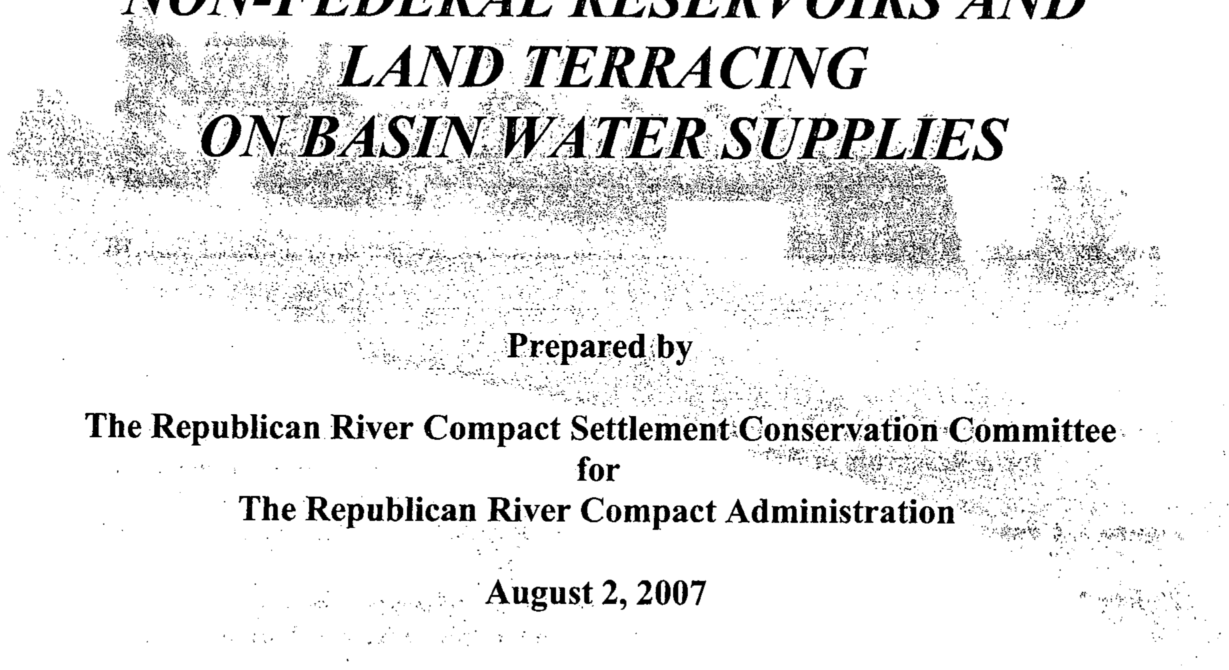
REPUBLICAN RIVER BASIN

Third Annual Status Report

STUDY ON THE IMPACTS OF NON-FEDERAL RESERVOIRS AND LAND TERRACING ON BASIN WATER SUPPLIES



Prepared by

The Republican River Compact Settlement Conservation Committee
for
The Republican River Compact Administration

August 2, 2007

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INTRODUCTION

On May 26, 1998, Kansas filed suit in the U.S. Supreme Court complaining that the State of Nebraska had violated the Republican River Compact. On January 19, 1999, the Court accepted the lawsuit and assigned Vincent L. McKusick as Special Master. The three original parties to the Compact; Kansas, Nebraska and Colorado became parties to the case and the United States entered the case as *amicus curiae.* In December 2001, the Special Master granted a stay to allow the parties time to attempt to negotiate a settlement. On March 28, 2002, the negotiation teams for Kansas, Nebraska and Colorado signed a Statement of Settlement stating they had negotiated an Agreement in Principle to settle the Kansas v. Nebraska and Colorado litigation. On December 15, 2002, the states completed a Final Settlement Stipulation and the Special Master approved the stipulation in February 2003. The United States Supreme Court, by decree dated May 19, 2003, approved the Final Settlement Stipulation.

The Stipulation required the States, in cooperation with the United States, form a Conservation Committee by January 31, 2003. Further the stipulation required the Conservation Committee to develop a proposed study plan by April 30, 2004, to determine the quantitative effects of Non-Federal Reservoirs and land terracing practices on water supplies in the Republican River Basin above Hardy, Nebraska, including whether such effects can be determined for each of the Designated Drainage Basins (refer to Section VI of the Final Settlement Stipulation).

In January of 2003 each state and the United States appointed individuals to represent them on the Conservation Committee. The Conservation Committee members participated in a series of meeting and conference calls to develop a study plan to quantify the effects of Non-Federal Reservoirs and land terracing practices on water supplies in the Republican River Basin above Hardy, Nebraska. The study plan was transmitted to members of the Republican River Compact Administration (RRCA) on April 30, 2004. A Memorandum of Understanding was also provided with the study plan to identify the responsibilities of each party for funding and completing the study.

Representatives of the Conservation Committee attended the annual Republican River Compact meeting in Burlington, Colorado, on June 8 and 9, 2004, and presented the study plan to the RRCA. The RRCA verbally approved the study plan during the meeting and the signature process for the Memorandum of Understanding formally approving the study proposal was completed on July 27, 2004. July 27, 2004 is the official beginning date for the 5-year study.

STUDY PLAN SUMMARY

The study relies primarily on soil water balance models to simulate the impact of terraces and Non-Federal Reservoirs on surface water supply. The study consists of four primary components: 1. Evaluation and modification of existing models, 2. Development of databases, 3. On-the-ground verification, and 4. Application of the water balance and GIS models. A thorough description of the study plan is provided in the Republican River Basin Study Plan proposal on the Impacts of Non-Federal Reservoirs and Land Terracing on Basin Water Supplies dated April 28, 2004.

PROGRESS SINCE APPROVAL OF STUDY PLAN

A status report describing the progress made in completing the four primary phases of the study follows:

1. Evaluation and Modification of the Existing Models: KSU is serving as the lead for the portion of the Research Project related to the development of the selected water balance model and for its application to land terraces and Non-Federal Reservoirs in the basin. Components of three computer simulation models, POTYLDR, SWAT, and CROPSM were considered for integration into one model for simulation of the impacts of land terraces and Non-Federal Reservoirs.

   The model will consist of four parts:

   1. A GIS pre-processor will generate input data for the water budget simulation model hydrology response units (HRUs),
   2. A unit area water budget simulation model will retrieve input data and will produce daily, monthly and annual water budgets for each HRU. Operation of a terraced field will be done as a HRU,
   3. A water budget simulation model of a small reservoir using daily outputs from the HRUs, and
   4. A GIS post-processor to combine results of the HRU and reservoir simulation models to produce monthly and annual recharge and runoff amounts for the subwatershed. Post processing will include adjustments for transmission losses that are expected to occur between amounts of upstream runoff predicted from the aggregate of the HRUs and reservoir simulation models and the stream flow at the outlet of the subwatershed.

   Interactions and interfacing for data handling are in progress.

   The overall POTYLDR model will serve as the basic operational framework for the water budget simulation model to operate the HRUs. The model runs on a daily water budget of the inputs of precipitation and outputs of evaporation, transpiration, surface runoff and recharge and the resulting daily change in water amounts in the interception account, soil water volume, and snow storage accounts for each combination of conditions at the various locations within the basin.

   A more precise method to simulate terraces has been developed. The POTYLDR original model used the RCN Method for the entire field using the upslope contributing area and the terrace channel area. The new approach uses a three-area system to model the operation of a terrace – the upslope area, a flat-bottom section representing the terrace channel, and a second flat bench section that is higher in elevation than the terrace bottom to represent the sloping sides of the terrace channel. These three defined areas allow for a more complete water balance calculation for the terraced area by operating a separate water balance for each of the areas

In the case of small reservoirs in a sub-basin, a separate simulation sub-model is being developed to simulate the operations of the reservoir. It uses the reservoirs characteristics needed, stage-storage-area-discharge relationships, to simulate the operation of the reservoir. Where information is available for particular reservoirs, it will be used directly. For those reservoirs without sufficient information to simulate them directly, they will be represented by a "typical reservoir" and results scaled to account for the reservoirs in the sub-basin.

The model will be applied to conditions in the selected test sub-basins, Prairie Dog Creek above Sebelius Lake and Medicine Creek above Harry Strunk Lake by the end of 2007.

A more detailed discussion of the water balance model and modeling approach is included in Appendix F.

2. Development of Databases: Initial work was started to collect data and develop databases for Non-Federal Reservoirs and land terracing in the Republican River basin. Each state has completed an inventory of the Non-Federal Reservoirs in their portion of the basin. These inventories includes data related to reservoir location, size, date constructed, dam height and other reservoir characteristics. The inventories prepared by each state are included as Appendix A.

   GIS mapping of terraced fields within the Republican River basin in Nebraska and within the Sappa Creek Basin in Kansas were previously prepared by the University of Nebraska. The mapping of terraced fields in Nebraska is being updated to current images. Digitized mapping provides a database of location and size of each of the terraced fields located within this portion of the basin. A comparable GIS mapping for the Republican River basin in Colorado and the remaining portion of the Republican River basin in Kansas above Hardy, Nebraska was completed in May 2007. Maps of the terraced lands in the basin are included as Figure 1 and Figure 2 in Appendix E.

   Soils data from the SSURGO database have been downloaded for all counties in the Republican River Basin and processed to provide data for input to the POTYLD model. The data are currently being overlaid with watershed boundaries to develop characteristics for the hydrologic response units used to simulate the hydrology of selected subwatersheds. Data from the automated weather data network (AWDN) operated by the High Plains Regional Climate Center have been downloaded and processed to provide daily values of reference crop evapotranspiration for weather stations in Nebraska. Those data were used to calibrate the Hargreaves method on a monthly basis to use in simulating the water balance of subwatersheds over longer periods. Data from the cooperative program operated by NOAA and the National Weather Services has also been assembled for the period from 1949 through 2006. These data only include air temperature and daily rainfall. They will be used with the calibrated Hargreaves method to provide reference evapotranspiration data across the watershed and daily rainfall at selected weather stations. Datasets from the National Hydrograph Dataset have been downloaded and will be used to delineate watershed boundaries. Landuse datasets have been downloaded from the USGS and NASS. Tillage practices have been investigated for each county using the CTIC database. This information will be used to define conditions in hydrologic response units. A more detailed discussion of the development of databases is included in Appendix G.

3. On-the-Ground Verification: Initial study efforts were to establish sample monitoring sites in the field for both reservoirs and terraces as a part of the on-the-ground verification. The monitoring sites consist of monitoring at one reservoir and five terrace sites for detailed data collection and monitoring and a larger sample of 32 reservoir sites for continual remote monitoring and recording of reservoir water levels and water surface area over the study period.

Reservoirs

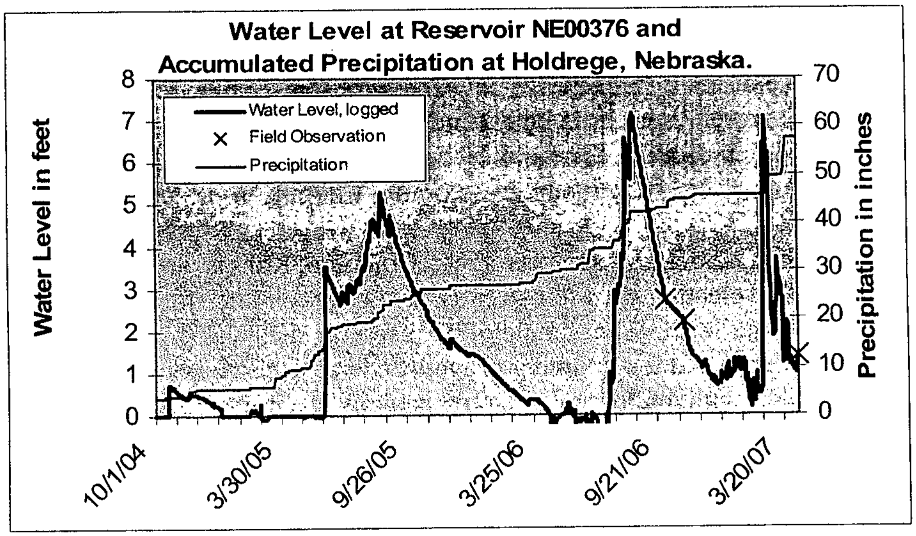
Two levels of investigation are needed for the non-federal reservoirs: (1) monitoring of a sample of reservoirs to characterize how and when these reservoirs fill and drain and (2) an investigation at one reservoir to better understand evaporation from these small reservoir. There are 716 non-federal reservoirs in the basin as reported by the States, Appendix A. There are 6 non-federal reservoirs in Colorado, 148 in Kansas, and 562 in Nebraska.

(1) Larger Sample of 32 Reservoirs Sites: Colorado, Kansas, and Nebraska were responsible for selecting representative sample reservoir sites for the continuous monitoring of reservoir water level. The sample of 32 reservoir sites was proportioned among the states based on the estimated total number of Non-Federal Reservoirs in the Republican River Basin compared with number of these reservoirs in each respective state. Based on these proportions, 1 reservoir sites were assigned to Colorado, 11 to Kansas, and 20 to Nebraska.

Conservation Committee members and other Reclamation and State personnel met in McCook, Nebraska, on September 13, 2004, to begin installation of equipment and data collection at the reservoir sites. State and Reclamation staff continued installation of monitoring equipment as time allowed through the fall of 2004 and early spring of 2005. Monitoring equipment has been installed at a total of 32 sites. Initially plans were to install equipment at 35 sites, however, after reviewing the completed inventories for each of the states it was found that a much smaller number of reservoirs existed in Colorado than earlier estimated. Because of this, the 4 sites earlier planned for Colorado were reduced to one. Appendix C contains samples of this information for three reservoir sites; one in Kansas, one in Nebraska and one in Colorado. A list of the 32 reservoir sites being monitored is included in Appendix B.

The States will continue to make periodic site visits during the course of the study to retrieve water level data, determine reservoir surface area at corresponding water levels, and document overall conditions at the reservoir sites. Weather conditions resulted in very little runoff to most of the reservoirs between the fall of 2004 and the fall of 2006. Fifteen of the 32 reservoirs were dry during at least 2 of the 3 or 4 site visits prior to the fall of 2006. Runoff occurred at some monitored reservoirs during the fall of 2006 and the spring of 2007. Site visits during March and April, 2007, found that 20 of the 32 reservoirs had water stored. Site visits to the Kansas reservoirs in mid-June showed that all eleven reservoirs had stored water, many of them during a runoff event on or about April 24. Important information is being collected regarding how water levels fluctuate in these small reservoirs.

Figure 1 is an example of water level fluctuations for a reservoir in Nebraska. This reservoir is located west of Holdrege, Nebraska. The October 2004 through April 2006 precipitation totaled about 28.7 inches, 76 percent of average. Precipitation improved over the next year. The October 2004 through April 2007 precipitation totaled about 56.6 inches, nearly 8 inches in April 2007, and 89 percent of average. Maximum storage occurring in this reservoir during the observation period was estimated at about 14 acre-feet during August 17, 2006. Similar information on three other reservoirs, one in each State, is included in Appendix C.



Note: Provisional data used for chart.

Figure 1. Example of Water Levels and Accumulated Precipitation for a Reservoir in Nebraska.

Kansas and Nebraska have set up ftp sites to archive the data and to make it available to the Conservation Committee. Kansas has also agreed to archive the data for the Colorado reservoir on their ftp site.

This aspect of the study is essentially on schedule and no anticipated problems are expected at this time.

(2) Field Research at 1 Reservoir site: Some initial work has been done using the data collected at the small reservoirs to partition the water lost from the small reservoirs between evaporation and seepage. Monitoring of reservoir evaporation rates is lagging behind schedule. The Bowen Ratio equipment that will be used to measure evaporation from a small pond has not yet been installed. The system needs to float on a lake and cannot set on a dry riverbed without damaging some sensors. Thus, additional reservoirs have been explored for locating the measuring equipment, including reservoirs outside of the basin.

The research team has been concentrating on estimating seepage from the reservoirs, an important, but unquantified part of the daily water balance. Examination of the water level records from the ten sites in Kansas shows that during most of the time between September 2004 when measurements began and April 2007 these reservoirs had little water in them. One reservoir, DPL Hogan near Long Island, Kansas, has had two periods where there was enough good information to allow for estimates of seepage and overflow from the reservoir.

During a 3-hour period on April 5, 2005, overflow occurred. The total amount of runoff on this date was about 6.67 acre-feet (80 acre-inches) or about 1.0 inch from the 82 acre watershed. See Appendix F for more information about estimating seepage from the non-Federal reservoirs. The overall water balance for the April 5 through August 22, 2005 period is shown in the following table:

Table 1. – Water Balance for a Non-federal Reservoir in Phillips County, Kansas.

Water Balance parameter	Water Volume, in acre-feet	Water Volume, in acre-inches
Runoff	7.39	+ 88.7
Rainfall	0.35	+ 4.2
Overflow	2.33	- 28.0
Estimated Evaporation	0.52	- 6.2
Estimated Seepage	4.81	- 57.7
Change in Storage	0.08	+ 1.0

Land Terracing

Three separate levels of investigation are needed for the land terracing inventory: (1) an overall inventory to determine the number, location and size of all terraced fields in the Republican River basin above Hardy, Nebraska; (2) a survey of a sample set of terraced fields in the basin to acquire information on terrace type, condition and other physical characteristics; and (3) a monitoring program for 5 sample terraced fields for detailed water balance studies.

(1) Terrace Inventory: Nebraska completed the mapping of terraced lands in Nebraska and in the Sappa Creek Basin in Kansas prior to this study. UNL is presently updating that mapping. Mapping of terraced lands in Colorado and the remaining portion of the Republican River basin in Kansas above Hardy, Nebraska was completed by Reclamation in May 2007. Initial estimates from the mapping identified 2,309,559 acres in the Republican River Basin above Hardy, Nebraska with 220,335 acres in Colorado, 893,263 acres in Kansas, and 1,195,961 acres in Nebraska. Maps of the terraced lands are included as Figure 1 and Figure 2 in Appendix E. Appendix E also contains a tabulation of terraced land acreages by county and sub-basin. The ArcGIS files of the mapping for Colorado and Kansas have been provided to UNL for inclusion in the study database.

(2) Survey of Sample Set of Terraced Fields: It was initially believed that a sample set of 20-25 terraced fields in each county was needed to provide an adequate sample of the variation

in characteristics between the terraced fields. An investigation form identifying data that should be collected during the field investigations of the terraced fields is included in Appendix D.

The Conservation Committee made a recommendation to the RRCA at the July 27, 2005, annual meeting that a request for the Natural Resources Conservation Service (NRCS) assistance would be beneficial in assessing the condition of terraces. The RRCA agreed and sent a letter of request for assistance to the NRCS. In response to that request for assistance, the NRCS and the Conservation Committee developed a plan for a pilot study to assess terrace condition. The pilot study examined terraces in the Medicine Creek basin in Frontier County, Nebraska and in Prairie Dog Creek basin in Decatur County, Kansas. The Conservation Committee identified 15-20 potential terraced fields in each county, listed in Appendix D, and the NRCS completed an office assessment of 10 of these terraced fields per county, and field checked 2-3 of the sites per county. This assessment identified the as-built condition of the terrace and determined the present condition. Based on the results of the pilot study, a revised plan to assess terrace condition was developed. The revised plan prescribes site investigation of about 200 terraced fields, and an in-office assessment by NRCS of the types of terraces and characteristics of terraces constructed in each part of the basin. The NRCS concluded that they did not have the staff resources to perform the field work so UNL will serve as the lead in this part of the study. This component of the study is expected to get underway on a limited number of sites during the summer of 2007 and site investigation completed for the remaining sites by the late fall of 2007. The terrace condition assessment study plan is include in Appendix D.

(3) Field Research at 5 Terraced Sites: Five sites were selected for the field research on the impact of terraces. The sites include conservation bench terrace systems located near Culbertson, Nebraska and Colby, Kansas; level terrace systems with closed ends located near Curtis, Nebraska and Norton, Kansas; and a level terrace system with open end(s) located near Stamford, Nebraska (Figure 1 of Appendix G).

Data collection equipment has been installed at the five field research terraced sites. Equipment has been installed to measure and record precipitation and reference evapotranspiration at each site. Water level information is also collected in the terrace channel. Volumetric water content of the soil is being collected at various depths in both the contributing area above the terrace channel and in the terraced channel. Soil moisture data is also being collected using matric potential sensors in both the contributing area and in the terrace channel. Soil temperatures are also being collected. Figure 2 indicates the relative location of the contributing area and the terrace channel.

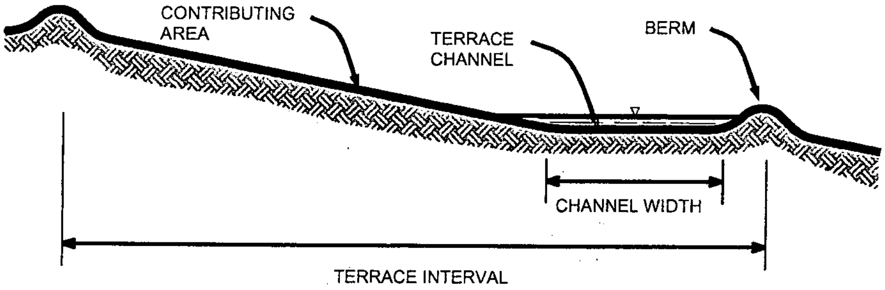


Figure 2. Cross Sectional View of Typical Terraced Land.

All field site instrumentation has completed. Data in the UNL progress report in Appendix G provides an overview of field results to date. A summary of data from the Curtis field site will illustrate the type of data being developed and the progress on this phase of the project.

The amount of water stored in the top 90 inches of the soil on the sloping or contributing area of the field and below the channel of the terrace is shown in Figure 3. These results show that the contributing area on the slope is consistently drier than the soil below the terrace channel. Since the soil is drier it will produce less evapotranspiration and deep percolation than the terrace channel. The soil water below the contributing area dried during this period while the soil beneath the terrace channel showed an increase of water content from the fall of 2006 to the spring of 2007.

The amount of water throughout the soil profile to 25 feet in the spring of 2006 is shown in Figure 4. These data illustrate that more water has infiltrated beneath the terrace channel than below the contributing area and that a significant portion of that amount has percolated through the crop root zone and will seep into the regional groundwater aquifer.

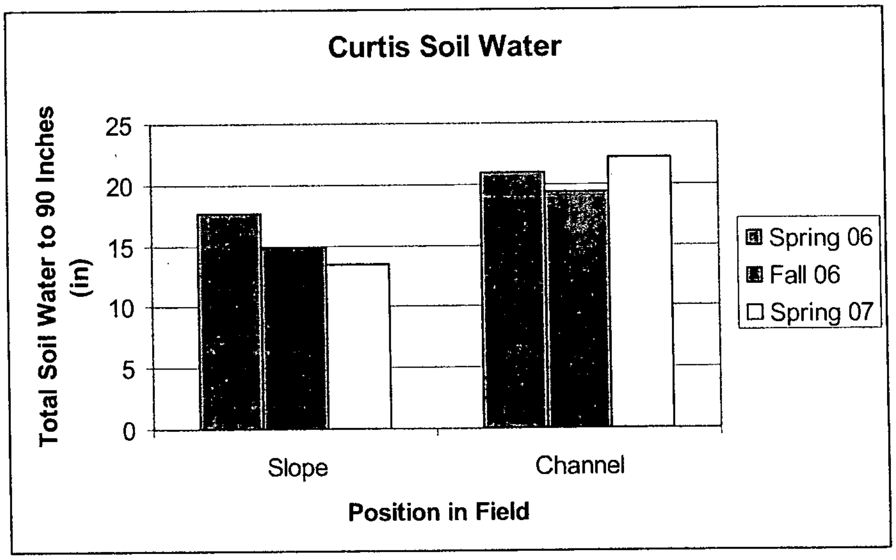


Figure 3. Soil water content in the top 90 inches of the soil profile for the contributing area and the channel of the terraced field at Curtis.

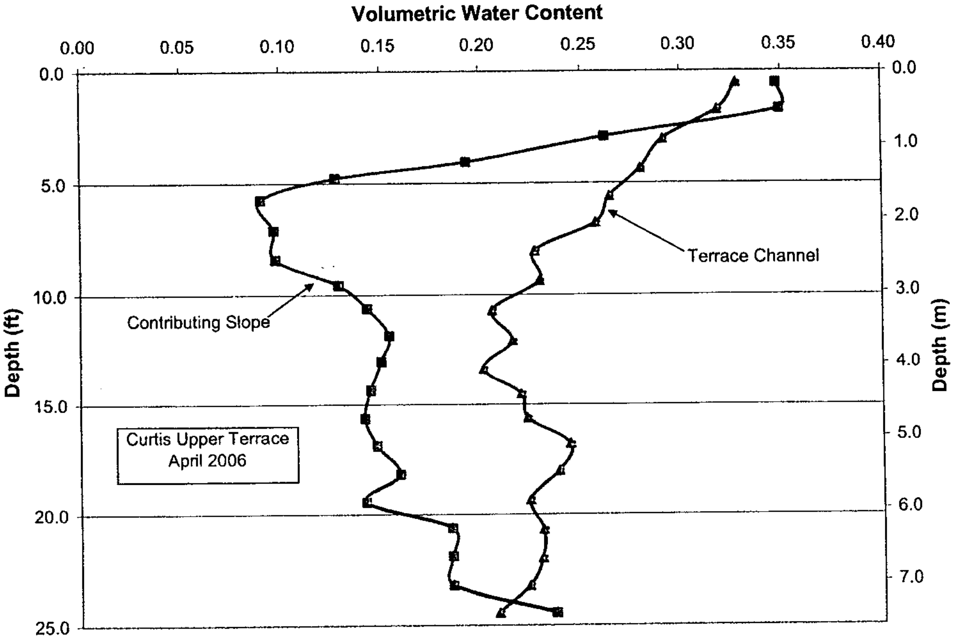


Figure 4. Soil water profiles beneath the contributing area and terrace channel for the Curtis site in the spring of 2006.

We have conducted ring infiltrometer tests to determine parameters for the Green-Ampt infiltration equation but have not fully partitioned the runoff from the contributing area into evapotranspiration and deep percolation at this time.

RRCA3rd Annual Status Rpt Fina... Appendix G.pdf (6 MB) Appendix F.pdf (234 KB)

Dear Ms. Bleed, and Messrs. Knox and Barfield:

On behalf of the RRCA Conservation Committee, please find attached a copy of the Third Annual Status Report for Study on the Impacts of Non-Federal Reservoirs and Land Terracing on Basin Water Supply. The report was prepared to report to you progress of the Study.

The body of the Report is less than 20 pages and essentially is a summary of progress with a few representative examples of the analysis of field data and examples of model work. I have also attached Appendices F and G, which are progress reports of KSU and UNL- these contain more detail. KSU is taking the lead in the water balance model work and UNL is leading the field investigation.

I will follow this email with another email that includes Appendices A, B, C, D, and E.

The Conservation Committee is prepared to discuss the Study with you at your annual meeting on August 14-15.

We expect to have printed copies of the report and appendices to you by about August 8 or 9.

Regards,

For the Conservation Committee
Scott Guenthner
Bureau of Reclamation
Billings, MT
406-247-7736

A more detailed discussion of the on-the-ground-verification, including data collection to help define the water balance at the land terraced sites, is included in Appendix G.

Stream Transmission Loss

The other aspect of the model development that is under study is transmission losses of streamflow during runoff events. Transmission loss is the quantity of water that enters a stream reach, but that does not flow out of the stream reach as surface flow. Transmission loss is usually associated with evaporation and percolation. The effects have important implications on loss of streamflow and recharge distribution within the basin. So, accounting for them will have effects on where and how terracing and small reservoirs affect both recharge and streamflow within the basin.

A small runoff event occurred from the area above the Ludell, KS stream gauge on Beaver Creek on April 24-26, 2007 that totaled 523 acre-feet of flow. This same event appears to have produced a small flow at the Cedar Bluffs, KS stream gauge on April 24, 2007 a few hours later that totaled 23 acre-feet of flow. Subsequently, the main flow that occurred above Ludell made its way past the Cedar Bluff gauge. The resulting hydrograph at Cedar Bluffs from the inflow from above Ludell passed the Cedar Bluffs gauge on April 25 -28, 2007 and totaled 400 acre-feet. This distance between these two gauges is 40.4 river miles. The volume of flow decrease between the two stations was 523-400 = 123 acre-feet. This amounts to a loss of volume of about 24%.

Jordan (1977) looked at flood flows extensively in Kansas and several of the streams are in the Republican Basin that concluded that the transmission loss in one mile for medium- to large-sized streams in western Kansas averages 2% of the flow volume at the beginning of each mile. Using the same technique as Jordon, the April 24-26 runoff event showed an average of only 0.67% of the hydrograph volume was lost per river mile. Considering the small size of the event and that flow was all within the channel, the lower loss observed here is reasonable. It also leads to the conclusion that transmission losses for in-channel flows are likely to be lower than for floods that have a larger area and greater hydraulic pressures that lead to the greater percentage losses that Jordon's work showed. More data is needed, however.

4. Application of the water balance and GIS models:

The model has been tested for different terrace type, cross-section dimensions, functioning conditions, and cropping pattern. Figure 5 is an example of the model results for a conventional, level, closed end terrace with different functioning conditions of the terrace. The information in the chart represents averages for 50 years.

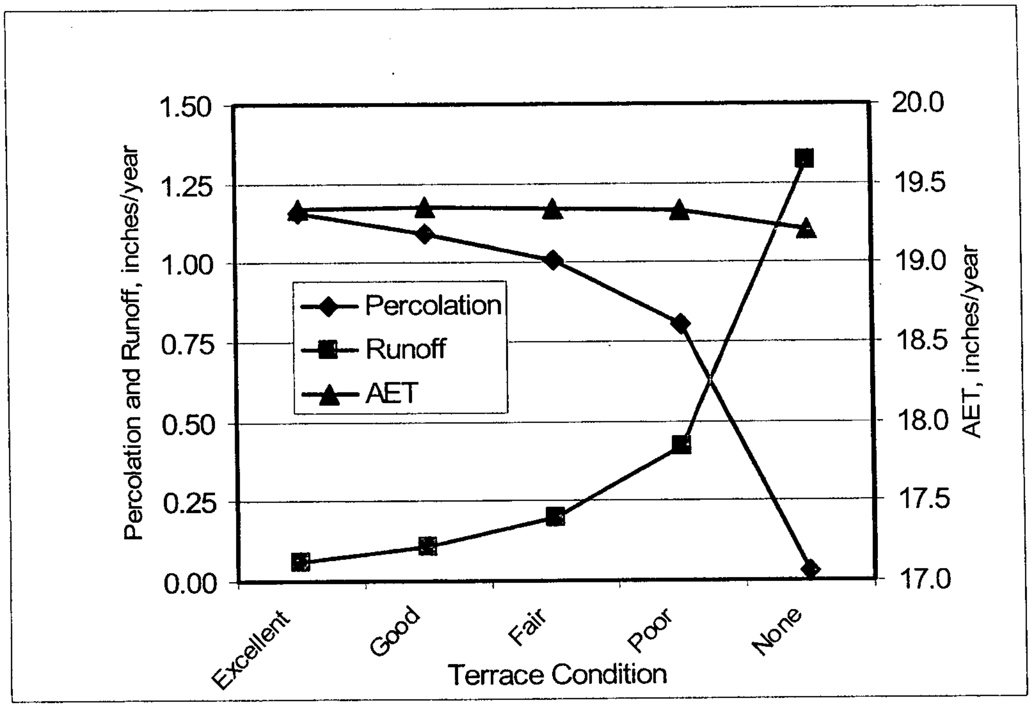


Figure 5. Effect of condition of conventional, level, closed-end terraces on the field water budget at Culbertson, Nebraska.

On the chart both interception and evapotranspiration are combined into the AET term to equal the amount of water lost from the area to the atomosphere. Percolation decreases considerable as the condition of the terrace degrades from as-build condition.

These results should be considered preliminary because we do not have enough field data to calibrate these. Based upon previous work, however, these results appear to be reasonable. See Appendix F for more detailed information on testing of the water balance model. The reader is reminded that all of these results are at the field level. The effect on the water supply at the subwatershed level must consider the extent and condition of the terraces in the subwatershed plus processes that affect runoff as it flows through the stream network.

Finally, the types of terraces, the condition of the terraces, and the cropping systems on them have marked effects on the water balance for the systems. Getting reasonable estimates of the areas of, types of, and condition of terraces in the various sub-watersheds will be important to making reasonable estimates of the effects of land terraces on runoff and percolation.

EXPENDITURES

The Final Settlement Stipulation specifies that the States and the United States will undertake this study at a cost not to exceed one million dollars of which the United States will be responsible for 75 percent of the cost and each State will be responsible for one third of the remaining 25% ($83,333 per State). The States' portion may be provided entirely through in-kind contributions. If the cost of the study exceeds one million dollars, the United States will be responsible for the entire additional amount.

The Study Plan Proposal of April 28, 2004, specified that the in-kind contributions of the States reported in the status reports would cover the period from April 1 of the previous fiscal year through March 31 of the current fiscal year. However, this status report includes costs for May 1 through April 30 as these costs provide a more up-to-date status. Table 1 shows the expenditures by each entity for each of the study years.

Table 2. -- Summary of Study Expenditures

	Study Proposal Development	*Study Expenditure Year*[1]					
		2005 Study Yr 1	**2006** Study Yr 2	**2007** Study Yr 3	**2008** Study Yr 4	**2009** Study Yr 5	**Total**
Colorado	$23,820	$5,625	$3,744	Not reported			$ 9,369
Kansas[3]	40,009	22,307	8,193	21,644			52,144
Nebraska	12,938	23,219	28,023	Not reported			51,242
KSU		0	45,400	77,121	9,165		131,686
UNL		0	189,400	142,406	15,099		346,905
Reclamation[4]		64,876	25,350	85,969	8,404		184,599
NRCS		0	7,125	0			7,125
Total		$116,027	$307,235	$327,140	$32,668		$783,070

[1] The Study was approved on July 27, 2004. The Study Expenditure Year for this table is defined as the period from July 27, 2004 through April 30, 2005 for Study Year 1, and May 1 through April 30 for the other study years, unless otherwise noted.

[2] Expenditures for May 1, 2007 thru June 18, 2007.

[3] Expenditures are July 1 through June 30 for 2005 and 2006, and July 1 through April 30, 2007.

[4] Expenditures separate from funds provided to KSU and UNL under agreements.

Study expenditures totaled $750,402 through April 30, 2007, with an additional amount of $32,668 during May 1 through early June, 2007, for a total expenditure of $783,070.

Colorado – Colorado has provided in-kind contributions toward the study by selecting one reservoir site, assisting with the installation of equipment for monitoring the operation of the reservoir, and by assisting with other work related to the study. Colorado has contributed $9,369 of in-kind services towards the study from the date of approval of the study on July 27, 2004 through April 30, 2006.

Kansas - Kansas Division of Water Resources, Department of Agriculture, has provided staff time, plus expenses in the form of per diem cost for travel, training, installation of instruments and monitoring and maintenance on the instruments on a sample of 11 reservoirs and by assisting with other work related to the study. During 2006, Kansas produced area-capacity tables for each of the 11 dams monitored as part of this study. Kansas has contributed $52,144 of in-kind services towards the study from the date of approval of the study on July 27, 2004 through April 30, 2007.

Nebraska – Nebraska has provided in-kind contributions toward the study by selecting sites, assisting with the installation of equipment for monitoring the operation of 20 reservoirs, and by assisting with other work related to the study. Nebraska conducts site visits to the 20 reservoir sites at least twice per year to download water level recorder data and to collect water surface perimeter data using GPS. Nebraska has contributed $51,242 of in-kind services towards the study from the date of approval of the study on July 27, 2004 through April 30, 2006.

United States

Reclamation – Reclamation committed staff time and funding for purchase and installation of equipment related to the larger sample of 32 reservoirs. In addition, Reclamation committed staff time for preparation and administration of the funding and for mapping of terraced fields (terrace inventory) in Colorado and Kansas. Total expenditures by Reclamation for the above work from the time the MOU was signed through April 30, 2007 were about $176,195. An additional $8,404 was expended from May 1 through May 30, 2007 for a total expenditure of $184,599.

Reclamation entered into a 5-year agreement with the UNL in early October of 2004 to fund the majority of UNL's role in the study effort. Funding to UNL became available in February of 2005. In March, 2005 Reclamation entered into a 5-year agreement with KSU to fund the majority of their role in the study. According to the agreements, Reclamation has agreed to provide $648,789 to KSU and UNL for the study effort.

> Kansas State University – Through April 30, 2007, KSU's Cooperative Agreement expenditures have been about $122,521 and an additional amount of $9,165 from May 1 through early June, 2007, for a total expenditure of $131,686. Reclamation has obligated a total of $200,600 to KSU leaving $68,914 of unexpended funds. Additional funding of $68,526 is budgeted to cover work performed during 2008.
>
> University of Nebraska - Through April 30, 2007, UNL's Cooperative Agreement expenditures have totaled about $331,806 and an additional amount of $15,099 from May 1 through early June 2007, for a total expenditure of $346,905. Reclamation has

obligated a total of $371,400 to UNL leaving $24,495 of unexpended funds. Additional funding of $8,263 is budgeted to cover work performed during 2008.

Reclamation modified the funding agreement with UNL in July 2007 to include an additional $98,000 to accomplish the terrace condition assessment described on page 10. The terrace condition assessment study plan is included in Appendix D. This component of the study is expected to get underway on a limited number of sites during the summer of 2007 and site investigation completed for the remaining sites by the late fall of 2007. Obligated funds that are unused in fiscal year 2007 will be available for work in future years.

NRCS– The NRCS committed staff time and travel expenses for the pilot study to identify as-built condition of the terraces and determine present condition. The expenditures for this work were $7,125 during 2006.

STUDY TIMELINE

For the first year, July 27, 2004 thru May 30, 2005, progress on the study was on schedule for installation and monitoring of the larger sample of 32 reservoirs but behind schedule on most other aspects of the study by 4-5 months. It was anticipated that only 2-3 months of potential data collection would be lost from the delay in installation of monitoring equipment for the detailed field research. Good progress was made in assembling geographic information needed for the study.

During the second year, June 1, 2005 thru May 30, 2006, the study has fallen further behind schedule, primarily caused by delays on installation of equipment to collect data at the field research sites on detailed information regarding the water balance for the small reservoir and land terrace sites. The Conservation Committee generally believes that good results can be obtained by the planned completion date of the study. Two and one-half to three years of detailed data collection at the reservoir and terrace sites should still provide good information regarding the water balance at the sites.

During the third year, June 1 2006 thru May 30, 2007, the research team expected to apply the model to conditions in the selected test sub-basins, Prairie Dog Creek above Sebelius Lake and Medicine Creek above Harry Strunk Lake by the end of 2006. This activity was not completed because of delays is obtaining an assessment of terraced land conditions in those basins, which has been shown to be an important factor in the water balance of terraces. The original study timeline allowed for calibration of the water balance model until July 1, 2008, so there is still adequate time to complete this task if the terrace condition assessment is completed by the end of 2007 as planned. The terrace condition assessment will place a priority for completing terraces condition assessment in the two test sub-basins to help meet the timeline for calibration of the water balance model.

PLANS FOR FOURTH YEAR

Data collection for the reservoir and land terrace sites will continue through this year and until the end of 2008. The assessment of terrace condition will be a major activity in the next year. The remaining objectives for the project are underway but depend on the form and development of the simulation models. The research team expects to develop the GIS interface during the summer and fall of 2007. Monitoring of reservoir evaporation will also be initiated during the summer and fall of 2007 and will be continued through 2008.

APPENDIX A

States Inventory of Non-Federal Reservoirs

APPENDIX
A1
COLORADO

Non Federal Reservoirs with a capacity of greater than 15 acre-feet

Dist	Reservoir Name	ID	Section	Twp	TD	Rng	RD	Northing	Easting	Normal Storage (AF)	Max Storage (AF)	Surface Area (Acres)	Presumptive Average Annual Surface Area (Acres)
49	Flagler	490103	3	9	S	50	W	4351090	673696	1360	3087	157	
65	Chief Creek 4 (Stalker)	650105	3	1	N	44	W	4440548	732420	143	291	27	6.75
	Holy Joe	650108	31	2	N	43	W	4441614	737129	24	24	6	1.5
	Rush Creek #2	650122	32	2	N	42	W	4442284	747806	29	39	2	0.5
	Hanshaw	650123	4	1	N	42	W	4441607	750785	26	38	6	1.5
	Rush Creek #1	650124	5	1	N	42	W	4441375	748094	28	57	14	3.5

Kansas Republican River Inventory of Dams 2003

Over 15 Acre-feet of Storage at the Principal Spillway

Dam Data

Wsn	County_code	Construction_Date	Stream_name	Designated Basin	Net_Evap	PS_Area	Ps storage	Section	Township	Range	Q3	Q2	Q1	Latitude	Longitude	Dam height
DCN-0006	CN		Jones CANYON CREEK-TR	Republican	180	58.04	477	11	1	37			SW	39.980	-101.443	40
DCN-0011	CN		JONES CANYON CREEK-TR	Republican	9	11.76	63	3	1	37			NE	40.000	-101.455	22
DCN-0012	CN	1/1/1958	JONES CANYON CREEK-TR	Republican	15	18.71	111	23	1	37			NW	39.958	-101.442	30
DCN-0013	CN	1/1/1958	CROSBY CREEK-TR	S.F. Republican	7	9.65	49	27	4	41			NW	39.680	-101.913	29
DCN-0016	CN	1/1/1959	REPUBLICAN RIVER-TR	S.F. Republican	4	5.65	23	6	1	39			NW	39.998	-101.747	21
DCN-0019	CN		SOUTH FORK REPUBLICAN-TR	S.F. Republican	9	11.16	59	11	1	39			NE	39.983	-101.668	35
DCN-0029	CN	1/1/1961	ARIKAREE RIVER-TR	Arikaree	5	6.43	28	17	1	41			NE	39.975	-101.943	29
DCN-0037	CN	1/1/1963	REPUBLICAN RIVER-TR	Republican	7	8.59	42	12	1	40			SW	39.990	-101.763	25
DCN-0045	CN		ARIKAREE RIVER-TR	Arikaree	8	9.96	51	27	1	42			NE	39.940	-102.018	27
DCN-0046	CN		CHERRY CREEK-TR	S.F. Republican	9	11.76	63	22	3	41			SW	39.778	-101.915	27
DCN-0049	CN		WEST FORK SAND CREEK	S.F. Republican	11	14.70	83	12	4	40			NW	39.723	-101.765	20
DCN-0050	CN		REPUBLICAN RIVER-TR	S.F. Republican	8	10.41	54	10	1	41			NW	39.988	-101.917	30
DCN-0051	CN		BIG TIMBER CREEK-TR	S.F. Republican	5	7.05	32	9	2	37			SW	39.890	-101.483	22
DCN-0052	CN		BIG TIMBER CREEK-TR	S.F. Republican	8	9.96	51	18	2	37			SW	39.877	-101.517	30
DCN-0053	CN	1/1/1969	BIG TIMBER CREEK-TR	S.F. Republican	16	20.79	126	8	2	37			NE	39.897	-101.493	24
DCN-0054	CN		BIG TIMBER CREEK-TR	S.F. Republican	7	9.50	48	19	1	37			NE	39.955	-101.510	20
DCN-0055	CN		Drury Creek	S.F. Republican	5	6.81	55.03	10	1	41			SW	39.710	-101.810	27
DCN-0056	CN	9/9/1970	ARIKAREE RIVER-TR	Arikaree	4	5.15	35.99	26	1	42			NW	39.940	-102.005	18
DCN-0057	CN	1/1/1971	BIG TIMBER CREEK-TR	S.F. Republican	3	4.41	27	4	3	38			SW	39.820	-101.588	23
DCN-0059	CN	1/1/1969	REPUBLICAN RIVER-TR	S.F. Republican	7	8.44	41	3	1	41			SE	39.995	-101.898	25
DCN-0060	CN	1/1/1968	REPUBLICAN RIVER-TR	S.F. Republican	6	8.13	39	11	1	41			NE	39.983	-101.885	24
DCN-0061	CN	1/1/1966	Jones CANYON CREEK-TR	Republican	14	18.00	106	26	1	37			NW	39.945	-101.447	29
DCN-0062	CN	1/1/1963	ARIKAREE RIVER-TR	Arikaree	11	14.56	82	5	1	41			SW	39.990	-101.948	30
DCN-0063	CN	1/1/1962	ARIKAREE RIVER-TR	Arikaree	7	8.59	42	8	1	41			SE	39.978	-101.943	28
DCN-0064	CN	1/1/1962	BIG TIMBER CREEK-TR	S.F. Republican	6	7.51	35	13	1	38			NE	39.968	-101.525	20
DCN-0065	CN	1/1/1950	BIG TIMBER CREEK-TR	S.F. Republican	7	8.74	43	5	2	37			NE	39.915	-101.487	27
DDC-0023	DC	1/1/1959	PRAIRIE DOG CREEK-TR	Prairie Dog	8	10.26	53	21	4	26			SE	39.690	-100.247	17
DDC-0028	DC		BEAVER CREEK-TR	Beaver	7	8.44	41	6	1	28			NW	39.998	-100.508	32
DDC-0029	DC	1/1/1965	PRAIRIE DOG CREEK-TR	Prairie Dog	6	7.21	33	35	4	28			SE	39.660	-100.430	30

Kansas Republican River Inventory of Dams 2003
Over 15 Acre-feet of Storage at the Principal Spillway
Dam Data

Wsn	County code	Construction Date	Stream name	Designated Basin	Net Evap	PS Area	PS storage	Section	Township	Range	Q3	Q2	Q1	Latitude	Longitude	Dam height
DDC-0030	DC	1/1/1965	SAPPA CREEK-TR	Sappa	9	11.61	62	15	2	27			NW	39.880	-100.340	20
DDC-0031	DC	1/1/1965	SAPPA CREEK-TR	Sappa	7	8.89	44	26	2	27			W2	39.850	-100.325	25
DDC-0032	DC	1/1/1965	SAPPA CREEK-TR	Sappa	12	14.56	82	10	2	27			NE	39.900	-100.337	28
DDC-0033	DC	1/1/1966	NORTH FORK SAPPA CREEK-TR	Sappa	7	9.05	45	8	3	29			SW	39.805	-100.605	32
DDC-0034	DC	1/1/1965	SAPPA CREEK-TR	Sappa	9	11.01	58	12	1	27			SW	39.980	-100.300	22
DDC-0038	DC	1/1/1967	BIG TIMBER CREEK-TR	S.F. Republican	10	12.20	66	28	3	27			NW	39.768	-100.360	27
DDC-0041	DC	1/1/1967	SOUTH FORK SAPPA CREEK-TR	Sappa	4	5.03	19	28	3	29			SE	39.760	-100.573	18
DDC-0042	DC	1/1/1968	SAPPA CREEK-TR	Sappa	5	5.81	24	2	1	27			SW	39.988	-100.325	32
DDC-0043	DC	1/1/1969	BEAVER CREEK-TR	Beaver	6	7.21	33	17	2	30			NE	39.882	-100.707	27
DDC-0049	DC	1/1/1973	SAPPA CREEK-TR	Sappa	21	26.75	185	23	1	26			SE	39.950	-100.203	28
DDC-0051	DC	1/1/1972	BEAVER CREEK-TR	Beaver	3	3.84	16	10	2	30			NE	39.902	-100.667	20
DDC-0052	DC	1/1/1972	BEAVER CREEK-TR	Beaver	5	6.72	24	11	2	30			NW	39.898	-100.657	22
DDC-0053	DC		SAPPA CREEK-TR	Sappa	11	13.52	87	29	4	30			NE	39.677	-100.710	20
DDC-0057	DC	1/1/1975	NORTH FORK SAPPA CREEK-TR	Sappa	6	7.51	35	2	3	30			SE	39.815	-100.647	17
DDC-0058	DC	1/1/1955	SAPPA CREEK-TR	Sappa	7	8.28	40	23	1	28			NE	39.953	-100.425	22
DDC-0060	DC	1/1/1965	ROCK DRAW	Sappa	12	15.43	88	36	1	29			SE	39.917	-100.520	23
DDC-0061	DC	1/1/1958	SPRING BRANCH-TR	Sappa	6	8.13	39	28	1	26			SW	39.932	-100.245	19
DDC-0062	DC	1/1/1958	SAPPA CREEK-TR	Sappa	9	11.46	61	26	1	27			SE	39.937	-100.313	20
DDC-0063	DC	1/1/1961	SAPPA CREEK-TR	Sappa	9	11.46	61	8	1	26			SE	39.975	-100.260	28
DDC-0064	DC	1/1/1971	BEAVER CREEK-TR	Beaver	97	30.61	201	1	1	29			W2	39.993	-100.528	30
DDC-0065	DC	1/1/1935	SAPPA CREEK	Sappa	231	72.84	807	29	2	28			SE	39.843	-100.487	22
DDC-0066	DC	1/1/1950	NORTH FORK SAPPA CREEK-TR	Sappa	5	5.96	25	12	3	30			SW	39.800	-100.640	20
DDC-0067	DC	1/1/1954	SOUTH FORK SAPPA CREEK-TR	Sappa	7	9.05	45	32	3	29			SE	39.745	-100.597	20
DDC-0068	DC	1/1/1962	SAPPA CREEK-TR	Sappa	5	6.12	26	1	2	27			SW	39.907	-100.300	20
DDC-0069	DC	1/1/1973	BIG TIMBER CREEK-TR	S.F. Republican	5	6.90	31	35	3	28			NE	39.748	-100.423	16
DDC-0070	DC	1/1/1972	BIG TIMBER CREEK-TR	S.F. Republican	8	9.50	48	11	4	28			SE	39.717	-100.422	15
DNT-0002	NT	5/1/1935	PRARIE DOG CREEK-TR	Prairie Dog	8	10.11	52	15	2	21			NW	39.885	-99.680	30
DNT-0043	NT		HORSE CREEK-TR	Prairie Dog	6	7.36	34	12	1	22			SE	39.975	-99.742	15
DNT-0066	NT		PRAIRIE DOG CREEK-TR	Prairie Dog	8	10.56	55	29	2	24			SE	39.843	-100.045	17
DNT-0067	NT	1/1/1938	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.59	42	24	2	25			SW	39.860	-100.087	18

Kansas Republican River Inventory of Dams 2003
Over 15 Acre-feet of Storage at the Principal Spillway
Dam Data

Wsn	County code	Construction Date	Stream name	Designated Basin	Net Evap	PS Area	Ps storage	Section	Township	Range	Q3	Q2	Q1	Latitude	Longitude	Dam height
DNT-0071	NT		PRAIRIE DOG CREEK-TR	Prairie Dog	11	14.41	81	17	2	24			SE	39.873	-100.040	23
DNT-0072	NT		SAND CREEK-TR	Prairie Dog	9	11.16	59	28	1	21			SW	39.930	-99.693	19
DNT-0074	NT		PRAIRIE DOG CREEK-TR	Prairie Dog	11	13.97	78	14	2	22			NE	39.878	-99.767	23
DNT-0075	NT		WILDCAT CREEK	Prairie Dog	7	8.74	43	1	2	21			SE	39.903	-99.630	21
DNT-0097	NT		PRAIRIE DOG CREEK-TR	Prairie Dog	9	11.76	63	3	3	22			SW	39.820	-99.790	30
DNT-0098	NT		PRAIRIE DOG CREEK-TR	Prairie Dog	13	16.01	92	30	2	24			SE	39.847	-100.062	21
DNT-0102	NT		PRAIRIE DOG CREEK-TR	Prairie Dog	5	6.90	31	4	4	25			SW	39.732	-100.148	26
DNT-0108	NT		SQUAW BRANCH-SAPPA CREEK-TR	Sappa	5	6.74	30	18	1	24			NE	39.967	-100.060	32
DNT-0127	NT	1/1/1962	PRARIE DOG CREEK-TR	Prairie Dog	5	6.12	26	1	3	23			SW	39.818	-99.862	26
DNT-0141	NT	1/1/1957	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.28	40	19	2	24			SE	39.858	-100.063	16
DNT-0142	NT	1/1/1950	LONG BRANCH SAPPA CREEK-TR	Sappa	8	9.50	48	3	2	25			SW	39.907	-100.123	16
DNT-0144	NT	1/1/1951	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.28	40	14	3	25			NE	39.795	-100.097	15
DNT-0145	NT	1/1/1949	PRAIRIE DOG CREEK-TR	Prairie Dog	7	9.35	47	35	3	25			NW	39.752	-100.108	16
DNT-0146	NT	1/1/1946	WALNUT CREEK-TR	Republican	6	7.98	38	10	2	24			NW	39.900	-100.013	16
DNT-0147	NT	1/1/1945	PRAIRIE DOG CREEK-TR	Prairie Dog	8	9.50	48	26	3	24			SW	39.760	-100.000	20
DNT-0148	NT	1/1/1948	BOY CREEK-TR	Sappa	11	13.39	74	23	1	24			SW	39.950	-99.992	22
DNT-0149	NT	1/1/1949	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.74	43	31	2	23			SW	39.830	-99.960	17
DNT-0150	NT	1/1/1949	DEER CREEK-TR	Sappa	8	10.11	52	28	1	23			NE	39.943	-99.912	15
DNT-0153	NT	1/1/1952	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.44	41	6	2	22			SW	39.900	-99.850	14
DNT-0154	NT	1/1/1953	N FORK PRAIRIE DOG CREEK-TR	Prairie Dog	6	7.96	38	32	1	22			NE	39.925	-99.815	14
DNT-0155	NT	1/1/1951	N FORK PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.59	42	29	1	22			SW	39.935	-99.823	16
DNT-0156	NT	1/1/1953	SAPPA CREEK-TR	Sappa	7	8.44	41	5	1	22			SW	39.993	-99.828	17
DNT-0157	NT	1/1/1950	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.28	40	8	3	22			SE	39.800	-99.818	18
DNT-0158	NT	1/1/1952	PRAIRIE DOG CREEK-TR	Prairie Dog	5	6.74	30	8	2	22			NW	39.893	-99.825	16
DNT-0160	NT	1/1/1951	PRAIRIE DOG CREEK-TR	Prairie Dog	6	7.67	36	15	3	22			NE	39.798	-99.780	15
DNT-0161	NT	1/1/1949	PRAIRIE DOG CREEK-TR	Prairie Dog	9	11.46	61	10	3	22			SE	39.805	-99.783	20
DNT-0162	NT	1/1/1956	PRAIRIE DOG CREEK-TR	Prairie Dog	6	7.82	37	16	2	22			NE	39.878	-99.800	17
DNT-0163	NT	1/1/1948	NORTH FORK PRAIRIE DOG CRK-TR	Prairie Dog	6	7.51	35	21	1	22			SE	39.947	-99.798	14
DNT-0167	NT	1/1/1950	PRAIRIE DOG CREEK-TR	Prairie Dog	7	8.59	42	27	1	21			SW	39.933	-99.675	16
DNT-0172	NT	1/1/1960	HORSE CREEK-TR	Prairie Dog	5	6.74	30	19	1	21			SW	39.950	-99.732	21

Kansas Republican River Inventory of Dams 2003

Over 15 Acre-feet of Storage at the Principal Spillway

Dam Data

Wsn	County code	Construction Date	Stream name	Designated Basin	Net Evap	PS Area	PS storage	Section	Township	Range	Q3	Q2	Q1	Latitude	Longitude	Dam height
DNT-0173	NT	1/1/1970	HORSE CREEK-TR	Prairie Dog	7	8.28	40	19	1	21			NW	39.953	-99.730	16
DNT-0174	NT	1/1/1960	SAPPA CREEK-TR	Sappa	6	7.51	35	17	1	22			NE	39.972	-99.820	13
DPL-0047	PL		CROW CREEK-TR	Republican	8	7.98	38	14	1	17			SW	39.963	-99.208	15
DPL-0060	PL		PRAIRIE DOG CREEK-TR	Prairie Dog	9	8.89	44	36	1	20			NW	39.927	-99.528	25
DPL-0063	PL		PRAIRIE DOG CREEK-TR	Prairie Dog	10	10.41	54	4	1	19			NW	39.997	-99.472	26
DPL-0066	PL		PRAIRIE DOG CREEK-TR	Prairie Dog	19	19.96	120	15	2	20			NW	39.882	-99.567	30
DPL-0067	PL	1/1/1937	CRYSTAL CREEK-TR	Republican	8	8.59	42	9	1	17			NW	39.987	-99.247	20
DPL-0087	PL		WALNUT CREEK-TR	Prairie Dog	20	20.65	125	15	1	18			NE	39.968	-99.332	34
DPL-0120	PL	1/1/1941	WEST CROW CREEK	Republican	9	8.89	44	20	1	17			NW	39.957	-99.263	13
DPL-0128	PL	1/1/1953	PRAIRIE DOG CREEK-TR	Prairie Dog	8	7.82	37	10	1	19			NW	39.985	-99.452	15
DPL-0133	PL	1/1/1930	PRAIRIE DOG CREEK-TR	Prairie Dog	13	13.53	75	4	2	20			NW	39.908	-99.580	15
DPL-0134	PL	1/1/1956	PRAIRIE DOG CREEK-TR	Prairie Dog	8	8.13	39	9	1	20			NW	39.983	-99.582	15
DPL-0136	PL	1/1/1950	PRAIRIE DOG CREEK-TR	Prairie Dog	9	8.89	44	30	1	20			NE	39.937	-99.612	15
DPL-0137	PL	1/1/1936	PRAIRIE DOG CREEK-TR	Prairie Dog	10	9.96	51	8	2	20			NW	39.893	-99.605	20
DPL-0138	PL	1/1/1965	PRAIRIE DOG CREEK-TR	Prairie Dog	9	9.05	45	10	1	20			NW	39.982	-99.567	17
DPL-0139	PL	1/1/1964	PRAIRIE DOG CREEK-TR	Prairie Dog	5	4.71	17	26	1	20			SE	39.937	-99.537	19
DPL-0140	PL	1/1/1972	PRAIRIE DOG CREEK-TR	Prairie Dog	6	6.28	27	6	2	20			NE	39.910	-99.612	18
DRA-0001	RA	12/1/1987	BEAVER CREEK	Beaver	12	12.80	70	5	3	33	NE	SE	SE	39.817	-101.038	8
DRA-0003	RA	1/1/1935	NORTH BEAVER CREEK-TR	Beaver	7	7.82	37	29	2	34			NW	39.852	-101.165	24
DRA-0018	RA	1/1/1937	NORTH BEAVER CREEK-TR	Beaver	14	15.57	89	33	2	35			SE	39.830	-101.243	23
DRA-0040	RA	1/1/1960	SOUTH FORK SAPPA CREEK-TR	Sappa	12	12.65	69	11	5	31			NE	39.638	-100.762	19
DRA-0042	RA	1/1/1960	BEAVER CREEK-TR	Beaver	8	8.59	42	26	3	34			NW	39.763	-101.105	19
DRA-0048	RA		MIDDLE FORK SAPPA CREEK-TR	Sappa	6	7.05	32	8	5	33			NE	39.633	-101.038	21
DRA-0049	RA	1/1/1961	NORTH FORK SAPPA CREEK-TR	Sappa	10	10.41	54	13	4	31			NE	39.712	-100.748	24
DRA-0050	RA	1/1/1962	LITTLE BEAVER CREEK-TR	Beaver	7	7.98	38	24	2	34			SE	39.860	-101.077	25
DRA-0053	RA	1/1/1962	BEAVER CREEK-TR	Beaver	11	11.91	64	9	2	31			SW	39.892	-100.807	23
DRA-0054	RA	1/1/1963	BEAVER CREEK-TR	Beaver	6	7.05	32	25	3	34			NE	39.770	-101.078	16
DRA-0055	RA	1/1/1964	DRIFTWOOD CREEK-TR	Driftwood	8	8.44	41	6	1	31			NW	40.000	-100.845	26
DRA-0056	RA	1/1/1964	BEAVER CREEK-TR	Beaver	8	8.74	43	2	3	31			NE	39.828	-100.765	19
DRA-0059	RA	1/1/1964	NORTH BEAVER CREEK-TR	Beaver	10	10.71	56	24	2	36			SE	39.858	-101.298	24

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Dam Data

Wsn	County code	Construction Date	Stream name	Designated Basin	Net Evap	PS Area	Ps storage	Section	Township	Range	Q3	Q2	Q1	Latitude	Longitude	Dam height
DRA-0060	RA	1/1/1965	NORTH FORK SAPPA CREEK-TR	Sappa	11	12.06	65	22	4	33			NE	39.693	-101.007	29
DRA-0061	RA	1/1/1965	MIDDLE FORK SAPPA CREEK-TR	Sappa	7	7.98	38	29	4	31			SW	39.673	-100.830	26
DRA-0064	RA	1/1/1965	BEAVER CREEK-TR	Beaver	6	6.90	31	33	2	32			NW	39.837	-100.923	18
DRA-0065	RA		MIDDLE FORK SAPPA CREEK-TR	Sappa	11	11.61	62	27	5	33			NW	39.593	-101.018	27
DRA-0067	RA		Burntwood / TIMBER CREEK-TR	Republican	13	14.27	80	7	1	36			NE	39.983	-101.400	26
DRA-0072	RA	1/1/1967	LITTLE BEAVER CREEK-TR	Beaver	3	3.30	23	24	3	35	NW	NE	NW	39.785	-101.198	37
DRA-0075	RA	1/1/1969	NORTH FORK SAPPA CREEK-TR	Sappa	8	8.89	44	24	4	33			NW	39.693	-100.977	22
DRA-0076	RA	1/1/1969	MIDDLE FORK SAPPA CREEK-TR	Sappa	10	10.71	56	36	4	32			SE	39.662	-100.855	26
DRA-0077	RA		SOUTH FORK SAPPA CREEK-TR	Sappa	5	5.03	19	11	5	31			SW	39.627	-100.777	30
DRA-0080	RA	1/1/1959	Burntwood / TIMBER CREEK-TR	Republican	9	9.81	50	18	1	36			SW	39.967	-101.402	32
DRA-0081	RA	1/1/1974	NORTH FORK DRIFTWOOD CREEK-TR	Driftwood	8	9.05	45	5	1	34			SE	39.993	-101.157	28
DRA-0083	RA	1/1/1966	BEAVER CREEK-TR	Beaver	6	7.00	50	9	3	32	NE	NE	NW	39.813	-100.918	47
DSH-0001	SH													39.335	-101.864	
DSH-0003	SH		SOUTH FORK SAPPA CREEK-TR	Sappa	6	8.13	39	17	8	37			NE	39.362	-101.472	17
DSH-0014	SH		SOUTH FORK SAPPA CREEK-TR	Sappa	8	10.11	52	29	9	38			SE	39.243	-101.582	16
DSH-0031	SH		BEAVER CREEK-TR	Beaver	5	6.59	29	3	6	37			N2	39.568	-101.435	27
DSH-0034	SH	1/1/1975	SOUTH FORK SAPPA CREEK-TR	Sappa	5	6.59	29	32	8	37			NW	39.320	-101.475	18
DTH-0011	TH		SOUTH FORK SAPPA CREEK	Sappa	15	18.99	113	29	8	36			NE	39.333	-101.360	22
DTH-0022	TH		MIDDLE FORK SAPPA CREEK	Sappa	15	19.27	115	8	7	36			N2	39.462	-101.358	17
DTH-0029	TH		MIDDLE FORK SAPPA CREEK-TR	Sappa	11	13.97	78	2	6	34			NW	39.567	-101.083	24
DTH-0036	TH	1/1/1962	PRAIRIE DOG CREEK-TR	Prairie Dog	6	7.51	35	6	7	31			SE	39.472	-100.830	17
DTH-0039	TH	23377	SOUTH FORK SAPPA CREEK-TR	Sappa	14	18.565	110	23	6	33			SE	39.513	-100.965	26
DTH-0040	TH	27760	SOUTH FORK SAPPA CREEK-TR	Sappa	7	9.19796	46	13	6	33			SW	39.527	-100.960	25

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CHASE	155	NE00709	IMPERIAL DAM	Frenchman Creek	W063925	1917	240	40	23.2	-101.696	40.464	NE4NW4S25 T06N R39W
CHASE	185	NE00710	HOFFMEISTER DAM	Frenchman Creek	W063831	1938	100	25	4.9	-101.672	40.444	NW4SE4S31 T06N R38W
CHASE	98	NE00708	ARTERBURN DAM	Frenchman Creek	W064112	1912	588	60	1.6	-101.931	40.495	SW4SW4S12 T06N R41W
CHASE	150			Frenchman Creek	W063922				2.1			
CHASE	146			Frenchman Creek	W063921				12.9			
CHASE	157	NE00707	KILPATRICK DAM NO 1	Frenchman Creek	W063930		0	0	0	-101.777	40.464	N2NE4S30 T06N R39W
CHASE	2311	NE01139	KILPATRICK DIV DAM	Frenchman Creek	W064022	1890	130	26	14.4	-101.836	40.470	NE4SE4S22 T06N R40W
DUNDY	2679	NE01931	STUTE NORTH DAM	Buffalo Creek	W024135		18	0	0.4	-101.916	40.099	W2NE4S35 T02N R41W
DUNDY	1680			Mainstem Republican River	W023620				0.6			
DUNDY	1655			Mainstem Republican River	W023834				12.9			
DUNDY	1657			Mainstem Republican River	W013813				1.9			
DUNDY	1647			Buffalo Creek	W024126				4.7			
DUNDY	1651	NE01929	KARA LAKE DAM	Mainstem Republican River	W013920		30	0	9.1	-101.743	40.045	NE4NE4S20 T01N R39W
DUNDY	1650	NE00611	ROCK CREEK DAM	Rock Creek	W013906	1934	511	49	0	-101.762	40.087	NE4S06 T01N R39W
DUNDY	1683	NE00612	ARROW HEAD DAM	Mainstem Republican River	W023705	1905	18	9	10.1	-101.521	40.167	NW4SE4S05 T02N R37W
DUNDY	2502	NE01131	KEISER DAM	Mainstem Republican River	W043635	1965	17	5	0.6	-101.353	40.268	NW4SE4S35 T04N R36W
FRANKLIN	1276			Mainstem Republican River	W021331				3.3			
FRANKLIN	1545			Mainstem Republican River	W011530				3.3			
FRANKLIN	1464			Mainstem Republican River	W011321				2.7			
FRANKLIN	1107			Mainstem Republican River	W021317				3.3			
FRANKLIN	1110			Mainstem Republican River	W021417				4.9			
FRANKLIN	1133			Mainstem Republican River	W021414				3.4			
FRANKLIN	1170			Mainstem Republican River	W021622				2.4			
FRANKLIN	1472			Mainstem Republican River	W011324				8.6			
FRANKLIN	1271			Mainstem Republican River	W021534				4.7			
FRANKLIN	1724			Mainstem Republican River	W031625				0.9			
FRANKLIN	1405			Mainstem Republican River	W011318				3.5			
FRANKLIN	1280			Mainstem Republican River	W021533				4.8			
FRANKLIN	1282			Mainstem Republican River	W021534				2.4			
FRANKLIN	1283			Mainstem Republican River	W021331				3.4			

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FRANKLIN	1471			Mainstem Republican River	W011421				2.1			
FRANKLIN	996			Mainstem Republican River	W021603				3.9			
FRANKLIN	2598			Mainstem Republican River	W011511				3.9			
FRANKLIN	1190			Mainstem Republican River	W021619				2.2			
FRANKLIN	1585			Mainstem Republican River	W011336				2.3			
FRANKLIN	1523			Mainstem Republican River	W011330				6			
FRANKLIN	1516			Mainstem Republican River	W011328				1.1			
FRANKLIN	1090			Mainstem Republican River	W021411				2.8			
FRANKLIN	1507			Mainstem Republican River	W011328				5			
FRANKLIN	1504			Mainstem Republican River	W011629				2.3			
FRANKLIN	1484			Mainstem Republican River	W011319				9.2			
FRANKLIN	899			Mainstem Republican River	W031429				3.9			
FRANKLIN	1469			Mainstem Republican River	W011321				1.8			
FRANKLIN	537			Mainstem Republican River	W041329				3.4			
FRANKLIN	1532			Mainstem Republican River	W011426				2.4			
FRANKLIN	577			Mainstem Republican River	W041434				3			
FRANKLIN	917			Mainstem Republican River	W031627				0.6			
FRANKLIN	1085			Mainstem Republican River	W021409				7.3			
FRANKLIN	650			Mainstem Republican River	W031301				3.4			
FRANKLIN	741			Mainstem Republican River	W031317				2.9			
FRANKLIN	849			Mainstem Republican River	W031422				3.5			
FRANKLIN	1465			Mainstem Republican River	W011319				8.1			
FRANKLIN	1102			Mainstem Republican River	W021516				0			
FRANKLIN	2567	NE00618	FRERICHS DAM NO 2	Mainstem Republican River	W031531	1961	46	1	0	-99.058	40.180	NE4SW4S31 T03N R15W
FRANKLIN	1033	NE00625	PHILLIPSON DAM	Mainstem Republican River	W021507	1949E	41	1	3.3	-99.054	40.159	NW4NE4S07 T02N R15W
FRANKLIN	802	NE00617	FRERICHS DAM NO 1	Mainstem Republican River	W031519	1961	50	9	4	-99.060	40.217	NE4NW4S19 T03N R15W
FRANKLIN	1202	NE00627	SAATHOFF DAM	Mainstem Republican River	W021628	1961	44	2	3.3	-99.124	40.115	NE4NE4S28 T02N R16W
FRANKLIN	775	NE00613	ADAM DAM	Mainstem Republican River	W031615	1949E	20	6	1.4	-99.114	40.224	E2SW4S15 T03N R16W
FRANKLIN	1321	NE00626	RASMUSSEN DAM	Mainstem Republican River	W011603	1960E	29	7	2.9	-99.109	40.077	SW4SE4S03 T01N R16W
FRANKLIN	1379	NE00408	KUGLER DAM	Mainstem Republican River	W011316	1962	55	13	6	-98.799	40.061	NW4NW4S16 T01N R13W
FRANKLIN	1387	NE00406	SINDT DAM	Mainstem Republican River	W011414	1945	116	20	13.3	-98.873	40.057	NW4NW4S14 T01N R14W

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FRANKLIN	972			Mainstem Republican River	W031432				1.8			
FRANKLIN	1589	NE02289	HAWKINS DAM NO 2	Mainstem Republican River	W011333	1965	27	4	1.2	-98.784	40.015	NE4NE4S33 T01N R13W
FRANKLIN	1060			Mainstem Republican River	W021412				2.6			
FRANKLIN	2590	NE00407	JAMES DAM	Mainstem Republican River	W021528	1935	35	10	2.9	-99.013	40.111	SE4NE4S28 T02N R15W
FRANKLIN	2620	NE00405	BERTRAND DAM	Mainstem Republican River	W041421	1940	43	9	0.5	-98.901	40.293	SE4SE4S21 T04N R14W
FRANKLIN	1547	NE02290	HAWKINS DAM NO 3	Mainstem Republican River	W011326	1965	46	7	8.8	-98.763	40.024	NW4SW4S26 T01N R13W
FRANKLIN	1609	NE02194	HAWKINS DAM NO 1	Mainstem Republican River	W011333	1965	88	13	4.4	-98.786	40.012	SE4NE4S33 T01N R13W
FRANKLIN	1498	NE02195	HAWKINS DAM NO 4	Mainstem Republican River	W011326	1965	65	13	7.8	-98.763	40.031	NW4NW4S26 T01N R13W
FRANKLIN	1531	NE00623	MONIE DAM	Mainstem Republican River	W011427	1949E	33	7	3.5	-98.878	40.026	SE4NE4S27 T01N R14W
FRANKLIN	1508	NE00616	COPLEY DAM	Mainstem Republican River	W011429	1963	23	4	2.5	-98.921	40.030	NW4NE4S29 T01N R14W
FRANKLIN	1395	NE00620	KAHRS DAM	Mainstem Republican River	W011518	1948E	65	10	8.5	-99.055	40.055	SW4NE4S18 T01N R15W
FRANKLIN	1071			Mainstem Republican River	W021509				1.7			
FRANKLIN	954			Mainstem Republican River	W031533				2.7			
FRANKLIN	1635			Mainstem Republican River	W011333				2.5			
FRANKLIN	1604			Mainstem Republican River	W011435				4.7			
FRANKLIN	965			Mainstem Republican River	W031433				4.3			
FRANKLIN	1530			Mainstem Republican River	W011429				3.1			
FRANKLIN	878			Mainstem Republican River	W031527				2.7			
FRANKLIN	1083			Mainstem Republican River	W021512				3.5			
FRANKLIN	2707	NE99903	COPLEY DAM	Mainstem Republican River	W011428	1962	22	0	1.9	-98.909	40.028	SE4NW4S28 T01N R14W
FRANKLIN	1566			Mainstem Republican River	W011329				5			
FRANKLIN	850	NE00615	BARTELS DAM	Mainstem Republican River	W031423	1961	85	14		-98.861	40.206	SE4SE4S23 T03N R14W
FRANKLIN	1026			Mainstem Republican River	W021403				3.6			
FRANKLIN	1578			Mainstem Republican River	W011336				3.3			
FRANKLIN	1042			Mainstem Republican River	W021512				4.4			
FRANKLIN	1048			Mainstem Republican River	W021508				8.8			
FRANKLIN	1570			Mainstem Republican River	W011330				3.7			
FRANKLIN	1584			Mainstem Republican River	W011435				5.6			
FRANKLIN	970			Mainstem Republican River	W031532				2.9			
FRANKLIN	932			Mainstem Republican River	W031635				2.7			
FRANKLIN	1501			Mainstem Republican River	W011330				8.5			

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FRANKLIN	1099			Mainstem Republican River	W021613				2.9			
FRONTIER	38			Mainstem Republican River	W072411				2.7			
FRONTIER	1836			Mainstem Republican River	W082618				2			
FRONTIER	179			Mainstem Republican River	W062522				6.9			
FRONTIER	1832			Mainstem Republican River	W052829				1.5			
FRONTIER	312			Mainstem Republican River	W052522				1.6			
FRONTIER	286			Mainstem Republican River	W052514				1.2			
FRONTIER	232			Mainstem Republican River	W062534				2.2			
FRONTIER	2359			Red Willow Creek	W053002				3			
FRONTIER	103			Mainstem Republican River	W072434				3.3			
FRONTIER	1850			Mainstem Republican River	W072615				1.3			
FRONTIER	40			Mainstem Republican River	W072613				2.4			
FRONTIER	46			Mainstem Republican River	W072417				2			
FRONTIER	55			Mainstem Republican River	W072522				1.4			
FRONTIER	229			Mainstem Republican River	W062535				1.2			
FRONTIER	138			Mainstem Republican River	W062410				0.3			
FRONTIER	209			Mainstem Republican River	W062530				2.6			
FRONTIER	177			Mainstem Republican River	W062519				2.6			
FRONTIER	192			Mainstem Republican River	W062526				2.5			
FRONTIER	1838			Mainstem Republican River	W082623				1.9			
FRONTIER	2350			Medicine Creek	W062836				2.2			
FRONTIER	2400			Red Willow Creek	W053022				1.1			
FRONTIER	2274			Medicine Creek	W072934				2.1			
FRONTIER	2247			Medicine Creek	W072828				1.8			
FRONTIER	2192			Medicine Creek	W072606				1.3			
FRONTIER	2212			Medicine Creek	W072717				7.2			
FRONTIER	2228			Medicine Creek	W072620				3.2			
FRONTIER	114			Medicine Creek	W062706				2.8			
FRONTIER	2276			Medicine Creek	W072935				1.3			
FRONTIER	1830			Mainstem Republican River	W052816				2.8			
FRONTIER	2347			Medicine Creek	W062733				3.3			

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FRONTIER	1841			Mainstem Republican River	W082523				1.4			
FRONTIER	31			Medicine Creek	W072708				20.4			
FRONTIER	2354			Medicine Creek	W062734				1.9			
FRONTIER	1834			Mainstem Republican River	W082609				1.6			
FRONTIER	236			Mainstem Republican River	W062432				1.8			
FRONTIER	255			Mainstem Republican River	W052502				3.1			
FRONTIER	257			Mainstem Republican River	W052503				1			
FRONTIER	1861			Mainstem Republican River	W072404				1.8			
FRONTIER	149			Mainstem Republican River	W062508				3.1			
FRONTIER	2318			Medicine Creek	W062615				2.9			
FRONTIER	1856	NE02288	EASTERDAY RD STR	Mainstem Republican River	W082524	1976	19	6	1.3	-100.106	40.642	S2S24 T08N R25W
FRONTIER	199			Mainstem Republican River	W062526				3.4			
FRONTIER	124	NE01934	OELKERS DAM	Mainstem Republican River	W062404	1962	20	4	2.7	-100.050	40.515	SW4S04 T06N R24W
FRONTIER	184	NE01457	SERGEL DAM	Mainstem Republican River	W062423	1960E	39	8	1	-100.011	40.469	SE4SW4S23 T06N R24W
FRONTIER	264	NE00723	SAYER DAM NO 2	Mainstem Republican River	W052512	1966	40	10	3.8	-100.114	40.417	SW4NW4S12 T05N R25W
FRONTIER	263	NE00724	SAYER DAM NO 3	Mainstem Republican River	W052512	1966	31	8	1.6	-100.102	40.418	SW4NE4S12 T05N R25W
FRONTIER	206	NE01667	MONTER GROUP DAM	Mainstem Republican River	W062426	1979	58	8	2.5	-100.009	40.453	SW4SE4S26 T06N R24W
FRONTIER	65	NE01455	SCHURR DAM NO 1	Mainstem Republican River	W072525	1957E	39	7	3.6	-100.105	40.552	NE4NW4S25 T07N R25W
FRONTIER	97	NE01451	KOCH DAM NO 2	Mainstem Republican River	W072435	1959E	16	5	4.1	-100.011	40.530	NE4SW4S35 T07N R24W
FRONTIER	178	NE01453	MONTER DAM	Mainstem Republican River	W062423	1960E	50	9	0.9	-100.012	40.475	SE4NW4S23 T06N R24W
FRONTIER	86	NE01933	SCHAFFERT DAM	Medicine Creek	W072835	1962	20	4	1.4	-100.467	40.533	NW4SE4S35 T07N R28W
FRONTIER	95	NE00725	GILLILAND DAM NO 1	Medicine Creek	W062901	1967	72	14	3.5	-100.556	40.524	NE4NE4S01 T06N R29W
FRONTIER	2156	NE00729	LOWER MEDICINE CREEK 200	Medicine Creek	W082824	1974	35	7	0	-100.446	40.644	SW4SE4S24 T08N R28W
FRONTIER	2171	NE01319	NE SCHOOL LAND DAM	Medicine Creek	W082936	1952E	48	1	0	-100.559	40.620	S2NE4S36 T08N R29W
FRONTIER	2177	NE01313	FRONTIER CO RD DAM 1	Medicine Creek	W082736	1966	55	8	3.4	-100.339	40.614	S2SW4S36 T08N R27W
FRONTIER	2273	NE00726	HINTON DAM	Medicine Creek	W072632	1967	28	6	3.5	-100.288	40.538	NE4NE4S32 T07N R26W
FRONTIER	20	NE00728	UPPER MEDICINE CREEK 370	Medicine Creek	W082934	1973	24	5	4.6	-100.598	40.615	SW4SE4S34 T08N R29W
FRONTIER	2666	NE01201	UPPER MEDICINE CREEK 80-A	Medicine Creek	W082908	1982	21	3	0.6	-100.636	40.682	W2NE4S08 T08N R29W
FRONTIER	2314	NE01736	LOWER MEDICINE CREEK 160	Medicine Creek	W062710	1979	59	9	0	-100.370	40.500	W2SE4S10 T06N R27W
FRONTIER	200	NE01448	DWINELL DAM	Mainstem Republican River	W062426	1960E	39	5	0.5	-100.011	40.462	SE4NW4S26 T06N R24W
FRONTIER	2377	NE01450	KALER DAM	Red Willow Creek	W053016	1955E	17	7	1.7	-100.737	40.405	E2NW4S16 T05N R30W

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FRONTIER	196			Mainstem Republican River	W062526				3.1			
FRONTIER	61			Mainstem Republican River	W072423				1.5			
FRONTIER	2807	NE01460	WOOD DAM	Medicine Creek	W062724	1969E	27	4		-100.328	40.480	NE4NE4S24 T06N R27W
FRONTIER	2659	NE00727	ELSON DET DAM 1-S	Medicine Creek	W082802	1967	15	6		-100.471	40.685	SW4SW4S02 T08N R28W
FRONTIER	2668	NE01311	COLE DAM	Medicine Creek	W082830	1970	161	13		-100.540	40.629	S2SE4S30 T08N R28W
FRONTIER	24	NE01617	RUGGLES DAM	Medicine Creek	W072802	1974	45	5	2.2	-100.465	40.609	SW4NE4S02 T07N R28W
FRONTIER	2815	NE01621	UPPER MEDICINE CREEK 410	Medicine Creek	W082929	1976	17	5		-100.646	40.641	NW4NW4S29 T08N R29W
FRONTIER	1833	NE99980	BELLAMY DAM	Mainstem Republican River	W082606	1961E	28	6	3	-100.319	40.687	SW4SW4S06 T08N R26W
FRONTIER	2813	NE01528	UPPER MEDICINE CREEK 390-B	Medicine Creek	W082930	1975	26	6		-100.649	40.630	SE4SE4S30 T08N R29W
FRONTIER	210			Mainstem Republican River	W062527				2.4			
FRONTIER	2658	NE00718	TEEL DAM	Red Willow Creek	W073032	1956	198	28	0.9	-100.756	40.531	NE4SW4S32 T07N R30W
FRONTIER	1854	NE01316	HUEFTLE DAM	Mainstem Republican River	W082419	1964	40	7	2.2	-100.088	40.643	SE4SW4S19 T08N R24W
FRONTIER	2371	NE01624	SUGHRONE DAM	Mainstem Republican River	W052707	1978	56	6	1.7	-100.437	40.419	SW4NW4S07 T05N R27W
FRONTIER	2390	NE00715	DRY CREEK 2-A	Mainstem Republican River	W052721	1959	79	23	5.1	-100.384	40.391	E2NE4S21 T05N R27W
FRONTIER	2410	NE00720	DRY CREEK 1-A	Mainstem Republican River	W052728	1959	15	6	3.9	-100.394	40.376	E2NW4S28 T05N R27W
FRONTIER	67	NE01444	BROCKMEIER DAM	Mainstem Republican River	W072425	1962	82	18	3.6	-99.995	40.546	NE4SW4S25 T07N R24W
FRONTIER	64	NE01456	SCHURR DAM NO 2	Mainstem Republican River	W072527	1971	21	4	1.7	-100.139	40.552	N2NE4S27 T07N R25W
FRONTIER	79	NE02235	ROWLEY DAM	Medicine Creek	W072835	1967	0	0	1.5	-100.467	40.538	NE4S35 T07N R28W
FRONTIER	2814	NE01605	ZYSSET DAM	Medicine Creek	W062617	1974	42	9		-100.303	40.492	SW4NW4S17 T06N R26W
FRONTIER	137			Mainstem Republican River	W062411				0.1			
FURNAS	906			Beaver Creek	W032326				1.9			
FURNAS	672	NE00482	JOHNSON DET DAM 3	Mainstem Republican River	W032512	1958	27	6	0	-100.095	40.242	E2W2S12 T03N R25W
FURNAS	1568	NE02131	DENZEL LOFGREEN RD DAM	Sappa Creek	W012333	1975	15	4	3	-99.920	40.016	N2S33 T01N R23W
FURNAS	2615	NE01323	GROVE DAM	Mainstem Republican River	W042106	1961	101	14	1.7	-99.735	40.339	SE4SW4S06 T04N R21W
FURNAS	607	NE00477	LUEKING DAM	Mainstem Republican River	W032203	1940	40	8	5	-99.787	40.260	NW4NE4S03 T03N R22W
FURNAS	1000			Beaver Creek	W022206				2.3			
FURNAS	907			Beaver Creek	W032229				1.7			
FURNAS	742			Mainstem Republican River	W032515				1.2			
FURNAS	953			Beaver Creek	W032436				2.3			
FURNAS	963			Beaver Creek	W032335				2.6			
FURNAS	1109			Beaver Creek	W022316				1.6			

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FURNAS	1106			Beaver Creek	W022515				2.1			
FURNAS	1174			Beaver Creek	W022421				2.6			
FURNAS	479			Mainstem Republican River	W042215				1.2			
FURNAS	935			Mainstem Republican River	W032536				2			
FURNAS	893			Beaver Creek	W032426				2.3			
FURNAS	2667	NE01202	CADWALLADER DAM	Mainstem Republican River	W032111	1935	37	5	0.4	-99.666	40.235	SW4SW4S11 T03N R21W
FURNAS	1025	NE01937	MEYERS DAM	Beaver Creek	W022512	1962	21	4	1.4	-100.087	40.157	SW4NE4S12 T02N R25W
FURNAS	1633	NE01154	ATKINSON DAM	Prairie Dog Creek	W012136	1958	36	6	2.8	-99.643	40.004	SW4SW4S36 T01N R21W
FURNAS	911	NE01324	KLECKNER DAM	Mainstem Republican River	W032532	1937	21	6	2.3	-100.157	40.189	NE4NE4S32 T03N R25W
FURNAS	2619	NE00478	PAINE DAM	Mainstem Republican River	W042221	1940	60	10	2	-99.801	40.296	SE4SE4S21 T04N R22W
FURNAS	444	NE01203	KRUMME DAM	Mainstem Republican River	W042309	1935	42	5	1.9	-99.920	40.329	SW4NE4S09 T04N R23W
FURNAS	455	NE01328	ZIEBELL DAM	Mainstem Republican River	W042210	1952	50	5	2.4	-99.799	40.322	SW4SW4S10 T04N R22W
FURNAS	2670	NE01322	FURNAS CO RD DAM 1	Sappa Creek	W012426	1972	42	6		-99.989	40.016	SE4SE4S26 T01N R24W
FURNAS	2638	NE02646	FURNAS COUNTY FARMS STOCK DAM	Mainstem Republican River	W032125	1978E	47	5	0.6	-99.632	40.202	NE4NE4S25 T03N R21W
FURNAS	2639	NE01155	THEOBALD DAM	Beaver Creek	W032233	1961	52	13	0.6	-99.802	40.177	S2SE4S33 T03N R22W
FURNAS	2672	NE01327	WILSONVILLE DAM	Beaver Creek	W022526	1961	72	2		-100.118	40.114	SW4NW4S26 T02N R25W
FURNAS	2671	NE01326	STURTEVANT DAM	Beaver Creek	W032131	1952	37	7	0.7	-99.731	40.184	SW4NE4S31 T03N R21W
FURNAS	1246	NE01325	MCCUE DAM	Beaver Creek	W022536	1935	125	17	0.8	-100.094	40.099	SW4NW4S36 T02N R25W
FURNAS	1041	NE01935	GAREY DAM	Beaver Creek	W022312	1941	29	5	0.9	-99.862	40.155	SW4NE4S12 T02N R23W
FURNAS	1049	NE00481	VAN CLEAVE DAM	Beaver Creek	W022207	1946	130	21	1.5	-99.841	40.152	SW4SE4S07 T02N R22W
FURNAS	1189	NE00480	CAMPBELL DAM	Beaver Creek	W022222	1942	80	13	1.7	-99.786	40.120	SW4SE4S22 T02N R22W
FURNAS	1503	NE01321	EHRKE DAM	Sappa Creek	W012126	1955E	48	6	1.6	-99.666	40.029	NW4NW4S26 T01N R21W
FURNAS	602	NE00479	BROEKER DAM	Mainstem Republican River	W032204	1941	106	16	4.2	-99.809	40.262	N2N2S04 T03N R22W
FURNAS	469			Mainstem Republican River	W042418				1.4			
FURNAS	395			Mainstem Republican River	W042406				2.5			
FURNAS	844			Mainstem Republican River	W032528				0.3			
FURNAS	407			Mainstem Republican River	W042203				2.7			
FURNAS	408			Mainstem Republican River	W042205				1.7			
FURNAS	482			Mainstem Republican River	W042218				2.5			
FURNAS	640			Mainstem Republican River	W032407				1.4			
FURNAS	494			Mainstem Republican River	W042521				2.8			

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FURNAS	451			Mainstem Republican River	W042510				2.9			
FURNAS	888			Mainstem Republican River	W032528				1			
FURNAS	763			Mainstem Republican River	W032114				2.7			
FURNAS	427			Mainstem Republican River	W042301				2			
FURNAS	472			Mainstem Republican River	W042516				3.3			
FURNAS	416			Mainstem Republican River	W042403				2.1			
FURNAS	1390			Sappa Creek	W012317				1.3			
FURNAS	1479			Sappa Creek	W012219				1.3			
FURNAS	1332			Sappa Creek	W012308				1.5			
FURNAS	1455			Sappa Creek	W012220				3			
FURNAS	1389			Sappa Creek	W012217				1.3			
FURNAS	1298			Sappa Creek	W012205				2.3			
FURNAS	453			Mainstem Republican River	W042312				3.5			
FURNAS	635			Mainstem Republican River	W032408				1.7			
FURNAS	723			Mainstem Republican River	W032414				2.3			
FURNAS	785			Mainstem Republican River	W032319				1.5			
FURNAS	503			Mainstem Republican River	W042523				1.7			
FURNAS	473			Mainstem Republican River	W042313				1.3			
FURNAS	701			Mainstem Republican River	W032418				1.7			
FURNAS	686			Mainstem Republican River	W032411				2			
FURNAS	666			Mainstem Republican River	W032411				2.6			
FURNAS	651			Mainstem Republican River	W032209				1			
FURNAS	641			Mainstem Republican River	W032412				1.4			
FURNAS	517			Mainstem Republican River	W042222				4.7			
FURNAS	422			Mainstem Republican River	W042202				2.1			
GOSPER	96	NE99972	BOGLE DAM NO 1	Mainstem Republican River	W072233	1960	23	3	2.5	-99.818	40.530	NW4SE4S33 T07N R22W
GOSPER	318	NE00730	BARNETT DAM	Mainstem Republican River	W052420	1961	54	12	0.7	-100.061	40.388	SE4NE4S20 T05N R24W
GOSPER	161			Mainstem Republican River	W062316				3.1			
GOSPER	237			Mainstem Republican River	W062333				1.8			
GOSPER	202			Mainstem Republican River	W062327				3.2			
GOSPER	140			Mainstem Republican River	W062212				3.7			

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GOSPER	119			Mainstem Republican River	W062306				2.3			
GOSPER	115			Mainstem Republican River	W062304				1.9			
GOSPER	215			Mainstem Republican River	W062130				1.9			
GOSPER	371			Mainstem Republican River	W052231				2.6			
GOSPER	240	NE01336	ESSMEGER DAM	Mainstem Republican River	W062335	1958E	48	10	1.1	-99.905	40.439	SW4SW4S35 T06N R23W
GOSPER	180	NE99974	CARLSON DAM NO 1	Mainstem Republican River	W062222	1958	39	7	2.5	-99.807	40.476	S2NW4S22 T06N R22W
GOSPER	267			Mainstem Republican River	W052408				6.5			
GOSPER	243			Mainstem Republican River	W062235				2			
GOSPER	302			Mainstem Republican River	W052314				1.4			
GOSPER	158			Mainstem Republican River	W062218				2.2			
GOSPER	291			Mainstem Republican River	W052215				2.3			
GOSPER	1892			Mainstem Republican River	W062311				2.1			
GOSPER	389			Mainstem Republican River	W052434				3.5			
GOSPER	1898	NE01338	GARDNER-LARSON DAM	Mainstem Republican River	W052118	1963E	26	7	1.9	-99.746	40.401	S2NE4S18 T05N R21W
GOSPER	303			Mainstem Republican River	W052218				1.5			
GOSPER	360			Mainstem Republican River	W052226				2.2			
GOSPER	314			Mainstem Republican River	W052419				1.2			
GOSPER	348			Mainstem Republican River	W052427				2.5			
GOSPER	203	NE01352	SALISBURY DAM	Mainstem Republican River	W062229	1963	46	11	6	-99.844	40.463	SE4NW4S29 T06N R22W
GOSPER	197			Mainstem Republican River	W062225				2.7			
GOSPER	183			Mainstem Republican River	W062221				2.9			
GOSPER	93	NE00409	FADER STEWART DAM	Mainstem Republican River	W072333	1963	21	6	0.7	-99.928	40.531	SE4NE4S33 T07N R23W
GOSPER	156	NE99976	KUCK DAM	Mainstem Republican River	W062213		31	5	2.6	-99.762	40.492	SW4NE4S13 T06N R22W
GOSPER	322	NE00736	GROSS DAM NO 1	Mainstem Republican River	W052420	1961	46	13	3	-100.063	40.382	SW4SE4S20 T05N R24W
GOSPER	70	NE99977	WHALEY-REYNOLDS DAM NO 2	Mainstem Republican River	W072227		25	0	1.2	-99.804	40.549	SE4NW4S27 T07N R22W
GOSPER	275	NE00738	HELMS DAM	Mainstem Republican River	W052412	1958E	0	0	1.2	-99.992	40.410	SE4SW4S12 T05N R24W
GOSPER	363	NE01347	MAASKE DAM	Mainstem Republican River	W052129	1951E	43	3	3.1	-99.731	40.367	SE4SW4S29 T05N R21W
GOSPER	278	NE01342	HARMON DAM	Mainstem Republican River	W052209	1951	0	0	2.3	-99.818	40.411	SW4SE4S09 T05N R22W
GOSPER	345	NE99973	WHITE DAM	Mainstem Republican River	W052227	1953E	28	7	1	-99.805	40.375	SE4NW4S27 T05N R22W
GOSPER	292			Mainstem Republican River	W052217				3.1			
GOSPER	367	NE01343	HILGER DAM	Mainstem Republican River	W052434	1954E	44	10	3	-100.023	40.359	W2NE4S34 T05N R24W

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GOSPER	285	NE00731	BERGSTRESSER DAM	Mainstem Republican River	W052417	1959	33	9	3.6	-100.065	40.403	SW4NW4S17 T05N R24W
GOSPER	170			Mainstem Republican River	W062216				4			
GOSPER	110			Mainstem Republican River	W062205				2.6			
GOSPER	301			Mainstem Republican River	W052315				1.4			
GOSPER	80			Mainstem Republican River	W072230				1.6			
GOSPER	99			Mainstem Republican River	W072131				4.3			
GOSPER	2803	NE01346	LEISING DAM	Mainstem Republican River	W052326	1966	27	1		-99.905	40.370	NW4SW4S26 T05N R23W
GOSPER	51			Mainstem Republican River	W072315				0.9			
GOSPER	2804	NE01351	MONTER DAM	Mainstem Republican River	W052322	1958E	87	16		-99.920	40.385	N2SW4S22 T05N R23W
GOSPER	50			Mainstem Republican River	W072216				2.3			
GOSPER	54			Mainstem Republican River	W072322				1.2			
GOSPER	105			Mainstem Republican River	W072232				1.1			
GOSPER	60			Mainstem Republican River	W072223				2.6			
GOSPER	59			Mainstem Republican River	W072323				1.4			
GOSPER	49			Mainstem Republican River	W072317				1.7			
GOSPER	109			Mainstem Republican River	W062206				1.7			
GOSPER	102			Mainstem Republican River	W072334				1.7			
GOSPER	265			Mainstem Republican River	W052208				4.4			
GOSPER	293			Mainstem Republican River	W052415				1.6			
GOSPER	238			Mainstem Republican River	W062135				3.3			
GOSPER	354			Mainstem Republican River	W052230				3.8			
GOSPER	2362			Mainstem Republican River	W052202				7.9			
GOSPER	34	NE01348	MCKENZIE DAM	Mainstem Republican River	W072312	1957E	27	1	3.4	-99.882	40.593	S2NW4S12 T07N R23W
GOSPER	273	NE00742	MORGAN DAM	Mainstem Republican River	W052311	1956	20	8	3.3	-99.902	40.412	SW4SW4S11 T05N R23W
GOSPER	266	NE01349	MENZE DAM	Mainstem Republican River	W052311	1960E	31	9	7	-99.903	40.418	SW4NW4S11 T05N R23W
GOSPER	269	NE00745	SCOTT DAM	Mainstem Republican River	W052407	1957	53	13	6.3	-100.087	40.411	SE4SW4S07 T05N R24W
GOSPER	289	NE00734	FLAMMANG DAM	Mainstem Republican River	W052418	1961	95	15	0.8	-100.085	40.402	NW4SE4S18 T05N R24W
GOSPER	76	NE01337	FORD DAM	Mainstem Republican River	W072325	1959E	18	6	3.3	-99.884	40.540	SW4SW4S25 T07N R23W
GOSPER	2611	NE01715	ROBINSON DAM	Mainstem Republican River	W062328	1976	21	6	1	-99.933	40.459	SW4NE4S28 T06N R23W
GOSPER	2612	NE00746	STAGEMEYER DAM	Mainstem Republican River	W052413	1959E	42	7	0.6	-99.991	40.396	SE4SW4S13 T05N R24W
GOSPER	52			Mainstem Republican River	W072320				1.8			

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GOSPER	181	NE01329	ANDERSON DAM	Mainstem Republican River	W062324	1949	40	4	4.4	-99.872	40.472	N2SE4S24 T06N R23W
GOSPER	262	NE00747	WALTERS DAM	Mainstem Republican River	W052104	1957	56	10	1.6	-99.712	40.423	SE4SW4S04 T05N R21W
GOSPER	92	NE01355	WHAYLE REYNOLDS DAM NO 1	Mainstem Republican River	W072234	1963	170	20	10.6	-99.800	40.526	SW4SE4S34 T07N R22W
GOSPER	299	NE00741	MEYERS DAM	Mainstem Republican River	W052417	1960	61	14	0.9	-100.064	40.395	SW4SE4S17 T05N R24W
GOSPER	83	NE01332	BOGLE DAM NO 2	Mainstem Republican River	W072232	1964	74	17	5.2	-99.838	40.536	NW4NE4S32 T07N R22W
GOSPER	2801	NE01330	BAILEY DAM	Mainstem Republican River	W052119	1962E	16	5		-99.743	40.380	SW4SE4S19 T05N R21W
GOSPER	2802	NE01335	EBMEIER DAM	Mainstem Republican River	W062127	1964	54	11		-99.693	40.460	SE4NW4S27 T06N R21W
GOSPER	111			Mainstem Republican River	W062203				3.4			
GOSPER	69			Mainstem Republican River	W072329				1.5			
GOSPER	113			Mainstem Republican River	W062203				2.3			
GOSPER	2613	NE00737	GROSS DAM NO 2	Mainstem Republican River	W052429	1961E	19	7	0.7	-100.064	40.373	SW4NE4S29 T05N R24W
HARLAN	419	NE99982	BRYAN DAM	Mainstem Republican River	W041805		20	0	0.9	-99.371	40.344	SE4NE4S05 T04N R18W
HARLAN	1715	NE01965	MCNIEL DAM	Mainstem Republican River	W041804		0	0	0.9	-99.356	40.343	SW4NE4S04 T04N R18W
HARLAN	890	NE99860	FREAS DAM	Mainstem Republican River	W032030		18	5	1.2	-99.627	40.197	NW4SW4S30 T03N R20W
HARLAN	858			Mainstem Republican River	W031830				2.8			
HARLAN	2651	NE00495	STAMFORD 2-A	Sappa Creek	W022009	1968	70	10		-99.584	40.148	S2S2S09 T02N R20W
HARLAN	1319	NE00492	HAEKER DAM	Mainstem Republican River	W011902	1946	125	20	9.8	-99.426	40.080	NE4SE4S02 T01N R19W
HARLAN	2643	NE01214	LUBECK DAM	Sappa Creek	W012012	1937	80	10	0.9	-99.524	40.073	NW4NE4S12 T01N R20W
HARLAN	493			Mainstem Republican River	W041917				6.6			
HARLAN	466			Mainstem Republican River	W041811				2.6			
HARLAN	1475			Prairie Dog Creek	W011821				3.2			
HARLAN	1509			Prairie Dog Creek	W011927				2.5			
HARLAN	1558			Prairie Dog Creek	W011926				1.5			
HARLAN	1432			Sappa Creek	W012019				2			
HARLAN	1284			Sappa Creek	W022032				5.4			
HARLAN	1399			Sappa Creek	W012017				1.9			
HARLAN	1612			Mainstem Republican River	W011835				6.4			
HARLAN	624	NE01359	EINSPAHR DAM	Mainstem Republican River	W031903	1955E	36	12	7.1	-99.459	40.250	SW4SW4S03 T03N R19W
HARLAN	2808	NE01466	HOFFMAN DAM	Mainstem Republican River	W041732	1955E	32	8		-99.269	40.265	SE4SW4S32 T04N R17W
HARLAN	2805	NE01362	LUEKING DAM	Mainstem Republican River	W042018	1950E	42	14		-99.623	40.312	NE4SW4S18 T04N R20W
HARLAN	2712	NE01169	ZIEGLER DAM	Mainstem Republican River	W031722	1955E	48	12	0.7	-99.231	40.212	NW4SW4S22 T03N R17W

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HARLAN	2636	NE01360	FLASNICK DAM	Mainstem Republican River	W031819	1952	36	9	0.8	-99.388	40.213	SE4NE4S19 T03N R18W
HARLAN	1191	NE02232	HARDEN BATTIN DAM	Mainstem Republican River	W021822	1966	31	1	1.6	-99.343	40.118	SE4SW4S22 T02N R18W
HARLAN	1134	NE01165	OTT DAM	Mainstem Republican River	W021715	1972	28	8	2	-99.220	40.136	NE4SE4S15 T02N R17W
HARLAN	2633	NE01163	HARMS DAM	Mainstem Republican River	W031713	1961	50	10	2.3	-99.193	40.230	SE4NW4S13 T03N R17W
HARLAN	2628	NE01966	RICHARDS DAM	Mainstem Republican River	W031806	1968	23	4	2	-99.395	40.259	SW4NE4S06 T03N R18W
HARLAN	608			Mainstem Republican River	W031802				3.4			
HARLAN	600	NE02233	LEON JOHNSON DAM	Mainstem Republican River	W032005	1963	16	1		-99.600	40.259	NW4NE4S05 T03N R20W
HARLAN	727			Mainstem Republican River	W031818				3.5			
HARLAN	589	NE01681	MILROSE DAVID NO 2	Mainstem Republican River	W041934	1975	16	5	3.1	-99.456	40.264	S2SW4S34 T04N R19W
HARLAN	806	NE00491	CROW DAM	Mainstem Republican River	W032019	1941	79	16	1.3	-99.619	40.215	SW4NE4S19 T03N R20W
HARLAN	496	NE01364	MCDONALD DAM	Mainstem Republican River	W041916	1945	70	10	2.8	-99.475	40.309	SE4SW4S16 T04N R19W
HARLAN	871	NE01682	MURDOCK DAM	Mainstem Republican River	W032025	1966	25	4		-99.531	40.200	NW4S25 T03N R20W
HARLAN	467	NE02286	PETERSON GR STAB DAM	Mainstem Republican River	W041909	1970	21	2	2.1	-99.479	40.321	SW4SW4S09 T04N R19W
HARLAN	2650	NE00496	STAMFORD 3-A	Sappa Creek	W022008	1968	43	8	1.4	-99.598	40.148	S2SE4S08 T02N R20W
HARLAN	940			Mainstem Republican River	W031836				4.5			
HARLAN	847			Mainstem Republican River	W031823				4.8			
HARLAN	2637	NE01361	FREAR DAM	Mainstem Republican River	W032029	1950E	59	5	0.4	-99.604	40.205	NE4NW4S29 T03N R20W
HARLAN	1595			Mainstem Republican River	W011733				1.7			
HARLAN	2647	NE00493	WOLF DAM NO 1	Prairie Dog Creek	W011831	1952	74	11	0.5	-99.401	40.014	NW4NW4S31 T01N R18W
HARLAN	811	NE01365	RICHARDS DAM	Mainstem Republican River	W031924	1947	42	8		-99.420	40.209	NW4SW4S24 T03N R19W
HARLAN	2711	NE01363	MASSEY DAM	Mainstem Republican River	W031820	1955E	28	7	1	-99.386	40.206	SW4SW4S20 T03N R18W
HARLAN	1125			Mainstem Republican River	W021716				1.8			
HARLAN	421			Mainstem Republican River	W042004				1.9			
HARLAN	535			Mainstem Republican River	W041929				5			
HARLAN	1699			Mainstem Republican River	W011713				2.9			
HARLAN	768	NE01366	SCHLUNTZ DAM	Mainstem Republican River	W031717	1947	42	14	7.7	-99.268	40.224	NE4SW4S17 T03N R17W
HARLAN	483			Mainstem Republican River	W041915				3.1			
HARLAN	1574			Mainstem Republican River	W011736				2.1			
HARLAN	982			Mainstem Republican River	W031731				4.6			
HARLAN	980			Mainstem Republican River	W031836				3.7			
HARLAN	1117			Mainstem Republican River	W021817				3.8			

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County	EVAP_ID	NIDID	Dam_Name	RRC Sub-Basin	Dir Twn Rng Sec	Year Completed	Normal Storage	Normal Sfc Acres	Avg Digitized Area	Dam Longitude	Dam Latitude	Approximate Legal Location
HARLAN	415			Mainstem Republican River	W042005				0.4			
HAYES	123			Mainstem Republican River	W063209				0			
HAYES	261			Red Willow Creek	W053109				1.5			
HAYES	82	NE01468	FELKER DAM	Mainstem Republican River	W073232	1964	136	18	1.7	-100.985	40.524	SW4SW4S32 T07N R32W
HAYES	245	NE02323	BLACKWOOD CREEK 12-A	Mainstem Republican River	W053209	1988	28	17	8.2	-100.956	40.420	NW4NE4S09 T05N R32W
HAYES	1813	NE02209	BLACKWOOD CREEK 62-A	Mainstem Republican River	W053206	1985	46	8	0.8	-100.989	40.423	SE4SE4S06 T05N R32W
HAYES	25	NE01467	HAYES CNTR SPECIAL USE DAM	Red Willow Creek	W073211	1936	406	70	29.5	-100.927	40.585	SW4SW4S11 T07N R32W
HAYES	2690	NE02141	BLACKWOOD CREEK 61-A	Mainstem Republican River	W053208	1983	43	8		-100.973	40.412	NW4SE4S08 T05N R32W
HAYES	2693	NE02325	BLACKWOOD CREEK 72-A	Mainstem Republican River	W063326	1989	40	7		-101.035	40.452	SE4SW4S26 T06N R33W
HAYES	343			Frenchman Creek	W053336				2.3			
HAYES	2213	NE02369	BLACKWOOD CREEK 11-A	Mainstem Republican River	W073424	1992	115	22	1.6	-101.124	40.564	NW4NE4S24 T07N R34W
HAYES	2296			Red Willow Creek	W063203				1.9			
HAYES	1812	NE02324	BLACKWOOD CREEK 63-A	Mainstem Republican River	W063231	1989	16	4	2.5	-100.995	40.441	SE4SW4S31 T06N R32W
HAYES	2161	NE01469	SCOTT DAM	Mainstem Republican River	W083328	1968	0	0	0	-101.080	40.625	SW4SW4S28 T08N R33W
HAYES	172			Mainstem Republican River	W063222				3.8			
HAYES	2649	NE00313	SMITH DAM	Frenchman Creek	W053319	1962	22	6		-101.105	40.382	SW4SE4S19 T05N R33W
HAYES	250			Frenchman Creek	W053410				2.9			
HAYES	2614	NE00312	KROTTER DAM	Frenchman Creek	W053434	1944	40	7	0.7	-101.156	40.355	NE4SE4S34 T05N R34W
HAYES	249			Frenchman Creek	W053409				3.3			
HAYES	2294			Mainstem Republican River	W063206				2.1			
HAYES	163			Mainstem Republican River	W063221				3.3			
HAYES	1816			Mainstem Republican River	W073304				2.8			
HAYES	2384			Mainstem Republican River	W053213				0.2			
HAYES	1815			Mainstem Republican River	W073413				1.5			
HAYES	258	NE02253	BLACKWOOD CREEK 51-A	Mainstem Republican River	W053210	1985	69	12	2.2	-100.937	40.409	SW4SE4S10 T05N R32W
HITCHCOCK	2640	NE01474	HOYT DAM	Driftwood Creek	W023115	1955E	38	8		-100.804	40.135	NW4SE4S15 T02N R31W
HITCHCOCK	2621	NE01477	SHACKELFORD DAM	Frenchman Creek	W043332	1960E	28	8	2	-101.061	40.275	NE4NE4S32 T04N R33W
HITCHCOCK	504	NE01476	NOWKA DAM	Frenchman Creek	W043227	1940E	27	14	5.5	-100.914	40.281	SE4SE4S27 T04N R32W
HITCHCOCK	2618	NE00497	KROTTER SCHLAGER	Frenchman Creek	W043326	1945	55	10	0.3	-101.012	40.287	SW4NE4S26 T04N R33W
HITCHCOCK	411	NE01475	MILLER DAM	Mainstem Republican River	W043109	1960E	24	7	0.6	-100.831	40.330	SW4NW4S09 T04N R31W
HITCHCOCK	2806	NE01367	CARSE DAM	Frenchman Creek	W043331	1963	25	4		-101.092	40.267	SW4S31 T04N R33W

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County	EVAP ID	NIDID	Dam Name	RRC Sub-Basin	Dir Twn Rng Sec	Year Completed	Normal Storage	Normal Sfc Acres	Avg Digitized Area	Dam Longitude	Dam Latitude	Approximate Legal Location
HITCHCOCK	2622	NE01368	PRIOR DAM	Frenchman Creek	W043436	1963	19	4	1.3	-101.104	40.264	SW4SE4S36 T04N R34W
HITCHCOCK	2644	NE01472	DAHNKE DAM	Mainstem Republican River	W013513	1960E	19	5	0.7	-101.213	40.052	NE4SE4S13 T01N R35W
HITCHCOCK	884	NE01171	KUGLER DAM	Mainstem Republican River	W033132	1935	72	17	0	-100.850	40.185	S2NW4S32 T03N R31W
HITCHCOCK	2560			Mainstem Republican River	W033334				4.2			
HITCHCOCK	2635	NE01683	KORELL DAM	Mainstem Republican River	W033123	1976	15	3	0.5	-100.784	40.206	S2SE4S23 T03N R31W
HITCHCOCK	373	NE02270	BLACKWOOD CREEK 32-A	Mainstem Republican River	W043202	1985	61	17	0.7	-100.907	40.349	NW4NW4S02 T04N R32W
HITCHCOCK	2689	NE02132	RD PROJ RS-17-1(103)	Mainstem Republican River	W023103	1981	23	20		-100.816	40.163	NW4SW4S03 T02N R31W
HITCHCOCK	2594	NE01473	GOLDING DAM	Mainstem Republican River	W013510	1955E	47	11	0.6	-101.263	40.067	NE4SW4S10 T01N R35W
HITCHCOCK	465			Frenchman Creek	W043217				1.4			
HITCHCOCK	1674			Mainstem Republican River	W023519				0.2			
LINCOLN	9	NE00322	WELLFLEET DAM	Medicine Creek	W093016	1931	270	80	30.2	-100.736	40.751	SE4NE4S16 T09N R30W
LINCOLN	2708	NE99905	MORTENSEN DAM	Medicine Creek	W092822	1962	20	1	1.6	-100.506	40.734	NW4SW4S22 T09N R28W
LINCOLN	14			Medicine Creek	W092735				1.8			
LINCOLN	15			Medicine Creek	W092736				1			
LINCOLN	2090			Medicine Creek	W092811				2.7			
LINCOLN	2116			Medicine Creek	W092734				1.8			
NUCKOLLS	1293			Mainstem Republican River	W010605				4.7			
NUCKOLLS	1426			Mainstem Republican River	W010619				3.3			
NUCKOLLS	1209			Mainstem Republican River	W020630				0.8			
NUCKOLLS	1312			Mainstem Republican River	W010806				2.6			
NUCKOLLS	1266			Mainstem Republican River	W020632				2.4			
NUCKOLLS	1292	NE02251	TIETJEN BANKS IRR STR	Lower Republican River	W010505	1985	100	22	10.9	-97.912	40.080	NW4SW4S05 T01N R05W
NUCKOLLS	1413			Mainstem Republican River	W010619				3.2			
NUCKOLLS	1111	NE01616	CHILDRESS DAM	Mainstem Republican River	W020817	1950	45	13	0.5	-98.241	40.141	SE4NE4S17 T02N R08W
NUCKOLLS	1400			Mainstem Republican River	W010714				2.4			
NUCKOLLS	1454	NE02055	WILTON DAM	Mainstem Republican River	W010622	1967	21	3	3	-97.978	40.033	SW4SE4S22 T01N R06W
NUCKOLLS	1126			Mainstem Republican River	W020715				1.5			
NUCKOLLS	1177			Mainstem Republican River	W020722				6.3			
NUCKOLLS	1600			Mainstem Republican River	W010835				15			
NUCKOLLS	1461			Mainstem Republican River	W010623				3.5			
NUCKOLLS	1275			Mainstem Republican River	W020633				1.2			

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NUCKOLLS	1393			Mainstem Republican River	W010614				6.9			
NUCKOLLS	1353			Mainstem Republican River	W010612				3.7			
NUCKOLLS	1588	NE00238	KALDAHL DAM	Lower Republican River	W010533	1970	19	5	3.1	-97.889	40.009	NE4SW4S33 T01N R05W
NUCKOLLS	1435			Lower Republican River	W010624				3.1			
NUCKOLLS	1601	NE00240	CALDER DAM	Lower Republican River	W010533	1970	29	7	5.6	-97.881	40.006	SE4SE4S33 T01N R05W
NUCKOLLS	1186	NE02252	FRAHM RD STR	Mainstem Republican River	W020723	1987	31	5	1.8	-98.071	40.119	SE4SE4S23 T02N R07W
NUCKOLLS	1108	NE00234	GEBHARDS DAM	Mainstem Republican River	W020715	1968	48	10	5.4	-98.098	40.137	NE4SE4S15 T02N R07W
NUCKOLLS	1148	NE00244	SCHIERMEYER DAM	Mainstem Republican River	W020721	1972	68	12	5.3	-98.105	40.129	SE4NE4S21 T02N R07W
NUCKOLLS	1162	NE01375	CHILDRESS DAM	Mainstem Republican River	W020822	1968	22	4	2	-98.212	40.127	SE4NW4S22 T02N R08W
NUCKOLLS	1193	NE00339	GRUMMERT DAM	Mainstem Republican River	W020725	1966	24	4	2.9	-98.053	40.113	SE4NE4S25 T02N R07W
NUCKOLLS	1377			Mainstem Republican River	W010716				5.8			
NUCKOLLS	1571	NE00346	GIBSON DAM	Mainstem Republican River	W010833	1967	23	3	8.8	-98.229	40.017	NE4NW4S33 T01N R08W
NUCKOLLS	1269	NE00236	HIGER DAM	Mainstem Republican River	W020631	1969	76	16	10.6	-98.033	40.089	S2SE4S31 T02N R06W
NUCKOLLS	1510	NE00231	JOHNSTON & THOMPSON DAM	Mainstem Republican River	W010828	1967	36	9	2.3	-98.229	40.027	SE4NW4S28 T01N R08W
NUCKOLLS	1196	NE02269	BILL HILL DAM	Mainstem Republican River	W020630	1987	32	7	3.6	-98.043	40.112	NW4S30 T02N R06W
NUCKOLLS	1386	NE00335	BLACKSTONE DAM	Mainstem Republican River	W010615	1953	45	10	4.4	-97.988	40.051	NW4SW4S15 T01N R06W
PERKINS	7			Mainstem Republican River	W103531				0			
PERKINS	2675	NE01483	SCHACK DAM NO 2	Red Willow Creek	W103508	1964	19	4	0.4	-101.324	40.855	E2NE4S08 T10N R35W
PERKINS	1806			Frenchman Creek	W093707				6.8			
PERKINS	2713	NE01485	HARMS DAM	Red Willow Creek	W103509	1950E	78	16	0.2	-101.314	40.849	NE4SW4S09 T10N R35W
PERKINS	1945			Frenchman Creek	W113901				27.7			
PHELPS	2683	NE01967	JENSEN DAM	Mainstem Republican River	W041835	1969	18	3	0.4	-99.328	40.276	NW4NW4S35 T04N R18W
PHELPS	333	NE02068	ERICKSON DAM	Mainstem Republican River	W051820	1963	24	4	2.8	-99.388	40.380	SW4SE4S20 T05N R18W
PHELPS	1758	NE02069	JOHNSON DAM	Mainstem Republican River	W051834	1965	22	3	3.1	-99.351	40.352	SE4SW4S34 T05N R18W
PHELPS	2685	NE02067	THORELL DAM	Mainstem Republican River	W051930	1963	18	3	0.4	-99.520	40.366	SW4SE4S30 T05N R19W
PHELPS	2688	NE02070	PETERSON DAM	Mainstem Republican River	W052025	1965	24	4	0.2	-99.532	40.373	SE4NE4S25 T05N R20W
PHELPS	2684	NE02066	BERGMAN DAM	Mainstem Republican River	W062020	1962	25	4	1.1	-99.623	40.472	SW4S20 T06N R20W
PHELPS	241	NE00376	AREHART DAM	Mainstem Republican River	W062036	1995E	20	7	2.5	-99.543	40.441	E2SW4S36 T06N R20W
PHELPS	317	NE02071	HINSON DAM	Mainstem Republican River	W052019	1967	24	4	2.3	-99.629	40.392	NE4NE4S19 T05N R20W
RED WILLOW	1450			Beaver Creek	W012928				0.5			
RED WILLOW	2653	NE00563	DRY CREEK SOUTH 4-A	Mainstem Republican River	W023025	1965	97	15		-100.656	40.117	NW4NE4S25 T02N R30W

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RED WILLOW	1423			Beaver Creek	W012923				1.7			
RED WILLOW	1084			Driftwood Creek	W023017				3.2			
RED WILLOW	397			Mainstem Republican River	W042606				1.9			
RED WILLOW	652			Mainstem Republican River	W032809				9.4			
RED WILLOW	657			Mainstem Republican River	W032811				2.9			
RED WILLOW	497			Mainstem Republican River	W042720				3.1			
RED WILLOW	507			Mainstem Republican River	W042619				2.4			
RED WILLOW	530			Mainstem Republican River	W042728				2.7			
RED WILLOW	487			Medicine Creek	W042613				2			
RED WILLOW	463			Medicine Creek	W042614				2.1			
RED WILLOW	2676	NE01490	KOMETSCHER DAM	Mainstem Republican River	W042804	1963	29	5	0.4	-100.482	40.350	NE4NE4S04 T04N R28W
RED WILLOW	2617	NE00558	LARINGTON DAM	Red Willow Creek	W042922	1964	45	8	1.5	-100.589	40.304	SW4NW4S22 T04N R29W
RED WILLOW	668			Mainstem Republican River	W032711				3.7			
RED WILLOW	2652	NE00562	DRY CREEK SOUTH 1-F	Mainstem Republican River	W013002	1965	68	15		-100.667	40.081	SE4NE4S02 T01N R30W
RED WILLOW	1241	NE00560	DRY CREEK SOUTH 3-A	Mainstem Republican River	W022931	1964	72	16	1.4	-100.639	40.094	NE4SW4S31 T02N R29W
RED WILLOW	2665	NE01192	VANVLEET DAM	Beaver Creek	W012733	1935	115	17		-100.381	40.015	NW4NW4S33 T01N R27W
RED WILLOW	2809	NE01489	HAAG DAM	Beaver Creek	W012629	1950E	47	14		-100.285	40.030	NW4NW4S29 T01N R26W
RED WILLOW	420	NE02261	SAYER DAM	Mainstem Republican River	W042604	1962	51	9	1	-100.265	40.338	SE4SW4S04 T04N R26W
RED WILLOW	2623	NE01496	SPENCER DAM	Mainstem Republican River	W043033	1955E	38	15	4.1	-100.716	40.267	SE4SW4S33 T04N R30W
RED WILLOW	2816	NE01809	BLACKWOOD CREEK P-5	Mainstem Republican River	W033016	1981	42	8		-100.705	40.228	NE4SE4S16 T03N R30W
RED WILLOW	2691	NE02150	BLACKWOOD CREEK P-2	Mainstem Republican River	W033006	1984	154	25	0.1	-100.753	40.254	NE4SW4S06 T03N R30W
RED WILLOW	2810	NE01492	MATHENY DAM	Beaver Creek	W012726	1950E	38	10		-100.330	40.021	NW4SE4S26 T01N R27W
RED WILLOW	2642	NE00561	DRY CREEK SOUTH 1-E	Mainstem Republican River	W013001	1965	84	16	0.9	-100.663	40.077	SW4SW4S01 T01N R30W
RED WILLOW	711	NE01191	SMITH DAM	Mainstem Republican River	W032617	1935	64	14	3.4	-100.289	40.228	SW4NW4S17 T03N R26W
RED WILLOW	2812	NE01494	SCHAFFERT DAM	Mainstem Republican River	W022706	1950E	88	18		-100.406	40.173	NE4NE4S06 T02N R27W
RED WILLOW	2811	NE01493	QUIGLEY DAM	Mainstem Republican River	W022705	1955E	81	17		-100.397	40.171	SW4NW4S05 T02N R27W
RED WILLOW	2692	NE02151	BLACKWOOD CREEK P-3	Mainstem Republican River	W033007	1984	30	7		-100.746	40.240	N2SE4S07 T03N R30W
RED WILLOW	2654	NE00564	DRY CREEK SOUTH 1-D	Mainstem Republican River	W012907	1965	53	11		-100.645	40.075	NW4NW4S07 T01N R29W
RED WILLOW	2641	NE00559	DRY CREEK SOUTH 2-A	Mainstem Republican River	W022918	1964	61	15	2.9	-100.637	40.137	SW4SE4S18 T02N R29W
WEBSTER	918			Mainstem Republican River	W031029				4.7			
WEBSTER	638			Mainstem Republican River	W031204				3.5			

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WEBSTER	735			Mainstem Republican River	W031218				2.9			
WEBSTER	1310			Mainstem Republican River	W010901				3.9			
WEBSTER	1740			Mainstem Republican River	W021209				2.7			
WEBSTER	692			Mainstem Republican River	W031111				4.7			
WEBSTER	697			Mainstem Republican River	W031010				4.8			
WEBSTER	857			Mainstem Republican River	W031029				4.9			
WEBSTER	843			Mainstem Republican River	W031023				2.6			
WEBSTER	840			Mainstem Republican River	W031023				4.5			
WEBSTER	702			Mainstem Republican River	W031108				3.2			
WEBSTER	829			Mainstem Republican River	W031121				3.8			
WEBSTER	1637			Mainstem Republican River	W011233				5.7			
WEBSTER	760			Mainstem Republican River	W030915				4.6			
WEBSTER	964			Mainstem Republican River	W030933				4			
WEBSTER	538			Mainstem Republican River	W041125				3.3			
WEBSTER	549			Mainstem Republican River	W041030				3.3			
WEBSTER	558			Mainstem Republican River	W041125				1.2			
WEBSTER	563			Mainstem Republican River	W041030				5.9			
WEBSTER	571			Mainstem Republican River	W041031				4.4			
WEBSTER	586			Mainstem Republican River	W041135				4.5			
WEBSTER	790			Mainstem Republican River	W031224				1.9			
WEBSTER	780			Mainstem Republican River	W031214				3.3			
WEBSTER	833			Mainstem Republican River	W031122				6.9			
WEBSTER	1047			Mainstem Republican River	W021211				5.1			
WEBSTER	1444			Mainstem Republican River	W011119				3.5			
WEBSTER	1114			Mainstem Republican River	W020915				3.9			
WEBSTER	1088			Mainstem Republican River	W021007				5.7			
WEBSTER	949			Mainstem Republican River	W031235				4.3			
WEBSTER	1074			Mainstem Republican River	W021212				5.4			
WEBSTER	863			Mainstem Republican River	W031125				4.2			
WEBSTER	1069			Mainstem Republican River	W021007				3.7			
WEBSTER	1067			Mainstem Republican River	W021108				3			

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WEBSTER	1341			Mainstem Republican River	W011211				5.6			
WEBSTER	1058			Mainstem Republican River	W021112				2.3			
WEBSTER	1406			Mainstem Republican River	W011015				2.5			
WEBSTER	1576			Mainstem Republican River	W011031				2.3			
WEBSTER	1040			Mainstem Republican River	W021112				7.4			
WEBSTER	1039			Mainstem Republican River	W021009				3.2			
WEBSTER	1579			Mainstem Republican River	W011034				9.2			
WEBSTER	1580			Mainstem Republican River	W011231				3.2			
WEBSTER	1593			Mainstem Republican River	W011235				4			
WEBSTER	1596			Mainstem Republican River	W010931				3.8			
WEBSTER	1557			Mainstem Republican River	W011227				2.1			
WEBSTER	728			Mainstem Republican River	W031213				5.9			
WEBSTER	1565			Mainstem Republican River	W011227				2.5			
WEBSTER	831			Mainstem Republican River	W031022				2.2			
WEBSTER	1613	NE00692	TWIN OAKS DAM	Mainstem Republican River	W011132	1960E	40	4	4.7	-98.582	40.010	SW4NE4S32 T01N R11W
WEBSTER	1597	NE00691	TALKINGTON DAM	Mainstem Republican River	W011233	1962	16	3	0.7	-98.682	40.009	NE4SW4S33 T01N R12W
WEBSTER	1577	NE00688	SCHOLTZ DAM	Mainstem Republican River	W010936	1957	21	4	3	-98.280	40.015	NW4NE4S36 T01N R09W
WEBSTER	1575	NE01761	JENSEN DAM	Mainstem Republican River	W010932	1974	28	11	7.5	-98.364	40.015	NW4NW4S32 T01N R09W
WEBSTER	1415	NE00270	OHMSTEDE DAM	Mainstem Republican River	W010917	1947	237	32	16.7	-98.351	40.048	SE4SE4S17 T01N R09W
WEBSTER	1007	NE00273	GESTRING DAM	Mainstem Republican River	W021005	1968	40	11	4.8	-98.464	40.169	E2 E2S05 T02N R10W
WEBSTER	588	NE00689	SEEMAN DAM	Mainstem Republican River	W041034	1959E	33	8	1.2	-98.431	40.266	SW4SE4S34 T04N R10W
WEBSTER	568	NE00690	SIEBRASS DAM	Mainstem Republican River	W041032	1952E	28	7	3.5	-98.468	40.275	N2NE4S32 T04N R10W
WEBSTER	1492	NE00680	JOHNSTON DAM	Mainstem Republican River	W010927	1957E	18	4	5.8	-98.320	40.028	NE4S27 T01N R09W
WEBSTER	1212			Mainstem Republican River	W020927				5.5			
WEBSTER	634			Mainstem Republican River	W031102				3.2			
WEBSTER	1236			Mainstem Republican River	W021130				2.6			
WEBSTER	1561			Mainstem Republican River	W011229				3.3			
WEBSTER	1375			Mainstem Republican River	W011207				4.2			
WEBSTER	886	NE02116	SCHUTTE DAM	Mainstem Republican River	W030928	1963	23	3	4.3	-98.331	40.194	E2SE4S28 T03N R09W
WEBSTER	693	NE02118	FRANK DAM	Mainstem Republican River	W031112		17	0	2.4	-98.518	40.241	NW4SW4S12 T03N R11W
WEBSTER	744	NE00676	BARTELS DAM	Mainstem Republican River	W031215		0	0	5.5	-98.665	40.228	SE4NW4S15 T03N R12W

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WEBSTER	1513	NE00686	OHMSTEDE DAM-1	Mainstem Republican River	W010929	1945	21	14	4.8	-98.360	40.028	NE4NW4S29 T01N R09W
WEBSTER	1337			Mainstem Republican River	W010907				42			
WEBSTER	1396			Mainstem Republican River	W011218				2.1			
WEBSTER	2694	NE02412	ELM CREEK 21-B	Mainstem Republican River	W021021	1995	55	15	1.5	-98.451	40.121	SE4S21 T02N R10W
WEBSTER	631			Mainstem Republican River	W031101				4.2			

APPENDIX B

32 Sample Reservoir Sites Monitored for Reservoir Level and Surface Area

APPENDIX B
32 Sample Reservoir Sites
Reservoir Surface Area Monitoring

RESERVOIR ID	RESERVOIR NAME	LOCATION	NORMAL STORAGE (Acre-feet)	NEAREST TOWN
COLORADO				
Flagler	Flagler Reservoir	NW1/4SE1/4 Sec. 3 T9S, R50W		Flagler, 4 miles East
KANSAS				
DDC-0057	Dennis Shirley Rd. Fill Dam	SE1/4SE1/4 Sec 2 T3S R30W	35	Oberlin, ____ miles SW
DRA-0001	Atwood Lake	SW1/4SE1/4 Sec 5 T3S R33W	70	Atwood, North side of City
DRA-0083	Holste Dam	NE1/4NW1/4 Sec 9 T3S R32W	50	Atwood, 6.52 miles E, Nr. Lundell
DNT-1AA	Archer Dam	SE1/4SW1/4 Sec 35 T2S R32W		
DRA-0056	Olson Dam	NW1/4NE1/4 Sec 2 T3S R32W		
DPL-Hogan	Hogan Dam	SW1/4SW1/4 Sec 25 T1S R20W		Long Island, E. side of Rd.
DPL-Knape	Knape Dam	NW1/4SW1/4 Sec 7 T1S R18W		Woodruff, 1 mile East
DCN-Zimb	Zimbelman Dam	SW1/4NW1/4 Sec 24 T3S R41W		St. Francis, 4 miles west
DCN-Otto	Calvin Raile Dam	SW1/4NW1/4 Sec 12 T4S R40W		St. Francis, 1.5 miles east
DDC-Moore	L. Moore Dam	SE1/4SW1/4 Sec 3 T3S R29W		Oberlin, south edge of town
DNT-Arford	Arford Dam	SW1/4 SW1/4 Sec 6 T2S R22W		Norton, 3 miles North
Nebraska				
NE00244	Schiemeyer Reservoir	SE1/4NE1/4 Sec. 21, T2N, R7W	68.3	Nelson,
NE00376	Arehart Dam	NE1/4SW1/4 Sec. 36, T6N, R20W	24	Bertrund,
NE00406	Sindt Dam	NW1/4NW1/4 Sec. 14 T1N R14W	116	Franklin,
NE00478	Paine Dam	SW1/4SW1/4 Sec. 21 T4N R22W	60	Edison,
NE00482	Johnson DET Dam 3	E1/2W1/2 Sec. 12 T3N R25W	27	Cambridge, 5 miles SE
NE00496	Stamford Dam 3-A	S1/2Se1/4 Sec. 8, T2N, R20W	43	Stanford,
NE00557	Dry Creek 3-A	W1/2NE1/4 Sec. 9 T4N R27W	11	Bartley/Indianola, 7 miles N.
NE00559	Dry Creek South 2-A	SW1/4SE1/4 Sec. 18 T2N R29W	61	McCook, 4 miles south
NE00617	Frerichs Dam	NE1/4NW1/4 Sec. 19, T3N, R15W	50	Macon,
NE01139	Kilpatrick Dam	NE1/4SE1/4 Sec. 20, T6N, R40W	130	Champion,

RESERVOIR ID	RESERVOIR NAME	LOCATION	NORMAL STORAGE (Acre-feet)	NEAREST TOWN
NE01152	Anderson Reservoir	NE1/4SE1/4 Sec. 12, T2N, R37W	8.8	None
NE01171	Kugler Dam/Miller Reservoir	S1/2NW1/4 Sec. 32 T3N R31W	72	Culbertson,
NE01290	Meents Dam	SE1/4NE1/4 Sec. 28, T3N, R9W	11.6	St. Stephens,
NE01311	Cole Dam	S1/2SE1/4 Sec. 30, T8N, R28W	161	Curtis,
NE01316	Hueftle Reservoir	SE1/4SW1/4 Sec. 19, T8N, R24W	34.6	Eustis,
NE01337	Ford Reservoir	SW1/4SW1/4 Sec. 25, T7N, R23W	35	Elwood,
NE01357	Bantam-Coe Reservoir	SE1/4SW1/4 Sec. 23, T1N, R19W	8	None
NE01468	Felker Dam	SW1/4SW1/4 Sec. 32, T7N, R32W	0.5	None
NE01485	Harms Reservoir	NE1/4SW1/4 Sec. 9, T10N, R35W	1	Grainton,
NE01492	Matheny Reservoir	NW1/4SE1/4 Sec. 26, T1N, R27W	0	Danbury,

RESERVOIR SURFACE AREA MONITORING
AT 32 SELECTED RESERVOIR SITES

Either emergency spill or outlet works elevation is needed, depending on which elevation controls the full pool level.

RESERVOIR ID	RESERVOIR NAME	Existing Elevation-Area-Capacity Data: Source	Existing Elevation-Area-Capacity Data: Date	Elevation Data: Top of Dam	Elevation Data: Emergency Spillway	Elevation Data: Logger Cap	Elevation Data: Outlet Works	Elevation Data: Sensor	Elevation Data: Bottom of Reservoir
COLORADO									
Flagler	Flagler Reservoir	None available			100	100.0		83.33	
KANSAS									
DDC-0057	Dennis Shirley Rd. Fill Dam	KDA acap table		108.5	94.6	100.0		88.7	
DRA-0001	Atwood Lake	KDA acap table			still needed	100.0		82.43	
DRA-0083	Holste Dam	KDA acap table				100.0	97.64	87.5	
DNT-1AA	Archer Dam	KDA acap table		102.38	96.86	100.0		84.66	
DRA-0056	Olson Dam	KDA acap table		104.35	98.75	100.0		83.95	
DPL-Hogan	Hogan Dam	KDA acap table		101.37	97.82	100.0		88.85	
DPL-Knape	Knape Dam	KDA acap table		102.15	97.58	100.0		88.2	
DCN-Zimb	Zimbelman Dam	KDA acap table		102.72	97.12	100.0		85.3	
DCN-Otto	Calvin Raile Dam	KDA acap table		103.9	98.9	100.0	97.3	86.6	
DDC-Moore	L. Moore Dam	KDA acap table		107.95	94.2	100.0		86.7	
DNT-Arford	Arford Dam	KDA acap table		102.4	97.2	100.0		87.3	

RESERVOIR SURFACE AREA MONITORING AT 32 SELECTED RESERVOIR SITES

		Existing Elevation-Area-Capacity Data		Elevation Data					
RESERVOIR ID	RESERVOIR NAME	Source	Date	Top of Dam	Emergency Spillway	Logger Cap	Outlet Works	Sensor	Bottom of Reservoir
NEBRASKA									
NE00244	Schiermeyer Reservoir	SCS design sheet	Nov-71	102.03	98.77	100.0	95.6	90.35	
NE00376	Arehart Dam	Available		102.6	93.4	100.0		86.64	
NE00406	Sindt Dam	SCS design sheet	1945 est.	101.48	95.89	100.0		still needed	
NE00478	Paine Dam	DWR acap table	Jun-00	100.55	95.85	100.0		still needed	
NE00482	Johnson DET Dam 3	SCS design sheet	May-57		still needed	100.0		still needed	
NE00496	Stamford Dam 3-A	SCS design sheet	1968 est.	109.22	107.3	100.0		still needed	
NE00557	Dry Creek 3-A	SCS design sheet	Jan-59		still needed	100.0		still needed	
NE00559	Dry Creek South 2-A	SCS design sheet	Jul-64			100.0	95.0	82.4	
NE00617	Frerichs Dam-1	None available		97.08	91.93	100.0		86.18	
NE01139	Kilpatrick Dam	None available		101.4	90.05	100.0		still needed	90.25
NE01152	Anderson Reservoir	DWR acap table	Nov-02	105.7	104.05	100.0	92.25	84.25	
NE01171	Kugler Dam/ Miller Reservoir	DWR acap table	Jul-03		still needed	100.0		still needed	
NE01290	Meents Dam	DWR acap table	Oct-04	101.56	98.28	100.0	93.36	90.6	
NE01311	Cole Dam	Available		117.1	116	100.0		86.92	
NE01316	Hueftle Reservoir	DWR acap table	Mar-05	101.66	99.47	100.0		87.42	
NE01337	Ford Reservoir	DWR acap table	Jun-02	97.22	94	100.0		86.82	
NE01357	Bantam-Coe Reservoir	None available		103.96	101.41	100.0	90.16	87.26	
NE01468	Felker Dam	DWR acap table	Jun-03	105.23	still needed	100.0		still needed	92.25
NE01485	Harms Reservoir	DWR acap table	Feb-03	104.6	103.75	100.0		89.55	
NE01492	Matheny Reservoir	DWR acap table	Apr-04	100.56	96.18	100.0		87.34	

APPENDIX C

EXAMPLE OF DATA COLLECTED
FOR
THREE OF THE 32 MONITORED RESERVOIR SITES

Appendix C1

State: Nebraska

Reservoir ID: NE00559
Reservoir Name: Dry Creek South 2-A
Owner: Middle Republican NRD

Basic Inventory Information (Completed prior to site visit from Neb. Inventory List)

Designated Basin: Republican Main Stem
Dam Location (lat)________(long)________
PLS SW1/4SE1/4, Sec 18, Twp 2N, Rge 29W
Drainage Area (sq mi) 3.6 sq. miles

Dam Height (ft) 37 ft.; Dam Length (ft) 1557 ft

Water Depth at Normal Full Pool (NFP) (ft)________, Surface Area at NFP (acres) 15
Storage at NFP (acre-feet) 61

Maximum Storage (acre-feet) 827

Purpose of Use Flood Control/Stock Water
Year Completed 1955

General Site Information

Driving directions to reservoir: See attached Map. Located approximately 4 miles south of McCook. Range road into reservoir site is very rough.

Additional comments/information:

Reservoir ID: NE00559

State: Nebraska

Reservoir name: Dry Creek South 2-A

Owner: Middle Republican NRD

Initial Site Visit and Equipment Installation

Date of Installation Sept. 14, 2004 ;

Party members

Brad Edgerton, Neb. DNR
Tom Cyre, Kan. DWR
Megan Sullivan, CO, DWR
Scott Guenthner, USBR
Shane Stanton, Neb. DNR
George Austin, Kan. DWR
David Rebis, CO. DWR
Dale Ellerton, USBR
John Witler, Neb. DNR
Megan Sullivan, CO. DWR
Gordon Aycock, USBR
Jack Wergin, USBR

Location of Sensor (lat) N. 40 08.170 (long) W100 38.248

Location of Concrete Overflow Outlet (lat) N40 08.207 (long) W10 38.231

Notes and Sketch of Site Elevation Survey

At a minimum, provide information to determine relative elevations for the spillway, low level outlet invert, logger cap, water level, and apparent normal high water mark.

Sensor Reading 0.81 (feet)

Surface Water Area (calculated by GPS)

Area at water level 0.64 (acres), Perimeter .16 miles

*Area at apparent normal high water mark 11.2 (acres), Perimeter .93 miles

*Lowest overflow outlet invert elevation

Reservoir ID: NE00559

State: Nebraska

Reservoir Name; Dry Creek South 2-A

Owner: Middle Republican NRD

Initial Site Visit and Equipment Installation (continued)

General seepage conditions downstream of dam – check one

______Dry X Greener Vegetation ______Standing water

General inflow conditions at head of reservoir – check one

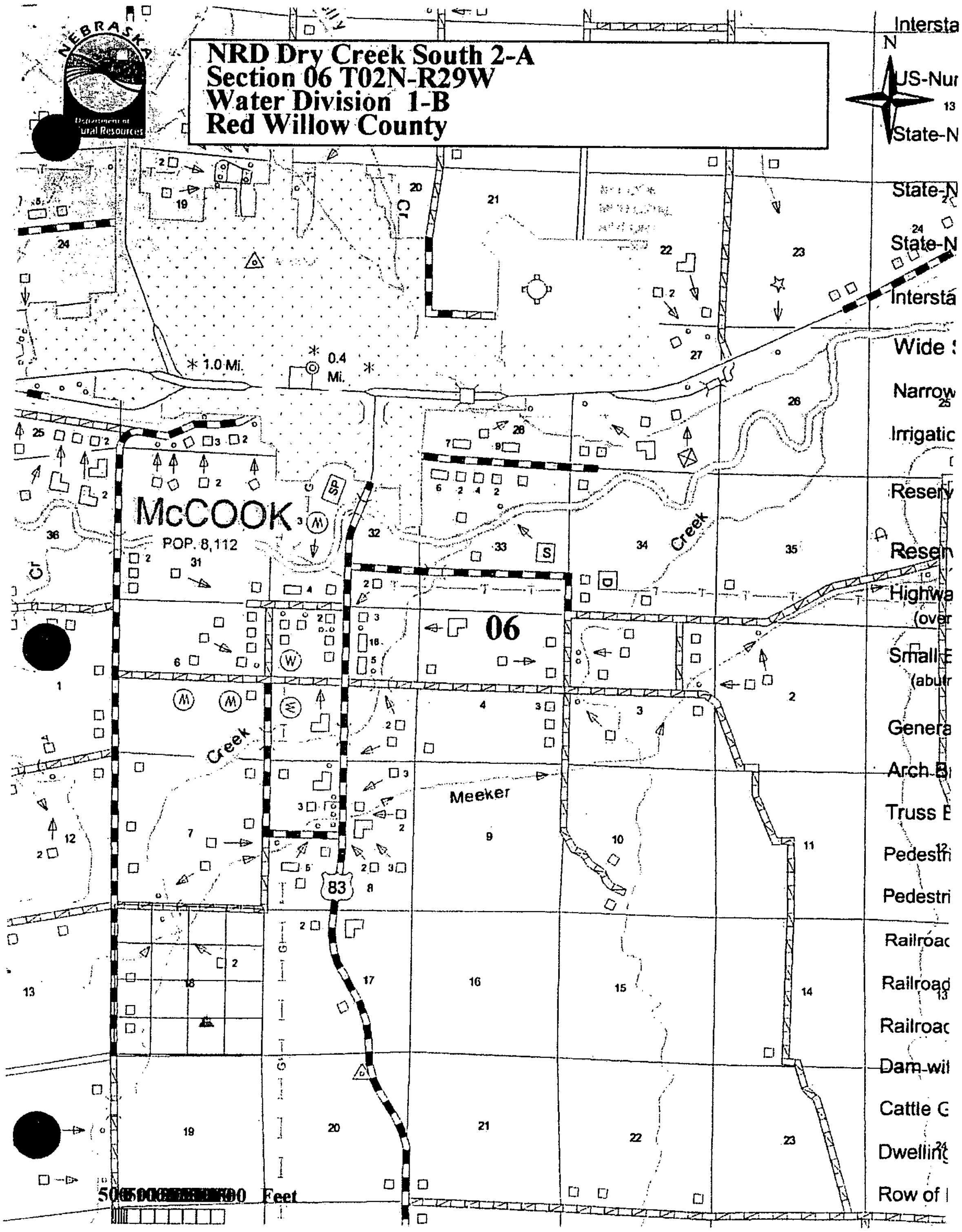
X Located on normally dry channel

______Measurable inflow (estimate if possible)

______Apparent spring feed

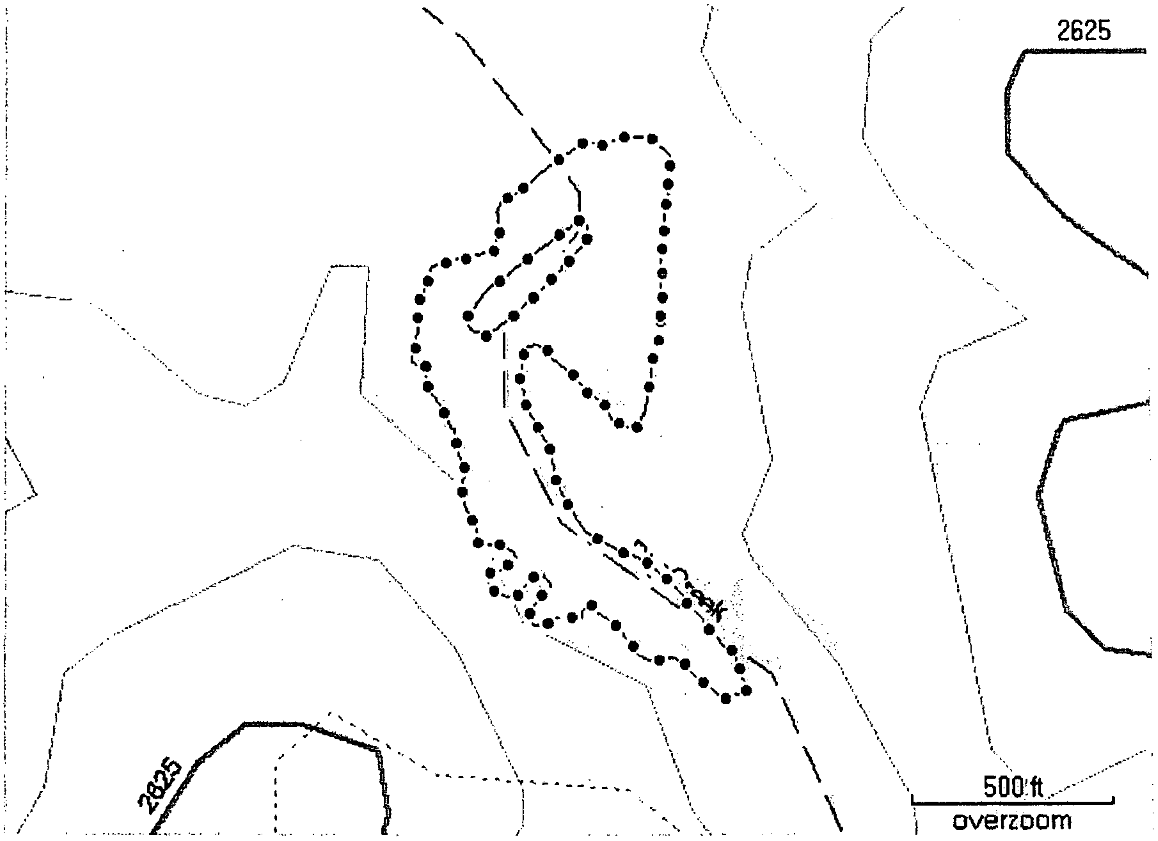
Additional comments/information:

Photographs See Attached

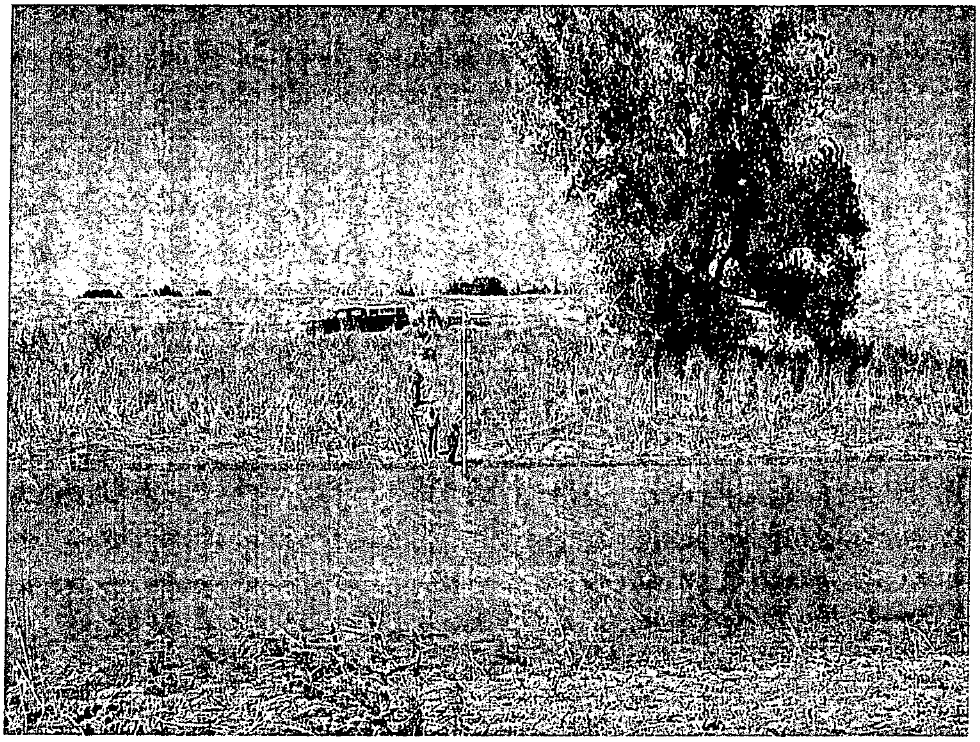


NRD Dry Creek South 2-A
Section 06 T02N-R29W
Water Division 1-B
Red Willow County

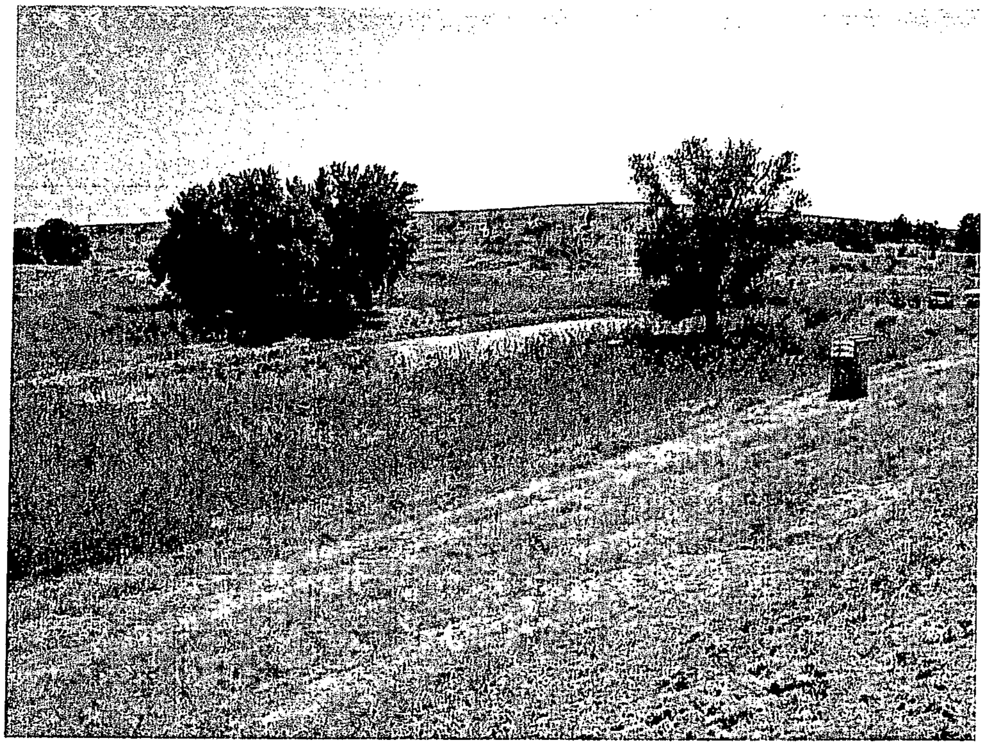
GPS Tracking
Dry Creek South 2-A
NE00559
South of McCook, NE



<u>Yellow Tracking</u>: Observed normal water level, surface area 11.2 acres
<u>Blue Tracking</u> : Observed water level on Sept. 14, 2004, surface area .64 acres.



NE0059, Showing Installation of Water Logger



NE00559 From Top of Dam

Reservoir ID NE00559
State (circle one): Nebraska
Reservoir name Dry Creek South 2-A
Owner: Middle Republican NRD

Additional Site Visits

Date 10-24-2005
Party members Shane Stanton
John Witler

Water Level
Sensor/Logger 3.34 (feet)
Hand level ______ (feet); in relation to top of cap on logger.

Surface Area at water level 1.1 (acres)

General seepage conditions downstream of dam – check one
XX Dry ______Greener Vegetation ______Standing water

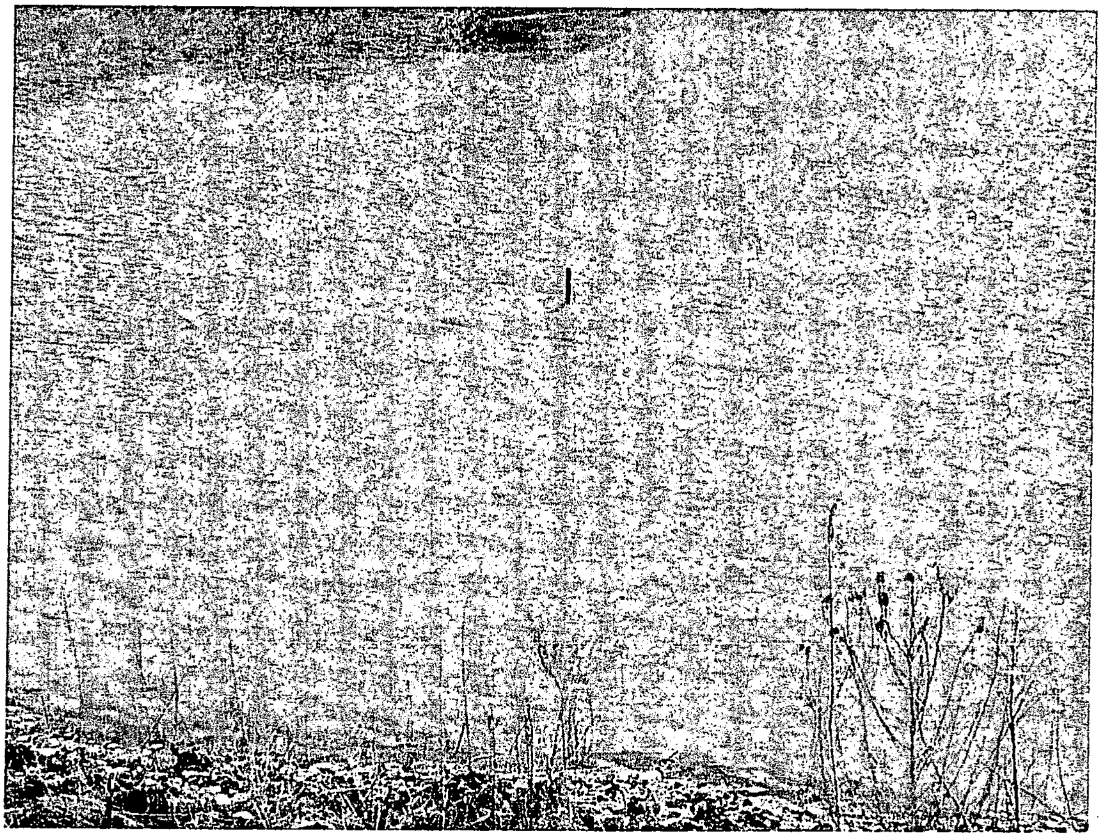
General inflow conditions at head of reservoir – check one
XX Located on normally dry channel
______Measurable inflow (estimate if possible)
______Apparent spring feed

Filename of downloaded data: NRD#1 on palm/gps NE00559

Observations Palm malfunction – lost data

Photographs

- Describe: One picture of T-post in water, one foot of T-post above water level. file name: ______
- Describe: ______; file name: ______
- Describe: ______; file name: ______



Taken 10/24/05 NE00559 Location of sensor in reservoir. Photo by Shane Stanton

State (circle one): Nebraska

Reservoir ID NE00559
Reservoir name Dry Creek South 2-A
Owner: Middle Republican NRD

Additional Site Visits

Date 4-18-2006
Party members Shane Stanton

Water Level
Sensor/Logger 1.07 (feet)
Hand level 6 inches under water(feet); in relation to top of cap on logger.

Surface Area at water level 0.4 (acres)

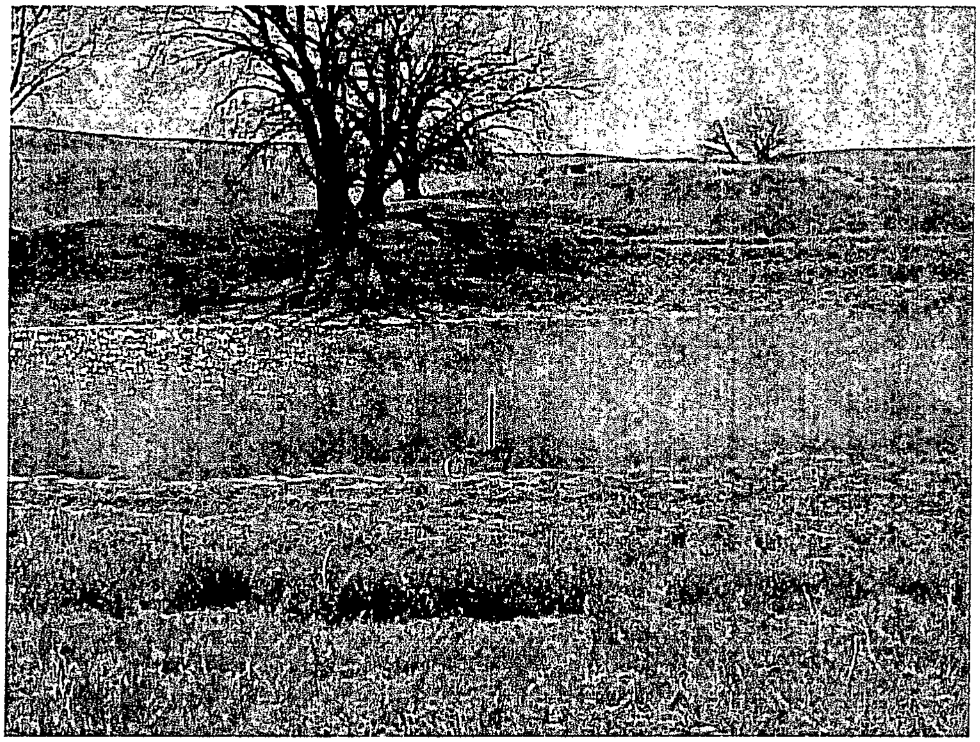
General seepage conditions downstream of dam – check one
XX Dry ______Greener Vegetation ______Standing water

General inflow conditions at head of reservoir – check one
XX Located on normally dry channel
______Measurable inflow (estimate if possible)
______Apparent spring feed

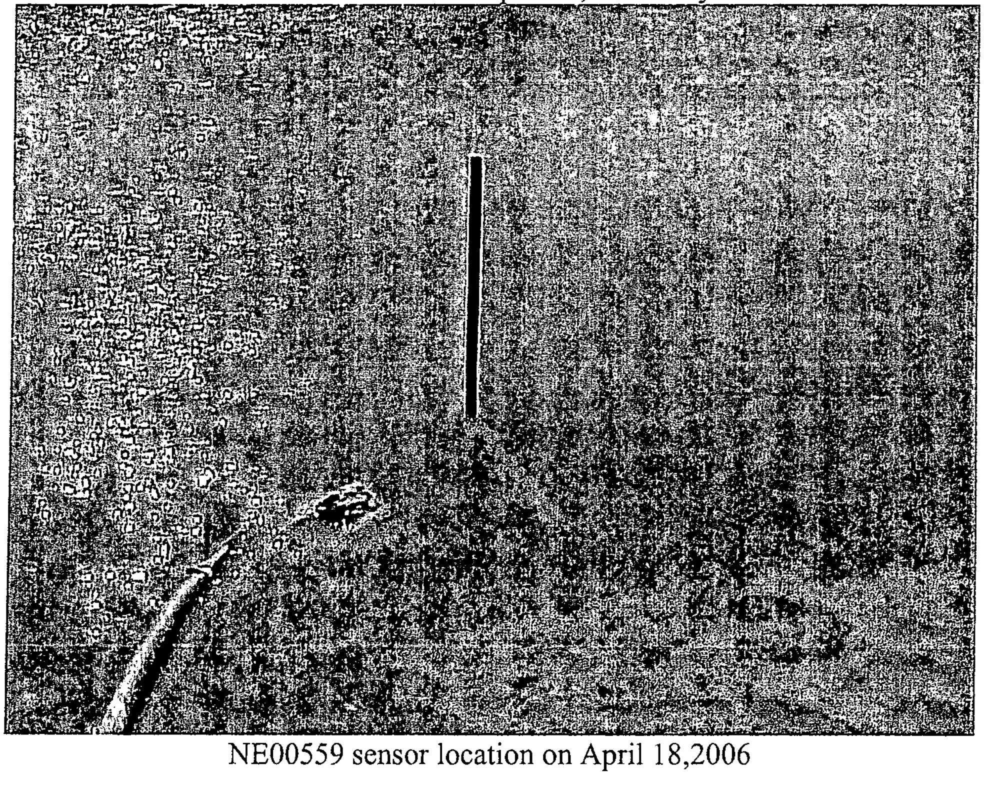
Filename of downloaded data: ____________

Observations Sensor approx 6 inches under water

Photographs
- Describe: ______________ file name: ______________
- Describe: ______________; file name: ______________
- Describe: ______________; file name: ______________



Ne00559 location of sensor on April 18,4006 By Shane Stanton



NE00559 sensor location on April 18,2006

State (circle one): Nebraska

Reservoir ID NE00559
Reservoir name Dry Creek South 2-A
Owner: Middle Republican NRD

Additional Site Visits

Date 10-02-2006
Party members Shane Stanton

Water Level
Sensor/Logger 0.94 (feet)
Hand level ____

Surface Area at water level Dry (acres)

General seepage conditions downstream of dam – check one
XX Dry ____ Greener Vegetation ____ Standing water

General inflow conditions at head of reservoir – check one
XX Located on normally dry channel
____ Measurable inflow (estimate if possible)
____ Apparent spring feed

Filename of downloaded data: ____

Observations Reservoir is Dry.

Photographs

- Describe: ____ file name: ____
- Describe: ____; file name: ____
- Describe: ____; file name: ____

NE00559 Oct 2, 2006, Photo of the reservoir from the logger. By S. Stanton DNR

NE00559 Oct 2, 2006, Photo of the sensor in the reservoir. By S. Stanton DNR

State (circle one): Nebraska

Reservoir ID NE00559
Reservoir name Dry Creek South 2-A
Owner: Middle Republican NRD

Additional Site Visits

Date 3-26-2007
Party members S. Stanton

Water Level
Sensor/Logger 0.84 (feet)
Hand level ________

Surface Area at water level Dry (acres)

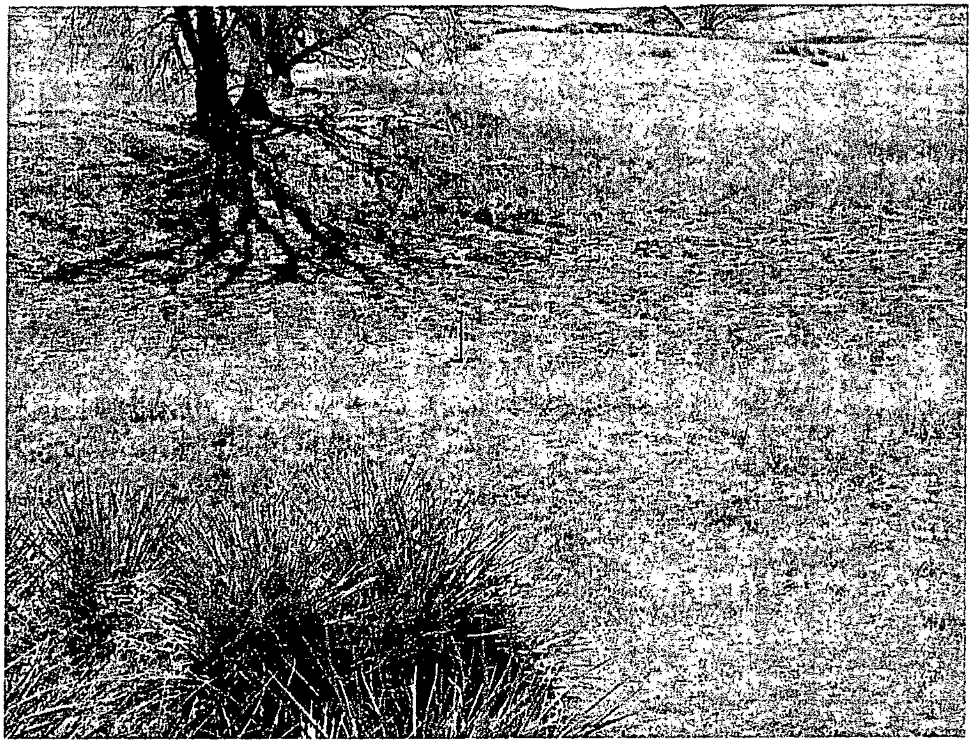
General seepage conditions downstream of dam – check one
XX Dry
______Greener Vegetation
______Standing water

General inflow conditions at head of reservoir – check one
XX Located on normally dry channel
______Measurable inflow (estimate if possible)
______Apparent spring feed

Filename of downloaded data: ________

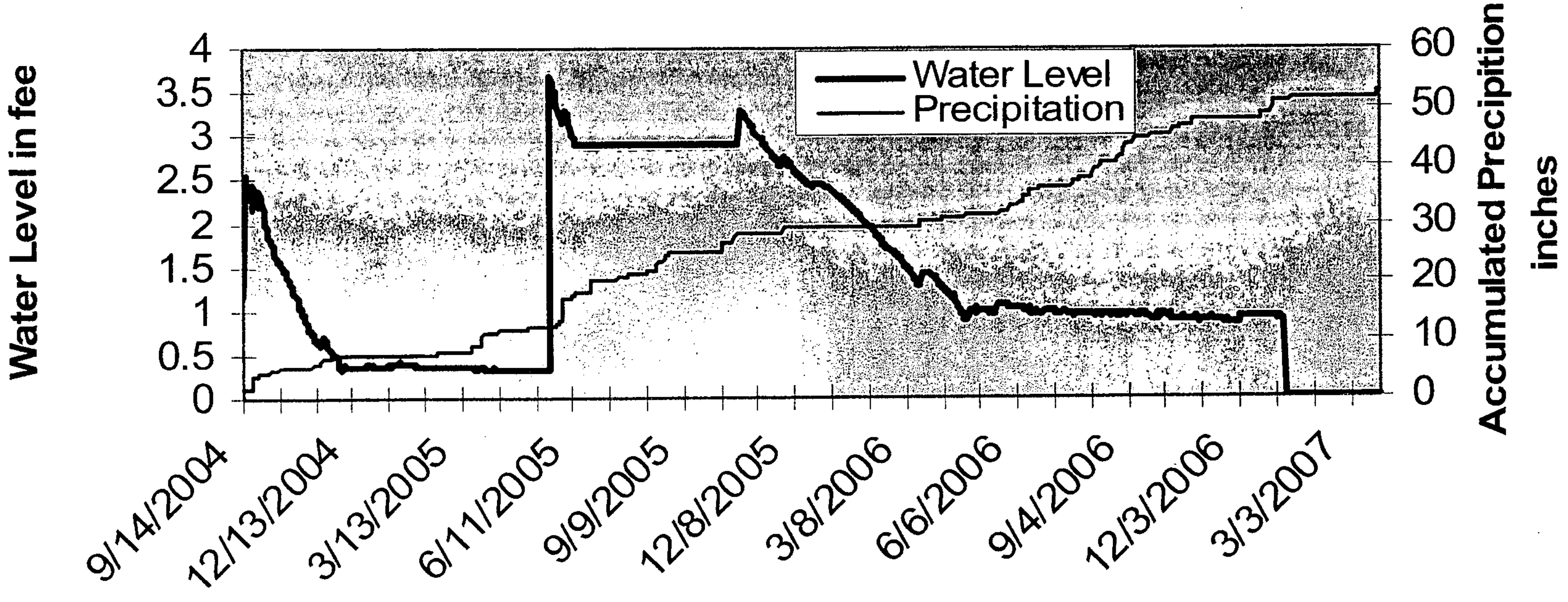
Observations Reservoir is Dry.

Photographs
- Describe: ________ file name: ________
- Describe: ________; file name: ________
- Describe: ________; file name: ________



NE00559 Taken March 26, 2007, Photo of dry Reservoir. By Shane Stanton,DNR

Water Level at Reservoir NE00559 and Accumulated Precipitation at McCook, Nebraska.



Note: Data missing for June 13 through October 24, 2005.
Preliminary data. Water Levels less than 0.94 ft fall 2006 indicates dry reservoir.

Appendix C2

State: Kansas

Reservoir ID DRA-0056
Reservoir name Olson Dam
Owner: Elda Olson

Basic Inventory Information (can be complete prior to site visit)

Designated Basin Beaver Creek
Dam Location (lat) 39' 49.626 (long) 100' 45.910
PLS NWNE1/41/4, Sec 2, Twp 35, Rge 32
Drainage Area (sq mi) 0.70

Dam Height (ft) 18.3; Dam Length (ft) 315'

Water Depth at Normal Full Pool (ft) 14.8, Surface Area at NFP (acres) ______
Storage at NFP (acre-feet) ______

Maximum Storage (acre-feet) ______

Purpose of Use Stockwatering
Year Completed ______

General Site Information

Driving directions to reservoir. 12.5 miles west of Oberlin. South side of Hwy 36

Additional comments/information: ______

Reservoir ID DRA-0056

State: Kansas

Reservoir name Olson Dam
Owner: Elda Olson

Initial Site Visit and Equipment Installation

Date of Installation Oct. 14, 2004 ;

Party members	(name)	(agency)
	Dale Ellerton	USBR, McCook, NE
	Steve Schiltz	USBR, McCook, NE
	Tom Cyre	KS DWR

Location of data logger (lat) 39’ 49.626 (long) 100’ 45.925
Location of spillway benchmark (lat)____ (long)____

Notes and Sketch of Site Elevation Survey

At a minimum, provide information to determine relative elevations for the spillway, low level outlet invert, logger cap, water level, and apparent normal high water mark.

Sensor Reading -0.03 (feet)

Surface Water Area (calculated by GPS)
Area at water level 0.52 (acres)
Area at apparent normal high water mark ____ (acres)

Reservoir ID DRA-0056

State: Kansas

Reservoir name Olson Dam

Owner: Elda Olson

Initial Site Visit and Equipment Installation (continued)

General seepage conditions downstream of dam – check one

_X_ Dry ______Greener Vegetation ______Standing water

General inflow conditions at head of reservoir – check one

_X_ Located on normally dry channel

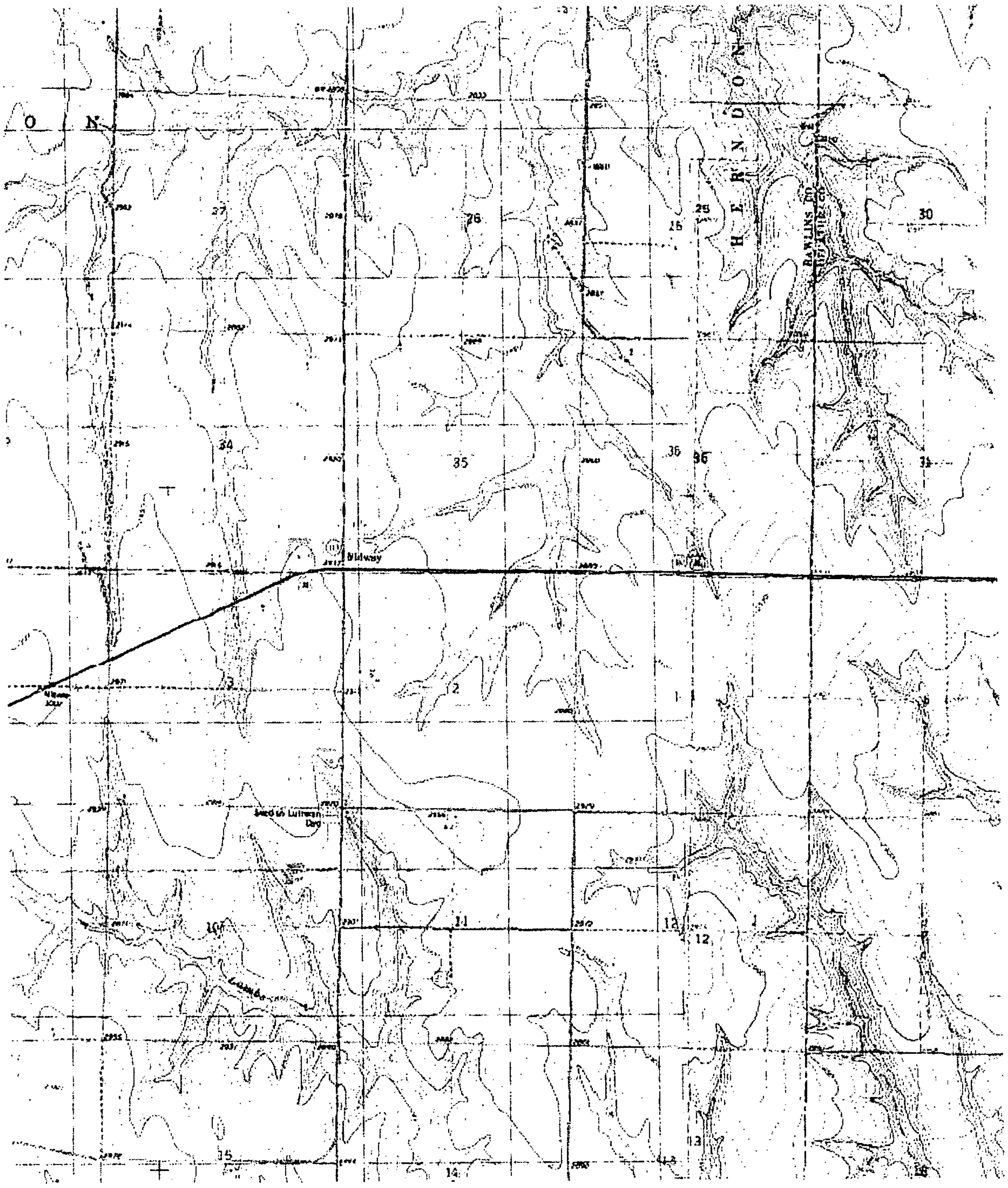
______Measurable inflow (estimate if possible)

______Apparent spring feed

Additional comments/information:

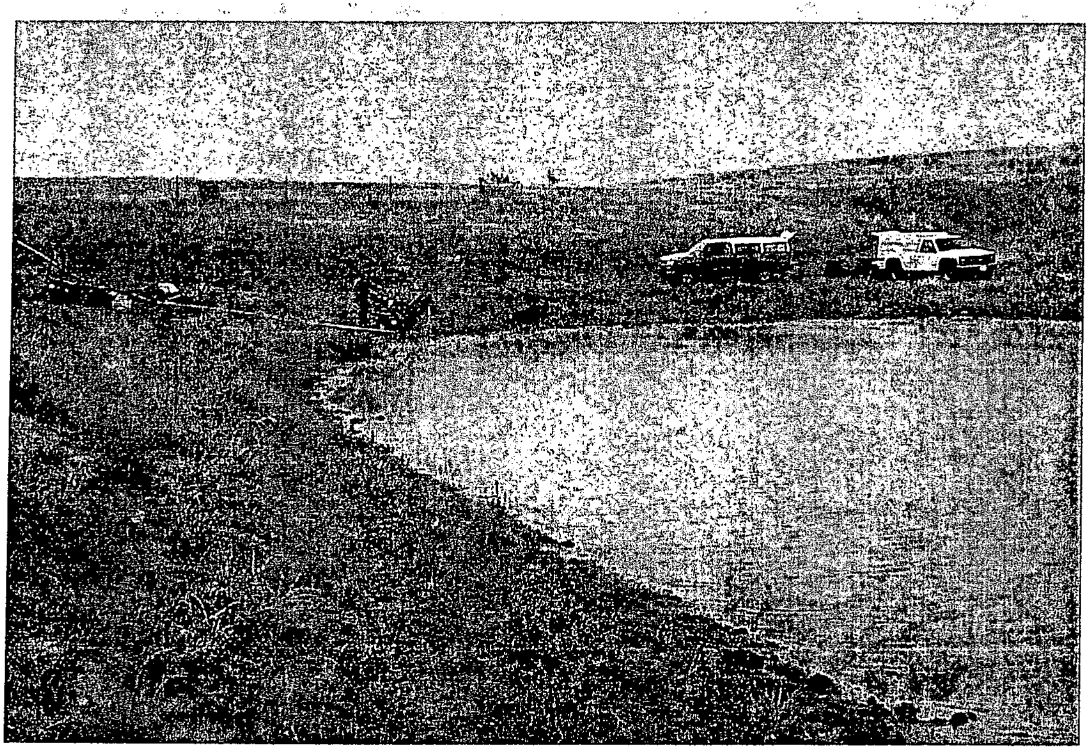
Photographs

- From top dam viewing downstream; filed name: dra56.wpd
- From top of dam viewing upstream; filed name: dra56.wpd
- From upstream with view dam and spillway; filed name: dra56a.wpd
- View of logger location; filed name: dra56a.wpd
- Describe: ______; filed name: ______
- Describe: ______; filed name: ______

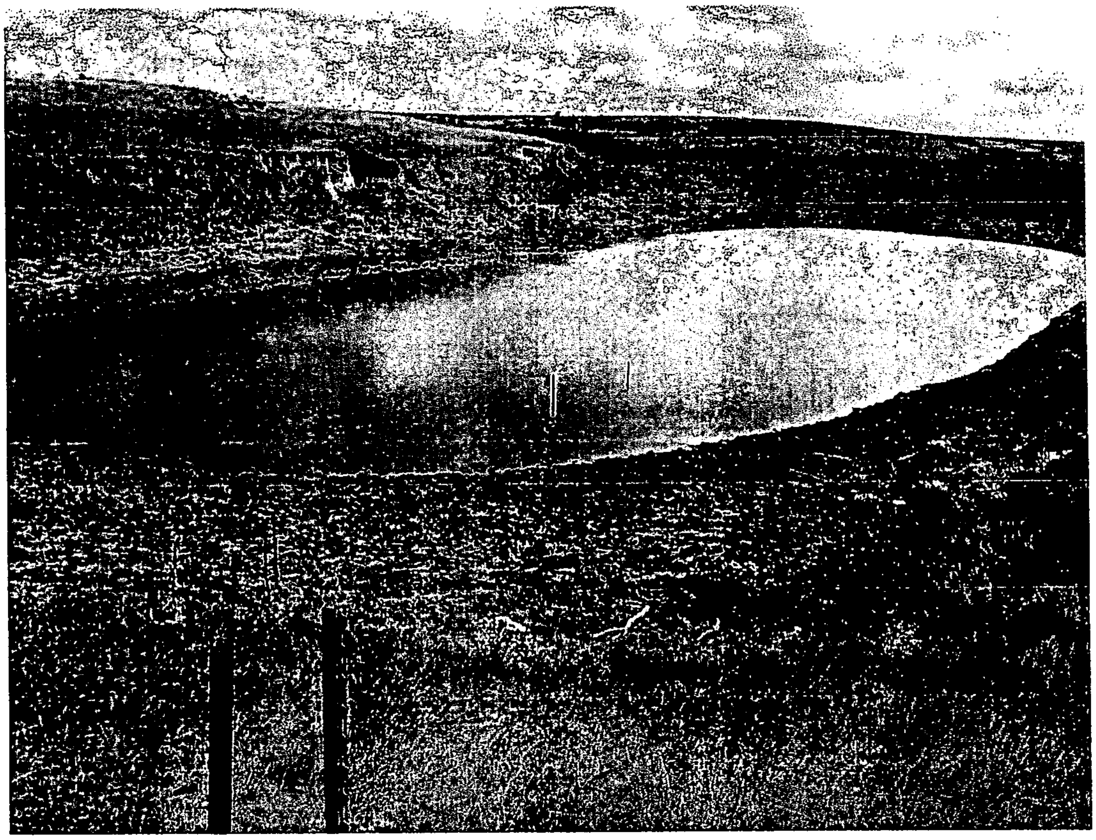


DRA-0056, Reservoir Located at Center of Map just South of Highway

Olson Reservoir, DRA-0056 showing installation of Water Logger

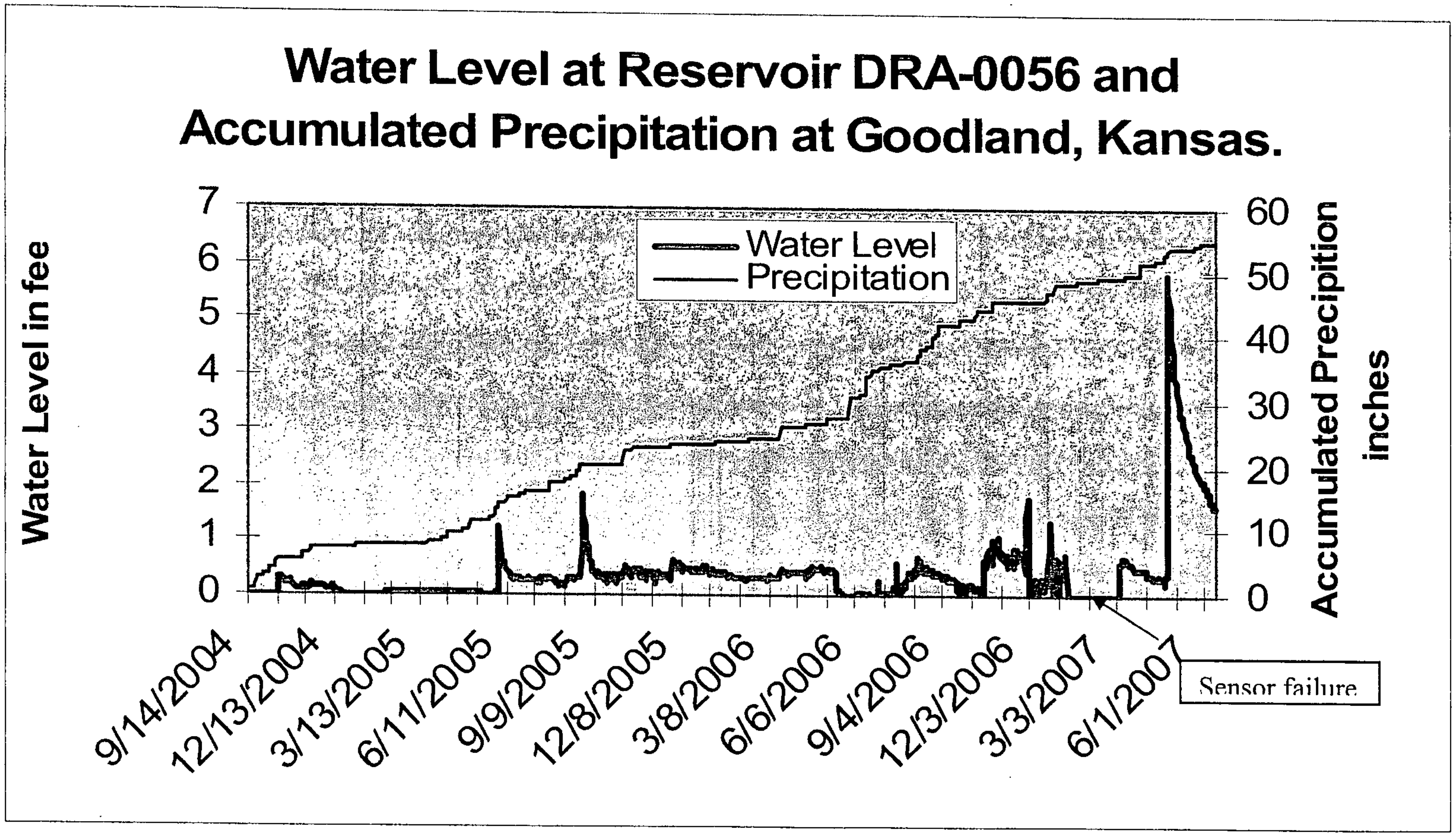


DRA-0056 Upstream looking back at dam and emergency spillway



DRA – 0056 Photo taken 8-23-05, 4:51 pm, looking to the Southeast. Also known as the Olson Dam located 14½ miles East and ¾ mile North of Atwood, Ks. Located in the Northeast ¼ of Sec. 2-3-31W, Rawlins Co.

Surface area measured using a hand held Garmin 60CS GPS Unit and found to be approximately 0.54 acres. Elevation of water surface in relation to top of cap on logger: [(100.00 ft. – 18.91 ft.) + 4.46 ft.] = 85.55 ft. Dam located on a normally dry channel. Recent rainfall accounted for current level. No runoff entering dam at time of photo.



Water Level at Reservoir DRA-0056 and Accumulated Precipitation at Goodland, Kansas.

Appendix C3

Reservoir ID Flagler Reservoir
Reservoir name Flagler Reservoir
Owner: State of Colorado

State: Colorado

Basic Inventory Information (can be complete prior to site visit)

Designated Basin South Fork Republican
Dam Location (lat) N 39 17.617 (long) W 102 59.183
PLS NWSW 1/41/4, Sec 3, Twp 9S, Rge 50W
Drainage Area (sq mi) ____

Dam Height (ft) ____; Dam Length (ft) ____

Water Depth at Normal Full Pool (ft) ____, Surface Area at NFP (acres) ____
Storage at NFP (acre-feet) ____

Maximum Storage (acre-feet) ____

Purpose of Use Recreation
Year Completed ____

General Site Information

Driving directions to reservoir. See Attached Map, East of Flagler, CO

Additional comments/information: ____

Reservoir ID Flagler Reservoir

State: Colorado

Reservoir name Flagler Reservoir
Owner: State of Colorado

Initial Site Visit and Equipment Installation

Date of Installation September 17, 2004 ;

Party members

(name)	(agency)
Dave Rebis	Colorado, DWR
Dale Ellerton	USBR, McCook
Gordon Aycock	USBR, Billings
Scott Guenthner	USBR, Billings

Location of data logger (lat) N 39 17.620 (long) W 102 59.238
Location of spillway benchmark (lat)____________ (long)______

Notes and Sketch of Site Elevation Survey

At a minimum, provide information to determine relative elevations for the spillway, low level outlet invert, logger cap, water level, and apparent normal high water mark.

Sensor Reading .69 (feet)

Surface Water Area (calculated by GPS)
Area at water level 19.7 (acres), Perimeter 1.32 miles
Area at apparent normal high water mark ______(acres)

Reservoir ID Flagler Reservoir

State: Colorado

Reservoir name Flagler Reservoir
Owner: State of Colorado

Initial Site Visit and Equipment Installation (continued)

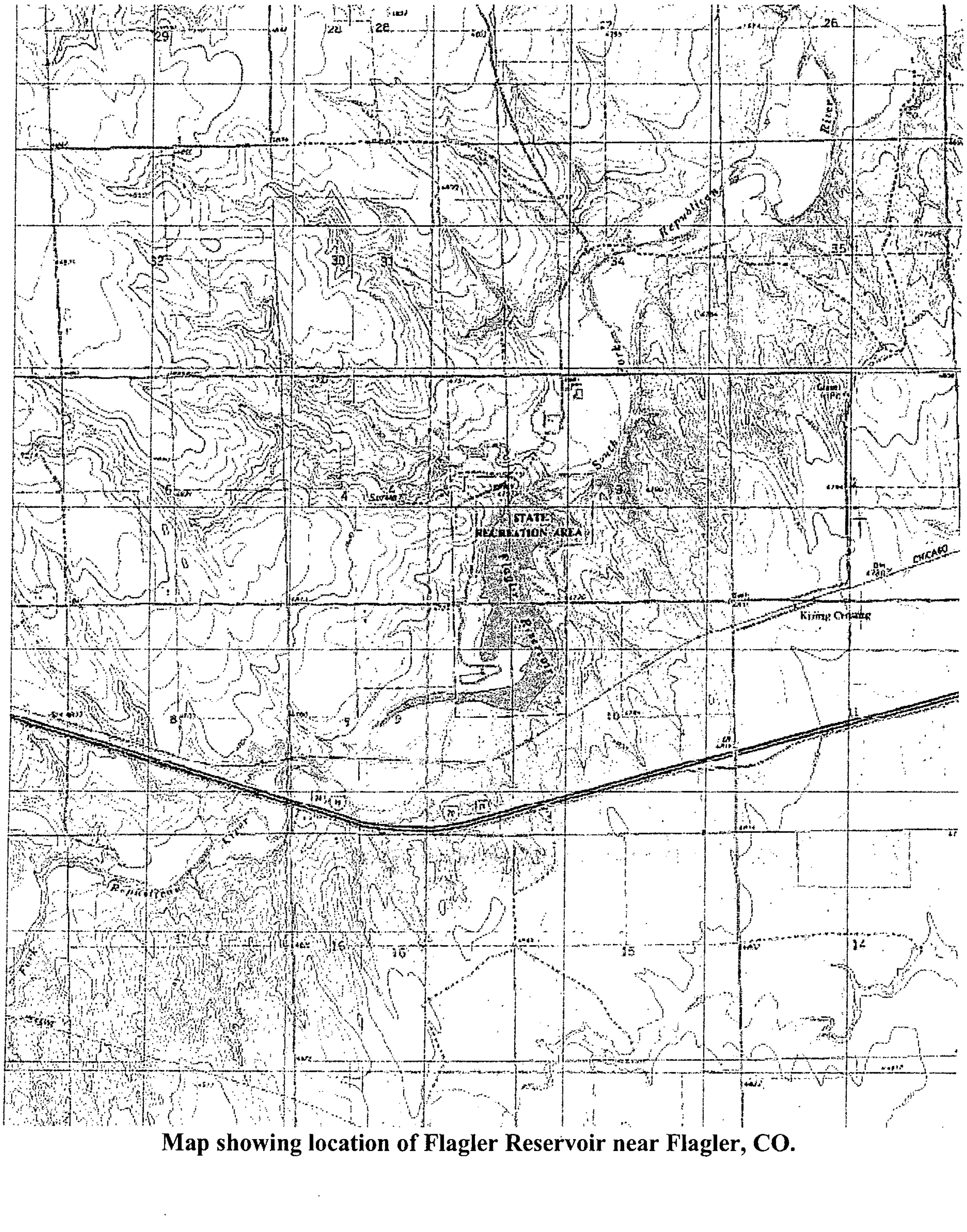
General seepage conditions downstream of dam – check one
______Dry X____Greener Vegetation ______Standing water

General inflow conditions at head of reservoir – check one
______Located on normally dry channel
______Measurable inflow (estimate if possible)
X____Apparent spring feed (Observed on west side of reservoir)

Additional comments/information: Considerable spring seepage and standing water along west side of reservoir.

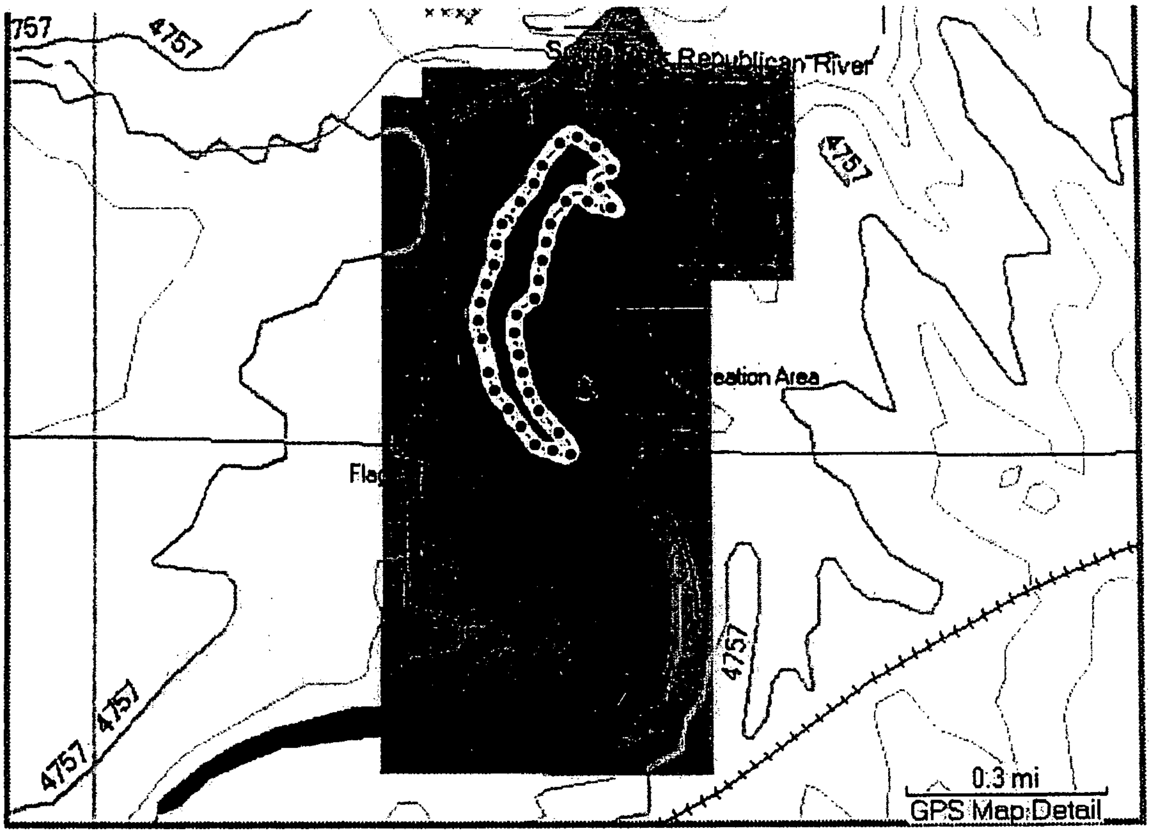
Photographs

- From top dam viewing downstream; filed name: __________
- From top of dam viewing upstream; filed name: __________
- From upstream with view dam and spillway; filed name: __________
- View of logger location; filed name: __________
- Describe: __________ ; filed name: __________
- Describe: __________ ; filed name: __________



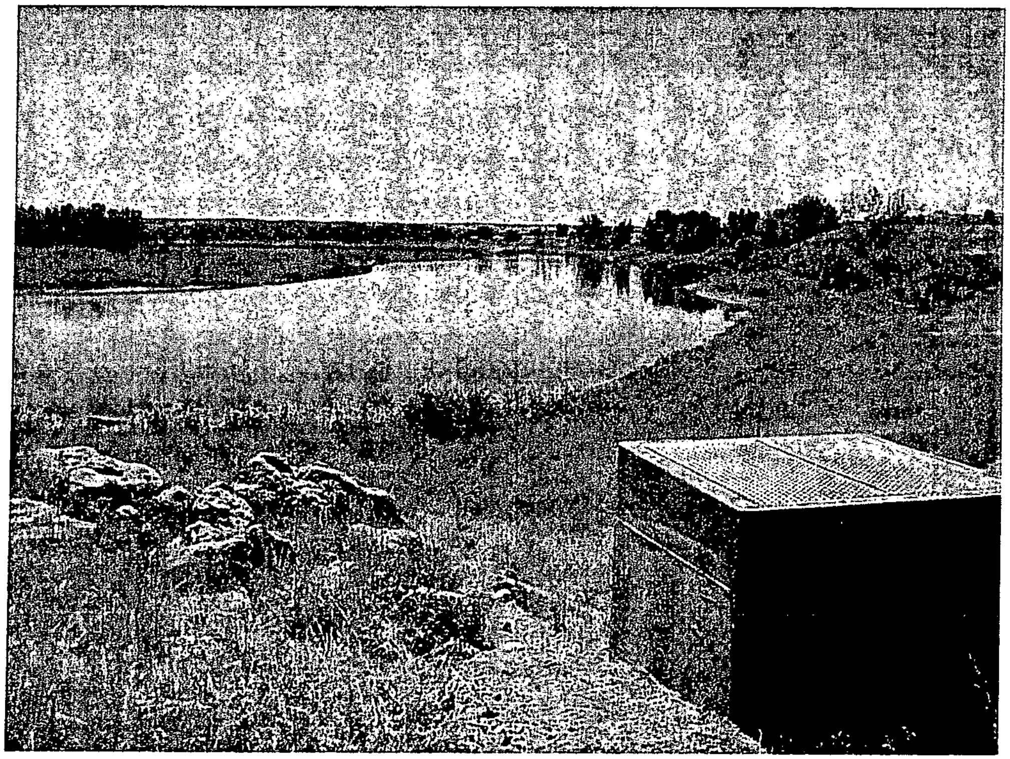
Map showing location of Flagler Reservoir near Flagler, CO.

GPS Tracking
Flagler Reservoir

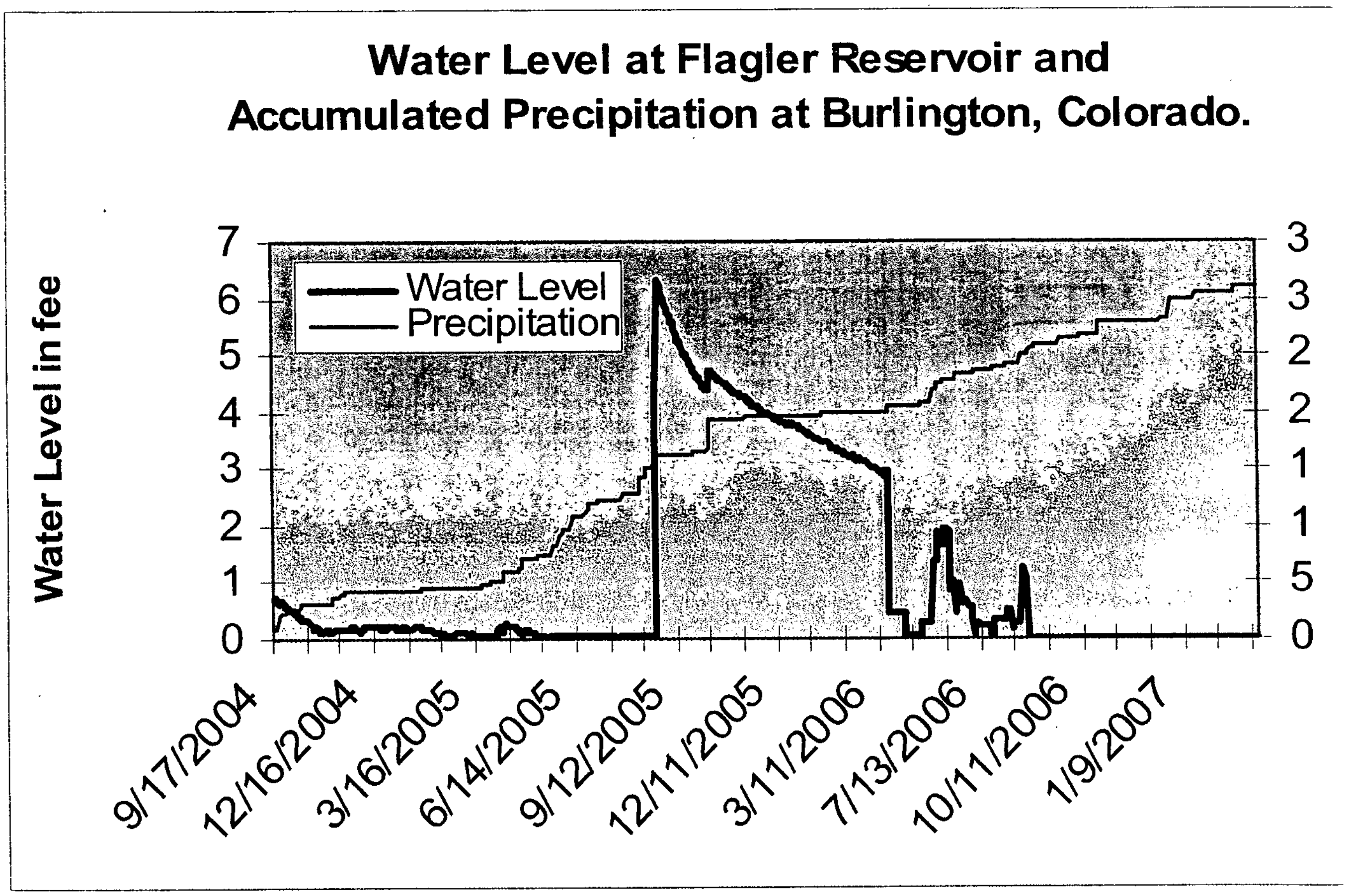


Tracking shows water surface area of 19.7 acres during site visit on Sept. 17, 2004.

Flagler Reservoir looking from boat ramp on south side downstream towards dam.



Flagler Reservoir looking upstream from dam next to river outlet control box. Water Logger was installed in spillway about 50 feet upstream from control box.



Water Level at Flagler Reservoir and Accumulated Precipitation at Burlington, Colorado.

App D

Proposal to Determine Condition of Terraces in the Republican River Valley

From: Derrel Martin (UNL), Jim Koelliker (KSU), Gordon Aycock (USBR), Scott Guenthner (USBR) and David Griffith (NRCS)

Background

One phase of the project to determine the effect of terraces and small reservoirs on the depletion of flows in the Republican River involved the assessment of the condition of terraces in the watershed. At the time the project was commissioned it was not clear how that task would be funded even though it was recognized that the NRCS was the most qualified to conduct the assessment. Initial simulation with the POTYLD model indicates that the condition of conservation terraces significantly affects the prediction of evapotranspiration, recharge and runoff. Thus, this phase is proving to be very important for credibility of the study.

A pilot study was conducted in Frontier County, Nebraska and Decatur County, Kansas to develop a technique to obtain the needed information. The pilot project involved selection of 10 terraced fields that were evaluated by personnel in NRCS field offices. The in-office portion of the analysis involved determination of the type of terraces installed, some design parameters and an estimate of the expected quality of the terrace. Three fields out of the ten were selected for an in-field survey to determine the quality of the terrace. The in-field analysis involved surveying the cross-section of the terrace and the profile of the terrace channel, along with an in-field assessment of the storage capacity relative to the constructed capacity. The analysis process required approximately 40-50 hours per county for the in-office and field analysis. Results of the pilot project showed that NRCS professionals could generally estimate representative values for much of the information obtained from the in-office assessment and that the actual condition in the field could be different than expected. The protocol for the pilot project is attached as an Appendix 1.

Another phase of the overall project is to map the terraced lands in the watershed to determine the amount of land terraced and to develop input datasets for simulation modeling. An initial assessment of the digitized data indicates that approximately 2.3 million acres are terraced in the Nebraska and Kansas portions of the basin. The lands in Colorado have not been digitized to date. The average size of polygon in the Kansas dataset is about 145 acres which would give about 15,800 polygons for the Nebraska and Kansas portions of the watershed. In some cases there may be more than one field per polygon; therefore, there are probably more than 20,000 terraced fields in the Nebraska and Kansas portion of the watershed.

The final component for consideration is that the Bureau of Reclamation has tentatively secured additional funding of approximately $50,000 to underpin the study focused on determination of the condition of terraces.

Proposed Activity

Our proposal involves an estimation component and an assessment component.

Estimation Component

The first component entails county by county estimation by NRCS professionals of:

- The types of terraces installed across the watershed,
- Typical design parameters for terraces across the basin, and
- The quality of terraces within the watershed.

We are asking the NRCS evaluator to estimate the distribution of terrace designs within each county of the watershed. Terrace designs would be designated as conservation bench terraces with closed-ends, closed-end normal cross-section level terraces, open-end level terraces, and gradient terraces that drain to a waterway or pipe outlet. We would like to know the percentage of the terraced land in each county that fits into each terrace category.

The terrace design parameters would include typical values for the ridge height at construction, terrace interval, cropping practices, percentage of terraced land that is irrigated, etc.

The quality of the terraces would be classified by the same rating system used for the assessment portion of the evaluation. NRCS professionals would estimate the percentage of terrace types in the county that have a storage capacity determined by the following rating system:

1. = Nearly new or excellent terrace that is functioning close to design storage capacity
2. = Excellent condition; functioning at more than 75% of design storage capacity
3. = Good condition; functioning at about 50% of design storage capacity.
4. = Poor condition; functioning at less than 25% of design storage capacity
5. = Non-functional terrace with very little storage capacity or that has been breached.

Assessment Component

The assessment component would involve in-field measurements based on the protocol used in the pilot study. We would select up to 200 fields (about 1% of the terraced fields) to survey the cross-section and profile, and to complete the observations described in the pilot-study protocol.

Most likely an employee would be hired by one of the Universities to conduct the surveys. The most desirable employee would have good knowledge of the NRCS system and would be able to work with NRCS field offices to secure permission to conduct the study and to utilize NRCS equipment from the local or regional office. An ideal employee would be a retired NRCS professional who had field office experience. Building a multi-person team and/or multiple teams would expedite the survey.

Scope of Work

Estimation Component

All or parts of eight counties are included in the Republican Basin in Kansas, with 7 counties in Colorado and 16 counties in Nebraska. Our initial estimate is that an NRCS professional should be able to complete the estimation component of the study with no more than one person-day per state. There should not be any significant cost for this component of the study.

Survey Component

Experience from the pilot study indicates that surveying a field will require approximately one-half day per field. Thus, a total effort of approximately 100 person-days would be necessary to measure 200 fields. The process could be expedited with a two-person team, multiple teams and/or utilization of all terrain vehicles to more quickly traverse the terrace channel for the profile survey. We envision that the potential support from the USBR would fund the bulk of this portion of the study as long as surveying equipment was available and if there was some NRCS field office assistance in arranging field access for the surveys. In-kind contributions of personnel from either NRCS and/or state agencies would also assist in more timely completion of the surveys. The field surveys could be conducted starting anytime and are possible as long as cropping systems and weather allows.

Appendix 1. Memo and form sent to NRCS field offices for pilot study of terrace condition

May 4, 2006

To: NRCS Personnel
From: Derrel Martin
Re: Survey to determine the condition and capacity of terraces in the Republican Basin

Background

The research project partially described in this memorandum was mandated by the Republican River Settlement and focuses on determining the impact of terraces on streamflow depletion in the Republican River Basin. Quantification of these impacts relies on hydrologic modeling of runoff, deep percolation and evapotranspiration from land that has been terraced, and estimates of these quantities if the land had not been terraced. Estimation of impacts at the watershed scale depends on the amount of land terraced, the types of terraces installed, the designed function of the terraces and the current condition of the terraces relative to their capability to perform as designed. We are mapping the distribution of terraced land across the watershed and have installed equipment in selected fields to measure the characteristics and hydrologic functions of a sampling of terraces. A survey is proposed to determine the distribution of the types of terraces installed and the current capacity of terraces across the watershed.

As a precursor to the basin-wide survey we are evaluating the methods used to obtain the required information. Thus, we are asking for your help in developing the procedure to obtain reliable information across the basin. Dave Griffith has explained that we will use Frontier County Nebraska and Decatur County, Kansas as pilot locations to test our procedure. The form Dave will provide has been developed to gather information from the terraces to be sampled from your county. The information needed on the form is described in the following section.

Procedure

The profile and cross-section surveys on the form are similar to methods traditionally used to evaluate terraces. The extra information is located at the lower right portion of the form. The desired information for those cells is described below.

- % Of Field Above The Top Terrace: We are interested in an estimate of how much of the field lies above the top terrace. This value could be determined from ArcView analysis of an aerial photograph of the fields or could be estimated in a reliable fashion.

- Terrace Condition: We are interested in the current storage capacity of the terraces relative to the design capacity. We developed a rating system shown at the bottom of the form. For example, if the field is very near the condition of a newly terraced field, enter a value of 1. If in your estimation the storage capacity of the terrace has dropped to 50% of the design capacity, enter a value of 3, etc. Please indicate if the terraces have been breached.

- Average Horizontal Interval and Terrace Length: Please estimate the average horizontal distance between terraces and the average length of terrace in the field. While there will be variation of these values within a field, please estimate the most representative interval and length for the field.

- Terrace Type: Describe the type of terrace installed in the field surveyed. "Con ^{y}" represents a conservation terrace designed to store water in the terrace channel after a storm until the water seeps into the soil. Use other abbreviations to describe the types of terrace you encounter. Please provide a description of the abbreviations you use.

- End Closure: Please describe how the ends of the terrace sections were constructed or if the water exits from the terrace channel through piped outlets. If the ends of the terrace are designed to store the "full" depth of water that the channel will hold, designate the end closure as "full". If the ends are designed to allow some outflow through the ends before water reaches the storage capacity of the channel, designate the end closure as "partial". Partial closure can be used to protect terraces from overtopping. If the ends of the terrace do not impede outflow, designate the end closure as "open". If a mixture of conditions is used, please describe the conditions employed in the selected field.

- Evidence of Ponding: We know that some terraces pond water long enough to "drown-out" crops. We are asking you to make your best guess as to whether this condition is common at the selected field.

- Land Use Information: Please estimate the cropping rotations that are typically used on the selected field. What crops are raised and what is a typical rotation?

- Farming Direction: Describe if the producer generally farms on a contour. If straight rows are used, are the rows generally parallel to most of the terrace ridges or is the row direction independent of the terrace layout?

- Residue Cover: Please estimate the percent residue cover for this field. Indicate what time of the growing season your estimate represents if the estimate is for one of the fields analyzed from the office.

- Irrigated or Dryland: Indicate "I" if the field is irrigated and "D" if the field is dryland.

If you have suggestions to improve the data gathering process please include your suggestions with the results of this pilot test.

Thank you for your time. We know you are busy and we greatly appreciate your assistance.

Profile															
Terr.#	Rod reading and Station														
	Sta														
	Ridge														
	Chann														
	Chann														
	Sta														
	Ridge														
	Chann														
	Chann														
	Sta														
	Ridge														
	Chann.														
	Chann														

CROSS-SECTION

Ter. No.	Sta.	Length of slopes				Eff. Height (ft)
		...Cat...........	B.W.	Front	: ·c	

Location	County:.		State		PITY::	
Field Acres		5 PielikAbove To Terrace :		Group # (from list)		
Data Gathered in the field		OR	! Data:GatheredfrunkRecorda			
Terrace Condition		Ave Horizontal Interval, Ft		Mg Length..		
Land Use Practices	Terrace Type (PC, Y- :: Chan, or other aa.noted	Eud Clo,surc,(Full, . Partial; Pi .e,Ottier		Evidence of Pcinding in Channel:		
	Crops (row clip, small grain alfalfa; CRP, other)			Production System (natation, ecofallow etc.)"::		
	Farming Direction (on contour Straight row, other-please note)		Avg Residue Cover (%)::	. BrigatiqUe or Dryland Mr		

Data Collected By Date

Signed:

Representing:

Signed:

Representing:

Signed:

Representing:

**Terrace Condition Rating System:*

1. *= Nearly new or excellent terrace that is functioning very close to the design storage capacity*
2. *= Excellent condition; functioning at more than 75% of design storage capacity*
3. *= Good condition; functioning at about 50% of design storage capacity.*
4. *= Poor condition; functioning at less than 25% of design storage capacity*
5. *=Non-functional terrace with very little storage capacity*

Notes:

Personnel		
Contract for field surveyor @ $240/day		
Project planning and coordination, 12 days		$2,880.00
Field data collection, 120 days		$28,800.00
Analysis of top and bottom terrace land areas, 5 days		$1,200.00
Compile data, review notes and prepare report, 10 days		$2,400.00
Review final results and report, 2 day		$480.00
	Subtotal	$35,760.00
Student research assistant @ $12/hour		
Data entry, 60 hours		$720.00
Compile, graph, and analyze data, 170 hours		$2,040.00
	Subtotal	$2,760.00
Equipment		
Four-wheel drive utility vehicle		$7,500.00
Trailer for utility vehicle		$1,500.00
Surveying equipment		$12,000.00
Notebook computer		$3,000.00
Miscellaneous		$1,000.00
	Subtotal	$25,000.00
Operating		
Field Surveyor		
Field mileage, 100 mi/d, 120 d, $0.485/mi		$5,820.00
Lincoln mileage, 4 trips, 400 mi/trip, $0.485/mi		$776.00
Motel and per diem, 45 nights, $100/night		$4,500.00
Fuel and maintenance for utility vehicle		$2,000.00
Project Management/Supervision		
Field mileage, 3 trips, 800 mi/trip, $0.485/mi		$1,164.00
Motel and per diem, 10 nights, $100/night		$1,000.00
Other operating expenses		
Publication costs		$1,500.00
Professional meeting presentation		$1,500.00
Miscellaneous Supplies		$1,000.00
	Subtotal	$19,260.00
Total Direct Cost		**$82,780.00**
Facilities and Administrative Costs (@ 17.5%)		**$14,486.50**
Project total		**$97,266.50**

TIMETABLE: Terrace Condition Assessment/Survey Project

	2007							2008						
Task	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	Comments
Order equipment	■													
Project planning/coordination		■												Field surveyor begins July 1
Field data collection		■	■	■	■	■	■	■	■	■	■	■		Data collection begins July 15
Data entry and analysis		■	■	■	■	■	■	■	■	■	■	■		Student assistant begins Jan 10
Report preparation												■	■	
Publication preparation														
Meeting presentation													■	

APPENDIX E

INVENTORY
OF
TERRACED LANDS

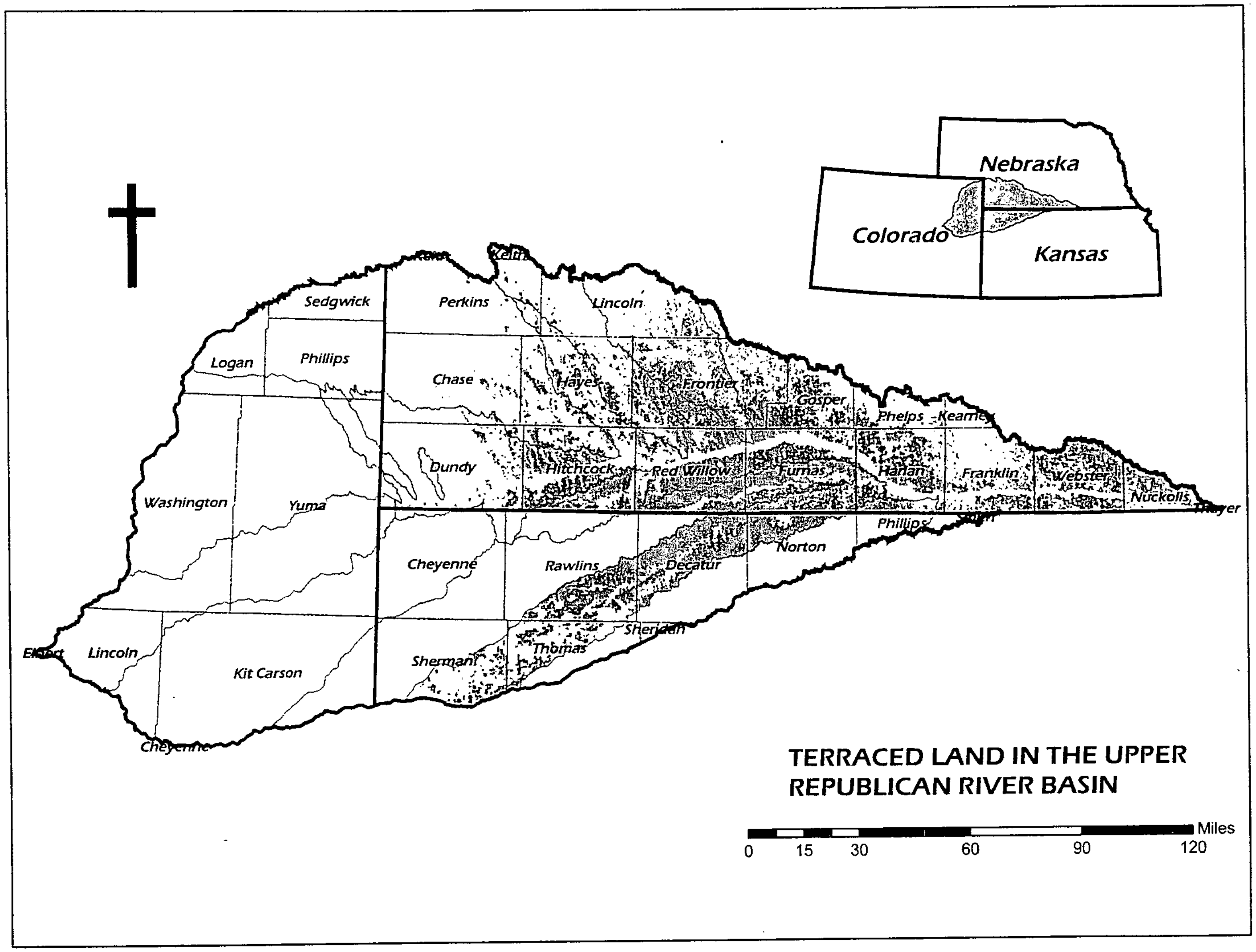


Figure 1. Location of terraced lands as digitized for Nebraska and the Sappa Creek Watershed in Kansas (Prepared by UNL).

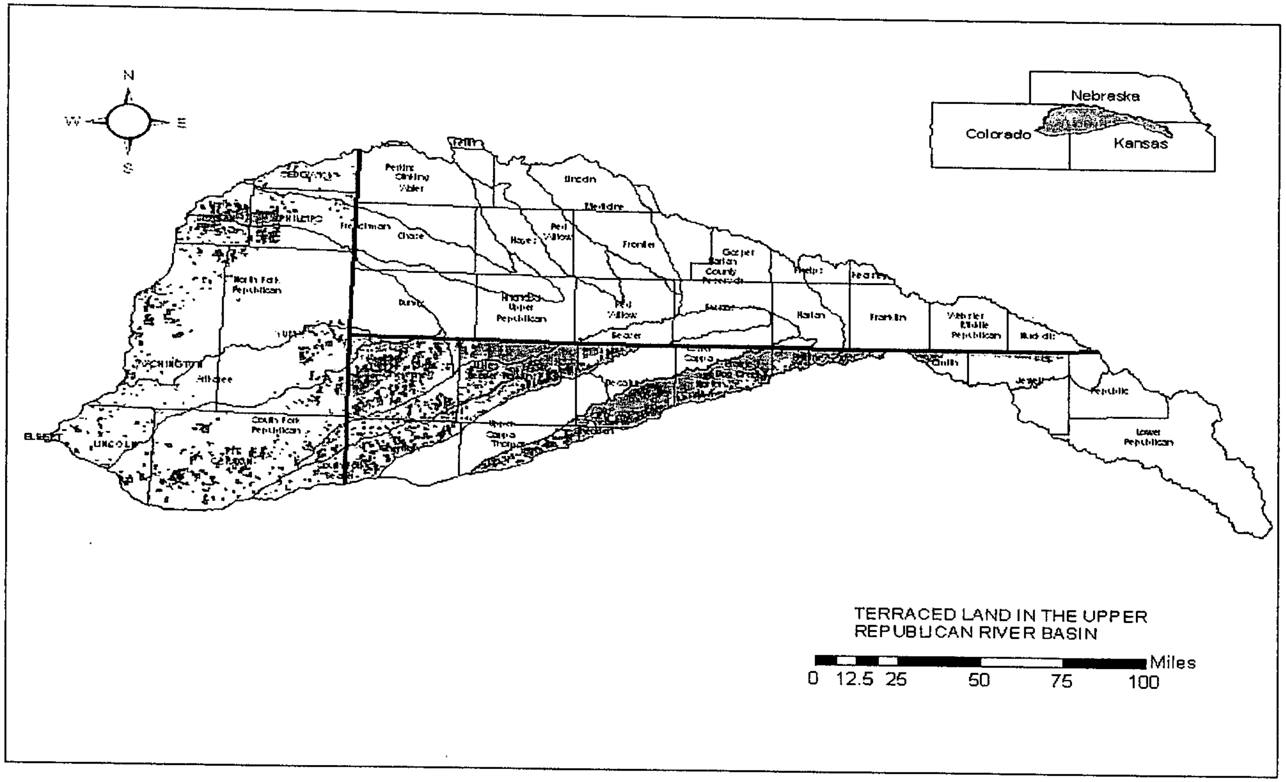


Figure 2. Location of terraced land as digitized for Prairie Dog Creek Watershed in Kansas (Prepared by Reclamation).

Table 1. Summary of acres of terraced land in the Republican River Basin based on digitization from DOQ images.

County	Arikaree River	Beaver Creek	Buffalo Creek	Driftwood Creek	Frenchman Creek	Main stem	Medicine Creek	North Fork Republican River in Colorado	Prairie Dog Creek	Red Willow Creek	Rock Creek	Sappa Creek	South Fork Republican River	Total
Colorado														
Elbert	674													674
Kit Carson	876	9,734											50,963	61,573
Lincoln	11,312												6,422	17,734
Logan					15,438			16,161						31,599
Phillips					27,840			12,954						40,794
Sedgwick					4,790									4,790
Washington	2,618							31,658					316	34,592
Yuma	14,865							5,448					8,266	28,579
Kansas														
Cheyenne	2,144	16,273				4,722							79,455	102,594
Decatur		26,140							104,069			116,925		247,134
Jewell						8,784								8,784
Norton									104,152			45,522		149,674
Phillips						7,688			10,920					18,608
Rawlins		94,150				50,528			1,194			79,876		225,748
Sheridan									4,756					4,756
Sherman		34,595				83						27,114		61,792
Smith						6,349								6,349
Thomas		320							30,364			37,140		67,824

Table 1. Summary of acres of terraced land in the Republican River Basin based on digitization from DOQ images-continued.

County	Arikaree River	Beaver Creek	Buffalo Creek	Driftwood Creek	Frenchman Creek	Main stem	Medicine Creek	North Fork Republican River in Colorado	Prairie Dog Creek	Red Willow Creek	Rock Creek	Sappa Creek	South Fork Republican River	Total
Nebraska														
Chase					9,042	4,663								13705
Dundy					2,852	22,020								24,872
Franklin						27,788								27,788
														0
Frontier						92,398	69,045			27,518				188,961
Furnas		82,000				66,486	1,804		412			55,503		206,205
Gosper						55,277								55,277
														0
Harlan						51,775			14,751			24,131		90,657
Hayes					17,707	28,782	407			16,781				63,677
Hitchcock				64,597	27,116	109,555								201,268
														0
Kearney						164								164
Keith										65				65
Lincoln					103	1,219	10,826			1,589				13,737
														0
Nuckolls						26,349								26,349
Perkins					2,054	3,114				3,120				8,288
Phelps						7,915								7,915
														0
Red Willow		69,048		6,889		106,625	3,267			19,515		6,465		211,809
Thayer						41								41
Webster						55,183								55183
Colorado	30,345	9,734			48,068			66,221					65,967	220,335
Kansas	2,144	171,478				78,154			255,455			306,577	79,455	893,263
Nebraska		151,048		71,486	58,874	659,354	85,349		15,163	68,588		86,099		1,195,961
Republican Basin	**32,489**	**332,260**		**71,486**	**106,942**	**737,508**	**85,349**	**66,221**	**270,618**	**68,588**		**392,676**	**145,422**	**2,309,559**

Table 2. Summary of terraced parcels by county and watershed based on digitization from DOQ images.

County	Arikaree River	Beaver Creek	Buffalo Creek	Driftwood Creek	Frenchman Creek	Main stem	Medicine Creek	North Fork Republican River in Colorado	Prairie Dog Creek	Red Willow Creek	Rock Creek	Sappa Creek	South Fork Republican River	Total
Colorado														
Elbert	3													3
Kit Carson	6	61											241	308
Lincoln	57												20	77
Logan					103			103						206
Phillips					132			43						175
Sedgwick					35									35
Washington	22							151					1	174
Yuma	75							43					58	176
Kansas														
Cheyenne	23	134				37							460	654
Decatur		227							766			1,377		2,370
Jewell						175								175
Norton									895			767		1,662
Phillips						227			203					430
Rawlins		698				342			7			690		1,737
Sheridan									47					47
Sherman		247										146	1	394
Smith						198								198
Thomas		1							120			217		338

Table 2. Summary of terraced parcels by county and watershed based on digitization from DOQ images-continued.

County	Arikaree River	Beaver Creek	Buffalo Creek	Driftwood Creek	Frenchman Creek	Main stem	Medicine Creek	North Fork Republican River in Colorado	Prairie Dog Creek	Red Willow Creek	Rock Creek	Sappa Creek	South Fork Republican River	Total
Nebraska														
Chase					74	29								103
Dundy					14	161								175
Franklin						512								512
Frontier						1,208	681			303				2,192
Furnas		1,109				911	31		1			948		3,000
Gosper						835								835
Harlan						650			153			333		1,136
Hayes					163	253	12			186				614
Hitchcock				376	166	658								1,200
Kearney						2								2
Keith										1				1
Lincoln					2	23	132			15				172
Nuckolls						506								506
Perkins					20	30				22				72
Phelps						127								127
Red Willow		518		65		1,148	29			109		90		1,959
Thayer						1								1
Webster						1,154								1154
Colorado	163	61			270			340					320	1,154
Kansas	23	1,307				979			2,038			3,197	461	8,005
Nebraska		1,627		441	439	8,208	885		154	636		1,371		13,761
Republican Basin	**186**	**2,995**		**441**	**709**	**9,187**	**885**	**340**	**2,192**	**636**		**4,568**	**781**	**22,920**

APPENDIX F

DETAILED PROGRESS REPORT
OF
KANSAS STATE UNIVERSITY

Progress Report for the Period: June 1, 2006-May 1, 2007

Electronic file: Progress Report May 2007.doc (Word document)

Cooperative Agreement Between The Bureau of Reclamation and Kansas State University: Modeling and Field Experimentation to Determine the Effects of Land Terracing and Non-Federal Reservoirs on Water Supplies in the Republican River Basin Above Hardy, Nebraska

Prepared by: James Koelliker, Principal Investigator
Biological and Agricultural Engineering Department
Seaton Hall, Kansas State University, Manhattan, KS 66506
koellik@ksu.edu, 785-532-2904

Kansas State University Responsibilities:

a. Lead the effort to evaluate existing water balance modeling methods and improvement of those models. At least three models will be studied to determine the most reliable methods. The following sections describe the work done so far.

Water Budget Model Evaluations:

In cooperation with the University of Nebraska-Lincoln, three water budget models were evaluated and the **POTYLDR** (**POT**ential **Y**ie**LD** Model **R**evised) developed by Kansas State University (Koelliker 1994 and 1998) will serve as the basic framework for the water budget simulation model.

The Overall Modeling Approach for this Project

The KSU and UNL teams met three times to work on details of this project. Also, we have shared information and data as needed via e-mail and ftp procedures. The development of the computer simulation model has been a continuing topic that has received considerable attention.

The total model will consist of four parts:

1) A GIS pre-processor framework to define geographical areas, extract characteristics of the areas from GIS coverages such as soils, land use, extent of terracing, applicable meteorological stations, and other information that can be put in GIS format. This pre-processor will generate input data for the water budget simulation model hydrologic response units (HRUs).

2) A unit area water budget simulation model capable of receiving input data for individual land-use, soil, conservation practices, and location combinations throughout the basin that will operate on a daily basis for at least 25 years to produce output of daily, monthly and annual water budgets for each applicable HRU. The operation of a terraced field will be done as an HRU as described later in detail.

3) A water budget simulation model of a small reservoir using daily outputs from the applicable HRUs for that represent its watershed conditions and reservoir stage-storage-area-discharge relationships as well as estimated seepage loss rate under the surface area of the reservoir

4) A GIS post-processor to combine results from the HRU and reservoir simulation models on an areal basis to produce monthly and annual recharge and runoff amounts from the sub-basin. Finally, a simple percent-per-mile transmission loss factor based upon the flowpath-length within the sub-basin will be used to redistribute runoff into infiltration losses to add to recharge and reduce surface runoff from the sub-basin.

The GIS pre-processor and post-processor aspects of the project are being led by the Nebraska cooperators of this project. Interactions and interfacing for data handling are in process.

Revisions to the POTYLDR Model for this Project

The overall POTYLDR model will serve as the basic operational framework for the water budget simulation model to operations the HRUs. It runs on a daily water budget of the inputs of precipitation and outputs of evaporation, transpiration, surface runoff and recharge and the resulting daily change in water amounts in the interception account, soil water volume, and snow storage accounts for each combination of conditions at the various locations within the basin.

Simulating Operations of Terraces

A more precise method to simulate terraces has been developed. The POTYLDR original model used the RCN Method for the entire field. This approach works acceptably if only surface water yield is required. Runoff results are acceptable even for level, closed-end terraces by reducing the RCN sufficiently. This method also produces additional recharge because it increases infiltration over the entire terraced field. It does not, however, provide for the increased infiltration that occurs only in the channel of the terraces in the field. This results in a lower estimate of overall recharge and an increase in total evapotranspiration from the terraced field, particularly from storage-type terraces. It also affects the infiltration, potential for crop damage from extended inundation which POTYLDR does not now consider. Previously, Koelliker (1985) had a version of POTYLD that simulated the operation of the upslope and terrace bottom for level, closed-end terraces and it was used to estimate the recharge from terraces in Northwest Kansas.

In this work to represent the water budget operations of land terracing to estimate the effects on streamflow and groundwater recharge needed to represent the cross-section of the terrace more correctly. To accomplish this, it is important to account for the periodic accumulation of runoff in the terrace channel and the subsequent dispensation of the accumulated runoff in the terrace channel. Many terraces in the Republican River Basin are built on the level and many of those terraces have their ends blocked to allow some runoff water to be retained in the channel. In these areas where soils have moderate infiltration, good hydraulic conductivity, and good ability to store water in the soil profile, the retained water can be used by crops or can percolate below the rooting zone during periods of heavier runoff. The percolation would eventually become groundwater recharge. The depth to which the retained water accumulates along with the total area over which the retained runoff is spread and how the area is cropped influences the division between additional crop use and recharge.

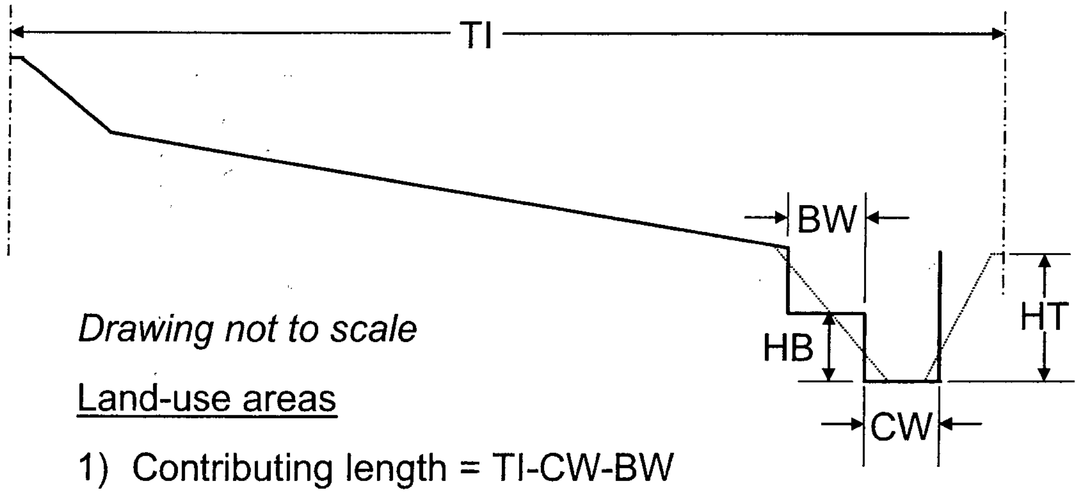
In the new approach, a three-area system is used to model the operation of a terrace – the upslope area, a flat-bottom section, and a second flat bench section that is higher in elevation than the terrace bottom to represent the sloping side areas. See Figure 5 for details. The contributing length is all of the land between two terraces or between the top of the field and the first terrace which is higher in elevation than the maximum level that water can reach when it collects above the terrace ridge. The channel bottom width is obvious. The transition area between these two areas is important because it can have important effects for larger events when more runoff accumulates more deeply. Representing the area outside the channel bottom of the terrace by a flat section, channel bench that has a user-defined height above the terrace channel and a used-defined width provides a flexible way to represent this second area in the terrace channel. These three defined areas allow for a more complete water balance calculation for the terraced area by operating a separate water balance for each of the areas.

Runoff is generated from the upslope portion and the transition area by the conditions used for the HRU. This runoff will be added to the channel bottom section as additional "precipitation" to create ponding. The channel bottom is assumed to infiltrate all rain on it to account for infiltration that occurs during the rain event. If the depth of ponding does not exceed the user-defined height of the channel bench (HB), none is added to the channel bench area. If there is additional water accumulated, the depth on the channel will increase and the depth on the bench area will increase until the entire amount of runoff is redistributed evenly over both the channel and the bench.

If the total depth of ponded water exceeds the storage capacity of the two storage sections minus infiltration, the terrace channel overflows back to the maximum storage volume and the overflow contributes to surface runoff from the terraced land use.

In the case of level terraces with open ends, only the bottom section is considered. Water is allowed to accumulate to an average depth of 0.5 feet on the channel bottom. Beyond that all water is lost that day as surface runoff.

The water budget simulation model for HRUs operates the water budget for each of the three areas for closed-end and level terraces. It then weights the results for each aspect of the water budget to produce a result that will be same as those for other HRUs without terraces. This is done currently with a spreadsheet.



Drawing not to scale

Land-use areas

1) Contributing length = TI-CW-BW
2) Channel Bench Width = BW (includes a portion on the front of the terrace ridge)
3) Channel bottom Width = CW

Figure 5. Geometrical representation of a terrace by POTYLDR for level terrace systems.

Gradient terraces are modeled using the regular method with a RCN to represent the entire field. There will be some differences in infiltration within the field but this difference is considered to be of similar magnitude of what is likely with fields without gradient terraces.

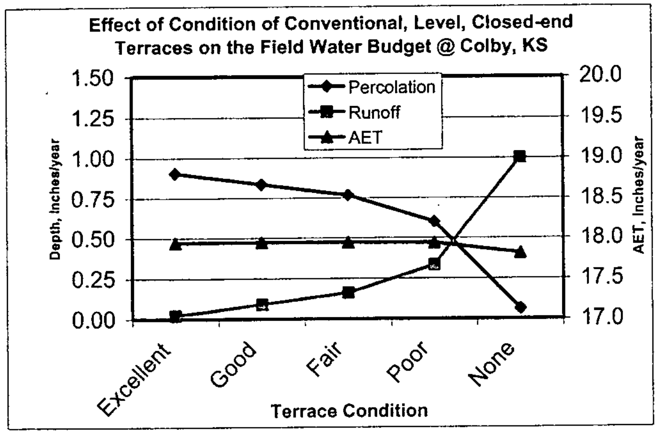
Results from simulations for Colby, KS and Culbertson, NE are contained in the following tables and graph combinations.

Tables 1-3 have the same format. In each table the eight columns contain the average annual water balance for two different terrace types, cross-sectional dimensions to represent the particular terrace condition for each type of terrace, and the terrace condition. The terrace is assumed to be one in a set on a sloping field with an average terrace interval. If spill occurs from a terrace it is assumed to be out the end or at a location that will not add additional water terraces below it. Average annual depths of water for each of the three different areas – channel bottom, channel bench, and upslope are shown along with the weighted field average for each component of the water budget. Graphs on the right-hand side of the table show the effect of terrace condition on field average runoff, percolation, and actual evapotranspiration (AET) for the two terrace types. The POTYLDR model estimates both an interception amount, water that remains on or near the surface and does not enter soil water in storage, plus evapotranspiration which is water lost by evaporation from the upper soil layer and by plant transpiration. On the graphs both interception and evapotranspiration are combined into the AET term to equal the amount of water lost from the area to the atmosphere.

Table 1. Simulated effect of terrace condition on the field water budget for a continuous cropping system at Colby, Kansas.

Location: Colby, KS (61-year average results)
Cropping: Continuous Grain Sorghum

Terrace Type	Conventional, Level, Closed-end					Flat-channel, Level, Closed-end				
Terrrace Condition	**Excellent**	**Good**	**Fair**	**Poor**	**None**	**Excellent**	**Good**	**Fair**	**Poor**	**None**
Terrace Characteristics, ft										
Interval (TI)	180	180	180	180		240	240	240	240	
Channel (CW)	10	10	10	10		40	40	40	40	
Bench (BW)	10	8	5	2		10	8	5	2	
Total height (HT)	1.5	1	0.75	0.4		1.5	1	0.75	0.4	
Bench height (HB)	0.75	0.5	0.37	0.1		0.5	0.33	0.25	0.1	
All values are in inches/year										
Precipitation	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.80
Reference Evapotranspiration	53.15	53.15	53.15	53.15	53.15	53.15	53.15	53.15	53.15	53.15
Runoff from										
Upslope	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bench	1.03	1.03	1.03	1.03	1.00	1.03	1.03	1.03	1.03	1.00
Terrace spill = Runoff	**0.02**	**0.09**	**0.16**	**0.33**	**1.00**	**0.00**	**0.00**	**0.01**	**0.08**	**1.00**
Percolation for the Field										
Channel Bottom	13.95	12.65	11.77	8.99	0.06	4.55	4.50	4.47	4.07	0.06
Channel Bench	1.35	1.74	2.04	3.76	0.06	0.21	0.40	0.59	1.09	0.06
Upslope	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Field Average Percolation	**0.90**	**0.83**	**0.77**	**0.60**	**0.06**	**0.81**	**0.81**	**0.81**	**0.74**	**0.06**
Evapotranspiration for the										
Channel Bottom	15.42	15.42	15.42	15.40	12.99	14.84	14.84	14.84	14.84	12.99
Channel Bench	13.56	13.76	14.00	14.65	12.99	13.31	13.42	13.49	13.82	12.99
Upslope	12.99	12.99	12.99	12.99	12.99	12.99	12.99	12.99	12.99	12.99
Field Average	13.16	13.16	13.15	13.14	12.99	13.31	13.31	13.31	13.31	12.99
Interception for the										
Channel Bottom	4.38	4.38	4.38	4.38	4.82	4.38	4.38	4.38	4.38	4.82
Channel Bench	4.56	4.56	4.56	4.56	4.82	4.56	4.56	4.56	4.56	4.82
Upslope	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82
Field Average	4.78	4.78	4.79	4.79	4.82	4.74	4.74	4.74	4.74	4.82
Change in Soil Water for the										
Channel Bottom	-0.06	-0.06	-0.06	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07
Channel Bench	-0.07	-0.06	-0.06	-0.07	-0.07	-0.07	-0.07	-0.07	-0.06	-0.07
Upslope	-0.07	-0.07	-0.07	-0.06	-0.07	-0.06	-0.06	-0.06	-0.06	-0.07
Field Average	-0.07	-0.07	-0.07	-0.06	-0.07	-0.06	-0.06	-0.06	-0.06	-0.07
Total out =	18.79	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.81	18.80
Difference =	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AET = (ET+ Intercept)	**17.94**	**17.94**	**17.94**	**17.94**	**17.81**	**18.05**	**18.05**	**18.05**	**18.05**	**17.81**



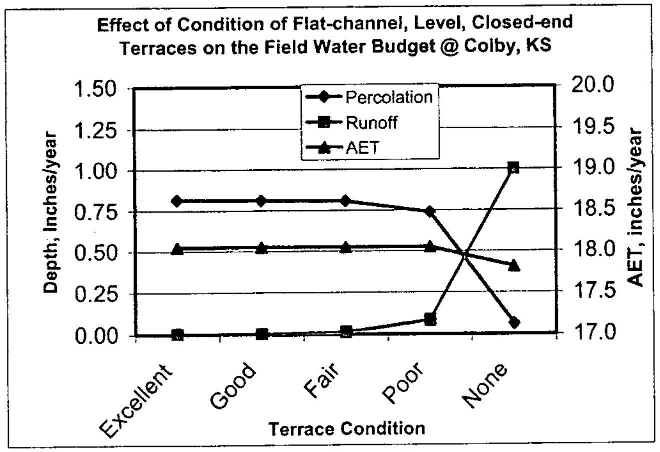
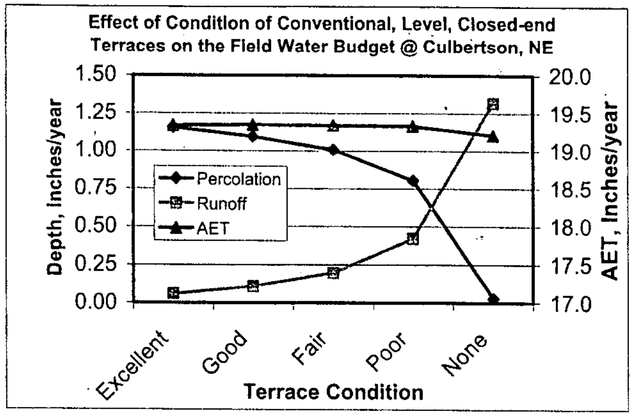


Table 2. Simulated effect of terrace condition on the field water budget for a continuous cropping system at Culbertson, Nebraska.

This version of POTYLDR uses 3 land uses -- the upslope, channel, and a bench at some height above the channel.

Location:	**Culbertson, NE (50-year average results)**									
Cropping:	Continuous Grain Sorghum									
Terrace Type	**Conventional, Level, Closed-end**					**Flat-channel, Level, Closed-end**				
Terrrace Condition	**Excellent**	**Good**	**Fair**	**Poor**	**None**	**Excellent**	**Good**	**Fair**	**Poor**	**None**
Terrace Characteristics, ft										
Interval (TI)	180	180	180	180		240	240	240	240	
Channel (CW)	10	10	10	10		40	40	40	40	
Bench (BW)	10	8	5	2		10	8	5	2	
Total height (HT)	1.5	1	0.75	0.4		1.5	1	0.75	0.4	
Bench height (HB)	0.75	0.5	0.37	0.1		0.5	0.33	0.25	0.1	
All values are in inches/year										
Precipitation	20.52	20.52	20.52	20.52	20.52	20.52	20.52	20.52	20.52	20.52
Reference Evapotranspiration	52.58	52.58	52.58	52.58	52.58	52.58	52.58	52.58	52.58	52.58
Runoff from										
Upslope	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Bench	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.32
Terrace spill = Runoff	**0.06**	**0.11**	**0.20**	**0.42**	**1.32**	**0.00**	**0.01**	**0.03**	**0.10**	**1.32**
Percolation for the Field										
Channel Bottom	18.98	17.63	16.46	12.88	0.03	6.14	6.05	5.93	5.54	0.03
Channel Bench	1.37	1.99	2.41	5.52	0.03	0.31	0.47	0.56	1.21	0.03
Upslope	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Field Average Percolation	**1.16**	**1.09**	**1.01**	**0.80**	**0.03**	**1.06**	**1.05**	**1.02**	**0.96**	**0.03**
Evapotranspiration for the										
Channel Bottom	16.66	16.66	16.66	16.66	14.35	16.47	16.47	16.47	16.47	14.35
Channel Bench	15.10	15.39	15.68	16.31	14.35	14.66	14.80	14.95	15.75	14.35
Upslope	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35
Field Average	14.52	14.52	14.52	14.50	14.35	14.72	14.72	14.72	14.72	14.35
Interception for the										
Channel Bottom	4.40	4.40	4.40	4.40	4.86	4.40	4.40	4.40	4.40	4.86
Channel Bench	4.58	4.58	4.58	4.58	4.86	4.58	4.58	4.58	4.58	4.86
Upslope	4.86	4.86	4.86	4.86	4.86	4.86	4.86	4.86	4.86	4.86
Field Average	4.82	4.82	4.83	4.83	4.86	4.77	4.77	4.78	4.78	4.86
Change in Soil Water for the										
Channel Bottom	-0.01	-0.01	-0.01	-0.01	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03
Channel Bench	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.02	-0.03
Upslope	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Field Average	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Total out =	20.53	20.52	20.52	20.53	20.53	20.52	20.52	20.52	20.53	20.53
Difference =	-0.01	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01	-0.01
AET = (ET+ Intercept)	**19.34**	**19.35**	**19.34**	**19.33**	**19.21**	**19.49**	**19.49**	**19.49**	**19.50**	**19.21**



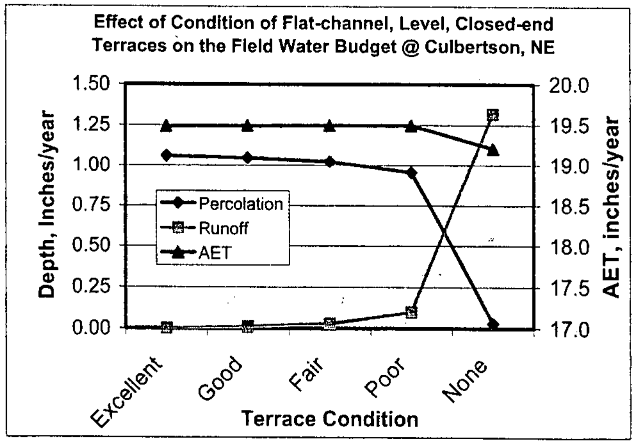
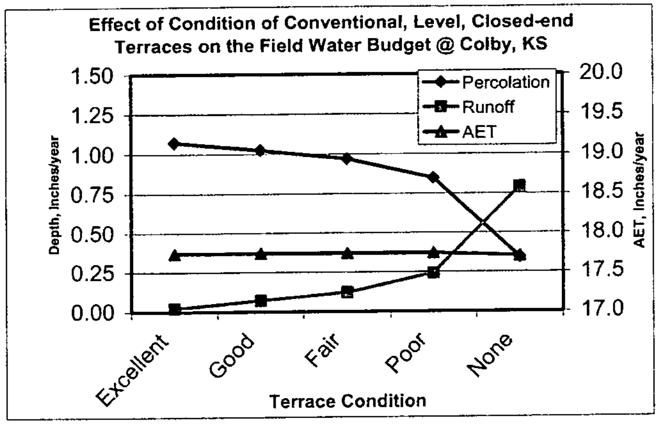
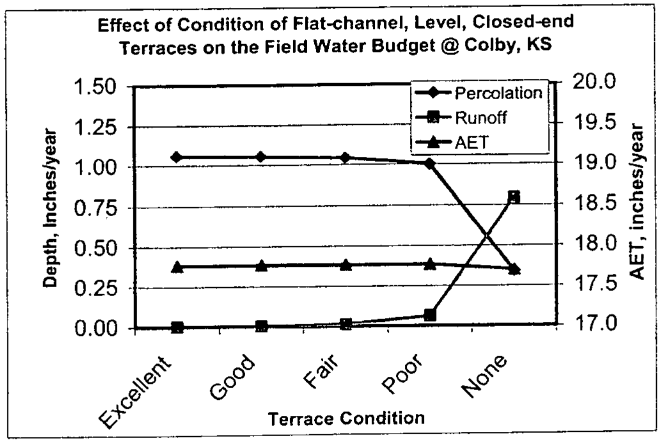


Table 3. Simulated effect of terrace condition on the field water budget for a 3-year cropping system at Colby, Kansas.

Location: Colby, KS (61-year average results)
Cropping: Wheat-Corn-Fallow, 3-year rotation with wheat in Year 1

Terrace Type:	Conventional, Level, Closed-end					Flat-channel, Level, Closed-end				
Terrrace Condition	**Excellent**	**Good**	**Fair**	**Poor**	**None**	**Excellent**	**Good**	**Fair**	**Poor**	**None**
Terrace Characteristics, ft										
Interval (TI)	180	180	180	180		240	240	240	240	
Channel (CW)	10	10	10	10		40	40	40	40	
Bench (BW)	10	8	5	2		10	8	5	2	
Total height (HT)	1.5	1	0.75	0.4		1.5	1	0.75	0.4	
Bench height (HB)	0.75	0.5	0.37	0.1		0.5	0.33	0.25	0.1	
All values are in inches/year										
Precipitation	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.80	18.80
Reference Evapotranspiration	52.68	52.68	52.68	52.68	52.68	52.68	52.68	52.68	52.68	52.68
Runoff from										
Upslope	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Bench	0.81	0.81	0.81	0.81	0.79	0.81	0.81	0.81	0.81	0.79
Terrace spill = Runoff	**0.02**	**0.07**	**0.12**	**0.24**	**0.79**	**0.00**	**0.00**	**0.01**	**0.06**	**0.79**
Percolation for the Field										
Channel Bottom	12.31	11.42	10.74	8.70	0.34	4.60	4.54	4.49	4.24	0.34
Channel Bench	1.54	1.87	2.16	4.08	0.34	0.57	0.77	0.92	1.42	0.34
Upslope	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Field Average Percolation	**1.07**	**1.02**	**0.97**	**0.85**	**0.34**	**1.06**	**1.05**	**1.04**	**1.00**	**0.34**
Evapotranspiration for the										
Channel Bottom	13.93	13.93	13.93	13.92	12.88	13.73	13.73	13.73	13.73	12.88
Channel Bench	13.12	13.21	13.25	13.54	12.88	13.08	13.10	13.10	13.22	12.88
Upslope	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88
Field Average	12.95	12.95	12.95	12.95	12.88	13.03	13.03	13.03	13.02	12.88
Interception for the										
Channel Bottom	4.37	4.37	4.37	4.38	4.82	4.37	4.37	4.37	4.37	4.82
Channel Bench	4.55	4.55	4.55	4.56	4.82	4.55	4.55	4.55	4.55	4.82
Upslope	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82
Field Average	4.78	4.78	4.79	4.79	4.82	4.73	4.74	4.74	4.74	4.82
Change in Soil Water for the										
Channel Bottom	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Channel Bench	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Upslope	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Field Average	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Total out =	18.79	18.80	18.79	18.79	18.80	18.79	18.79	18.79	18.80	18.80
Difference =	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00
AET = (ET+ Intercept)	**17.73**	**17.74**	**17.74**	**17.74**	**17.70**	**17.76**	**17.77**	**17.77**	**17.77**	**17.70**





Terrace condition is based upon the general ability of the terrace to function as designed. Excellent = designed capacity, Good = about 75% of design capacity, Fair = about 50% of design capacity, and Poor = about 25% of design capacity to retain water.

For conventional level, closed-end terraces, condition is quite important on both spill from the terrace, runoff out of the end of the terrace, and percolation. As more runoff is retained, percolation increases considerably. The field average AET increases only slightly with more retention of runoff in the channel. For flat-channel, level, closed-end terraces, condition is less important on the water balance as long as the terrace has some capacity to retain and spread runoff. AET is higher on flat-channel terraces because the runoff water is retained more effectively and it is spread over a larger area so that percolation is slightly less, too.

Tables 1 and 2 are for different locations which have some effect on the parts of the water budget. Runoff at Colby is less than at Culbertson, so both spill and percolation are less at Colby.

Table 3 shows the effect of adding fallow periods to the cropping system when compared to annual cropping. Percolation is increased and runoff is decreased for all three areas and AET is decreased.

Finally, Table 4 shows a comparison of the water budgets of different cropping patterns on terraced cropland with conventional terracing in good condition and unterraced pasture. The cropland systems produce less runoff than the unterraced pasture and they also produce more percolation. All cropping systems have less AET than pasture, also. The effect of the amount of time the cropping system is in fallow has a marked effect on percolation.

These results should be considered preliminary because we do not have enough field data to calibrate these. Based upon previous work, however, these results appear to be reasonable. The reader is reminded that all of these results are at the field level. The effect on the water supply at the subwatershed level must consider the extent and condition of the terraces in the subwatershed plus processes that affect runoff as it flows through the stream network. Also, terraces have changed to some extent where percolation and groundwater recharge is occurring within the subwatershed and there is a delay in water being recharged from terraces before it reaches the groundwater system.

Finally, the types of terraces, the condition of the terraces, and the cropping systems on them have marked effects on the water balance for the systems. Getting reasonable estimates of the areas of, types of, and condition of terraces in the various sub-watersheds will be important to making reasonable estimates of the effects of land terraces on runoff and percolation.

Table 4. Comparison of the results of water budget simulations for three different cropping systems on cropland with conventional, level, closed-end terraces in good condition with unterraced pasture in good condition at Colby, Kansas.

	Wheat-Corn-Fallow	**Continuous Grain Sorghum**	**Wheat-Fallow**	**Good Pasture**
Terrrace Condition	**Good**	**Good**	**Good**	**None**
Terrace Characteristics, ft				
Interval (TI)	180	180	180	
Channel (CW)	10	10	10	
Bench (BW)	8	8	8	
Total height (HT)	1	1	1	
Bench height (HB)	0.5	0.5	0.5	
All values are in inches/year				
Precipitation	18.80	18.80	18.80	18.80
Reference Evapotranspiration	52.68	53.15	52.47	53.12
Runoff from				
Upslope	0.79	1.00	1.33	
Bench	0.81	1.03	1.35	
Terrace spill = Runoff	**0.07**	**0.09**	**0.18**	**0.42**
Percolation for the Field				
Channel Bottom	11.42	12.65	18.24	
Channel Bench	1.87	1.74	3.44	
Upslope	0.34	0.06	0.47	
Field Average Percolation	**1.02**	**0.83**	**1.59**	**0.00**
Evapotranspiration for the				
Channel Bottom	13.93	15.42	13.13	
Channel Bench	13.21	13.76	12.58	
Upslope	12.88	12.99	12.20	
Field Average	12.95	13.16	12.27	13.63
Interception for the				
Channel Bottom	4.37	4.38	4.37	
Channel Bench	4.55	4.56	4.55	
Upslope	4.82	4.82	4.81	
Field Average	4.78	4.78	4.77	4.81
Change in Soil Water for the				
Channel Bottom	-0.03	-0.06	-0.02	
Channel Bench	-0.03	-0.06	-0.02	
Upslope	-0.03	-0.07	-0.02	
Field Average	-0.03	-0.07	-0.02	-0.07
Total out =	18.80	18.80	18.79	18.79
Difference =	0.00	0.00	0.01	0.01
AET = (ET+ Intercept)	**17.74**	**17.94**	**17.04**	**18.44**

Small Reservoir Operations Simulations

In the case of small reservoirs in a sub-basin, a separate simulation sub-model is being developed to simulate the operations of the reservoir. It uses the reservoirs characteristics needed, stage-storage-area-discharge relationships, to simulate the operation of the reservoir. The simulation model uses the output of runoff from the simulated HRU results of the runoff from unit area water budget model runs for the land uses in the reservoir watershed from the sub-basin as inputs to the reservoir. It also uses the precipitation and evapotranspiration in the area as the final inputs to the reservoir operations simulation. Overflow and net seepage from the reservoir with time will be provided as input to the GIS processing routine for the sub-basin where the amount of the sub-basin in the watershed for the reservoir will be subtracted from the overall area of the sub-basin to account for the reservoir. Where information is available for particular reservoirs, it will be used directly. For those reservoirs without sufficient information to simulate them directly, they will be represented by a "typical reservoir and results scaled to account for the reservoirs in the sub-basin.

Evaluation of the Water Balance of Small Federal Reservoirs to Estimate Seepage Losses and Improved Modeling Techniques

More than 400 small, federal reservoirs have been constructed in the Republican River Basin. Many of these reservoirs do not have principal or pipe spillways. Ten such reservoirs in Kansas are being monitored continuously to determine the water level in them. As a part of this project we are attempting to determine the effect of these reservoirs on surface runoff and groundwater recharge. In order to make reasonable estimates for these reservoirs, we have been working on developing a daily water balance to estimate seepage and overflow.

The ten reservoirs in Kansas have been fitted with continuous water level recorders, water level reported hourly to the nearest 0.01 foot, provided by the Bureau of Reclamation, and installed and operated by the Kansas Division of Water Resources. All of these reservoirs have been surveyed by DWR personnel and they have developed information about storage volume and surface area at each water level. Also, the spillway discharge characteristics have been determined. Thus, the continuous water level measurements can be used to provide a continuous accounting of the water volume, surface area, and overflow discharge for these reservoirs. This information has been provided to us to use in this study.

We have been concentrating on estimating seepage from the reservoirs because most of then seldom overflow. To estimate seepage, we use a water balance for a reservoir by volume, acre-inches, as follows:

$$\text{Seepage} = \text{Precipitation} + \text{Runoff} - \text{Evaporation} - \text{Overflow} \pm \Delta S \qquad \text{(Equation 1)}$$

Precipitation is from the nearest reporting station

Evaporation = Reference evapotranspiration for grass from nearest station(s)

Overflow = Estimated from recorded water level and spillway characteristics

ΔS = f (depth change and area (volume) table, stage-storage table)

Runoff or inflow volume must be estimated to adjust seepage to a reasonable amount each day that runoff occurs. There is uncertainty about runoff, but it occurs only occasionally whereas seepage is continuous when water is present. Several other uncertainties are contained in this solution. Precipitation data may be from a reporting station up to 20 miles away. Estimating evaporation from the grass reference evapotranspiration may not agree well during some parts of the year. Finally, water level is reported to the nearest 0.01 of a foot or 0.12 inch. Seepage rates as we will show are low most of the time, so this increment of measurement is nearly as large as the average seepage daily rate when water depths are low. Because of this measurement limitation, we are using a 3-day average seepage rate to reduce scatter of values for graphing purposes. The seepage value plotted for a particular day is the average of the amount for yesterday, today, and tomorrow for all graphs.

Examination of the water level records from the ten sites has shown that most of the time since measurements began in August and September 2004 and available through April 2007 that these reservoirs have had little water in them. One reservoir, DPL Hogan has had two periods where there was enough good information to allow us to estimate seepage and overflow from it.

Details about **DPL-Hogan:**

Location:

County: Philips, KS.
Longitude: 99.533^{0}W
Latitude: 39.931^0 N
Nearest rainfall station: Long Island, Kansas (1424807) is about three miles away.
Evaporation: From nearest station, weighted average for Colby and Scandia.

Reservoir details:

Surface area at minimum water level (0.63 ft) = 0.08 acre
Surface area at maximum water level (9.29 ft) = 1.08 acres
Drainage area = 82 acres

A water balance spreadsheet, on a daily basis to solve Equation 1, has been developed. The spreadsheet contains a LookUp Table so that the volume in storage and surface can be determined each day, as well. Hourly sensor data was extracted to obtain the water level at midnight to facilitate the daily balance. The water level versus water storage volume and surface area relationships provided were used to develop stage-storage-area relationships in the LookUp Table so that exact values are provided automatically for each day. As Equation 1 shows, seepage is determined by adding rainfall on the reservoir surface, estimating runoff from the drainage area, deducting evaporation from the reservoir surface, and determining the change in water storage from the previous day. Runoff water from the catchment was estimated for days when it occurred by inspection so that seepage rate versus time was reasonably consistent. Reservoir rainfall, evaporation and seepage were expressed both in depth (in.) and in volume (acre-inches).

Daily seepage volume was converted to depth by dividing the volume by the surface area for the day.

During a 3-hour period on April 5, 2005, overflow occurred. There, the hourly data was used to determine the volume of overflow of about 29 acre-inches. The total amount of runoff on this date was about 80 acre-inches or 1.0 inches from the watershed. The rainfall for the day was 3.50 inches.

Figure 1 shows the water depth or level and calculated daily seepage rate following the April 5, 2005 event until August 22, 2005. The reservoir filled to overflowing and then had a gradual drop in water level that was interrupted by several small runoff events. The overall water balance for this period was,

Seepage = Rainfall + Runoff – Evaporation – Overflow $\pm\Delta S$, to nearest 0.1 acre-inches.
57.7 = 4.2 + 88.7 – 6.2 -28.0 – 1.0

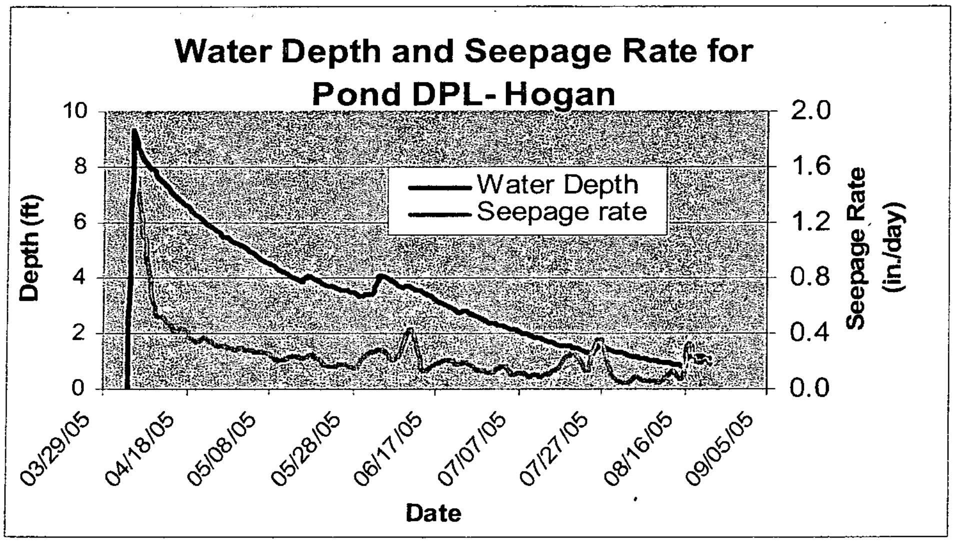


Figure 1. Daily water depth or level and estimated seepage rate for a small reservoir near Long Island, Phillips County, Kansas in 2005.

The water level in the reservoir increased from nearly empty to a maximum of about 9.3 feet in just a few hours. Overflow continued for about three hours and then the drop in water level was due mainly to seepage plus some from evaporation. During this period of examination, rainfall at Long Island totaled 15.7 inches and estimated evaporation totaled 22.0 inches. Seepage depth totaled 33.2 inches. The average surface area during this period was 0.32 acres (maximum of 1.08 and minimum of 0.10).

While the depth of evaporation was about two-thirds of the depth of seepage for the period, seepage losses were nine times more than evaporation because of the high seepage rates when the reservoir filled initially during the next two weeks. The seepage rates into those parts of the reservoir area that are seldom inundated are high. Here, perennial grasses are prevalent and the rooting zone for them is likely deep and the soil there was likely dry when the event occurred. A substantial amount of the water lost as seepage in these areas may have remained within the rooting zone. So, the net amount of seepage that might become groundwater recharge may be considerably less than the total amount of seepage.

In Figure 2, we have plotted average daily seepage rate vs. water depth or level. The graph shows that at the greater water depths the average daily seepage rate is quite high compared to when the depth is low. It appears that a reservoir needs to be modeled in a fashion similar to a storage-type terrace in order to provide a better estimate of the amount of seepage that would become groundwater recharge. In the terrace system, we assume a channel bench that can infiltrate runoff when the water level is deep enough in the terrace. Here, we can use multiple benches to represent areas in the water storage area of the reservoir that will be inundated when the water exceeds their levels. These benches will have vegetation growing on them. In our field observations of most of the reservoirs in Kansas we noted that about the bottom one-third of the area had water or annual weeds that tolerate water on them. The next one-third generally had perennial grasses that could tolerate some flooding. The upper one-third below the spillway generally had perennial buffalo grass that does not like wet conditions. See Figure 3.

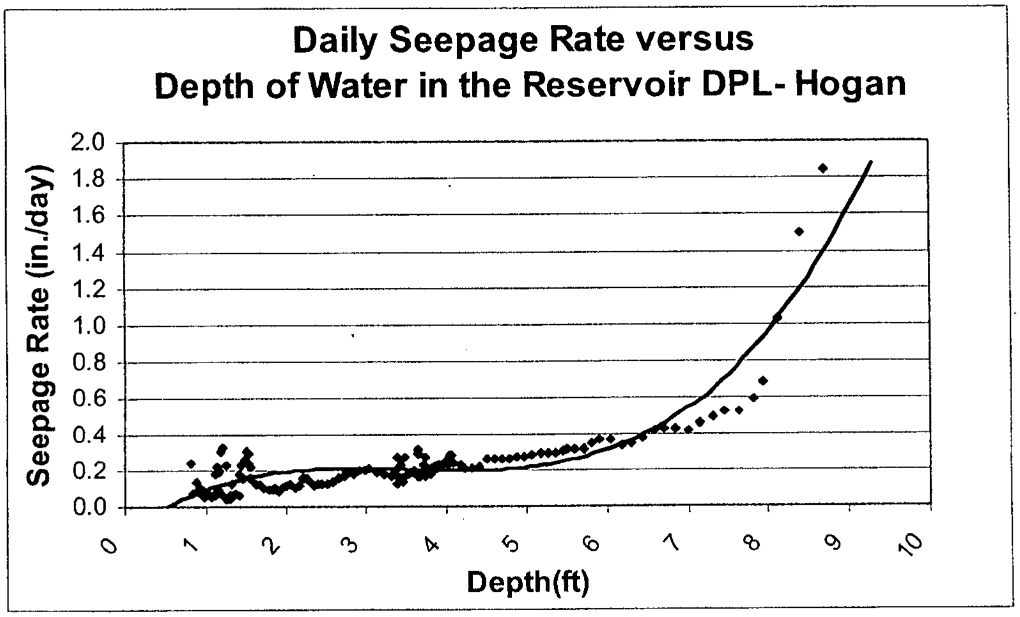
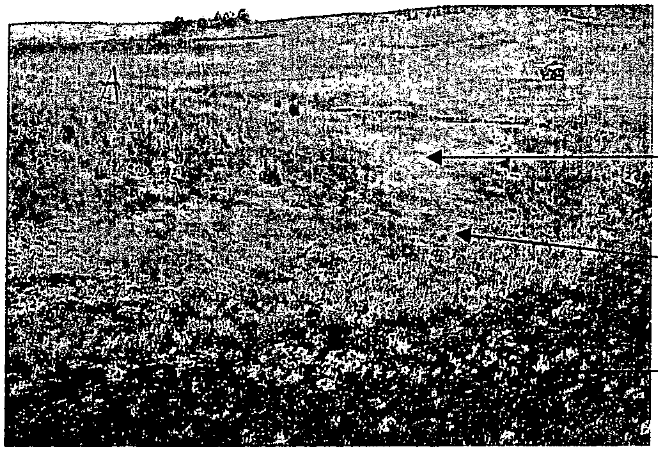


Figure 2. Average daily seepage rate versus depth for a small reservoir near Long Island, Phillips County, Kansas in 2005.

For DPL-Hogan if we use this approach for three levels to represent the reservoir, then we can estimate the daily seepage rate into the three areas. An important assumption in this approach is that the seepage rate for each level is a constant regardless of the depth of water over it. And, seepage rate, S_i is greater for areas at higher levels above the reservoir bottom, $S_1<S_2<S_3$.



Top third – buffalograss

Middle third – water tolerant perennial grasses

Lower third – a few annual weeds and bare soil

Figure 3. Typical side of a small reservoir that shows vegetation differences in the pool with depth above the bottom.

By inspection of Figure 2, for depths between 0 and 3 feet, we estimated the rate of seepage to be 0.15 inch/day. For depths between 3 and 6 feet, the average seepage rate is about 0.25 inch/day. Finally, for depths between 6 and 9 feet, the average seepage rate is about 0.75 inch/day. Therefore, the average seepage rate for the area below 3 feet is 0.15 inch/day. However, we have to solve for the seepage rate in the areas of the reservoir above 3 feet.

Seepage for depths between 3 and 6 feet, the average rate, $S_{3\text{-}6} = S_1 \text{ x } A_1 + S_2 \text{ x } A_2$

From inspection of the surface area vs. water level relationship for this reservoir,
$A_1 =$ 0.25 acres, $A_2 =$ 0.57-0.25 = 0.32 acres, and $A_3 = 1.08 - 0.57 = 0.51$ acres.

$S_{3\text{-}6} = 0.25 \text{ inch/day} = (0.15 \text{ inch/day} \text{x} 0.25 \text{ acres}) + (S_2 \text{x} 0.32 \text{ acres})$

$$S_{3\text{-}6} = \left(\frac{0.85 \times 0.25}{0.32}\right) = 0.66 \text{ inch/day}$$

Seepage for depths between 6 to 9 feet,

$$S_{6\text{-}9} = 0.75 \text{ inch/day} = (0.15 \text{ inch/day} \text{x} 0.25 \text{ acres}) + (0.66 \text{ inch/day} \text{x} 0.32 \text{ acres}) \\ + (S_3 \text{x} 0.51 \text{ acres})$$

$S_{6\text{-}9} = (0.75-(0.15\text{x}0.25)-(0.66\text{x}0.32))/0.51$

$S_{6\text{-}9} = 0.98$ inch/day

This approach should provide better estimates of the net amount of seepage for these reservoirs because the POTYLDR model will run a daily soil water balance on each area to determine the amount of percolation below the rooting depth. This percolation will be net seepage from each area. Results from the three areas will be summed to estimate total net seepage or groundwater recharge. We are planning to implement this approach as a part of our simulation work for these reservoirs.

During March and April 2007, the Hogan reservoir had more runoff into it and the water level increased to nearly four feet and then gradually dropped. We performed the same daily water budget analysis by inspection on our spreadsheet to estimate the daily seepage rates. Those results are plotted in Figure 4. We again obtained similar results for average rates of daily seepage. This time the average was 0.14 inch/day. Again, seepage was much larger than evaporation, 11.6 vs. 2.3 acre-inches for the period.

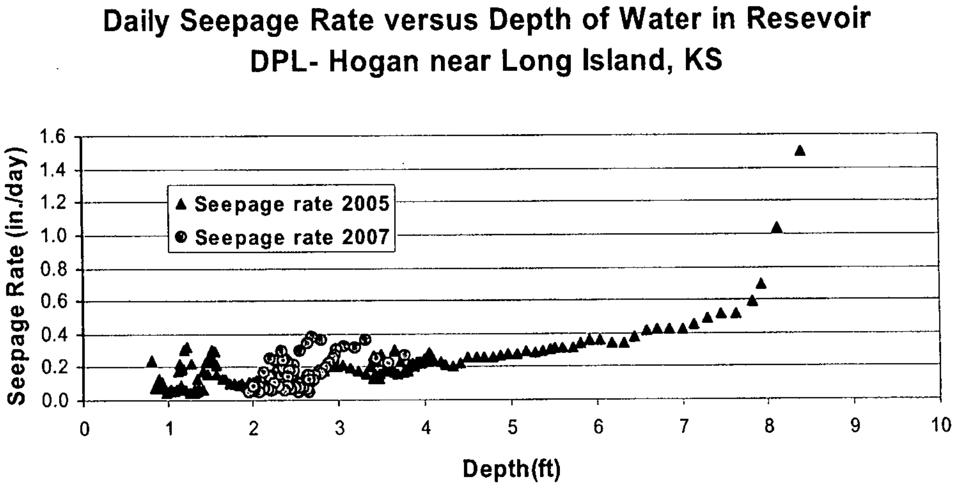


Figure 4. Average daily seepage rate versus depth for a small reservoir near Long Island, Phillips County, Kansas in 2005 and 2007.

This analysis points out that a water balance for these reservoirs is possible, but the precision is not great. Overall results, however, appear to be realistic. We need more data from other reservoirs to improve this analysis. The runoff into these reservoirs also provides valuable information for adding to our understanding about rainfall-runoff relationships in the basin.

Previously, we have modeled the water budget of individual reservoirs with generalized relationships of surface area and volume vs. depth. Where actual relationships are available, we have used those for the same purpose. We will use actual relationships where they are available in this work, but we will have to use generalized relationships where we have no data. The portions of the subwatersheds above the small federal reservoirs will be modeled separately from the remainder of the area so that we can account for the water budget operations of them to estimate the amount of groundwater recharge and overflow from them. The results from the reservoirs will be combined with the simulated values for the remaining parts of the subwatershed to produce the total amounts for the entire subwatershed in the GIX processing scheme.

Transmission Losses for Runoff

The other aspect of the model development that is under study is transmission losses of streamflow during events. For our previous work in the Wet Walnut watershed in Kansas (Ramireddygari et al., 2000), we developed a physical relationship based upon actual recharge studies that were done in that watershed. Jordan (1977) looked at flood flows extensively in Kansas and several of the streams are in the Republican Basin. He concluded that the transmission loss in one mile for medium- to large-sized streams in western Kansas averages 2% of the flow volume at the beginning of the mile. He concluded that this value can be used for each succeeding mile. For purposes of this study, using the general relationship from Jordon may be as good as we can expect to achieve. The effects have important implications on loss of streamflow and recharge distribution within the basin. So, accounting for them will have effects on where and how terracing and small reservoirs affect both recharge and streamflow within the basin.

A small runoff event occurred from the area above the Ludell, KS stream gauge on Beaver Creek on April 24-26, 2007 that totaled 523 acre-feet of flow is shown below in a graph prepared by George Austin, Kansas DWR. This same event appears to have produced a small flow at the Cedar Bluffs, KS stream gauge on April 24, 2007 a few hours later that totaled 23 acre-feet of flow. Subsequently, the main flow that occurred above Ludell made its way past the Cedar Bluff gauge. The resulting hydrograph at Cedar Bluffs from the inflow from above Ludell passed the Cedar Bluffs gauge on April 25 -28, 2007 and totaled 400 acre-feet. This distance between these to gauges is 40.4 river miles. The volume of flow decrease between the two stations was 523-400 = 123 acre-feet. This amounts to about a loss of volume of about 24%.

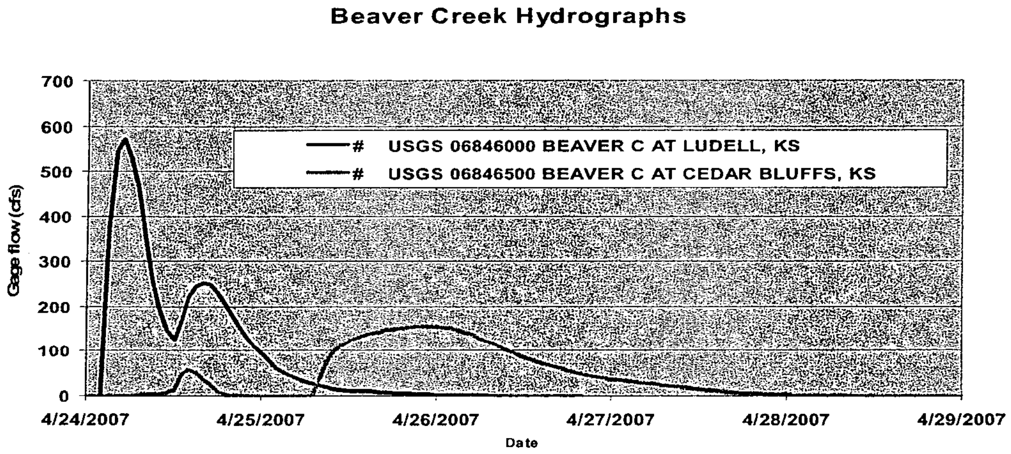


Figure 6. Transmission losses evaluation for April 24-29, 2007 event on Beaver Creek, KS.

Applying the technique by Jordan (1977) looked at flood flows extensively in Kansas and several of the streams are in the Republican Basin that concluded that the transmission loss in one mile for medium- to large-sized streams in western Kansas averages 2% of the flow volume at the beginning of the mile showed an average of only 0.67% of the hydrograph volume was lost per river mile. This particular event on Beaver Creek was a small flow and all of the flow remained was within the stream channel. Considering the small size of the event and that flow was all within the channel, the lower loss observed here is reasonable. It also leads to the conclusion that transmission losses for in-channel flows are likely to be lower than for floods that have a larger area and greater hydraulic pressures that lead to the greater percentage losses that Jordon's work showed. More data is needed, however.

b. Lead the effort to modify and apply a version of the selected water balance model to the land terraces and non-Federal reservoirs in the basin.

Most of the progress on this task is described above.

c. Select and administer postdoctoral research assistant(s), graduate assistant(s), and/or undergraduate student assistant(s) to complete Research Project effort.

Personnel working on this project at this time are Koelliker, 30% time, and Ravikumar, a 50% time doctoral graduate student. Dr. Phil Barnes, a research-extension engineer in our department, is working with us on the field work aspects of this project. He has worked closely with our Nebraska colleagues in securing and setting up and instrumenting our terraced fields. His total time commitment is about 5%.

Dr. David Chandler, assistant professor, in the civil engineering department at Kansas State University began in August 2006. Dr. Chandler has considerable experience and reputation watershed modeling of natural systems. He will be working 30% time on this project.

d. Collaborate with UNL on modeling efforts and field work involved with monitoring a small sample of land terraces and non-Federal reservoirs.

The two terrace sites in Kansas, one near Norton and the other one at the Kansas State University Experiment Field at Colby continue to be monitored. Data reporting is being done by UNL and a non-technical presentation and summary has been prepared by Dean Eisenhauer. An unofficial report from the farmer at the Norton site showed that the wheat yield in the terrace channel of the conventional level, closed-end type was about twice as great as for the upslope area of the terraces.

As described earlier in this report, we have worked with the Kansas DWR personnel on the small federal reservoirs that have been instrumented in Kansas. We accompanied them during several of the surveys to determine characteristics of the reservoir and spillway. We examined conditions in the watersheds of them, too.

e. Provide an update on the Research Project activities to Reclamation and the Conservation Committee by May 1st and December 1st of each year. The update due by May 1 will allow the Conservation Committee time to review the update and brief the RRCA at their annual meeting normally scheduled in June of each year.

This report is my May 2007 update on our work.

f. Lead in the preparation of a final report on or before June 1, 2009 that summarizes the results of the Research Project and addresses items a, b, c, and d included under B.6. Deliverable Products.

Report will be delivered when the project is nearing completion.

Assessment of Progress on This Agreement:

Work on the project is proceeding. Koelliker has been spending more time on the work than originally expected. My appointment and the nature of the work make this a better way to proceed. I have one doctoral student to lead and direct to get HRU modeling work done. The details of modeling of land terraces and now making revisions to more effectively represent the reservoirs have been the major focuses for the most of the past year. We are beginning to get some datasets developed of weather and climate data. Dr. David Chandler has added to our knowledge of water budget simulation modeling and increased our capabilities to work on effective interfacing the HRU and small reservoir modeling with the GIS aspects of this overall project.

We got to get the HRU model operational for terraces in fall 2006. We have yet to begin applying it to conditions in the test sub-basins, Prairie Dog Creek above Sebelius Lake and Medicine Creek above Harry Strunk Lake. We are progressing with more model development, but we are still awaiting data about terrace conditions.

Resources for completing this major watershed simulation effort are limited. We will try to make the most of them, but if this work should become a basis for decisions affecting the Republican Rive Compact agreements, then the level of detail at which we are forced to work because of limited financial resources are likely not sufficient.

Finally, as of June 1, 2007, Koelliker was appointed as the interim head of the Civil Engineering Department at Kansas State University. This is a 0.5-time assignment which will limit his time to work on this project. Dr. Chandler will be more involved and we are looking for a dedicated computer programmer to help with modifications of the model.

References Cited:

Jordan, P. R. 1977. Streamflow transmission losses in western Kansas. Journal of the Hydraulics Division, Proc. of the ASCE, Vol. 103, No. HY8, pp. 905-919.

Koelliker, J.K. 1985. Evaluation of the recharge capability of level terraces in Northwest Kansas Groundwater Management District #4. Final Completion Report. 81 pp. Copies available from the Biological and Agricultural Engineering Department, Kansas State University.

Koelliker, J.K. 1994. User's manual for POTential YieLD Model Revised. Biological and Agricultural Engineering Department, Kansas State University, Manhattan, KS.

Progress Report

Modeling and Field Experimentation to Determine the Effects of Land Terracing and Non-Federal Reservoirs on Water Supplies in the Republican River Basin Above Hardy, Nebraska

Cooperative Agreement No. 05EC601962

Reporting Period: May, 2006 – May 2007

Principal Investigator: Derrel Martin
Department of Biological Systems Engineering
University of Nebraska-Lincoln
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1. Project Objectives

This a joint project between the University of Nebraska-Lincoln, Kansas State University and the Bureau of Reclamation. The project involves the following responsibilities:

1. Field experimentation to quantify the water balance for representative terraced land sites and small non-federal reservoirs. Subprojects include:
    a. Installation, calibration and maintenance of monitoring equipment.
    b. Identification of suitable monitoring sites.
    c. Collection of water balance data from representative sites.
    d. Processing and summarizing research results.
    e. Limited studies will be conducted to estimate the transmission losses in ephemeral streams and other waterways.
2. Modification, calibration and verification of simulation models used to predict the effects of reservoirs and terraces on subwatersheds that provide water to the riparian area adjacent to the Republican River.
3. Development of databases required to simulate the water balance of subwatersheds.
4. Development of a Geographic Information System to aggregate and process input data for simulation models and to process simulation results to enhance understanding of depletive effects of terraces and reservoirs.
5. Conduct simulations to develop comparisons between conditions with and without terraces and small reservoirs.
6. Integration of model results and supporting data and programs to develop an overall project report.

APPENDIX G

DETAILED PROGRESS REPORT
OF
UNIVERSITY OF NEBRASKA-LINCOLN

2. FIELD MEASUREMENT

Terrace Research Sites

Five sites were selected for the field research on the impact of terraces. The sites include two conservation bench terrace systems located near Culbertson, Nebraska and Colby, Kansas; two level terrace systems with closed ends located near Curtis, Nebraska and Norton, Kansas; and one level terrace system with open end(s) located near Stamford, Nebraska (Figure 1).

Rectrified digital imagery photographs from the USDA-FSA for each site are shown in Figures 2-4. The soil mapping units from the SSURGO databases are included for each site on the field maps. The soils at the sites are predominately silt loam with Keith Silt Loam being more prominent at the Western Sites (*i.e.*, Culbertson and Colby) and Holdrege Silt Loam most prominent at the three eastern sites (*i.e.*, Curtis, Norton and Stamford).

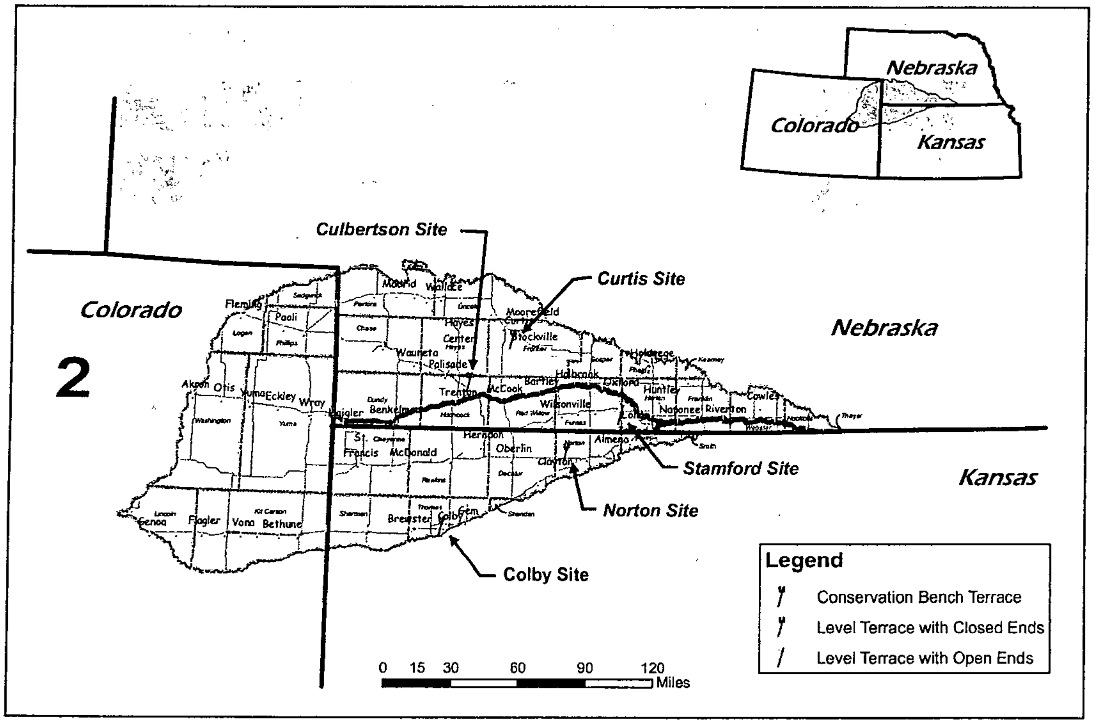
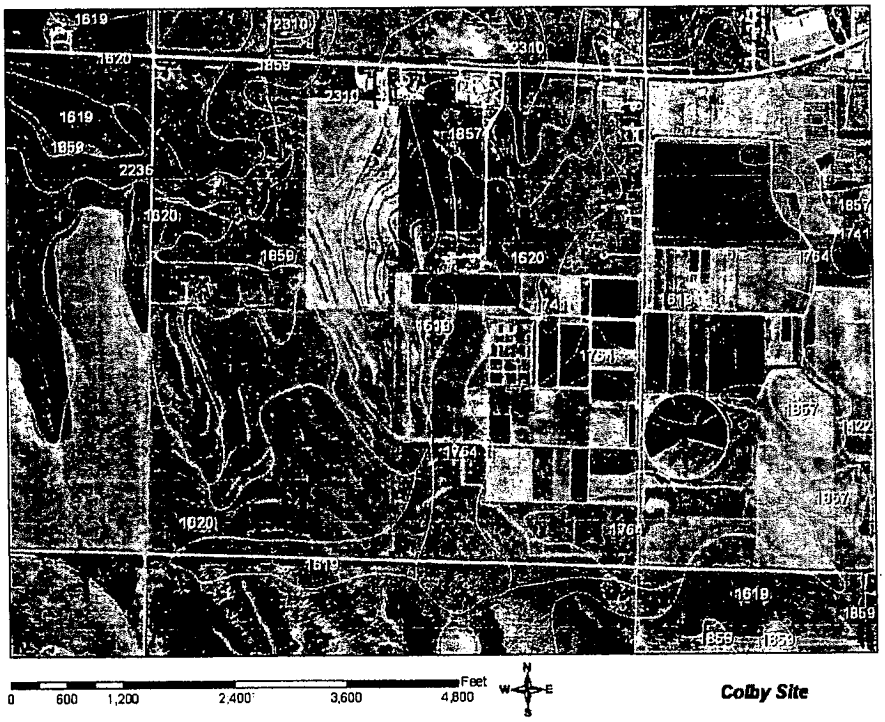
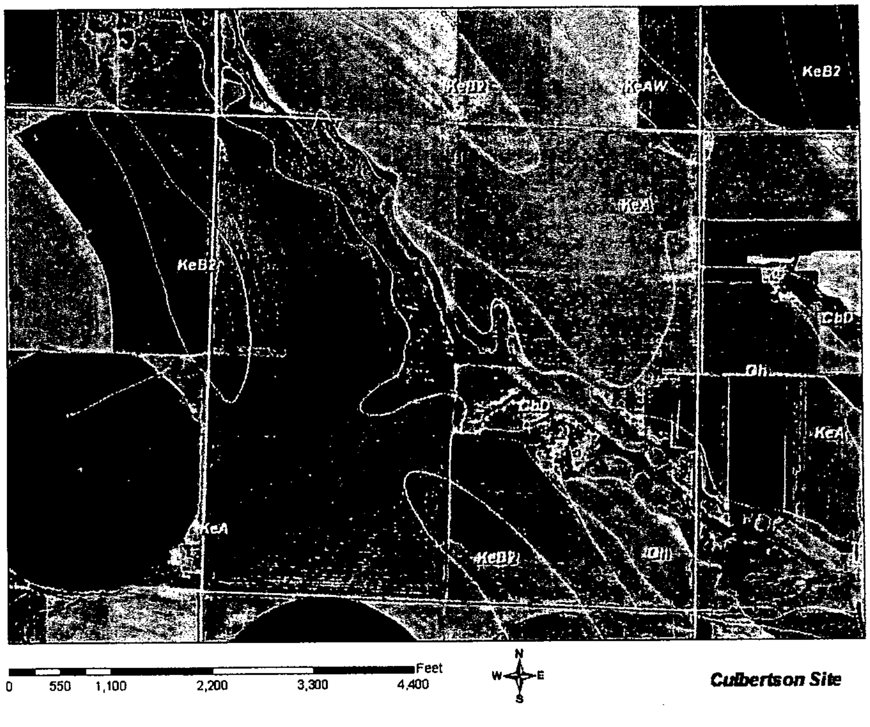


Figure 1. Location of conservation terrace research sites in the Republican River Basin.

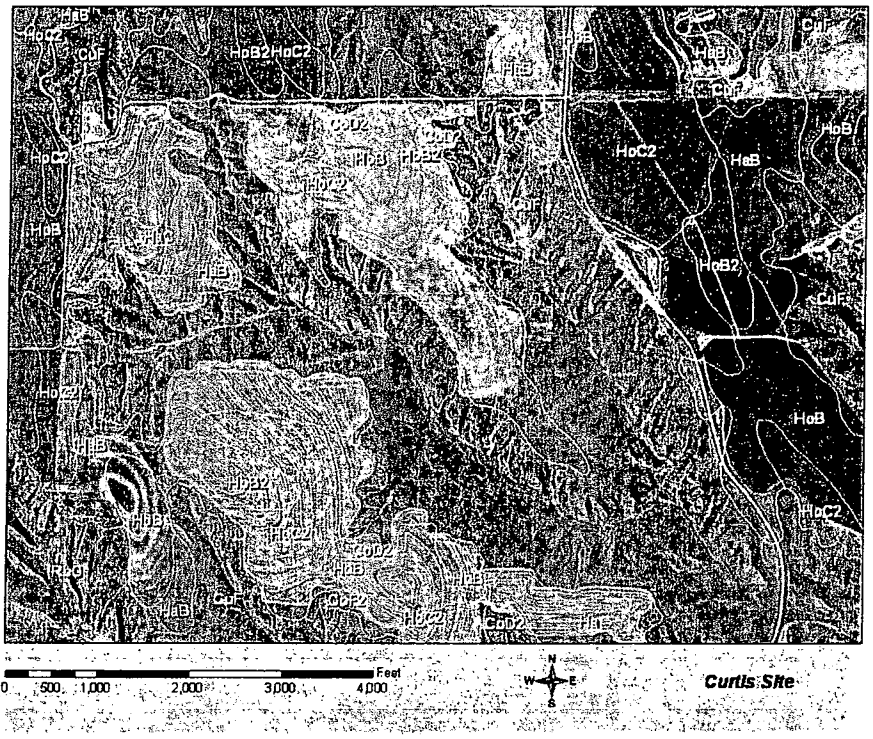


Colby Site



Culbertson Site

Figure 2. Maps of the Colby and Culbertson research sites.



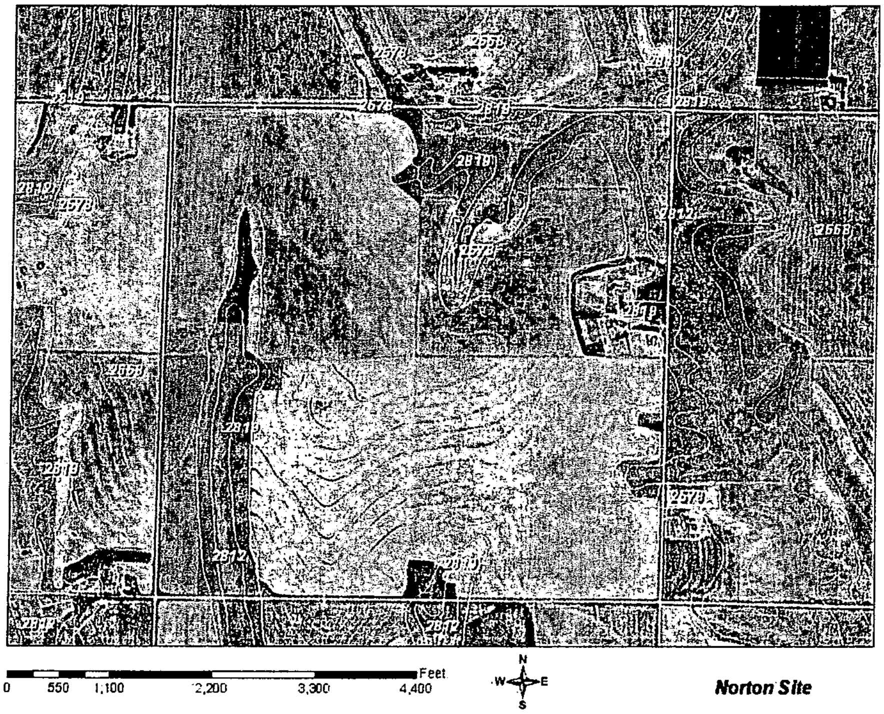


Figure 3. Maps of the Curtis and Norton research sites.

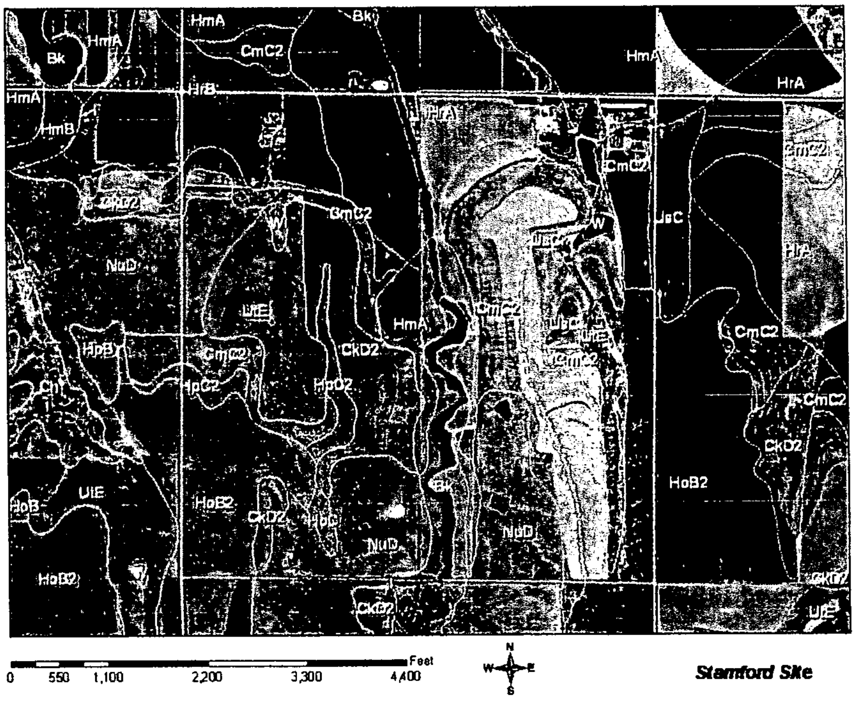


Figure 4. Maps of the Stamford research sites.

Terrace Measurements

The water cycle components that we are monitoring are illustrated in Figure 5. Terrace systems capture runoff water from the upland contributing area and temporarily store the water in the terrace channel. Terrace systems with closed ends retain the water in the channel until it infiltrates or is used as evapotranspiration (ET). Other terraces are open on the ends to allow water to slowly flow from the terrace. When large storms occur the depth of runoff from the contributing area may exceed the storage capacity of the channel and some water may overtop the terrace end or ridge. A significant portion of the water that overtops terraces, or that flows from the ends of open-ended terraces, will likely end up in streams; however, some of the water also seeps into dry channels between the field and the stream. Water that stays in the channel can go to either water use by crops or deep percolation in the channel. Deep percolation beneath the crop root zone ultimately reaches the local groundwater where it may (1) return to the stream as baseflow, (2) be pumped for irrigation or (3) be stored in the ground water system. Our goal for this portion of the project is to determine the amount of water that runs into terrace channels and to partition the captured water into either deep percolation or evapotranspiration.

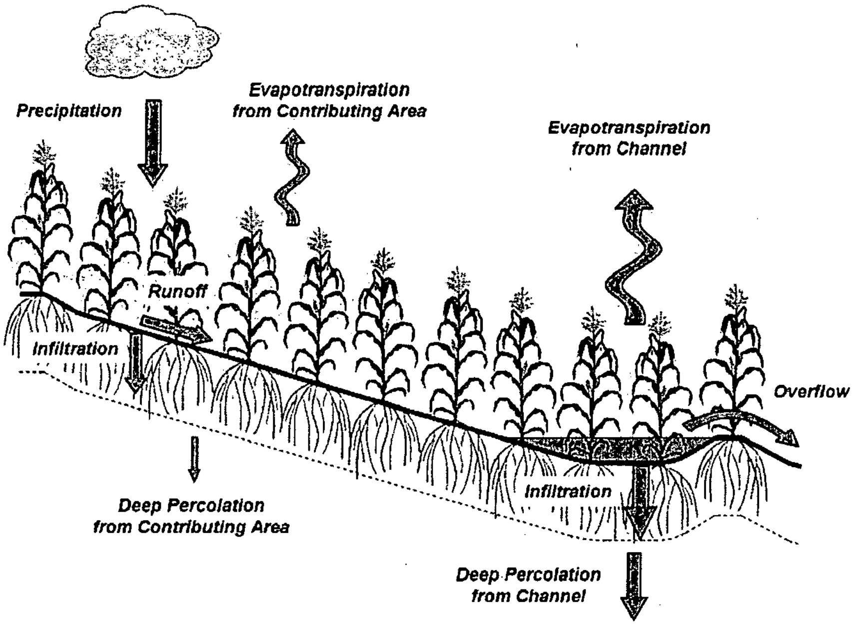
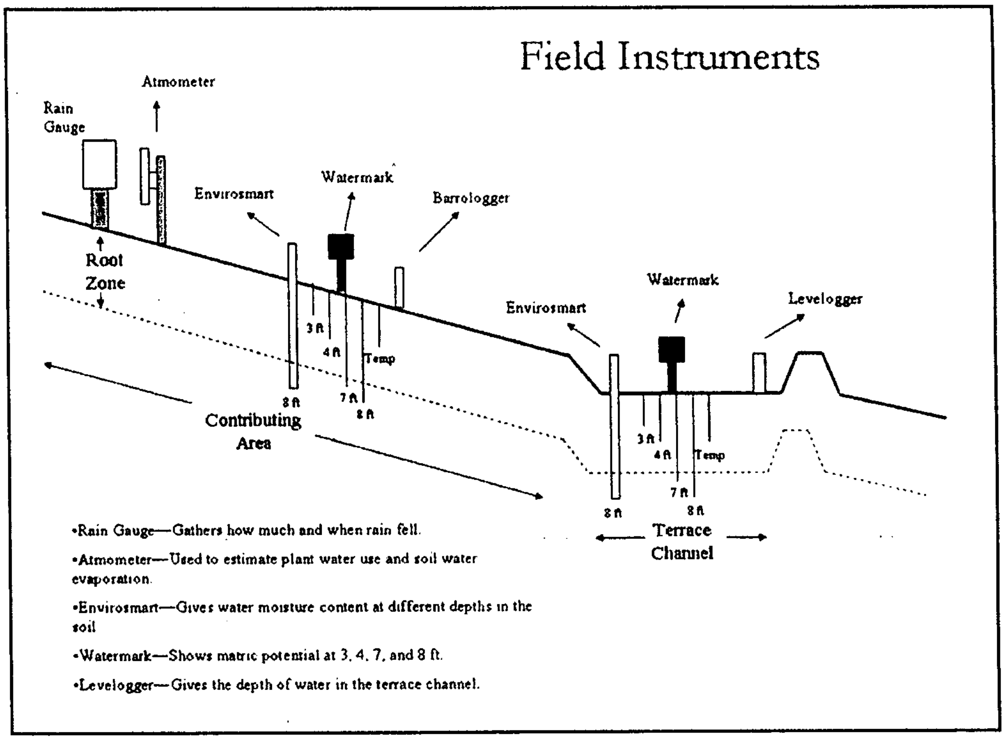


Figure 5. Hydrologic components of terraced fields.

While the instrumentation varies among sites, the general layout of the field equipment is illustrated in Figure 6. Rainfall is measured with 8-inch diameter Hydrological Services TB4-L tipping bucket rain gauges (Figure 7). Reference evapotranspiration (ET) data is being collected using a Model E atmometer, which was made by the ETgage Company. Reference ET is the potential water use by a well-watered alfalfa crop that is about 18 inches tall. The reference crop ET provides a basis for computing the actual water use of crops.

Mini LT Leveloggers made by Solinst (Figure 8) are being used to measure inflows into two terrace channels at each site. The Leveloggers were installed along the bottom of two terrace channels and give pressure readings at pre-set time increments during precipitation events. The Leveloggers were installed vertically inside a 2-inch diameter PVC pipe. The pipe has a total length of 3 feet, with 1 foot buried underground (Figures 9 and 10). The Levelogger measures the pressure due to water ponded in the channel which is converted to the depth of water ponded in the terrace channel. The local cross-section of the terrace channel was surveyed to relate the depth of water in the terrace to the volume of water stored in the terrace.



- Rain Gauge—Gathers how much and when rain fell.
- Atmometer—Used to estimate plant water use and soil water evaporation.
- Envirosmart—Gives water moisture content at different depths in the soil
- Watermark—Shows matric potential at 3, 4, 7, and 8 ft.
- Levelogger—Gives the depth of water in the terrace channel.

Figure 6. Layout of field equipment

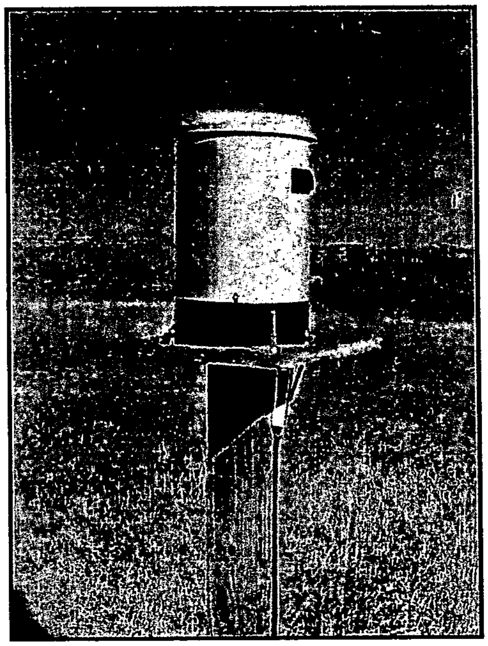


Figure 7. Tipping bucket rain gauge.

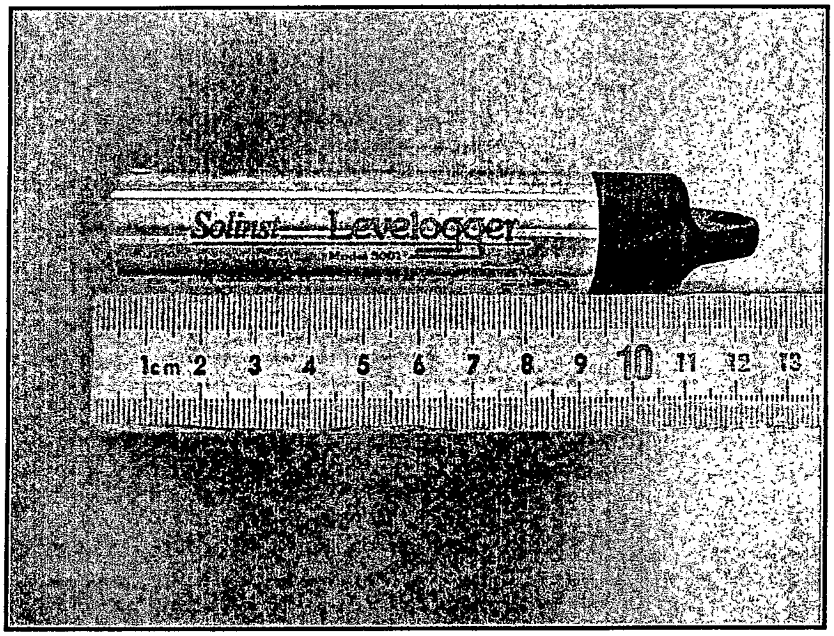


Figure 8. Solinst Levelogger used to determine the height of water in the terrace channels.

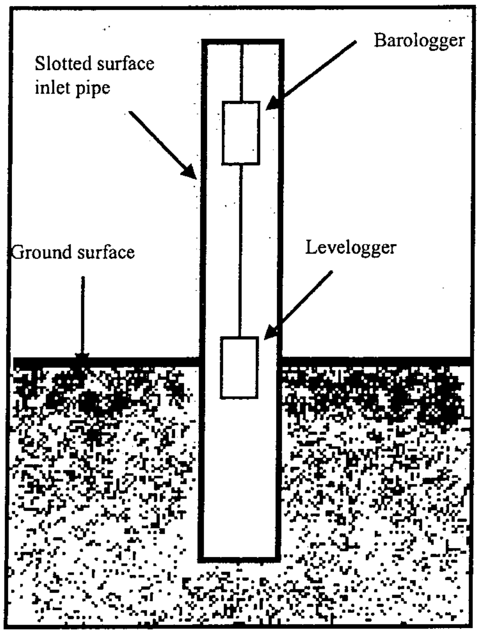


Figure 9. Cross-section of Levelogger installation.

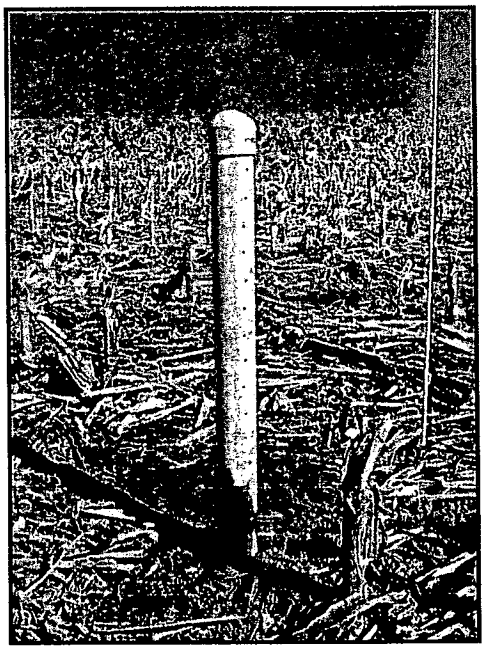


Figure 10. Levelogger installation.

Outflow from the terrace channel is being measured for the level terrace system with open ends at Stamford. A velocity-area meter has been installed in a wooden flume sections in the terrace channel (Figure 11). The combination provides a continuous recording of the rate of water flowing from the terrace channel. This allows us to determine the amount of runoff that infiltrates in the channel and the rate of outflow.

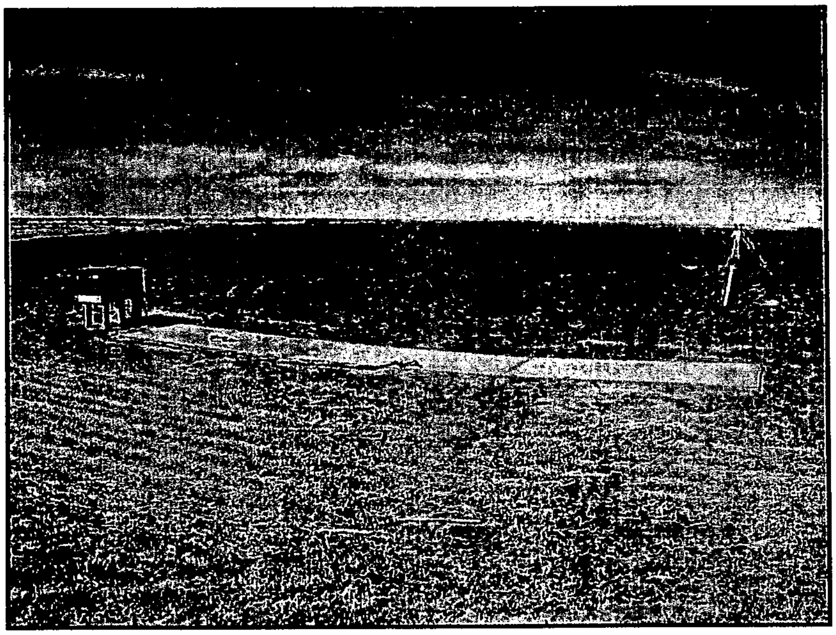


Figure 11. Flume section used for outflow measurements at the Stamford site. The flume section has approximate bottom and top widths of 2.44 m (8 ft) and 7.3 m (24 ft), respectively. The area/velocity meter is placed in the center of the constructed channel, as shown in the figure. The channel has a length of 1.22 m (4 ft).

Soil water both in the crop root zone and beneath thye root zone (down to 8 feet) are monitored with the various instruments illustrated in Figures 12-17.

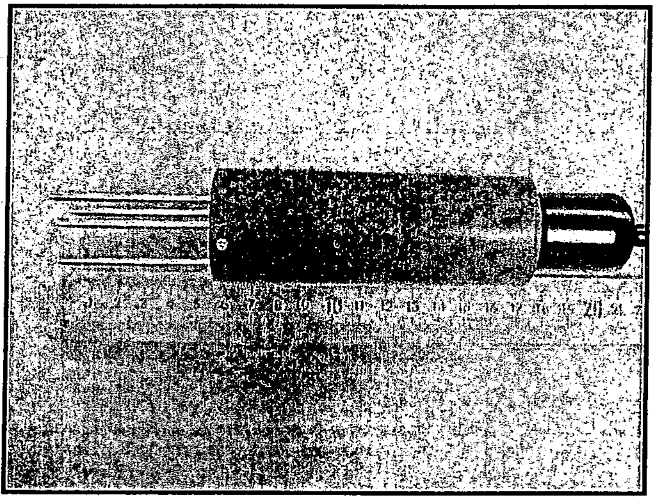


Figure 12. ThetaProbe sensor used for measuring volumetric water content.

Figure 13. ThetaProbe installation. A Giddings probe was used to install the sensors to a depth of 2.29 m (7.5 ft).

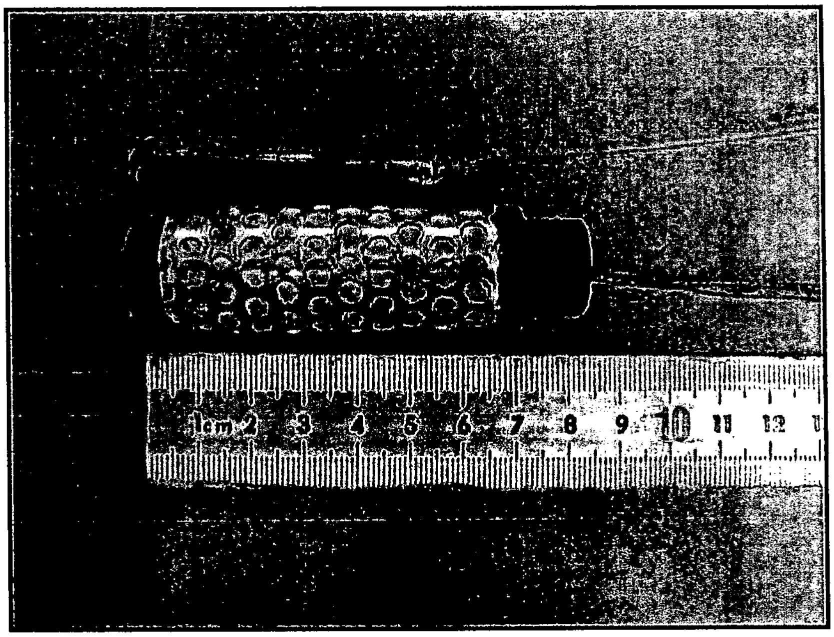


Figure 14. Watermark sensor used for measuring soil matric potential. Also pictured is a soil temperature sensor.

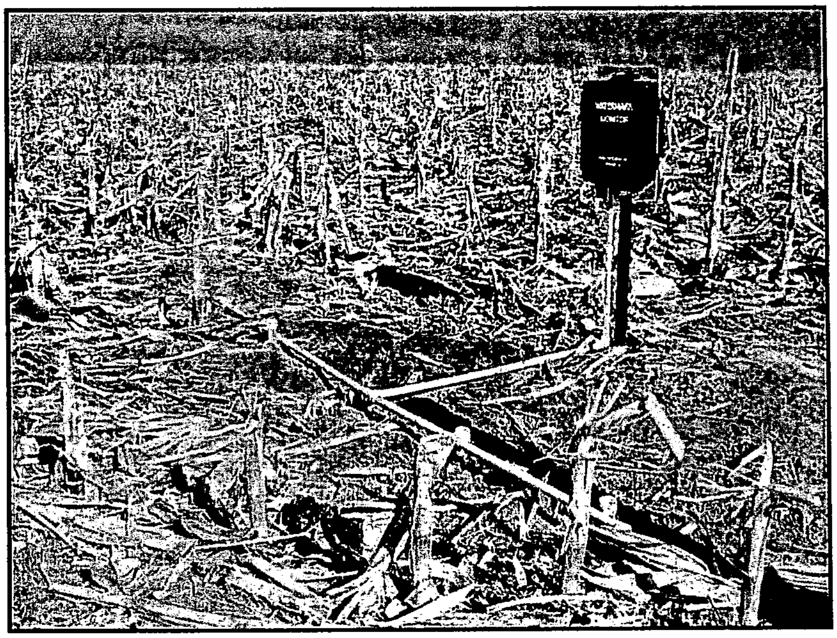


Figure 15. Watermark sensors/datalogger installation. Extra CPVC pipe was used to keep sensor wires from being damaged.

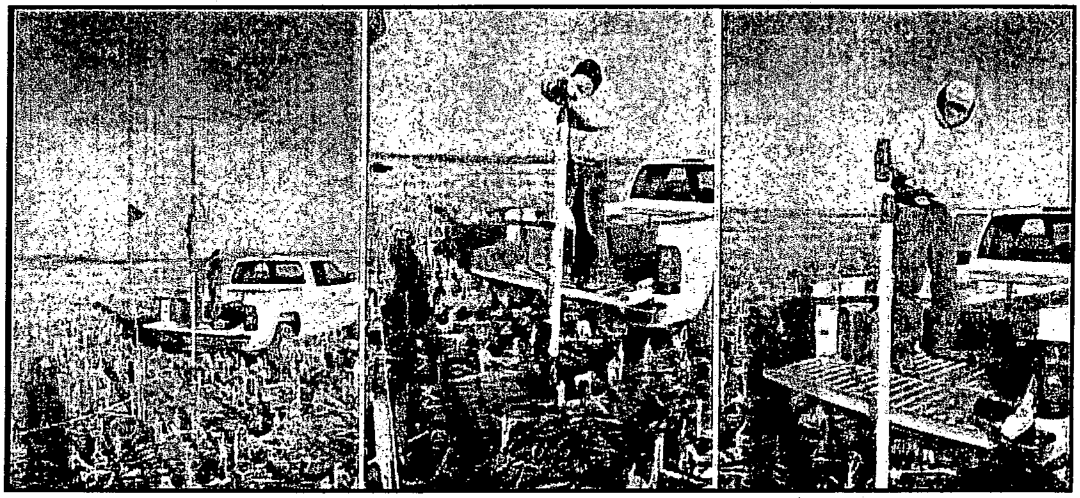


Figure 16. EnviroSMART probe installation. Photo on far left shows auger being placed inside of the access tube. Center photo shows auger being used, and photo on the far right shows the access tube being pounded into the ground after auguring. This process was repeated several times to complete the access tube installation.

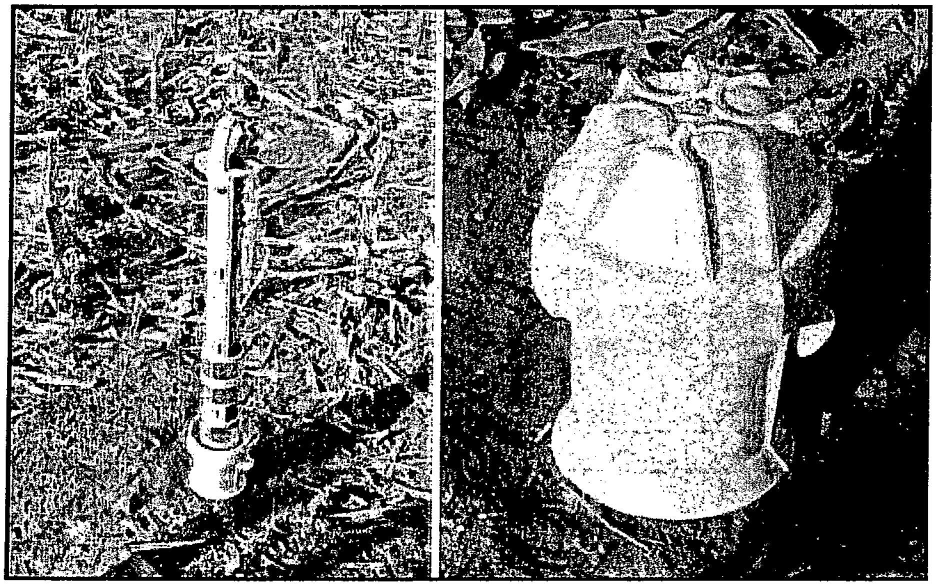


Figure 17. EnviroSMART probe installation into the access tube (left), and the completed access tube/ EnviroSMART probe installation (right).

Data from the field sensors are continuously gathered and stored in data loggers. The data from the loggers are downloaded to a computer during monthly field visits.

A Geoprobe direct push sampler (Figure 18) was used to gather soil samples near each set up of instruments in April of 2006. Two samples were taken in the contributing area and two in the terrace channel. The soil samples were taken to a depth of 25 feet and stored in sealed plastic tubing. The goal of these cores is two fold: to obtain a water content profile to a depth of 25 feet and to collect undisturbed samples for lab determination of hydraulic conductivity.

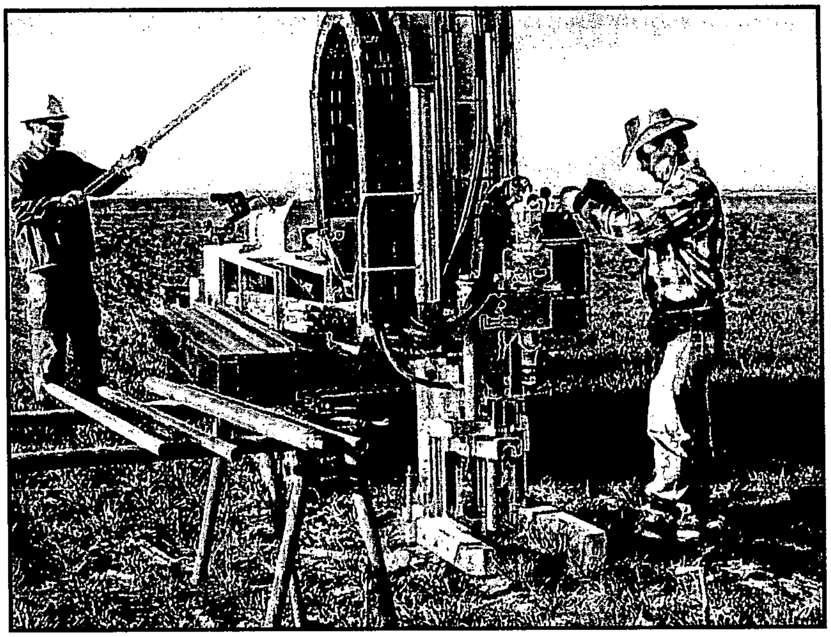


Figure 18. Geoprobe sampling of soils to 25 feet in the spring of 2006.

Results

Rainfall and ET

The rainfall and reference ET data for 2006 are shown in Tables 1 and 2. The automated rain gages and the atmometers cannot be operated during freezing temperatures thus data are only shown for March through October. Note, reference ET is not actual crop water use but a measure of the amount of water used by a fully established alfalfa crop that is well watered.

Table 1. March- October Rainfall for 2006 (inches)

Month	Colby	Culbertson	Curtis	Norton	Stamford
January					
February					
March	0.36	0.98	0.76	0.54	0.90
April	0.51	0.32	0.53	1.51	1.39
May	1.34	0.89	0.99	2.91	1.10
June	2.89	4.15	3.42	3.89	3.39
July	1.50	1.03	2.07	1.49*	1.97
August	2.07	3.15	2.47	3.74*	2.83
September	2.53	3.10	2.82	2.38	2.34
October	3.36	2.08	1.46	2.69	2.46
November					
December					
Total	14.56	15.70	14.52	19.15*	16.38

* The Norton site is missing data for most of July and August because of a bad data sensor; the missing data was replaced with Norton Dam rainfall.

Table 2. Reference ET Data (inches) for 2006

Month	Colby	Culbertson	Curtis	Norton	Stamford
June		4.17	4.08		4.46
July	3.54[1]	10.24	10.03	4.21[1]	10.62
August	6.29	6.72	6.56	7.34	6.83
September	3.53	3.34	3.28	3.54	3.18
October					
June - Sept. Total	-	24.47	23.95	-	25.09

1. Note: Instruments not installed at Colby and Norton until late July

Table 3, which contains data for the Curtis site, illustrates the type of water balance data we are collecting at all sites. The calculated ET is based on the atmometer data and adjusted for soil water and the progression of crop development during the season. These values are still initial and undergoing analysis. Data at the other sites are being compiled.

Table 3. Field water balance for May 17-August 25, 2006 at the Curtis site. Site was in corn in 2006.

Position in field	Rainfall (in)	Change in soil moisture (in)	Crop ET based on soil moisture (in)	Crop ET calculated (in)
Contributing Slope	8.61	-3.24	11.85	14.40
Terrace channel	8.61	-1.58	10.19	17.21

Water Storage

Terraces are designed to store runoff from the contributing area. The data in Figure 19 illustrates how storage in the terrace channel correlates to rainfall for the spring of 2007 at the Curtis site. The water level in the terrace is measured with the water level logger described above. The data in Figure 19 show that there is some random variation in sensor output due primarily to variations in temperature and barometric pressure. However, there are well defined periods where the water level corresponds to rainfall. The peak water level at about day 88 through 92 corresponds to a period of snow melt. Water was ponded in the channel for about five days which indicates that most of this water would have infiltrated in the terrace channel since evaporation rates at this time of year would only have contributed to about 2.5 cm. Ponding lasted about the same length of time for the event that began on day 101. About five inches (12.7 cm) of rain was received from day 111 through 115. The water level in the terrace rose to over 50 cm during this time and some outflow at the end of the terrace was evident from field investigations. After day 115 the water level dropped about 1 cm per day. Evaporation was a significant portion of the decline during this period. These data illustrate the procedures used to measure runoff into terrace channels and the storage characteristics of the channel. We are integrating these types of data for all field sites and integrating into an analysis procedure to partition runoff into evaporation, evapotranspiration and deep percolation.

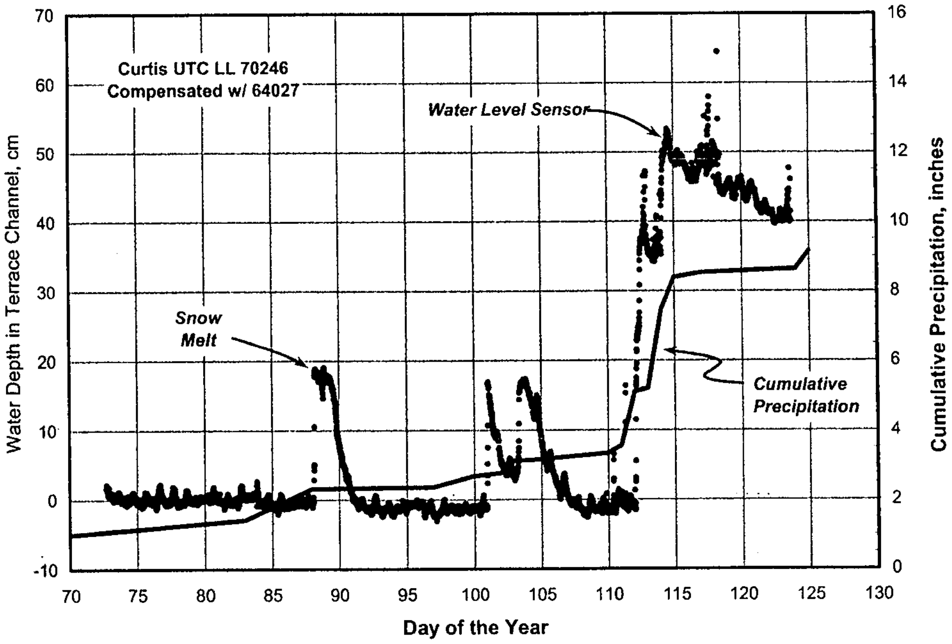


Figure 19. Water level in a terrace channel at the Curtis site during the spring of 2007 and the amount of precipitation during that period.

Soil Moisture

The total soil water to the 90-inch soil depth in spring of 2006, fall of 2006, and spring of 2007 for each site are shown in Figures 20-24. At the Colby site the soil water decreased during the summer because of crop water use. During the winter both the contributing slope and terrace channel gained about 6 inches of water due to the high winter precipitation. At Culbertson, there was a gain in soil water after the wheat harvest and before fall. Over winter, the terrace channel gained about 3 inches of water but the contributing slope had a net loss about 4 inches, probably due to drainage and evaporation. At Curtis, there was a loss of soil water during the summer due to crop water use. Over winter, the terrace channel gained about 3 inches and there was a net loss of water on the contributing slope of about 1 inch, again due to drainage and evaporation. The gain in soil water at the Norton site during the summer probably occurred after the wheat was mature. At this site, there was a gain in soil water in the terrace channel of 1.5 inches and a net loss on the contributing slope of about three inches. At the Stamford site, there was a gain of about 2-3 inches in soil water because of fallowing and a loss of soil water over the winter because of drainage and evaporation.

We estimated that the over-winter precipitation penetrated to depths of 8-12 inches on the contributing slope at all sites except at Colby where it appeared to have penetrated to at least 72 inches. In the channels water generally penetrated to between 56 and 90 inches at all sites except Stamford, where the penetration of winter precipitation was only to about 12 inches. This is probably because the terraces at Stamford are open-ended and do not store water. Overall the channel data confirms that water is penetrating beneath the depth of the plant root zones making it available for percolation to the ground water.

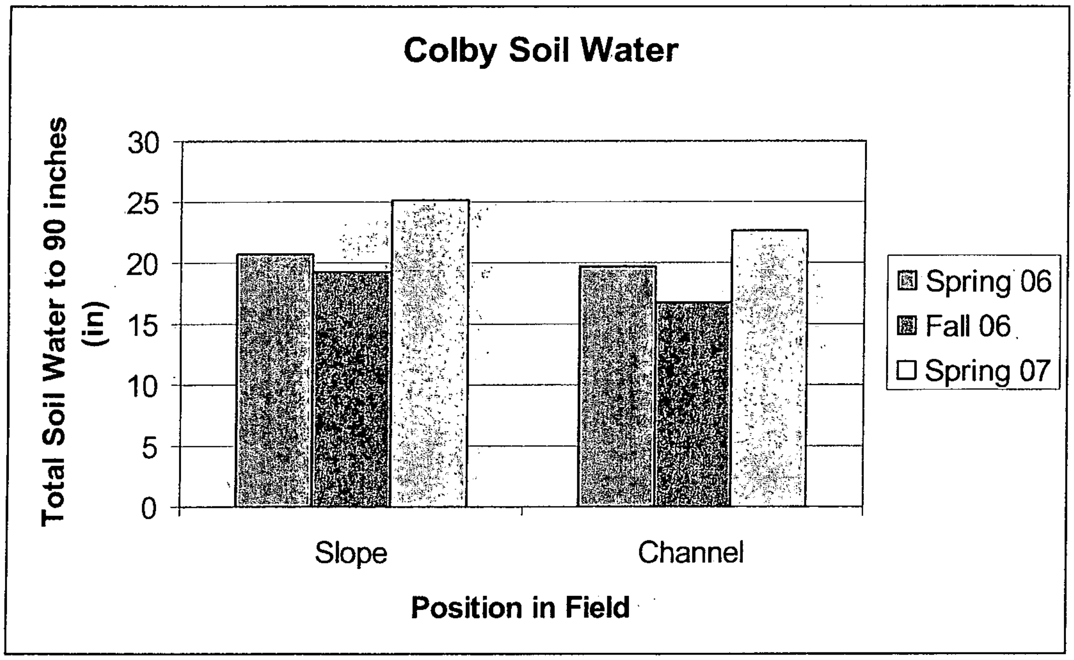


Figure 20. Total soil water to 90 inches for the Colby site where grain sorghum grew during the 2006 season.

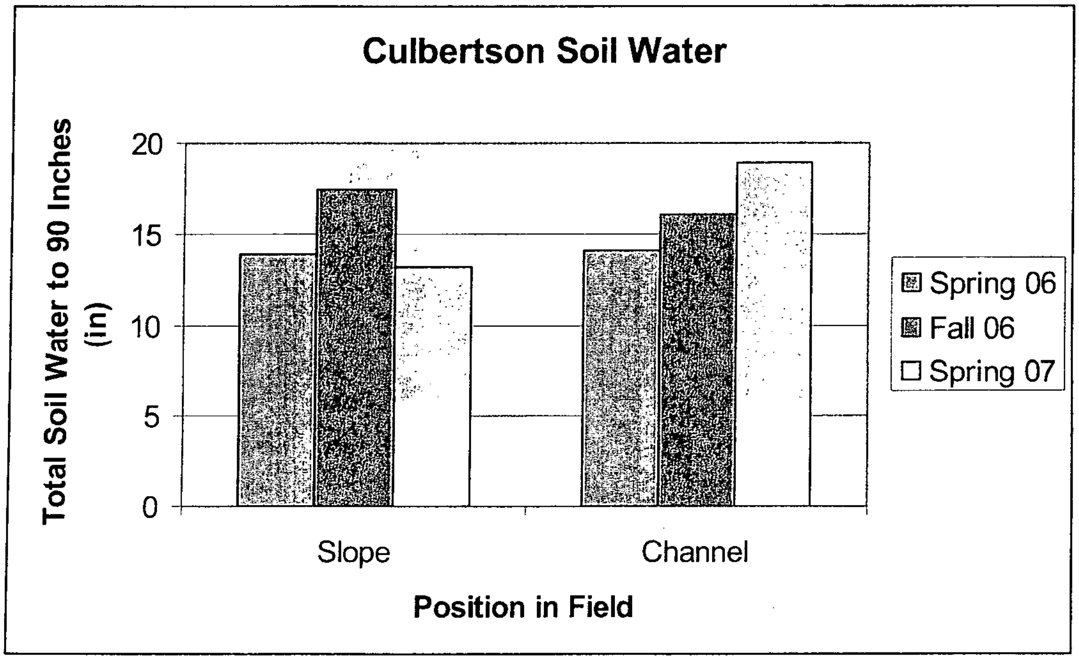


Figure 21. Total soil water to 90 inches for the Culbertson site which was planted to winter wheat from the fall of 2005 through July of 2006.

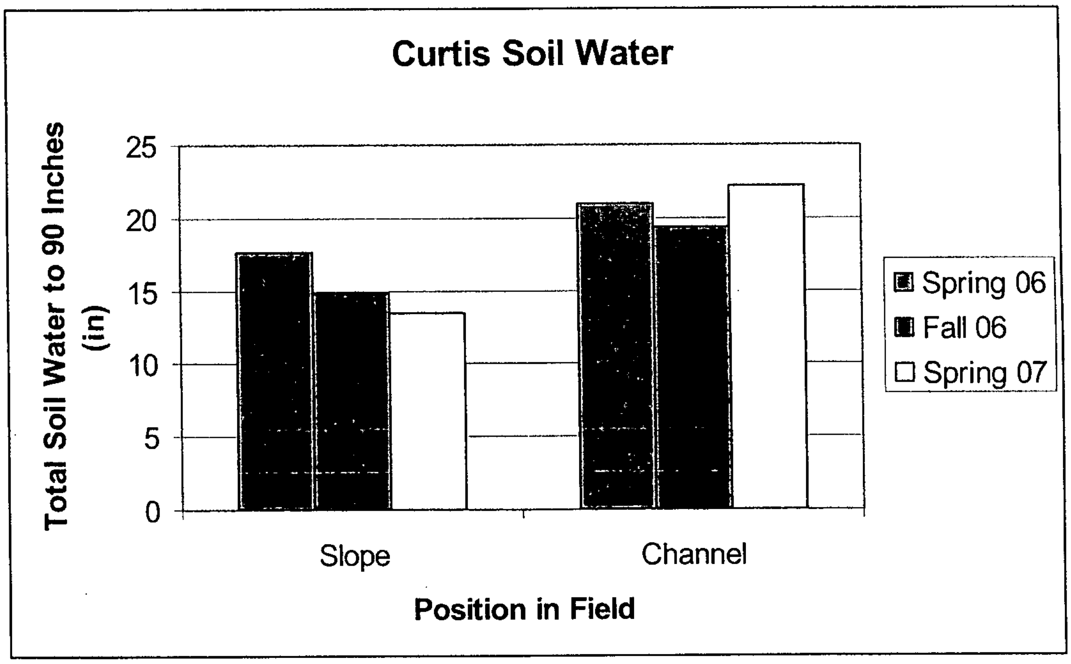


Figure 22. Total soil water to 90 inches for the Curtis site which was planted to corn.

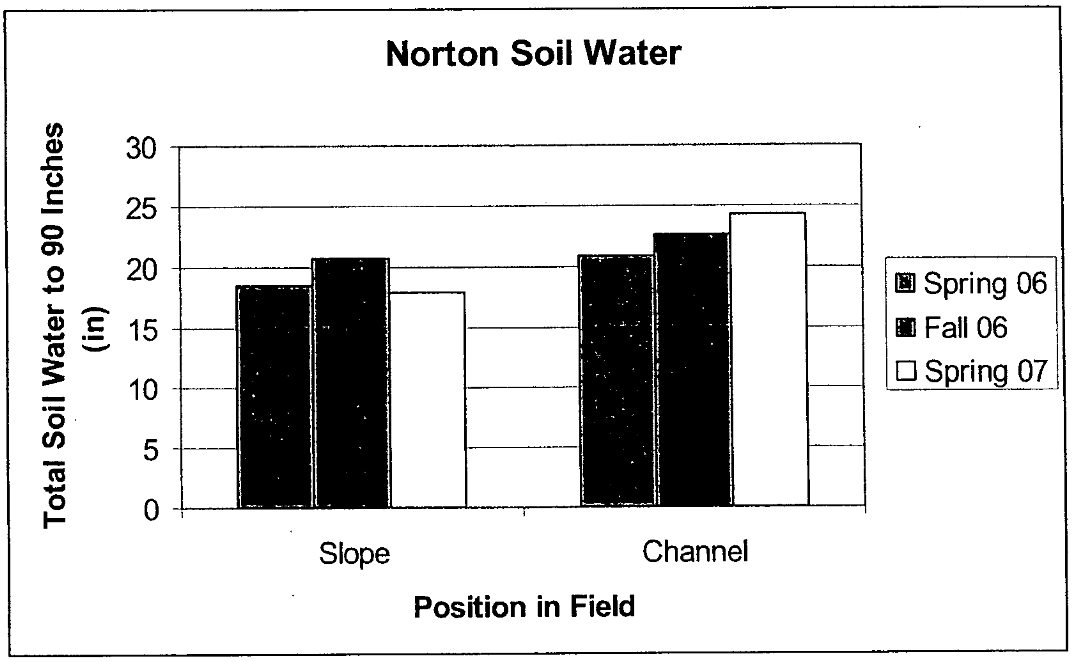


Figure 23. Total soil water to 90 inches for the Norton site which was planted to winter wheat from the fall of 2005 through July of 2006.

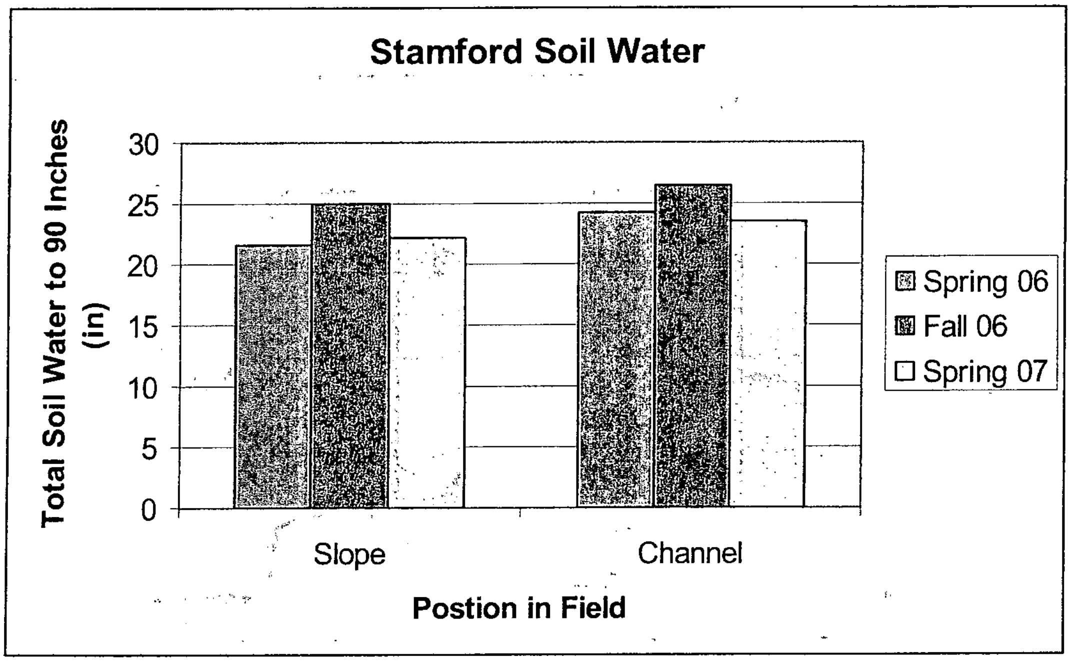
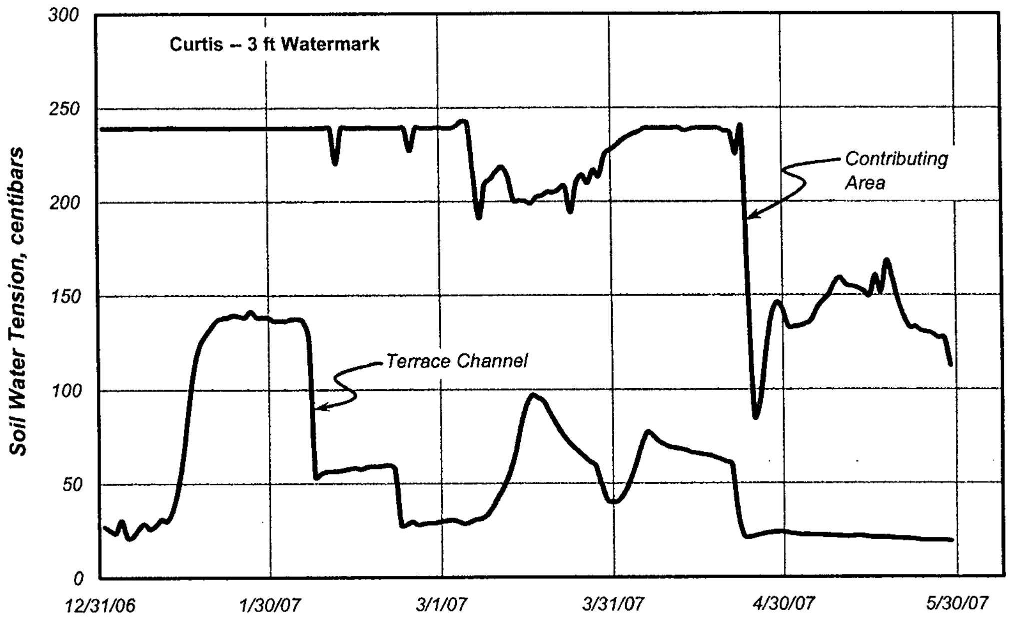


Figure 24. Total soil water to 90 inches for Stamford site which was fallowed during the summer of 2006.

The potential for enhanced deep percolation from terrace channels, and potentially recharge of groundwater aquifers, is illustrated by the difference in soil water potential or tension as illustrated in Figure 25 for the spring of 2007 at the Curtis field. The soil water tension is a measure of how tightly the soil holds water due to capillarity. A high reading means that the water is held tightly by the soil and therefore the rate of water flow in the soil will be slow. Smaller water tension values indicate that water is freer to move in the soil due to the force of gravity. A tension of 30-35 centibars represents a typical range for the field capacity tension for the soil at Curtis. The hydraulic conductivity is a measure of the ability of soils to transmit water. As the soil dries water migrates to smaller pores in the soil matrix and the hydraulic conductivity decreases rapidly. The hydraulic conductivity at field capacity is about 125 times the conductivity at a soil water tension of 200 centibars for silt loam soils like at Curtis. The conductivity at 50 centibars is about forty times the value at 200 centibars. Thus, the data in Figure 25 illustrates that the soil is consistently wetter beneath the terrace channel than below the contributing area and that the terrace channel has the potential for enhanced recharge compared to the contributing area.



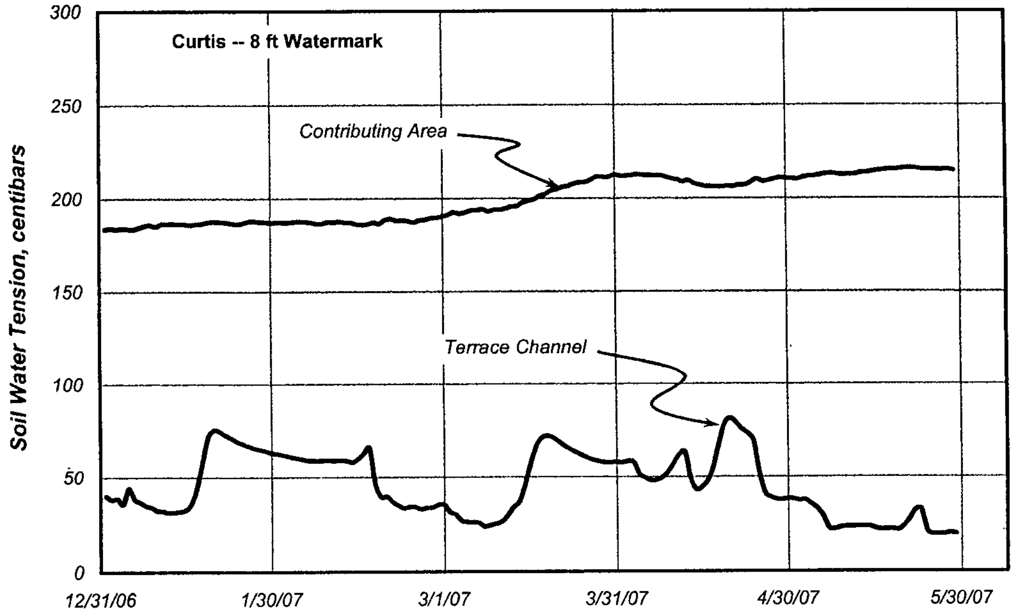


Figure 25. Soil water tension three and eight feet below the soil surface of the terrace channel and the contributing area at the Curtis site (values represent the average of four locations for each location).

The geoprobe samples taken in April, 2006 were used to develop water content profiles to a depth of 25 feet. These profiles show the long-term effects of a terrace on infiltration and deep percolation. Figure 26 is an example of two water content profiles from Curtis, NE showing the difference between the water below the slope area and terrace channel. The higher water content beneath the terrace channel throughout most of the profile illustrates that more water is moving vertically beneath the terrace channel than under the contributing slope in the field. Since this water is beneath the expected crop root zone (about 6-feet) it appears that this water is percolating from the terrace channels. This water will likely find its way to the ground water system and then eventually to the stream or be used for irrigation. The water content profiles for all sites are included in Figures 27-36.

Future Field Work

The field sites have now been instrumented and monitored for about one-year. Since each site has a three-year eco-fallow crop rotation, we hope to monitor each site for at least two more years. Water infiltration tests are planned for each site for each year so that we learn more about how water enters these soils during each phase of the crop rotation.

Acknowledgement

We are very appreciative of the cooperation of each landowner/operator at the field sites. There cooperation is imperative to the success of this project. The cooperators include:

Ron Hoyt, Culbertson, Nebraska	John Scharf, Curtis, Nebraska
Tim Schulze, Norton, Kansas	Brian Lubeck, Stamford, Nebraska
Dan Foster and Freddie Lamm, KSU Northwest Experiment Station, Colby, Kansas.
We also want to thank Steve Melvin with UNL Extension and his staff for their assistance with the field work.

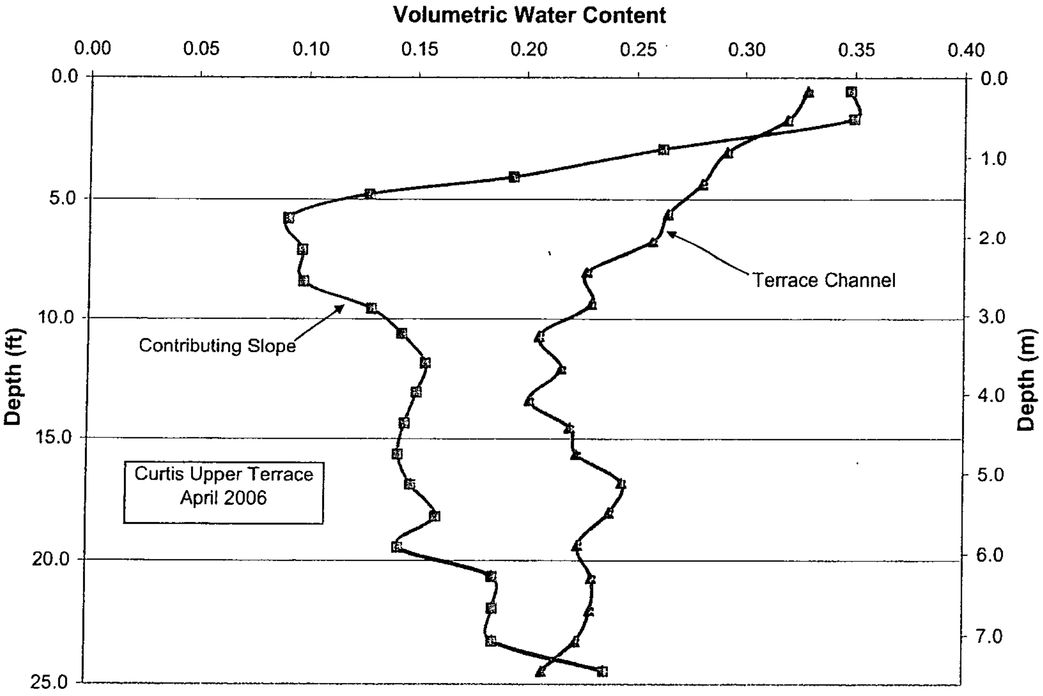


Figure 26. Volumetric Water Content Profile for the upper terrace at the Curtis site.

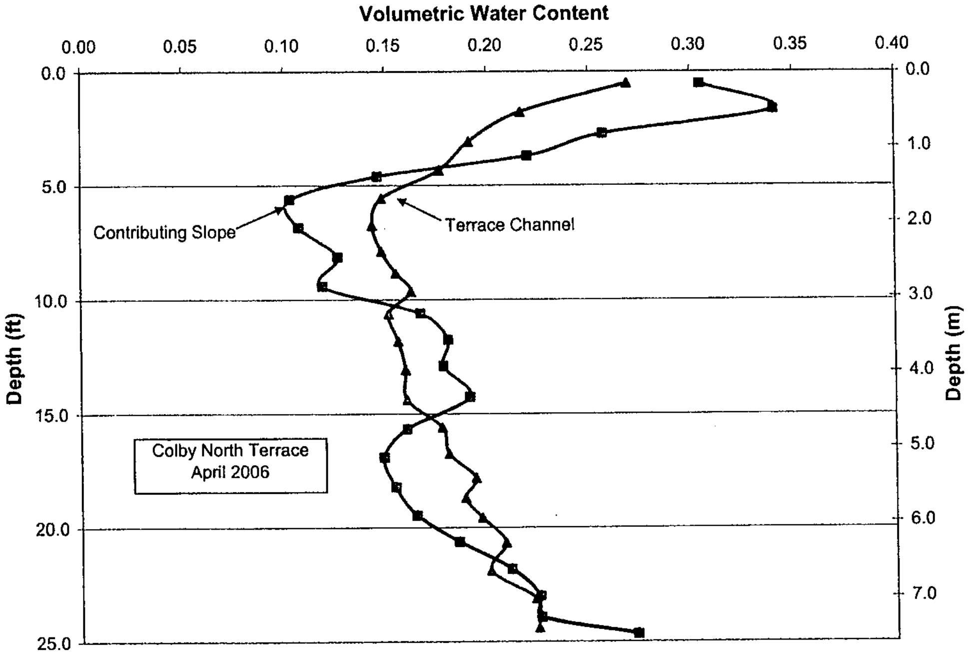


Figure 27. Volumetric water content profile for the north side of the terrace at the Colby site.

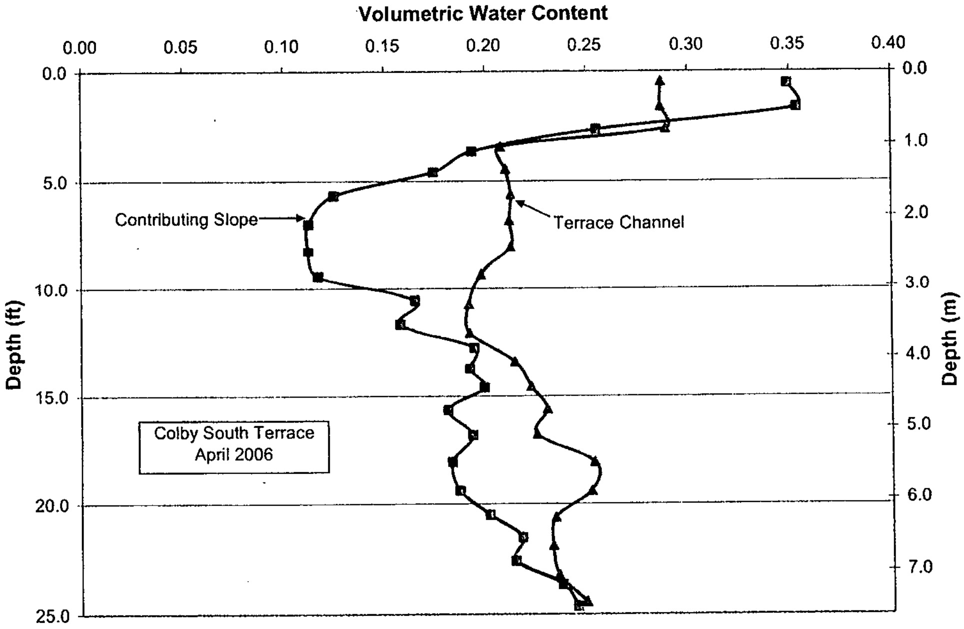


Figure 28. Volumetric water content profile for the south side of the terrace at the Colby site.

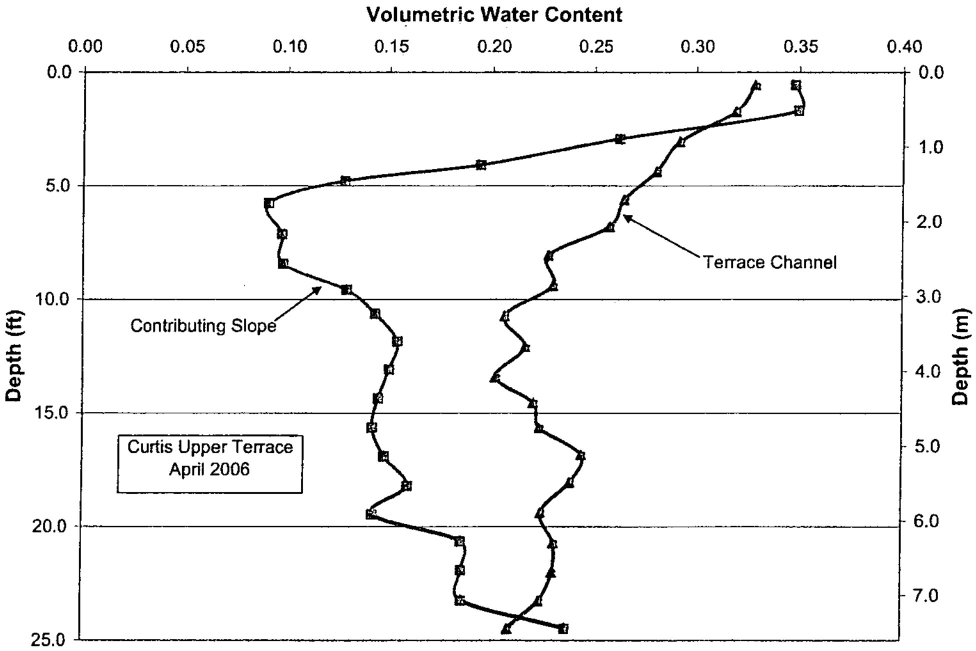


Figure 29. Volumetric water content profile for the upper terrace at the Curtis site.

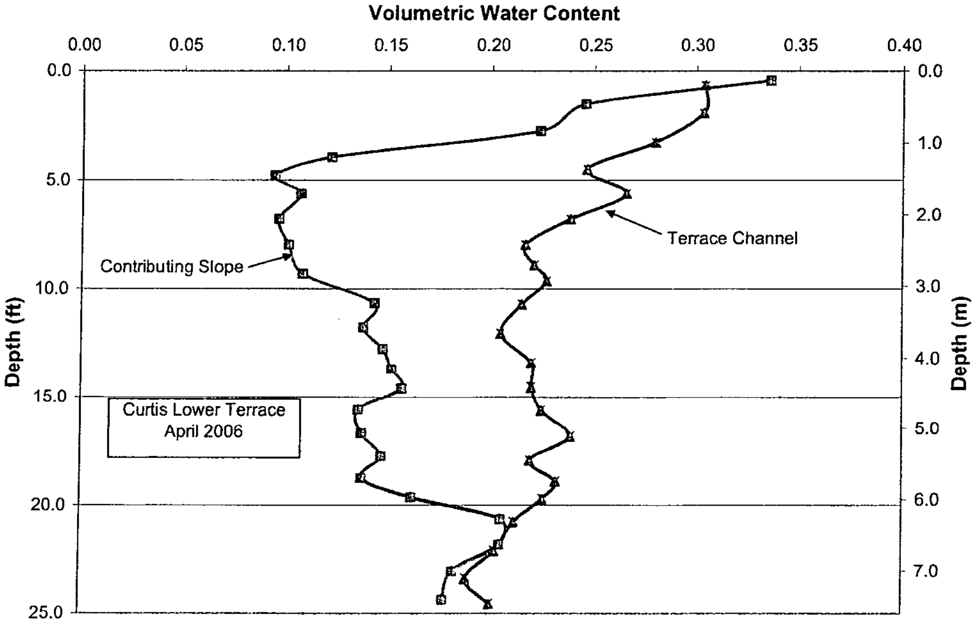


Figure 30. Volumetric water content profile for the lower terrace at the Curtis site.

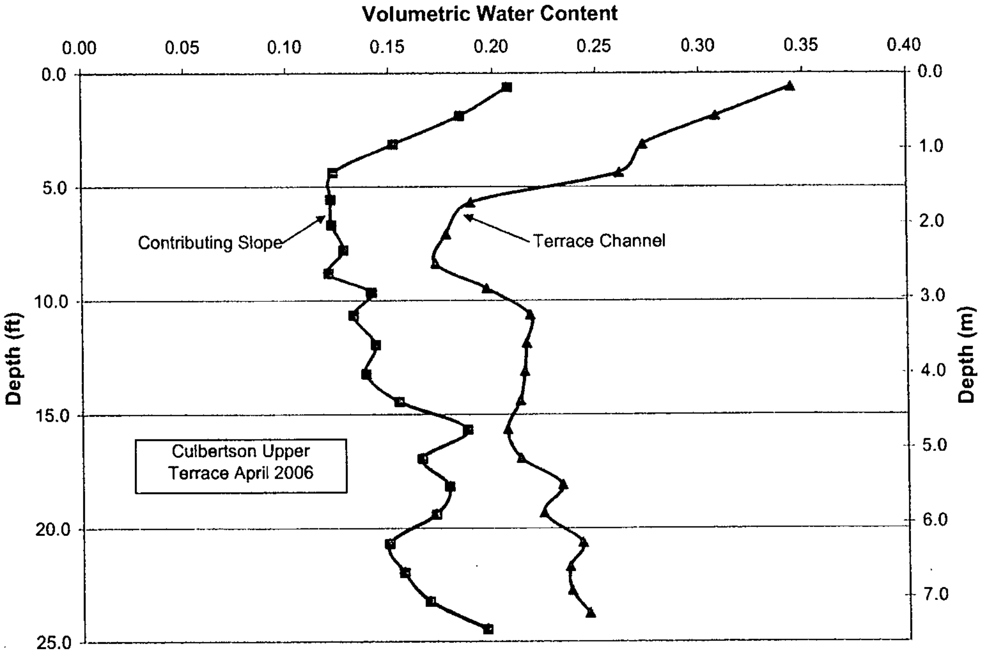


Figure 31. Volumetric water content profile for the upper terrace at the Culbertson site.

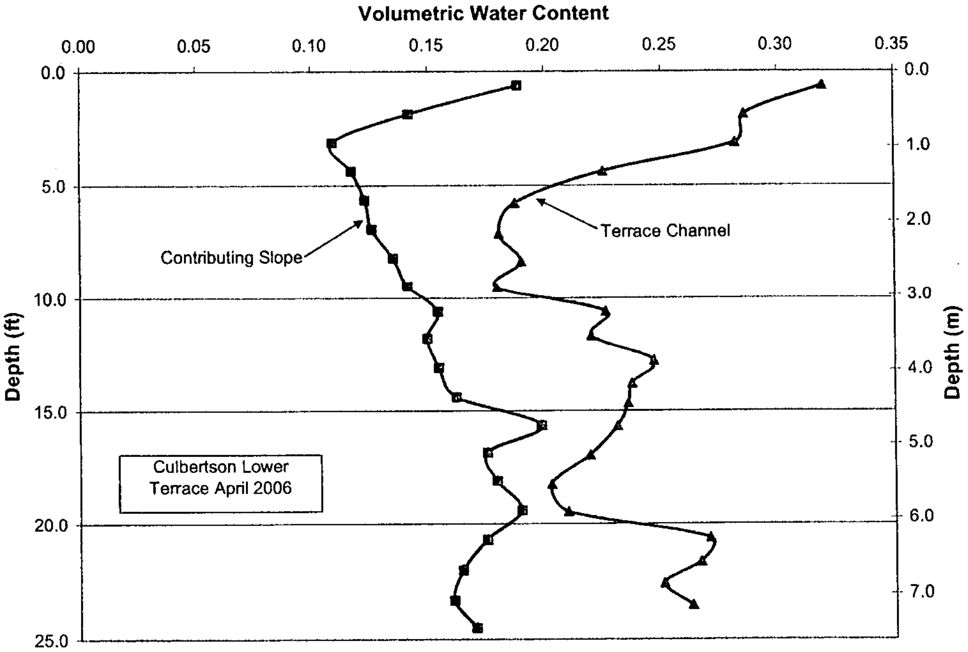


Figure 32. Volumetric water content profile for the lower terrace at the Culbertson site.

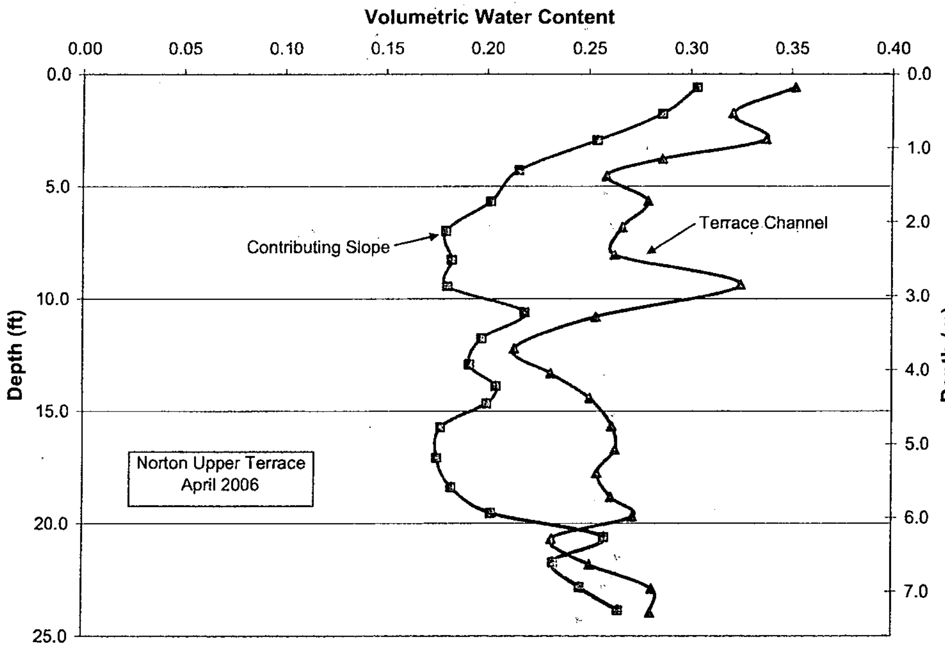


Figure 33. Volumetric water content profile for the upper terrace at the Norton site.

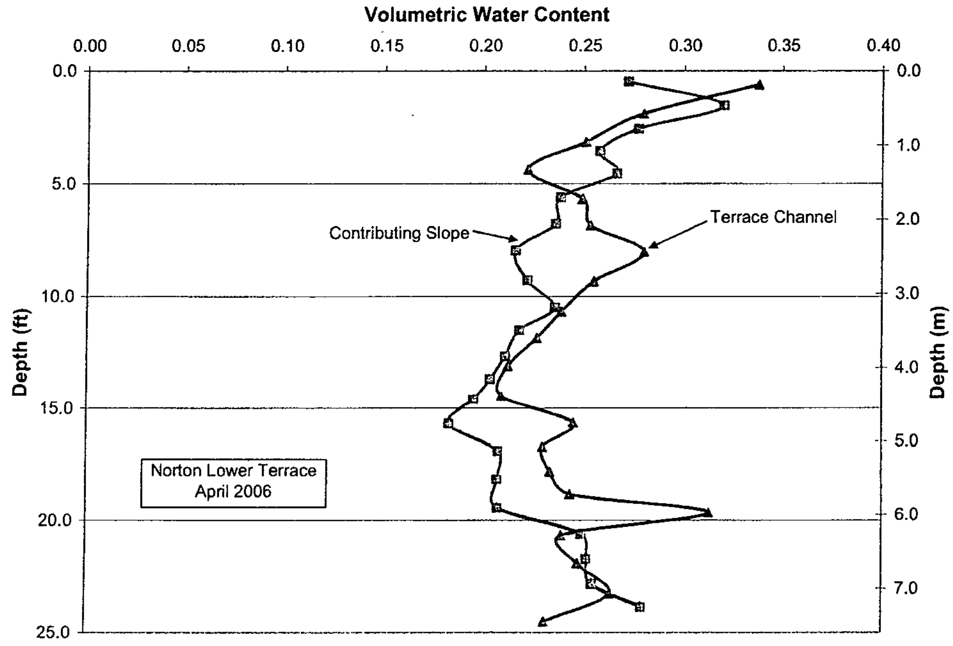


Figure 34. Volumetric water content profile for the lower terrace at the Norton site.

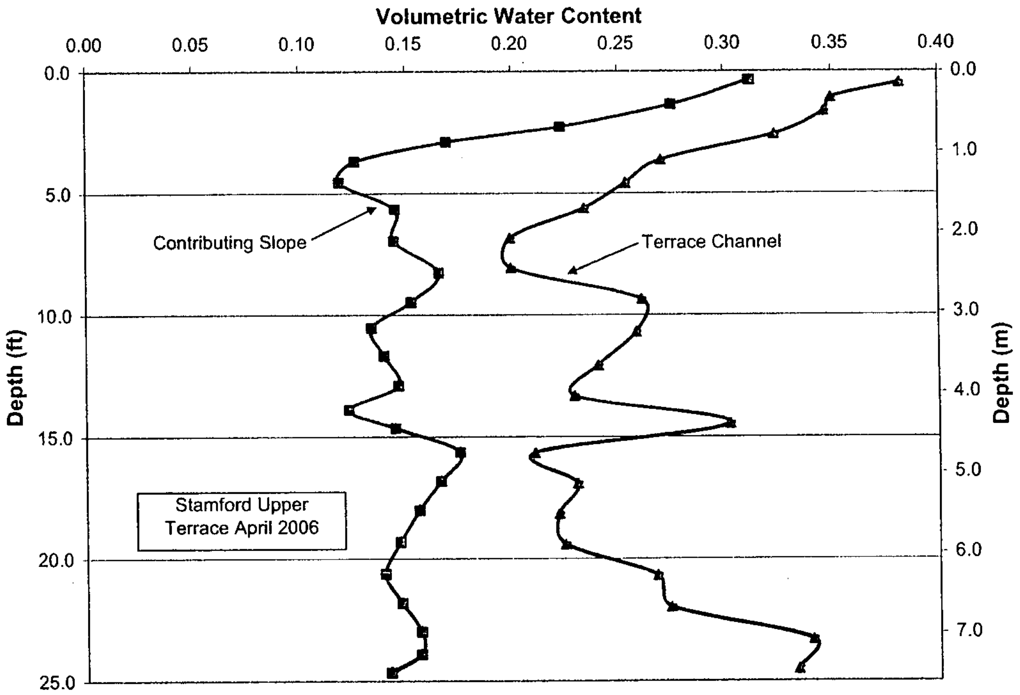


Figure 35. Volumetric water content profile for the upper terrace at the Stamford site.

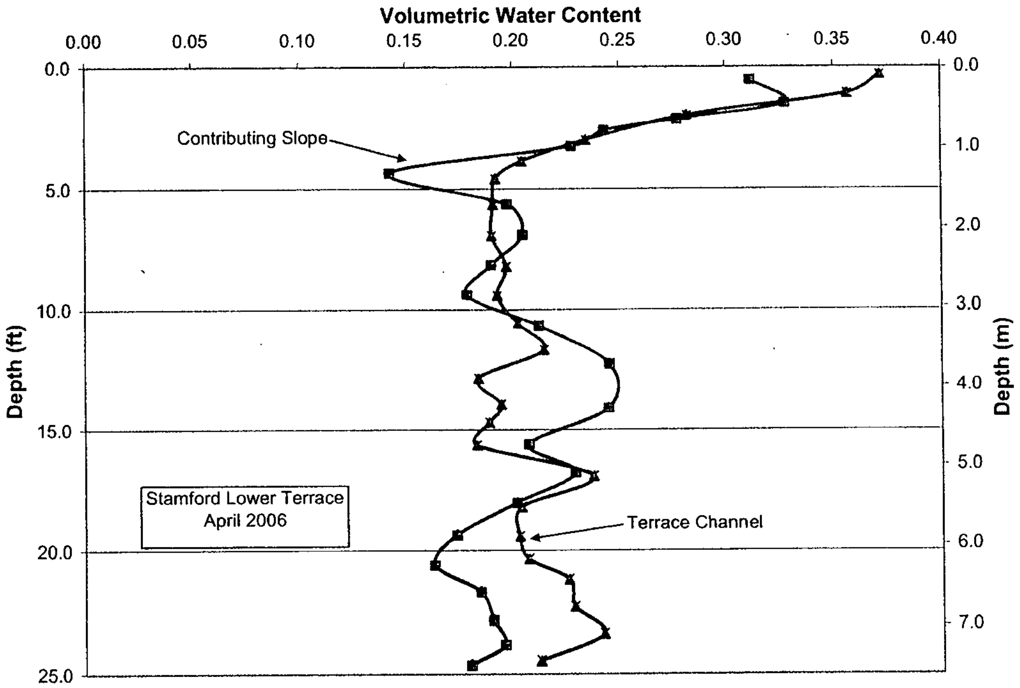


Figure 36. Volumetric water content profile for the lower terrace at the Stamford site.

3. Database Development

Databases have been developed for use in simulating the hydrologic impact of small reservoirs and terraces. The databases include the following data.

Soils

The SSURGO database has been downloaded for all counties in the Republican River Basin. These data are illustrated in the soil maps that are included in Figures 2-4. The SSURGO dataset is a digital soil survey prepared for each county. It includes two data components: spatial and tabular data. The spatial data component is available as either ESRI ArcGIS shape file or coverage. This data component allows users to display spatial distribution of soil series in each county. Each shape file or coverage is associated with attribute tables which are available in a variable length, pipe delimited, ASCII file format. The soil types are defined in the attribute tables by a numerical code called the map unit key or mukey. The mukey field provides a many-to-one relationship from the shape file to tabular data sources. With the Microsoft Access SSURGO template database the user can import attribute tables in a geodatabase. The attribute tables include soil property values which are associated with each soil series in the shape file or coverage. For the POTYLDR model, the required soil properties are located in the mapunit, component, and chorizon tables (Table 4). The definition of soil parameters and their units are listed on Table 5.

We reclassified the soil data because each polygon in the SSURGO shapefile or coverage represents a different soil type, which may appear more than once throughout the dataset. In addition, a single record in the shapefile or coverage may fall into an association of multiple horizons. Reclassifying soil data provides delineation of representative hydrologic response units in the watershed. Table 6 shows the classification algorithm used for soil reclassification.

Table 4. Description of required SSURGO 2.2.1.attribute tables to prepare soil information for POTYLDR model

Table physical name [a]	Data Source Description
Mapunit	Includes soil types that are associated with each soil series in a SSURGO shapefile or coverage
Component	Includes soil parameters such as % composition, hydrologic group
Chorizon	Includes soil properties for horizon of each soil component such as bulk density, % clay, % silt, and % sand.

Chorizon
Horizon depth
Field capacity
Saturation
Wilting point
% Clay
% Sand
% Silt
Chorizon key
Chkey

Component
Hydrologic group
Drainage class
Albedo
Mukey
Cokey

Mapunit
Mapunit
Name
Symbol
Acres
Mukey

a: Mapunit has one-to-many relationship to the component table. Component table has one-to-many to relationship to the Chorizon table. The bold field in each table is primary key for that table. Tables are related through their primary key.

Table 5. SSURGO 2.2.1. soil parameters used for the POTYLDR model

Variable Description	SSURGO 2.2.1 Variable	Unit
Mapping unit identifier	Mukey	unitless
Soil name	Sname	unitless
Soil component percent	Comppct	%
Soil hydraulic group	Hydgrpc	unitless
Texture of the soil layer		unitless
Depth from soil surface to bottom of layer	Hzdepb_r;	cm
Soil water content at 15 bar, wilting point	15 bar H_2O	%
Soil water content at 1/3 bar, field capacity	0.33 bar H_2O	%
Soil water content at saturation	Saturated H_2O	%
Clay content	Claytotal_r	[% of soil weight]
Silt content	Silttotal_r	[% of soil weight]
Sand content	Sandtotal_r	[% of soil weight]
Soil albedo	Albedodry	

Table 6. Soil classification algorithm for hydrologic analysis of large sub-basins

1. Define boundaries of sub-basin/basin for which soil series will be classified.
2. Append soil spatial data (polygons) for each county in the basin boundary.
3. Clip resulting map from step 2 using the basin boundary map
4. The resulting map should display the soil series in the basin.
5. Use map unit and component attribute tables for each county. Join the records in the map unit table to the matching records in the component table
6. For each county, use resulting table from step 5 and chorizon attribute tables. Join the records in the resulting table to the matching records in the chorizon table[2]
7. For each mukey on the final table, calculate available soil water (ASW)
8. Sort the dataset based on hydrologic group (Group A, B, C, D)
9. For each hydrologic group, estimate a mean ASW.
10. For each hydrologic group, identify unique soil groups based on mean ASW
11. Create a new field and mukey for each soil group in step 10. Rename original mukey.
12. Map soil series based on modified mukey from step 11
13. Overlay the land use and soil series maps to identify land use-soil group polygons

Weather Data

Two types of weather data have been assembled. Data from the automated weather data network (AWDN) operated by the high plains Regional Climate Center are being used to compute reference crop evapotranspiration using the hourly Penman-Monteith Method developed by the ASCE-EWRI (2005).The AWDN data are also used to calibrate the Hargreaves equation for the Great Plains. The Hargreaves method only requires the daily maximum and minimum air temperature to estimate reference crop ET. The calibrated Hargreaves method is then used with data from the Cooperative program operated by NOAA and the National Weather Service (NWS). These data are referred to as the NWS data. These records only include the daily maximum and minimum air temperature and the amount of precipitation received for the day. The Hargreaves method is used with these data to develop estimates of reference crop ET as used in the CROPSIM and POTYLD models. The location of the AWDN and NWS weather stations selected for simulation across the basin are presented in Figure 37.

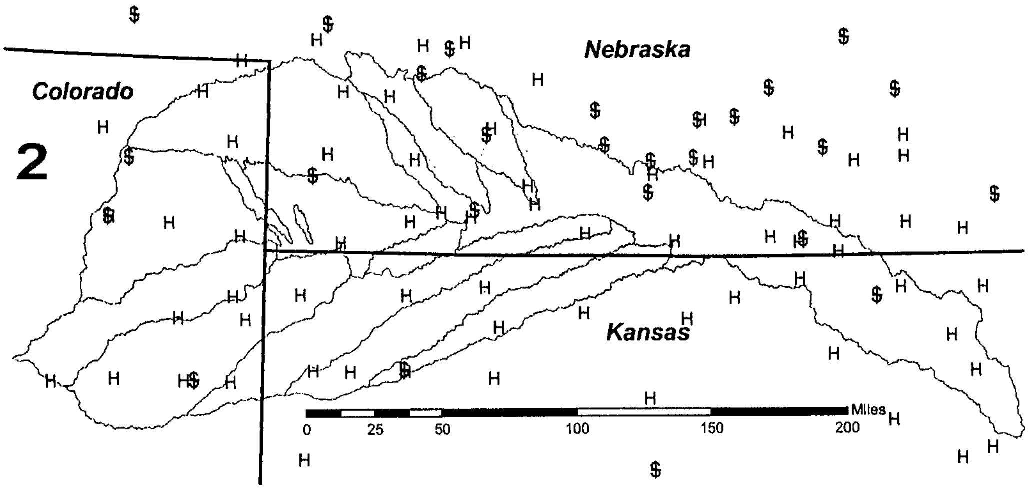


Figure 37. Location of AWDN stations (pentagon symbol) and NWS stations (circular symbols).

These weather data have been used with a Penman-Monteith to compute the daily reference crop ET for the AWDN stations in Nebraska. These results were used to calibrate a Hargreaves model for the region. The calibrated Hargreaves model was used to estimate daily reference crop ET for the NWS stations in the Nebraska portion of the model area for the period from 1949 through 2006. The reference ET data was used with the CROPSIM model to simulate ET for corn, grain sorghum, soybeans, alfalfa, sunflowers, edible beans, and wheat for the period from 1950 through 2006. Results were simulated for three soil types along with traditional tillage systems for each crop and region in the Nebraska portion of the study area. These results will be compared to simulations from POTYLD to improve ET estimates for the study. A similar process is underway to conduct simulations for the Colorado and Kansas portions of the watershed.

Other Databases

Several other databases have been developed for the project as briefly described below.

- Datasets from the NHD have been downloaded and are being used to delineate watershed boundaries and to define contribution areas for specific reservoirs. The NHD data is being combined with digital elevation models to also define subwatersheds for simulation.
- Landuse data has been downloaded from USGS and NASS Crop Layer sources. These data will be used to define cropped areas from native range, urban and riparian ecosystems. We will combine these data with county NASS data to develop cropping patterns for hydrologic response units.
- Public land survey system data has been developed for the region.
- Highway and city locations have been incorporated.
- Tillage practices have been investigated for each county using the CTIC database. We plan to use these data to represent current practices in developing hydrologic response units.

- Irrigation well locations are available for Nebraska. Dataset for other states are being explored. We will utilize pumpage records or estimates to simulate the hydrology of irrigated units in the region.
- Stream flow records, including baseflow separation, has been initiated but is not complete. Records from the Republican River Compact Settlement will be used in the initial phase of analysis of baseflow contributions.
- Roads from various sources have been included.
- Digital Orthophoto Quadrangles
    - 1999 DOQQs mosaiced for each county of Nebraska
    - 2006 DOQQs mosaiced for each county for RRB (source: FSA)
- County boundaries.
- County crop yield data from NASS
- Cropland data layer from FSA for NE

GIS data layers all used the UTM zone 14 and NADH 1983 datum for map projections.

Digitizing Terrace Fields

The location of terraced land in Nebraska and the Sappa Creek watershed in Kansas were originally digitized by Nebraska based on 1994 DOQQ images. We are in the process of updating these data to current conditions to more nearly match the time frame for the areas of the watershed digitized by the Bureau of Reclamation. The FSA data and field boundaries from CLU (common land unit) data were used in creating the updated terrace shape files. Updating has been done on a county-by-county basis in NE. With the new procedure each shape has a unique ID within each county. The updated is based on the FSA dataset which contains photographic information obtained for the National Agricultural Imagery Program (NAIP) for 2006 and is comprised of scanned photographs that were acquired with a precision aerial mapping camera. The data for counties in NE, KS, and CO are downloaded from the following site: http://datagateway.nrcs.usda.gov/GatewayHome.html

4. Future Tasks

Activities for the upcoming year will focus primarily on the following tasks.

1. Survey of condition of a representative sampling of terraced fields.
2. Continued monitoring of the water balance components of terraced fields.
3. Infiltration studies to help partition runoff into evapotranspiration and deep percolation.
4. Development of GIS, databases and data processing procedures to facilitate use of the POTYLD model and integration of simulation results.
5. Integration of field results into modeling studies.
6. Measurement of evaporation rates from small reservoirs.