DESIGN AND IMPLEMENTATION OF WATER ACCOUNTING DATABASE FOR RIVERSIDE IRRIGATION DISTRICT

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ABSTRACT

The Riverside Irrigation District (RID) provides irrigation water to about 22,474 acres in northeast Colorado. Its primary water supplies, direct flow and reservoir water, are supplemented by District wells and farmer owned wells. The wells' water rights are relatively junior; therefore, without augmentation to replace out of priority depletions, senior water rights could be injured. RID has developed a plan of augmentation for replacement of out-priority depletions. The plan involves the use of accretions from groundwater recharge as the primary source of replacement water with reservoir water as a backup supply. A database has been developed for RID that allows it to manage RID's augmentation plan to ensure that all out-of-priority depletions to the South Platte River are replaced. The database includes tools for accounting of well pumping, recharge diversions, wellhead depletions, net recharge, streamflow depletions and accretions and farm unit crop water use. An extensive reporting section of the database allows RID to meet its reporting requirement to Colorado's State Engineer and to plan participants.

INTRODUCTION

The Riverside Irrigation District (RID) provides irrigation water to about 22,474 District Acres in Weld and Morgan Counties, Colorado. It is located about 120 miles northeast of Denver, Colorado, and is in the South Platte River basin. The primary water supply for RID is provided by the Riverside Reservoir and Land Company (The Company) and RID's direct flow water rights for 417 cfs. RID owns about 80 percent of The Company. The physical facilities of The Company and RID include about 100 miles of canal, Riverside Reservoir (63,000 acre-feet), Vancil Reservoir (6,000 acre-feet) and seven wells. Within RID, numerous landowners have irrigation wells that are used to provide supplemental water. The wells are tributary to the South Platte River. The wells' water rights are relatively junior; therefore their depletions of the South Platte River could cause injury to senior water rights if they are not replaced in time and amount. RID has developed a plan of augmentation for replacement of out-priority depletions. The plan involves the use of accretions from groundwater recharge as the primary

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source of replacement water. The senior reservoir rights of the plan participants back up the groundwater recharge. Operation of the plan of augmentation is monitored using a relational database.   This paper describes the design and functionality of the relational database that imports well data, calculates water use, well stream depletions, recharge stream accretions and available augmentation water, and includes special reporting features used to meet tracking and reporting requirements for RID and the State of Colorado's Department of Water Resources.

Water within RID is proportionally distributed using District Acres. Each District Acre represents one acre of irrigable land on which District taxes are paid, and entitles the owner to a proportional share of the total District water delivered from Riverside's reservoir, direct flow water right and recharge accretions.

RID PLAN OF AUGMENTATION

RID's plan of augmentation is currently pending in Colorado's Water Division One Water Court. RID has operated an annual plan, approved by Colorado's State Engineer, since 2004. In its pending water court application and its approved annual plan, RID replaces out-of-priority stream depletions attributable to the historical pumping and current year pumping using 1) recharge accretions, and, 2) augmentation water stored in Vancil Reservoir by exchanging it up-ditch to Riverside Reservoir from where it will be released to the river. Furthermore, should the need arise; five District wells are used for augmentation. The recharge accretions are available to RID from several decreed recharge plans for which the recharge and diversions facilities have been developed. RID or The Company use from 50 to 100 percent of the accretions or recharge credit available from the decreed plans. Owners of District Acres are entitled to a prorata share of The Company's portion of those plans. RID currently has 99 wells to be included in its plan of augmentation.

DESCRIPTION OF RID DATABASE

Careful monitoring of water resources of the District plan participants is key to successful operation and management of the RID plan of augmentation and to preventing injury to other South Platte River water rights. Operation of the plan of augmentation is monitored using a relational database. The database imports well, groundwater and recharge data, calculates water use, well stream depletions, recharge stream accretions and available augmentation water, and includes special reporting features used to meet tracking and reporting requirements for RID and the State of Colorado's Department of Water Resources. The database can be used to project the impact of future pumping and recharge prior to authorizing additional water use by District members. It allows the District to project depletions and accretions in future years.   The power of relational databases allows large quantities of data to be easily recorded and managed. RID has implemented this multipart database to record and track aquifer impact due to

well pumping and depletions for 99 wells, as well as recharge diversions and accretions for around 140 recharge sites for a 20 year period.

DATABASE DESIGN

RID's relational database consists of four parts: Owner Information and Billing, Well Pumping and Depletions, Farm Unit Maintenance and Crop Calculations, and Augmentation/Recharge Sites. Each part performs distinct functions, but all necessary data is shared within the four sections. The design of each database section includes 1) a program, and 2) all the necessary data tables. This modular design allows changes to be made to the program portion without having any impact on the existing data. Additionally, the data tables are segregated by plan year to reduce the size of the operational database. Historical data is kept separately and utilized during report generation.

Owner Information and Billing

This portion of the database allows RID to maintain owner information and to bill well users based on actual pumping vs. annual pumping allocations. Owner data tracked includes name, address and contact information. Also within this portion of the database, annual bills are prepared using the reported well pumping and calculated wellhead depletions maintained in the Well Pumping and Depletions portion of the database. Annual pumping allocations are made and owners are billed based on their actual pumping and wellhead depletions. Over-pumping charges and any additional fees can be assessed as necessary.

Farm Unit Maintenance and Crop Calculations

The Farm Unit Maintenance and Crop Calculations portion of the database allows maintenance of farm units, weather importing, crop evapotranspiration calculations, calculation of farm unit water balances and reporting.

Farm Unit Maintenance: The RID office maintains farm unit information. An ID number as well as a farm unit description identify each farm unit. The number of District Acres, sprinkler and flood irrigated acres and surface or well-irrigated acres are recorded, along with a listing of all wells assigned to the farm unit. Crop types and acreage are specified and the headgates used to supply surface water are listed. The type of wellhead depletion calculation used for the farm unit is selected, either the WHDF or CWR method. These methods are described in detail later in the paper. Finally, any additional sources of surface water (not supplied by RID) are included. The farm unit irrigation efficiency is determined based on the extent of use of flood and/or sprinkler irrigation for the farm unit.

Weather Importing and Crop Calculations: Weather data is a key element of the crop calculations. Currently the database utilizes weather data from Northern Colorado Water Conservancy District's (NCWCD) Brush weather station. This

data is downloaded from the NCWCD website on a monthly basis, and the daily records are imported.   Weather data includes maximum, minimum and average temperature, average relative humidity, average dew point, total precipitation, maximum wind speed, and total wind. The database has the capability of adding other weather station data as it becomes available.

Crop growing season information is required by the crop calculations. The start and end dates for the major crops in RID's area are updated annually. These crops include corn, beets, beans, grain, sorghum (silage and hay), winter wheat (fall and spring), alfalfa and grass. Other crops can be added as required. The crop dates section includes a temperature-plotting feature in order to determine the growing season for alfalfa and grass.

Operation during the Irrigation Season: Each headgate in the RID system has been assigned a soil type with corresponding soil parameters. This information, along with the appropriate crop data and the daily weather data, is utilized to calculate all the relevant parameters necessary to generate each crop's consumptive irrigation requirement (CIR). CIR values for each crop type by headgate/soil type are recorded for use with the water balance calculations.

Calculation of Farm Unit Water Balances: In general, each farm unit utilizes surface water in addition to well irrigation. When metered pumping data is not available, well usage can be determined by calculating the overall farm unit CIR. The RID office records surface water information, for both direct flow and district allocation. This information is imported into the database by headgate. Crop ET is calculated using a calibrated Hargreaves with monthly calibration coefficients to estimate standardized reference evapotranspiration long (Etrs) and mean monthly crop coefficients, (Kcrs). CIR on the lands under each farm unit is calculated on a monthly basis. The portion of CIR met by surface water is determined as the measured surface water deliveries times the farm unit irrigation efficiency. The remaining CIR is then assumed to be met by well pumping. Currently, the RID farm units are not utilizing this option.

Farm Unit Reports: There are many reports that can be generated from this section of the database. Farm unit surveys are printed annually and sent to each well owner. These reports give the owner all information used the previous year - District Acres, acreage by irrigation type and crop, and any additional sources of surface water. The owner notes any changes and the report is returned to the RID office. There is a farm unit summary report, which gives the RID manager a quick view of all farm units, including total District Acres and number of wells. The crop calculation report lists all crop coefficients, precipitation and CIR by crop and soil type. And the farm unit water balance summary report shows all water sources, crops and wells, and lists the farm unit CIR and consumptive use factors by month.

Wells and Recharge

The Well and Recharge portions of the database are generally very similar in their design, operation and function. There are, however, a couple of exceptions that will be noted. On the operating menus of the Well and Recharge accounting, RID has several options which include entering and maintaining structure information, viewing and editing current data, meter reading entry and monthly pumping or recharge calculations, calculation of projected pumping or recharge, wellhead depletions or net recharge and stream impacts (depletions, accretions and net impact), and preparation of various reports, including the monthly required submittal to the State Engineer's Office. The Well portion has the added functions of entering or editing farm unit data. The Recharge portion has the added function of importing recharge data from the accounting of decreed recharge plans.

Structure Information: The RID office maintains structure information. Each well or recharge structure is identified by an ID number, as well as a farm unit designation. A farm unit is group of wells or recharge sites that are owned or operated by a single owner or entity. Well farm units are separated from recharge farm units even if they have the same owner. The structure description, type of impact (depletion or accretion), parameters for calculation of stream depletions or accretions, along with the location, legal description, water right information, and water measurement parameters are maintained. Additional information required to project monthly pumping or recharge diversions or calculate wellhead depletions, net recharge or stream impacts is also recorded here. This information includes pro-rate factors, years of actual data, final year for estimated data, and the projected or future data estimation method. There are six options for estimating projected data. They include using the amount from the previous year, setting a pumping water order or net recharge diversion that is distributed over the operating year, using the average, minimum or maximum value of all recorded data for the structure, or zero. Estimating methods are set for each well or recharge structure.   Currently, all RID wells are pumping limit is set by RID's Superintendent. The projected recharge diversions are calculated using either average net recharge or zero.

In the Well section of the database, the RID office can record the monthly depletion factors by well, and the monthly water orders and water order distributions (used for pumping projections) by farm unit. These values are used for the projected pumping calculations discussed later.

Meter Reading Entry and Monthly Pumping/Recharge Calculations: Monthly pumping or recharge data can be entered or calculated in several different ways. Individual meter readings can be entered, and the monthly pumping or recharge diversion amount is automatically calculated based on the flow meter parameters. There are 13 methods that can be used for meter data entry, including kilowatt usage, electric meter readings, four different units for flow meter volume

readings, four different units for flow meter volumes, hours pumping, hour meter readings, and a manual calculation entry. Multiple meter readings can be imported monthly using an Excel spreadsheet with a specific format. These meter readings are recorded and the appropriate method used to calculate the monthly pumping or recharge diversion amounts. Monthly pumping or recharge diversion amounts for a structure can be imported directly from an Excel spreadsheet with a set format, and finally monthly data can be entered directly by structure. Pumping or recharge diversion records can be printed from this section if desired. The pumping or recharge diversion data can be viewed by month for each individual well or recharge structure.

Annual Projected Pumping, Wellhead Depletions and Stream Impact: The RID database offers a projection feature for well pumping that is used for annual planning. Pumping by farm unit is allocated based on allowable wellhead depletions per District Acre.   Each farm unit is given an initial pumping allocation based on the District shares for each individual farm unit owner. The RID manager can then apply a unit factor to this pumping allocation in order to arrive at the overall annual pumping allowance for all well owners in the District's plan. This annual planning process is an iterative process in which the RID manager assigns water orders, projects pumping, calculates stream impact, and then compares this data with available replacement water for the year. These steps are repeated until the overall pumping/replacement plan values are satisfactory. Final farm unit water orders are then set by the RID manager using the final allocations and his judgment. Projected pumping is calculated using the water order and the water order distribution for each farm unit.   The projection calculation distributes the water order evenly between all wells in a farm unit based on the monthly percentage values set by the farm unit's water order distribution.

Annual Projected Recharge and Stream Impact: The RID database offers a projection feature for recharge that is used for annual planning. Each farm unit is given an initial recharge allocation based on each decreed plan's limitation. The RID manager can then apply various factors to this recharge allocation in order to arrive at overall annual recharge estimation. For these projected amounts, each individual recharge farm unit is assigned a different amount of net recharge depending upon the projection criteria set-up for each farm unit by the RID superintendent. Generally, the projected amount will be an average amount or zero. Projected recharge is calculated using the estimated recharge and monthly distribution for each farm unit.   The projection calculation distributes the estimated recharge evenly between all structures in a farm unit based on the monthly percentage values set by the farm unit's recharge estimation distribution.

Irrigation Season Well Operations: As actual measured monthly pumping is recorded, the projected pumping calculation distributes the remaining farm unit water order over the subsequent months in the plan's year. This feature allows the RID manager to track actual pumping progress versus planned pumping

throughout the year. Each month after the pumping data has been recorded and the remaining projections calculated, wellhead depletions and stream impact are generated. Wellhead depletions can be calculated using two methods - wellhead depletion factor (WHDF) and crop water requirement (CWR). Currently, all wells use the WHDF method: the CWR method is a backup methodology in case of a flow meter failure.

Wellhead Depletions by the WHDF Method: In this method, wellhead depletions are determined based upon the amount of water pumped times a wellhead depletion factor (WHDF). The WHDF's vary depending upon the use of the wells. The wells in RID's proposed plan of augmentation are used for either irrigation use or livestock feed yard uses. Each well has an individual set of monthly WHDFs. When the wellhead depletion calculations are done using this method, each monthly pumping value is multiplied by the appropriate monthly WHDF. These values are for used in the stream depletion calculation. The following WHDF's were described in the RID's April 2002 augmentation plan application and are currently in use:

- For surface irrigation by groundwater in either a supplemental or sole source supply the WHDF shall be 0.40.

- For sprinkler irrigation by groundwater the WHDF shall be 0.75.

- For use other than irrigation, such as feedlot or dairy operation, a WHDF is determined by a separate calculation.

Wellhead Depletions by the CWR Method: In this method, wellhead depletions are calculated by estimating the amount of the crop consumptive irrigation requirement (CIR) not met by surface water. For each farm unit, CIR is the depth of irrigation water, exclusive of precipitation, stored soil water, or ground water (not provided by a well) that is required consumptively for crop production. Under the RID system, it is crop Et minus net precipitation.

Crop ET is calculated using a calibrated Hargreaves with monthly calibration coefficients to estimate Etrs and mean monthly Kcrs coefficients. Net precipitation is calculated using the SCS method described in USDA, 1970. Weather data from a nearby weather station is used in the calculation. The database has the capability of adding weather data from other stations.

Measurement of delivery of surface water from all sources to the individual farmer and laterals headgates is required. Each spring, plan participants report type of crops and number of acres irrigated for each crop to the RID manager. In this method, wellhead depletions are calculated as the total farm CIR minus CIR met by surface water.

CIR on the lands under each well is calculated on a monthly basis. The portion of CIR met by surface water is determined as the measured deliveries times the farm unit irrigation efficiency. The farm unit efficiencies used are 65 percent for surface irrigated systems and 75 percent for sprinkler-irrigated systems. For those farms that are delivering their surface water through an unlined ditch lateral, an estimated 5 percent loss in the lateral is also deducted. For those farms that are delivering their surface water through a lined ditch lateral or closed conduit lateral, no additional loss occurs. These values were assumed based on similar augmentation and recharge plans decreed in the South Platte River Basin.

Wellhead depletions for actual and projected pumping values become input data for a groundwater unit response model, which calculates the allowable pumping and estimated stream depletions for the time period selected by the RID manager. This calculation is generated using the data for the current plan year. Reports can be viewed showing stream impact for the current plan year, or with all historical impact included as well. Reporting options are discussed in the next section.

Recharge Operations: As actual measured monthly diversions are recorded, the projected recharge calculation distributes the remaining farm unit recharge estimation over the subsequent months in the plan's year. This feature allows the RID manager to track actual recharge progress versus planned recharge throughout the year.

Each month after the diversion data has been recorded and the remaining projections calculated, stream impacts are generated. Diversion values for actual and projected recharge become input data for a groundwater unit response function model, which calculates the allowable recharge and estimated stream depletions for the time period selected by the RID manager. This calculation is generated using the data for the current plan year. Reports can be viewed showing stream impact for the current plan year, or with all historical impact included as well. Reporting options are discussed in the next section.

End of Year Operation: At the completion of the operational year, the final stream impact for the year is archived into a separate historical database. The totals from this database are included when historical impact values are used for reporting.

Reporting

There are many reports that can be generated from the report menu of the Well and Recharge sections of the database. All reports have options for changing the first year of data to view and selecting the number of decimal places to show. All data is provided by month and year. Pumping data, wellhead depletions, recharge diversions, net recharge and stream impact reports are available by individual structure (well or recharge site). Net stream impact for the current year or for the current year plus all historical data can be viewed, along with detailed net stream

impact itemized by structure. All input data used to calculate the stream depletions or recharge accretions of a structure is available for viewing or as a printed report. Pumping reports include annual allotments, pumping to date by individual well, and a summarized pumping to date report. All input and net impact for a single structure can be selected, or the RID manager can view all structure information, monthly pumping, and net stream impacts on a well-by-well basis. There are also reports for pumping or stream impact by user groups. The RID manager can designate a user group, or selection of structure, if specific location or well type summaries are desired. Additionally, an overall summary report can be printed.

Reports with specific formats in Excel must be submitted monthly to the State Engineer's office, and these are automatically generated from the database for electronic submittal. These reports include the well owner information report and the RID Augmentation Plan report. The Augmentation Plan report includes a summary of the monthly impacts due to current well pumping, recharge, water transfers and historical pumping, daily net impact values, daily depletions, daily accretions and daily transfers.