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The South Platte River as an Irrigation Source - The Importance of Ground Water Data

Prepared For: Weld County Farm Bureau

By: John C. Halepaska and Associates, Inc.
Consulting Ground Water Engineers
26 West Dry Creek Circle, Suite 640
Littleton, Colorado 80120
303-794-1335

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The South Platte River as an Irrigation Source – The Importance of Ground Water Data

EXECUTIVE SUMMARY

The South Platte along with the Arkansas and Rio Grande Basins are three large alluvial valleys in Colorado where irrigated agriculture is practiced. They are similar in that both surface and ground water are used for irrigation and senior surface water right owners have alleged that junior wells are depleting the river flows thus causing injury. Ground water return flows are largely responsible for the river flows except during spring snow melt or following summer thunderstorms. Management of the ground water resource is essential to manage the river flows thus preventing injury to senior surface water owners and to provide adequate flows to satisfy Colorado's responsibility to compacts with downstream states.

The purpose of this project, and thus this report, was to collect and review existing ground water level data which would allow one to draw conclusions and recommendations on the importance of ground water in satisfying the water needs for irrigated agriculture in the South Platte River Basin. The cursory review of the South Platte ground water data allows conclusions to be drawn about the importance of having good water level information to make management decisions that would maximize the use of both ground and surface water to meet the river basin needs while still protecting senior water rights from injury.

More detailed analyses of the local hydrology and geology should be made to substantiate these preliminary conclusions and thus develop the confidence needed to make administrative decisions that would allow both junior and senior water rights to rely upon both ground and surface water to meet their demands. Provisions must be made to allow use of ground water during drought periods when surface runoff is greatly reduced or non-existent. Methodologies must be developed to accurately predict how well pumping will deplete river flows as well as estimate the timing, place and amount of river accretions caused by artificial recharge. Data from continuous data logger wells suggests the Glover (AWAS) method does not accurately predict either river depletions or accretions.

Colorado needs to commit financial support and to assign the responsibility to a specific State agency for collecting and storing the necessary ground water level data to allow water administrators, managers and planners to make good decisions. The current practice of requiring the aquifer to remain full so as to float surface flows in the river does not maximize the water available for use by South Platte River citizens. In fact, analyses of the Julesburg South Platte River gauge shows that Colorado is now allowing large quantities of stream flow to go to Nebraska above and beyond the compact requirements. These high outflows appear to be caused input by all time high ground water levels. **A preliminary conclusion is that strict priority water administration that has been required since December 31, 2005 together with increased artificial recharge is responsible for much of the increased flows to Nebraska above and beyond the amount required by the South Platte River compact.**

This project illustrates the importance of having good ground water level data to understand how the ground and surface water systems interact. More detailed analyses and field research are needed to confirm some of the observations and hypothesis made in this study. If Colorado is to maximize the use of both its ground and surface water for its citizens, then it is necessary to know with reasonable certainty the status of the ground water resource.

INTRODUCTION

The South Platte River as an Irrigation Source – The Importance of Ground Water Data

Early settlers in the South Platte valley recognized immediately that river water availability was directly connected to the snow pack. Once the pack disappeared, the river flow quickly diminished and the opportunity to travel by or divert from the river ceased. However, as the early farmer began to divert water from the river via ditches for irrigation, the water levels in the aquifer began to increase and the associated return flows caused the river to flow at a higher flow rate for a longer period of time. By the early 1900's the South Platte became a perennial stream from Denver to Julesburg.

Surface reservoirs were constructed in the late 1800's to provide a supplemental supply for irrigation when river flows decreased. During the early 1900's wells were dug and pumped by centrifugal pumps powered by internal combustion or steam engines to supplement both the direct flow diversions and reservoir releases. Code in his 1941 report *"Use Of Ground Water For Irrigation in the South Platte Valley of Colorado"* states there were 1955 wells in existence that pumped 233,000 acre feet in 1940. Over 80 percent of them were used as a supplemental supply to ditch diversions. Large numbers of irrigation wells were later constructed in the drought years: 1940, 1953-1957 and 1964. No new wells to irrigate new lands were permitted after 1965 when the State Engineer was required to deny new permits in over appropriated basins unless there was a court decreed augmentation plan.

As wells were drilled and used, competition between well and ditch users was immediate. The legislative and water court clashes have existed ever since. Current practice requires junior well users to augment and make the river whole in time and place, independent of the instantaneous availability of water in the river and the water stored in the aquifer. While this process comes as close as possible to a guarantee for the senior water rights, it diminishes the value of the aquifer as a water source. In addition, it guarantees that during the next drought that the seniors will be water short. Under this philosophy, it matters not how much water is stored in the alluvial aquifer, be it millions or tens of millions of acre-ft of water.

Irrigation farming depends on the soil moisture NOW and the opportunity to maintain favorable soil moisture for the life of each crop. In a broad general sense river flows and their availability for diversion in any given year depends upon:

- snow pack,
- weather conditions affecting snow melt,
- aquifer return flows,
- compact requirements,
- summer rains,
- irrigation application methodologies,

- surface water storage,
- groundwater storage,
- evapotranspiration including phreatophytes.

How an individual irrigator fits within the priority system is the final straw in the equation of timing and amount of water received. In addition there have historically been gentlemen agreements worked out between various factions to allow some flexibility over strict priority administration of the resource.

Notably absent in the list of variables is the specific amount of water stored in the aquifer, as its only current function is to "Float the river" and provide current and future return flows to the river. Therefore, each drop of water in the aquifer, independent of its particular travel time to the river, and independent of the total amount of water in the aquifer, has as its sole function to return to the river to better guarantee the availability of water to senior surface water rights. A variety of theoretical methods are available to estimate the impact of recharging or pumping water at a particular location on the river as a function of timing and amount. **All of the methods assume highly idealized initial conditions that must prevail over the life of the prediction, guaranteeing incorrect answers, and where the degree of error is always unknown in time and space.**

Because many of the current decreed augmentation plans have been formulated on incorrect assumptions and data, it is now possible for a junior well with a court decreed augmentation plan to continue to pump during low river flow conditions when a senior right holder would not have water to divert. Many of the current decreed augmentation plans utilize artificially recharged water to replace river depletions caused by well pumping. The Glover method has inaccuracies based upon its many assumptions, and there is no guarantee the augmentation decree will prevent injury to senior rights during low flow periods.

When the next severe drought occurs and river flows are nonexistent, junior well pumpers with augmentation decrees relying on artificial recharge accretions back to the river will be allowed to pump, but senior surface rights will be without water. Both irrigators and municipalities with surface rights may be without water; augmented wells relying upon senior surface flows for replacement flows will not be allowed to pump; and the aquifer will remain full.

One obvious remedy would be for all users to divert by wells and the ditches be used solely to recharge the aquifer. Under this example, the seniors would be able to divert during drought or normal times and the juniors would get a diminished allocation during drought depending upon meeting the compact and considering the quantity of water in storage. Under this example the large quantity of water stored in the aquifer would be available to both juniors and seniors to bridge surface water shortages during times of drought.

It is well recognized that ground water return flows are responsible for South Platte River flows

throughout the year and these are supplemented by spring snow melt runoff and surface runoff from summer thunderstorms. To manage surface flows it is necessary to manage the ground water levels. Conjunctive management of both the ground and surface water to maximize the available water for Colorado's citizens was required when the 1969 Ground Water Management Act was passed and is still the law today.

Management of both the ground and surface water to optimize the available water would require knowledge of the status of the various hydrologic processes described above which impact the river flows. The challenge would be to get current water right owners to agree to operating all or a part of the South Platte in a basin management plan. This would allow the water administrators, managers and planners to operate the various storage and delivery systems to protect senior rights while allowing junior rights including well owners the right to divert or pump. Flexibility would have to be built into the process. Data would be needed to make good management decisions. The water now stored in the aquifer would be considered as a viable resource and criteria must be developed on how much can be pumped where and when as well as using the aquifer as a storage vessel to capture excess surface flows.

Management would use current data such as snow pack data; aquifer water levels; surface reservoir storage; predicted weather conditions such as El Nino; compact delivery requirements; and predictions for municipal, irrigation, recreational and other water needs. Data would be collected throughout the fall and winter months so that the management decisions could be implemented throughout the following spring and summer seasons. Adjustment in management policies and decisions are expected as more experience is gained and new facilities are added.

This discussion is presented to illustrate the importance of ground water data and to begin the process of defining the manageable water in the alluvial aquifer. It is argued in various publications that the South Platte alluvium holds between 10 and 15 million acre-ft of water. As a practical issue, it doesn't matter how much water is in the aquifer. The important quantity is the amount of water that can be managed on a year-in year-out basis without impacting outstanding water rights. For example, if the top 1 million acre ft represents that fraction of the aquifer available for use without causing a shortfall for other rights, then that quantity is represented by water levels representing the top and bottom of the managed interval. Under this representation, management decisions would include: where, when, and how much to pump or artificially recharge.

This report also includes data from the Julesburg stream gaging station as it relates to the South Platte River compact. While, it is still too early to judge the outcome of strict administration of water rights in Colorado's Platte River, the data trends show that Colorado has passed significant quantities of water to Nebraska above and beyond what is required by the compact. These amounts seem to be increasing. Certainly the rising ground water levels in the South Platte River alluvium are causing greater annual ground water return flows and thus greater river

flows into Nebraska. Continued monitoring of water levels in the Platte River alluvium, attention to the points identified above, and general publication of the results should help guide the necessary future legislative, administrative and legal trends to better guide and administer conjunctive water use in the South Platte valley.

This report has been organized to address the seven Tasks that were funded in the Weld County Farm Bureau proposal, Project No. 5977. In addition Halepaska and Associates has included data along with discussion and conclusions of the flow that has passed through the Julesburg stream gauge into Nebraska for the 2006-2010 period. A number of conclusions are presented along with some recommendations for future action.

TASK 1: Capture and Tabulate Ground Water Observation Well Measurements Made by the Individual Agencies

During the summer and fall of 2009 there were a number of anecdotal reports from irrigators, well drillers, pump installers and other water users that the ground water levels in the South Platte River alluvium between Denver and Julesburg were significantly higher than in previous years.

To evaluate the authenticity of those reports, it was necessary to collect fall of 2009 measurements of the depth to the water table in wells that had a previous record which could be used for comparisons. In previous years the water levels had been measured by Colorado State University, (CSU), (1920's – 1976); US Geological Survey, (USGS), (1950's – 1980's); Colorado Division of Water Resources, (DWR), (1990's – Present); Central Colorado Water Conservancy District, (CCWCD), (1988 – Present); Lower South Platte Water Conservancy District, (LSPCD), (2002 – Present); and infrequent measurements by other federal, state and private agencies. CCWCD measures over 100 wells in the spring and fall from Commerce City to Fort Morgan. DWR measured approximately 70 wells in the spring and fall from Denver to Julesburg plus an additional 38 continuous South Platte Decision Support System (SPDSS) data logger wells. The LSPCD has been measuring 38 wells on a monthly schedule for the reach from Ovid to Julesburg.

Because of the State of Colorado's budget constraints for fiscal year 2009, DWR did not have funds available to make measurements of their network in the fall of 2009. To assure that data were collected from the Weld/Morgan County line eastward to Julesburg, an effort was undertaken to seek funding and to contract for measurement of a select group of wells. The Colorado Corn Growers Association provided funding. Canfield Drilling Company was hired to measure wells in Morgan County. Kuntz Pump and Well Supply LLC measured wells in Logan and Sedgwick counties. **These data show that for the reach from Fort Morgan to the Nebraska state line, 84 percent of the measured wells had water levels that were either the highest or 2nd highest ever recorded.** Canfield and Kuntz

were hired to measure the same wells in April 2010. Table 1 summarizes their data. The data are tabulated in Appendix A and the well locations are shown in Task 2. A discussion of those data is also presented in Appendix A.

Table 1: Summary of Wells Measured by Canfield and Kuntz in December 2009 and April 2010. See Tables II, III and IV in Appendix A for Individual Well Data.

	# Measured December, 2009			# Measured April, 2010		
	A	B	C	A	B	C
Morgan County						
West of Ft. Morgan	18	0	0	18	0	0
East of Ft. Morgan	15	11	73	15	6	40
Logan County	29	26	90	29	19*	66
Sedgwick County	14	12	86	16	6	38
Ft. Morgan Julesburg Total	58	49	84	60	31	52

A - Actual number of wells measured.
B - Number of wells having highest or 2nd highest water level on record.
C - Percent of wells having either highest or 2nd highest ever on record.
*One well pumping.

Data were obtained from CCWCD which included fall measurements made in 2009 for more than 100 wells that were part of their regular observation well network. The location of CCWCD's long term observation well network are shown on the maps included in Task 2. These data and well hydrographs are presented in Appendix B.

Data from the LSPWCD were obtained in an electronic excel file. They include monthly measurements for some of the 38 wells located north and west of Julesburg. Some of those wells were measured infrequently. Hydrographs for 25 of those wells are included in Appendix C.

There are some discussions of the CCWCD and LSPWCD data in Task 4.

Task 1 Conclusions

1) The December 2009 recorded water levels were at an all time high level in 84 percent of the wells between Fort Morgan and the Nebraska State line.

2) The April 2010 measurements were even higher in 52 percent of those same wells. Historically spring measurements of water table elevations decline from the previous

fall measurements. This unusual response could be due to the large amount of artificial recharge done in the fall and winter of 2009-2010.

3) Water levels in the western half of Morgan County – west of Fort Morgan were lower than those in the 1960-70 period. See discussion in Task 6 that the levels have been rising in that area since December 2005.

4) Strict water administration since December 31, 2005 has decreased ground water pumping. Also since that date **artificial recharge has increased significantly**. The facts are that ground water levels were at all time record high in December 2009 and continue to rise in April 2010 which would be responsible for increased ground water return flow to the South Platte River. The actual cause of the increased flow at the Julesburg gauging station is the cumulative impact of all the hydrologic processes in the Basin.

TASK 2: Location of Ground Water Monitoring Wells

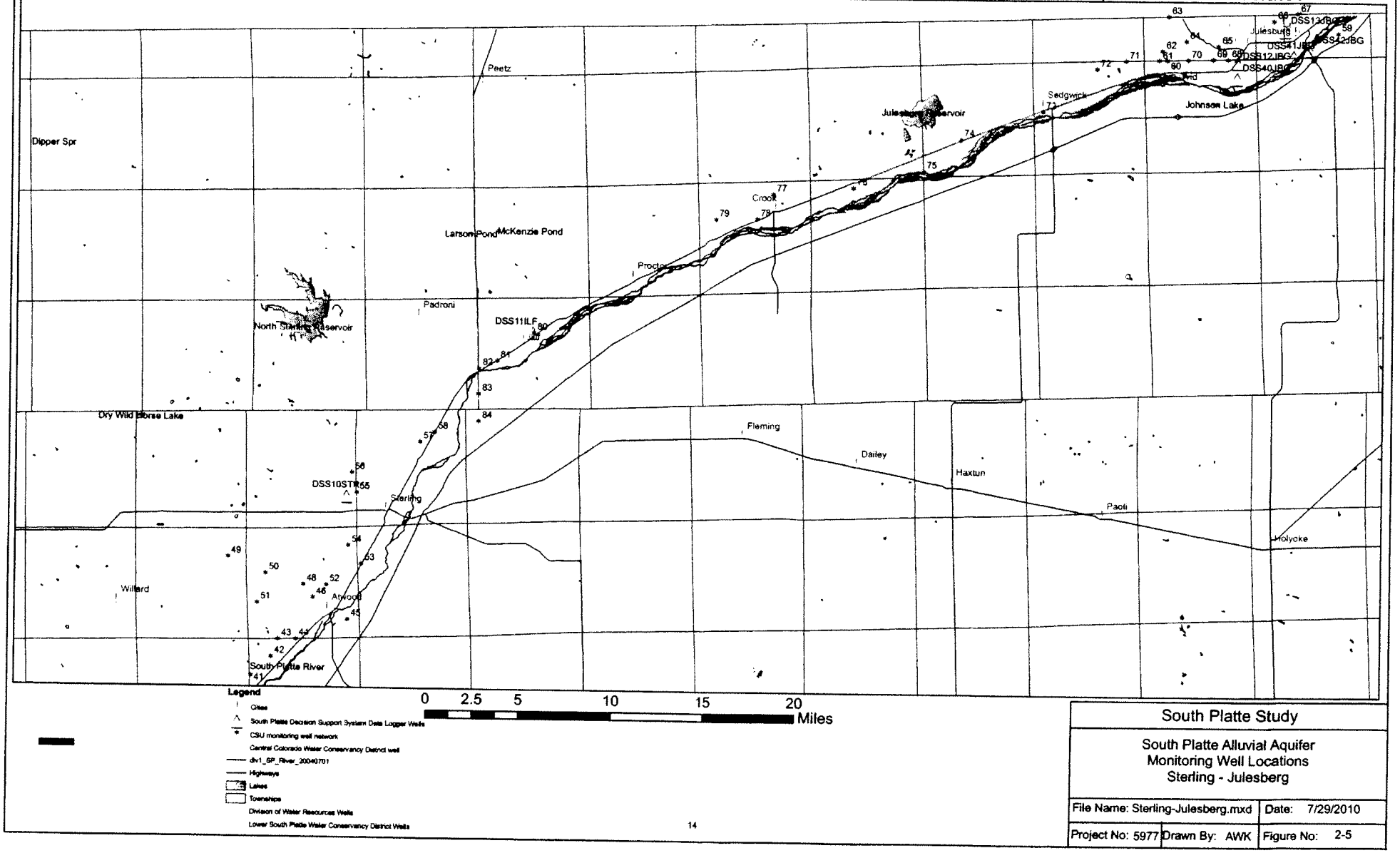
There has been concern about what ground water observation wells have historically and are now being measured and how are those data now being used in South Platte River management decisions. The purpose of Task 2 was to develop a map showing where water table measurements historically and currently are being collected. GPS coordinates for the wells measured by Canfield and Kuntz plus CCWCD, LSPWCD, SPDSS data logger wells, and some additional wells measure by DWR have been plotted on six maps. The first map, Figure 2-1, shows the entire Denver to Julesburg reach. It also shows five sub reaches for which enlarged scaled maps, Figures 2-2 thru 2-6, show each well and its identifier number which corresponds to the well number in Appendices A, B, C and D. The different color and shape of the well symbol identifies the data collection agency.

During the early years, 1930-1960, the location of observation wells was often just an estimate based upon some legal description of the parcel of land where the well was located. When USGS topographic maps became available in the 1950-1970 era, the location of the wells was improved. Finally with the use of satellites and GPS measuring devices, it is now possible to locate monitoring wells quite accurately. These locations and GPS devices are most useful to assure the same well is being measured by new field data collectors.

There are a number of places on the location maps where it appears there are at least two wells at the same location that are measured by different agencies. This is in fact true. For example, there is a well now measured twice yearly by both CCWCD and DWR located on the north side of Platteville and west of highway 85 which is labeled F05 green dot and also 148 yellow triangle. That same well was previously measured by CSU from 1947-1976 and later by the USGS from 1976-1984. There are a number of other

similar examples.

To collect all the data for a single well and merge it into a single file with a single hydrograph is potentially challenging. If the well was originally measured by Code in the 1930's, it is possible to have nearly 80 years of historic record with multiple periods of both drought and above normal water supply. Those long term records also provide valuable data to show the effect of adding the numerous new irrigation wells from the 1930's up to 1965 when well permits for a new well were first denied.



South Platte Study		
South Platte Alluvial Aquifer Monitoring Well Locations Sterling - Julesberg		
File Name: Sterling-Julesberg.mxd		Date: 7/29/2010
Project No: 5977	Drawn By: AWK	Figure No: 2-5

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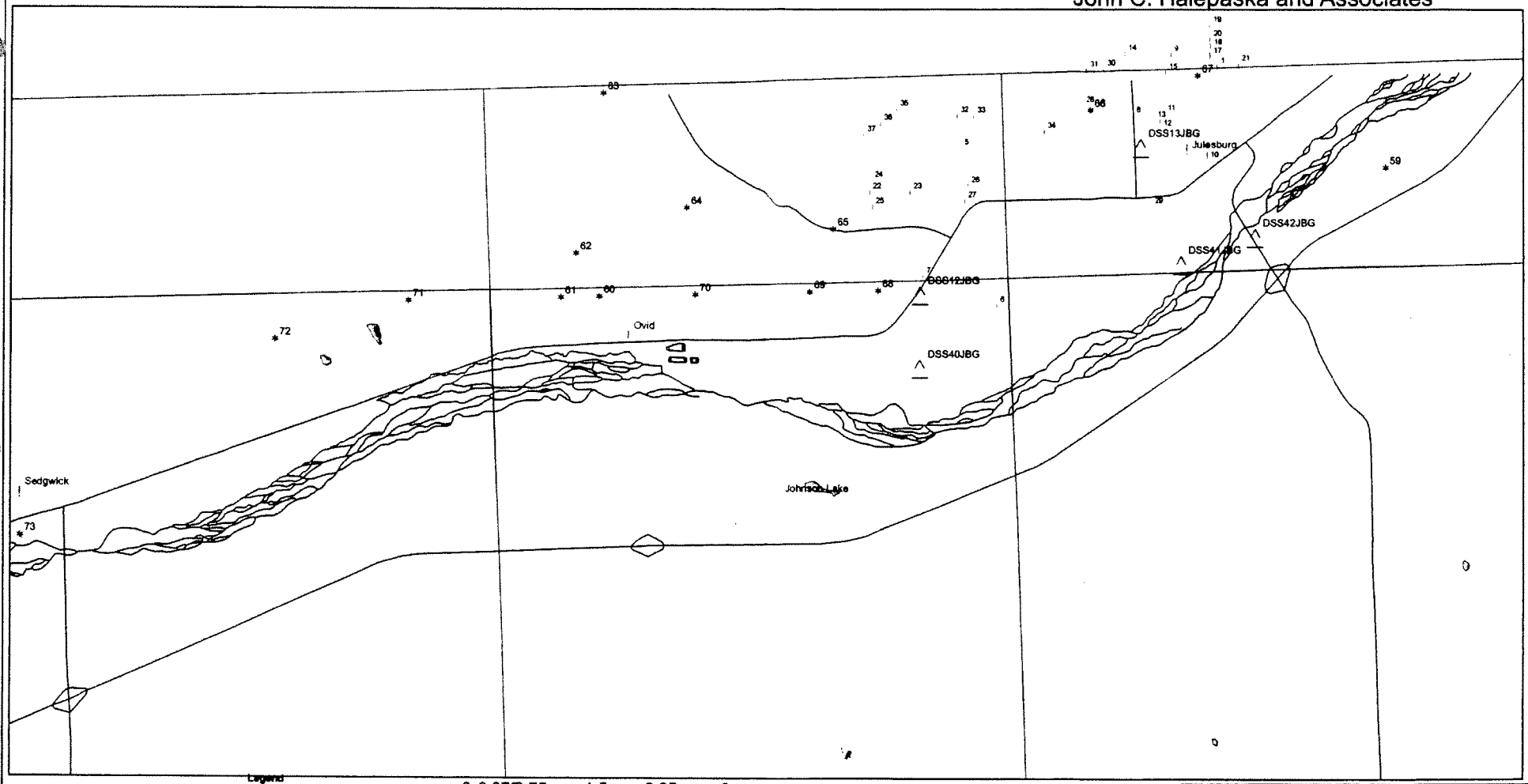

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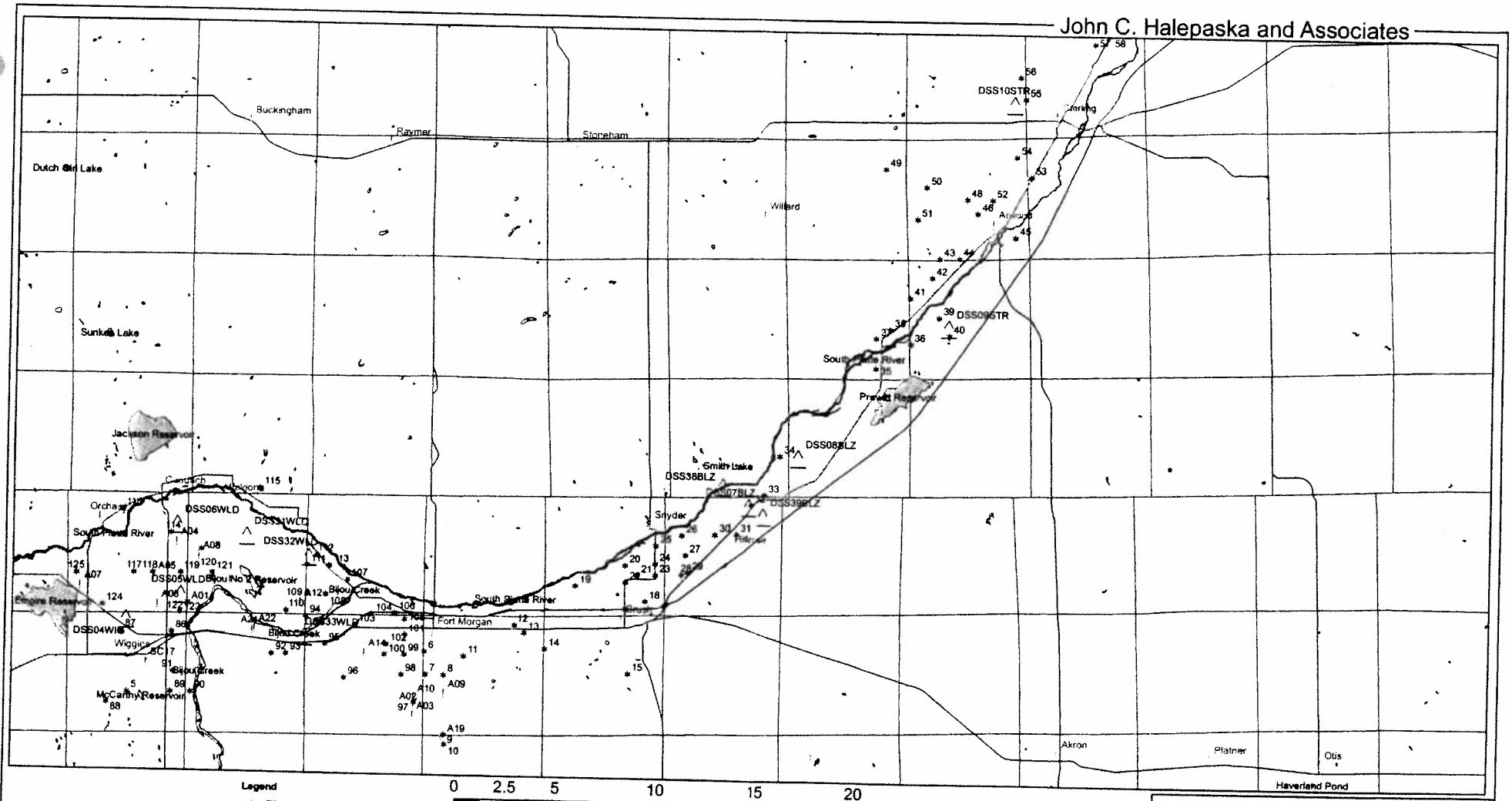
South Platte Study

South Platte Alluvial Aquifer
Monitoring Well Locations
Julesberg Area

File Name: Julesberg Area.mxd		Date: 7/29/2010
Project No: 5977	Drawn By: AWK	Figure No: 2-6



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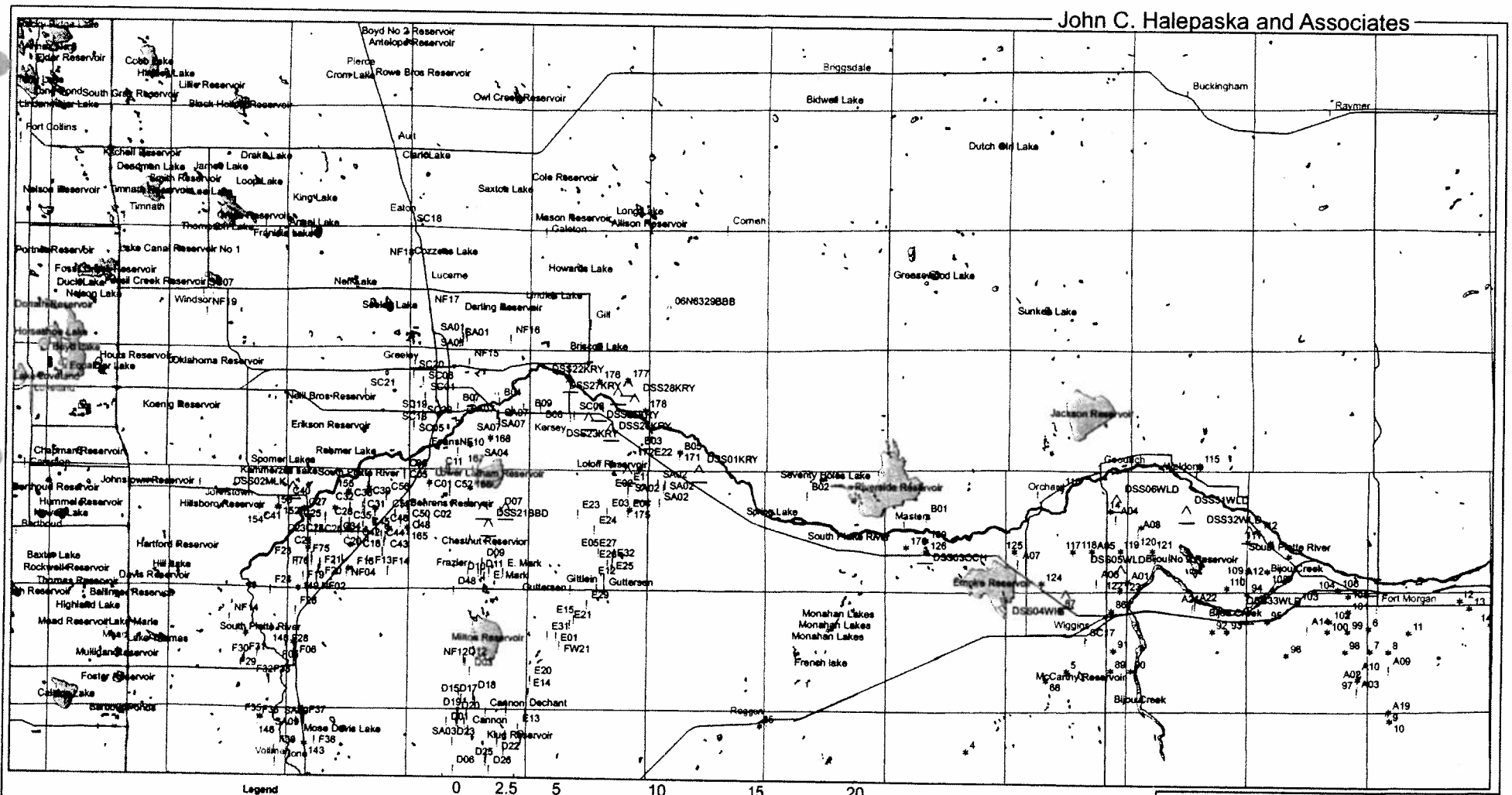
South Platte Study

South Platte Alluvial Aquifer
Monitoring Well Locations
Prewitt Reservoir Area

File Name: Prewitt Reservoir Area.mxd		Date: 7/29/2010
Project No: 5977	Drawn By: AWK	Figure No: 2-4



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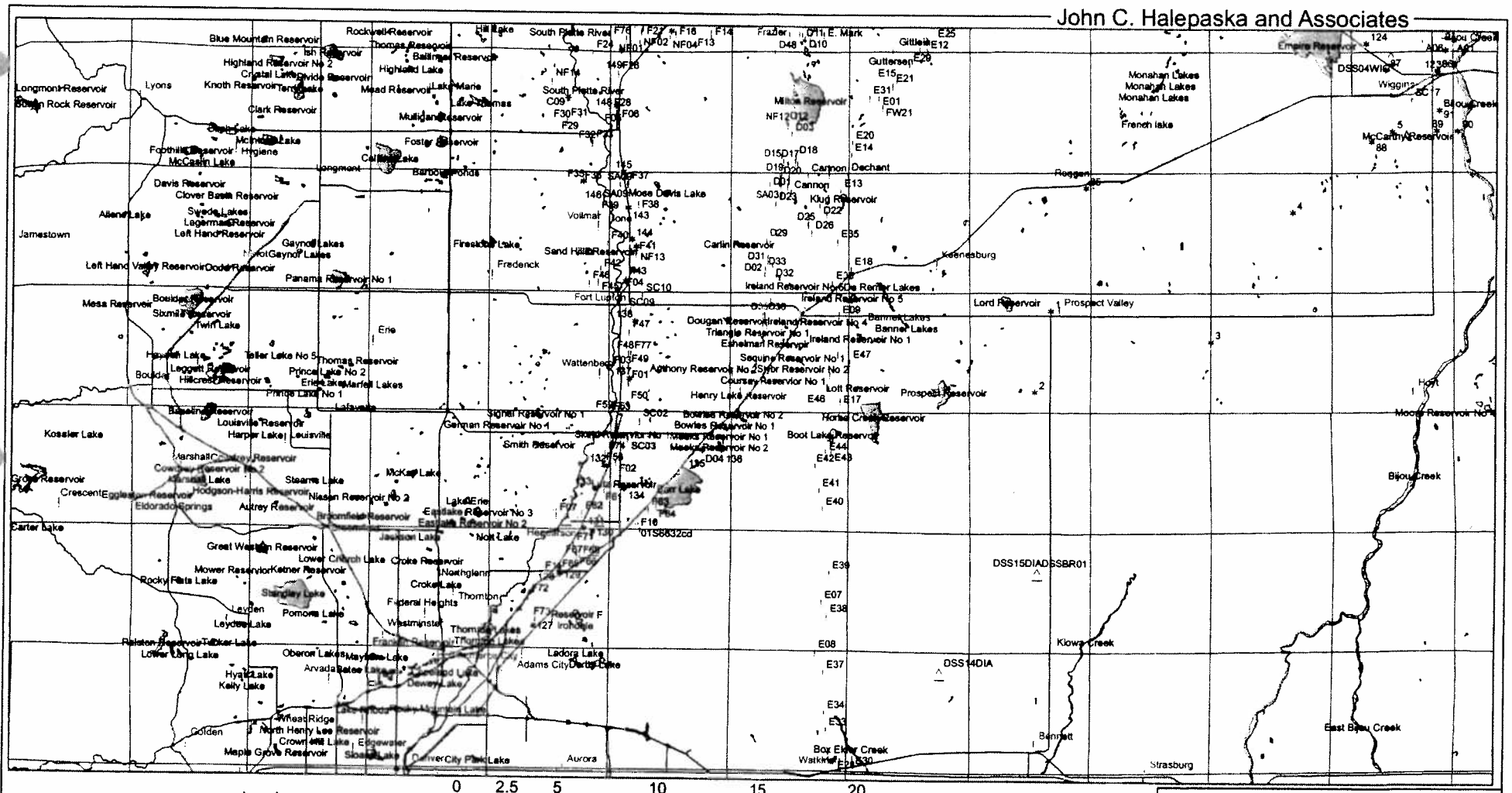
South Platte Study

South Platte Alluvial Aquifer
Monitoring Well Locations
Riverside Reservoir Area

File Name: Riverside Reservoir Area.mxd		Date: 7/29/2010
Project No: 5977	Drawn By: AWK	Figure No: 2-3



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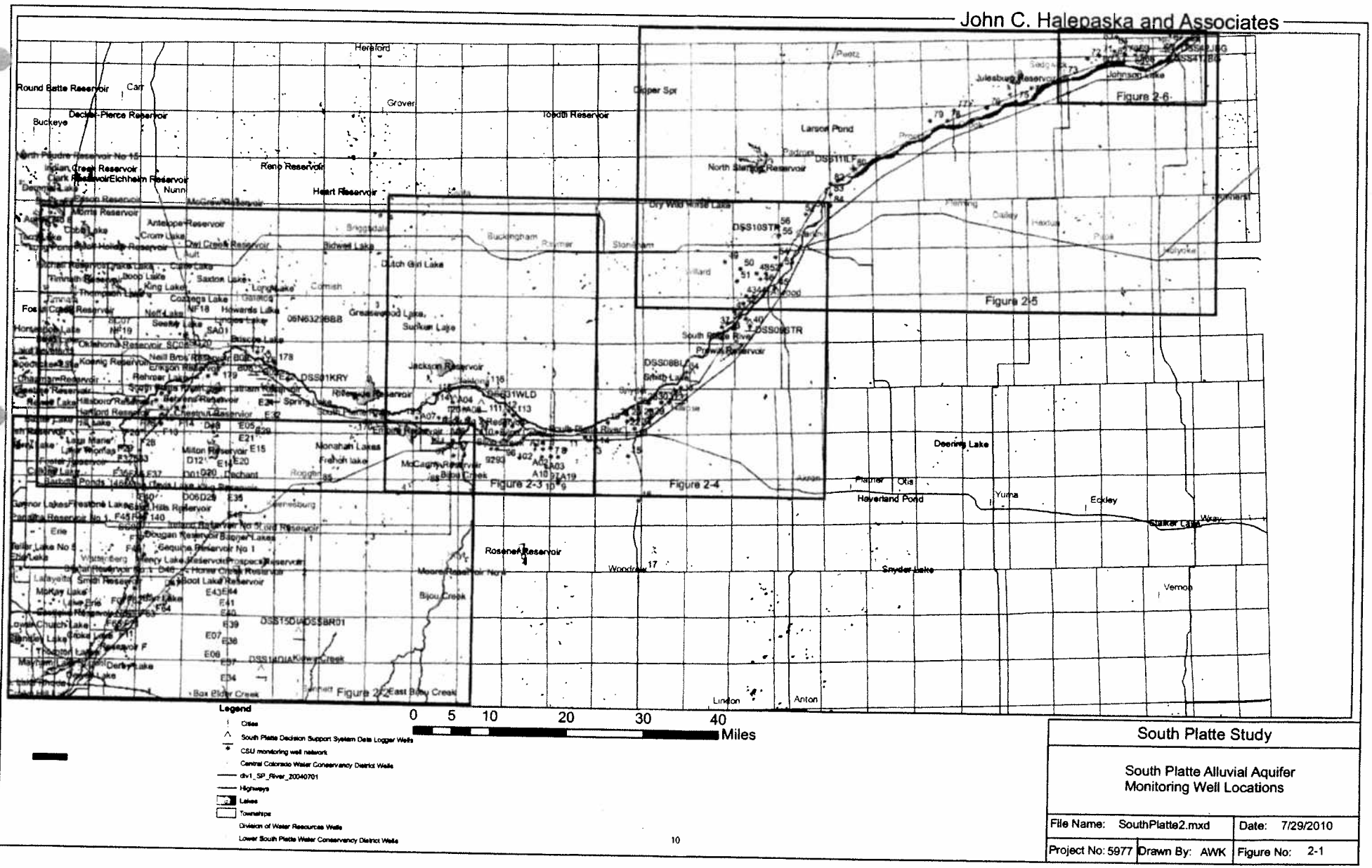
South Platte Study

South Platte Alluvial Aquifer
Monitoring Well Locations
Barr Lake Area

File Name: Barr Lake Area.mxd	Date: 7/29/2010
Project No: 5977 Drawn By: AWK	Figure No: 2-2



South Platte Study

South Platte Alluvial Aquifer
Monitoring Well Locations

File Name: SouthPlatte2.mxd		Date: 7/29/2010
Project No: 5977	Drawn By: AWK	Figure No: 2-1

TASK 3: Collection of Data from CCWCD and LSPWCD

CCWCD Network

It has been known for some time that CCWCD had a very active ground water level monitoring program. Measurement of wells first began in 1988, with additional wells subsequently added. Today, their computer excel spreadsheet contains data on over 200 wells for which 153 have measurements made in the fall (November) and spring (late March or early April) of each year. Some of the wells are measured infrequently or have only a few data points.

After discussion CCWCD granted permission to include their data in this study. Halepaska and Associates extracted data from their excel spreadsheet and prepared a single page report for each of 153 wells which contains a table of the observed water level readings for each measurement date and then those data were plotted as a hydrograph. The compiled data and hydrograph for each well is attached as Appendix B.

No detailed analyses of the CCWCD monitoring well data has been done, but a brief scan of the hydrographs shows significant difference in the hydrograph shapes. The data and hydrographs represent different hydrologic basins i.e.: Boxelder Creek and Beebee Draw drainages, the South Platte River mainstem from Denver to Gilcrest, the Greeley to Kersey reach and the area around Wiggins.

The GPS locations for the CCWCD well data were used to plot their respective locations in Task 2 Figures 2-1 thru 2-4. The green dots representing those wells are reasonably well distributed for the Boxelder and Beebee Draw drainages as well as the South Platte mainstem from Denver to a point east of Kersey. The density of the monitoring network surrounding Wiggins and on to Fort Morgan is not as good. The well identifier number on the location maps Figures 2-1 thru 2-4 are the same as the well identifier number for each well record page included in Appendix B.

LSPWCD Network

The LSPWCD has recognized the importance of monitoring ground water level data for some time. The town of Julesburg, which uses only ground water, has had water supply problems for a number of years involving both quantity and quality issues. Beginning in January 2002 a number of existing production wells and newly constructed dedicated monitoring wells have been measured monthly by the town of Julesburg and the data entered into a computerized spreadsheet maintained by the LSPWCD. Some additional wells have been added over the years and some have been dropped from the network.

Data for 38 wells were supplied by the LSPWCD to Halepaska and Associates. The well

locations were between Ovid and Julesburg and all wells are north and west of the South Platte River. Several of the wells are located north into the state of Nebraska. The wells are generally in the vicinity of Julesburg's production well fields and/or near recently developed artificial recharge ponds.

Similar to the CCWCD data, the depth to water table measurement data for each well were used to plot a hydrograph for that well. Hydrographs for 25 wells have been prepared and appear as Appendix C. The location of the 38 wells was established by GPS coordinates and was used to plot the well locations in Task 2 Figures 2-1, 2-5 and 2-6. There is a brief discussion of what those well data show in Task 4.

TASK 4: Discussion of Ground Water Monitoring Well Data Collected by CCWCD and LSPWCD

Permission was granted for inclusion of monitoring well data from both CCWCD and LSPWCD. Their data were provided in electronic format and included location data for each well plus an extensive file for each well containing the date of measurement and the depth to the water table below the selected measurement point. The measurement data were used to plot a well hydrograph of the water level fluctuations for each well.

CCWCD has data for approximately 200 wells in their database, but only 153 have five or more measurements. Halepaska and Associates retrieved data from the electronic file and prepared a tabulation of the measured water levels and plotted the resulting hydrograph for each of the 153 wells. The individual sheets for each of the wells can be found in Appendix B. Detailed analyses of that data have not been made, but a cursory review shows there are annual fluctuations from year to year and some long term and regional trends.

The CCWCD data shows that for the South Platte mainstem alluvium that the spring to spring to spring measurements are about the same each year from Denver downstream to the Weld/Morgan county line. The fall measurements are much more variable resulting in higher water levels in years that have above normal rainfall and surface canal deliveries and lower water levels in years with below normal canal deliveries and increased pumping.

In the case of the well records from the Weld/Morgan county line east to Fort Morgan there has been a more or less continuous drop in the water table through December 2005. The continuous drop in the water table reversed itself in 2006 and the regional trend is now rising water levels. This illustrates the impact of curtailed well pumping by many of the irrigation wells in the Bijou Hill area (known as orphan wells of Wiggins) as a result of the water court's decision in the Empire Lodge Case and 2003 and 2004 legislative changes. The seasonal trend is also different from the area upstream, i.e.: fall readings are lower than spring readings. In that case ~~to~~ consumptive use from irrigation pumping exceeds

the local area recharge.

Data from the 38 monitoring wells measured monthly supplied by the LSPWCD clearly shows how water levels fluctuate throughout the year and also provide regional and long term trends. The regional geology suggests they reflect water levels from terrace deposits that drain toward the South Platte River.

The LSPWCD yearly water level fluctuations from 2002 thru 2005 were more or less stable (little or no change) followed by a gentle rise in the regional and yearly trend from 2006 to present. The November 2009 or May 2010 measurement were at an all time high in 19 of the 25 hydrographs in Appendix C. The seasonal water tables decline during the peak irrigation pumping period of May thru October followed by water level recovery after pumping ceases in early October. The number of artificial recharge ponds has increased dramatically in the Ovid to Julesburg reach since 2005. Since 2005 there have been some rises in the water tables in the November thru April period which suggest artificial recharge is responsible for those rises.

Certainly the data from the SPDSS data logger wells described in Tasks 5 and 6 provides the most information on how local and regional water levels change throughout the year. However the monthly or even the twice a year measurement program of CCWCD are valuable to document the status of the ground water resource. Those data illustrate the cumulative impact of well pumping, artificial recharge, return flows of canal seepage or deep percolation of irrigation water, evapotranspiration including non-beneficial use by phreatophytes plus other hydrologic processes that impact river flows. The construction of gravel pits which are then lined or use slurry cut off walls are now having major impact on the South Platte River from Denver to Platteville. The CCWCD data seems to identify that impact, but does not quantify the change in river flows.

TASK 5: Access and Use of SPDSS Data Logger Well Data

The South Platte Decision Support System, SPDSS, project funded by the Colorado Water Conservation Board in 2001 contained many tasks. One of the tasks was to construct a series of dedicated ground water level monitoring wells and equip them with pressure transducers and data logger equipment which would measure and record water levels in the wells on an hourly frequency. This was then considered to be a continuous record.

A total of 35 new monitoring wells were constructed and three additional existing wells were also equipped with data logger equipment. One of the additional wells was a standby well located in the Sterling production well field (DSS10STR), another was an existing large diameter irrigation well (DSS08BLZ) and the third was an existing U.S. Geological Survey dedicated monitoring well (DSS07BLZ). Construction of the 35 dedicated monitoring wells occurred in the summer of 2003 and data collection began in

August 2003 for most wells.

The 38 SPDSS data logger wells are located on the Task 2 maps (Figures 2-1 through 2-6). The wells all have GPS coordinates as well as legal descriptions for their accurate location. Task memorandum in the SPDSS series contains more information including geologic logs as well as well construction reports for the 35 new dedicated wells.

The data loggers are generally downloaded to a computer storage file at least once annually. During the downloading process the equipment is serviced, batteries replaced, and an independent measurement of the depth to the water table is made and used to potentially recalibrate the equipment.[1]

Review of the SPDSS Phase 3 Task 39 Water Level Measurement Technical Memorandum does not describe the basis for locating the dedicated monitoring wells. They are not uniformly distributed. Seven of the wells (Appendix D Figures D-1 to D-7) are either bedrock Denver Basin Formation wells or are alluvial wells overlying the Denver, Arapahoe or Laramie Foxhills Formations which are hydraulically connected thus producing hydrographs which may or may not be representative of the South Platte alluvium. Four of the wells (Appendix D Figures D-8 to D-11) are located within 100 feet of the South Platte River adjacent to the stream gaging stations at Henderson, Kersey, Balzac and Julesburg. Three other wells (Appendix D Figures D-12 to D-14) are located very close, less than 100 feet, to surface canals, drain ditches or other wells in Sterling's municipal well field and thus their hydrographs may not be representative of the South Platte alluvium.

The remaining 24 wells have been sorted further into three separate subgroups:

- a group of wells that are located down gradient and below one or more surface canals or surface irrigated fields;
- a group of wells located upgradient above any surface canals or surface irrigation;
- a group of wells that may be in areas where some surface water irrigation occurs, but the amount of water pumped for irrigation exceeds the surface water deliveries.

The data from these data logger wells is valuable to assess and monitor the status of the ground water resource. Continuous records from the data logger wells significantly compliment the twice yearly measurement of observation wells by CSU, USGS, DWR, CCWCD, LSPWCD and other federal, state and private agencies.

1 In early 2008, Bob Longenbaugh was contracted to accompany Elizabeth Pottorff of DWR to download data from the SPDSS wells. In addition he made independent observations and took field notes and pictures to document nearby hydrologic impacts i.e.: locations of canals, streams, irrigated fields and irrigation wells which would influence the ground water levels in the monitoring wells. There hasn't been any detailed analyses of those field observations and the recorded water table fluctuations. Some general observations have been made and are briefly discussed in Task 6.

Data logger data for the SPDSS wells were used to plot 38 hydrographs. Those hydrographs are included as Appendix D Figures D-1 thru D-38. Task 6 contains further discussions of what the data logger hydrographs show.

TASK 6: Comments on What the SPDSS Data Logger Wells Show

Daily average water level data were downloaded from Hydro Base or extracted from a disk provided by DWR to plot the 38 individual well hydrographs reproduced in Appendix "D". Each hydrograph is different although there are some similarities and common trends. Each hydrograph represents the combined impacts of the hydrologic events that are happening in the immediate or nearby vicinity of that well.

A number of the data logger wells are located within 100-300 feet from a nearby large capacity irrigation well. Using the water table fluctuation data with data from the irrigation well (flow rate and pumping period) it would be possible to accurately calculate the geologic parameters of hydraulic conductivity and storage coefficient.

A more detailed review of four of the hydrographs suggests that well pumping causes a rapid decline of the water level forming a cone that continues to deepen and spread while pumping continues. When pumping ceases, that water level rapidly recovers and the cone may disappear in a few days or weeks.

This is not to say that the pumping will not cause river depletions, but does raise the question whether there are depletions due to previous years pumping. Use of ground water theory, Glover Method, computes increasing depletions to the River caused by long term pumping based on a number of assumptions and initial conditions. That is not supported by the observation well data and suggests that strict application of ground water theory is producing erroneous results. One explanation is that the assumptions made to use the theoretical calculations are not valid or are changing over time. The observation well data illustrates the true cumulative impact of well pumping, artificial recharge, return flows from canal seepage and surface water irrigation, evapotranspiration, deep percolation of precipitation and other lesser physical processes. Record high ground water levels indicates impacts to the river and not accumulative depletions due to pumping 30 years ago.

Where the data logger is in an area influenced by surface irrigation, water level decline may be superimposed upon a rising ground water trend due to the deep percolation of either canal seepage or percolation form gravity irrigation. The impact would be even different, if non-beneficial evapotranspiration from phreatophytes was occurring nearby. How does one thus accurately calculate the impact of irrigation well pumping on the South Platte River. ?

To illustrate some of the types of conclusions which can be drawn from the SPDSS hydrographs please refer to Appendix "D" and Figures 6-1 thru 6-4 where expanded hydrographs are displayed and discussed for four of the wells.

Task 6 Conclusions

1) The continuous record (hourly data) from the pressure transducers shows how water levels change with time. Historic records were not collected to show when a specific nearby irrigation well turns on and later is turned off, the hydrographs show how the water levels decline and later recover. For those wells located in the South Platte alluvium and in an area beneath a surface canal with irrigated fields, the water level recovers quickly after pumping ceases, often in a period equal to the length of pumping plus one or two days. In this case, there wouldn't be a longterm depletion to the River.

2) For conditions where the observation well is located in the alluvium with upgradient canals and irrigated fields, the water levels rise from the time the canals begin to run in the spring until they are shut off in the fall. This is followed by a decline in water levels caused by drain back to the River. The successive spring measurements are often within plus or minus 0.50 feet of the previous spring readings and represent the aquifer as returning to an equilibrium condition.

3) **For most of the South Platte River alluvium the return to the spring equilibrium conditions each year described in 2) above represents the aquifer being full for the prevailing conditions. All excess water delivered by surface irrigation plus depletions caused by well pumping and non-beneficial evapotranspiration have drained back to the River during the fall and winter period. Because the water table has returned to the equilibrium condition each and every spring for many years, there are no long term River depletions carried over from year to year caused by irrigation pumping.**

4) The all time high water tables observed in December 2009 and April 2010 show that accumulated depletions caused by previous years well pumping do not exist. This coupled with the data logger well data showing how water levels rapidly recover after pumping stops and also that for much of the South Platte alluvium that the spring water levels return to the equilibrium condition suggest the long term depletive affect due to well pumping calculated by The Glover Method are a theoretical artifact. There should not be any long term well depletion impact on the South Platte River due to pre 2009 or earlier pumping for most of the wells. Only where the monitoring wells were <u>not</u> at an all time high can there be long term depletions.

5) Where the observation well is in the alluvium, near an irrigation well and does not have an upgradient irrigation canal or nearby surface irrigated field, example DSS04WIG, the water levels start to decline in the spring when irrigation pumping begins and continue to decline until irrigation ceases in the fall when water levels begin to recover. Where the consumptive use of the pumped ground water exceeds the recharge to the aquifer, there will be a downward trend in the hydrograph (DSS04WIG for the 2003-2006 period). For that same observation well, the long term trend was upward (DSS04WIG for the 2006-2010 period) indicating recharge exceeded the ground water consumptive use. The curtailment of irrigation well pumping after December 31, 2005 was probably responsible for that change.

6) Note that for the DSS04WIG well there is a completely different seasonal fluctuation than for the DSS02MLK or DSS030CH as described in conclusion 2 above. Water levels are highest in the spring followed by steady decline during the summer due to pumping. When pumping ceases water levels begin to rise until the next spring.

7) Artificial recharge has increased dramatically since 2005. South Platte River flows are diverted during the non-irrigation season and the water is delivered to recharge ponds or spreading basins where it recharges the aquifer causing rising water tables. For example, the DSS09STR well hydrograph see Appendix D Figure D-27, is for a well located one half mile north of the South Platte Ditch recharge pond. Recorder data for the amount and timing of recharge that occurred from that pond exist and the observation well shows when and how much the water table rose. The rise in the water table due to recharge has changed the spring water table elevations (higher than the historic equilibrium levels). This explains why April 2010 water level measurements were higher than December 2009 measurements.

8) Higher ground water levels in April will result in increased ground water return flows to the River in successive months. If the return flow of artificially recharged waters exceeds the depletions caused by well pumping then there will be excess flow in the River. It is possible that the rising water levels as noted in the LSPWCD data for the 2006-2010 period were caused by artificial recharge which have resulted in greater summertime flows that are going to Nebraska, see Figures 10-4 and 10-5.

TASK 7: Evaluation of DWR's Hydro Base to Store "User Supplied" Data

There was a desire to store the December 2009 and April 2010 data collected by Canfield and Kuntz as well as the CCWCD and LSPWCD data into a public ground water observation well database. A meeting was held July 13, 2010 with DWR and CWCB staff to explore the possibility of using DWR's Hydro Base to store such data. Hydro Base is a data storage computer program meant to support the Colorado Decision Support Systems and was developed by CWCB. It stores a variety of data including: gaging station data,

diversion data, reservoir data, water rights records, well records and much more including a subset for observation well measurements.

At the July 13, 2010 meeting the senior DWR and CWCB staff present stated that the Hydro Base observation well database could not currently be used to store "user supplied" data. There was considerable discussion of what is now in the Hydro Base files and how the system works. The pertinent points included:

- Only data downloaded from the U.S. Geologic Survey National Water Information System (NWIS) and data collected by DWR staff is now being loaded to Hydro Base. "User supplied data" is not currently being accepted.

- Updates to Hydro Base are only made once yearly on July 1 of each year.

- Decisions on whether to allow "user supplied" data into Hydro Base would have to be made by management level staff at DWR and CWCB.

- If "user supplied" data is to be allowed, it would have to be the responsibility of the agency supplying the data to meet certain standards including doing the research to identify well permit numbers, land owners etc. so that DWR staff would not have to spend their time.

There was some discussion of what parameters should be required in a public database and what additional parameters may be optional but desirable. There was also discussion that the database should store the original data collected and not just summary or average data. For example, the SPDSS data logger wells collect hourly data but currently average daily values are computed and stored.

If agencies are required to do too much research, or the requirements for passing the data to a public database are too costly or time consuming, then they will likely not enter their data into the public database. The success of a public database will be to collect as much data as possible with appropriate qualifiers so a user can decide whether and how he can use the data.

Subsequent to the July 13, 2010 meeting a review was made of data files that DWR staff provided at the January 22, 2010 meeting. Those files now contain various different sources of "user supplied" information that was captured by DWR prior to the creation of Hydro Base.

The data from Canfield and Kuntz for the December 2009 and April 2010 data were provided to Elizabeth Pottorff of DWR and for those wells that were on the DWR observation well network the Canfield and Kuntz data were entered into Hydro Base on

July 1, 2010. The other Canfield, Kuntz, CCWCD and LSPWCD data will not be entered into Hydro Base. Restrictions due to both funding and staff time prevented DWR from entering more data.

Task 7 Conclusions

1) Hydro Base cannot currently be used to store "user supplied" data.

2) Updates to Hydro Base are done only once per year on July 1st.

3) Efforts are needed to identify and/or develop a public database to store all ground water observation well data. Further review of what parameters are mandatory and what are optional, but desirable, should be undertaken by data collectors, data users, water administrators, ground water modelers and others.

4) Efforts should be made to identify other agencies or firms that collect ground water level data throughout Colorado and solicit their participation to create, maintain, and update the needed public file for all of Colorado.

5) Funding and staffing to create and maintain the public database should be given priority consideration. This project has demonstrated how use of ground water observation well data is needed to understand how the ground and surface water interact. Making water administration decisions or planning for conjunctive use of ground and surface water without adequate ground water data is a big mistake.

TASK 10: Julesburg Gauge Flow Records

Halepaska and Associates have retrieved stream gauge records for the South Platte River at Julesburg from Hydro Base for the water year 2006 to 2010 period. The purpose of seeking those records was to determine how much water Colorado is sending to Nebraska above and beyond what is required by the river compact. Flows measured at that point represent a final "report card" on how well Colorado has been managing water within the South Platte River watershed.

The river flow channels at Julesburg are complex requiring that flows from three separate gauges be added to acquire the total flows passing Julesburg. Data were retrieved from Hydro Base for the three separate gauges and the calculations were made as follows: Total flow at Julesburg = South Platte River at Julesburg (Channel #1, ONEJURCO) + South Platte River at Julesburg (Channel #4, PLAJULCO) + South Platte River at Julesburg (Right Channel #2, PLAJURCO). The Division 1 office in Greeley of DWR has confirmed this is the correct formula for computing the flow past Julesburg.

The South Platte River Compact between Colorado and Nebraska requires Colorado to deliver flow of 120 cubic feet per second (cfs) past the Julesburg gauge between April 1 and October 15. There are no flow requirements throughout the remainder of the year except as may be required by the Tri-State Agreement.

Halepaska and Associates first retrieved and summed the daily stream flow records for the three gauges mentioned above from the beginning of water year 2006 (October 1, 2005) through August 2, 2010. Those daily flow rates and their variability are displayed as the blue line on Figures 10-1 thru 10-5. The river flows are a function of several hydrologic inputs including: snow melt runoff, surface runoff from precipitation, consumptive use by crops and phreatophytes, ground water return flows, canal diversions, reservoir releases and others. It is not possible to quantify the contribution from each process. Certainly ground water return flows is known to be one of the major factors.

For water year 2006 there were only a few days in April when the river flows exceeded the 120 cfs compact requirement during the 4/1/06 – 10/15/06 period. For water year 2007 there was significant river flow above the 120 cfs requirement in the 4/1/07-6/15/07 period. Precipitation coupled with spring snow melt in the upper portion of the watershed caused some of this excess flow. During water year 2008 there were only a few days in April and September of 2008 where river flows exceeded the compact requirement. For water year 2009 there were some significant summer thunderstorms in June and July of 2009 which added flow past the Julesburg gauge. Finally in water year 2010 there was a combination of rainfall events and snow melt runoff in May and June which added water to the river and caused flows at Julesburg to exceed the compact requirement. In late 2009 when the water tables were at an all time high the ground water return flows would also be at an all time high and were partly responsible for the excess flows to Nebraska.

During the non-compact flow requirement period, there are significant quantities of flow passing into Nebraska. During that period water is not being diverted for direct flow irrigation in Colorado, but since 2005 there have been increasing diversions in Colorado to artificial recharge ponds. This increased rate of artificial recharge plus curtailment of junior wells has been responsible for the highest water tables ever on record. Anecdotal reports from area residents include reports of wet basements, field drainage problems and accumulation of salts on the land surface due to the high water tables.

Calculations were made to compute the volume of water (acre feet per day) passing the Julesburg gauge in excess of the compact requirement. Those daily values were then plotted as a double mass curve for each of the 2006 thru 2010 water years as shown by the red line in Figures 10-1 thru 10-5. The accumulated annual volume of excess flow above the compact requirement was then plotted for each water year as Figure 10-6. Outflows from Colorado appear to be increasing since 2005.

As a result of the Colorado Supreme Court decision in the Empire Lodge Case coupled with new legislation in 2003 and 2004, there is a December 31, 2005 requirement that every well must have either a court decreed augmentation plan or a temporary substitute supply plan in order to pump. This resulted in approximately 4,000 of the 9,000 decreed irrigation wells in the South Platte Basin between Denver and Julesburg being either totally or partially curtailed from pumping since 12/31/2005. Ground water pumping has been significantly reduced.

In addition the gentlemen's agreement concerning how surface reservoir storage was allowed to operate out of priority has been changed to strict priority administration. In essence both the ground and surface water are now under strict priority administration and the river has a priority call most of the year. This requires that all well pumping must be fully augmented resulting in the wells not being able to pump under their own priority.

Water levels in the monitoring wells throughout most of the South Platte River alluvium, as previously discussed in this report, are at an all time high record level. Those high water table levels are responsible for:

- Causing more return flow of ground water back to the river and increased annual flow at Julesburg.
- Result in higher evapotranspiration losses and increased non-beneficial use by phreatophytes.

The large volumes of water passing the Julesburg stream gauge clearly illustrate that current Colorado water administration policy is not maximizing the beneficial use of South Platte River flows for use in Colorado. Three questions are relevant:

- **Are those increasing flows caused by strict priority administration of both surface and ground water?**
- **Is the increased level of artificial recharge partially responsible for the high ground water table and is that causing more river flow to Nebraska?**
- **What legislative changes must be made to return flexibility to the State Engineer in order to have conjunctive management of both the ground and surface water that will maximize water availability?**

This study has considered the South Platte River Compact and the requirement to deliver the 120 cfs flow. No effort was made to consider the Tri-State Agreement for endangered species flow requirements. The authors recognize the existence of the Tri-State Agreement and that Colorado is still finalizing Water Court decrees to use water from the Tamarack Wildlife Refuge. There are several alternative proposals to meet the endangered species flow requirements. Certainly management of both the ground and surface water must consider the Tri-State Agreement.

Figure 10-1
Julesberg Gauge Water Year 2006 Discharge

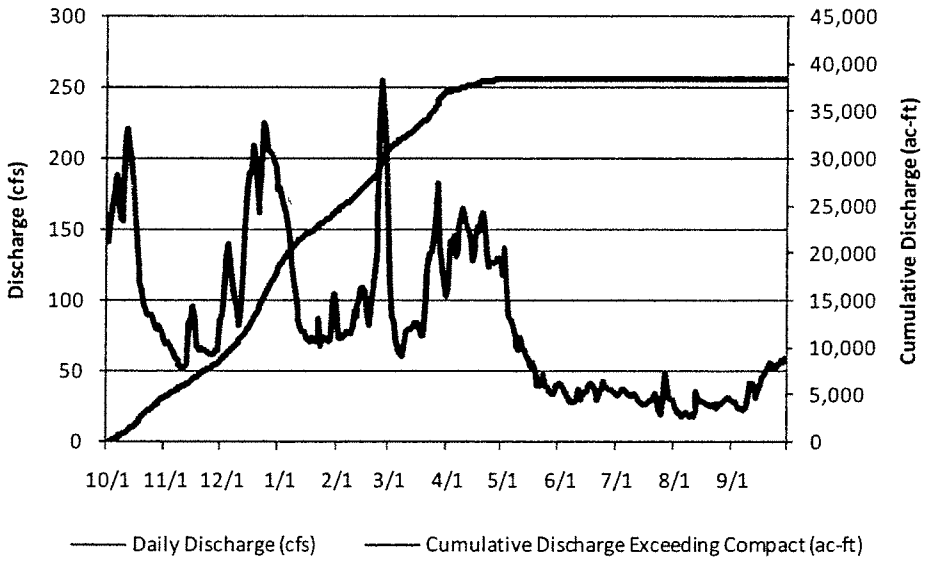


Figure 10-2
Julesberg Gauge Water Year 2007 Discharge

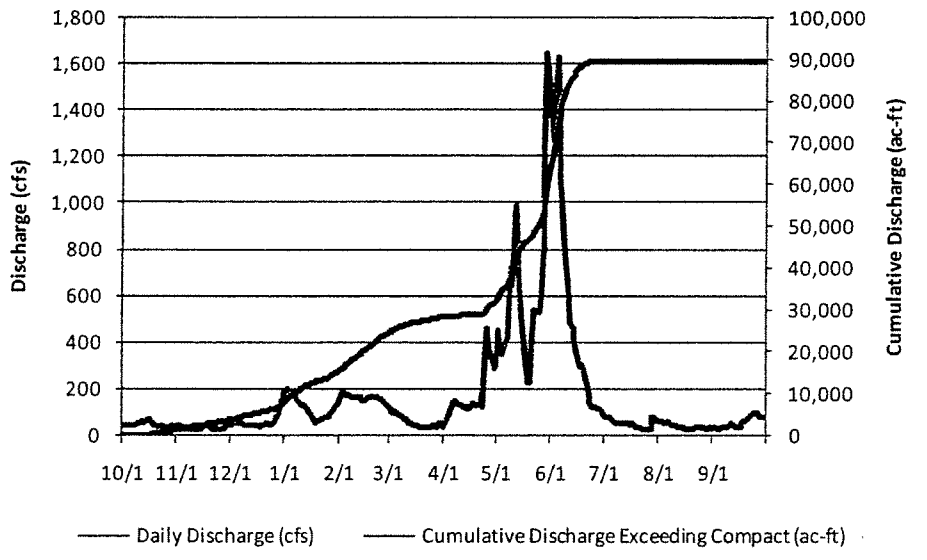


Figure 10-3
Julesberg Gauge Water Year 2008 Discharge

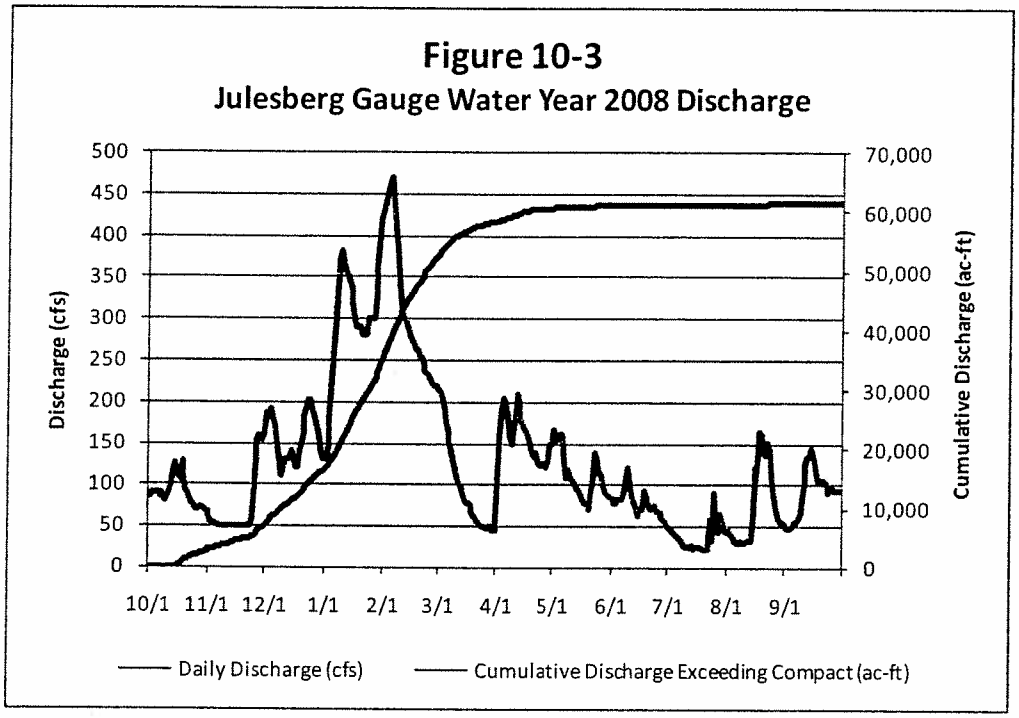
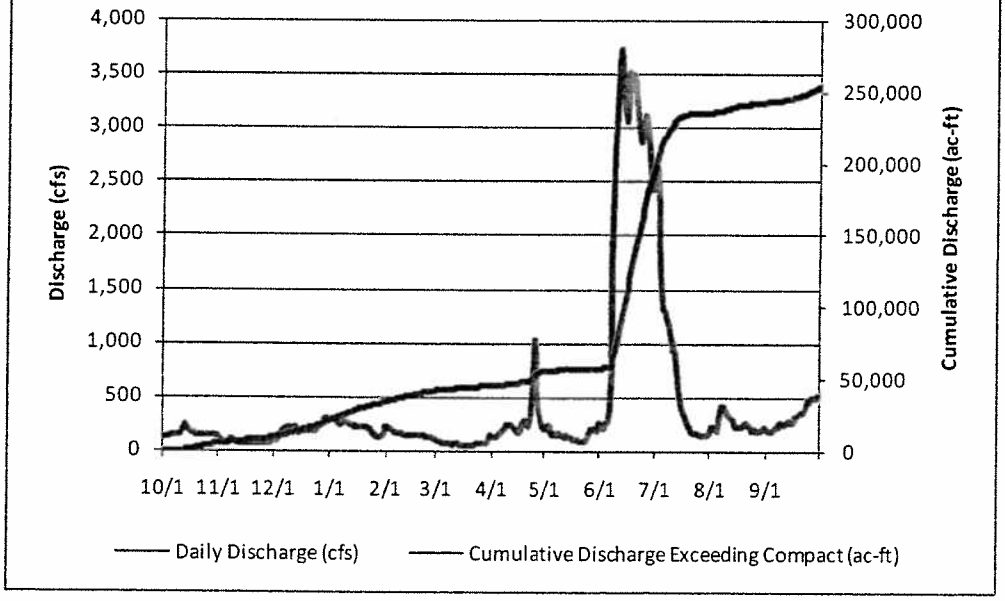


Figure 10-4
Julesberg Gauge Water Year 2009 Discharge



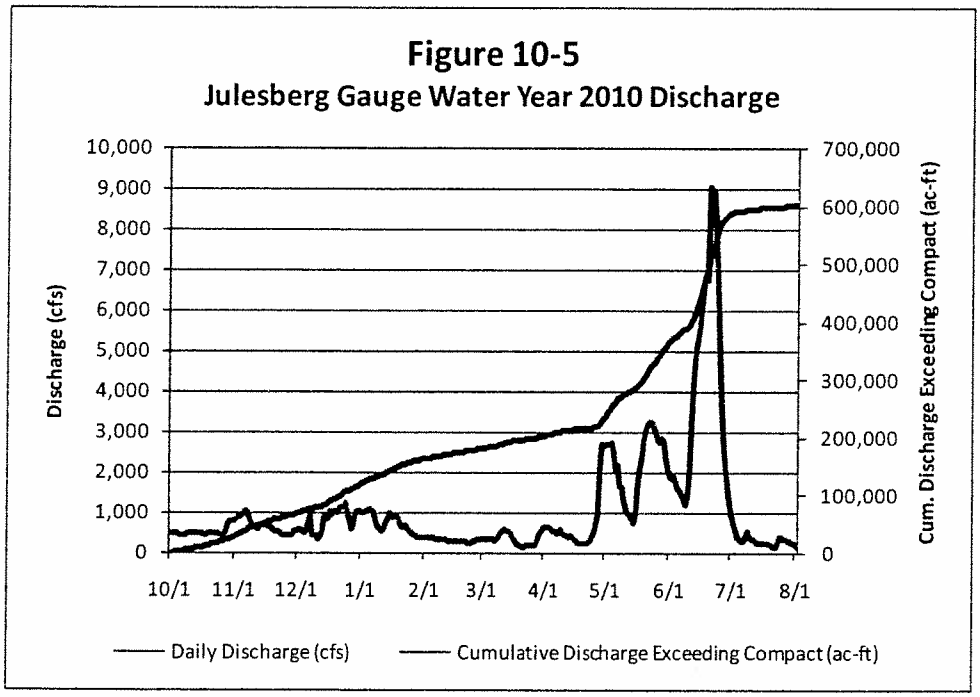


Figure 10-5
Julesberg Gauge Water Year 2010 Discharge
Discharge (cfs)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Cum. Discharge Exceeding Compact (ac-ft)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
10/1
11/1
12/1
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
Daily Discharge (cfs)
Cumulative Discharge Exceeding Compact (ac-ft)

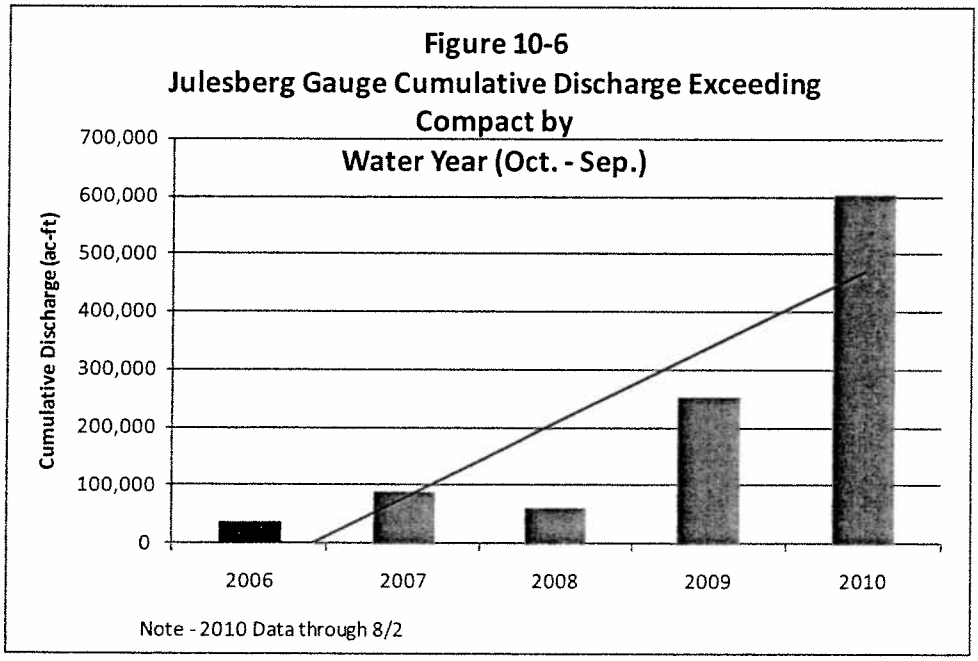


Figure 10-6
Julesberg Gauge Cumulative Discharge Exceeding Compact by
Water Year (Oct. - Sep.)
Cumulative Discharge (ac-ft)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
2006
2007
2008
2009
2010
Note - 2010 Data through 8/2

CONCLUSIONS

1. Julesburg stream gauge records show Colorado is sending significant quantities of water to Nebraska above that needed to satisfy the compact.

2. Ground water levels were at an all time record high throughout most of the Denver to Julesburg reach in December 2009 and again in April 2010.

3. An integral part of managing river flows is to manage ground water levels.

4. Colorado's conjunctive use of both ground and surface water as practiced in the 1970-2000 period is no longer legally possible.

5. The data from the continuous data logger wells is valuable to assess and monitor the status of the ground water resource. Twice yearly and monthly ground water measurements also provide valuable information.

6. Depletive effects to the river due to well pumping in many cases do not appear to be long-term. A number of the hydrographs show that impacts due to pumping are erased annually.

7. Methodologies must be developed and employed to accurately estimate stream depletions caused by well pumping and accretions to the river due to artificial recharge. Failure to have accurate methodologies will result in injury and will also make conjunctive water administration and management difficult.

8. The increasing amount of water flowing out of Colorado to Nebraska indicates that Colorado's current water administration policies are not maximizing beneficial use of both the ground and surface water of the South Platte River.

9. There is no current centralized repository for storing all available ground water level data. Budget limits and concerns about quality control currently restrict DWR from being in a position to accept other agencies' data.

10. Currently there is no universal agreement on pumping ground water during drought periods for use by both senior and junior water rights.

11. Interpretation of the enclosed data suggests water administration relying more upon the empirical field data and less on the theoretical equations would best serve to maximize the use of both the ground and surface water of the South Platte River.

RECOMMENDATIONS

1. JCHA recommends a detailed analysis be performed of the geologic and hydrologic impacts that are causing individual water level fluctuations. JCHA expects that, if such analyses were performed, some strong conclusions could be made about what causes the ground water levels to fluctuate, and how those fluctuations impact the South Platte River flows. A better understanding of those relationships would enable water administrators and planners to better manage both the ground and surface water to maximize the beneficial use for Colorado's citizens.

2. Perform an in-depth evaluation of The Glover Method's (AWAS) ability to accurately predict river depletions caused by well pumping or river accretions due to artificial recharge.

3. Determine what other technologies (finite difference modeling) could be used to more accurately predict river depletions and accretions caused by pumping or artificial recharge. Should finite difference modeling provide more accurate answers, then what are the required data inputs needed to assure reliable answers?

4. Colorado must return to conjunctive management of both ground and surface water in the South Platte Basin. That is the only way to maximize the water available to Colorado citizens. A management entity must be developed.

5. Legislative changes are needed to provide a method to allow the pumping of ground water during drought periods.

6. There must be a commitment by Colorado to collect adequate ground water data in the future. This includes adequate funding and assignment of a state agency responsible for collecting the data.

7. JCHA recommends that efforts be made to identify and/or develop a public database to store all ground water observation well data. Funding and staffing for this database should be given priority consideration.

8. An effort must be made to identify other agencies or firms that collect ground water level data throughout Colorado and solicit their participation to create, maintain, and update the needed public ground water level database for all of Colorado.

9. JCHA recommends a meeting be held between DWR and CWCB staff, observation well data collection agencies, data users and others to review:

    a. What parameter data should be collected;
    b. Location information;
    c. Key or unique identifiers;
    d. Procedures to assure quality control (both QA and QC);
    e. Methods for handling changes in mean sea level elevations when pumps are changed or wells are redrilled.

10. Consideration should be given to construct and instrument more data logger wells for more uniform distribution throughout the Denver to Julesburg reach. Some of those wells should be in the Denver to Platteville reach to document hydrologic affects of gravel pit construction and water storage projects.

Robert A. Longenbaugh
Robert A. Longenbaugh, P.E.
Retired Consultant Water Engineer

John C. Halepaska
John C. Halepaska, PH.D., P.E.
President

Jason Rose
Jason Rose
Associate/Senior Project Hydrogeologist