REPUBLICAN RIVER BASIN

Kansas

v.

Nebraska and Colorado

REPORT FULFILLING REQUIREMENTS OF SECTION VI B.1, FINAL SETTLEMENT STIPULATION

AND

STUDY PLAN PROPOSAL ON THE IMPACTS OF NON-FEDERAL RESERVOIRS AND LAND TERRACING ON VIRGIN WATER SUPPLY

Prepared by

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

March 29, 2004

Conservation Committee Concurrence
on
Report Fulfilling Requirements of Section VI B.1, Final Settlement Stipulation
and
Study Plan Proposal
for determining
Impacts from Non-Federal Reservoirs and Land Terracing
On Virgin Water Supply – Republican River Basin

The undersigned representatives of the States of Kansas, Nebraska, Colorado, and the United States hereby acknowledge that they have participated in and contributed to the activities of the Conservation Committee in preparing the subject Report and Study Plan Proposal, and concur that this Report and Study Plan Proposal should be submitted to the Republican River Compact Administration for their review and consideration.

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George Austin, State of Kansas

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Gayle Starr, State of Nebraska

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Megan Sullivan, State of Colorado

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Doug Christensen,
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INTRODUCTION

A. Background

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 litigation. On December 15, 2002, the states completed a Final Settlement Stipulation and the Special Master approved the stipulation in February 2003.

The Stipulation required the States, in cooperation with the United States, form a Committee by January 31, 2003 to be known as the Conservation Committee. 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. A list of the current Committee membership is attached as Appendix A.

B. Statement of Problem

Agricultural conservation practices have been widely established in the Republican River Basin. The primary purpose of these practices is to conserve water for improved crop yields, reduce soil erosion, improve water quality and provide for stock watering. These practices may also have secondary impacts on surface runoff and streamflow yield and enhancement of groundwater recharge. In the Republican River Basin initial survey data indicates that land terraces serve about 1.7 million acres and there are several thousand water bodies. Only limited attempts have been made to address the impact of land terraces and reservoir development on streamflow and these studies draw differing conclusions. Concurrent with the implementation of ponds and terracing was the development of irrigation from groundwater and changes in cropping and tillage practices. As these developments also impact surface flows, it adds complexity to the analysis of the effects of ponds and terraces. There is a need to investigate this issue in more detail to determine if more conclusive findings can be made regarding how land terraces and non-federal reservoirs impact the Compact water allocations for Colorado, Kansas and Nebraska.

The study is intended to assess the impacts of non-federal reservoirs and land terracing on the water supply within the Republican River Basin above Hardy, Nebraska, including the effects for each of the Designated Drainage Basin identified in the Republican River Compact.

C. Committee Responsibilities

As outlined in Section VI of the Final Settlement Stipulation, the Conservation Committee is required to complete the following by April 30, 2004:

1. Evaluate the available methods and data relevant to studying the impacts of non-federal reservoirs and land terracing practices on water supplies, including a review of any existing studies and their applicability to the Basin;

2. Determine the general types of data that are available and relevant to the study;

3. Determine the availability of data throughout the basin, and assess the level of accuracy and precision of the data;

4. Agree on standards for data;

5. Identify additional data necessary to determine the quantitative effects of non-federal reservoirs and land terracing practices on water supply;

6. Propose a methodology for assessing area-capacity relationships for non-federal reservoirs; and

7. Submit to the Republican River Compact Administration (RRCA) a proposed study plan to determine the quantitative effects of non-federal reservoirs and land terracing practices on water supplies, including whether such effects can be determined for each Designated Drainage Basin.

This report is intended to fulfill the Committee responsibilities by addressing each of the above assignments.

STUDY DESCRIPTION

A. Previous Studies Reviewed

A number of previous studies were reviewed to determine if studies already exist that are applicable to determining the impacts of non-federal reservoirs and land terraces on the water supply in the Republican River Basin. While several of these studies provide good insight into potential methods for addressing this issue, none of the studies that were reviewed provide results that can be directly applied to determine actual impacts of reservoirs and terraces on the water supply in the Republican River Basin. A list of the studies that were reviewed is included as Appendix B

B. Study Methodologies Evaluated

The Committee considered and evaluated a number of different potential study methodologies. The methodologies reviewed are summarized below.

1. Multiple Regression: Multiple regression procedures are widely used in social and natural science research to develop relationships between several independent, or predictor, variables and a single dependent variable. Multiple regression involves the discovery of the relationships between various parameters and obtaining an equation that satisfies that relationship. This procedure may be applicable to addressing the question of whether the development of reservoirs and/or land terraces has had an impact on the surface water supply in the Republican River Basin. In other words, is there a correlation between the development of non-federal reservoirs and/or land terraces and the decline in streamflow? A significant problem with this approach is that it requires accurate records on the historical development of both reservoirs and terraces. Such data may be difficult to locate and assemble. In addition, building of ponds and terracing occurred simultaneously with the development of irrigation from groundwater, installation of surface water irrigation projects and changes in cropping and tillage practices. All of these factors contribute to declines in streamflow. In such cases, proportioning streamflow declines to specific practices can be difficult and imprecise.

2. Synoptic and Hydrogeomorphic Assessment: Methods have been developed that assess changes in a watershed based on characterized physiographic (topographic, geologic, pedologic and hydrologic) features and cultural practices (land use, land cover or hydrologic modifications). Early versions of these types of studies were referred to as Synoptic Assessment. Synoptic Assessment appears to have evolved into Hydrogeomorphic Assessment (HGM). The HGM method has been widely applied to wetland assessment. Shafer, et al. (2002)[1] define the HGM method as a "collection of concepts and methods for developing functional indices, and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in the region."

Once developed, the HGM method allows for rapid and relatively inexpensive analysis of the condition of wetlands (or watersheds) across a basin. It has proved useful for repetitive assessment over broad areas. The disadvantages of the HGM method for the Republican River Study are that:

a. Development of the required models and functional indices could involve substantial time and effort.
b. Some important relationships for terraces and ponds may not be adequately described in past applications to wetland ecosystems.

[1]Shafer, D. J., Herczeg, B., Moulton, D. W., Sipocz, A., Jaynes, K., Rozas, L. P., Onuf, C. P., and Miller, W. 2002. "Regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions to northwest Gulf of Mexico tidal fringe wetlands," ERDC/EL TR-02-5, U.S. Army Engineer Research and Development Center, Vicksburg, MS, (found at http://www.wes.army.mil/el/wetlands/pdfs/trel02-5.pdf).

c. The HGM method would require modification to estimate the quantitative effects of terraces and ponds rather than an index compared to reference conditions.

More research is needed to develop plans for the HGM method and to evaluate its potential for quantifying the effects of non-federal reservoirs and land terracing practices on water supplies in the Republican River Basin above Hardy, Nebraska.

3. Rational Method (Technical Bulletin No. 1352): The rational method of analysis consists essentially of applying experience and knowledge of known effects to the problem. A central tenet of the method is dividing the problem into elements based on climate, evapotranspiration, soils, topography, vegetation, land use and treatment, and streamflow. Only those elements subject to effects of conservation use and treatment of land are analyzed in the method. Applying logic to the water-yield problem indicates that water yields are residuals from precipitation after the demand of evapotranspiration are met. The challenge with the Rational Method is to develop relationships to translate experience and knowledge into quantitative relationships.

4. Soil Water Balance (Budget) Models: (POTYLDR, SWAT & Others) Water balance or budget models simulate the daily change in the water budget for different climatic and land-use conditions to estimate the dispensation of precipitation as interception, runoff, actual evapotranspiration, percolation, and change in water content in the soil. Some water balance models that are being considered are briefly described below.

a. The Potential Yield Revised Model (POTYLDR) simulates the water budget of representative tracts of land on a daily basis. The model allows for different land uses and estimates the water yield on a monthly or annual basis for a drainage area. The model was developed for High Plains conditions and includes the range of land uses found in the Republican River Basin. Runoff curve numbers (RCN) are used to partition daily precipitation into runoff and infiltration. The RCN technique has been widely used to predict runoff from design storms and to design soil water control facilities. It follows that the RCN method can predict runoff over a period of time provided the antecedent moisture condition, how wet the soil was at the time of each storm, can be determined. This technique to assess runoff through a computer simulation model is now used widely in watershed simulation models. Recently, POTYLD was modified to include additional refinements and to include irrigation; consequently, the name was changed to POTYLDR.

b. The Soil Water Assessment Tool (SWAT) was developed by the USDA-ARS to simulate the impact of land use and management on watersheds. The model includes many processes to predict crop and plant development, plant water use, runoff, deep percolation and recharge and the water balance of reservoirs. The model integrates readily available soil

characteristics and builds on georeferenced databases for land and stream elevations. A geographic information system is used to simplify data management and to better present results. The method has been widely used across the United States, at varying resolutions, to assess water management issues. The method provides estimates of the inflow of water and sediment into reservoirs which may enhance long-term simulation of the effects of ponds and terraces. The model was recently modified to include estimates of irrigation demand.

c. Other models have been developed to simulate watershed processes. Those models contain components that are more robust than some procedures in either POTYLDR or SWAT. Research will be undertaken to extract important relationships from such models or to use such models to improve POTYLDR or SWAT to better account for the effects of terraces and ponds. Special care will be necessary to ensure that the impact of practices are not double counted when using water balance models and the groundwater model developed for the Republican River Settlement. Examples of areas that may contain overlap are the evapotranspiration from phreatophytes.

5. Direct Measurement: Ultimately, methods used to quantify the effects of terraces and ponds must be shown to be accurate. Limited amounts of directly measured empirical data are available to quantify impacts. Additionally, there have been many simultaneous changes in the basin that obscure effects of ponds and terraces when inflows and outflows to reservoirs are measured. Thus, there is a need to directly measure the effects of ponds and terraces for modern production practices. This portion of the study will involve the selection and monitoring of typical reservoirs and land terraces over several years. Monitoring would involve measurement of the dimensions of selected structures and installation of equipment for the measurement of such parameters as soil water profiles, precipitation, inflow, outflow, seepage, plant water use and evaporation. These data will be used to characterize the water balance for terraced and un-terraced lands, and for a range of reservoir conditions. Measurements of the water balance over several years on land upland from the terrace and from the terrace channel, as well as measurements of land that is not terraced, will provide for direct comparison of the effects of terracing. Evaporation and seepage from a range of reservoirs will also be assembled to provide data for the quantitative effects of ponds and the change of the effects with age and condition of the reservoir. Ultimately, these data will be used to calibrate and verify models identified in the previous section.

6. Analysis of Crop Yield Comparison: The impact of the land terracing could be estimated as the difference in evapotranspiration from the land area before terracing versus after terracing. One of the purposes of terracing is to increase crop yield. The increase in evapotranspiration resulting from terracing could be estimated by comparing the crop yield for a terraced area with a non-terraced area growing the same crop and with similar topography, soils and management. The difference in crop yield could then be equated to a difference in

evapotranspiration required to provide the increase yield. The study would involve detailed record keeping on selected farms over a multi-year period to compare yields. Results could then be used to estimate regional differences in water use. Yield records, from the field, would be used to correlate regional yield results. Data collected from these measurements could be used as an independent method or to provide values for calibration and verification of other methods.

7. Combination of Methods: It is unlikely that any one method alone will provide the reliability required for the study. Therefore, a combination of the described methods will be pursued to provide for independent corroboration of study results.

C. Recommended Study Methodology

Each of the above methodologies was carefully reviewed by the Committee to identify the best method(s) for assessing the effects of non-federal reservoirs and land terracing practices. Pros and cons for each method were assessed and it was determined that a method that relies primarily on soil water balance models to simulate the impact of terraces and small reservoirs will provide the best results. Field experiments involving direct measurements will be used to verify processes in the simulation models and to provide accurate parameters. Crop yield comparisons will also be made as a means of comparing evapotranspiration with and without a terrace. The study will also rely on historical climatic records and surface water flows for simulation and verification. Other data required for accurate modeling will be inventories of current land use practices and georeferenced soil, stream and reservoir data. The individual phases of the study are delineated below.

1. Evaluation and Modification of Existing Models: This phase of the project is primarily an evaluation of the existing modeling methods included under the Soil Water Balance Models listed above and improvement of those models. At least three models will be studied to determine the most reliable methods. Most likely components of several procedures will be integrated into one model for simulation of impacts of terraces and small reservoirs. At this time the POTYLDR and SWAT models appear to show the best promise for this study. A modified version of POTYLDR will be used, with enhancements from other models, to account for the effects of terraces and ponds on water supply.

At the current time the POTYLDR model is not interfaced with a geographic information system (GIS) to efficiently integrate information for models simulation or to summarize simulation results. A major initial effort will include the integration of the model with an ARCVIEW GIS. Data layers will be developed for the spatial inputs required to operate the model. Since the simulations with the POTYLDR model will be used to simulate the impacts of terraces and small reservoirs for individual water sheds and not the whole Republican River Basin in one simulation, it will be important to efficiently disaggregate the basin into subwatershed that are modeled independently. The GIS will facilitate this process and will integrate with the other layers of information needed to operate the model.

2. Development of Databases: Several databases will be required for the project. Other information will likely be necessary as the project progresses. Data will be needed for at least the following:

a. Soils information including the distribution of soil series in the basin, and soil type and slope distribution.
b. Location and Properties of Streams and Rivers
c. Location and extent of terraced lands
d. Location and properties of small reservoirs
e. Delineation of watersheds
f. Topography
g. Land use practices
h. Farming practices
i. Climatic conditions
j. Precipitation amount, rate, and distribution.
k. Stream flow records

3. On-The-Ground Verification: Methods used to quantify the effects of terraces and ponds must be shown to be accurate. Limited amounts of directly measured empirical data are available to quantify impacts. Additionally, there have been many simultaneous changes in the basin that obscure effects of ponds and terraces. Thus, there is a need to directly measure the effects of ponds and terraces for modern production practices. This portion of the study will involve the selection and monitoring of a sample of typical reservoirs and land terraces over a period of several years. Monitoring would involve measurement of the dimensions of selected structures and installation of equipment for the measurement of such parameter as soil water profiles, precipitation, inflow, outflow, seepage, plant water use and evaporation.

a. Monitoring Requirements

The following parameters will need to be carefully measured and monitored to perform an accurate evaluation of water use from reservoirs and terraces.

1. Type of terrace/reservoir
2. Condition of terrace/reservoir
3. Physical characteristics of terrace/reservoir
4. Soil type
5. Slope of drainage
6. Reservoir Aspect
7. Prevailing Wind Direction and Speed
8. Precipitation Amount and Pattern
9. Spatial Distribution of Sampling Sites
10. Crop Management Practices
11. Seepage/Deep Percolation
12. Evaporation/Evapotranspiration

b. Field Studies for Terraced Land

A small sample of about 8 representative terraced fields will be selected for detailed water balance studies. The studies will involve the installation of soil water measurement instrumentation that will log the soil water content of the soil profile through and below the root zone. Measurement sites will be installed in the upland portion of the terraced field and in the terrace channel. The fields will be carefully surveyed to provide slopes and terrace characteristics. Outlets to the terraces will be included in the survey. Where possible, flow measurement equipment will be installed to monitor the surface runoff from the terraced field. Precipitation will be measured with recording rain/snow gauges. Farming practices will be inventoried. Local soil properties will be measured and all equipment will be locally calibrated. The depth of water in terrace channels will be continually monitored.

Crop yields from producer fields will be used to compare consumptive use or terraced and un-terraced land. Experiments will be included on terraced fields to measure the yield in sectors perpendicular to the centerline of the terrace channel. This will allow for the comparison of the effect of the terrace and provide for comparisons under identical conditions unlike what would occur if adjacent fields were evaluated. The yield comparison methodology allows for integration of the effects over larger areas and measurement in numerous locations and fields. The data will be used in modeling studies to ensure that simulation of cropping systems is sufficiently accurate for modeling the watershed of the Republican River Basin. The data will also provide a direct comparison of the effects of terracing versus the non-terraced fields.

c. Field Studies for Non-Federal Reservoirs

The water balance of representative non-federal reservoirs will be determined. A small sample of about 5 reservoirs will be selected for detailed monitoring. Measurements will include development of the volume/area versus stage relationships for the reservoir. Sediment deposition in the reservoir will also be assessed. Equipment will be installed within a small sample of selected reservoirs to measure the stage, turbidity and water temperature. Evaporation rates from the reservoir will be measured using submerged tanks with stage recording equipment. Water conditions within the tanks will be monitored similar to methods used outside of the tanks. Seepage rates will be computed as the residual of daily water level changes minus the measured evaporation rate. The effect of the depth of water on evaporation rates will be studied to ensure that measurements are accurate for the whole reservoir. A range of reservoirs will be instrumented to provide for conditions found across the basin. Characteristics of the watershed that affect the water supply to reservoir will be determined and quantified.

A larger sample of about 50 reservoirs will be monitored 4-6 times during each year, to determine how the reservoir surface area fluctuates during the year. The reservoir's surface area will be measured by using inexpensive Global Positioning Systems (GPS) receivers. With the use of a GPS receiver a field person could track their path around the reservoir at a water level and use the GPS unit's built-in calculator to determine the reservoirs surface area. These surface area measurements, along with the more detailed monitoring data collected for the small sample of reservoirs, will be used to calibrate the water balance models for the full set of non-federal reservoirs in the basin with storage capacities of 15 acre-feet or greater. A detailed description of the monitoring program for this larger set of reservoirs is included as Appendix D.

This data should be useful to the RRCA and its Engineering Committee as they consider revisions to methods to determine the consumptive use due to non-federal reservoirs.

4. Application of the Water Balance and GIS Models: The Water Balance Model will be used to simulate conditions for typical cropping, soil and other condition in what can be referred to as representative hydrologic units. The representative hydrologic units provide the water balance for a typical field or reservoir in a portion of the subwatershed. The total contribution from similar lands in the subwatershed will be computed by scaling up the results to the amount of land for the respective land use. A GIS model will be needed to determine the number of representative hydrologic units required for a subwatershed and to scale up simulation for each representative hydrologic unit. The GIS model will also provide summaries of impacts of terraces and small reservoirs for components of subwatershed and will be used to integrate the results for the subwatershed being simulated. Four model simulations will be made for a sample study period of about 30 years using climatic conditions from 1972 through 2002. Simulations will be made for conditions with no terraces or non-federal reservoirs, with terraces but no non-federal reservoirs, without terraces but with non-federal reservoirs, and with both terraces and non-federal reservoirs. The modeling results will be summarized for each of the subwatersheds individually.

In addition to other effects, terracing and non-federal reservoirs increase the opportunity for recharge into the Basin's groundwater systems. To the extent these practices increase recharge, they may also enhance baseflows in the Basin. The RRCA groundwater model is the best tool available for determining the impact of recharge changes on the Basin's baseflows. Thus part of this study effort will be to use the RRCA groundwater model to estimate the impact terraces and non-federal reservoirs have on baseflows in the Basin. This impact will be included in the study as an integral part of the overall impact terraces and non-federal reservoirs have on the basin water supply.

5. Anticipated Problems: Over time a number of changes have occurred that affected both terraces and non-federal reservoirs. A number of reservoirs have silted in or breached. When center pivots were installed a number of terraces

were either taken out or modified to allow easier passage of the pivot. Due to these changes finding terraces and reservoirs that provide a representative and statistically accurate sample may be difficult. Also locating comparable terraced and non-terraced fields could be difficult. Using terraced and non-terraced areas of the same field may greatly simplify comparability of findings. Finding matched fields in terms of the parameters and variables listed above will also be difficult.

Although both POTYLDR and SWAT include techniques for simulating transmission losses there are a number of complications in accurately addressing this issue. Other procedures for addressing transmission losses will also need to be evaluated and tested to ensure that the final model is as accurate as possible.

A more detailed description of the Study Plan is included as Appendix C.

DATA REQUIREMENTS FOR STUDY

A. Relevant Data Needs

The following is a list of the identified relevant data needs for each identified category related to the study:

1. Non-Federal Reservoirs
    a. Surface area of reservoirs
    b. Reservoir volume
    c. Reservoir Type (use)
    d. Condition of reservoir (% silted in, breached, etc.)
    e. Reservoir location
    f. Contributing Drainage Area
    g. Date Reservoir Constructed

2. Land Terraces
    a. Surface area of land terrace
    b. Land terrace type
    c. Condition of terrace (% silted in, replaced with sprinkler irr., etc.)
    d. Land terrace location
    e. Contributing Drainage area
    f. Date terrace constructed/retired or replaced with sprinkler irrigation

3. Soil Characteristics
    a. Permeability
    b. Hydrologic groups
    c. Soil water holding capacity

4. Geologic Characteristics
    a. Presence and distribution of aquitards or aquicludes

5. Drainage Characteristics
    a. Slope Percent of Degree
    b. Slope Length
    c. Topographic characteristics

6. Streamflow Records
    a. Total stream flow
    b. Baseflow
    c. Surface Flow (non-baseflow)

7. Precipitation
    a. Amount
    b. Timing
    c. Frequency
    d. Intensity
    e. Location

8. Evaporation/Evapotranspiration
    a. Climatic data
    b. Pan Evaporation
    c. RRCA Model

9. Landuse/Landcover
    a. Past Cropping Patterns
    b. Current Cropping Patterns
    c. Future Cropping Patterns
    d. Tillage Practices

B. Potential Data Resources

A review was conducted to determine the available data resources. These resources include the following:

1. National Resources Inventory (NRI): NRI is the Federal Government's principal source of information on the status, conditions and trends of soil, water and related resources in the United States (non-Federal lands). Relevant data collected includes: a) land cover/use, b) irrigation, c) conservation practices, d) wetlands, e) conservation reserve program, and f) farmsteads. This data will be especially helpful in identifying terraces. There are 2203 primary sampling units monitored within the Republican River Basin.

2. Soil Survey Geographic Database (SSURGO): For decades the Natural Resources Conservation Service (NRCS) has been mapping and updating soil surveys in every county of the United States. In recent years NRCS has been digitizing these soil surveys making soils information electronically available via the internet. In the original soil mapping, the soil scientists mapped ponds to a minimum size of .037 acres. These ponds have been retained in the digitizing process, but have been adjusted to match the signature on the orthophotography.

The depth of the ponds cannot be determined from SSURGO.

3. Digital Orthroquads (DOQ): A digital orthophotograph is a digital image of an aerial photograph with image distortions removed, and corrections made. These DOQs are developed from 1999 NAPP flight coverage flown under the National Aerial Photography program.

4. State Inventory of Dams: Each state has some type of inventory for its dams. These inventories generally include information on location, stream, certain physical characteristics of the dam and construction data.

5. National Inventory of Dams (NID): As a result of the National Dam Inspection Act of 1972 and other related acts that followed, the Corps of Engineer conducted a nation-wide inventory of approximately 77,000 dams. The current NID is the result of an evolutionary process. The Corps continues to work closely with the Association of State Dam Safety Officials, FEMA and other state and federal agencies to update and publish the NID. A web-enabled version of the 1998-1999 NID update was posted to the Internet in January 1999. This database provides information on various dam and reservoir parameters for most of the dams in the Republican River Basin.

6. Republican River Compact Administration Groundwater Model: The groundwater model includes data on soil characteristics, streamflow records, precipitation, evaporation, ET, and landuse/landcover. One application of this model that is proposed in the study plan is to determine the changes in baseflow from the groundwater recharge changes caused by land terraces and non-federal reservoirs.

7. Satellite Imagery: Satellite imagery is available from several sources. Landsat 4/5 imagery is available from about 1984-present with a resolutions of 30 meters. Landsat 7 imagery is available from about 1999-2003 (now non-functional) with a resolution of 30 meters. Prices of each image scene ranges from $450 to $600. Scene size is about 100 miles by 100 miles for 30 meter resolution. ASTER images are presently available for visible and near infrared at 15 meter resolution and for shortwave infrared at 30 meter resolution. Commercial visible and near infrared images from Space Imaging are available with resolution of 1 meter. Cost of Space Imaging scenes are more expensive at about $1,500 per scene.

C. Available Data

Committee members representing Colorado, Nebraska and Kansas along with the United States each made a review of their available data and identified datasets relevant to the above data needs list. A summary of these datasets was prepared and is attached as Appendix E.

D. Additional Data Collection

Following acceptance of the study proposal by the RRCA the need for additional data

will be identified and procedures for collecting this data will be worked out.

E. Data Standards

It was agreed among the committee members that it would be counterproductive to further analysis the datasets until after the study proposal has been accepted by the RRCA. Once this has occurred, specific data required for that methodology will be reviewed for availability, reliability and accuracy.

METHODOLOGY FOR ASSESSING AREA-CAPACITY RELATIONSHIP FOR NON-FEDERAL RESERVOIRS.

An evaluation of various methods for assessing area-capacity relationship was conducted. Actual field survey data is available for a number of the Non-federal Reservoirs in the Republican River Basin. It is recommended that where this data is available it should be used to develop area-capacity for those specific reservoirs. Where field surveys have not been conducted to provide current or design information as to the reservoir's area-capacity relationship, the following polynomial formula can be used to provide an acceptable estimate.

$$\textbf{Area} = -.00009 \times \textbf{Volume}^2 + 0.1604 \times \textbf{Volume} + 2.01$$

Appendix F contains the analysis that was prepared to develop the above equation

TIME FRAME

The starting date for the study will be the date the MOU is signed between Colorado, Nebraska Kansas, Reclamation and the NRCS. This date is anticipated to be near the middle of June. The study will then run for a five year period or until June of 2009. A summary report will be provided to the RRCA at the completion of the study and, if desired by the RRCA, a final detailed report will be provided approximately 6 months following the completion of the study. A timeline diagram for the study is included in Appendix G.

STUDY ADMINISTRATION

The Committee recommends that the RRCA administer the study though the Conservation Committee. The Conservation Committee would carry out most of the administrative function under the direction of the RRCA.

STUDY RESPONSIBILITIES

A. United States

The United States is responsible for providing 75% of the cost of the study, which is not planned to exceed one million dollars. If the cost of the study exceeds one million dollars, the United States will be responsible for the entire additional amount. The Bureau of Reclamation (Reclamation) will develop agreements with the University of Nebraska – Lincoln (UNL) and Kansas State University (KSU) to fund the study work

performed by these universities. Both Reclamation and the NRCS will assist in providing any of their data resources that are useful to the study effort.

B. States

Each State will be responsible for one third of the 25% cost share required by the States for the Study, as outlined in the Final Settlement Stipulation. The States' portion may be provided entirely through in-kind contributions. As required by the Stipulation, each State will be responsible for inventorying the non-federal reservoirs in their respective State. The data base developed from this inventory will include location, properties and the existing condition of each of these reservoirs. Each State will also initiate and carry out a program for monitoring reservoir surface area for a sample of reservoirs as described in section B.3.c, Study Description.

C. University of Nebraska – Lincoln (UNL)

Reclamation will contract with UNL for the field study work involved with monitoring a small sample of land terraces and non-federal reservoirs as described under section B.3, Study Description. Derrel Martin with UNL will provide the lead for this contract work. It is anticipated that a Postdoctoral research assistant and two undergraduate student assistants will be employed in this efforts. These individuals will also assist with modifying and applying a version of the POTYLD water balance model to the land terraces and non-federal reservoirs in the basin.

D. Kansas State University (KSU)

Reclamation will contract with KSU for the development of a revised version of the POTYLD water balance model and for its application to land terraces and non-federal reservoirs in the basin (see section B.1, Study Description). James Koelliker with KSU will provide the lead for this contract work.

E. Coordination of Study Effort

UNL and KSU will closely coordinate their work to ensure a coherent study effort. Both Universities will share their work with Colorado State University (CSU). Comments and recommendations provided by CSU will be carefully considered by both UNL and KSU. Regular status reports will also be provided by UNL and KSU to the Conservation Committee. The States, Reclamation and NRCS will carefully coordinate their individual efforts to collect data and establish data bases that will be useful to completion of the study effort.

The MOU and cooperative agreements contained in Appendix H provide additional detail on the responsibilities of each of the entities involved in this study.

BUDGET REQUIREMENTS

Budget requirements are still being assessed but preliminary estimates are as follows:

A. Equipment	
8 Sites to Monitor Terraced Land Water Balance	$ 64,000
5 Sites to Monitor Reservoir Water Balance	$ 30,000
2 Computers	$ 8,000
Sub-total	$102,000
B. Personnel for 5 year Study	
2 Postdoctoral Research Assistants for Field Experiments, Modeling and Data Analysis (total of 10 person-years)	$400,000
2 Undergraduate Student Assistants (for 5 years)	$ 40,000
Sub-total	$440,000
C. Travel	
Research sites and Project Coordination	$ 20,000
Professional	$ 8,000
Sub-total	$ 28,000
D. Data Collection and evaluation by States	In-kind[1]
E. Direct Costs	$570,000
F. Indirect (@ 17.5% of Total direct)	$ 99,750
G. Additional Federal Costs (Assistance, oversight, administration)	$ 80,250
H. Total	$750,000

[1] The in-kind services provided by the states will equal $250,000. This will result in a total study cost of $1,000,000 which is the maximum cost allowed by the Settlement Stipulation.

AGREEMENTS

A general memorandum of understanding (MOU) has been drafted for signature by Colorado, Kansas, Nebraska, Reclamation and the Natural Resources and Conservation Service to identify individual responsibilities for completing and funding the study. Funding contracts or agreements will also be entered into between Reclamation and UNL, and Reclamation and KSU. Other agreements to fulfill various aspects of the study may also be needed. Some of these potential agreements may include Cooperative agreements and Interagency (Federal) agreements

A copy of the Draft Study MOU and contract/agreements with UNL and KSU are included in

Appendix H.

STATUS REPORTS

UNL and KSU will provide a status reports on the study progress to the Committee on a semi annual basis on December 1 and again on May 1. The Committee will integrate the semiannual status reports from UNL and KSU with other components of the study for an annual status report to the RRCA. The annual status reports will be provided to the RRCA about two weeks prior to the RRCA annual meeting which is normally held in early June of each year.

PRODUCTS/SUMMARY REPORT

At the end of the five year study period a number of study products will be prepared and provided to the RRCA. These products will be prepared by the study group in a summary document that contains the following:

A. An inventory of all of the non-federal reservoirs located in the Republican River Basin above Hardy, Nebraska with a storage capacity of between 15 acre-feet and 200 acre-feet. This inventory will include the reservoir's location, storage capacity at normal full pool, type of use and the reservoir's present operating status and condition.
B. An inventory of all of the land-terraces located in the Republican River Basin above Hardy, Nebraska. This inventory will include the land terrace's location, size, and type of terrace (open ended or closed). Where practical the inventory will also include the present status and condition of each terrace.
C. The quantitative effect of the non-federal reservoirs on water supply for each of the designated drainage basins and for the full Republican River Basin above Hardy, Nebraska.
D. The quantitative effect of land-terraces on the water supply for each of the designated drainage basins and for the full Republican River Basin above Hardy, Nebraska.
E. The combined effect of both non-federal reservoirs and land terraces on water supply for each of the designated drainage basins and for the full Republican River Basin above Hardy, Nebraska.

A detailed list of the products that the Committee presently plans to develop and provide to the RRCA upon completion of this study is included as Appendix I.

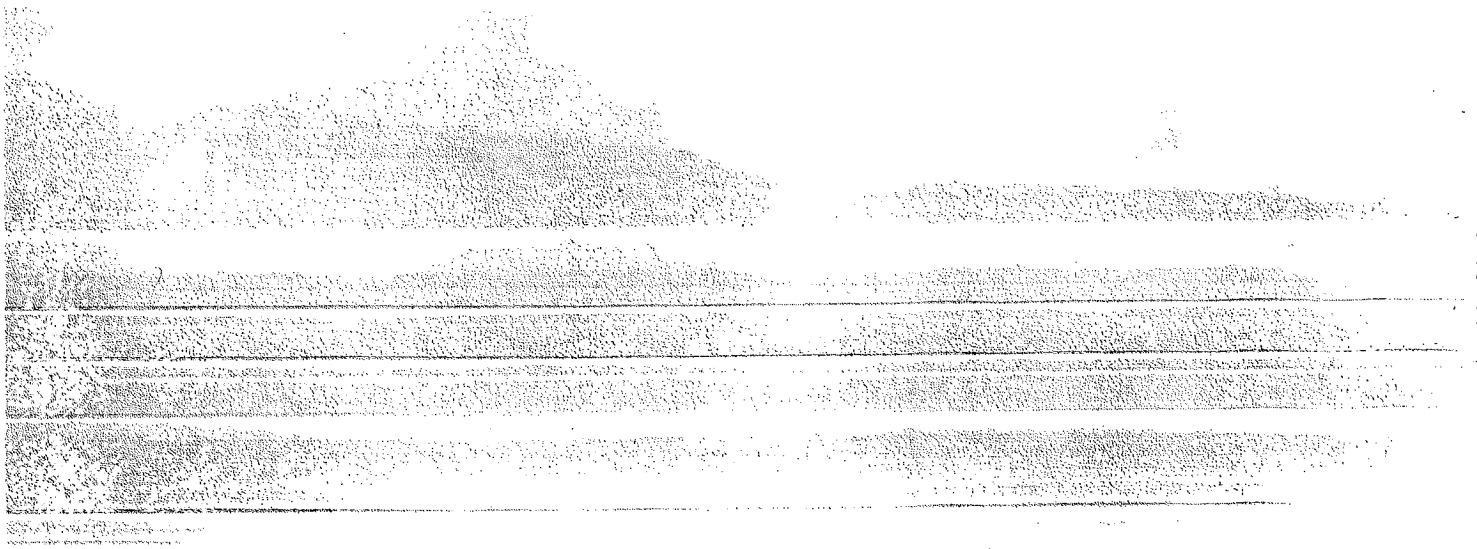
FINAL REPORT

Following completion of the study and delivery of a summary document to the RRCA, the RRCA will determine the need for a formal study report. If the RRCA determines that a final study report is required this report will be completed within 6 months following a request for the report by the RRCA. At this time it is recommended that this study report be prepared by the Conservation Committee to include the following:

A. Executive Summary
B. Study Purpose and Goals
C. Description of the Study Area
D. Budget
E. Study Time-frame
F. Organization and Authority
G. Study Methodology
H. Description and Documentation for the Water Balance Model used in study
I. Data collected and data bases used in study
J. Inventory of non-federal reservoirs and land terraces located in Republican River Basin
K. Findings and Conclusions
L. Appendices

It is also anticipated that the doctoral researchers participating in the study will prepare and publish professional papers documenting the study and its results. The doctoral researchers will provide the RRCA with a copy of any professional papers they prepare related to this study.


A



APPENDIX A

REPUBLICAN RIVER CONSERVATION COMMITTEE MEMBERS

United States

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Derrel Martin	Biological Systems Engineering 230 LWC University of Nebraska Lincoln, NE 68583-0726 dlmartin@unlnotes.unl.edu	402-472-1413

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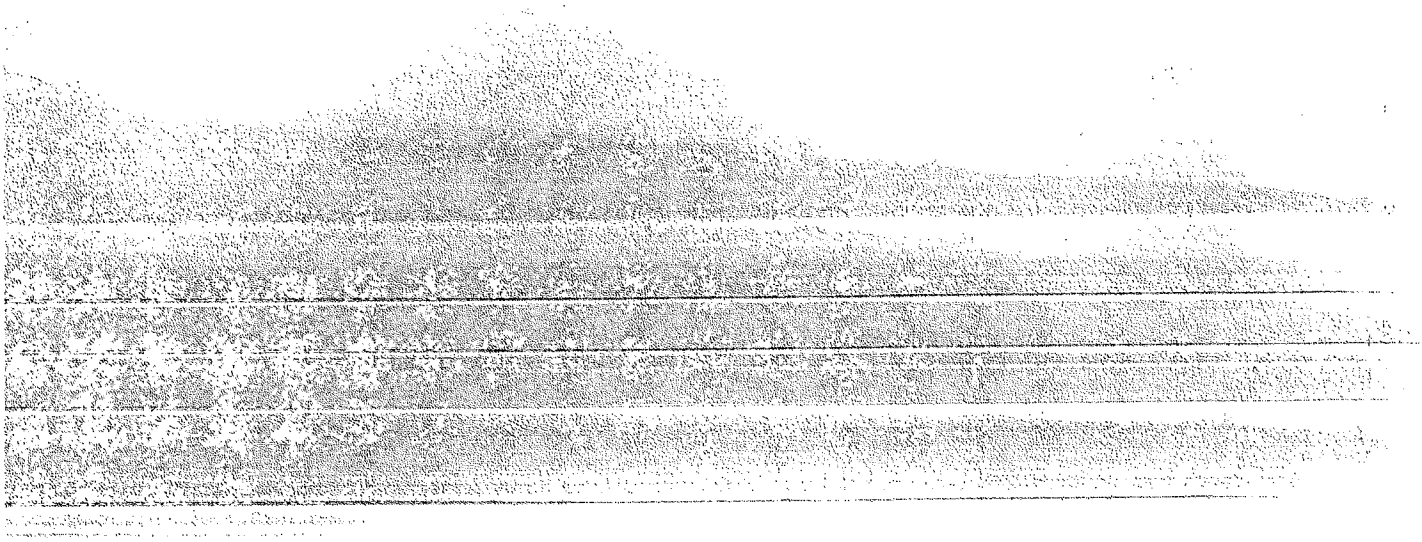
B



APPENDIX B

LIST OF PREVIOUS STUDIES REVIEWED

A. Perspectives on Sustainable Development of Water Resources in Kansas: James K. Koelliker, Ph. D., P.E., Professor and Head Department of Biological and Agricultural Engineering, Kansas State University, 1998.

B. Estimating Yield From Watershed Undergoing Changes: J.K. Koelliker, R.S. Govindaraju and S.L. Lewis; 1995.

C. Republican River Basin Water Management Study, Colorado, Nebraska, Kansas (Portions of Report): Bureau of Reclamation, February 1985.

D. Impact of Improved Agricultural Water Use Efficiency on Reservoir Storage in Sub-Humid Areas: James K. Koelliker, September 1984.

E. Missouri River Basin Hydrology Study Final Report (Portions of Report): Missouri Basin States Association, May 1983.

F. Technical Paper Agriculture Water Use Including Identification of Irrigated Lands (Portions of Report): Agricultural Water Use Work Group, Missouri Basin States Association, September 1982.

G. The Missouri River Basin Comprehensive Framework Study: Monthly Streamflow Tables and Depletion Estimates (Portions of Report); Prepared by Task Force on Depletions, Work Group on Hydrologic Analyses and Projections, Standing Committee on Comprehensive Basin Planning, Missouri Basin Inter-Agency Committee; May 1966.

H. Evaluation of Relative Effect of Conservation Measures and Groundwater Pumping on Reduction in Streamflow in Selected Sub-basins of the Republican River: A senior project for Water Science Major Bachelor of Science in Natural Resources Degree, University of Nebraska, Dorothy Pedersen, June 1999.

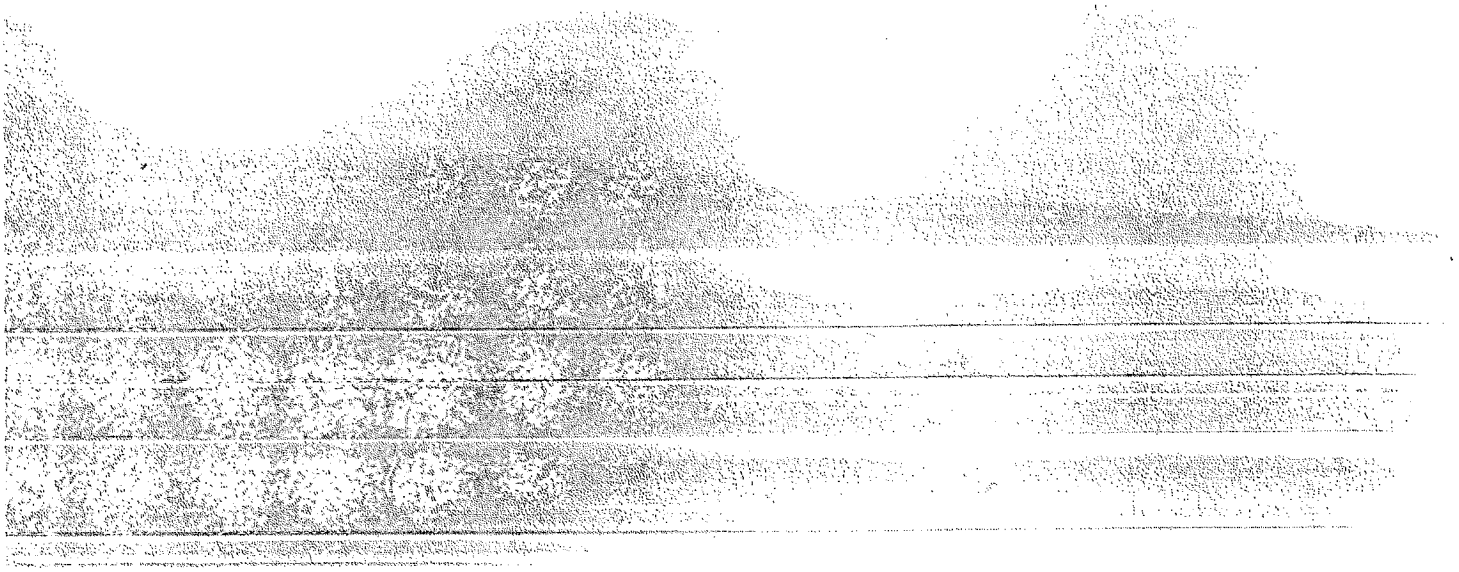
I. Republican River Basin, Nebraska, Water and Related Land Resources Study Report: (Portion of Report) U.S. Department of Agriculture; Economics, Statistics, and Cooperatives Service; Soil Conservation Service and Forest Service, 1978.

J. Development of a Procedure for Estimating the Effects of Land and Watershed Treatment on Streamflow, Technical Bulletin No. 1352: by A.L. Sharp and W.J. Owen, U.S. Department of Agriculture, and A.E. Gibbs, Bureau of Reclamation; March 1966.

K. Modeling the Effect of Soil and Water Conservation Practices on Watershed Yields in Central and Eastern Kansas: A Master's Thesis by Mathias A. Scherer III, Kansas State University, approved by James K. Koelliker, 1983.

L. The Effects of Ponds and Small Reservoirs on the Water Resources of Texas: Prepared by the Texas Society of Professional Engineers and the Texas Section of the American Society of Civil Engineers, 1974.

C



APPENDIX C

DRAFT

Kansas markup 03-25-2004

Modeling and Field Experimentation to Determine the Effects of Terracing and Nonfederal Reservoirs on Water Supplies in the Republican River Basin above Hardy, Nebraska

Joint Research Project of the
University of Nebraska-Lincoln
Kansas State University
Colorado State University

Proposal by

Derrel Martin
University of Nebraska-Lincoln

Study Duration:
April 2004 – April 2009

March 3, 2004

Background

A provision in the settlement of the litigation on the Republican River requires a study to determine the impact of field terraces and non-federal reservoirs on streamflow depletion. An early assessment of the amount of land terraced was developed by the USDA-NRCS using results from the National Resources Inventory. Results of that analysis show that approximately 2.3 million acres have been terraced above the stream gage near Hardy, Nebraska (Figure 1). Note: see my note in my e-mail on the dam inventory An associated inventory was made using the SSURGO soils database from the USDA-NRCS to estimate the number of ponds in the basin (Figure 2). These initial surveys are approximate and indicate the scope of development in the basin. It must be noted that the ponds inventory includes various types of water bodies that do not fit within the definition of "small non-federal reservoirs". The proposed study, and associated projects, will provide a more thorough evaluation of not only the amount of land terraced and the number of reservoirs of concern, but also an assessment of the condition of those structures and their impact on streamflow.

The information in Figures 1 and 2 highlight some characteristics that are helpful in designing the study:

- Approximately 2.3 million acres are terraced which represents more than 15% of the Republican River Basin above the Hardy gage,
- Most of the terraced land is located in the central portion of the basin (e.g. only about 9% of the terraced land is in Colorado), and
- Most of the ponds are located in the eastern half of the Nebraska portion of the basin and in the Kansas portion of the basin with few ponds in Colorado.

These results show that the impact of terraces and small reservoirs will likely be most significant in the portions of the basin in Nebraska and Kansas.

Terraces can be designed to serve several purposes. In almost all cases, terraces reduce the rate of overland flow from the treated land which reduces erosion and sediment transport to other waterways. The sketch in Figure 3 shows the characteristics of terraced land. A berm is constructed at intervals within the field. The soil used to form the berm is removed from the channel just upstream of the berm. Occasionally soil from the land immediately downstream of the berm is also used to form the berm. The upland portion of the terraced land has the same slope as before completion of the terraces. Water that runs off of the upland region is retained for a period of time within the channel. Some terraces are designed to retain water for short periods in the channel. This type of terrace often has a piped outlet to drain water from the terrace channel. The channel is sloped to allow water to flow either to an outlet or to the end of the terrace where water flows into a drainage channel. Some terraces are designed with a level

channel. These are frequently referred to as conservation terraces. Conservation terraces may have open ends where water can freely flow from the channel, or the ends of the berm may wrap upstream to retain water within the terrace channel. Conservation terraces were designed to retain significant amounts of water in the channel and they seldom include piped outlets that discharge water from the terrace channel to an outlet. Terrace channels can be overtopped if the amount of runoff from the upland area exceeds the storage volume of the channel. Terraces are typically designed to store the runoff volume for a 10-year storm of 24-hour duration.

The type of terrace found varies across the Republican River Basin. Terraces with piped outlets that detain water for short periods are most common in the eastern portion of the basin where rainfall is more substantial. In these areas the main function of the terrace is to decrease erosion by shortening the slope length and by temporarily detaining runoff in the channel. Water is often discharged into grassed waterways that are less erosive than field conditions. It is likely that terraces in the eastern portion of the basin have less effect on the volume of streamflow; they mostly flatten the height of the runoff hydrograph. Closed-ended terraces with level channels or benches are more common in the central and western portions of the watershed. Conservation terraces are expected to have a more substantial effect on streamflow depletion because they not only detain runoff, they retain substantial portions of the runoff from a storm and provide for either increased groundwater recharge or larger evapotranspiration amounts.

Land in the channel of the terrace may be used to raise crops the same as the upland area, or the crops in the channel may be submerged for a long enough period that they perish. An example of the storage of water in a terrace is illustrated in Figure 4. If crops actively grow in the terrace channel, the extra water that infiltrates can be used for evapotranspiration. However, if crops in the channel drown, the amount of evapotranspiration will be considerably less. Channels of such terraces offer the potential to recharge groundwater aquifers. Thus, water retained on the field that would have run off to streams without terraces will instead recharge the groundwater aquifer. Recharge may eventually contribute to streamflow as groundwater discharge or it could be pumped for irrigation or other water supplies.

Assessing the impact of terraces must include estimates of the rate of infiltration of water in the terrace channel and on the upland portion of the inter-terrace area. Farming and cultural practices that enhance infiltration on the upland area will result in less storage in the terrace channel and less groundwater recharge. Thus, tillage and cultural practices used on terraced land must be determined to adequately represent the effect of terraces.

Small reservoirs were constructed in the Republican River Basin to reduce soil erosion, flooding and to provide water supplies for livestock and other needs. The supply of water into the reservoir depends on the farming practices, cropping patterns, and terracing upstream of the reservoir. Note: Move the discussion that follows up in the document A sequence develops where farming practices that affect

infiltration have the first impact on the runoff of water toward streams. Water that runs off the upland portion is next intercepted by the terraces in the field. Water that ultimately runs off of the field is transported in channels as the water makes its way to a stream. Some water that enters the transmission channel is lost to evaporation, seepage to the groundwater and storage as soil water. Little of the field runoff that enters long, dry, channels may actually research the stream. These losses of water are referred to as transmission losses. It is necessary to account for those losses in order to predict the inflow into reservoirs on streams. Some water that enters the reservoir will evaporate while the water is stored. Transmission losses depend on the soil characteristics in the conveyance channel, the water content of the soil when water is introduced and the depth and width of flow in the channel. The water that seeps through the conveyance channel could be stored in the soil and used for evapotranspiration by plants that grow in the channel. Some of the water that seeps through the channel can result in groundwater recharge.

Some water will also seep through the bottom and sides of the reservoir and usually contributes to groundwater recharge. The seepage may reappear downstream of the reservoir if the aquifer beneath the reservoir is very shallow or if the aquifer is thin such that seepage of the water from the reservoirs flows horizontally below the soil surface and returns to the stream. The rate of evaporation of water from reservoirs depends on the climate, water temperature, reservoir depth and the turbidity of the water. The total volume of water evaporated also depends on the surface area of the reservoir. Seepage rates from reservoirs depend on the soils at the reservoir site, sediment accumulation in the reservoir and the height of water in the reservoir.

Partitioning precipitation into streamflow, groundwater recharge and evaporation or evapotranspiration depends on many processes and is quite dynamic. Generally those factors are best represented by using water-balance models that simulate those processes. To properly use water balance models it is necessary to accurately represent the processes, to develop parameters that describe local conditions and to build databases to represent soil, crop, climate and management practices. The models are configured to account for the diversity of conditions within watershed to provide aggregate water fluxes for streamflow, groundwater recharge and evapotranspiration. Reservoirs can be included in the simulation to account for all processes in the watershed. Experimental data are needed to calibrate and verify the model. Experimental data will provide a direct measurement of the effects of terraces on a limited number of fields and will be useful in explaining the role of terrace in agricultural hydrology. However, not enough sites can be measured to provide an integral impact for the whole watershed. Thus, models will be necessary to aggregate estimates for watersheds.

Once properly calibrated, models can be used to compute the differences in streamflow, recharge and evapotranspiration for two scenarios. This provides a means to separately quantify the effect of

terraces and reservoirs. Such quantification would generally require up to four simulations that would represent:

- No terraces and no reservoirs
- Terraces but no reservoirs
- No terraces but reservoirs, and
- Both terraces and reservoirs.

This proposal describes methods to model the effects of terraces and small reservoirs on streamflow and recharge, and experiments needed to calibrate the model and verify model results.

Soil Water Balance (Budget) Models

Water balance or budget models simulate the daily change in the water budget for different climatic and land-use conditions to estimate the dispensation of precipitation as interception, runoff, actual evapotranspiration, percolation, and change in water content in the soil

The POTYLDR Model simulates the water budget of representative tracts of land on a daily basis. The model allows for different land uses and estimates the water yield on a monthly or annual basis for a drainage area. The model was developed for High Plains conditions and includes the range of land uses found in the Republican River Basin. Runoff curve numbers (RCN) are used to partition daily precipitation into runoff and infiltration. The RCN technique has been widely used to predict runoff from design storms and to design soil water control facilities. It follows that the RCN method can predict runoff over a period of time provided the moisture condition at the time of each storm can be determined. This technique to assess runoff through a computer simulation model is now used widely in watershed simulation models. Recently, POTYLD was modified to include additional refinements and to include irrigation; consequently, the name was changed to Potential Yield Revised (POTYLDR).

The Soil Water Assessment Tool (SWAT) was developed by the USDA-ARS to simulate the impact of land use and management on watersheds. The model includes many processes to predict crop and plant development, plant water use, runoff, deep percolation and recharge and the water balance of reservoirs. The model integrates readily available soil characteristics and builds on georeferenced databases for land and stream elevations. A geographic information system is used to simplify data management and to better present results. The method has been widely used across the United States, at varying resolutions, to assess water management issues. The method provides estimates of the inflow of water and sediment into reservoirs which may enhance long-term simulation of the effects of ponds and terraces. The model was recently modified to include estimates of irrigation demand.

Other models, such as CROPSIM, have been developed to simulate some watershed processes.

Those models contain components that are more robust than some procedures in either POTYLD or SWAT. Important relationships from such models will be uses to improve POTYLD and/or SWAT to better account for the effects of terraces and ponds and evapotranspiration. Special care will be necessary to ensure that the impact of practices are not double counted when using water balance models and the groundwater model developed for the Republican River Settlement

Crop Yield Trends

The impact of the land terracing could be estimated as the different in evapotranspiration for the land area before terracing versus after terracing. This estimation method is based on a linear relationship between crop yield and evapotranspiration (Figure 5.) One of the purposes of terracing is to increase crop yield. The increase in evapotranspiration resulting from terracing could be estimated by comparing the crop yield for a terraced area with a non-terraced area growing the same crop and with similar topography, soils and management. The difference in crop yield could then be equated to a difference in evapotranspiration required to provide the increase yield. Yields for sections of the inter-terrace area starting at the edge of the upland berm and extending through the terrace channel can be measured to determine the difference in yield with terraces compared to the yield for only the upland area. Yield differences can be used to estimate regional differences in water use. Data collected from these measurements could be combined with the distribution of the amount of land terraced and the cropping patterns found on terraced land to provide an independent estimate of the increase in consumptive use or evapotranspiration due to terraces.

Procedure

The study will rely primarily on soil water balance models to simulate the impact of terraces and small reservoirs on the streamflow in the Republican River Basin. Field experiments will be used to verify processes in the simulation models and to provide accurate parameters. The study will also rely on historical climatic records and surface water flows for simulation and verification. Other data required for accurate modeling will be inventories of current land use practices and georeferenced soil, stream and reservoir data. The phases of the project are delineated below.

Modification and Evaluation of Existing Models

This phase of the project includes the evaluation of existing modeling methods and improvement of those models. At least three models will be studied to determine the most reliable methods. Most likely components of several procedures will be integrated into one model for simulation of the impacts of

terraces and small reservoirs. Models currently under consideration are the POTYLDR, SWAT and CROPSIM models. The POTYLDR model has been used to simulate the effects of agricultural practices on streamflow in the Republican River Basin and neighboring watersheds in the past. The model includes provisions for the impacts of reservoirs as well. Therefore, the POTYLDR model will be the initial program that will be used for the water balance simulations. Routines from the CROPSIM model will be included to use modern methods to compute evapotranspiration using the Penman-Monteith method and crop coefficients for the plants in the basin. The routine in CROPSIM to account for the water balance of the channel of the terrace and the upland area in the inter-terrace area will also be implemented into the POTYLDR model. Infiltration characteristics in the upland areas and in the channel will be simulated with the Green-Ampt method as well as the NRCS curve number method. The effects of crop residue on infiltration and curve numbers will be implemented based on the methods in CROPSIM or the SWAT model. Snow melting and subsequent infiltration will be modeled using routines from the SWAT model or other models that are appropriate for winter water balances. Transmission losses as simulated with the SWAT model will be compared with the transmission loss factor used in the POTYLDR model. Other processes in the POTYLDR model will be evaluated and tested to ensure that the model is as accurate as possible.

At the current time the POTYLDR model is not interfaced with a geographic information system (GIS) to efficiently integrate information for models simulations or to summarize simulation results. A major initial effort will include the integration of the model with an ARCVIEW GIS. Data layers will be developed for the spatial inputs required to operate the model. Since the simulations with the POTYLDR model will be used to simulate the impacts of terraces and small reservoirs for individual watersheds and not the whole Republican River Basin in one simulation, it will be important to efficiently disaggregate the basin into subwatersheds that are modeled independently. The GIS will facilitate this process and will integrate with the other layers of information needed to operate the model.

A schematic diagram of the representation of a subwatershed as used in the POTYLDR model is shown in Figure 6. The model does not attempt to distribute crops and field conditions to individual land holdings. Instead the model simulates conditions for typical cropping, soil and other conditions in what can be referred to as representative hydrologic units. The representative hydrologic units provide the water balance for a typical field in a portion of the subwatershed. The total contribution from similar lands in the subwatershed is computed by scaling up the results for one field to the amount of land for the respective land use. The GIS model will be needed to determine the number of representative hydrologic units required for subwatersheds and to scale up simulations for each representative hydrologic unit. The GIS model will also provide summaries of the impact of terraces and small reservoirs for components of the subwatershed and will be used to integrate for the subwatershed being simulated.

It will be necessary to characterize modern farming practices to provide for accurate simulation. Data for county level information as illustrated in Figure 7 will be used to develop statistical distributions of farming practices for the last twenty years. These farming practices will be held constant throughout the simulation as the main effects that are of interest are the impacts of terraces and small reservoirs for the existing farming practices.

Databases

Several databases will be required for the project. Data will be needed for at least the following:

- Soils information including the distribution of soil series in the basin
- Location, type, condition and distribution of terraces
- Location and properties of small reservoirs
- Location and properties of streams and rivers
- Delineation of watersheds
- Topography
- Land use practices
- Farming and crop management practices
- Climatic and meteorological conditions
- Stream flow records
- Soil type and slope distributions
- Precipitation amount, rate and distribution

Other information will likely be necessary as the project progresses.

Field Studies On Terraced Land

Methods used to quantify the effects of terraces and ponds must be shown to be accurate. Limited amounts of directly measured empirical data are available to quantify impacts. Additionally, there have been many simultaneous changes in the basin that obscure effects of ponds and terraces when inflows and outflows to reservoirs are measured. Thus, there is a need to directly measure the effects of ponds and terraces for modern production practices. This portion of the study will involve the selection and monitoring of typical reservoirs and land terraces over several years. Monitoring would involve measurement of the dimensions of selected structures and installation of equipment for the measurement of such parameter as soil water profiles, precipitation, inflow, outflow, seepage, plant water use and evaporation. The expected layout of field measurements is illustrated in Figure 8. It is important that the

monitoring equipment provide continuous logging of soil water contents and the elevation of water in the terrace channel. Without continuous monitoring it will not be possible to capture the infiltration and runoff process of individual events as it will be very difficult to travel to experimental sites in a timely fashion. Rainfall rates and amounts will also be measured along with the temperature and humidity of the air, wind speeds and solar radiation at the site.

These data will be used to characterize the water balance for terraced and unterraced lands. Measurements of the water balance over several years on land upland from the terrace and from the terrace channel will provide for direct comparison of the effects of terracing. The data will also be used to compute the infiltration rates in the upland areas and the terrace channel. The fields will be carefully surveyed to provide slopes and terrace characteristics. Outlets to the terraces will be included in the survey. Monitoring equipment will be used to monitor the amount of water flowing from the terrace channel for those terrace systems that have open ended channels and/or piped outlets. Where possible, flow measurement equipment will be installed to monitor the surface runoff from the terraced field. Precipitation will measured with recording rain/snow gauges. Farming practices will be inventoried. Local soil properties will be measured and all equipment will be locally calibrated. The depth of water in terrace channels will be continually monitored. Crop yields from the upland areas, terrace channels and terrace backslopes will be measured. In summary the terraced fields used in the water balance studies will include monitoring for:

1. Sites in the upland portion and the terrace channel
2. Survey slopes, terrace characteristics and outlets
3. Soil water measured to log water content in and below root zone
4. Monitor surface runoff
5. Recording rain/snow gauges
6. Farming practices inventoried
7. Soil properties measured and all equipment calibrated
8. Depth of water in terrace channels continually monitored
9. Yields measured in upland areas, terrace channels and backslopes

Additional sites will be included that involve less detailed sampling will be added to the field studies as time and financial resources allow. These sites will have a minimum of monitoring data but will be selected to provide for a wider distribution of conditions across the basin. Equipment will be installed in these fields to periodically monitor soil water in the upland area and the terrace channel. The amount of time that water is ponded in the channel will be observed. The characteristics of the less intensively sampled sites will be determined through field surveys.

The transmission loss for channels conveying runoff water from individual fields will be measured to accurately account for inflows into downstream water bodies and streams. Flows measurements will be made along selected conveyance channels to estimate the transmission loss. Soil properties in the conveyance channel will be measured to provide independent computation of seepage rates from the channel. Changes in soil water along and beneath the channel will be monitored to determine the amount of storage and subsequent evapotranspiration along the channel.

Results from the field studies will be used in two ways. First, the data will provide a direct record of the water balance of terraced fields. Second, the data will be used to verify the procedures used in the simulation models for terraced lands. The field results will be analyzed for the conditions of the terraces at the site to allow for improved simulation for the range of terraced conditions found in the basin. Data for earlier studies will be reviewed and combined with current studies to augment verification data.

Experiments for Small Reservoirs

The water balance of selected small reservoirs will be measured. Measurements will include development of the volume/area versus stage relationships for the reservoir. Sediment deposition in the reservoir will also be assessed. Equipment will be installed within selected reservoirs to measure the stage, turbidity and water temperature. Evaporation rates from the reservoir will be measured using submerged tanks with stage recording equipment. Water conditions within the tanks will be monitored similar to the methods used outside of the tanks. Seepage rates will be computed as the residual of daily water level changes minus the measured evaporation rate. The effect of the depth of water on evaporation rates will be studied to ensure that measurements are accurate for the whole reservoir. A range of reservoirs will be instrumented to provide for conditions found across the basin. Conditions of the watershed that affect the water supply to the reservoir will be quantified.

The detailed reservoir monitoring will provide data on the water balance and partition of the water into inflow, evaporation, storage, seepage and outflow. The data will be used to develop relationships to predict evaporation and seepage rates from the reservoirs on a per unit area basis. The total water loss will be computed by multiplying the area of the reservoir with selected characteristics time the per unit area lost rate. Equipment will be used to measure evaporation rates and monitor reservoir stage. Measurements of turbidity and water temperature will be included to determine the sensitivity of evaporation to these factors. It will be necessary to assess conditions within the watershed upstream of the reservoir to provide water yields for the reservoir. Sediment deposition will be assessed to determine if seepage rates are adversely affected by the sediment deposition depth. Data from the reservoir study will be used to verify modeling results and to provide a direct water balance of reservoirs.

Crop Yield Experiments

Crop yields from producer fields will be used to compare consumptive use for terraced and unterraced land. Experiments will be included on terraced fields to measure the yield in sectors perpendicular to the centerline of the terrace channel. This will allow for the comparison of the effect of the terrace and provide for comparisons under identical conditions unlike what would occur if adjacent fields were evaluated. The yield comparison methodology allows for integration of the effects over larger areas and measurement in numerous locations and fields. A short coming of the method is that it does not quantify the recharge gain as only consumptive use or evapotranspiration will be determined. The method relies on an empirical yield-ET relationship that will need to be developed and tested against existing data in the basin. It is critical that the experimental procedure be designed to avoid bias. Also since recent years have been quite dry and grain yields were very small or nonexistent, it will be necessary to account for all plant biomass not just the grain yield. The second shortcoming is that if the terrace channel floods and crops die it will be necessary to estimate evaporation for the exposed soil since there would be no crop water use.

The data will be used in modeling studies to ensure that simulation of cropping systems is sufficiently accurate for modeling the watershed of the Republican Basin. The data will also provide a direct comparison of the effects of terracing.

Deliverable Products

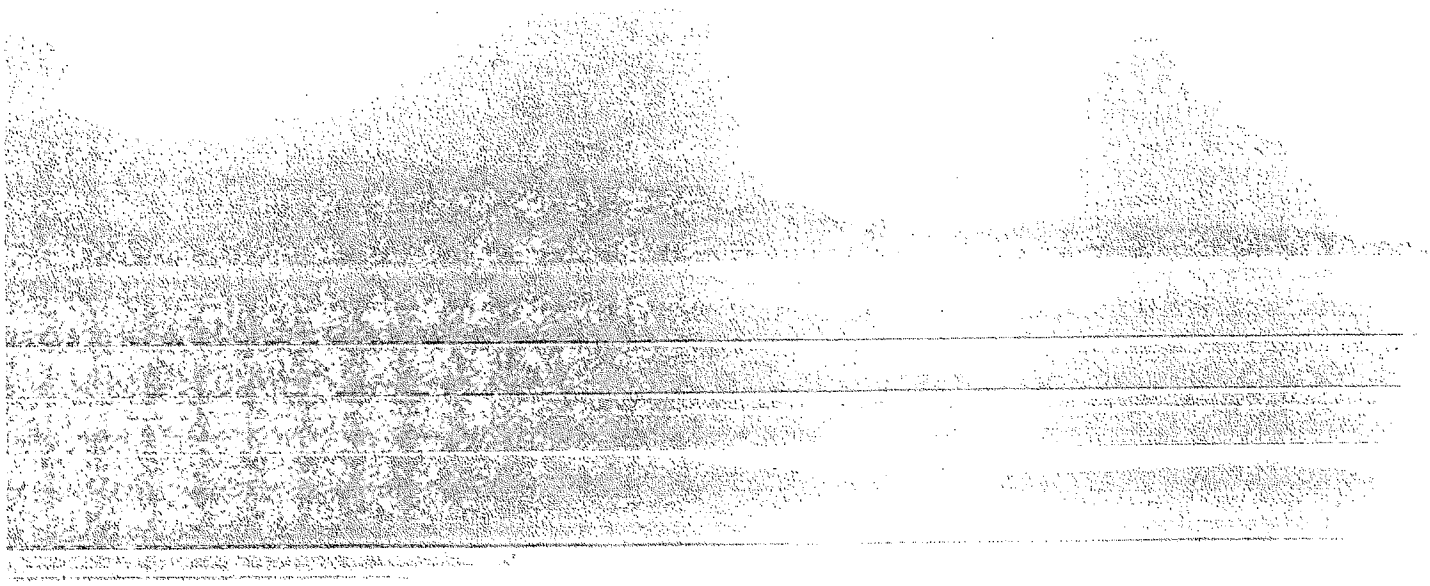
The ultimate product from the simulations studies will be comparisons of the amount of evapotranspiration, deep percolation or groundwater recharge, and streamflow for individual subwatersheds or portions of the subwatersheds (Figure 9). Four simulations will be made for a period of 30 years using climatic conditions from 1972 through 2002. Simulations will be made for conditions with no terraces or reservoirs, with terraces but no reservoirs, without terraces but with reservoirs, and with both terraces and reservoirs. The water balance will be summarized for the subwatersheds individually. It is the committee's belief that resource limitations will preclude definitive modeling of the mainstem reach with the significant number of surface diversions and returns, reservoirs operations, and other complexities. Therefore, there will not be an attempt to integrate all results to provide the impact for the whole Republican River Basin above the Hardy gage. Instead resources will be focused on providing the best estimates of the relative amount of change for tributary subwatersheds.

Tentative Budget

The tentative budget for the project is listed in Table 1. Final costs have not been finalized.

Table 1. Tentative Budget	Cost
Equipment:	
8 Sites to Monitor Terraced Land Water Balance	$64,000
5 Sites to Reservoir Water Balance	$30,000
2 Computers	$8,000
Total Equipment	$102,000
Personnel (for 5 years of project):	
2 Postdoctoral Research Assistants for Field Experiments, Modeling and Data Analysis (total of 10 person-years)	$400,000
2 Undergraduate Student Assistants (for 5 years)	$40,000
Total Personnel	$440,000
Travel:	
Research Sites and Project Coordination	$20,000
Professional	$8,000
Total Travel	$28,000
Direct Costs	$570,000
Indirect (@ 10% of Total Direct)	$57,000
Total	$627,000

D



APPENDIX D

RESERVOIR SURFACE AREA AND WATER LEVEL MONITORING

Purpose of the Study:

The purpose of this monitoring program is to characterize how non-federal reservoirs operate during the water year. Generally, the Conservation Committee would like to determine the changes in surface area for the reservoirs over the course of wet, dry and average runoff years in response to runoff (inflows) and outflows. Outflows of interest include releases from the reservoir made through outlet works (if any) that can lower water levels below the emergency spillway, evaporation from the water surface and the saturated shoreline, seepage through the dam and infiltration loss. Specifically, the surface area of these reservoirs needs to be known for key times of the year to estimate the volume of water lost through a combination of evaporation, seepage and infiltration loss.

Background

There are approximately 450-750 reservoirs of interest in the Republican River Basin. Detailed data will be collected from 5 to 8 of these reservoirs to understand the inflow/outflow processes governing how these reservoirs operate for inclusion in the proposed study plan model. Less detailed data is needed for a larger sample of reservoirs to ensure that the water balance model accurately describes how the reservoirs operate throughout the entire Republican River Basin.

The collection of data on non-federal reservoirs is necessary to calibrate and verify the model used in the proposed five-year study. While the original data are known on many of the reservoirs in the basin, it is unlikely that except in large water supply reservoirs, any information exists about the current data. Changes in volume and area due to sedimentation; reservoir stage levels on a time interval basis; and the outflows to the stream, as water supply, as seepage, and as evaporation; are some of the data that are not reported on non-federal reservoirs in the basin.

The selection of sites for this data collection, monitoring program must be representative of the climatic and hydrologic variability in the basin, both temporally and spatially. The selection should also represent various geological characteristics such as soil types, depth of foundation, seepage rate, depth to bedrock, extent of alluvial deposits and connectivity between the alluvial and regional aquifers. The selection may also need to include different types of reservoirs. For example, a tail-water collection pit has different characteristics in the nature of its inflow / outflow regime as well as construction, surface area, and volume when compared to a farm pond. The variability in these structures also may be evident by geographic location as local practices may vary according to geopolitical boundaries.

Ideally, the sample group of reservoirs should have well defined area–capacity relations at the start of the study. However, this is likely not the case. It is believed that at best most of the reservoirs will only have the water level depth, surface area, and volume for the reservoir at its principal spillway crest, or full pool level.

Information collected during the 5-year study could result in better defined area-capacity relationship, at least for the normal operating range for each of the reservoirs monitored

Updating Physical Data of Non-Federal Reservoirs

The ultimate destiny of all reservoirs is to be silted full. The speed with which these reservoirs fill are a function of the frequency and volume of inflow, the storage volume of the reservoir, the reservoir's outflow operations and the soils and practices upstream of the reservoir. Using the existing reservoir data to accurately reflect impacts of the reservoir on its stream is necessary to properly calibrate the model. The measurement of reservoirs' surface area, elevation, volume must be done accurately and currently. Detailed information should be collected at the selected study sites. The detailed information should include:

- Current Area, Elevation, Capacity of the reservoir
- Type of reservoir impoundment, dammed or excavated
- Type of use of the reservoir, irrigation, stock or water supply
- Geology underlying the reservoir, seepage potential
- Drainage Area, size, type of land use, soils, upstream conservation practices
- Character of adjacent upstream and downstream riparian corridor
- Daily Area (computed from Daily Stage)
- Daily Precipitation (gaged by weather station)
- Daily Evaporation (computed from weather data and Daily Area)
- Daily Stage and Storage(gaged)
- Daily Outflow, (computed from Daily Stage)
- Daily Inflows (gaged)
- Daily Seepage (computed from Water-balance of Daily Precipitation, Daily Evaporation, Daily Outflow, Daily Storage)

The number of total reservoirs needed for the detailed study is somewhat uncertain, but 5 to 8 would probably cover the most common soil, topographic and climatic variations and should be identified by the study contractor

Broad-Scale Reservoir Monitoring

On reservoirs not in the detailed study, periodic areal surveys should be conducted. The surveys would measure the surface area of the reservoir to be used with data collected elsewhere to calculate values comparable to the data collected under the detailed study.

Areas can be computed with reasonable accuracy (horizontal position 3 meters) by using inexpensive Global Positioning Systems (GPS) receivers. The Garmin Etrex Legend which costs, with software and accessories, approximately $450 is an example. A field person would merely have to continuously track their path around the reservoir at water level and use the GPS unit's built-in area calculator. The track can also be uploaded into a computer and the area can computed from the distances, and coordinates.

Aerial photos can be acquired for different periods of the year to catch the critical operational cycle of each reservoir. Surface area of the reservoirs can be determined after proper

identification of water surface boundaries. Satellite images could also be investigated for accuracy in determining surface area. The advantage of this option is the limited time required by office staff (GIS) to measure a large number of reservoirs in one day. Some site visits may be required to verify results. The disadvantage of this option is the risk of not getting clear photos due to cloudy conditions and potential problems associated with accurately identifying and measuring the reservoir surface area on the photos. Cost of obtaining photos will also need to be assessed. Using digital copies of photos would likely be the most efficient and least costly.

Other more sophisticated instruments of survey-grade GPS can be used to collect more precise information. Survey-grade GPS instruments would be used to collect such information as a Quality Assessment, Quality Control measure.

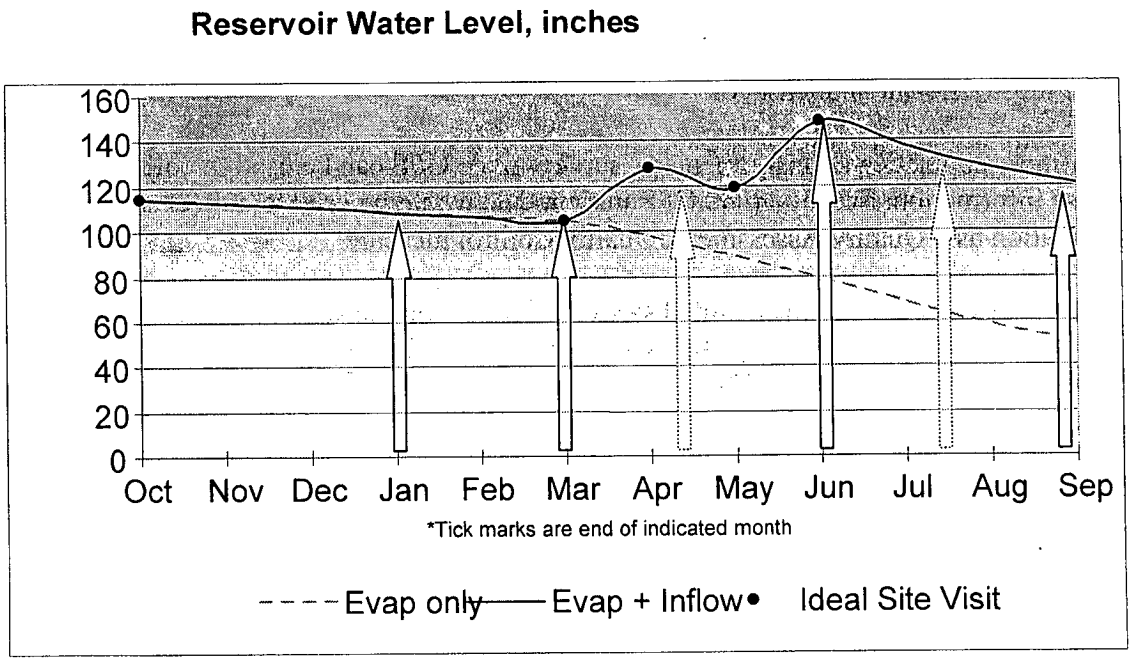
For the reservoirs outside the detailed study, dependent on the state resources, approximately, 50 reservoirs should be tracked. This would constitute about 10% of the reservoirs in the Basin, with most in Nebraska. Each state should be responsible for determining the structures that should be tracked. For non-federal reservoirs larger than 200 acre-feet, the evaporation charges used in the compact accounting process are based actual measurements or as 100 percent of the normal pool area.. These reservoirs should be included in the broad-scale monitoring program, which continues into the future. For non-federal reservoirs less than 200 acre-feet, about 20% of the structures should be considered for inclusion in the broad-scale study. Some smaller percent, 5%, should continue past the study period.

Alternatively or concurrently, Staff/Crest gages (See Appendix A for details) should be placed on each reservoir in the broad-scale monitoring program. This information would allow the monitor to establish reservoir stages that may indicate outflows between monitoring visitations. In addition, precipitation gages such as the KSU Irri-gage. (See Appendix B for details) could be used to gather on-site data.

Frequency of data collection

Based on available evaporation charts for the Republican River Basin, about 85 percent of the evaporation occurs during the April through October period. Data collected in early April and during October could provide key times to define surface area changes during the winter months, and serve as end points for the main evaporation season. It is also important to identify the times when the reservoirs gain water due to inflow. Inflow to the reservoirs can occur at any time of the year but is more common during May and June. Ideally, data should be collected just after the reservoir water level peaks, or when the reservoir level reaches its full pool level. There will likely be times when the reservoir gains water more than once a year. Thus, data should be collected more frequently during the spring and early summer to help identify peak reservoir levels. During the May and June measurements, the maximum water surface area should be determined if possible. Class A pan evaporation and precipitation data could be used to estimate when peak water levels occurred. Reservoir surface area data should be collected a minimum of 4 times during the year to determine the 4 or 6 critical time periods necessary to characterize water level fluctuations. More frequent measurements may be required during years with several significant inflow events.

The following is a graphic example of a hypothetical annual reservoir operation with the respective ideal data collection times.



The actual inspection interval will be dependent on the entity making the measurements, but the expectation is that the minimum inspection program would be quarterly involving measurements in January, March, June and September. Additional inspections Mid-April and Mid-July should be considered.

Costs of Survey, Instrumentation and Monitoring Program

Costs associated with the programs include a capital outlay for instrumentation, hardware, and software; transportation; and labor. In this analysis, the weather stations are assumed to be part of the total study and therefore, their costs are not assigned to the dams. The tables below detail the costs for the initial costs to be paid through the study contract and the initial costs met by the states. The initial costs for the study are $40,250 and for the states, $1,700. The annual costs of monitoring to the study or other non-state partners are $16,500; to the states, $6,650.

Initial Costs: Assigned to study.

Item	#	Cost per	Total Cost
Staff/Crest Gage (non-electronic)	50	800	$40,000
Precipitation Gage (non-recording)	50	5	$250
Total			**$40,250.00**

Initial Costs Assigned to the States (in-kind)

Item	#	Cost per	Total Cost
GPS Instrumentation (semi-recreational)	4	$425	$1,700
Total			**$1,700**

Annual Monitoring Costs Assigned to study or other non-state partners

Item	#	Cost per	Total Cost
Monitoring Inspections per year, Stage	300	$55[1]	$16500.00
Total			**$16500.00**

Annual Monitoring Costs Assigned to the States (in-kind)

Item	#	Cost per	Total Cost
Gage Calibration inspections QA/QC	20	$195[2]	$3900.00
Monitoring Inspections per year, Area	25	110[3]	2750
Total			**$6650.00**

[1] Note: The unit costs are estimates based on more detailed information as available. For example, in Kansas, the Division of Water Resources makes inspections of "Blatant and Recurrent Over-pumpers" (BRO) and their wells. There two types of BRO inspections. First, the initial inspection is conducted to collect detailed data such as well type, pump serial numbers, acres irrigated, meter installation, etc. Then, spot check inspections are done which basically read the meter to check usage. Unit Costs including transportation have been determined for Northwest Kansas for about 30 BRO wells so in number and location, DWR represent a similar distribution compared to the selected dams.

[2] See Footnote 1.

[3] See Footnote 1.

Appendix A

USGS

CHAPTER 4.-MEASUREMENT OF STAGE

(from S.E. Rantz, 1982, USGS WSP 2175)

CREST-STAGE GAGE

The crest-stage gage is a device for obtaining the elevation of the flood crest of streams. The gage is widely used in the U.S.A. because it is simple, economical, reliable, and easily installed. Because of those attributes the crest-stage gage has become a basic instrument in regional studies of flood frequency. For such studies the network of standard gaging stations is augmented by a network of crest-stage gages, thereby providing flood-peak information at a great many sites in the region at reasonable cost.

A crest-stage gage is also a valuable adjunct to the nonrecording gage at nonrecording gaging stations. It provides a record of the peak stages of stream rises, and those stages can be used with the observer's routine readings when sketching the estimated continuous stage graph through the plotted points of observed stage.

Many different types of crest-stage gages have been tested by the U.S. Geological Survey. (See, for example, Friday, 1965, and Carter and Gamble, 1963.) The one found most satisfactory is a vertical piece of 2-in (0.05 m) galvanized pipe containing a wood or aluminum staff held in a fixed position with relation to a datum reference. (See fig. 4.3.) The bottom cap has six intake holes located as shown in figure 4.3. to minimize nonhydrostatic drawdown or superelevation inside the pipe. Tests have shown this arrangement of intake holes to be effective with velocities up to 10 ft/s (3 m/s) and at angles up to 30 degrees with the direction of flow. The top cap contains one small vent hole.

The bottom cap, or a perforated tin cup or copper screening in cup shape attached to the lower end of the staff, contains regranulated cork. As the water rises inside the pipe the cork floats on the water surface. When the water reaches its peak and starts to recede the cork adheres to the staff inside the pipe, thereby retaining the crest stage of the flood. The gage height of a peak is obtained by measuring the interval on the staff between the reference point and the floodmark. Scaling can be simplified by graduating the staff. The cork should be cleaned from the staff before replacing the staff in the pipe to prevent confusion with high-water marks that will be left by subsequent peak discharges.

The datum of the gage should be checked by levels run from a reference mark to the top of the staff, the graduated staff being of known length. The gage itself should be serviced on a regular basis. However, the staff should not be removed from the pipe for any reason when the stage is high. If, after such removal, the staff is reinserted when water stands high in the pipe, the resulting surge of the water displaced by the staff will leave an artificial "high-water mark" on the staff.

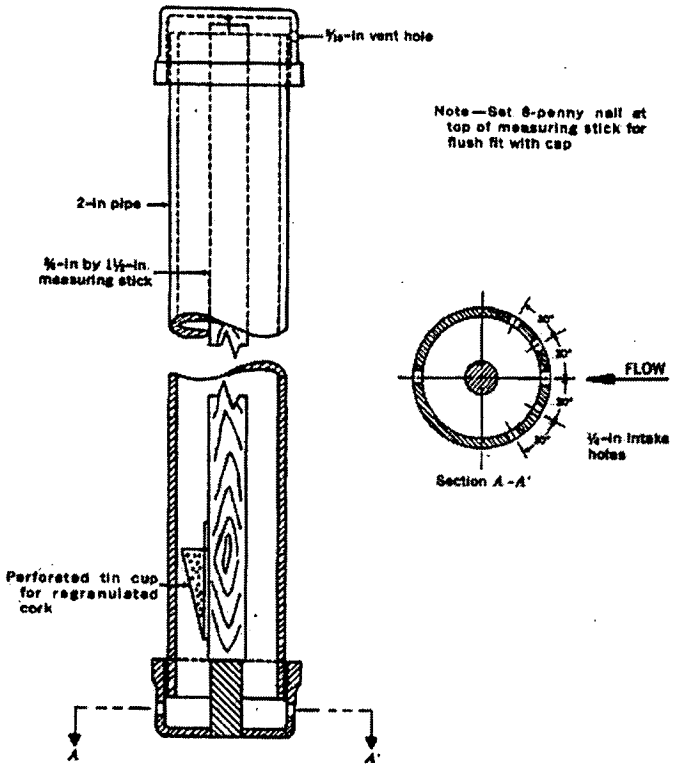


Figure 4.3.- Crest-stage gage.

Appendix. B. Excerpted from a brochure:

IrriGage – A Useful Tool for Irrigation and Rainfall Water Measurement

- Simple, user-friendly rain monitor that allows minimal water evaporation for accurate readings.
- Water in the IrriGage can be retained for a week with less than a 1 percent loss.
- This makes collection of readings easier for you by letting the field dry.
- Let the Mobile Irrigation Lab team help you make your own IrriGage.

The IrriGage is a modified rain gauge. It features a large, sharp-edged collection barrel made of thin-wall, 4-inch PVC pipe. This provides a large opening for an accurate catch of rainfall or irrigation events. Water collected in the barrel drains into a storage bottle attached to the bottom of the collection barrel through a small diameter hole. Once in the storage bottle, the water is retained with minimal loss over time. Many types of rain gauges have substantial water loss due to evaporation in just a few hours. Water in an IrriGage could be retained for a week with less than a 1 percent loss. This eliminates the need to immediately read and record the rainfall after a rain event. The IrriGage is constructed with a small diameter support tube mounted on the outside of the barrel. This allows the IrriGage to be easily mounted on a length of electrical conduit, re-bar, or electric fence post. The mounting posts can be driven easily into the ground at the desired measurement location.

Steps to Calibrate IrriGage

1. Measure inside diameter to the nearest 1/16 or 1/32 of an inch and convert to decimal equivalent. Divide by 2 to determine radius (r).
2. Calculate volume for 1 inch of depth in the IrriGage barrel as follows:
   a. Volume (ml / inch) =3.14 x radius $_2$ (inches) x 1-inch depth x 16.39ml/in $_3$ = 51.49 x radius $_2$ = ml/in
3. Determine fractional quantities for the desired scale on storage bottle. For example, a 1/4 inch measurement scale might be a satisfactory scale for the storage bottle. 1/4 x (Volume Step 2) = Fractional scale quantity
4. Obtain a graduated cylinder with milliliter markings, measure out Step 3 volume and pour into storage bottle. Permanently mark or etch scale onto bottle. Repeat Step 4 as many times as desired, adding the new quantity to the existing level in the bottle.

Kansas State University Agricultural Experiment Station
and Cooperative Extension Service
MF-2552 August 2002

E

APPENDIX E

AVAILABLE DATA

The Conservation Committee developed a list of data believed to be needed to assess the impacts of non-federal reservoirs and land terraces on the water supply in the Republican River Basin. A task group, with representatives from each state and the Federal government, identified datasets that meet the data needs identified by the Conservation Committee. This summary of data needs and identification of potential datasets to meet the needs should be considered a preliminary assessment of available data. Part of the study process will be to fully identify what data is needed; if the needed data is available and the source of data; and if the needed data is not available, how to best collect the data.

Data are needed for each of the following identified categories:

1. Non-Federal Reservoirs
2. Land Terraces
3. Soil Characteristics
4. Geologic Characteristics
5. Drainage Characteristics
6. Streamflow Records
7. Precipitation
8. Evaporation/Evapotranspiration
9. Landuse/Landcover

Primary Data Sources

The primary data sources identified by the task group are:

1. National Resources Inventory (NRI)
2. Soil Survey Geographic Database (SSURGO)
3. Digital Orthoquads (DOQ)
4. State Inventory of Dams
5. National Inventory of Dams (NID)
6. Republican River Compact Administration Goundwater Model
7. Satellite Imagery – various sources

Each of these primary data sources is described in more detail below or in the main body of the proposed plan of study.

This appendix is organized by the data need categories listed above. Many of the categories have more specific identification of data needs. Listed under the specific data needs by who provided the information is a summary description of the data and how to obtain the data.

General Information

Colorado: The Colorado Decision Support System contains information on stream flow, diversions, and some climatic data, pertinent to the Republican River Basin in Colorado (Water Districts 49 and 65). Under *Station Data*, stream flow records, as well as climatic data (including precipitation, temperature, and evaporation) can be found.

Under *Structures,* information is available on decreed water rights (source, location, estimated capacity, measuring device, water court case number of decree), as well as total diversion made under these rights during a water year.

http://cdss.state.co.us/db/index.asp.

Nebraska: The majority of Nebraska data sets can be accessed on the Internet. The metadata documenting the data is also available on-line.

http://nrcnt3.dnr.state.ne.us/ or http://www.dnr.state.ne.us/databank/,

Kansas: The majority of Kansas data sets are available from the Data Access and Support Center, DASC. Data sets are documented on-line.

http://gisdasc.kgs.ukans.edu/.

United States: The USDA Geospatial Data Gateway provides one stop shopping for natural resources or environmental data. The website allows users to browse and select data from a catalog, customize the format, and have it downloaded or shipped on CD.

http://lighthouse.nrcs.usda.gov/gateway/gatewayhome.html.

A. General types of relevant data available

1. Potential data sources

a. National Resource Inventory (NRI) – Terraces/Tillage

United States: A statistically based sample of land use and natural resource conditions and trends on U.S. nonfederal lands. Source: USDA/NRCS;

Contacts: NE = Wayne Vanek, Doug Garrison. KS = Larry Kuder. CO = Kelly Pace

http://www.nrcs.usda.gov/technical/NRI/.

b. Soil Survey Geographic Database (SSURGO) data base - Small reservoirs

Nebraska: Nebraska identified this source of Nebraska data although the data base originated with the NRCS. This data is a digital soil survey and generally is the most detailed level of soil data developed through the National Cooperative Soil Survey by NRCS. The information was prepared by digitizing maps, by compiling information onto a planimetric correct base and digitizing, or by revising digitized maps using remotely sensed and other information. The following website is for Nebraska data.

http://www.dnr.state.ne.us/databank/ssurgo2.html

United States: USDA/NRCS Soils, including SSURGO data discussed above.

http://soils.usda.gov/

c. Digital Orthroquads

Kansas: 2002 Orthophotos (DASC)

Nebraska: A digital ortho-photograph is a digital image of an aerial photograph with image distortion removed, and corrected for aircraft pitch, yaw and altitude, landscape relief, and camera lens (optic correction) orientation. These DOQs are developed from 1999 NAPP flight coverage flown under the National Aerial Photography Program.

The aerial photographs are exposed using 10-inch wide film at 20,000 feet above land surface, with 6 inch focal length camera, resulting in 1:40,000 scale image.
http://www.dnr.state.ne.us/databank/coq.html

United States: Source: USDA Aerial Photo Field Office (APFO);
http://apfonet.apfo.usda.gov/imagerystatus.html

d. State Inventory of Dams

Colorado: Dams are categorized within the following four groups: Jurisdictional, Non-jurisdictional, Livestock Water Tank, and Erosion Control Dam. Dams are considered Jurisdictional if the height is greater than 10 feet, or the capacity is more than 100 acre-feet, or the surface area is more than 20 acres. The State Engineer must approve these structures prior to construction. If the structure is less than listed above (non-jurisdictional), no prior approval is necessary, however a *Notice of Intent to Construct* must be filed. The information in the database for these Jurisdictional and Non-jurisdictional dams includes the name, location, stream, physical characteristics of the dam (height, length, and storage capacity), and construction date.

Livestock Water Tanks are dams constructed to capture run-off water on rangeland to provide water for livestock. The dams are constructed on normally dry water courses, cannot be greater than 15 feet in height and cannot be used for irrigation. A permit is required unless the height is less than 5 feet and the capacity is less than two acre-feet. Erosion Control Dams (ECD) also require a permit, may be constructed on a normally dry watercourse, and the height cannot exceed 15 feet. However, the purpose of an ECD is not to store water. The information within the database maintained for these structures includes the location, owner's name, construction date, approximate drainage area, approximate capacity, and height.

Nebraska: The dams inventory database includes all dams which have minimum height of 6 feet and exceed a storage capacity of 50 acre feet, or have minimum height of 25 feet and exceed a storage capacity of 15 acre feet or have a "high" or "significant" hazard classification. The data also describes the type of dam, the completion date, the dam height and length, the county the dam is located in and various other informative data. This data can also be retrieved by county, owner, dam identification number, township and range or varies other purposes.
http://nrcnt3.dnr.state.ne.us/Dams/index.aspx

United States: USDA/NRCS Dams Inventory-There are a set of rules NRCS follows for which dams are inventoried found in the NRCS Engineering Field Manual, Chapter 5, page NE 5-23L. Here is a summary:

- Built with NRCS technical and/or financial assistance
- All Class B&C hazard
- Class A hazard more than 6 ft high and 50 ac-ft or more storage
- Class A hazard more than 25 ft high and 15 ac-ft or more storage

National Dam Inventory, U.S. Corps of Engineers - includes data for 77,000 federal and non-federal dams. The information is incomplete for the purposes of the study dependent on the updates provided by the states. The current web version is the 1998-1999 update is:

http://crunch.tec.army.mil/nid/webpages/nid.cfm

e. RRCA Model: Input and output data

Soil Characteristics - Each model grid cell was characterized as one of the following soil types: a) fine grained (clay), b) medium grained (loam), c) course grained (sand), d) main stem alluvium, and e) tributary alluvium. The purpose in the classification was to determine precipitation recharge.
See the map at http://www.republicanrivercompact.org/vl2p/html/soill2o.html.

Recharge curves can be accessed at:

http://www.republicannvercompact.org/vl2p/html/ch04.html.

Streamflow Records - for 65 gages within the RRCA groundwater model domain, USGS and state streamflow records were collected, the record was corrected for known surface water diversions, and a Baseflow separation completed by the model committee. Baseflow separation spreadsheets can be downloaded from:

http://www.republicanrivercompact.org/vl2p/html/ch00.html.
(Right-click the "Baseflow database" link).

Precipitation - Annual precipitation data was collected and used in the model for 33 locations within the model domain. In addition, for each year, this data was kriged to produce a cell by cell distribution of precipitation for every year.

http://www.republicanrivercompact.org/vl2p/html/ch00.html.
(Right-click on the "Precipitation Source Data" link.)

Evaporation/Evapotranspiration - each state developed their own pumping estimates, generally based on or confirmed with estimates of crop irrigation requirement. These estimates are not part of the model data sets included in the final data sets that make up the model but can likely be obtained from the states.

Landuse / Landcover - The model data include area irrigated in each model grid cell by year, 1940-2000. This will be updated annual by the Engineering committee.

http://www.republicanrivercompact.org/vl2p/html/irr.html.

Ground surface elevation - average ground surface elevation data for each model grid cell.

http://www.republicanrivercompact.org/vl2p/html/ground.html

Precipitation Recharge - Based on the soils annual precipitation, and recharge curves by soil types the monthly and annual estimates of precipitation recharge were determined.

http://www.republicanrivercompact.org/vl2p/html/rcp.html.

Total monthly recharge, including irrigation recharge.
http://www.republicanrivercompact.org/v12p/html/rcp.html.

f. The Conservation Technology Information Center (CTIC) – Tillage
United States: The Conservation Technology Information Center (CTIC) is a national, nonprofit public-private partnership working to promote soil and water quality and equip agriculture with affordable, integrated management solutions. NRCS State Contacts: NE – Tim Schaaf 402-362-5700; KS - Bud Davis 785-823-4552;
CO - Jim Sharkoff 720-544-2812.
http://www.ctic.purdue.edu/CTIC/CRM.html

g. Satellite/Aerial Photos
Kansas: Kansas Satellite Image Database, KSID (KARS/DASC), 2000-2001 consists of terrain-corrected, precision rectified spring, summer, and fall Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper (TM+) imagery covering the state of Kansas.

Nebraska: The idea of a civilian Earth resources satellite was conceived in the Department of Interior in the mid-1960's. The National Aeronautics and Space Administration (NASA) embarked on an initiative to develop and launch the first Earth monitoring satellite to meet the needs of resource managers and Earth scientists. The USGS entered into a partnership with NASA in the early 1970's to assume responsibility for the archive management and distribution of Landsat data products.
http://www.dnr.state.ne.us/otherresources/landsat.html

United States: Historic Aerial Photos, USDA Aerial Photo Field Office (APFO)
http://apfonet.apfo.usda.gov/.

Also see University of Nebraska-Lincoln Conservation and Survey Division (1930s to present) for Nebraska data only.
http://csd.unl.edu/csd.htm

2. Non-Federal Reservoirs data needs

General
Kansas: Kansas Division of water resources has permitted dams over 30 AF at top of dam since 1929. Many smaller dams have also been permitted. Design data submitted on applications for permit to construct includes information on most of the data needs identified below. In 2003, the statutes were changed to require a permit only when the dam exceeds 50 AF at top of dam and a height of 6 feet(regardless how much the volume exceeds 50 AF).

a. Surface area of reservoirs
Colorado: See General Information.

Nebraska: Nebraska Department of Natural Resources Databank of dam safety program dam inventory. The source file is a Microsoft Access Dam Inventory Database.
http://dnrdata.dnr.state.ne.us/Dams/Search.aspx?mode_=county

United States: See State Inventory of Dams

b. Reservoir Volume
Nebraska: Nebraska Department of Natural Resources Databank of dam safety program dam inventory. The source file is a Microsoft Access Dam Inventory Database.
http://dnrdata.dnr.state.ne.us/Dams/Search.aspx?mode=county

c. Reservoir type (use)
Nebraska: Reservoirs with a surface water storage permit can be queried at the following website address. Owners are not required to get a water right if they don't intend to irrigate from the reservoirs. Some reservoirs would be used for erosion control and stock watering, etc.
http://dnrdata.dnr.state.ne.us/SWR/MainSearch.aspx?mode=division

d. Condition of reservoir (% silted in, breached, etc.)
Nebraska: Dams that meet the criteria for inclusion in our Dam Safety Program will be inspected periodically. Inspection notes contain breach information and may contain notes on sedimentation, and dry condition at time of inspection.

e. Reservoir location
Nebraska: The safety of dams inventory database is ported to an ESRI ArcView shapefile every weekday evening. Location accuracy was reviewed and improved in 2003.
http://dnrdata.dnr.state.ne.us/Dams/damsutm.zip
http://dnrdata.dnr.state.ne.us/Dams/dams_Stateplane.zip.

f. Contributing Drainage Area
Nebraska: Nebraska Department of Natural Resources Databank of dam safety program dam inventory. The source file is a Microsoft Access Dam Inventory Database.
http://dnrdata.dnr.state.ne.us/Dams/Search.aspx?mode=county

g. Date Reservoir Constructed/retired
Nebraska:
http://nrcnt3.dnr.state.ne.us/Canal/Reservoir/index.asp

3. Land Terraces data needs

General data
United States: USDA/NRCS electronic Field Office Technical Guide (eFOTG) - Technical guides are the primary scientific references for NRCS. They contain technical information about the conservation of soil, water, air, and related plant and animal resources.
http://www.nrcs.usda.gov/technical/efotg/

Surface area of land terrace
Nebraska: Digitized areas with contour and terraced areas in Nebraska portion of basin. Hand digitized interpretation of land cover patterns as visible on digital aerial photography.

Compact Disk with ESRI format data.

Contributing Drainage Area
Colorado: On compact disk – HUC Level 4.

Kansas: National Hydrography Dataset (NHD) in DASC. HUC Boundary 14-digit level is available (as well as HUC 8 and 11) and includes detailed hydrologic data containing information about surface water features such as lakes, ponds, streams, rivers, springs and wells.

Data related to land terrace type, condition of terrace (including retired or replaced with sprinkler irrigation), and land terrace location will be assessed during the study.

4. Soil Characteristics

a. Permeability
Kansas: SSURGO - Certified Soil Survey Geographic. Soil survey polygons attributed SCS map symbol (MUSYM, MUID, STSYM). The original 24K Detailed Soils polygon coverage is currently being certified by NRCS Fort Worth. The 24K Detailed Soils polygon coverage will be replaced by the Certified SSURGO as they are delivered to DASC. See the SSURGO Status Map to determine if your area has been replaced by the Certified SSURGO data.

Soils Lite - Certified Soil Survey Geographic tables summarized and combined into one table for use with either 24K Soils or SSURGO polygon and line data. Data are named by county FIPS codes, except for Leavenworth/Wyandotte counties which are named 601 and Linn/Miami counties which are named are 602.

United States: See additional info on Data Gateway or NRCS Soils website.
http://soils.usda.gov/.

b. Hydrologic group
Kansas: See Contributing Drainage Area.

c. Soil water holding capacity
Kansas: See SSURGO database above under Permeability.

Nebraska: Soil Mapping Units Interpretative Records data can be retrieved by physical and chemical and engineering properties of soils, water features, crop yield, and other soil characteristics.
http://nrcnt3.dnr.state.ne.us/Soils/soil.asp;
ftp://linux1..dnr.state.ne.u.s/pub/data/state/smud_1st.txt

5. Geologic Characteristics

a. Presence and distribution of aquitards or aquicludes

Kansas: KGS Geohydrology - Don Whitimore/Brownie Wilson may have information.

United States: UNL Conservation and Survey Division Geologic GIS. Data for Nebraska only.

http://csd.unl.edu/csd/specials/gisdata.html.

6. Drainage Characteristics

a. Slope Percent or Degree

Kansas: SSURGO/Digital Raster Graphics (DRG) - Scanned USGS 24K, 100K, and 250K topographic maps with collars clipped out and in the Lambert Conformal Conic coordinate system. Also available in UTM NAD 27 and NAD 83. National Elevation Dataset (NED in DASC). The NED is a seamless mosaic of elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data.

b. Slope Length

Kansas: Calculate from NED (DASC)

c. Topographic characteristics

Colorado: Digital Raster Graphics, DRG, scanned from USGS topos 24K, 100K, and 250 K, DEM – 30 meter, and NED – 30 meter.

Data available on compact disk.

Kansas: DRG/100k Contours (30 meter) (DASC)

Nebraska: A Digital Elevation Model (DEM) is a sampled array of elevations for a number of ground positions referenced horizontally and are usually spaced at regular intervals. The DEMs are produced in 7.5 minute quadrangle units which correspond to USGS 7.5 topographic maps with contour lines spaced at 10 feet interval and drawn to 1:24,000 scale. The level-2., 30meter interval, DEMs are elevation data generated from hypsography (contours) Digital line graphs (DLLs) that have been processed or smoothed for consistency and edited to remove identifiable systematic errors. Source: UN-L Conservation and Survey Division or NE DNR DEM/Topographic GIS Data for Nebraska Only.

http://www.dnr.state.ne.us/databank/dem.html,
http://www.nrc.state.ne.us/databank/spat.html;
http://csd.unl.edu/csd/specials/gisdata.html

7. Streamflow Records

Streamflow data, including annual, monthly, and daily stream flow, baseflow, and surface flow are available as follows:

Colorado: See Colorado Decision Support System described under General Information.

Nebraska: The streams and canals database can be retrieved by station ID number, county or station name for information on streamflow for a monthly, daily, or annual time period in table format.

http://nrcnt3.dnr.state.ne.us/Canal/CanalIndex.asp
http://nrcnt3.dnr.state.ne.us/Canal/Stream/index.asp

The peak flow database can be retrieved by station ID number or name, or county to state the maximum streamflow was in annual time period in table format for a gaging station.

http://nrcnt3.dnr.state.ne.us/peakvalue/peakindex.asp

United States: See discussion under Precipitation on USDA/NRCS National Water and Climate Center Data.

Water Supply Forecasting http://www.wcc.nrcs.usda.gov/wsf/
Stream Flow http://www.wcc.nrcs.usda.gov/wsf/wsf-strmflow-data.html
Snow Pack http://www.wcc.nrcs.usda.gov/snowcourse/sc-snowpack.html
Reservoirs: http://www.wcc.nrcs.usda.gov/wsf/wsf-reservoir.html

The US Geological Survey data can be accessed at the following sites:
Colorado: http://waterdata.usgs.gov/co/nwis/nwis
Nebraska: http://waterdata.usgs.gov/ne/nwis/nwis
Kansas: http://waterdata.usgs.gov/ks/nwis/nwis

8. Precipitation

Precipitation data including amount, timing, frequency, intensity, and location are available as follows:

Colorado: See Colorado Decision Support System under General Information.

Nebraska: The precipitation database can be retrieved by station ID number, county or station name to tell how much rainfall occurred in a monthly, daily, or hourly time period. The precipitation database is monthly, daily and hourly data in table format.

http://nrcnt3.dnr.state.ne.us/PrecipHourly/index.asp,

The snowfall database can be retrieved by station ID number, county or station name to tell how much snowfall occurred in a monthly or daily time period. The snowfall database is monthly or daily data in table format.

http://nrcnt3.dnr.state.ne.us/Snow/index.ast)

United States: USDA/NRCS National Water and Climate Center Climate Data: The climate data currently used in Conservation Planning are generally observed by the National Weather Service (NWS) Cooperative Network. This nationwide network currently consists of nearly 8,000 active climatic stations. Observations at cooperative stations are performed by private citizens, institutions (such as utilities and television stations), or state and federal agencies. The digital record of these observations is called the Summary of Day (TD-3200). The National Water and Climate Center Climate Data include information on climate, water supply forecasting, streamflow, precipitation, snowpack, and reservoir information, as well as other information.

Climate Data http://www.wcc.nrcs.usda.gov/climate/

Precipitation Data http://www.wcc.nrcs.usda.gov/wsf/wsf-precip.html

PRISM (Parameter-elevation Regressions on Independent Slopes Model)
http://www.ncgc.nrcs.usda.gov/branch/gdb/products/climate/index.html

9. Evaporation/Evapotranspiration

Evaporation and evapotranspiration data including climatic data, pan evaporation, and RRCA model data are available as follows:

Nebraska: The evaporation database can be retrieved by station ID number, county or station name for information on evaporation in a monthly or daily time period. The evaporation database is monthly or daily data in table format.
http://nrcnt3.dnr.state.ne.us/Eval)/index.asp

United States: See discussion under Precipitation on USDA/NRCS National Water and Climate Center Data.

10. Landuse/Landcover

Landuse and landcover data such as tillage practices are available as follows

Nebraska: The digitized land use survey data is a digital product of the unrectified aerial photographs of Nebraska. The field data was obtained by Consolidated Farms Service Agency and was digitized by the Nebraska Department of Natural Resources. It is based on 8 acre cell size and each county contains on the average 20 different land use symbols.
http://nrcnt3.dnr.state.ne.us/SpatialK/LandUse/index.aspx

The extent to which data are needed on past, present, and future cropping practices will have to be assessed during the study.

B. Additional Data Sources

Colorado:

Groundwater Wells – All high-capacity wells (e.g. irrigation wells) must be either registered, if constructed prior to 1965, or permitted if constructed after 1965. Small-capacity wells (e.g. domestic use) constructed after 1972 must also obtain a permit prior for construction. A database of all permits issued is maintained by the State Engineer's office. The data includes owner information, location, use, depth, date of construction, and date of first beneficial use.

Surface Water Rights – A tabulation of water rights and diversions with the Republican River Basin in Colorado is maintained by the State Engineer's Office. The tabulation can be accessed through the Colorado Decision Support System described above.

Nebraska:

Soil Erosion C-Factor - The C-factor is the cropping and management factor expressed as a ratio of soil loss under a specific cropping and management system to the soil loss under a clean-till, continuous fallow system. The raster data: The digitized c-factor survey data is a digital product of the unrectified aerial photographs of Nebraska. The field data was obtained by Consolidated Farms Service Agency and was digitized by the Nebraska Department of Natural Resources.

http://nrcnt3.dnr.state.ne.us/SpatiaIK/CFactor/index.aspx

Soil Erosion P-Factor-The P-Factor is the erosion control practice factor expressed as a ratio of soil loss with contouring, strip cropping or terracing to soil loss with straight row up-and down farming. For raster data: The digitized p-factor survey data is a digital product of the unrectified aerial photographs of Nebraska. The field data was obtained by Consolidated Farms Service Agency and was digitized by the Nebraska Department of Natural Resources.

http://nrcnt3.dnr.state.ne.us/SpatiaIK/PFactor/index.aspx

Registered Groundwater Wells-Current Nebraska Statues require that all new water wells be registered with the Nebraska Department of Natural Resources within 30 days of completion of the well, except test holes in existence for 10 days or less, dewatering wells with intended use of 90 days or less, domestic or livestock wells completed prior to September 9, 1993, and soil vapor monitoring wells.

http://nrcnt3.dnr.state.ne.us/wellssgl/default.asp

Surface Water Rights-The Nebraska Department of Natural Resources has jurisdiction over all matters pertaining to surface water, rights for storage, irrigation, power, manufacturing, instream flows and other beneficial uses. This includes the distribution of available supply during times of water shortages and adjudication of established water rights. Any person who wishes to divert and use the waters of a natural stream or lake must first get a permit or water right from the Department.

http://nrcnt3.dnr.state.ne.us/SWR/index.asl)x

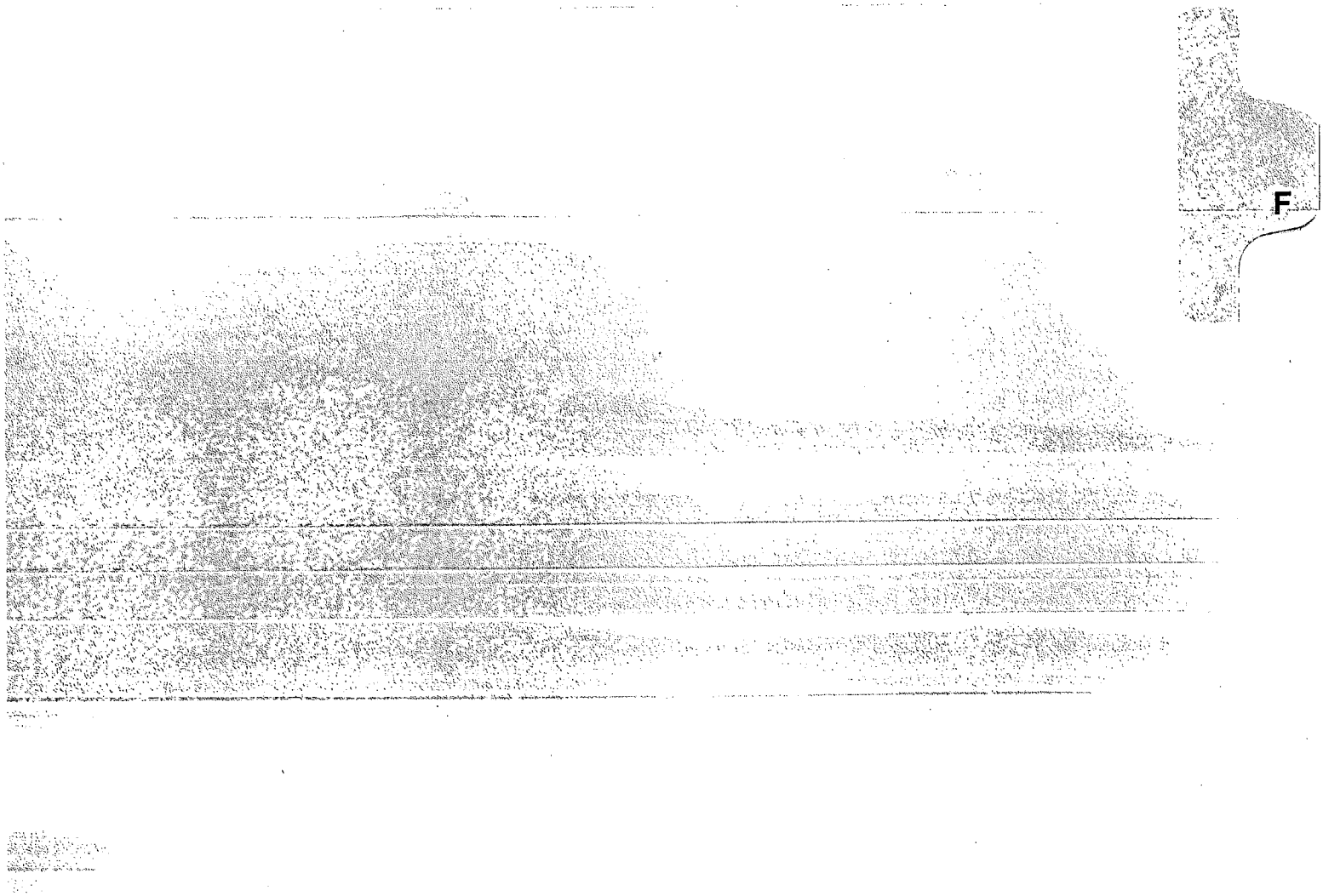
Hydrologic Units & Streams- Description: The Nebraska Department of Natural Resources in cooperation with NRCS, USGS. DEQ and NGP delineated and computerized the boundaries of drainage areas that formed the basic hydrologic units needed for water resources planning and other uses. These basic hydrologic units were designed so they could be aggregated to many combinations of watershed or river basins. They have been integrated into the NRCS computer data system so they are available to all with the facilities to access the Natural Resources Data Bank.

http://www.dnr.state.ne.us/databank/hydro.html

United States:

USDA/FSA Common Land Unit (CLU) - A Common Land Unit (CLU) is the smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner and a common producer association. A CLU is delineated from permanent features such as fence lines, roads, and or waterways. This requirement minimizes the number of changes that will be required in the CLU boundary. Currently, all Service Center Agencies maintain a wide array of information related to land units. This information is fragmented among paper documents and computer systems. All this scattered information related to CLU's can be consolidated. CLUs are currently being digitized to produce a CLU data layer. Digitizing involves using GIS to draw border lines on top of the original orthophotograph, calculate the area of the polygon and attach elements of data, such as a label or a field number or a record identifier, to this polygon shape. For Service Centers, these polygons will represent CLU boundary lines. Each CLU defined in the GIS database will be automatically identified and tracked, for national purposes, with an ID number assigned by the automated system. This ID is not visible to the user, but can be accessed when needed. The ID is a computer-generated number that is a combination of the longitude and latitude coordinates of the CLU center point and this ID will be unique to the Nation and will never be reused.

http://fsagis.usda.gov/fsagis/programs/clu/clu_dig_status.cfm
http://apfonet.apfo.usda.gov/statusmaps/clustat.pdf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Appendix F

METHODOLOGY FOR ASSESSING AREA-CAPACITY RELATIONSHIP FOR NON-FEDERAL RESERVOIRS

A. Review of Past Efforts to Address Non-Federal Reservoir Capacity

1. In a internal study in 1991 of 1,520 dams in Kansas Division of Water Resources, the formula for volume of storage at the top of dam was found to be 0.34 x height x surface acres ($V = 0.34 \times h \times A$). This is essentially the equation for a pyramidal or conic volume ($1/3 \times h \times A$). The range of values were from 0.2 to 1.0 (rectangular "lagoon", $1 \times h \times A$). The .34 is the average of all 1,520 dams with a standard deviation of .099.

In November 2003, further work was completed on the 1520 dams of the 1991 study resulted in an equation for 839 dams statewide with a volume between 15 and 200 Acre-feet (AF). The regression formula is
Area = .1113 x Volume + 1.86 with an $R^2 = 0.611$.

For a 15 AF dam, the area is 3.52 acres; for 200 AF, 24.12 acres.

2. Since cubes, rectangular parallelepid, prisms, pyramids, and frustums of pyramids are all examples of prismatoids, the formula for the volume of a prismatoid subsumes most of the volume formulas.[1]

$V = 1/6\ h\ (B_1 + 4M + B_2)$, where B_1 is the area of the lower base, M is the area of the midsection, B_2 is the area of the upper base, and h is the altitude.[2]

3. In 2002-03, Kansas Division of Water Resources contracted with Kansas Applied Remote Sensing (KARS) of the University of Kansas to update the Dam Inventory for Kansas using satellite imagery. For the High Plains region, a regression equation was computed using only the surface area of the reservoir. $V = -71.272 + 11.496 * Area$. This equation had an Adj. $R^2 = .959$. The nature of the underlying data for this study is unknown and therefore could not be verified.

The formula results in 7.5 acres for a 15 AF dam, and 23.60 acres for 200 AF.

4. NRCS inventory of each state contains data concerning dams on which NRCS participated technically. These dams are not inclusive of dams outside the NRCS assistance, but do include dams that are not included the states' inventories.

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[1]CRC Standard Mathematical Tables, 19th Ed. 1971.

[2]Agriculture Handbook 590, Ponds – Planning, Design, Construction. Natural Resources Conservation Service. Revised November, 1997. p. 59.

The information for the counties in each state could be used in producing area-capacity relationships (which may vary due to topographic differences). Full-pool reliability could be estimated since NRCS designs the water supply to meet probability standards.

B. Evaluation of Area-Capacity Relations Using the National Dam Inventory (NDI) Data

The National Dam Inventory is available on the Web and can be downloaded by state in text form. This data for Colorado, Kansas and Nebraska was downloaded on November 21, 2003. The text files were then imported into a Microsoft Excel spreadsheet. Colorado had 1,652 dams in the NDI; Kansas, 5,859; Nebraska, 2,074 for a total of 9,585 dams.

The total number of dams was culled to 588 dams by limiting the dams to those located between the 39 to 41 degrees latitude and 98 to 104 degrees longitude with the information for normal pool volume and surface area. This rectangular area encompasses most of the Republican River Basin above Hardy, Nebraska and includes therefore most of the RRC Groundwater Model domain. A map showing approximate locations of the dams with relationship to the model domain is attached.

Further culling of dams due to poor information was conducted to a total number of 486 dams. Some of the errors that led to not including a dam were, latitudes or longitudes of 999.99 degrees, computed normal pool depths substantially greater than the total height of dam, and structures with volumes for normal pool of less than 2 acre-feet or with no value shown.

Using Excel's charting program, charts were prepared. The areas and volumes for various populations of dams were plotted as x-y graphs. The charting function was used to compute linear regression equations and R^2 values. For the total population 486 dams with 5 to 3000 acre-feet normal pools, this analysis results in the linear regression equation, Area = 0.0867 x Volume and $R^2 = 0.6842$.

For a 15 AF dam, the Area equals 1.3 acres; for 200 AF, 17.34 acres.

In discussion with some of the members of the task group, it was pointed out that the linear regression equation provides for a single height value. If a second order polynomial regression equation were used, then the R^2 is improved, but also the height will be variable with volume and area. This is more representative of the physical character of these reservoirs.

The following tabulation of the various methods or dam populations is provided for comparison.

Method	Area Formula	R^2	Sample size	15AF Area	200 AF Area
KDWR	0.1113V +1.86	0.61	839	3.52	24.12
KARS	(V+71.272)/11.496	0.959	Unknown	7.50	23.60
NDIS [1]	0.0867 V	0.6842	486	1.3	17.34
NDIS [2]	-.00002 V^2 + 0.1228 x V + 3.75	0.7557	486	5.59	27.51
NDIS [3]	-.00006 V^2 + 0.1377 x V + 4.33	0.7322	205	6.33	29.47

NDIS[4]	**-.00002 V^2 + 0.182 x V + 1.47**	**0.5217**	**384**	**4.20**	**37.07**
NDIS[5]	**-.00009 V^2 + 0.1604 x V + 2.01**	**0.6722**	**413**	**3.60**	**30.49**

[1]Linear regression for reservoirs of 5 to 3000 acre-feet.
[2]Polynomial regression for reservoirs of 5 to 3000 acre-feet.
[3]Polynomial regression for reservoirs of 51 to 950 acre-feet.
[4]Polynomial regression for reservoirs of 15 to 200 acre-feet.
[5]Polynomial regression for reservoirs of 15 to 500 acre-feet.

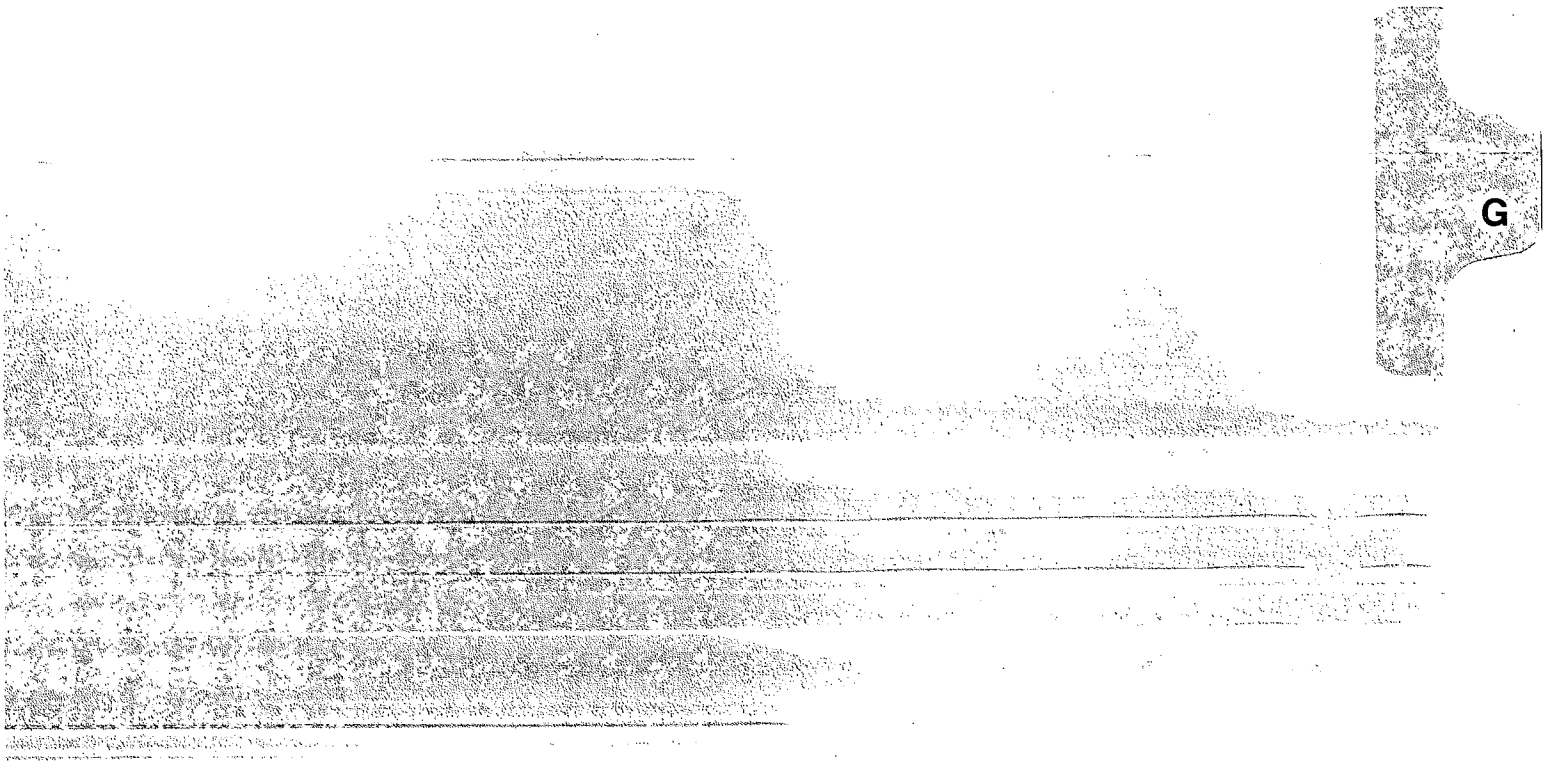
A. Recommended Procedure for Determining an Area-Capacity Relationship

Actual field survey data is available for a number of Non-federal Reservoirs in the Republican River Basin. Where this data is available it should be used to develop area-capacity for those specific reservoirs. Where a field survey has not been conducted to provide current or design information as to the reservoir's area-capacity relationship, the fifth NDIS formula for dams of 15 to 500 acre-feet should be accepted as the estimating method.

Area = -0.00009 x Volume^2 + 0.1604 x Volume + 2.01.

Attached.

Map showing approximate locations of dams used in this study.
Chart: Normal Capacity, 15 to 500 AF vs. Area



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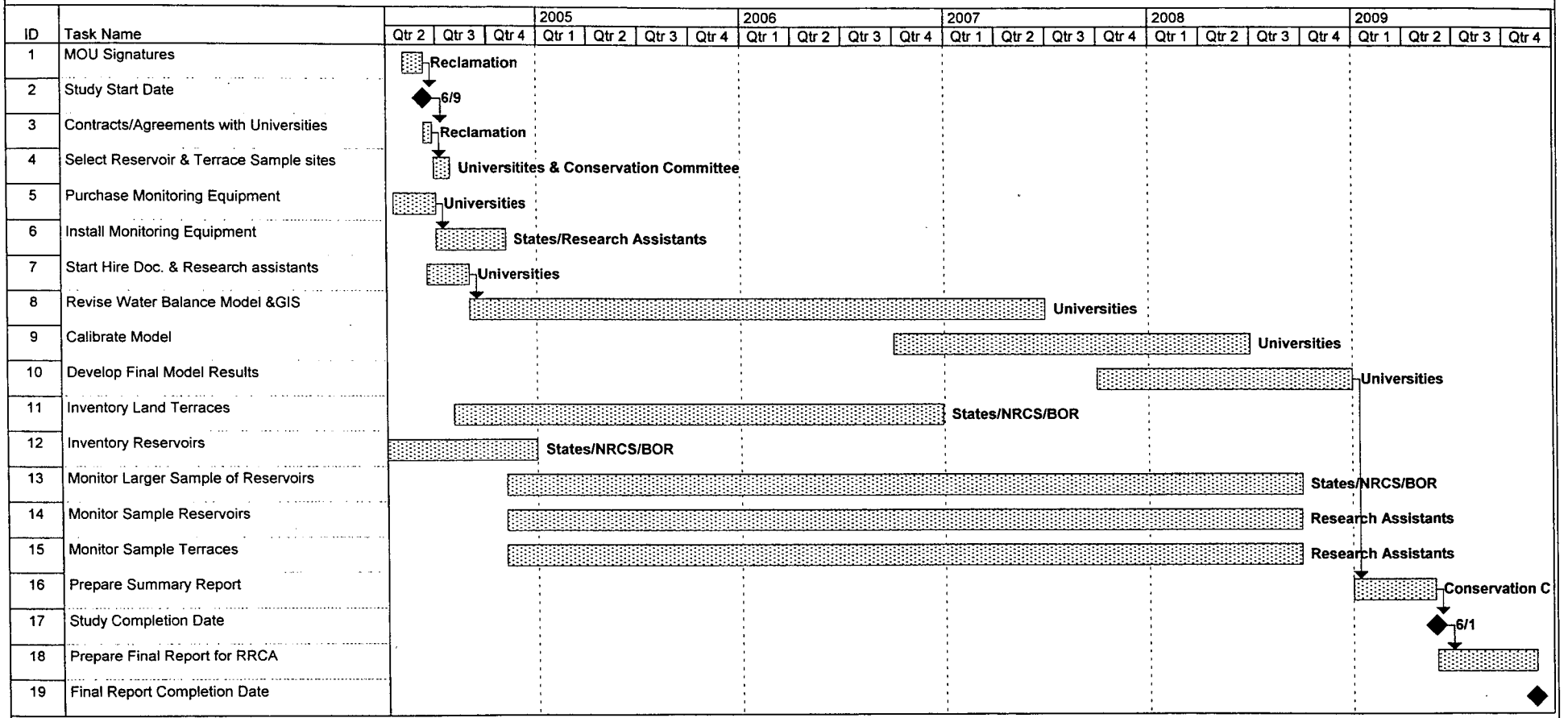
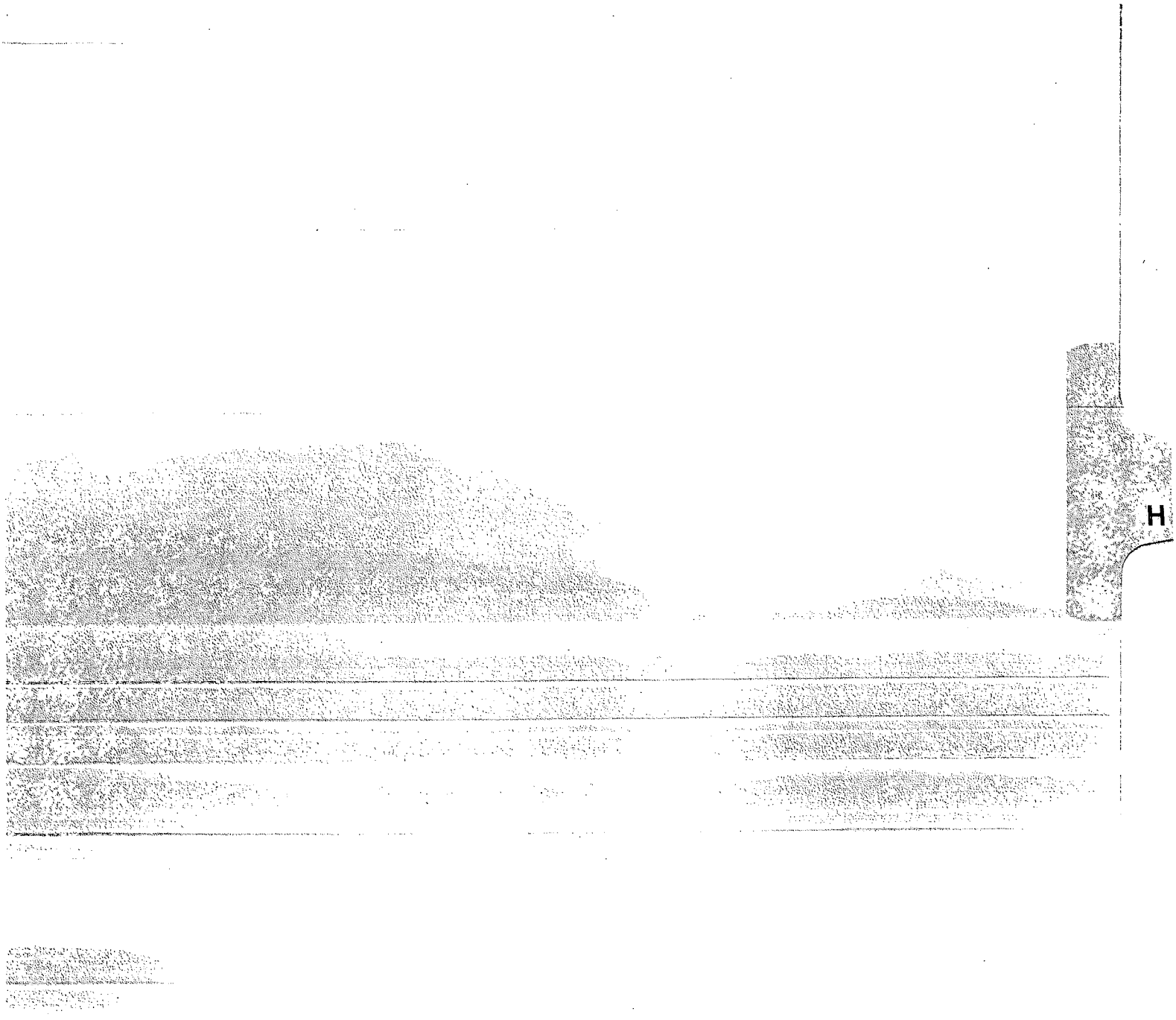
APPENDIX G
REPUBLICAN RIVER CONSERVATION STUDY
DRAFT



Project: Study Time Line
Date: Tue 3/30/04

Task
Split
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Split
Rolled Up Milestone
Rolled Up Progress
External Tasks
Project Summary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APPENDIX H1

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GREAT PLAINS REGION

MEMORANDUM OF UNDERSTANDING
MOU NO. XXXXX
FOR
Republican Basin Water Study
Impacts from Non-Federal Reservoirs and Land Terracing

This Memorandum of Understanding (MOU) between the United States Department of the Interior, Bureau of Reclamation Great Plains Region (Reclamation), the United States Department of Agriculture, Natural Resources Conservation Service (NRCS), and the States of Colorado, Kansas, and Nebraska (States), identifies the roles, work, and funding responsibilities for completing a proposed study to determine the quantitative effects of Non-Federal Reservoirs and land terracing practices on water supplies, including whether such effects can be determined for each Designated Drainage Basin. The parties will abide by the terms and provisions expressed or referenced herein.

Bureau of Reclamation

Maryanne Bach
Regional Director
Great Plains Region

Date: _____

Natural Resources Conservation Service

Richard Van Klaveren
Regional Conservationist
Northern Plains Region

Date: _____

State of Colorado

Hal Simpson
State Engineer
Colorado Division of Water Resources

Date: _____

State of Kansas

Adrian J. Polansky
Secretary
Kansas Department of Agriculture

Date: _____

State of Nebraska

Roger Patterson
Director
Nebraska Department of Natural Resources

Date: _____

I. BACKGROUND, INTRODUCTION, PURPOSE, AND OBJECTIVE

A. Background

1. Republican River Basin

The Republican River Basin begins in Eastern Colorado, flows through Northwest Kansas into Southwest Nebraska, flows back into Northcentral Kansas near the town of Hardy, Nebraska, and eventually flows into Milford Reservoir.

Development of federal projects in the basin include seven Reclamation Reservoirs and Lakes (Bonny, Swanson, Enders, Hugh Butler, Harry Strunk, Keith Sebelius, and Lovewell), two Corps of Engineers reservoirs (Harlan County, Milford), and six irrigation districts (Frenchman Valley, H & RW, Frenchman-Cambridge, Almena, Bostwick in Nebraska, and Kansas Bostwick).

2. Republican River Compact

The States of Colorado, Kansas, and Nebraska and a representative of the United States negotiated the Republican River Compact during the early 1940s. The major purposes of the Compact are to provide for the most efficient use of the waters of the Republican River Basin for multiple purposes; to provide for an equitable division of such waters; to remove all causes, present and future, which might lead to controversies; to promote interstate comity; to recognize that the most efficient utilization of the waters within the Basin is for beneficial consumptive use; and to promote joint action by the States and the United States in the efficient use of water and the control of destructive floods.

The Republican River Compact, signed in 1943 by the states of Colorado, Kansas, and Nebraska, and ratified by Congress and approved by the President, allocates the average annual virgin water supply of the Republican River, between the states of Colorado, Nebraska, and Kansas. Under the Compact, the total allocation given to each State is to be derived from the listed tributaries, and for Nebraska and Kansas, from the mainstem of the Republican River.

The Compact makes specific allocations to each of the three states in 14 different subbasins and includes provisions for adjustment to the virgin water supply and allocations based on future records and/or changing conditions. The virgin water supply is defined as the water supply within the Basin undepleted by the activities of man.

3. Republican River Compact Administration

The Republican River Compact Administration (RRCA) serves as the administrative body of the Compact and is composed of State Officials responsible for administrating the public water supplies in each state. Currently these include the State Engineer of the Division of Water Resources of the Colorado Department of Natural Resources, the Chief Engineer of the Division of Water Resources of the Kansas Department of Agriculture, and the Director of the Department of Natural Resources for the State of Nebraska. The RRCA was created in 1959 in order to develop and refine methods to annually estimate the virgin water supply and consumptive uses within the basin and to administer the Compact. The RRCA meets at least annually to report on events pertaining to the Compact and to take any necessary action regarding the administration of the Compact.

4. Settlement Stipulation

In May of 1998, the State of Kansas filed a motion with the U. S. Supreme Court alleging that Nebraska violated the Compact by allowing the proliferation and use of groundwater wells hydraulically connected to the Republican River and its tributaries, and by failing to protect the surface flows from other unauthorized appropriations.

In December, 2001 the Special Master assigned to the case agreed to postpone the progression of the case in order to allow the three Compact States, Colorado, Kansas, and Nebraska, to engage in settlement negotiations. These negotiations culminated in a settlement package that was approved by the Governors and Attorneys General of all three states in December, 2002.

The States agreed to resolve the pending litigation regarding the Republican River Compact by means of a Final Settlement Stipulation and a Proposed Consent Judgment.

B. Introduction

1. Final Settlement Stipulation

As directed in the Final Settlement Stipulation, dated December 15, 2002, the States, in cooperation with the United States, formed a Conservation Committee to evaluate the available methods and data relevant to studying the impacts of Non-Federal Reservoirs and land terracing practices on water supplies, including a review of any existing studies, the availability of data, level of accuracy of data, and identify additional data necessary. The Conservation Committee is also required to submit to the RRCA a proposed study plan to determine the quantitative effects of Non-Federal Reservoirs and land terracing practices on water supplies, including whether such effects can be determined for each Designated Drainage Basin

Following the RRCA's acceptance of the proposed study plan, the States and the United States will undertake the study at a cost not to exceed one million dollars, of which the United States will be responsible for 75% of the cost and each State will be responsible for one third of the remaining 25%. The States' portion may be provided entirely through in-kind contributions. If the study exceeds one million dollars, the United States will be responsible for the entire additional amount. The States, in cooperation with the United States, shall agree upon the timetable for the completion of such study, which shall be completed within five years of the date the proposed study plan is accepted by the RRCA.

2. Conservation Committee

As outlined in the Final Settlement Stipulation, the States, in cooperation with the United States, formed a Conservation Committee in order to develop information that may allow the States to assess the impacts of Non-Federal Reservoirs and land terracing on the water supply and water uses within the Basin.

The Conservation Committee is comprised of representatives from the Bureau of Reclamation, the Natural Resources Conservation Service, and the States of Colorado, Kansas, and Nebraska. A listing of individuals serving on the Conservation Committee is included as appendix B.

C. Objective and Purpose

The objective of this MOU is to provide a guide to complete the proposed study that will determine the quantitative effects of Non-Federal Reservoirs and land terracing practices

on water supplies, including whether such effects can be determined for each Designated Drainage Basin.

The purpose of this MOU is to generally describe the following:

1. The scope of work, including the roles and responsibilities for Reclamation, the NRCS, and the States.

2. Roles and responsibilities of the RRCA and the Conservation Committee.

3. The funding arrangement between the United States and the States to complete the study

4. The term of the MOU and required clauses

5. Assign representatives from Reclamation, NRCS, and the States that are responsible for monitoring activities of this MOU.

II. SCOPE OF WORK

A. Roles and Responsibilities

1. Roles and Responsibilities common to Reclamation, NRCS, and States

a. Conservation Committee – Reclamation, NRCS, and the States agree to serve on and support the Conservation Committee, which will serve as the managing body for the study. The Conservation Committee will:

(1) coordinate, select, and assign specific study tasks to appropriate entities, including keeping focus of separate tasks and combining all tasks into the final report.

(2) coordinate activities of selected entities to ensure study timelines remain obtainable. Meet with selected entities on a minimum of semiannual basis in order to monitor study activities.

(3) provide an annual update of study activities to the RRCA at the RRCA's annual meeting, which will include status report, updated timeline, financial report, and future funding estimates.

(4) Prepare a final report on the study after the study results have been accepted by the RRCA.

b. Serve as a source of specific expertise in the proposed study, including compliance with State laws and regulations, hydrology, and water rights. Activities include providing analysis related to specific expertise, providing writing and editing services for relevant documentation, and participating in public meetings as needed.

c. Provide staff support and equipment required to complete specific study tasks, including information and assistance to entities selected to complete the study.

d. Participate in technical reviews of study and assist with preparation of update reports that will be presented to the RRCA.

e. Participation in the joint study by all parties is contingent upon the appropriation of funds by their respective State Legislatures and Congress. Participation by the States in this study is contingent upon participation and funding by the United States.

f. Attend meetings as necessary with the public, federal, state, regional and local agencies for the purposes of facilitating communication and receiving comments, as may be necessary, desirable, or required by law, and insofar as such meetings are relevant to the study.

g. Develop and annually update a Study Timeline (included in appendix C). All parties acknowledge and understand that the Study Timeline is a target or goal and that there are many influences outside the control of the signatories to this agreement that could affect progress. Reclamation, the NRCS, and the States will work to resolve any issues which could delay the process and will meet periodically to update and revise the schedule.

h. All agencies will provide records of study expenditures including in-kind services to the Conservation Committee prior to the annual study status report to the RRCA.

i. All agencies will be notified in writing of any changes to personnel assigned to the Conservation Committee.

2. Reclamation

a. Appoint appropriate staff to serve on the Conservation Committee.

b. Budget and program Federal funding required to complete the study.

c. Enter into grant agreements, cooperative agreements, and/or interagency agreements with agencies chosen by the RRCA and/or the Republican Conservation Committee to complete the proposed study.

3. NRCS

a. Appoint appropriate staff to serve on the Conservation Committee.

b. Utilize existing staff, funding, and expertise in order to contribute to the completion of the study.

4. States

a. Republican River Compact Administration - States will continue to serve on and support the Republican River Compact Administration (RRCA), which has the following responsibilities related to the study.

(1) Each States Compact Commissioner of the RRCA shall be responsible for appointing state representatives to serve on the Conservation Committee.

(2) The RRCA is responsible for approval of the proposed study plan prepared by the Conservation Committee

(3) The RRCA will provide guidance to the Conservation Committee and associated agencies involved in completing the study.

(4) The RRCA will review the annual study updates provided by the Conservation Committee and/or agencies assigned to complete the study at the RRCA annual meetings or as requested. Based on this review the RRCA will provide comments and direction to the Conservation Committee indicating the need for adjustments to the study to ensure that the desired study goals are met

(5) The RRCA is responsible for the final acceptance of the completed study.

b. Through their respective Conservation Committee and RRCA members, the States will review all grant, cooperative, and/or interagency

agreements drafted to complete specific study tasks to ensure that these agreements are in line with the objective of the study

c. Each State will be responsible for one third of the 25% cost share required by the States for the Study, as outlined in the Final Settlement Stipulation. The States' portion may be provided entirely through in-kind contributions.

d. Each State will provide annual in-kind service records to the Conservation Committee in order to verify each State's share of the 25% funding requirement as outlined in the Final Settlement Stipulation.

III. FUNDING

It is mutually agreed upon by all parties that this MOU is neither a fiscal nor funds obligation document. Any endeavor by any party that involves the reimbursement, contribution of funds, transfer of anything of value between the parties will be handled in accordance with applicable laws, regulations, and procedures. Such endeavors shall be outlined in separate agreements; shall be made in writing by representatives of involved parties; and shall be independently authorized by appropriate statutory authority. This MOU does not provide such authority.

Nothing in this MOU will require changes in any funding obligations, nor require any party to assume new funding obligations.

A. FEDERAL FUNDING

The United States will be responsible for 75% of the costs of the study, which is not planned to exceed one million dollars. If the cost of the study exceeds one million dollars, the United States will be responsible for the entire additional amount.

B. NON-FEDERAL FUNDING

Each State will be responsible for one third of the remaining 25% of the cost of the study, up to the one million dollar limit.

The States' portion may be provided entirely through in-kind contributions.

IV. PAYMENT FOR SERVICES

Payment for services to will be accomplished through separate grant agreements, cooperative agreements, and/or interagency agreements between Reclamation and the agencies selected to complete specific aspects of the study.

Federal funding estimates for the study period is included as Appendix C. The Conservation Committee will update costs and funding estimates as the study proceeds.

It is understood that the costs estimated above are preliminary and difficult to estimate, and that actual costs may be lesser or greater than estimated above. When specific study tasks are assigned, the Conservation Committee will make appropriate adjustments to the timetable and funding estimates.

Notwithstanding any other provision of this MOU, the financial obligations of the States hereunder shall be limited to 25% of the first one million dollars for the costs of the study. The United States will be responsible for 75% of the first one million dollars and 100% of the costs of the study in excess of one million dollars.

V. TERM OF THE MOU

This MOU will remain in effect until December 31, 2009, or an earlier date if the study and final report are completed and accepted by the RRCA prior to December 31, 2009.

This MOU may be terminated upon any of the following conditions:

1. Mutual agreement.
2. Insufficient appropriation of funds, by a respective state legislature, for completion of study.
3. Insufficient appropriation of funds by Congress to the Bureau of Reclamation for completion of study.
4. Completion and RRCA acceptance of the study.

If the MOU is terminated, any unexpended funds previously advanced to the States (or entities contributing to the study) by Reclamation will be accounted for and returned to Reclamation within sixty (60) days of the termination of this MOU.

This MOU may be extended or amended at any time by written consent by the designated representatives of the parties hereto.

This MOU is renegotiable upon agreement by all parties.

VI. REQUIRED CLAUSES

During the performance of this MOU, the participants agree to abide by the terms of Executive Order 11246 on nondiscrimination and will not discriminate against any person because of race, color, religion, sex, or national origin.

No member or delegate to Congress, or resident Commissioner, shall be admitted to any share or part of this MOU or to any benefit arising from it. However, this clause does not apply to this MOU to the extent that this MOU is made with a corporation for the corporation's general benefit.

VII. KEY OR RESPONSIBLE PERSONNEL

The following people will serve as representatives for this MOU:

A. Reclamation representative:

Gordon Aycock, Technical Specialist
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B. NRCS representative:

Steve Garner, Northern Plains Engineering Team
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C. Colorado representative:

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D. Kansas representative:

George Austin, Interstate Water Issues Team
Kansas Department of Agriculture
Division of Water Resources
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E. Nebraska representative:

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Appendix A

Conservation Committee

UNITED STATES

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Appendix B

Republican River Compact Administration

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Appendix C

Study Timeline

Appendix D

Study Proposal

Impacts from Non-Federal Reservoirs and Land Terracing on Virgin Water Supply

APPENDIX H2

Agreement No. XXXXXXXX

Cooperative Agreement
Between
The Bureau of Reclamation
and
The University of Nebraska - Lincoln
for
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

I. AUTHORITY

This Cooperative Agreement (agreement) is entered into between the United States of America, acting through the Department of Interior, Bureau of Reclamation, hereinafter referred to as "Reclamation", and the University of Nebraska-Lincoln, hereinafter referred to as "UNL", pursuant to the XXXXXXXXXXXX and No. 126, Original, In the Supreme Court of the United States, State of Kansas (Plantiff) v. State of Nebraska and State of Colorado (defendants), Before the Honorable Vincent L. McKusick, Special Master, Final Settlement Stipulation, December 15, 2002, Section VI. Soil and Water Conservation Measures, B. (page 30) In order to attempt to develop information that may allow the States to assess the impacts of Non-Federal Reservoirs and land terracing on the water supply and water uses within the Basin, the States agree to undertake a study, in cooperation with the United States, of the impacts of Non-Federal Reservoirs and land terracing on the Virgin Water Supply.

II. BACKGROUND AND OBJECTIVE

A. REPUBLICAN RIVER BASIN

The Republican River Basin begins in Eastern Colorado, flows through Northwest Kansas into Southwest Nebraska, flows back into Northcentral Kansas near the town of Hardy, Nebraska, and eventually flows into Milford Reservoir.

Development of federal projects in the basin include seven Reclamation Reservoirs and Lakes (Bonny, Swanson, Enders, Hugh Butler, Harry Strunk, Keith Sebelius, and Lovewell), two Corps of Engineers reservoirs (Harlan County, Milford), and six irrigation districts (Frenchman Valley, H & RW, Frenchman-Cambridge, Almena, Bostwick in Nebraska, and Kansas Bostwick).

B. REPUBLICAN RIVER COMPACT

The States of Colorado, Kansas, and Nebraska and a representative of the United States negotiated the Republican River Compact during the early 1940s. The major purposes of the Compact are to provide for the most efficient use of the waters of the Republican River Basin for multiple purposes; to provide for an equitable division of such waters; to remove all causes, present and future, which might lead to controversies; to promote interstate comity; to recognize that the most efficient utilization of the waters within the Basin is for beneficial consumptive use; and to promote joint action by the States and the United States in the efficient use of water and the control of destructive floods.

The Republican River Compact, signed in 1943 by the states of Colorado, Kansas, and Nebraska, and ratified by Congress and approved by the President, allocates the average annual virgin water supply of the Republican River, between the states of Colorado, Nebraska, and Kansas. Under the Compact, the total allocation given to each State is to be derived from the listed tributaries, and for Nebraska and Kansas, from the mainstem of the Republican River.

The Compact makes specific allocations to each of the three states in 14 different subbasins and includes provisions for adjustment to the virgin water supply and allocations based on future records and/or changing conditions. The virgin water supply is defined as the water supply within the Basin undepleted by the activities of man.

C. LAWSUIT AND SETTLEMENT

In May of 1998, the State of Kansas filed a motion with the U. S. Supreme Court alleging that Nebraska violated the Compact by allowing the proliferation and use of groundwater wells hydraulically connected to the Republican River and its tributaries, and by failing to protect the surface flows from other unauthorized appropriations.

In December, 2001 the Special Master assigned to the case agreed to postpone the progression of the case in order to allow the three Compact States, Colorado, Kansas, and Nebraska, to engage in settlement negotiations. These negotiations culminated in a settlement package that was approved by the Governors and Attorneys General of all three states in December, 2002.

The States agreed to resolve the pending litigation regarding the Republican River Compact by means of a Final Settlement Stipulation and a Proposed Consent Judgment. As directed in the Final Settlement Stipulation, dated December 15, 2002, the States, in cooperation with the United States, formed a Conservation Committee to evaluate the available methods and data relevant to studying the impacts of Non-Federal Reservoirs and land terracing practices on water supplies, including a review of any existing studies, the availability of data, level of accuracy of data, and identify additional data necessary.

The Conservation Committee is also required to submit to the RRCA a proposed study plan to determine the quantitative effects of Non-Federal Reservoirs and land terracing practices on water supplies, including whether such effects can be determined for each Designated Drainage Basin.
The study plan proposed by the Conservation Committee includes field experiments and water balance modeling in the Republican River Basin, compilation and collection of data by the States, and reporting to the RRCA.

D. OBJECTIVE

The objective of this agreement is to provide for implementation of the Republican River Conservation Study Plan (Study Plan) approval by the RRCA. A Memorandum of Understanding between the States of Colorado, Kansas, and Nebraska, the Bureau of Reclamation, and the Natural Resources Conservation Service outlines each agency's responsibilities in relation to the completion of overall study.

* * * We could include the MOU as an attachment or just leave a reference to the MOU * * *

The purpose of this agreement is to provide a mechanism for Reclamation to provide technical and financial assistance to UNL for the modeling, field experimentation and other work related to completion of the study to determine the effects of land terracing and non-federal reservoirs on water supplies in the Republican River Basin above Hardy, Nebraska. The study is required as part of the Settlement Stipulation as mentioned above.

III. PUBLIC BENEFIT

Determining the effects of land terracing and non-federal reservoirs on water supplies in the Republican River Basin above Hardy will provide valuable information in determining the present and future water supply in the basin.

Completing the proposed study is a requirement of the Settlement Stipulation, in which the States of Colorado, Kansas, and Nebraska agree to resolve the litigation in the United States Supreme Court regarding the Republican River Compact. Study results will provide a better understanding of the overall use of water in the basin and assist in preventing future conflicts over the allocation of this water resource.

IV. STATEMENT OF WORK

A. STUDY RESPONSIBILITIES

1. Funding

The United States is responsible for providing 75% of the cost of the study, which is not planned to exceed one million dollars. Colorado, Kansas, and Nebraska will each be responsible for one third of the remaining 25% of the study costs as outlined in the Final Settlement Stipulation. 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 Bureau of Reclamation (Reclamation) will develop agreements with the University of Nebraska – Lincoln (UNL) and Kansas State University (KSU) to fund the study work performed by these universities. Both Reclamation and the Natural Resources Conservation Service (NRCS) will assist by providing data resources that are useful to the study effort.

2. University of Nebraska – Lincoln (UNL)

UNL will serve as the lead for the field study work involved with monitoring a small sample of land terraces and non-federal reservoirs. It is anticipated that Postdoctoral research assistants and undergraduate student assistants will be employed by UNL in this efforts. These individuals will also assist with evaluating existing modeling methods and improvement of those models. Most likely components of several procedures will be integrated into one model for simulation of the impacts of land terraces and non-federal reservoirs. Status reports on study efforts will be provided to Reclamation and the Conservation Committee by May 1st and December 1st of each year.

3. Coordination of Study Effort

Under a separate agreement with Reclamation, Kansas State University (KSU) will also be participating in the study. KSU will be responsible for the development of the selected water balance model and for its application to land terraces and non-federal reservoirs in the basin. UNL and KSU will closely coordinate their work to ensure a coherent study effort. Both Universities will share their work with Colorado State University (CSU). Comments and recommendations provided by CSU will be carefully considered by both UNL and KSU. The States, Reclamation and NRCS will carefully coordinate their individual efforts to collect data and establish data bases that will be useful to completion of the study effort.

B. STUDY PROPOSAL

A detailed description of the study proposal is included with this agreement in Attachment 1. The following is a brief description of the study.

1. Study Procedure

The study will rely primarily on soil water balance models to simulate the impact of land terraces and non-federal reservoirs on the streamflow in the Republican River Basin. Field experiments will be used to verify processes in the simulation models and to provide accurate parameters. The study will also rely on historical climatic records and surface water flows for simulation and verification. Other data required for accurate modeling will be inventories of current land use practices and georeferenced soil, stream and reservoir data.

2. Modification and Evaluation of Existing Models

UNL (with assistance of KSU through a separate agreement with Reclamation) will evaluate existing modeling methods and improvement of those models. At least three models will be studied to determine the most reliable methods. Most likely components of several procedures will be integrated into one model for simulation of the impacts of land terraces and non-federal reservoirs.

3. Databases

Several databases will be required for the project, including information on soils, terraces (location, type, condition, and distribution), reservoirs (locations and properties), streams and rivers (locations and properties), delineation of watersheds, topography, land use practices, farming and crop management practices, climatic and meteorological conditions, stream flow records, historic weather data.

4. Field Studies on Terraced Land

Methods used to quantify the effects of land terraces must be shown to be accurate. There is a need to directly measure the effects land terraces for modern production practices. This portion of the study will involve the selection and monitoring of a sample of land terraces over several years. Monitoring will include the measurement of the dimensions of selected structures and installation of equipment for the measurement of such parameter as soil water profiles, precipitation, inflow, outflow, seepage, plant water use, and evaporation. It is important that the monitoring equipment provide continuous logging of soil water contents and the elevation of water in the reservoir or terraced channel.

These field study results will be used to provide a direct record of the water balance of terraced field and to verify the procedures used in the simulation models for terraced lands.

Initial study plans include selecting eight terraced sites to install extensive monitoring equipment. Additional sites may be added that involve less detailed sampling if time and financial resources allow.

5. Experiments for Non-federal Reservoirs

This study will also include measuring the water balance of selected non-federal reservoirs compared to the same areas without the reservoirs. Measurements include development of the volume/area versus stage relationships for each reservoir. Equipment will be installed within selected reservoirs to measure the stage, turbidity and water temperature, along with evaporation rates. The detailed reservoir monitoring will provide data on the water balance and partition of the water into inflow, evaporation, storage, seepage and outflow. The study will include a range of reservoirs to represent the diversity in the basin. Data from the study will be used to verify modeling results and to provide a direct water balance the non-federal reservoirs in the Republican River basin.

Initially, five reservoir sites will be selected for detailed monitoring. Additional sites will be monitored by the states by use of staff gages to determine annual reservoir storage fluctuation under different weather and runoff conditions. Data collected by the states will be incorporated into the study by UNL

6. Deliverable Product

Four model simulations will be made based on runoff and climatic conditions represented by the historic period of 1972 through 2002. Simulations will be made for conditions with no land terraces or non-federal reservoirs, with land terraces but no non-federal reservoirs, without land terraces but with non-federal reservoirs, and with both land terraces and non-federal reservoirs. These model runs will then be used to calculate and summarized the following:

a. The quantitative effect of the non-federal reservoirs on water supply for each of the designated drainage basin and for the full Republican River Basin above Hardy, Nebraska.
b. The quantitative effect of land terraces on the water supply for each of the designated drainage basins and for the full Republican River Basin above Hardy, Nebraska.
c. The combined effect of both non-federal reservoirs and land terraces on water supply for each of the designated drainage basins and for the full Republican River Basin above Hardy, Nebraska.

C. AGENCY RESPONSIBILITIES

1. The University of Nebraska-Lincoln shall:

   a. Serve as the lead for the field study work involved with monitoring a small sample of land terraces and non-federal reservoirs.
   b. Select and administer Postdoctoral research assistant(s) and undergraduate student assistant(s) to complete study effort.
   c. Collaborate with KSU 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.
   d. Collaborate with KSU and assist with modifying and applying a version of the selected water balance model to the land terraces and non-federal reservoirs in the basin.
   e. Utilize Federal funds for the purchase and installation of remote monitoring equipment; purchase of computer hardware, software, other equipment; and for personnel expenses, including travel, necessary to monitor and study the effects of land terraces and non-federal reservoirs in the Republican River Basin.
   f. Provide an update on the study 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.
   g. Provide a report on or before June 1, 2009 that summarizes the results of the study and addresses items a, b, and c included under B.6. Deliverable Product.

2. Reclamation will:

   a. Provide funding assistance (not to exceed $750,000 for the 5 years of the study period) for the UNL and KSU's study expenses.
   b. Provide UNL and KSU with any data it has in its possession that is relevant to the study.
   c. Provide technical assistance for the installation of equipment acquired under terms of this agreement.
   d. Address National Environmental Policy Act (NEPA) requirements for activities covered by this agreement.
   e. Provide a Grant and Cooperative Agreement Officer's Representative (GCAOR) to coordinate this agreement.

V. TERMS OF THE AGREEMENT

A. IMPLEMENTATION

This agreement becomes effective on the date shown in Block 17a of Form 7-2277, United States of America, Department of the Interior, Bureau of Reclamation, Assistance Agreement and shall remain in effect until December 31, 2009.

B. MODIFICATIONS

Any changes to this agreement shall be made by means of a written modification. Reclamation may make changes to the agreement by means of a unilateral modification to deal with administrative matters, such as changes in address, no-cost time extensions, the addition of previously agreed upon funding, or deobligation of excess funds at the end of the agreement. Additionally, a unilateral modification may be utilized by Reclamation if it should become necessary to suspend or terminate the agreement in accordance with 43 CFR 12.83 or 43 CFR 12.961, as applicable.

All other changes shall be made by means of a bilateral modification to the agreement. No oral statement made by any person, or written statement by any person other than the Grants and Cooperative Agreements Officer (GCAO), shall be allowed in any manner or degree to modify or otherwise effect the terms of the agreement.

All requests for modification of the agreement shall be made in writing, provide a full description of the reason for the request, and be sent to the attention of the GCAO. Any request for project extension shall be made at least 45 days prior to the expiration date of the agreement or the expiration date of any extension period that may have been previously granted. Any determination to extend the period of performance or to provide follow-on funding for continuation of a project is solely at the discretion of Reclamation.

C. ENFORCEMENT

In accordance with 43 CFR 12.83 or 43 CFR 12.962, as applicable, if UNL materially fails to comply with any term of this agreement, whether stated in a Federal statute or regulation, an assurance, in a State plan or application, a notice of award, or elsewhere, Reclamation may take one or more of the following actions as appropriate:

1. Temporarily withhold cash payments pending correction of the deficiency by UNL or more severe enforcement action by the awarding agency;

2. Disallow (deny both use of funds and any matching credit for) all or part of the cost of the activity or action not in compliance;

3. Wholly or partly suspend or terminate the current award for the UNL program;

4. Withhold further awards for the program; or

5. Take other remedies that may be legally available.

D. TERMINATION

In accordance with 43 CFR 12.84 or 43 CFR 12.961, as applicable, and except as provided for in the Enforcement Provision, above, this agreement may be terminated in whole or part only as follows:

1. By Reclamation with the consent of the UNL in which case the two parties shall agree upon the termination conditions, including the effective date and in the case of partial termination, the portion to be terminated, or

2. By the UNL upon written notification to Reclamation, setting forth the reasons for such termination, the effective date, and in the case of partial termination, the portion to be terminated. However, if, in the case of a partial termination, Reclamation determines that the remaining portion of the award will not accomplish the purposes for which the award was made, Reclamation may terminate the award in its entirety under either the Enforcement Provision or paragraph 1 of this Provision.

VI. REPORTING REQUIREMENTS AND DISTRIBUTION

Failure to comply with the reporting requirements contained in this agreement may be considered a material non-compliance with the terms and conditions of the award. Non-compliance may result in withholding of future payments, suspension or termination of the agreement, recovery of funds paid under the agreement, and withholding of future awards.

A. FINANCIAL REPORTS – All financial reports shall be signed by an Authorized Certifying Official of UNL.

1. SF-269 or SF-269a Financial Status Report – This form is utilized to report total expenditures for the reporting period. The SF-269 must be used if UNL is accountable for the use of program income; otherwise, the SF-269a may be used.

An original and two copies of this form shall be submitted semi-annually within 30 days following the reporting period.

A final SF-269 or SF-269a shall be submitted within 90 days following completion of the agreement.

2. SF-272, Report of Federal Cash Transactions - This report shall be submitted by the UNL if they choose to draw down cash advances by means of

electronic funds transfer or Treasury check. UNL shall identify in the 'Remarks" section the amount of cash advances received in excess of 3 days prior to disbursement and explain actions taken to reduce excess balances.

An original and two copies of this form shall be submitted on a semi-annual basis within 15 days following the end of the reporting period.

B. PROGRAM PERFORMANCE REPORTS

1. Interim Reports – UNL shall submit an original and two copies of program performance reports on a semi-annual basis by May 1st and December 1st of each year. Program performance reports shall contain the following:

(a) A comparison of actual accomplishments with the goals and objectives established for the reporting period;

(b) Where project output can be quantified, a computation of the cost per unit of output;

(c) When appropriate, reasons why goals and objectives were not met; and

(d) Other pertinent information including, when appropriate, analysis and explanation of cost overruns or high unit costs.

2. Final Report – An original and two copies of the final program performance report shall be submitted no later than 90 days following expiration or termination of the agreement.

C. SIGNIFICANT DEVELOPMENTS

During the term of the agreement, UNL must immediately notify the GCAO if any of the following conditions become known:

1. Problems, delays or adverse conditions which will materially impair their ability to meet the objectives of the agreement;

2. Favorable developments which enable UNL to meet time schedules and objectives sooner than or at less cost than projected or to produce more beneficial results than originally planned.

D. REPORT DISTRIBUTION

Copies of reports shall be distributed as follows:

	GCAO (Block 6, Page 1)	GCAOR (Block 8, Page 1)
Financial Reports	2	1
Performance Reports	1	2
Significant Developments	2	1

VII. PAYMENT POLICY

Acceptance of a financial assistance agreement from Reclamation creates a legal responsibility on the part of UNL to use the funds and property provided in accordance with the terms and conditions of the agreement. Reclamation has a reversionary interest in the unused balance of funding and in any funds improperly applied.

Payments to UNL are made in accordance with the basic standards and methods stated in the payment regulations at 43 CFR 12.61 or 43 CFR 12.922, as applicable to this agreement. These requirements are intended to minimize the time elapsing between the transfer of funds from the Federal government and the disbursement of these funds by UNL.

Payment will be made in advance or by reimbursement as follows:

A. ADVANCE PAYMENT – UNL shall be paid in advance provided (1) they maintain or demonstrate the willingness and ability to maintain procedures to minimize the time elapsing between the transfer of funds and their disbursement by the recipient, (2) they comply with reporting requirements for timely submission of cash disbursement and cash balance reports, and (3) they impose these same standards on subrecipients.

Advances to UNL shall be limited to the minimum amounts needed and shall be timed to be in accordance with the actual, immediate cash requirements of the recipient in carrying out the purpose of the agreement. The timing and amount of cash advances shall be as close as administratively feasible (generally no more than 3 days) to actual disbursements for direct program costs and the proportionate share of allowable indirect costs.

B. REIMBURSEMENT – Reimbursement shall be the preferred method of payment when a recipient (1) does not meet the requirements for advance payment stated above; (2) does not have financial management systems that meet the standards in 43 CFR 12.60 or 43 CFR 12.921, as applicable; or (3) has been converted to payment restrictions for non-compliance with the terms and conditions of the agreement. Reimbursement is also the preferred method of payment for agreements involving construction.

VIII. PAYMENT METHOD

A. ELECTRONIC FUNDS TRANSFER (EFT) – In accordance with the Debt Collection Improvement Act of 1996, 331 CFR part 208, effective January 2, 1999, all Federal payments to recipients must be made by EFT unless a waiver has been granted in accordance with 31 CFR 208.4. Reclamation utilizes the Automated Clearinghouse (ACH) Vendor Express payment system for EFT. Whether funds are paid in advance or as a reimbursement, the actual payment will be made through Vendor Express. Vendor Express allows the Government to transfer funds to recipient's financial institution along with explanatory information regarding the payment.

B. ENROLLMENT – Upon award, UNL will receive a copy of the SF-3881, ACH Vendor/Miscellaneous Payment Enrollment Form. This form is required to implement the Vendor Express system and to notify Reclamation of any change or corrections to financial institution information.

C. REQUESTING PAYMENTS – Requests for advance or reimbursement may be made by the following methods:

1. SF-270, Request for Advance or Reimbursement – On a monthly basis, UNL may submit an original and two copies of a properly certified SF-270 form to the address identified in Block 6, page 1 of the 7-2277 form. For advance payments, this form may be submitted on a monthly basis, at least two weeks prior to the date on which funds are required, and on the basis of expected disbursements for the succeeding month and the amount of Federal funds already on hand. Requests for reimbursement may be submitted on a monthly basis. Requested funds are delivered to the recipient via ACH Vendor Express. This form is available on the internet at http://www.whitehouse.gov/omb/grants/index.html.

2. SF-271, Outlay Report and Request of Reimbursement for Monitoring Equipment Installation (??) Programs – The SF-271 shall be used for construction agreements paid by the reimbursement method, letter of credit, electronic funds transfer, or Treasury check advance, except where the advance is based on periodic requests from the recipient, in which case the SF-270 shall be used. This request may be submitted on a quarterly basis, but no less frequently than on an annual basis. UNL may submit an original and two copies of a properly certified SF-271 form to the address identified in Block (6), page 1, of the 7-2277 form. The SF-271 form is available on the internet at http://www.whitehouse.gov/omb/grants/index.html.

3. Automated Standard Application for Payments (ASAP) – UNL may utilize the Department of Treasury ASAP payment system to request advances or reimbursements. ASAP is a recipient-initiated payment and information system designed to provide a single point of contact for the request and delivery of

Federal funds. Once a request is made through ASAP, funds are provided to the recipient either through ACH or Fedwire. Further information regarding ASAP may be obtained from the ASAP website at http://www.fms.treas.gov/asap. Upon award, you will be provided with information regarding enrollment in the ASAP system.

IX. PAYMENTS

Upon execution of this agreement and receipt of Standard Form (SF) 270, Request of Advance or Reimbursement of Funds, Reclamation will transfer funds not to exceed $_____ to UNL for UNL's expenses incurred in the completion of the study work identified in this agreement. All payments will be made to UNL by Reclamation through electronic fund transfer and in accordance with 43 CFR 12.61. The required SF270 will be sent to the following address:

Bureau of Reclamation
Attn. Jack Wergin
P.O. Box 1607
Grand Island, NE 68802
Phone: 308-389-4622, ext. 209
Fax: 308-389-4780
e-mail: jwergin@gp.usbr.gov

X. FUNDS AVAILABLE FOR PAYMENT

The Government's obligation under this agreement is contingent upon the availability of appropriated funds from which payment for agreement purposes can be made. No legal liability on the part of the Government for any payment may arise until funds are made available to the GCAO for this agreement, and until UNL receives notice of such availability, to be confirmed in writing to the Recipient by the GCAO.

Pursuant to the Act of Congress of June 17, 1902 (32 Stat. 388), and acts amendatory thereof or supplementary thereto, all commonly known as Reclamation Law, funds for payment under the first year of this agreement are included in the fiscal year 2004 Energy and Water Development Appropriation Act, Public Law XXX-X. Funding for any optional year of the agreement is contingent upon subsequent Congressional funding.

XI. REIMBURSABLE COSTS AND LIMITATIONS

A. UNL shall provide all personnel, services, facilities, equipment, materials and supplies, and perform all travel which may be necessary and appropriate for the proper performance of this agreement. Costs so incurred will be paid for as provided herein. Reclamation's obligation to provide funding to UNL for costs incurred in these connections shall be limited to UNL's direct and indirect costs associated with this

agreement. All such direct and indirect costs must be determined to be allowable under the regulations contained in 48 CFR Subpart 31.2 or an OMB Cost Principle Circular, as applicable, which are incorporated herein through the General Provisions of this agreement.

B. UNL shall not incur costs or obligate funds for any purpose pertaining to operation of the program or activities beyond the expiration date stated in the agreement. The only costs which are authorized for a period of up to 90 days following the award expiration date are those strictly associated with closeout activities for preparation of the final report.

C. Reclamation shall not be obligated to provide funding to UNL and UNL shall not be obligated to continue performance under the agreement or to incur costs in excess of the costs set forth in the annual project budget unless the GCAO has furnished UNL a modification to increase the available funding for the agreement.

XII. BUDGET REVISIONS

UNL shall follow the requirements at 43 CFR 12.70(c) or 43 CFR 12.925, as applicable, when making revisions to budget and program plans. Additionally, approval shall be requested for transfers of amounts budgeted for indirect costs to absorb increases in direct costs, or vice versa.

XIII. PROCUREMENT STANDARDS

When utilizing Federal funds for the procurement of supplies and other expendable property, equipment, real property, and other services under this agreement, UNL shall utilize the Procurement Standards set forth at 43 CFR 12.76 or 43 CFR 12.940 -12.948, as applicable. UNL may be required to submit evidence that its procurement procedures are in compliance with the standards stated therein. Additional guidance for contracting with small and minority firms, and women's business enterprises is included in the General Provisions section of this agreement.

XIV. PROPERTY STANDARDS

All property, equipment and supplies acquired by UNL with Federal funds shall be subject to usage, management, and disposal in accordance with the Property Standards at 43 CFR 12.72 - 12.73, or 43 CFR 12.930 - 12.937, as applicable.

XV. INSPECTION

Reclamation has the right to inspect and evaluate the work performed or being performed under this agreement, and the premises where the work is being performed, at all reasonable times and in a manner that will not unduly delay the work. If Reclamation performs inspection or evaluation on the premises of UNL or a subrecipient, UNL shall furnish and shall require

subrecipients to furnish all reasonable facilities and assistance for the safe and convenient performance of these duties.

XVI. AUDIT

UNL is responsible for obtaining audits in accordance with the Single Audit Act Amendments of 1996 (31 U.S.C. 7501-7507) and revised OMB Circular A-133, "Audits of States, Local Governments, and Non-Profit Organizations". Audits shall be made by an independent auditor in accordance with generally accepted government auditing standards covering financial audits. Additional audit requirements applicable to this agreement are found at 43 CFR 12.66 or 43 CFR 12.926, as applicable. General guidance on the single audit process is included in a pamphlet titled, "Highlights of the Single Audit Process" which is available on the internet at http://www.dot.gov/ost/m60/grant/sincontact.htm.

XVII. INDEMNIFICATION

UNL shall indemnify and hold the United States of America harmless from any and all losses, damages, liability on account of personal injury, death, or property damage, or claim for personal injury, death, or property damage of any nature whatsoever and by whomsoever made, arising out of activities of UNL, its employees, or agents under this agreement.

XVIII. UNL'S PROJECT MANAGER

UNL's Project Manager for this agreement shall be:

xxx, Director
University of Nebraska - Lincoln
xxxx
Lincoln, NE 685xx-xxxx
Phone: 402-471-xxx
Fax: 402-471-xxx
e-mail: xxxx@unl.edu

XIX. KEY PERSONNEL

UNL's key personnel and administrative point of contact for this agreement is:

Derrel Martin
Biological Systems Engineering
230 LWC
University of Nebraska
Lincoln, NE 68583-0726

Phone: 402-372-1856
Fax: 402-xxx-xxxx
e-mail: dlmartin@unlnotes.unl.edu

In accordance with 43 CFR 12.70(d)(3) or 43 CFR 12.925, as applicable, UNL shall request prior approval from Reclamation before making any changes in the key personnel identified above.

XX. GRANT AND COOPERATIVE AGREEMENT OFFICER'S REPRESENTATIVE (GCAOR)

A. The GCAOR for this agreement will be:

Jack Wergin
Bureau of Reclamation
P.O. Box 1607
Grand Island, NE 68802-1607
Phone: 308-389-4622, ext. 209
Fax: 308-389-4780
e-mail: jwergin@gp.usbr.gov

B. GCAOR Responsibilities

The GCAOR is authorized to act only on technical matters during the term of this agreement. The GCAOR and UNL's Key Personnel shall work closely to insure that all requirements of the agreement are being met. The GCAOR's responsibilities include, but are not limited to, the following:

1. Assist UNL concerning the accomplishment of the tasks described in the agreement;
2. Provide information to UNL which assists in the interpretation of the tasks; and
3. Review, and where required, approve reports and information to be delivered to the Government.

C. GCAOR Limitiations

Technical assistance must be within the general scope of the agreement. The GCAOR does not have the authority to and may not issue any technical assistance which:

1. Constitutes an assignment of additional work outside the general scope of the agreement;
2. In any manner causes an increase or decrease in the total estimated cost or the time required for performance; or

3. Changes any of the expressed terms, conditions, or specifications.

XXI. BUDGET

* * * * * * *

an idea for this section is to include an original budget estimate, and also reference a budget that will be revised annually and include this updated annual budget as an attachment – this updated budget could be adjusted in modifications that add annual funding appropriations. The budget figures below address funding for both UNL and KSU. Estimates of cost will need to be split out for each University before final agreements are developed.

* * * * * * *

A. Total Study Costs (5 years)

1. Equipment Estimate

8 Sites to Monitor Terraced Land Water Balance	$ 64,000
5 Sites to Monitor Reservoir Water Balance	$ 30,000
2 Computers and Software	$ 8,000
Total Equipment	$102,000

2. Personnel Estimates (for 5 years of project)

2 Postdoctoral Research Assistants for Field Experiments	$400,000
2 Undergraduate Student Assistants	$ 40,000
Total Personnel	$440,000

3. Travel

Research Sites and Project Coordination	$ 20,000
Professional	$ 8,000
Total Travel	$ 28,000

4. Direct Costs	$570,000
5. Indirect Costs (17.5% of Direct Costs)	$ 99,750
6. Total Project Cost Estimate	$669,750

B. Cost Estimate by Fiscal year (Oct. 1 – Sept. 30)

FY04	$ 150,000
FY05	$ 135,000
FY06	$ 135,000
FY07	$ 135,000
FY08	$ 135,000
FY09	$ 60,000
====	=========
Total	$ 750,000

XXII. GENERAL PROVISIONS

This agreement is subject to, and in accordance with, the following rules, regulations, exhibits and provisions:

A. Reclamation's General Provisions are incorporated and made part of this agreement.

B. UNL may subcontract for activities as may be necessary under this agreement.

C. Reclamation shall not be a party to or be obligated in any manner by subcontracts entered into between UNL and other parties except as otherwise provided by federal law.

D. UNL is the responsible authority regarding the settlement and satisfaction of all subcontractual and administrative issues arising out of subcontracts and procurement awarded by UNL in support of this agreement.

XXIII. PROPERTY STANDARDS - REAL PROPERTY

In accordance with 43 CFR 12.71 or 43 CFR 12.932, as applicable, if real property is acquired in whole or in part under this agreement, it shall be subject to the following regulations:

A. Title - Title to real property acquired under this agreement shall vest upon acquisition in UNL or Subrecipient, shall be used for the originally authorized purpose of the project as long as it is needed, and shall not be disposed of or encumbered without Reclamation

approval.

B. Disposition - When the real property is no longer needed for the originally authorized purpose, UNL or Subrecipient shall request disposition instructions from Reclamation. The instructions shall provide for one of the following alternatives:

C. Transfer - UNL may be permitted to transfer the property to another Federally-sponsored project if UNL determines that the property is no longer needed for the purpose of the original project. Use in other projects or programs shall be limited to those with have purposes consistent with those authorized for support by the Department of the Interior.

D. Retention of Title - UNL may be allowed to retain the title after compensating Reclamation for that percentage of the current fair market value of the property attributable to the Federal government's financial participation in the project.

E. Sale of Property - UNL may be directed to sell the property under guidelines provided by Reclamation, and to compensate Reclamation in an amount calculated by applying Reclamation's percentage of participation in the cost of the original purchase to the proceeds of the sale after deduction of any actual and reasonable selling and fix-up expenses. When UNL is directed to sell the property, sales procedures shall be followed that provide for competition to the extent practicable and result in the highest possible return.

F. Transfer of Title - UNL may be directed to transfer title to Reclamation or to an eligible third-party. UNL shall be entitled to compensation for its attributable percentage of the current fair market value of the property.

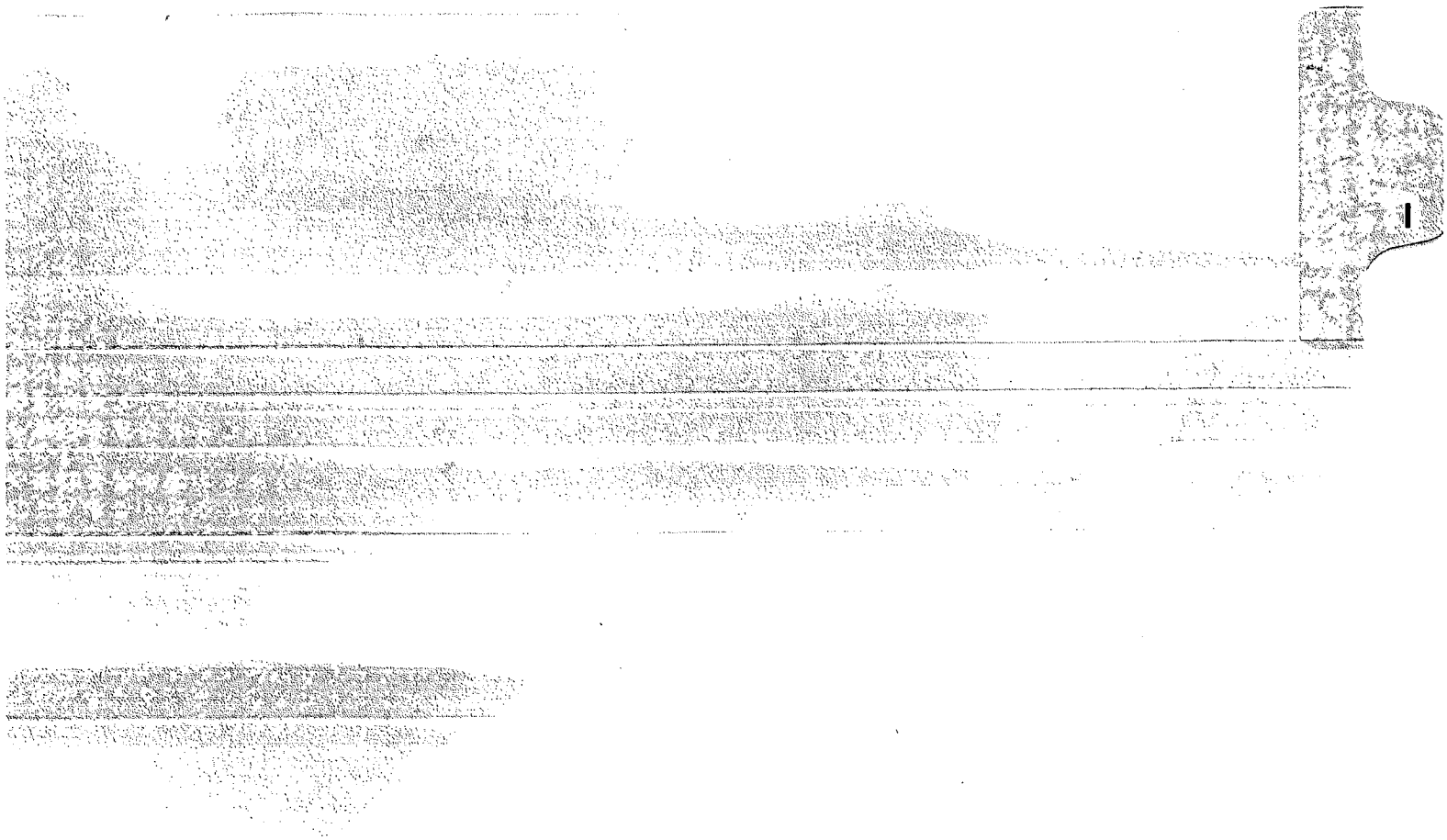
XXIV. PREAWARD INCURRENCE OF COSTS

UNL shall be entitled to have incurred costs for this agreement, in a total amount not to exceed $125,000 for allowable costs incurred on or after April 1, 2004, which if had been incurred after this agreement was entered into, would have been allowable under the provisions of the agreement.

Attachment A

Modeling and Field Experimentation to Determine the Effects of Terracing and Nonfederal Reservoirs on Water Supplies in the Republican River Basin above Hardy, Nebraska

Joint Research Project of the
University of Nebraska-Lincoln
Kansas State University
Colorado State University



APPENDIX I

LIST OF EXPECTED STUDY PRODUCTS

Expected Products to be delivered to the Conservation Committee and\or the RRCA:

1. Report/professional paper documenting results of study quantifying the impacts of non-federal reservoirs and land terraces on water supplies for each of the designated drainage basins under current management conditions.

2. Documentation of proposed fieldwork and modifications to the water balance model.

3. Semi-annual reports documenting fieldwork, progress on modification of the water balance model and preliminary model runs.

4. Documentation and user's guide for the water balance model.

5. Documentation on assessing area-capacity relationship for non-federal reservoirs (this has been completed and is contained in the proposal report).

Potential Products resulting from study:

1. Quantified effects of non-federal reservoirs on water supply for each of the designated drainage basins under current management conditions.
    a. Difference in evaporation – with and without reservoir
    b. Difference in groundwater recharge – with and without reservoir
    c. Difference in ET (within, around and downstream of the reservoir)
    d. Estimated transmission losses within the drainage basin, with and without the reservoirs.
    e. Total impact on water supply as measured at the gaging station near the bottom of each designated drainage basin.

2. Inventory of non-federal reservoirs
    a. Location
    b. Size, including surface area, water depth, and storage capacity at normal full pool (spillway)
    c. Type of Use
    d. Status/condition
    e. Description of data standards applied to define above

3. Average reservoir surface area for different seasons of year
    a. Results from reservoir surface area monitoring program
        i. Information collected at sites (as outlined in Appendix D: Reservoir Surface Area Monitoring)
        ii. Selection of sites for data collection and monitoring
        iii. Number of reservoirs monitored
        iv. Frequency of measurements
        v. Type of reservoir monitored
        vi. Characteristics of reservoirs monitored

4. Quantified effect of land terraces on water supply for each of the designated drainage basins under current management conditions.
    a. Difference in evaporation – with and without terrace
    b. Difference in groundwater recharge
    c. Difference in ET for terraced vs. non-terraced area
    d. Estimated transmission losses within the drainage basin, with and without the terraces.
    e. Difference in crop yields – terraced vs. non-terraced area
    f. Quantification of impacts at points within each drainage basin

5. Inventory of Land Terraces
    a. Location
    b. Size (effective surface area).
    c. Field size/land area treated
    d. Type of terrace (closed/open)
    e. Status/condition
    f. Description of data standards applied to define above
    g. Total impact on water supply as measured at the gaging station near the bottom of each designated drainage basin.

6. Estimate of the extent of the effect of non-federal reservoirs and terraces on baseflow in part through the use of the RRCA Ground Water Model