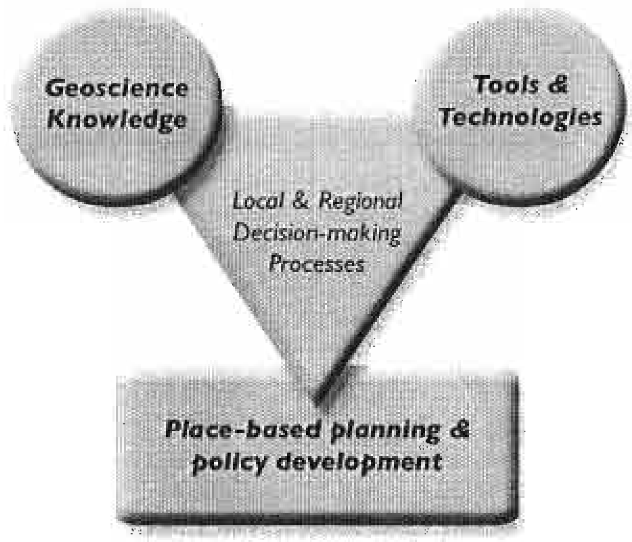

Figure 2. Components of the 'Pathways' project.

The 'Pathways' approach consists of a three-part framework (Figure 3) that relies on principles of collaborative decision making to integrate geoscience knowledge with short and long –term planning and policy activities identified by local and regional agencies responsible for water resource management in the Okanagan. We make use of 'what-if' scenario modelling and landscape visualization tools to assist community and regional district level planners in evaluating the potential impacts of alternate growth strategies on available groundwater resources in the region. The scenario models incorporate the outputs of aquifer characterization and watershed modelling studies carried out by GAOB and other research partners, and provide a framework for assessing the consequences of land use and community planning decisions with respect to both aquifer vulnerability and sustainable yield of groundwater resources. In addition, Pathways capitalizes on emerging information technologies to create collaborative decision environments where project members and community partners can exchange knowledge and manage information relevant to both the resource assessment and vulnerability assessments on an on-going basis.

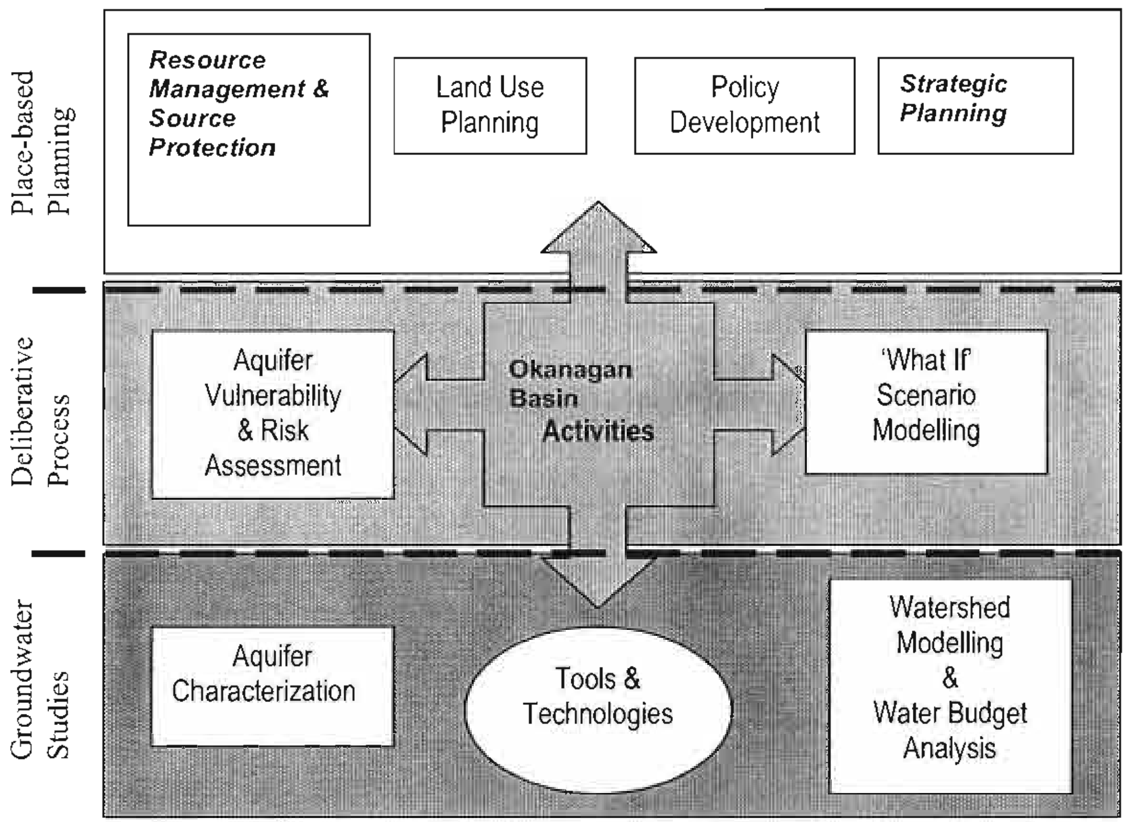

Figure 3. Pathways' three-tier approach to link groundwater studies with short and long-term planning activities.

Collaboration with Local Governments

Representatives from the BC Ministry of Water, Land and Air Protection (MWLAP) and the NRCan Pathways project met with local and regional government agencies in December 2004 and January 2005 to identify site-specific groundwater resource management issues, to provide an overview of the GAOB research and outreach activities, and to explore collaboration opportunities with ongoing water resource management activities. These consultations reiterated the interest in further understanding surface/groundwater interaction and provide a means of developing a groundwater science program that better reflects the needs of community and regional district planners in the Okanagan Basin.

Conclusions

This regional partnership project will enhance the knowledge of groundwater in this important region of the province and will assist in answering important questions on sustainability and management of the groundwater resources in the Okanagan Basin. The development of partnerships and establishing working relationships with agencies and key stakeholders will build in credibility to the project and provide a sense of ownership to those involved. One key objective of the study is to ensure the results are used and incorporated into the business needs of communities in the Okanagan Basin. Community outreach programs will engage the public and raise awareness of this important resource.

Water quality in the Okanagan Basin: dependence on spatial and temporal drivers.

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Abstract

Key water quality concerns in the Okanagan Valley include the presence and levels of pathogens, turbidity, organic color; and nutrients in water. All of these variables are affected by water management decisions in the basin, and all vary temporally and spatially. The high degree of spatial and temporal variation is driven mainly by variation in climate, surficial geology, hydrology, land- and water-use. Complicating management decisions is the variation in sensitivity of different compartments of the water resources to perturbation of hydrology and land- and water-use.

The ultimate source of water, precipitation, has excellent water quality throughout the basin, however precipitation is distributed unevenly and generally increases with increasing elevation. Water quality at any point in the basin depends on local watershed properties and water supply, and on the watershed properties and supply from the up-slope catchment. Thus, much of the variation in water quality is driven by a combination of properties along a hydrologic flowpath.

In this paper, I evaluate spatial and temporal trends (seasonal and long-term) along Okanagan Basin flow paths within/from high and low elevation watersheds, and along the mainstem lakes. Data and mechanistic models are applied to assess sensitive elements of the basin that may provide early warnings of threats to water quality.

Okanagan Basin Water Quality: Background and History

The Okanagan Basin is a relatively small watershed (8,200 km^2). The lower elevations have a semi-arid climate and are dominated by relatively large mainstem lakes. Precipitation increases with increasing elevation into the forested plateau, and subalpine and alpine highlands. Most of the water in the Okanagan Basin is derived from the higher elevations of the basin, remote from the population centers.

Variation in water quality is dependent on the interaction of water with materials and biota along its flow path. Thus, water interacts with soils, rocks and sediments; and plants, animals and microorganisms. These interactions can be modified by human activities. For example, forestry, road building and ranching and modify the highland watershed. In contrast, agriculture and urbanization modify low elevations of the watershed.

Because of rapid population growth in the 1960s, concerns emerged that water use might exceed water supply and that water quality would be degraded. The governments of Canada and British Columbia undertook a study of the Okanagan Basin (Okanagan Basin Study, OBS) to assess threats to water supply and water quality, and provide recommendations to safeguard the water resource. The perceived threats to water quality were from plant nutrients (esp. phosphorus), pathogenic organisms, and turbidity from erosion in watersheds. These variables occur naturally in water, but are strongly affected by modifications of the watershed. The different water quality variables are associated with different management problems. Nutrients cause excessive growth of algae that degrade water quality for aesthetic and recreational purposes, and for drinking. E. coli causes gastroenteritis, sometimes severe enough to cause death in humans. Finally, turbidity in water degrades the aesthetic quality and interferes with normal disinfection of drinking water.

Sampling for water quality was conducted in 1969-1971 in streams, groundwater, and lakes. Results of sampling conducted indicated that ground waters were generally good water quality with a tendency to be rich in calcium, magnesium and bicarbonate.

Stream water quality was often good for all of the 22 study creeks (Table 1, from OBS 1974). However exceedences were recorded in all creeks for turbidity, color and total phosphorus. Maximum values for the study creeks were 2-100 times acceptable levels for turbidity, 1.5-9 times acceptable levels for color 1-100 times acceptable levels for phosphorus. In general, these exceedences are associated with high flow during snowmelt (freshette). More than half of the creeks had fecal choliform densities in excess of acceptable levels.

All of the lakes had relatively low turbidity levels and color levels, and where measured low levels of fecal choliform bacteria, however bacterial sampling was focussed mainly on beach areas. Phosphorus levels varied considerably among lakes. Kalamalka Lake and parts of Okanagan Lake had excellent quality, with low levels of nutrients and associated algae. In contrast, Wood Lake, Skaha Lake and Osoyoos Lake had levels of nutrients sufficient to stimulate high levels of algae and degrade water quality.

Table 1. Raw water quality from Okanagan Basin Streams 1969-1971

CREEK NAME	LOCATION AND STATION	PHYSICAL			BIOLOGICAL	
		COLOR True Color Units	TURBIDITY Jackson Turbidity Units	TOTAL PHOSPHORUS parts per million	TOTAL COLIFORM DENSITY Organisms per 100 mls	FECAL COLIFORM DENSITY Organisms per 100 mls
GENERALLY ACCEPTED CRITERIA FOR DRINKING WATER STANDARDS		15	5	0.065	1000	100
Inkaneep	At Mouth (501)	5-75	1.5-165	.007-.359	1,263	115
Vaseux	At Mouth (504)	5-65	0.2-11	.003-.039	70	5
Shuttleworth	At Mouth (506)	0-75	0.2-140	.003-.424	918	65
Ellis	At Mouth (510)	5-85	0.9-260	.007-.457	542	8
Penticton	At Mouth (511)	10-70	0.7-62	.003-.350	516	26
Trout	At Mouth (512)	0-40	0.2-210	.003-1.27	850	20
Peachland	At Mouth (514)	0-65	0.2-57	.003-.245	349	6
Powers	At Mouth (516)	5-65	0.3-60	.007-.330	490	14
Westbank	At Mouth (517)	5-45	4.0-230	.038-1.27	5,420	232
Bellevue	At Mouth (519)	0-60	0.2-35	.001-1.24	240	6
Mission	At Mouth (520)	5-50	0.5-43	.003-.783	500	86
Mission	Above Urban Area (536)	5-50	0.4-26	.007-.205	109	9
Brandt's	On Guy Street (522)	10-70	2.4-115	.058-2.70	169,000	980
Lambly	At Mouth (523)	0-75	0.1-16	.007-3.79	86	4
Shorts	At Mouth (526)	0-50	0.2-150	.007-3.40	918	13
Equesis	At Mouth (528)	0-45	0.5-160	.009-1.21	939	123
Kelowna	At Mouth (521)	5-65	3.1-13	.020-.750	5,420	1,122
Kelowna	Above Urban Area (537)	5-90	1.7-44	.072-.300	800	238
Deep	Above Armstrong (540)	5-75	0.3-13	.033-.108	1,300	163
Deep	At Mouth (529)	10-110	0.5-70	.050-.717	1,300	129
Vernon	At Okanagan Lake (530)	5-20	1.8-63	.039-1.86	5,420	430
Vernon	Above Ellison Lake (524)	0-110	0.2-1000	.007-5.69	109	8
Coldstream	At Mouth	0-45	0.4-53	.016-.750	1,410	177

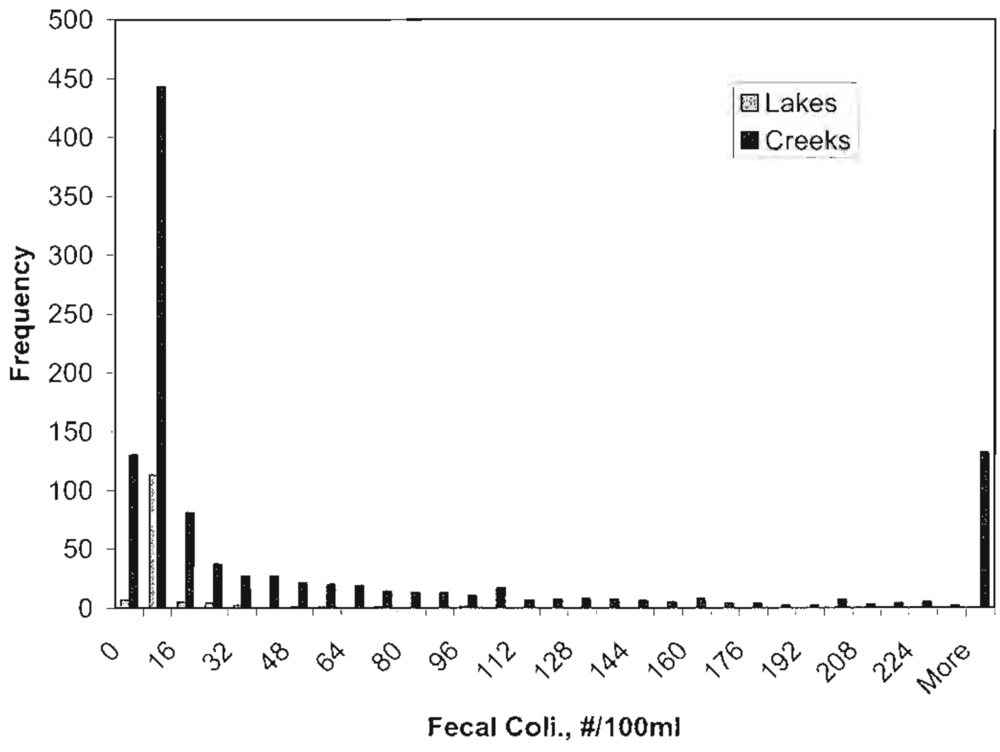
Evaluation of water quality and the drivers of water quality degradation led to recommendations for water quality protection. The recommendations included buffer zone around creeks to protect water quality from forestry and agricultural activities; upgrades to waste water treatment facilities to limit phosphorus and fecal choliform loading to lakes; and limitations to growth rate owing to the direct relationships between population growth and urban and wastewater related degradation of water quality.

Okanagan Basin Water Quality: The Present

Implementation of the recommendations of the OBS has been partially achieved. In the forested higher elevation watershed, buffer zones are required generally around creeks under the codes of forest practices in British Columbia. All of the major centres in the Okanagan Basin have advanced wastewater treatment capacity and loadings of nutrients to the mainstem lakes from wastewater decreased. Possibly the greatest exceedence of OBS recommendations is in population growth. Rates of population growth remain among the highest in Canada. For examples rates averaged 4% per year in Kelowna for 1988-1999.

Streams in the Okanagan Basin continue to show elevated levels of turbidity, fecal choliforms, color, and phosphorus. While buffer zones are effective in reducing turbidity from soil erosion, high flows during freshette conditions are sufficiently powerful to erode most stream channels in the Okanagan Basin. Confounding the interpretation of these changes, water storage reservoirs have been constructed to supply increasing water needs. Water storage reservoirs and attenuate flood flows from snowmelt and increase the residence time of water in the highlands. Storage of water in reservoirs can potentially decrease turbidity in creeks in two ways. First, the power available for channel erosion in freshette is reduced. Secondly, storage reservoirs scavenge efficiently fine particles from water by sedimentation. Given the high temporal variation, turbidity levels are probably not significantly different from levels measured for the OBS.

Levels of fecal choliforms in stream waters are slightly lower to relatively unchanged since the OBS (Fig 1). Given, that fecal choliforms are present in warm-blooded animals, occurrences of high levels of fecal choliforms are inevitable. In addition to fecal choliforms,



Cryptosporidium and Giardia occur commonly in Okanagan Basin stream waters. These parasites are particularly problematic because they are more resistant to normal disinfection with chlorine. Water storage reservoirs reduce significantly pathogen levels as they are scavenged or die during residence in the reservoirs. Water discharged from reservoirs apparently recruits pathogenic organisms along the flow path to lower elevations where most intakes are located.

Water color and phosphorus levels in stream water are similarly unchanged. Recent studies have shown that forest harvesting has little effect on levels of phosphorus in streams. However there is evidence to show that levels of organic color can increase after forest harvesting. Since the OBS, organic color has been linked to formation of trihalomethanes (THMs) during normal chlorination. With THM formation potential of 50 ug per mg of dissolved organic carbon (DOC), there is ample dissolved organic matter in many Okanagan Basin streams to exceed the Canadian guideline of 100 ug L^{-1} after normal chlorination. Nutrients and the dissolved organic substances causing color can be scavenged in storage reservoirs, however the net effect of reservoir construction on nutrients and color is unknown.

Trepanier Creek receives drainage from the Brenda Mine site that is rich in molybdenum. On-site measures and timing of drainage releases are in place to minimize the degradation of water quality in Trepanier Creek, especially for use in irrigation of forages where high levels of molybdenum are associated with molybdenosis in cattle. High levels of molybdenum appear to be specific to Trepanier Creek.

Few problems were identified in groundwater quality during the OBS. Most of the identified aquifers are in the low elevations of the basin. Consequently, groundwater problems typical of urban and agricultural land have been identified subsequently in shallow aquifers of the Okanagan Basin. For example, nitrate from agriculture and septic tanks contaminates shallow, low-elevation aquifers in the south Okanagan. Similarly, leakage from underground storage tanks, especially from gas stations, has cause local contamination of shallow ground waters and receiving waters. Locally, high levels of fluoride occur in water in aquifers with fluorite-rich recharge areas. In general, the Okanagan Basin experiences problems of groundwater contamination that are typical of agricultural and urban areas.

Nutrients remain the primary water quality problem in the Okanagan Basin mainstem lakes. Turbidity, fecal choliforms (Fig 1) and color levels remain low. Nutrient and productivity status of Okanagan Basin lakes is categorically unchanged since the OBS. Okanagan and Kalamalka Lakes remain low productivity or oligotrophic lakes, whereas Ellison, Wood, Skaha, and Osoyoos Lakes are moderately to highly productive or mesotrophic to eutrophic. Upgrades to wastewater treatment have reduced the per capita nutrient load to the lakes. Nutrient levels remain at about levels observed from the OBS. Reductions in municipal loading of phosphorus to the lakes has been somewhat compensated by population growth – roughly double the population of the OBS. The clearest example of the positive effect of upgrades to wastewater treatment are in Vernon Arm of Okanagan lake where an irrigation-based system reduced concentrations of phosphorus and abundances of algae from levels more than double the lake average to levels typical of the main basins of Okanagan Lake.

Potential changes in phosphorus and algal biomass in the chain of Ellison, Wood and Kalamalka Lakes is complicated because of changes to both nutrient loading and to hydrologic residence time in the lakes. Nutrient loading to these lakes has likely decreased as septic systems have been replaced with modern wastewater treatment. Concurrently, the closure of the Hyram Walker distillery and the cessation of the discharge of large volumes of low-nutrient cooling water from the distillery have increased the water residence time in these lakes. Cooling water discharges diluted and flushed nutrients down the chain of lakes. This caused reductions in nutrient levels and productivity in Wood Lake but increases in Kalamalka Lake. Closure of the distillery is consistent with observed decreases in phosphorus levels in Kalamalka Lake. However, the expected rebound of Wood Lake to its former high level of phosphorus has not occurred, possibly due to reductions in phosphorus loading.

The dynamics of nutrients in the Okanagan mainstem lakes does not apparently follow quantitatively predictions from conventional nutrient dynamic models. However, nutrient concentrations increase generally with increasing areal loadings among the lakes: the oligotrophic lakes (Kalmalka and Okanagan) have loadings of about 150-200 mg m^{-2} y^{-1}, whereas the mesotrophic to eutrophic lakes have loadings of 350-900 mg m^{-2} y^{-1}. Deviations from model predictions could also be due to differences between the model calibration lakes and the Okanagan mainstem lakes. Though, considered independent statistically for purposes of modeling, nutrient loading and hydrologic flushing rate are not independent because the flushing water invariably contains some nutrients. In the case of the Okanagan mainstem lakes, much of the water flushed through lower elevation lakes has had previous residence in a lake. This unusual hydrologic phenomenon may be sufficient to put the Okanagan mainstem lakes outside the normal distribution of nutrient dynamics. Finally, for the low nutrient lakes (Kalamalka and Okanagan Lakes), analytical detection limits for phosphorus probably limit accuracy of model estimation. Detection limits for phosphorus are 0.001 mg/L – often 15-25% of measured phosphorus levels in lake water. Thus, only relatively large changes can be detected.

In spite of the uncertainties, all of the Okanagan mainstem lakes demonstrate high net phosphorus mass transfer (aka. settling) rates (Fig. 2). Consequently, concentrations of phosphorus depend very strongly on hydrologic residence time. Long hydrologic residence time affords more time for mechanisms of phosphorus retention to operate and greater dilution of phosphorus loading. Thus, observed phosphorus retention rate (the net proportion of phosphorus loading that is lost to sediments) depends highly on hydrologic flushing, though still somewhat outside the model norms (Fig. 3). Accurate lake-specific predictive models could be calibrated for Okanagan mainstem from the relatively large interannual natural variation in phosphorus loading.

Among all sources of water, the highest quality will probably come from a subset of small aquifers. Optimally, the residence times will be short enough to minimize dissolution of minerals that contribute to hardness and salinity, yet long enough to adequately remove organic color and pathogens from water. The adequacy of such supplies to serve a significant portion of the Okanagan Basin population is questionable. Water in Kalamalka and Okanagan Lakes is high quality. The long residence time of these lakes vastly reduces turbidity, natural color, phosphorus and fecal choliform levels. The rapidly flushed lakes (Wood, Skaha, Osoyoos Lakes) generally have low water color and fecal choliforms relative to streams, but the can have elevated nutrient levels and turbidity from episodic, excessive growths of algae (algal blooms). Taken together, the most abundant and highest quality waters in the Okanagan Basin are in Kalamalka and Okanagan Lakes.

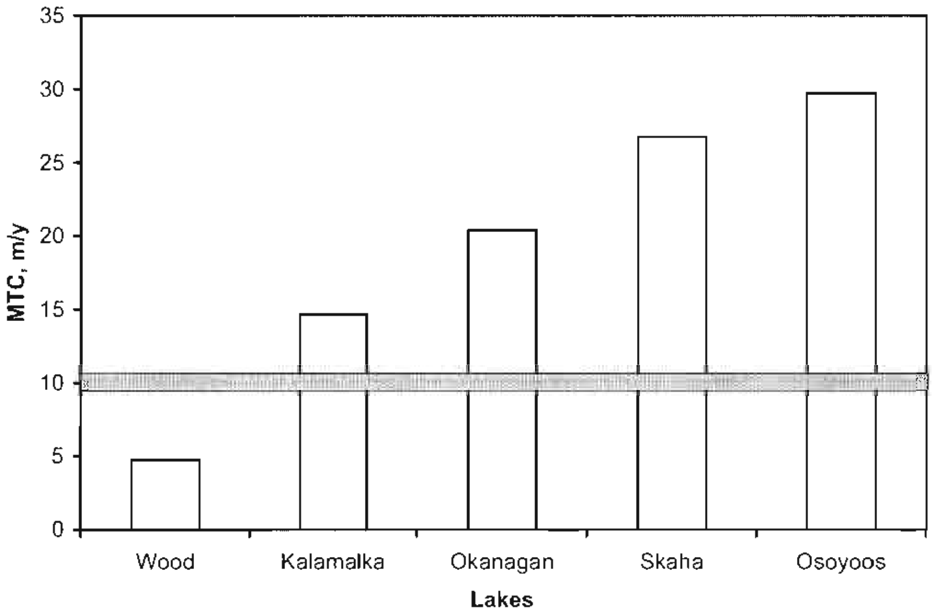


Figure 2. Mass transfer coefficients for phosphorus in Okanagan Basin Lakes. Normal values are around 10 m y^{-1} (grey bar).

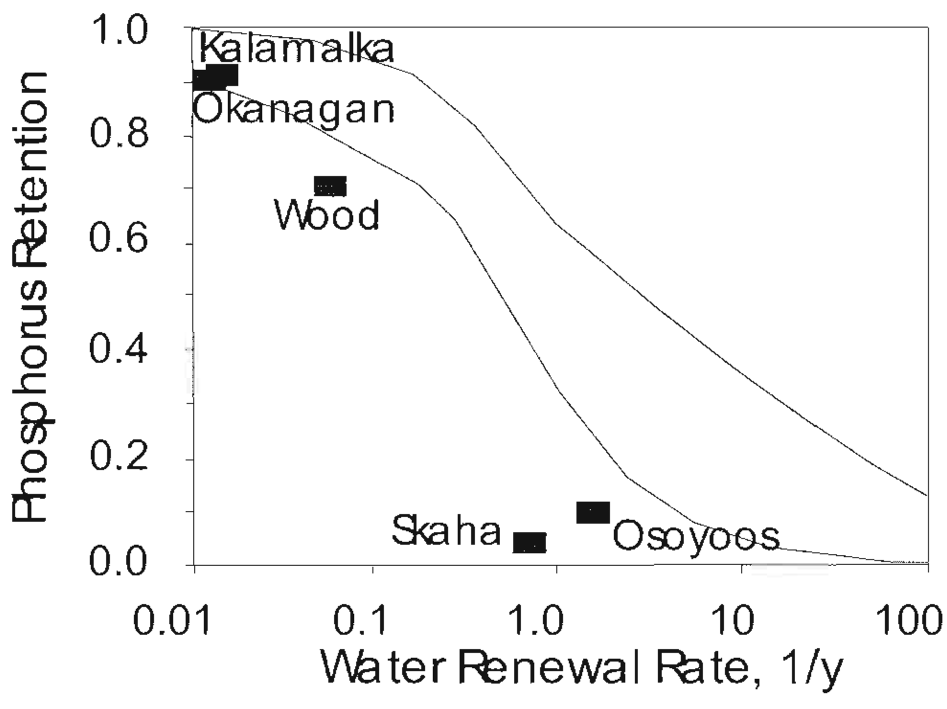


Figure 3. Phosphorus retention for Okanagan Basin Lakes. The area between the curves is the range of model predictions for different models of phosphorus dynamics.

Okanagan Water Quality: The Future

It is likely that future water quality problems will include a subset of the water quality problems of today. Many of the water quality problems in Okanagan Basin streams (turbidity, color, phosphorus and fecal choliforms) are natural but can be exacerbated by human activities. Best practices will reduce the human component of the problem, but for many streams water quality problems will persist. Water quality problems in Okanagan Basin ground waters will be revealed in time as groundwater assessment occur. The main challenges will continue to be preserving the quality of our best and most abundant water supplies. This challenge is made difficult because these water supplies occupy the lowest elevations in the basin. Consequently all uses of land and water in the Okanagan Basin will affect these water supplies.

Point sources of water quality problems (waste and industrial water discharges) in the Okanagan Basin have largely been addressed. Many of the non-point source problems (poorly functioning septic tanks, and of agriculture and urbanization) are challenges for our future. Quite possibly the most difficult decisions will be over trade-offs of water quality (and quantity) with development and population growth.

New water quality concerns are likely to emerge that may threaten future water supplies. In particular, as pharmaceutical use increases so does the occurrence of pharmaceuticals and their derivatives in wastewater. These substances are designed to be bioactive, and have unintended effects in the environment. The likelihood that substances having short environmental lifetimes (e.g. estrogen) would pose threats to lake water quality is diminished somewhat by the hydrology of the basin and the location of population centres. Rapid environmental degradation will limit levels of these substances in long residence time lakes. In contrast, rapidly flushed lakes will limit levels by dilution. The most significant threats to Okanagan Basin water quality could come from soluble and persistent substances. The Okanagan Basin is sensitive to such contaminants because water supplies are low relative to the population. We owe much of our present high water quality to the capacity for the mainstem lakes to "purify" the water they receive.

Okanagan Basin Water Quality: Recommendations

1) Develop lake-specific calibrated models of lake water quality. These models will certainly be useful for predicting the response of lakes to nutrient loading changes. They will also provide the fundamental framework to model the behavior of other water quality variables. This approach could be extended to water storage reservoirs to evaluate their role in modifying stream water quality
2) Develop decision support tools that incorporate water quality tradeoffs in decision making. High quality water in the Okanagan Basin is highly valued for economic, social and environmental purposes. Decision-making that compromises water quality should account for the trade-offs.

Acknowledgement: Thanks to E. Radomske for compiling the reports and data, and to colleagues on whom these ideas have been bounced.

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Fisheries and Aquatic Resources in the Okanagan Basin Past, Present and Future.

by
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Abstract
The Okanagan Basin study and Okanagan Basin Water Agreement (OBWA) of the 1970's highlighted the high degree of interdependence among the state of fisheries, aquatic resources and the quantity and quality of water supplies. The Canada-BC OBWA was created to identify and then address water supply issues where resource managers face competing objectives such as flood control, drought relief, support of recreational activities, conservation and restoration of fisheries and aquatic resources. Further, the Okanagan Basin study identified rapid growth of human populations in the basin as a critical threat to sustainable management of both water quantity and quality. Attempts to conserve and restore fisheries and aquatic resources in the Okanagan Basin during the 30 plus years since the OBWA have been marked by successes and setbacks. Successes include: reducing water quality threats to fish through reductions in nutrient loading; managing water to avoid property losses from flood or drought events with due consideration of risks to fisheries and aquatic resource values; increased levels of engagement by communities of place to resolve aquatic resource management issues and increased awareness that aquatic resources and ecosystem services have value at local to "global' levels. Setbacks encountered include: conflicts as human population growth increases pressure on water and habitat that are critical to aquatics resources (e.g. Summerland and Trout Ck in 2003); failure to control the spread and impact of exotic species on native species (e.g. mysids shrimp impacts on salmonids); erosion of linkages between human populations and fisheries resources and the lack of consensus on the relative value of natural ecosystems to human populations in the Okanagan Valley. Challenges to consider in the near future include: managing cumulative impacts of human populations on aquatic resources, identifying viable options for aquatic ecosystem restoration, preparing for climate change impacts and, last but not least, maintenance of an aquatic stewardship ethic.

Impacts of Population Growth on Okanagan Water Resources

by

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Abstract

A major driver of future demand for water is population growth. With the diversity of the economy and abundant community amenities, rapid population growth in the Okanagan Basin is projected to continue. This growth is driven by strong rates of in-migration. Both new comers and today's residents will be challenged in their perceptions of an unlimited supply of fresh water.

An increase in population, from 315,000 today to over 460,000 residents in the next 25 years is realistic. At current rates of water use in the Okanagan Basin, and under present management regimes, water demand is forecast to outstrip available supply in some regions.

Using BC Stats population projections and potential future settlement patterns, this paper examines three growth scenarios for the Okanagan in year 2031. The implications for water demand and water resources will become apparent and provide the context for considering alternative approaches to land and water management within the Okanagan.

1.0 Introduction

This paper uses provincial population projections, assumptions of water supply, and typical rates of water use to demonstrate the potential impacts of population growth within the Okanagan Basin. Three future land use scenarios are assessed for purpose of comparing impacts on water supply.

When examining the impacts of growth, water resource agencies and non-government organizations rely on provincial planning frameworks to manage for growth. A description of current provincial land use planning frameworks is provided as context to this paper.

2.0 Current Population

Population and demographic characteristics of the Okanagan are projected and updated on a six - month basis by BC Stats for purpose of capital (infrastructure) planning. The numbers are verified every five years, upon release of Statistics Canada Census data, and the projections are typically found to be correct (within an acceptable one or two percent margin of error).

The statistics are published by Regional Districts (Okanagan Similkameen, Central Okanagan, and North Okanagan) referred to in this paper as "South, Central and North". Current population, as of December 2004 is 314,728 persons within the Okanagan Basin. In the rest of this paper, the author will cite current population as **315,000** residents.

CURRENT POPULATION[10]			
South	Central	North	Total Basin
78,012	162,555	74,161	314,728

The current population, though small compared to some regions of Canada, is high when compared to the amount of fresh water found in the desert climate of the Okanagan. Statistics Canada reported the critical factors, in 2003[11]:

"Over the past 30 years, the population of British Columbia's Okanagan-Similkameen river basin has more than doubled, the fastest growth rate among the 23 major river basins in Canada. However, this scenic region in the British Columbia interior also has one of Canada's lowest renewable supplies of fresh water.
The Okanagan-Similkameen basin has only 0.1% of the country's renewable supply of fresh water. In comparison, the Great Lakes-St. Lawrence basin has 6.8% of the renewable supply of fresh water, the Pacific Coastal basin has 15.8%, and the Northern Quebec basin has 16.0%.
From 1971 to 2001, the population of the Okanagan-Similkameen basin increased 137% to 285,145.
The impact of this strong growth in population can also be examined on the basis of two other indicators: the number of people for every square kilometer of land, and the number for every square km of surface water.
In 2001, the Okanagan-Similkameen river basin ranked first in Canada in terms of the number of people for each square km of surface water, and second only to the Great Lakes-St. Lawrence river basin in terms of population density for every square km of land.
The Okanagan-Similkameen river basin had nearly 439 people for every square km of surface water. This was well ahead of its closest rival, the South Saskatchewan River basin, which had almost 284 people for every square km. British Columbia's Fraser River valley was a close third, with 224. The Great Lakes-St. Lawrence basin, the most populated basin in Canada, had only 131 people for every square km of water.
In terms of land, an average of just over 30 people lived in every square km of land in the Great Lakes-St. Lawrence river basin in 2001, the highest ratio in Canada. The Okanagan-Similkameen river basin was in second place with about 18 people for every square km of land."

3.0 Current Water Use

Statistics on water use are not maintained on a routine basis. The most recent provincial publication on water quantity in the Okanagan basin comes from a technical report published in 1994 by W. Obedkoff, BC Water Management Division.

[10] BC Stats *Municipal Population Estimates, 2004* Website release December 2004. Note, this table excludes the population of four municipalities situated outside of the Okanagan Basin but within the Regional Districts – namely Enderby, Lumby, Princeton and Keremeos. Population of these four communities is currently 8,669 residents. Remaining population statistics in this paper include the four municipalities within their respective regional district population numbers.

[11] Statistics Canada, December 3 2003 website release citing the 2003 edition of *Human activity and the environment: Annual statistics 2003.* Okanagan Similkameen river basin in this Statistics Canada report includes the Basins of the Okanagan and the Similkameen Rivers (not to be confused with the Okanagan Similkameen Regional District)

Other water use statistics have been derived through federal climate change research and through individual community planning programs. The results are applied to the entire Okanagan Basin in this paper simply for purpose of examining the impacts of population growth and alternative land use scenarios.

In using these statistics, the author acknowledges that the results related to water use are subject to varying degrees of error. Caution is needed in analyzing population growth impacts until up-to- date and verifiable water use surveys are conducted throughout the basin. However, for purpose of this preseutation, the following assumptions of annual water use are applied:

<table>
<tr><td>Total Water Licensed Quantity (2002):</td><td>476.8 million cubic meters</td></tr>
<tr><td colspan="2">Source: Environment Canada report [12] citing Land aud Water BC water license query</td></tr>
</table>

<table>
<tr><td>Water Used for Domestic Purpose (2004):</td><td>157.5 million cubic meters</td></tr>
<tr><td colspan="2">Based on Lakeview Irrigation District estimate by UMA (1992) cited by Summit [13] of 1,370 L/day per person in drought years consisting of 370L/day for indoor use and 1,000 L/day outdoor use. Equivalent to 500 cubic meters per year per resident and incorporates all non-agricultural uses including commercial, industrial, rural residential irrigation and distribution losses.
Range of other research reports District of Peachland at 900 L/day per person, year 2000 estimates for Lakeview Irrigation District at 865 L/day per person both cited by Summit, and City of Penticton at 677 litres per day per person residential/commercial use cited by Environment Canada, 2004 [14].
Based on a current population of 315,000 residents.</td></tr>
</table>

<table>
<tr><td>Water Used for Agricultural Purpose (2004):</td><td>256.5 million cubic meters</td></tr>
<tr><td colspan="2">Based on figure of "three acre-feet per acre per year" cited as commonly used by provincial water resource managers to assess and application for irrigation connection. Equivalent to 9,250 cubic meters per hectare. Range is from 1 to 4 acre-feet per year, depending on soil types, location in the Okanagan, and individual system allocations.
Total area of land irrigated in Okanagan Basin assumed at 27,739 hectares [15]; equivalent to 15% of the total 176,000 hectares in the Basin designated Agricultural Land Reserve [16].</td></tr>
</table>

<table>
<tr><td>Total Water Used (2004):</td><td>414 million cubic meters</td></tr>
<tr><td colspan="2">Based on domestic and agricultural estimates above. This number does not include water volumes to uses such as conservation flows and international flow agreements.</td></tr>
</table>

The author notes that the assumed rates of agricultural and domestic uses are higher than most communities are recording. However, work completed in 1994 by W. Obedkoff[17] concluded that water use consumption in the Okanagan at that time was 356 million cubic meters, about 75% of the then licensed 385,000 acre-feet. This use had risen since the rate recorded in 1971 [18] of 286 million cubic meters (231,554 acre-feet).

[12] Environment Canada *Expanding the Dialogue on Climate Change and Water Management in the Okanagan Basin, British Columbia Final Report,* June 30, 2004; page 15

[13] Regional District of Central Okanagan *Trepanier Landscape Unit Water Management Plan* 2004; by Summit Environmental Consultants Ltd., Volume 1 page 69.

[14] Environment Canada *Expanding the Dialogue on Climate Change and Water Management in the Okanagan Basin, British Columbia Final Report June* 30, 2004; page 135

[15] Environment Canada, *Expanding the Dialogue on Climate Change and Water Management in the Okanagan Basin*, June 2004; by Stuart Cohen and others, page 91

[16] Agricultural Land Reserve website December 2004 statistics by Regional District.

[17] Province of BC, Water Management Division, *Okanagan Basin Water Supply*, March 1994 by W. Obedkoff.

[18] Okanagan Study Committee (Okanagan Basin Study) Technical Report No. 7 *Preliminary Estimates of Present Water Requirements in the Okanagan Basin,* 1972

Thus the author accepts that domestic and agricultural water use today may be 414 million cubic meters, particularly in the routine drier years and that the calculations in this paper may be assumed correct for purpose of looking at the theoretical impacts of future population growth.

4.0 Historic and Projected Population Growth

Looking back to 1971, the Okanagan was home to 114,000 residents. Since then, the Basin has experienced strong rates of growth and anticipates continued growth over the next 25 to 30 years.

The South Okanagan Similkameen Regional District increased from 52,000 residents 25 years ago, to approximately 80,000 today and is projected at over 100,000 residents by year 2031.

In the Central Okanagan, 1976 saw a population of about 72,000 residents. By 2001, the population had doubled to 154,000. Anticipating a slightly slower growth rate over the next 25 years, the Central Okanagan will reach 250,000 residents.

The North Okanagan Regional District was home to 48,000 residents 25 years ago. Today, it is home to 77,000 residents and is projected to increase to 107,000 residents by year 2031.

Looking at the total basin, in 1976 it was home to 173,600 residents and has increased to 315,000 today. Projections show continued increase over the next 25 years so that by 2031, the Okanagan will be home to over 460,000 residents. In the rest of this paper, the author will cite an anticipated increase of 145,000 new residents in approximately the next 25 years.

POPULATION 1976 to 2031 [19]

	South	Central	North	Total Basin
1971				114,000
1976	52,700	72,900	48,000	173,600
1981	58,500	87,300	55,700	201,500
1986	61,000	92,800	56,900	210,700
1991	68,300	114,700	63,300	246,300
1996	78,800	141,900	74,300	295,000
2001	79,600	154,400	76,400	310,400
2006	80,400	165,600	78,900	324,900 [20]
2011	84,400	181,300	84,800	350,500
2016	89,800	199,400	91,300	380,500

[19] BC STATS *Quarterly Regional Statistics* First Quarter, 2004
[20] BC STATS release in December 2004 shows population of the three regional districts then at 323,397 and includes the four municipalities situated outside of the Basin.

2021	94,800	216,700	97,100	408,600
2026	99,300	233,600	102,400	435,300
2031	103,400	249,800	107,100	460,300

When examining growth rates, this increase in the Okanagan Basin from 1976 to 2031 equates to approximately 2.5% per annum. Some communities in some years have experienced rates as high as 8 % per annum. This higher rate is moderated over the long term by other years where the growth may be quite stagnant in some areas.

The strong rate of growth has been attributed to two general factors.

The first is economic diversity. The Okanagan's economy is good mix of agricultural, forestry and mining, tourism, public and service sectors. Communities are not especially vulnerable to slow downs in one economic sector – the impacts are moderated by other sectors in the same region.

The second key factor is an historic investment in community amenities and infrastructure. These amenities, coupled with a relatively warm and mild climate, make the Okanagan a very attractive region. Thus it experiences a strong rate of in migration of new residents, coupled with average birth rates, and a relatively small rate of out migration.

5.0 Impacts of Population Growth on Water Resources

For the purpose of this paper, an assumption is made that incoming residents (145,000 new by year 2031) will use the same amount of water as today, and that commercial, industrial and other domestic uses will increase at the same rate as residential use. Agricultural lands will not increase and water use will remain the same rate per area of productive land.

Annual Water Use in 2031 : Today's Trends		
		million cubic meters
Domestic Today		**157.5**
Agricultural Today		**256.5**
Increased Domestic	**145,000 x 500 cubic meters**	**72.5**
Total Basin Use 2031		486.5

The results of this scenario is that, by year 2031, accounting for population growth with no change in the volumes of water used, total water use in the Okanagan Basin is projected at 486.5 million cubic meters.

The challenge of this scenario is that the work done in year 1994 by W. Obedkoff indicated that the finite total limit of the water supply available for licensing in the Okanagan Basin was 435,000 acre feet, equivalent to only 532 million cubic meters.

Thus, under current rates of water use, the Okanagan Basin in 2031 would be nearing the finite limit of water supply. There would be no surplus if needed to handle unusually severe droughts, or to adapt to climate change impacts. Perhaps more critical to provincial resource managers is that no expansion of irrigated crops / agricultural land use would be supported. And critical to communities is that the experiences could dramatically vary from one watershed to another and one water purveyor to another.

6.0 Alternative Scenarios

In addressing the future impact of population growth, individual water purveyors and communities are examining an assortment of alternative scenarios. For purpose of this paper, two alternative land use scenarios are presented in order to demonstrate the potential impact on water use.

Both scenarios were compiled by a business advocacy group known as Okanagan Partnership[21], and have been characterized as follows.

Alternative Scenario 1: Sunshine Eclipse

The "Sunshine Eclipse" Scenario is characterized by

- **"Cookie Cutter" single family sprawl**
- **Bottled water, no metering**
- **Convert agricultural lands to residential (as needed) and irrigation to domestic water allocation.**

Applying this scenario, it could be assumed that the new population (145,000) will settle in single family homes, at a person per household density of 2.4 people per unit, similar to today, resulting in 60,415 new dwelling uuits and subdivisions at 6 units per hectare. Thus 10,070 hectares of agricultural land will be removed from crop irrigation.

Annual Water Use in 2031 : Sunshine Eclipse

		million cubic meters
Domestic Today		157.5
Agricultural Today		256.5
Increased Domestic	145,000 x 500 cubic meters	72.5
Reduced Agricultural	(10,070 x 9250 cubic meters)	(93.1)
Total Basin Use 2031		393.4

Alternative Scenario 2: Sustainable Prosperity

Okanagan Partnership's "Sustainable Prosperity" scenario is characterized by:

- **Water Meters, Conservation**
- **Native plant restoration, shared yard space, infill housing**
- **Agricultural Green Belts.**

In this scenario, agricultural water nse will remain the same as today. The new population (145,000) will settle in single-family dwellings on infill subdivisions (supported by extension of community sewer) and in town centre mixed density neighbourhoods. The result will be accommodation of growth with no new lawn space.

[21] Okanagan Partnership, *Okanagan Sustainable Prosperity Strategy, Final Report* June 2004

Residential water use will decrease to that found in Calgary – which is 490 L/day per person. The reduced volume is estimated to affect 50% (an assumed residential portion) of the total domestic use.

Annual Water Use in 2031 : Sustainable Prosperity		
		million cubic meters
Agricultural Today		**256.5**
Domestic Today and Future, half at current domestic rates	**50% of 460,300 at 500 cubic meters (1370 L/day/person)**	**115**
Other half of domestic at reduced rate	**50% of 460,300 at 178 cubic meters (490L/day/person)**	**41**
Total Basin Use 2031		412.5

7.0 Results of Alternative Scenarios

The three scenarios for year 2031, showing "Present Trends", or the alternatives – "Sunshine Eclipse" or "Sustainable Prosperity" demonstrate how impact on water resources might be modified – first by population growth, then by accommodating urban growth on agricultural land, or thirdly by dramatically conserving water used for residential purposes.

The results of the three scenarios are summarized:

Three Scenarios Annual Water Use in 2031, Okanagan Basin	
	million cubic meters
1. Today's Trends in 2031	**486.5**
2. Sunshine Eclipse	**393.4**
3. Sustainable Prosperity	**412.5**

Results show that population growth to year 2031, under current water use rates, would have a considerable impact on water resources. At a future water use volume of 486.5 million cubic meters per year, the scenario brings the Basin close to the finite supply of water available for allocation.

The impacts of population growth may be overcome if there is a reduction of agricultural land to provide for urban growth. In fact, the volume of water used on an annual basis might decrease from the 414 million cubic meters calculated for today to only 393.4 cubic meters. However, replacing agricultural crop production lands would have dramatic negative impact on the economy, landscape and character of the Okanagan, thus is not typically considered a reasonable method of managing for the impacts of population growth on water resources.

A third scenario demonstrates how population growth may be accommodated through a substantial decrease in residential water use (targeted at reducing outdoor irrigation), and would result in a total water use volume of 412.5 million cubic meters, similar to that being used today.

8.0 Planning Framework

The discussion of alternative scenarios and the selection of a preferred course of action (a "Plan") is one that, optimally, would occur at level of the Okanagan Basin. In the absence of this discussion at a regional level, it is the type of analysis now being conducted by many of the larger water purveyors, by stakeholder groups, and by some communities within the Basin.

In considering planning for growth, the author typically categorizes planning programs into strategic and operational (or regulatory).

Strategic plans

Strategic land use planning is a term sometimes used to describe planning for major drainage basins or large socioeconomic regions[22] and is commonly referred to as regional planning, resource land planning or strategic planning. Regardless of name, strategic planning is where the "top down" and the "bottom up naturally intersect and enables participants to consider relationship and linkages between levels of government and between social, economic and environmental objectives[23].

In the Okanagan Valley, there have been several strategic planning exercises with a common objective of managing for sustainable growth on a regional level. Such was the 1969 to 1972 Okanagan Basin Water Study. And similarly, the 1994-2001 Okanagan - Shuswap Land and Resource Management Plan (LRMP). Within the LRMP[24], there is a clear statement of community objectives pertaining to water resources, as well much background detailing the region's land and water resources in the early 1990's.

Strategic Planning between communities occurs through a Regional Growth Strategy framework. The Central Okanagan Regional Growth Strategy (1996-2000) resulted in a common vision statement that starts with *"The region's green spaces and water resources are managed to ensure their long-term health and sustainability"* and concludes with *Valley-wide cooperation is supported to sustain the health of our water, air and lands"*. A subsequent Water Resources Discussion Paper outlined strategies to achieve the Central Okanagan's vision. This same discussion paper provided the rationale for subsequent actions taken by communities of the Regional District, such as the Trepanier Landscape Unit (Westside) Water Management Plan.

The other strategic planning exercises currently underway in the Okanagan Basin include the Regional Growth Strategy for the South Okanagan and the business –led initiative known as the Okanagan Partnership. Another is the work of the Okanagan Nation Alliance, particularly in the long-term management of fisheries resources and treaty lands. A third is

[22] Paraphrasing Daryl W. Brown, BC Commission on Resources and Environment, March 1996
[23] Paraphrasing Daryl W. Brown, BC Commission on Resources and Environment, March 1996
[24] Refer to srmwww.gov.bc.ca/sir/lrmp.okan/

the Climate Change Adaptation research work recently conducted by Environment Canada in association with UBC and the Agriculture Research Station.

Regulatory and Operational Plans

Forming a link between strategic and operational plans, and between provincial and community based planning, at the community level is the Official Community Plan applicable to a municipality or regional district. A Physical Development Plan is the equivalent applicable to a First Nation community.

Taking direction from the Official Community Plan (OCP) is a Zoning Bylaw, which is strictly regulatory in nature. Once the "zoning is in place", development of land for particular land uses at established densities is a right of the property owner and there is little room for further public debate. Subdivision bylaws are also regulatory. In the subdivision bylaw, provision of domestic water is a requirement, but assumption has already been made that the land use is acceptable.

Servicing and infrastructure plans are typically done on the basis of future population assumptions and land use designations contained within the OCP. For instance, irrigation district water distribution designs, Ministry of Transportation Network Road plans, school and hospital district plans as well as cost recovery mechanisms are based on OCPs.

From a water planning perspective, the match to an Official Community Plan would be a provincial Water Allocation Plan. While there is generally an Official Community Plan in place within each of the communities, the author is not aware of any Water Allocation Plans undertaken in the Okanagan.

8.0 Conclusions

This paper has presented a potential impact of population growth in the Okanagan Basin. It uses BC Stats population projections with a great deal of certainty, and presents assumptions about current water use. These assumptions enable the impacts of future growth to be projected, and for the impacts of alternative land use scenarios to be modeled.

Until verifiable water use surveys are conducted, the impact of population growth cannot be truly ascertained. However, there is enough information to assume that population growth with no change in water use over the next 25 years will result in an unsustainable future where the finite supply of water is reached.

The impacts of population growth may be moderated through land use and water management decisions made today. This paper demonstrates how population may be accommodated either through replacement of agricultural lands or through substantial reduction in residential use, particularly in lawn and rural acreage irrigation.

Readers of this paper and participants at the CWRA conference will be among those most interested in exploring the many assumptions and considering the varied options that would enable the Okanagan to grow without threatening its water supply.

EXPLORING OPTIONS FOR ADAPTING WATER MANAGEMENT IN THE OKANAGAN REGION TO FUTURE CLIMATE CHANGE

by

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Abstract

A case study on the impacts of climate change on water resources and options for adaptation in the Okanagan Basin has recently been completed, and this is leading to a new phase which will further explore options for adaptation. The completed study was a collaborative effort between Environment Canada, Agriculture & Agri-Food Canada, BC Water Land & Air Protection, University of British Columbia, and consultants from the region. Regional partners from throughout the Okanagan, including representatives from Regional Districts, municipalities, water purveyors, fruit growers and First Nations, provided data and access to documents and sites, and were active participants in surveys and workshops.

The scenarios developed in this study describe a long term future with greater stress on Okanagan water resources, including increasing risk of drought. Many adaptation options are available, which could become part of a regional adaptation portfolio, but implementation would depend on incorporating such options into long term development plans. Stakeholders have indicated a number of potential social, political and legal obstacles and opportunities which would affect the implementation of these options. What is still missing is a mechanism for evaluating various adaptation options within these scenarios. The new study will build on earlier studies by developing a systems model for the Okanagan watershed, using regional expertise to assist in model construction. The model will then be used to facilitate a new dialogue on adaptation options.

Keywords: Climate change impacts, Adaptation, Water management, Okanagan, Stakeholder dialogue

Downscaling Global Warming into the Okanagan Context

Watersheds and water systems are known to be sensitive to climatic variations. Recent droughts in 2001 and 2003 are examples of how short-term extreme events have affected water supply, water demand, and perceptions of risk in the Okanagan. The drought of 2003 exposed some vulnerability, as illustrated by the emergence of local water conflicts (Moorhouse, 2003) and the implementation of emergency and longer term conservation measures (Watershed News, 2003; Johnson, 2004). Regardless of whether one could clearly state that these droughts were, or were not, caused by global warming, these droughts have raised awareness about climate-related sensitivities, and perhaps vulnerabilities. When coupled with recent and anticipated growth in population, concerns about fisheries, and long term directions in regional development, the implications of future climatic change become a relevant and important addition to the basket of concerns that need to be addressed by water planners and managers in this region.

Even after 25 years in the spotlight, since global warming was highlighted at the 1979 (First) World Climate Conference, human-induced climatic change remains a complex issue for researchers, as well as for resource management professionals who have to figure out how to cope with an uncertain future stress while still providing safe reliable service today. Considerable literature has emerged on the potential implications for hydrology in a number of watersheds around the world. In its review of world literature, the Intergovernmental Panel on Climate Change (IPCC) describes these effects, which vary from region to region (IPCC, 2001). Without going into detail here, the important lesson is that changes in temperature, precipitation amount and form, and evapotranspiration, will have implications for managed and unmanaged water systems. Each watershed will face its own set of unique challenges, as climate concerns interact with regional development goals, management constraints, social attitudes and the effects of technological and economic changes.

The interaction of these various forces has been described as integrated or cumulative threats to water supply. In other words, these are types of 'wicked' or 'meta-problems'. *Integrated threats* to the water supply are threats that emerge when combinations of stresses occur (*e.g.* conjunctive groundwater and surface water problems, expected changes in climate and population with associated changes in water demand, simultaneous changes in water uses, etc.). *Cumulative threats* refer to evolving impacts over time. These emerge slowly over long periods, but may create surprising situations that can lead to conflict. The process of attempting to solve these kinds of problems will commonly involve the participation of various agencies, possibly from all levels of government, the private sector, users/clients, relevant non-government organizations, and the general public. Furthermore, the problem-solving process may itself evolve over time rather than being predetermined from the outset. Climate change is a good example of a potential cumulative threat (Cohen, de Löe, et al., 2004).

We are therefore faced with the question of how to respond. In our view, the first step is to 'downscale' climate change into the regional context. However, we do not restrict ourselves to climate information alone. Downscaling has become an important research topic within the climate science community, as it grapples with the challenge of reducing uncertainties about future regional climatic change. But we feel it is important to translate future climate change scenarios into scenarios of water supply and demand changes, and then connect this with the reality of regional water management, including the operation of engineering structures (reservoirs, distribution channels, etc.), seasonal demands of irrigators and municipalities, and the in-stream needs of fish and aquatic ecosystems. This is what has led to the collaborative research effort on climate change and water management in the Okanagan.

Study Framework

This research effort began in 1997 with a series of interviews that asked some 'what if' questions. The 'what if' was an illustration of how climate change would lead to a new hydrograph of the Columbia River (Figure 1). These interviews suggested that there was a diversity of views regarding its implications, but also, that this kind of interaction could be the foundation for a useful dialogue on how the region might adapt to climate change (Cohen et al., 2000).

The Columbia River hydrograph represented a very large watershed. Would the Okanagan respond to a warming climate in this way? Could an expanded regional research effort also include a broader dialogue on impacts and adaptation, specific to the Okanagan context? What emerged was a series of case studies that has, after several years, brought us to the story being told this week at the B.C.-CWRA Conference.

The evolution of the study framework is shown in Figure 2. Two small case studies were launched in 2000, addressing hydrology and crop water demand (Cohen and Kulkarni, 2001; Neilsen et al., 2001). Subsequently, there was a joint effort which led to the recent completion of a larger collaborative work (Cohen, Neilsen et al., 2004). In addition to climate, hydrology and crop water demand, the new work also includes residential water demand, adaptation experiences, a preliminary look at costs of adaptation options, and a dialogue on potential implementation of adaptation options.

A follow-up exercise is just getting underway. Given the desire to move beyond qualitative discussions of adaptation, the current initiative includes development of a systems model which will provide an opportunity to simulate possible adaptive responses to the climate change scenarios obtained from the 2004 study. Langsdale describes this process in more detail (this volume).

Summary of 2004 Study

The study comprises five key components:

1. **Climate change scenarios**: downscaling global climate change scenarios to the regional level;
2. **Hydrological scenarios**: determining impacts of climate change on basin hydrology;
3. **Water demand scenarios**: developing future demand scenarios particularly for irrigated agriculture and municipalities, factoring in socio-economic trends;
4. **Adaptation options**: exploring previous management experiences and potential future approaches for augmenting water supply and/or reducing water consumption; and

5. **Adaptation dialogue with stakeholders**: learning about regional perspectives on adapting to climate change.

Climate Change Scenarios

Six scenarios of climate change were obtained using simulations from 3 global climate models and 2 scenarios of changes in global emissions of greenhouse gases. The climate models were the CGCM2 (Canada), CSIROMK2 (Australia) and HadCM3 (U.K.). The emission scenarios were from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) series. The two selected were the A2 (rapid growth) and B2 (modest growth).

Taylor and Barton (2004) provide detailed information on these scenarios. In general, they all point to warmer conditions in all seasons. Winters are projected to have increased precipitation, while scenarios for future summers tend to show decreases (see Neilsen et al., this volume). This differs from recent trends, in which an increase in summer precipitation has been observed (see Taylor, this volume).

Hydrological Scenarios

The six climate change scenarios were used to generate six hydrological scenarios for various catchments in the Okanagan watershed (Merritt and Alila, 2004). An example is shown in Figure 3. All scenarios exhibit an earlier snowmelt peak in spring, with reduced summer flows and increased winter flows. Total annual flows decrease (Figure 4).

Water Demand Scenarios

Crop water demand increases due to the longer warmer growing season. Additional details are provided in Neilsen et al. (this volume). When combined with the projected reduction in annual flows, the frequency of high risk years increases. A comparison of inflows to Lake Okanagan with projected crop water demand shows that the overall ratio of demand to supply would increase from approximately ¼ to ½ (Figure 5).

In addition, residential water demand is also expected to increase. A case study of Penticton shows that projected growth in population would be the main driver, with the climate change effect accelerating this projected increase (Figure 6).

Adaptation Options

The Okanagan has had considerable experience in adapting water systems to new challenges and opportunities. Examples include the regionalisation of water delivery systems in Vernon, and the installation of meters in the Southeast Kelowna Irrigation District (SEKID) and the City of Kelowna (Shepherd, 2004).

In each of these cases, a local response was initiated because of an observed or perceived issue that was interpreted as a signal for action. In SEKID's case, for example, the trigger was dry conditions in 1987. Decisions were made through various means, sometimes aided by provincial incentives, or influenced by environmental pressures or changing costs. So far, the SEKID and Kelowna cases appear to show that the measures were effective in reducing water demand, while it is too early to assess the outcome of regionalizing Vernon's water delivery (Shepherd, 2004).

Adapting to future climate change is a challenge for water managers, water users, and governance. There is a wide range of supply side and demand side measures available at varying costs (McNeill, 2004). The choice of measures will depend on the planning and development context both at the community level, and for the region as a whole.

Adaptation Dialogue with Stakeholders

As part of the 2004 study, workshops on community response were held in Oliver and Westbank (Figure 7). There was also a basin-wide workshop held in Kelowna. Rather than discussing technical aspects of adaptation (e.g. engineering), the dialogue focused on social acceptability, legal and political aspects. Details are provided in Tansey and Langsdale (2004).

Oliver participants expressed interests in expanding usage of groundwater, and agreed with the need to be more efficient water users. However, they were concerned that any improvements in efficiency of water use by agriculture might lead to a loss of water rights in favour of residential uses and lead to rapid population growth.

Westbank is part of a planning unit known as the Trepanier Landscape Unit (TLU). TLU is already experiencing rapid population growth. Participants expressed interest in increasing supply through pumping from Okanagan Lake, depending on the cost, and in improving efficiency through leak detection, and possibly other means (e.g. metering).

The basin-wide workshop, held in Kelowna, was a more strategic discussion. Support was expressed for basin-wide integration of land and water planning, and a governance structure to reflect this. Concern was expressed regarding a perceived lack of public awareness of regional water resource problems, and the need for expanded public education.

One additional observation is that the varying development contexts prevailing in various communities have to be considered when choosing climate change adaptation options for water management. It will be important to create a broad portfolio of options that can be readily applied throughout the region.

A Look Ahead

Building on the team approach of the 2004 study, a follow-up study on climate change adaptation has been initiated. There are two major components:

i) Development of a systems dynamics model of the Okanagan water system, using a group-based modelling approach in which local experts assist in model development (see Langsdale, this volume), and

ii) Exploring options for designing a strategy for reducing water demand.

This will be supported by some costing studies for selected sites. It is hoped that this will provide additional tools for assessing adaptation options that can fit into the water management and planning context of the Okanagan. We are encouraged by the inclusion of climate change in the Trepanier Landscape Unit Water Management Plan (RDCS and MSRM, 2004).

Acknowledgements

The authors acknowledge support and cooperation from: Environment Canada; Agriculture and Agri-Food Canada; British Columbia Ministries of Water Land and Air Protection and Sustainable Resource Management; District of Summerland; University of British Columbia; Okanagan Basin Water Board; Regional Districts of North Okanagan, Central Okanagan and Okanagan Similkameen; Water Supply Association; BC Fruit Growers Association; Okanagan Nations Alliance, and Okanagan-Similkameen Boundary Fisheries Partnership. Opinions expressed in this paper are those of the authors and not necessarily those of Environment Canada, Agriculture and Agri-Food Canada, University of British Columbia, Natural Resources Canada, or any collaborating agencies. The 2001 and 2004 studies, as well as the current initiative, are supported by the Climate Change Impacts and Adaptation Program, Natural Resources Canada, Ottawa.

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Projected streamflow for the Columbia Basin at The Dalles, Oregon.

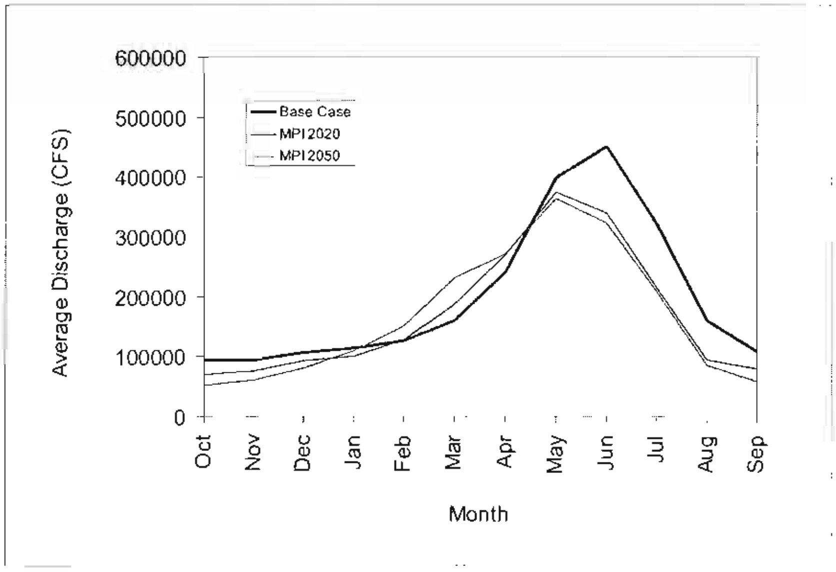


Figure 1. Projected changes in streamflow in the Columbia River at The Dalles, Oregon, based on a climate change scenario from the MPI model with the IS92a greenhouse gas emissions scenario (see Cohen et al., 2000). This emission scenario describes an intermediate rate of increase compared with the two scenarios used in the 2004 study.

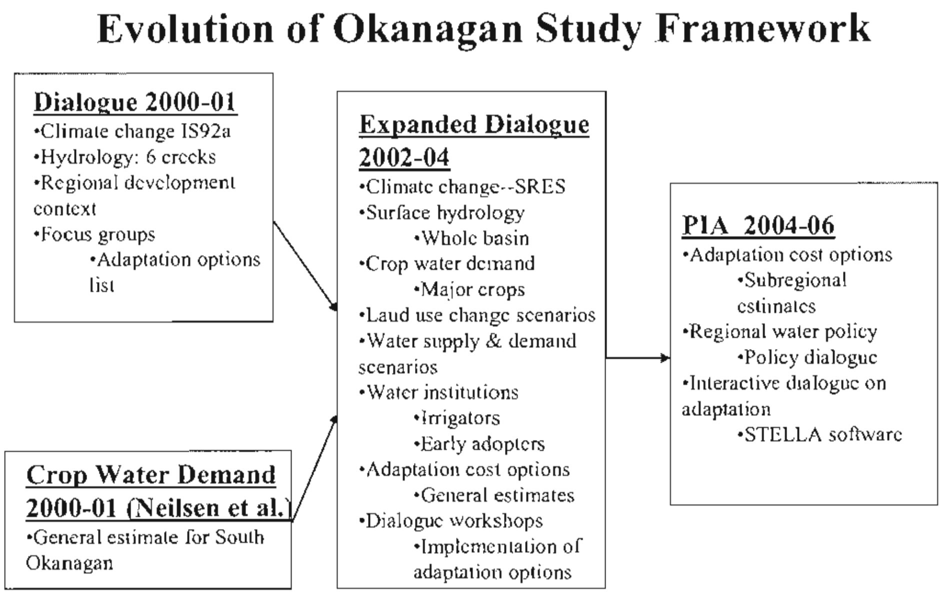
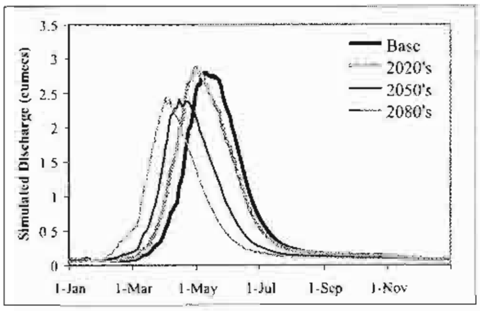
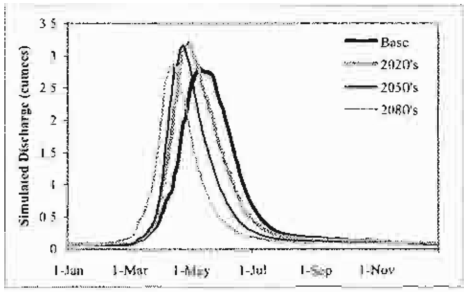


Figure 2. Evolution of Okanagan climate change & water management study framework.

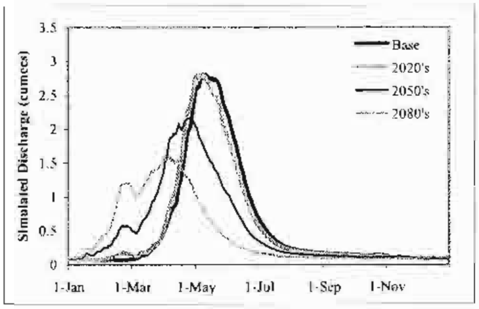
Scenario Hydrographs for Whiteman Creek (A2)



CGCM2



HadCM3



CSIROMk2

Figure 3. Hydrologic scenarios for Whiteman Creek, for the A2 emissions case (Merritt and Alila, 2004).

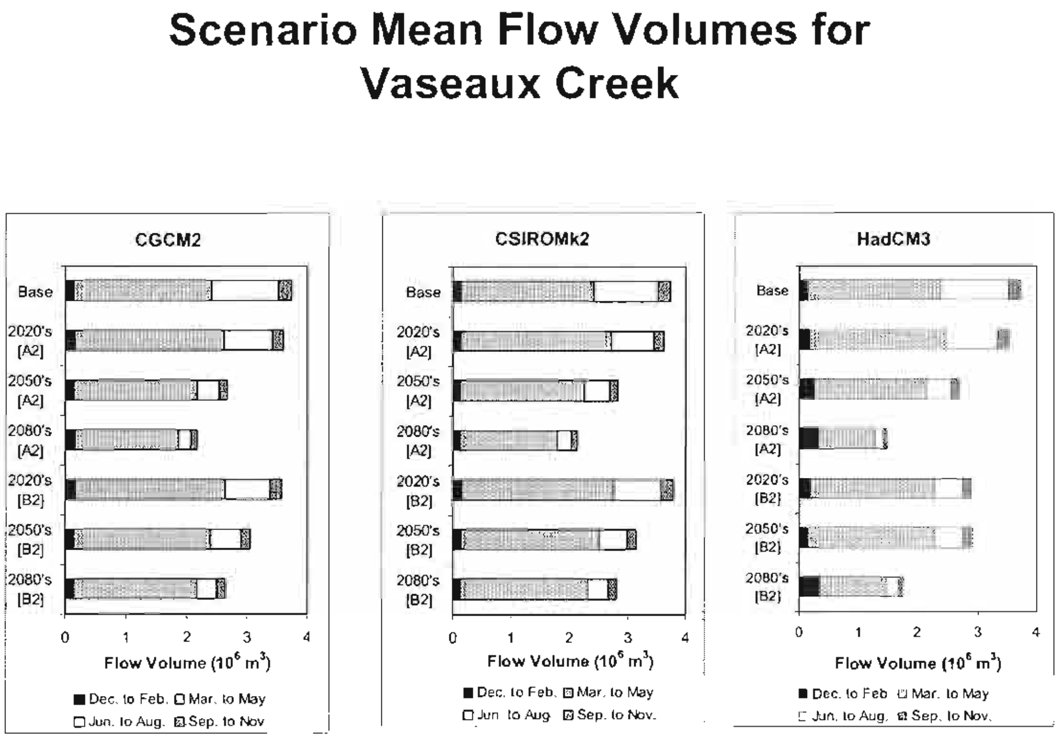
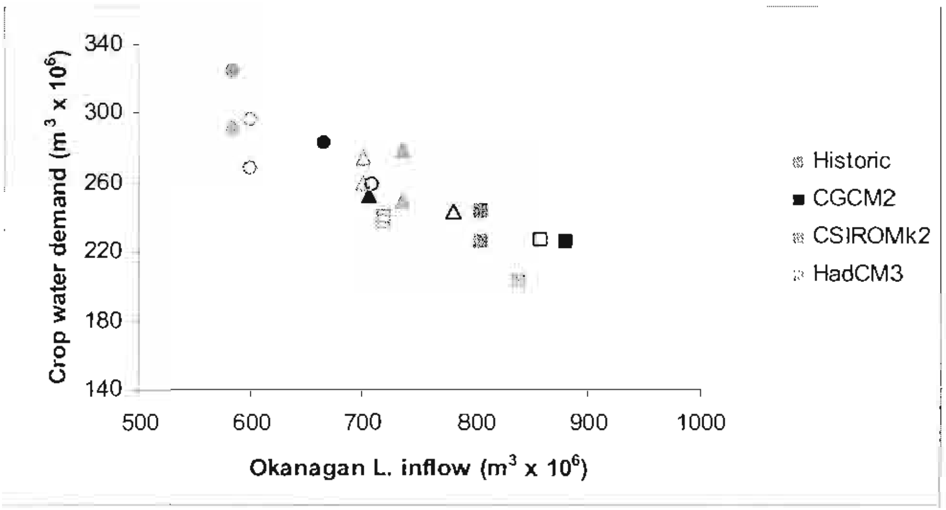


Figure 4. Changes in annual volume for Vaseaux Creek (Merritt and Alila, 2004).

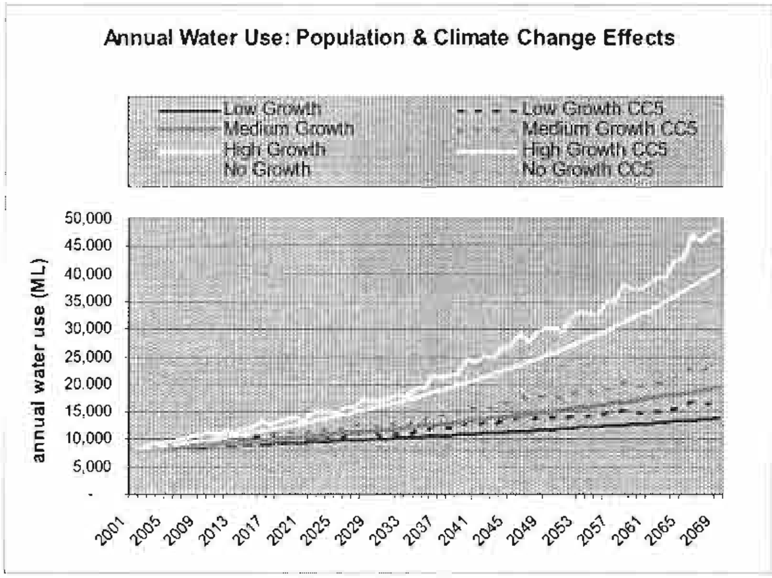
Okanagan Basin Annual Crop Water Demand Scenarios vs. Okanagan Lake Annual Inflow Scenarios



**filled symbols are A2; open symbols are B2*
■ = 2020s, ▲ = 2050s, ● = 2080s

Figure 5. Projected changes in Okanagan Lake inflows and crop water demand (Neilsen et al., 2004).

Residential Water Demand--Penticton



"CC5" refers to HadCM3-A2 climate change scenario.

Figure 6. Projected changes in residential water demand, Penticton due to population growth and climate change (Neilsen et al., 2004).

Figure 7. Study workshop in Westbank, BC, December 9, 2003.

Water Management Alternatives

by

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Abstract

A number of water management initiatives have been implemented since the Okanagan Basin Study, including the Okanagan Basin Water Board. Other initiatives include the Okanagan Fish-Forestry Guidelines, the Okanagan-Shuswap LRMP, recent efforts to improve the management of Okanagan Lake with an increased focus on fisheries resources, initiation of Watershed-based Fish Sustainability Planning, initiation of a drought management strategy, and the recent interest shown by the business community (the Okanagan Partnership) in improving water management. Recently there have been initiatives at the basin level to examine governance models that could be implemented without major changes to provincial legislation. The paper will refer to some of these initiatives, but will focus on the Okanagan Basin Water Board, its successes and limitations. The paper will also describe recent efforts of the Water Board to examine governance models, and recent provincial government proposals or changes in legislation that could lead to water management change. Barriers to change to a broader basin model will be examined.

The challenges for water management in Okanagan Basin are summarized in findings of the *Running On Empty? Water and Our Common Future Workshop* sponsored by the Okanagan Basin Water Board, March, 2004.

Keywords: water management, water governance,

1. Introduction

A workshop sponsored by the Okanagan Basin Water Board entitled "Running On Empty? Water and Our Common Future", was held Friday, March 19th, 2004 in Kelowna. The workshop was attended by approximately fifty participants including elected and non-elected representatives from all four orders of government (local, First Nations, provincial and federal), crown corporations, water purveyors and community organizations. The workshop focused on four key topics:

- Identifying the basin wide water management issues of the Okanagan.
- Identifying the actions to be taken to address basin wide issues in the Okanagan.
- Evaluating models for enabling the various agencies to work together to carry out required actions.
- Identifying the next steps in moving toward greater coordination and effectiveness in addressing water management issues of the basin.

The Honourable Bill Barisoff, Minister of Water, Land and Air Protection, the Honourable Ross Fitzpatrick, Senator and Mayor John Slater, Chair of the OBWB started the session by warning of the economic, social and environmental consequences of not developing a more coordinated and effective approach to the management of the Okanagan Basin's important water resources. The speakers challenged the participants to begin the work of designing a framework and establishing processes to enable the various orders of government and other agencies to work collaboratively with one another in order to provide for a sustainable economic, social and environmental future.

2. Identifying Basin Wide Water Management Issues

Mr. Jim Mattison, Comptroller of Water Rights and Mr. Paul Kluckner, Regional Director, Environment Conservation Branch, Environment Canada presented their views on water management issues confronting the Okanagan Basin. The speakers identified various concerns:

Water Supply

- Potential inability to meet future demand due to rapid growth and the impact of climate change.
- Inadequate storage capacity impacting water availability.
- Operations and maintenance of control structures and systems.
- Conflicts between competing demands on tributaries.
- Ability to change presented "vested" rights to provide for future demands.
- Limited understanding of the potential supply of groundwater.

Water Quality

- Ability to meet drinking water standards.
- Development within community watersheds and around reservoirs.
- Limited understanding of groundwater quality.

Conservation/Habitat Protection

- Protection of fish habitat and riparian areas by maintaining required conservation flows and water quality.
- Protection of endangered species.

Trans Boundary Issues

- Implication of possible changes to Order For Osoyoos Lake and other trans-boundary matters.

Research, monitoring, Assessment and Planning

- Lack of adequate basin wide research, monitoring and assessment.
- Lack of integrated basin wide planning and management of water resources due to complex jurisdictions.

Agricultural Use of Water

- Better understanding of the future agricultural use of water required.

Workshop participants identified and prioritized the issues presented. In addition to supporting these issues, workshop participants also identified a number of additional basin wide concerns. The fragmented authority for water management in the Okanagan was the principal deficiency cited along with lack of an appropriate governance framework to increase interagency collaboration to address basin wide water management issues. Other issues identified included:

- The need for groundwater legislation in the province.
- Recognition of the mandate and authority of First Nations in the management of the basin's water resources.
- More focus on demand side management and supply allocation.
- The need to integrate water management and land use planning on a basin wide scale.
- Enforcement of the conditions of water licenses.
- Changing the present "right to take" form of allocation to a more cooperative approach.
- The need to engage the public in decisions concerning water.

The three issues which received the highest priority ranking among workshop participants were:

- The potential inability to meet future demand for water given projected growth and climate change.
- The lack of integrated, basin wide planning and management of water resources.

- The lack of a suitable governance framework or authority at the basin wide level to ensure coordination and collaboration between the various orders of government and other agencies involved in the management of water resources.

3. Identifying Actions to Resolve Basin Wide Issues

Mr. Kevin Dickenson, Acting Director, Land and Water Management Division, Land and Water BC Inc. identified the actions which might be taken to address basin wide water management issues. Workshop participants supported the action presented and identified additional initiatives to be taken. The following actions were identified during the course of the workshop:

- Increased basin wide research and assessments on hydrology, climate change, drought, groundwater, water balance and licensing including exploring research opportunities with UBC-Okanagan University College.
- Protection of reservoir lakes.
- Increased basin wide water quality monitoring.
- Coordinated basin wide planning, management and decision-making.
- Coordinated basin wide demand management.
- Coordinated development of conservation and habitat protection programs.
- Coordinated approach to addressing trans-boundary issues.

Once again, the action identified as the most important first step to resolve water management issues in Okanagan was the design and implementation of a basin wide governance framework to ensure interagency collaboration. The importance of recognizing the rights of First Nations within this framework was also stressed.

4. Evaluating the Models for Working Together

Mr. David Marshall, Executive Director, Fraser Basin Council presented institutional models for water resources management drawing on both international and Canadian examples with a focus on the unique model used by the Fraser Basin Council. The Fraser Basin Council is a fully autonomous not-for-profit, non governmental organization with a unique model of governance. It is a non political and trans-partisan entity that relies heavily on consensus based decision making. It is a balanced and flexible partnership comprised of the four orders of government (federal, provincial, local and First Nations), the private sector and civil society. The Fraser Basin's core funding is shared on 1/3 basis by Federal, Provincial and Local Government with additional contributions from corporations, foundations and individuals as well as fee for service arrangements. The Council assumes various roles including catalyst, impartial facilitator, sustainability educator, jurisdiction and conflict resolution agent and resource in support of decision making. The Council does not interfere with local decision making or autonomy but provides an opportunity to discuss the effects of local actions on the basin in its entirety. It was recommended that any basin wide governance model for the Okanagan incorporate the following characteristics:

- Any governance model must be comprehensive and inclusive.
- The model should consider the need for social, economic and resource sustainability.
- The model should be based on an interdisciplinary approach.

- Dynamic leadership is key to success.
- The model should incorporate consensus base and transparent decision making.
- Sustainable funding and shared responsibility for funding is vital (all orders of government, private sector, not-for-profit sector, fee for service).
- The model must ensure that a basin wide perspective is taken.
- The model cannot result in conflict with existing jurisdictions or duplicate the competencies and authorities of others.

Next Steps

The participants of the workshop agreed upon the following course of action:

- There was consensus that a basin wide institutional framework was required to ensure coordination and foster increased collaboration among agencies involved in the management of water resources.
- It was agreed that an executive summary of the workshop would be circulated to participants to brief their respective boards, councils etc.
- It was agreed that a subcommittee be established to draft a concept for a basin wide water management framework consistent with the actions identified in the workshop. A subcommittee was established by the workshop participants.
- The concept would then be presented to the ministers, councils, boards and other agencies for endorsement.

Challenges and Innovations in Water Resources Management in the Okanagan Basin

by
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1. Abstract

The Okanagan Basin is the canary in the mine as far as climate change is concerned in British Columbia. Expanding water supplies is possible but additional sources are limited, tapping more groundwater is uncertain, and using more lake water is of concern for sustaining the Kokanee population in Okanagan Lake and to downstream water users. Drastic conservation measures are needed in order to sustain the water resources in the basin under current growth rates. The greatest reduction in water use is likely from improved methods of irrigation but significant reductions in use are also possible in domestic water use (>3% of the annual net inflow into Okanagan lake) and recreational water use such as golf course management. These overall conservation measures can provide sufficient additional water sources to sustain short-term growth but long-term concerns remain as a result of increased climatic variability that is acerbated by the widespread changes in land use, most of which are activities that are in the high water consumption category. Only a comprehensive strategy that addresses conservation, water use efficiency and growth limitation will suffice in the long-term viability of water resources.

2. Introduction

The Okanagan basin is likely one of the most critical watersheds in Canada because it is located in one of the driest regions in the country and is experiencing very rapid population growth and land use changes. It is projected that by 2020 more than 500,000 people will be living in the basin which is 17% higher than the high growth predictions made in the 1970's as part of the Okanagan Basin evaluation (O'Riordan 1972). Land use changes over the same time have also been substantive and most of them involve activities that are highly water consumptive (vineyards, golf courses, ski resorts), or have changed the land surfaces that impact the hydrological cycle (forestry). Some of these growth trends are summaries in Table 1 and show that in order to sustain the water use for the population and land use changes a rapid expansion of reservoirs has occurred. Most of the water detention, diversion and storage systems occurred in the upper parts of the watersheds that drain into the lake and this has not only altered streamflow but also significantly impacted the nutrient input into the lake. It is the aim of this paper to address the water challenges that face the region and offer some suggestions on what steps and actions need to be taken in order to avert a water crisis in the very near future. These include expansion of supplies, conservation options and short and long-term challenges.

Table 1. Population and land use changes in the Okanagan basin 1971-2001

Growth Indicators	1971	2001
Population	115000	317000
Golf Courses	7	50
Major Ski Areas	4	8
Wineries	<12	82
Area under grapes (ha)	955	2286
Water reservoirs & Storage Systems	81	147

3. The Water Challenges

The main water challenge in the region is how to balance water supply and demand given that the demand is increasing rapidly while the supply is becoming more variable and is declining in several areas of the basin because of increased evaporation from the storage systems, land use activities and increased temperatures due to global warming. The average annual rainfall in the region is 550 mm and there is a steep precipitation gradient from south to north (290 mm in Osoyos to 580 mm in Armstrong) and from low to high elevation (290 mm at 250 m elevation to 735 mm at 2350 m elevation). Most of the precipitation occurs in the higher elevation in the form of snow and this is the reason why most of the water storage systems were constructed in the upper portions of the watersheds.

a) Headwater challenges

Most of these headwater areas are forested and logging has been significant in all parts of these headwater systems. This has significantly altered surface conditions and influenced infiltration and surface runoff processes. It is very difficult to determine the overall effect of these widespread changes in forestry in the headwaters because very few active streamflow monitoring stations exist and few of them have long-term records. However, what is now becoming evident is that the rapid expansion of the water storage and diversion systems has had a significant impact on stream discharge and water quality downstream. Summer baseflow has become highly variable and nutrient input into the lake has been significantly curtailed because of the extensive storage systems in all watersheds draining into the lake (Hall et al. 2001, Andrusak et al. 2000 and 2004).

Not only have we altered the annual hydrological regime but the rapid expansion of ski-resorts are likely contributing to the decrease in water supplies because most rely on artificial snow making during the early part of the season and this process is very water demanding.

The main challenge in these headwater areas is how to store as much the water in the form of snow and rain during the winter so that it can be used during the long summers when the moisture deficit is widespread.

b) Watershed wide challenges

Almost all land use activities in the lower portion of the basin are very water consumptive. Orchards and vineyards, which are the main agricultural activities, can only be sustained with irrigation and although irrigation water use has become more efficient, rapid expansion of vineyards into previously uncultivated arid areas will require more water. As shown in Table 1 the area under grape production has more than doubled since the Okanagan Basin report in the early 1970's and the number of vineyards has increased from 12-80 over the same time period.

Similarly, golf courses are among the most water demanding land use activities. It has been estimated that a typical golf course uses the equivalent amount of water that would sustain 5000-7000 people on an annual basis (Pleumaron 1997). Given the rapid expansion of golf courses from 7 to 50 over the past 30 years this should be of concern to all water managers. With the rapid increase in residential population and the large seasonal influx of tourist in the summer and winter the demand for more domestic water is obvious.

The main challenge on a watershed wide basis is to determine the water supply capacity in each of the watersheds entering the lakes and then determine how much water should be left in each stream for environmental services. This is a difficult task because the science to determine minimum flow for environmental services is poorly developed. This was evident in the Trout Creek watershed during the summer of 2003 when water demand exceed supplies and water needs for environmental services was ignored. This is of particular concern in view of the Kokanee crisis that has been well documented over the past few years (Andrusak et al. 2004).

c) Using additional water sources.

There is enough evidence to suggest that in dry years most streamwater is over allocated. This means lake water and groundwater are the remaining water sources that will be under pressure. Extracting water from both of these sources is problematic. A comprehensive groundwater survey has only recently being initiated and the concern is not only for finding good aquifers with high quality water but recharge issues. Given the low annual rainfall opportunities for groundwater recharge is limited. A similar problem is emerging with lake water use. A drop in Okanagan Lake level of more than a meter will likely result in severely constraining water flow out of the lake. The consequences downstream will be dramatic because the climate in the downstream direction is progressively more arid and water use and fish populations will be adversely affected. A drop in the lake level of such a magnitude will have a devastating effect on the shore spawning Kokanee population.

The main challenge with using these potentially additional water supplies is how to determine sustainable levels of use.

d) Increased climatic variability.

According to Cohen et al. (2004) there is sufficient evidence that this region is more strongly responding in increased global warming than most other regions is Canada. Increased spring temperatures will result in earlier snowmelt and longer dry seasons. The risk of forest fires is also increasing both due to the rapid expansion of pine beetle infestation, higher temperatures, and housing expansion into forested areas. The 2003 fire season is likely an early warning of what could become more prevalent.

The increased temperatures will also result in increased evaporation from reservoirs and lakes. Hall et al. (2001) estimated that currently about one third of the annual inflow into Okanagan Lake lost through evaporation. Evaporative losses from the lake have been estimated to reach 300 Mio m^3.

The challenge is on how to adapt to these new and emerging conditions at a time when population pressure is increasing rapidly and the water demand from all the recreational activities and from agriculture is also increasing.

3. Innovative approaches to addressing the water challenges in the basin.

A comprehensive groundwater survey that is currently under way might provide some additional water for future growth, but the time has come where some serious conservation practices should be initiated. Demand control, which is often referred to as the "soft approach" to water management (Gleick 2002) is the most efficient and least costly approach to meet the immediate needs for additional water. There are four major savings that could be initiated a) Improved irrigation efficiency in agriculture, b) Domestic water use conservation, c) Water conservation for golf courses, d) Improved green water management.

a) Improved irrigation efficiency in agriculture

Overall, agriculture is the most water consumptive activity in the Okanagan and large water savings can be made by converting flood and sprinkler irrigation systems to drip irrigation. In the 1970's O'Riordan (1971) suggested that agriculture was diverting 77% of all water withdrawals and using 86% of all water consumption. He predicted that the withdrawals from agriculture in 2020 would be 32% and the consumptive use 42%. While the consumption for agriculture has been reduced due to the introduction of more efficient irrigation systems it still remains well above the projected levels. Expansion of grape production has likely been one of the causes for the slower than expected reduction in water use by agriculture despite the fact that most vineyards use efficient drip irrigation systems. Sprinkler systems and to a lesser extent flood irrigation are still practiced and research from semi-arid environments suggests that water savings of 30-50% is possible when converting from these to drip systems (FAO 2000). Some of the quantitative measurements conducted by Van der Gulick (personal communication) has clearly shown that massive savings can be made by such conversions.

b) Domestic water use conservation

Significant improvement need to be made in domestic water use. The average British Columbian uses 350 L of water /day and by converting every toilet from a conventional water flush system to a low flush system, we can reduce the domestic water use by 84% (Table 2). This saving is equivalent to 3% of the net annual inflow into the Okanagan Lake, or 3-6% of the current water storage capacity. This saving would mean that the daily per person consumption would be reduced to 209 L/Person/day which is still some 20-30% higher than current per person water consumption in many Scandinavian and other European Countries. If we add low water use systems in showers and other water utilities this can likely be further reduced without causing any inconveniences to the residents. An innovative education program would encourage everyone to be more careful in all their domestic water use activities.

Table 2. Potential domestic water use savings by introducing low flush toilets

	Conventional Flush	Low Flush Systems
Use per flush	21 L	3L and 6 L (2 buttons)
8 Flushes/person/ day	168 L /person/ day	27 L / person /day
Current Population	317'000 people	317'000 people
Total Water Use/ day	53.256 Mio L / day	8.559 Mio L / day
Total Annual Water Use For Toilet Use/ year	19.438 Mio m^3	3.124 Mio m^3
Total Annual Savings	16.438 Mio m^3 or 84% reduction	
% of net annual inflow into Okanagan Lake	2.6%	

c) Water conservation in golf courses and other recreational activities

Typical golf courses use about 2000-4000 m^3 of water/day (Pleumaron, 1997, UNESCO, 2000). In the Okanagan the summer golf season lasts at least 150-180 days. A conservative assessment as shown in Table 3, suggests that about 2 % of the average annual inflow into Okanagan Lake is used entirely for maintaining golf courses.

Table 3. Estimated water use for golf courses

Indicators	Amount of Water
Irrigation Schedule every 2^{nd} day @ 2500 m^3, 150 day season, 50 golf courses	10 Mio m^3 / year
Annual net inflow into Okanagan Lake	519 Mio m^3 / year
Percent of water inflow used for Golf Courses	2%

If we could persuade golf courses to only irrigate the putting area and use grey water for this purpose the annual water consumption could be reduced significantly while still maintaining the activity.

Making artificial snow also requires large quantities of water (Schreier, 2004). O'Donnell (1996) estimated that more than 1 billion L of water is used in a typical mountain resort in Europe. While much of this water will become surface runoff at the end of the winter it should be remembered that sublimation during snow making can be up to 30% of the water used. Given that 8 major ski resorts exist in the Okanagan this type of water loss should also be considered in determining what a sustainable level of water use should be in the basin.

d) Improved Green Water Management

Conventional water management has primarily focused on blue water management. This is the proportion of the Hydrological cycle that deals with surface runoff, water discharge in streams and lakes and groundwater. Green water is the proportion of the hydrological cycle that deals with rainfall that is intercepted by vegetation and soils and used for biomass production. Evaporation and evapotranspiration within that component of the cycle can be substantial and it has been shown by Rockstrom (2003) that there is about the same amount of water that moves through the blue water cycle as through the green water cycle. However, we rarely pay attention on how to effectively manage green water, which means minimizing evaporation and storing water in the soil for direct use in biomass production.

This is of particular interest in the Okanagan because large changes in surface conditions result from the widespread logging and the expansion of grape production into the desert environment. This is not an easy task because evapotranspiration measurements are difficult to make particularly when the forested environment is undergoing rapid alterations due to logging. However, what can be done effectively is maintaining soil conditions that maximize infiltration and minimize surface runoff. Since most of the water storage systems are in the headwater it is possible to increase the natural storage of water by maintaining high organic matter content in the soil, avoiding soil compaction, maintaining or restoring wetlands, and carrying out soil conservation practices. Increasing snow accumulation and maintaining snowmelt in the soil and in headwater storage has the potential to provide better water supplies during the dry summers.

4. The Long Term Challenge

The soft path approach has the potential to provide a significant additional amount of water that could be available for future growth. However, there are several concerns that should be addressed for the long-term management of the basin. These include: Increased climatic variability, water for environmental services, and pressures from downstream water users. Global warming and increased climatic variability is the largest threat to water managers in the basin. Not only will the evaporation rates increase with the increase in temperatures but also the risk of forest fires is likely increasing and this can have devastating short and long-term impacts on the hydrological cycle. With the spread of pine beetle, more fuel will be available and fires can significantly change the runoff vs. infiltration processes. The problems of maintaining water in streams during dry years is becoming more prominent and if we hope to maintain a healthy ecosystem and a sustainable fish population then trade-offs need to be made between human use and the environment. This is likely the most formidable challenge that is emerging with climate change.

The demand for water from the downstream users is likely increasing because the climate becomes significantly more arid as the river system flows south and since the Okanagan Basin is not part of the Columbia Basin treaty, it is likely that international issues over water will become evident.

Finally, maintaining water quality is an equally important task; particularly since the current problems of maintaining appropriate nutrient ratios in the lake is likely having an impact on maintaining the Kokanee population. Continued expansion of water detention systems in the headwaters will likely reduce the nutrient input (N and P) and climate change will aggravate the situation. Salinity problems in the lower portion of the basin could increase, and non-point sources of pollution from agriculture and recreational activities will remain a problem in need of innovative solutions.

5. Conclusions

The Okanagan basin is the "canary of the mine" in relation to climate change. It will likely be the first watershed in B.C. where the impact of global warming and increased climatic variability will be felt. This is being accelerated due to the rapid population growth and the land use conversions, most of which are in the high water use activities.

The challenge for all of us is how to find a level of growth that can be sustained given the available and likely declining water resources in the basin. Following the soft path of water management will help us in the short term because there appears to be sufficient savings that can be made to conserve water. However, even with the most effective conservation program current growth rates cannot be sustained in the long run and changes are needed that not only address growth limitations but also require behaviors changes.

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Governance and Allocation Models

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Abstract

For almost 100 years the International Joint Commission (IJC; Commission) has been involved in preventing and resolving problems on transboundary watersheds between Canada and the United States under the 1909 Boundary Waters Treaty. During that period, difficulties between the two countries over water have not degenerated into conflict and, for the most part, transboundary water resources have been managed successfully for the common benefit of Canadian and U.S. Citizens. The IJC and its system of boards have played a major role in this achievement. A number of forces of change as well as specific transboundary challenges (see *"The IJC and the 21st Century"*) are now coming into play, requiring the Commission to address transboundary water issues in a more integrative manner, including both biophysical and human aspects. The IJC's experience with the Great Lakes Water Quality Agreement in particular and its emphasis on "the ecosystem approach" has been instrumental in shaping the Commission's perspective. Dr. Murray Clamen will provide some examples of governance models that have been used successfully in Canada and internationally (Prairie Provinces Water Board, IJC watershed initiatives, the Murray-Darling basin in Australia) to encourage conference attendees to think beyond current management proposals for the Okanagan and explore other possible options.

Keywords: international joint commission, basin management, water governance,

[25] Secretary, Canadian Section, International Joint Commission

Changing Perspectives – Changing Paradigms: Demand management strategies and innovative solutions for a sustainable Okanagan water future

by

By Oliver M. Brandes[26] and Lynn Kriwoken[27]

"Only a broad and representative group of people with interests in a given river basin can determine what the optimum use of that river looks like."

(Postel and Richter 2003: 182)

Abstract

Water is vital to British Columbia's long-term prosperity – it is the foundation of our economy and growing communities, and is essential for a healthy environment. Despite its critical importance, water is undervalued and often wasted. People perceive it to be an abundant and virtually limitless resource. This myth of abundance is entrenched even in water-stressed areas such as the Okanagan, where drinking water supplies are at risk, conflicts among water users are common, economic opportunities are threatened, and aquatic ecosystem health and fisheries are declining. Population growth, coupled with the uncertain, yet increasingly evident impacts of climate change, will only increase these challenges in the future.

Water conservation and demand management are critical components in a lasting long-term and sustainable approach. Demand management offers a genuine win-win solution, as communities can reap both environmental and economic dividends from reducing water use.

To demonstrate that conservation is the next best source of 'new' water in regions where supply is limited, this paper outlines leading national and international demand management approaches. Included in this discussion are some of the critical factors for success, such as setting meaningful targets and promoting early adopters and innovative solutions.

The success of demand management in the Okanagan requires both the involvement of water users and the use of strategic planning to provide the appropriate mix and timing of measures for the region. Addressing this complexity and overcoming the barriers that limit the adoption of demand management are critically important. Beyond this, the paper provides a blue print for dialogue and change by outlining a soft path water management approach for the Okanagan basin.

This paper will demonstrate the need for people with diverse skills and expertise from across the region to animate the debate and create a shared Okanagan vision. Ensuring lasting solutions requires changes in beliefs, attitudes and opinions about water and draws on

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innovative tools and best practices from elsewhere to create a basin-wide, comprehensive and integrated 'made-in-the-Okanagan' approach.

1. Setting the Context – avoiding the arid future

"Water will become Canada's foremost ecological crisis early in this century"

(Schindler 2001)

Water is vital to British Columbia's long-term prosperity. Despite its critical importance, people perceive water as a virtually limitless resource. This myth of abundance is entrenched even in water-stressed areas such as the Okanagan, where drinking water supplies are at risk, conflicts among water users are common, economic opportunities are threatened, and aquatic ecosystem health and fisheries are declining.

Population growth in the Okanagan basin, coupled with the uncertain, yet increasingly obvious, impacts of climate change, will only increase these water supply challenges in the future. Widely held misconceptions or assumptions that the Okanagan basin possesses an abundance of available water have been replaced by pressing reasons to improve the region's water management for the future.

Water conservation and demand management are critical components of a long-term and sustainable approach. Demand management offers a genuine win-win solution, as communities reap both environmental and economic dividends from reducing water use.

Demand management includes a variety of measures, such as conservation-based pricing, water conserving plumbing fixtures, efficient drip irrigation for all outdoor watering (including stocks, crops, turf and gardens), and water reuse and recycling. Projecting how much water can be saved and made available to meet future water needs is simple enough and ample evidence exists, even within the Okanagan basin, to support the use of demand management measures.

However, achieving water savings through demand management does not just happen. It involves changes in perspectives and practices. It requires institutions to creatively manage and accelerate the adoption of more sustainable practices. To help realize this change, various critical factors for success have been identified – including the need for a ***shared vision for the basin***, the importance of ***knowledge*** about current and future supply limits, ***adaptive institutions*** to create solutions and lead innovation, and the critical importance of relentless ***education*** to create a lasting water ethic.

Action on each of these critical factors is necessary to achieve water sustainability in the Okanagan. Only when demand management is implemented within a comprehensive, basin-wide, and integrated framework will the full suite of innovative solutions be possible — and the potential for a fundamental shift in attitude and perspectives occur. This is the potential of a 'soft path' approach to water management.

In this context, the challenge of dealing with growing population, changing climate, and water supply limitations becomes an opportunity to embrace innovation and realize a sustainable future for the region's water.

1.1 Water in the Okanagan – a changing reality

Much of the Okanagan is arid or semi-arid. The climate is changing; the population is growing;[28] the agriculture economy is expanding;[29] and water supply conditions are shifting. (Cohen, Neilsen et al. 2004)

In the Okanagan, a changing climate puts significant stress on water supplies. Cohen, Nielsen et al. (2004: 2) suggest that many water supply systems in the Okanagan may not be able to meet future projected demands based on their current supply capacity. Water has always been, and will continue to be, critical to the region's future. But with these significant changes, future perspectives and approaches to water management must evolve if the region is to remain prosperous.

Managing water demands is an effective way of dealing with the current reality and future uncertainty associated with climate change and population growth. A comprehensive and integrated planning process that promotes a suite of locally appropriate demand measures should be the central focus of, what Cohen et al. (2004) calls, an "adaptation portfolio." Such an adaptation portfolio should also include improved planning for droughts and severe floods, improved water quality protection, and better monitoring. These adaptation options are considered "no regret" options that provide benefits regardless of climate change impacts. (Dolan, Kreutzwiser et al. 2000; Cohen and Miller 2001; Schindler 2001; Environment Canada 2004; Natural Resources Canada 2004)

Collectively, such an adaptation strategy is the best way to reduce the vulnerability that may face the Okanagan, and to meet the wide range of environmental, social, and economic objectives within the region. In particular, water demand management and capacity for institutional flexibility are critical hedges against an uncertain water future.

1.2 Meeting water needs through demand management

Managing water demands to meet water needs is part of a broad continuum of water management paradigms (see Box 1). At one end of the spectrum are *supply-side approaches* that increase capacity through large infrastructure such as additional pumps and reservoirs. At the other end of the spectrum is a truly long-term and comprehensive approach to planning and water resource development and use – a "soft path" for water.[30] In the middle of the spectrum is *demand-side management* (DSM),[31] an approach that includes education,

[28] BC Statistics estimated in 2002 that the population for the three regional districts in the basin exceeded 315,000. The growth in the basin is expected to continue to increase rapidly. BC Stats projected in 2002 that, over the next ten years, the population of the North Okanagan will increase by 15 percent, Central Okanagan by 21 percent and Okanagan-Similkameen by 9.5 percent. As the population grows, the demands on the water supply will increase.

[29] Agriculture is a particularly important component of the regional economy, which is highly dependant on a reliable supply of irrigation water, and "climate change is expected to impact both the demand for and availability of water for irrigation purposes." A significant concern for irrigation is changing availability of in-stream flows. The UBC watershed model for Okanagan streams "shows that a characteristic response to climate change scenarios is earlier peak flows" (Cohen et al. 2004). This changing availability means that in-stream flow would not be available for much of the growing season, causing the supply system to be taxed by early dependence on stored water, as occurred in 2003.

[30] "Soft path" for water is a term taken from the energy field. Amory Lovins first coined the term "soft energy paths" in a 1976 *Foreign Affairs* article, eventually developing an energy planning approach that took into account both carefully calculated requirements for energy services and energy economics. Environmental considerations were a core value in this analytical work.

[31] The following section includes an overview of various demand management measures, including technologies to improve water-use efficiency (e.g. toilets and drip irrigation) and the policy instruments used to motivate their

water-efficient technologies, regulatory regimes that promote efficiency and/or reuse and recycling, and conservation-based pricing.

Demand-side management refers to the planning and implementation of programs that influence the amount, composition, or timing of demand for a commodity or service. When the issue is scarcity, the demand management solution is to reduce use rather than automatically supply more of the service or resource being sought. In the context of population growth and urbanization, water demand management increases per-capita water-use efficiency; and, in the context of agricultural production, it entails "more crop per drop" to stabilize or reduce total water use.[32]

Conceptually, supply and demand management strategies are separated by their fundamentally different view of water as a resource. Supply-side management views freshwater as virtually limitless, with resources being developed according to human needs. Demand management, on the other hand, accepts the finite nature of water resources and focuses on improving efficiency—doing more of the same with less water.

Ultimately, by increasing water-use efficiency, demand management measures and programs mitigate the pressures of excessive water use on municipal and regional finances, infrastructure, and the aquatic ecosystems on which these systems rely.

At its core, a water demand management approach recognizes that developing new water sources may be too costly, and that influencing consumer demand is cost-effective. Brooks (2003a: 9) suggests that, "in almost every sector, cost-effective savings of 20 to 50 percent of water use are readily available." This is particularly true when environmental and full economic costs of water services are taken into account. For example, a recent study in California, which is already ahead of the Okanagan with respect to water conservation, demonstrates that total commercial, industrial, residential, and institutional water use could be cost-effectively cut by as much as 30 percent, using similar prices and existing off-the-shelf technologies. And this improvement can be achieved more quickly and cleanly than any new supply project under consideration (Gleick, Haasz et al. 2003).

In the Okanagan basin, both supply and demand approaches are employed, with the balance between them varying with geography, public attitudes, financial resources, and economic and political choices. Municipalities and their utilities, such as Kelowna and Vernon, employ a variety of demand management techniques, most commonly education programs, metering, watering restrictions and rebate for fixtures and toilets. Yet, supply-side initiatives are often still the primary focus.

'Soft path' for water

As demand management programs become more comprehensive, long-term, and integrated, they begin to fall into a more holistic approach to water management—the "soft path". Similar to a demand management approach, the soft path strives for sustainability and equity in water management by using demand management measures and increasing water productivity, rather than seeking out additional supplies. The soft path also ensures that

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use (e.g. building codes that require low-flow fixtures or grants for installing and using drip irrigation technologies).

[32] Brooks and Peters (1988: 3) specifically define water demand management as "any measure that reduces average or peak withdrawals from surface or groundwater sources without increasing the extent to which wastewater is degraded."

stakeholders are engaged in decision making and explicitly recognizes ecosystems as legitimate users of fresh water. (Wolff and Gleick 2002; Brooks 2003a)

The soft path for water specifically views water resources as finite and driven by ecological processes. Naturally, the soft path includes many aspects of demand management – in fact, demand management measures such as education, pricing, and conservation technology are important drivers to the whole soft path approach; however, it has a broader perspective. Fundamentally, the soft path challenges the way water is perceived – the focus is on *services* provided by water rather than water as the resource or commodity itself. (Gleick 2002; Brooks 2003)

Moving beyond simply doing the same with less water, the soft path seeks to change how water is used. The primary focus for the soft path approach is to ensure human needs for water are equitably met in the most ecologically sustainable way. This approach requires viewing water as a bundle of services rather than just a natural resource or commodity. Demand for water is not generally for water itself, except for drinking, food preparation, and personal hygiene – often accounting for less than one-third of total domestic water use. Water demand is mainly for services such as pleasing yards, food production, and sanitation. By focusing on the services, many more options can be conceived to satisfy demands, and these options will offer significant opportunities to reduce the pressure to increase water supplies.

A key feature of soft path planning is the recognition that many existing water needs can be met with far less water, and often with water of a *lower* quality than is currently used. High-efficiency toilets, for example, reduce the amount of water used for personal hygiene; however, there is significant potential to further increase water productivity by using reclaimed wastewater to flush toilets or by using dry sanitation systems that completely eliminate water use. The soft path for water is less a series of technical or economic choices than a series of socio-political choices (Brooks 2003a: 11).

To accomplish this fundamental change, however, requires comprehensive planning and clear objectives and targets (such as targets based on a clear understanding of water availability beyond *in situ* needs) and longer lead-times to allow the adoption of new processes and technologies.

Box 1: A continuum of water management

Characteristic	Supply-Side Approach	Demand management (DSM)	'Soft path' for water
Philosophy	Water resources are viewed as virtually limitless. The primary constraint is our capacity to access new sources or store larger volumes of water.	Water resources are viewed as finite and to be used efficiently. Conservation is key and economic cost-benefit analysis guides development strategies.	Water resources are viewed as finite and driven by ecological processes. The focus is on a fundamental re-evaluation of the way we develop, manage and use water.
Basic Approach	Reactive Currently, the status quo approach – developing resources according to human needs and wants.	Short-term and temporary Generally used as a secondary approach, complementing and deferring supply-side options or until future supplies are secured. However, when used in a comprehensive, integrated and long-term fashion, represents an incremental step towards a broader "soft-path" approach.	Proactive Long-term with potential for fundamental change in societal attitudes and resource use.
Fundamental Question	How can we meet the future projected needs for water given current trends in water use and population growth?	How can we reduce current and future needs for water to conserve the resource, save money and reduce environmental impacts?	How can we deliver the *services* currently provided by water in the most sustainable way?
Primary Tools and Examples	Large-scale, centralized, expensive engineering solutions. Examples include dams, reservoirs, treatment plants, pumping stations and distribution systems.	Innovative engineering and economic-based solutions focused on any measure that increases the efficiency and/or timing of water use. Examples include low-flow technologies, drip irrigation, conservation-based pricing, education, and policies and incentives to reduce use.	Encompasses the full suite of social sciences and generally relies on decentralized distribution coupled with management strategies aimed at ulti efficient ways of meeting end-use demand. The focus is on any measure that can deliver the services provide by the resource taking full costs (including environmental and social) into account and identifying new options to provide services associat with water use. Examples include drought resistant native landscaping, grey water reuse ultra-low-flow technologies, and dry sanitation.
Planning Process	Planners model future growth, extrapolate from current consumption, plan for an increase in capacity to meet anticipated future needs, and then locate and develop a new source of supply to meet that need.	Planners model growth and account for a comprehensive water efficiency and conservation program to maximize use of existing infrastructure. Increasing capacity would be a final option as part of a least-cost approach.	Planners model future growth, describe a desired sustainable water future state (or scenario) and then "backcast" to find a feasible and desirable path between the future and the present using tools such as DSM and ecosystem restoration to address degraded aquatic systems.
			Adapted from (Brandes, Ferguson et al. Forthcoming)

In a soft path approach, the focus moves beyond the technical and micro economic efficiencies of demand management, into the social realm of social, political, and cultural changes.

> *"The soft path will not be easy to follow. It will require institutional changes, new management tools and skills, and a greater reliance on actions by many individual water users rather than a few engineers. Yet when compared with the growing cost to society of continuing down the hard path, it is evident that a new way of thinking about our scarce water resources is long overdue." (Gleick 2002: 373)*

A soft path for water in the Okanagan would:

- focus on the underlying services that water provides and not necessarily the volume of water *per se*;
- view water conservation as the best "new supply" of water in the basin;
- match the quality of the water supply to the quality required by end users;
- maintain ecosystem health before allocating water for other social and economic human needs; and
- turn the current planning practices around and "backcast" from a desired future state.[33]

By achieving consensus on a desired future condition (a level of water extraction and use that ensures sufficient water remains available in the ecosystem to sustain ecological function), a basin-wide effort to promote the full suite of innovative solutions and conservation measures is possible – and a fundamental shift in attitude and perspectives may be realized.

1.3 Demand management measures

A wide variety of measures exist to reduce water use. Options range from simple technologies such as drip irrigation and low-flow fixtures and appliances, to alternative sources such as cisterns, rainbarrels, and reuse-recycling technologies. Other measures include education, regulation (watering restrictions and mandated best practices), economic incentives (full-cost accounting, conservation based-pricing, rebates for leading conservation technologies), and subsidies for less water-intensive crops.[34]

Box 2 provides a general list of water demand management measures that are applicable both to the municipal and agriculture sector, a more detailed table of options for improving

[33] To successfully "backcast" requires a vision of a desired future condition. This is a critical step; although it can be time-consuming and challenging, ensuring full stakeholder participation and ecological considerations are key to achieving an acceptable outcome.

[34] Good resources for a detailed discussion of the many options available for reducing water use include Vickers, A. 2002 "Handbook of Water Use and Conservation" Amherst, Waterplow Press; Gleick P, Haasz D, Henges-Jeck C, Srinivasan V, Wolff G, Cushing K, Mann A. 2003 "Waste Not, Want Not: The potential for Urban Water Conservation in California" Oakland, Pacific Institute (www.pacinst.org); American Water Works Association htttp://www.awwa.org; Water Wiser, National Water Efficiency Clearinghouse http://www.waterwiser.org; Canadian Water and Wastewater Association http://www.cwwa.ca; Canadian Council of the Ministers of the Environment (CCME) http://ccme.ca

agricultural on-farm irrigation efficiency and crop productivity can be found in the Appendix.[35]

Collectively, the measures of water conservation, efficiency, education, pricing, recycling and reuse represent significant opportunities to manage water demand and reduce water use. Sandra Postel (1997: 191) believes this "last oasis," is "large enough to get us through many of the shortages on the horizon buying time to develop a new relationship with water systems and to bring consumption and population growth down to sustainable levels."

Box 2: Water demand management measures

General Categories	Specific Examples
Socio-political strategies	• Information and education • Water policy • Water use permits • Landscaping ordinances • Water restrictions • Plumbing codes for new structures • Appliance standards • Regulations and by-laws • Turf limitation by-laws • Once-through cooling system bans
Economic strategies	• Rebates for more efficient technologies (e.g. toilets, showers, faucets, appliances, drip irrigation) • Tax credits for reduced use • Full-cost recovery policies • High-consumption fines and penalties • Pricing Structures o Seasonal rates o Increasing block rates o Marginal cost pricing o Daily peak-hour rates o Sewer and waste water charges
Structural-operational strategies	• Metering • Landscape efficiency • Soil moisture sensors • Watering timers • Micro and drip irrigation • Cisterns • Rain sensors • Efficient irrigation systems • Soaker hoses • Leak detection and repair • Water audits • Pressure reduction • System rehabilitation • Efficient technology o Dual flush toilets o Low-flow faucets o Efficient appliances (dishwashers/washing machines) • Recycling and Reuse – ranging from cooling and process water, to grey water for toilets or irrigation, to treating and reclaiming

[35] Improving agricultural water use is critical for the region due to relatively intensive use of water. Stephens et al. (2005), in the following paper, emphasize 3 steps: efficiency, uniformity and scheduling, as key for good irrigation practices.

	wastewater for reuse
Source: Adapted from (Brandes and Ferguson 2003: 40)	

2. Being Innovative – promoting and learning from the early DSM adopters

As we peer into the twenty-first century, water conservation is looking far more like an imperative than an option

(Vickers 2001: xv)

Many examples of successful water demand management programs and initiatives are readily available from Australia, Spain, California, Florida, Nevada, South Africa, and Israel. [36] Even here in the Okanagan basin, DSM measures range from cutting-edge leak detection, low-flow and reuse/recycling technologies, agricultural best management practices, drip irrigation systems, governance restructuring, conservation-based pricing systems, incentives and economic instruments, education and information programs, and creative stakeholder partnerships.

2.1 Learning from others

Water reuse-recycling and metering with conservation-based pricing incentives stand out as promising opportunities to reduce water use and promote water sustainability. These options are potentially key components for water management in regions of scarcity and limited supply, such as the Okanagan.

Conservation-based pricing and technological innovation for water reuse and recycling are synergistic. As prices reflect a "truer" cost of the resource, recycling and reuse options become more economically feasible, spurring innovation and technological advance. These advances, in turn, reduce costs, leading to further opportunities for cost-effective alternatives. Reuse and recycling and conservation-based pricing are also equally relevant across sectors – agricultural, industrial and municipal water.

Reuse and recycling

Water recycling may not always be the least-cost alternative, but it does offer the long-term economic benefit of future reliability, in addition to environmental benefits that other alternatives may not offer.

At present, water reuse and recycling in Canada is practised on a relatively small scale and varies regionally depending on the availability of water supplies and regulatory flexibility. (Schaefer, Exall et al. 2004) Typical examples include using treated municipal wastewater to irrigate agriculture non-food crops, urban parkland, landscaping, golf courses, some isolated facilities, and experimental housing. Reuse and recycling is a powerful component of demand management, especially in areas of steadily increasing water demands and conflicts among users. As an alternative source of water, reuse and recycling provides opportunities to save on future expansion of water supply infrastructure. Israel, for example, treats 70 percent of its wastewater, which is then used for agricultural irrigation. (Gleick 1998)

[36] For a detailed discussion of some leading examples, see Sustainable Use of Water California Success Stories (1999), Pacific Institute; Gleick et al. - Waste not Want not (2003), Pacific Institute; Vickers – Handbook of Water Use and Conservation (2001); Water Bucket Web page (www.waterbucket.ca), POLIS forthcoming report - Facing a Watershed: Ecosystem governance and sustainable water management for Canada (www.waterdsm.org); Global Water Partnership tool box (www.gwp.org).

Box 3: Closing the Loop

> By using municipal water supplies twice – once for domestic use and again for irrigation – would-be pollutants become valuable fertilizers, rivers and lakes are protected from contamination, irrigated land boosts crop production, and reclaimed water becomes a reliable, local supply. Unfortunately, conventional sanitary engineers tend to emphasize the linear approach to managing water and sewage – use, collect, treat thoroughly, and then dispose of waste. While the benefits of closing the cycle – use, collect, treat partially, and then use again – go unrealized. ... St Petersburg, Florida, for example, closed its cycle completely by reusing all of its wastewater and discharging none to surrounding lakes and streams. The city has two water distribution systems – one that delivers fresh water for drinking and most household uses, and another that distributes treated wastewater for irrigating parks, road medians, residential lawns, and for other functions that do not require drinking-quality water. For residents hooked up to the dual system, the reclaimed water costs only about 30 percent as much as the drinkable supply. Also, because of the nutrients it contains, using reclaimed water cuts down on the costs lawn fertilizers.
>
> (Postel 1997: 128, 134)

Roughly three percent of wastewater is reused in BC, and reuse is already a component of BC's water conservation strategy.[37] (Schaefer, Exall et al. 2004: 200) Vernon has recognized for some time that reclamation is not only a treatment method, but also an alternative supply approach. Other leading international examples using recycled water for agriculture include the Cities of Visalia and Santa Rosa in California.

The agricultural examples in Santa Rosa and Visalia mostly use secondary-treated wastewater on fodder and fibre crops. However, growers are also irrigating fruits and vegetables with tertiary treated water, and producing high-quality crops and high yields. (Fidell and Wong 1999) The Laguna water treatment plant provides water to about 4,100 acres of fodder, sod, and pasture, 500 acres of urban landscaping, 700 acres of vineyard, 250 acres of row crops, and seven acres of organic vegetables.[38] (Fidell and Wong 1999: 144)

The key lesson from these two examples is that both projects pushed current boundaries of acceptable uses for reclaimed water and have met almost no resistance – there have been no public complaints or marketability problems.

As noted in Box 3, recycled and reused water also has potential beyond the agricultural sector. The West Basin Water Recycling project in Los Angles County and the South Bay Water Recycling Program in Santa Clara County are examples of leading urban recycling projects.[39] (Owens-Viani, Wong et al. 1999)

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[37] In 2001, BC produced the fact sheet "Guide to Irrigation System Design with Reclaimed Water (BCMAFF 2001) to provide a reference for the design of irrigation systems in British Columbia, using reclaimed water in accordance with the Municipal Sewage Regulation. In May 2001, the Province published a Code of Practice for the Use of Reclaimed Water (BCMELP 2001), which serves as a guide for using reclaimed water in BC, and is designed to support the regulatory requirements prescribed in the Municipal Sewage Regulation (Schaeffer et al. 2004).

[38] The row crops are primarily several varieties of squash, started with recycled water then switched to well water when the fruit sets. Walnut yields in Visalia have increased since switching from surface water to recycled water.

[39] Urban water reuse and recycling also exists in Canada, including specific examples of residential and commercial enterprises including the Waterloo Region Green Home, Sooke Harbour House, Mt Washington Ski Resort, and the Conservation Co-op Residential Water Reclamation Project (an 84-unit apartment in the city of Ottawa). An outstanding example of a closed-loop system (full reuse of all incoming water) is the Toronto

Conservation-based pricing

Experience shows that creative thinking about water rates and prices can have a significant impact on water use and efficiency. In 1991, Irvine Ranch Water District (IRWD) replaced its flat rate-per-unit charge with an innovative ascending block-rate structure. IRWD's rate structure represents an aggressive approach to promoting conservation, and has formed the foundation of a larger water conservation program linked with an existing water recycling program. The program has expanded to include landscape and other water conservation incentives and an education program for all types of customers. As a result of its programs, IRWD has seen a significant drop in per-capita water use (see Box 4). (Wong 1999)

Box 4: Conservation-based pricing

The Irvine Ranch Water District rate structure was created to address drought through increasing wholesale costs and introducing fair customer water costs. It contributed to a long-term water conservation ethic in the district by sending appropriate signals to curtail excessive use.

Five key elements helped ensure the success of this rate structure: 1) adequate customer information and analysis; 2) structure design; 3) equity and customer acceptance; 4) revenue stability; and, 5) coordination with other conservation programs. Increased communications between customers and the agency was embedded in the design. The rate structure itself builds customer awareness, sets targets, and provides incentive for customers to use water efficiently.

The rate structure relies on science and historical water use to determine base allocations. These objective data provide the agency with a defensible standard for all customers. Flexibility was another key component in this rate structure. The rate structure established variances and allowed for adjustment to individual allocations. This flexibility was further enhanced by customer-friendly rebates for those who took action to correct excessive use or those who received new allocations. To make the program more politically acceptable, penalty charges are not used to raise general revenue, but are fed back into conservation programs.

(Wong 1999)

Instituting such a comprehensive pricing structure requires detailed information and, in particular, universal metering is a necessary pre-condition for success. Metering alone, without an adjustment to the pricing structure, can reduce water use. And it is generally accepted that to effectively manage a resource, it must be measured. For fresh water, this means metering.

2.2 Early adopters in the Okanagan

Success stories from within the Okanagan basin abound.[40] These innovative local solutions are proof that change is possible – and already occurring. Box 5 provides a list of many of the more successful initiatives in the region.[41]

Cohen et al. (2004), in a recent detailed report on water and climate change in the Okanagan, discusses some of these successful examples as case studies highlighting their achievement:

> *"Kelowna achieved the pre-set 20 percent reduction target of their single family metering project. Allocated yearly water allotments in SEKID were reduced by 10*

Healthy House, which is not connected to the city water system but draws on rainfall and snowmelt for its fresh water supply. (Brandes and Ferguson 2003)

[40] Stephens et al. (2005), in the following paper, discuss success stories such as the potential of the *Water Balance Model* and the Southeast Kelowna Irrigation District (SEKID) universal agricultural metering pilot project.

[41] For a detailed discussion of these success stories see the 2004 BC Water Conservation Survey at www.waterbucket.ca

percent. Although water reclamation [in Vernon] *was initially implemented as a water treatment strategy (and an effective one), it is now considered as a potential water re-use, and therefore, efficiency strategy."* (Cohen : vi)

Box 5: Okanagan Basin Demand Management Initiatives

Black Mountain Irrigation District:

Watershed protection, collaboration with other utilities, public education

City of Kelowna:

Residential and ICI metering, watering restrictions, demand management planning, water audits, benchmarking, voluntary in-home, low-flow fixture programs, leak detection, sector demand study, Green design/SmartGrowth, water supply upgrades, computer upgrades, watershed protection, residential technologies, programs, pilot programs, pricing review, water conservation applied to operations and maintenance, collaboration with other utilities, public education, education for elected officials

District of Lake Country:

Advisory committee, watering restrictions, sector demand study, Green design/SmartGrowth, computer upgrades; public education, education for elected officials

District of Summerland:

Watering restrictions, metering pilot, water supply upgrades, public education, education for elected officials

Greater Vernon Water:

Residential and ICI metering, demand management planning, water reuse, water supply upgrades, computer upgrades, voluntary in-home low-flow fixture program, public education

Lakeview Irrigation District:

Watering restrictions, sector demand study, computer upgrades, watershed protection, water conservation applied to operations and maintenance, public education

Rutland Waterworks District:

Metering, pricing review, watering restrictions, water supply upgrades, computer upgrades, collaboration with other utilities, drought management planning, demand management planning, water conservation applied to operations and maintenance, public education, education for elected officials

South East Kelowna Irrigation District:

Agricultural metering, collaboration with other utilities, sector demand study, water supply upgrades, computer upgrades, watershed protection, pilot programs, pricing review, drought management planning, demand management planning, water conservation applied to operations and maintenance, public education

Westbank Irrigation District:

Watering restrictions, water supply upgrades, computer upgrades, pilot programs, xeriscaping, public education, drought management planning

Adapted from (deVries 2004)

2.3 *Barriers and challenges*

The previous two sections demonstrate that many demand management solutions are available to water providers and end users, yet broad implementation in the Okanagan Basin (as in most of Canada) has been limited. To promote wider adoption of conservation initiatives and programs, and a comprehensive and long-term approach to demand management, a variety of barriers and challenges must first be overcome.

Some of the most significant and challenging impediments in the Okanagan include:

Root causes

- a myth of water abundance – the notion that more water is always available undermines efforts to pursue greater conservation;
- resistance to changes in water pricing – viewed as another government tax;
- a belief that reducing water use compromises standards of living;
- fragmentation of responsibility – water crosses international borders and water management involves multiple levels of government. This raises the question of who should bear the cost of water efficiency; and
- public perceptions and political agendas – for example in the Okanagan agricultural users have a strong sense of historically-entrenched ownership over water, and they continue to expect low water rates.

Entrenching factors

- insufficient data – little is known about total supply and use. For example, insufficient information about groundwater and surface water linkages and difficulty in monitoring quantities of water allocated in water licenses and the amount used;
- limited ability of managers to modify water rights (e.g. water licence transferability and conditions);
- disconnect between land use and water management - rapid population growth in the valley is challenging decision makers to find means to effectively integrate water management considerations into land use planning;
- perception that achieved efficiency will simply allow for further development in the region, without a change in the development agenda;
- concern that DSM savings are unreliable and/or insubstantial;
- general preference for high visibility projects;
- publicly subsidized infrastructure expansion without enforced DSM conditions, promotes supply-side solutions; and
- lack of funding for DSM projects and insufficient resources to develop 'good' DSM programs.

The evolution of water management in the region and the influence of root causes and entrenching factors maintain the unsustainable, supply-side focus of the current water management regime in the area. These barriers create a gridlock that limits the widespread adoption of demand management.

Overcoming this gridlock is challenging, but possible. Through an understanding of individual barriers and their inter-relationships, and with the active participation of all stakeholders, the region can create policies and action plans to overcome the existing inertia and promote widespread adoption of a comprehensive, integrated and long-term approach to DSM in the basin. Accomplishing this also requires moving beyond isolated strategies and tackling a number of barriers simultaneously and strategically – embracing a soft path approach to water management.

3. Creating change – a 'counter' story for water sustainability

"The water crisis is essentially a crisis of governance"

Finding the appropriate mix of water demand management tools best suited to the Okanagan is a relatively simple task. It involves planning, discussion, and some basic research, but it is a goal than can easily be accomplished. Many of the methods and technologies for water demand management have been around for centuries (Brooks 2003a:43). The more significant challenge is to change minds to lead fundamental change – the challenge is creating the "counter" story to the myth of abundance in the Okanagan, and thus changing the water management paradigm.

3.1 What's needed – a change in perspective

To what extent is the region prepared to go beyond merely being more water efficient to fundamentally changing the way it views and manages water? A change in perspective about water is the starting point. A belief must emerge that limits exist, and individuals in the region must respect the full range of economic, social, and environmental benefits that water produces.

Doug McKenzie-Mohr, a leading environmental psychologist, recognizes that changing behaviour can be very challenging. Conventional education programs are focussed on information dissemination and sometimes lack a thorough understanding of the barriers limiting the desired behavioural change. Social marketing is an alternative.[42]. It differs from conventional approaches because more time and effort is invested 'up-front' to understand the barriers to desired behavioural changes prior to program design and implementation. (McKenzie-Mohr 2004) Although such an approach is most appropriate at a local action level – it is a place to start and can be a part of a basin wide transformation.

New beliefs, attitudes, and opinions about water are possible. A water ethic and understanding of all the benefits from water as a bundle of services liberates us to seek innovative solutions and alternatives. A shared vision for the region ensures that the many disparate organizations, interests, and individuals can work in concert to create more sustainable behaviors and practices.

Water conservation and living in harmony with our local watershed can become the norm, no longer a 'regional success story' but instead 'the way we do things around here' – not just because it feels good, but because our future and our prosperity depend on it. And it all starts with how we view and manage the most fundamental resource – water.

Box 6: Creating a water ethic

"Adopting such an ethic [water ethic] would represent a historical philosophical shift away from the strictly utilitarian, divide-and-conquer approach to water management and toward an integrated, holistic approach that views people and water as related parts of a greater whole. It would make ns stop asking how we can further manipulate rivers, lakes, and streams to meet our insatiable demand, and instead to ask how we can best satisfy human needs while accommodating the ecological requirement of healthy water systems."

(Postel 1997: 185)

[42] The Region of Durham in Ontario has adopted this approach into its outdoor water efficiency program with notable success. The program commencing 1997, with the region employing summer students in a community-based social marketing program to work with homeowners to reduce residential lawn watering – resulting in a 32 percent reduction in peak water demand over a three-year period (Maas 2003: 16)

4. **Who's involved – governance more than just government**

Overcoming the inertia of the status quo in water management in the basin is difficult but necessary. Implementation of a basin-wide, comprehensive and integrated approach will require action by many different players, including all orders of government, the private sector, non-government organizations, and individuals.

'Good' governance and leadership by publicly accountable authorities are critical to ensure desirable outcomes. Governance certainly refers to more than just government; it includes broader institutions, such as business and 'civil society', and a full range of players who can creatively manage and accelerate the adoption of more sustainable water practices. However, government still has a critical role — especially as leaders signalling the importance of our water resources.

Governance must be adaptive and inclusive if it is to be successful at creating sustainable water solutions. Consensus among technical and scientific experts, resource managers and business leaders exists for the urgency of coordinated and collaborative action. This action must cross disciplines and organizations in order to deal with water sustainability challenges in the Okanagan basin. Effective action will involve enhanced communication, ongoing research, and the development and use of more integrated approaches. This will also require professional, private, and public-sector commitments that involve risk-taking, leadership, innovation, and follow-through to implementation.[43]

Fundamentally, good governance and the challenge of developing sustainability requires input, commitment, and engagement by all members of society.

5. **Getting there – a 'made-in-the-Okanagan' approach**

Many opportunities to create a sustainable water future for the Okanagan are available. Solutions exist – the challenge is making them happen. The following identifies some of the key factors that will enable water demand management and adoption of a basin-wide, comprehensive and integrated 'made-in-the Okanagan' approach:

- achieve a ***shared vision*** – a shared vision for water sustainability must be created by people from all sectors with diverse backgrounds, skills and expertise from across the basin;
- endorse ***basin-wide thinking*** – a clear understanding that everything in the basin is connected and that decisions and actions have impacts throughout the watershed;
- create ***knowledge*** – about current and future supply limits; anticipated demands through population and economic growth; financial impacts of water shortages on social and economic well-being; ecological limits, and the implications of exceeding these limits on habitat and species[44];
- choose ***appropriate options*** – allows for tailored options to address specific local needs, and starts by finding the appropriate suite of demand management measures to address water conservation for the region;

[43] Erik Karlsen personal communication December 22, 2004

[44] Knowledge is more than just data, but data is necessary for knowledge to evolve—currently, many data gaps exist. Important information on streamflow levels, groundwater resources, water use by various end users and the state of conservation is urgently needed.

- commit to ***standards and targets*** – clear expression of sector-specific performance standards and targets for conservation coupled with information about proven and practical ways of achieving these goals will promote success in achieving the targets;
- ensure ***technical and financial support*** – technical support is needed to assist in moving to water-efficient practices and the financial support is critical to help share the risk and overcome start-up deterrents of water-efficient capital and operating practices;
- promote ***early adopters*** – recognition of early and ongoing success embeds change and creates innovation;
- provide ***incentives*** – both the carrot and the stick can promote appropriate choices, such as changing crops to low water options or switching grass to cash;
- embed ***performance planning and adaptive management*** -- clearly define performance targets and commitments to achieve these; then monitor and report on these commitments and successes from the basin to the site level; and finally, adapt to changing conditions and make adjustments in response to experience. This allows for continual learning and new solutions for future problems; and
- ***educate, educate, educate*** – raises awareness and empowers people to be part of the solution. Relentless education about the benefits and potential of conservation and demand management is where to start, but ultimately we must educate about the critical need for a region wide water ethic. Specifically we must educate the end users, we must educate our leaders and we must educate our children for they are the future.

A social dilemma cannot be resolved with a technical solution – in the Okanagan, long-term water sustainability in the face of growing populations and a changing climate is a social dilemma and must be resolved with social solutions.

Social solutions entail a focus on the broader social and cultural contexts that shape attitudes and behaviors. To allow this requires institutions to creatively manage and accelerate the adoption of more sustainable solutions. These solutions must start from a paradigm that focuses not on managing watersheds, but managing people in watersheds – a paradigm that doesn't assume endless supply, dreaming up the large-scale technologies to harness it, but instead manages demand and uses innovation to ensure conservation.

Perspectives are changing. The science is clear. Solutions exist. The urgency for the region increases daily. The time for action is now. Changing the world one watershed at a time is the goal – for Canada the Okanagan is the place to start.

4. Appendix

Options for improving agricultural on-farm irrigation efficiency and crop productivity

Category	Option
Institutional	• Conservation coordinator • Conservation plan and program • Policies for efficient on=farm water use and penalties for inefficient use
Educational	• On-farm water audits • Field and workshop training programs • Training materials, workbooks, and software • Newsletters and periodicals • Internet information networks and listservs
Financial	• Conservation-oriented pricing • Water marketing • Low-interest loans • Grants and rebates for purchase of more efficient irrigation equipment and tools
Managerial	• On-farm water measurement (metering) • Soil moisture monitoring • Irrigation scheduling • Evaportranspiration rates and other data from weather station networks • Tailwater reuse • Conservation tillage • Canal and conveyance system lining and management • Limited irrigation/dryland farming • Deficit irrigation
Technical	• Laser-graded land levelling to allow more uniform application of water • Furrow diking to promote soil infiltration and minimize runoff • Low energy precision application (LEPA) to reduce water losses from evaporation and wind drift • Surge irrigation to spread irrigation applications uniformly • Drip irrigation to reduce water losses from evaporation, increase crop yields, and reduce chemical and energy use
Agronomic	• Enhanced precipitation capture (rainwater harvesting) • Reduced evaporation through improved use of crop residues, conservation tillage, and plant spacing • Sequencing crops to optimize yields, given soil and water salinity conditions • Selection of native and drought-tolerant crops to match climate conditions and water quality • Breeding of water-efficient crop varieties
	(Vickers 2001: 342)

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Water Balance Management in the Okanagan: Now What Do We Do?

by

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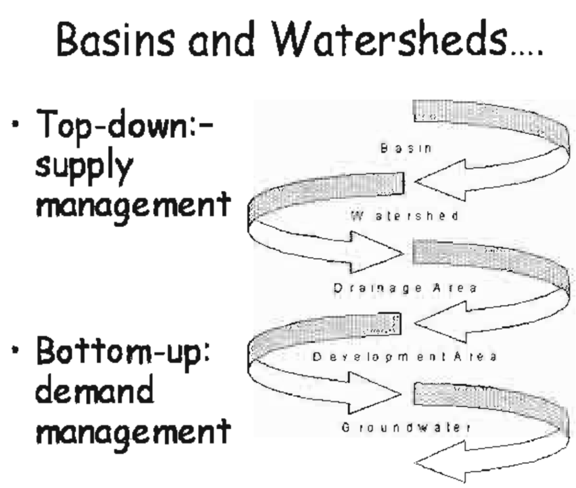
Abstract

The paper will focus on the Okanagan Basin as a 'water balance area'. In this regard, the graphic below provides context for framing this question: *Water In / Water Out – What's the Balance?* Two success stories will be presented to elaborate on what can be accomplished by promoting the water balance theme as a way of integrating water management with landscape development:



- **Demand Management of Irrigation District Water Supplies in the Okanagan Valley** – This 1988 initiative was comprehensive in assessing the potential for domestic and irrigation water conservation. It was also the trigger for a change in philosophy that resulted in implementation of new approaches and tools.
- **Water Balance Model for British Columbia** – This decision support and scenario modelling tool is changing the way people think about the relationship between the built and natural environments, and the way we develop the urban landscape.

In the Okanagan, approximately 70 percent of water use is for agricultural purposes. Given the sheer magnitude of the agricultural component of the 'Okanagan Water Balance', one of the purposes of the paper is to provide an historical bridge from the 1988 initiative to the present that addresses these three questions:

- What is our starting point?
- Where do we want to be?
- How will we get there?

The paper will suggest expanding the application of the Water Balance Model approach to all land uses in the Okanagan, and in particular agriculture.. In the urban environment, the main focus is on the individual development site because what we do at the site scale can create opportunities for cumulative benefits over time. In applying the water balance philosophy to the Okanagan in its entirety, the proposed paradigm will be: "the Basin is the site". This will consider rainfall and infiltration as well as water used for growing and processing various agricultural products in relation to water sources. Ultimately it will both pose and suggest answers to the question: *How much of the basin's water needs will have to be found through improved practices to ensure the ongoing vitality of its communities?*

Setting the Scene

The Water Sustainability Committee (WSC) of the British Columbia Water and Waste Association is pursuing the development and application of innovative approaches to the governance, planning, management and use of fresh water resources to meet water needs in British Columbia. As part of this initiative the WSC is promoting the use of events such as conferences and workshops to focus on actions that will lead to the sustainable use of these resources.

An action focus calls for strategies that influence and change those human activities that cause water supply problems and issues. This involves posing and answering three questions:

- **What** is the issue or problem?
- **So what** can be done about it?
- **Now what** will be done?

Uses run from drinking water to ecosystem support, to land and water based production such as agriculture, to commercial and industrial uses.

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Step 1 - What: The two statements below are extracted from the Conference Overview. They establish a tone and define the scope of the issue facing the Okanagan region:

- "The water resources of the Okanagan will be totally allocated in less than 25 years."
- "To move toward sustainable water management in the Okanagan requires difficult decisions now..."

Step 2 - So What: Given the foregoing frame-of-reference, a fundamental starting point for our paper involves the pursuit of a *water balance* approach: water used in the Okanagan should not exceed the ability for the natural restoration of supply. In proposing that the Okanagan Basin be viewed as a 'water balance area', the focus of our paper is expressed as follows:

Water OUT = Water IN!
What's the Balance?

Step 3 - Now What: The objective is to generate change towards the sustainable use of water resources by developing strategies that:

- Consider complexity.
- Address personal or organizational choice.
- Use performance planning and adaptive management approaches.

Presentation Road Map: Our paper is organized under four topic areas:

- Water Sustainability Action Plan for BC
- Irrigation Demand Management
- Designing with Nature
- Saving Water-on-the-Ground

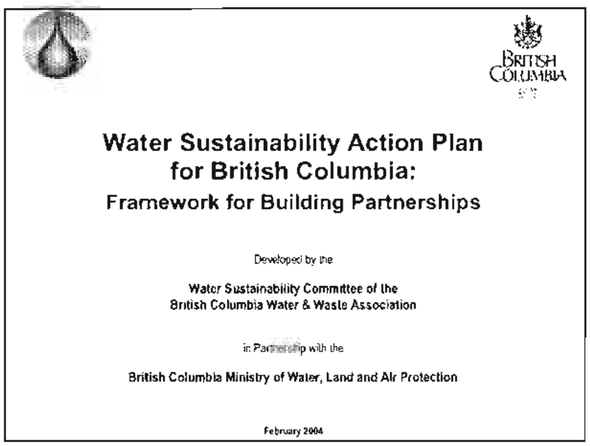
Emerging success stories are presented to elaborate on what is being accomplished by promoting the water balance theme as a way of integrating water management with landscape development and uses.

Water Sustainability Action Plan for British Columbia

The WSC has embarked on a partnership with the Province and other Stakeholders to develop and implement a fully integrated ***Water Sustainability Action Plan for British Columbia*** that will promote and facilitate sustainable approaches to water use and water resource management:

- At all levels – from the province to the household; and
- In all sectors – from domestic, resource, industrial and commercial, to recreational and ecosystem support uses.

The Action Plan builds on ***A Water Conservation Strategy for BC***, developed during the period 1997 - 2001 by the Province in partnership with the WSC.



The Action Plan provides an umbrella for grassroots initiatives that are informing Provincial policy through shared responsibility. The Action Plan recognizes that the greatest impact on land and water resources occurs through our individual values, choices and behaviour.

The mission of the WSC is to create a lasting legacy for British Columbians – by influencing choices and encouraging action by individuals and organizations so that water resource stewardship will become an integral part of land use and daily living.

"Soft Path" for Water: Managing water demands to meet water needs is part of a broad continuum of water management paradigms:

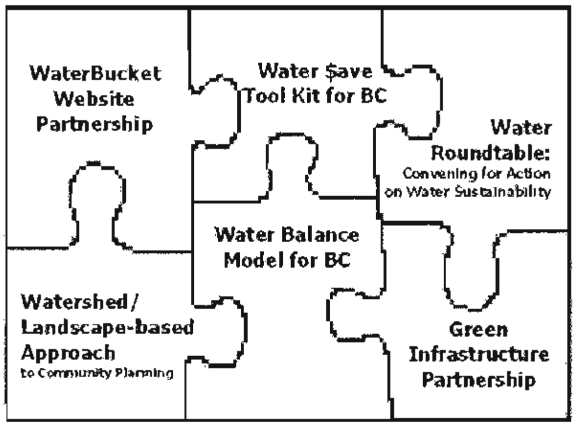
- At one end are supply-side approaches that increase capacity.

- At the other end is a truly long-term and comprehensive approach to planning and water resource development and use – called a *"soft path" for water.*
- In the middle of the spectrum is demand-side management (DSM); resources are to be used efficiently, conservation is key, and economic cost-benefit analysis guides decisions.

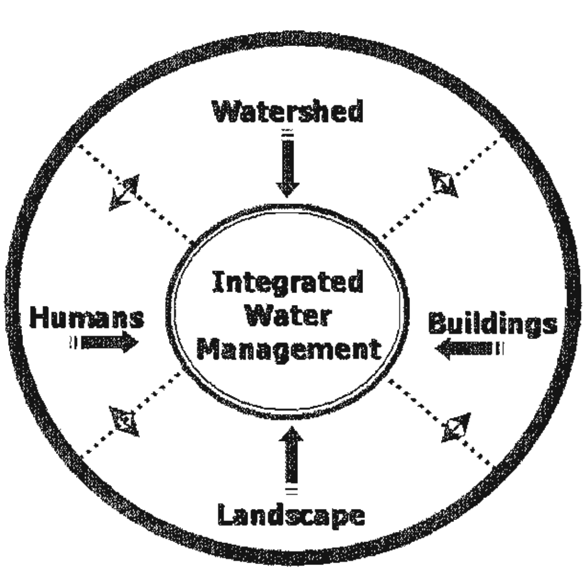
The philosophy behind the Action Plan reflects the "soft path" approach for water as described in the companion paper ***Changing Perspectives – Changing Paradigms***, by Oliver Brandes and Lynn Kriwoken.

An Integrated Landscape: The desired outcome is implementation of *on-the-ground changes* in policies, programs, applied research, practitioner education and standards of practice that lead to full integration of landscape (re)development and water management. In an 'integrated landscape', water is the unifying element.

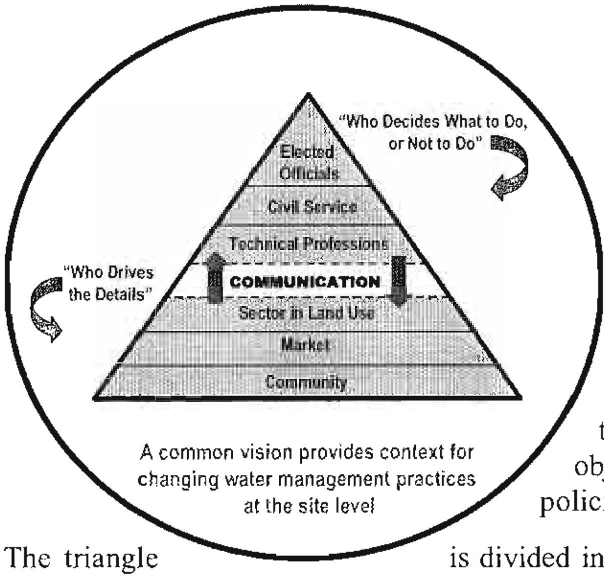
The Foundation: The Action Plan is comprehensive in scope and comprises six Elements, ranging from 'governance' to 'site design'. All six are referenced herein. Future elements will build on this foundation:



Integrated Water Management: The **waterbucket.ca** website will provide the complete story on integrated water management – *why, what, where* and *how* – and is the key to the communication strategy for the Action Plan. Everything is connected – and water management practices at the site scale can have either cumulative impacts or cumulative benefits at the watershed scale. The legacy of past practices is *cumulative impacts*. Behaviour and practices can be influenced and changed for the better: resulting in *cumulative benefits* over time.



Outreach and Continuing Education: The Outreach and Continuing Education Program (OCEP) for the Action Plan is being tailored to different target audiences, and is cascading in crossing boundaries as conceptualized by the graphic below. This is intended to illustrate what is involved in communicating across boundaries to build support for a shared vision.



The triangle symbolizes the decision process. The maximum freedom of decision exists at the top level, of course, when no decisions have yet been made and the issue is one of establishing the social objectives, and of formulating appropriate policies for their achievement.

The triangle is divided into two parts to mark the distinction between *those who decide what to do*, and *those who drive the details* once a policy decision is made. Through education and communication, the objective is to bring the parts together to move from talk to action in changing water management practices at the site level.

Irrigation Demand Management

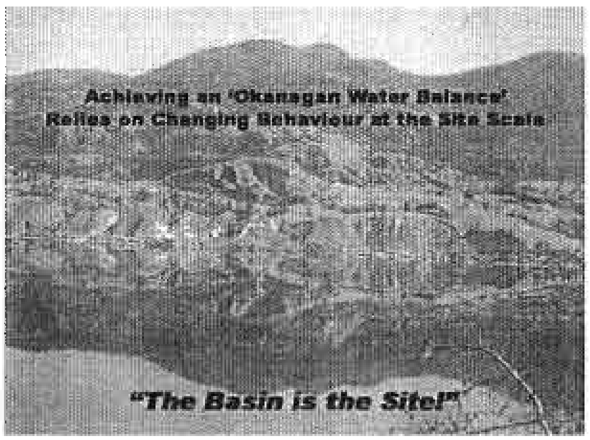
In the Okanagan, more than 70% of water use is for agricultural irrigation purposes. Of the other 30%, at least half is used for lawn, garden and open space irrigation in cities, towns and villages. In other words, over 85% of the total water supply is used for outdoor purposes.

In 1987, British Columbia experienced a drought that has had a lasting impact on the way we think about water. It raised awareness of the limited capabilities of water supply sources, especially those in the Okanagan. And it placed the spotlight on demand-side management as the way to stretch support capacities in the Okanagan.

Given the sheer magnitude of the agricultural and outdoor residential components of the 'Okanagan Water Balance', one of the purposes of our paper is to provide an historical bridge from the 1987 drought to the present that addresses these three questions:

1. What is our starting point?
2. Where do we want to be?
3. How will we get there?

Step 1 - Our Starting Point: After the 1987 drought, the Province commissioned a comprehensive study to assess the potential for domestic and irrigation water conservation in the Okanagan. The study was state-of-the-art in its approach: it quantified the probable benefits of a universal metering program, both for the agricultural and residential sectors; and also for on-farm irrigation system changes in reducing/eliminating wasteful uses of water.



Finalized in February 1990, this landmark study provides us with an historical baseline. It marks the turning point in philosophy that is now leading to new approaches and new tools in the Okanagan.

Step 2 - Where We Want To Be: The 1990 report on Okanagan Demand-Side Management established that the combination of universal metering plus irrigation system changes could potentially reduce total annual water use by **one-third**; and determined that this possible water saving could be used to stretch existing (1987) system capacities in order to:

- Increase the total irrigated farmland by ~40% in the Okanagan; or
- Support an additional 200,000 people.

Most of this potential saving (i.e. 87%) is in the agricultural sector. Hence, agricultural water use is the key to an Okanagan water balance management strategy.

Setting a Volume Target: At the end of the day, achieving a one-third saving relies on changing human behaviour at the site scale, whether the site is a residential lot in a city or a farm in the country.

One of the outcomes of the 1990 report was the ***TIE*** acronym to describe an integrated (or multi-prong) strategy for informed decision-making, eliminating waste and achieving a target annual volume; where:

- ***T***ool = meter
- ***I***ncentive = pricing system
- ***E***thic = education

Population Growth and Density: Over the past 30 years, the population of the Okanagan-Similkameen river basin has more than doubled (to 285,000 as of the 2001 Census), the fastest growth rate among the 23 major river basins in Canada. There are 18 people for every square km of land. For river basins, this is the second highest ratio in Canada. Yet even this statistic is deceptive, because the population is concentrated along the valley bottom.

Issue and Desired Outcome: Water is the unifying element for growth management in the Okanagan. The 'big picture' is distilled down to a set of succinct bullets as presented below to focus on what is most important.

Okanagan Water Balance Strategy: Reflecting on the changes that the writers have seen between 1987 and 2005, we suggest that four core principles guide development of an *Okanagan Water Balance Strategy*:

1. Understand that the Built Environment and Natural Environment are connected.
2. Embrace water as the unifying element for sustaining Okanagan livability.
3. Reduce agricultural water use primarily to expand the irrigated farmland base.
4. Reduce residential water use to support population growth in the urban centres.

These principles provide a basic framework for defining 'where we want to be'.

Step 3 - How We Will Get There: Figure 1 summarizes a set of nested processes that address needs for change, and provides a mind map to illustrate how 'we will get there'.

The goal is three-pronged in providing **security** – for the Okanagan situation, this means a sustainable supply of water; **certainty** regarding how security will be provided (e.g. water rights, demand management strategies, etc.) and a focus on overall **well-being** (e.g. livability and protection of the natural landscape).

The application of this process is intended to address needs at the challenge level, before they escalate to problems, issues and crises (or even chaos).

Process: The process starts at the lower left hand corner of the larger aggregate triangle and proceeds to its apex and then down the right side and along the bottom. It addresses three questions and then uses the answers to these to establish and engage in an adaptive management approach which in turn will generate ongoing knowledge to address changing needs.

1. **What** are the conditions that create the need for change? This involves generating and transferring knowledge that systematically addresses causal links.
2. **So what** are the options and what is the best choice? This involves looking for practical opportunities and overcoming barriers.
3. **Now what** are the strategies and actions that will provide the security, certainty and well-being needed for sustainable outcomes? This involves defining outcomes and making commitments to achieve these.

Adaptive Management: The final step involves monitoring performance of the action plans. The actions taken will lead to new conditions. Other influences will have changed conditions too. These changes – and knowledge about them – may result in the need to revisit the three overarching questions and go through the process again.

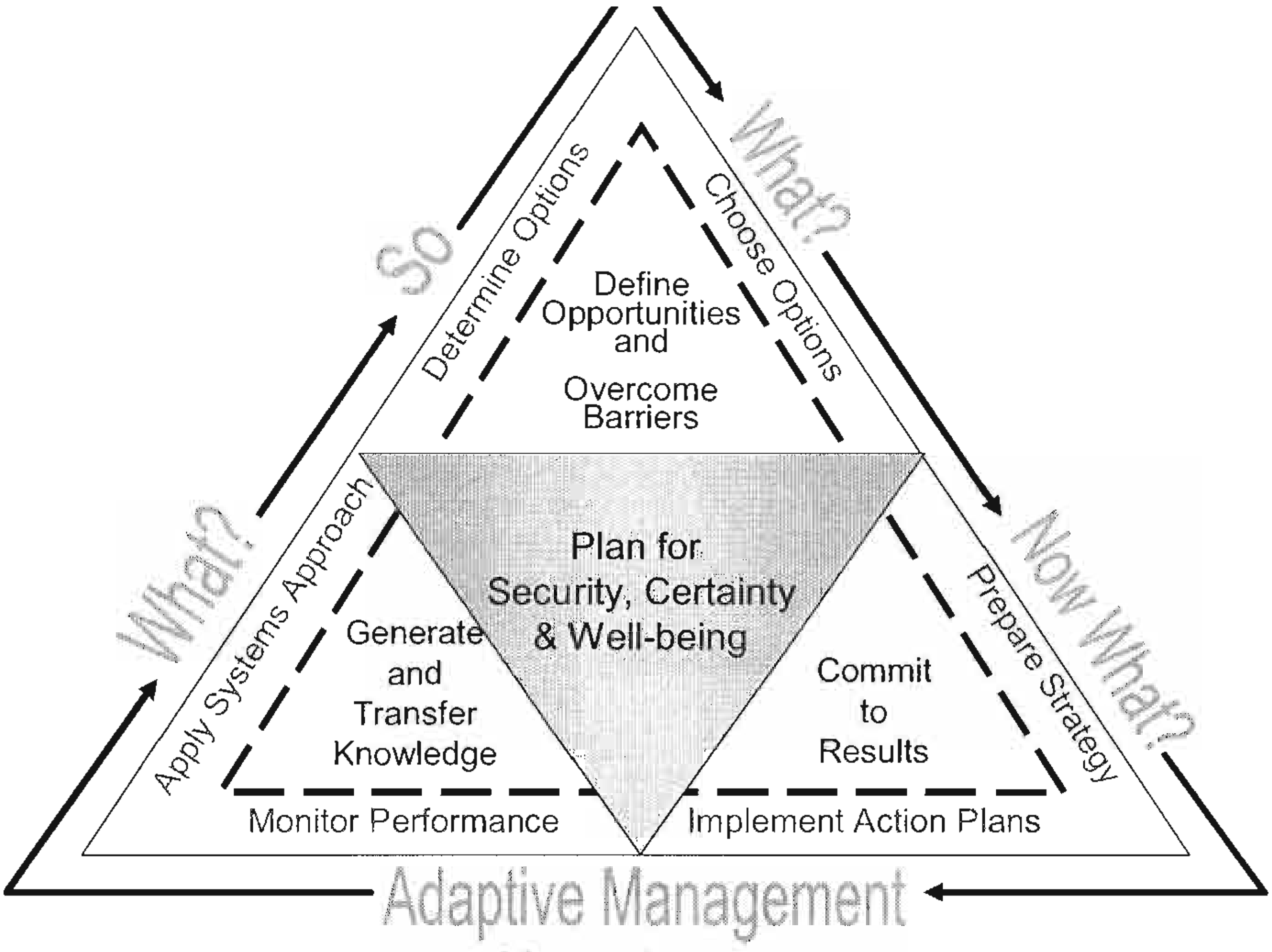


Figure 1

Turning Points: A further point about the choice of a triangular diagram to illustrate this process, rather than a circular or Venn diagram: making choices to go through this whole process requires *turning points*. At each corner a commitment must be made to proceed to the next step.

Designing with Nature

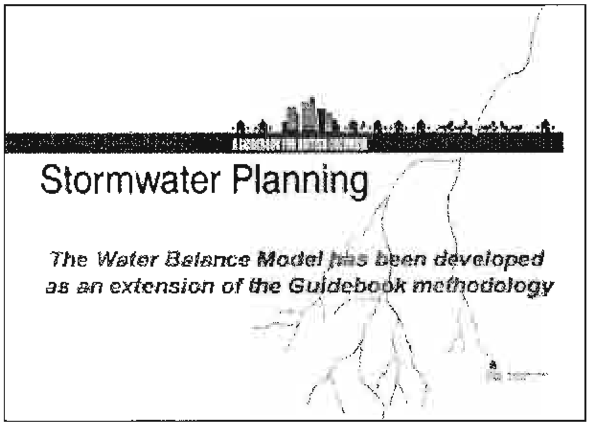
Rapid population growth, redevelopment of older neighbourhoods, and land use densification are creating opportunities to reverse past failures to prevent the creation of rainwater runoff and its negative environmental impacts.

To achieve this outcome, a **"design with nature"** approach strives to capture and retain most of the annual rainfall volume on development sites and along roadways. The focus is on preserving and/or enhancing the natural rainwater absorption characteristics of a site slated for (re)development.

The missing link in urban watershed planning and subdivision design has been a tool that could readily quantify the cumulative benefits – achieved at the neighbourhood and watershed scales – of reducing rainwater runoff volume at the site level. The *Water Balance Model for BC* eliminates this gap.

Water Balance Model: **Developed as an extension of *Stormwater Planning: A Guidebook for British Columbia,* the Water Balance Model (WBM) is a decision support and scenario modeling tool that was formally launched at the Urban Forum of the Annual Conference of the Union of BC Municipalities in September 2003. The WBM is web-based and can be found at** waterbalance.ca. **It is a success story.**

Long-Term Vision for the WBM: The vision for **waterbalance.ca** is that use of the WBM will become standard practice in British Columbia for land development decisions. The WBM promotes the water balance theme as a way of integrating water management with landscape development in the urban environment. Developed by an Inter-Governmental Partnership (IGP), the WBM enables users to compare scenarios for rainwater runoff volume reduction in order to achieve a light 'hydrologic footprint'. The WBM is the centrepiece of the *Water Sustainability Action Plan for BC.*



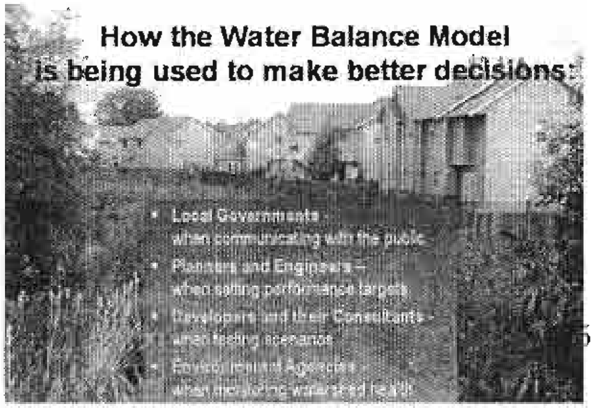
The Inter-Governmental Partnership: The IGP is a consortium of 21 local, regional, provincial and federal agencies; and with municipal representation from four regions: Greater Vancouver, the Fraser Valley, Vancouver Island and the Okanagan Valley. Early WBM supporters included the Real Estate Foundation of British Columbia and Urban Development Institute.

IGP Mission: The IGP mission is to enable local governments and landowners to make informed land development decisions and meet performance targets for runoff volume reduction and flow rate control at the source, where rain falls.

The Goal: The IGP is promoting changes in land development practices so that the built environment will preserve and/or restore the natural water balance over time.

Project Outcomes and Benefits: Over time, integrating suburban land development planning and design with volume-based rainwater runoff management strategies will achieve three outcomes:

- provide higher levels of watershed and stream protection;
- demonstrate due diligence; and,
- reduce infrastructure costs.



Integration of Perspectives: As a tool for subdivision design and local site development, the WBM promotes the integration of perspectives through a collegial and interdisciplinary approach that enables design professionals to collaborate to achieve community livability objectives:

- **Planners** ➔ Better Use of Space
- **Engineers** ➔ Infiltration Design
- **Landscape Architects** ➔Green Solutions
- **Educators** ➔ Social Marketing

Designed to evaluate the feasibility and effectiveness of site level rainwater management solutions, the WBM is emerging as the modeling tool of choice in making sustainable land development decisions because it demonstrates how to achieve a light ***'hydrologic footprint'*** under different combinations of land use, soil and climate conditions.

Case Study - Implementation of Integrated Approaches in the Greater Vancouver Region: The Greater Vancouver region has no more room to sprawl. This means that 75% of the next two million people will be housed in existing built-out watersheds. The resulting redevelopment is creating opportunities to restore watersheds over time. The rethinking of traditional approaches is built around integration of land use planning with volume-based rainwater management strategies.

Broad-based support for needed changes in municipal policies, regulatory tools and standard practices is being achieved through consensus processes that are keyed to an interdisciplinary, inter-departmental and inter-agency roundtable sharing of knowledge and experience.

The roundtable process results in 'integration of perspectives' which in turn leads to 'integrated solutions'. Experience has shown that when the right people with the right knowledge are involved right at the start in an interdisciplinary roundtable process, a 'knowledge-based' approach is both time-efficient and cost-effective in developing 'integrated solutions'.

For the past decade, the 22 cities comprising the Greater Vancouver Regional District (GVRD) have been pioneering development and implementation of integrated approaches to rainwater management and landscape development. Because the regional vision is to improve the built environment and protect the natural environment, policy objectives are being translated into on-the-ground tools that are transforming the way the urban landscape is developed and serviced.

UniverCity, the sustainable community that will ultimately house a population of 10,000 adjacent to Simon Fraser University atop Burnaby Mountain, is a symbol of what the future looks like for Greater Vancouver. This project has demonstrated how to move from policy to implementation: *UniverCity* is a complete urban community that demonstrates principles of sustainable development through a balanced approach, one that builds a compact community while protecting natural systems. One of the underpinning principles is to manage watercourses and rainwater runoff to protect aquatic habitat in affected watersheds.

The *UniverCity* project enabled pilot testing of innovative approaches and methodologies to achieve regional policy objectives for watersheds. The successful *UniverCity* experience then provided the foundation for a series of regional and provincial initiatives in British Columbia that are linked and cascading from high level to ground level, notably:

- ***Watershed/Landscape-Based Approach to Community Planning:*** This approach involves 'planning with reference to watershed-based features'. Produced by an inter-municipal and inter-agency working group of the GVRD Technical Advisory Committee, this document articulates a philosophy and defines a planning methodology for integration at three levels-of-effort and three scales of attention (i.e. watershed, neighbourhood and site). This approach is also an element of the *Water Sustainability Action Plan for BC*.

- ***Stormwater Planning: A Guidebook for British Columbia:*** This guidance document is a prime application of the watershed/landscape-based approach, and has received recognition throughout North America, in part because at its heart is a pragmatic 'water balance methodology' that enables local government to set performance targets for land development and rainwater management at the site, neighbourhood and watershed scales. The Guidebook is built around an adaptive management philosophy for 'constant improvement'.

  In the context of the Guidebook, watershed/landscape-based planning means that resource, land use, and community design decisions are made with an eye towards their potential impact on the watershed. Therefore, what happens at the scale of the individual parcel and street affects what happens at the watershed scale.

- ***The Water Balance Model for British Columbia***: The success of the Water Balance Model in British Columbia has generated interest in expanding the focus of the tool to reach a national audience. Work is proceeding on a national portal: *Water Balance Model for Canada.*

- ***The Green Infrastructure Partnership:*** The mission of the Green Infrastructure Partnership is to provide leadership by developing practical tools and instruments for green infrastructure design practices and regulation, and by encouraging their application in BC. The core deliverable is a **Model Subdivision Bylaw and Green Infrastructure Standards** complete with options for land development regulation province-wide. Implementation by municipalities will be voluntary, but once embraced, implementation will be by regulation.

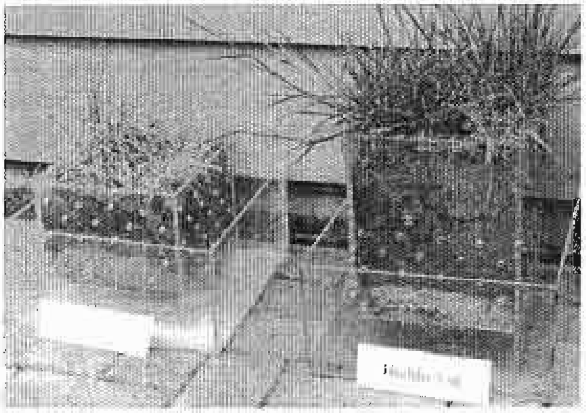
Saving Water on-the-Ground

Over 85% of the total Okanagan water supply is used for outdoor purposes. Therefore, our proposed *Okanagan Water Balance Strategy* revolves around how water is applied to the land.

Integrated Urban Solutions: The WBM has focussed attention on the significance of soil depth plus the value of amended soils to achieve 'integrated solutions':

- **Rainwater Management:** Soil depth serves as a sponge to capture rainfall and slowly release it to natural hydrologic pathways. A thick layer of topsoil will result in healthier gardens and virtually eliminate runoff from landscaped areas.
- **Drought Management:** Deeper amended soils retain more water which provides a greater resistance to drought. Well rooted lawns and gardens require less irrigation and stay green longer.

Okanagan Agricultural Strategy: The 1990 report was the genesis for development of an *Okanagan Agricultural Strategy* that has been taking shape over the past 15 years. The Ministry of Agriculture, Food & Fisheries (MAFF) has been collaborating with Okanagan communities to implement a GIS-based land use information system:



- The strategy is founded on a water balance way-of-thinking.
- The desired outcome is a database that covers the entire Okanagan Basin.
- The goal is to know what is happening on the ground, property-by-property.
- The objective is to enable farmers to make informed decisions on how they can manage their irrigation systems properly to save water.
- The result is a planning tool that benefits both the agricultural and urban sectors.

The Database: MAFF is partnering with local jurisdictions to collect and computerize the following data, property-by-property:

- Land Use
- Crop Types
- Irrigation Systems
- Soil Conditions

The pilot for this program was the Southeast Kelowna Irrigation District (SEKID), the first Okanagan jurisdiction to implement universal agricultural metering after experiencing repeated water shortages during the period 1987 though 1992. The 1994 metering program provided the starting point for development of a computer-based *Demand Management Program* that has enabled SEKID to successfully weather subsequent droughts.

Agricultural inventories have since been completed for Summerland and Kelowna. Vernon and the Central Okanagan Regional District are pending.

Key Message: The combination of universal metering plus a land use database means a comprehensive *Water Requirements Report* can be generated for each property. This compares property-specific needs with:

- Actual metered use; and,
- Water use on other properties that have the same soil conditions, crop types and irrigation systems.

The SEKID experience has shown that the agricultural community will make changes to irrigation systems and water use practices when farmers can be shown that the need for action is founded on commonsense plus conclusive data.

The combination of reliable GIS land use information and water use data is fundamental to an effective Demand Management Program because this combination enables tracking of trends. If system managers and farmers can see how the 'big picture' is changing over time, then they can make operational decisions that are timely and informed.

Universal Metering Programs: In 1990, the City of Penticton and the Rutland Waterworks District were the only fully metered water systems in the Okanagan. Today, all three major urban centres (Kelowna, Vernon and Penticton) have implemented universal metering.

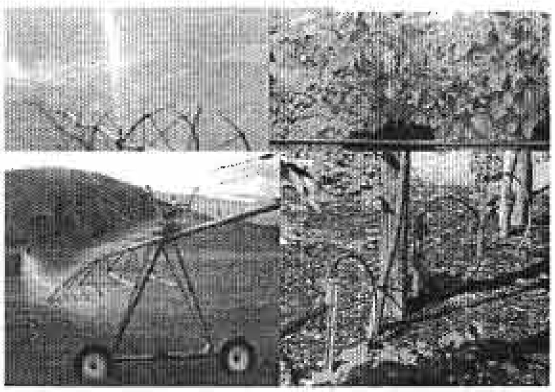
The 1990 report helped to create early momentum for change in Okanagan water use practices. For example, the research into flowmeter types resulted in the three major North American meter manufacturers donating their products to the *Okanagan Valley Meter Demonstration Program* (OVMDP). This achieved three objectives:

- Provided Irrigation Districts with the opportunity to become familiar and comfortable with the meters under actual operating conditions, and over a period of years.
- Created an opportunity to experiment with meter installation standards.
- Yielded site-specific data on actual on-farm water use and the potential for water savings.

National Water Supply Expansion Program for Agriculture: Initiated in 2004, this program provides funding for universal agricultural irrigation metering. Okanagan municipalities and irrigation districts that have so far applied for grants include Summerland, Vernon, Glenmore and Osoyoos.

The program will also provide funding for on-farm initiatives that improve water supply, water conservation and irrigation scheduling. Monies are also available to regional governments and water purveyors for conducting regional groundwater assessments, water management planning, and enhancing agricultural supplies by developing reservoirs and supply infrastructure

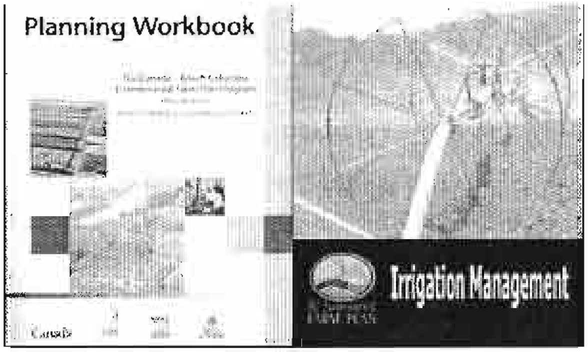
Environmental Farm Planning: A new Federal/Provincial initiative that is being delivered through the BC Agriculture Council is the *Environmental Farm Planning Program.* Key information is highlighted below:

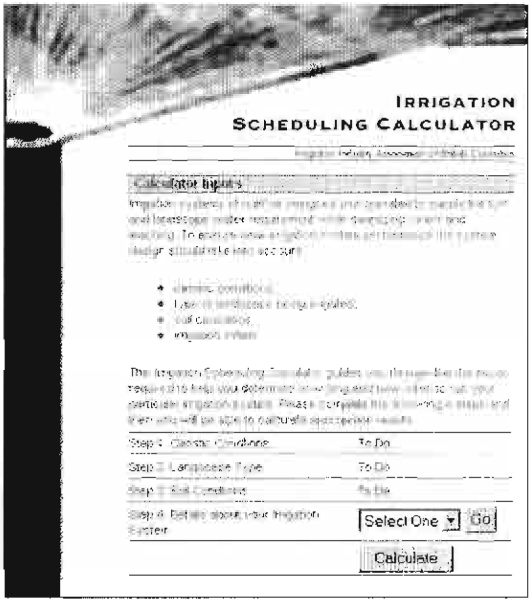


- 6000 plans to be funded in next 6 years;
- 13 commodity groups have signed on;
- 60 farm planners have been trained;
- $2,000 grants available to prepare *Irrigation Management Plans*; and,
- $10,000 grants available to implement efficient, uniform irrigation systems.

The scope of an Irrigation Management Plan is summarized as follows:

- Assesses system performance;
- Evaluates crop and soil conditions;





- Determines when to irrigate; and,
- Quantifies how much to irrigate.

To obtain funding for new more efficient systems, the system design must be certified to obtain funding. Designers can obtain certification through a training program:

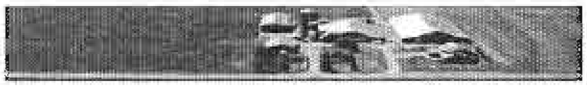
Irrigation Scheduling: Another key message is that poor irrigation systems cannot be managed effectively to save water! To get it right, an Irrigation Management Plan comprises three steps:

- **Step #1:** Select the most ***efficient*** type of system possible.
- **Step #2:** Design the system to obtain the best ***uniformity***.
- **Step #3:** Then ***schedule*** the system according to soil moisture or climate.

The significance of these three key words -*efficiency / uniformity / scheduling* - is not generally well understood. Poor uniformity, for example, means more water must be applied to ensure that the entire target area receives enough water. This results in most of the area having too much water applied. Continuing education is therefore an essential and integral component of the Okanagan Agricultural Strategy.

Irrigation Scheduling Calculator: To assist turf designers and managers determine when and how much to irrigate, an on-line tool is being developed. This calculator will be integrated with the climate information available at www.farmwest.com:

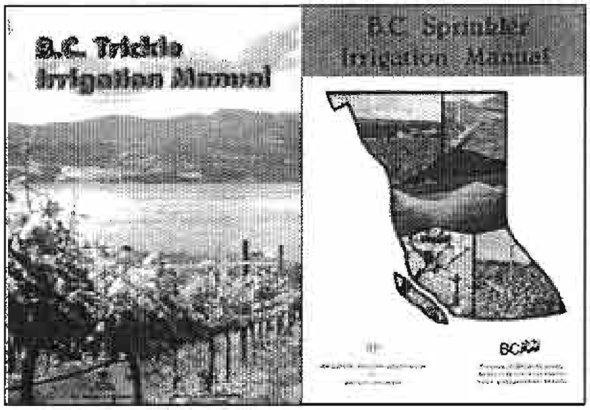
Looking Ahead



In the Okanagan, over 85% of the total water supply is used for outdoor purposes in the urban and agricultural sectors. Because agricultural irrigation accounts for more than 70% of total water use, it is the key to an ***Okanagan Water Balance Strategy***. Based on the information presented in this paper, steps to 'water sustainability' and associated desired outcomes for agricultural irrigation are summarized as follows:

- **Proper System Selection and Good Design:** Improving Uniformity
- **Irrigation System Assessment:** Environmental Farm Planning.
- **Irrigation Scheduling:** Climate Monitoring & Soil Moisture Monitoring.
- **Implementing Conservation Techniques:** Improving Efficiency & Managing and Monitoring Water Use.

Agriculture is an integral part of the Okanagan fabric: It creates the 'look-and-feel' that is part of the Okanagan tourist experience; it is an essential component of the Okanagan economic engine; and it contributes to the provincial food supply. Therefore, saving water should be driven by incentives for the agricultural community.



Build a Vision, Create a Legacy: Four core principles should guide development of an *Okanagan Water Balance Strategy*:

1. Understand that the Built Environment and Natural Environment are connected.
2. Embrace water as the unifying element for sustaining Okanagan livability.
3. Reduce agricultural water use primarily to expand the irrigated farmland base.
4. Reduce residential water use to support population growth in the urban centres.

Practical Tools: Available tools that will enable the Water Balance Strategy to move 'from vision to fruition' include:

- **Urban:** *Water Balance Model for BC,* found at **waterbalance.ca**
- **Agriculture:** *Irrigation Scheduling Calculator,* found at **farmwest.com**

The Scheduling Calculator being developed by IIABC can also be used by homeowners to achieve more efficient outdoor water use.

BC Water Roundtable – Convening for Action on Water Sustainability: The Roundtable is an Element of the *Water Sustainability Action Plan.* Reaching the critical mass necessary to make Integrated Water Management mainstream requires a transformational event – the ***BC Water Roundtable*** – that will be the catalyst for comprehensive partnership action leading to on-the-ground changes in policies, programs, applied research, practitioner education, and standards of practice.

This CWRA Conference is the kick-off event for a process that will involve research plus building commitment during the period leading up to the Roundtable in 2006. The objective is to broaden the province-wide base of support for this shared vision: ***full integration of landscape (re)development and water management.***

Information Management As It Relates To The Okanagan Water Shed: Our Common And Life-Sustaining Heritage

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Abstract

The economy of the Okanagan is limited by water availability and quality. The environment of the Okanagan Basin is unique in the world, rich in species diversity and is limited by a water supply that is vulnerable to water quality and quantity stress. The natural water supply within the Okanagan Basin can only be regarded as a renewable resource if water is used wisely on a long-term basis and annual consumption is controlled within a sustainable framework. The present growth trend in the Okanagan Basin is unsustainable, unless major changes are made to the way in which we manage and regulate the use of our common and life-sustaining heritage: the waters of the Okanagan.

In managing the water resource, one problem is that planners, professionals and researchers find it difficult to locate critical information about the Okanagan Basin because of the isolated existence of databases at disparate locations. Survey results (October 2003) reinforce the need to systematically focus the information available on Okanagan water. The survey revealed a commonly shared need for comprehensive, organized and easily accessible listing of excising data and research related to the Okanagan Basin and information on the location of the data and research from all available sources (including all levels of government, researchers, and consultants) creating a "community of knowledge". There are a variety of examples of information management systems developed by government agencies, universities and regional organizations. In developing a model to facilitate access to information that is not constrained by obscurity or a variety of regional boundaries the Okanagan Basin Information Network was developed. This paper describes a model based on an incremental approach to building an information network, driven by need and supported by university infrastructure

Introduction

Watershed information networks (WIN) are important tools allowing decision makers to organize, understand and manage information. This research paper seeks to identify ways and means to achieve the overall target of managing information at basin level by exploring different information management systems. At this level, the pressure to develop more water resources is increasing, and the challenge is to use water more sustainably, avoiding institutional, environmental and social pitfalls.

One anticipated objective of managing regional water information within a basin is to generate and apply knowledge on how to manage trade-offs and promote synergies to enhance water sustainability. These objectives will be achieved through research, capacity building and outreach activities in three key areas at a basin level:

- integrated decision support tools and information;
- innovative technologies and management strategies; and
- effective policies and institutional mechanisms.

Effective integrated management of water resources at basin level is complicated by the fact that the use of water and land at one location affects how water is used at another location, often in counterintuitive or complex ways. Misunderstandings can lead to policies that adversely affect one set of users, while trying to improve conditions for others. There are at least two major dimensions to this: the consequences of upstream use on downstream availability, and how actions taken at one scale affect uses and users at other scales[45]. Improved information and appropriate decision support tools are needed to understand fully the constraints, opportunities and consequences of different intervention strategies. It is expected that through such improved understanding policy makers, planners, development agencies, and resource users will make more informed decisions at a basin level. The key issues and questions to be addressed will include the following:

- Resource status and use options must be explored. What are the prospects for agricultural, fisheries, and livestock intensification, for the optimization of fisheries, farming and forest systems, for preserving unique ecosystems such as wetlands and upland catchment areas? What are the most efficient, equitable, and sustainable water allocation mechanisms for agriculture, fisheries and urban and industrial use, acceptable to all basin stakeholders?
- Effective basin water management requires a better understanding of the complex set of water-related interactions that occur across temporal and spatial scales, especially the upstream-downstream interaction. What are the consequences of various upstream interventions of the downstream ecosystem and its people? Are there win-win solutions?
- Trade-offs between economic and environmental security must be understood. Livelihoods are derived both from natural and managed eco-systems. There is a pressing need to reduce impacts of managed eco-systems on natural ones, and to manage water to meet the needs of both. How can trade-offs between different uses be managed to ensure a pro-development approach and improved regional sustainability and prosperity?
- Monitoring and evaluation provide valuable management information, and yet most of our agricultural ecosystems are inadequately monitored and evaluated. What indicators are required for different basins and sub-basins? What is the minimum data set requirement? How should such data

[45] http://www.waterforfood.org

be collected, stored, analyzed and disseminated to ensure that it is accepted by all stakeholders and that it is effectively used for decision making?

"What-if" scenarios generated using predictive tools assist in understanding the consequences of possible interventions in terms of economic growth, environmental sustainability and other important objectives. What tools are available and under what conditions should they be used? How can local stakeholders be involved in predicting the future of their environment and quality of life? How do the results of previous basin studies be integrated into the decision-making processes of the policy makers, planners, development agencies and resource users?

Information systems that have been developed globally are reviewed in the context of exploring the development of a water information management system for the Okanagan Basin of British Columbia. Located in the rainshadow of the Coast and Cascade Mountains, the Okanagan is a semi-arid region that is highly dependent on limited water resources. Water impacts many aspects of the Valley's economy including value-added agriculture, forestry and tourism[46]. Population projects made in the 1974 Okanagan Basin Water Study[47], significantly underestimated the current population of the Okanagan. Today, the Okanagan has approximately 325,000 people. It is projected that by 2020, there will be over 500,000 residing in the region (BC Stats, 2004).

Exacerbated by the rapid expansion of economic activities, general increase in population and affects of global climate change[48], the Okanagan Basin has become increasingly vulnerable. Developing local watershed information is one key factor in ensuring the long-term viability of the Basin. One tool that can be used to provide this information to stakeholders is the use of a WIN. WINs are a neutral facilitator of information that work in conjunction with public and private organizations to create an integrated network of data and information to meet the needs of a variety of stakeholders. There are many benefits of having a web-based watershed information network for the Okanagan Valley. These benefits fit into three main categories: data and information access, organization, and education. Effects of increased consumption, compounded by decreased supply due to global warming will require information collection (hydrometric stations), quality interpretation of the data, and a policy framework that reacts to good information of the day and extrapolates good choices for future smart growth of the Okanagan region. The Okanagan with its small basin size, hydrologic and spatial variability compared to other watersheds (see Appendix A) make it a ***living laboratory*** for applying best practices that include the development of an information management systems for water resources.

Information Management Basics

Information management professionals must be familiar with the theory and practice of storing, organizing, retrieving and analyzing information in a variety of settings in business, the public sector, and the academic world. Technical expertise alone is not sufficient for success; information managers are expected to perform and manage a multiplicity of information related tasks. In order to function effectively they need to:

- understand how to organize information

[46] Okanagan Partnership Society. Okanagan Competitiveness Strategy. 2004. ICF Consulting
[47] Summary Report Of The Consultative Board including The Comprehensive Framework Plan prepared under the Canada-British Columbia Okanagan Basin Agreement March 31,1974 B.C. Water Resources Service, Parliament Buildings, Victoria, BC.
[48] Expanding the Dialogue on Climate Change & Water Management in the Okanagan Basin, British Columbia. Cohen, S., D. Neilsen, and R. Welbourn (eds.). 2004 http://www.climatechange.gc.ca/english/publications/okanagan

- analyze user information needs
- design or evaluate information systems that allow for efficient and effective user interaction
- provide and assure the quality and value of information to decision makers
- understand the natural, economic and social environment in which their organization functions
- be familiar with relevant issues in law, economics, and ethics.

Water resource information management is inherently interdisciplinary, requiring aspects of computer science, resource science, economics, business, law, library/information studies, and communications.

What is metadata?

In reviewing information needs for decision making, the means of organizing data is important. Metadata provides detailed answers concerning "who, what, why, how, and when" questions that typically surround a data set.

Metadata is defined, simply, as "data about data" [49]. Similar to the way in which a library record describes information about a book or journal article, a metadata record describes content, quality, condition, and other characteristics of scientific data in a standardized format.

Maintaining metadata records in a standardized format has intrinsic value for organizations on several levels. Metadata is critical to maintaining the usefulness of data over time. Metadata offers "data permanence" by capturing essential information, through a common set of terms, about how data was collected and processed in a particular study. The creation of metadata records saves organizations time and money, in that data from completed studies can be reused in the future. Standardized metadata benefits the user in searching for data, assessing its applicability, obtaining access, and completing data transfer through data catalogues and clearing houses. Data sets are described differently by various organizations. The following are three definitions of a "data set."

Data and Information Access

There can be several stakeholders in watershed management. They range from scientists, elected officials and policy makers, to business community representatives, students and local stakeholders. Access to region-based data and information about the watershed is one of the fundamental needs of these stakeholders. It is what enables these individuals to make informed decisions as they relate to the watershed in question. WINs are able to fill this need by coordinating and housing regional watershed data in one space. A short survey of WINs is summarized in Appendix D. For example, the Red River Decision Information Network (RRBDIN)[50] has a large database of many types of watershed information including GIS data, static and interactive maps, high-resolution topographic maps, an inventory of water resource models, and hydraulic and hydrologic data (RRBDIN, 2004). Visitors to the RRBDIN are able to find the up-to-date watershed data they require easily and efficiently without having to research other sites and are thus able to make informed regional decisions based on that data. A similar database of geospatial information can be found on the Rideau Valley Conservation Authority (RVCA)[51] website. Within the RVCA's Watershed Information System, stakeholders can find technical reports, data, and geographic information as they relate to watershed planning, surface water quality and quantity, groundwater, and aquatic and terrestrial ecology (RVCA, 2004). As information becomes available, it is added to the RVCA Watershed Information System to provide users with current information to base decision on.

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[49] Hutchison, V.B. 2003. Making your data more valuable. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX–Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8. pp. 117–120.

[50] Red River Basin Decision Information Network. (2004). http://www.rrbdin.org/

[51] Rideau Valley Conservation Authority. (2004). http://www.rideauvalley.on.ca/welcome/index.html

Watershed Information Networks also present information in a method that addresses various knowledge levels and requirements. Thus allowing all stakeholders, whether professionals or concerned citizens, to participate and learn about the state of their watershed. The information presented can range in complexity from technical reports of data and management plans to basin fact sheets and general maps of watersheds. The Boulder Area Sustainability Information Network (BASIN)[52] is an example of such a network. BASIN contains a large spatial data catalog of real-time technical watershed data and maps as well as databases of historical watershed data (BASIN, 2004). However, because BASIN is a community-based project, the data and information is displayed in a public-friendly manner, with easy-to-use data searches and explanations of parameters and data collection methods.

Organizational Benefits

Not only do WINs serve stakeholders as data and information providers, they also help stakeholders organize, protect and restore watershed resources by helping to build and mobilize local watershed group capacity. WINs can act as a "clearinghouse" of information for these groups, providing them with guides on how to start a watershed organization, fundraising tips, and tax information for non-profit groups. The Georgia River Network (GRN)[53] is one such network. The GRN provides watershed groups with hands-on assistance in becoming efficient and successful conservation leaders in their respective watershed regions. In addition, the GRN offers workshops and training sessions to its members on professional development, media skills, and tools for effective watershed protection (GRN, 2004). As a neutral facilitator of information, WINs can also help drop barriers between public and private organizations, improve communication, and coordinate their conservation efforts into a single vision or project.

Moreover, WINs benefit communities by providing detailed lists of regional watershed groups. This supplies these groups with a list of contacts to collaborate with and increases the dispersion of information between them as well as offers the public a list of possible volunteer opportunities with local watershed groups in their respective regions. The Ohio Watershed Network[54] has an interactive map of contact information. It is broken up by county and allows the user to find their respective county and find a comprehensive list of watershed groups in their area.

Education

Public involvement and volunteerism are crucial to the restoration and sustainability of watersheds; however, many citizens who live within watersheds are unaware of the current state of their watersheds or how to protect them. WINs help to alleviate this lack of awareness through educational programs aimed at increasing individual participation in watershed stewardship. This includes the use of newsletters, email lists, personal action practices to reduce water waste and pollution, and watershed knowledge quizzes. For example, BASIN has developed extensive education and communication programs to effectively utilize watershed information and present it to the public in an attractive way (BASIN, 2004). An entire section of BASIN's website is dedicated to personal action where the public can find practical ideas on how to protect water quality, water-wise landscaping, household cleaning alternatives, and various water-related quizzes and essays on sustainability.

WINs can also provide resources for educators to help them teach their students conservation principles. The Missouri Watershed Information Network (MoWIN)[55] has an extensive list of resources for

[52] Boulder Area Sustainability Information Network. (2004). http://bcn.boulder.co.us/basin/
[53] Georgia River Network. (2004). http://www.garivers.org/
[54] Ohio Watershed Network. (2004). http://ohiowatersheds.osu.edu/index.html
[55] Missouri Watershed Information Network. (2004). http://outreach.missouri.edu/mowin/

elementary, middle and high school educators and gives them easy access to curriculum units, lesson plans, and activities. By increasing knowledge and awareness among younger community members, Watershed Information Networks help communities prepare for the future and ensure their sustainability. Expected outputs will include:

- Improved understanding of issues of scale, upstream-downstream interactions and basin governance requirements, documented in publications
- Effective technical and management strategies adapted to specific locations, addressing the conjunctive management of surface water, groundwater and rainwater, as well as the rural-urban, and agriculture-ecosystem interfaces
- A basket of tools for sustainable river basin management
- Improved data and information for local, regional and global use
- Capacity built to put understanding into practice and to utilize tools
- Capacity built to manage basin water resources sustainably
- A methodological framework for use by researchers and practitioners of integrated river basin management.

Best Practices: Agencies responsible for collecting and disseminating information

In reviewing information management literature, there are numerous examples of organizations that collect, organize and disseminate water information for decision makers. This section provides for a quick overview of international, national and regional organizations that play a roll in managing water information. The following are description of a select number of information management tools developed to support sustainable water management decision making.

International

AQUASTAT

AQUASTAT[56] is a global database of water statistics maintained by the Food and Agriculture Organization of the United Nations. AQUASTAT collects its information from a number of sources--national water resources and irrigation master plans; national yearbooks, statistics and reports; FAO reports and project documents; international surveys; and, results from surveys done by national or international research centers. In most cases, a critical analysis of the information was necessary to ensure consistency among the different data collected for a given country.

AQUASTAT was developed by FAO in 1993; data have been available on-line since 2001. Most freshwater data are not available in a time series, and the global data set contains data collected over a time span of up to 30 years. AQUASTAT updates their website as new data become available, or when FAO conducts special regional studies. Studies were conducted in Africa in 1994, the Near East in 1995-96, the former Soviet republics in 1997, selected Asian countries in 1998-99, and Latin America & the Caribbean in 2000. Data from the Blue Plan on Mediterranean water withdrawals were last updated in 2002. Most data updates include revisions of past data.

California Irrigation Management Information System (CIMIS)

[56] http://www.fao.org/ag/agl/aglw/aquastat/main/index.stm

The California Irrigation Management Information System (CIMIS) illustrated in Figure 1 is a program of the Office of Water Use Efficiency (OWUE), California Department of Water Resources (DWR) that manages a network of over 120 automated weather stations in the state of California. CIMIS was developed in 1982 by DWR and the University of California, Davis to assist irrigators in managing their water resources efficiently. Efficient use of water resources benefits Californians by saving water, energy, and money.[57]

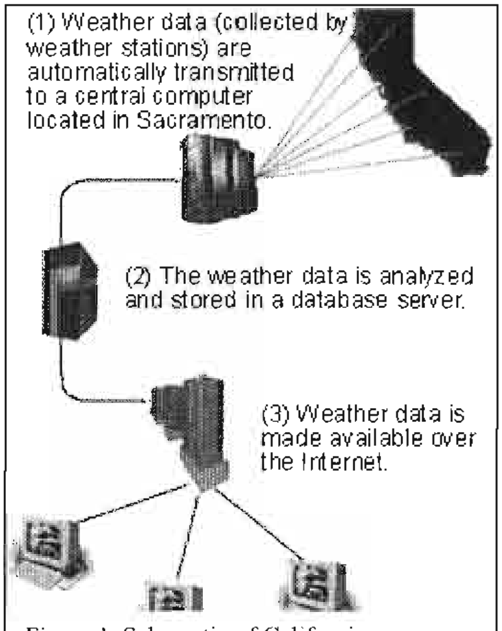

Figure 1. Schematic of California Irrigation Management System[13]

Although CIMIS was initially designed to help agricultural growers and turf managers administering parks, golf courses and other landscapes to develop water budgets for determining when to irrigate and how much water to apply, the user base has expanded over the years. In addition to those mentioned above, current CIMIS data users include local water agencies, fire fighters, air control board, pest control managers, university researchers, school teachers and students, construction engineers, consultants, hydrologists, state and federal agencies, utilities, lawyers, weather agencies, and many more.

The number of registered CIMIS data users has also been growing steadily over the years. Currently, there are over 6000 registered CIMIS data users. It is worth mentioning here that this number reflects only those that are primary users of the CIMIS data. It has been established that many users get the CIMIS data from these primary users for various uses. Examples include local water districts and consultants providing the CIMIS data to their clients. Therefore, there are secondary and tertiary CIMIS data users that have not been accounted for by the figure presented here.

<u>Co-operatively Implemented Information Management System</u>
Alaska's Co-operatively Implemented Information Management System[58] (CIIMMS) began in 1999 as a project funded by the Exxon Valdez Oil Spill Trustee Council focusing on information needs in Cook Inlet in south-central Alaska (Figure 2). The project was developed in response to public requests for better access to data and information pertaining to proposed oil and gas lease sales. The state has attempted to meet this need with CIIMMS, a unique interactive Web site providing a single portal to accessing Alaska natural resource information (***http://info.dec.state.ak.us/ciimms***).

CIIMMS was developed in a phased approach. Initial efforts centered on defining user needs, identifying existing data and resources, and developing an initial set of system specifications to

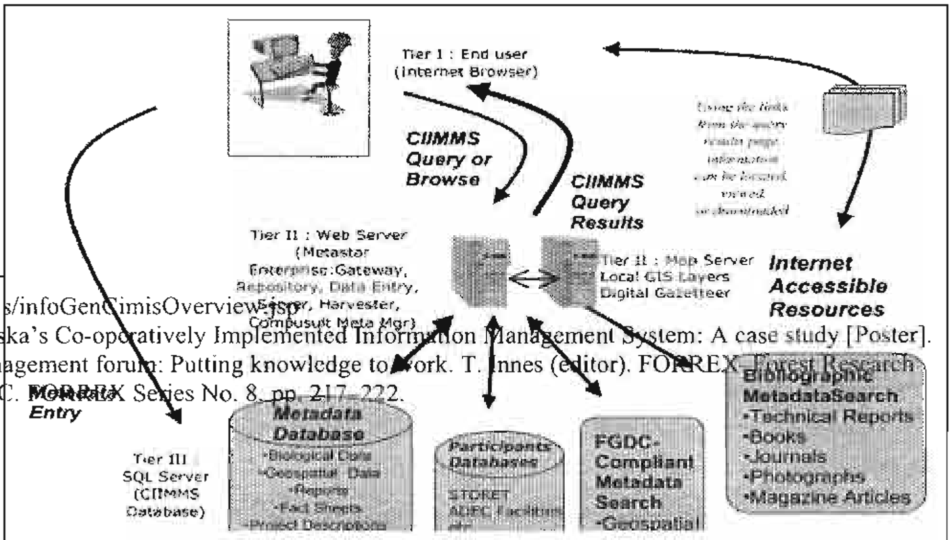

Figure 2. Schematic of **<u>Co-operatively Implemented Information Management System</u>**[14]

[57] http://wwwcimis.water.ca.gov/cimis/infoGenCimisOverview.jsp.
[58] Fries, C. and R. Kunibe. 2003. Alaska's Co-operatively Implemented Information Management System: A case study [Poster]. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8, pp. 217-222.

implement a prototype system that focused initially on the Kenai River. Following the development of a prototype, the results of extensive user outreach were used to develop and implement a final set of system specifications that focused on Cook Inlet. Results of the Cook Inlet implementation have since been applied to the entire state of Alaska.

Canadian Information Systems

GeoConnections

GeoConnections is a national partnership initiative led by Natural Resources Canada. Through GeoConnections, the federal, provincial, and territorial governments are working with industry and post secondary institutions to build the Canadian Geospatial Data Infrastructure (CGDI). The CGDI and geospatial infrastructures are integrated, on-line networks that deliver access to geospatial data and services for applications, better business and policy decision making, and value-added commercial activities. Major components of these infrastructures include: technical experts, policies, distributed and networked databases, and enabling technologies and services[59].

Canadian Geoscience Knowledge Network

Since 1998, Canadian Geological Surveys have been collaborating on development of the Internet-based Canadian Geoscience Knowledge Network[60], or CGKN. The objective of the CGKN is to link the geoscience knowledge holdings of the 12 federal, provincial, and territorial geological surveys and to support access to these data in consistent and interoperable form through on-line services. The CGKN will become the Internet portal for Canadian government geoscience data and the geoscience node of the Canadian Geospatial Data Infrastructure.

Open standards and a distributed network architecture are being used to permit participants to benefit from the cost savings of collaborative development with minimal impact on local operational requirements. Standards for data management, exchange, and delivery are recognized as the foundation of the CGKN and a coordinated and open effort is under way to establish these standards. The overall CGKN effort is coordinated by a Data Infrastructure Working Group and involves a number of subgroups addressing specific disciplines and functions. Activities involve a combination of federal, provincial, and private sector participants with both scientific and technical expertise. Subgroups currently exist to address bedrock geology, surficial geology, geochemistry, geophysics, sedimentary basins and petroleum resources, and mineral deposits. Existing international technical standards and specifications are being adopted wherever possible to ensure the future interoperability of CGKN data sets and facilitate the use of standard software components and services. Current CGKN technical standards are based on OGC standards and specifications such as web mapping, web feature, and geodata discovery services. Participants in the CGKN believe maximum benefit will be achieved through harmonization with other international data management initiatives and establishment of common international geoscience standards. For more information, see: Canadian Geoscience Knowledge Network (***http://cgkn.net***) and Canadian Geospatial Data Infrastructure ***(http://geoconnections.org)***.

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[59] Wilson, C. 2003. GeoConnections: A program to develop the Canadian Geospatial Data Infrastructure [Abstract]. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX–Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8. p. 115.

[60] Broome, J. 2003. The Canadian Geoscience Knowledge Network: Delivering geoscience on the Internet [Poster Abstract]. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX–Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8. p. 209.

Geoscience Data Repository

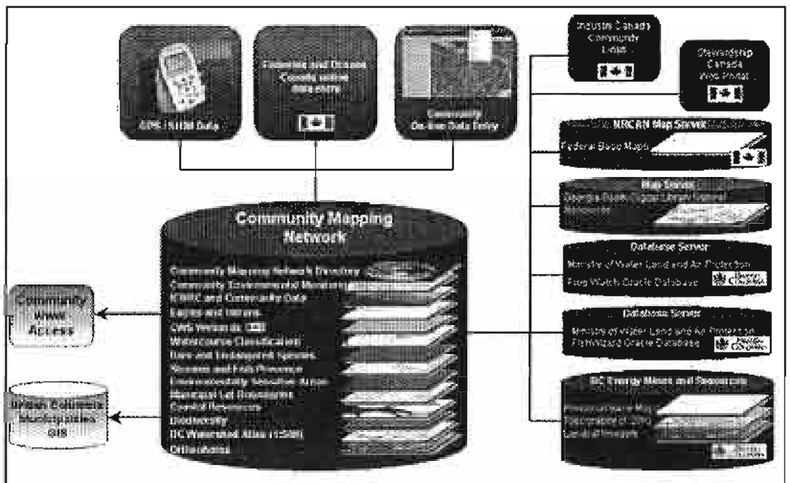
The Geoscience Data Repository (GDR)[61] is an initiative of the Earth Sciences Sector of Natural Resources Canada working in conjunction with the Geological Survey of Canada (GSC). The project is national in scope, involving all regional offices of the GSC from Dartmouth, Nova Scotia to Sidney, British Columbia. Following international standards, such as the North American Digital Geologic Map Data Model and the OpenGISWeb Map Server Specification, the GDR will represent the Earth Sciences Sector's node of the Canadian Geoscience Knowledge Network (CGKN) allowing clients to discover and access consistent and standardized geoscience data, maps, and publications.
The GDR's purpose is to:

- Facilitate more efficient data management throughout the GSC, both at the local level and the national level
- Facilitate efficient data transfer between data management staff and GSC/external data clients
- Provide a robust means to catalogue and backup the GSC's data holdings
- Provide a means to publish, publicize, and distribute the GSC's digital products via the Internet

British Columbia Information Systems

The Community Mapping Network

The Community Mapping Network[62] (Figure 3) is a consortium with interests in collecting and sharing natural resource information including, but not limited to, fish and wildlife distribution, streams and wetlands, rare and endangered species, and coastal resources. The Community Mapping Network[63] is made up of a number of community groups, organizations, and individuals that collect and map natural resource information. A steering committee is responsible for managing CMN that includes representatives from the BC Conservation Foundation, Fisheries and Oceans Canada, Canadian Wildlife Service, Ministry of Agriculture, Food and Fisheries, Fraser Valley Regional District, Greater Vancouver Regional District, local governments, and community groups. The primary goal of the CMN is to provide a service that collects and integrates natural resource information, maps, and mapping information to promote sustainable resource management and to assist planning sustainable communities.



Farmwest: BC Climate Data

Climate data is an important piece of the puzzle for many management decisions

[61] Houlahan, T., J. Francis, P. Huppé, and R. Kung. 2003. The Geoscience Data Repository [Poster Abstract]. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX–Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8. p. 197.
[62] Mason, B. and R. Knight. 2003. Sharing natural resource information across British Columbia through the Community Mapping Network. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX–Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8. pp. 147–154.
[63] Porter, G.L. 2002. Planning sustainable communities: a compilation of community mapping case studies from the Lower Mainland and Sunshine Coast of British Columbia. On-line at the Community Mapping Network. URL: www.shim.bc.ca.

within watersheds. Farmwest is a website for BC Agriculture that provides near real-time climate data (updated daily) and other production information to farmers throughout the province. Over the three years that Farmwest has been in operation, the usefulness of having this climate information available has become apparent to other sectors—not only agriculture[64].

The Farmwest website (***www.farmwest.com***) was launched in 2000 by the Pacific Field Corn Association (PFCA). The climate page provides weather forecasts and climate information for agriculture from 41 Environment Canada climate stations around British Columbia. Farmwest packages the climate information to provide temperature monitoring, weather forecasting, corn heat units, growing degree days, T-sum calculator for manure management, and evapotranspiration for irrigation scheduling. Although the site mainly provides agricultural information, the temperature monitor and forecasts are of interest to anyone who watches the weather.

Major gaps in information for management of the water resources on a basin-wide basis
Government networks reduced
Under federal-provincial cooperative arrangements, Canada has about 2,800 water quantity and quality monitoring stations (2,600 hydrometric stations, which constitute the main national water resource inventory, and over 200 water quality monitoring stations). The network is supplemented by various special-purpose and often shorter-term networks established by provinces, territories, the federal government, power companies, and others for their own needs.

In 1998/99 the BC Government, Ministry of Environment, Lands and Parks – Resources Inventory Branch operated the hydrometric network of 500 stations in cooperation with Environment Canada and established a test and training hydrometric network of eight stations. One of the stated 1999/2000 ministry priorities was to involve staff in hydrometric station de-commissioning. With the reduction of hydrometric stations in the Okanagan, some water purveyors have resorted to hiring third party consultants to re-establish important monitoring stations[65].

Today, in British Columbia, the aquatic information branch – Water Information Section, Ministry of Sustainable Resource Management (MSRM) coordinates and implements the collection, analysis, storage and distribution of water resource information, such as stream flow, water levels, water quality, snow pack, and stream and floodplain surveys.
Exploration of models for information management in the Okanagan basin

"The federal government endorses an integrated approach to planning and development of water resources...Increasingly, watersheds are becoming the preferred spatial unit for water resource planning. It is an approach that makes sense at any scale of planning..."(Environment Canada, 1987)
The Okanagan Watershed
The Okanagan region with an area of 6,187 km^2 and a population of 325,000 is a *Living Laboratory* - a microcosm for understanding freshwater systems. The Okanagan Basin is particularly suited to the study of Water Resource Science and Management because of its small size and consequently water supply, high population and growth rate, and its diverse economy and land uses. The Okanagan Basin watershed is in many ways a microcosm of the future of Canada, and an analog for the water-limited world. Appendix A

[64] Nyvall, J. 2003. Real-time climate information on the Internet: Its many uses and applications to agriculture and others. *In* Natural resources information management forum: Putting knowledge to work. T. Innes (editor). FORREX–Forest Research Extension Partnership, Kamloops, B.C. FORREX Series No. 8. pp. 159–161.
[65] Dobson Engineering Ltd. Water Supply and Hydrology Study For the McCulloch Reservoir Water Supply Area – Year 1-2003 Report.

compares the Okanagan watershed to international watersheds facing similar water limitations and increased population pressures, .

In 1969, the Okanagan Bain Study (OBS) was initiated in the Okanagan Basin in cooperation with the Province of BC and the Government of Canada. The OBS represented a new approach to water management, bringing together the combined skills of many experts in such fields as water quantity, water quality, waste treatment, socio-economics, limnology and fisheries. Many new approaches were developed, and many new challenges encountered during the evolution of a plan for the development and management of the basin's water resource. The study generated watershed decision rules that are scalable and applicable to other watersheds throughout the world.

Efforts to develop universally accessible databases in the Okanagan

The British Columbia Freshwater Institute (BCFI), an Okanagan University College mandated organization, has been consulting with regional stakeholders to identify the need for developing a regional information network. The BCFI's mandate is to develop and facilitate an interdisciplinary, collaborative network of academic, industry and government partners in support of water and water related research and training.

As a preliminary step, the BCFI inventoried Okanagan basin information sources. Although not necessarily a comprehensive list, Table 1 provides an example of the numerous organizations involved in collecting, storing and using information and data. In some instances the information is difficult to access, is not linked and has multiple access points.

Table 1. Inventory of Okanagan Basin Water Information Sources

Information Source	Holdings
SIR	• Okanagan Valley GIS Database – "seamless system"
PARC	• Agriculture land-use map (completed in 1990's) recently updated o Incorporated mapping of all vineyards into terrestrial ecosystem GIS database o Standardized formatting (TRIM) for all recipient information data. o PRISM values in points in temperature o Downscaling model for climate change. (i.e. crop change demand). o Agriculture land-use map ▪ Interpret factors that influence climate
Environment Canada and other federal government agencies	• TRIM information: Standardized meta data, historical data, water quantity data (ENVIRON DAT) o Weather/ climate data o Water quantity and quality data o Fisheries data o Elevation models that include: - Drainage basins - Rivers - Lakes - Roads - Psychometric curves - Daily statistics - Real time hydrometric stations (info back to 1916) - Environment Canada: Land use maps (resolution 30m)

FORREX (Forest Research Extension Partnership)[66]	• NRIN – provides a technology infrastructure—a coordinated metadata capture and distribution system. o A coordinated meta-data searchable catalogue system. o Identifies available information and its location
Okanagan University College	• Digitized Okanagan Basin Study (1972) study • Research data
BC Provincial Government	• Forest maps • Biogeoclimatic zones • Soil Maps • TRIM • Fishery Information • Water quantity and quality data • Fisheries data • Well drilling data
Water purveyors, improvement districts, and irrigation districts	• Watershed information • Water quality data • Hydrologic data • Groundwater information
Municipalities and Regional Districts	• Watershed information • Water quality data • Hydrologic data • Groundwater information
First Nation Communities	• Fisheries data • Historical record
Private Sector (e.g. consultants, industry)	• Hydrologic data • Water quality information • Groundwater information

During three town hall meetings hosted by the BCFI, a number of information management issues were discussed and explored. Information management has the potential to provide for a number of benefits to support Okanagan basin research and provide for informed decision making. Appendix C illustrates national and provincial organizations interested in sharing their water data. The BCFI proposed the development of an Okanagan Basin Information Network (OBIN) to support the better management of basin water information. In addition to the development of an OBIN project charter, developing a gap analysis that would include technology requirements, resources required to build and maintain an OBIN system, defining formats and function and the associated costs was identified as priority deliverables.

Okanagan Basin Information Network: Project Goal

The goal of Okanagan Basin Information Network (OBIN) was defined to develop a water environmental information network to meet the needs of researchers, planners and professionals for the Okanagan Basin. The primary goal is to provide a single portal for stakeholders' queries. Guiding principles for OBIN are:

- Build incrementally;
- Layer information: utilize a phased approach (Appendix B);
- Start with "top 100" Okanagan water web links; and
- Add additional layers as driven by a business case.

66 formerly the Southern Interior Forest Research Extension Partnership

Description of available information in the Okanagan: Information sources

Table 2 provides a summary of information gathered during information management workshop hosted by the BC Freshwater Institute on April 3, 2002. The workshop represented many stakeholders that included: Okanagan First Nations, Okanagan Basin Water Board (OBWB), Environment Canada, Agriculture Canada-Pacific Agri-Food Research Centre (PARC), scientists, several Okanagan municipalities and regional districts.

Table 2. Synthesis of data management needs.

Inputs	Activities	Outputs	Short-Term Outcomes	Long-Term Outcomes
• Staff • Technology • Collaborators • Funding • Information - PARC DB - Environment Canada DB - Okanagan Basin Study conducted in the early 1970's provides for an invaluable baseline dataset - Other DB	• Risk assessments • Data gathering • Synthesis of data • Education • Gap analysis • Survey available information products	• Document identifying project components & outcomes (Project Charter) • Information inventory • Agreements to keep data current and accessible • Documents relating to aquatic species at risk • Documents relating to urban runoff • Technical data that is understandable	• Protection of water supply • Improved understanding of freshwater science, issues, and problems • Improved knowledge about rural sewage treatment technologies • Improved understanding of technical data • Increased awareness of current research • Reduced duplication of research effort • Conservation of wildlife habitat	• Sustainable watershed • Objective: technically sound and ethical basis to manage Okanagan Valley water. • Eco-regional planning • Improved decision-making • Improved resource management • Scientifically based tools for species at risk legislation

Needs Assessment

The BCFI with support from Western Economic Development Canada conducted a water information needs survey[67] in the fall of 2003 to assess the need for a clearinghouse of water information. Westcoast CED Consulting Ltd. was selected and contracted to design, pre-test, and conduct the survey. Through numerous meetings with users/providers of Okanagan water information, BCFI identified the need to clarify:

- the level of demand for an integrated, accessible and updateable information network on water in the Okanagan,
- the type of information to be held; and
- how information will be held and accessed.

[67] Okanagan Basin Information Network Survey Results. October 2003, West Coast CED Consulting Ltd. Prepared for the BC Freshwater Institute

Okanagan stakeholders identified the need for a long-standing and cost effective information network that meets the needs of the end users. A summary of feedback from Okanagan stakeholders who participated in the survey identified the following needs:

Shared Need

The survey revealed a commonly shared need for a comprehensive, organized and easily accessible listing of existing data and research related to the Okanagan Basin. This would include information on the location of the data and research, from all available sources (including all levels of government, researchers, and consultants).

Web Linked

Respondents stated that a web link to data and/or the actual storage of the data at a website would provide a valuable service, but decisions regarding "how" constituents would access information is dependant on a number of factors – including the results of a more in depth identification and analysis of business solutions, and whether or not a user interface/application is developed for manipulation of the data, in particular, GIS data.

Responsiveness

Survey subjects agreed that the resources have to be responsive to meet the needs of the constituents and be organized in levels or layers of access such as limitations of use, quality and accuracy of data.

Forum

Respondents described the value of creating a "***community of knowledge***", a forum for those interested in water related issues in the Okanagan Basin. The forum would be a good communication tool, an educational tool, a forum for discussion of standardization of data collection, as well as a tool to create an online community.

Informed Decision Making

Respondents from across the spectrum of governments and agencies represented anticipate that the information network would improve the capacity of managers, planners and elected and appointed officials to make informed decisions and support an ecosystems based approach to planning and management.

Operating Principles

In support of the needs assessment, the BCFI has developed a project charter identifying key principles in developing the OBIN. An incremental model will drive the development of the OBIN. The following process will drive the development of additional layers of the OBIN project:

1. Identify needs;
2. Identify solutions;
3. Identify means to support and fund solutions; and
4. Build it.

Probable Constituents

Potential constituents of the OBIN might include municipalities, regional districts, water purveyors, scientists, policy makers, consultants, appointed/elected representatives, First Nations, private land owners, business community representatives, crown land managers and parks managers. The result will be a more efficient and informed decision-making process and broad access to information not constrained by being undisclosed, unidentified, or a variety of regional boundaries.

Successful Performance Measures

The OBIN project will be evaluated using the following performance measures:

- constituent use of web portal;
- stakeholders share information though the network;
- stakeholders provide feedback on ease of use; and
- advisory Committee is satisfied with process.

Conclusion

The Okanagan watershed, due to its small size, semi-arid climate, increasing population and sensitive environment, make it an analog of the water-limited world and a living laboratory to implement best practices. The Okanagan has the opportunity to leverage the data collection conducted during the comprehensive Okanagan Basin Study[68] conducted 30 years ago. The Okanagan Basin study needs to be updated allowing for the unique opportunity to compare current state of the basin with that of the early 1970's. Due to the ongoing and ever increasing demand for the Okanagan's limited water resources, the coordination and management of information is timely.

A non-exhaustive list of water information management systems were reviewed to identify best practices that could be applied to an Okanagan watershed WIN. Large organizations such as the United Nation's AQUASTAT and British Columbia's Community Mapping Network are models of clearinghouses, bringing a variety of water information sources under one umbrella. Another example, the California Irrigation Management Information System, originally designed for agricultural growers needs, has incrementally grown to encompass a variety of stakeholders (over 6000 registered) that benefit from centralized weather data that is analyzed and stored in one location and then distributed over the internet. It is important that the Okanagan and other water basins not reinvent the wheel rather draw on the experience from other regions.

One fundamental question facing the Okanagan is the determination of the basin water budget. The water budget is simply an accounting procedure similar to the bookkeeping required to balance a checking account. If the balance on a given date and the amounts of transactions are known, the balance can be calculated at any time. In addition, the time when all funds would be withdrawn can be determined so that an overdraft is avoided[69]. An Okanagan WIN will support the development of an Okanagan water budget.

Recent trends in government staff and funding for data collection show continued cuts and departmental re-organizations. Increased government resources need to be made available in order to find the balance between economic development and environmental integrity when developing policy necessary for the sustainable management of land and water resources. In order for government to provide effective delivery of integrated, science-based, land and water information for a wide range of decision makers and processes, adequate resources are required to collect and manage data within an Okanagan WIN.

The creation of an Okanagan WIN has many benefits that include generating and applying knowledge, promoting synergies, enhancing water sustainability, enhancing the development of an Okanagan basin water budget, supporting improved decision making, encouraging the exploration of water resources options, enhancing effective basin water management, allowing for the better understanding of trade-offs

[68] Summary Report Of The Consultative Board including The Comprehensive Framework Plan prepared under the Canada-British Columbia Okanagan Basin Agreement March 31,1974 B.C. Water Resources Service, Parliament Buildings, Victoria, BC.
[69] http://www.cimis.water.ca.gov/cimis/infoIrrSchedule.jsp

between economic and environmental security, monitoring and evaluating Okanagan water resources and allowing for the generation of "what-if " scenarios.

An Information Network, with the appropriate funding support, could provide for a central repository of information – a community of knowledge. While the BC Freshwater Institute's OBIN project is a prototype for information exchange in the Okanagan region of British Columbia, its potential for utilization elsewhere and expansion beyond water is vast. The long-term opportunity to also serve national interests involve entering a partnership with a national information network (such as CISE[70]) while maintaining the local service. Stakeholders that required simple data retrieval would be able to use either portal while those with more complex needs would be much better served by the regionally-dedicated Okanagan Basin Information Network (OBIN).

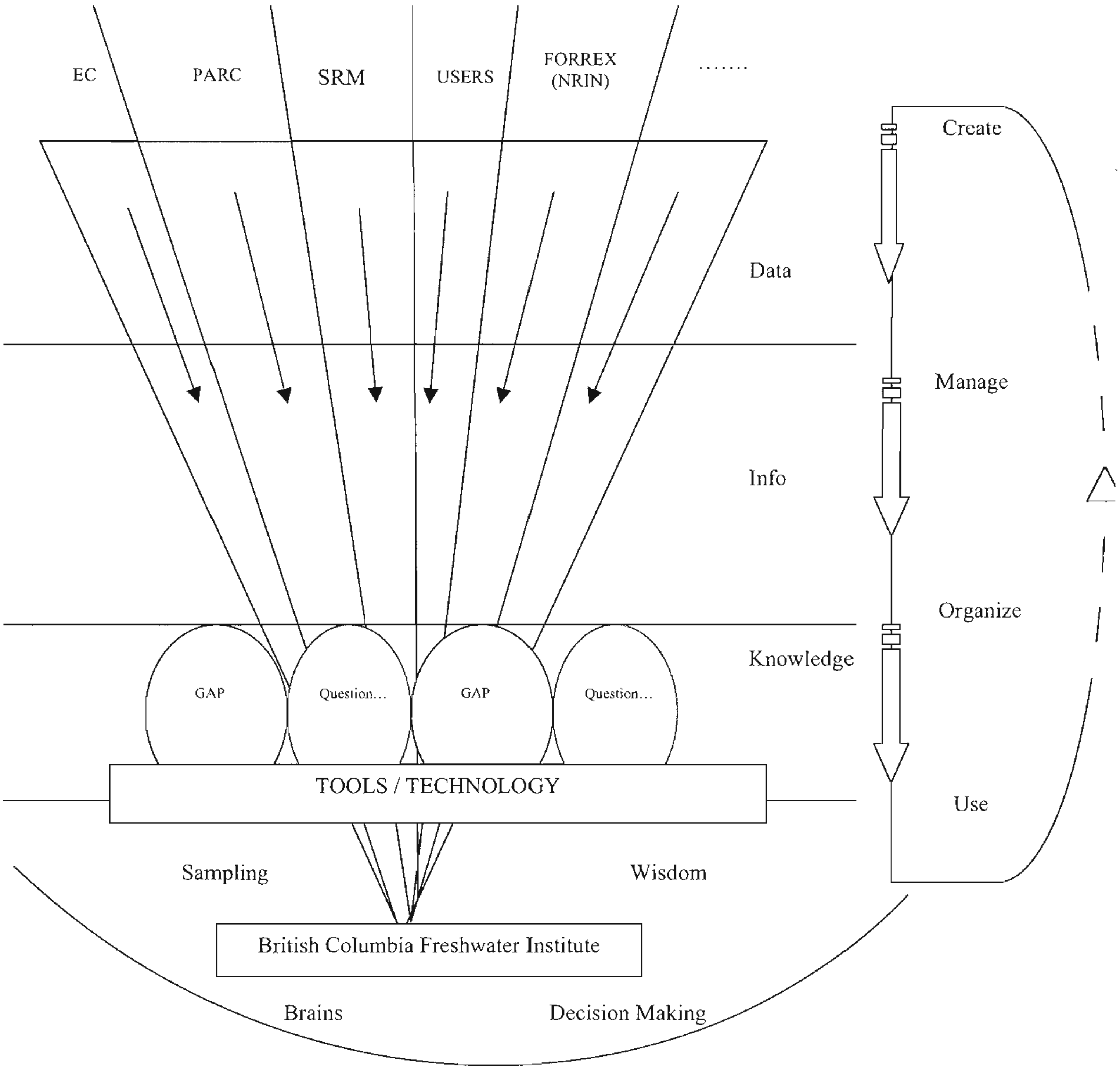
Broad support has been shown to develop an Okanagan Basin WIN that brings together a number of currently uncoordinated data sources. Federal (Environment Canada and Pacific Agri-Food Canada) and Provincial (Ministry of Sustainable Resource Management) stakeholders are willing to share their information within an Okanagan basin WIN structure. There is a commonly shared need for a comprehensive, organized and easily accessible listing of existing data and research related to the Okanagan Basin, and information on the location of the data and research from all available sources (including all levels of government, researchers and consultants). The challenge of developing an incremental strategy that supports ongoing maintenance and operations of an Okanagan WIN needs to be met. Regional leadership and collaboration between post-secondary institutions, all levels of government and business leaders will support creating and sustaining an Okanagan WIN.

[70] Canadian Information System for the Environment

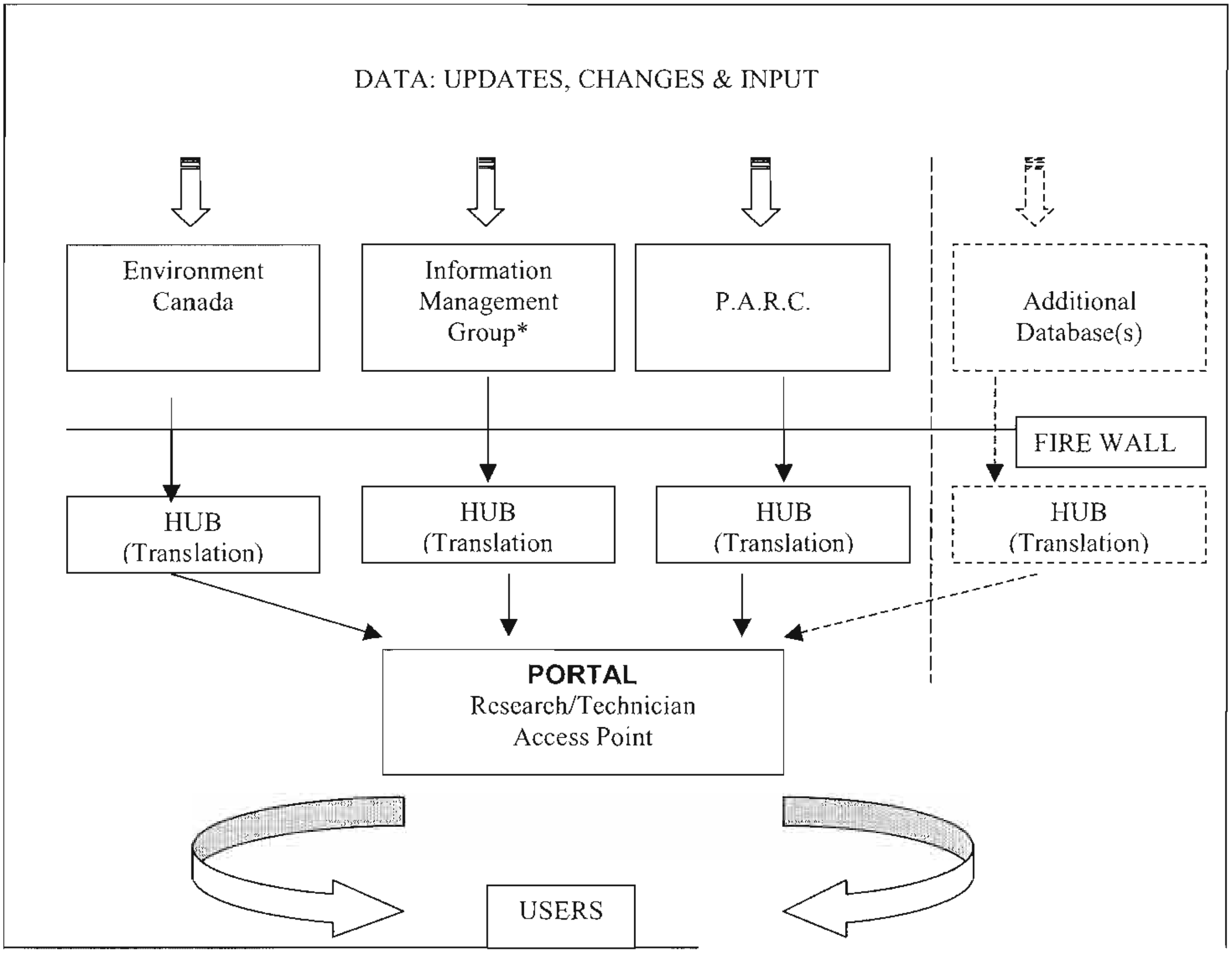
Appendix A. Comparison of international Water Basins

	Area (km^2)	Rainfall	Irrigated area	Population	Relevant issues		
Okanagan basin	8,200	254 mm and 381 mm (south) 381 mm to 508 mm (north)	50,562 ha	323,397	Limited water supply	Population growth	Climate change
São Francisco basin	634,000	1,500 mm (upper basin) and 350 mm (lower basin)	333,000 ha	15.2 million	Water use conflicts; disorganized use	Population growth	Increasing water demand
Nile river basin	3,300,000	2,000 billion m3	Over 5.5 million ha	280 million	Limited water supply	Population growth	Ensuring food security
Yellow river basin	795,000	452mm (600mm-southeast to 200mm-northwest)	7.3 million ha (including 2.47 million ha outside of the basin)	110 million	Water supply and demand conflict	Frequent drought & flood disasters	Impact on agricultural production and human life
Volta basin	400,000	1,000 mm	5,000 ha	7 million	Water use conflict. agriculture vs. residential and industrial	Population growth	Agricultural and hydroelectric demands expected to increase
Mekong river basin	795,000		2 million ha	60-65 million	Sustainable agricultural, fisheries and economic development	Preserving environment & biodiversity	
Limpopo river basin	413,000	Average 530 mm (Range: 200-1,200 mm)	244,000 ha	14 million	Frequent droughts & unsecure crop production	Over utilization of water resources	Water pollution from industrial activities
Karkheh basin (Iran)	50,764	Southern region: 150 mm; northern region: 750 mm	1,064,089 ha of the irrigable lands (378,164 ha used for irrigated crops)	3.78 million	Water scarcity, poverty pockets and environmental problems	Increased runoff volume and intensity	Severe water and wind erosion farm lands
Indo-Gangetic basin	861,140	600 mm (northwestern region) 1,700mm (eastern coastal zone)	12.4 million ha	440 million	Limited water supply; overexploitation	Weak and inadequate water governance/management institutions	Water pollution & contamination
Andes river basin	8,226,000	Extremely variable (<100 mm to >2,000 mm)	3,657,056 ha Less than 10 percent of the area.	162.5 million	Land use and climatic change	Conflicts exist between extremely diverse groups	Production affected by natural hazards, climate & seasonal fluctuations

Appendix B. A schematic of an Okanagan Basin Information Network system – a decision support matrix.



Appendix C. Proposed model for integrating various sources of water information



* Ministry of Sustainable Resource Management

Appendix D. Survey of Watershed Information Networks best practices

Network	Location	Best Practices
Anacostia Watershed Network	Maryland, District of Columbia, USA	Web links to local restoration and protection groups Lists of natural attractions in the basin to visit Web links to restoration progress, maps and data Environmental Monitoring for Public Access and Community Tracking Project (EMPACT) -provides public with up-to-date and understandable environmental information
Cayuga Lake Watershed Network	Southern New York USA	Online water monitoring database Host of numerous projects to increase public involvement including essay contests, Lakefest and lake-wide citizen monitoring program Access to Network publications, data Information about bylaws, policies, Online quarterly newsletter, Cayuga Lake Watershed Network News 5-year Progress Report for Network
Great Lakes Information Network (GLIN)	Great Lakes Region covering Ontario, Minnesota, Wisconsin Michigan, Illinois, Indiana, Ohio Pennsylvania and New York	Access to GIS data and maps of region Information on various environmental topics, including air, land, water, pollution, flora and fauna Links for educators on the history, environment and geography of the Great Lakes region Hosts more than 100 email lists on various topics, both public and private Links to various tourist attractions in the region Resources for businesses and their connection to the environment
Boulder Area Sustainability Network (BASIN)	Boulder, Colorado USA	Region-specific information about water quality, stream flow, weather and climate and flash floods Spatial Data Catalog, including real-time data, maps and live cameras Water Quality Index and information Links to watershed reports Information section on personal activities for the public in conserving the Boulder watershed Links and resources for educators on watershed sustainability

Network	Location	Best Practices
Red River Basin Decision Infonnation Network (RRBDIN)	Red River Region, covering S. Manitoba, North Dakota, South Dakota and Minnesota	Internet-based decision support system for regional problem solving Fonnation of a Project Review Team and Project Design Team to continually evaluate the effectiveness of the RRBDIN, comprised of interested parties, organisations and agencies from the Red River Basin Large infonnation database, inclnding GIS data, static maps, interactive maps, high resolution topographic data, inventory of water resource models, and hydraulic and hydrologic data
Ohio Watershed Network (OWN)	State of Ohio, USA	Interactive map of links to watershed groups in each county Targets community members and natural resources professionals Map-making tool to help the public identify their watershed Steps on how to lead a watershed education program Information for public on community-based watershed management, its characteristics, and keys to successful management Links to watershed resources and references including a glossary of terms, funding programs, online publications relating to Ohio watersheds, curriculum materials and software downloads
Prairie Rivers Network	State of Illinois, USA	Clear mission statement and list of past accomplishments and current projects List of volunteer opportunities for public participation Access to online archived materials is by password only Fundraising efforts include online store through Amazon.com of Network publications
Georgia River Network (GRN)	State of Georgia, USA	GRN workshops for members on leadership development and forming a non-profit group Information for watershed organisations including by-laws, fundraising tips, and tax information for non-profit organisations Watershed directory of data and non-profit organisations A "What's New" section to highlight recent events and tools online 5 year Strategic Plan for GRN and annual reports online for public viewing
California Watershed Network (CWN)	State of California, USA	Helpful hints for watershed organisations on how to work alongside elected officials Links to data resources outside CWN Online news articles and local events related to CWN

Network	Location	Best Practices
Missouri Watershed Information Network (MoWIN)	State of Missouri, USA	List of local watershed contacts Resources for watershed education List of management plans for Missouri's watersheds as well as other reports and d Links to data resources outside MoWIN Extensive glossary of watershed terms, called Acronym City
U.S. Environmental Protection Agency Watershed Information Network (WIN)	Continental USA, including Alaska, Hawaii and Puerto Rico	Roadmap to information services on the WIN site Spotlight section on current projects in selected watersheds Inventory of nationwide and general websites or information sources offering environmental data and maps News archive of watershed-related stories in the USA "Surf your Watershed" interactive map to help public identify their local watershe well as information summaries for each state's watersheds
United Kingdom Rivers Network (UKRN)	United Kingdom, including Wales, England, Scotland, Ireland and Northern Ireland	Comprehensive list of national, regional and local watershed groups Education and Information section to increase public awareness News archive includes river-related news articles dating back to 1995 Adopt-a-River campaign to increase public awareness and involvement
Inland Rivers Network (IRN)	Murray-Darling Basin, Southeast Australia	Background information on the state of the Murray-Darling Basin's river and wetl Public can subscribe to an email list and receive all media releases related to the IF List of key campaign areas of the IRN

CANADIAN WATER RESOURCES CONFERENCE
B.C. BRANCH

KELOWNA, BC, FEBRUARY 23 - 25, 2005

POSTER PRESENTATIONS

Hydrogeology of the Kelowna Area

R. Allard [1], J. Sacre [2], B. Wilson [3]
[1, 2] Golder Associates Limited, [3] Kelowna Joint Water Committee (Chair)

rallard@golder.com

The Hydrogeology of the Kelowna Area is a poster prepared by Golder Associates and the Kelowna Joint Water Committee, which provides a general overview of the hydrogeology in the Greater Kelowna area. The poster is an output from the initial stage of development of a groundwater protection plan for a compendium of water purveyors in the area and will be used as a tool for public education on the importance of source monitoring and protection. The poster includes perspective mapping of the area along with contouring of static water levels and a cross section through the Greater Kelowna Aquifer.

Keywords: Kelowna, Hydrogeology, Source Protection

Effects of Group Selection on Snow Ablation

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Group selection is a silvicultural system in which logged openings are in the order of one hectare, in contrast to clearcutting where openings are in the order of 40 hectares. Researchers are studying this alternative system in high elevation forests because we think it maintains usability by caribou while allowing some timber harvesting.

The effect of group selection on snow ablation rate was studied for 5 years at an ESSF research site in the Quesnel Highland. Replicated ten-hectare plots were established with 30 percent of the area harvested in the form of circular openings having uniform sizes and spacing. Opening with diameters of 1, 2, and 5 tree heights (1H, 2H, and 5H) were used. In the highest snow year, plots with 1H openings had average May ablation rates that were indistinguishable from the unlogged forest. However, average May ablation rates from plots containing 3H and 5H openings were 5 and 13 percent respectively, greater than the unlogged forest.

Keywords: Snow ablation, group selection

Bow River Basin Waterscape poster- public outreach model for the Okanagan?

Bob Turner[1]
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Natural Resources Canada, along with partners, is developing a series of large-format, richly-illustrated, information posters on water issues within Canadian communities and river basins. Posters have recently been developed for Bowen Island and the Gulf Islands, B.C. (www.geoscape.nrcan.gc.ca). A poster is currently being developed for the Bow River Basin in Alberta, a watershed that includes the metropolitan Calgary area, Canada's fastest growing urban region. Partners on the poster include Alberta Environment, Bow River Basin Council, City of Calgary, Calgary School Board, Calgary Science Center, Environment Canada, and Parks Canada. Development of a similar waterscape poster is under consideration for the Okanagan Basin.

Waterscape posters engage a community in its water management issues by clearly illustrating key community water issues such as local water use, the hydrology of surface and groundwater, land use impacts on water quality and quantity, and ideas for improved conservation and resource protection. Considerable community consultation occurs during the poster design. A poster steering committee with members from local governments and water boards, community groups, water and groundwater professionals, scientists, and educators guides the development of the poster and plans for its use within the community.

The Upper Penticton Creek Watershed Experiment: Research Providing Water Resource Management Solutions in the Okanagan Basin

R. Winkler[1], D. Spittlehouse[1], T. Giles[1], B. Heise[2], Y. Alila[3], G. Hope[1], and D. Gluns[1]

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The Upper Penticton Creek Watershed Experiment includes three, 5 km^2, high elevation watersheds typical of the Okanagan Plateau. This long-term study focuses on improving our understanding of water delivery from forested watersheds and how changes in forest cover affect both water quantity and quality. Data collected over the past 20 years enables researchers to study the effects of road construction and logging on diverse watershed features and processes including streamflow, snow accumulation and melt, water use by vegetation, stream channels, aquatic invertebrates, and water quality.

Our research shows that logging 20% of a small watershed has not produced detectable changes in the quantity and quality of water delivered from this watershed, however, changes have occurred within the areas cut. For example, maximum snow accumulation in a clearcut can increase by 15% to 30%, and melt rates by 1.3 to 1.5 times, that observed under mature forest cover. Earlier snowmelt from logged areas at higher elevations may produce runoff that coincides with melt from lower elevation forests, which over a substantial area may result in changes in water delivery from the watershed. Modelling suggests that changes in streamflow occur once 30% of the watershed has been logged. However, peak streamflows are unlikely to increase more than 50% regardless of the extent of forest cover removal, unless runoff is concentrated by roads. The importance of riparian protection has also been highlighted at Upper Penticton Creek where maximum stream temperatures in clearcut areas were 9 °C higher than in the forest. These changes have not negatively affected aquatic biodiversity, which to date has remained constant or increased. Chemical water quality following logging over 20% of the experimental watersheds did not change. Elevated concentrations of suspended sediment have been observed during the high spring runoff periods, when runoff from roads flows directly into stream channels.

The research results from Upper Penticton Creek are used in forest development planning and to model the effects of logging, climate change, and forest regrowth on streamflow. Logging in the experimental watersheds has increased to 30% and 50% and research into the effects of these more extensive changes continues.

Key Words: Upper Penticton Creek, Forestry, Hydrology, Research

B.C. CWRA Conference
"Water – Our Limiting Resource"
Towards Sustainable Water Management in the Okanagan

February 23, 24 & 25, 2005
Manteo Resort - 3762 Lakeshore Road, Kelowna, BC, Canada V1W 3L4

Overview

Water in the Okanagan Basin is a limited resource that is already heavily allocated to uses such as agriculture, domestic water supply and maintaining a minimum streamflow for fisheries and other aquatic environment needs. At present per capita usage rates, the water resources of the basin will be totally allocated in less than 25 years. Communities that rely on reservoirs or streams are already starting to experience shortages in drought years, and minimum flows in streams are often below conservation levels. The resource will continue to be subject to increasing demands due to increases in population and the impacts of climate change. To move toward sustainable water management in the Okanagan Basin requires difficult decisions now that will include reducing demand, new governance models that consider the basin as a whole, and more pro-active management.

The first day of the conference will be hosted in collaboration with the City of Kelowna and will feature presentations of papers submitted on the theme of water management in the Okanagan Basin. The second day of the conference will feature invited speakers focussing on the state of the basin and an overview of the issues. A status report on the Okanagan Basin study of 1974 will set the stage, and will be followed by presentations on the current status of water availability, licensing and use, groundwater, water quality, and aquatic resources in the basin, and on the projected water resource implications of climate change and population growth.

Day three will focus on finding short-term and long-term solutions to the water management crisis that are both pragmatic and implementable. The conference will conclude in a plenary workshop leading to the development of a set of specific recommendations, which will be provided to decision-makers as an expression of the concerns of water experts and others concerned with water management not only from the Okanagan basin, but from other areas of the province and elsewhere.

Key conference outputs will include the Proceedings (both hard-copy and CD) and a set of recommendations for improved water management assembled by delegates.

*For information on **sponsorship** opportunities, please contact*
Rob Scherer, email: rob.scherer@forrex.org, tel: (250) 762-5445 ext. 7516

*For information on **exhibiting** opportunities, please contact:*
Kathy Lee, email: kathy.lee@bchydro.bc.ca, tel: (604) 528-1450

*For information on **volunteering**, please contact:*
Jillian Tamblyn, email: jtamblyn@syilx.org, tel: (250) 707-0095

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Program Overview

Poster Session	February 23, 24 and 25
Case Studies	February 23
State of the Basin	February 24
Solutions	February 25

Accommodation Information

Conference Hotel:
Manteo Resort: 3762 Lakeshore Rd. rooms starting at $114/night 1-800-445-5255

Other nearby hotels:

Kelowna Lakeshore Inn	3756 Lakeshore Rd.	1-877-657-5253
Pandosy Inn	3327 Lakeshore Rd.	1-877-762-5858
Siesta Motor Inn	3152 Lakeshore Rd.	1-800-663-4347

Poster Session

Wednesday February 23 – Friday February 25:

Hydrogeology of the Kelowna Area — Remi Allard, Golder Associates Ltd.

Characterizing Stream Shade in the Southern Interior — Pat Teti, B.C. Ministry of Forests

Effects of Group Selection on Snow Ablation — Pat Teti, B.C. Ministry of Forests

Bow River Basin Waterscape Poster – Public Outreach Model for the Okanagan
Bob Turner, Natural Resources Canada

The Upper Penticton Creek Watershed Experiment: Research Providing Water Resource Management Solutions in the Okanagan Basin
Rita Winkler, B.C. Ministry of Forests

Cotton Creek Research Project: a partnership approach to watershed management
Georg Jost, UBC

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Wednesday February 23 – Case Studies:

8:30	Welcoming Remarks – Paul Whitfield, CWRA B.C. Branch President and Valerie Cameron, CWRA National President	
	Welcome to the Okanagan and the Conference - Chief Stewart Phillip, Chair, Okanagan Nation Alliance	
8:45	Conference Overview – Brian Guy, Conference Chairperson	
	Morning Session A Chaired by Don Dobson, Dobson Engineering Ltd.	**Morning Session B** Chaired by Mark Watt, City of Kelowna
9:00	Okanagan Lake Foreshore Inventory and Mapping – Brent Magnan, Regional District of Central Okanagan	Trepanier Landscape Unit Water Management Plan – Brian Guy, Summit Environmental Consultants Ltd.
9:30	The Physical Limnology of Okanagan Lake - Lillian Zaremba, Hay & Co. Consultants Ltd.	In the Hands of the Community - Michael Zbarsky, University of Victoria
10:00	Refreshment Break	
10:30	Snow & Snow Surveys in the Okanagan Basin - Alan Chapman, Ministry of Water, Land, and Air Protection	Central Okanagan Post Fire Rehabilitation Project– Michelle Kam, City of Kelowna
11:00	The Changing Climate of the Okanagan Basin – Bill Taylor, Environment Canada	The Experimental Reintroduction of Sockeye into Skaha Lake, BC – Kari Long, Okanagan Nation Alliance
11:30	Changes in Crop Water Demand in Response to Climate Change and Associated Risks in Water Supply for Agriculture in the Okanagan – Denise Neilson, Agriculture Canada	The Okanagan Fish-Water Management Tool (OKFWM) – Clint Alexander, ESSA Technologies Ltd.
12:00	Lunch and presentation by Mark Watt, Environment Manager, City of Kelowna	
	"Basin Water - the Kelowna Expectation"	

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Wednesday February 23 – Case Studies (continued):

	Afternoon Session A Chaired by Michelle Kam, City of Kelowna	**Afternoon Session B** Chaired by Rob Scherer, Okanagan University College and FORREX
1:30	Trends in Water Demand & Consumption in the Glenmore – Ellison Improvement District - Greg Henderson and Amanda Bridge, GEID	Significant Advances in IT and Water Supply and Demand Management At Greater Vernon Services- T. Vandenburg, Greater Vernon Water
2:00	Application of the Water Use Plan Approach to Resolve Water Management Issues on Trout Creek in Summerland - David Sellars, Water Management Consultants Ltd.	Water Management Decision Support Tool - Stacy Langsdale, University of B.C.
2:30	Refreshment Break	
3:00	South East Kelowna Irrigation District: Agricultural Water Conservation Program Review – Toby Pike, SEKID	Risk-Based Wellhead Protection Planning – Scott Schillereff, EBA Engineering Consultants Ltd.
3:30	The Race for Water: Reflections on the 1974 Okanagan Basin Study – John Janmaat, Acadia University	Simulated Streamflow Response to Large-Scale Forest Harvesting in Upper Penticton Creek - Marcus Schnorbus and Younes Alila, University of B.C.
4:00	Assessment of Water Quality Trends and Revised Water Quality Objectives for Okanagan Lake – Vic Jensen, Ministry of Water, Land and Air Protection	Summerland Water Intake Feasibility Study – Edwin Wang, Hay & Co. Consultants Ltd.
4:30 – 6:00	"Meet and Greet" Social Gathering	

B.C. CWRA Conference
"Water – Our Limiting Resource" - Towards Sustainable Water Management in the Okanagan

CWRA ACRH
Canadian Water Resources Association — Association Canadienne des Ressources Hydriques
B.C. Branch

February 23, 24 & 25, 2005
Manteo Resort - 3762 Lakeshore Road, Kelowna, BC, Canada V1W 3L4

Thursday February 24: State of the Basin and Overview of the Issues

8:30 Welcoming Remarks – Hon. Bill Barisoff, Minister of Water, Land, and Air Protection

Overview of Day 2 – Brian Guy, Conference Chair

Morning Session Chaired by Wenda Mason, Land and Water B.C.

8:45 Okanagan Basin Study – 30 Years Later - Don Dobson, Dobson Engineering Ltd.

9:30 Water Availability and Use in the Okanagan Basin – Kevin Dickenson, Land and Water B.C.

10:15 Refreshment Break

10:45 Groundwater Assessment in the Okanagan Basin – Vicki Carmichael, Ministry of Water, Land and Air Protection

11:30 Water Quality in the Okanagan Basin: Dependence on Spatial and Temporal Drivers - Jeff Curtis, Chair, Freshwater Science Program, Okanagan University College

12:15 Lunch and Presentation of CWRA Awards

Afternoon Session Chaired by Brian Symonds, MWLAP

1:30 Fisheries and Aquatic Resources in the Okanagan Basin: Past, Present, and Future - Deana Machin, Okanagan Nation Alliance

2:15 Impacts of Population Growth on Okanagan Water Resources – Leah Hartley, Regional District of Central Okanagan

3:00 Refreshment Break

3:30 Exploring Options for Adapting Water Management in the Okanagan Region to Future Climate Change – Stewart Cohen, Environment Canada and University of British Columbia

4:15 Water Management Initiatives in the Okanagan - Robert Hobson, Chair of the Central Okanagan Regional District

5:00 State of the Basin Summary – Brian Guy, Conference Chair

6:30 Banquet and Presentation by Dr. Tom Siddon – retired academic and former federal Minister of Fisheries: "Science vs. Politics - Finding the Balance"

B.C. CWRA Conference
"Water – Our Limiting Resource" - Towards Sustainable Water Management in the Okanagan

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Friday February 25: Finding the Solutions

8:30 Overview of Day 3 – Denis Davis

Morning Session Chaired by Denis Davis

8:45 Challenges and Innovations in Water Resources Management in the Okanagan Basin – Dr. Hans Schreier, University of B.C.

9:15 Governance and Allocation Models – Murray Clamen, International Joint Commission

10:00 Refreshment Break

10:30 Changing Perspectives – Changing Paradigms: Demand Management Strategies and Innovative Solutions for a Sustainable Okanagan Water Future - Lynn Kriwoken, Ministry of Water, Land, and Air Protection and Oliver Brandes, POLIS Project

11:00 Water Balance Management in the Okanagan: Now What Do We Do? – Kim Stephens, KSA Associates Ltd.

11:30 Information Management as it Relates to the Okanagan Watershed: Our Common and Life Sustaining Heritage - Nelson Jatel, B.C. Freshwater Institute

12:15 Lunch and Presentation by Denis Davis, retired Director General, Environment Canada: "Why Action Now?"

1:30 Plenary Workshop – Development of Recommendations for Improved Water Management in the Okanagan (small group and plenary discussions) – led by Victor Cumming, Westcoast CED Consulting Ltd.

3:10 Summary of Plenary Recommendations – Victor Cumming

Conference Review and Wrap-up – Brian Guy, Conference Chair

3:45 Press Conference

B.C. CWRA Conference
"Water – Our Limiting Resource" -
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B.C. Branch

REGISTRATION FORM

	Member	Student (note 4)	Non-Member (note 5)	Amount
Early Registration (By January 14, 2005)				
Full Conferenee, February 23-25, 2005 (note 1)	$325	$180	$415	
Single Day February 23, 24, or 25 (note 2)	$175	$95	$200	
Late Registration (After January 14, 2005)				
Full Conference, February 23-25, 2005 (note 1)	$375	$210	$465	
Single Day, February 23, 24, or 25 (note 2)	$205	$115	$230	
Banquet, February 24, 2005	$50	$50	$50	
	Cost	**Quantity**		
Proceedings	$60/copy			
			Sub-Total	
			7% GST (Registration No. 10077-3799 RT0001) (note 6)	
			Total	

Notes:

(1) Includes lunehes, coffees, banquet and proceedings; (2) Includes lunehes and coffees but NOT banquet or proeeedings; (4) Requires student ID; (5) Includes CWRA membership for 2005; (6) Government employees are exempt from GST – if you wish to claim a GST exemption, please provide a photocopy of the provincial government credit card.

Register early as space is limited at Manteo. Please register by February 9, 2005. Cancellations will be accepted in writing only until February 9, 2005. Please forward this registration form with a cheque or money order, payable to the Canadian Water Resources Association, or fax this form with your VISA / MasterCard information to: Yvonne Wai, c/o Earth Tech Canada Inc., 1901 Rosser Ave., 6th Floor, Burnaby, B.C., Canada, V5C 6S3, Tel: (604) 298-6181, Fax: (604) 294-8597, E-mail: yvonne.wai@earthtech.ca

Name Mr./Ms./Mrs./Dr First Name Initial Last Name

Title / Organization

Address

City | Province / State

Country | Postal Code / Zip Code

Telephone No. | Fax No.

E-mail

Are vegetarian meals required? (Yes / No)

Do you have food allergies? (Yes / No / Please list above)

If you wish to pay by VISA or MasterCard, please fill out the following information and sign below:

VISA / MasterCard number | Expiry Date (MM/YY)

Card Holders Name

Signature