

To: Bill Graham, Idaho Department of Water Resources

From: Carter Borden, DHI Inc.

Date: October 8, 2003

Subject: Upper Salmon River MIKE Basin Model (USRMBM)

Dear Mr. Graham:

This memorandum describes the initiative by the Idaho Department of Water Resources (IDWR) to develop a surface water budget model for the Upper Salmon River basin, Idaho. The purpose for developing the Upper Salmon River MIKE Basin Model (USRMBM) is to quantify and collectively represent sources and uses of streamflow throughout the Upper Salmon River system upstream of the Salmon River near Stanley, Idaho.

The model construction occurred from June to September 2003. During this period, IDWR and DHI, Inc. personnel worked quickly to build the river network, compile and populate the model with existing data, and identify data gaps. The result of this phase is a skeleton model with a defined network, data files ready for population with data, and customized supporting spreadsheet files for processing and loading data and aiding in the calibration of the model. A calibrated model was not possible at the conclusion of this phase due to insufficient stream and diversion flow data throughout the basin. The model will be able to evaluate diversion operations in the Upper Salmon River basin upon collection and incorporation of the stream and diversion flow data into the model, and once the model has been calibrated.

This memorandum provides an overview of the methods and data used in the construction of the model. Specifically, the memorandum includes:

- A brief description of the numerical model used for the demonstration
- Summaries of data and assumptions that went into the model setup
- Results from the modeling effort
- Data gaps to be filled
- Recommended studies to further refine the model.

As this report supplies a summary of the activities for the USRMBM, much of the background material for the modeling effort can be found in the attached document *Evaluation of Diversion Operation Plans to Meet Negotiated Flow Targets for Salmon and Steelhead in the Lemhi River Basin Using the MIKE Basin Model* (DHI 2003). For the Lemhi River, sufficient data was available to construct a calibrated surface water budget model. With data, the surface water model will be able to perform similar analyses in the Upper Salmon River basin

BACKGROUND

IDWR is charged with the management of the waters of Idaho. Management of the waters of Idaho involves accounting for the needs and desires of multiple interested parties for the same resource. In the Upper Salmon River Basin, IDWR must balance the needs of fish and wildlife versus the needs of the landusers. For fish and wildlife needs, two specific items that IDWR must consider are the FCRPS Biological Opinion Action 151 and the CBFWP Provision A-8. By the FCRPS Biological Opinion Action 151, BPA shall, in coordination with NMFS, experiment with innovative ways to increase tributary flows by, for example, establishing a water brokerage. By CBFWP PROVISION A-8, the Council recommends

that BPA establish a funding agreement for land and water acquisitions. The Council will establish a mechanism, including an advisory entity, which can act flexibly, quickly and responsibly in approving funding for land and water acquisition proposals.

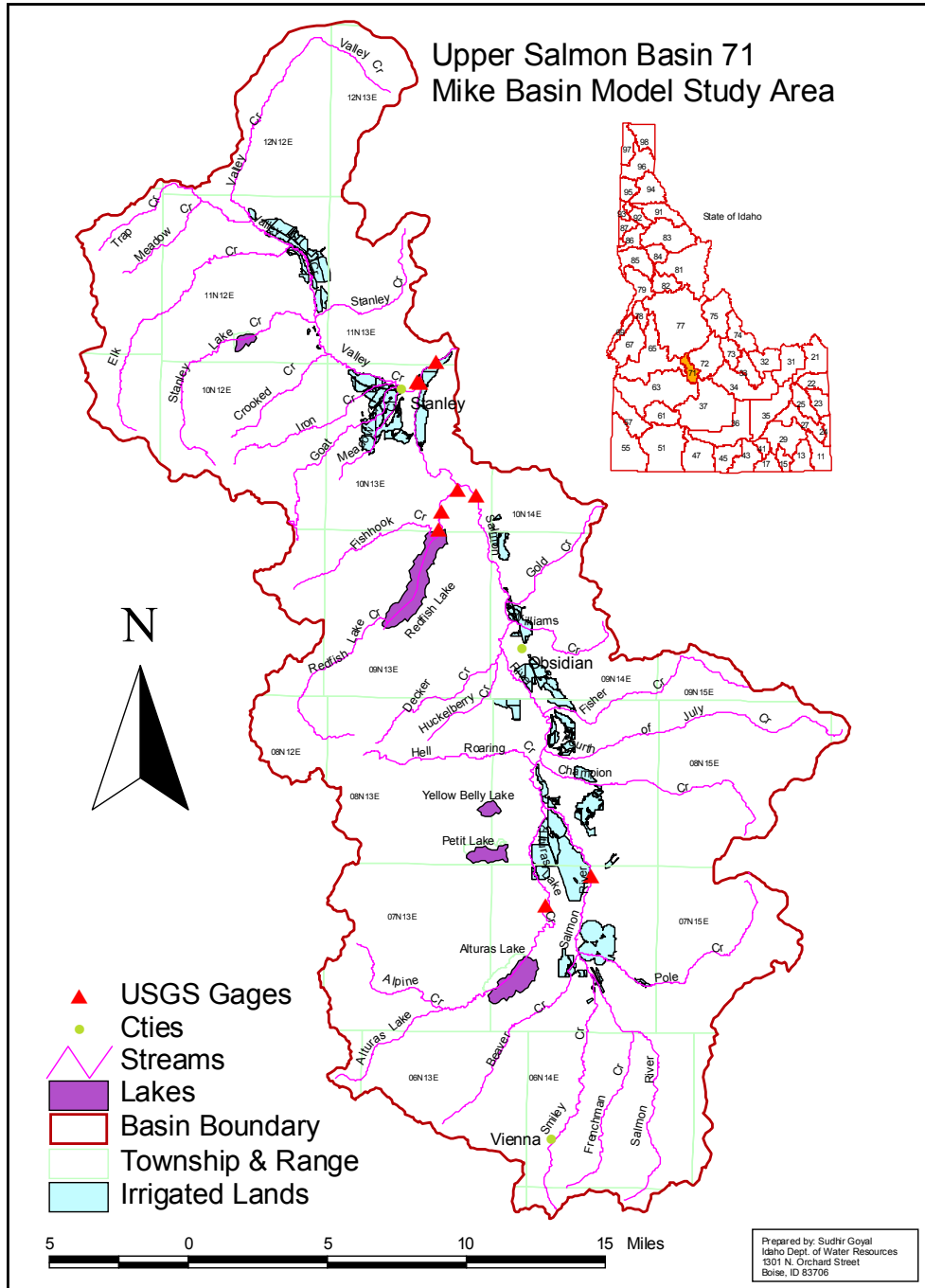


Figure 1. Upper Salmon River Basin #71. The study reach includes the Salmon River Basin upstream from Stanley, Idaho as well as Valley Creek, Elk Meadow Creek, Iron Creek, Goat Creek, Meadow Creek, Fisher Creek, Fourth of July Creek, Champion Creek, Pole Creek, Smiley Creek, and Beaver Creek.

Towards managing the waters with the multiple interests, IDWR is developing and using new technologies. They are employing GIS to assist with prioritizing watersheds. Towards understanding the water allocation and movement in basins, IDWR is using MIKE Basin: a surface water budget tool. IDWR will use MIKE Basin to:

- Evaluate watershed priorities
- Move forward with existing water transaction proposals
- Develop new water transactions with special focus on Basin 71.
- Implement monitoring and evaluation processes

MODEL USED: MIKE BASIN

MIKE Basin is an integrated water resource management and planning computer model that integrates a Geographic Information System (GIS) with water resource modeling (DHI 2003). This gives managers and stakeholders a framework within which they can address multisectoral allocation and environmental issues in a river basin. In general terms, MIKE Basin is a mathematical representation of the river basin, including the configuration of the main rivers and their tributaries, the hydrology of the basin in space and time, and existing as well as potential major water use schemes and their various demands for water.

MIKE Basin is a network model in which the rivers and their main tributaries are represented by a network of branches and nodes. Branches represent individual stream sections while the nodes represent confluences, diversions, locations where certain water activities may occur (municipal, industrial, reservoir, and hydropower water uses), or important locations where model results are required. The river system is represented in the model by a digitized river network that can be generated directly on the computer screen in ArcView 3.2 (a GIS software package). All information regarding the configuration of the flow simulation network, location of water users, reservoirs and intakes, and outlets of return flow are also defined by on-screen editing.

Basic model inputs are time series data for catchment run-off, diversion, and allocation of water for the off-river nodes. Catchment runoff can be specific runoff data or gage data. Diversion nodes require either a time series of water allocation to each branch or an equation partitioning flow to each branch based on incoming flows to the diversion node. Irrigation nodes require time series data for demand, fraction of the demand satisfied by ground water, fraction of the demand returning to the river branch, and lag time for the return fraction to re-enter the stream. Water demand can be specified directly from an input time series or indirectly from agricultural use information.

Once the water usage has been defined, the model simulates the performance of the overall system by applying a water mass balance method at every node. The simulation takes into account the water allocation to multiple usages from individual extraction points throughout the system. Results from the model can be viewed as:

- A time series or monthly summary in graphic or tabular form.
- A map of visualized groups of results for the entire or any specified part of the model network in the ArcView Graphical User Interface (GUI). Map views can be stepped through time to generate animation files. The GUI can help create graduated color result presentations for many combinations of results. Several result groups can be animated simultaneously (e.g. flow in the mainstem of the stream and extractions by users). Animations can be saved as a Windows movie (*.avi file) and imported into PowerPoint presentations.
- Model results stored in a database that can be queried using Microsoft Access. The user can create programs in Microsoft Access to automatically generate reports to display results.

MIKE Basin has additional capabilities, including the ability to simulate municipal, industrial, reservoir, and hydropower water users; apply priorities to water distribution; simulate ground water use; and simulate transport and degradation of substances affecting water quality in rivers and reservoirs. Water quality substances that MIKE Basin simulates include ammonia/ammonium, nitrate, oxygen, total phosphorus, and organic matter. Organic matter is represented in terms of biological oxygen demand and chemical oxygen demand. A more complete description of the capabilities and applications of MIKE Basin can be found at <http://www.dhisoftware.com/mikebasin/>.

UPPER SALMON RIVER MIKE BASIN MODELING

Developing the skeleton model of the USRMBM involved building the river network; compiling, formatting, and inputting the available data; and developing customized MS-Excel spreadsheets. The model network has the following criteria:

- USRMBM encompasses the Upper Salmon River upstream from Stanley, Idaho as well as selected tributaries including Valley Creek, Elk Meadow Creek, Iron Creek, Goat Creek, Meadow Creek, Fisher Creek, Fourth of July Creek, Champion Creek, Pole Creek, Smiley Creek, and Beaver Creek.
- Model simulations are run on a daily time step from 63 offtake nodes along the Upper Salmon River and its tributaries and 66 irrigation nodes (representing the irrigated area associated with the offtake nodes).
- Multiple irrigation nodes are used on several diversions (VC-5-6, FJC-3, PC-1, BC-0, and BC-0A) where water is applied in several distinct locations and the water allocation to those separate fields has been determined.
- Return locations for each irrigation node represent the downstream location where the majority of the return fraction is believed to have returned to the Upper Salmon River and its tributaries.
- Catchment nodes at upstream end of the Upper Salmon River and selected tributaries represent direct flow input into the model.
- Catchment nodes at the USGS Valley Creek stream gage at Stanley, Idaho represent a point where reach gains/losses can be incorporated.
- A MS-Excel spreadsheet calculator was used to determine the return fraction parameter for a irrigation node.

The following section describes the construction methods, data availability, and assumptions for the USRMBM.

Network Setup

Information contained in the river network was compiled from GIS coverages, aerial photographs, IDWR GIS shapefile for point of diversion (POD) and point of use (POU) locations, and USGS gaging station locations. The planar course of the Upper Salmon River and selected tributaries were digitized in ArcView from aerial photographs. The locations of the 63 offtake nodes were determined by IDWR's POD GIS shapefile. The 66 irrigation nodes, representing the irrigated area associated with each offtake node, were determined by linking the water right identification number in both IDWR's POD and POU GIS shapefiles. Mark Moulton, hydrologist for the Sawtooth National Recreational Area (SNRA), Allen Merrit (IDWR), and Kelly Christiansen (IDWR), were instrumental in establishing the model network and verifying that this information represented actual field conditions.

The mainstem course of the Upper Salmon River and selected tributaries were digitized using aerial photographs. Tributaries in the USRMBM include Valley Creek, Elk Meadow Creek, Iron Creek, Goat Creek, Meadow Creek, Fisher Creek, Fourth of July Creek, Champion Creek, Pole Creek, Smiley Creek,

and Beaver Creek. For the mainstem Salmon River and tributaries, 63 offtake nodes (diversions) were digitized from IDWR's POD shapefile. Sixty-six irrigation nodes, representing the irrigated area associated with each offtake node, were linked determined by linking the water right id in the IDWR's POU and POD shapefile and confirmed by Mark Moulton and Allen Merritt.

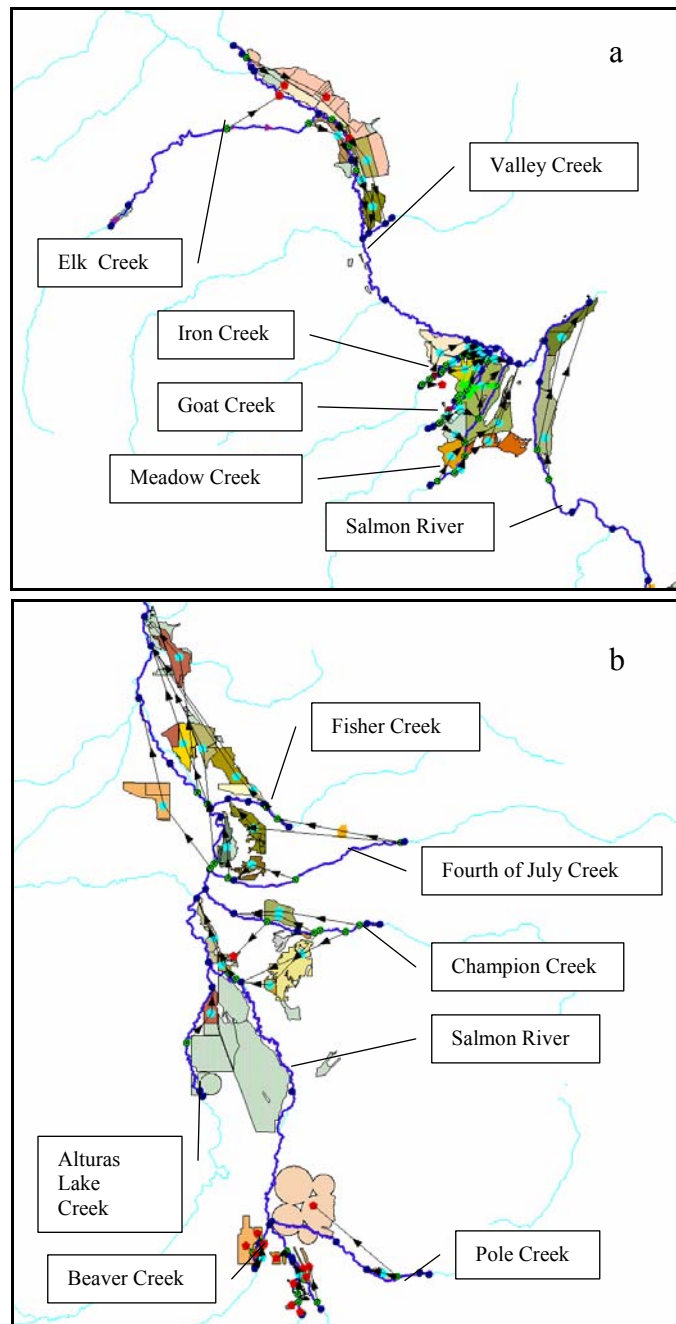


Figure 2a&b. Northern (a) and southern (b) portions of the USRMBM network. Green circles represent offtake nodes (diversion locations), blue circles represent general computational nodes, light blue and red pentagons represent irrigation nodes, thick blue lines represent creeks, thin black and green lines represent connections between the river and the irrigation nodes, and the colored polygons represent places of use. Note, the thin black and green lines do not follow the exact path of diversions ditches.

For most offtake nodes (diversions), multiple irrigators share the diverted water throughout the irrigation season. In the USRMBM, all irrigators using water from an offtake node are represented by a single irrigation node because the water is being applied to fields in the same general area; further, the authors are unaware of any records identifying location and timing of flood irrigation application within an irrigation area during the study period.

For five offtake nodes (diversions VC-5-6, FJC-3, PC-1, BC-0, and BC-0A) water is applied in several distinct locations. Water allocation to those separate fields served by each diversion was determined and multiple irrigation nodes were associated with respective offtake nodes. For BC-0, and BC-0A, water is diverted to POUs on either side of Beaver Creek and thus all water being diverted is assumed to flow to only one of the two irrigation nodes at any one time. If future analysis requires refinement of water allocation within these or other irrigation areas, then the USRMBM can easily be reconfigured to incorporate additional data and improved knowledge about the system.

For Iron, Goat, and Meadow Creeks, many point of diversions point to several large places of use that spans across creeks (Figure 3). At the completion of this phase of the project, partitioning of the large place of use to associated the point of diversions was not possible without further investigation. Since neither Goat Creek nor Meadow Creek were tributaries of primary interest in the study, no further analysis was conducted. If future analysis requires greater knowledge of water allocation with these creeks, then the USRMBM can easily be adapted to account for the greater complexity.

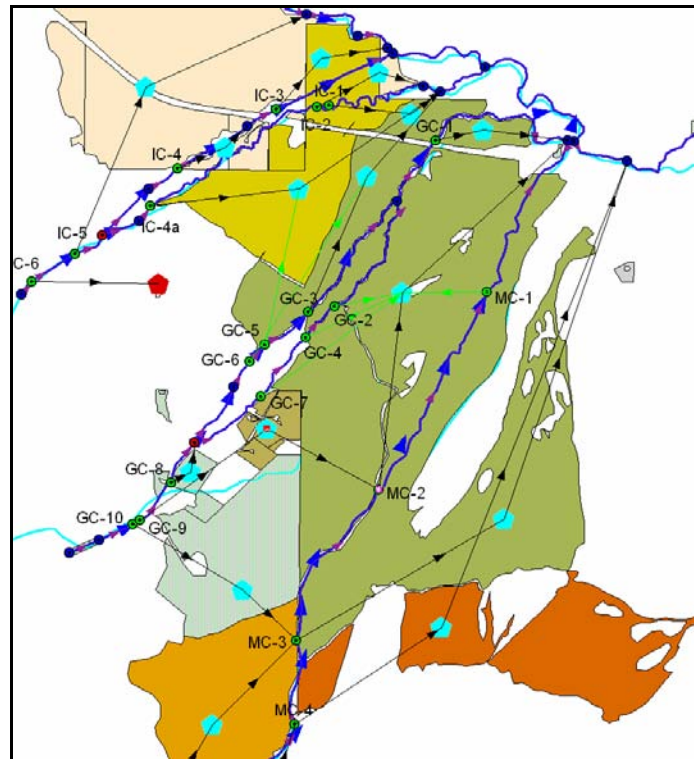


Figure 3. USRMBM setup for Iron, Goat, and Meadow Creeks. Green circles represent offtake nodes (diversion locations), blue circles represent general computational nodes, light blue and red pentagons represent irrigation nodes, thick blue lines represent creeks, thin black and green lines represent connections between the river and the irrigation nodes, and the colored polygons represent places of use. Note, the thin black and green lines do not follow the exact path of diversions ditches. The diversion labels IC-#, GC-#, and MC-# refer to Iron, Goat, and Meadow Creeks, respectively.

Exact location, timing, and quantity of return flows are a function of flood irrigation practices and the physical conditions of the irrigated area. In many cases, irrigation returns re-enter the river through surface and subsurface paths that are disseminated along reaches bordering the irrigated fields. In the USRMBM, return flow nodes were associated with respective irrigation nodes and were located at a downstream point along the Upper Salmon River or the selected tributaries where the majority of the return flow was considered to return. Diverted water that is not lost to evapotranspiration and does not re-enter the stream by the return node enters either the intermediate ground water system (IGW) or the regional ground water system (RGW). The IGW system returns to the stream within the study reach; the RGW system contains water assumed no longer to interact with the surface water river system and, consequently, is no longer tracked with the USRMBM simulation model.

To provide unique identities to offtake nodes (representing PODs) and irrigation nodes (representing POU), labels were attached to each for easing recognition in the USRMBM, naming time series files, and labeling for the MS-Excel interfaces. Offtake node labeling was a modified combination of the SNRA (Moulton personal communication 2003) and IDFG (Sharon Merritt, personal communication 2003) nomenclature. Labels along the mainstem Salmon River are labeled S-39 through S-47. Format for the diversion labels on tributaries are the first letters in the tributary name followed by a number. Numbers generally start with 1 for the diversion nearest the confluence with the mainstem Salmon River and increase upstream. For example, diversions along Meadow Creek are denoted MC-1, MC-2, MC-3, and MC-4 (Figure 3). Exceptions to the naming convention are VC-5-6, BC-0, BC-0A, which were taken from the SNRA labels.

Catchment nodes are placed in locations where water is gained or lost directly to the river system. For the USRMBM, catchment nodes were placed at the upstream end of the Upper Salmon River and the select tributaries. In addition, catchment nodes were placed at the USGS gage at Valley Creek near Stanley, Idaho. These gages will be used to calculate the reach gains that represent precipitation, tributary underflow, and other components that are not explicitly included in the model and were assumed to represent residual between simulated and observed streamflow measurements at a gauging station.

Time Series Input Data

In MIKE Basin, the movement of water into and out from the river system is specified with time series data. Catchment and irrigation nodes require time series data in the USRMBM. Catchment nodes represent stream inflow and reach gains and losses. Time series input information is required for the 66 irrigation nodes to define irrigation demand, ground water fraction (fraction of demand satisfied by ground water), return fraction (fraction of demanded water that returns to the stream at specified return locations), and lag time (the linear routing of return flow from the irrigated fields back to the river).

At the completion of the first phase, only a subset of the required data was available. However, all time series files necessary for the USRMBM have been developed and many are linked to MS-Excel spreadsheet that automates loading data. The following section describes the available and missing data for the catchment and irrigation node time series data set required.

Catchment Nodes

Catchment runoff - represents locations in the model where water is introduced directly to the stream system. For the USRMBM, this is the upstream end of the tributaries and at gauging stations. In the USRMBM, limited time series input information from streamflow gauging station records is available. Currently, only one active long-term gauging station is located within the Upper Salmon Basin at Valley Creek (period of record 1911-present) near Stanley, Idaho.

To estimate the streamflow at each catchment node for the coarse model, the USGS method for estimating monthly discharge rates in ungauged basins was used (Hortness and Berenbrock 2001). The method uses a regression curve based on drainage area, slope, percentage of slopes greater than 30%, and percentage of forested vegetation to determine a mean monthly discharge.

During the 2003 summer field season, the USGS deployed stream gages upstream of diversions on Fourth of July Creek, Pole Creek, Upper Valley Creek, Elk Creek, and Upper Salmon River as part of biological studies (Maret, personal communication, 2003). Except for the Elk Creek stream gage, the stream gages will remain in place for the 2004 summer field season. Additional stream gages will be placed on Smiley Creek, Beaver Creek, Champion Creek, Iron Creek (replacing the Elk Creek gage), and the Salmon River between Smiley and Beaver Creeks. These will be incorporated into the USRMBM upon release of the results by the USGS.

The next phase of the USRMBM will involve rainfall-runoff modeling to estimate streamflow in the ungauged tributaries. This will have the added benefit of allowing users to examine different climatic conditions when studying water distributions throughout the basin.

Reach gains/losses - account for contributions to the Upper Salmon River from precipitation, ground water gains/losses, and tributary inflow. In the USRMBM, the reach gains/losses are the difference between the observed and simulated conditions for each time step during the simulation period. The authors are not aware of any data that provide information related to these contributions in the same temporal and spatial resolution of the USRMBM. At the completion of this phase, adjustments in the reach gains/losses remained uncalibrated.

Irrigation Nodes

Irrigation Demand - Daily diversion data was unavailable at the completion of the modeling effort. Therefore, to provide a coarse demonstration of the system, the water right discharge specified in IDWR's POU GIS coverages was routed for the entire irrigation season. According to Allen Merritt, the common operation of diversions is to turn on in late April through May and continually divert water throughout the remainder of the irrigation season (Merritt, personal communication 2003).

For offtake nodes (diversions) VC-5-6, FJC-3, and PC-1, where water is diverted to multiple locations, the demand quantity was split according to the relative percentage of the area. For offtake nodes BC-0 and BC-0A, where water is routed to either side of the Beaver Creek, the full amount of water routed to one irrigation node at any time step. For the coarse demonstration, the diverted water for BC-0 and BC-0A was alternated to each side weekly for the duration of the study area.

Ground Water Fraction - ground water is not used to augment irrigation in this portion of the Upper Salmon River basin. This value in all irrigation nodes was set at zero.

Return Fraction - The quantity of water returning to the system at the downstream return node is a function of antecedent soil moisture, initial ground water levels, crops irrigated, irrigated area, evapotranspiration rates, distance from the river, ditch loss, and the portion of the infiltrated water that seeps into the intermediate ground water system. The IGW system for these calculations represents the portion of the diverted water that will infiltrate to the subsurface but is not expected to return to the Upper Salmon River and selected tributaries, in this particular model, until the next downstream gauging station node.

For the USRMBM, a return fraction calculator was developed in Microsoft Excel to assimilate these factors and compute the return fraction on a daily time step. The return fraction calculator equation is:

$$RF = Demand * DL * IGW_{DL} + (Demand + ER * \sum_{i=1}^n A_{CT} - DL - (\sum_{CT=1}^n (ET_{CT} * A_{CTS}))) * IGW_{IS} + (\sum_{CT=1}^n (ET_{CT} * A_{CTF})) * IGW_{IF}$$

RF is the return fraction.

Demand is the diverted water.

DL is the fraction of the demand that is lost to ditch loss.

CT denotes the crop type (pasture, grass hay, and alfalfa hay in the Lemhi River basin); in this equation, this value is constant.

ET_{CT} is the evapotranspiration associated with the crop type.

A_{CTS} is the irrigated area for a crop type for sprinkler irrigation; here, this value is constant.

A_{CTF} is the irrigated area for a crop type for flood irrigation; in this equation, this value is constant.

ER is the effective rain.

n is the number of crop types.

The variables *IGW_{DL}*, *IGW_{IS}*, and *IGW_{IF}* are the portions of the infiltrated flow from ditch loss, sprinkler, and flood irrigation that enter the IGW.

The return fraction equation is simply the mass balance of the water entering an irrigation node. Irrigated area was calculated from the diversion coverage provided by IDWR. The crop type was assumed to be pasture for all irrigation nodes in the study basin (Moulton, personal communication, 2003). For fields irrigated with sprinklers, sprinkler rates were assumed to be 0.75 inches per day per acre (Sager, personal communication, 2003).

To determine the irrigated areas (*A_{CT}*) associated with each diversion, the POD and POU GIS shapefiles developed as part of the Snake River Basin Adjudication were linked by water right number. Assignment of the place of use areas of each water right to a point of diversion was confirmed by Allen Merritt.

Most individual points of diversion serve several places of use. For modeling purposes, multiple places of use associated with an individual point of diversion were aggregated. Precipitation, evapotranspiration, amount of water applied, losses to ground water, etc., were determined for each aggregate polygon. Because some lands receive water from multiple diversions, some polygons overlapped in small areas. For each overlap instance, the area was assigned to only one point of diversion.

Evapotranspiration (*ET*) can be determined by using either the Allen-Brockway (A-B) method, Agrimet stations, or SEBAL data. There is no Agrimet station data available for the Basin 71 study area. For the A-B method, we used the reference ET, crop coefficient, and calibration coefficients given in A-B method for Basin 71 area. Temperature data from Stanley weather station was used in the calculation. This data has been included in the course demonstration.

SEBAL (the Surface Energy Balance Algorithm for Land) was also considered to determine ET rates for the Basin 71 study area for 2003 irrigation season. One image for each month for the irrigation season (June – October) was processed and used to extrapolate daily ET data using Stanley weather station data. The SEBAL method, which uses LANDSAT images, gives better spatial variability than A-B and Agrimet based ET and its temporal variability is derived by utilizing weather station data. SEBAL does not work for the image scenes covered by clouds. The SEBAL ET data would be used for water budget calculations in the next phase of this study when more satellite images, the refined place of use (POU) coverage, and diversion data would be available.

Conveyance loss (*DL*) is the loss of water during transport from the point of diversion (at the source) to the on-farm places of use. Water is lost through seepage through the soil, leakage through headgates and other structures, evaporation from the water surface, and transpiration from plants growing in or near the

channel. For the soil loss, a calculator was developed to implement the Worstell method seepage loss estimation (Hubble 1991), a method commonly used by IDWR. This method requires an estimation of the soils seepage rate, measurement of the top width of the water surface at various points along the canal, and the canal length. The estimated seepage loss is multiplied by the canal length (miles) to determine the canal's total conveyance loss. Tables in the *Guidelines for the Evaluation of Irrigation Diversion Rates* (Hubble 1991) are useful in determining soil textures and the appropriate seepage rates. For the coarse demonstration, ditch loss was not calculated.

The intermediate ground water portion (IGW) of the *return fraction* is difficult to measure and thus is a parameter used for calibration in the USRMBM. For the coarse demonstration, the IGW value for all irrigation nodes was 0.10.

Lag Time - Timing of return flows from irrigated lands to the Upper Salmon River and selected tributaries depends on the irrigated field's location in relation to the closest water, the degree of channel surface flow returns, and ground water flow direction and rate. In MIKE Basin, delayed return flow is described using a linear reservoir equation (DHI 2003). The MIKE Basin user can specify the lag time to control the timing of the return fraction. In the USRMBM, lag times are expected to vary for each irrigation node and will be used to calibrate the model. For the coarse demonstration, the lag time for all irrigation was 7.

Microsoft Excel Interface

To expedite the processing, formatting, and entering of data into the model, as well as the calibration and running of scenarios, DHI personnel developed a series of Microsoft Excel files and associated macros that interface with the USRMBM. These files and macros provided a more user-friendly platform and helped automate repetitive tasks, organize the data, and prevent errors in data handling. Two important Microsoft Excel files include:

- **USRMBMDivInput.xls** – Organizes the input data for all the irrigation nodes. It contains the daily values for the parameters required by irrigation nodes: demand, ground water fraction, return fraction, and lag time. This workbook contains the return flow calculator and macros that automatically load the data into the proper USRMBM input files. This workbook should be used when running scenarios where diversion schemes are altered and need to be loaded into the USRMBM. A summary table of all the parameters for each diversion can be generated using a macro.
- **USRMBMCatchmentInput.xls** – Organizes the input data for all the catchment nodes. It contains the daily stream flow values for the inflow locations in the system. Stream data can be pasted into the Excel file so that macros automatically load the data into the appropriate MIKE Basin time series files.
- **USRMBMCalib.xls** – Helps calibrate the model. The files run repetitive MIKE Basin simulations for calibration, load results from previous simulations for viewing, load the results into the comparative analysis with the 1999 Upper Salmon River and its tributaries seepage run, and calculate reach gains used in the first calibration effort for the USRMBM. Macros drive all the tasks except for the reach gain calculations. Note that one base MIKE Basin simulation must be run from the ArcView GUI before additional simulations can be run directly from within Microsoft Excel.

COARSE DEMONSTRATION OF THE USRMBM

A course demonstration of the USRMBM was created for public demonstration purposes and to ensure the model was correctly constructed. At this phase, the USRMBM is missing required times series data and remains uncalibrated. Except for conceptual demonstration, no results should be used from the model until

the proper data has been input and the USRMBM calibrated. The course demonstration can be used to demonstrate the capabilities of the model and is a repository for the current data available.

RECOMMENDATIONS FOR FURTHER DEVELOPMENT OF THE USRMBM

Though IDWR and DHI personnel completed the initial phase of the USRMBM, additional analysis and data collection are required to develop a calibrated model. These recommendations do not reflect any additional data and analysis that may be required to address specific question posed to the model in the future. However, implementing these recommendations will provide greater insight into water movement in the Upper Salmon River and its tributaries basin, and thus can provide a greater foundation for the USRMBM.

Data Collection

The quantity and location of data collection will be a function of time, budget, and the questions users would like to address using the USRMBM. As the limiting element in the calibration of the USRMBM is the stream flow and diversion discharge time series information, these are of utmost importance for development of the model. Specific data needs are:

- *Daily inflow rates for all the tributaries* - At the completion of the first phase, no data exists for any of the tributaries in the study area. Inflow quantities were approximated using the USGS regression equations for estimating monthly discharge in ungauged basins in Idaho (Hortness and Berenbrocks 2001). During the 2003 summer field season, the USGS collected tributary inflow on five of the tributaries in the USRMBM. The USGS will continue to monitor four of the five tributaries and add four more in the 2004 summer field season. While this data will provide a good foundation for developing inflow time series data, these are temporary gauges and will not provide long-term data records. If permanent gauges cannot be established on all the tributaries, a method must be devised that combines gauging streams inflows on select tributaries with statistical means of extrapolating the record to other basins. The select gauges should be focused on streams deemed most significant to the study.
- *Stream gauging upstream and downstream of sensitive areas* –The USRMBM does not account for contributions to the Upper Salmon River from precipitation, ground water gains/losses, and tributary inflow. Therefore, to determine the absolute quantity of water in the river throughout the system, the model must be “updated” by using observed flow in the stream: The difference between the observed and simulated results is the reach gains/losses. To obtain the observed values, stream gauging is necessary.

At the completion of the first phase, only the USGS gauge on Valley Creek at Stanley, Idaho was operational and permanent. It is recommended that stream gauges be placed upstream of any sensitive area in order to insure that the model simulated the correct discharge in the river when diversion operations are being evaluated. For the USRMBM, this implies that the primary tributaries of concern be monitored as well as a gauge near the upstream end of the Buster Back ranch along the Upper Salmon River (This section of the river has been known to dry out during summer months and provide a migration barrier for fish).

- *Daily diversion discharge* – Operation of the diversions significantly influences flow in the Upper Salmon River and select tributaries. To quantify the influence of diversions, daily measurements of discharge should be made. The discharge can be measured directly using a structural measuring device, such as a weir or flume, or indirectly by measuring water level from a staff gauge or measured with a pressure transducer. If the water level is obtained, a stage-discharge rating curve

is necessary to convert the stage records to discharge. In the Lemhi Basin, the stage reading are collected daily by the screen tenders.

Modeling

The primary modeling tasks are populating the USRMBM with data and calibrating the model. Calibration involves adjusting the lag times and IGW values to attempt to match the simulated and observed water discharges. The MS-Excel file *USRMBMCalib.xls* has been developed to aid in this process. As part of the USGS 2003 summer field studies, discharge measurements were collected along the channel and at the points of diversion. These will provide a valuable data set for calibration of the lag time and IGW parameters.

The secondary modeling task is to refine the model network around the Iron, Goat, and Meadow Creeks. Currently, water movement within this area is poorly understood due to the complexity of canals and diversion. At the onset of the first phase, these tributaries were deemed less important than other tributaries in the basin. If these tributaries become important to simulate on a more refined scale, additional analysis will have to be conducted and the results implemented in the USRMBM.

Additional Analysis

Analysis not crucial to development of a calibrated model, but would increase the understanding of water movement in the basin is studies of precipitation, seepage runs, and ground water.

Precipitation analysis – Currently precipitation will be incorporated into the USRMBM as reach gains. However, early in the irrigation season when large frontal storms enter the basin, stream flow may be influenced. There are four weather stations in the Basin: Horton Peak, Banner Submit, Vienna Mine, and Stanley. Except Stanley, the stations are located at higher elevations in mountains and do not represent the precipitation on agricultural lands, which is mostly located in the valley at lower elevations. We would use daily precipitation data of the Stanley weather station in our future computations of water balance and ET. In the next phase of this study, we would use higher elevation weather station data in the rainfall-runoff package of MIKE Basin to determine flows in the ungedged streams of the basin.

Seepage Run - A concurrent seepage run and simulation would provide greater foundation for calibrating and refining the USRMBM. Seepage runs are recommended at the onset of the irrigation season when the Upper Salmon River and its tributaries becomes reduced and again late in the irrigation season.

Ground Water - Ground water levels and return periods are important in dictating the instream flows during the spring runoff period and late summer and early fall when the snowmelt contribution is negligible. In the USRMBM, the parameters most affected by the ground water-surface water interaction are the initial abstraction early in the irrigation season and IGW lag time later in the irrigation season. Further analysis of ground water well hydrographs, sensitivity of the initial abstraction duration and magnitude, and IGW lag time would improve the model representation of the natural system. Coupling these analyses with field study, such as seepage runs or piezometer studies, could further improve the understanding of ground water behavior in the Upper Salmon River and its tributaries basin.

CONCLUSIONS

From June until September 2003, IDWR and DHI personnel completed the first phase in the surface water budget model development for the Upper Salmon River, Idaho. The surface water budget model is developed in MIKE Basin, a river network model that is based on an ArcView platform. In general terms, MIKE Basin is a mathematical representation of the river basin encompassing the configuration of the main

rivers and their tributaries, the hydrology of the basin in space and time, and existing as well as potential major water use schemes and their various demands for water.

The completed first phase in the USRMBM development has resulted in a skeleton surface water budget model and Microsoft Excel interface. The primary limiting factors in the development of a calibrated model are the streamflow and diversion time series data. Once collected, MS-Excel interfaces allow users to automate loading of time series data and expedite calibration of the model.

Upon calibration, this tool will enable the user to evaluate operation plans by viewing the simulation results with a GIS background that can show the river, points of diversion and return flows, irrigation canals, and canal service areas superimposed on aerial photography of the area. Several Microsoft Excel interfaces were developed to facilitate input and output operations to the USRMBM. These interfaces also allow users, having little operational knowledge of MIKE Basin, to run scenarios from Microsoft Excel interfaces and to use MIKE Basin as the computational kernel instead of having to interact directly with MIKE Basin.

Developing the skeleton USRMBM involved building the river network and compiling, computing, formatting, and inputting the data. The river network configuration primarily reflects Allen Merrit's and Mark Moultons's knowledge of the Upper Salmon River and its tributaries. The USRMBM encompasses the Upper Salmon River upstream from Stanley, Idaho and selected tributaries within the basin. Select tributaries include Valley Creek, Elk Meadow Creek, Iron Creek, Goat Creek, Meadow Creek, Fisher Creek, Fourth of July Creek, Champion Creek, Pole Creek, Smiley Creek, and Beaver Creek.

The model network has 63 offtake nodes along the Upper Salmon River and its tributaries and 66 irrigation nodes (representing the irrigated area associated with the offtake nodes). Multiple irrigation nodes are used on several offtake nodes (diversions VC-5-6, FJC-3, PC-1, BC-0, and BC-0A) where water is applied in several distinct locations and the water allocation to those separate fields has been determined. Return locations for each irrigation node represent the downstream location where the majority of the return fraction is believed to have returned to the Upper Salmon River and select tributaries. Catchment nodes at the upstream end of the Upper Salmon River and selected tributaries represent direct flow input into the model.

Model data required includes stream gage records; daily discharge data for each diversion; and irrigated area, ET rates, crop type, and area serviced by sprinkler irrigation within each irrigated area. At the completion of the first phase of the USRMBM development, insufficient time series data existed to develop a calibrated model. For the course model development, catchment inflow was estimated using the methods developed by the USGS for ungaged basins (Hortness and Berenbrock 2001) and daily diversion rates were estimated from the water rights in the IDWR records. To calculate the quantity of return flow, a calculator was developed in Microsoft Excel to determine the daily return rate to the river system based on ET rate, irrigated area, crop type, ditch loss, sprinkled area, and loss to the intermediate ground water system. Microsoft Excel sheets were developed to augment data processing, data population into the time series files that support MIKE Basin, calibration of the USRMBM, and analysis of alternatives.

Though IDWR and DHI personnel worked quickly to complete the first phase in the USRMBM development, additional analysis and data collection are needed to develop a fully calibrated model. Further data collection for stream and diversion flow is essential to accurately quantify water movement throughout the basin. Areas of concern where data is limited or poorly understood should receive additional streamflow measurements.

The USRMBM is a dynamic model that can be refined and expanded as data becomes available and as new questions are identified. The USRMBM's first phase of development was intended to establish a skeleton

surface water budget model that could later be populated with data to demonstrate how the Upper Salmon River and its tributaries system can be operated to meet streamflow targets. With data and further analysis, the USRMBM can be used to develop irrigation operations for later in the irrigation season.

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