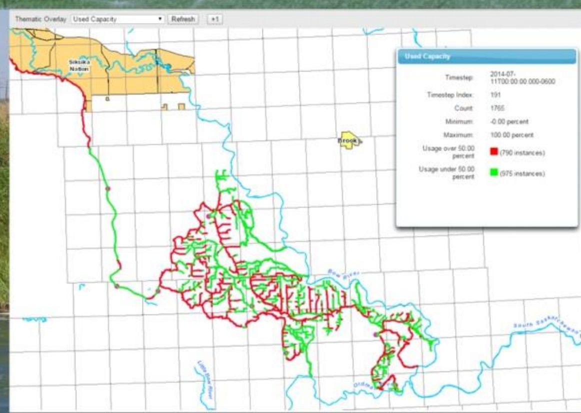

Final Report, Agreement Number AI-EES 2072

Redevelopment and Enhancement of the Irrigation Demand Model as a Tool for Basin Water Management

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Redevelopment and Enhancement of the Irrigation Demand Model as a Tool for Basin Water Management

Ron McMullin, Executive Director
Alberta Irrigation Projects Association (AIPA)

Jennifer Nitschelm, Director
Basin Water Management Section and
Irrigation Secretariat
Alberta Agriculture and Forestry (AAF)

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EXECUTIVE SUMMARY

With the completion of the redevelopment and enhancement of the Irrigation Demand Model version 3 (IDM-3), researchers and river basin managers have a user-friendly platform available to calculate irrigation water demand in Alberta, both past and future, and assess factors that impact it. Irrigation water demand data is vital knowledge used by decision makers in managing water resources, particularly in the South Saskatchewan River Basin (SSRB) where more than 90% of Alberta's irrigation occurs. The IDM-3, now owned by the Minister of Agriculture and Forestry, and residing on a server of the Department, will be publically available and remotely accessible to external users on the condition of some basic training with the Department. New GIS capabilities, simplified data entry, graphical presentation of results, and greater ease for scenario analysis are key enhancements that increase the model's utility beyond that of the IDM-3 model precursors.

The volume of water licenced to Alberta's 13 irrigation districts for diversion is 3.45 billion cubic metres per year. This equates to about 40 per cent of the annual flow in the Alberta portion of the SSRB. Irrigation districts diverted approximately 45 per cent of their licenced volume over the past 10 years. As the largest consumptive user of water in Alberta, irrigation is a significant factor in water management in the Province. Output from the IDM-3 will be useful to all who model or otherwise study basin water management and are involved in water-related decision making in the SSRB.

The enhancements made to the model as a result of this project include the following:

The redeveloped model IDM-3

a) is GIS-based which facilitates spatial representation of conveyance networks, visualization of certain results, the selection of sub-blocks of irrigation districts to model, making and evaluating changes to delivery system characteristics such as changing an open lateral to a pipeline, and/or changes to on-farm delivery equipment used on specific parcels, insertion of a reservoir anywhere in the irrigation delivery system, etc.;
b) simplifies selection of variables to be examined, and whether a parameter is included or excluded from a run;
c) is useful in analyzing efficiency gains from rehabilitation of the irrigation delivery system and adoption of improved on-farm water management practices;
d) includes seepage and evaporation from canals and reservoirs in water loss calculations;
e) enables the user to insert a reservoir, small or large with user-defined storage capacity and operation rule curves, anywhere in the irrigation network and incorporates the operation of the reservoir into demand management calculations (the original model did not include reservoirs or their operation);
f) makes scenario analysis much simpler than the original model: individual variables can be changed readily rather than having to input an entire data set for each scenario run. This facilitates scenario analysis, such as testing the implications of climate change weather sets, crop type shifts, area expansion, etc. on irrigation demands;
g) produces output files for use in Alberta Environment and Park's Water Resources Management Model and other models requiring irrigation demand data for basin water management evaluations;
h) produces graphical presentations of results;

i) includes a "Help" section and provides useful error messages;
j) is written using up-to-date software that is compatible with the Department's requirements; and
k) is publically and remotely accessible, with some training from Alberta Agriculture and Forestry staff.

Some of the anticipated uses of the IDM-3 are

1. The amount of water needed for a sustainable agriculture economy in the irrigated region will be regularly assessed using this model, and the volume and timing of water needed will be compared to available supply to determine whether demands can be met. Trends in demands will be assessed to determine the impact of crop types, climate change, and growth on the demand for water from agriculture, communities and businesses supplied by the irrigation system.
2. Part of the irrigation district demand is water that is delivered by the irrigation system to communities, farms and rural water cooperatives for their domestic water, and the model will be used in assessing security of these supplies.
3. The model will provide water demand information to other models which will be used by stakeholder partnerships and government staff to evaluate decisions based on enhanced knowledge, and shared responsibility for water management.
4. The model will be used to determine the efficiency gains that can be achieved by changes in on-farm irrigation systems and by rehabilitating portions of the irrigation delivery system. This will enhance conservation of water, and will likely reduce diversions from river systems.
5. The model will be used to determine whether enough water has been saved through efficiency gains to warrant expansion of the irrigated acreage, which would result in more productivity of water allocated to irrigation.

With the enhancements to this redeveloped model, it is expected the model will be a valuable tool for researchers and government staff to explore options for water management and formulate policies and actions to provide for the social, economic and environmental needs of Albertans.

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Project Description

Introduction/challenge

Irrigation district members of the Alberta Irrigation Projects Association (AIPA), Alberta Agriculture and Forestry (AAF), and Alberta Innovates – Energy and Environment Solutions (AI-EES) have collaborated to redevelop and enhance the current Irrigation Demand Model (IDM) used in providing data for water basin management decision making. The enhanced model will provide information needed by public and private entities as they formulate policy and consider and act on emerging and future water management challenges, including economic and environmental opportunities in the South Saskatchewan River Basin (SSRB). Irrigation water use accounts for more than 80% of the water that is consumed in the SSRB. With the closure of much of the SSRB to further water allocation applications, innovative solutions are required to ensure the best and most efficient use of water.

The demand for irrigation water in the basins of the Bow and Oldman Rivers is a key component of water withdrawal from southern rivers in the Province of Alberta, and hence, of basin water management in that region. The region is characterized by relatively high heat units and moderate to low precipitation, with water being the key limiting factor to growing a diversity of crops and supporting a large livestock industry. Development of irrigation systems early in the 20th century was a key factor in economic and social development in the region and a widely expanded, modern irrigation system continues to be a significant part of the social fabric of southern Alberta. Over 50 crop types are now grown on approximately 560,000 ha (1.4 million acres) of irrigated land and over 60 per cent of Canada's fed cattle are produced in the region. In addition to thousands of irrigated farms receiving water through the irrigation system, many communities, rural water cooperatives, food processors, market gardens, recreation areas, and wetlands rely on water supplied via the irrigation system.

The volume of water licenced to Alberta's 13 irrigation districts for diversion is 3.45 billion cubic metres per year. This equates to about 40 per cent of the average annual flow in the Alberta portion of the South Saskatchewan River Basin (SSRB). As the largest consumptive user of water in Alberta, irrigation is a significant factor in water management in the Province. Being able to assess potential demand for irrigation water is key to basin water management decisions now and into the future.

The modeling of the irrigation water delivery system has evolved over the decades, since computers were introduced, to facilitate management decisions regarding irrigation water diversion and use in the SSRB. Several components including an on-farm irrigation demand model, an irrigation network (delivery system) model, a database conversion subroutine that prepares input data, and a scenario builder used to modify the input to look at irrigation expansion, were amalgamated into an "Irrigation Demand Model." The original IDM has a number of deficiencies in its usefulness.

a) It is not accessible to external users
b) It does not account for infrastructure capacity limitations
c) GIS technologies are only minimally used, limiting the ease of use and the utility of the model
d) Reservoirs to store and supply water are not simulated
e) The routing algorithm is very simple, and, as a result, the routing of the water in the network is not optimal and at times unrealistic
f) The error logs tend to be very large and difficult to work with

g) Some of the individual tools comprising the IDM are not integrated and the demand data for the entire simulation has to be stored in files for importing into the other model components; therefore, processing is slow and tedious.
h) A large number of steps are required to run a simulation and numerous external tools are required for setting up the simulation, handling the output, and analyzing the results.
i) The technology that IDM is based on is outdated, is increasingly difficult to support, and does not meet current AAF IT standards for software.

This project has corrected these deficiencies, producing a user-friendly model with much greater utility than the precursor versions and will be readily available for researchers and decision-makers. The new model will expand the knowledge of researchers and water managers who are developing improved plans and practices for basin water management and those assessing future risks of and adaptation to shifts in climate and agricultural changes. Because the IDM-3 will be available to external users, more researchers will have the opportunity of examining various scenarios that may impact water demand in the South Saskatchewan River Basin and its sub-basins.

Technology or Research description

The redeveloped model, IDM-3, addresses past deficiencies and contains the following enhancements:

1) A linear programming engine is used for routing of water in the network in an optimal way,
2) Reservoirs and reservoir functionality are simulated, with ease of insertion of a reservoir in the GIS layer and reservoir characteristics into the data set via dialog boxes,
3) All the IDM components are now integrated into IDM-3 allowing for faster and more flexible operation of the model,
4) Extensive GIS capabilities simplify the task of inputting data into the model and improve the usability and intuitiveness of the user interface,
5) Output of the model can be tailored for input into Alberta Environment and Park's WRMM model, which is used by the Department in their assessments of water use in the SSRB,
6) The model includes user-friendly screens and dialogues, including GIS mapping and graphical presentation of model output,
7) The model produces useful error messages,
8) Calculation of seepage and evaporation from canals and reservoirs are included in water balance calculations and outputs,
9) Calculation of potential evapotranspiration and lake evaporation are incorporated into the model, and
10) External users can access the model remotely.

The IDM-3 is designed to simulate the entirety of all 13 irrigation districts, individual districts, portions of an individual district, or a private irrigation project. Some of the model's new capabilities allow the model to

1) Calculate irrigation demands and return flows (at the irrigation project level and the on-farm level)
2) Calculate seepage losses from open canals and reservoirs
3) Calculate evaporation for open canals and reservoirs
4) Calculate reservoir levels and volumes of water stored for and supplied to the distribution system
5) Identify capacity restrictions in the network of open canals and pipelines.

In order to facilitate performing a "what-if" analysis, IDM-3 includes a scenario-builder tool that can be used to alter a base case and create various scenarios. These scenarios can then be simulated by IDM-3. A comparison of the individual outputs will show the effects of the change. Examples of scenarios include

- Changes in cropping patterns
- Changes to irrigation water application methods (system types)
- Increases to irrigation area, such as expansion of a district
- Changes to conveyance structures such as pipelines, addition of a reservoir
- Use of different weather sets to simulate changes to temperature or precipitation

Project goals/objectives

The project has the following goals:

1) Develop a model of irrigation water demand to assist researchers and water managers in analyzing irrigation water diversions (which meet irrigation demand), crop water use (which drives irrigation demand), and return flows (excess of water diverted over-and-above irrigation demand to keep the system operational) in the SSRB.
2) Enhance the ease of use and utility of the model by adding GIS capability, functionality of reservoirs, enhanced scenario analysis, seamless data transfers within the model, data formatted for external models requiring this information, graphical presentation of results, etc.
3) Make the IDM-3 accessible to the public from remote locations; this is fostered by transferring ownership of the model and any associated IP from GENIVAR Inc. (and its successor, WSP Canada Inc.) to the Minister of Agriculture and Forestry, plus the creation of a "Help" directory in the program.

Work scope overview and modeling details

A detailed description of the work done to produce the model can be found in Appendix 1, the 51-page "Scope and Project Plan" document used to guide work completed in this project. Appendix 1 is attached to this report. Preparing the "Scope and Project Plan" initially put the project behind-schedule but was invaluable in guiding the work that has resulted in a model that water managers and researchers will find user-friendly as they search for answers to pressing questions about water demand in the SSRB.

The deliverables for the project follow in Table 1. Upon completion of each deliverable by WSP Canada Inc., AAF staff evaluated and tested each deliverable and, when satisfied with the operation and/or results of the deliverable, signed-off for payment of work completed. Funds were administered by AIPA staff. Several challenges arose in meeting initial deliverable dates, in particular, the discovery of a flaw in the original IDM code which had to be corrected, and a challenging deliverable which took much more time than initially expected requiring adjustments at AAF's request to meet the criteria for sign-off of the deliverables. Predicting the timeframe required for programming is challenging. As a result two amendments to the contract between WSP and AIPA extending the completion of the project were agreed to by both parties and the work progressed to completion.

Table 1. IDM-3 Project Deliverables & Milestones Schedule

	Deliverable	Start Date	Delivery Date (GENIVAR)	Completion Date	Details	Verifiable
1	**Project Scoping Completed**		**30-Nov-13**	20-Dec-13	Project scope document, execution plan, and budget completed.	Signed documents.
2	**Detailed Design: Data Model Completed**	**01-Jan-14**	**13-Feb-14**	plus 10 business days	Data model portion of Detailed Design Document completed. Design will continue while deliverable is being reviewed by IT.	ARD IT review and sign off.
3	**Detailed Design: Object Model Completed**	**13-Feb-14**	**29-Mar-14**	plus 15 business days	Object model portion of Detailed Design Document completed. Design will continue while deliverable is being reviewed by IT.	ARD IT review and sign off.
4	**Detailed Design: Application Pages & Description Completed**	**29-Mar-14**	**23-May-14**	plus 15 business days	Application Pages & Description portion of Detailed Design Document completed. Design will continue while deliverable is being reviewed by IT.	ARD IT review and sign off.
5	**Milestone 1** **IDM-3 Application Phase 1 Completed: Detailed Design**	**23-May-14**	**21-Jun-14**	plus 15 business days	Remainder of Detailed Design Document completed. Development of the Solver Application will begin while Detailed Design is being reviewed by IT.	ARD IT review and sign off.
6	**Solver Application Completed**	**21-Jun-14**	**25-Aug-14**	plus 10 business days	Solver application (server application that solves LP problems using IBM CPLEX) completed and deployed to UAT. Conversion of model engine demand components will begin.	GENIVAR (now WSP) will run example Linear Programming (LP) problems in UAT and validate that the results are correct. ARD Lethbridge will witness runs, verify results, and sign off. ARD IT will review code and sign off.
7	**Model Engine Demand Components Library Conversion Completed**	**25-Aug-14**	**08-Oct-14**	plus 10 business days	Model engine components associated with calculating on-farm demand converted from C# to Java. Tested and verified against IRM-4. Conversion of model engine network components will begin.	GENIVAR will run an example IRM project and will validate against output generated by IRM. ARD Lethbridge will witness runs, verify results, and sign off.

8	**Model Engine Network Components Library Conversion Completed**	**08-Oct-14**	**13-Dec-14**	plus 10 business days	Model engine components associated with the network converted from C# to Java. Tested and verified against IDM-2. Development of persistence entities will begin.	GENIVAR will run an example IDM-2 project and will validate against output generated by IDM-2. ARD Lethbridge will witness runs, verify results, and sign off.
9	**Persistence Entities Implementation Completed**	**13-Dec-14**	**04-Jan-15**	plus 10 business days	Persistence entities (Java classes associated with storing and reading data from the database) implemented. Development of servlets will begin.	GENIVAR will supply and run a test program to demonstrate that entities can be created, modified, and deleted. ARD Lethbridge will witness runs, verify results, and sign off.
10	**Servlets Implementation Completed**	**04-Jan-15**	**05-Feb-15**	plus 10 business days	Servlets (Java classes the perform functions requested by the application) implemented. Development of network simulator will begin.	GENIVAR will supply and run a test program that demonstrates the proper operation of the servlet methods. ARD Lethbridge will witness runs, verify results, and sign off.
11	**Network Simulator Completed**	**05-Feb-15**	**01-Apr-15**	plus 10 business days	IDM-3 model engine completed and tested against a manually constructed IDM-3 project (XML) file. Results compared to IDM-2. Modification of model engine will begin.	GENIVAR will supply and run a manually constructed IDM-3 project file and compare the results to IDM-2. ARD Lethbridge will witness runs, verify results, and sign off.
12	**Milestone 2** **IDM-3 Application Phase 2 Completed: Code Conversion and Model Engine Development**	01-Apr-15	24-Apr-15	plus 10 business days	Modifications to model engine completed (e.g., reservoir algorithm changes, filling algorithm changes, downtime losses changes…). Deployed to UAT. Development of model configuration pages will begin.	With support from GENIVAR, ARD Lethbridge will run test IDM-3 projects to verify proper implementation of modifications. ARD Lethbridge will sign off. ARD IT will review code and sign off.
13	**Model Configuration Pages Completed**	**24-Apr-15**	**29-Jun-15**	plus 10 business days	Web pages associated with the configuration of an IDM-3 project completed and deployed to UAT. Development of time series chart, grid, and export functions will begin.	ARD Lethbridge will test the web pages and sign off.
14	**Time Series Chart, Grid, and Export Completed**	**29-Jun-15**	**12-Aug-15**	plus 10 business days	Web pages associated with displaying the time series data in a grid or chart or exporting to CSV file completed and deployed to UAT. Development of scenario builder pages will begin.	ARD Lethbridge will test the web pages, review output, and sign off.
15	**Scenario Builder Pages Completed**	**12-Aug-15**	**24-Sep-15**	plus 10 business days	Web pages associated with configuring and applying a Scenario Builder scenario completed and deployed to UAT. Writing of help file and preparations for deployment to PRD will begin.	ARD Lethbridge will test web pages and sign off.

16	**ARD IT Code Review**	**24-Sep-15**	**31-Oct-15**	plus 15 business days	Code reviewed by ARD IT. GENIVAR will fix any deficiencies identified.	ARD IT sign-off.
17	**Milestone 3** **IDM-3 Application Phase 3 Completed: Application Development**	24-Sep-15	15-Nov-15	30-Nov-15	IDM-3 application completed and deployed to PRD. Help document completed. Training delivered. Detailed Design Document updated to reflect as-built system. 60 day warranty period begins.	ARD Lethbridge to test IDM-3 in PRD and sign off. ARD IT sign-off.

Completion date = ARD will complete evaluation of deliverable and a) if the deliverable is substantively complete, approve payment , or b) if the deliverable has substantive deficiencies, provide details on the deficiencies to GENIVAR for revision

Approach and Results

Results of model development and sample simulations

The following screen shots exemplify and illustrate the results of this project:

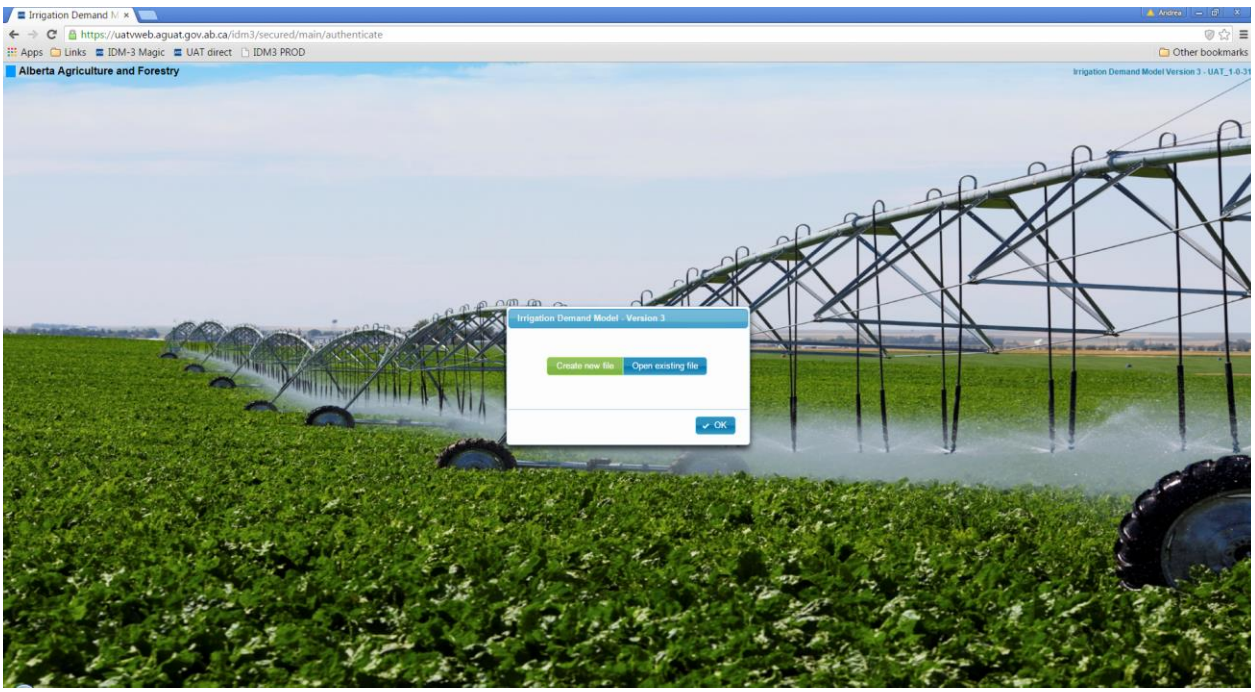


Figure 1. IDM-3 Welcome screen.

(The application can be accessed online through a web browser. Users external to GOA will be able access the application remotely.)

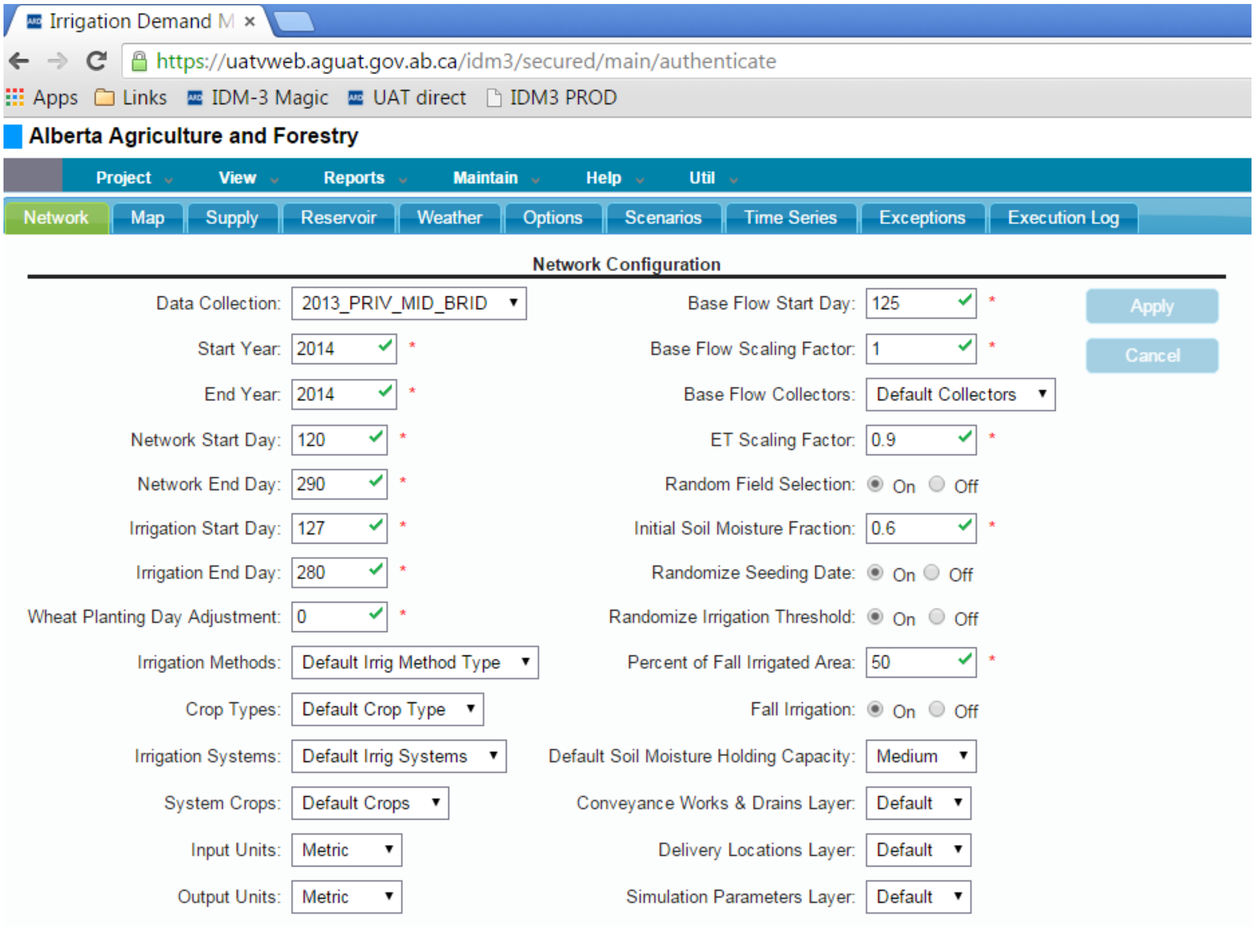


Figure 2. Dialog page used to set up a project.

(Data in the model will be organized in data collections consisting of individual districts, districts within a basin or private irrigation. Data collections will contain yearly district data that a user can modify for a specific project.)

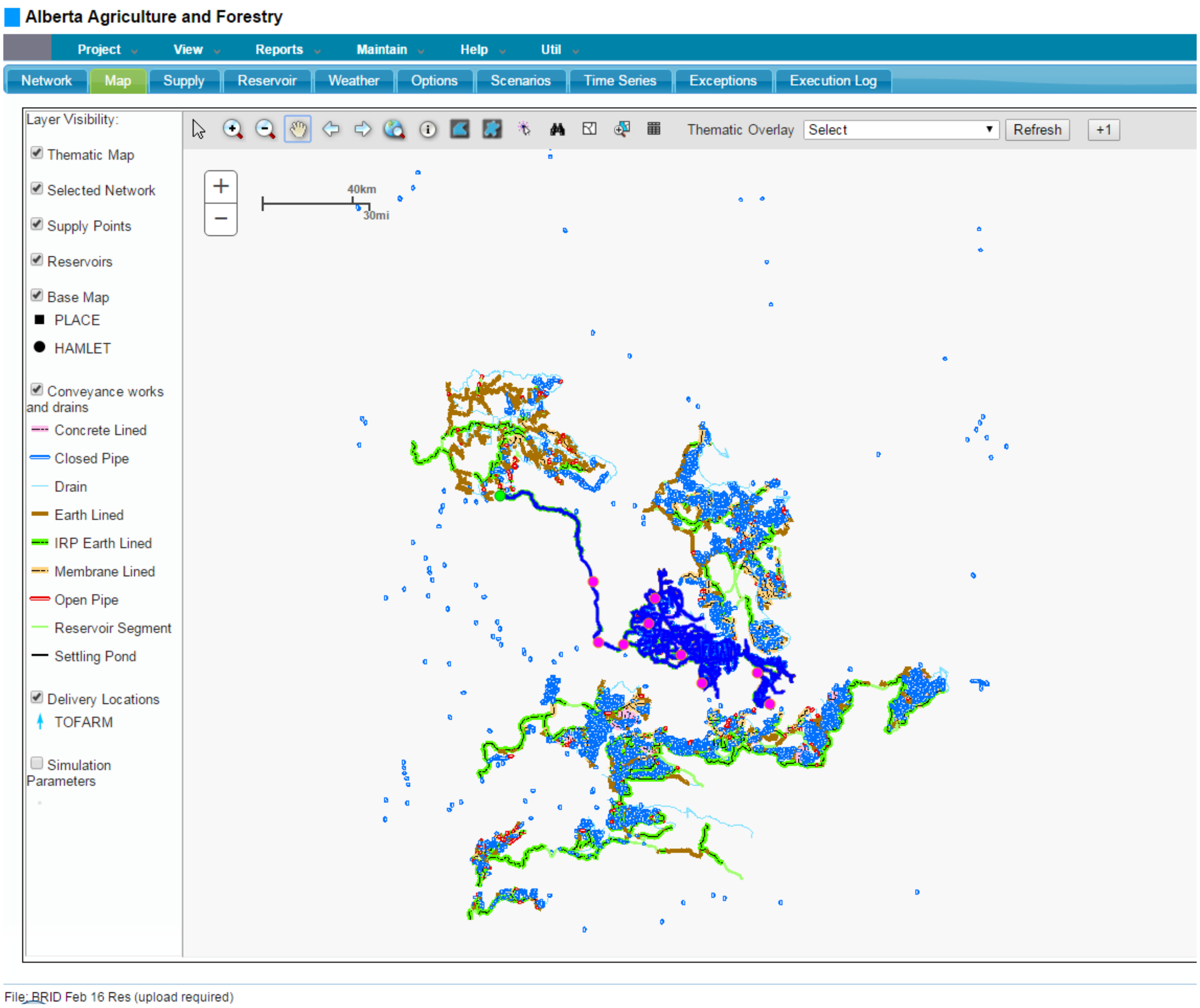


Figure 3. Sample GIS-based view of irrigation district infrastructure in Alberta.

(IDM-3 incorporates ArcGIS technologies and mapping functions for displaying and interacting with spatial data. The user can select any part of the network for a simulation and can zoom in to see the details of a specific segment of the irrigation network. There are approximately 8,000 km of canals, laterals and pipelines in this modelled network.)

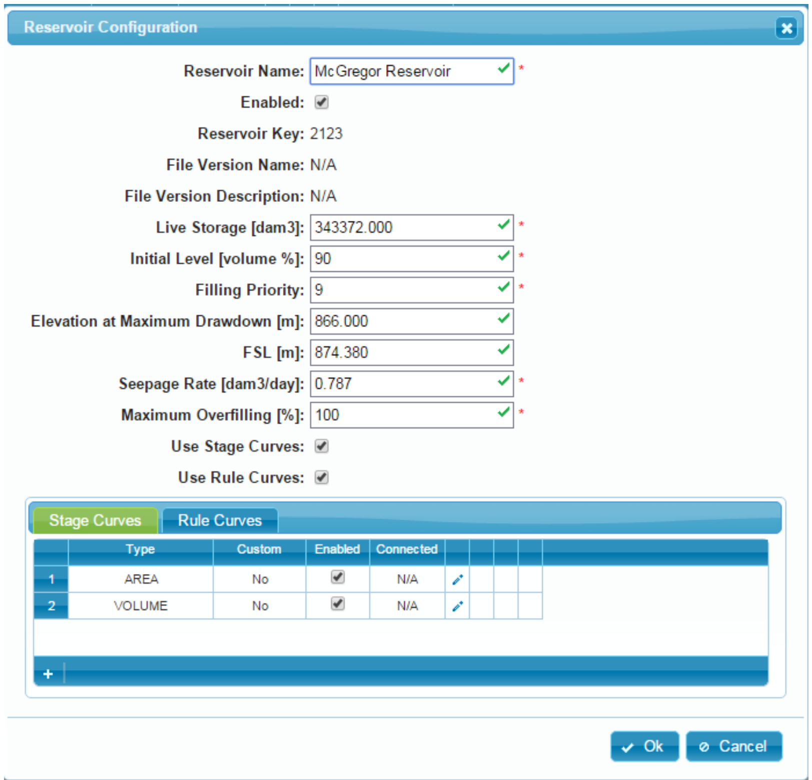


Figure 4. Reservoir description/data page.

(IDM-3 can model reservoir storage, a new feature in the model. The user can customize the configuration of a reservoir and easily add that new reservoir at any location in the network.)

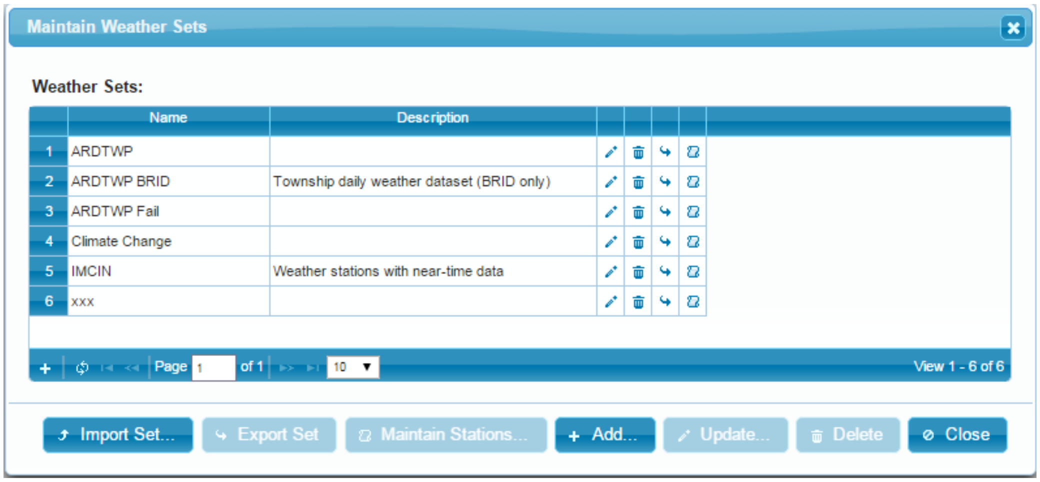


Figure 5. Weather set selection page.

(Multiple weather sets can be added to the IDM-3 database to model different weather scenarios such as potential impacts of climate change. Evapotranspiration can be calculated using several equations depending on the availability of weather variables.)

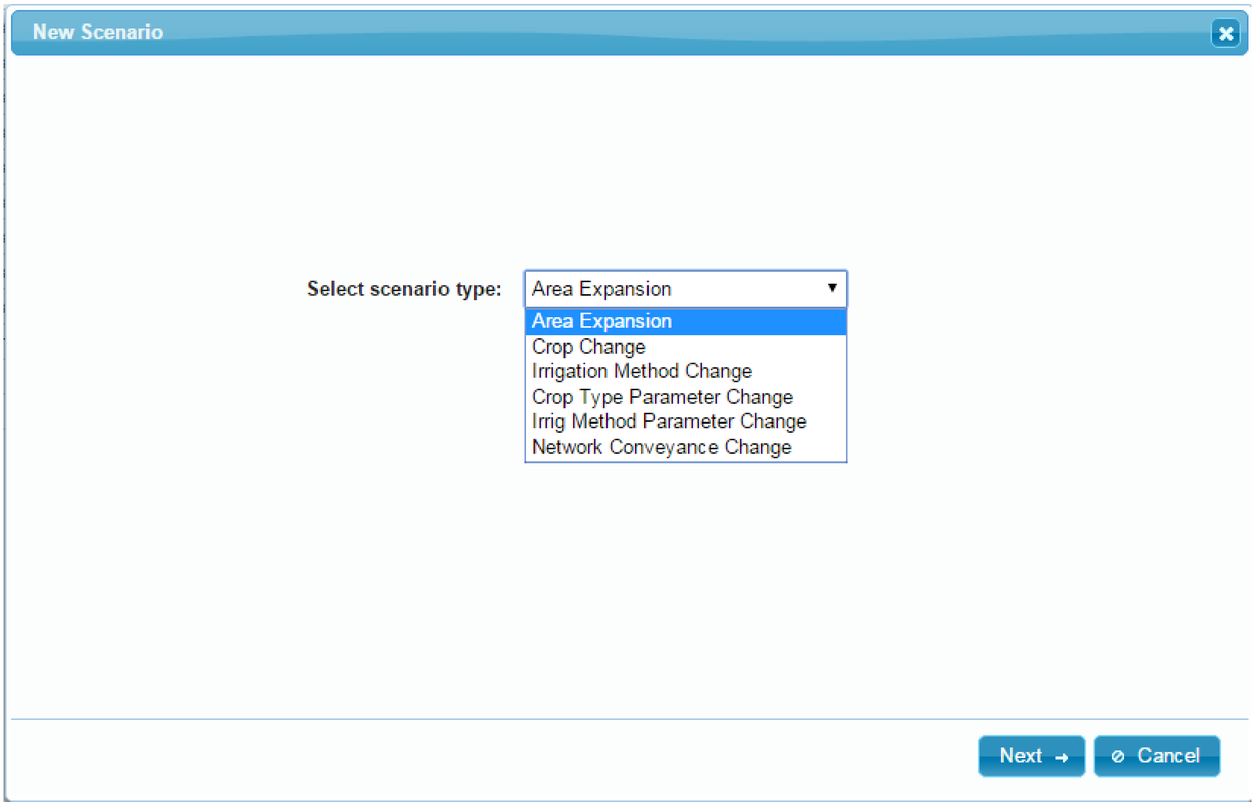


Figure 6. Scenario selection page.

(Several types of scenarios can be modeled with IDM-3 including area expansion, changes to crop types and irrigation method types, changes to crop and irrigation system parameters, and changes to infrastructure. Changes can be configured for the entire district, by blocks within the district or by spatial query. The process of creating a new scenario has been simplified compared with the process required in IDM-1.)

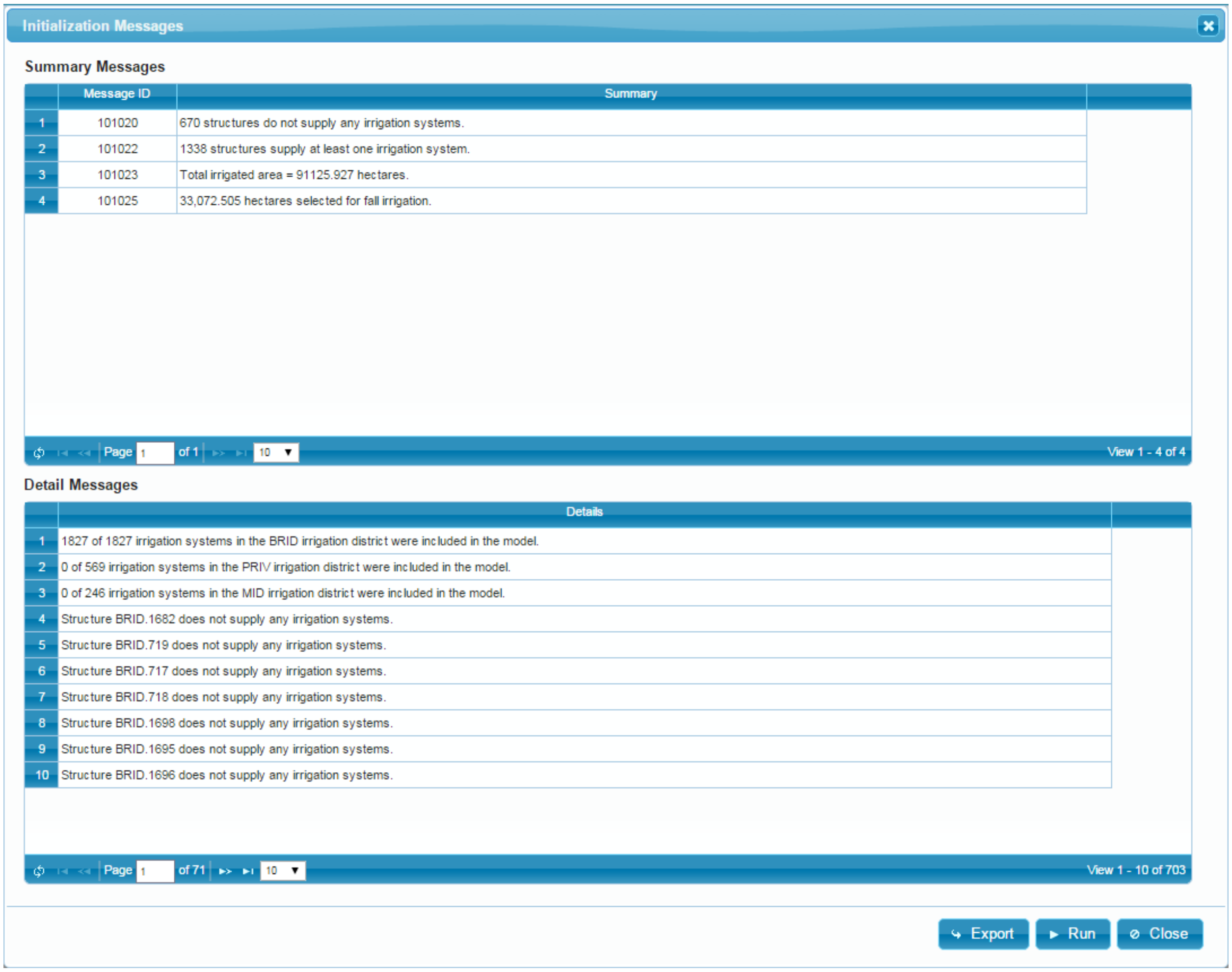
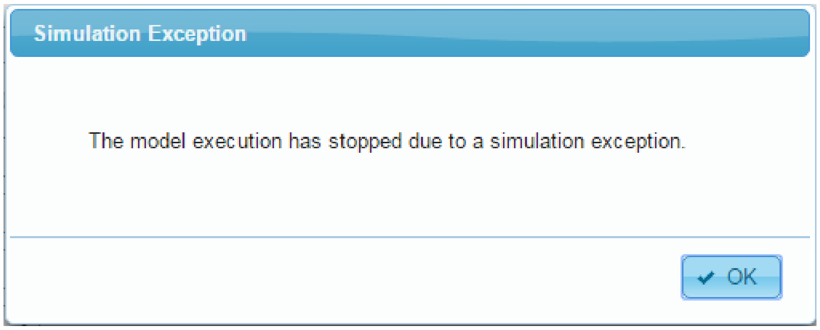


Figure 7. Initialization messages page.

(Initialization messages allow the user to identify issues with a project before running it. These messages can help to clean up the input data and help the user to understand what will be included in a simulation and how the model will handle the input data.)



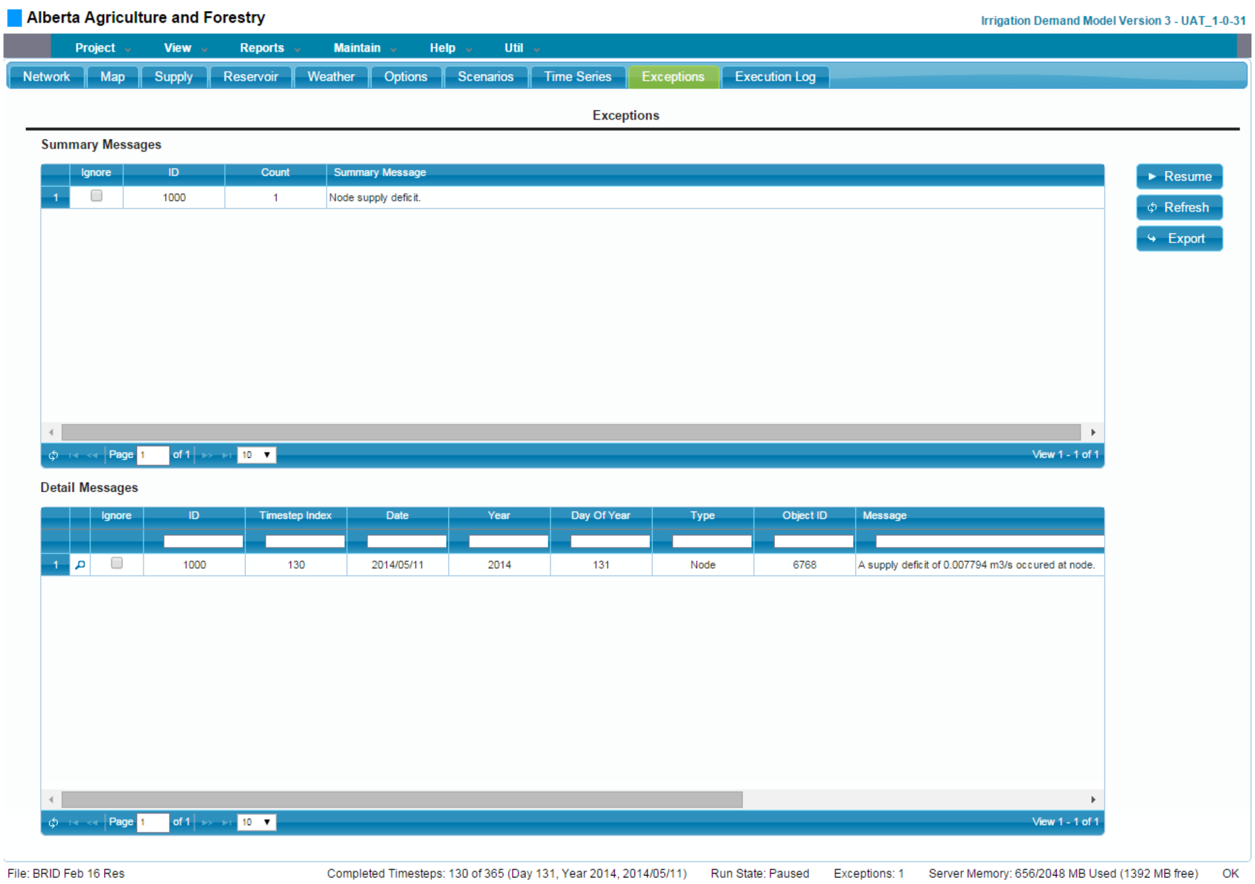


Figure 8. Model exception page during a simulation.

(During a model run, the model will stop running if it finds a model exception. The user can choose to ignore similar exceptions and resume the simulation. Exception messages can be exported for further analysis and to resolve problems in the input data.)

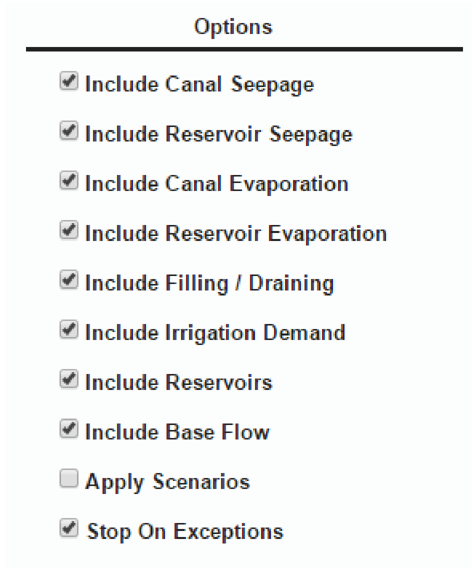


Figure 9. Calculation (component) selection page.

(The user has the ability to control which calculations or components are included in a simulation.)

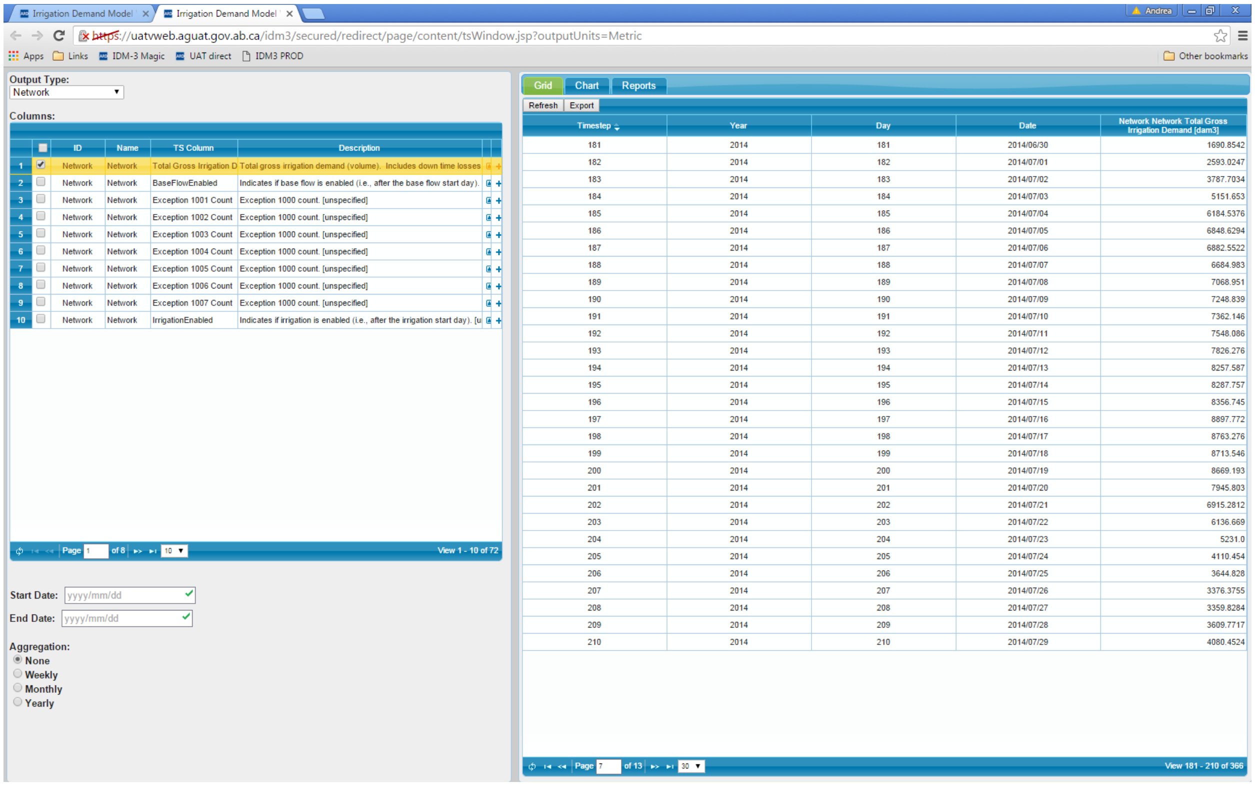


Figure 10. Time series data view page.

(IDM-3 includes an interface for displaying time series data associated with a model simulation. The data/output can be aggregated and shown in tabular form or as a chart.)

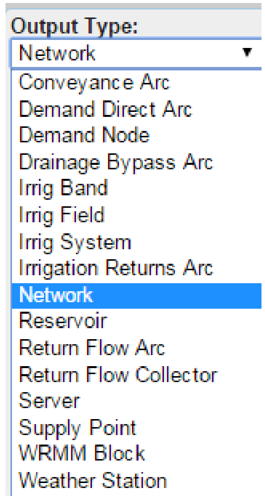


Figure 11. Output selection page.

(IDM-3 produces a wide range of output variables under each output type listed here. It creates a default set of output for the user but the user can also customize the variables and instances to be displayed.)

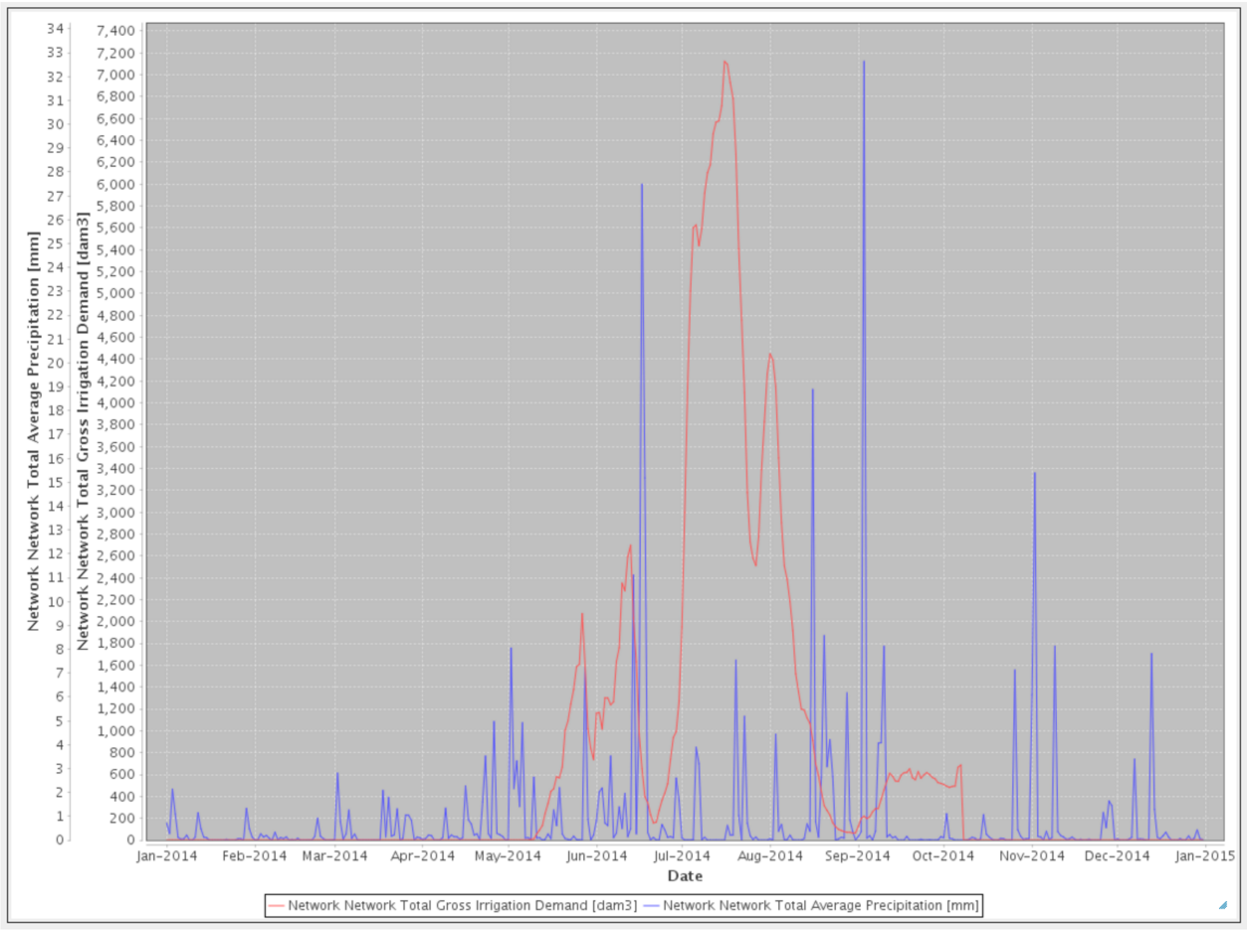


Figure 12. Sample data output chart.

(The graph shows typical output calculated by an IDM-3 simulation for Total Gross Irrigation Demand (red) and compares it with Total Average Precipitation (blue).)

Alberta Agriculture and Forestry

Crop Type by Irrigation District

System ID	Crop ID	PFL	Crop Code	Crop Name	Area [hectares]
Irrigation District: BRID					
IS.BRID.635	IS.BRID.635:F	0151718SEXXXW4	AL2	ALFALFA 2 CUT	49.70
IS.BRID.237	IS.BRID.2371:I	0131330SEXXXW4	AL2	ALFALFA 2 CUT	7.04
IS.BRID.248	IS.BRID.2486:I	0131326NEXXXW4	AL2	ALFALFA 2 CUT	19.09
IS.BRID.113	IS.BRID.1132:I	0121320NWXXXW4	AL2	ALFALFA 2 CUT	22.26
IS.BRID.117	IS.BRID.1174:I	0131328SWXXXW4	AL2	ALFALFA 2 CUT	44.76
IS.BRID.117	IS.BRID.1174:I	0131321NWXXXW4	AL2	ALFALFA 2 CUT	24.65
IS.BRID.858	IS.BRID.858:F	0161833SWXXXW4	AL2	ALFALFA 2 CUT	53.70
IS.BRID.953	IS.BRID.953:F	0141934SWXXXW4	AL2	ALFALFA 2 CUT	23.88
IS.BRID.111	IS.BRID.1118:I	0121307NWXXXW4	AL2	ALFALFA 2 CUT	11.76
IS.BRID.117	IS.BRID.1173:I	0131321SWXXXW4	AL2	ALFALFA 2 CUT	17.40
IS.BRID.216	IS.BRID.2162:I	0131319NEXXXW4	AL2	ALFALFA 2 CUT	33.43
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IS.BRID.126	IS.BRID.1260:I	0121413SEXXXW4	AL2	ALFALFA 2 CUT	31.61
IS.BRID.240	IS.BRID.2404:I	0131730SEXXXW4	AL2	ALFALFA 2 CUT	12.14
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IS.BRID.120	IS.BRID.1202:I	0131329NWXXXW4	AL2	ALFALFA 2 CUT	10.11
IS.BRID.238	IS.BRID.2385:I	0131219SWXXXW4	AL2	ALFALFA 2 CUT	18.43
IS.BRID.115	IS.BRID.1159:I	0131313SWXXXW4	AL2	ALFALFA 2 CUT	0.69
IS.BRID.115	IS.BRID.1159:I	0131313SWXXXW4	AL2	ALFALFA 2 CUT	12.69
IS.BRID.797	IS.BRID.797:F	0161803NEXXXW4	AL2	ALFALFA 2 CUT	36.30
IS.BRID.137	IS.BRID.1372:I	0151822NEXXXW4	AL2	ALFALFA 2 CUT	48.48
IS.BRID.112	IS.BRID.1121:I	0121318NWXXXW4	AL2	ALFALFA 2 CUT	20.23
IS.BRID.110	IS.BRID.1106:I	0131218SWXXXW4	AL2	ALFALFA 2 CUT	10.83
IS.BRID.110	IS.BRID.1106:I	0131218SWXXXW4	AL2	ALFALFA 2 CUT	26.54
IS.BRID.680	IS.BRID.680:F	0141810NWXXXW4	AL2	ALFALFA 2 CUT	29.74
IS.BRID.892	IS.BRID.892:F	0141908SEXXXW4	AL2	ALFALFA 2 CUT	29.14
IS.BRID.892	IS.BRID.892:F	0141908NEXXXW4	AL2	ALFALFA 2 CUT	14.16
IS.BRID.892	IS.BRID.892:F	0141908NWXXXW4	AL2	ALFALFA 2 CUT	29.14
IS.BRID.892	IS.BRID.892:F	0141908SWXXXW4	AL2	ALFALFA 2 CUT	13.76
IS.BRID.119	IS.BRID.1191:I	0131326NEXXXW4	AL2	ALFALFA 2 CUT	4.94

Figure 13. Sample summary report of input data for specific irrigated parcels.

(IDM-3 can prepare several reports summarizing the data included in a project.)

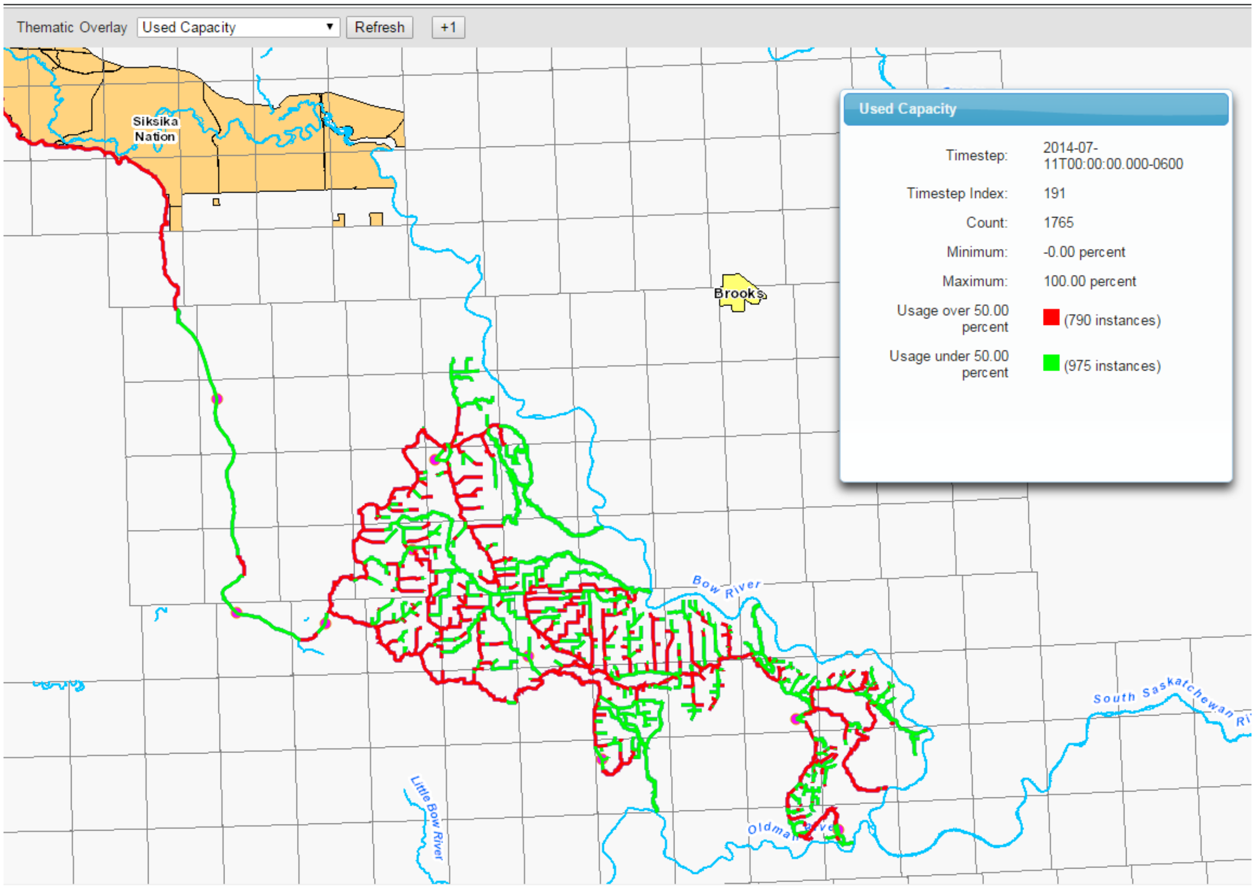

Figure 14. Sample GIS-based evaluation: potential bottlenecks in a delivery system.

(Thematic maps built by IDM-3 can be used to display different model output in a spatial way. This map from a simulation shows segments of the network where the flow in a canal or pipeline exceed 50% of its design capacity (in red). This feature can be used to show possible capacity constraints in the infrastructure network.)

Figure 15. Sample output chart of actual reservoir operation compared with operational rule curve.

(This graph shows the simulated elevation of a district reservoir (blue) following its rule curve (red) very closely.)

Key steps in project.

Along the path to successful completion of the project, a number of key events took place:

1) AI-EES approved the funding of a collaborative project with Alberta Irrigation Projects Association and Alberta Agriculture and Forestry.
2) GENIVAR Inc., which developed and owns the original IDM code, was contracted to redevelop and enhance the model. WSP Canada Inc. (WSP) assimilated GENIVAR Inc. partway through the project and continued the project.
3) WSP prepared a "Scope and Project Plan" document to guide the development of the model and facilitate an evaluation of the proposed work to accomplish the project.
4) Key AAF and AIPA staff met with AAF IT architecture personnel to determine the model platform and assess costs of acquiring licences for portions of the model (the solver). The IT personnel prepared a 7-page analysis of the architecture of the model and platform.
5) AAF procured the solver at its own expense.
6) AIPA member districts supplied data needed to develop and run the model, including detailed district delivery system descriptions and locations, current crops grown, and current on-farm irrigation systems for each and all irrigated parcels within the districts.
7) WSP enhanced and redeveloped the model according to the scoping and planning document.
8) AAF checked/tested deliverables of model components and once any deficiencies were corrected by WSP, AAF authorized payment.
9) AIPA administered the project, made payments to WSP, and tracked and encouraged progression in the model development and evaluations.
10) AIPA prepared and presented two talks on the IDM-3 model redevelopment and enhancement at AI-EES events.
11) AIPA prepared two interim reports and this final report.
12) AIPA transferred the model and IP rights to the Minister of Agriculture and Forestry, which was in accordance with the contract with WSP.

Project outcomes

1) The IDM model was redeveloped and enhanced, providing a user-friendly platform for researchers, policy formulators, and decision makers to examine irrigation demand within the SSRB. IDM-3, the new version of the model developed in this project, is GIS based and has added utilities that increase the ease of populating the model, inputting and manipulating data, examining additional factors that affect water demand, and viewing output.
2) Ownership of the IDM-3 model code and IP has been transferred to the Minister of Alberta Agriculture and Forestry.
3) A 60-day warranty period has now commenced and AAF staff will fully test the model and WSP will fix deficiencies that are discovered.

4) The model will be available to external users. This will allow academic and business researchers, irrigation districts, as well as Government of Alberta staff, to use the model. A "Help" page and documentation will assist new users, who will also receive some initial training from AAF staff as a requirement for use of the model.
5) Irrigation district staff will be able to access the model to determine expansion capacity, evaluate opportunities for efficiency gains from irrigation rehabilitation work and on-farm equipment upgrades, test the utility of adding reservoirs to the irrigation network and identify bottlenecks in delivering water to farms and other water users.
6) New utilities that broaden the value and potential use of the model include the addition of reservoir analysis, where the user can insert a reservoir anywhere in the irrigation network and specify its characteristics and operational rule curves; GIS capability to manipulate the irrigation delivery system, select areas to be evaluated, and view certain results pictorially; ease of data input and parameter selection; enhanced scenario analysis; greater ease of climate change analysis; and the formatting of output data to facilitate use of data by other basin water management models, such as WRMM and OASIS.
7) This project contributes to all three Water for Life goals and is based on many of the strategy's principles. Working with partnerships, shared responsibility for water management, developing knowledge for decision making and action to guide water management all overlap with goals of Alberta's Water Research Strategy.

Important lessons learned

1. The preparation of the "Scope and Project Plan" was a time-consuming but tremendous resource in guiding the work done in this project.
2. Collaboration takes communications, and with 5 parties involved in this project (AI-EES, AAF Irrigation staff, AAF IT staff, WSP, and AIPA) regular feedback and connection helped get "over the bumps" in this project.
3. Setting model development timelines is challenging as the timeframe to complete a specific deliverable is difficult to predict for a unique project.
4. Working together, keeping standards high, and all parties being patient with one another can produce a good end product, even though not all goes as planned.
5. Dividing up a lengthy project into specific deliverables as check-points (and payment points) along the way helps everyone know exactly where the project is in its progress.
6. Something of real value takes time, effort and resources.

Relevance and Impact

What do the project results mean for Albertans?

Pressures on water resources in the SSRB have grown with increasing demands from a rapidly expanding population within the SSRB. Projections of global demand for increased food production also point to a growing need for water to produce food for the world. Climate change is happening and will have repercussions on water supply and management. Decisions will need to be made that balance the needs for water for environmental purposes, municipal use, resource extraction, recreation and aesthetics, and food production. Decisions will need to be made that determine how the Province and its people cope with/manage a changing water supply due to climate variability. Those decisions will be local and provincial, will be the basis of government policy and legislation, and will impact every person in the SSRB with ripple effects throughout the Province and beyond.

The redeveloped and enhanced IDM-3 will provide some very important information needed by decision makers as we face increased water demands and fluctuating supplies. Irrigation accounts for 80 per cent of water use in the basin and so being able to predict irrigation water demand and examine factors that impact it and to what degree they impact water demand will be vital in water management within the SSRB. The IDM-3 will be a valuable tool in providing that data for consideration.

Some of the trends in water use will show increased demands, but the IDM-3 can also be used to show where reductions in demands can come from. For example, with change of on-farm irrigation systems and rehabilitation of canals and laterals, water conveyance inefficiencies and demands are reduced. Changes in crop types planted can either increase or decrease water use, since the consumptive use of crops varies from crop to crop. The IDM-3 will be useful in identifying water-saving practices and in estimating the amount of water that can be saved. It will also prove useful in studying how much water can be used to expand irrigation for the purpose of producing food for a global population that needs more calories, more protein, and enhanced nutrition.

In economic terms, each hectare of irrigated land adds $2400 to Alberta's economy[1] through primary production, food processing and associated economic linkages; if more water is available to expand irrigation, then agriculture can diversify and generate more dollars for Alberta's economy. An expansion of 10% in irrigation districts would add annually $360 million to the provincial Gross Domestic Product. Alternatively, water saved could be used as a buffer to reduce risk to irrigators, to supply domestic water for rural and urban communities, to create additional wetlands, to increase riparian habitat, to increase flows for instream needs, etc.

Output from a sample simulation in Figure 16 shows how much water would be required to expand the Bow River Irrigation District, the third largest district, by 25 per cent from the area it irrigated in 2013 as an example. The total irrigation demand volume increase for the season would be 60,040 dam^3 of water for the on-farm irrigation portion alone. Capacity of the main canal and individual laterals coming off the main canal would need to be examined in the GIS layer to evaluate whether they had adequate capacity to handle the extra flow to that particular block of the district. Whether the expansion could be

[1] Economic Value of Irrigation in Alberta. 2015. Paterson Earth & Water Consulting Ltd., Lethbridge, Alberta. 115pp. (Electronic copies available from AIPA)

accommodated by the existing irrigation distribution system and within the current licence conditions for the district could then be evaluated using answers given by the IDM-3 model.

On a ten-year running average basis, irrigation districts already reduced annual irrigation demand by over 500,000 dam^3 over the period of 2005-2014, even with an annual growth of about 1 per cent. There is still room for further reductions as the irrigation distribution system is rehabilitated and as farmers upgrade to higher efficiency systems on the 28% of the area still irrigated with less efficient systems. Estimates of future potential water savings can be calculated using IDM-3.

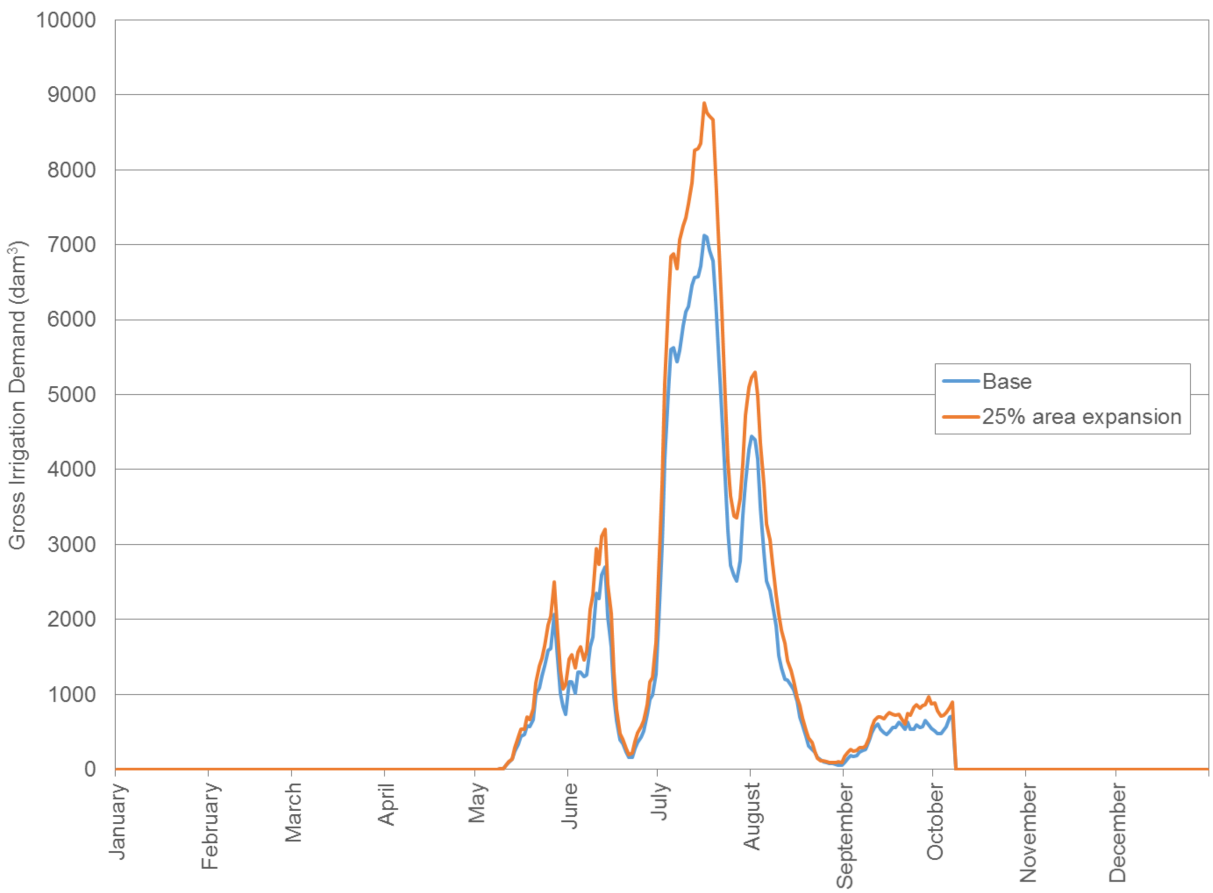

Figure 16. Chart of daily irrigation demand resulting from a 25% expansion of the Bow River Irrigation District.

(This graph compares model output for two separate simulation scenarios. The chart shows total gross irrigation demand volume calculated by IDM-3 for the Bow River Irrigation District for the area irrigated in 2013 (91,126 hectares) in blue and the corresponding demand for a 25% area expansion scenario (113,907 hectares) in orange. Both scenarios were run using the observed weather conditions of year 2014. The annual increase in demand for a year like 2014 due to a 25% expansion is predicted to be 67,040 dam^3.)

Overall Conclusions

Researchers, irrigation districts, and Alberta Agriculture and Forestry now have an enhanced and user-friendly model, IDM-3, to predict irrigation water demand in Alberta, evaluate factors that impact that demand, and view many of the results via GIS, graphical and tabular output. Irrigation demand modeling data will now be more readily available in a compatible format for other river basin management models such as WRMM used by Alberta Environment and Parks, and OASIS used by various research organizations.

IDM-3 will be available for external use and will be maintained by Alberta Agriculture and Forestry. The Minister of AAF is now the owner of the IDM-3.

This is a major step forward in river basin management water use and demand prediction based on historical data and projecting into the future. Policy, governance and investment decision making regarding water management in the "closed" SSRB will be enhanced by results of this new tool for river basin management.

Next Steps, Communications Plan

The IDM-3 will be available for access by academic researchers, irrigation districts, government agencies and others interested in modeling irrigation demand. One of the major outcomes of the project was to make this model readily available to all who can benefit from its use. This will facilitate basin water management research which is anticipated to drive policy formulation, investment, adaptation to climate change, and change of practice.

A number of potential users of the model have already expressed interest. Once the warranty period has ended and any discrepancies have been fixed, and internal testing has been completed, an open house will be held in Lethbridge, Alberta for parties interested in learning about IDM-3 capabilities, input requirements, and the "Help" utility. The open house would feature one day for irrigation districts and the second day for researchers, Alberta Environment and Parks staff and other interested parties to attend. Notice of this open house will be sent to interested parties, and announcements will be sent to selected researchers at Alberta's three major universities.

A presentation on the model will be made at two conferences, one being the November AIPA conference in Calgary and the other at the Canadian Water Resources Association conference in Montreal in May.

Comments by users of the model will be solicited as an ongoing opportunity to further enhance the model.

Scientific Achievements

Presentations on the IDM-3 model project have been made at the following events:

1) AI-EES Water Resources Sustainability Workshop, Edmonton, AB, May 22-23, 2013. Ron McMullin described the IDM-3 project at this event, where many other "water" researchers funded by AI-EES were in attendance.

2) AI-EES Water Innovation Program Forum, Calgary, AB, May 26-27, 2015. Ron McMullin gave a presentation to members of Alberta's water community and water researchers on the purpose of the IDM-3 project and the progress made in the model's development.

3) Northwest Irrigation Operators Conference in Boise, Idaho on February 16, 2016. The IDM-3 project was one of four key AIPA success stories presented at the NWIO conference this year. The presentation made by Ron McMullin, AIPA's Executive Director and NWIO board member, is part of a biennial report on happenings in irrigation in Alberta at this conference focussed on irrigation in the Pacific Northwest.

Ron McMullin and Jennifer Nitschelm provided information on the IDM-3 project to Jon Sweetman which became part of an AI-EES publication describing active research projects in 2015.

Final Financial Report

The Tracking Document listing the deliverables, their completion, their sign-off and the issuance of payments by AIPA to WSP is found in Table 2. This document details the cash receipts and expenditures for the project.

In summary, AI-EES committed up to $250,000 cash to this collaborative project. A $50,000 hold back was retained by AI-EES until the completion of the project. The irrigation districts committed $100,000 cash from special funding from the Irrigation Rehabilitation Program for the project to be held in trust by the Bow River Irrigation District (BRID). Alberta Agriculture and Forestry committed in-kind contributions (salaries and benefits) of $260,000. WSP received a total of $327,600 for their services and AIPA $5,000 for administration and reporting. A final payment from AI-EES to AIPA of $32,542.86 is anticipated.

The summary budget from the "Contribution Agreement re: 'Redevelopment and Enhancement of the Irrigation Demand Model as a Tool for Basin Water Management" document (page 20) can be found in Table 3. Note that the $3,000 in the "Research Plan and Budget" table of the aforementioned document (page 17) for a start-up meeting and contract preparation were not required by AIPA.

Table 2. Irrigation Demand Model-3 Project Deliverables/Receipts/Expenditure Tracking Document

Deliverable	Target Completion Date	AAF Signoff Date	Invoice Date	Invoice / Payment	AIPA Payment Date	Source of Funds
1 Scoping & Plan Doc	Nov 30, 2013		Dec 18, 2013	$15,000	Jan 10, 2014	BRID
2 Data Model	Feb 13, 2014	April 30, 2014	May 1, 2014	$20,000	May 12, 2014	BRID
3 Object Model	Mar 29, 2014	June 30, 2014	July 3, 2014	$20,000	July 14, 2014	AI-EES
4 Application Pages	May 23, 2014	July 31, 2014	Aug 25, 2014	$25,000	Aug 31, 2014	AI-EES
5 Schema, Data base	June 21, 2014	Sept 18, 2014	Sept 19, 2014	$13,440	Sept 19, 2014	AI-EES
6 Solver App	Aug 25, 2014	Oct 2, 2014	Oct 7, 2014	$30,000	Oct 17, 2014	AI-EES
7 Engine Demand	Oct 8, 2014	Nov 28, 2014	Dec 4, 2014	$20,000	Dec 29, 2014	AI-EES
8 Engine Network	Dec 13, 2014	Feb 11, 2015	Feb 20, 2015	$30,000	Feb 28, 2015	BRID
9 Persistence Entity	Jan 4, 2015	Apr 29, 2015	May 22, 2015	$10,000	May 31, 2015	AI-EES
10 Servlets	Feb 5, 2015	May 20, 2015	June 26, 2015	$15,000	Jun 30, 2015	AI-EES
11 Network Simulator	Apr 1, 2015	May 20, 2015	June 26, 2015	$25,000	Jun 30, 2015	AI-EES
12 Phase 1 Testing	Apr 24, 2015	Dec 9, 2015	Dec 16, 2015	$10,720	Dec 18, 2015	AI-EES
13 Model Config	Jun 29, 2015	Sept 28, 2015	Sept 30, 2015	$30,000	Sept 30, 2015	AI-EES
14 Output & Reporting	Aug 12, 2015	Jan 11, 2016	Jan 22, 2016	$20,000	Jan 31, 2016	AIPA/AI-EES
15 Scenario Builder	Sep 24, 2015	Feb 10, 2016	Feb 26, 2016	$20,000	Mar 2, 2016	BRID
16 AAF IT Code Review		Jan 4, 2016	n/a	n/a	n/a	n/a
17 Phase 2 Testing	Nov 30, 2015	Feb 29, 2016	Mar 2, 2016	$23,440	Mar 2, 2016	AIPA/BRID
AIPA: Administration and Reporting			As Per Project Contract	$5,000		AIPA
TOTALS				$332,600		

<u>Source of Funds</u>

January 9, 2014	BRID	$15,000
May 13, 2014	BRID	$20,000
June 6, 2014	AI-EES	$129,000
March 5, 2015	BRID	$30,000
March 27, 2015	AI-EES	$71,000
March 4, 2016	BRID	$35,000

Interest on Account as of March 7, 2016 was $57.14. This amount is included in the sum amount received from AI-EES (below).

<u>Totals as of March 7, 2016</u>
Receipts $300,057.14: $200,057.14 AI-EES $100,000 BRID
Payments $332,600: WSP $327,600; AIPA $5,000

AI-EES committed up to $250,000 of which $50,000 was held back until the completion of the project. AIPA has covered the hold-back portion for deliverable completions that were invoiced by WSP and the administration/reporting amount of the contract due AIPA. The amount requested from the AI-EES $50,000 hold-back as a result of the project completion is $32,542.86 ($332,600 - $300,057.14).

Table 3. Budget Table from Contribution Agreement

Description (include task breakdown as appropriate)	Year 1	Year 2	Year 3
Capital			
Operating Materials & Supplies	$10,000 Cash		
Contractors & Key Vendors	$ 115,000 Cash	$ 215,000 Cash	
Personnel (Actual Salary & Benefits)	$ 150,000 (ARD) $ 20,000 (District)	$ 110,000 (ARD) $ 10,000 (District)	
Overhead (if any)	$ 4,000 Cash	$ 6,000 Cash	
Contingency (if any)			
Total	$ 129,000 Cash $ 170,000 IK $ 299,000 Total	$ 221,000 Cash $ 120,000 IK $ 341,000 Total	

Year 1 = April 2013 – March 2014, Year 2 = April 2014 – March 2015
$ are either "cash", or "IK" meaning in-kind contributions committed by participants

Appendix "1"

(See attached "Scope and Project Plan" document.)