GILA RIVER INDIAN COMMUNITY WATER RESOURCES DECISION SUPPORT SYSTEM — A MODELING SYSTEM FOR MANAGING A MULTI-SOURCE CONJUNCTIVE USE WATER SUPPLY FOR LONG-TERM SUSTAINABILITY

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ABSTRACT

The Gila River water rights settlement will restore to the Gila River Indian Community (GRIC) a water supply necessary to meet present and future demands on their tribal homeland. The settlement provides water from nine water sources, including delivery from four irrigation districts, treated municipal effluent, irrigation return flow and supplemental groundwater. The Gila River Indian Community Water Resources Decision Support System (WRDSS) was developed to effectively manage this complex water supply and protect the underlying aquifer. The WRDSS consists of three model components: Overall Water Resource Analysis (OWRA); Interface Manager (IM); and the Ground Water Analysis (GWA).

The OWRA model component tracks water delivery and the salt load from a water source to any delivery point through a branching flow network. Water supply preferences and priorities can be specified for each user for each water source. Water is delivered based on supply preference when water is abundant and by priority when water is short. Seepage and evaporation losses in the delivery and drainage systems, deep percolation from agricultural nodes, and costs and returns are also computed by the OWRA. The OWRA is tied to the GWA via the Interface Manager.

The Interface Manager is the tool used to convert output from the OWRA to a format that is compatible with the input requirements of the GWA. The OWRA estimates deep percolation and seepage from the conveyance network and irrigated areas. The IF spatially maps these groundwater recharge inputs to the

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grid cell network used in the GWA model. Any groundwater demand expressed by the OWRA is also specified as an input to the GWA on an established time-step.

The Ground Water Analysis component is a modeling tool based on MODFLOW (MacDonald and Harbaugh, 1988), to simulate surface/groundwater interactions and groundwater flow conditions, and MT3D (Zheng, 1990) to evaluate changes in groundwater quality over time. The GWA is used to evaluate the groundwater demand, in terms of yield and water quality, specified by the OWRA. As the groundwater demand changes so do the economics of pumping and water quality. This requires iterations between the OWRA and the GWA.

INTRODUCTION

Central Arizona Project Settlement Act

The Gila River Indian Community (GRIC) Water Rights Settlement was authorized by Title II of the Arizona Water Settlements Act (S. 437), also referred to as the Central Arizona Project Settlement Act of 2003. The settlement is the result of 13 years of negotiation between 35 parties, including the Gila River Indian Community (Community), the Federal Government, and various water users in the Gila River basin. Under the agreement, the Gila River Indian Community will receive a permanent entitlement to 653,500 acre-feet of water per year. This water supply is intended to meet the municipal, residential, industrial, recreational and commercial water requirements of the Community and supply irrigation water to approximately 146,000 acres of crop land. As a part of the settlement, funding is provided to enhance the water delivery system, to connect the various sources, and deliver water to all 146,000 acres of agricultural lands.

Water Supply

Nine water sources are identified in the settlement agreement representing water rights to 653,500 acre-feet per year. Since flow from some sources is highly variable, ground water is used to balance the supply. The sources also vary in water quality and cost, and some have associated storage while others are direct flow. They enter the reservation at several locations shown on Figure 1. Table 1 describes the sources of water identified in the settlement and the quality of each source. This high variability in water sources leads to challenging water management, especially when coupled with the requirement of delivering water to municipal, residential, industrial, environmental, recreational and agricultural uses while managing water and salt levels in the aquifer. A quick review of Figure 1 points out the complexity of the water balance problem.

Water Resources Decision Support System

The Water Resources Decision Support System (WRDSS) was developed as part of the Gila River Indian Community Comprehensive Water Management Plan (Keller-Bliesner Engineering, et al, 2001) to effectively manage this complex water supply and protect the aquifer. The WRDSS consists of three model components: Overall Water Resource Analysis (OWRA); Interface Manager (IF); and the Ground Water Analysis (GWA).

The WRDSS is a management and planning tool to help answer questions such as:

- What is the sustainable size of the irrigated area?
- How should poorer quality water be used?
- How should groundwater resources be used and developed?
- What is the potential for groundwater recharge?
- How do various scenarios affect the economics of the project?

The focus of this paper is the OWRA and the Interface Manager (IM). The GWA will be mentioned briefly but the reader is referred to the paper by Flynn et al., (2006), included in these proceedings.

Table 1. P-MIP Water Source Descriptions

Water Source	Description	TDS – mg/l
San Carlos Indian Irrigation Project	**Existing water supply with both direct flow and storage water. Highly variable supply.**	**Mean - 785**
Central Arizona Project (CAP)	Decreasing supply with time as upper basin develops.	Mean - 550
Salt River Project	Deliverable at up to 6 locations. Has some storage, but at lower priority.	Mean - 734
Chandler Exchange*	Delivered as produced with no storage. Some blending required.	Mean – 1,200
Mesa Exchange*	Same as Chandler Exchange except different delivery location.	Mean – 1,200
Haggard Decree	Limited to west side only. Delivered as return flow from SRP supplemented with groundwater.	Drain – 1,060 Well – 2,480
R.W.C.D **	Delivered through the RWCD Canal.	Mean - 734
Drains	Non-regulated return flow entering the reservation. Expected TDS about 775 mg/l.	Mean - 775
Ground Water Wells	Existing and new wells on reservation. Used supplemental to surface supply. Widely varying annual diversion. TDS will change with time from irrigation losses and recharge from flows in the Gila and Santa Cruz Rivers.	Current range 550 – 3,600

* Reclaimed water from Chandler and Mesa is received at no cost in exchange for their use of Community CAP water. Delivery is 1.25 times the CAP water.
** Roosevelt Water Conservancy District.

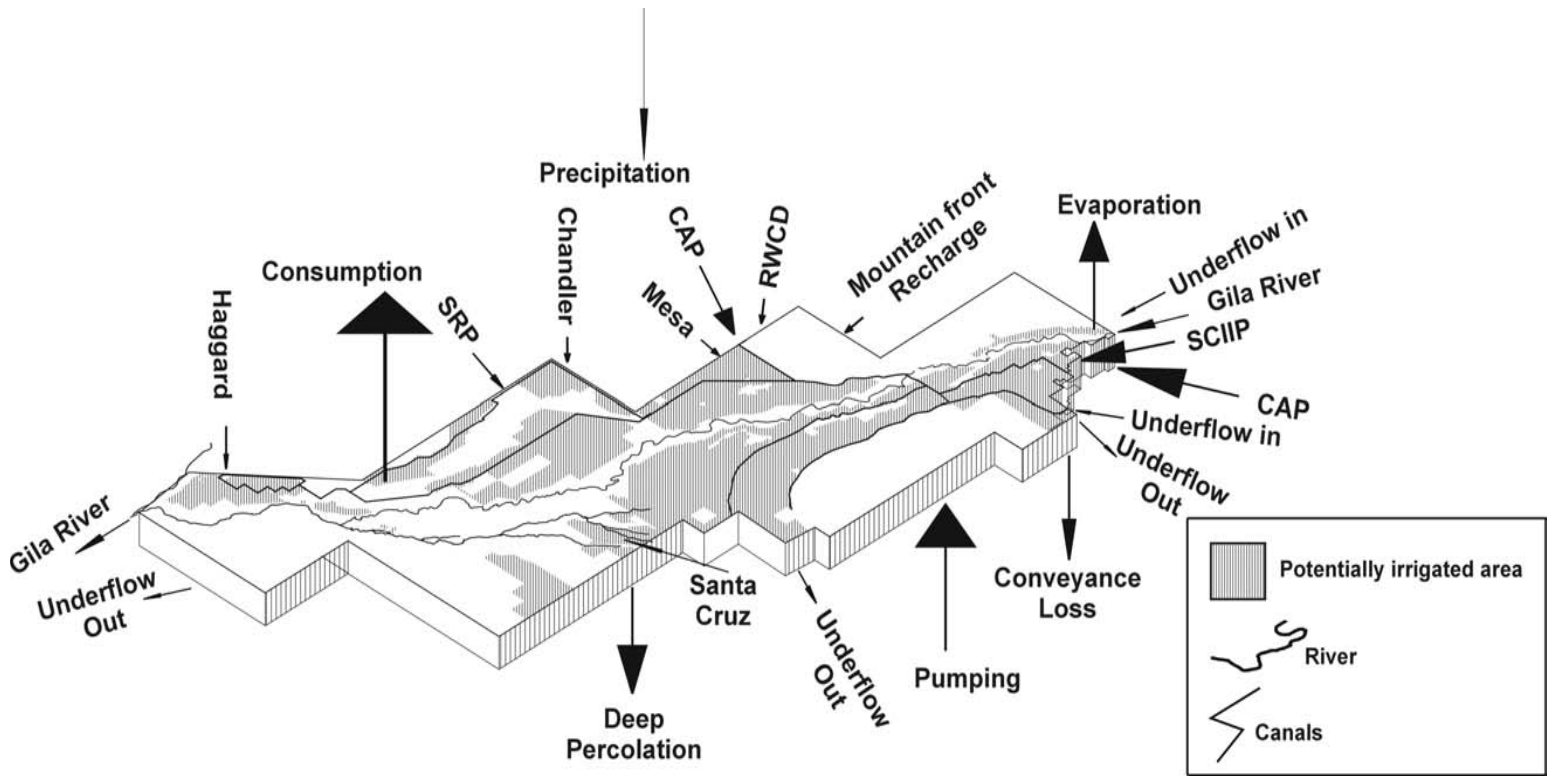

Figure 1. Water Balance Schematic for the Gila River Indian Reservation Showing Water Sources.

OWRA

Overall Water Resources Analysis Description

The OWRA is a surface water planning model designed to run on Windows based PCs. It has been successfully tested on both Windows 2000 and Windows XP operating systems. The software is written in Microsoft Visual Basic.Net and uses a web based deployment technology. This gives the user the option of updating to the most current version automatically if one is available.

As currently designed, the OWRA simulates surface water and salt flow and associated costs though a river basin on a monthly time step. It models water and salt flow from sources to demands through a branching node network. A model is built through a graphical user interface by dragging simulation objects or nodes from either an object tree or pallet to the model workspace. These objects represent features found in a typical basin. The OWRA has the following node types:

Demand Nodes
- Agricultural
- Municipal and Industrial
- Recharge or Wetland

Source Nodes
- Source
- Reservoir
- Well Field

Reach Nodes
- Reach
- Diversion

Utility Nodes

Connections between nodes define flow paths along which water can be allocated during a simulation. Such connections are made by simply dragging a link from one object to another. One end of the link has an arrow and shows the direction of water flow. A section of an example model is shown in Figure 2.

Each object has a set of properties specific to the physical characteristics of the node. Figure 2 shows an example property window for an agricultural demand node object. The node is configured on the “Basic Information” tab. The “Memo” tab contains a mini word processor that may be used for documentation. The “Output” tab contains pertinent model simulation data for the node. Simulation data are only available after a model run has been completed.

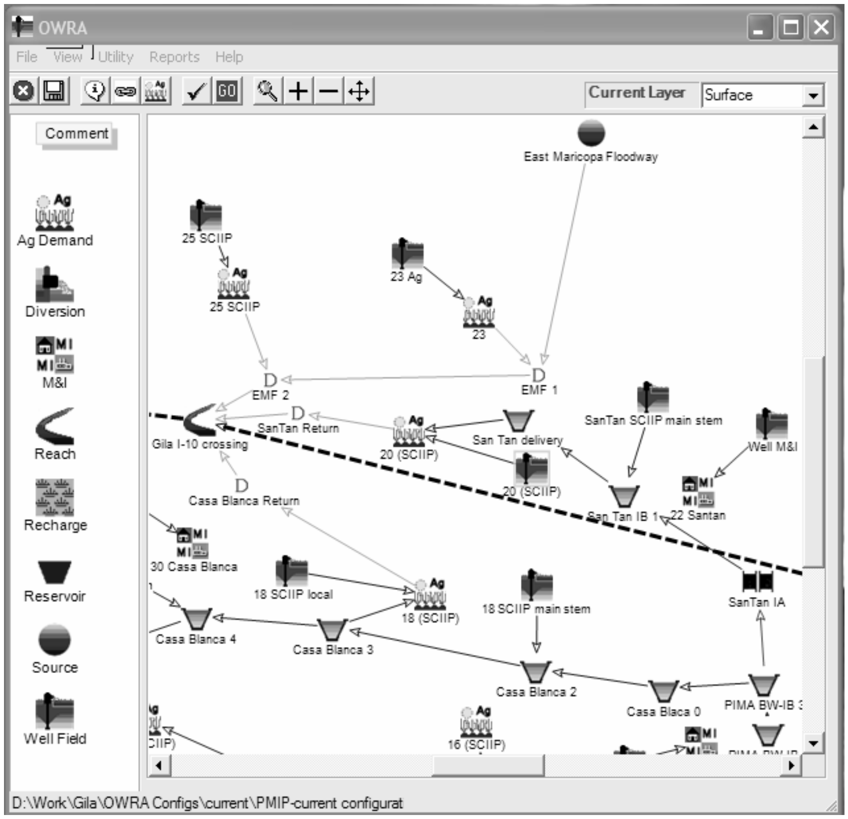

Figure 2. Screen capture of the OWRA with a typical model.

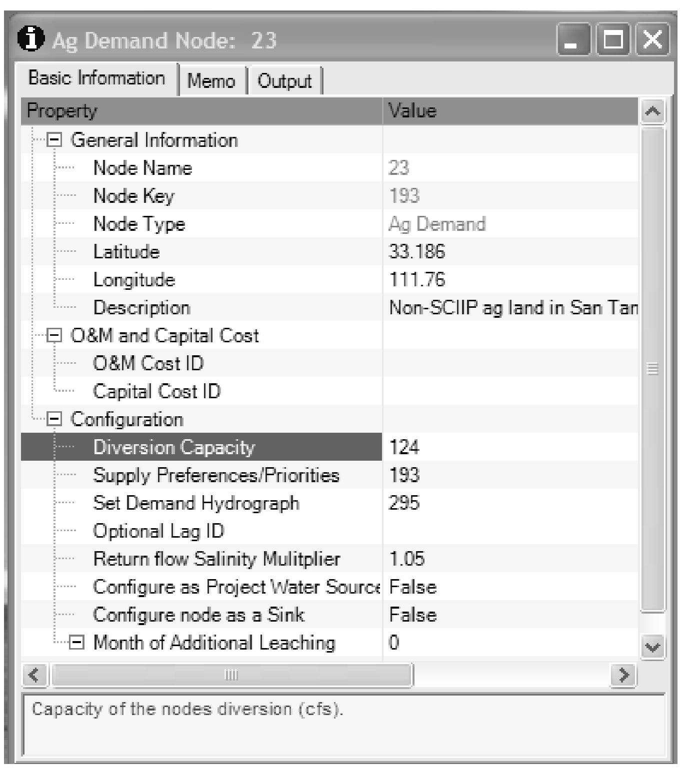

Figure 3. Agricultural Demand Property Window.

Source Preferences and Priorities

The user specifies what water sources may be used by each demand node. The list of sources is ranked by preference and by priority. A water user may prefer water from a particular source due to quality or cost considerations but may have a junior right. During simulation an attempt is made to allocate water by preference. If this fails due to inadequate supply, then water is allocated by priority.

The model tracks the volume of water and associated salt along any flow path from the source to the demand. Each flow path is tracked independently. The difference between the volume of water allocated at the source and the volume of water delivered to the demand are the intervening reach seepage and evaporation losses. The use of individual flow paths makes it possible to track the "color" of water delivered to every demand node. The concept of flow paths is discussed further in the next section.

Flow Paths

In the OWRA, flow paths are physical pathways that water follows from a source node to a demand node. Every model configuration must have at least one flow path. Complex networks may have hundreds of nodes and thousands of flow paths. Flow paths are defined implicitly by the arrangement and connection of individual nodes in the network, as configured by the user. The OWRA automatically identifies each feasible flow path at the start of a simulation by building a detailed list of unique paths. Conveyance loss coefficients, consisting of evaporation and seepage, are determined for each flow path as the list is constructed. During simulation the volume of water that must be released from a supply node to satisfy the water requirement at a specific downstream demand node is determined, subject to all physical limitations such as reach and structure capacities and losses along the flow paths.

Administrative losses, or spills, at the ends of canal branches, are not considered in the model. This is because the model calculates water allocations, not actual system operations, which involve complex decisions to deal with unanticipated events such as sudden rainstorms, emergency maintenance needs, unforeseen changes in water demands, and others. However, if an operational spill is consistent and known, it can be specified as a non-consumptive demand in the model.

Demands

The OWRA simulates water demands and uses for three types of demand nodes: irrigated agriculture, municipal and industrial, and recharge and wetlands. Agricultural demand nodes are the most complex and are specified according to the crop mix and acreage, which can vary with time, and the associated consumptive irrigation requirement. For each crop in the mix the irrigation system mix is defined along with the associated tail water and deep percolation fractions of the delivered water. Salt balance is maintained within the crop tolerance by determining the leaching requirement for each crop and irrigation method combination. Leaching requirements that are not satisfied during the crop season are specified by dedicated leaching events. The capital and operation and maintenance costs associated with irrigation are combined with the net crop return, which is adjusted for water shortage and salinity, to compute the return to land and water.

Municipal and industrial demands are specified as time varying series with lagged return flow fractions. Recharge basins and wetlands are treated as infiltration basins with specified seepage and time varying evaporation losses.

OWRA Simulation Results

Monthly output data from the OWRA simulations are saved to a Microsoft Access database for processing by the Interface Manager (IM). Data saved for each node depends on the node type. Since the primary purpose of the OWRA is to simulate long term planning level operation of the PMIP irrigation project and its affect on the underlying aquifer, the associated groundwater pumping and recharge through deep percolation including their salt concentrations are key output data.

INTERFACE MANAGER

The Interface Manager is a separate application that has two major functions. The first is to convert the recharge and pumping data simulated by the OWRA into a format that is compatible with the GWA. The second is to convert pumping data from the GWA into a format compatible with the OWRA.

When processing OWRA output to create GWA input, the IM reads the OWRA output database and produces two primary tables. These are a recharge table and a pumping table. Monthly seepage and deep percolation from OWRA nodes are tabulated along with the salinity in the recharge table. The water allocated monthly from each well field node, initial pumping depth and salinity are compiled in the pumping table.

The GWA is based on a MODFLOW groundwater model developed by Aspect Consulting (Flynn et al., 2006). From a two dimensional perspective (x and y dimensions) the groundwater model uses 4664 800 m x 800 m (0.5 mile x 0.5 mile) grid cells to represent the GRIC model domain. Using GIS, the OWRA node boundaries were overlaid on the groundwater grid cells to produce a factor that represents the proportion of an OWRA node that overlays a particular groundwater cell. This is referred to as a cell node deep percolation factor. Each

OWRA node that intersects a groundwater grid cell has a cell node deep percolation factor. It is possible for a single groundwater grid cell to receive recharge from multiple OWRA nodes. For linear features such as stream and canal reaches, each grid cell that a reach crosses is given a factor representing the portion of the reach that crosses the cell.

The recharge for each grid cell is calculated by the IM by summing the product of the associated cell node deep percolation factors times the deep percolation or seepage volumes for the overlaying nodes. The recharge salinity is a weighted average of the deep percolation and or seepage from each node.

The IM produces a 3-dimensional plot showing the average annual recharge by groundwater cell as shown in Figure 4. The IM also writes two text files, one for recharge and one for pumping that are read by the GWA.

When the IM is using GWA output to create OWRA input, pumping data are read from an output file created by the GWA and written back to the OWRA database. In the first iteration, well field capacities, pumping depths and salinities were assumed by the OWRA based on initial groundwater conditions. As stress is put on the groundwater aquifer due to pumping, all three of these variables may change. If the variables change more than a user adjustable tolerance, then another OWRA – GWA iteration is completed. This iterative process continues until the change in the modeled groundwater data is less than the set tolerance.

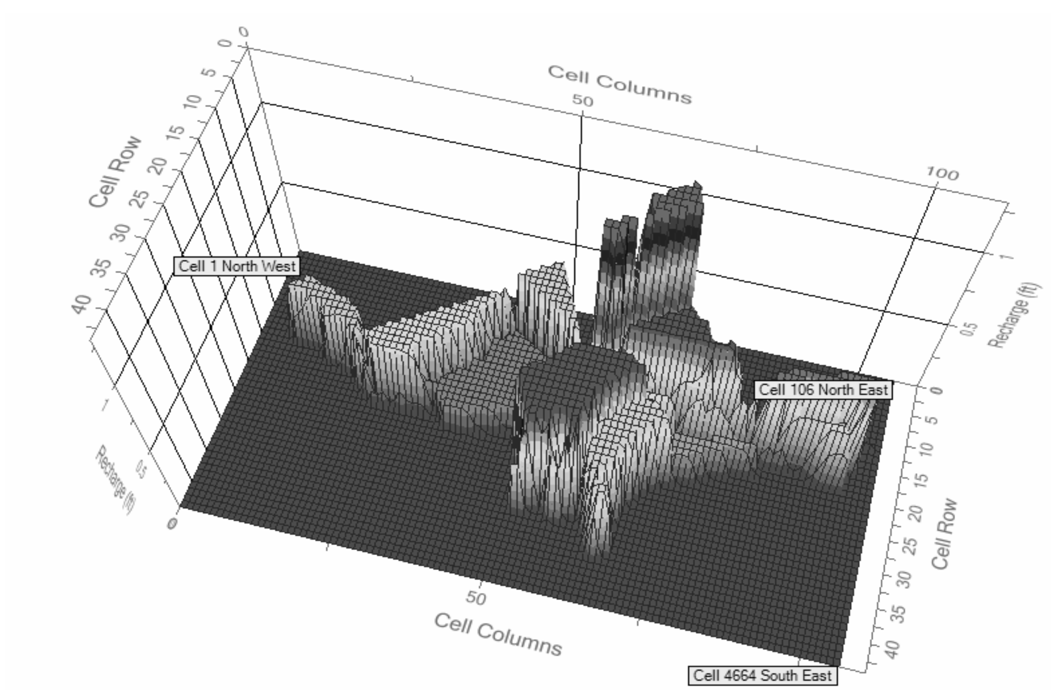

Figure 4. Interface Manager Plot of Average Annual Recharge by Groundwater Grid Cell.

CONCLUSION

The OWRA, IM and the GWA are three components that make up the Gila River Indian Community Water Resources Decision Support System (WRDSS). The WRDSS is a key tool to be used by GRIC in developing, managing and protecting its surface and groundwater resources. WRDSS has the flexibility and comprehensiveness necessary to evaluate the complex and varied interactions among multiple water sources and uses within GRIC to assure long-term sustainability of the land and water resources.

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