From:	Swanda, Marvin R
To:	Wergin, Jack B; Scott, Craig D; Peck, William E
Subject:	FW: Conservation Study - Terraced land info.
Date:	Monday, April 13, 2009 9:17:50 AM
Attachments:	Appendix F - KSU.pdf RRCA 4th Annual Status Rpt Jul312008.DOC

From: Guenthner, R S (Scott)
Sent: Monday, April 13, 2009 9:50 AM
To: Swanda, Marvin R
Cc: Aycock, Gordon L; Erger, Patrick J
Subject: Conservation Study - Terraced land info.

Marv: I have attached the main body of the Conservation Committee 4th Annual Status Report from Aug 2008 and Appendix F of that report which is Jim Koelikker's summary of work up until Aug 2008. This is where the information was pulled from I provided to Gordon and you for the deposition.

You might want to look at Pg 14 of the main report for the discussion of the work on Prairie Dog Cr, and at the Appendix F , Table 2 and Table 4. The preliminary work on Prairie Dog Cr reflects the impact of terraces on 141,300 acres of land by reduction in streamflow of 3,200 acre-feet. We had estimated that if Prairie Dog Cr was representative of the basin in Nebraska, which has 1,200,000 acres of terraces, than there was a potential reduction in streamflow from terraces of about 27,000 af <- for terraces in Nebraksa only. We need to continue to stress that this information from the Conservation study is very preliminary and the results from the study will not be avaialbe until they are reported to the RRCA in August 2009.

It may also be important to know that there are 2,309,559 (2.3 million) acres of terraced land in the basin above Hardy, 220,000 in Colo., 890,000 in Kansas, and 1,196,000 in Neb (pg 8 of report).

I believe the estimated impact of terraces of 175,000 af referenced in the S&T proposal came from the Republican River basin Water Management Study, 1985. The study lumped together ponds, terraces and crop residue management - those impacts totalled 238,200 af. I believe we backed out the crop residue management amount to get to the 175,000 af referenced in the proposal. I would need to go through the engineering appendix of that report to confirm this. Let me know if we need to do this.

Please call if you have any questions.

scott

Progress Report for the Period: May 1, 2007-June 1, 2008

Electronic file: Progress Report June 2008.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
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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 additional work done during the past year.

Water Budget Model Evaluations:

In cooperation with the University of Nebraska-Lincoln, three water budget models were evaluated and the **POTYLDR** (**POT**ential **YieLD** Model **R**evised) developed by Kansas State University (Koelliker 1994) 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 two 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.

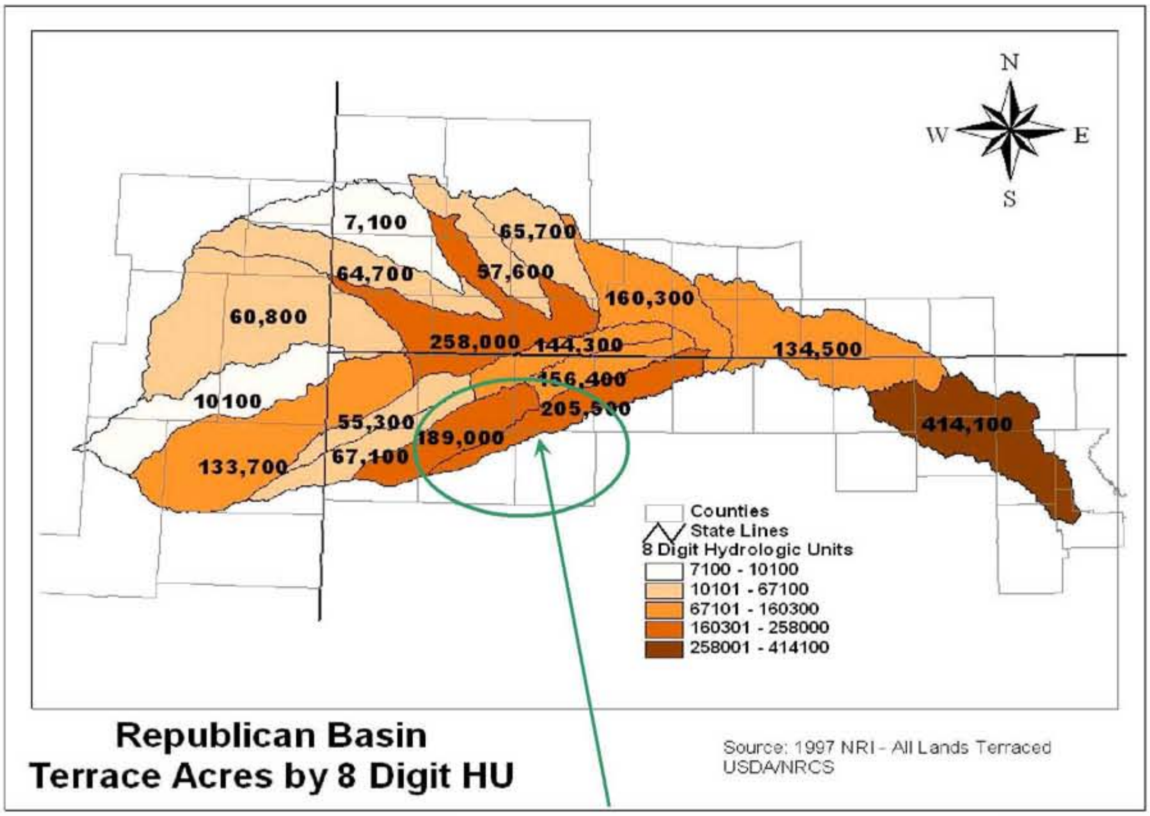
Revisions to the POTYLDR Model for this Project

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 the Water Budget for Prairie Dog Creek above Keith Sebelius Lake as a Representative Sub-basin

To evaluate the overall approach to the model simulation, the USGS 06847900 PRAIRIE DOG C AB KEITH SEBELIUS LAKE, KS was chosen as a representative sub-basin on the south side of main stem of the Republican River. It is an unregulated stream that has a total drainage area of 590 square miles all of which is describing as contributing. The watershed begins in west central Thomas County west of Colby and extends generally northeastward to the streamgaging station about 10 miles west of Norton. The sub-basin includes parts of Sheridan, Decatur, and Norton Counties. Total stream length is nearly 100 miles. See Figure 1.

Soils in the watershed are dominated by deep, fine-grained silt loams with moderate runoff potential, and good water-holding capacity. Most areas have low to moderate slopes. Soils are susceptible to water erosion and wind erosion if not protected by residue or cover crops. Where slopes are not great, the soils are well suited to crop production. The sub-humid climate makes good water management important to successful dryland farming.



Prairie Dog Creek Above Sebelius Lake, KS
Prairie Dog Creek Near Woodruff, KS
205,500 acres terraced in 1997 out of a total area of 644,500 acres
Area in Prairie Dog Creek Above Sebelius Lake, KS is 377,500 acres
Estimated terraced acres is 120,000 in 1997

Figure 1. Location of Prairie Dog Creek above Sebelius Lake, KS and estimate of terraces in the sub-basin in 1997, USDA NRCS 1997 Natural Resources Inventory.

The climate of watershed is a dry, continental. With the exception of a severe deficiency in some years it is generally favorable for the successful growth of many crops. Annual precipitation increases from an annual average of 18 inches in the west to about 22 inches at the streamgaging station. Average annual evaporation is near 60 inches.

Land use in the watershed is dominated by cropland (59%) as reported by the USDA National Agricultural Statistics Service 2002 Census for the four counties and shown in Table 1.

Table 1. Land in cropland and cropland that is terraced in the Prairie Dog Creek above Sebelius Lake Sub-basin.

Land in cropland taken from
USDA National Agricultural Statistics Service, 2002 Census
http://www.nass.usda.gov/Census/Pull_Data_Census

County	Area, ac	2002 Cropland Area, ac	Cropland Percent	Part of Watershed Area, %	Cropland in County in Prairie Dog Watershed, acres	Total Land in County in Prairie Dog Watershed, acres	Prairie* Dog Creek Area Terraced Lands	Percent of Cropland** in Terraced Fields
Thomas	688,000	566,418	82	28%	87,044	105,728	30,364	35%
Sheridan	574,080	360,344	63	5%	11,851	18,880	4,756	40%
Decatur	572,160	282,306	49	65%	121,101	245,440	104,069	86%
Norton	563,840	288,731	51	2%	3,867	7,552	2,083	54%
Values for the Watershed				100%	223,863	377,600	141,272	63%
					0.59			

*Values from terracing mapping portion of this project as reported in the Third Annual Status Report
Area in Norton County above the streamgaging station is estimated.
**Assumes all terraced land is used for crops

Terraced lands for this analysis were assumed to be in cropland. As shown in Table 1, an average of 63% of the cropland in the sub-basin is terraced. Terraced land includes all of the field area with terraces on it. Generally, about ten to fifteen percent of a terraced field is below the lowest terrace and as such the runoff from that area is not retained. Therefore, runoff from the terraced land was increased to reflect this situation and percolation was reduced to account for the area for which no additional infiltration would occur.

The streamgaging station began operation in 1963 to provide estimates of inflow to Keith Sebelius Lake. Long-term average streamflow has been 8.16 cfs, 5,900 acre-feet/year, or 0.19 inches/year over the drainage area. The greatest year of streamflow, 1965, totaled 38,600 acre-feet and the lowest was 200 acre-feet in 1981. Average annual streamflow for the past 15 years, 1992-2006 has been about 6,400 acre-feet, slightly above the long-term average.

The previously-developed version of POTYLDR was used to simulate the operation of important land use conditions as representative HRUs. Terraced cropland systems were represented by conventional level, closed-end terraces in good conditions with a 3-year crop rotation of wheat-rowcrop-fallow with good residue management. Unterraced cropland was represented by the same cropping system but with no terraces. The remainder of the watershed was represented by range/pasture with good management practices. For analysis purposes, the average for a simulation with 60 years of continuous daily precipitation and minimum and maximum temperature were made to get the average values for use in the overall sub-basin water balance. Table 2 shows an overall long-term water balance for the sub-basin using the weighted amounts of land represented by the three HRUs. The weighted average runoff from the HRUs at the edge of the field averaged 0.44 inches/year.

In previous annual reports we reported that transmission losses in this area were estimated to be about two percent per mile of travel in the stream system. In Table 3, the area of the sub-basin was divided into five equal portions and the distance of travel from

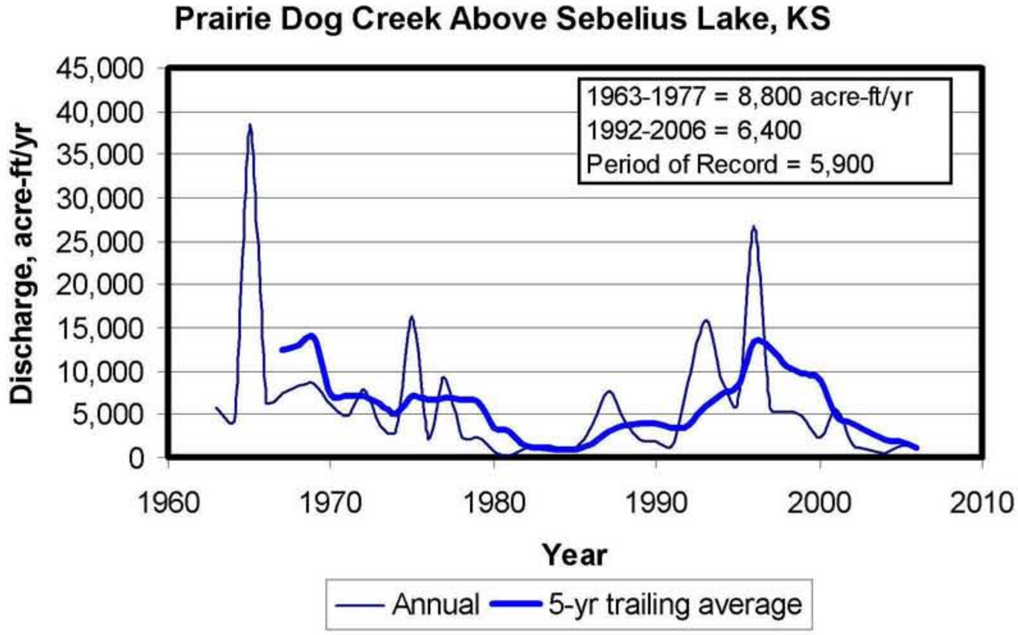


Figure 2. Annual measured streamflow from the sub-basin.

Table 2. Average annual water budget for the Prairie Dog Creek above Sebelius Lake sub-basin for current conditions.

	Total Watershed Values	Cropland With Terraces	Cropland Without Terraces	Other Land Simulated as Pasture/Range
Area, acres	377,600	141,272	82,591	153,737
Effects on the Surface Water System				
Runoff at the edge of field, inches	0.44	0.25	0.85	0.40
Acre-ft	13,900			
Transmission losses of runoff in stream system to first measurement point, %	60			
Net streamflow at measurement point, acre-ft	5,600			
Effects on the Alluvial Groundwater System				
Net efficiency of transmission losses to enter the groundwater system, %	60			
Net contribution to alluvial groundwater system, acre-ft	5,000			
Transmission losses that do not become usable groundwater, acre-ft	3,300			
Portion of unusable transmission losses that return as baseflow, %	25			
Net baseflow contribution to streamflow from transmission losses, acre-ft	800			
Transmission losses that are lost by evapotranspiration, acre-ft	2,500			
Effects on the General Groundwater System				
Percolation from the field, inches	0.41	0.7	0.4	0.15
Gross percolation from the field, acre-ft	12,900			
Effectiveness of percolation contribution to groundwater system, %	80			
Net increase in recharge to groundwater system from the field, acre-ft	10,300			
Field percolation lost as evapotranspiration, acre-ft	2,600			
General groundwater system contribution to streamflow, % of additional recharge	0			
Net contribution of groundwater system contribution to baseflow, acre-ft	0			
Net streamflow, acre-ft	6,400	0.20 inches		
Net recharge to groundwater system, acre-ft	15,300	0.49 inches		
Note: All volumes are rounded to the nearest 100 acre-ft				

the center of each section was estimated. Then, the proportion of edge of the field runoff that would be estimated to reach the streamgage was calculated for each section and averaged. This approach shows that about 40% of the field runoff would be expected to reach the streamgage. Or, the transmission loss of runoff in the stream system is estimated to be 60%. Also, the percent of the total streamflow at the streamgage was calculated for each of the fractions of the sub-basin. This analysis shows that nearly 70% of the total streamflow at the streamgage would be expected from the 40% of the sub-basin nearest the streamgage.

Table 3. Estimated effects of transmission loss and distance from the streamgage on amount of flow from fractions of the sub-basin.

Fractions From Upper to Lower End of Watershed	Estimated Runoff Upstream inches/yr	Proportion to gauge	Transmission Losses Percent reduction/mile	Upstream Runoff Travel, miles	Estimated Net Streamflow From Upstream, inches/yr	Depth From Fractions of Watershed, inches/yr	Percent of Total Streamflow at Gauge
Upper 20%	0.30	0.20	2.0%	80	0.06	0.01	6%
20%	0.35	0.30	2.0%	60	0.10	0.02	10%
Middle 20%	0.40	0.36	2.0%	50	0.15	0.03	15%
20%	0.50	0.49	2.0%	35	0.25	0.05	25%
Lower 20%	0.65	0.67	2.0%	20	0.43	0.09	44%
100%	0.44	0.40	Average values			0.20	100%

Applying the transmission loss factor of 60% produces the estimate of the contribution of runoff to streamflow at the streamgage of 5,600 acre-ft. In addition, an estimated 10% of transmission losses subsequently are expected to return to the stream to produce base flow following major runoff events. This increases average total streamflow to 6,400 acre-ft. This value is quite close to the average for the past 15 years of the record.

Since the effect of terracing on recharge is also an expected result from this study, the percolation from the three HRUs is used to estimate that value, too. There is less certainty about this long-term value for calibration purposes. The percolation from the Pasture/Range HRU was increased by 0.05 inches to account for the effects of the small impoundments that are mostly in them. About 20% of the sub-basin is estimated to be above a small dam. These dams trap most of the runoff from above them and it subsequently escapes as seepage or evaporation. With average runoff of 0.5 inches per year and half of the runoff becoming percolation from seepage, this produces a weighted average additional percolation of 0.05 inches over the area in range/pasture and decreases the average runoff from that same area by 0.1 inches.

The weighted average percolation from the HRUs is 0.41 inches/year or 12,900 acre-ft/year. The effectiveness of this percolation to actually become usable groundwater is uncertain. Some of it may return as springs or get close enough to the surface to be drawn up by deep-rooted vegetation. The estimated effectiveness used here is 80%. The net recharge from the land is then estimated to be 10,300 acre-ft/year. Adding the land recharge to the alluvial groundwater recharge then produces an estimated total annual average recharge of 15,300 acre-ft or about 0.5 inches over the sub-basin.

Simplifications for this initial analysis are several. Irrigated land was not separated. All soils were assumed to be similar, deep silt loams with good water-holding capacity. Operations of small dams were not directly simulated. Actual terrace conditions as far as water storage capacity were represented by an average in between good and fair condition. The sub-basin was not sub-divided into smaller sections. Conservation Reserve Program land was not specifically identified nor were any lands that were terraced that were not in cropland. Nonetheless, the water balance for the sub-basin is judged to be of a usable starting basis to examine the impact of the terraced lands on changes in streamflow and groundwater recharge.

The effects of the terraced lands can be estimated by considering the extent of the land terraced in the sub-basin and the difference between the average depth of runoff and the depth of percolation between the terraced land and the same land assuming it were unterraced. This assumes that the terraced land, if it were unterraced, has the same runoff and percolation characteristics as the unterraced land in the sub-basin.

Table 4 presents this analysis for the sub-basin. Here, the same assumptions about transmission losses, dispensation of water lost as transmission losses, and groundwater dispensation used for the entire sub-basin water budget are made. Also, the estimate of additional evapotranspiration on the terraced land because of the additional water stored in the soil of the terraces is presented to account for where that water moves in the sub-basin.

Edge-of-field runoff is reduced by 7,100 acre-ft by the terraces which results in a decrease of direct streamflow at the streamgage of 2,800 acre-ft. Because less runoff enters the stream valley, transmission losses are reduced by an estimated 4,300 acre-ft resulting in an estimated 2,600 acre-ft less groundwater recharge to the alluvial groundwater system. Also, the reduction in base flow from transmission losses amount to an estimated 400 acre-ft streamflow.

The increase in percolation from terraced lands is 3,500 acre-ft of which 80% is estimated to become usable groundwater while the other 20% is estimated to be lost by evapotranspiration within the sub-basin. The estimated increase in groundwater recharge is 2,800 acre-ft.

Useful evapotranspiration on the terraced lands is estimated to be about 2,800 acre-ft or 80% of the additional infiltration in the terrace channel that remains in the soil for subsequent plant use. The remaining 20% is estimated to be wasted by direct evaporation or by damaging the crop in the channel in wetter seasons.

The estimated net effects of the terraces are that streamflow from the sub-basin is reduced by 3,200 acre-ft/year and net groundwater recharge is increased by 200 acre-ft/year. There is not a direct method to determine if these values are, indeed, correct. Field measurements that are a part of this larger study a showing that terraces of the type in this sub-basin are preventing nearly all runoff from above them from being lost. Also, substantial amounts of percolation below the terrace channel are being measured.

Table 4. Estimated effects of terraced land in the Prairie Dog Creek above Sebelius Lake sub-basin on the average annual water budget for current conditions.

	Cropland With Terraces	Cropland Without Terraces
Area, acres	141,272	82,591
Effects on the Surface Water System		
Runoff at the edge of field, inches	0.25	0.85
Difference in runoff at edge of field for areas with terraces, inches	(0.6)	
Difference in runoff at edge of field produced by terraces, acre-ft	(7,100)	
Transmission losses of runoff in stream system to streamgage, %	60	
Net change in surface runoff portion of streamflow at streamgage, acre-ft	(2,800)	
Effects on the Alluvial Groundwater System		
Reduction in transmission losses because of less runoff, acre-ft	(4,300)	
Net efficiency of transmission losses to enter the groundwater system, %	60	
Net change in stream system contribution to alluvial groundwater system, acre-ft	(2,600)	
Transmission losses that do not become usable groundwater, acre-ft	(1,700)	
Portion of unusable transmission losses that return as baseflow, %	25	
Net change in baseflow contribution to streamflow, acre-ft	(400)	
Transmission losses that are lost by evapotranspiration, acre-ft	(1,300)	
Effects on the General Groundwater System		
Percolation from the field, inches	0.7	0.4
Increase in percolation from the field, inches	0.3	
Gross increase in percolation from the field, acre-ft	3,500	
Effectiveness of percolation contribution to groundwater system, %	80	
Net increase in recharge to groundwater system from the field, acre-ft	2,800	
Field percolation lost as evapotranspiration, acre-ft	700	
General groundwater system contribution to streamflow, % of additional recharge	0	
Net increase in general groundwater system contribution to baseflow, acre-ft	0	
Effects of Terraces on Dryland Cropping System		
Net increase in potentially useful dryland evapotranspiration, inches	0.3	
Net increase in potentially useful dryland evapotranspiration, acre-ft	3,500	
Effectiveness of additional evapotranspiration for crop production, %	80	
Net increase in useful dryland evapotranspiration, acre-ft	2,800	
Net change in streamflow, acre-ft	(3,200)	
Net change into the groundwater recharge system, acre-ft	200	

Note: All volumes are rounded to the nearest 100 acre-ft

There is not a good source of the adoption of terracing in this sub-basin over time. The first use of terraces in the sub-basin probably started in the 1940s. Earlier work by Koelliker et al. (1981) for the South Fork of the Solomon River did gather data from the USDA Agricultural Conservation and Stabilization Service for the miles of terraces for which cost-share payments were made for terrace construction by county up to 1980. Using those data and projecting a similar rate of terrace adoption indicate that by 1963 terraces would have been in place on nearly 40% of the amount of land with terraces currently.

This analysis represents to overall approach for estimating the effects of terraced lands on streamflow. Indirectly, it also includes estimated effects of small dams in the sub-basin; however, those effects are still being worked on in another part of this project.
This analysis needs to be applied to a sub-basin in the Nebraska portion of the basin to provide more confidence that is will produce results that are judged to be reasonable before it is applied to sub-basins throughout the basin.

Finally, the system to automate the simulation of a larger suite of HRUs has to be built so that more complete combinations of soils, land uses, terraces types and terrace conditions can be simulated and then aggregated for each of the sub-basins to be evaluated in the entire basin.

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

The third annual report on this project showed our work on small, federal reservoirs have been constructed in the Republican River Basin to estimate the seepage rate from them. We have continued to work with data for the DPL-Hogan reservoir because it is the one for which there is usually water in 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 = 80 acres

We reported a relationship between daily seepage rate and depth of water in it. Additional analysis of data through March 2008 shows that it follows this same relationship.

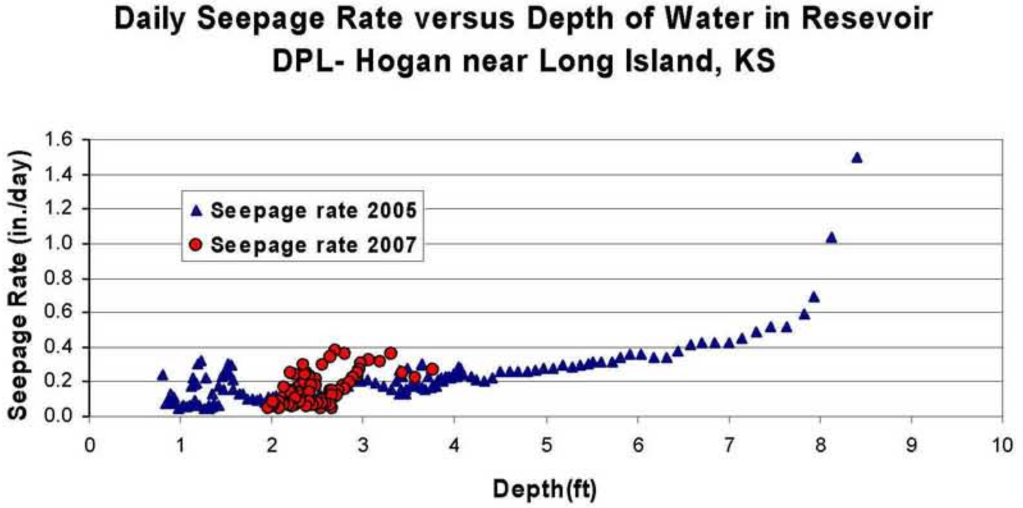


Figure 3. Average daily seepage rate versus depth for a small reservoir near Long Island, Phillips County, Kansas in 2005 and 2007.

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 10% time for the past year, and Ravikumar, a 50% time doctoral graduate student. Koelliker served as interim head of civil engineering at KSU for the past year. His duties will end June 30, 2008 and he will have more time to work on this project. 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 worked 30% time on this project until December 2007 until he accepted a permanent position in civil engineering at KSU.

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.

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 have continued to correspond with them about the data and characteristics of these reservoirs and drainage areas.

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 the May 2008 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 more slowly than desired. Koelliker has been interim head of Civil Engineering at K-State which has limited his time on the project. Those interim duties will end by July 1, 2008 and he will be spending more time on this work. The doctoral student on the project is concentrating on modeling small reservoirs to determine the net amount of percolation from them.

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, 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 River Compact agreements, then the level of detail at which we are forced to work because of limited financial resources are likely not sufficient.

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 at this time. Additional time will be needed to get the overall modeling package into a usable form to give to the agency.

References Cited:

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

Koelliker, J.K., J.J. Zovne, J.M. Steichen, and M.W. Berry. 1981. Study to assess water yield changes in the Solomon Basin, KS: Part I --Final Report. Kansas Water Resources Research Institute, Manhattan, KS.

REPUBLICAN RIVER BASIN

Fourth 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

July 31, 2008

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E. Inventory of Terraced Lands.

F. Detailed Progress Report of Kansas State University.

G. Detailed Progress Report of University of Nebraska-Lincoln

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 CROPSIM 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 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.

A more detailed discussion of the water balance model and modeling approach was included in the Third Annual Status Report, August 2, 2007, and additional information is included in Appendix F of this report.

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 include 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

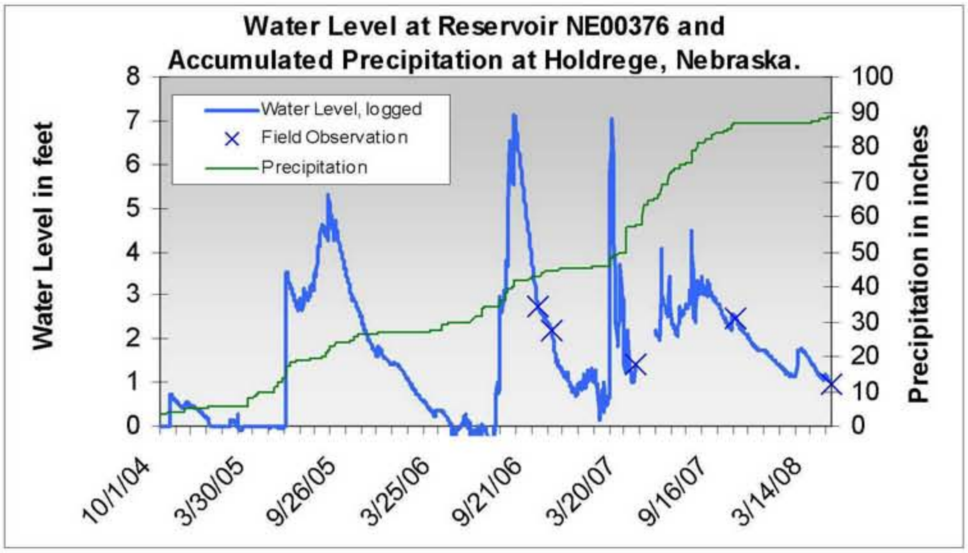
Two levels of investigation are needed for the non-federal reservoirs: (1) monitoring of a sample of reservoirs to characterize how and when these reservoirs fill and drain and (2) an investigation at one reservoir to better understand evaporation from these small reservoirs. There are 716 non-federal 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, 2007 showed that all eleven reservoirs had stored water, many of them during a runoff event on or about April 24. Site visits to the 20 reservoirs in Nebraska during the week of April 21, 2008 found that 11 of the reservoirs were dry. However, site visits to the 11 reservoirs in Kansas during early June 2008 found only two dry reservoirs. 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 two years. The May 2006 through May 2008 precipitation totaled about 66 inches, nearly 8 inches in April 2007, and 120 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 a Single 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. The research team had planned on using a Bowen Ratio system at one reservoir site to measure evaporation from a small pond. This approach has been abandoned because of difficulty in finding a small reservoir in which to install this expensive equipment. The research team will instead focus on using a process-based model for reservoir evaporation with calibration data from a reservoir in an arid watershed in central

Kansas. Both modeling and measurements will be used to improve the predictions for the POTYLDR model.

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 of the Third Annual Status Report 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 Table 1:

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

Additional analysis of data on DPL Hogan reservoir through March 2008 shows that it follows the same relationship between daily seepage rate and depth of water as determined from the previous analysis.

Land Terracing

Three separate levels of investigation are needed for land terracing: (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 storage condition was developed. The revised plan prescribes site investigation of about 200 terraced fields. UNL is serving as the lead in this part of the study. The terrace condition assessment study plan is include in Appendix D.

The survey is being conducted through the use of a survey-grade GPS system that was loaned to the project by the Kansas Department of Water Resources. The GPS system was installed on an all terrain vehicle to allow for rapid surveying of terraces and field boundaries. The survey-grade GPS provides accurate spatial and vertical resolution of the field topography. The GPS system logs the horizontal location and the elevation within the field. The system is being used to define field boundaries and to develop estimates of the storage capacity of two terraces within each field that is surveyed. Figure 2 is an example of the type of topographic map that results from the survey of a 35 acre field with seven terraces. For this specific example field, one terrace would store 0.89 inches of runoff from the contributing drainage area, and one terrace would store 1.05 inches of runoff. A more detailed description of the survey process and utilization of the data is presented in Appendix G.

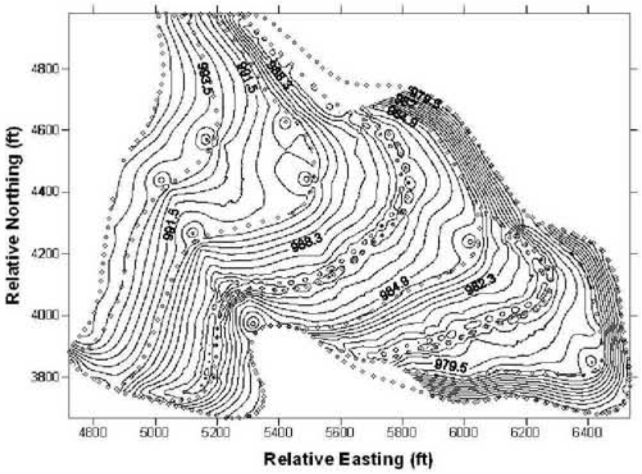


Figure 2. Topographic map of terraced field produced from field survey.

(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 3 indicates the relative location of the contributing area and the terrace channel. The five terraced fields have been monitored for two growing seasons.

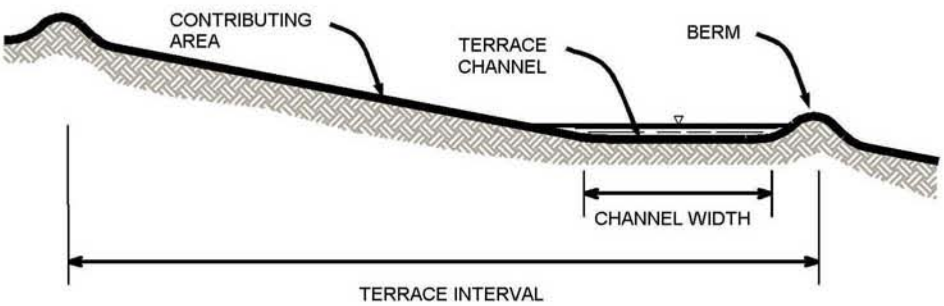


Figure 3. Cross Sectional View of Typical Terraced Land.

A more thorough description of monitoring at the terrace sites and an overview of the data collected has been presented in the Second and Third Annual Report so it is not repeated in this report.

The field measurements provide data on the characteristics of the water balance for the terrace channel and the contributing area. However, it is very difficult to directly measure either ET or deep percolation on small areas. A process-based model was used to simulate crop growth and the water balance for each area. The model provides estimates of all aspects of the water balance including ET and deep percolation

The process-based model was calibrated using measurements from the field sites. Initial calibrations were made and the model used to simulate some initial results for a limited number of conditions. Table 2 has the results of the simulated water balance at the Norton, Kansas site. Our goal is to improve the partitioning of water into runoff, deep percolation, and ET.

Table 2. Simulated water balance for the cooperator's field near Norton, Kansas, for the period January 1, 2005 through December 31, 2007.

	Contributing Slope	*Terrace Channel*
Precipitation (cm)	165	165
Runoff (cm)	3.88	0.00
Run-on (cm)	0	325
ET (cm)	157.7	186.8
Deep Percolation (cm)	28.2	310.0
Change in Storage (cm)	-24.8	-6.7

The simulated deep percolation from the terrace channel is about ten times the amount for the contributing area for the two-year period from 2005 through 2007 at the Norton site. The evapotranspiration from the terrace channel over the two-year period was about 30 cm more than for the contributing area.

The accuracy of partitioning precipitation into runoff, deep percolation or evapotranspiration from the contributing area and partitioning in the terrace channel depends on estimating the rate of infiltration. The infiltration rate depends on the hydraulic conductivity of the soil which in turn depends on the tillage practices employed. The POTYLD model used to simulate the water balance of cropping practices depends on the curve number method to estimate infiltration. Routines were developed to adjust the curve number for the POTYLDR model based on hydraulic conductivity and tillage practices to improve simulation of the water balance for the terraced fields.

The resulting hydraulic conductivity-curve number relationship is shown in Figure 4. As illustrated the curve number could range from a low of 60 to a maximum value of 85.

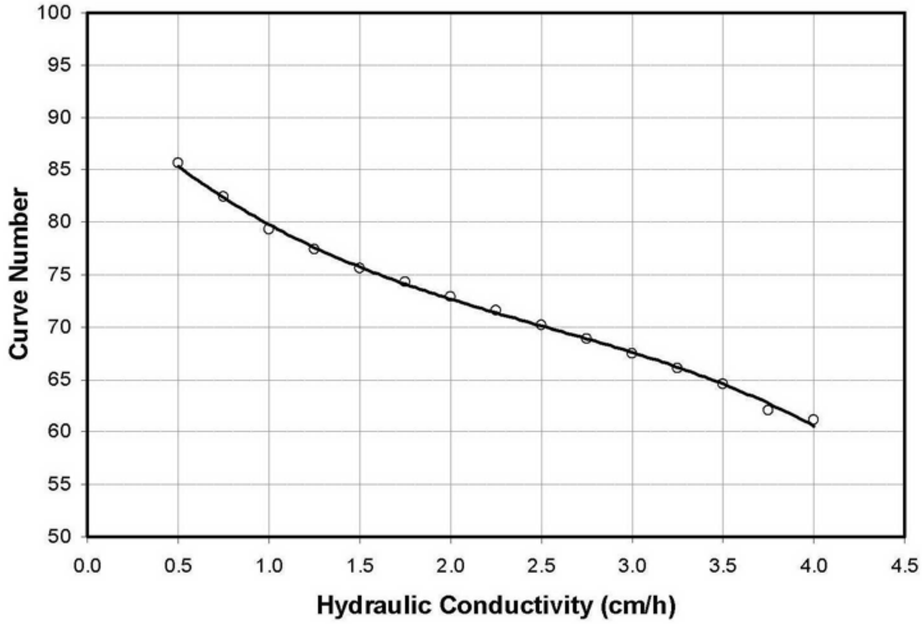


Figure 4. Effect of change in hydraulic conductivity on the curve number.

Model simulations were used to determine the variability of hydraulic conductivity from eco-fallow cropping systems. The pattern for the curve number for a three-year period for an eco-fallow system is shown in Figure 5. The curve number for the three-year period varies from about 70 to about 75.

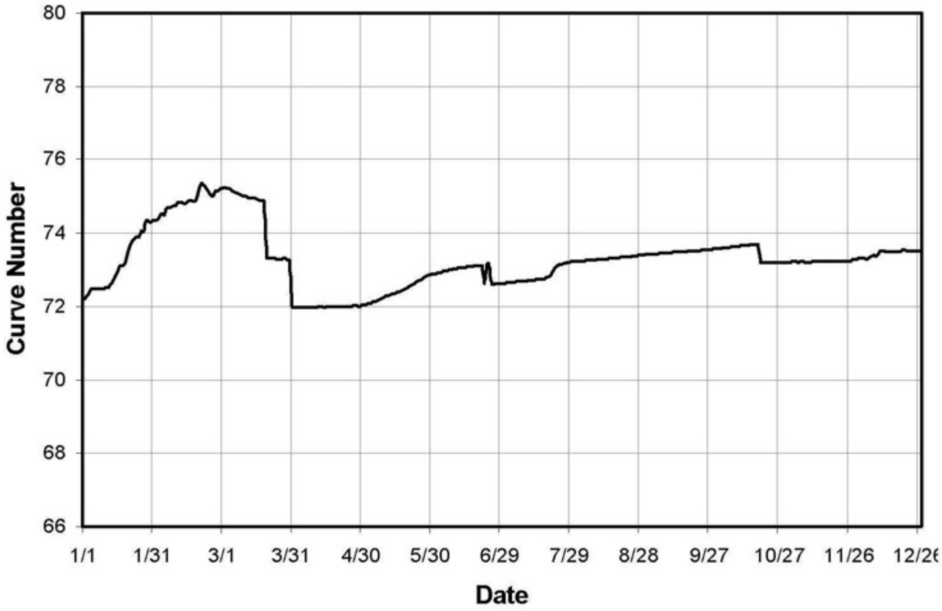


Figure 5. Simulated change in curve number due to tillage and erosion effects.

These results show the nature of the variability in the curve number for one of the cropping systems that is common in the Republican Basin. We will continue to apply these mechanistic models to improve the input parameters for the POTYLDR model.

A more detailed discussion on data collection to help define the water balance at the terraced sites and using that data to develop input to the POTYLDR water balance model 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. A summary of preliminary work is described in more detail in the Third Annual Status Report. Those results and the results discussed below should be considered preliminary because they do not include enough field data to properly calibrate the model. Based upon previous work, however, the results appear to be reasonable.

To further evaluate the overall approach to the model simulation, the USGS 06847900 PRAIRIE DOG C AB KEITH SEBELIUS LAKE, KS was chosen as a representative sub-basin on the south side of the main stem of the Republican River. It is an unregulated stream that has a total drainage area of 590 square miles all of which is described as contributing. The watershed begins in west central Thomas County west of Colby and extends generally northeastward to the streamgaging station about 10 miles west of Norton. The sub-basin includes parts of Sheridan, Decatur, and Norton Counties. Total stream length is nearly 100 miles.

The previously-developed version of POTYLDR was used to simulate the operation of important land use conditions as representative HRUs. Terraced cropland systems, 141,272 acres, were represented by conventional level, closed-end terraces in good conditions with a 3-year crop rotation of wheat-rowcrop-fallow with good residue management. Unterraced cropland, 82,591 acres, was represented by the same cropping system but with no terraces. The remainder of the watershed, 153,737 acres, was represented by range/pasture with good management practices. For analysis purposes, the average for a simulation with 60 years of continuous daily precipitation and minimum and maximum temperature were made to get the average values for use in the overall sub-basin water balance.

The weighted average runoff from the HRUs at the edge of the field averaged 0.44 inches/year. After adjustment for transmission losses, the estimate of the contribution of runoff to streamflow at the streamgage was 6,400 acre-feet. This value is quite close to the average for the past 15 years of the record.

The effect of terracing on recharge is estimated using the percolation from the three HRU's. The weighted average percolation from the HRUs is 0.41 inches/year or 12,900 acre-ft/year. The effectiveness of this percolation to actually become usable groundwater is uncertain. Some of it may return as springs or get close enough to the surface to be drawn up by deep-rooted vegetation. The estimated effectiveness used here is 80%. The net recharge from the land is then estimated to be 10,300 acre-ft/year. Adding the land recharge to the alluvial groundwater recharge then produces an estimated total annual average recharge of 15,300 acre-feet or about 0.5 inches over the sub-basin.

The effects of the terraced lands can be estimated by considering the extent of the land terraced in the sub-basin and the difference between the average depth of runoff and the depth of percolation between the terraced land and the same land assuming it were unterraced. This assumes that the terraced land, if it were unterraced, has the same runoff and percolation characteristics as the unterraced land in the sub-basin.
The estimated net effects of the terraces are that streamflow from the sub-basin is reduced by 3,200 acre-ft/year and net groundwater recharge is increased by 200 acre-ft/year. There is not a direct method to determine if these values are, indeed, correct. Field measurements that are a part of this larger study are showing that terraces of the type in this sub-basin are preventing nearly all runoff from above them from being lost. Also, substantial amounts of percolation below the terrace channel are being measured.

This analysis represents to overall approach for estimating the effects of terraced lands on streamflow and groundwater recharge. Indirectly, it also includes estimated effects of small dams in the sub-basin; however, those effects are still being worked on in another part of this project. This analysis needs to be applied to a sub-basin in the Nebraska portion of the basin to provide more confidence that is will produce results that are judged to be reasonable before it is applied to sub-basins throughout the basin.

A more detailed discussion on the application of the water balance model, evaluation, and discussion of results is included in Appendix F.

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 3 shows the expenditures by each entity for each of the study years.

Table 3. -- 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	Not reported		9,369
Kansas[3]	40,009	22,307	8,193	21,644	22,129		74,273
Nebraska	12,938	23,219	28,023	34,846	32,453		118,541
KSU		0	45,400	77,121	65,920	3,561	192,002
UNL		0	189,400	142,406	74,120	11,894	417,820
Reclamation[4]		64,876	25,350	85,969	13,685		189,880
NRCS		0	7,125	0			
Total		$116,027	$307,235	$361,986	$208,307		$1,001,885

[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, July 1 through April 30, 2007, and May 1, 2007 through April 30, 2008.

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

Study expenditures totaled $986,430 through April 30, 2008, with an additional amount of $15,455 during May 1 through early June, 2008, for a total expenditure of $1,001,885.

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. During 2007, Kansas purchased and supplied a survey grade GPS system to the University of Nebraska staff to use for conducting the terrace condition assessments and an equipment lease cost of $8,000 has been included in contributions by Kansas. Kansas has contributed $74,273 of in-kind services towards the study from the date of approval of the study on July 27, 2004 through April 30, 2008.

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 surveyed these (and other non-federal) reservoirs to produce area-capacity tables. Nebraska has contributed $118,541 of in-kind services towards the study from the date of approval of the study on July 27, 2004 through April 30, 2008.

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, 2008 were about $189,880.

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. Reclamation modified the funding agreement with UNL in July 2007 to include an additional $98,000 to accomplish the terrace condition assessment.

Kansas State University – Through April 30, 2008, KSU's Cooperative Agreement expenditures have been about $188,441 and an additional amount of $3,561 from May 1 through early June, 2008, for a total expenditure of $192,002. Reclamation has obligated a total of $269,126 to KSU leaving $77,124 of unexpended funds.

University of Nebraska - Through April 30, 2008, UNL's Cooperative Agreement expenditures have totaled about $405,926 and an additional amount of $11,894 from May 1 through early June, 2008, for a total expenditure of $417,820. Reclamation has obligated a total of $477,266 to UNL leaving $71,754 of unexpended funds. Obligated funds that are unused in fiscal year 2008 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 expenditure for this work was $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

During the fourth year, June 1, 2007 thru May 30, 2008, the terrace condition assessment got underway with two of the counties in Nebraska containing the most terraces nearly completed by mide-June 2008. Field data collection at terrace sites has been completed for two of the three years that are typical of ecofallow, common in the Republican River Basin. Preliminary water balance partitioning was completed for example terrace sites. The field data was used along with various simulation models to develop information for adapting the POTYLDR model to represent conditions in the Republican River Basin. The field data collection and adaptation of the POTLYDR model is necessary to improve the partitioning of water into runoff, deep percolation, and evapotranspiration. The POTYLDR model was used to simulate the operation of important land use conditions as representative HRUs in the Prairie Dog Creek basin above Keith Sebelius Lake in Kansas. This evaluation included making estimates of the effects of terracing on streamflow and groundwater recharge for the sub-basin. Model calibration was not completed within the expected timeframe, which will mean less time to develop final model results.

PLANS FOR FIFTH AND FINAL YEAR

Data collection for the reservoir and land terrace sites will continue until May 2009. The assessment of terrace condition will continue and the Conservation Committee will need to gauge the progress of the assessment survey by about mid-October and determine how many more terraced sites can be surveyed in order to complete the study within the expected time. The research team will continue to use the process-based models with field data to develop input data for the water balance model. As additional water balance model data is developed, the model will be refined and use to update the Prairie Dog Creek subbasin and applied to the Medicine Creek subbasin. The water balance model will than be applied to the remaining subbasins. It is expected that a draft summary report of the study will be available for presentation to the Compact Administration during the late summer of 2009.