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To: Bill Graham, Idaho Department of Water Resources

From: Scott King and Carter Borden, DHI Inc.

Date: September 30, 2004

Subject: Pahsimeroi River MIKE Basin Model

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 Pahsimeroi River Basin, Idaho. The purpose for developing the Pahsimeroi River MIKE Basin Model (PRMBM) is to quantify and collectively represent significant sources and uses of streamflow throughout the Pahsimeroi River system upstream of its confluence with the Salmon River near Ellis, Idaho.

The model construction occurred from July to September 2004. During this period, IDWR and DHI, Inc. personnel developed the river network, compiled and populated the model with existing data, and identified 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 is 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 Pahsimeroi 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 PRMBM, much of the background material for the modeling effort can be found in *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 sufficient data, the PRMBM may be expected to perform similar analyses in the Pahsimeroi River Basin.

The National Fish and Wildlife Foundation is acknowledged and appreciated for funding this project. Appreciation is also expressed for the assistance of several individuals, including Bill Graham, Sudhir Goyal, and Roxanne Brown from IDWR. In addition, Jim Martiny, Pahsimeroi River Watermaster, and Bob Loucks, IDWR contractor, provided extremely valuable insight into the use and delivery of water within the Pahsimeroi 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 increasingly many areas, IDWR must balance the needs of fish and wildlife versus the needs of land users. 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.

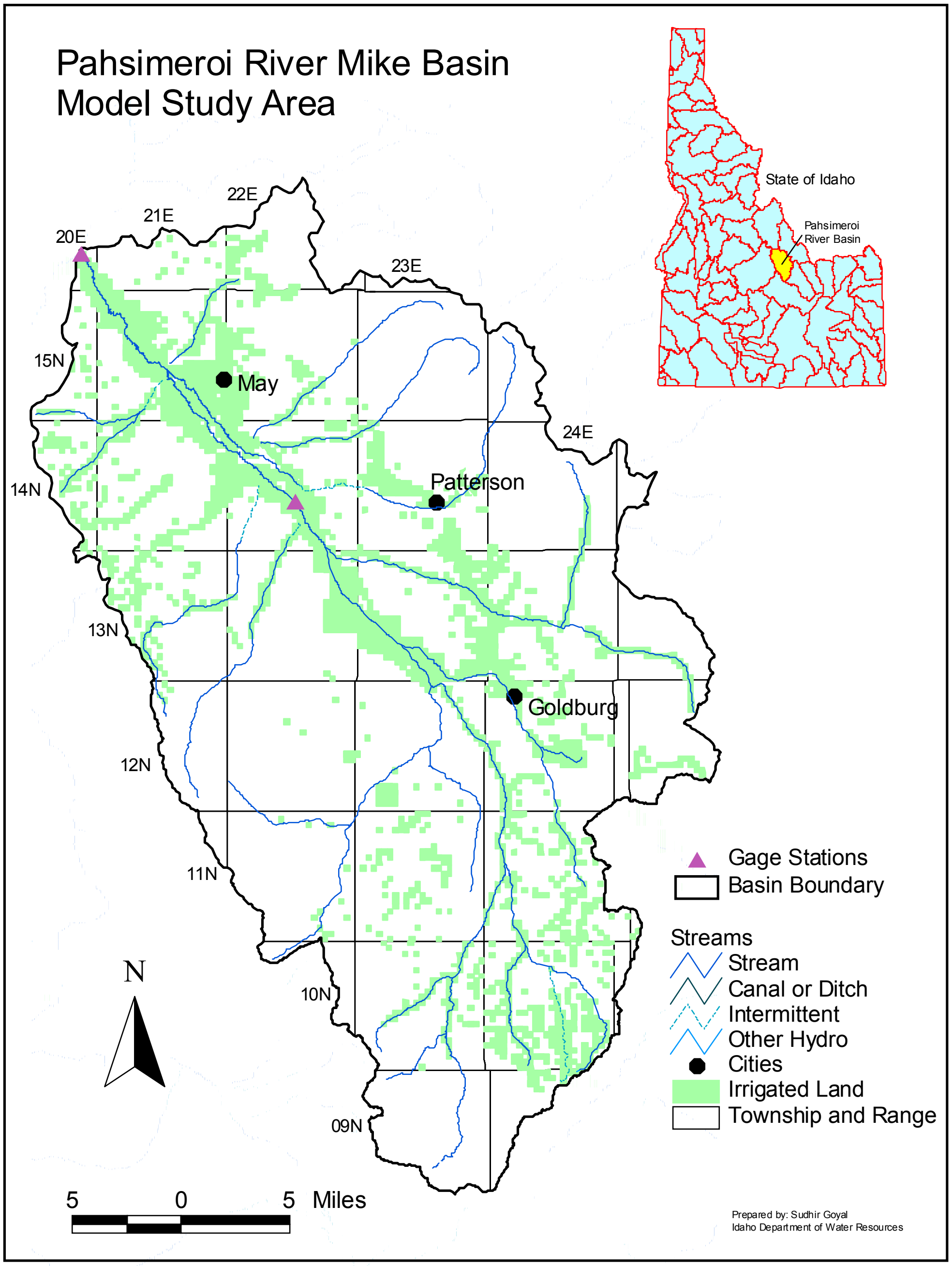

Figure 1. Pahsimeroi River Basin #73. The study reach includes the Pahsimeroi River upstream from Ellis, Idaho as well as Big, Big Springs, Falls, Goldburg, Morgan, Morse, Patterson, & Sulphur Creeks.

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 may use MIKE Basin to:

- Evaluate watershed priorities
- Move forward with existing water transaction proposals
- Develop new water transactions with special focus on Basin 73
- Implement monitoring and evaluation processes
- Improve communication within the department and with the public regarding water movement and use within Basin 73
- Achieve more efficient delivery and regulation of water rights within the basin

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.x (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 constituents 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/.

PAHSIMEROI RIVER MIKE BASIN MODELING

Developing the skeleton model of the PRMBM 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:

- PRMBM encompasses the Pahsimeroi River from its confluence with Burnt Creek near Goldburg to its confluence with the Salmon River at Ellis, Idaho as well as selected tributaries including Big, Big Springs, Falls, Goldburg, Morgan, Morse, Patterson, & Sulphur Creeks.
- Model simulations are run on a daily time step from 55 offtake nodes along the Pahsimeroi River and its tributaries and 56 irrigation nodes (representing about 25,900 acres of irrigated area associated with the offtake nodes).
- Generally, one diversion node is connected to one irrigation node, and the irrigation node represents an irrigation scheme, often a group of fields irrigated from the same diversion. However, some diversion nodes have connected to them multiple irrigation nodes (e.g. P-05, P-07, P-09, P-11, & PBSC-07) where water is applied to more than one distinct location and where return flows are expected to enter at significantly different locations.
- Return locations for each irrigation node represent the downstream location where the majority of the return fraction is expected to have returned to the Pahsimeroi River and its tributaries.
- Catchment nodes at upstream network boundaries of the Pahsimeroi River and selected tributaries represent direct flow input into the model. In addition, catchment nodes are also inserted along the Pahsimeroi River to represent gaining reaches.
- Catchment nodes at the USGS Pahsimeroi River stream gage near its confluence with the Salmon River at Ellis, Idaho, and the gage at Furey Lane represent points where reach gains/losses can be incorporated.
- A MS-Excel spreadsheet calculator is used to determine the return fraction parameter for an irrigation node. In addition, this spreadsheet allows for simple upload of time series records, such as gage readings, into the model.

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

Network Setup

Information contained in the river network was compiled from GIS coverages, aerial photographs (primarily from two sources including 2003 SPOT satellite imagery and 1992 DOQQs), IDWR GIS shapefile for point of diversion (POD) and place of use (POU) locations, GPS point of diversion locations acquired by BLM, IDWR, and other sources, and USGS gaging station locations. The planar course of the Pahsimeroi River and selected tributaries is based on 1:24,000 scale NED GIS shapefile provided by IDWR, with minor modifications to better represent actual conditions. Selected tributaries in the PRMBM include Big, Big Springs, Falls, Goldburg, Morgan, Morse, Patterson, & Sulphur Creeks.

The locations of the 55 offtake nodes were determined primarily with a combination of GPS point locations, IDWR's POD GIS shapefile, image interpretation, and watermaster knowledge. The 56 irrigation nodes, representing the irrigated area associated with offtake nodes, were determined by linking the water right identification number in both IDWR's POD and POU GIS shapefiles, along with input from the watermaster and image interpretation. Jim Martiny (Pahsimeroi River watermaster), Bob Loucks (IDWR contractor), and Roxanne Brown (IDWR) were instrumental in establishing the model network and verifying that this information represented actual field conditions.

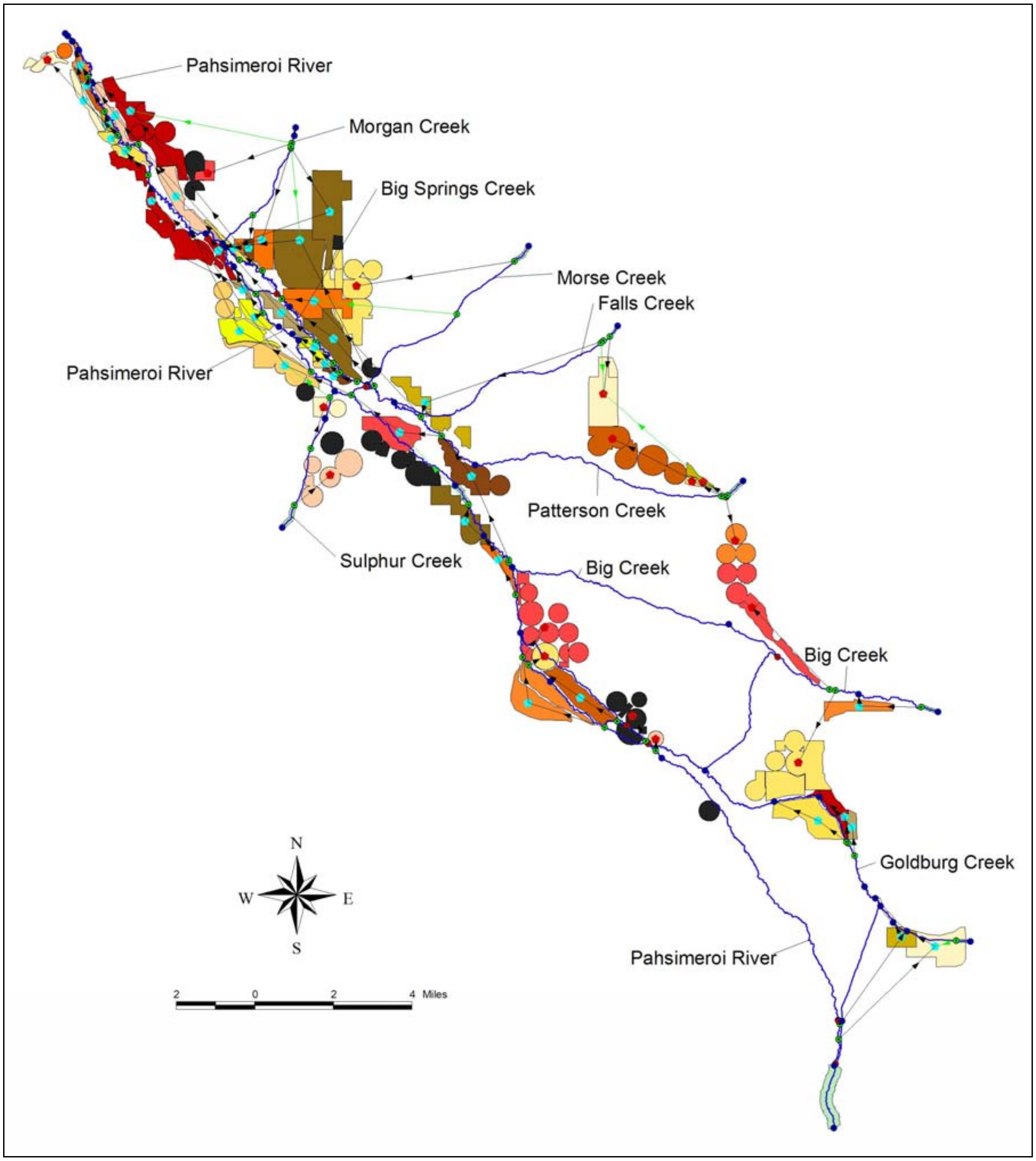

Figure 2. PRMBM network. Thick blue lines represent streams and cross-conveyance ditches. Three different types of circles representing nodes are located on the thick blue stream lines, with green representing offtake nodes (irrigation diversion locations), blue are general computational nodes, and red are diversion nodes (cross-ditch diversion locations). Light blue and red pentagons represent irrigation nodes, thin black and green lines represent connections between the river and irrigation nodes, and the colored polygons represent places of use. Note the thin black and green lines do not follow the exact path of ditches.

For some offtake nodes (diversions), multiple irrigators share the diverted water throughout the irrigation season. In the PRMBM, 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 irrigation applications within an irrigation area during the study period.

Location, timing, and quantity of return flow are functions of irrigation practices and the physical conditions of the irrigated area. In many cases, irrigation returns re-enter the river through both surface and subsurface paths that are dispersed along reaches bordering the irrigated fields. In the PRMBM, return flow nodes were associated with respective irrigation nodes and were located at a downstream point along the Pahsimeroi River or the selected tributary where the majority of the return flow is expected 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 to no longer interact with the surface water river system and, consequently, is no longer tracked within the PRMBM simulation model.

To provide unique identities to offtake nodes (representing PODs) and irrigation nodes (representing POUs), labels were attached to each for easing recognition in the PRMBM, naming time series files, and labeling for the MS-Excel interface. Offtake node labeling is based on the IDFG diversion nomenclature. Labels along the mainstem Pahsimeroi River are labeled P-2 through P-24. Format for the diversion labels on tributaries is the creek name followed by a number, except for Big Springs Creek which is reduced to *PBSC*. Numbers generally start with 1 for the furthest downstream diversion and increase upstream. For example, diversions along Patterson Creek are denoted Patterson-1, Patterson-2, Patterson-3, and Patterson-4. Exceptions to this naming convention usually incorporate a decimal point and tenths-fraction to denote diversions between two already named diversions (e.g. PBSC-3.5).

Catchment nodes are placed in locations where water is gained or lost directly to the river system. For the PRMBM, catchment nodes were placed above the uppermost diversions of interest on the Pahsimeroi River and the select tributaries. In addition, catchment nodes were placed at the USGS gage on the Pahsimeroi River near Ellis, Idaho, and at the Pahsimeroi River Furey Lane gage. For future calibration, these gages will be used to calculate 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 gaging station.

Points of Diversion and Injection

In the Pahsimeroi River Basin, several large ditches are used to convey streamflow from one stream system to another. IDWR identifies the upper end of such ditches as "point of diversion," and the lower end of the ditch where it discharges into the receiving stream as a "point of injection." Except during periods of high runoff, some of these diversions and ditches may completely block the flow of the stream, conveying 100 percent of the flow out of one stream system into another. Others are regulated by the watermaster. Table 1 lists the ditch name, the source diverted, and the stream receiving the diverted flow (injection).

Ditch Name	Source of Diversion	Receiving Stream
Alger Ditch	Pahsimeroi River (upper reach)	Goldburg Creek
California Ditch	Big Creek	Goldburg Creek
Goldburg Cross Ditch	Goldburg Creek	Pahsimeroi River (middle reach)
Mulvania Ditch	Big Springs Creek	Pahsimeroi River (lower reach)
Ellis Cross Ditch	Big Springs Creek	Pahsimeroi River (lower reach)

Table 1. Major ditches used for diversion and injection within the Pahsimeroi River basin.

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 PRMBM. Catchment nodes represent stream inflow and reach gains and losses. Time series input information is required for the 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). In the context of the PRMBM, irrigation *demand* is defined as the quantity of water diverted from the stream.

At the completion of the first phase, only a subset of the required data was available. However, time series files necessary for the PRMBM have been developed and 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 PRMBM, this is the upstream boundary of the tributaries and at gaging stations. In the PRMBM, very limited time series input information from streamflow gaging station records is available. As of September 2004, only one active long-term gaging station (USGS ID 13302005) is located within the Pahsimeroi Basin. This gage is located on the Pahsimeroi River upstream of its confluence with the Salmon River at Ellis, Idaho (period of record 1984-present). In addition, new gages were installed by the USGS on Falls Creek near May (USGS ID 13301620), and on the Pahsimeroi River at Furey Lane (USGS ID 13301515). Information from the Falls Creek gage (2002-03) is included as time series input for the PRMBM, and Furey Lane data will be included as it becomes available.

A short period (1910-1913) of continuous gage data is available for Big Creek above the diversions (USGS ID 13301500). In order to provide an estimate of streamflow for each tributary catchment node for the coarse model, the Big Creek flow data was daily-averaged and converted to a unit discharge (cfs/mi^2). This unit discharge is then applied to other tributaries including Big, Goldburg, Morgan, Morse, Patterson, and Sulphur Creeks.

A series of discharge measurements was made once per month from May through October 1971 on the Pahsimeroi River below the confluence of the East Fork and West Fork near Dickey (Young and Harenberg 1973). These discharges are used in the PRMBM to provide catchment runoff for the upper boundary of the Pahsimeroi River.

It must be clearly understood that these inputs to the tributaries do not represent current stream flows, but are applied as a means as introducing flow into the system in order to obtain coarse model results. Future phases of the PRMBM development will involve rainfall-runoff modeling to estimate streamflow in the ungaged 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 Pahsimeroi River from precipitation, ground water gains/losses, and tributary inflow. In the PRMBM, the reach gains/losses are the difference between the observed and simulated conditions for each time step during the simulation period. Data collected at the Furey Lane and Ellis gages can in the future be used to assist in determining gains and losses. However, due to the lack of tributary gages and of diversion measurements, adjustments in the reach gains/losses remain 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, all diversions are assumed to demand 0.02 cfs per acre for flood irrigation, and 0.015 cfs per acre for sprinkled irrigation, for the entire irrigation season. Acreage is based on shapefiles depicting place of use. Sprinkled irrigation was determined based on image interpretation.

Ground Water Fraction – Some irrigated lands receive both ground and surface water supplies. However, the proportion of each is not clear at this time. In those cases where ground water contributions are significant, the ground water fraction is assumed to be one-half of total demand.

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 Pahsimeroi River and selected tributaries, in this particular model, until the next downstream gaging station node.

For the PRMBM, 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 shapefiles developed primarily by the authors. For simplicity at this time, the crop type was assumed to be pasture for all irrigation nodes in the study basin.

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. As the vast majority of these shapes are based on claims only (only a few recommendations are available for this basin), place of use shapes provided by IDWR were nominal 40-acre tracts that rarely represent the actual irrigated lands. Significant effort by the authors was placed on creating and improving the place of use shapes. Assignment of the place of use areas to a point of diversion was confirmed during two meetings with the Pahsimeroi River watermaster Jim Martiny, IDWR contractor Bob Loucks, and IDWR Senior Agent Roxanne Brown.

Many 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.

Evapotranspiration *(ET)* can be determined by using the Allen-Brockway (A-B) method, Agrimet stations, SEBAL, or METRIC data. Agrimet station data is not available for the Basin 73 study area. For the A-B method, we use the reference ET, crop coefficient, and calibration coefficients given in A-B method for Basin 73 area. This data has been included in the course demonstration.

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 layer lining the ditch, 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 soil 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. In addition, the USGS is currently in the process of assessing seepage losses along the Falls Creek channel. Results of this study may be useful for future applications of conveyance loss to the PRMBM. For this 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 PRMBM. 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 Pahsimeroi 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 PRMBM, 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 1.

Diversion Nodes

Flow Dependent Diversion - In the PRMBM, diversion locations where a ditch conveys flow from one stream to another are represented by diversion nodes (not to be confused with irrigation nodes). For each diversion node, either a time series or rating curve is required to specify the quantity of diverted flow. Mr. Martiny has assisted in providing estimates of conveyance capacity for several of these ditches. For others where capacity has not been provided, the current PRMBM model simply conveys the first 30 cfs from the source stream to the supply stream. In the PRMBM, *diversion node* conveyance capacity is defined by specifying a *flow dependent diversion* and a rating curve describes discharge as a function of inflow to the node. In the future, as more data is gathered regarding these conveyance ditches, the model can easily be updated to reflect actual conveyance capacity and system operation.

Microsoft Excel Interface

To expedite the processing, formatting, and entering of data into the model, DHI personnel developed a Microsoft Excel file and associated macros that interface with the PRMBM. The file and macros provide a more user-friendly platform and help automate repetitive tasks, organize data, and minimize errors in data handling. The Microsoft Excel file:

- **PRMBM_InputFiles.xls** – Organizes the input data for all irrigation and catchment nodes. It contains the daily values for the parameters required by irrigation nodes: demand, ground water fraction, return fraction, lag time, and deficit carryover. This workbook contains the return flow calculator for irrigation nodes and macros that automatically load the data into the proper PRMBM input files. This workbook should be used when running scenarios where diversion schemes are altered and need to be loaded into the PRMBM. In addition, the file 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. A summary table of all the parameters for each diversion and catchment can be generated using a macro.

COARSE DEMONSTRATION OF THE PRMBM

A course demonstration of the PRMBM was created for public demonstration purposes and to ensure the model was correctly constructed. At the conclusion of this phase, the PRMBM 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 PRMBM calibrated. The course setup can be used to demonstrate the capabilities of the model, is a repository for the current data available, and can help identify data gaps to guide future data collection efforts.

RECOMMENDATIONS FOR FURTHER DEVELOPMENT OF THE PRMBM

Though IDWR and DHI personnel completed the initial phase of the PRMBM, 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 Pahsimeroi River and its tributaries, and thus can provide a greater foundation for the PRMBM.

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 PRMBM. As the limiting element in the calibration of the PRMBM 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 tributaries* - At the completion of the first phase, no current discharge data exists for any of the tributaries in the study area. Inflow quantities were approximated using a historic, short duration of daily discharge data from Big Creek which was averaged and applied to other tributaries based on unit discharge (cfs/mi^2). During the 2004 summer field season, the USGS collected tributary inflow on the Pahsimeroi River at Furey Lane. While this data will provide a foundation for developing inflow time series data, these are temporary gages and will not provide long-term data records. If permanent gages cannot be established on tributaries, a method should be devised that combines gaging stream discharges on select tributaries with statistical means of extrapolating the record to other basins. The select gages should be focused on streams deemed most significant to the study.

- *Stream gaging upstream and downstream of sensitive areas* –The PRMBM does not account for contributions to the Pahsimeroi 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 gaging is necessary.

  At the completion of this first phase, only the USGS gage at the bottom end of the Pahsimeroi River at Ellis, Idaho was operational and permanent. It is recommended that stream gages be placed upstream of any sensitive areas in order to insure that the model simulates the correct discharge in the river when diversion operations are being evaluated. For the PRMBM, this implies that the primary tributaries of concern be monitored as well as the gage at Furey Lane along the Pahsimeroi 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 irrigation diversions significantly influences flow in the Pahsimeroi River and its tributaries. To quantify the influence of diversions, daily measurements of discharge should be made and recorded. IDWR has recently required installation of measuring devices on diversions in the Pahsimeroi basin. Measurements made during this field season can be imported into the PRMBM_InputFiles.xls Excel interface after they are submitted by the watermaster.

Modeling

The primary remaining modeling tasks are populating the PRMBM 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.

Additional modeling tasks include application of water right recommendations from SRBA as they become available. It is expected that POU and POD shapes developed by the authors will not always coincide with those developed through the SRBA. Numerous irrigated locations are complex and not clearly understood (e.g. "The Pines") and will require a more in-depth investigation through the SRBA than was possible in this project. Other potential future tasks include incorporation of the MIKE Basin ground water model, inclusion of ditch conveyance capacity and seepage losses, application of precipitation records, and refinement of crop consumptive uses (ET).

The interaction between surface water and ground water in the Pahsimeroi River Basin is complex and extensive. This large interchange of water from the surface to the subsurface and back to the surface is a distinctive feature of the basin. The Pahsimeroi River is principally ground-water fed where water from the surrounding mountains seldom reaches the river as direct stream flow (Young and Harenberg, 1973). Future model development may involve linking MIKE Basin to a more sophisticated ground water model for greater accuracy.

Additional Analysis

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

Precipitation analysis – Currently, precipitation will be incorporated into the PRMBM as reach gains. However, it is expected that at times during the irrigation season, stream flow is influenced by precipitation. There is one weather station within the Basin (May 2 SSE COOP) and one nearby (Moonshine SNOTEL). Other nearby out-of-basin sites may also be helpful to this project. Daily precipitation data from the May 2 SSE weather station could be used in future computations of water balance and ET. In the next phase of this study, higher elevation weather station data could be used in the rainfall-runoff package of MIKE Basin to provide flow estimates for the ungaged streams in the basin.

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

Ground Water - It is well known that in the Pahsimeroi basin there is a complex interaction between surface water and ground water. Spring discharges comprise a major supply for several irrigators. 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 PRMBM, 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 Pahsimeroi River and its tributaries basin.

CONCLUSIONS

From July until September 2004, IDWR and DHI personnel completed the first phase in the surface water budget model development for the Pahsimeroi 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 PRMBM 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. The complex ground water-surface water interaction in the basin may also prove to be a limiting condition.

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. The Microsoft Excel interface was developed to facilitate input and output operations to the PRMBM. 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 PRMBM involved building the river network and compiling, computing, formatting, and inputting the data. The river network configuration primarily reflects Jim Martiny's and Bob Loucks's knowledge of the Pahsimeroi River and its tributaries. The PRMBM encompasses the Pahsimeroi River upstream from its confluence with the Salmon River at Ellis, Idaho and selected tributaries within the basin., including Big, Big Springs, Falls, Goldburg, Morgan, Morse, Patterson, & Sulphur Creeks.

The model network has 55 offtake nodes along the Pahsimeroi River and its tributaries and 56 irrigation nodes (representing the irrigated area associated with the offtake nodes). Multiple irrigation nodes are used on several offtake nodes where water is applied in several distinct locations. Return locations for each irrigation node represent the downstream location where the majority of the return fraction is expected to have returned to the Pahsimeroi River and select tributaries. Catchment nodes at the upstream end of the Pahsimeroi 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 PRMBM development, insufficient time series data existed to develop a calibrated model. For the course model development, catchment inflow was primarily estimated by applying unit daily discharge determined from a short duration of stream discharge records available for Big Creek. Daily diversion rates were estimated based on application of a generic 0.02 and 0.015 cfs per irrigated acre for flood and sprinkled irrigation, respectively. 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 PRMBM, and analysis of alternatives.

Though IDWR and DHI personnel worked quickly to complete the first phase in the PRMBM 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 PRMBM is a dynamic model that can be refined and expanded as data becomes available and as new questions are identified. The PRMBM'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 Pahsimeroi River and its tributaries system can be operated to meet streamflow targets. With data and further analysis, the PRMBM can be used to develop irrigation operations for later in the irrigation season.

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