South Saskatchewan River Basin Adaptation to Climate Variability Project

Initial Assessment of the Current State of the Foundational Blocks to Support Adaptation in the SSRB

October 31, 2012

ALBERTA watersMART
Water Management Solutions

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This report is available and may be freely downloaded from the Alberta Water Portal website at www.albertawater.com.

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Acronyms and Abbreviations

ARD	(Alberta) Agriculture and Rural Development
ACRU	Agricultural Catchments Research Unit
AI-EES	Alberta Innovates – Energy and Environment Solutions
AIMM	Alberta Irrigation Management Model
AIPA	Alberta Irrigation Projects Association
ALCES	A Landscape Cumulative Effects Simulator
AUMA	Alberta Urban Municipalities Association
BRBC	Bow River Basin Council
BRID	Bow River Irrigation District
BROM	Bow River Operations Model
BRP	Bow River Project (2010)
CRP	Calgary Regional Partnership
EID	Eastern Irrigation District
EPEA	*Environmental Protection and Enhancement Act*
ESRD	(Alberta) Environment and Sustainable Resource Development
FITFIR	First in Time, First in Right
GIS	Geographic Information Systems
GoA	Government of Alberta
GUI	Graphic User Interface
ID	Irrigation District
IDM	Irrigation District Model
IWMSC	Irrigation Water Management Study Committee
MRWCC	Milk River Watershed Council of Canada
MTO	Multiple Time step Optimization
NMM	Network Management Module
OASIS	Operational Analysis and Simulation of Integrated Systems
OSSK	Oldman and South Saskatchewan River Basins
OWC	Oldman Watershed Council
SEAWA	South East Alberta Watershed Alliance
SSRB	South Saskatchewan River Basin (includes the sub-basins of the Red Deer River, Bow River, Oldman River, and the South Saskatchewan River)
SWAT	Soil and Water Assessment Tool
WPAC	Watershed Planning and Advisory Council
WRMM	Water Resources Management Model

1 Executive Summary

While Alberta's economy is fuelled by hydrocarbons, it runs on water. The province is facing important water challenges, including an expanding population, accelerating economic growth, and the increasing impact of this growth on the environment. With the added challenge of climate variability and change, sound water management decisions are becoming more complex and more critical to Alberta's prosperity.

These challenges are perhaps felt most urgently in the South Saskatchewan River Basin (SSRB), which is home to over one-third of Alberta's population. Major water uses in the SSRB include food production and agriculture (with irrigation being the largest single water user), municipal and residential, and industrial and thermal. Water is also used to meet instream needs such as channel transportation, aquatic health, riparian health, healthy fish populations, wetlands, and recreational requirements.

Water supply in the SSRB is affected by many factors. Conditions associated with natural climate variability are already familiar to residents; research suggests that global climate change impacts are likely to exacerbate these conditions by producing more extreme events and altering the timing and type of precipitation that supports surface water systems. At the same time, pressure on regional water supplies is increasing with rising demand for products from irrigated agriculture, and with demands to service an expanding population and thriving economy. The health of Alberta's natural resources and its economic vitality depend on an integrated understanding of natural climate variability as well as improved management capacity to confront the prospects and potential impacts of climate change.

In this context, the *South Saskatchewan River Basin Adaptation to Climate Variability Project* was launched in early 2012, with financial support from the Climate Change Emissions Management Corporation. Building on the 2010 Bow River Project, this initiative will integrate existing data, tools, capacity and knowledge of water users and decision makers to improve understanding and explore how to manage for the range of potential impacts of climate variability throughout the SSRB's river systems. This understanding will support collaborative testing and development of practical adaptive responses to climate variability, from the local community scale to the provincial scale. Through its four phases, the project will engage many people and groups to build:

- An evidence-based analysis of potential climate variability and change, and the effects this may have on total water availability and timing of flows from the headwaters,
- A collaborative forum for key water users and interests to assess and address the impacts of climate variability on the SSRB,
- A common understanding of feasible and practical mechanisms for adapting to water impacts from climate variability and change, and
- Increased capacity for an informed, collaborative and adaptive approach to water resource management throughout the SSRB.

The SSRB project attempts to leverage existing resources, avoid duplication, continue building awareness of the resources that are already available for use in the basin, and drive the identification and development of new adaptation foundational blocks.

Phase 1 of the SSRB project identified five foundational blocks that could support adaptation and integrated water management over the long term:

1. Data
2. Tools
3. Capabilities
4. Engagement processes
5. Frameworks.

This report is a preliminary scan of both existing resources and resources in development in all five categories, along with the various agencies that are involved in their application and development. This document is a work in progress and is not being published as a final report. It will be publicly shared as appropriate with those interested and with those engaged in the SSRB Adaptation Project.

One area was examined in more detail than others due to its significance to the overall project. Specifically, the project needed a more detailed assessment of the data and tools available to select the best fit-for-purpose tools to support the project's modelling work. Drawing on expert advice from modelling practitioners in Alberta and elsewhere, the Phase 1 project team and a select group of modelling experts developed fit-for-purpose criteria to assess models that could potentially be used in subsequent phases of the project. The conclusion was to use OASIS for the SSRB Adaptation Project modelling; more detailed analysis and rationale for this decision are noted in the report.

This Phase 1 report also provides a list of initial observations about limitations and opportunities related to river management in the SSRB. The comments have not been vetted or verified, nor do they necessarily reflect the views of the project team.

This report lays the foundation for the additional work to occur as the project undertakes more collaboration and detailed testing and modelling for the Bow, Oldman and South Saskatchewan basins.

2 Introduction

Alberta's heritage and its social, economic and environmental history are directly tied to its water resources. While Alberta's economy is fuelled by hydrocarbons, it runs on water, and the province's continued prosperity depends on sound water management decisions. In the face of climate variability and change, these decisions are becoming more complex and more critical.

Alberta is confronting important water challenges, including an expanding population, accelerating economic growth, and the increasing impact of this growth on the environment as the climate continues to shift.

The province's geographical landscape encompasses the spine of the Rocky Mountains on its western border, semi-desert plains in the south, parklands in central Alberta and boreal forest across the north. The mountain regions are the water towers for much of western Canada, while eastern and northern flowing rivers are vital to this province as well as our downstream neighbours.

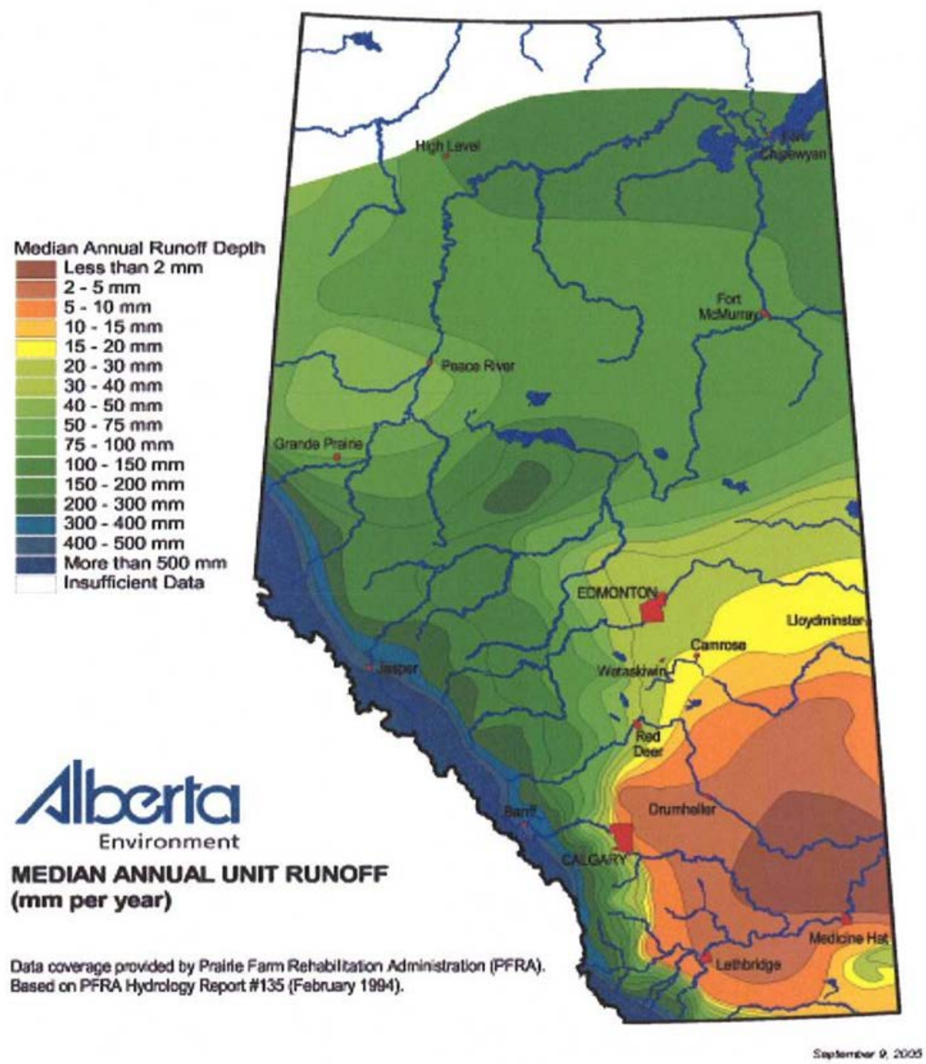
Water supply varies considerably throughout Alberta as seen in Figure 1. Water demand is also variable, particularly between southern and northern regions. The health of Alberta's natural resources and its economic vitality depend on an integrated understanding of natural climate variability as well as improved management capacity to confront the prospects and potential impacts of climate change.

These challenges present a timely opportunity to capitalize on the knowledge and experience of community and business leaders, government departments, water managers and licence holders, environmental organizations and watershed groups. Water and climate adaptation issues are complex with many facets, and cannot be solved by any single initiative or sector. Alberta has a history of successfully meeting sustainability challenges through multi-sector collaboration and engagement, and the South Saskatchewan River Basin Adaptation to Climate Variability project will further enhance that legacy.[1]

This document is a work in progress and is not being published as a final report. It will be publicly shared as appropriate with those interested and with those engaged in the SSRB Adaptation Project.

[1] See Section 3 and Appendix A for more information on this project.

Figure 1: Median Annual Unit Runoff

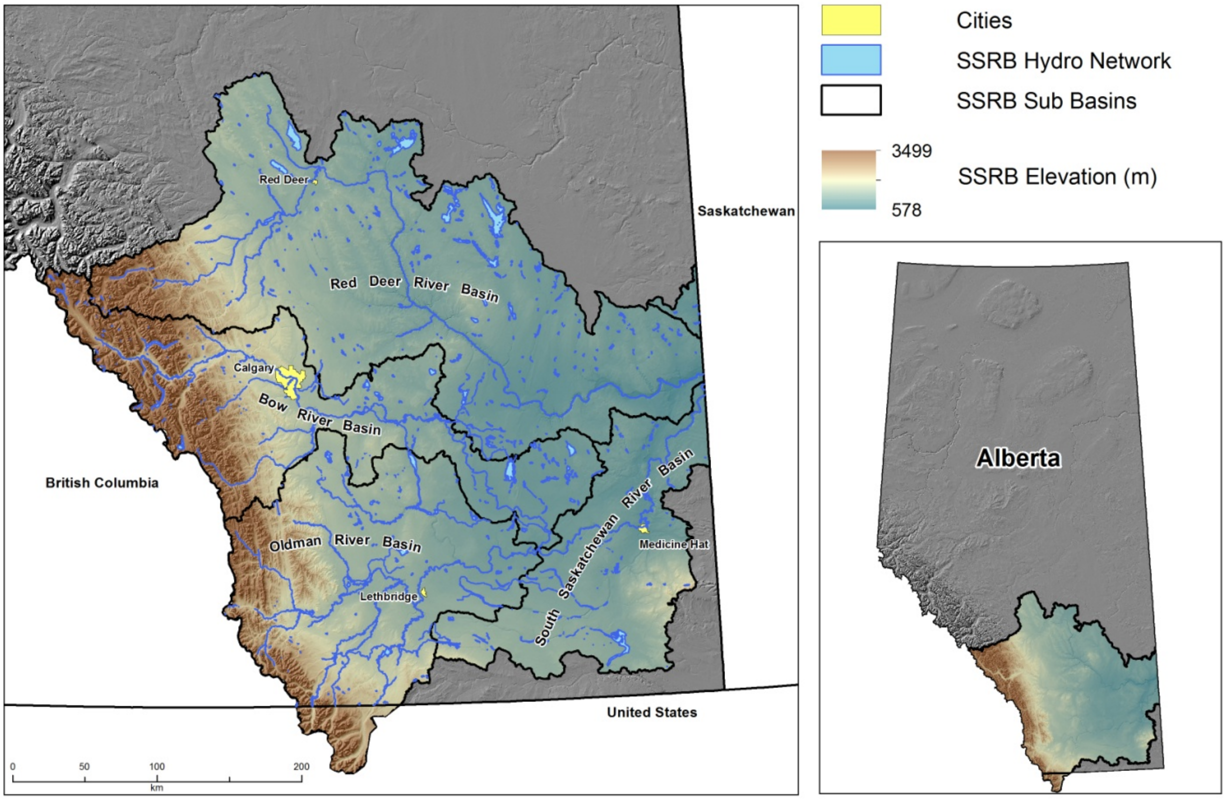


Source: Alberta Environment, 2005
http://www3.gov.ab.ca/env/water/gwsw/quantity/learn/what/sw_surfacewater/sw3_surface_runoff.html

2.1 The South Saskatchewan River Basin

The South Saskatchewan River Basin (SSRB) comprises four major sub-basins: the Bow, Oldman, Red Deer, and South Saskatchewan (see Figure 2). It stretches from the Continental Divide in Alberta, across the Saskatchewan and US borders. Both of these border crossings are subject to formal apportionment agreements.

Figure 2: South Saskatchewan River Basin



The SSRB is home to over one-third of Alberta's population, most of whom are urban dwellers in the Bow basin. Major water users in the SSRB include municipal and residential users, industrial and thermal users, and agriculture, including irrigation, which is the largest single water user. Water is also used to meet instream needs such as channel transportation, aquatic health, riparian health, healthy fish populations, wetlands, and recreational requirements. Table 1 shows the main water users in the Alberta area of the SSRB.

Table 1: Major Water Users in the SSRB (Alberta)

Category	Uses	% of water withdrawals*
Municipal and residential	Commercial, industrial, rural and urban residential	7.7
Industry and thermal	Mining, oil and gas, thermal, hydroelectric	4.4
Agriculture	Irrigation, stock watering	87.9

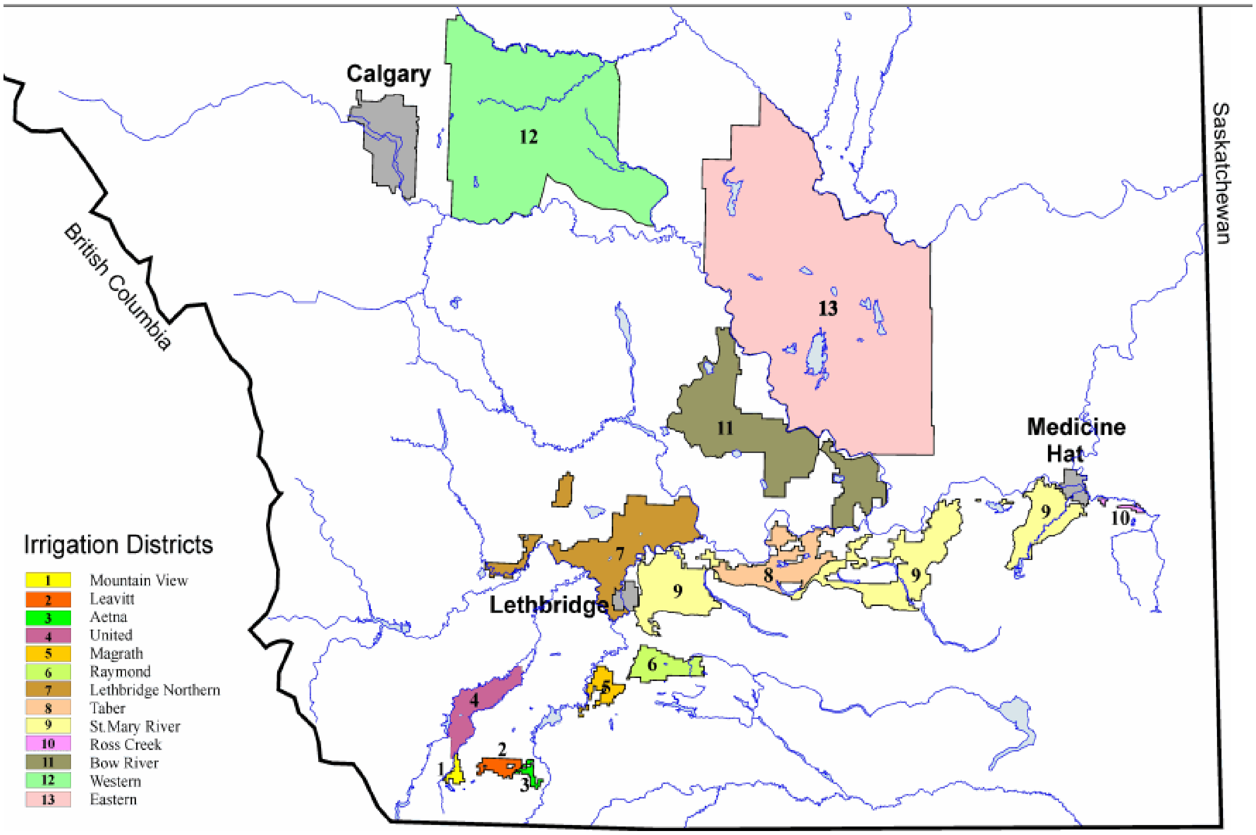
* *Source:* Martz *et al.,* 2007

Alberta has 13 irrigation districts, ranging in size from less than 526 hectares to over 145,600 hectares.[2] The six largest districts account for over 90% of the total irrigated land area. Irrigation districts are

[2] In Imperial units, this range is from less than 1,300 acres to over 360,000 acres.

created as corporations by the provincial *Irrigation Districts Act,* which sets the framework under which they operate. Each district holds water licences issued according to the provincial *Water Act* (*Appendix 1: Alberta's Irrigation Districts*) and prior legislation. Irrigation Districts are some of the largest licence holders in the SSRB with, for example, 89% of the licensed water in the Oldman River Basin (Alberta Environment, 2007). Irrigation is the largest of all uses in the SSRB, with estimated withdrawals of 2.5 billion m^3 annually (Martz *et al.,* 2007). Livestock water use is estimated at 84 million m^3 (Martz *et al.,* 2007). Figure 3 shows the location of Alberta's irrigation districts.

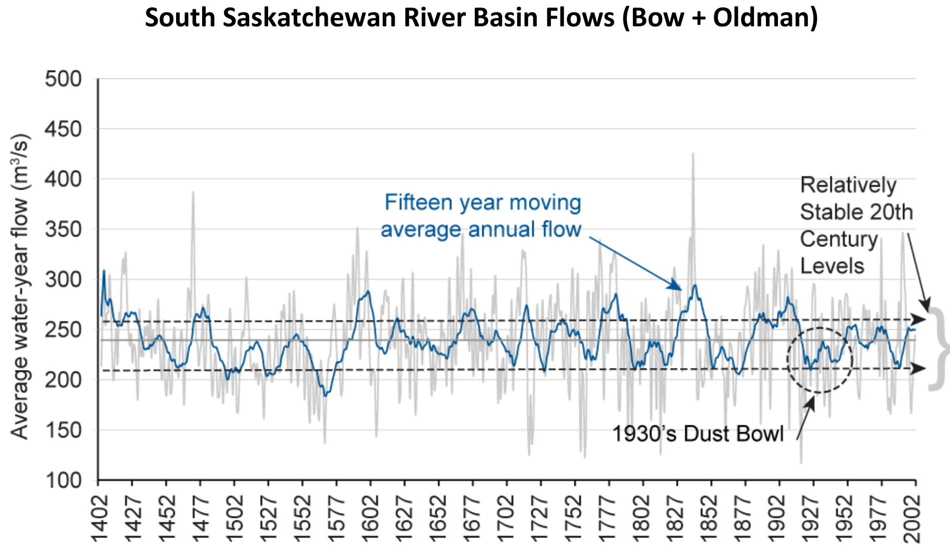
Figure 3: Alberta's Irrigation Districts



Source: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr12911/$FILE/irrigationdistricts.gif

Changes in water resources are often viewed as one of the first and most important impacts of a changing climate. The historic record demonstrates the wide range in climate variability in the SSRB over the last 600 years (see Figure 4). Based on current research it is expected that the timing and nature of southern Alberta's water resources will continue to exhibit annual and seasonal variability (Rood *et al.,* 2008; Forbes *et al*., 2011; Kienzle *et al.,* 2011).

Figure 4: Historic Drought and Flood Record



Source: Axelson *et al.,* 2009

It can be difficult to manage the delicate balance between water supply and the demands of population growth and economic development while recognizing the environmental impacts of those activities.

Water supply in the SSRB is affected by many factors. Natural climate variability and climate change pose a huge challenge to Alberta and to those downstream, as the headwaters for major east- and north-flowing rivers arise in Alberta. Global climate change impacts are likely to produce more extreme events and alter the timing of precipitation that supports surface water systems by shifting from primarily snowpack-driven events to more winter rainfall (Field *et al*., 2007; Sauchyn and Kulshreshtha, 2008). Melting of Rocky Mountain glaciers will produce lower natural summer flows and Alberta has limited storage options to capture the flow that does occur.

At the same time, global demand for products from irrigated agriculture is growing, and an expanding population and a thriving economy are placing ever-increasing pressure on water supplies in the region. Water is also needed to address environmental and recreational needs throughout the river system. The Government of Alberta acknowledged water supply pressures in the SSRB by closing much of the basin to new allocations in 2006.

Alberta faces uncertain climate conditions; whether these are due to natural climate variability or actual climate change matters not. Albertans clearly need a better collective understanding of how the sub-basins in the SSRB are responding to these changes. Then more robust and flexible water management strategies can be developed to adapt to these changing conditions in a manner that best assures water for people, nature and the economy for years to come.

3 SSRB Adaptation to Climate Variability Project

Acknowledging the importance and urgency of finding options for adapting to climate variability and change in the SSRB, the Climate Change Emissions Management Corporation awarded funding for the *SSRB Adaptation to Climate Variability Project* in January 2012. The funds were provided to Alberta Innovates – Energy Environment Solutions and WaterSMART Solutions Ltd. to support the first stage of this adaptation work (see Appendix A for more information on the SSRB project).[3]

Building on the 2010 Bow River Project,[4] this initiative will integrate existing data, tools, capacity and knowledge of water users and decision makers to improve understanding and explore how to manage for the range of potential impacts of climate variability throughout the SSRB's river systems. This understanding will support collaborative testing and development of practical adaptive responses to climate variability, from the local community scale to the provincial scale. The project will engage many people and groups to build:

- a common understanding of feasible and practical mechanisms for adapting to climate variability and change, and
- increased capacity for an informed, collaborative and adaptive approach to water resource management throughout the SSRB.

The first stage of the project is divided into four coordinated phases:

Phase 1 - Foundational Blocks: Initial Assessment

The first phase of work, which is the focus of this report, is an initial assessment of the data, tools, capabilities, processes and frameworks that already exist and could form elements of the foundational blocks to support integrated water management by water users, decision makers and other interested parties over the long term. It identifies the core resources for the project and critical gaps to be addressed, and aims to leverage existing knowledge, tools, and experiences while avoiding duplication of work already completed or underway.

Phase 2 - Bow River Basin: Adaptation and Live Test Year

The second phase will re-engage Bow River Project participants and engage new organizations and individuals with an interest in the Bow River Basin to: advance climate adaptation decision making related to water resources, explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options. Phase 2 work will provide support for a virtual river test year, or perhaps an actual test year of modified flow, to better match identified changes in management strategies to the three goals in Alberta's *Water for Life* strategy.

Phase 3 - Oldman River Basin and South Saskatchewan River Modelling

In the third phase, participants will model the Oldman River Basin and the South Saskatchewan River to the Alberta border. Users, decision makers and others in the Oldman and South Saskatchewan River (OSSK) Basins will set principles to guide and inform the modelling work, incorporating an environmental and climate adaptation focus.

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[3] In this report, unless otherwise noted, reference to "the project" or "the SSRB project" means the South Saskatchewan River Basin Adaptation to Climate Variability Project.

[4] For more information on the Bow River Project, see http://www.albertawater.com/index.php/projects-research/ssrb-adaptation-project?layout=edit&id=547

Phase 4 - Foundational Blocks: Development

The final phase will see development of new adaptation foundational blocks. This work will be based on the gaps identified in the initial assessment.

All four phases will be documented and the reports made publicly available.

4 Phase 1- Foundational Blocks: Initial Assessment

Phase 1 of the SSRB project was designed to identify existing data, tools, capabilities, processes and frameworks that could support integrated water management over the long term. It summarizes a preliminary view of the current state of adaptation resources and begins to present observations on where there may be gaps that should be addressed or opportunities that should be explored.

4.1 Scope

This report was designed and intended as a preliminary summary of the foundational blocks currently in place in the SSRB; additional elements and resources are likely to be identified during this project. The focus of this preliminary research was in the Bow, Oldman and South Saskatchewan regions as that is the scope of the project's modelling work.

One of the objectives of this report is to ensure that the project leverages and avoids duplication of existing resources. Another focus is to continue to build awareness of resources that are already available for use in the basin as well as possibly drive the identification and development of new adaptation foundational blocks. If needed, an updated version of this report or an addendum will be prepared to capture additional information. It is important to note that one area was explored in more detail. Specifically, a more detailed assessment of the data and tools available was needed to select the best fit-for-purpose tool to support the project's modelling work. The results of the assessment are presented in Section 6.3.

Five foundational blocks were the focus of the Phase 1 work, as noted and defined for the purpose of this project in Table 2.

Table 2: Foundational Blocks

Foundational Block	Definition
Data	Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions
Tools	Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences
Capabilities	The ability of an individual or entity to meet its objectives and/or to execute a specified course of action (e.g., skills and training programs)
Engagement Processes	Activities, methods and relationships between established, practices decision makers, river users and/or interested parties
Frameworks	The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the SSRB

4.2 Methodology

4.2.1 Primary and Secondary Research Approach

The project team adopted a two-pronged research approach: primary research was done by gathering local and regional perspectives from experienced individuals, and secondary research involved a review of existing data and online research. This approach was based on a participatory method to gather pertinent background information to determine and characterize the current state of river flow management in the SSRB.

4.2.2 Tool Selection Approach

The following additional steps were undertaken to determine the best fit-for-purpose model for the SSRB Adaptation Project work:

1. Draft fit-for-purpose criteria for model assessment
2. Finalize criteria with collaborative river management modelling practitioners with the following perspectives:
   - Academia (Columbia University; University of California, Davis; University of Texas, Austin)
   - Industry (Optimal Solutions Ltd.; US Army Corps of Engineers)
   - Modelling specialists (Alberta Environment and Sustainable Resource Development; HydroLogics Inc.)
3. Validate model assessment criteria with project participants
4. Solicit and compile inputs on model assessments using finalized criteria
   Perspectives were obtained from:
   - Industry (Optimal Solutions Ltd.)
   - Modelling specialists (Alberta Environment and Sustainable Resource Development; HydroLogics Inc.)
   - Academia (University of Saskatchewan).
5. Prepare comparison on river management models
6. Advise and secure Project Steering Committee decision

4.2.3 Finalized List of Criteria Used to Assess Tools

The project team then developed a final list of 50 criteria for assessing tools, based on the results of the steps described in Section 4.2.2, above. The criteria are stated in question format:

1. Is one or more experts in using and modifying the model available essentially full-time, or at least on-call, over the next two years who will report to directly to the project leader for performance and payment reviews during that period?
2. Are there four or five qualified model operators who can be made available together for several interactive workshops using the model over the next two years?
3. Is there sufficient expertise available to integrate data from other models in a timely manner and required by the project leader, such as electricity pricing on an hourly basis, operating multiple irrigation districts together, or integrating Global and Regional Circulation Models and land cover models into the determination of water flows?
4. Are the expert operators referred to above, experienced in leading collaborative processes using the model results interactively during the course of a day with stakeholders changing assumptions and running them through the model to test "what if" assumptions?

5. Have these collaborative uses of the model been used in Alberta? Please provide three references who have participated.
6. Is the model “user friendly”? What specific attributes make it user friendly?
7. Is it easy to enter, review and alter operating rules?
8. Have these collaborative processes been used in jurisdictions other than Alberta? Please provide three references who have participated.
9. Is the model freely available for use by trained stakeholders as part of a collaborative modelling project (e.g., can it live in the public domain)?
10. Is there sufficient training provided for one or more select groups of stakeholders to enable them to take over operating the model for their own purposes?
11. Can your model enable the trained stakeholder users to change all the various assumptions and inputs to the model, link it to new data, models and/or the results from these other models?
12. Is there a graphical user-interface that is user-friendly and easy to use? What kind of interface does the model use (e.g., MS Windows™, DOS prompt, GIS based)?[5]
13. How easy is it to create a new project and how long would it takes a person familiar with the model to enter all necessary information for a medium size river basin?
14. Is it able to model a broad range of suggested alternatives (e.g., operating rule)? What does it take to add an alternative operating rule?
15. Can informed stakeholders participate in the model building and validation in a way that makes sense to them (e.g., process that builds confidence and trust in the model)?
16. Does the model accept flexible river basin network configuration (i.e., can it be applied on any river basin regardless of inter basin transfers, locations of tributaries and diversions)?
17. Can the model output be presented in a graphical or other way that is meaningful to stakeholders and the general public?
18. Can it produce real time results when multiple operating rules are changed (e.g., less than 30 minutes)?
19. What is the range of time steps that can be addressed by the model (i.e. daily, weekly, monthly, any multiple of one day, any multiple of hours)?
20. Does the model have input data limitations? Can it accept a variety of types of data (e.g. not just hydrology, but also economic drivers, development, recreation, water quality, groundwater, water policies, operational rules)?
21. Can it accept user defined inputs (e.g., flow or demand patterns)?
22. Is the model logic (e.g., an operating rule) transparent and open to users?
23. Can the model handle the existing FITFIR licensing system and possible changes in Alberta's water allocation system?
24. Does the model have comprehensive documentation (i.e., user manuals, sample runs) which is regularly maintained? What kind of user support is available to the model users?
25. Can the model link to other models sequentially (e.g., ACRU, SWAT, AWQ model, ALCES)?
26. What is the cost of acquiring the model and is there an annual fee related to technical support and maintenance?
27. How does the model deal with situations where travel times through the modelled region are longer than the simulated time step length? Does the model resort to (a) hydrologic channel routing; (b) time lag of demands and runoff; or (c) other solutions, and if so, please explain?

[5] Most of the acronyms and abbreviations noted in this Section, 4.2.3, are written out fully in the Acronyms and Abbreviations list on page iii.

28. Can the model include hydrologic channel routing routines (i.e., Muskingum, Streamflow Synthesis and Reservoir Regulation (SSARR)) in the solution process, and if so, how does it deal with the fact that the routing coefficients are a function of flow when the flow varies between the dry and wet flow seasons?
29. Is there a standard set of tools that come as part of the model to help analyze the output and interpret the model results for each scenario?
30. Can the model function as an operation and planning decision support tool (e.g., real-time and short/long term)?
31. What is the upper limit on the number of components in the model? If there is no upper limit, what is the known maximum of components that had been used in a single model application?
32. Is the programming language common (e.g., Fortran, VB, C++)? Is it easy to use or learn?
33. What kind of optimization solver does the model use (e.g., Linear Programming, Mixed Integer programming, Non-linear programming), and what is the name of the solver vendor?
34. Can the model use penalties (i.e., cost factors or weights) to represent priority of allocation? Is there a module that is part of the model that can help determine the best set of penalties that represent a particular allocation priority policy?
35. Can the model include apportionment agreement constraint, expressed by a requirement to pass certain minimum flow volume over a designated period, typically calculated as a percentage (50%) of the natural flow series available for that location? How is this constraint modelled in a single time step and multiple time step solution framework?
36. Can a model include diversion licence constraints, where the flow in a diversion canal can be limited by the maximum licensed volume over a certain operating period, such as the irrigation season? How is this constraint modeled in a single time step solution framework, and how is it modelled in a multiple time step solution framework?
37. Can the model provide solutions with equal relative deficits between two or more selected water users, such that they share the same deficits over one or more simulated time steps?
38. What are the available options for modelling canal losses (i.e., as a fixed loss, a linear function of flow in the return channel, or a non-linear function of flow)?
39. Can the upper limit on flow in any channel be represented as a function of time, such that a gradual opening and closing of a large diversion structure is modelled as intended?
40. Is the model capable of representing flow-to-flow relationship using a non-linear curve that shows maximum flow in a lateral diversion canal as a function of the incoming flow into the weir where the diversion channel originates (e.g., the BRID diversion structure)?
41. Can the model connect to external databases?
42. Does the model use any database to store information related to various modelling scenarios? If yes, which database is used?
43. How does the model handle net evaporation (i.e., is the net evaporation applied at the beginning or at the end of the time step; is it half at the beginning and half at the end; or is it ignored altogether)?
44. Can a built model be expanded and added to?
45. Is the model capable of solving more than one time step simultaneously (i.e., is it able to provide optimal solutions both in space and in time over the entire hydrologic year or years)?
46. Is the model coupled with any GIS software and if so, which one? If not, can it?
47. Can it do any statistical analysis or Monte Carlo simulation?
48. Can it exchange information with other models while running in parallel?

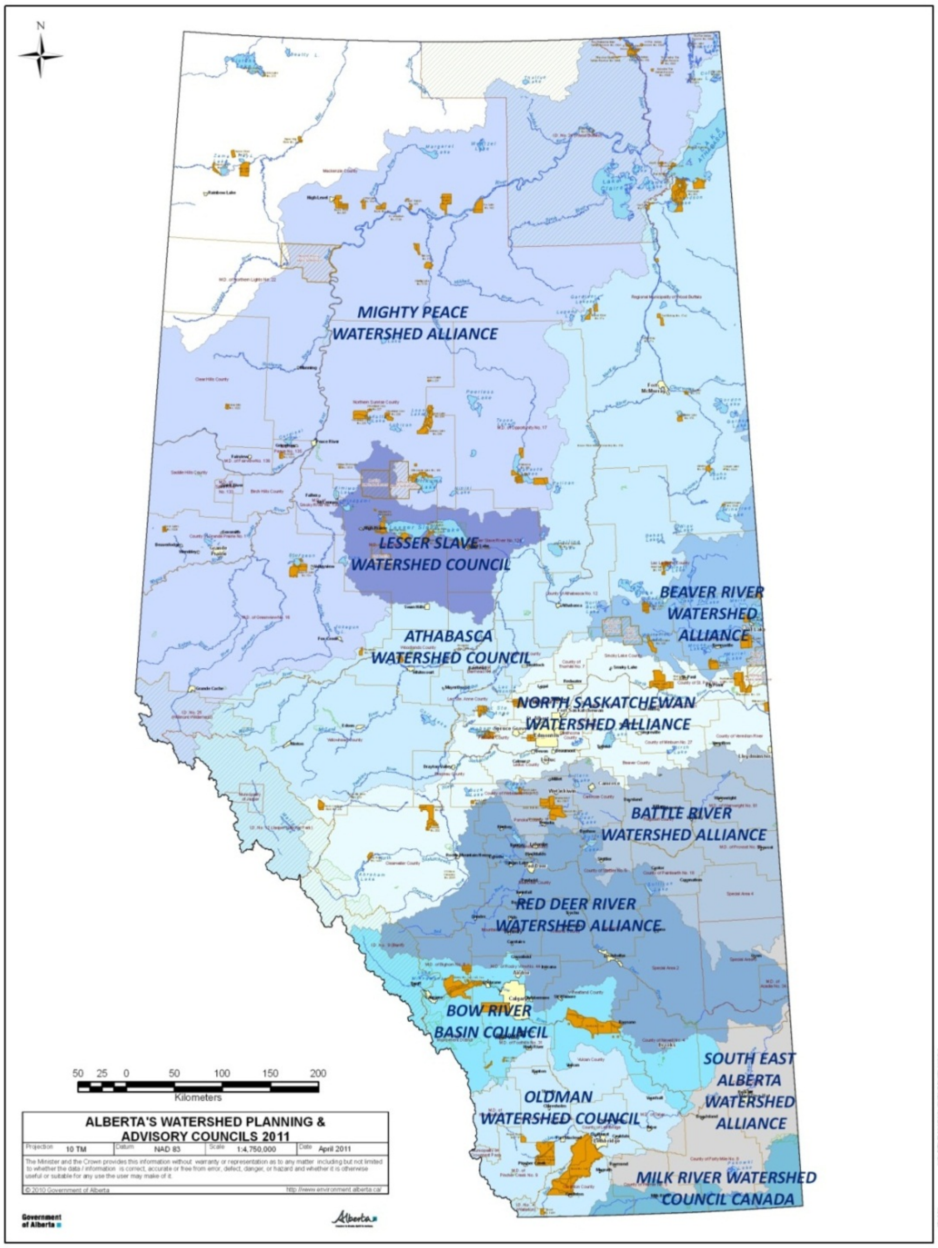
49. Is the operational model based on the use of optimization within the Multiple Time step Optimization (MTO) solution framework with hydrologic channel routing, or is it an inferential statistical model based on one of the machine learning algorithms?
50. Could the model use real time data in real time, assuming necessary real time data come from hydrometric and meteorological forecasts?

More information on the process for developing criteria to assess the tools, plus the assessment responses from modelling experts, is noted in Section 6.3 and in Appendices B, C and D.

5 Data

Data represent one of the key foundational blocks and are defined, for the purpose of this project, as "distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions." The project team examined existing data sets for the SSRB as well as data that are in development, noting that SSRB data sets should be consistent, comprehensive and accessible. Alberta's Watershed Planning and Advisory Councils (WPACs) have been gathering data, as reflected in Table 3. The map in Figure 5 shows the location of WPACs across the province.

Figure 5: Alberta's Watershed Planning and Advisory Councils



Source: Alberta Environment and Sustainable Resource Development, http://www.waterforlife.alberta.ca/images/wfl-P-WPACs-map.jpg

5.1 Existing Data

The project team conducted a preliminary scan of existing data and sources that it considered relevant and useful for exploring and adapting to climate variability in the SSRB. Arranged alphabetically, Table 3 summarizes the existing data of which the team is aware so far.

Table 3: Existing Data

DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.	
Data	**Description**
Data related to current and anticipated municipal footprint	• Municipalities have the following information in various forms: - Existing stormwater runoff into the canal system - Future stormwater runoff into the canal system - Current water demand - Expected future runoff and water use based on population projections. • SouthGrow has posted municipal footprint information on its website at http://southgrow.com.
First Nations' Water Allocation Needs Assessments	• Siksika Nation, the Blood Tribe, Piikani Nation and the Stoney Tribe have all completed a water allocation needs assessment. These assessments contain data related to existing water use and future water needs and are organized by use. While currently not publicly available, there may be an opportunity to obtain pertinent data from these completed assessments in the future. • The project will use, at the very least, the information contained in existing Alberta Regulations for First Nation's water needs, in the absence of any other more current information.
Irrigation Data	• Weather Data - Maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, rainfall, wind run, solar radiation, evapotranspiration potential, lake evaporation. • Crop Data - The base data include information on the crops that can be simulated by the Irrigation Requirements Module (IRM). This includes such things as minimum and maximum root depth and crop coefficients, which are used to calculate evapotranspiration. The Network Management Module (NMM) does not use these data directly but does include it in data sets prepared for the IRM. The configuration data include the crop type for each field connected to the network. - Soil type (i.e., fine, coarse, medium). - Crops grown (i.e., a single parcel of land can be broken down into any number of cropped fields). - Method of irrigation, which can be tied to each cropped field. • Irrigation system performance and efficiency data - The base data also include information on the types of irrigation systems that can be simulated by the IRM. As with crop data, the NMM does not use these data directly but includes them in the data sets it creates for the IRM.

<table>
<tr><th colspan="2">DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.</th></tr>
<tr><th>Data</th><th>Description</th></tr>
<tr><td></td><td>• GIS Shapefiles
- The NMM uses the data from three layers in the GIS. They are:
▪ A Conveyance Works layer that contains all of the conveyance works segments;
▪ A Structures layer that contains all of the diversion, spillway, and tail outs structures; and
▪ A Reservoir layer that contains all of the reservoirs.</td></tr>
<tr><td>Land Cover</td><td>• Digital Elevation Model (DEM)
• Glacier mass-balance data
• Circa 2000 Land Cover data set (or updated version of it)
• Soil data (from the Agricultural Region of Alberta Soil Inventory Database, or AGRASID, soil maps, specifics on porosity, wilting point, field capacity, the portion of water redistributed from surface to subsurface horizons, and from subsurface to groundwater store and texture)
• Albedo
• Crop coefficients
• Alberta Vegetation Inventory data sets and Leaf Area Index.</td></tr>
<tr><td>Local Operating Database (LOD)</td><td>• A Microsoft SQL Server database that is the central repository for information used by the various components of the Irrigation District Model (IDM) suite of tools. The LOD contains the following information:
- District Network Version (created by the IDM DB Convert)
- Weather data
- Crop parameters (root depth, planting date, harvest date, irrigation threshold, etc.)
- Crop coefficients (used in the calculation of evapotranspiration)
- Irrigation system parameters (water use rate, coverage rate, etc.)
- WRMM inputs and outputs.</td></tr>
<tr><td>Meteorological Data (all daily unless noted)</td><td>• Maximum temperature
• Minimum temperature
• Total precipitation
• Snow pillows
• Snow surveys
• Incoming solar radiation or shortwave radiation
• Sunshine hours (potential and actual)
• Wind (speed and direction)
• Interpolated surfaces (e.g., Parameter-elevation Regressions on Independent Slopes Model (PRISM)) (all variables that exist)
• A-Pan evaporation
• Relative humidity.</td></tr>
</table>

<table>
<tr><th colspan="2">DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.</th></tr>
<tr><th>Data</th><th>Description</th></tr>
<tr><td>SouthGrow Water Related Data</td><td>SouthGrow is an organization comprising 22 communities in south-central Alberta. Its mandate is to work together to achieve prosperity for the region. The organization’s website contains data related to: water sources, availability of water in SouthGrow region, licence restrictions, water transfers, water requirements for economic development, and other data. (See http://southgrow.com/investing-southgrow/water-economic-development)</td></tr>
<tr><td>Streamflow and River Data</td><td>Naturalized streamflow data (weekly or daily)
Recorded Flows (daily) - Hydrometric Data
Runoff coefficients
Water use (actual)
Demand and licence data
Reservoir information (Surface Area Elevation tables, normal curves, storage capacities, etc.).</td></tr>
<tr><td>Water Licences</td><td>Information and data regarding water licences in the SSRB are available through the Water Allocation Licence Viewer Search System (Licence Viewer). Users can search for and view:
Licence and registration documents held by ESRD
Summaries of licences and registrations that can be used to access documents.
(Source: http://ssrb.environment.alberta.ca/licence_viewer.html)</td></tr>
</table>

DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.	
Data	**Description**
Watershed Planning and Advisory Councils (WPAC)	• Bow River Basin Council (BRBC) - Web-based State of the Watershed Module and Maps, and paper report - *Bow Basin Watershed Management Plan Phase I* - *Protecting Riparian Areas: Creative Approaches to Subdivision Development in the Bow River Basin* - *Fish Creek Water Quality Monitoring Report* - Various other informative reports on the Bow Watershed and the BRBC (Source: http://www.brbc.ab.ca/) • Oldman Watershed Council (OWC) - *Oldman Watershed Council State of the Watershed Report* - *Groundwater Study of Willow Creek Watershed Illustrates Need for More Groundwater Monitoring* - *Southern Rockies Watershed Project* - *Oldman River Basin Water Quality Initiative Surface Water Quality Summary Report - 1998-2003* - Various other informative reports on the Oldman Watershed and the OWC (Source: http://oldmanbasin.org/) • South East Alberta Watershed Alliance (SEAWA) - Web-based State of the Watershed Module and Maps and paper report - *Surface Water Quality in the SSRB* - *Geography of the SSRB* - Various other informative reports on the South Saskatchewan Watershed and SEAWA (Source: http://www.seawa.ca/) • Milk River Watershed Council of Canada (MRWCC) - *State of the Watershed* - *The Study of Erosion and Sedimentation on the Milk River* - *Milk River Supplemental Water Supply Investigation* - Various other informative reports on the Milk River Watershed and MRWCC (Source: http://www.milkriverwatershedcouncil.ca/)

5.2 Data in Development

The team also became aware of many projects that are developing data for possible future use in assessing climate variability and adaptation opportunities. As with existing data, more information is expected to emerge during subsequent phases of this project. Table 4 summarizes the projects and activities now underway that are developing these data.

Table 4: Data in Development

<table>
<tr><th colspan="2">DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.</th></tr>
<tr><th>Data in Development</th><th>Description</th></tr>
<tr><td>Academic Data</td><td>Many academic studies and projects in the SSRB are collecting and creating water-related data. Examples include work being done at the University of Lethbridge to:
Create an atlas of the movement, distribution and amount of water (hydrology) and climate (called the hydroclimatological atlas) for Alberta. The data will be used to create detailed maps of the movement, distribution and amount of water and patterns of climate variables; these maps will eventually be available online.
Examine processes that control water temperature in mountain streams where changes in water temperature due to environmental change are important concerns. Water temperature influences water quality, ecosystem function, and the health of fish species.</td></tr>
<tr><td>AI-EES work with Alberta Agriculture and Rural Development (ARD) to Update the IDM</td><td>This work is exploring updates to the current suite of irrigation models so that they could interact with river management models on a time-step by time-step basis. Some of that work has already started with ARD, and the model updates will begin in earnest in the fall of 2012.</td></tr>
<tr><td>ARD Off-Stream Storage</td><td>This study will evaluate the opportunities and impacts of potential storage sites in the SSRB and will include social, economic, environmental, structural and operational analysis. Comprehensive conclusions and possible recommendations will direct policy and guide decision makers on future development in the basin.</td></tr>
<tr><td>Alberta Watershed Toolkit Project</td><td>This project will build capacity and encourage leadership in sustainable stewardship of Alberta watersheds. With support from diverse agencies and organizations, Sustainability Resources Ltd. and the Alberta Centre for Sustainable Rural Communities are developing an inventory of on-the-ground best management practices, examples of stewardship and conservation initiatives, literature and case studies, and community leadership in watershed management from across Alberta.</td></tr>
</table>

DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.	
Data in Development	**Description**
Development of Centralized Modelling Repository System - ESRD	This project involves developing a centralized Modelling Repository System and compiling information on modelling projects undertaken by ESRD.
Evaluation of modelling tools across media (air, land, water and bio-diversity) - ESRD	This project will see the development of comprehensive model evaluation criteria, a modelling catalogue system, an inventory of all the modelling tools used by ESRD and an acceptable modelling toolbox. The project will also evaluate various environmental models and tools and their suitability from a science perspective for ESRD and Government of Alberta (GoA) decision making. The intent is to help standardize modelling requirements and ensure modelling work is being done in a cumulative effects manner with acceptable science rigour.
Hydrological impacts of climate change in the Castle River watershed, Alberta, Canada	This research is part of the larger Vulnerability and Adaptation to Climate Extremes in the Americas project. This study will conduct hydrological modelling of future climatic conditions to assess the impact of extreme conditions at the local or regional scale in a rural community in the Eastern Slopes of the Rockies. The Castle River, the largest river in the Castle watershed is a natural river, making the study area an excellent location to examine the impact climate change will have on the Oldman River basin. This study seeks to include crop modelling, as well as modelling of the whole Oldman basin.
Irrigation Council	The Irrigation Council reports directly to the Minister of Agriculture and Rural Development. It will likely be providing new data sources from two initiatives: reservoir storage to choose the best locations; and groundwater mapping to identify groundwater volumes and surface links.
Southern Rockies Watershed Project	This project was initiated in March 2004 to investigate the likely impacts of land cover changes (e.g., natural disturbance by wildlife) on water resources and to monitor their recovery in front range headwater streams of the Oldman River basin. This research is also providing crucial information on hydrology of high water-yielding Rocky Mountain watersheds that generate most of the water supply to settled regions of the Oldman River basin. Two specific projects are: • **Enabling Integrated Source Water Supply and Protection in Alberta** This project involves an assessment of source water and drinking water treatment vulnerabilities to specific upstream land disturbances: wildfire and forest management. The assessment will create a template that can be applied to a broader range of environments and provincial water uses. • **Managing wildfire risk to municipal waterworks systems in Alberta** The Canadian Water Network (CWN), in partnership with ESRD and AI–EES, has launched a new research project within CWN's Secure Source Waters Consortium. The project will directly support development of a

DATA: Distinct pieces of factual information, formatted in a specific way for analysis and/or to make decisions.	
Data in Development	**Description**
	decision-support approach to a) determine what changes due to wildfires in forested areas could potentially overwhelm operational capacity of downstream municipal drinking-water supply plants, and b) help identify best management strategies to mitigate risks to public health posed by the impacts of wildfire to municipal supplies.
The Functional Flows Project	The Functional Flows project, supported by Alberta Innovates – Energy and Environment Solutions and the National Science and Engineering Research Council, is developing guidelines for the prescription of instream flow patterns that will sustain and restore river ecosystems. The project also seeks to implement functional flow regimes in the Oldman basin to allow cottonwood recruitment and sensitivity to the aquatic conditions to support trout and whitefish.
Upper Little Bow River Impact Monitoring	The impacts of the new Little Bow/Highwood project, which involved the expansion of the Little Bow Canal, implementation of the Twin Valley Dam, and the development of an operations plan that would satisfy the economic goals and conserve riverine ecosystems, continue to be monitored. A staged monitoring program is underway, triggered by particular flow regimes that would involve substantial flow augmentation.
Water for Economic Development Project (SouthGrow)	SouthGrow has worked with its 22 member municipalities and the Irrigation Districts through the Alberta Irrigation Projects Association (AIPA) and ARD to identify challenges and opportunities in the region associated with water licence allocations. This phase of the project also involves the provincial government, rural governments and the professional water and research community. It is expected to culminate in a Statement of Collaboration between member communities and the Irrigation Districts to ensure water for economic development in the communities to the year 2050.
Water Information System Kisters Inc (WISKI)	WISKI (version 7 being used) is an environmental data management system developed by Kisters that can be used to store and manage surface and groundwater data, dam safety, hydropower generation, meteorological data, and other information. ESRD is implementing WISKI to manage and store all of its monitoring data from various networks and to support flow forecasting needs.
Watershed Planning and Advisory Councils	BRBC, OWC, SEAWA and MRWCC are in various stages of developing their respective Integrated Watershed Management Plans.

6 Tools

For the purpose of this project, tools are defined as "mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences." The project team looked at existing tools as well as tools that are in development, noting that SSRB tools should be transparent, practical, interactive and fit-for-purpose.

6.1 Existing Tools

As was done for data, the project team conducted a preliminary scan of existing tools that it considered relevant and useful for exploring climate variability in the SSRB, many of which are models and data management tools.

Table 5: Existing Tools

TOOLS: Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences.	
Tool	**Description**
A Landscape Cumulative Effects Simulator (ALCES)	The ALCES® Group has developed integrated simulation tools to assist progressive resource managers and planners develop strategies and land-use options that optimize societal goals. The ALCES® product suite (Integrator, Municipality, Wildlife Manager, Optimizer and Mapper) is powerful and fast, and has been proven in a diverse range of projects. (Source: http://www.alces.ca/downloads/ALCES_Group_and_Services_Intro.pdf)
Agricultural Catchments Research Unit (ACRU)	The ACRU agro-hydrological modelling system is a multi-purpose, multi-level, integrated physical conceptual model that can simulate total evapotranspiration, soil moisture storage, land cover and climate change impacts on water resources, and streamflow at a daily time step (Schulze, 1995). When accurately parameterized and verified, this tool can simulate many elements of the hydrological cycle, which establishes the fundamental basis for hydrological impact studies. ACRU is used in the St Mary, Oldman, North Saskatchewan, Athabasca, and Battle River watersheds.
Alberta Irrigation Management Model (AIMM)	The AIMM is a decision support tool software package that assists irrigation producers with their irrigation scheduling decisions. The AIMM software runs as a MS Windows™-based program with an agronomic record-keeping component incorporated into the program. AIMM acquires the climate parameters required to calculate evapotranspiration and irrigation recommendations from the Irrigation Management Climate Information Network website. Producers choose the station that is closest to their irrigation field from any of the current climate stations on-line. (Source: http://www.agric.gov.ab.ca/app49/imcin/aimm.jsp)
District Data Information Tool (DDIT)	DDIT is used to track the number, owner and types of irrigation systems in a district, the crop type and crop area under these systems, and the delivery times and amount of water delivered to these systems. It can also track water allocation trades within districts and data can be summarized in a variety of reports. (Source: http://www.windserver.com/IDM2.html)

TOOLS: Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences.	
Tool	**Description**
Generate Earth Systems Science Input (GENESYS)	The physically-based GENESYS hydro-meteorological model will be used to analyze the regional impacts of historical data, and to forecast future trends in the hydrology and climatology of selected watersheds within the SSRB. It is used in the St. Mary and North Saskatchewan watersheds and in parts of the Oldman River basin.
IDM Export and IDM Import	Network Management Module (NMM) Network Versions (described below) can be moved between Local Operating Database (LOD) instances with the Irrigation District Model (IDM) Export and IDM Import tools. IDM Export writes all of the information contained in a NMM Network Version into a group of text files. These text files can then be transferred to other computers and imported into other instances of the LOD using the IDM Import tool. Network Versions may also be backed up and restored using these tools. (Source: Irrigation Water Management Study Committee (IWMSC), 2002)
Import Irrigation Base Data File (IBDF)	The Import IBDF tool is used to import Irrigation Base Data files and Hydrological Base Data files into the Local Operating Database. These files are generated by the Network Management Module and contain input data for the Water Resources Management Model (WRMM). Importing the data contained in these files makes it easily accessible to automated analysis tools used to compare the WRMM output to the input or to compare the output from multiple scenarios. (Source: IWMSC, 2002)
Import Water Resources Management Model WRMM Output	The Import WRMM Output tool is used to import the output generated by the WRMM into the LOD. This output consists of Ideal (requested) water use and Actual water use, with the difference being the deficit. Importing the data into the LOD makes it easily accessible for automated analysis such as comparison to the WRMM output from several scenarios. (Source: IWMSC, 2002)
Irrigation District Model (IDM) (sometimes referred to as the Irrigation Demand Model or Irrigation District Module)	The IDM suite of tools was developed specifically for the study of irrigation requirements and basin supply in irrigation districts in southern Alberta. At the core are the Network Management Module and the Irrigation Requirements Module. (Source: IWMSC, 2002)
Irrigation Requirements Module (IRM)	The IRM is used to determine on-farm irrigation water demand by modelling the crop water user, irrigation systems and irrigation methods. (Source: IWMSC, 2002)

TOOLS: Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences.	
Tool	**Description**
Network Management Module (NMM)	The NMM models the flow of water in an irrigation water distribution network. It uses the network information obtained from the Input Data Set and demand data produced by the Irrigation Requirements Module, and calculates daily demand and flow rates at all points in the network; conveyance losses; and return flows. These data can be summarized and formatted by NMM to produce Irrigation Base Data files that contain input data for the WRMM. (Source: IWMSC, 2002)
Oldman Watershed Council (OWC) Research and Monitoring Project Directory	This directory summarizes water-related research and monitoring projects underway in the Oldman watershed. It is limited to surface water at this time. The OWC Watershed Science Team hopes the directory will increase awareness about these projects and play an important role in future collaborations. Each project summary has a map that shows the location of the project by sub-basin(s) of the Oldman watershed.
Operational Analysis and Simulation of Integrated Systems (OASIS)	OASIS software is a powerful tool that enables parties with diverse and often conflicting goals (e.g., cities, power facilities, environmentalists, and agriculturalists) to work together to develop operating policies and solutions that mutually satisfy their diverse objectives. It can model virtually any water system in the world, from small and simple to large and complex. OASIS is a major advancement in the modelling of water and hydropower systems, featuring unprecedented ease of use and effectiveness of results. OASIS is being used in most of the SSRB.
Scenario Builder	Scenario Builder is used to create a modified copy of an existing NMM Network Version. It creates different expansion scenarios so that the size and frequency of deficits can be compared to the base case. Three types of scenarios can be created. - Crop change where the irrigated area stays the same but the cropping pattern is changed. - System change where the irrigated area stays the same but the irrigation method used changes. - Area expansion where the cropping pattern and irrigation method used stays the same but the irrigated area is expanded. (Source: IWMSC, 2002)

TOOLS: Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences.	
Tool	**Description**
Soil and Water Assessment Tool (SWAT)	The SWAT is a computationally efficient simulator of hydrology and water quality at various scales. It is a mechanistic time-continuous model that can handle very large watersheds in a data-efficient manner. SWAT was developed to quantify the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land uses, and management conditions over long periods of time. Its main components are hydrology, climate, nutrient cycling, soil temperature, sediment movement, crop growth, agricultural management, and pesticide dynamics. The SWAT is used in the quantification of Alberta's water resources, including all components of the water balance for the whole province at the sub-basin spatial and monthly temporal scale.
Water Resources Management Model (WRMM)	WRMM is a large computer model, developed originally as a planning tool for surface water resources utilization, with a river basin being the fundamental unit of study. Use of the model has evolved in two forms: a) Basin Planning, which uses many years of historical supply and demand data to project future conditions, allowing the assessment of long-term water use alternatives; and b) Operational Planning, which evaluates the short-term (i.e., next few days or weeks) future consequences of different operational strategies. It is used in the most of the SSRB and in the North Saskatchewan River basin.

6.2 Tools in Development

The team was made aware of several tools now being developed, as described in Table. 6.

Table 6: Tools in Development

TOOLS: Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences.	
Tool in Development	**Tool**
River Basin Assessment Tool	The River Basin Assessment Tool (RBAT) is the apportionable flow calculation program. The initial phase of the RBAT program was completed in 2010. During testing a number of desired features that would improve the program were identified, some of which were necessary to allow implementation of the program for apportionable flow calculations. A request for proposals has been issued to upgrade the model.

TOOLS: Mechanisms for gathering, analyzing and presenting information for a range of purposes and audiences.	
Tool in Development	**Tool**
Water Management Model (WMM)	The WMM is similar to WRM-DSS (described below) and OASIS (described in Table 5), but performs well using a multiple time-step optimization (MTO); examples of the WMM's attributes include: - Deficit sharing in time over the entire irrigation season; - Inclusion of diversion licence constraint in MTO runs; - Inclusion of the apportionment constraint in MTO runs; - Proper handling of net evaporation; and - Proper handling of reservoir outflow constraints.
Water Resource Management Model – Decision Support System (WRM-DSS)	ESRD is significantly advancing the WRMM capabilities to develop a new Decision Support System (DSS) as the model "engine" and a new Graphic User Interface simplifying access and usability for users. The enhanced system will continue to support regulatory approvals (e.g., as a detailed system optimizer) and is being expanded to support operational decision making (e.g., working at shorter time steps). The external user access for WRM-DSS is still to be defined and a web interface will be developed in the future.

6.3 Selection of Fit-for-Purpose Tool for this Project

As a prelude to assessing tools, the team identified existing tools that could potentially be used in the SSRB project (Table 5). This is not an exhaustive list, as many tools have been, are being and will be developed that can model water resources and physical hydrological processes in the SSRB. Several good modelling tools, namely CALSIM, HEC-PRM and STELLA, were not applied in the SSRB context as several challenges in using these models for the project were noted:

- CALSIM cannot be used in Multiple Time step Optimization (MTO) mode.
- HEC-PRM uses only monthly time step and also uses a network flow solver that cannot represent non-network constraints such as return flows being modelled as a fraction of consumptive use, or maximum outflow limits being a function of the available storage.
- STELLA is a general purpose simulation environment and not developed specifically for the water resources sector. When used in MTO mode, it may be virtually impossible to use optimization due to the size of equations that need to be compiled manually, and even if it were possible it would require significant skills on the part of the modeller.

Unlike its approach with other foundational blocks, the project team undertook a more detailed assessment of two specific tools as part of Phase 1; these were a) the Water Resource Management Model – Decision Support System (WRM-DSS), and b) Operational Analysis and Simulation of Integrated Systems (OASIS). To facilitate the modelling work in Phases 2 and 3, the project Steering Committee needed to decide by July 2012 which model would be used for the SSRB project. Section 4.2.2 briefly described the process used to select the most appropriate model and Section 4.2.3 described the criteria that would be used to assess the models. The tables in Appendices C and D provide detailed assessments of the models using the criteria that were developed collaboratively with input from various perspectives.

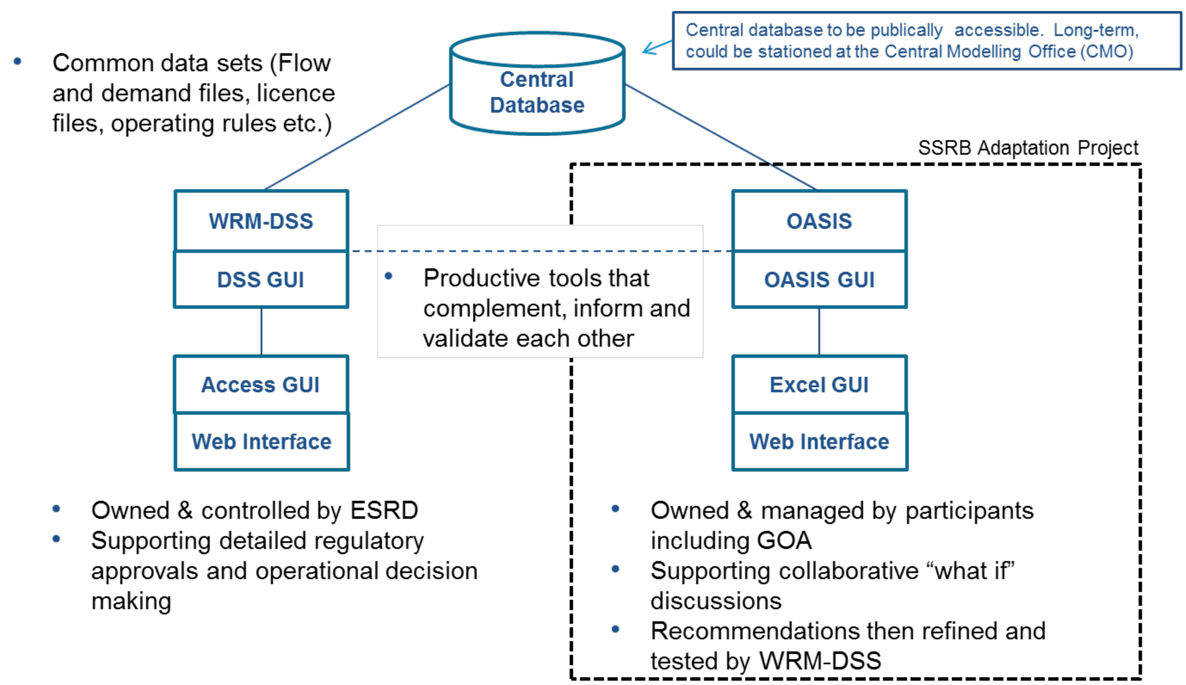
Following this assessment, the Steering Committee agreed that OASIS would be used for the SSRB Adaptation Project modelling. Figure 6 presents the two models, and the reasons for the selection of OASIS are summarized as follows:

- The Bow River Operational Model, which used OASIS, is already built and ready to support adaptation discussions.
- OASIS is familiar, trusted and supported by stakeholders.
- OASIS support resources are already identified and engaged full time.
- OASIS provides the training to expand current capabilities.
- OASIS has the ability to accept a variety of types of data beyond hydrology data (e.g., hourly power prices, climate scenarios)
- OASIS has the component capacity to include the Bow, Highwood, Oldman, South Saskatchewan, and the southern tributaries in the SSRB as one integrated model.

The assessment recognized that each model serves a valid purpose for water management in the SSRB and should be developed in a manner that is complementary, each to the other. Although OASIS would be used for this project, the WRM-DSS and OASIS should be developed in parallel, as they can complement, inform, and validate each other. Collaborative modelling processes will support and strengthen working relationships among all parties, thus building greater capacity and credibility for adaptation and water management decisions in the SSRB.

The project team recommended to the Project Steering Committee that the WRM-DSS and OASIS be developed in parallel as complementary tools, offering distinct benefits, with a common data foundation, for long-term use in the SSRB.

Figure 6: Complementary View of the WRM-DSS and OASIS Models



7 Capabilities and Capacity

Capabilities and capacity are defined for the purpose of this project as “the ability of an individual or entity to meet its objectives and/or to execute a specified course of action (e.g., skills and training programs).” Integrally tied to the capabilities within a basin is the capacity to apply those capabilities. For this report, capacity can be viewed as the availability of the right people, the appropriate time frames, and the necessary budgets to complete the work required for effective river management and adaptation. The scope of the SSRB Adaptation Project does not include a comprehensive audit of the capacity in place in the SSRB. At some point, this quantitative review and identification of potential gaps in the system’s capacity would be a valuable step in building the adaptive resilience of the SSRB.

7.1 Existing Capabilities

Table 7 summarizes the existing capabilities identified by the project team.

Table 7: Existing Capabilities

CAPABILITIES: The ability of an individual or entity to meet its objectives and/or to execute a specified course of action (e.g., skills and training programs).	
Capability	**Description**
Basic Knowledge	Both undergraduate and graduate programs are available in the SSRB for people new to river management. For example, the University of Lethbridge offers a range of Bachelor degree level classes through its Geography faculty: Fluvial Geomorphology, Environmental Resources Management, Weather and Climate, Microclimatology, Hydrology, Irrigation Science, Integrated Watershed Management. Graduate study is supported through the Geography Faculty and the University’s Water Institute for Sustainable Environments.
Fundamental and Applied Science	Alberta has a strong and diverse academic community that supports and advances the many aspects of science related to river management. Researchers and students at the Universities of Lethbridge, Alberta, and Calgary, and at Athabasca University provide a steady flow of knowledge and insight related to the basic science of the environment and river systems as well as the application of this science to the practical challenges of their basins. As examples, Dr. Stewart Rood at the University of Lethbridge has an extensive body of research related to the riparian health of the SSRB river system, and Dr. Cathy Ryan at the University of Calgary has done considerable research related to water quality and dissolved oxygen levels.
Operational Decision Making	Additional capabilities are required to make the operational decisions about when and how water should be moved through the river system. Examples of such capabilities include: knowledge of the river system, the related science and the regulatory framework; experience and perspective on current and future water demands; judgment to balance the trade-offs required in a multi-user system; familiarity with infrastructure needs and limitations. These capabilities already exist in many places in the SSRB including the Government of Alberta, the irrigation districts, the municipalities and the many watershed groups and non-government organizations.

CAPABILITIES: The ability of an individual or entity to meet its objectives and/or to execute a specified course of action (e.g., skills and training programs).	
Capability	**Description**
People Management	Given the wealth of knowledge and experience already resident in the SSRB, an additional capability required for the longer term management and adaptation of the basin will be the ability to develop and transfer knowledge and experience across individuals and generations. This requires sufficient time and investment in formal and informal people management and development, including, for example, mentoring programs, succession planning and knowledge management.
Regulating and Licensing	Water diversions in the SSRB are managed primarily through a system of water licences issued by ESRD under the *Water Act*. A rigorous system and highly capable and trained individuals are required to plan, assign and manage these licences. These individuals can be found in ESRD, the organizations holding the water licences, and in many other groups engaged in the ongoing conversation about water regulations in the basin. In addition to the skills and knowledge of the individuals involved, many related studies and perspectives have been published offering opinions, insight and research.

8 Engagement Processes

In its analysis of foundational blocks, the team noted the importance of engagement processes in finding collaborative solutions. For the purpose of this project, engagement processes are defined as "activities, methods and relationships between established, practices decision makers, river users and/or interested parties."

8.1 Existing Engagement Processes

Alberta has a history of involving people in processes that could affect them or in which they have a stake in the outcome, so the project team was not surprised to find a wide range of engagement processes in this preliminary scan. Nevertheless, this list is not exhaustive and the team recognizes that additional formal and informal engagement processes are likely to be in place involving many individuals and organizations. The results of the initial scan of existing engagement processes are summarized in Table 8.

Table 8: Existing Engagement Processes

ENGAGEMENT PROCESSES: Activities, methods and relationships between established, practices decision makers, river users and/or interested parties.	
Process	**Description**
Alberta Irrigation Projects Association (AIPA)	The mandate of the AIPA is to "increase the level of understanding of irrigation's value to the Province of Alberta and to promote progressive water management practices." AIPA employs a broad spectrum of research and education engagement techniques to achieve their mandate. (Source: http://www.aipa.ca)
Calgary Regional Partnership (CRP)	The CRP is a regional inter-municipal association comprising 14 municipalities. Its mission is to work together to shape and champion a regional vision resulting in a healthy environment, enriched communities, sustainable infrastructure and a prosperous economy. The organization uses various internal and external engagement processes to achieve its mission.
Environmental Non-governmental Organizations (ENGOs)	ENGOs (e.g., the Alberta Wilderness Association) have a broad spectrum of engagement techniques including, but not restricted to, meetings and forums, annual general meetings, activities for the broader public, website questionnaires, and others. Included in the ENGO category are Watershed Stewardship Groups.
ESRD, Irrigation Districts (IDs), and/or other party conference calls and/or meetings	Scheduled and *ad hoc* conference calls and/or meetings between ESRD, Irrigation Districts and/or other parties take place on a regular basis during the spring, summer and fall. Examples include: - Regular conference calls and/or meetings between ESRD, TransAlta, EID, WID and the City of Calgary. - Daily conference calls between ESRD and Mountain View ID. - Daily conference calls between ESRD and Aetna ID. - Daily conference calls between ESRD and Leavitt ID. - Weekly meetings involving ESRD, Taber ID, Raymond ID and St Mary ID.

ENGAGEMENT PROCESSES: Activities, methods and relationships between established, practices decision makers, river users and/or interested parties.	
Process	**Description**
Intrabasin Water Coordinating Committee for the SSRB	As directed by the *Approved Water Management Plan for the SSRB*, an intrabasin committee comprising representatives of the four sub-basins in the SSRB (from the BRBC, OWC, SEAWA and Red Deer River Watershed Alliance) and ESRD was formed. It advises ESRD on how to manage water during periods of water shortage in any or all of the sub-basins, and on how best to meet the requirements of the *Master Agreement on Apportionment*. (Source http://ssrb.environment.alberta.ca/pubs/IWCC_ToR.pdf)
Irrigation Council	The Irrigation Council is a provincial agency that reports to the Minister of Agriculture and Rural Development. Its purpose is to support the Minister by providing relevant advice and regulatory administration for irrigation sustainability. The Council is made up of five public members and two government representatives, one from ESRD and one from ARD.
South Saskatchewan Regional Plan (SSRP)	The SSRP is one of seven regional plans being developed under Alberta's Land-use Framework by the provincial government in consultation with Albertans. Recognizing the value of local and regional perspectives, various engagement techniques, such as the Regional Advisory Council, online workbooks, and others, have been and are being used to gather local and regional input.
SouthGrow	SouthGrow is an economic development alliance of 22 south central Alberta communities working together to "accelerate and enhance quality of life, development and sustainability for the communities of the SouthGrow region of Alberta." The organization has a broad spectrum of internal and external engagement processes related to economic development.
The 2010 Bow River Research Project (BRP)	The BRP was a collaborative project of water stakeholders who hold over 95% of the licensed water on the Bow River. It assessed changes to water storage and flows in the Bow System with the goal of modelling the Bow River and its tributaries for environmental sustainability and improvement to enhance social and economic development opportunities throughout the basin in accordance with the goals of Alberta's *Water for Life* Strategy. Participants included: Alberta Innovates – Energy and Environment Solutions, Alberta WaterSMART, Bow River Basin Council, Bow River Irrigation District, Calgary Regional Partnership, City of Calgary, County of Newell, Ducks Unlimited Canada, Eastern Irrigation District, HydroLogics Inc., Rocky View County, Trout Unlimited Canada, Water and Environmental Hub, Western Irrigation District, Alberta Environment and Sustainable Resource Development, Alberta Agriculture and Rural Development, and Alberta Tourism, Parks and Recreation.
Watershed Planning and Advisory Councils (WPACs)	The four WPACs in the portion of the SSRB covered by this phase of the project (the Bow River Basin Council, Oldman Watershed Council, South East Alberta Watershed Alliance, and Milk River Watershed Council Canada) have a broad spectrum of engagement activities including, but not restricted to, meetings and forums, annual general meetings, and website questionnaires.

8.2 Engagement Processes in Development

Several engagement processes are being developed in the SSRB and the team expects that others may be identified during the course of this project. Table 9 summarizes three processes in development.

Table 9: Engagement Processes in Development

ENGAGEMENT PROCESSES	
Process	**Description**
GoA Water Conversation	ESRD has announced it will be having water conversations with Albertans in the near future. Southern Alberta's current market for buying and selling limited water licences is expected to be part of these discussions.
Montana – Alberta St. Mary and Milk Rivers Water Management Initiative	The focus of this initiative is to explore and evaluate options for improving Alberta's and Montana's access to their respective share of the water of the St. Mary and Milk Rivers and make a joint recommendation on preferred options to provincial and state governments for their consideration and approval.
The 2012-2014 SSRB Adaptation Project	This initiative will build on and integrate existing data, tools, capacity and knowledge of water users and decision makers to improve understanding and explore how to manage for the range of potential impacts of climate variability throughout the SSRB's river systems. The project will re-engage Bow River Project participants and engage new organizations and individuals with an interest in the Bow River Basin to: advance climate adaptation decision making related to water resources, explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options. In addition, it will convene a new group of participants to model the Oldman River basin (Oldman River and Southern Tributaries, including the Belly, St. Mary and Waterton Rivers), and the South Saskatchewan River to the Alberta border. Throughout the model building, participants will discuss work that has been or is being done, and possible next steps in building the capability and capacity for adaptation around river management in the SSRB.

9 Frameworks

For the purpose of this project, frameworks are defined as “the broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the SSRB.” Water, air, land and biodiversity constantly interact with each other, and given these interrelationships, the lists below are not considered to be exhaustive.

9.1 Existing Frameworks

Frameworks have been developed and enacted by various bodies to address water and other issues at the international, national, provincial and regional levels, as noted in Table 10 below.

Table 10: Existing Frameworks

FRAMEWORKS: The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the South Saskatchewan River Basin.	
Policy, Regulatory or Planning System	**Description**
TRANSBOUNDARY	
Master Agreement on Apportionment	• Schedule A of the 1969 *Master Agreement on Apportionment* for the South Saskatchewan River between Alberta and Saskatchewan allows Alberta to “divert, store or consume” from the river system each year, a volume of water equal to one-half of the apportionable flow of the South Saskatchewan River at the Alberta-Saskatchewan boundary. The remaining volume of flow must be allowed to pass downstream into Saskatchewan. • The exception to this general rule is that Alberta is entitled to divert, store or consume a minimum of 2.1 million acre-feet in any year. The effect of this exception is that during years when the volume of natural flow is less than 4.2 million acre-feet (a rare occurrence), Alberta may pass less than one-half of the apportionable flow to Saskatchewan. If at any time during a year Alberta wants to divert, store or consume more than half the apportionable flow, a flow rate of 1,500 cubic feet per second (cfs) must be maintained at the Saskatchewan border, unless the natural flow is less than 3,000 cfs, in which case half the natural flow must be passed. *(There is no policy in Alberta as to the amount of water each sub-basin of the SSRB must contribute to the Saskatchewan apportionment.)*
Boundary Waters Treaty, 1909	This treaty outlines the principles and mechanisms to help resolve disputes and to prevent future ones, primarily those concerning water quantity and water quality along the boundary between Canada and the United States.
FEDERAL LEGISLATION	
Federal Fisheries Act	The *Fisheries Act*, dating back to Confederation, is federal legislation pertaining to the management and protection of Canada’s fisheries resources. It applies to all fishing zones, territorial seas and inland waters of Canada and is binding on federal, provincial and territorial governments.

FRAMEWORKS: The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the South Saskatchewan River Basin.	
Policy, Regulatory or Planning System	**Description**
Navigable Waters Protection Act	The *Navigable Waters Protection Act* ensures the efficient use of Canadian waterways and public access to them.
Migratory Birds Convention Act	This Act ensures the protection of migratory birds, their eggs and their nests.
Indian Act	This Act is a Canadian statute that pertains to registered Indians, their bands, and the system of Indian reserves.
National Defence Act	The *National Defence Act* establishes Non-Public Property as a special class of Crown property to be used for the benefit of serving and former members of the Canadian Forces and their families. In the SSRB, the Department of Defence has some jurisdictional control over environmentally sensitive land just outside of Medicine Hat.
PROVINCIAL LEGISLATION	
Alberta Land Stewardship Act	The *Alberta Land Stewardship Act* is the supporting legislation for the Land-use Framework. It governs the establishment and implementation of regional plans.
Water Act	• The *Water Act* defines both approvals (which govern the construction of works, or the undertaking of an activity within a water body, such as the operation of a water or wastewater treatment plant), and licences (which govern the diversion and use of surface water or groundwater). Licences are given a priority number based on the date that the completed application was received by ESRD. • "First-in-time, first-in-right" (FITFIR) refers to the priority system for allocating water based on the seniority of the licence (that is, older licences have higher priority). FITFIR has been a key principle of granting and administering water allocations in Alberta since 1894 and continues to be the system of water allocation under the *Water Act*. It is active only when there is insufficient water to meet the needs of all licence holders. (Source: Alberta Water Council, 2009; and Legislative History of Water Management in Alberta, http://www.environment.alberta.ca/02265.html)
***Water Act* - Regulations**	The *Water Act* has two Regulations: Water (Ministerial) and Water (Offences and Penalties). Other water quantity regulations include the Bow, Oldman and South Saskatchewan River Basin Water Allocation Order; and the Oldman River Basin Water Allocation Order.

FRAMEWORKS: The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the South Saskatchewan River Basin.	
Policy, Regulatory or Planning System	**Description**
***Water Act* - Codes of Practice**	Alberta has a number of water quantity Codes of Practices including: - Temporary diversion of water for hydrostatic testing - Pipelines and telecommunication lines crossing a water body - Watercourse crossings - Outfall structures on water bodies.
***Water Act* - Policies and Guidelines**	• As defined in Alberta's *Water Act*, a Water Conservation Objective is the amount and quality of water necessary for the protection of a natural water body or its aquatic environment. It may also include water necessary to maintain a rate of flow or water level requirements. From the *Water Act*: *"Water Conservation Objective" means the amount and quality of water established by the Director under Part 2, based on information available to the Director, to be necessary for the protection of a natural water body or its aquatic environment, or any part of it; protection of tourism, recreational, transportation or waste assimilation uses of water; or management of fish or wildlife, and may include water necessary for the rate of flow of water or water level requirements.* • There are Bow River sub-basin objectives, Oldman River sub-basin objectives, Red Deer River sub-basin objectives, and South Saskatchewan River sub-basin objectives.
***Environmental Protection and Enhancement Act* (EPEA)**	The purpose of this Act is to support and promote the protection, enhancement and wise use of the environment. Its individual regulations cover a wide range of activities, from beverage container recycling and pesticide sales, to wastewater and storm drainage. The Act provides for the management of contaminated sites, storage tanks, landfill management practices and enforcement.
EPEA - Regulations	EPEA has a number of water regulations including: - Activities Designation Regulation - Administrative Penalty Regulation - Conservation and Reclamation Regulation - Forest Resources Improvement Regulation - Pesticide (Ministerial) Regulation - Pesticide Sales, Handling, Use and Application Regulation - Substance Release Regulation - Wastewater and Storm Water Drainage (Ministerial) Regulation - Wastewater and Storm Water Drainage Regulation.
EPEA - Codes of Practice	Water Quality Codes of Practice under EPEA include: - Landfills - Pesticides - Release of Hydro Static Test Water - Wastewater Systems Using a Lagoon - Wastewater Systems Consisting Solely of a Wastewater Collection System.

FRAMEWORKS: The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the South Saskatchewan River Basin.	
Policy, Regulatory or Planning System	**Description**
Fisheries (Alberta) Act	This Act ensures the protection of fish habitat. It restricts the marketing of fish. licenses Albertans to fish, and states that fishery guardians can be appointed to administer this Act.
Forest and Prairie Protection Act	This Act establishes regulations for fire control, prevention and education in the forested and prairie land in Alberta.
Forest Reserves Act	The *Forest Reserves Act* provides a process for acquisition of land in order to sustain a forest reserve.
Public Lands Act	This Act deals with the selling and transfer of public land, as well as the management of rangeland and activities permitted on designated land.
Agricultural Operations Practices Act	This Act ensures that the livestock industry in Alberta can grow to meet opportunities presented by local and world markets while maintaining environmentally sustainable practices.
Municipal Government Act	This Act governs the purpose, power and capacity of municipalities.
Health Authorities Act	This Act governs the health regions in Alberta.
Wildlife Act	Under the premise that wildlife is a Crown resource, this Act enables the hunting and trapping of wildlife with the understanding that the remains of dead animals are the property of the Crown unless otherwise specified; it also addresses the conservation of species at risk (endangered and threatened).
Provincial Parks Act and Wilderness Areas, Ecological Reserves, Natural Areas and Heritage Rangelands Act	This Act provides guidance pertaining to activities and restrictions in Provincial Parks, Wildland Provincial Parks and Provincial Recreation Areas. It operates in the public interest of protecting and managing areas in the province to preserve the intrinsic value of these areas while protecting them from impairment or industrial development for future generations. The establishment of heritage rangelands to protect grassland ecology is also within the purview of this Act.
Irrigation Districts Act	This Act establishes the structure, governance, powers and duties for the formation and operation of Irrigation Districts. It pertains to the construction, operation, and maintenance of irrigation works as well as the conveyance and delivery of water, and its diversion and use under the *Water Act*.
PROVINCIAL AND REGIONAL PLANS	
Cabinet Approved Water Management Plan for the South Saskatchewan River Basin	This plan is designed to strike a balance between water consumption and environmental protection while bearing in mind economic and social objectives and ecological requirements. The plan includes provisions for combining innovative, efficient and productive water use and improved management of aquatic ecosystems.

<table>
<tr><th colspan="2">FRAMEWORKS: The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the South Saskatchewan River Basin.</th></tr>
<tr><th>Policy, Regulatory or Planning System</th><th>Description</th></tr>
<tr><td>Alberta’s Land-use Framework</td><td>The Land-use Framework provides a decision-making blueprint for sustaining a growing economy while balancing social and environmental goals. Its three main principles are:
- Healthy economy supported by our land and natural resources;
- Healthy ecosystems and environment; and
- People-friendly communities with recreational and cultural opportunities.</td></tr>
<tr><td>Alberta’s Land-use Framework: South Saskatchewan Regional Advisory Council’s (RAC) Advice to the Government of Alberta</td><td>The RAC was established to advise the Government of Alberta on benefits, choices and tradeoffs to balance economic development with environmental and social considerations. Specifically, the RAC provided advice on water quality and quantity, watershed integrity and headwaters, economic development, conservation and best management practices to reduce the human footprint and fragmentation of those landscapes with high conservation value in the region.</td></tr>
<tr><td>Water for Life: Alberta’s Strategy for Sustainability</td><td>• The Water for Life strategy, renewed in 2008, has the same three goals as the original strategy:
- Safe, secure drinking water;
- Healthy aquatic ecosystems; and
- Reliable, quality water supplies for a sustainable economy.
• These goals will be met through knowledge and research, partnerships, and water conservation.</td></tr>
<tr><td>Water Management Plans for the Upper Highwood and Upper Little Bow Rivers</td><td>These Plans were prepared in two volumes. Volume 1 includes recommendations for water quantity management in the watersheds of the Upper Highwood and Little Bow Rivers. Volume 2 describes how to meet the Water Licence requirements for the Highwood Management Plan (based on the recommendations from the Highwood Management Plan Public Advisory Committee).</td></tr>
<tr><td>Calgary Metropolitan Plan</td><td>The Calgary Metropolitan Plan is a vision for a sustainable region. It includes statements of regional outcomes, integrated strategies, and policies as well as conceptual maps that will help the region achieve its vision over the next 60 to 70 years.</td></tr>
<tr><td colspan="2">AGREEMENTS</td></tr>
<tr><td>GoA / First Nations’ Water Agreements</td><td>To date, the following agreements have been negotiated between the Government of Alberta and First Nations:
- Blood Tribe Water Agreement (Irrigation)
- Siksika Nation Water Agreement</td></tr>
</table>

9.2 Frameworks in Development

The team was made aware of several other frameworks now in development, as described in Table 11.

Table 11: Frameworks in Development

FRAMEWORKS: The broad and complex group of policy, regulatory and planning systems that govern and/or guide river management in the South Saskatchewan River Basin.	
Policy, Regulatory or Planning System in Development	**Description**
GoA and First Nations' Water Allocation Agreements	GoA and the Blood Tribe (Kainai Nation), Piikani Nation, Stoney Tribe and Tsuu T'ina Nation are in the process of negotiating their respective Water Allocation Agreements.
Alberta Urban Municipalities Association (AUMA) Water Policy	The AUMA's members are Alberta's 277 urban municipalities. The organization represents and advocates for the interests of all members to both the provincial and federal governments as well as other provincial and federal organizations. The AUMA's goal is to develop a strong partnership between all three levels of government through a shared vision with long-term planning. Recognizing increasing water demands and decreasing water supply, AUMA is focused on water allocation and has developed a Draft Water Policy. Feedback on this document was to be submitted by June 15, 2012. (See: http://www.auma.ca/live/MuniLink/Communications/Member+Notices?contentId=15021)
WPAC Integrated Watershed Management Plan (IWMP)	The four WPACs in the SSRB (BRBC, OWC, MRWCC and SEAWA) are tasked under the provincial *Water for Life* strategy with completing a State of the Watershed for their sub-basin and then developing an Integrated Watershed Management Plan (IWMP). Each WPAC has completed a State of the Watershed report and they are in various stages of IWMP development.
South Saskatchewan Regional Plan (SSRP)	The SSRP is an initiative of the Government of Alberta, initiated through the Ministry of Environment and Sustainable Resource Development. Polices will be established for the region to ensure three equally important outcomes: healthy economy, healthy ecosystems and environment, and people friendly communities.

10 Initial Observations

During the informal discussions and formal interviews held throughout Phase 1 of this project and as part of the preparations for Phase 3 (Oldman and South Saskatchewan modelling), participants provided comments and observations about limitations and opportunities related to river management in the SSRB. These comments have been captured as “initial observations” and grouped into common themes. Although some are worded in the first person, they are not direct quotes; also, the comments have not been vetted or verified, nor do they necessarily reflect the views of the project team.

10.1 Observations Related to Data and Tools

Demand Data

- Many licence holders draw widely varying volumes of water from the rivers in the SSRB; only a small percentage of these licence holders report their water use data.
- There is a lack of real time demand data from Irrigation Districts, and possibly from other licence holders, in the Oldman and South Saskatchewan basins.
- There is a lack of real time water withdrawal data from private irrigators and municipalities, which presents a challenge for operational, quick turnaround decision making.
- It would be beneficial for river operators to have current year crop data by geography. Changing crop prices result in the agriculture industry changing crops quickly and different crops have different water needs in terms of volume and timing.

Supply Data

- There are limitations in the historical statistical information used to assist in predicting weather.
- We do not appear to have streamflow data sets for the SSRB rivers showing how the systems might be affected by future climate change and variability.
- We currently have limited supply data. The available naturalized flows data set for the SSRB rivers only goes up to 2001. (ESRD is working on updated naturalized streamflow data for the SSRB for 2001-2010; it should be released in late 2012.)

Water Quality Data

- There are insufficient scientific data on pollutant impacts (chemicals, pharmaceuticals, etc.) from treated water returning to the river system.

Data Transparency and Availability

- The following comment is extracted from the 2010 Bow River Project Final Report and still appears to be valid:

  OPPORTUNITY 4: Encourage and enable transparency and open data
  Collaborative and transparent processes can successfully address complex, multi-faceted issues, yielding cost-effective and innovative approaches. The right information is a fundamental element for success, but often this valuable data and other information are held by the provincial government and it is not always easy to determine what is available and how to access it. The Government of Alberta and stakeholders are encouraged to explore ways and means of making their many excellent resources more easily accessible to researchers and others engaged in initiatives similar to the Bow River Project.

Tools

- It could be advantageous to have a tool and the necessary data correlating historic weather forecasts with requested demands and actual withdrawals.
- It could be advantageous to have a tool and the necessary data to forecast demand needs vs. the time of year, based on the historic record.
- There is an opportunity to have ongoing and collaborative discussions about tools and models to share what has been learned, improve understanding of the unique needs of SSRB river management work, and continue to build the spirit of collaboration.
- There appears to be a need for appropriate tools to support collaborative "what if" discussions about river management and operations.

10.2 Observations Related to Capabilities

Multi-stakeholder Balancing of Interests

- It is a challenge to manage environmental interests (longer term) and municipal and irrigation water demands within the context of current river flows and volumes (shorter term).
- Irrigation Districts (IDs) are very adept water managers but typically approach this task from their own perspective rather than from a regional perspective. Irrigation operations function at a local level but water is at least at a catchment or basin level.
- The following comment is extracted from the 2010 Bow River Project Final Report and still appears to be valid:

  OPPORTUNITY 1: Manage the Bow River System in an integrated, adaptive, end-to-end manner, considering all users, interests and values

  At present, many parties manage the Bow River System on a reach-by-reach basis for independent purposes, including power generation, irrigation, and meeting municipal needs. Social and environmental considerations such as fisheries, aquatic and riparian habitat, and recreation are not always factored into management decisions, although they can have important economic spin-offs too. Integrated management would optimize opportunities for licence holders, the environment and other users along the entire system

River Planning

- The focus in the SSRB is on managing for the short term, with little to no long-term planning. Longer term planning occurs only when short-term management needs are met and is affected by differing stakeholder concerns. At present, longer term planning is done on an *ad hoc* basis.
- The Irrigation Branch of GoA was able to support the IDs more in the past and the Branch used to have planning services. They no longer have this capacity.

River Operations

- Alberta Agriculture and Rural Development is heavily focused on water quality right now, which risks creating a gap in attention to supply and demand.
- We have water storage issues in the Oldman-South Saskatchewan basins.
- There is a need for research, development and implementation of irrigation and stock watering strategies.

10.3 Observations Related to Engagement Processes

- There appears to be a heavy reliance on informal and *ad ho*c communications between parties.
- There may be an opportunity for more interaction between the WPACs and IDs.
- There are few mechanisms and little authority for change at the WPAC level.
- Engagement processes related to river management are fragmented and information flow can be limited.
- There is an opportunity to build language bridges between stakeholders to enhance the ability of organizations and the basin to adapt to change.
- It can be difficult to gather all perspectives and engage all parties in river management conversations despite the fact that river management should be open and transparent.
- The following comment is extracted from the 2010 Bow River Project Final Report and still appears to be valid:

  OPPORTUNITY 3: Identify and consolidate the functions required to enable integrated, adaptive management of the Bow River System

  The opportunity to take a new direction would mean re-managing the Bow River as an integrated system from source to confluence, with a new long-term management function. The Government of Alberta could continue to be ultimately accountable for administration of water and watershed management activities, but the success of these efforts in the Bow Basin depends on a shared approach to management involving the key water managers and users of the resource. The potential roles, processes and authorities of a shared management function should be designed by a multi-stakeholder group, comprising at least some of the members of the Bow River Project Research Consortium, and should draw on the many successful examples from other jurisdictions.

10.4 Observations Related to Frameworks

- FITFIR has the potential to create a competitive environment and facilitate the fracturing of relationships. For example, in the past, smaller IDs have called priority on each other late in a low-flow season, resulting in conflict.
- Who is in charge of drains? A problem arises when local flooding causes angst between IDs and municipalities. There is a need for a clearer definition of ownership for physical off-field drainage.
- The focus of minimum flow requirements should be on volumes to support environmental interests being met.

11 The Foundational Blocks in the SSRB Context

Phase 1 of this project has focused on developing a picture of the current state of the many aspects and considerations available and involved in managing the SSRB – what the project is calling the "foundational blocks":

1. Data
2. Tools
3. Capabilities
4. Engagement processes
5. Frameworks.

These five foundational blocks, identified by the project team and described in earlier sections of this report, are connected to each other by many layered, complex relationships.

It would be a fascinating and potentially valuable exercise to map these multi-layered relationships and the foundational blocks within them. This map could illustrate in more detail how the individuals and organizations work to achieve their specific goals in the broader context of the SSRB. Designing, developing, and testing such a complex relationship map is well beyond the mandate and resources of the current study, but may be something for others to consider based on this initial documentation.

Many of the foundational blocks are commonly used by multiple groups, and some are specific to single functions. The people involved in water management have multiple interactions with each other through both formal and informal activities. While this complicated web has had many successes in managing the water in the SSRB, this project and others are working to further develop its efficacy and resiliency.

As a result of what has been learned through Phase 1 activities, this project's participants will be more aware of the foundational blocks already in place for the SSRB. This will ensure that existing resources are leveraged and, perhaps more importantly, not duplicated. This report will enhance the ability to promote collaboration by helping to identify potential common objectives and points of interaction.

Building on the success of the 2010 Bow River Project (BRP), the SSRB project will continue to support and facilitate cross-sector collaboration and sharing of diverse skills, knowledge and experience. The BRP demonstrated that knowledgeable people, working constructively and collaboratively, could address challenging issues by taking a straightforward, evidence-based approach to find opportunities for improvement.

The elements that contributed to the success of the BRP are being emulated in this larger, more complex project, with the ultimate intent of helping those in the wider SSRB to better understand the potential implications of climate variability and change for their region. Based on this information, they will then be better able to develop options and choices to mitigate and adapt as demand for water increases, and as weather patterns and climate change over time. Key strengths of the SSRB project are its focus on openness and transparency, fact- and evidence-based analysis, common goals, and the desire to engage a wide range of participants to ensure their perspectives are part of the discussion.

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Glossary

Unless otherwise noted, the definitions in this glossary were taken or adapted from Alberta Environment's *Approved Water Management Plan for the South Saskatchewan River Basin (Alberta), 2006.*

Alberta Irrigation Projects Association (AIPA) ~ The AIPA participates in research and provides up-to-date information about the status and benefits of irrigation and its associated water management infrastructure to its members, the Government of Alberta, provincial and federal government departments and agencies, local governments, water management stakeholders and the public. (Source: http://www.afrea.ab.ca/aipa)

Aquatic Environment ~ (As defined in Alberta's *Water Act)* The components of the earth related to, living in or located in or on water or the beds or shores of a water body, including but not limited to all organic and inorganic matter, and living organisms and their habitat, including fish habitat, and their interacting natural systems.

First-In-Time, First-In-Right ~ FITFIR refers to the priority system for allocating water based on the seniority of the licence (that is, older licences have higher priority). FITFIR has been a key principle of granting and administering water allocations in Alberta since 1894 and continues to be the system of water allocation under the *Water Act*. It is active only when there is insufficient water to meet the needs of all licence holders. (Alberta Water Council, 2009; and Legislative History of Water Management in Alberta, http://www.environment.alberta.ca/02265.html)

Instream Flow ~ The rate of flow in a river, without reference to its purpose.

Instream Needs / Instream Flow Needs (IFN) ~ This is the scientifically determined amount of water, flow rate, water level, or water quality that is required in a river or other body of water to sustain a healthy aquatic environment or to meet human needs such as recreation, navigation, waste assimilation, or aesthetics.

Instream Objectives ~ Regulated flows that should remain in the river via dam operations or as a restriction on licences. Below dams, Instream Objectives are in place in throughout the SSRB, although some offer only limited protection of the aquatic environment. Instream Objectives have usually been set in response to fish habitat instream needs (the Fish Rule Curve) and/or water quality.

Irrigation District ~ An organization that owns and manages a water delivery system for irrigation for a given region. In Alberta, there are 13 irrigation districts. Some districts convey water for other purposes, such as municipal use and stockwatering.

Natural Flow / Natural Rate of Flow ~ Natural flow is the flow in rivers that would have occurred in the absence of any man-made effects on, or regulation of, flow. For purposes of water management, natural flow is a calculated value based on the recorded flows of contributing rivers; a number of factors concerning the river reaches (e.g., evaporation, channel losses); and water diversions. This is also known as "re-constructed flow" and "naturalized flow."

Return Flow ~ Water that is included in an allocation and is expected to be returned to a water body after use and may be available for reuse, although the water quality characteristics may have changed during use. (Canadian Association of Petroleum Producers, Draft Water CEP Plan)

Riparian Area ~ The area along streams, lakes, and wetlands where water and land interact. These areas support plants and animals, and protect aquatic environments by filtering out sediments and nutrients originating from upland areas.

Riparian Vegetation ~ The vegetation that exists in riparian areas and is supported by the interaction of the water and land.

River Basin ~ An area of land drained by a river and its associated streams or tributaries.

SouthGrow ~ SouthGrow is an economic development alliance of 22 south central Alberta communities committed to working together to achieve prosperity for the region. Representing over 130,000 people, SouthGrow is committed to assisting communities, organizations, businesses and people in the region to further their economic development goals and to maintain the high quality of life. (Source: http://southgrow.com/)

Surface Water ~ Water bodies such as lakes, ponds, wetlands, rivers, and streams. It may also refer to sub-surface water or groundwater with a direct and immediate hydrological connection to surface water (for example, water in a well beside a river).

Water Allocation ~ The amount of water that can be diverted for use, as set out in water licences and registrations issued in accordance with the *Water Act.* (Canadian Association of Petroleum Producers, Draft Water CEP Plan)

Water Diversion (or withdrawal) ~ Describes the amount of water being removed from a surface or groundwater source, either permanently or temporarily. (Canadian Association of Petroleum Producers, Draft Water CEP Plan)

Water Licence ~ A water licence provides the authority for diverting and using surface water or groundwater allocation. The licence identifies the water source, the location of the diversion site, an amount of water to be diverted and used from that source, the priority of the “water right” established by the licence, and the condition under which the diversion and use must take place.

Watershed ~ An area of land that catches precipitation and drains into a body of water, such as a marsh, stream, river or lake.

Watershed Planning and Advisory Councils ~ Independent, non-profit organizations that have been designated by Alberta Environment to assess the condition of their watershed and prepare plans to address watershed issues. They also conduct education and stewardship activities throughout their watershed. WPACs typically include representatives of key stakeholders in the watershed, including provincial, municipal and federal governments, important industrial sectors, conservation groups, and aboriginal communities. They engage watershed residents in their work and seek consensus on solutions to watershed issues. (from http://www.waterforlife.alberta.ca/01261.html)

Appendix A: SSRB Adaptation Project Introduction Memo

South Saskatchewan River Basin Adaptation to Climate Variability Project
May 2012

A new project being launched this spring will harness the energy and creativity of southern Albertans to explore practical options for adapting to climate variability and change. Water is fundamental to community sustainability and growth, and the way water is managed in the South Saskatchewan River Basin (SSRB) will become even more important in the face of changing weather patterns and climate.

In January 2012, the Climate Change Emissions Management Corporation awarded funding for the *SSRB Adaptation to Climate Variability Project*. The funds were provided to Alberta Innovates-Energy Environment Solutions and WaterSMART Solutions Ltd. to support the first stage of this adaptation work.

This initiative will build on and integrate existing data, tools, capacity and knowledge of water users and decision makers to improve understanding and explore how to manage for the range of potential impacts of climate variability throughout the SSRB's river systems. This understanding will support collaborative testing and development of practical and implementable adaptive responses to climate variability, from the local community scale to the provincial scale. Using existing analytical and decision-support tools, the project will engage many people and groups to build:

- a common understanding of feasible and practical mechanisms for adapting to climate variability and change, and
- increased capacity for an informed, collaborative and adaptive approach to water resource management throughout the SSRB. This will enable organizations, communities and individuals to assess their risks in near real-time and determine their most suitable responses to climate variability within the physical realities of SSRB river flows, requirements and infrastructure.

The first stage of the project is divided into four coordinated phase:

Foundational Blocks: Initial Assessment

The first phase of the work is an initial assessment of the data, tools, capabilities, processes and frameworks that already exist and could form elements of the foundational blocks to support integrated water management by water users, decision makers and other interested parties over the long term. This work will identify the core resources for the project, identify critical gaps to be addressed, and ensure existing knowledge, tools, and experiences are leveraged, while avoiding duplication of work already completed or underway.

Bow River Basin: Adaptation and Live Test Year

The second phase will re-engage Bow River Project participants and engage new participants with an interest in the Bow River Basin to: advance climate adaptation decision making related to water resources, explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options. Participants will also document the net benefits of re-managing flows in the Bow River and identify infrastructure options that could assist with adaptation strategies. All of this work will provide support for a 'virtual' river test year, or perhaps an actual test year of modified flow, to better match the three Water for Life goals

Oldman River Basin and South Saskatchewan River Modelling

In the third phase, participants will model the Oldman River Basin (Oldman River and Southern Tributaries, including the Belly, St. Mary and Waterton Rivers), and the South Saskatchewan River to the Alberta border. Users, decision makers and others in the Oldman and South Saskatchewan River (OSSK) Basins will form a river consortium and set principles to guide and inform the model-based work, incorporating an environmental and climate adaptation focus. A comprehensive river system model for the OSSK Basins will be developed. Inputs to the SSRB from the Milk River will be part of this data, but the Milk will not be explicitly modelled. Throughout the model building, participants will discuss work that has been or is being done, and possible next steps in building the capability and capacity for adaptation around river management in the SSRB.

Foundational Blocks: Development

The final phase will see development of new adaptation foundational blocks. This work will be based on the gaps identified in the initial assessment, which may include acquiring, updating, or purchasing useful data and tools for future work to develop adaptation options for integrated river management.

This project will take approximately two years to complete. It should significantly advance climate adaptation resilience in the SSRB, leave a legacy of data, information and tools, and inform similar future work throughout the rest of the SSRB. We hope, with subsequent support, to then expand the work to encourage climate adaptation throughout the entire SSRB.

Project updates and reports can be accessed through the Alberta WaterPortal at: www.albertawater.com

If you have any specific questions regarding this work, please contact AI-EES or WaterSMART Solutions Ltd.

Appendix B: Memo Requesting Feedback on Criteria Used to Assess Tools

Our Project
Using existing analytical and decision-support tools, the project will engage many people and groups to build:

- a common understanding of feasible and practical mechanisms for adapting to climate variability and change, and
- increased capacity for an informed, collaborative and adaptive approach to water resource management throughout the SSRB. This will enable organizations, communities and individuals to assess their risks in near real-time and determine their most suitable responses to climate variability within the physical realities of SSRB river flows, requirements and infrastructure.

Using a modelling tool we will explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options. Participants will also document the net benefits of re-managing flows in the Bow River and identify infrastructure options that could assist with adaptation strategies.

A full model of the Oldman River Basin (Oldman River and Southern Tributaries, including the Belly, St. Mary and Waterton Rivers), and the South Saskatchewan River to the Alberta border will be constructed. An Oldman and South Saskatchewan (OSSK) river consortium will set principles to guide and inform the model-based work with an environmental and climate adaptation focus.

Our Objective
Confirm our selection of the best overall fit-for-purpose tool for SSRB collaborative river modelling.

Our Criteria

- Can it develop a working model of a system relatively quickly?
- Does the model have input data limitations?
- Can it accept user defined inputs e.g. flow patterns?
- Is the model logic transparent and open to users?
- Is it easy to enter, review and alter operating rules?
- Is it able to model all suggested alternatives?
- Can stakeholders participate in the model building and validation?
- Does it have a graphical programming interface?
- Can the model present data on maps or in GIS?
- Can it produce real time results (~30 minutes)?
- Can the model output be presented in a meaningful way to stakeholders?
- Can the model link to other models sequentially (e.g., ACRU, SWAT, AWQ model, ALCES)?
- Can it exchange information with other models while running in parallel?
- Is the model accessible to all participants?
- Are there available resources to run the model?

This is not a thorough technical assessment of the models, but rather an assessment of the models as a fit-for-purpose tool relative to the goals of the SSRB adaptation project.

Appendix C: WRMM Assessment Responses

Note to Reader: Many acronyms are used in the following table; as most of them are technical terms and appear only in this table, they are not included in the list of Acronyms and Abbreviations near the front of this report.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
1	Is one or more experts in using and modifying the model available essentially full-time, or at least on-call, over the next two years who will report to directly to the project leader for performance and payment reviews during that period?	Alberta Environment and Sustainable Resource Development ("the department") staff are not available full time to conduct modelling for this project. However, we are available to provide guidance, should the WRMM model platform be selected exclusively for the project. There are expert consultants in Alberta who have been involved in past projects and who may be interested in undertaking the work. Dependant on the consultant, they will have either good or very extensive experience using the department's model platform and in some cases will have direct past involvement in development of SSRB models.	Yes	Yes	I have been working full-time on WRMM and some water policy analysis based on WRMM over last year. My focus on WRMM for over next two years depends on my next position.
2	Are there four or five qualified model operators who can be made available together for several interactive workshops using the model over the next two years?	The department has three modellers with WRMM experience. There are also three consultants in Alberta with direct past experience with the model.	No	We have three in Global Institute	I believe creating interface for WRMM could have a good potential to create interactive workshops.
3	Is there sufficient expertise available to integrate data from other models in a timely manner and required by the project leader, such as electricity pricing on an hourly basis, operating multiple irrigation districts together, or integrating Global and Regional Circulation Models and land cover models into the determination of water flows?	We rely on the expertise of others to provide such information. WRMM is able to simulate irrigation district operation.	Yes (hourly data cannot be handled by the WRMM)	Yes	Regarding WRMM structure of modelling process, we would be able to feed the model with specific information, if we have created applicable interface. We can communicate with WRMM model, regarding SCF and HBDF files.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
4	Are the expert operators referred to above, experienced in leading collaborative processes using the model results interactively during the course of a day with stakeholders changing assumptions and running them through the model to test "what if" assumptions?	Department staff is experienced in collaborative modelling with stakeholders. However, WRMM has not been used in direct interactive sessions. We have built specialized utilities in past to review model results interactively.	Yes	Yes…We developed few interface environments for that.	I believe the most important task, is to develop user friendly interface for WRMM. This is something that I have tried to build for policy analysis. However, it needs time and efforts.
5	Have these collaborative uses of the model been used in Alberta? Please provide three references who have participated.	We have used collaborative processes in developing the SSRB water management plan and the Highwood Management Plan as well as ongoing negotiations with Montana on apportionment. Some of the Basin Advisory committees that were used in the SSRB plan development eventually evolved into the current Watershed Planning and Advisory Committees. The Highwood Public Advisory Committee headed by Shirley Pickering is still active today in the Sheep basin.	Yes (Alberta Environment, TransAlta, City of Calgary)	Yes Tom Tang, Dave McGee and Kent Berg	We (Global Institute for Water Security, U of S, Saskatoon, SK) conducted a pilot study for the Upper Oldman River Basin, which hasn't finished yet.
6	Is the model "user friendly"? What specific attributes make it user friendly?	The advantage of the WRMM is that the user does not need to write programs to create a basin model. The user puts together a basin from a pre-determined list of components such as Reservoirs, Natural Channels, Diversion Channels, Return Flow Channels, Withdrawal components, Inflows and Mandatory withdrawals, Irrigation Blocks, Inflows and Control Structures. A basin model is assembled much like a tinker toy. The department's original WRMM operates using text file inputs. These files are easy to create and use with some training. Output results are written to text files and optionally to an MS Access™ database. MS Excel™ spreadsheets can be linked to the output database and MS Access™ itself can be used to create custom graphics and any additional post-processing for custom display. The most recent WRMM application that the department is developing is called WRM-DSS which	The WRMM is a work in progress, interface is still under development	Depending who the users is. It is friendly to me.	It is in early stage of idea development. It's not clear if we can invest time and effort on this at the moment.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
		has the option of using traditional text file input identical to WRMM or an independent Graphical User Interface (GUI) that allows users to easily create a model schematic and enter properties of the various objects of the schematic. The GUI replaces text file editing through the use of a database. For WRM-DSS, the schematic, model properties and outputs can be stored in an MS SQL Express database (free download from Microsoft) that can be easily linked into using MS Access. There are some default charts built into the GUI, but any custom charts can be developed using programs that link to the SQL Express database. The GUI is also extensible, which means that new common graphics can be developed and incorporated into it as needed.			
7	Is it easy to enter, review and alter operating rules?	Yes.	Yes	If you write a code to do so, yes…By hand, nightmare	The idea that we have seems practical and makes operating rules easy to manipulate.
8	Have these collaborative processes been used in jurisdictions other than Alberta? Please provide three references who have participated.	WRMM has been used by the province of Saskatchewan. We understand that some contractors have used the model on projects in Indonesia and China.	Yes (Gov. Agencies of Saskatchewan, Indonesia, and China)	Yes, in Saskatchewan Bart Ogema, Howard Wheater	No
9	Is the model freely available for use by trained stakeholders as part of a collaborative modelling project (e.g. can it live in the public domain)?	The WRMM model engine has been freely available for use since before the year 2000. In future after complete development, the WRM-DSS engine will be also be available for free to the public. Part of the development plan for the WRM-DSS GUI will be to create a web application wherein a version of our basin models will be available to the public to use and perform some simple modelling. The DSS engine will be incorporated into the Web application.	Yes	Yes	WRMM is freely available. But we do not have user interface freely available. I believe it is practical to develop one.
10	Is there sufficient training provided for one or more select groups of stakeholders to enable them to take over	The department does not have the resources to provide training to end-users at present.	Yes (this would most likely have to be provided by private consultants)	No	No

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
	operating the model for their own purposes?				
11	Can your model enable the trained stakeholder users to change all the various assumptions and inputs to the model, link it to new data, models and/or the results from these other models?	Yes, with the criterion that this involves a “qualified user” with database skill and programming knowledge to be effective to provide ongoing user support.	Yes	Yes	No
12	Is there a graphical user-interface that is user-friendly and easy to use? What kind of interface does the model use (MS Windows™ based, DOS prompt, GIS based)?	Yes, see previous response above. The GUI under development by the department is windows based with the capability of developing a schematic over a raster image (such as an orthophoto or map with world coordinates) or a GIS based map layer developed in other software such as ESRI map products. The GUI, however, is not intended to be a GIS product.	It is currently under development, not sure how much testing has been completed	We developed a MATLAB-based research interface to play and modify the model	New version of WRMM does.
13	How easy is it to create a new project and how long would it take a person familiar with the model to enter all necessary information for a medium size river basin?	It is easy to create a new project and easy to create inputs. Depending on model size and data availability, a small to medium size model with fewer than 50 components could take a few days or so of full time dedication. However, creating a basin model is not for the casual user because it can be a time consuming chore especially if all entries must be developed from scratch. Large basins such as the SSRB planning schematic can require a model design text file (called the system control file) of over 4500+ lines of text and roughly 20,000 lines x 475 columns of data contained in other time series input files.	Yes, several days	5 seconds by the use of our code for the whole SSRB Alberta.	Depends on experience and ability to work with software
14	Is it able to model a broad range of suggested alternatives (e.g., operating rule)? What does it take to add an alternative operating rule?	For WRMM, changing operating rules is a straight forward exercise, but can also be a complex exercise depending on how many components are being changed and the size of the model. Depending on the intended purpose, it may be necessary to create independent utilities that can quickly and easily modify inputs such as the time series data input.	Yes, a change of relevant penalties or zone bounds in the input data file describes an alternative scenario	Sure…We developed a code for parameters perturbation and modification	It’s possible, which depends on the capabilities of interface

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
15	Can informed stakeholders participate in the model building and validation in a way that makes sense to them (e.g. process that builds confidence/trust in the model)?	Yes. The Highwood planning exercise was an example of stakeholders directing scenario development after they had become knowledgeable about the basin and model outputs. However, the advisory committee was not directly building models in interactive sessions.	Yes	Not really sure what you mean in here	It's possible, which depends on the capabilities of interface
16	Does the model accept flexible river basin network configuration (i.e. can it be applied on any river basin regardless of inter basin transfers, locations of tributaries and diversions)?	Yes, given the correct configuration properties of the basin.	Yes	Yes	I am not sure
17	Can the model output be presented in a graphical or other way that is meaningful to stakeholders and the general public?	Yes	Yes	We developed a code for that	It's possible, which depends on the capabilities of interface
18	Can it produce real time results when multiple operating rules are changed (less than 30 minutes)?	This depends on the basin schematic. WRMM can handle a large SSRB schematic (about 700 components containing 74 years of data on a 1 week time step) within 5 minutes, WRM-DSS will take within 30 minutes because of a change in the way it solves a model schematic, but should provide a better optimal solution than WRMM.	Same answer as for OASIS	Of course…Whole SSRB weekly run takes less than a minute with 73 years of simulations	It's possible, regarding fast running time of WRMM
19	What is the range of time steps that can be addressed by the model (i.e. daily, weekly, monthly, any multiple of one day, any multiple of hours)?	All of the listed time steps can be developed. However, the functionality of WRMM is limited when using time steps of less than a week. Because WRMM is intended as a planning model, for running 52 weeks a year, it has a maximum of 52 time steps per cycle. This is sufficient to support real time operational needs for a seven to thirteen day period in 6 hour increments. WRM-DSS is being developed as an operational tool and will eliminate the WRMM limitation of 52 time steps in a cycle.	Any multiple of one day Maximum number of time steps in a year is 52, so daily model is limited to 7 weeks horizons	I worked with weekly and monthly	If an interface developed for WRMM to manipulate the operational policies, then all capabilities of WRMM could be anticipated for interface as well.
20	Does the model have input data limitations? Can it accept a variety of types of data (e.g.	WRMM is a specific water allocation tool and is not intended as a surrogate for other specialized models designed specifically for groundwater, economics or	There are limits to the number of all components (500) and limits to each	Not in the model itself but you can plug that to WRMM using an	Depending the input data that WRMM model accepts, there should be

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
	not just hydrology, but also economic drivers, development, recreation, water quality, groundwater, water policies, operational rules)?	water quality. This is not to say that output of a water allocation run cannot be put into other models for analysis. In the SSRB and Highwood Planning exercises, output from WRMM was provided to other specialists to run in their models such as water quality and fish habitat models to get an understanding of other impacts.	type of component listed in the User Manual. No water quality data. Not sure what is meant by "development" data?	interface code.	specific data format for the model.
21	Can it accept user defined inputs (e.g. flow or demand patterns)?	Yes.	Yes	Yes	It's possible, which depends on the capabilities of interface
22	Is the model logic (e.g. an operating rule) transparent and open to users?	The user creates operating rules (referred to as policies in WRMM) for the various components according to easy to understand set of rules. These, by definition are transparent to the users. The internal program mechanism of the WRMM executable is isolated from the user. WRMM is a compiled executable program that the user runs. The executable reads the user input files (either text files or database tables) and creates a mathematical formulation of the river basin in terms of linear equations that are "solved" and the result is saved in text output or a database for the user to then interpret with charts and tables. The component objects of WRMM are not programmable beyond the current source code of the WRMM engine. We have found that effective pre-processing of data and creative schematic creation can cover most situations we have had to model in past. If we find there is a need for extending WRMM capabilities, being owners of the source code we can change the internal methods of the program.	Yes	Yes	In some degree. It depends on the experience and knowledge of the user
23	Can the model handle the existing FITFIR licensing system and possible changes in Alberta's water allocation system?	Yes.	Yes	Yes	I am not sure

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
24	Does the model have comprehensive documentation (i.e. user manuals, sample runs) which is regularly maintained? What kind of user support is available to the model users?	Yes. The department is not a software retailer and we do not provide end-user support.	Yes. The user support is limited from ESRD, but it can be obtained from the private sector	Yes	----
25	Can the model link to other models sequentially (e.g. ACRU, SWAT, AWQ model, ALCES)?	The nature of using databases for WRM-DSS and WRMM output is intended to accommodate linking to other models. This would require creation of utilities to post process our model result into the appropriate data files in specific formats to input to other models. These utilities have not yet been developed by the department, but a database/computer programmer would be capable of creating such utilities.	Yes	Needs interface	Programming would provide these abilities.
26	What is the cost of acquiring the model and is there an annual fee related to technical support and maintenance?	The WRMM engine is free. When development is complete, WRM-DSS will be free except that because it uses a commercial solver developed by an independent company, users are require to purchase a licence for the solver software. The desktop version of the GUI is not currently available to outside users, but will a web version will be part of future web site development.	No cost	At the moment nothing. Soon $6,000 or so for LINDO licence.	---
27	How does the model deal with situations where travel times through the modelled region are longer than the simulated time step length? Does the model resort to (a) hydrologic channel routing; (b) time lag of demands and runoff; or, (c) other solutions, and if so, please explain?	WRMM has a time-lag function, but we do not use it. The WRM-DSS engine uses channel routing.	The model can read HBDF input data file only as weekly or monthly data. So planning runs should have time step longer than the travel time. Daily runs for up to 52 days with SSARR or Muskingum routing are possible, but will suffer from the same problems indicated for OASIS, but MTO is not an available option in combination with channel routing within the WRMM.	This is a major limitation	WRMM has this capability.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
28	Can the model include hydrologic channel routing routines (i.e., Muskingum, SSARR) in the solution process, and if so, how does it deal with the fact that the routing coefficients are a function of flow when the flow varies between the dry and wet flow seasons?	Both Muskingum and SSARR routing options are available in WRM-DSS.	Model is limited to 52 time steps in total when used with channel routing, and the routing coefficients must be constant	On paper yes, in reality I don't really know.	New version of WRMM might has this functionality.
29	Is there a standard set of tools that come as part of the model to help analyze the output and interpret the model results for each scenario?	There is a results viewer available. We use a contractor to modify the results viewer as appropriate. As mentioned, custom post processing and charts can also be created in MS Access and Excel to handle other specialized charting.	Yes	Never use them. I just use the WRMM.exe to find the model simulation.	Depends on the capabilities of interface if developed.
30	Can the model function as an operation and planning decision support tool (real-time and short/long term)?	WRM-DSS is being developed for these functions specifically.	Yes, although the power of optimization with channel routing is restricted (see the paper in WRR by N. Ilich)	Yes	Programming and linkage between WRMM model and user interface would provide a real time decision support system for any purposes.
31	What is the upper limit on the number of components in the model? If there is no upper limit, what is the known maximum of components that had been used in a single model application?	WRMM has approximately an 800 component limitation. WRM-DSS does not have a component limitation, except based on computer memory capacity. Theoretically WRM-DSS should be able to handle as many components as the user cares to build, but time of processing will be much greater as the schematic gets big (beyond 1000 components).	Total number of components of all kinds is limited to 500	500 at the moment.	Optimization result would be more accurate when you use smaller configuration with less components. However, WRMM has the ability of modelling large number of components.
32	Is the programming language common (e.g. Fortran, VB, C++)? Is it easy to use or learn?	The WRMM engine is built in C++ exclusively. WRM-DSS contains both C++ and C#.net modules. Neither engine is programmable by the user, but the department owns the source code and uses external contractors to modify the code if necessary to add features, or fix problems. No programming language is required to build a river	WRM-DSS is written in C++, there is no need to know its source code to run it	It depend who wants to use it. I guess WRMM is fantastic in research work but I don't really know how the general public can communicate with that	I have used VB for a pilot user interface. Each programming language has its own limitation and advantage.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
		basin model. In text file mode, the properties of river basin components are entered using specific syntax rules. The GUI is built in C#.net. The GUI is not programmable by the user. The department owns the source code of this application. The GUI replaces text files for data entry.			
33	What kind of optimization solver does the model use (Linear Programming, Mixed Integer programming, Non-linear programming), and what is the name of the solver vendor?	WRMM has an internal solver called the OKA (Out-Of-Kilter Algorithm) WRM-DSS uses Lindo Systems mixed integer barrier solver version 6.	Lindo Systems for LP and Mixed Integer Problems	LP	WRMM use linear programming, however new version of WRMM might has the capability of non-linear programming.
34	Can the model use penalties (i.e. cost factors, or weights) to represent priority of allocation? Is there a module that is part of the model that can help determine the best set of penalties that represent a particular allocation priority policy?	Yes in answer to use of penalties. There is no built-in facility to specify an optimal penalty system based on allocation priority.	Yes. No such module is available.	Yes	Yes. In the WRMM there is no module to determine the best set of the penalties. However, I have conducted a pilot study to show how we can adjust penalties for a particular policy.
35	Can the model include apportionment agreement constraint, expressed by a requirement to pass certain minimum flow volume over a designated period, typically calculated as a percentage (50%) of the natural flow series available for that location? How is this constraint modelled in a single time step and multiple time step solution framework?	Yes, Apportionment channels are included as a component. Two requirements are satisfied simultaneously: minimum volume a downstream jurisdiction is entitled to have over a specified period of time and the instantaneous minimum flow entitlement of the downstream jurisdiction. The model attempts to meet the annual target, but must make decisions in single time steps. Therefore an annual apportionment requirement might not always be met. The single time-step solution is in place for both WRMM and WRM-DSS versions. The multiple time-step solution is under development in WRM-DSS and requires testing.	Yes, only for STO. This feature is not yet available in the MTO solution mode	Yes.	Yes, WRMM has this ability. I refer you to the recent paper by Ilich (2011) in Journal of Hydroinformatics for detail discussion on these two different time step modelling.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
36	Can a model include diversion licence constraints, where the flow in a diversion canal can be limited by the maximum licensed volume over a certain operating period (such as the irrigation season)? How is this constraint modeled in a single time step solution framework, and how is it modelled in a multiple time step solution framework?	Yes. Diversion channels can be limited to a volume per cycle or be unconstrained in volume. A maximum instantaneous flow can be defined. In single time step operation, the model tracks volume diverted and cuts off the channel before the specified volume limit is exceeded. The multiple time-step option in WRM-DSS is under development. Early development versions of WRM-DSS specify the entire volume licence limit as a side constraint to the model. The model decides how much to divert in each time step, taking into account the maximum instantaneous flow limit and the annual volume limit.	Yes, only for STO. This feature is not yet available in the MTO solution mode	Yes	Yes, WRMM can handle this. Ilich (2011) would be helpful again.
37	Can the model provide solutions with equal relative deficits between two or more selected water users, such that they share the same deficits over one or more simulated time steps?	This option is available in WRM-DSS for components of similar type, and requires test verification.	Yes, only for STO solution mode, not available in the MTO mode	No	I am not sure
38	What are the available options for modelling canal losses (i.e. as a fixed loss, a linear function of flow in the return channel, or a non-linear function of flow)?	Canal loss parameters can be specified for a diversion canal. The user specifies the first and last time intervals of canal loss. WRMM allows you to specify only a fixed canal loss, while in WRM-DSS, the fixed canal loss and a proportion of canal flow can be specified.	Yes, fixed loss or linear function of flow	Nothing in particular but it can be modelled as a fixed loss easily	WRMM model can be considered values for channel losses
39	Can the upper limit on flow in any channel be represented as a function of time, such that a gradual opening and closing of a large diversion structure is modelled as intended?	Yes.	Yes	No	Yes, it is defined as a function of time.
40	Is the model capable of representing flow to flow relationship using a non-linear curve that shows maximum flow in a lateral diversion canal	Yes.	Yes	No	WRMM can model flow through weir as well, especially for reservoir operation.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
	as a function of the incoming flow into the weir where the diversion channel originates? (e.g., the BRID diversion structure).				
41	Can the model connect to external databases?	External linkages to the model database can be created through utilities external to the model platform.	Yes	Not in a raw form. It needs interface.	This is possible, regarding two text files (SCF and HSBF) that model use for inputs and optional policies. However, programming is required for building this linkage.
42	Does the model use any database to store information related to various modelling scenarios? If yes, which database is used?	Yes. WRM-DSS uses Microsoft's Sql server. The free express version can be downloaded from Microsoft for use in on a pc. Both model inputs and results are stored in the database. In WRMM, outputs are stored in one MS Access .mdb file. The user requires Microsoft Access to read the file.	Currently works only with MS Access DB	We link the WRMM to MATLAB and use MATLAB .MAT files as our data base	WRMM does store all information for one specific run at the time. Therefore, an interface is required for this purpose.
43	How does the model handle net evaporation (i.e. is the net evaporation applied at the beginning or at the end of the time step; is it half at the beginning and half at the end; or is it ignored altogether)?	Under WRMM, half of the net evaporation (evaporation minus precipitation) is subtracted from the water surface elevation of the reservoir at the start of each calculation time interval, and the other half at the end. In WRM-DSS, evaporation is determined dynamically while calculating the mass balance of a reservoir in a specific time-step. WRMM requires reservoir data to be entered in storage vs. elevation and WRM-DSS has the additional option of specifying area vs. elevation.	Yes, half at the beginning and half at the end of the time step	HALF-HALF	Net evaporation is an input value to the model. The time interval is like other inputs and varies as daily or weekly.
44	Can a built model be expanded and added to?	Yes.	Yes	Yes	Depends on the structure of modules. As far as I know there is a potential to do that for WRMM.
45	Is the model capable of solving more than one time step	WRMM does not have multiple time step capability. This feature is under development in WRM-DSS.	Yes, but only steady state (without channel routing),	No	Yes, WRMM does that.

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	WRMM- ESRD	WRMM- Industry perspective	WRMM- Academic perspective	WRMM- Academic perspective
	simultaneously, i.e. is it able to provide optimal solutions both in space and in time over the entire hydrologic year (or years)?		and without some constraints such as diversion licence limit, equal deficits and apportionment		
46	Is the model coupled with any GIS software and if so, which one? If not, can it?	The model is not directly coupled to GIS software. The GUI has provision to use a GIS map underlay. Modifications to the database structure could allow coupling to GIS software with addition of lat and long coordinates of components if needed.	No	No	I think new version of WRMM has this capability.
47	Can it do any statistical analysis or Monte Carlo simulation?	No. Any statistical analysis is done as a post process by external utilities. The model engines do not have a built-in Monte-Carlo simulation routine. This would be a pre-process to create a time series of natural flow inputs to the model.	No	Again, you can plug it into a MCS scheme	No, an interface is needed.
48	Can it exchange information with other models while running in parallel?	No. Note that other models such as some water quality models can take a long time to run (minimum of one day up to a week of computer time).	No	Yes, you need interface	No, but an interface can facilitate this task.
49	Is the operational model based on the use of optimization within the Multiple Time step Optimization (MTO) solution framework with hydrologic channel routing, or is it an inferential statistical model based on one of the machine learning algorithms?	The operational version of the model (WRM-DSS) is based on simultaneous optimization of all components in one pass, including channel routing. The MTO version is under development. There are no machine learning algorithms incorporated into the engine.	The model cannot be used properly as an operational tool yet since MTO runs cannot be conducted with channel routing		WRMM is an optimization model with in the multiple time step framework.
50	Could the model use real time data in real time, assuming necessary real time data come from hydrometric and meteorological forecasts?	Yes (WRM-DSS), provided the appropriate utilities are in place to populate the model input database with real-time data. Direct connections to the department's WISKI system are under investigation.	Yes, but the runs could be conducted only on a steady state basis. If a daily model run is used with routing, reservoir outflow must be fixed manually in STO mode, MTO mode is not available	Yes	There is a potential for this. However, an interface is needed to feed WRMM model on real time bases and run and evaluate the results.

Appendix D:OASIS Assessment Responses

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	OASIS - Modelling Practitioner Perspective	OASIS – Industry Perspective
1	Is one or more experts in using and modifying the model available essentially full-time, or at least on-call, over the next two years who will report to directly to the project leader for performance and payment reviews during that period?	Yes – A. Michael Sheer, and to a lesser extent, Daniel Sheer	Yes
2	Are there four or five qualified model operators who can be made available together for several interactive workshops using the model over the next two years?	A. Michael Sheer, Daniel Sheer, Sam Lebherz, Dean Randall, Mike Nemeth	Yes
3	Is there sufficient expertise available to integrate data from other models in a timely manner and required by the project leader, such as electricity pricing on an hourly basis, operating multiple irrigation districts together, or integrating Global and Regional Circulation Models and land cover models into the determination of water flows?	Already performed in BROM, can/will be performed again. Land Cover/Circulation will have to discuss running in parallel vs. sequentially	Yes
4	Are the expert operators referred to above, experienced in leading collaborative processes using the model results interactively during the course of a day with stakeholders changing assumptions and running them through the model to test "what if" assumptions?	Yes – as with the BRP	Yes
5	Have these collaborative uses of the model been used in Alberta? Please provide three references who have participated.	Yes – the BRP Ref: Megan Van Ham, Earl Wilson, Jim Webber	Yes
6	Is the model "user friendly"? What specific attributes make it user friendly?	Yes. Fast run time (<15 min) English-like code Automated performance measure generation Ability to quickly generate new performance measures on the fly Quickly modifiable in a group setting GUI interface	Yes/No (OCL language is not user friendly, it was built for experts)
7	Is it easy to enter, review and alter operating rules?	Yes, although the more complex the rule, the longer it takes to implement. Simple rules can be implemented without any code at all.	Yes
8	Have these collaborative processes been used in jurisdictions other than Alberta? Please provide three references who have participated.	Bow River Project (BRP) – Megan Van Ham Kissimmee Basin Hydrologic Assessment, Modeling,	Yes

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	OASIS - Modelling Practitioner Perspective	OASIS – Industry Perspective
		and Operations Planning Study (KBMOS) – Mark Abbott, Earth Tech, 301 Clematis Street, Suite 300, West Palm Beach, FL 33401 (561)-671-4335, mark.abbot@aecom.com OASIS Model for the Susquehanna River Basin Commission – Drew Dehoff, adehoff@srbc.net, 717-238-0423 x221	
9	Is the model freely available for use by trained stakeholders as part of a collaborative modelling project (e.g. can it live in the public domain)?	That's up to the client. HydroLogics has done so in the past, and have no objections to doing so in the future. The Delaware River Model, for example, is publicly accessible by anyone.	I don't think so.
10	Is there sufficient training provided for one or more select groups of stakeholders to enable them to take over operating the model for their own purposes?	HydroLogics is happy to do so for others, and Mike Nemeth already has full training. Some stakeholders, i.e., Stu Rood, have already begun tinkering with OASIS models.	Yes
11	Can your model enable the trained stakeholder users to change all the various assumptions and inputs to the model, link it to new data, models and/or the results from these other models?	Absolutely, and easily for most things - though it depends on what's being changed.	Yes
12	Is there a graphical user-interface that is user-friendly and easy to use? What kind of interface does the model use (windows based, dos prompt, GIS based)?	Yes, OASIS uses a Windows based GUI	Yes
13	How easy is it to create a new project and how long would it take a person familiar with the model to enter all necessary information for a medium size river basin?	With simple operating rules and all data available, a week or less including QA/QC.	Yes
14	Is it able to model a broad range of suggested alternatives (e.g. operating rule)? What does it take to add an alternative operating rule?	Yes. Simple alternative operations; e.g., A new rule curve can be implemented in under 15 minutes. More complex operating rules, such as the BRP's Water Bank, can take many days.	Yes
15	Can informed stakeholders participate in the model building and validation in a way that makes sense to them (e.g. process that builds confidence/trust in the model)?	Yes, HydroLogics builds each model with active involvement from stakeholders. They help out with everything and ensure the model is working correctly every step of the way. Their participation is the only way to ensure a fully functioning and reasonably accurate model.	Yes
16	Does the model accept flexible river basin network configuration (i.e. can it be applied on any river basin	Yes. These can all be introduced and coded as necessary with applicable governing rules.	Yes

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	OASIS - Modelling Practitioner Perspective	OASIS – Industry Perspective
	regardless of inter basin transfers, locations of tributaries and diversions)?		
17	Can the model output be presented in a graphical or other way that is meaningful to stakeholders and the general public?	Yes, the model itself produces most simple graphs and our plotmaker tool automates graph production in Excel.	Yes
18	Can it produce real time results when multiple operating rules are changed (less than 30 minutes)?	Yes, OASIS models typically have a run-time of <15 minutes from "Run to Results." It also has "gaming mode" in which participants can make live decisions on a time-step to time-step basis overriding programmed operations.	Depends on problem size, constraints, time step, nature of the run (STO / MTO)
19	What is the range of time steps that can be addressed by the model (i.e. daily, weekly, monthly, any multiple of one day, any multiple of hours)?	Timestep can be anything as dictated by the data available and the client (e.g., we could run 23.7 second timesteps if the data was there).	Daily, weekly, monthly
20	Does the model have input data limitations? Can it accept a variety of types of data (e.g. not just hydrology, but also economic drivers, development, recreation, water quality, groundwater, water policies, operational rules)?	The model can accept anything as an input, but how those inputs are generated may need to be external. OASIS does not do economics modelling, for example, though it could use output from one to inform internal operating rules.	Not sure on the max. number of components that OASIS can handle
21	Can it accept user defined inputs (e.g. flow or demand patterns)?	Yes. The GUI has locations for this data to make input especially simple for users.	Yes
22	Is the model logic (e.g. an operating rule) transparent and open to users?	Yes, users have access to every layer of the model.	Yes
23	Can the model handle the existing FITFIR licensing system and possible changes in Alberta's water allocation system?	Yes, as has been proven in the BRP.	Yes
24	Does the model have comprehensive documentation (i.e. user manuals, sample runs) which is regularly maintained? What kind of user support is available to the model users?	Model documentation, user manual, and sample runs are available. Course materials for learning to use OASIS are also freely available on the web.	Yes
25	Can the model link to other models sequentially (e.g. ACRU, SWAT, AWQ model, ALCES)?	Yes. Depending on the external model, however, this has varying degrees of difficulty.	Yes
26	What is the cost of acquiring the model and is there an annual fee related to technical support and maintenance?	Traditionally, HydroLogics provides the model for "free" and charges for services in building the model (excluding a $1500 licence charge for the solver). We attempt to train our clients in the model's use so that they are self-sufficient after the project. We will continue to provide support afterwards if requested, but charge for that time as needed or negotiated.	Not sure
27	How does the model deal with situations where travel times through the modelled region are longer than the simulated time step length? Does the model resort to (a) hydrologic	OASIS uses Muskingum routing to operate lag reservoirs that fill and release according to the routing coefficients.	Hydrologic channel routing (Muskingum). This however may restrict the use of the model if used in STO (see the relevant publication in

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	OASIS - Modelling Practitioner Perspective	OASIS – Industry Perspective
	channel routing; (b) time lag of demands and runoff; or, (c) other solutions, and if so, please explain?		Water Resources Research by N. Ilich). It may be possible to avoid this problem with OASIS if MTO is used, although it could be complicated.
28	Can the model include hydrologic channel routing routines (i.e. Muskingum, SSARR) in the solution process, and if so, how does it deal with the fact that the routing coefficients are a function of flow when the flow varies between the dry and wet flow seasons?	It is possible to adjust Muskingum routing coefficients to account for seasonality, but at current BROM uses a single coefficient for the whole year. This has been sufficient for most purposes so far.	OASIS uses LP solver which requires that the routing coefficients be constant. It is not clear if unique channel routing can be read for each time step, but even if so that would require iterative runs.
29	Is there a standard set of tools that come as part of the model to help analyze the output and interpret the model results for each scenario?	Yes, One-Var can generate most simple outputs (flows, storages, etc.) and PlotMaker (an MS Excel™ based tool) which can generate other performance measures developed by the stakeholders.	Yes
30	Can the model function as an operation and planning decision support tool (real-time and short/long term)?	The model currently operates as a long term decision support tool. OASIS is in the process of being converted into a real-time decision support tool in another watershed, but it is a significant undertaking.	Yes, although the power of optimization with channel routing is restricted (see the paper in WRR by N. Ilich)
31	What is the upper limit on the number of components in the model? If there is no upper limit, what is the known maximum of components that had been used in a single model application?	At the moment the limit is 999 nodes, and a similar number of arcs. This is being upgraded in the (unreleased) newest version of OASIS. The largest model to date was the SSRB Model, which contained approximately 280 nodes.	Not sure
32	Is the programming language common (e.g. Fortran, VB, C++)? Is it easy to use or learn?	OASIS uses OCL, a custom language that is English-like and comparatively easier to learn that C++ or Fortran.	Not sure
33	What kind of optimization solver does the model use (Linear Programming, Mixed Integer programming, Non-linear programming), and what is the name of the solver vendor?	OASIS uses the XA liner programming solver developed and supported by Sunset Software Technology, Inc.	XA Solver for LP and Mixed Integer Problems
34	Can the model use penalties (i.e. cost factors, or weights) to represent priority of allocation? Is there a module that is part of the model that can help determine the best set of penalties that represent a particular allocation priority policy?	The model uses penalties for allocation priority directly. At the moment there is no optimization on these penalties, although HydroLogics has begun experimenting with genetic algorithms that could do so in the future.	Yes. No such module is available
35	Can the model include apportionment agreement constraint, expressed by a requirement to pass certain minimum flow volume over a designated period, typically calculated as a percentage (50%) of the natural flow series available for that location? How is this constraint modelled in a single time step and multiple time step solution framework?	The model can, and does in the BROM, through the use of perfect knowledge to ensure compliance. In other words, the model knows in advance the total flow volume that will arrive for each year, and ensures the 50% criterion is met.	Yes, for both STO and MTO by using the OCL language to write the constraints
36	Can a model include diversion licence constraints, where the flow in a diversion canal can be limited by the maximum	Yes, and this has been implemented for the IDs in BROM. The irrigation districts are given a maximum	Yes, for both STO and MTO by using the OCL language to write the constraints

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	OASIS - Modelling Practitioner Perspective	OASIS – Industry Perspective
	licensed volume over a certain operating period (such as the irrigation season)? How is this constraint modeled in a single time step solution framework, and how is it modelled in a multiple time step solution framework?	diversion for the year, and each day's diversions are deducted from that total until it reaches zero. At that point no further diversions are allowed. This is reset each year.	
37	Can the model provide solutions with equal relative deficits between two or more selected water users, such that they share the same deficits over one or more simulated time steps?	OASIS uses a minmax constraint which keeps any two variables as close as possible within a given timestep.	Yes, for both STO and MTO by using the OCL language to write the constraints (provided that users know how to set this up)
38	What are the available options for modelling canal losses (i.e. as a fixed loss, a linear function of flow in the return channel, or a non-linear function of flow)?	All are available, although non-linear loss will likely (though not necessarily) be converted into a piece-wise linear function.	Yes, fixed loss or linear function of flow, OCL should be used to define the function
39	Can the upper limit on flow in any channel be represented as a function of time, such that a gradual opening and closing of a large diversion structure is modelled as intended?	Absolutely, though it will be limited by the timestep the model is run at.	Yes
40	Is the model capable of representing flow to flow relationship using a non-linear curve that shows maximum flow in a lateral diversion canal as a function of the incoming flow into the weir where the diversion channel originates? (e.g., the BRID diversion structure).	Yes, and this is done using piecewise-linearization for the BRID Headworks in BROM	Yes, using the OCL language
41	Can the model connect to external databases?	Yes, though BROM is not set up to do so currently.	Yes
42	Does the model use any database to store information related to various modelling scenarios? If yes, which database is used?	Yes, OASIS uses HEC-DSSVue (*.dss, free from the US Army Corps of Engineers) to store output and input data and Microsoft access files (*.mdb, free mdb readers are available) to store model/GUI information.	HEC Hydrologic DB
43	How does the model handle net evaporation (i.e. is the net evaporation applied at the beginning or at the end of the time step; is it half at the beginning and half at the end; or is it ignored altogether)?	Evaporation is read in length units (i.e. mm or in) and evaluated based on the Surface area of a lake calculated through SAE tables at the end of a simulated timestep.	Yes, beginning of the time step or otherwise as defined using the OCL language
44	Can a built model be expanded and added to?	Yes.	Yes
45	Is the model capable of solving more than one time step simultaneously, i.e. is it able to provide optimal solutions both in space and in time over the entire hydrologic year (or years)?	No. This model solves one timestep at a time. Genetic Algorithms allow for some optimization across timesteps, but these are not presently designed for BROM.	Yes
46	Is the model coupled with any GIS software and if so, which one? If not, can it?	No, although HydroLogics is experimenting with coupling on another project for output visualization.	No
47	Can it do any statistical analysis or Monte Carlo simulation?	OASIS itself does not perform statistical analyses – although the software can run in what is called "position analysis" mode which allows for probability analyses.	Not sure

	Fit-For-Purpose Modelling Criteria for the SSRB Adaptation Project	OASIS - Modelling Practitioner Perspective	OASIS – Industry Perspective
48	Can it exchange information with other models while running in parallel?	Yes, and this has been done in the past.	Not sure
49	Is the operational model based on the use of optimization within the Multiple Time step Optimization (MTO) solution framework with hydrologic channel routing, or is it an inferential statistical model based on one of the machine learning algorithms?	Channel routing (lagging an attenuating flows) is typically done using the Muskingum method of hydrologic channel routing, but other methods can be used as well. The only requirement is that mass balance be maintained.	OASIS could use MTO with channel routing over short periods assuming no big changes of flow over the time horizon and proper MTO setup
50	Could the model use real time data in real time, assuming necessary real time data come from hydrometric and meteorological forecasts?	It is possible, but requires substantial modification. This is necessary for the real-time operations tool we are developing for another client.	Yes, assuming MTO is properly set up, or reservoir outflow is manually fixed if STO is used (otherwise a problem will occur as documented in the WRR paper by N. Ilich)