Appendix E

CONSERVATION MEASURES STUDY PHASE I

8200 Cody Drive
Suite A
Lincoln, Nebraska 68512-9550

Phone: 402.435.5441
Fax: 402.435.7108

MEMORANDUM

To: **Platte Basin Coalition**

From: **The Flatwater Group, Inc.**

Date: **23 December 2013**

Re: **Final Technical Memorandum on Conservation Study**

The purpose of this technical memorandum is to describe the results of the review and inventory completed for this effort, including a matrix describing the availability of data and its usefulness in achieving the project purpose, a description of three potential methods for implementing an approach to assess the effects of conservation measures that can be utilized to develop a Scope of Work for Phase II, and a cost estimate for each method.

I. Proposed Definition of Conservation Measures

The proposed definition for "conservation measures" is included below. This definition was developed with input and feedback from a number of sources, including Coalition members, but relied primarily on research done on existing State Statute related to the term or similar terms. As has been discussed elsewhere, the terms "conservation measures", "conservation practices" and "conservation activities" are all used within the text of the Groundwater Management and Protection Act – arguably interchangeably. Since the primary statute language of interest for this project uses the term "conservation measures", it is that term which has been adopted, for the most part, in this effort. In some cases, the term "conservation practices" may have been used, in which case the term should be considered synonymous with "conservation measures":

Conservation measures*, for the purposes of Neb. Rev. Stat. §46-715(5)(c), shall mean practices designed to control or prevent soil erosion, enhance the beneficial use of precipitation and irrigation water, or reduce non-beneficial water consumption.*

II. Other Definitions

Several other terms have been used in this effort which will be defined here to help establish a consistent "language" and hopefully avoid confusion over terminology.

A. Techniques – for each of the identified conservation measures, the matrix includes at least one "technique" to develop estimates of recharge, runoff, and/or ET. These techniques may include simple equations or algorithms found in textbooks or research papers, complex computer models, physical site sampling procedures, or other processes used to develop these estimates.

B. Methods – the Coalition itself used the term "methods" within its Scope of Work RFP for Phase I tasks. Three methods are identified in this effort as potential ways to derive estimates, for all conservation measures throughout the entire study area, of changes to recharge, runoff, and ET. Methods are made up of a suite of "techniques" to address the entire list of identified conservation measures.
C. Matrix – the "Matrix on Quantification of Conservation Impacts to Streamflow", developed by the project team to fulfill the requirement in the Scope of Work directing the team to "include a matrix describing the availability of data and its usefulness in achieving the project purpose". The Matrix includes a list of all conservation measures considered, and preliminary estimates as to the availability of data on the respective measures and the potential magnitude of impact to streamflow created by each measure.
D. Base Conditions – the Matrix includes estimates of the impact to recharge, runoff, and ET, using the qualitative terms of "increase", "decrease", "no change", or "not applicable". In order to make these estimates, "base conditions" had to be established for each conservation measure listed. For instance, in making an estimate of changes to runoff resulting from conversion to surge irrigation, the base conditions used to estimate these changes were established as furrow irrigation with gated pipe.
E. Evapotranspiration (ET) – the conversion of liquid water into vapor which leaves the watershed through evaporation from the soil, plants, or free-water surfaces, or through transpiration through plants.
F. Recharge – the movement of water from the surface to ground water, through the vadose zone.
G. Overland Runoff – the movement of water over the surface as a result of excess precipitation, irrigation, meltwater, or other surface water sources. This may include return flow.
H. Return Flow – the portion of diverted surface water returning to the stream, which is a component of overland runoff.

III. Magnitude of Impact and Frames of Reference

In order to make estimates of the assumed basin-wide[1] magnitude of impact associated with the various conservation measures, it is important to define and explain the time frames that are important for this particular study.

The language that governs the study of the impacts of conservation measures is contained within State Statute, in Neb. Rev. Stat. §46-715(5)(c):

> *Any integrated management plan developed under this subsection shall identify the overall difference between the current and fully appropriated levels of development. Such determination shall take into account cyclical supply, including drought, identify the portion of the overall difference between the current and fully appropriated levels of development that is due to conservation measures…*

---

[1] Basin-wide impact in the context of this review includes consideration of the total number of conservation measures installed across the entire basin, meaning the cumulative effect for each conservation measure, rather than a comparison of conservation measures on a per acre basis.

In addition, the definition in Neb. Rev. Stat. §46-706(27) provides additional guidance in terms of how conservation measures factor into the difference between the two levels of development:

> *Overall difference between the current and fully appropriated levels of development means the extent to which existing uses of hydrologically connected surface water and ground water and conservation activities result in the water supply available for purposes identified in subsection (3) of section 46-713 to be less than the water supply available if the river basin, subbasin, or reach had been determined to be fully appropriated in accordance with section 46-714;*

Using this language as a basis, Figure 1 shows a simplified representation of a hypothetical comparison of water supplies against the combined impacts from water uses and conservation measures. As shown, this graphic assumes that the supply remains constant between the period when the basin become fully appropriated and the current overappropriated time period. In this example, both the water uses and the impacts from conservation measures – which are assumed to have negative impacts to streamflow in this example – grow between fully appropriated to overappropriated conditions. The statutory language appears to call for the determination of the difference in the impacts from conservation measures between these two points in time, as indicated by the green double-arrow in Figure 1.

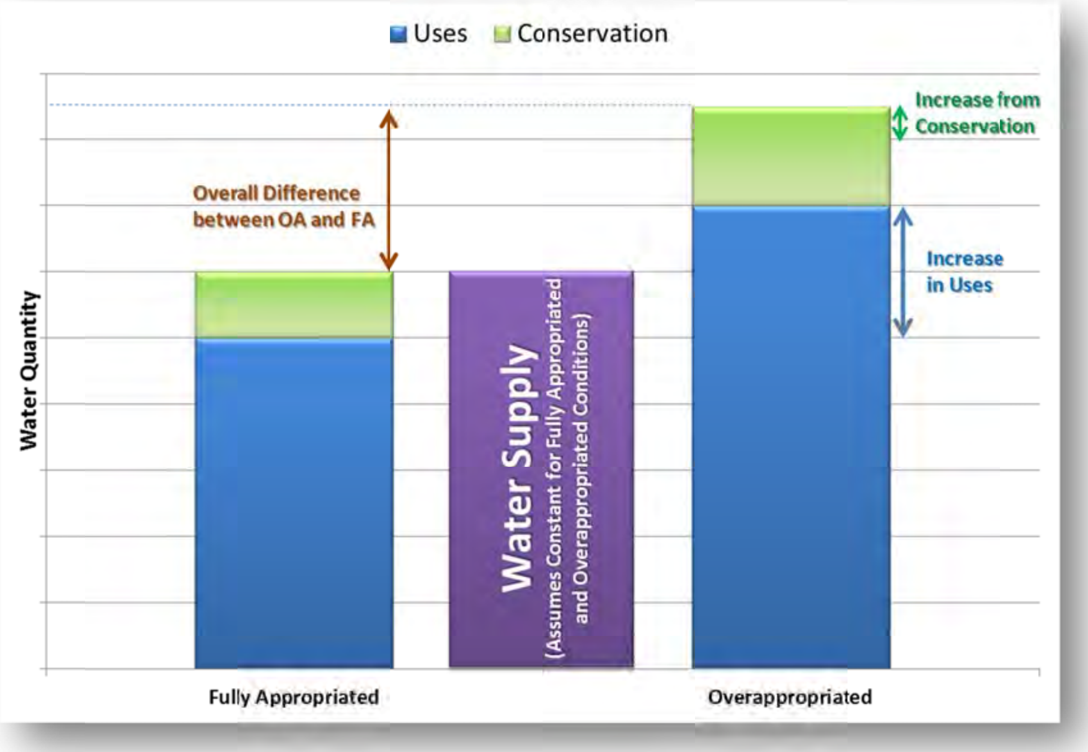

Figure 1: Water Uses, Supplies, and Conservation Impacts

To illustrate this relationship, we can consider a simplified example of conservation measures in the basin. Assume that only one single conservation measure is in place in the basin: Measure A. We can also assume for this simple example that water uses increased by 20 acre-feet per year between the time at which the basin became fully appropriated and the current date. If we assume that Measure A was put into place before the point in time when the basin became fully appropriated, we can estimate the impact that the measure had on streamflow by considering the difference in streamflow between base conditions and conditions with Measure A in place. For example, we might estimate that under base conditions, without Measure A, we might have seen a streamflow of 100 acre-feet per year, whereas with Measure A in place, we actually saw only 90 acre-feet per year as of the point in time when the basin became fully appropriated. As a result, we would estimate that Measure A had a negative impact to streamflow of approximately 10 acre-feet per year at the time the basin became fully appropriated.

As the next step, we could estimate the impact to streamflow from Measure A as of the present time, using the same overall methodology. If estimated streamflow for the current time period would have been 80 acre-feet per year without Measure A, and only 65 acre-feet per year with Measure A, we would estimate a current level of negative impact from Measure A of 15 acre-feet per year.

Finally, we could estimate the change in conservation impacts between the fully appropriated and current overappropriated periods, which would simply be the difference between the 10 acre-feet per year and 15 acre-feet per year, which is 5 acre-feet per year of additional negative impacts to streamflow. It’s this 5 acre-feet per year of additional impacts to streamflow that could be used to quantify the portion of the difference between the current and fully appropriated levels of development associated with conservation measures, as shown in Figure 1 with the double-arrow labeled “Increase from Conservation”. Water managers may also be interested in the overall impact to streamflow of conservation measures as of the current time, which would in this example be the entire 15 acre-feet per year quantity.

It’s important to note that while the example described above would indicate a negative impact to streamflow, some conservation measures could show a positive impact. For example, deficit irrigation is a conservation measure that could result in increases to streamflow as a result of lower levels of ET. It’s also possible that these positive impacts to streamflow could grow over time – including between the time that the basin became fully appropriated and the present – which could result in a decrease in negative impacts from those particular conservation measures (note that the impacts shown in the figure represent negative impacts to streamflow).

In all cases, it will be important to determine the date at which the various conservation measures were initiated, both for the time period prior to the point of fully appropriated conditions[2] and up to the current time. This is similar to the way in

---

[2] The year 1984 was assumed to be the date when the basin became Fully Appropriated for purposes of completing this review.

which depletions to streamflow are assessed for groundwater wells – the addition of new wells must be tracked over time, and the level of depletion caused by each well must also be tracked over the lifetime of pumping and beyond due to the continuing lag effects.

IV. Literature Review Summary

The project team examined a variety of sources for its literature review, including publications from the University of Nebraska's School of Natural Resources, handbooks from state and federal resources agencies, relevant textbooks, phone conversations with representatives of irrigation manufacturing companies, other texts recommended by the University faculty on our team, and general internet searches. An attempt was made to find materials that were relevant to conditions throughout the study area, with an understanding that the geographic extent of the study area prevents using a "one size fits all" approach in terms of assessing the impacts of conservation measures. In some cases, literature was found that was specific to a particular portion of Nebraska. However, in many cases, the literature pertained to areas entirely outside of Nebraska. Because of these facts, it will be crucial for future efforts that any techniques for estimating impacts from conservation measures identified in this literature review be adjusted, or replaced altogether, to ensure accurate representation of the unique conditions in different portions of the study area.

The remainder of this section will involve briefly highlighting some of the primary sources identified in the literature review for the major categories of conservation measures. A more complete listing of the literature review sources can be found as a separate tab of the "matrix" spreadsheet. The citations listed in this section apply to the abbreviated codes used in that listing.

Structural Conservation Measures

1. Conservation terraces – journal articles on conservation terrace system hydrology were reviewed. Impacts to runoff, recharge and ET were evaluated on a field scale (L3, L32), small watershed (L20), and basin scale (L21, L32). Impact estimates from these studies could be applicable to the Platte River watershed for basins with similar characteristics. Hydrologic models have been found effective in modeling terrace systems including the Water Erosion Prediction Project (WEPP) (L2, L20), Root Zone Water Quality Model (RZWQM) (L2), the Hydrologic Modeling System (HEC-HMS) (L4), and Analytical Surface Water and Groundwater Modeling (L21). General area and spatial location of terraced land can be obtained as available from the U.S. Bureau of Reclamation and USDA-NRCS; however, field locations and characteristics of terraces across the basin will require surveys and perhaps digitization of terraced fields.
2. Non-jurisdictional/non-permitted small dams – this conservation measure category includes structures that are not included in Nebraska DNR's dam database, and therefore the National Hydrography Dataset from USGS (L24) would be used as a GIS resource to catalog small impoundments in the basin. Based on areas of small impoundments, location in the watershed, and other spatial data (soils, precipitation, etc.), the calculations from L2, L25, and L83 could be applied to quantify impact on streamflow from small dams. Location

and surface area of typical reservoirs could be determined from digitization of aerial photographs.

3. Jurisdictional/permitted dams – for this constructed conservation measure, a publication (L25) from the Journal of Soil and Water Conservation was reviewed that quantified groundwater recharge from seepage from flood reservoirs. The study goal was to determine the potential for increasing groundwater recharge. Average seepage rates for two reservoirs were measured to be 0.50 and 0.59 inch/day at the Clay and York County sites respectively. These calculations could be applied on a larger basin scale by considering the specific conditions at the sites and by utilizing GIS inventories of dams in the basin.
4. Canal rehabilitation – for this practice, research was conducted with the use of electrical resistivity to quantify seepage losses in unlined irrigation canals for a test reach of 100 feet (L11). This technique could be applied on a larger scale to quantify the impact on streamflow after canal rehabilitation. Nebraska DNR conducted a demonstration project (L13) with Nebraska irrigation districts to estimate canal seepage in the Platte Basin. The results of that study could be applied in this study. Canal seepage estimates can be calculated based on the findings of the demonstration project. The USDOI-USBR and irrigation districts often maintain records of the amount of water diverted from streams or reservoirs, and the average amount of water delivered to farms. These data provide an overall water conveyance efficiency. The USDOI-USBR also administers a WaterSMART program (L12) on a national level that includes reporting on canal seepage and conversion to buried pipeline.
5. Conversion from open laterals and canals to pipelines – for this measure, CNPPID has studied (L14) and analyzed the conversion to buried pipeline as an improved measure of efficiency for water conveyance. These improvements have an effect on streamflow in regard to impacts to canal return flows and changes in seepage. CNPPID estimates a reduction in transportation loses (due to seepage and evaporation) by 45-50% based on their research and study of irrigation canals in the Central Platte Region.
6. Irrigation runoff recovery systems or return-flow facilities – this conservation measure was described in Nebraska as part of a study in the Republican River basin by the Lower Republican NRD (L48) that successfully used soil moisture sensors for water conservation of irrigation water. The program provided soil moisture sensors to farmers to monitor soil moisture in fields with a goal of reducing irrigation volumes and improving timing and efficiency of irrigation application.

Non-Structural Conservation Measures

1. Changes in tillage practices – journal articles focusing on tillage practices were reviewed (L37, L53) along with University of Nebraska-Lincoln CropWatch publications (L52, L54) and USDA FSA data and statistics (L45, L46). Steady ponded infiltration rates from L53 and soil permeability and runoff potential rates from L54 for different tillage systems could be used to estimate effects at the field level water balance. Farm Service Agency (FSA) data on the approximate locations of different practices would require FOIA procedures. The Conservation Technology Information Center (http://www.ctic.purdue.edu/) maintains a database of conservation practices and related conservation

resources including web sites, documents, and research results. These data usually include county-level estimates of the adoption of various conservation treatments over time. These data will provide a resource to assess tillage changes.

2. Changes in irrigation management – for irrigation scheduling, while information on the general process is fairly easy to find, information relevant to its impact on recharge, runoff, and ET is not. A 2005 NebGuide (L75) was reviewed which looks at the use of atmometers to schedule irrigation for crops, including corn and soybeans. This document, and others like it (L77, L78), present how scheduling can be accomplished to optimize the fulfillment of ET requirements for the crop. For deficit irrigation, several sources were found that discuss impacts to yield and ET for crops in west-central Nebraska, including corn and soybeans (L76, L79, L80). These studies were focused in the North Platte and Curtis areas, but provided information on ET responses that could be used elsewhere as well. The Water Optimizer program was developed to evaluate irrigation management options for deficit irrigation and provide estimates of the net return expected from deficit irrigation. Irrigation practices considered for these studies included center pivot irrigation and subsurface drip. Additional information on irrigation management was found concerning reductions in irrigation supplies, which could be used to help determine impacts from conversion of irrigated lands to dryland crops or rangeland (L84).
3. Improvements in irrigation efficiency – for these practices, the University of Nebraska has several publications, including NebGuides and Extension Circulars, which are useful in providing estimates of application efficiencies for a given practice (L16, L17). These water application efficiencies are generally given in terms of percentage values, and are defined as “the fraction of the total volume of water delivered to the farm or field to that which is stored in the root zone to meet the crop evapotranspiration needs”. While these application efficiencies do not translate directly to estimates of runoff or recharge, they provide an estimate for an important component of the water balance at the field level. For surge irrigation, one study of note was conducted from 1990 to 1993 by researchers at Colorado State (L62), which included estimates of reductions in deep percolation associated with surge technology. For variable rate irrigation with center pivots, most of the major irrigation manufacturing companies were contacted directly by phone to inquire as to estimated impacts, but only limited information was obtained as a result (L63, L64, L65) – probably due in part to the relative infancy of this particular technology. The Farm Irrigation Rating Index (http://www.wcc.nrcs.usda.gov/ftpref/wntsc/Irrigation/FIRI/FiriMan.pdf) is a program developed by the USDA-NRCS to evaluate the impacts of irrigation management changes on the irrigation efficiency. This program can provide a framework for integration of expected outcomes.
4. Changes in crop rotation pattern/mixes – for conservation measures involving the conversion of irrigated continuous corn to alternative irrigated crops in rotation with corn, there is literature that considers the change in ET resulting from the altered crop rotations (L66 for example). For dryland crops, there is also documentation on impacts on ET resulting from various crop rotations (L81). For the four conversion practices involving CRP or CREP lands, journal articles dealing with Conservation Reserve Program (CRP) lands were reviewed (L59,

L60, L61). L60 has runoff, recharge, and ET variable mean annual measurements for lands under crop production and lands under CRP by region. Farm Service Agency (FSA) data could potentially be used to spatially locate CRP lands and how they change over time (L45, L36).

5. Changes in crop production intensity – several sources were located that describe the processes and impacts from changing crop production intensities (L85, L86, L87, L88, L89). These include looking at higher plant populations, narrower row spacing, and skip-row planting. The findings in these references and studies often included descriptions of the impact to ET resulting from these changes in intensity.
6. Implementation of soil moisture sensors – for soil moisture sensors, a significant amount of literature is available describing the basic operation and management techniques concerning the practice (L47, L92). Sensors have been adopted in some portions of Nebraska, and certain NRDs have provided cost-share opportunities for producers to help pay for their installation (L48). Specific information on the level of impacts to recharge, runoff, and ET, however, is more difficult to locate.
7. Changes in rangeland management – journal articles focusing on rangeland management impacts were reviewed (L55, L56, L57). These articles list infiltration rates for different grazing intensities. These infiltration rates can be used at the field level in water balance calculations. The National Resources Inventory website (L58) has GIS data on topics ranging from rangeland health to rangeland locations to soils and plant species. The GIS data may be helpful in determining rangeland locations relative to streams and may be used in translating field level impacts to streams.
8. Application of buffers – Journal articles on conservation buffer hydrology were reviewed. Research has been conducted on the ability to model hydrology and trapping efficiency of overland runoff with the Vegetative Filter Strips Modelling System (VFSMOD) (L29, L30). Trapping efficiencies have been estimated on a field (L29, L31) and small watershed (L5) scale. Impacts to ET from conversion of cropland in riparian zones to grass and forest buffer have been estimated for climate regions across Nebraska (L30, L82). Area and spatial location of conservation buffers can be obtained as available from the USDA-NRCS.
9. Management of phreatophytes/invasive vegetation – a journal article on case studies in Kansas in the Arkansas and Cimarron River basins was reviewed. In the article (L90), the White method (White 1932) utilized specific yield of an alluvial aquifer and the difference in net change of water level in monitoring wells in areas without vegetation control and areas with vegetation control on a daily time step to quantify impact of phreatophyte on groundwater ET. An additional study in the Platte and Republican River basins provided the observed impacts on invasive species removal on ET (L91). Specifically, a portion of the study calculated potential water savings from invasive species removal along riparian corridors using direct observations and an ecosystem/land surface model.

V. Geographic Uniqueness

No two parts of the State, or two areas within the study area, are the same, and each location has its own unique attributes with respect to climate, soil types, tillage practices, cropping techniques, terrain, groundwater and surface water availability and use, institutional frameworks, and other features. It will be crucial during any future phase of this effort that this recognition of “geographic uniqueness” be incorporated into all techniques used to derive estimates of impacts due to conservation measures. While an attempt was made within the Matrix to acknowledge this fact, and to include elements that reflect more than one area within the study area, it is not possible within a simple summary table of this sort to include all the potential combinations and permutations necessary to represent the full range of possibilities. However, future estimates will require various techniques that are tailored for the different regions instead of using a “one size fits all” approach.

These issues of geographic uniqueness will be important not only in making estimates of the changes to runoff, recharge, and ET on a field-level basis, but also in terms of how these field-level impacts are translated to impacts to streamflow. As will be discussed later in this memorandum, this process of translation must consider the geographic location of where the conservation measures are in place, as well as the region between those locations and the stream or tributary. The use of GIS coverages that include geographically indexed parameters would likely greatly facilitate this process, as would local knowledge and understanding of the particular region of interest.

As mentioned above, groundwater and surface water resources, in terms of availability and use, vary across the study area. The source of irrigation supplies is important in determining the timing and magnitude of any changes due to conservation measures. These effects are complex, but still require careful consideration in developing estimates of the impacts from conservation measures. One example is within the western portion of the study area, where extensive conversion has taken place from furrow irrigation using surface water to center pivots using either surface or groundwater. The timing of impacts to streamflow, the changes to surface water return flows that used to serve as a supply for downstream irrigators, and potential increases in overall ET resulting from better distribution of irrigation supplies to the crop, all could have significant impacts to the overall water balance. As a result, these aspects would also need to be considered in any future estimates of impacts to streamflow from conservation measures.

VI. Translations of Impacts to the Stream

As has been mentioned elsewhere, the focus of Phase I efforts involved identifying techniques capable of estimating changes to runoff, recharge, and ET. For the most part, the calculations, models, and other techniques found to derive estimates for these factors often only included impact estimates at the field level, and not in terms of depletions or accretions to a stream. As a result, it will be necessary to develop a protocol, or set of potential protocols, to translate the field-level impacts into impacts at the stream. For example, review of a certain conservation measure might suggest that by implementing the practice at a particular location, 50 acre-feet of additional recharge would occur at the field-level. Unless the location is directly adjacent to a stream, it’s unlikely that the additional recharge will immediately result in a 50 acre-feet increase in stream flow.

A. Recharge – to translate impacts to recharge from the field level to the stream, some type of protocol is required to simulate the movement of groundwater between the location of the conservation measure and the stream location of interest. One potential option would be to use a mathematical model such as MODFLOW, which is regularly used throughout much of the State. More basic analytical models, such as the Jenkins Method, could also be used to translate the recharge impacts to the stream. Another simpler approach could involve using stream depletion factor (SDF) maps already developed for other purposes to make rough estimates of impacts to streamflow from recharge changes.
B. Runoff – to translate impacts to runoff from the field level to the stream, a surface water-based approach would be required to estimate stream impacts. One possible protocol would be the Soil and Water Assessment Tool (SWAT) model, which is specifically designed to estimate impacts from changes in land use and land management practices. Transmission losses are estimated based on channel geometry and hydraulic conductivity using the method described in Chapter 19 of the SCS Hydrology Handbook. The Agricultural Policy/Environmental eXtender (APEX) model is another technique which could be used to translate local runoff changes to stream impacts. Simpler approaches could involve applying a range of percentage values, based on professional judgment and known geographic factors, to estimate what percent of the runoff change might eventually translate to streamflow changes.
C. Geospatial Accuracy – any protocol for translating impacts from the field-level to the stream will require some consideration of the location of the conservation measure. For some conservation measures, there is readily available and highly accurate geospatial information, such as the location of center pivot systems. For other conservation measures, little or no geospatial information may exist. Depending on the level of accuracy required, different approaches could be taken to estimate the location for the different measures. GPS measurements could be precisely established through site visits and surveys, although the logistics of this level of effort could be considerable, and it would still require some knowledge of approximately where the conservation measures are in place. In some cases, it may be sufficient to assume a fairly even geospatial distribution across irrigated lands, and simplified GIS maps of irrigated acres are available, for certain historical periods, throughout the study area. Additional geospatial information for conservation measures may be available from the local NRDs, through DNR, or through University or other sources.
D. Infrastructure Impediments – certain structures such as road embankments, ditch alignments, railroads, and hydraulic structures, have an impact on the transmission of surface overland runoff from the location of the local impact to the respective stream. While these structures have not been defined through this effort as conservation measures, they could affect the way in which changes to runoff and recharge are translated from the field-level to the stream. Adjustment of hydrologic routing parameters such as time of concentration and infiltration area could be used to evaluate these impediments. Where possible, these structures could be included in the particular protocol adopted for this translation work, and used to predict stream impacts.

VII. Description of the Three Methods

Three methods have been identified which include a suite of potential techniques to estimate impacts to streamflow resulting from all of the listed conservation measures. These methods (low intensity, medium intensity, and high intensity) are based on the level of expert opinion and literature review, models, and field measurement used to develop estimates of streamflow impacts for each conservation measure. A separate table (Tab 3 – Expertise and Methods) has been developed, which will be included with this technical memorandum, indicating the technical expertise required to conduct the evaluation of impacts, the models that could be used for that purpose, and potential field measurements that could be conducted. A separate table (Tab 4 – Budget and Methods) also includes a range of cost estimates for each conservation measure based on the level of intensity of each method. Economies of scale could also come into play into these cost estimates, and some suggestions are made as to how to reflect those cost savings by applying estimated “cost adjustment factors”.

In terms of time frames to implement any of the three methods, project durations will depend on the input of human resources, and any estimates at this stage will be only general estimates. As a starting point, activities under the “low intensity” could be on a 6-12 month time frame, medium intensity efforts could be 2-3 years, and high intensity activities could require 4-6 years.

VIII. Conclusions

The information produced through this Phase I document, the Matrix, and the corresponding supporting documents, should provide a foundation to make future decisions on which conservation measures to include and potential methods for developing estimates of impacts to streamflow for any Phase II efforts. The three methods presented serve as an initial attempt to categorize the resources and techniques needed to produce these estimates of streamflow impacts for each of the conservation measures. The Matrix includes an indication of the estimated overall magnitude of impacts from each of the conservation measures, the required resources and budget to conduct investigations to gage these impacts, and the availability of data associated with each conservation measure.

Conservation Study

Conservation Measure and Matrix Category Descriptions

Conservation Measure Descriptions

Structural

1. **Conservation Terraces** – Earthen embankments and channels constructed across a slope at suitable spacings and with acceptable grades for one or more of the following purposes: to reduce soil erosion, provide for maximum retention of moisture for crop use, or improve water quality (L72).
2. **Non-jurisdictional/Non-permitted Small Dams** – Stream impoundment that is < 15 AF in storage volume and < 25 feet in height built for soil and water conservation purposes. Permits from DNR are not required for these structures.
3. **Jurisdictional/Permitted Dams** – Stream impoundment that is > 15 AF in storage volume and/or > 25 feet in height built for soil and water conservation purposes. Permits from DNR are required for these structures.
4. **Canal Rehabilitation** – Conveyance improvements made to canals that include lining with impervious materials or chemical treatments and repairs and/or improvements to the infrastructure of the canal system (automating gates and checks, etc).
5. **Conversion from open laterals and canals to pipelines** – This practice involves converting open irrigation laterals and canals to buried pipeline to improve conveyance efficiency.
6. **Irrigation runoff recovery systems or return-flow facilities** – A system of ditches, pipelines, pumps and reservoirs to collect and convey surface (tailwater) or subsurface runoff from an irrigated field for reuse. Sometimes called tailwater reuse facilities or pumpback facilities (L73), these impoundments are constructed to capture field runoff as a water source for irrigation on nearby fields.

Non-Structural

1. **Changes in Tillage Practices** – The adoption of conservation tillage and/or no-till practices. This practice includes the reduction of non-growing season tillage and residue management. Conservation tillage is a tillage practice that leaves plant residues on the soil surface for erosion control and moisture conservation. This is sometimes defined as tillage that leaves at least 30% residue cover on the surface after the planting operation (L72). No-till is a tillage system in which the soil is not tilled except during planting when a small slit is made in the soil for seed and agrochemical placement (L73).
    a. **Dryland** – changes in tillage practices under dryland conditions.
    b. **Irrigated** – changes in tillage practices under irrigated conditions.
2. **Changes in Irrigation Management** – The adoption of irrigation management strategies to conserve water:

   a. **Irrigation Scheduling** - Irrigation scheduling is the process of determining when to irrigate and how much water to apply, based upon measurement or estimates of soil moisture or water used by the plant (L73).
   b. **Deficit Irrigation under Allocations** - strategies that allow plant stress, resulting in lower ET and lower yields, usually as a result of allocation requirements. Irrigation water flow meters are often used as a tool to employ this practice.
   c. **Conversion of irrigated land to dryland cropland** – as suggested, conversion of irrigated cropland to dryland conditions.
   d. **Conversion of irrigated land to rangeland** – as suggested, conversion of irrigated cropland to rangeland. Rangeland conditions could include the use of grazing.

3. **Improvements in Irrigation Efficiency** – Irrigation efficiency is the ratio of the average depth of irrigation water that is beneficially used to the average depth of irrigation water applied, expressed as a percent (L73). Technological advances used to improve irrigation efficiency include but are not limited to the following:
   a. **Surge irrigation with furrow irrigation** – surge irrigation is an irrigation technique wherein flow is applied via gated pipe to furrows intermittently, using a programmed surge valve to alternate flows to either side of the valve during a single irrigation set (L73), resulting in more uniform water applications from the top to the bottom of the field. Matrix entries for this conservation measure are relative to base conditions for conventional gated pipe with furrow irrigation.
   b. **Variable Rate Irrigation with center pivots** – center pivot conversion that enables variable irrigation application rates to different portions of the field through variable pivot travel speed and/or through enabling individual sprinklers or groups of sprinklers to vary application rates during a circle. This is usually done in conjunction with GIS technology to monitor the pivot’s position in the field. Matrix entries for this conservation measure are relative to base conditions for conventional center pivot systems.
   c. **Conventional gated pipe with furrow irrigation –** the use of conventional gated pipe to deliver water to the field through furrow irrigation. Matrix entries for this conservation measure are relative to base conditions for open ditch irrigation using siphon tubes or check structures.
   d. **Conventional center pivots –** standard center pivot systems consisting of a tower, or set of towers, rotating around a central station via tracked propulsion, delivering water through sprinklers set along the tower axes. Matrix entries for this conservation measure are relative to base conditions for conventional gated pipe with furrow irrigation.
   e. **Subsurface Drip Irrigation –** the use of buried pipes, tubes, or tape to provide irrigation supplies through below-surface application, directly to the root zone. Matrix entries for this conservation measure are relative to base conditions for conventional gated pipe with furrow irrigation.

4. **Changes in Crop Rotation Pattern/Mixes** – The adoption of crop rotation practices for nutrient management purposes, soil conservation and reduced water consumption.

    a. **Irrigated Crops: lower consumption crops in rotation with corn**. Rotation crops might include soybeans, winter wheat, sugar beets, dry beans, or other crops, depending on the region.
    b. **Dryland Crops**:
        i. **Conversion of wheat-fallow rotation to eco-fallow system** with corn (or grain sorghum or millet)-wheat-fallow.
        ii. **Conversion of cropland to rangeland** – as indicated, conversion from cropland to rangeland that can include grazing.
    c. **CRP/CREP Conversion**:
        i. **Dryland Cropland to CRP/CREP** – The conversion of dryland cropland to CRP (Conservation Reserve Program) or CREP (Conservation Reserve Enhancement Program) is a soil management technique used to remove highly erodible lands and fragile soils from crop production.
        ii. **Irrigated Cropland to CRP/CREP** – Same as above, except for irrigated lands.
5. **Changes in crop production intensity** – the adoption of management practices that increase crop production on less land with better crop hybrids (e.g. higher plant populations, narrower row spacing, skip row, etc.).
    a. **Higher plant populations** – planting more seeds per unit area.
    b. **Narrower row spacing** – reducing the space between rows.
    c. **Skip row planting** – a practice in which certain rows are not planted to improve yields in times of water scarcity. Examples include planting one row and skipping the next, planting two rows and skipping two rows, and planting two rows and skipping one row.
6. **Implementation of soil moisture monitoring program** – The adoption of sensors for irrigation scheduling decisions by monitoring the soil moisture status.
7. **Changes in rangeland management** – changes that affect range condition and, as a result, ET from rangeland, including the adoption of management techniques that more efficiently utilize available animal forage and reduce overgrazing (e.g cross-fencing, pasture rotation, cedar burns, etc.).
8. **Application of Buffers** – Buffers can include riparian buffers, filter strips, and grassed waterways. Riparian buffers are streamside plantings of trees, shrubs, and grasses that can intercept contaminants from both surface water and ground water before they reach a stream and that help restore damaged streams (L74). Filter strips are strips of grass used to intercept or trap field sediment, organics, pesticides, and other potential pollutants before they reach a body of water (L74). Grassed waterways are strips of grass seeded in areas of cropland where water concentrates or flows off a field. They are primarily used to prevent gully erosion (L74).
9. **Management of Phreatophytes/Invasive Vegetation** – This practice involves the management and removal of phreatophytes and invasive vegetation to reduce evapotranspiration.

Matrix Category Descriptions

Assumed Magnitude of Impact – This category is a preliminary estimate of the overall magnitude of impacts to streamflow based on expert opinion and literature on a basin-wide scale. Basin-wide impact in the context of this review includes consideration of the total number of conservation measures installed across the entire basin, meaning the cumulative effect for each conservation measure, rather than a comparison of conservation measures on a per acre basis. The impact magnitude will be assigned as high, medium or low. This impact estimate is based on the difference in streamflow between fully appropriated conditions (assumed to have occurred in 1984 for these purposes) and current overappropriated conditions. As a result, the high, medium and low entries provide a very rough indication of how great this change in streamflow caused by a particular conservation measure compares to the change in streamflow resulting from the other conservation measures in the basin. In laypersons terms, the impact estimates are graded on a curve.

Availability of Information

For these three sub-categories, high quality information is readily available (RA), has limited availability (LA), or not available (NA):

- **ET, Overland Runoff, Recharge** – Information availability concerning the quantity of flow via the three categories of hydrologic processes considered in this evaluation: evapotranspiration (ET), overland runoff, and recharge and irrigation return flow. For example, surge valves for surface irrigation have been extensively studied with respect to their impacts on recharge and return flow and overland runoff and therefore we assigned a Readily Available "RA" value for information availability.
- **Spatial** – Information availability for the location of the respective conservation practices. For canal rehabilitation, it is likely that irrigation districts will have detailed spatial information about location of these practices, and as a result that practice was assigned a Readily Available "RA" level of spatial information availability in the matrix.
- **Implementation Timing** – Availability of temporal information on when practices were historically put in place. For conversion of open laterals or canals to pipe, irrigation districts will likely have good information about the timing of these improvements, and as a result we assigned that practice an "RA" value in the matrix.

Is Local Impact Quantified on Annual Basis – This column defines whether local impact to ET, recharge, and runoff is available on an annual time step. If annual time step is not available then additional work is needed to determine annual impacts to streamflow. "Y" indicates the annual quantification is available, and "N" indicates it is not. For example, for surge irrigation, information is available on an annual time step ("Y"), since the impact only occurs during the irrigation season, which is the same time that quantified impact information is available.

Conservation Measure/Practice Impact on – For these three categories, information is provided on whether the conservation measure increases, decreases, or does not change (NC) one of the three components of the water balance, on an annual basis:

- **Overland Runoff**
- **Recharge**
- **Net Effect on ET**

MATRIX ON QUANTIFICATION OF CONSERVATION IMPACTS TO STREAMFLOW

PAGE 1 of 2

Final

23 December 2013 Version

	Assumed Magnitude of Impact	**AVAILABILITY OF INFORMATION**			**Is Local Impact Quantified on Annual Basis**	**Conservation Measure/Practice Impact on**		
		ET, Overland Runoff, & Recharge	**Spatial**	**Implementation Timing**		**Overland Runoff**	**Recharge**	**NET Effect on ET**
Structural	(LOW, MED, HIGH)	Not Available (NA), Limited Availability (LA), Readily Available (RA)			Y or N	INCREASE, DECREASE, NO CHANGE (NC), NOT APPLICABLE (NA)		
1. Conservation terraces	LOW +	RA	LA	LA	Y	DECREASE	INCREASE	INCREASE
2. Non-jurisdictional/Non-permitted Small Dams	LOW +	RA	LA	LA	Y	DECREASE	INCREASE	INCREASE
3. Jurisdictional/Permitted Dams	LOW +	RA	RA	RA	Y	DECREASE	INCREASE	INCREASE
4. Canal rehabilitation	LOW -	LA	LA	LA	Y	NA	DECREASE	DECREASE
5. Conversion from open laterals and canals to pipelines	LOW -	LA	LA	LA	Y	NA	DECREASE	DECREASE
6. Irrigation runoff recovery systems or return-flow facilities	LOW	RA	LA	LA	Y	DECREASE	INCREASE	NC
7. Others								
Non-Structural								
1. Changes in tillage practices								
1.a. Dryland	MED to HIGH -	RA	LA	RA	Y	DECREASE	INCREASE	INCREASE
1.b. Irrigated	LOW +	RA	LA	RA	Y	DECREASE	INCREASE	DECREASE
2. Changes in irrigation management								
2.a. Irrigation scheduling	LOW	LA	LA	LA	Y	DECREASE	DECREASE	DECREASE
2.b. Deficit irrigation	LOW *see Tab 2	LA	LA	LA	Y	NC	DECREASE	DECREASE
2.c. Conversion of irrigated land to dryland cropland	LOW	NA	NA	NA	Y	DECREASE	DECREASE	DECREASE
2.d. Conversion of irrigated land to rangeland	LOW	NA	NA	NA	Y	DECREASE	DECREASE	DECREASE
3. Improvements in irrigation efficiency								
3.a. Surge irrigation with furrow irrigation	LOW	LA	LA	LA	Y	DECREASE TO NC	DECREASE	NC
3.b. Variable Rate Irrigation with center pivots	LOW	LA	LA	LA	Y	DECREASE	DECREASE	NC TO DECREASE
3.c. Conventional gated pipe with furrow irrigation	LOW	LA	LA	LA	Y	NC	DECREASE	NC
3.d. Conventional center pivots	LOW - *see Tab 2	RA	RA	RA	Y	DECREASE	DECREASE	NC TO DECREASE
3.e. Sub-surface drip irrigation	LOW	LA	LA	LA	Y	DECREASE	DECREASE	DECREASE
4. Changes in crop rotation pattern/mixes								
4.a. Irrigated Crops: lower consumption crops in rotation with corn	MED +	RA	RA	RA	Y	NC	NC	DECREASE
4.b. Dryland crops								
4.b.i. Conversion of wheat-fallow rotation to eco-fallow syst	LOW TO MED -	LA	LA	LA	Y	DECREASE	DECREASE	INCREASE
4.b.ii. Conversion of cropland to rangeland	LOW -	LA	LA	LA	Y	DECREASE	DECREASE	INCREASE
4.c. CRP/CREP conversion								
4.c.i. Dryland Cropland to CRP/CREP	MED -	RA	RA-subject to FOIA	RA-subject to FOIA	Y	DECREASE	DECREASE	INCREASE
4.c.ii. Irrigated Cropland to CRP/CREP	LOW TO MED +	RA	RA-subject to FOIA	RA-subject to FOIA	Y	DECREASE	DECREASE	DECREASE
5. Changes in crop production intensity								
5.a. Higher plant populations	LOW -	LA	LA	LA	Y	NC	NC	NC
5.b. Narrower row spacing	LOW -	LA	LA	LA	Y	NC	NC	NC
5.c. Skip row planting	LOW +	LA	LA	LA	Y	NC	NC	NC
6. Implementation of soil moisture sensors	LOW	LA	LA	LA	Y	DECREASE	DECREASE	DECREASE
7. Changes in rangeland management	LOW	LA	LA	LA	Y	HEAVY TO LIGHT = DECREASE	HEAVY TO LIGHT = DECREASE	HEAVY TO LIGHT = INCREASE
8. Application of Buffers	LOW	LA	LA	LA	Y	DECREASE	VARIES	VARIES
9. Management of Phreatophytes/Invasive vegetation	LOW +	LA	RA	RA	Y	NC	INCREASE	DECREASE
10. Others								

Structural	ssumed Basin-Wide Magnitud Of Impact (Low, Med, High)	Characteristics of Sub-basins with Significant Impacts	Rationale (Assumes FA conditions reached in 1984. Impact magnitudes are basin-wide and relative to those from other conservation measures in the basin.)
1. Conservation terraces	**Low +**		The base condition for this practice is unterraced dryland fields. Most terraces were in place before the basin became Fully Appropriated. Surface effects of ET increase and direct runoff reduction occur over a short period, so the effect of this practice on direct overland runoff is included in historical values. Seepage from the terrace channels requires long periods to reach the water table if the vadose zone is thick. About 15% of the land In the Republican River Basin (actually about 10% when considering land above the lower terrace) has been treated with conservation terraces. We expect that the percentage in the Overappropriated study area is less than the Republican Basin. Thus, some small increases in streamflow could result relative to the impacts to the stream from the terraces at the time the basin became Fully Appropriated.
2. Non-jurisdictional/Non-permitted Small Dams	**Low +**		The base condition for this practice would be land without dams. Most permitted dams were in place before the basin became Fully Appropriated. Surface effects of increased ET and storage occur over a short period so the effect is included in the recorded stream flow data. Seepage from dams requires extended periods to reach the water table due to transport through the vadose zone; however, dams are located in stream valleys that would be closer to groundwater than upland areas such as terrace lands. Thus, some small increases in streamflow could have resulted since the basin became Fully Appropriated.
3. Jurisdictional/Permitted Dams	**Low +**		The base condition for this practice would be land without dams. Most permitted dams were in place before the basin became Fully Appropriated. Surface effects of increased ET and storage occur over a short period so the effect is included in the recorded stream flow data. Seepage from dams requires extended periods to reach the water table due to transport through the vadose zone; however, dams are located in stream valleys that would be closer groundwater than upland areas such as terrace lands. Thus, some small increases in streamflow could have resulted since the basin became Fully Appropriated.
4. Canal rehabilitation	**Low -**		The base condition for this practice is unlined canals. The impact is considered low because of the low amount of change since the basin became Fully Appropriated. The primary impact is reduced seepage and spills with a small reduction of evaporation from the canal. The ultimate outcome for of lining and piping is probably delivery of more water to irrigated lands than before, which could result in a higher consumptive use proportion . The impact is negative because the "water savings" is thought to be utilized by crop ET.
5. Conversion from open laterals and canals to pipelines	**Low -**		The base condition for this practice is surface water delivery though an earthen canal. The primary impact is reduced seepage and spills with a small reduction of evaporation from the canal. Evapotranspiration from waterlogged areas due to seepage/spills is consumptive. Seepage from the canal that percolates beyond root zones of nontarget plants will recharge the groundwater. The ultimate outcome for of lining and piping is probably delivery of more water to irrigated lands than before, which could result in a higher consumptive use proportion . Therefore, we believe that the impact has negatively affected streamflow to a slight degree since the basin became Fully Appropriated.
6. Irrigation runoff recovery systems or return-flow facilities	**Low**		The base condition for this practice is surface irrigation, mainly furrow using gated pipe, without runoff recovery. The impact of runoff recovery is to reduce the amount of irrigation runoff that leaves the field. The impact on stream flow is low because few systems have been put in place since the basin became Fully Appropriated.
7. Others			
Non-Structural			
1. Changes in tillage practices			
1.a. Dryland	**MED To HIGH -**		The base condition for this practice is a disked tillage system in the east and a stubble mulch system in the west. Conversion to conservation tillage generally produces more infiltration and less evaporation from the soil surface if adequate residue is present. Infiltrated water often results in increased crop yield and therefore more evapotranspiration (ET) for dryland areas. The reduction of runoff from the field and increased ET from dryland areas could noticeably reduce streamflow. Conversion to reduced tillage has occurred since the late 1970s and we continue to see conversions, so a large portion of the impact likely would have occurred after the basin became Fully Appropriated. There is also a strong east-west impact as reductions in ET depend on the frequency of rainfall for dryland fields. When the interval between wetting events is long the initial ET rate is suppressed, but if the period is long enough, about the same amount of water may evaporate from the soil. Dryland cropping is widespread across the basin so we believe that the practice will have had a noticeable negative impact on streamflow.
1.b. Irrigated	**Low +**		Our base condition for irrigated cropland is a disked tillage system. Conservation tillage does not increase crop ET for irrigated land unless the field is deficit irrigated. The primary impact on irrigated fields would be to reduce evaporation and thus reduce ET. The impact on irrigated lands is different than for dryland because the wetting frequency is higher than for dryland crops, there is more crop residue for some irrigated crops than for dryland, and transpiration rates are not influenced by the additional residue. Therefore, we expect less of an impact than for dryland but a positive increase in streamflow due to reduced evaporation and thus reduced ET.
2. Changes in irrigation management			
2.a. Scientific Irrigation scheduling	**Low**		The base condition for this practice non-scientific irrigation scheduling. The impact is considered low because we believe that the increase in this practice has been minimal since the basin became Fully Appropriated. The practice should have a positive impact on streamflow because of fewer irrigation water applications thus less wetting of the plant leaves and soil. Evaporation should be reduced. But with an unknown change in adoption since the fully appropriated condition, we rated this as low.
2.b. Deficit irrigation	**Low+**	The impact can be medium to high + in sub-basins that have implemented water allocations that restrict water withdrawals to levels that would result in either deficit irrigation or a change in crop selection.	The base condition would be the fully irrigated condition, that is, irrigation application to the level that there is no plant water stress. When plant water stress occurs, transpiration is reduced. On a basin scale the impact is considered low because the level of adoption since the basin became Fully Appropriated will be relatively small but where adopted the impact would be medium to high +.

2.c. Conversion of irrigated land to dryland cropland	**Low**		The base condition is irrigated cropland. This practice would reduce ET significantly but the impact is considered low since the conversion to dryland has been minimal since the basin became fully appropriated.
2.d. Conversion of irrigated land to rangeland	**Low**		The base condition is irrigated cropland. This practice would reduce ET significantly but the impact is considered low since the conversion of irrigated cropland to rangeland would be minimal if any occurred at all since the basin became fully appropriated.
3. Improvements in irrigation efficiency			There is widespread misunderstanding about the impact of irrigation efficiency on water balances. The deciding factor is to determine the pathway for the water affected by conversion to more efficient irrigation methods.
3.a. Surge irrigation with furrow irrigation	**Low -**		Our base condition here is the conversion from traditional furrow irrigation using gated pipe. Utilization of surge flow usually provides more rapid advance of water across the field for water applied. This usually reduces deep percolation at the upper end of the field and reduces crop water stress if water did not usually reach the lower end of the field in a timely manner. The reduction of deep percolation is probably more significant than increased crop water use in most applications. We feel that the impact is low because there is little land area that utilizes surge flow irrigation. In addition, if the primary effect is changing deep percolation, then the water that percolates is not consumptive and eventually affects recharge.
3.b. Variable Rate Irrigation with center pivots	**Low**		The base case for Variable Rate Irrigation (VRI) is a traditional center pivot irrigation system. VRI allows for the application of varying depths across the field in a targeted manner. There could be various goals in using VRI. One approach could be to reduce pumping on areas of the field that hold more water than lighter textured soils. Application depths could also be curtailed on nonproductive areas of the field. When combined with areas that are deficitly irrigated under water allocation programs the amount of ET could be increased if water that was not needed in part of the field resulted in deep percolation at that location and is instead is applied on areas that usually receive less water and experience more stress. In the latter case, VRI could increase ET. VRI is new so any impacts are the result of recent developments and certainly occurred after the basin became Fully Appropriated. VRI will most certainly reduce leaching of agricultural chemicals, which will positively impact groundwater quality.
3.c. Conventional gated pipe with furrow irrigation	**Low**		The base case for this practice is furrow-irrigated land using siphon tubes. Conversion to gated pipe has generally occurred some time ago so the changes since the basin became Fully Appropriated are primarily small. The primary impact of using gated pipe rather than siphon tubes would be the difference in seepage from on-farm ditches and perhaps some spills. The difference in seepage depends on the type of ditch used for supply siphon tubes. Concrete-lined ditches would have little seepage. Earth lined ditches would have more seepage. However, leaky gates for gated pipe can also contribute to seepage at the head of the field. In some case, leaks from gates can be as bad as seepage from an earthen ditch. Evaporation from the open water surface of an open ditch is generally small. Finally, with groundwater supplies the percolation from the ditch or gated pipe is primarily seepage, which returns eventually to the aquifer.
3.d. Conventional center pivots	**Low -**	There could be subbasin exceptions where irrigation water distribution before conversion was so nonuniform that it caused lower ET and subsequent yield reductions. In these cases, the impacts to streamflow could be greater than the overall basin estimate.	The base case for this practice is fields furrow irrigated with gated pipe. There has been a continual conversion from gated pipe to center pivots all across the basin. Key issues for this practice are the amount of land irrigated with the pivot compared to the furrow irrigated field, and changes in the adequacy of irrigation on the areas of the field that may have been under irrigated with furrow irrigation. Runoff from center pivots should be less than for furrow irrigation. The key is how the runoff is managed. If the water is recycled to the field through reuse systems then the main loss of water is seepage in the reuse system and increased evaporation/evapotranspiration from open water surface and weeds along conveyance channels. With center pivots some of the water evaporates in the air and evaporation from the canopy is generally more than the transpiration would have been. Combined evaporation losses from evaporation in the air, drift losses and canopy evaporation increases is generally less than ten percent. In our view there is a small negative impact on streamflow on a basin-wide level since the basin became Fully Appropriated.
3.e. Sub-surface drip irrigation	**Low**		The base case for this practice is furrow-irrigated land using gated pipe. The conversion to SDI has certainly occurred since the basin became Fully Appropriated. Issues with SDI are similar to that for conventional center pivots. The amount of land irrigated is probably about the same as for furrowed irrigated land. Evapotranspiration from SDI can be somewhat less than for furrow irrigation, as the soil surface remains dry. Losses from SDI are primarily due to deep percolation if the field is not properly scheduled. Those losses would recharge groundwater aquifers eventually. Evapotranspiration could increase if the furrow system did not provide adequate supplies. SDI would dramatically reduce runoff of irrigation water and perhaps rainfall as well. If crop yields increase due to improved irrigation distribution, then ET likely increased. The areal extent of SDI is still quite small so we have rated its impact as low.
4. Changes in crop rotation pattern/mixes			
4.a. Irrigated Crops: lower consumption crops in rotation with corn	**Med +**	The impact can be medium to high + in sub-basins that have implemented water allocations that restrict water withdrawals to levels that would result in either deficit irrigation or a change in crop selection.	The base condition would be irrigated corn with full-season hybrid selection that matches the geographic area. The impact of changes in crops with lower ET is often the result of the shorter growing season for alternative crops. Thus, shorter season corn hybrids could also be considered in this option. Changes from corn to soybean in much of the basin could have been significant since the Fully Appropriated condition.
4.b. Dryland crops			
4.b.i. Conversion of wheat-fallow rotation to eco-fallow	**Low To Med -**		The base condition for this practice would be wheat-fallow rotation with mulch tillage. The negative impact of this change is due to increased crop ET which is a result of producing two crops in a three year period versus one crop in two years. Overall magnitude depends on level of change since the Fully Appropriated Condition.

4.b.ii. Conversion of cropland to rangeland	**Low -**		The base condition for this practice would be dryland cropland, either wheat-fallow or eco-fallow, with mulch tillage. The negative impact of this change is due to increased rangeland ET associated with the longer growing periods of rangeland and possibly due to the deeper root zone that is expected for the perennial vegetation. The deeper root zone results in a larger soil moisture reservoir for storing water for subsequent ET. Overall magnitude depends on level of change since the Fully Appropriated Condition but we assume that it is minimal if at all.
4.c. CRP/CREP conversion			
4.c.i. Dryland Cropland to CRP/CREP	**Med -**		The base condition for this practice would be dryland cropland, either wheat-fallow or eco-fallow, with mulch tillage. The negative impact of this change is due to increased ET on the CRP/CREP land associated with the longer growing periods of CRP/CREP land and possibly due to the deeper root zone that is expected for the perennial vegetation. The deeper root zone results in a larger soil moisture reservoir for storing water for subsequent ET. Overall magnitude depends on level of change since the Fully Appropriated Condition and we assume that the adoption has been significant.
4.c.ii. Irrigated Cropland to CRP/CREP	**Low To Med +**		The base condition for this practice would be irrigated cropland, mainly corn. The positive impact of this change is due to reduced ET during periods of moisture stress on the CRP/CREP land. Overall magnitude depends on level of change since the Fully Appropriated Condition and we assume that the adoption has been significant.
5. Changes in crop production intensity			
5.a. Higher plant populations	**Low -**		The base condition for this practice is a normal planting density of about 30,000 corn plants per acre for irrigated land. The primary effect of increasing the density is that the canopy closes earlier in the season. For most irrigated crops the leaf area index for previous populations were well above the amount of leaf area that would produce full ET. Higher populations allow for more ET somewhat earlier in the season and the canopy may senesce more slowly but not materially. We expect that this impact will be a small increase in ET but not materially. Impacts on dryland will be minimal as precipitation generally dictates ET.
5.b. Narrower row spacing	**Low -**		This practice compares to a traditional row width of about 30 inches. The impact on planting narrower crop rows allows the canopy to close more quickly and perhaps last a little longer at the end of the growing season. Narrower rows do not increase the leaf area index materially. The net effect will be a small increase of ET early and late in the season, which would deplete streamflow slightly. Impacts on dryland will be minimal as precipitation generally dictates ET.
5.c. Skip row planting	**Low +**		The base condition for this practice is planting rows at equal spacing for all rows. Skip-row involves not planting one row out of a set; *i.e.* skipping a row. One scheme skips one row and plants one row (every-other row skipped), a second scheme involves planting two rows and skipping one row with a three row basic unit. Skipping a row allows for storage of precipitation over the wider width which requires more time for the roots of the crop to reach during the season. The additional storage provides water to allow crops to complete crop development and increase grain development. In the most arid areas, the impacts will probably be small as precipitation is the limiting factor and this practice is only altering the time during the season when the water is used for ET. In wetter years, and in the more humid areas, there is a chance that some of the stored water in the skipped row will not be needed for the season. If the skipped row was planted ET would have been higher. The effect is that ET would be decreased in wetter years when the row is skipped. This practice has only been adopted since the basin became Fully Appropriated and is not widely implemented - thus we believe this impact will be small.
6. Implementation of soil moisture sensors	**Low**		The base condition for this practice would be irrigated cropland without soil moisture sensors. Assuming that the sensors are used for scientific irrigation scheduling we're assuming that the impact is low because we believe that the increase in this practice has been minimal since the basin became Fully Appropriated. The practice should have a positive impact on streamflow because of fewer irrigation water applications thus less wetting of the plant leaves and soil. Evaporation should be reduced.
7. Changes in rangeland management	**Low**		The primary management practice change for rangeland is the management of grazing duration and intensity. Higher levels of range management generally provide periods on intense grazing and then regrowth periods. The base practice would be where animals are free to graze the whole pasture. Enhanced management can have two effects: (1) taller grass in some portions of the field after intense grazing and (2) maintenance of different grass mixtures, as periodic grazing does not allow time for the animals to graze out the desirable grasses with regrowth of less desirable species. Enhanced management has gained popularity since the time at which the basin became Fully Appropriated and has become significantly widespread. We believe that enhanced management would lead to slight increases in ET due to more regrowth but that the impact would be small. If ranchers planted a different grass species, the impact could be different.
8. Application of Buffers	**Low**		The base condition for this practice would be cropland, either irrigated or dryland. The impact of this change would be due to a change in ET. If changing from irrigated land to buffers, the impact would be positive since ET would likely go down. The opposite would occur with dryland cropland. Since the Fully Appropriated Condition, we assume that the adoption has been low and thus the impact is low.
9. Management of Phreatophytes/Invasive vegetation	**Low +**		The base condition for this practice would be a riparian zone with native species that existed up to thirty years ago. Invasive species include salt cedar phragmites, Russian olive and red cedar trees. Research has shown that removing the invasive species next to a stream results in the majority of the impact ocurring in the first few years after clearing. Once invasive species are removed, a mixture of understory species quickly fill the area where the invasive species were located. The species that we have observed are the native climax vegetation and thus the potential reduction of ET from clearing invasive species is smaller than some reports. In addition, the fraction of the watershed that is affect by riparian species removal is small for the whole watershed. Thus, we expect the impact to be a small positive impact when considered over a long period.
10. Others			

MATRIX ON QUANTIFICATION OF CONSERVATION IMPACTS TO STREAMFLOW

Final

23 December 2013 Version

	--- Expertise Needed for Project ---										---Type of Models Needed ---								---- Measurement Methods ---										
Structural	Agronomist/Soil Scientist	Rangeland ecologist	Riparian ecologist	Microclimatologist	Eco-hydrologist	Agricultural hydrologist	Irrigation engineer	Hydrauic engineer	Vadose zone hydrologist/soil physiscist	Groundwater geologist/engineer	Spatial analysis (GIS, etc.)	Irrigation hydraulics (SRFR, Sirmod,CPNozzle)	Surface hydrology (SWAT, WEPP, HEC-HMS, MIKE-SHE)	Root zone hydrology (Cropsim)	Evapotranspiration (Models that use Penman Monteith)	Vadose zone hydrology (HYDRUS, RZWQM)	Groundwater hydrology (MODFLOW)	Integrated hydrologic model (MIKE-SHE, Farm Process/MODFLOW)	Groundwater levels	Matric potential and water content in intermediate vadose zone	Matric potential and water content in root zone	Tracers in vadose zone	Stream flow (Gauging stations)	Field runoff (flumes, weirs)	Evapotranspiration (BREB, Eddy Co-variance, Remote Sensing)	Infiltration	Seepage	Plant Growth and Management Practices	**Literature Review Reference** *See other worksheet*
1. Conservation terrace						X		X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X		X	L2, L3, L4, L5, L10, L18, L19, L20, L21, L22, L23, L32
2. Non-jurisdictional/Non-permitted Small Dams						X		X	X	X	X		X			X	X		X	X			X	X	X		X	X	L25
3. Jurisdictional/Permitted Dams						X		X	X	X	X		X			X	X		X	X			X	X	X		X	X	
4. Canal rehabilitation						X	X	X	X	X	X					X	X		X	X			X	X			X		L14
5. Conversion from open laterals and canals to pipelines						X	X	X	X	X	X	X				X	X		X	X			X	X			X	X	L15, L14
6. Irrigation runoff recovery systems or return-flow facilities							X				X	X				X	X							X			X	X	L16, L27
7. Others																													
Non-Structural																													
1. Changes in tillage practices (I --> irrigated, R --> Rainfed)																													
1.a. Dryland	X					X			X	X	X		X	X	X	X	X	X		X	X	X		X	X				L37, L45, L46, L52, L53, L54
1.b. Irrigated	X					X	X		X	X	X		X	X	X	X	X	X		X	X	X		X	X				L37, L45, L46, L52, L53, L54
2. Changes in irrigation management																													
2.a. Scientific irrigation scheduling							X		X	X	X	X		X	X	X	X	X		X	X	X		X	X			X	L33, L35, L41, L75, L77, L78
2.b. Deficit irrigation	X						X		X	X	X			X	X	X	X	X		X	X	X			X			X	L76, L79, L80
2.c. Conversion of irrigated land to dryland cropland	X					X	X		X	X	X			X	X	X	X	X		X	X	X			X			X	
2.D. Conversion of irrigated land to rangeland		X				X	X		X	X	X			X	X	X	X	X		X	X	X		X	X			X	
3. Improvements in irrigation efficiency																													
3.a. Surge irrigation with furrow irrigation							X		X	X	X	X						X						X		X			L17, L41, L42, L43, L62
3.b. Precision irrigation with variable rate center pivot technology							X		X	X	X	X						X		X	X					X			L63, L64, L65
3.c. Conversion to gated pipe with furrow irrigation							X		X	X	X	X				X	X	X		X	X			X		X			L16, L27
3.d. Conversion to conventional center pivot systems							X		X		X	X		X		X	X	X		X	X	X	X			X			L16, L27
3.e. Conversion to sub-surface drip irrigation							X		X	X	X	X		X		X	X	X		X	X	X							L16, L27
4. Changes in crop rotation pattern/mixes																													L66
4.a. Irrigated crops: more lower water consumption crops in rotation with corn	X			X		X	X		X	X	X			X	X	X	X	X		X	X	X			X			X	
4.b. Dryland crops																													
4.b.i. Conversion of wheat-fallow rotation to eco-fallow system	X					X			X	X	X		X	X	X	X	X	X		X	X	X		X	X			X	
4.b.ii. Conversion of cropland to rangeland	X					X			X	X	X		X	X	X	X	X	X		X	X	X		X	X			X	
4.c. CRP conversion																													
4.c.i. Dryland Cropland to CRP	X					X			X	X	X		X	X	X	X	X	X		X	X	X		X	X			X	L45, L46, L59, L60, L61
4.c.ii. Irrigated Cropland to CRP	X					X			X	X	X		X	X	X	X	X	X		X	X	X		X	X			X	L45, L46, L59, L60, L61
5. Changes in crop production intensity																													
5.a. Higher plant populations	X					X			X	X	X		X	X	X	X	X	X		X	X	X			X			X	
5.b. Narrower row spacing	X					X			X	X	X			X	X	X	X	X		X	X	X			X			X	
5.c. Skip row planting	X					X			X	X	X			X	X	X	X	X		X	X	X			X			X	
6. Implementation of soil moisture sensors							X		X	X	X		X	X	X	X	X	X		X	X	X			X			X	
7. Changes in rangeland management		X				X			X	X	X		X	X	X	X	X	X		X	X	X		X	X			X	L38, L55, L56, L57, L58
8. Application of Buffers			X			X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X			X	L5, L28, L29, L30, L31
9. Management of Phreatophytes/Invasive vegetation			X			X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X			X	
10. Others																													

MATRIX ON QUANTIFICATION OF CONSERVATION IMPACTS TO STREAMFLOW

Final

23 December 2013 Version

	Multiplier for Low Intensity*	Multiplier for Medium and High Intensity*	Quality			
			Low Intensity	**Medium Intensity**	**High Intensity**	
			Expert dominant	**Expert + model**	**Expert + Model + Field**	
			60%	30%	15%	Uncertainty
Structural			$50,000	$300,000	$600,000	Baseline Values**
1. Conservation terrace	3	4	$150,000	$1,200,000	$2,400,000	
2. Non-jurisdictional/Non-permitted Small Dams	2.5	3.5	$125,000	$1,050,000	$2,100,000	
3. Jurisdictional/Permitted Dams	2	3	$100,000	$900,000	$1,800,000	
4. Canal rehabilitation	2	4	$100,000	$1,200,000	$2,400,000	
5. Conversion from open laterals and canals to pipelines	2	4	$100,000	$1,200,000	$2,400,000	
6. Irrigation runoff recovery systems or return-flow facilities	2	2	$100,000	$600,000	$1,200,000	
7. Others						
Non-Structural						
1. Changes in tillage practices (I --> irrigated, R --> Rainfed)						
1.a. Dryland	3.5	4.5	$175,000	$1,350,000	$2,700,000	
1.b. Irrigated	3.5	4.5	$175,000	$1,350,000	$2,700,000	
2. Changes in irrigation management						
2.a. Scientific irrigation scheduling	2	3	$100,000	$900,000	$1,800,000	
2.b. Deficit irrigation	3	4	$150,000	$1,200,000	$2,400,000	
2.c. Conversion of irrigated land to dryland cropland	5	6	$250,000	$1,800,000	$3,600,000	
2.D. Conversion of irrigated land to rangeland	5	6	$250,000	$1,800,000	$3,600,000	
3. Improvements in irrigation efficiency						
3.a. Surge irrigation with furrow irrigation	1	2	$50,000	$600,000	$1,200,000	
3.b. Precision irrigation with variable rate center pivot technology	3	4	$150,000	$1,200,000	$2,400,000	
3.c. Conversion to gated pipe with furrow irrigation	1	2	$50,000	$600,000	$1,200,000	
3.d. Conversion to conventional center pivot systems	2	3	$100,000	$900,000	$1,800,000	
3.e. Conversion to sub-surface drip irrigation	2	4	$100,000	$1,200,000	$2,400,000	
4. Changes in crop rotation pattern/mixes						
4.a. Irrigated crops: more lower water consumption crops in rotation with corn	4	5	$200,000	$1,500,000	$3,000,000	
4.b. Dryland crops						
4.b.i. Conversion of wheat-fallow rotation to eco-fallow system	4	5	$200,000	$1,500,000	$3,000,000	
4.b.ii. Conversion of cropland to rangeland	4	5	$200,000	$1,500,000	$3,000,000	
4.c. CRP conversion						
4.c.i. Dryland Cropland to CRP	4	5	$200,000	$1,500,000	$3,000,000	
4.c.ii. Irrigated Cropland to CRP	4	5	$200,000	$1,500,000	$3,000,000	
5. Changes in crop production intensity						
5.a. Higher plant populations	2	3	$100,000	$900,000	$1,800,000	
5.b. Narrower row spacing	2	3	$100,000	$900,000	$1,800,000	
5.c. Skip row planting	2	3	$100,000	$900,000	$1,800,000	
6. Implementation of soil moisture sensors	2	3	$100,000	$900,000	$1,800,000	
7. Changes in rangeland management	4	5	$200,000	$1,500,000	$3,000,000	
8. Application of Buffers	4	5	$200,000	$1,500,000	$3,000,000	
9. Management of Phreatophytes/Invasive vegetation	5	6	$250,000	$1,800,000	$3,600,000	
10. Others						

Evaluation of Multiple Practices - As a starting estimate, multiply the sum of costs of all individual practices by the following cost adjustment factors

No of Practices	Cost Adjustment Factor
1	1.00
2	0.66
3	0.52
4	0.44
5	0.38
6	0.34
7	0.31
8	0.29
9	0.27
10	0.25
>10	0.25

Here is an example of how to apply the cost adjustment factor:

Consider a project with medium intensity analysis of conservation terraces, canal rehabilitation, and augmentation. The associated single practice costs are $1.2 M, $1.2 M, and $1.8 M. If the projects were completed individually, the cost total would be $4.2 M. But if all three projects were pooled into one project, the total cost would be $4.2 M X 0.52 = $2.2 M. The cost adjustment factor in this case in 0.52, the factor for three practices.

Activities associated with low intensity are dominated by the use of expert opinion and the published literature with the assistance of some modeling and little if any field measurement

Activities associated with medium intensity are dominated by the use of expert opinion, the literature, and a strong emphasis on modeling and a small amount of field measurement if needed

Activities associated with high intensity are dominated by the blend of expert opinion, the literature, extensive use of models and a significant amount of field measurement

* The multiplier accounts for system complexity and what is already known

**Baseline values are relative values and are used in conjunction with the multipliers to determine the estimated budget

	MODEL	AUTHOR/AGENCY	DATE	Link (if applicable)	SUMMARY	GEOGRAPHIC SCALE	TEMPORAL SCALE	CONSERVATION PRACTICES	REFERENCES	ADDITIONAL INFORMATION
M1	POTYLD POTential YieLD Model Revised.	Koelliker, J.K. Kansas State University	1994	http://www.kgs.ku.edu/Publications/Bulletins/239/Koelliker/index.html	POTYLD assesses the effects of land use and conservation practices on large wathershed. POTYLD functions on a daily time step to calculate water budget fro different land uses and estimates the water yield on a monthly or annual basis for a drainage area. Hydrologic processes considered include evapotranspiration, transpiration, interception, runoff, snow, soil water evaporation, infiltration and redistribution. Spatial calculations performed for hydrogic response units.	Watershed	Daily	Ponds and terraces. Buffers, conservation reserve programs, tillage practices, irrigation methods and management, crop rotation, and grazing management conservation practices can be evaluated through infiltration parameters.	Koelliker, J. K., 1994a, User's manual for POTential YieLD Model Revised: Kansas State University, Manhattan, Civil Engineering Department Arabi, M., R.S. Govindaraju, M. Sophocleous, and J.K. Koelliker. 2006. Use of distributed models for watershed management: Case Studies. In Watershed Models. V.P. Singh, and D. Frevert, eds. CRC Press, Taylor and Francis Group, New York, pp 503-526.	POTYLD utilizes values of runoff curve numbers (RCN) to predict the split between runoff and infiltration for land uses from daily amounts of rainfall and snowmelt (See chapter I for more information on RCN values). Individual land uses and conservation-practice conditions can be described by a RCN, and the RCN technique is used widely to predict runoff from design storms. It follows that the RCN method can predict runoff over a period of time provided the antecedent moisture condition (AMC), 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 watershedsimulation models. Recently, POTYLD has been modified to include additional refinements and to include irrigation; consequently, the name was changed to Potential Yield Revised (POTYLDR) (Koelliker, 1994a, 1994b).
M2	SWAT Soil and Water Assessment Tool	S.L. Neitsch, J.G. Arnold, J.R. Kiniry, J.R. Williams Grassland, Soil and Water Research Laboratory - Agricultural Research Service Blackland Research Center - Texas AgriLife Research	2009	http://swat.tamu.edu/documentation/	SWAT is used to predict the impact of land management practices on water, sediment and agricultural chemical yields. SWAT functions on a continuous daily time step to simulate the hydrologic water balance. Model inputs include climate, hydrologic response units (GIS based spatially unique areas of land cover, soil type and management practices), ponds, groundwater, and channel data. Water balance equations calcuate the change in daily soil water content from precipitation, surface runoff, evapotranspiration, seepage into the vadose zone, and ground water returnflow and recharge. Additional hydrologic considerations include canopy storage, infiltration, redistribution, lateral subsurface flow, surface runoff, pond storage, and tributary channel routing and transmission losses. Model is available in a GIS format (ArcSWAT).	Watershed	Daily	Ponds, terraces, buffers, conservation reserve programs, tillage practices, irrigation methods and management, crop rotation, and grazing management.	S.L. Neitsch, J.G. Arnold, J.R. Kiniry, J.R. Williams. 2011. Soil and Water Assessment Tool Theoretical Documentation Version 2009. Texas Water Resources Institute Technical Report No. 406. Arnold, J. G., D. N. Moriasi, P. W. Gassman, K. C. Abbaspour, M. J. White, R. Srinivasan, C. Santhi, R. D. Harmel, A. van Griensven, M. W. Van Liew, N. Kannan, M. K. Jha. 2012. SWAT: Model Use, Calibration, and Validation. Transactions of the ASABE. Vol. 55(4): 1491-1508. Gassman, P. W., J. R. Williams, X. Wang, A. Saleh, E. Osei, L. M. Hauck, R. C. Izaurralde, J. D. Flowers. 2010. The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses. Transactions of the ASABE. 53(3): 711-740. Srinivasan, R., X. Zhang, J. Arnold. 2010. SWAT Ungauged: Hydrological Budget and Crop Yield Predictions in the Upper Mississippi River Basin. Transactions of the ASABE. Vol. 53(5): 1533-1546	The Soil and Water Assessment Tool (SWAT) is a public domain model jointly developed by USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research, part of The Texas A&M University System. SWAT is a small watershed to river basin-scale model to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds.
M3	RZWQM2 Root Zone Water Quality Model	L.R. Ahuja, K.W. Rojas, J.D. Hanson, M.J.Shaffer, L. Ma USDA-ARS	2000	http://www.wrpllc.com/books/rzwqm.html	RZWQM2 is used to predict the hydrologic response of alternative crop-management systems. RZWQM2 functions on a daily timestep and one-dimensional soil profile. The model simulates crop development and the movement of water, nutrients, and pesticides over and through the root zone on a field level. Model inputs include daily weather data, soil properties, and managment practices. Hydrologic processes include infiltration; flow through soil matrix, micropores, and macropores; fluctuating water table; tile drain, bare, and residue-covered soil evaporation; crop transpiration; soil water redistribution between rainfall and irrigation events; and snow accumulation and melt. Model is available in a GIS format (RZWQM2-GIS).	Field	Annual	Terraces, buffers, conservation reserve programs, tillage practices, irrigation methods and managment, crop rotation, and grazing management.	Ahuja, L. R., K. W. Rojas, J., D. Hanson, M. J. Shaffer, and L. Ma (eds). 2000. The Root Zone Water Quality Model. Water Resources Publications LLC. Highlands Ranch, CO.	The Root Zone Water Quality Model (RZWQM) was developed in the 1990's by a team of USDA Agricultural Research Service (ARS) scientists. A majority of the team members are part of the present Agricultural Systems Research Unit, Fort Collins, CO. Parts of the model have been revised and enhanced with cooperation of the ARS Northwest Watershed Research Laboratory, Boise, ID, and the ARS Nematode Research Laboratory, Tifton, GA. The next generation, RZWQM2 has been revised and enhanced to include the DSSAT 4.0 Cropping System Models with the cooperation of the University of Georgia and DSSAT modeling group. Additional crops and model enhancements for applications are done in cooperation with users nationally and internationally with the USDA ARS Agricultural System Research Unit RZWQM2 team.
M4	WEPP Water Erosion Prediction Project	D.C. Flanagan and M.A. Nearing (ed.) USDA-ARS National Soil Erosion Research Laboratory	1995	http://www.ars.usda.gov/Research/docs.htm?docid=18073	WEPP is a continuous simulation model used in hillslope and watershed applications. WEPP functions on a daily timestep Model inputs include climate, slope, soil and cropping management data files. Hydrologic processes include infiltration, runoff, soil evaporation, plant transpiratioin, soil water percolation, plant and residue interception of rainfall, depressional storage, and soil profile drainage by subsurface tiles. Translation is modeled with the kinematic wave equation.	Watershed or Field	Event, Monthly, or Annual	Ponds, terraces, buffers, conservation reserve programs, tillage practices, irrigation methods and management, crop rotation, and grazing management.	D.C. Flanagan and M.A. Nearing (ed.). 1995. USDA - Water Erosion Prediction Project (WEPP) Hillslope Profile and Watershed Model Documentation. NSERL Report No. 10. USDA-ARS National Soil Erosion Research Laboratory. Lane, L. J., D. L. Schertz, E. E. Alberts, J. M. Laflen, and V. L. Lopes. 1988. The US National Project to Develop Improved Erosion Prediction Technology to Replace the USLE. Proc. IAHS Intrl. Symposium on Sediment Budgets, Porto Alegre, Brazil, 11- 15 Dec. 1988, IAHS Publ. No. 174, pp. 473-481. Lane, L.J., J.E. Gilley, M. Nearing, and A.D. Nicks. 1988. The USDA Water Erosion Prediction Project. National Conf. on Hydraulic Engineering, Colorado Springs, CO. August, 1988.	The Water Erosion Prediction Project (WEPP) model is a process-based, distributed parameter, continuous simulation, erosion prediction model for use on personal computers. Processes considered in hillslope profile model applications include rill and interrill erosion, sediment transport and deposition, infiltration, soil consolidation, residue and canopy effects on soil detachment and infiltration, surface sealing, rill hydraulics, surface runoff, plant growth, residue decomposition, percolation, evaporation, transpiration, snow melt, frozen soil effects on infiltration and erodibility, climate, tillage effects on soil properties, effects of soil random roughness, and contour effects including potential overtopping of contour ridges. The model accommodates the spatial and temporal variability in topography, surface roughness, soil properties, crops, and land use conditions on hillslopes. In watershed applications, the model allows linkage of hillslope profiles to channels and impoundments. Water and sediment from one or more hillslopes can be routed through a small field-scale watershed. Almost all of the parameter updating for hillslopes is duplicated for channels. The model simulates channel detachment, sediment transport and deposition. Impoundments such as farm ponds, terraces, culverts, filter fences and check dams can be simulated to remove sediment from the flow.
M5	HEC-HMS Hydrologic Modeling System	US Army Corps of Engineers Hydrologic Engineering Center	2000	http://www.hec.usace.army.mil/software/hec-hms/documentation.aspx	HEC-HMS is an event based rainfall - runoff response model. Model inputs include meterologic, infiltration, transformation, and reservoir routing data. Model results include overland runoff volume and flow rate. Model is available in a GIS format (HEC-geoHMS).	Watershed	Event	Ponds and terraces. Buffers, conservation reserve programs, tillage practices, irrigation methods and managment, crop rotation, and grazing management conservation practices can be evaluated through infiltration parameters.	Hydrologic Engineering Center. 2000. Hydrologic Modeling System (HEC-HMS): Technical Reference Manual. U.S. Army Corps of Engineers. Davis, CA	The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of dendritic watershed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. The program is a generalized modeling system capable of representing many different watersheds. A model of the watershed is constructed by separating the hydrologic cycle into manageable pieces and constructing boundaries around the watershed of interest. Any mass or energy flux in the cycle can then be represented with a mathematical model. In most cases, several model choices are available for representing each flux. Each mathematical model included in the program is suitable in different environments and under different conditions. Making the correct choice requires knowledge of the watershed, the goals of the hydrologic study, and engineering judgment. The program features a completely integrated work environment including a database, data entry utilities, computation engine, and results reporting tools. A graphical user interface allows the seamless movement between the different parts of the program. Program functionality and appearance are the same across all supported platforms.
M6	HYDRUS 2D	J. Simunek and M. Sejna PC-Progress, Prague, Czech Republic	2007	http://www.pc-progress.com/en/Default.aspx?hydrus-2d	Hydrus-2D is a finite element model used to simulate the movement of water and root uptake in the vadose zone comprised of uniform or nonuniform soils. Simulation time increments are user dependent ranging from seconds to days. Flow and transport can occur in the vertical plane, the horizontal plane, a three-dimensional region exhibiting radial symmetry about a vertical axis, or in a three-dimensional region. The water flow part of the model can deal with (constant or time-varying) prescribed head and flux boundaries, as well as boundaries controlled by atmospheric conditions. Soil surface boundary conditions may change during the simulation from prescribed flux to prescribed head type conditions (and vice versa). The code can also handle a seepage face boundary, through which water leaves the saturated part of the flow domain, and free drainage boundary conditions. Nodal drains are represented by a simple relationship derived from analog experiments.	Field	Seconds to Days	Canal rehabilitation, conversion of canal open laterals to buried pipes, and conversion to drip irrigation.	Šimůnek, J. and M. Šejna. 2007. HYDRUS 2D/3D Software Package for Simulating Two- and Three-Dimensional Movement of Water, Heat, and Multiple Solutes in Variably-Saturated Media User Manual Version 1.02. PC-Progress, Prague, Czech Republic. Šimůnek, J., D. Jacques, G. Langergraber, S. A. Bradford, M. Šejna, and M. Th. van Genuchten. 2013. Numerical modeling of contaminant transport with HYDRUS and its specialized modules, Invited paper for the Special Issue "Water Management in Changing Environment", Editor M. S. Mohan Kumar, Journal of the Indian Institute of Science, 93(2) 265-284, ISSN: 0970-4140 Coden-JIISAD.	HYDRUS is a Microsoft Windows based modeling environment for the analysis of water flow and solute transport in variably saturated porous media. The software package includes computational finite element models for simulating the two- and three-dimensional movement of water, heat, and multiple solutes in variably saturated media. The model includes a parameter optimization algorithm for inverse estimation of a variety of soil hydraulic and/or solute transport parameters. The model is supported by an interactive graphics-based interface for data-preprocessing, generation of structured and unstructured finite element mesh, and graphic presentation of the results. The program can handle flow domains delineated by irregular boundaries.
M7	VFSMOD-W Vegetative Filter Strips Modelling System	Rafael Munoz-Carpena, John E. Parsons University of Florida	2011	http://abe.ufl.edu/carpena/vfsmod/	VFSMOD is a numerical model used to study hydrology and sediment transport through vegetative filter strips. VFSMOD functions on a field scale and event basis to calcualte outflow and infiltration of overland runoff. Model inputs include rainfall hyetographs or inflow hydrographs, soil infiltration parameters and soil water content, and surface storage.	Field	Event	Buffers and conservation reserve programs.	Rafael Munoz-Carpena, John E. Parsons. 2011. VFSMOD-W Vegetative Filter Strips Modelling System Model Documentation and User's Manual Version 6.x. University of Florida.	
M8	CROPSIM	Derrel Martin University of Nebraska			CROPSIM is a numerical model used to calculate soil water balance. CROP-SIM functions on a daily time-step at the field or watershed. Model inputs include climatic, soil, phenology, land cover, and management data. Water balance equations estimate ET, deep percolation, and runoff.	Watershed or Field	Daily, Monthly, or Annual	Buffers, conservation reserve programs, tillage practices, irrigation methods and management, crop rotation, and grazing management conservation practices.		
M9	Water Optimizer	Chris Thompson, Ray Supalla, and Derrel Martin University of Nebraska	2010	http://agecon.unl.edu/wateroptimizer/download.html	Water Optimizer is a spreadsheet based model used to predict the profit maximizing cropping strategy and corresponding amount of applied irrigation water. Model inputs include crop type, soil type, irrigation system, well and pump characteristics, well or canal delivery, and power source.	Field	Season	Irrigation management and improvements in irrigation efficiency.	Water Optimizer Decision Support Tool for Deficit Irrigation Multi-field Water Optimizer Model	Water Optimizer is a suite of optimization programs to predict the profit maximizing cropping strategy and corresponding amount of applied irrigation water when water supplies are limited. The Water Optimizer Suite consists of four separate, but similar models; the basic Water Optimizer, a multi-field Water Optimizer, a multi-year Water Optimizer and an independent budget calculator. The single-field single-year model seeks to maximize the average annual net return subject to water supply constraints and user specified cropping limitations. The single-field single-year model is the platform for which the multi-year and multi-field tools are built upon.
M10	RHEM A Rangeland Hydrology and Erosion Model	M.A. Nearing, H. Wei, J.J. Stone, F.B. Pierson, K.E. Spaeth, M.A. Weltz, D.C. Flanagan, M.Herandez	2011	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CC8QFjAA&url=http%3A%2F%2Fwww.nrcs.usda.gov%2FInternet%2FFSE_DOCUMENTS%2Fstelprdb1045656.pdf&ei=VUszUuXGKuOT2QWS-oDICQ&usg=AFQjCNH-9JxKQbCUEqImWoa8vU-BLsx4YA&sig2=LrTavJ6t44LBttLBS7h6Gg&bvm=bv.52164340,d.b2I	The Rangeland Hydrology and Erosion Model (RHEM) is a web based tool designed to model and predict runoff and erosion rates on rangelands. This model can also assist in assessing rangeland conservation practice effects. RHEM is a process-based erosion prediction tool specific for rangeland application, based on fundamentals of infiltration, hydrology, plant science, hydraulics and erosion mechanics. It is designed to use data that are routinely collected by rangeland managers and in national monitoring programs such as the Natural Resources Conservation Service (NRCS) National Resource Inventory (NRI). Using RHEM allows land managers to be proactive in preventing accelerated soil loss on rangelands by targeting areas for conservation management that are most vulnerable to soil erosion.	Watershed or Field	Event, Monthly, or Annual	Rangeland Management.	Nearing M, Wei H, Stone J, Pierson F, Spaeth K, Weltz M, Flanagan D, and Hernandez M. 2011. A Rangeland Hydrology and Erosion Model. In Transactions of the Asabe. 54 (3): 901-908. Wei H, Nearing M, Stone J, and Breshears D. 2008. A Dual Monte Carlo approach to estimate uncertainty and its applications to the Rangeland Hydrology and Erosion Model. In Transactions of the Asabe. 51(2): 515-520. Wei h, Nearing M, and Stone J. 2007. A comprehensive sensitivity analysis framework for model evaluation and improvement using a case study of the Rangeland Hydrology and Erosion Model. In Transactions of the Asabe. 50(3): 945-953	
M11	MODFLOW Modular Ground-Water Model	Arlen W. Harbaugh U.S. Geologic Survey	2005	http://pubs.usgs.gov/tm/2005/tm6A16/PDF.htm	MODFLOW is a three dimensional finite-difference model used to calculate groundwater budget. MODFLOW functions on a user defined time increment (seconds to years) over a model grid. Model inputs include pressure head, soil medium type and layer thickness, aquifer hydraulic conductivity and transmissivity, and riverbed conductance.	Model Grid	Seconds to Years	The groundwater translation portion of all conservation practices	MODFLOW-2005, The U.S. Geologic Survey Modular Ground-Water Model - The Ground-Water Flow Process	
M12	MIKE-SHE	DHI Water and Environment	2012	http://www.mikebydhi.com/Products/WaterResources/MIKESHE.aspx	MIKE SHE is a physically based hydrological and water quality modeling system that simulates surface and groundwater movment. MIKE SHE functions on a minute or day time step at a watershed scale. Hydrologic processes include evapotranspiration, overland flow, channel flow, soil water and ground water movement. Model inputs include topopgraphy, precipitation, land use, reference ET, rivers and lakes, overland flow, unsaturated zone, groundwater table, and saturated zone characteristics. MIKE SHE is GIS compatible.	Watershed	Minutes or Days	Ponds, terraces, buffers, conservation reserve programs, tillage practices, irrigation methods and management, and crop rotation, and grazing management.	DHI Software. 2007. MIKE SHE USER MANUAL VOLUME 2: REFERENCE GUIDE. Jason Yan, Joyce Zhang. Evaluation of the MIKE SHE Modeling System. http://s1004.okstate.edu/S1004/Regional-Bulletins/Modeling-Bulletin/MIKESHEfinal.html	
M13	SPUR Simulation of Production and Utilization of Rangelands	Wight (ed.), J.R.	1983		SPUR (Simulating Production and Utilization of Range Land) is a simulation and process model. Its purpose is to determine and analyze management scenarios as they affect rangeland sustainability and to forecast the effects of climate change on rangelands. ELM , BLUE GRAMA and ROOTS were studied extensively during the construction of this plant growth model.			Rangeland Management.	Wight (ed.), J.R. 1983.SPUR--simulation of production and utilization of rangelands : a rangeland model for management and research. Washington, D.C. : U.S. Dept. of Agriculture, Agricultural Research Service , no. 1431. Carlson, D.H. and T.L. Thurow. 1996. Comprehensive evaluation of the improved SPUR model (SPUR-91). Ecological Modelling. 85(2–3):229-240.	
M14	SPAW	Saxton, K. E. and P. H. Willey	2006		The SPAW (Soil-Plant-Air-Water) computer model simulates the daily hydrology of agricultural fields and ponds including wetlands, lagoons and reservoirs. Field hydrology is represented by daily climatic descriptions of rainfall, temperature and evaporation; a layered soil profile with automated water characteristics; annual crop growth; and management with crop rotation and irrigation. Pond, lagoon, and wetland simulations which have agricultural watershed fields or producer operations as their water source provide daily inundation levels as controlled by multiple input and depletion processes. Data input and file selection are by graphical screens. Simulation results are both tabular and graphical. Typical applications include analyses of crop water status, deep seepage, wetland inundation duration and frequency, lagoon designs, and water supply reservoir reliability.			Ponds	Saxton, K.E. 1989. Models for predicting water and energy relationships in soils under limited rainfall conditions. Proc. Inter. Symp. on Managing Sandy Soils, Jodhpur, India, Feb. 6-10, 1989. Saxton, K.E. and G.C. Bluhm. 1982. Regional prediction of crop water stress by soil water budgets and climatic demand. Trans. of Am. Soc. Agric. Engr. 25(1):105-110. Saxton, K.E. and P.H. Willey. 1999. Agricultural Wetland and Pond Hydrologic Calculations Using the SPAW-II. Model. Paper No. 992030, Proc., Amer. Soc. Agric. Eng. Meeting, Toronto, ON, July 18-21, 1999. Saxton, K.E. and P.H. Willey. 2004. Agricultural Wetland and Pond Hydrologic Analyses Using the SPAW model. Proc. Self-Sustaining Solutions for Streams, watersheds and Wetlands Conf., Amer. Soc. Agric. Engr., Sept. 12-15, 2004, St. Paul, MN. Saxton, K. E. and P. H. Willey. 2006. The SPAW Model for Agricultural Field and Pond Hydrologic Simulation. Chapter 17 in: Mathematical Modeling of Watershed Hydrology, V. P. Singh and D. Frevert, Editors; CRC. Press, pp 401-435.	

M15	WinSRFR	Bautista, E., A.J. Clemmens, T.S. Strelkoff, J. Schlegel.	2009		WinSRFR integrates and supercedes the legacy SRFR, BORDER, and BASIN programs developed by the former U.S. Water Conservation Lab. The application provides a Windows interface to those programs and will also serve as the foundation for future development. WinSRFR is a tool to help evaluate and design border, basin, and furrow irrigation systems. The tool will assist the user in determining the optimum efficiencies and water utilization. Based on user input the model will calculate advance times, recession times, infiltration depths, runoff, deep percolation, and will provide graphical display of the efficiency and options evaluated. The model is targeted for use by the field office technicians and engineers. For USDA-NRCS, the package that is posted on the ITS Team Services website is the only certified version of this software authorized for installation on ITS workstations. Contact local ITS personnel for installation. Non NRCS users may obtain a copy of the software from the ARS Arid Land Agricultural Research center products and service page			Irrigation Methods and Management	Bautista, E., A.J. Clemmens, T.S. Strelkoff, J. Schlegel. 2009. Modern analysis of surface irrigation systems with WinSRFR. Agricultural Water Management 96 (2009) 1146–1154. Strelkoff, T.S., Clemmens, A.J., Schmidt, B.V., 1998. SRFR, Version 3.31—A model for simulating surface irrigation in borders, basins and furrows. US Department of Agriculture Agricultural Research Service, U.S. Water Conservation Laboratory, Phoenix, AZ.	
M16	FIRI 1.2 Farm Irrrigation Rating Index	John Dalton USDA-NRCS	2005	http://www.wcc.nrcs.usda.gov/ftpref/wntsc/Irrigation/FIRI/FiriMan.pdf	FIRI 1.2 is a procedure to approximate or quantify approximate water conservation through changes made to irrigation systems or through management. The program provides a standardized means of documenting change for various cost share programs and planning efforts. The model has potential application as a tool for field and watershed scale quantification of irrigation changes and the impact to water quality.			Irrigation Methods and Management		
M17	DPEVAP	Thompson, A. L., D. L. Martin, J. M. Norman, J. A. Tolk, T. A. Howell, J. R. Gilley, and A. D. Schneider.	1997		DPEVAP is an evaporation model to water losses during sprinkler irrigation of a plant canopy under field conditions. The model combines equations governing water droplet evaporation and droplet ballistics with a plant-environment energy model. The plant-environment model includes droplet heat and water exchange above the canopy and the energy associated with cool water impinging on warm leaves and soil. The combined model is intended for use in evaluating various sprinkler irrigation systems with respect to water efficiencies during irrigation of a crop.			Irrigation Methods and Management	Thompson, A. L., D. L. Martin, J. M. Norman, J. A. Tolk, T. A. Howell, J. R. Gilley, and A. D. Schneider. 1997. Testing of a water loss distribution model for moving sprinkler systems. Trans. ASAE 40(1): 81-88. Martin, D. L., W. L. Kranz, A. L. Thompson, and H. Liang. 2012. Selecting sprinkler packages for center pivots. Transactions of the ASABE. 55(2): 513-523.	
M18	AquaCrop	Raes, D., Steduto, P., Hsiao, T.C., Fereres, E. and Heng L. Food and Agriculture Organization of the United Nations	2009		Estimating attainable yield under water-limiting conditions remains central in arid, semi-arid and drought-prone environments. To address this need, FAO has been developing a yield-response to water model, AquaCrop, which simulates attainable yields of the major herbaceous crops. As compared to other crop models, AquaCrop has a significantly smaller number of parameters and a better balance between simplicity, accuracy and robustness. Root zone water content is simulated by keeping track of incoming and outgoing water fluxes at its boundaries, considering the soil as a water storage reservoir with different layers. Instead of leaf area index, AquaCrop uses canopy ground cover. Canopy development, stomatal conductance, canopy senescence and harvest index are the key physiological crop responses to water stress. Evapotranspiration is simulated as crop transpiration and soil evaporation and the daily transpiration is used to derive the daily biomass gain via the normalized biomass water productivity of the crop. The normalization is for reference evapotranspiration and CO2 concentration to make the model applicable to diverse locations and seasons, including future climate scenarios. AquaCrop accommodates different water management systems, including rainfed agriculture and supplemental, deficit, and full irrigation. Simulations can be carried out both on calendar and thermal time, and the developing versions will incorporate effects of nutrient regimes, particularly nitrogen, and of soil salinity. AquaCrop is mainly addressed to extension services practitioners, consulting engineers, governmental agencies, NGOs and farmers associations.			Buffers, conservation reserve programs, tillage practices, irrigation methods and management, crop rotation, and grazing management conservation practices.	Raes, D., Steduto, P., Hsiao, T.C., Fereres, E. and Heng L. 2008. AquaCrop Calculation Procedure, Prototype Version 2.3a. FAO, Rome, Italy, 64 p. AquaCrop. 2009. The FAO Crop Model to Simulate Yield Response to Water: I. Concepts and Underlying Principles. Agron J. 101: 426–437. D. Raes, P. Steduto, T.C. Hsiao, and E. Fereres. 2009. AquaCrop—The FAO Crop Model to Simulate Yield Response to Water: II. Main Algorithms and Software Description. Agron J. 101: 438–447 T.C. Hsiao, L.K. Heng, P. Steduto, B. Rojas-Lara, D. Raes, and E. Fereres. 2009. AquaCrop—The FAO Crop Model to Simulate Yield Response to Water: III.Parameterization and Testing for Maize. Agron J. 101: 448–459.	
M19	DSSAT Decision Support System for Agrotechnology Transfer	Jones, J.W.,G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman and J.T. Ritchie	2003		Decision Support System for Agrotechnology Transfer (DSSAT) is a software application program that comprises crop simulation models for over 28 crops (as of v4.5). DSSAT is supported by data base management programs for soil, weather, and crop management and experimental data, and by utilities and application programs. The crop simulation models in DSSAT simulate growth, development and yield as a function of the soil-plant-atmosphere dynamics, and they have been used for many applications ranging from on-farm and precision management to regional assessments of the impact of climate variability and climate change. It has been in use for more than 20 years by researchers, educators, consultants, extension agents, growers, and policy and decision makers in over 100 countries worldwide.			Irrigation Methods and Management	Jones, J.W.,G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman and J.T. Ritchie. 2003. The DSSAT cropping system model. Europ. J. Agronomy 18:235-265.	

CODE	SUBJECT	ARTICLE TITLE	AUTHOR/AGENCY	DATE	Article Link (if applicable)	SUMMARY	GEOGRAPHIC SCALE	TEMPORAL SCALE	NOTES
L1	General Conservation	CEAP Benchmark Watersheds: Synthesis of Preliminary Findings	C. Richardson, D. Bucks, & E. Sadler	2008	http://www.jswconline.org/content/63/6/590.short	The initial CEAP findings demonstrate progress toward the overall goals of quantifying conservation practice effects and providing tools to transfer the knowledge to points where they are applied under future conservation policy.	Nation-wide and site specific	Years	Mostly talks about using SWAT but if we could get the runoff data then would be very helpful. Does talk about individual sites (2 in Iowa are closest). The Iowa sites have buffers but since a lot is tile drained, the buffers don't work on drained water. (Also if tile drained then probably don't want to reduce runoff to streams)
L2	Terraces and Small Dams	Impacts of Non-Federal Reservoirs and Land Terracing on Basin Water Supplies	Republican River Compact Settlement Conservation Committee for The Republican River Compact Administration	2013		The study applied water balance and GIS models to summarize the impacts from basins with Non-Federal reservoirs and land terraces within the Republican River watershed. The Potential Yield Revised (POTYLDR) model was used to analyze inflow. The Water Erosion Prediction Project (WEPP) model was used to analyze terrace infiltration, and the Root Zone Water Quality Model (RZWQM) was used to analyze field hydrology. Transmission losses were analyzed using percent per mile estimates. A net seepage model was developed for reservoirs in watershed.	Regional	Years	Impacts to groundwater recharge, surface runoff, and ET were estimated and plotted for HUC-12 subbasins by terraces, reservoirs, and both terraces and reservoirs. These estimates could be applied to similar subbains in the Platte River watershed.
L3	Terraces	Field Scale Hydrology of Conservation Terraces in the Republican River Basin	B. Twombly	2009	CYT Theses LD3656 2008 .T866	Developed a field scale water balance model to evaluate conservation bench and level broadbase terraces in the Republican River basin. Field measurements were used to calibrate a RZWQM hydrologic model.	Fields in Republican Basin	Years	Conservation bench terraces in Colby, KS yielded 79.4% to deep percolation and 19.0% to ET. Broadbase terraces in Norton, KS yielded 45.5% to deep percolation and 42.4% to ET.
L4	Terraces	Modeling and Monitoring the Hydrology of Conservation Terrace Systems	T. Yonts		CYT Theses LD3656 2006 .Y668	Developed a field scale HEC-HMS model to evaluate conservation bench terraces, and steep backslope terraces with underground and grassed waterway outlets. The model was able to represent the detention effects of the terrace systems, but did not account for infiltration.	N/A	Event Basis	Shows potential for using HEC-HMS model for future work.
L5	Buffers & Terraces	Watershed Scale Impacts of Buffers and Upland Conservation Practices on Agrochemical Delivery to Streams	T. Franti, D. Eisenhauer, M. McCullough, L. Stahr, M. Dosskey, D. Snow, R. Spalding, & A. Boldt	Sep-04	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1024&context=usdafsfacpub	Researchers compared two adjacent watersheds (340 and 400 acres) to evaluate the impact of conservation buffers on surface runoff. These watersheds feed Clear Creek, which is a tributary to the Platte River in Central Nebraska. Monitoring occured in 2002 and 2003, with similar monthly rainfall for April-June. The buffer watershed produced only 27mm of runoff compared to 47mm in the other.	Watershed	April-June for 2 years	Study provides measure of overland runoff reduction on a small watershed basis by conservation buffers.
L6	Invasive Riparian Vegetation	Do Invasive Riparian Woody Plants Affect Hydrology and Ecosystem Processes	J. Huddle, T. Awada, D. Martin, X. Zhou, S. Pegg, & S. Josiah	Apr-11	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1300&context=natrespapers	This paper summarizes other papers. Table 2 on page 59 (12 in pdf) is very helpful. It says that in a region with 600 mm of annual precip, if you remove the trees along a river in a watershed, then you should gain around 200 mm of water yield. (I'm sure Dr. Martin can give us a better summary)	Watershed and by tree	Monthly/ Annual	Table 2 on page 59 (12 in pdf) is very helpful. It says that in a region with 600 mm of annual precip, if you remove the trees along a river in a watershed, then you should gain around 200 mm of water yield. Dr. Martin is an author on study.
L7	Narrow Grass Hedges	Narrow Grass Hedge Effects on Runoff and Soil Loss	J. Gilley, B. Eghball, L. Kramer, & T. Moorman	Jan-00	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1128&context=biosysengfacpub	Switchgrass hedges (6 yrs old) substantially reduced runoff and soil loss. Under no-till, plots with corn residue and grass hedges averaged 52% less runoff than similar plots without hedges. Under tilled conditions, plots with corn residue and hedges averaged 22% less runoff than those without hedges. Plots without corn residue but with hedges had 41% less runoff than those with hedges.	3.7 m x 10.7 m plots in fields.	Study applied simulated rainfall to plots for 2 hours.	Narrow Grass Hedges are an effective conservation measure, especially when used in conjunction with no-till or reduced-till farming systems. This study quantifies those effects at field plot level.
L8	Terraces & Small Dams	Modeling and Field Experimentation to Determine the Effects of Terracing and Small Reservoirs on Water Supplies in the Republican River Basin above Hardy, Nebraska	Scott Guenthner	2009	http://www.usbr.gov/research/projects/detail.cfm?id=9517	Website says to contact the Principal Investigator for info about the results. There is also this website: http://www.calmit.unl.edu/people/airmak2/Projects/RepublicanRiverBasin.htm	Republican River Basin	2006-2009	Research question posed: "How are land terracing and small reservoir development affecting surface and ground water supplies?" Author/USBR may have data results from study.
L9	Terraces & Small Dams	Republican River Basin Hydroligic Simulation to Address Water Quality and Quantity (USDA And Kansas State)	KSU	Jun-10	http://www.reeis.usda.gov/web/crisprojectpages/0203306-republican-river-basin-hydrologic-simulation-to-address-water-quality-and-quantity.html	The impacts section says that an estimate of effects on land terracing on streamflow for the Prairie Dog Creek above Keith Sebelius Lake average about 3,200 AF/yr of reduction in streamflow and about 200 AF/yr increase in groundwater recharge.	Republican River Basin	2005-2010	Estimation of the effects of land terracing approach and overall estimate.
L10	Ponds and Terraces	Effect of watershed structures on water supply availability.	Koelliker, J.K., S.R. Ramireddygari, M.A. Sophocleous	1999	ASAE Paper No. 99-2123. St. Joseph, MI.: ASAE.				
L11	Canal Seepage	Determining Irrigation Canal Seepage with Electrical Resistivity	R.H. Hotchkiss, C.B. Wingert and W.E. Kelly		http://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9437%282001%29127%3A1%2820%29	Procedures to quantify seepage losses in unlined irrigation canals for test reach of 100ft	100 ft section of canal		
L12	Canal Seepage & Conversion to buried pipeline	WaterSMART: A Three-Year Progress Report	USDOI - USBR	Oct-12	http://www.usbr.gov/WaterSMART/docs/WaterSMART-thee-year-progress-report.pdf	Progress report on USBR WaterSMART. Includes case-studies about water reuse, conservation and effiiciency	Nationwide		
L13	Canal Seepage	Canal Seepage Groundwater Recharge 2011 Demonstration Projects	DNR/Pat Goltl	2011	- http://dnr.ne.gov/IWM/Presentations/CanalSeepageProjects6212012.pdf	Demonstration project with group of Nebraska irrigation districts to estimate canal seepage in Platte Basin as part of PRRIP	Platte Basin	2011-2012	Canal seepage estimates in Platte Basin can be quantified.
L14	Conversion to buried pipeline	CNPPID - Irrigation Division	CNPPID		http://www.cnppid.com/Irrigation_Division.htm	Article by CNPPID about their progress on improving canal delivery efficiency	Central Platte Basin	1975-present	Reduced transportation losses (seepage and evap) by 45 to 50%)
L15	Canal Loss and Recharge Volume	Upper Platte River Recharge and Flood Mitigation Demonstration Project: Part of Conjunctive Management Toolbox	Nebraska DNR	Jan-13	http://dnr.ne.gov/IWM/Reports/2011RechargeTM2013.pdf	Technical memo prepared that provides brief summary of canal losses and related recharge volumes	Platte Basin	Sept-Dec 2011	Spreadsheet developed through study could be tool for calculating recharge by canals using canal loss data.
L16	Irrigation Efficiency	Irrigation Efficiency and Uniformity, and Crop Water Use Effiiciency	S. Irmak, L.O. Odhiambo, W.L. Kranz, and D. Eisenhauer	2011	http://ianrpubs.unl.edu/live/ec732/build/ec732.pdf	Nebraska Extension circular describes various irrigation efficiency, crop water use efficiency, and irrigatino uniformity evaluation terms that are relevant to irrigation systems and management practices currently used in Nebraska, in other states, and around the world.	Statewide		Includes formulas to calculate water conveyance efficiency, water application effiiciency, and other delivery efficiency calculations.
L17	Surge Irrigation Management	Surge Irrigation Management	C.D. Yonts	Jul-08	http://www.ianrpubs.unl.edu/live/g1868/build/g1868.pdf	Water delivery efficiceny improvement due to surge irrigation			
L18	Terraces	Terrace dimension changes and the movement of terrace ridges resulting from different farming practices	Schoenleber, L. H		Washington, D.C. : U.S. Dept. of Agriculture, Soil Conservation Service, [1941] CYT S591 .A15 no.40-41 1941	Article by CNPPID about their progress on improving canal delivery efficiency			Canal efficiency information

L19	Terraces	The Nebraska Terrace Program : technical documentation : a technical report / prepared by Ron J. Gaddis and Curtis Winters	Gaddis, Ron J. (Ronald Jay), 1934-; Winters, Curtis N. (Curtis Neal)		UNL Libraries - [S.l. : s.n., 197-?] CYT S627.T4 N43 1970zx hdbk or http://www.worldcat.org/title/nebraska-terrace-program-technical-documentation-a-technical-report/oclc/016655790				
L20	Terraces	Modeling Runoff and Sediment Yield from a Terraced Watershed Using WEPP	Mary Carla McCullough, University of Nebraska - Lincoln Dean E. Eisenhauer, University of Nebraska - Lincoln Mike Dosskey, USDA National Agroforestry Center	2008	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1020&context=usdafsfacpub	The Watershed Erosion Prediction Project (WEPP) was used to estimate 50-year runoff and sediment yields for a 291 ha watershed in eastern Nebraska that is 90% terraced and which has no historical gage data. Modeled results were comparable to published data.	Eastern Nebraska		Demonstrates ability to model terraces with a process based continous simulation model.
L21	Terraces	Analytical Modeling of Irrigation and Land Use Effects on Streamflow in Semi-Arid Conditions: Frenchman Creek, Nebraska	J. Traylor	2012	http://digitalcommons.unl.edu/geoscidiss/32/	Streamflow reductions in Frenchman Creek in Republican River basin caused by irrigation, conservation terrace construction and other practices were analyzed by author using analytical model.	Republican River Basin		
L22	Terraces	USDA - Water Erosion Prediction Project (WEPP) Hillslope Profile and Watershed Model Documentation	D.C. Flanagan and M.A. Nearing (ed.)		http://www.ars.usda.gov/Research/docs.htm?docid=18073	Model Documentation for WEPP erosion model. Hydrologic component is based on the Green-Ampt infiltration and kinematic wave equations.	N/A	N/A	N/A
L23	Terraces	Conservation Practive Physical Effects Worksheet	Nebraska NRCS		http://www.ne.nrcs.usda.gov/technical/NEConservationPracStandards.html	Separate worksheet for each conservation practice. Evaluates physical effects on water quality.			
L24	Ponds	National Hydrography Dataset	USGS		http://nhd.usgs.gov/data.html	GIS vector dataset containing features including lakes, ponds, streams, rivers, canals, dams and stream gages. Age of data varies by location.	Nationwide Coverage - Shapefile	N/A	
L25	Ponds	Potential for groundwater recharge with seepage from flood-retarding reservoirs in south central Nebraska.	Eisenhauer, D. E., D. M. Manbeck, and T. H. Storck.	1982	Journal of Soil and Water Conservation. 37(1): 57-60	Groundwater recharge potential with seepage from flood reservoirs			
L26	Terraces	Effectiveness of terraces/grassed waterway systems for soil and wtaer conservation: a field evaluation.	Chow, T.L.	1999	Journal of Soil and Water Conservation. (Third Quarter): 577-593.	Soil and water conservation as result of grassed waterways and terraces			
L27	Surface Irrigation Systems	Guidelines for designing and evaluating surface irrigation systems	Walker, W.R.	1989	http://www.fao.org/docrep/t0231e/t0231e00.htm#Contents	Many equations and techniques for evaluating surface irrigation systems			
L28	Buffers	Two-Dimensional Overland Flow and Sediment Transport in Vegetative Filter	Helmers, M.J.	2003	Unpublished PhD Dissertation	?			
L29	Buffers	A design aid for sizing filter strips using buffer area ratio	M.G. Dosskey, M.J. Helmers and D.E. Eisenhauer	2011	http://nac.unl.edu/research/publications.htm	Used VFSMOD to estimate water % trapping efficiency by filter strips. Provides results for various soils, C factors based on Buffer to Watershed Area Ratios	Field and Watershed	Event	Provides nomographs for determining water trapping efficiceny based on buffer to watershed area ratio.
L30	Buffers	Evapotranspication of Cropland and Grass or Forest Buffers in Riparian Zones in Nebraska	Doroty I. Pedersen	2008		Thesis assessed the potential change in evapotranpiration resulting from the conversion of riparian zones from crop to native grass or forest buffers. Three climate regions (East, Central, West) were evaluated based on annual precipitation ranges. The FAO 56 Penman-Montieth dual crop coefficient method was used to model ET.	Regional	Annual	Provides charts of annual ET estimates for the East, Central and West regions for forest, grass, and cropland in riparian zones and estimates of potential change in ET for conversion of cropland to buffer.
L31	Buffers	Filter Strip Performance and Processes for Different Vegetation, Widths and Contaminants	T.J. Schmit, M.G. Dosskey, and K.D. Hoagland	1999	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.nrem.iastate.edu%2Fclass%2Fassets%2FFor460-560%2FManaging%2520AFS_hydrological%2520functions%2FSchmitt%2520et%2520al._1999.pdf&ei=s6ryUZ_RFtPOyAH-54CoCw&usg=AFQjCNGdfJAqG7LSfVzzwU5PLA5qTY5esA&sig2=NkN7Majj-npj3PO9ncRq9w&bvm=bv.49784469,d.aWc	Buffer test plots near Mead, NE were used to determine water trapping efficiency of runoff for grass, grass-shrub-tree, and contour sorghum vegetation.	Regional	Event Based	Provides water trapping efficiencies for test plots that could be scaled and applied on a field or watershed basis.
L32	Terraces	Estimating groundwater recharge from conservation bench terraces	Neibling, W.H. and J.K. Koelliker	1977	http://krex.k-state.edu/dspace/handle/2097/11410	Research was conducted in Garden City, Kansas on bench terraces with 2:1 and 4:1 watershed:bench area ratios. Computed annual groundwater recharge for each scenario for the time period of 1945-1974.	Republican River Basin	Annual	Provides estimates of impacts to groundwater recharge, surface runoff, ET, and change in soil moisture for watersheds with and without conservation bench terraces under a wheat-fallow rotation (Table 7). For instance, a bench terrace with 4:1 and 2:1 watershed:bench area ratio increases groundwater recharge by 4.78cm/yr and 2.26cm/yr, respectively.
L33	Irrigation Management	Irrigation Management Practices in Nebraska	R. Supalla, W. Miller, & B. Juliano	Sep-96	http://digitalcommons.unl.edu/ageconfacpub/67/	This article surveyed 898 irrigators (SW and GW) and says that as of 1996, only 15% reported using Surve Valves while 89% of gravity irrigators vaired flow rates between irrigations, 75% varied flow rates between hard and soft rows, 80% used every other row irrigation, and 51% used less than 12 hr sets.	Nebraska-wide	-----------------	This article helps to determine a rough estimate of how many irrigators statewide were using management practices in 1996.
L34	Cropland Conservation	Environmental Benefits of Conservation on Cropland: The Status of Our Knowledge	M. Schnepf & C. Cox	2006	http://www.swcs.org/en/publications/environmental_benefits_of_conservation_on_cropland/	This book contains D. Eisenhauer's Chapter 3 (See NS3)	International		
L35	Irrigation Scheduling, Crop Residue, Water App. Methods	Chapter 3: Water Management Practices, Irrigated Cropland	D. Eisenhauer	2006	http://www.swcs.org/en/publications/environmental_benefits_of_conservation_on_cropland/	Irrigation Scheduling can reduce water applications by 12% (Ferguson et al. 1990). Duke et al. 1978 showed a 5 to 20% reduction. Crop residue can reduce net depletion of groundwater by 50 to 75mm a year (Boldt et al. 1999). Types of irrigation application also affect efficiency.	---------------------	------------------	Irrigation Scheduling can reduce water applications by up to 20%. Crop residue can reduce net depletion of groundwater. Types of irrigation application also affect efficiency.
L36	Soil cover, Tillage	Agronomy Society Monograph No. 23 "Dryland Agriculture"	G. Peterson, P. Unger, & W. Payne			This is a 900 page book. This summary is for Chapter 3 pages 39-79. This chapter talks about soil cover, tillage, and other things that might not pertain to runoff. Cover slows runoff and increases water storage in soil. Tillage methods that retain crop residue on surface are benifitial for increasing water capture.	---------------------	------------------	Soil Cover and tillage methods that leave surface residue slow runoff and thus increase water storage in the soil. (There could be other things to gain in this monograph, I just looked at Chapter 3 for now.)
L37	Tillage	Hydraulic Conductivity, Infiltration, and Runoff from No-till and Tilled Cropland	J. Deck (D. Eisenhauer was advisor)		http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1013&context=biosysengdiss	More runoff on tilled fields than no-till. (pg 39) In center pivot fields, one had 14.9% irrigation runoff for tilled and 1.7 for no-till. Another had 52% for tilled and 38% no-till. No-till showed greater residue, depressional storage, and higher aggregate stability which pointed to higher amounts of water infiltration.	Fields in NE	2008-2010	Significantly more runoff on tilled fields than no-till sometimes.

L38	Mapping ET	Mapping Evapotranspiration	Jozsef Szilagyi/UNL	2010	http://watercenter.unl.edu/archives/2010MappingET.asp	Mean annual ET was mapped across Nebraska using a calibration-free ET mapping technique (CREMAP)	Statewide	2000-2009	
L39	Estimation of Recharge	Regional Estimation of Total Recharge to Ground Water in Nebraska	J. Szilagyi, F.E. Harvey and J.F. Ayers	2005	http://info.ngwa.org/gwol/pdf/pdf/050381131.pdf	Use of GIS land cover, elevation of land and groundwater levels, base recharge, and recharge potential. Possible verlay with conservation practices.	Statewide		Includes statewide map of recharge potential and recharge rates
L40	ET Mapping for CPNRD	Evapotranspiration Mapping for the Central Platte NRD, Nebraska	A. Kilic and I. Ratcliffe	2012	http://watercenter.unl.edu/Symposium2012/PresentationsOne/Kilic.pdf	Presentation that addresses need for better water depletion information to improve GW management, water balance and models and conjunctive management of SW and GW	Central Platte Basin	1997-2011	Applies METRIC energy balance model with Landsat imagery to develop monthly ET maps at field scale
L41	Irrigation Management Practices	Irrigation Management Practices in Nebraska	UNL		http://water.unl.edu/web/cropswater/management	Discusses irrigation management factors that indicates that irrigators should be scheduling their irrigation applications to make maximum use of precipitation and reduce excess use of irrigation water.	Nebraska-wide		
L42	Effective water use	Effective Use of Irrigation Water	M. Jensen	Jun-98	http://www.cast-science.org/publications/?effective_use_of_water_in_irrigated_agriculture&show=product&productID=2846	Report provides a comprehensive description of irrigation in the U.S. and basic principles of irrigation management.	nationwide		
L43		Natural Resource Commission	M. Quinn						Original document not located
L44	Water Use Efficiency	CALFED Water Use Efficiency Program			http://www.calwater.ca.gov/calfed/library/Archive_WUE.html				
L45	USDA FSA CRP Summary of Practices by Acre	USDA FSA CRP Summary of Practices Acreages for Prior Year Contracts Beginning in Program Year 1986	USDA	2006	https://arcticocean.sc.egov.usda.gov/CRPReport/yearly_report.do?method=displayReport&report=1997-r1meplra-31	Table that lists conservation practices and acreages by type and by county in Nebraska	Statewide	1986-present	Quantifies acreages of conservation practices by county
L46	USDA FSA Conservation Program Statistics	CRP Contract Summary and Statistics	USDA	2012	http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=rns-css	Conservation program statistics by state	State level		Lists acreages of conservation practices at state level
L47	Corn Irrigation Water Management Using ET and Soil Moisture Sensors	Corn Irrigation Water Management Using ET and Soil Moisture Sensors	Texas A&M	2011	http://itc.tamu.edu/documents/demonstrations/Colorado%20County%20Corn%20Report%202011.pdf	Results from two on-farm demonstrations			
L48	Soil Moisture Sensor Project in LRNRD	Soil Moisture Sensor Project in LRNRD	Kearney Hub (placeholder)	2011	http://www.kearneyhub.com/news/local/article_16d00b54-d084-11e0-b323-001cc4c03286.html	Article serves as placeholder in literature review for study results	Republican River Basin	2011	Successful use of soil moisture sensors for water conservation
L49	Crop Rotation	USDA-NASS CropScape - Cropland Data Layer 1997 - Current.	USDA - National Agricultural Statistics Service (NASS).	1997-current	http://nassgeodata.gmu.edu/CropScape/	Cropscape data provides raster coverage by crop type including dual crop systems on an annual basis from 1997-current.	Nationwide Coverage - Raster. Pixels are 30 or 56 meters.	1997-current	Raster coverage by crop type
L50	Crop Intensity	USDA-NASS Census of Agriculture. Years 2007, 2002, 1997, 1992...	USDA - National Agricultural Statistics Service (NASS).		http://www.agcensus.usda.gov/index.php	Census data by crop and county. Harvested Acres, Irrigated Acres, Harvested Yield, Irrigated Yield	County	Every 5yrs including 2007, 2002, 1997, 1992	
L51	Crop Intensity	Dryland Cropping Intensification: a fundamental solution to efficient use of precipitation	Farahani, H.J., G.A. Peterson, and D.G. Westfall	1998	Adv. Agron. 64: 197-223.	Article discusses a fundamental solution to efficient use of precipitation			
L52	Tillage Reduction	Agricultural Irrigation Management: Reduce the Need for Irrigation: Maintain Crop Residue, Reduce Tillage	UNL Water: Agricultural Irrigation	1986-87	://water.unl.edu/web/cropswater/reduce	Research at Garden City, KS showed that up to 30% of ET can be evaporation during irrigation season for corn and soybean on silt loam soils. Study suggests that 2.5-3.0 inch water savings is possible when wheat straw or no-till corn stover is present from early June to end of growing season.	Kansas and Nebraska	Numerous years over course of the study	One component of study estimates 5-12 inches of water are available over the entire season for continuous no-till compared to tilled, depending on rainfall events and frequency. More rainfall or the more a crop is irrigated then the more greater the water savings.
L53	Tillage	Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems	Azooz, R.H. and Arshad, M.A.	1995	http://pubs.aic.ca/doi/pdf/10.4141/cjss96-021	Long-term no-till practices kept soil pore structure and continuity undisturbed, which contributed to significantly greater hydraulic conductivity and infiltration rates in no-till than in conventional till.	fields in Canada	2 growing seasons	Long term no-till had more infiltration (less runoff) than conventional till fields
L54	Tillage	Nebraska crop production & pest management information	Jasa, P.	2006	http://cropwatch.unl.edu/web/cropwatch/archive?articleid=1545591	Long-term no-till practices resulted in higher soil permeability and a greater rainfall rate needed to create runoff.	Nebraska		Long term no-till had more infiltration (less runoff) than conventional till fields
L55	Rangeland Management	Infiltration Rates: Three soils with three grazing levels in Northeastern Colorado	Rauzi, F. & Smith, F.	1973	https://journals.uair.arizona.edu/index.php/jrm/article/viewFile/6165/5775	Infiltration rates on light and moderately grazed lands were higher than for heavily grazed pastures (less plant material).	Northeast Colorado		
L56	Rangeland Management	Hydrologic Impact of Grazing on Infiltration: A critical Review	Gifford, G.F. & Hawkins, R.H.	1978	http://www.mojavedata.gov/deserttortoise_gov/documents/copyright_questions/STDY_Hydrologic_Impact_Of_Grazing_On_Inflitration_A_Critical_Review_GiffordG_0478.pdf	Some infiltration data exists for various range conditions and soil groups and is included in this summary paper.			
L57	Rangeland Management	Soil Bulk Density and Water infiltration as affected by grazing systems	Abdel-Magid, A.H., Schuman, G.E. & Hart, R.H.	1987	Journal of Range Management 40(4), July 1987	Infiltration was significantly lower under the heavy stocking rate than under the moderate at the end of the grazing season.	Cheyenne, WY		
L58	Rangeland Management	National Resources Inventory (with GIS)		2010	http://www.ncgc.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/?cid=stelprdb1041620	The National Resources Inventory website has GIS data about Rangeland health, locations, plant species, soil, etc.	Nationwide		Could use this data to locate rangeland and rangeland health with could be correlated to infiltration rates.
L59	CRP	A web-based GIS Decision Support System for managing and planning USDA's Conservation Reserve Program (CRP)	Rao. M et al.	2006	http://www.hidro.ufcg.edu.br/twiki/pub/Disciplinas/GeotecnologiaAplicada/Heber.pdf	This "program/model" could be useful in determining the CRP based conservation measures impacts. In this paper, the CRP-DSS is a prototype.			
L60	CRP	Many papers in this reference but one is "Conservation Reserve Program: Effects on Soil, Water and Environmental Quality"	Many papers in this reference but for "Conservation Reserve Program: Effects on Soil, Water and Environmental Quality", Blackburn, W.H.; Newman, J.B.; & Wood, J.C.		http://www.nativefishlab.net/library/textpdf/19864.pdf#page=31	Specifically in the "Conservation Reserve Program: Effects on Soil, Water and Environmental Quality" paper, they showed that Annual runoff and deep perc decreased and ET increased for most study sites when going from crop to CRP.	Many Western States		
L61	CRP	A Soil Quality Framework for Evaluating the Impact of CRP	Karlen, D.L.; Gardner, J.C.; & Rosek, M.J.	1998	http://wsudowntownseattle.wsu.edu/econ_development/articles/ASoilQualityFrameworkforEvaluatingtheImpactofCRP_Karlen.pdf	CRP generally increased long-term infiltration. Also, using no-till practices to return CRP land to crop production preserved soil quality benefits while tillage destroyed them almost immediately.	Southern Iowa		
L62	Surge Irrigation	Report to the United States Department of the Interior, Bureau of Reclamation Cooperative Agreement, for Surge Irrigation Research and Development Program, Grand Valley Unit	CSU Cooperative Extension?	1993?	http://www.prsurge.com/works/reclam.html	Field studies of surge use on different fields in Front Range of Colorado. Estimates of deep percolation reductions in %	Grand Valley of CO	Primarily 1993, but some 1990-1993.	Could be used to develop simplified estimates of reductions in recharge, based on the percentages developed in the studies. Limited years available, and only conducted in Front Range area.
L63	Variable Rate Irrigation (VRI)	Key Performance Indicators for Variable Rate Irrigation Implementation on Variable Soils	ASABE Meeting Presentation, Carolyn Hedley, Ian Yule, Mike Tuohy, Iris Vogeler	2009	http://elibrary.asabe.org/abstract.asp?aid=27439&t=2&redir=&redirType=	Soil water balance used on three sites to determine performance indicators for variable rate irrigation, including drainage water loss.	New Zealand	Primarily 2007-2008, but some 2004-2009.	"Drainage water" appears to include all water above soil capacity, and would include both recharge (deep perc) and overland runoff.
L64	Variable Rate Irrigation (VRI)	Agricultural Management Options for Climate Variability and Change: Variable-Rate Irrigation	Calvin Perry, Clyde Fraisse, and Daniel Dourte (University of Florida)	2012	http://edis.ifas.ufl.edu/pdffiles/AE/AE49000.pdf	General info on the practice, including a few references.	Global	No specific time period	No quantifiable techniques mentioned - just a reference document.

L65	Variable Rate Irrigation (VRI)	Variable Rate Irrigation: Concept to Commercialization	Calvin D. Perry and Andrea W. Milton (University of Georgia)	2007	http://www.ag.auburn.edu/auxiliary/nsdl/scasc/Proceedings/2007/orals/Perry.pdf	General description of practice, focused on Southeast US	Southeast U.S.	No specific time period	No quantifiable techniques mentioned - just a reference document.
L66	Crop Rotations	Crop Rotations with Full and Limited Irrigation and Dryland Management	J.p. Schneekloth, N.L. Klocke, G.W. Hergert, D.L. Martin, R.T. Clark	1991	http://panhandle.unl.edu/c/document_library/get_file?folderId=490416&name=DLFE-8307.pdf	Changes in ET - Yield relationships through different crop rotations, including moving from continuous corn to wheat-corn-soybean rotation.	West-Central Nebraska	Mainly 1986-1989	
L67	Road Effects on Hydrology	Effects of Roads on Hydrology, Geomorphology, and Disturbance Patches in Stream Networks	J.A. Jones, F.J. Swanson, B.C. Wemple and K. U. Snyder	Sep-99	http://myweb.facstaff.wwu.edu/wallin/envr435/pdf_files/jones_etal_2000.pdf	Article outlines view of how road networks interact with stream networks at landscape scale and effects on biological and ecological processes in streams and riparian systems	Oregon forests		
L68	Ecological Effects of Roads	Roads and Their Major Ecological Effects	R.T.T. Forman and L.E. Alexander	1998	http://pracownia.org.pl/pliki/roads_and_their_major_ecological_effects.pdf				
L69	Streamflow Alteration from Roads	Alteration of Streamflow Characteristics Following Road Construction in North Central Idaho	J.G. King and L.C. Tennyson	Jul-10	http://onlinelibrary.wiley.com/doi/10.1029/WR020i008p01159/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false	Road construction effect on percent of exceedance flows in watershed			
L70	TIGER/Line Shapefiles and TIGER/Line Files.	Shape files for roads	U.S. Census Bureau	2006-current, 2000, 1992	http://www.census.gov/geo/maps-data/data/tiger-line.html	Shapefiles of roads	Statewide	2006-current, 2000, 1992	
L71	Historic Road Maps	Current and Histroi	Nebraska Counties and Nebraska Department of Roads		Obtain by County or from NDOR	Roads maps available statewide at state and/or county level	state or county		
L72	Terraces	Design, layout, construction and management of terrace systems	American Society of Agricultural and Biolgical Engineers	Jan-12	http://elibrary.asabe.org/abstract.asp?aid=41193&t=2&redir=&redirType=	ASABE Standard S268.5			
L73	Soil and Water	Soil and water terminology	American Society of Agricultural and Biolgical Engineers	Sep-07	http://elibrary.asabe.org/abstract.asp?aid=24145&t=2&redir=&redirType=	ASABE Standard S526.3			
L74	Buffers	Buffers, common-sense conservation	U.S. Department of Agriculture	1997		Program Aid 1615			
L75	Irrigation Scheduling	Using Modified Atmometers for Irrigation Management	Suat Irmak, Jose O. Payero, and Derrel L. Martin	Oct-05	http://www.ianrpubs.unl.edu/epublic/live/g1579/build/g1579.pdf	UNL NebGuide G1579			
L76	Deficit Irrigation	Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency and dry mass	J.O. Payero, D.D. Tarkalson, S. Irmak, D. Davison, J.L. Petersen	2009	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1051&context=biosysengfacpub	Agricultural Water Management 96 (2009) 1387 - 1397	Study done in North Platte, NE	Measurements taken 2005-2006	
L77	Irrigation Scheduling	Irrigation Scheduling: Checkbook Method	Steven R. Melvin, C.Dean Yonts	2009	http://ianrpubs.unl.edu/live/ec709/build/ec709.pdf	UNL Extension Circular			
L78	Irrigation Scheduling	Irrigation Scheduling Using Crop Water Use Data	C. Dean Yonts, Norman L. Klocke	Jun-85	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2195&context=extensionhist	UNL NebGuide G85-753			
L79	Deficit Irrigation	Yield Response of Corn to Deficit Irrigation in a Semiarid Climate	Jose O. Payero, Steven R. Melvin, Suat Irmak, David Tarkalson	2006	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1050&context=biosysengfacpub	Agricultural Water Management 84:1-2 (july 16, 2006), pp. 101-112			
L80	Deficit Irrigation	Response of Soybean to Deficit Irrigation in the Semi-Arid Environment of West-Central Nebraska	J. O. Payero, S. R. Melvin, S. Irmak	2005	http://bse.unl.edu/c/document_library/get_file?uuid=135188a2-de0c-4687-8a53-9e89b55060c0&groupId=4614475&.pdf	Transactions of the ASAE, Vol. 48(6): 2189-2203			
L81	Crop Rotations	Evaluating decision rules for dryland rotation crop selection	David C. Nielsen	2011	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1872&context=usdaarsfacpub	Field Crops Research 120(2011) 254-261			
L82	Buffers	Consumptive Use Calculator. Evapo-Transpiration Calculations for Cover Types in a Non-Stressed Enviorment	USDA-NRCS	2009	http://www.dnr.ne.gov/PRRIP/docs/PRRIP_NE_DepletionPlan.html	Documentation for a spreadsheet analysis of monthly ET estimates for crop and riparian vegetative covers. Allows for computation comparison across 8 regions along the Platte River Watershed on various soil types.	Regional	Monthly/ Annual	Calcuates monthly ET estimates for buffer and cropland covers.
L83	Small Dams	Modeling Small Reservoirs in the Great Plains to Estimate Overflow and Ground-Water Rehcarge	Ravikumar B. Choodegowda	2009		Developed models to estimate reservoir overflow, gross seepage, and groundwater recharge to evaluate the aggregate effect of small dams in the Republican River Basin. The models utilize POTYLDR for inflow and reservoir water balance inputs.	Republican River Basin	Monthly/ Annual	Researchers found that these reserveroirs reduce streamflow by 74 to 97%. 90 to 95% of retained streamflow contributed ground-water recharge. Model and or estimates could be applied to Platte River Basin.
L84	Irrigation Management	Field Scale Limited Irrigation Scenarios for Water Policy Strategies	N. L. Klocke, J. P. Schneekloth, S. R. Melvin, R. T. Clark, J. O. Payero	2004	http://panhandle.unl.edu/c/document_library/get_file?folderId=490416&name=DLFE-8309.pdf	Applied Engineering in Agriculture 20(5): 623-631			
L85	Crop Production Intensity	Recommended Seeding Rates and Hybrid Selection for Rainfed (Dryland) Corn in Nebraska	Robert N. Klein, Drew J. Lyon	Jun-11	http://www.ianrpubs.unl.edu/live/g2068/build/g2068.pdf	UNL NebGuide G2068			
L86	Crop Production Intensity	Skip-Row Planting Patterns Stabilize Corn Grain Yields in the Central Great Plains	Drew J. Lyon, et al	Feb-09	http://www.plantmanagementnetwork.org/pub/cm/research/2009/skip/	Plant Management Network publication			
L87	Crop Production Intensity	Skip-Row Planting and Irrigation of Graded Furrows	J. T. Musick, D. A. Dusek	1982	http://naldc.nal.usda.gov/download/512/PDF	Transactions of the ASAE Vol. 25, No. 1, pp. 82-87 & 92			
L88	Crop Production Intensity	Grain sorghum water use with skip-row configuration in the Central Great Plains of the USA	Akwasi A. Abunyewa, Richard B. Ferguson, Charles S. Wortmann, Drew J. Lyon, Stephen C. Mason, Suat Irmak, and Robert N. Klein	Oct-11	http://agronomy.unl.edu/c/document_library/get_file?p_l_id=4128278&folderId=5159199&name=DLFE-68503.pdf	African Journal of Agricultural Research Vol. 6(23), pp. 5328-5338, 19 October 2011			
L89	Crop Production Intensity	The effect of row spacing and seeding rate on biomass production and plant stand characteristics of non-irrigated photoperiod-sensitive sorghum	John L. Snider, Randy L. Raper, and Eric B. Schwab	Jan-12	http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1881&context=usdaarsfacpub	Publications from USDA-ARS/UNL Faculty. Paper 876, 2012			
L90	Phreatophytes/Invasive Vegetation	A Field Assessment of a Method for Estimation of Ground-Water Consumption By Phreatophytes	J.J. Butler, G.J. Kluitenberg, D.O. Whittemore	2008	http://water.usgs.gov/wrri/07grants/progress/2003KS33B.pdf	KGS and KSU Study researched magnitude of phreatophyte impact to stream-aquifer systems in Kansas. Equation to calculate ET consumption of GW prior and post vegetation treatment.	Arkansas and Cimarron River basins in Kansas	Data collected 2003-2008	
L91	Phreatophytes/Invasive Vegetation	Riparian Vegetation Impacts on Water Quantity, Quality, and Stream Ecology	D. Scott, E. Istanbulluoglu, J. Lenters, and Kyle Herman	2012	http://www.eas.unl.edu/~pmykleby/riparian/Documents/NETFinalReport.pdf	Goal of study was to develop quantitative understanding of the role of riparian vegetation dynamics, including invasive species, within Republican and Platte River basins.	Platte and Republican River basins	Reporting Period 2008-2012	
L92	Soil Moisture Sensors	Watermark Granular Matrix Sensor Soil Matric Potential for Irrigation Management	Suat Irmak, Jose O. Payero, Dean Eisenhauer, William Kranz, Derrel Martin, Gary Zoubek, Jennifer Ress, Brandy VanDeWalle, Andrew Christeiansen, Dan Leininger	2006	http://ianrpubs.unl.edu/live/ec783/build/ec783.pdf	UNL Extension Circular EC 783			