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Appendix F

CONSERVATION MEASURES STUDY PHASE II

PHASE II CONSERVATION MEASURES STUDY: IRRIGATION EFFICIENCIES AND TILLAGE PRACTICES

2017

Phase II Conservation Measures Study

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To: Marc Groff, The Flatwater Group
Thad Kuntz, Adaptive Resources, Inc.
From: Kara Sobieski
Date: June 30, 2016
Re: **POAC Impact of Soil and Conservation Measure Study**
Surface Water Model Approach and Results

This technical documentation summarizes the general approach and results for the surface water components of the Platte Overappropriated Area Committee (POAC) Impact of Soil and Conservation Measures Study. This documentation is intended to provide sufficient information to understand how the surface water model datasets were developed and/or revised for the POAC effort and the specific results from these components as they are integrated into the Western Water Use Management (WWUM) Model. This documentation, and surface water model dataset results, will be integrated into a larger document with the results from the WWUM consumptive use and ground water modeling efforts for this study.

Background

The purpose of the Conservation Measures Study is to evaluate impacts that select conservation measures may have on streamflow, in terms of amount, timing, and location, by modifying and analyzing the existing COHYST and WWUM models. The conservation measures that were ultimately selected for evaluation include changes in tillage practices and on-farm irrigation efficiencies. The impact of these conservation measures was evaluated by comparing the results of a model scenario that reflects the conservation measure to the results of a Baseline Scenario. In order to isolate the impact of a specific conservation measure using the WWUM surface water model, it is necessary to develop this Baseline Scenario in which each parameter that will be adjusted in subsequent comparative analyses is explicitly represented and can be individually adjusted while holding all other model parameters constant. The impact of the conservation measure can be analyzed in terms of change in streamflow, consumptive use, diversions, and pumping.

Baseline Scenario

The Conservation Measures Baseline Scenario is based on the existing WWUM surface water model, which reflects the historical climate conditions, hydrology, land-use conditions, and irrigation demands over the 1953 to 2013 period. A considerable amount of information and operations from the existing WWUM model was carried forward into this Baseline Scenario, however some changes were necessary in order to explicitly represent each conservation measure analyzed in this study. This section discusses revisions made to the WWUM model that resulted in the Baseline Scenario; if not specifically discussed below the Baseline Scenario used the information or operations from the existing WWUM model. Information on data and model development of the existing WWUM model is discussed in detail in the *Western Water Use Management Model Water Resources Model User's Manual* and not reproduced herein. Note that although the WWUM model includes irrigated lands in Wyoming, conservation measures were not implemented for these lands.

A comparison of the Baseline Scenario to the historical streamflow at the Lewellen gage is provided at the end of this section; additional comparisons of the Baseline Scenario results to Alternative Scenarios are provided in the Results section below. Note that the following summaries include the water supply, consumptive use, and shortages for surface water only and co-mingled irrigated lands in both Wyoming and Nebraska; Wyoming lands were included because their water use impacts the water availability at downstream diversions and streamflow in Nebraska. The summaries exclude results from ground water only irrigated lands because only a portion of the ground water irrigated acreage is included in the WWUM model.

Additional North Platte Project Supply

Many of the irrigation districts and ditches in the North Platte River Valley have three water supplies available; direct diversion of natural surface water, storage releases from the North Platte Project reservoirs; and supplemental ground water supplies. For the original WWUM modeling effort, the historical surface water diversions included both the natural flow portion and the storage releases from the Project reservoirs; estimated or metered ground water supplies supplemented the surface water diversions.

For the POAC effort, the model is used to estimate the surface and ground water supplies to meet demands that vary from historical due to changes in efficiencies or tillage practices. If these changes create a situation where an irrigation district or ditch can no longer divert natural flow under its direct rights (e.g. they are being called out by senior water rights or the river is dry), many irrigation districts or ditches have the option to meet the remaining irrigation demand by either calling for additional upstream reservoir releases or supplementing with more ground water supplies. For this effort, it is assumed that ditches would call for additional upstream reservoir releases, if available, before incurring pumping costs for additional ground water supplies. Therefore, the POAC modeling effort simulates the opportunity for irrigation districts and ditches currently under contract to receive Project reservoir water to call for additional reservoir releases during the late irrigation season (e.g. July and August).

The historical reservoir releases are already a component of the upstream streamflow that is an input into the model, these additional reservoir releases would be above and beyond the natural flow and reservoir releases already reflected in the streamflow input. Depending on reservoir storage and runoff conditions, the reservoir releases reflected in the streamflow may already be the maximum releases available from the Project reservoir allocation/quota; there may not be additional water available in the reservoirs to call for and release. In order to understand when additional reservoir releases may have been available to irrigators in the North Platte River Valley, an assessment of the reservoir contents of Pathfinder Reservoir was performed to determine years when there would have been sufficient carryover in the reservoir that would accommodate additional storage releases. Additional reservoir releases were estimated to be available in years with significant storage in the reservoir as long as those years were not followed by a dry period. The assessment indicated that 25,000 acre-feet per month of additional releases could feasibly have been made in July and August in the following years during the study period:

Table 1: "Surplus" Years for Additional North Platte Project Reservoir Releases

1973	**1983**	**1988**	**1999**
1974	1984	1996	2000
1975	1985	1997	2010
1976	1986	1998	2011
1980	1987		

For years without additional storage and for irrigation districts or ditches that are not entitled to contract reservoir releases, irrigation demand shortages were generally met from additional supplement ground water supplies, if available.

Mutual Ditch Approach

Metered co-mingled pumping is available for the most recent five years of the WWUM model study period; however it was necessary to develop co-mingled pumping estimates back in time. During the initial model development, it was assumed that the irrigation districts and ditches in the North Platte River Valley operated as mutual ditches, whereby available surface water supplies are evenly applied first to meet crop demands and remaining shortages are met by ground water supplies on lands that receive this supplemental supply. Comparisons of metered co-mingled pumping to estimated co-mingled pumping revealed that some districts and ditches did not operate as such, and the estimated pumping more closely matched those that operated under a "maximum supply" approach. The maximum supply approach occurs when ground water is used first on lands with the highest irrigation efficiency (i.e. sprinkler irrigation), and surface water is used first on lands with lower irrigation efficiency (i.e. flood irrigation) with any shortages being met from ground water supplies. In some "maximum supply" instances, the surface water supply is sufficient to meet the full crop irrigation requirement, however users still pumped ground water. Districts and ditches were assigned as either mutual ditch or maximum supply based on the pumping comparison, and that approach was used, along with the availability of surface water supplies and the crop irrigation requirement, to estimate co-mingled pumping back in time for the WWUM model.

As on-farm irrigation efficiency is a conservation measure analyzed in this study, the Baseline Scenario needed to reflect a single approach. As a majority of the co-mingled lands in the basin operate as a mutual ditch, this approach was selected for implementation in the Baseline Scenario.

Model Demand

The model allocates water to an irrigation district or ditch "demand" when there is water physically and legally available under their water rights. Using the mutual ditch approach, the model demand will first be met by physically and legally available surface water including additional reservoir releases, and then remaining un-met demand can be supplemented from ground water pumping for lands with co-mingled supplies. The WWUM model was simulated based on historical conditions; therefore the demand for each irrigation district or ditch was equal to recorded historical diversions. In order to simulate diversions under varying streamflow conditions, and account for the change in efficiencies and tillage practices, the demand was revised under each POAC scenario.

For the Baseline Scenario, the model demand was calculated by dividing the net irrigation requirement (NIR) by the average monthly system efficiency in order to "back up" the irrigation demand to the headgate. Developing the demand using this approach allows the model to allocate the amount of water needed to meet the irrigation requirement after accounting for conveyance and irrigation application losses. The Baseline Scenario demand is based on the NIR data developed for the WWUM effort, and the average monthly system efficiency is a result of the WWUM consumptive use analysis reflecting the ratio of historical diversions to NIR. The average monthly system efficiency values capture the range of efficiencies throughout the year; low system efficiency in the early summer runoff and high system efficiency later in the season when streamflow supplies are reduced. These average efficiencies capture the seasonal irrigation practices, including diversions to wet canals and fields in the early spring.

As on-farm irrigation efficiency is a conservation measure analyzed in this study, the variable system efficiency values used in the Baseline Scenario were not used to develop the demand of individual alternative scenarios. The general approach to developing demand discussed above was used in the alternative scenarios; additional details regarding the development of the demand for each POAC scenario are provided in the scenario discussions below.

Ground Water Allocations

Recent ground water allocations determined by the NRDs, which can limit the amount of ground water that irrigators pump and apply to irrigated land, were not implemented in the Baseline or Alternative Scenarios. Due the variability under which irrigators can use their allocations, it is difficult to anticipate how this water management practice may be incorporated and appropriately modeled in each alternative.

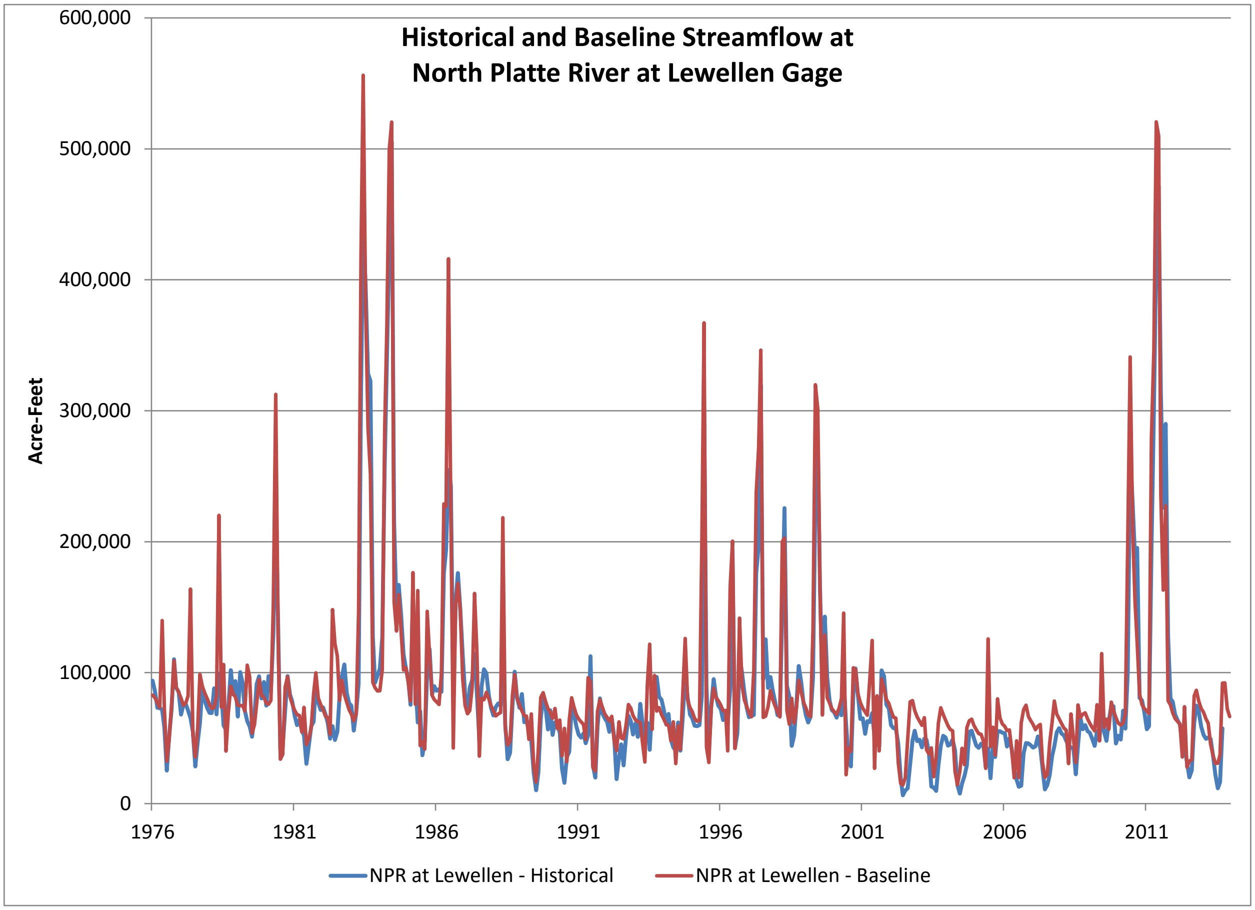
In the Baseline and Alternative Scenarios, ground water pumping is a simulated value based on the availability of surface water supplies to meet irrigation requirement and the ability of existing wells to pump to meet any remaining irrigation requirement. Therefore, pumping is only limited by the capacity of the wells and irrigation requirement, not by historical metered pumping amounts or allocations for the POAC modeling effort.

Impact to Streamflow

The revisions discussed above were applied to the WWUM model in order to create the POAC Baseline model and the model was simulated. Simulated diversions, pumping, and streamflow from the Baseline Scenario were reviewed and compared to historical records to confirm the revisions were implemented appropriately and to understand the impact of the revisions to streamflow. The cumulative effect of the differences between historical and simulated streamflow can be seen at the Lewellen gage, and as shown in **Figure 1** below, they are generally small in magnitude relative to the streamflow amount with a larger impact during dry periods.

The Lewellen gage is the integration point between the upper and lower basin POAC modeling efforts. Based on the differences shown below, it is not recommended that the lower basin POAC modeling efforts be revised to reflect the Baseline Scenario inflow; however coordination is recommended to carry the impact of Alternative Scenarios into the lower basin system.

Figure 1: Historical vs. Baseline Scenario Streamflow Comparison



First-Tier Scenario

The First-Tier Alternative Scenarios represent the "low bookend" to the potential conservation measures. Two alternatives were developed and simulated in this tier:

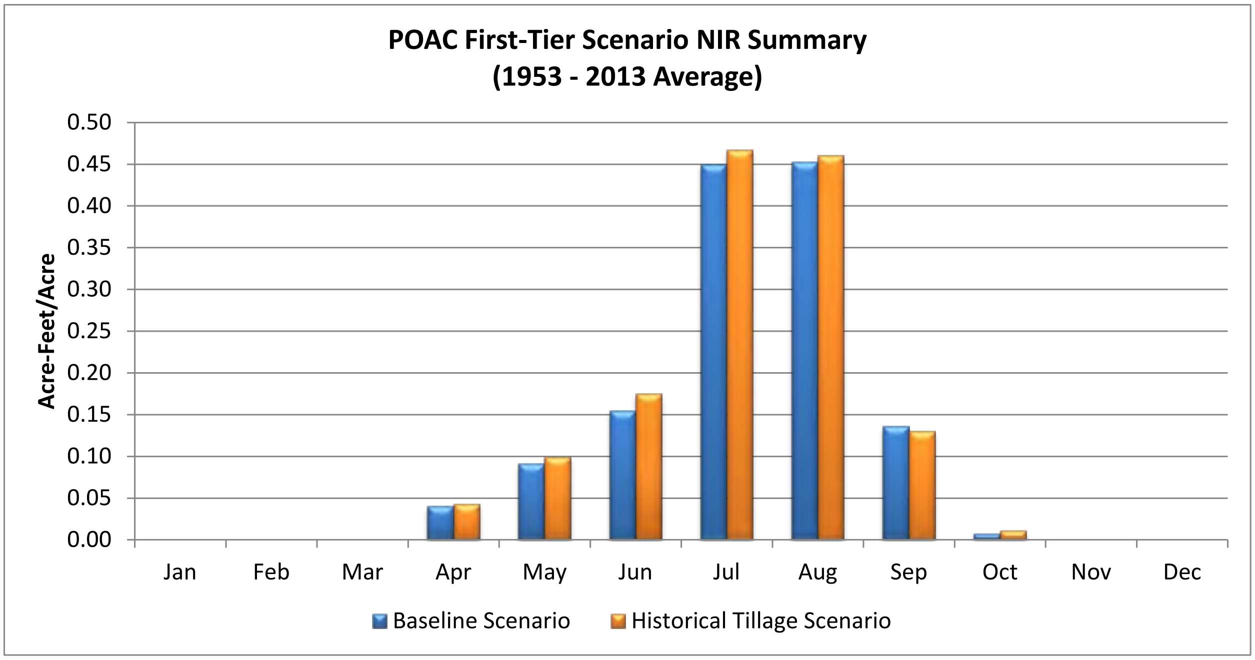
- Historical (circa-1950's) tillage practices, implemented in the model via revised NIR values.
- Low irrigation efficiencies; 50 percent on-farm efficiency for flood application and 60 percent for sprinkler application

Historical Tillage Scenario

This scenario isolates the impact of applying historical circa-1950's tillage practices throughout the full study period. The consumptive use and water allocation tools used by WWG to analyze the alternatives are not able to specifically adjust tillage practices; therefore the impact of this alternative was captured in revised NIR values as provided by The Flatwater Group (TFG) from the CropSim model. Refer to the TFG documentation for more information on how the revised tillage practices were modeled in CropSim. Accounting for historical cropping patterns in the

North Platte River Valley, the model-wide Historical Tillage NIR is greater than the Baseline NIR by approximately 4 percent, raising the unit NIR from 1.33 acre-feet/acre to 1.38 acre-feet/acre annually. As shown in **Figure 2**, the Historical Tillage Scenario has a similar monthly distribution as the Baseline Scenario NIR with the largest differential of NIR in June and July.

Figure 2: First-Tier NIR Summary

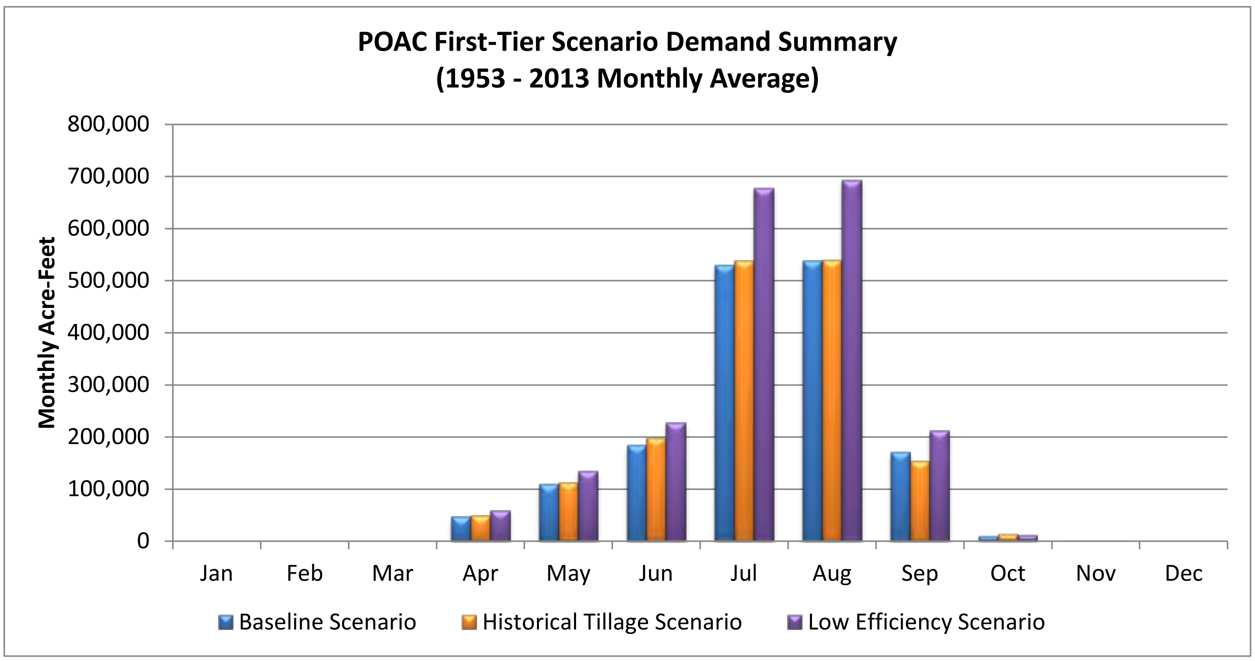


The model demand for this scenario is developed by dividing the Historical Tillage Scenario NIR by the average monthly historical system efficiency for each structure in the model to "back up" the revised demand to the headgate. Due to the minimal increase to NIR, the resulting demand for the Historical Tillage Scenario is only 1 percent greater on average annually than the Baseline Scenario demand. The increase in demand is not equal to the increase in NIR because the revised tillage practices affect crops differently under variable hydrological conditions (e.g. precipitation, soil moisture conditions). See **Figure 3** at the end of this section for a comparison of the average monthly demand from First-Tier Scenarios to the Baseline Scenario.

Low Efficiency Scenario

This scenario isolates the impact of a reduction in the Baseline Scenario on-farm application efficiencies from 65 to 50 percent for flood application, and from between 70 to 85 percent to 60 percent for sprinkler application. The model demand for this scenario was developed by dividing the Baseline Scenario NIR by the revised system efficiency for each structure in the model to "back up" the revised demand to the headgate. The revised system efficiency was calculated by first determining the composite on-farm efficiency accounting for the amount of flood and sprinkler acreage annually served by each structure, then multiplying this composite value by the canal efficiency. For example, if a structure served 100 acres total, with 75 acres served by sprinkler and 25 acres flood irrigation, the composite on-farm efficiency would be 57.5 percent. In this example, if the conveyance efficiency for the structure was 70 percent, then the system efficiency would be approximately 40 percent. Note that one composite system efficiency value was developed for each year in order to capture the change in acreage and the improvement from flood to sprinkler irrigation practices over time. The resulting demand for the Low Efficiency scenario is approximately 25 percent greater on average annually than the Baseline Scenario demand. **Figure 3** reflects the average monthly demand from First-Tier Scenarios compared to the Baseline Scenario.

Figure 3: First-Tier Demand Summary



Second-Tier Scenario

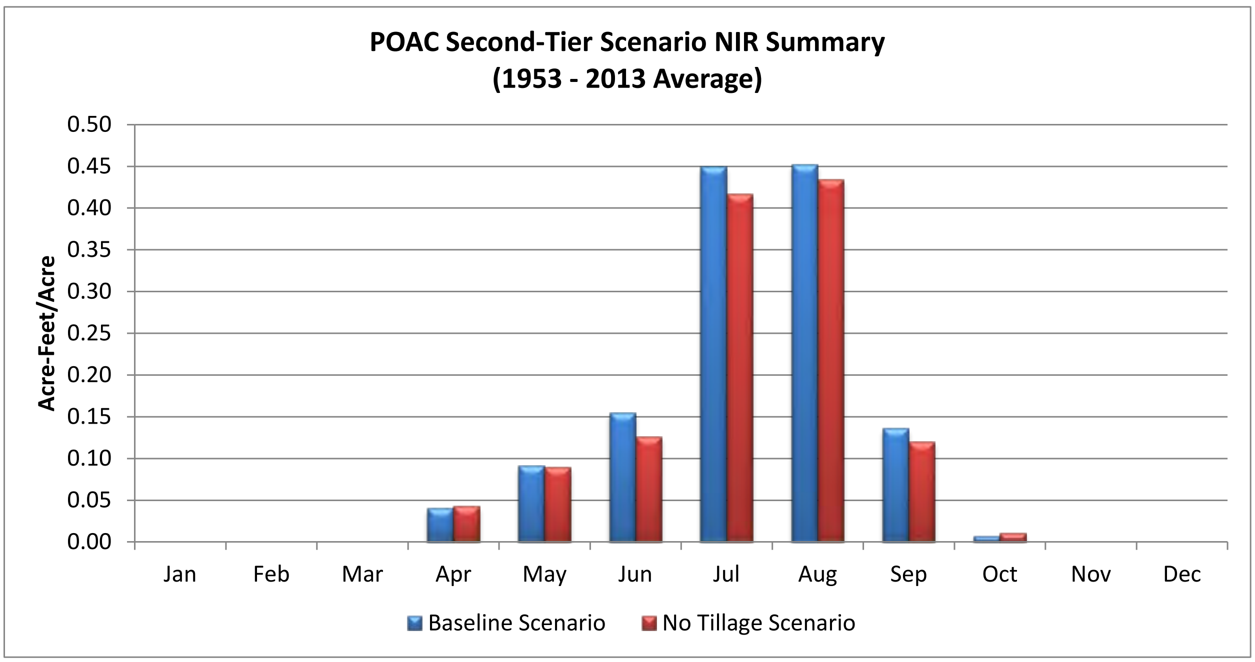
The Second-Tier Alternative Scenarios represent the "high bookend" to the potential conservation measures. Two alternatives were developed and simulated in this tier:

- No tillage practices, implemented in the model via revised NIR values.
- High irrigation efficiencies; 90 percent on-farm efficiency for flood and sprinkler application

No Tillage Scenario

This scenario isolates the impact of applying no tillage practices throughout the full study period. As discussed in the Historical Tillage scenario section above, refer to the TFG documentation for more information on how the no tillage practices were modeled in CropSim. Accounting for historical cropping patterns in the North Platte River Valley, the model-wide No Tillage NIR is less than the Baseline NIR by approximately 7 percent, reducing the unit NIR from 1.38 acre-feet/acre to 1.24 acre-feet/acre annually. As shown in **Figure 4**, the No Tillage Scenario has a similar monthly distribution as the Baseline Scenario NIR with the largest differential of NIR in June and July.

Figure 4: Second-Tier NIR Summary

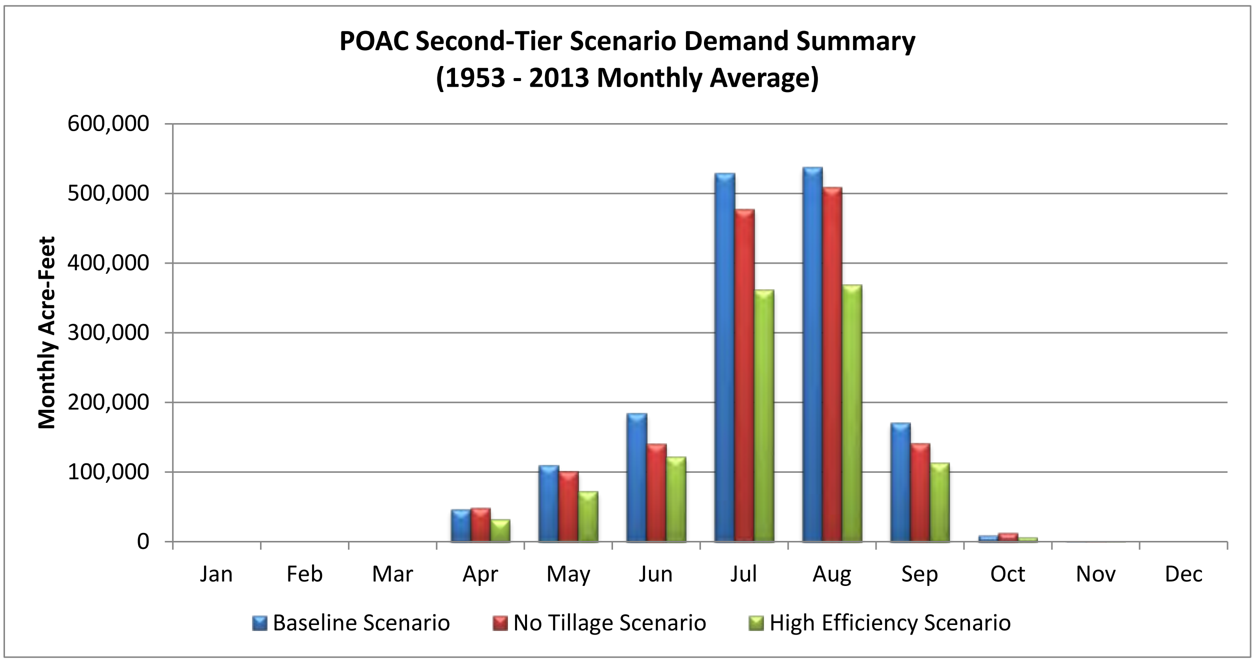


The model demand for this scenario is developed by dividing the No Tillage Scenario NIR by the average monthly historical system efficiency for each structure in the model to "back up" the revised demand to the headgate. The resulting demand for the No Tillage Scenario is 10 percent less on average annually than the Baseline Scenario demand. As discussed above, the decrease in demand is not equal to the decrease in NIR because the revised tillage practices affect crops differently under variable hydrological conditions. See **Figure 5** for a comparison of the average monthly demand from Second-Tier Scenarios to the Baseline Scenario.

High Efficiency Scenario

This scenario isolates the impact of an increase to the Baseline Scenario on-farm application efficiencies to 95 percent for both flood application and sprinkler application. The model demand for this scenario was developed by dividing the NIR by the revised system efficiency for each structure in the model to "back up" the revised demand to the headgate. As the increased efficiency is the same for both flood and sprinkler application, it is not necessary to develop the acreage-weighted composite on-farm efficiency as outlined for the Low Efficiency Scenario. Rather, the revised system efficiency was calculated by multiplying the increased on-farm efficiency by the canal efficiency. The resulting demand for the High Efficiency scenario is approximately 30 percent less on average annually than the Baseline Scenario demand. **Figure 5** reflects the average monthly demand from Second-Tier Scenarios compared to the Baseline Scenario.

Figure 5: Second-Tier Demand Summary



Model Integration Deliverables

The Baseline and four scenarios were simulated over the 1953 to 2013 period and the results were delivered to the POAC technical consultants for integration into the consumptive use and ground water models. The following data types were provided in the deliverable:

- Conveyance Loss: Monthly time series of conveyance loss associated with the simulated diversions in each scenario; integrated into the ground water model as canal and lateral recharge.
- Simulated On-Farm Diversions: Simulated diversions less conveyance loss; integrated into the consumptive use model as surface water supply.

- Simulated Co-Mingled Pumping: Simulated pumping on co-mingled lands: integrated into the consumptive use as supplemental ground water supply and ground water model as pumping demands.

Refer to the documentation associated with the POAC Scenario consumptive use and ground water models for more information on the integration of these components.

Scenario Results

The First and Second Tier scenarios were intended to "bookend" low and high levels of conservation on the North Platte River Valley in order to provide a cursory understanding of how water supply and streamflow may react under these conditions. As a comparative modeling approach was used, this section provides tabular and graphical results from each scenario as they compare to the Baseline Scenario results. Note that graphical results focus on the efficiency scenarios as the tillage scenarios did not impact water availability or streamflow as significantly as the efficiency scenarios.

The following notes and observations can be drawn from the results:

- As discussed in the Baseline Scenario section, conservation measures were not implemented for irrigated lands in Wyoming, which constitute approximately one quarter, or 92,000 acres, of the surface water and co-mingled acreage in the North Platte Valley. The following summaries include their diversions, use of additional upstream storage, co-mingled pumping, consumptive use, and shortages because their water use impacts the water availability at downstream diversions and streamflow in Nebraska.

- Only a portion of the ground water only acreage in the North Platte River Valley is included in the surface water model, therefore the following summaries exclude the water use on these lands. Full reporting of the POAC conservation measures on ground water only lands is provided in the POAC documentation of the ground water model scenarios. Ground water related information presented herein is limited to supplemental/co-mingled ground water supplies only.

- The Low Efficiency Scenario resulted in an increase of river diversions and additional upstream storage releases as shown in **Figures 6 and 7**, however many structures are still limited by the amount of surface water available for diversion. The bulk of these shortages are met from co-mingled pumping, which increases two-fold in this scenario compared to the Baseline Scenario. Under 2002 drought conditions, annual co-mingled pumping exceeded 250,000 acre-feet in this scenario (**Figure 8**).

- As discussed above, the Historical Tillage Scenario and No Tillage Scenario results are relatively similar to the Baseline Scenario. Results from the Historical Tillage Scenario, as shown in **Table 2**, indicate that the increase in NIR is generally met from additional upstream storage release and co-mingled pumping, as the historical diversions are similar in magnitude to the Baseline Scenario. This correlates with the monthly distribution of the Historical Tillage NIR; it is greater than the Baseline Scenario in July and August when streamflow is lowest and additional diversions are not available.

- The No Tillage Scenario results reflect reduced river diversions, upstream storage releases, and co-mingled pumping that corresponds in magnitude to the reduction in NIR for the scenario. This reduction in overall supply, however, results in a less than 2 percent impact on the streamflow at the Lewellen gage.

- The High Efficiency Scenario results reflect a significant increase in consumptive use, with almost 60,000 acre-feet of additional consumptive use each year compared to the Baseline Scenario results. As expected in water short systems and reflected in **Figure 9**, consumptive use increases when efficiency increases. The consumptive use is generally met by more efficient use of the river diversions, resulting in a significant reduction in upstream releases and co-mingled pumping. Co-mingled pumping is reduced to 11,000 acre-feet on average annually in this scenario, and dropping to less than 1,000 acre-feet during wet years as reflected in **Figure 8**.

- As reflected in **Figures 12** through **14** below, the conservation measures cause the greatest impact on the streamflow at the Lewellen gage during dry years. The Low Efficiency scenario results in higher streamflow volumes annually by reducing the amount of water available to crop consumptive use and increasing the return flows during the non-irrigation season when they are generally not re-diverted or consumed. Conversely, the High Efficiency scenario has greater consumptive use of diverted water with reduced return flows during the non-irrigation season. This impact equates to over 58,000 acre-feet less streamflow at the Lewellen gage on average annually over the 1953 to 2013 period.

Table 2: POAC Scenario Results Summary

Percent Change of the Baseline Scenario
Average Annual (1953 – 2013)

Water Use Parameter	**Baseline**	**First-Tier Scenarios** Low Efficiency	Historical Tillage	**Second Tier Scenarios** No Tillage	High Efficiency
Total River Diversions [1]	1,353,000	**+ 7%**	No Change	**- 6%**	**- 19%**
Additional Upstream Storage Releases [2]	22,000	**+ 23%**	**+ 5%**	**- 23%**	**- 86%**
Co-mingled Pumping	41,000	**+ 110%**	**+ 7%**	**- 15%**	**- 73%**
NIR	544,000	No Change	**+ 4%**	**-7 %**	No Change
Consumptive Use	450,000	**- 12%**	**+ 3%**	**- 5%**	**+ 13%**
NIR Shortages	94,000	**+ 59%**	**+ 11%**	**- 17%**	**- 63%**
Return Flows	927,000	**+ 20%**	**- 1%**	**- 7%**	**- 37%**
North Platte River at Lewellen Streamflow	1,092,000	**+ 5%**	**- 1%**	**+ 2%**	**- 5%**

[1] Includes direct diversions, diversion of Additional Upstream Storage Releases, and diversions to storage at Inland Lakes.

[2] Average based on years when additional upstream storage was made available, see "Surplus" Years table.

Figure 6: Diversion Summary

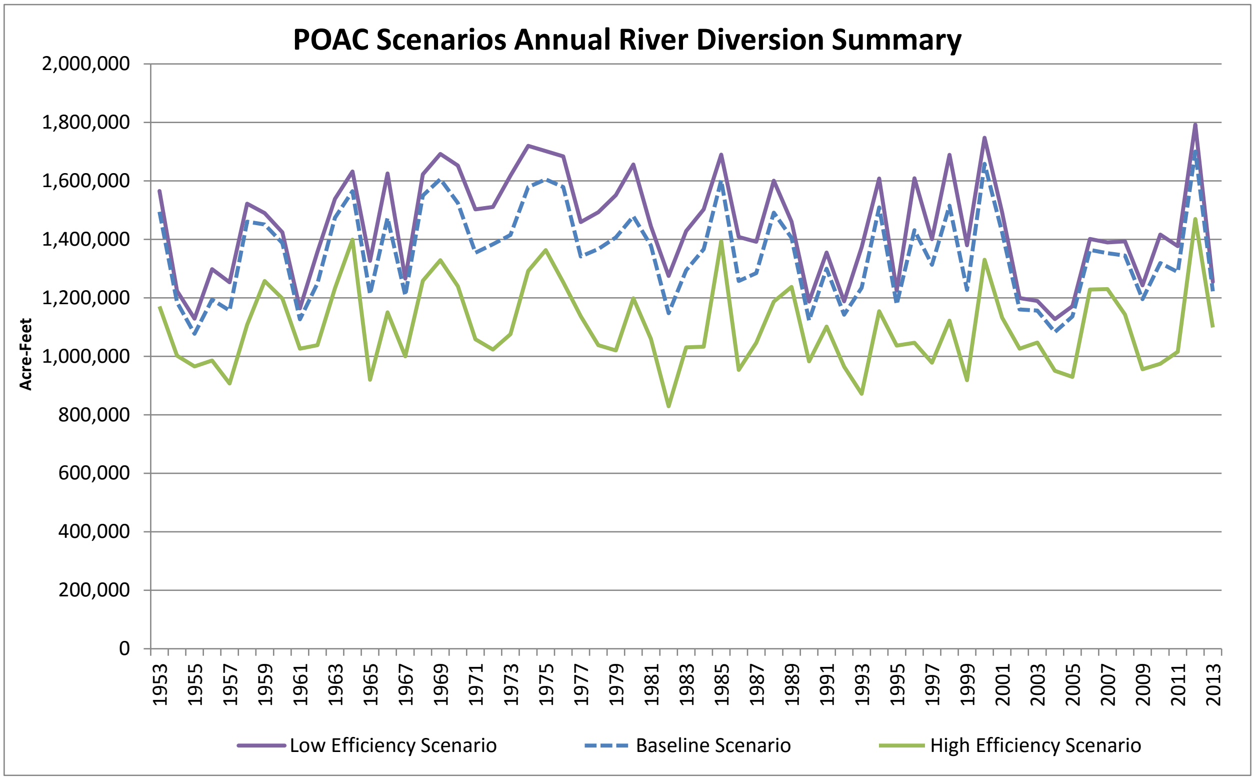


Figure 7: Additional Upstream Storage Release Summary

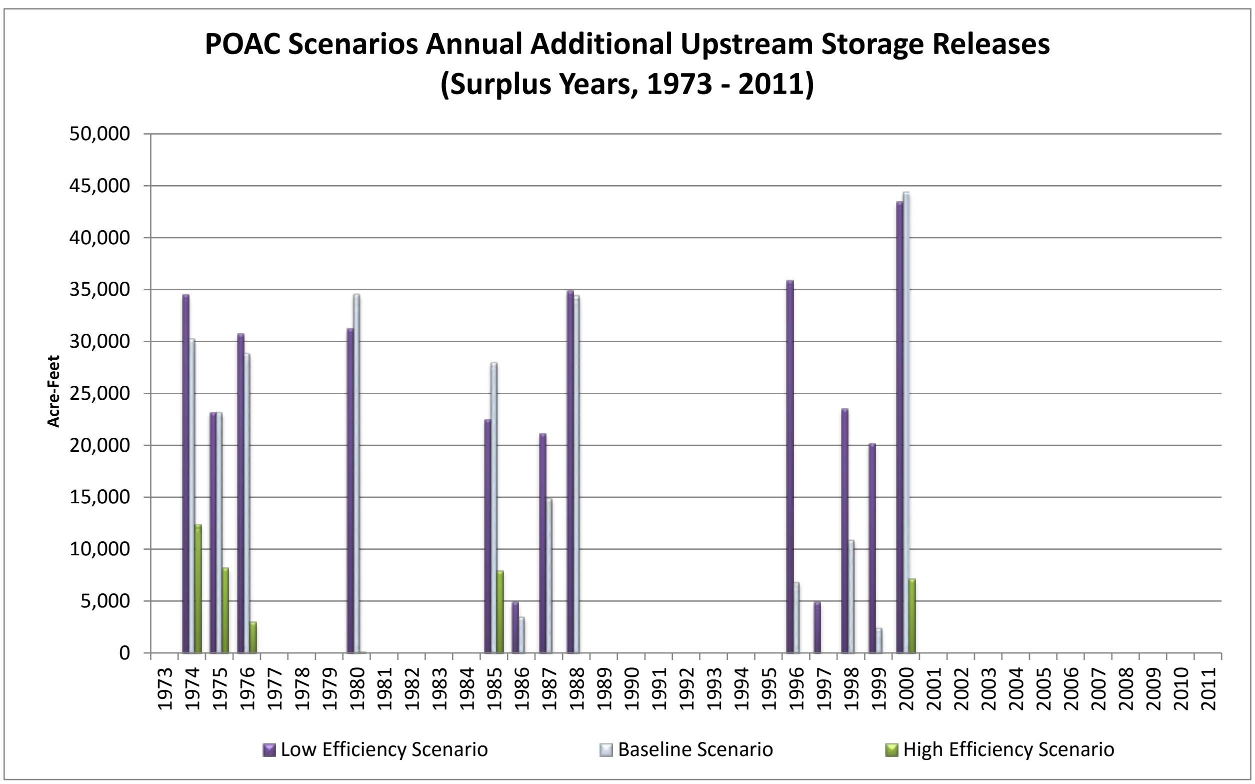


Figure 8: Co-mingled Pumping Summary

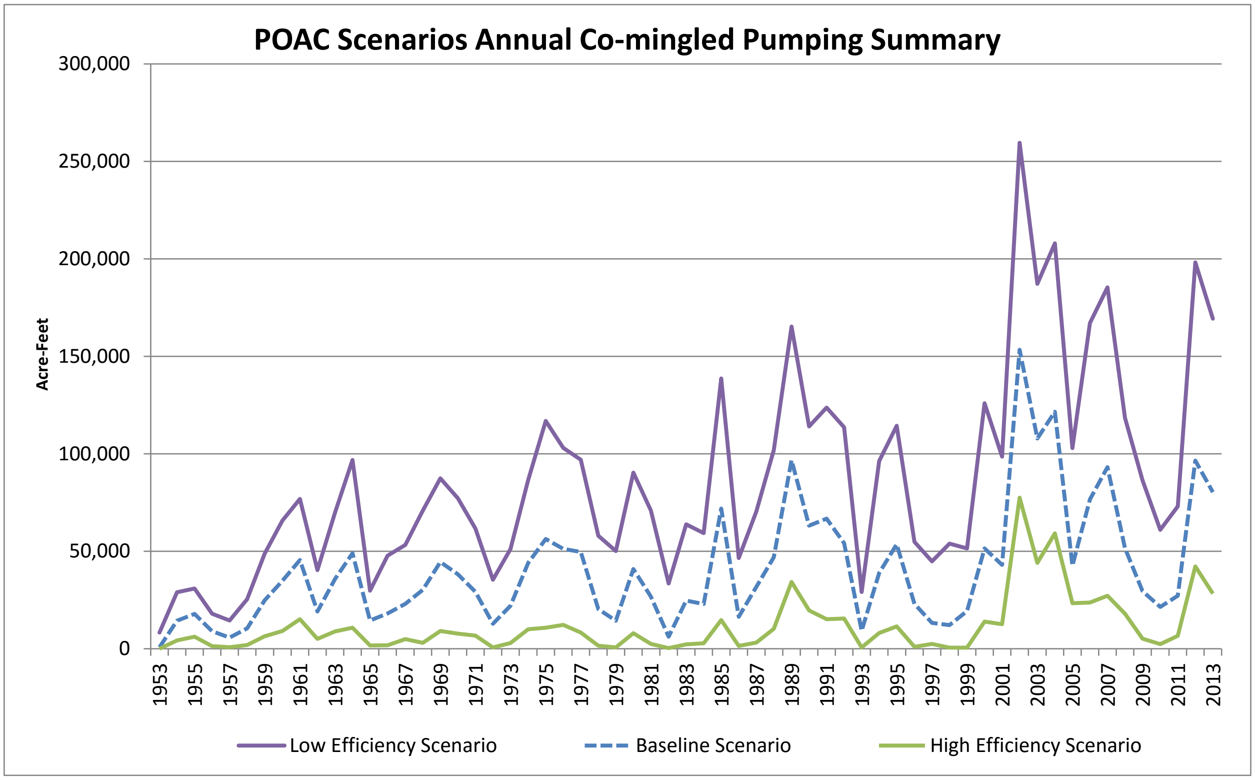


Figure 9: Consumptive Use Summary

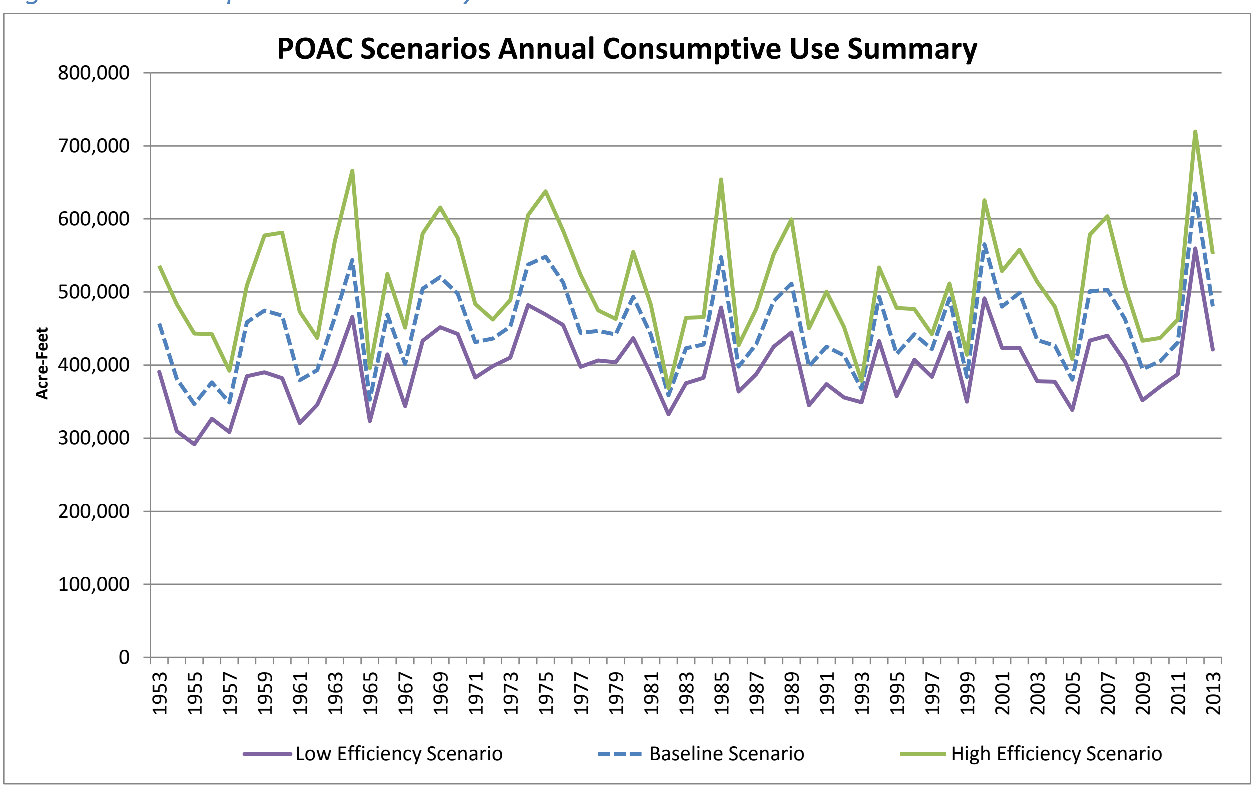


Figure 10: NIR Shortage Summary

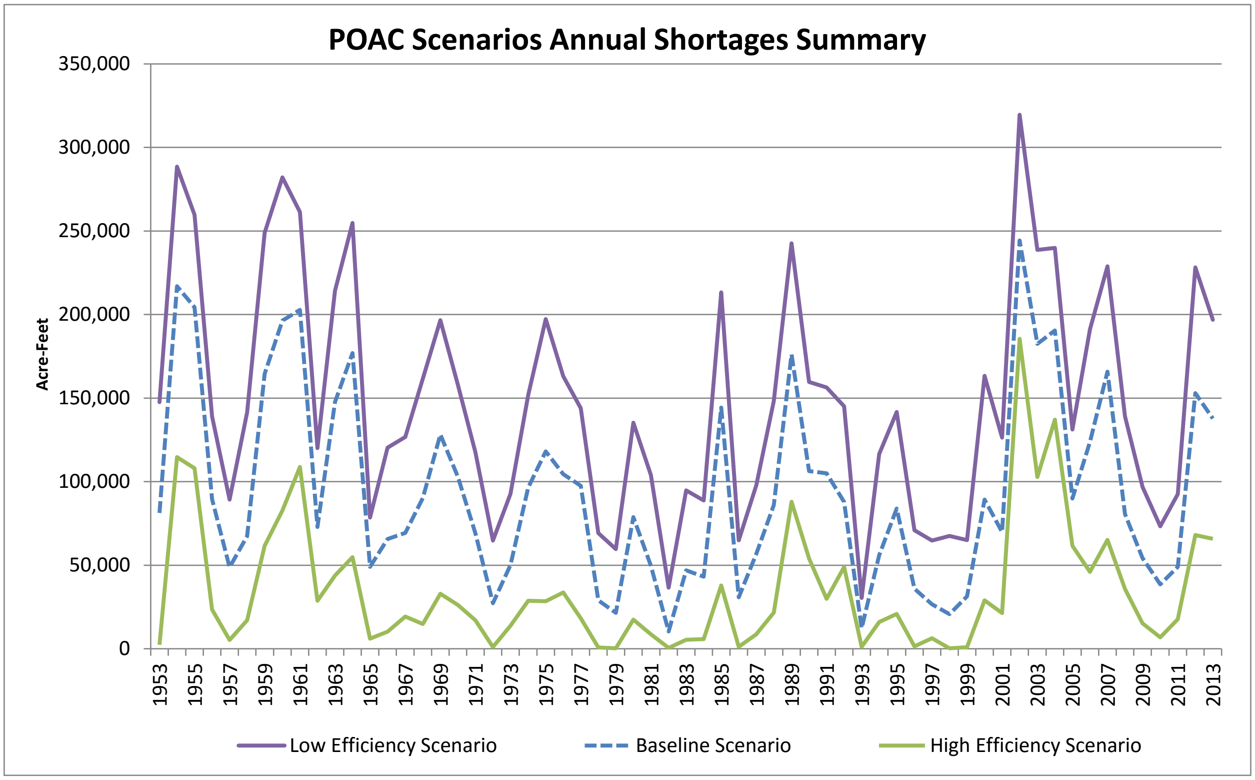


Figure 11: Return Flow Summary

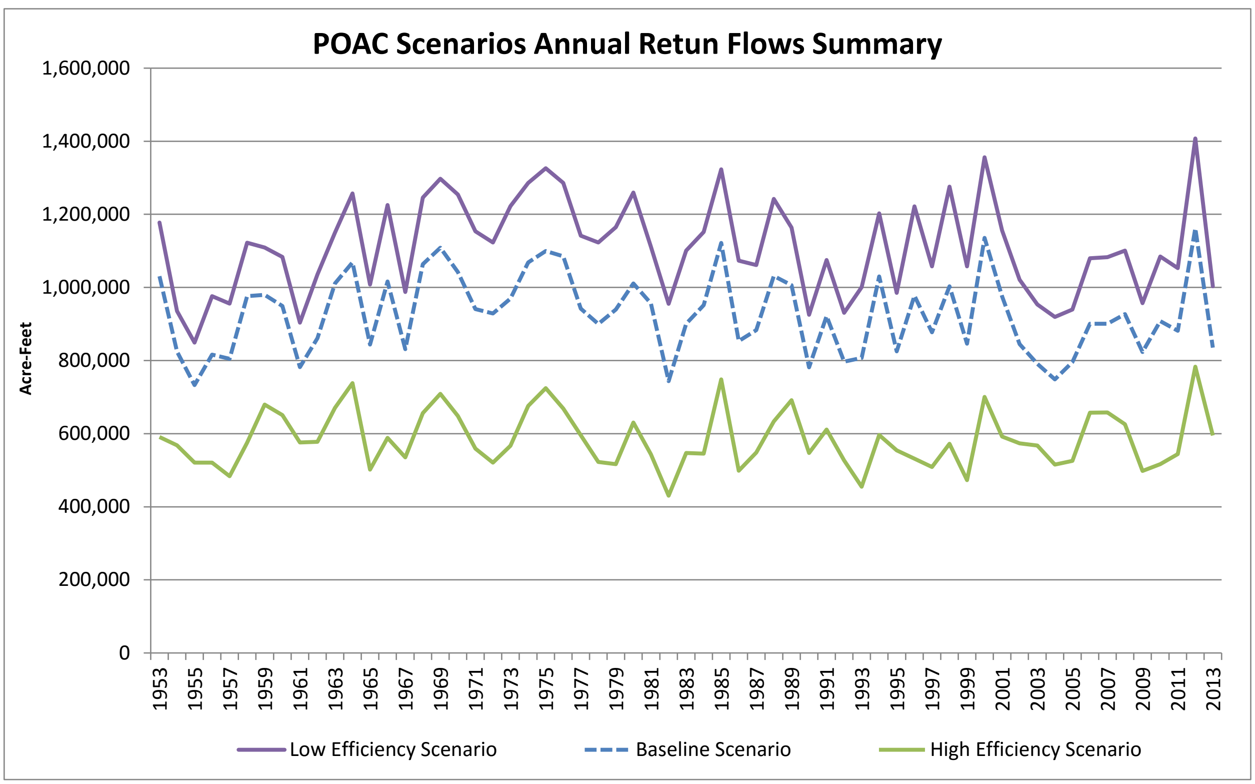


Figure 12: Annual Streamflow Summary

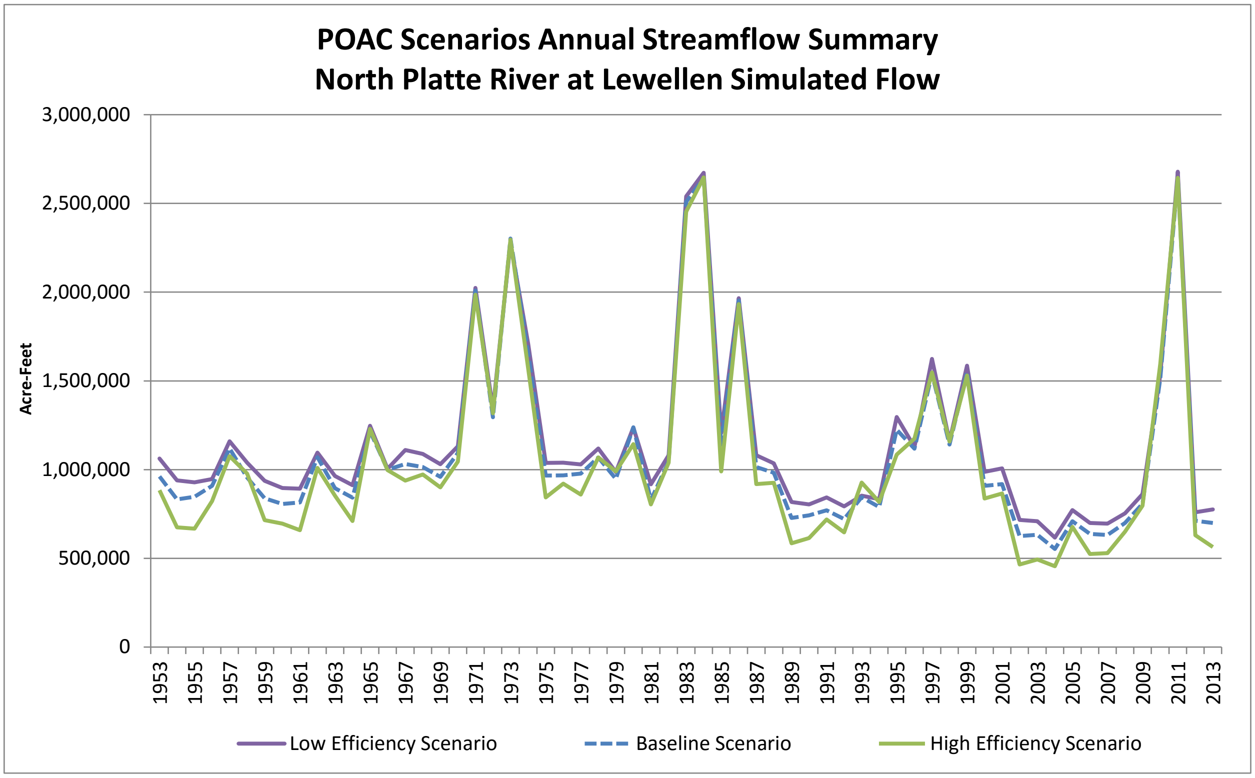


Figure 13: Average Monthly Streamflow Summary

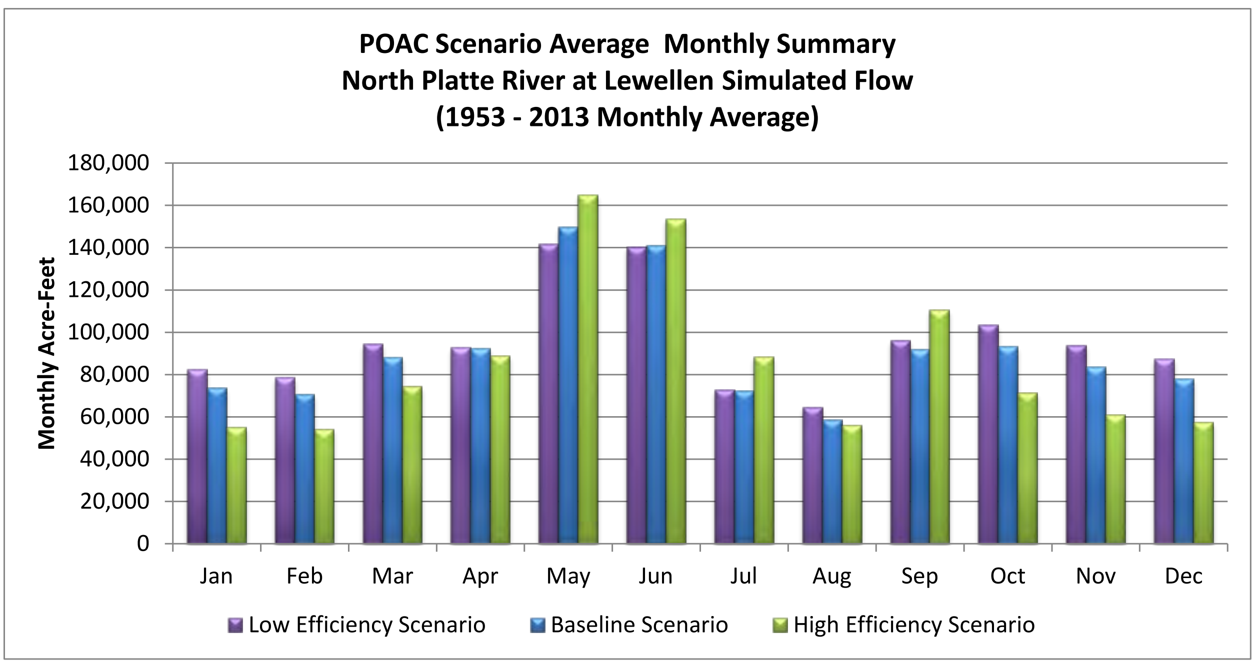
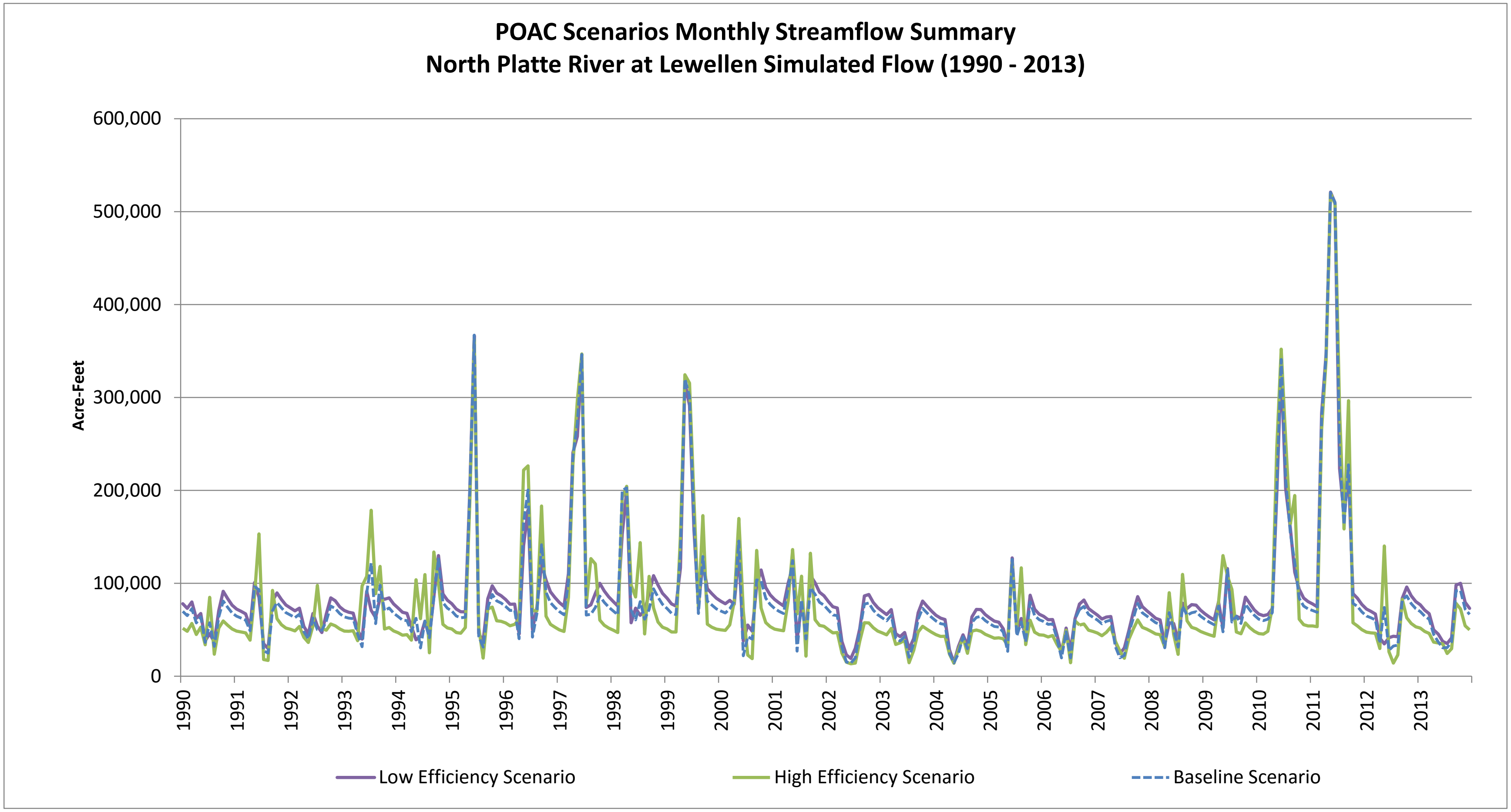


Figure 14: Monthly Streamflow Summary



Adaptive Resources, Inc.

To: File
From: Thad Kuntz, P.G., Heath Kuntz, Joe Reedy, G.I., and Jason Yuill
CC:
Date: 9/1/2017
Re: Conservation Measures Study - Ground Water Modeling Analysis and Results

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INTRODUCTION AND EXECUTIVE SUMMARY

The Conservation Measures Study (Study) uses the Western Water Use Management Modeling (WWUMM) suite of models to estimate the effects of different irrigation efficiency and tillage practices on the ground and surface water resources in the North Platte and South Platte Natural Resources Districts (Districts). The Study is comprised of four analyses, comparing four modified simulations to a historical baseline simulation using the surface water operation model, ground water model, and regionalized soil water balance model. The study period used the existing model's time frame of May 1953 through April 2013.

The first two analyses modeled changes in irrigation practices as compared to the baseline simulation. The irrigation practices considered were low and high irrigation application efficiencies required to meet crop irrigation demands. The baseline simulates historical irrigation efficiencies while the low irrigation efficiency simulation utilizes irrigation applied through either flood irrigation or inefficient early center pivot sprinklers. The high irrigation efficiency simulation applies irrigation using highly efficient sprinkler irrigation technology.

Like the irrigation practice analyses, the tillage practice analyses used a baseline simulation that employs the historical tillage practices on irrigated lands. The baseline simulation was compared to two simulations using either circa-1950's tillage practices or a minimum tillage, or no-till simulation. Each simulation maintained these practices over all irrigated lands and years.

The results of the Study indicate that the effects of each practice vary between the Districts. North Platte Natural Resources District (NPNRD) realizes increased stream baseflow as a result of low efficiency irrigation methods and minimum tillage practices. The increase in stream baseflow from low-efficiency irrigation methods is likely an effect of the additional recharge that occurs from increased surface water diversions in response to the higher irrigation demand, as the North Platte River is a surface water dominated system with an abundance of canals. To a smaller degree, a minimum till approach also has the potential to increase stream baseflow by increasing the amount of recharge into the aquifer through higher infiltration rates and reduced soil evaporation. South Platte Natural Resources District (SPNRD) sees increased stream baseflow as a result of high efficiency irrigation methods and minimum tillage practices. The South Platte River and Lodgepole Creek systems are ground water dominated and may realize greater stream baseflow (or decreased stream baseflow depletion in losing reaches) from decreases in ground water withdrawals, which reduces ground water capture prior to entering the Lodgepole Creek or South Platte River. A minimum till approach has a similar impact in SPNRD as NPNRD. Graphs representing pumping, recharge, and stream baseflow are provided in the text of this report.

CONCEPTUAL DESIGN OF THE ANALYSES

The simulations conducted for this study were completed by modifying the historic irrigation efficiencies and tillage practices of the WWUMM. These modifications are applied throughout the modeling time frame of 1953 through 2013. The following is a list and description of each model simulation and the accompanying modifications:

- Baseline Model – No modifications, irrigation efficiencies and tillage practices reflect historic values and practices.
- High Irrigation Efficiency - All irrigated lands irrigation efficiencies were set at center pivot sprinkler efficiency of 95%.
- Low Irrigation Efficiency – All irrigated lands irrigation efficiencies were set at flood/gravity or low-efficiency center pivot sprinkler irrigation of 50% or 60% respectively.
- Minimum or No Tillage Practices – All irrigated lands tillage practices were set to minimum tillage or no till practices depending on the crop type.
- Circa-1950's Tillage Practices – All irrigated lands tillage practices were set to conventional tillage practices prevalent in the 1950's.

The results from each modified model are compared to the baseline model result. The comparison provides the estimated change in stream baseflow (ground water portion of total streamflow) as a consequence of the different pumping and tillage scenarios.

MODELING ANALYSES

The WWUMM suite is comprised of a regionalized soil water balance (RSWB) model, surface water operations (SWO) model, and ground water (GW) model. The model area includes the Southern Panhandle of Nebraska as well as portions of Colorado and Wyoming. For this Study, simulations were carried out by The Flatwater Group (TFG, operating the RSWB model), Wilson Water Group (WWG, operating the SWO model), and Adaptive Resources, Inc. (ARI, operating the GW model). Using the existing WWUMM, the following changes were made to generate a baseline model for these analyses.

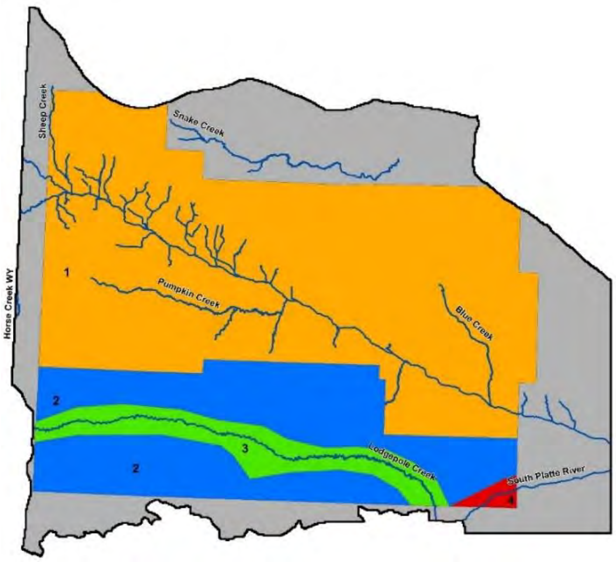
1. The original WWUMM SWO model was modified to create a new baseline model, in which all surface water lands are considered to be mutual ditch, and all users within a canal system share the surface water equally. This change may affect the surface water diversion demands and commingled pumping. In the original modeling, two methods were employed, determined by the amount of diversion and the pumping characteristics of each irrigation district or canal company.
2. If additional storage water was available in the Wyoming reservoirs, the SWO model could utilize that excess water.
3. Only modeled pumping estimates were used to complete a comparison with each conservation practice. Without using metered pumping, the models can determine the change in surface water deliveries, pumping, recharge, and stream baseflow without confusing the comparison with allocation pumping restrictions.

To complete each modified modeling analysis, TFG modified the irrigation efficiencies and tillage practices of the baseline RSWB model to generate net irrigation requirement, recharge, and ground water only pumping datasets. Using information from the RSWB model, the SWO model simulated the surface water system and generated canal recharge and commingled pumping. These datasets were provided to ARI in the form of recharge and pumping which was incorporated with the steady-state municipal, industrial, feedlot, and domestic wells. The final well and recharge files were used in the GW model analyses.

The hydrostratigraphic unit process is a zonal analysis tool that tracks changes in ground water flow and volume at specific model cells. For this Study, the active model area was partitioned based on NRD boundaries, as well as roughly estimated basin boundaries (determined from pumping distribution) in

SPNRD. The map of zones used in the hydrostratigraphic unit process is demonstrated in Figure 1. Zone one encompasses NPNRD, zones two through four encompass SPNRD, with zone three isolating Lodgepole Creek and zone 4 isolating the South Platte River in SPNRD. Figure 1 demonstrates the hydrostratigraphic unit zones used in all analyses.

Figure 1 – Partitioned Ground Water Model Area



MODEL RESULTS

The following ground water model components were summarized by month to complete a total water budget and change analysis:

- Stream baseflow
- General head boundaries (representing lakes)
- Evapotranspiration (ET)
- Well pumping
- Ground water storage

The simplified calculation below is used to determine impacts to the surface water system for the analysis:

$$Modified\ Model - Baseline\ Model\ = Ground\ Water\ Impacts$$

The monthly change in stream baseflow in the North Platte River (including tributaries), Lodgepole Creek, and the South Platte River for the different scenarios was converted to annual volumes for evaluation of the simulation results. The recharge and pumping rates were similarly converted to annual volumes for comparison to stream baseflow. The recharge and pumping volumes include all recharge or pumping simulated flows that occurred in each District, or in each basin (Figure 1). Figure 2 provides the annual change in stream baseflow for the North Platte River (and tributaries) in the NPNRD.

Figure 2 - Annual Change in Stream Baseflow NPNRD: Irrigation Efficiency

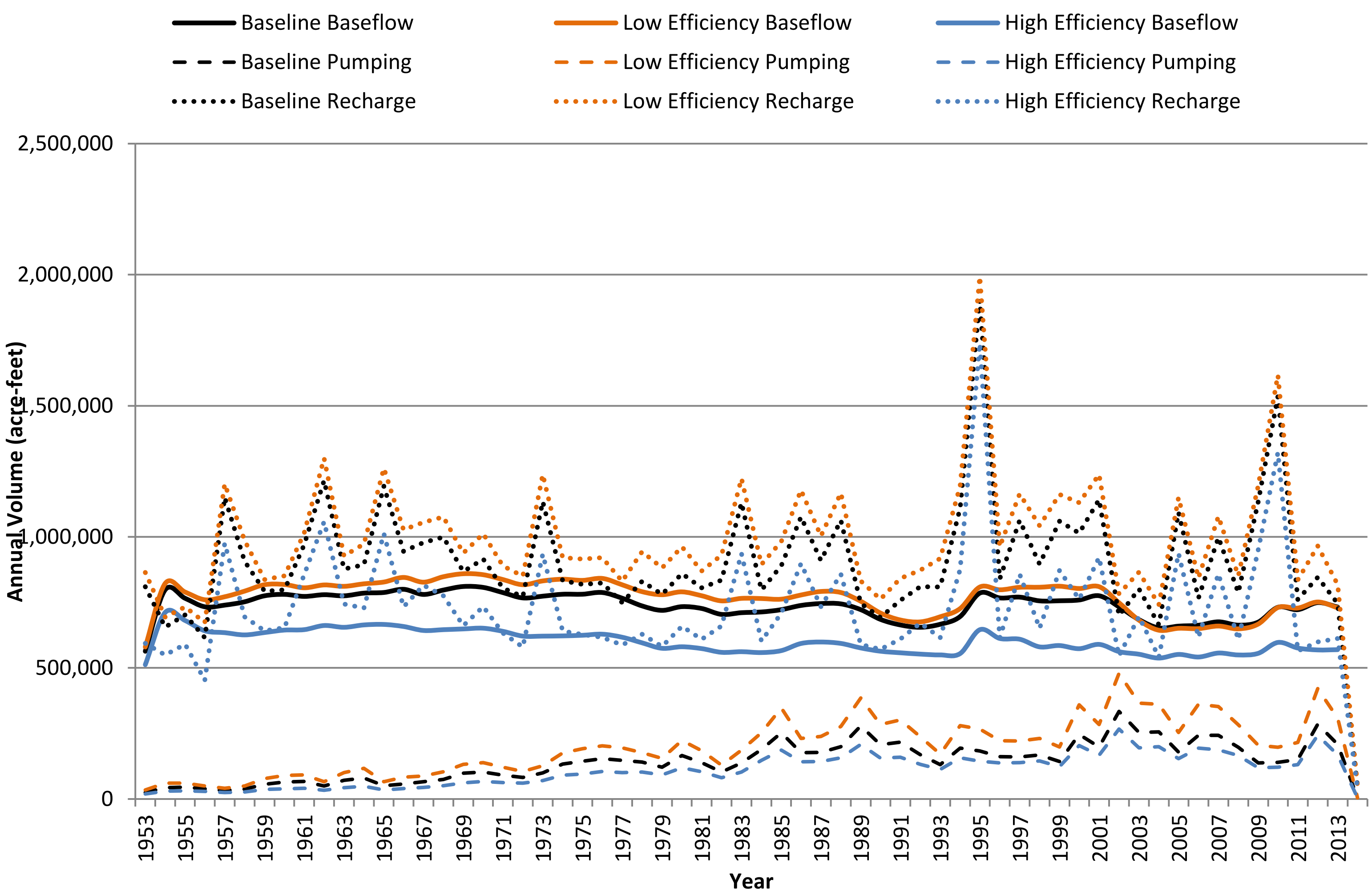


Figure 3 provides the annual change in stream baseflow for Lodgepole Creek and the South Platte River in SPNRD.

Figure 3 - Annual Change in Stream Baseflow SPNRD: Irrigation Efficiency

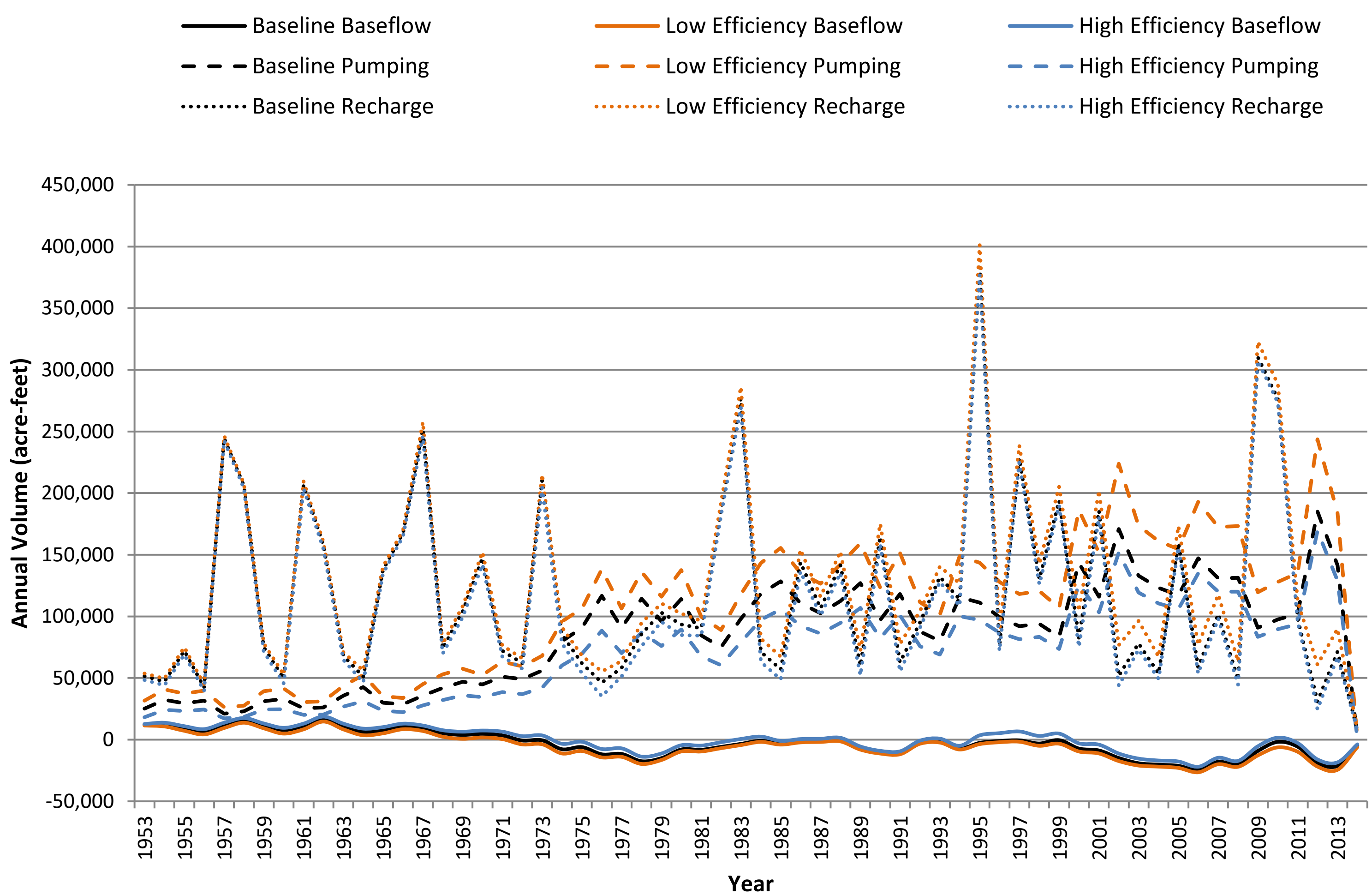


Figure 4 provides the annual change in stream baseflow for the South Platte River in the SPNRD.

Figure 4 - Annual Change in Stream Baseflow in Lodgepole Creek Only: Irrigation Efficiency

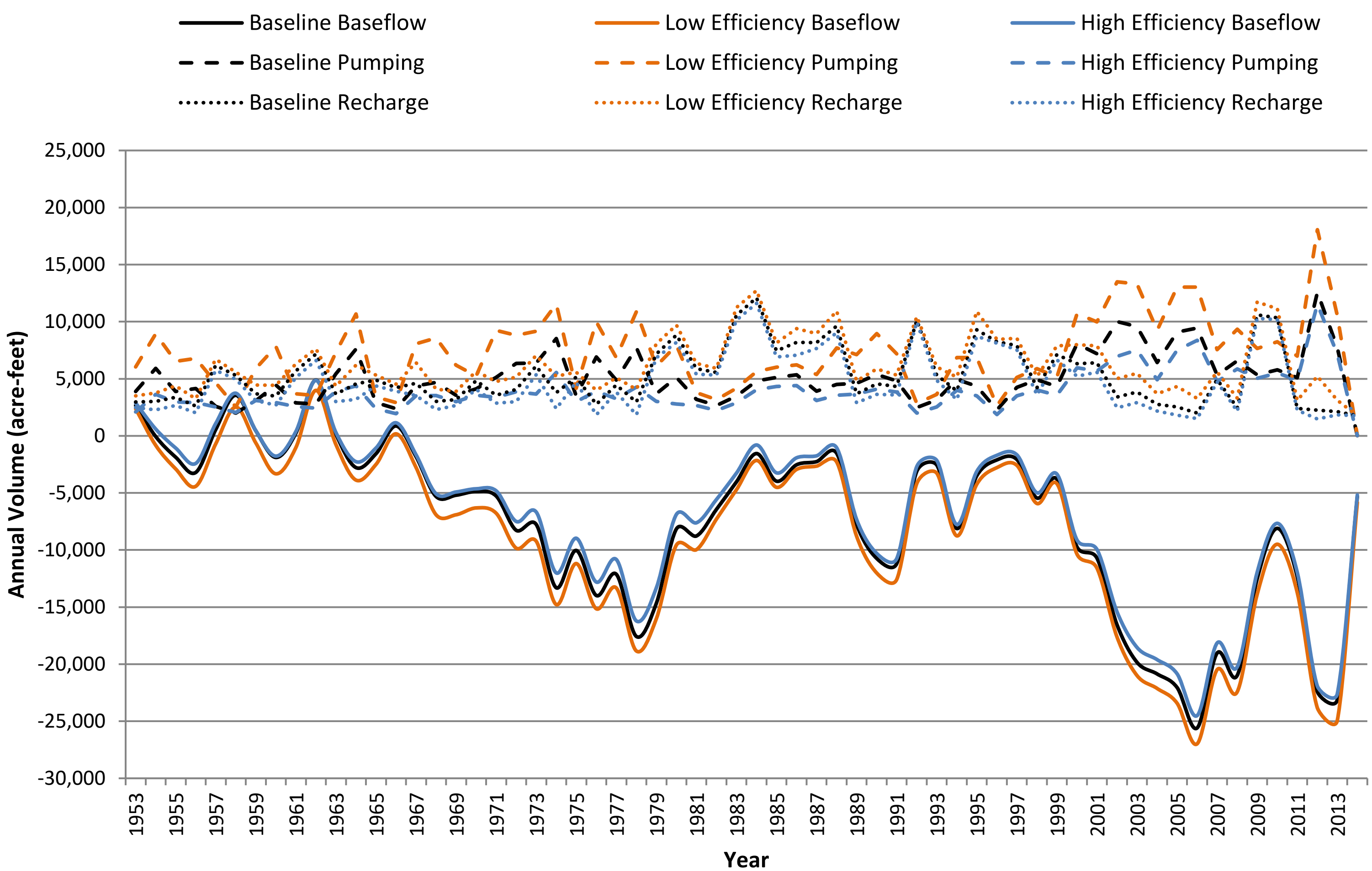


Figure 5 provides the annual change in stream baseflow for Lodgepole Creek in the SPNRD.

Figure 5 - Annual Change in Stream Baseflow in the South Platte River Only: Irrigation Efficiency

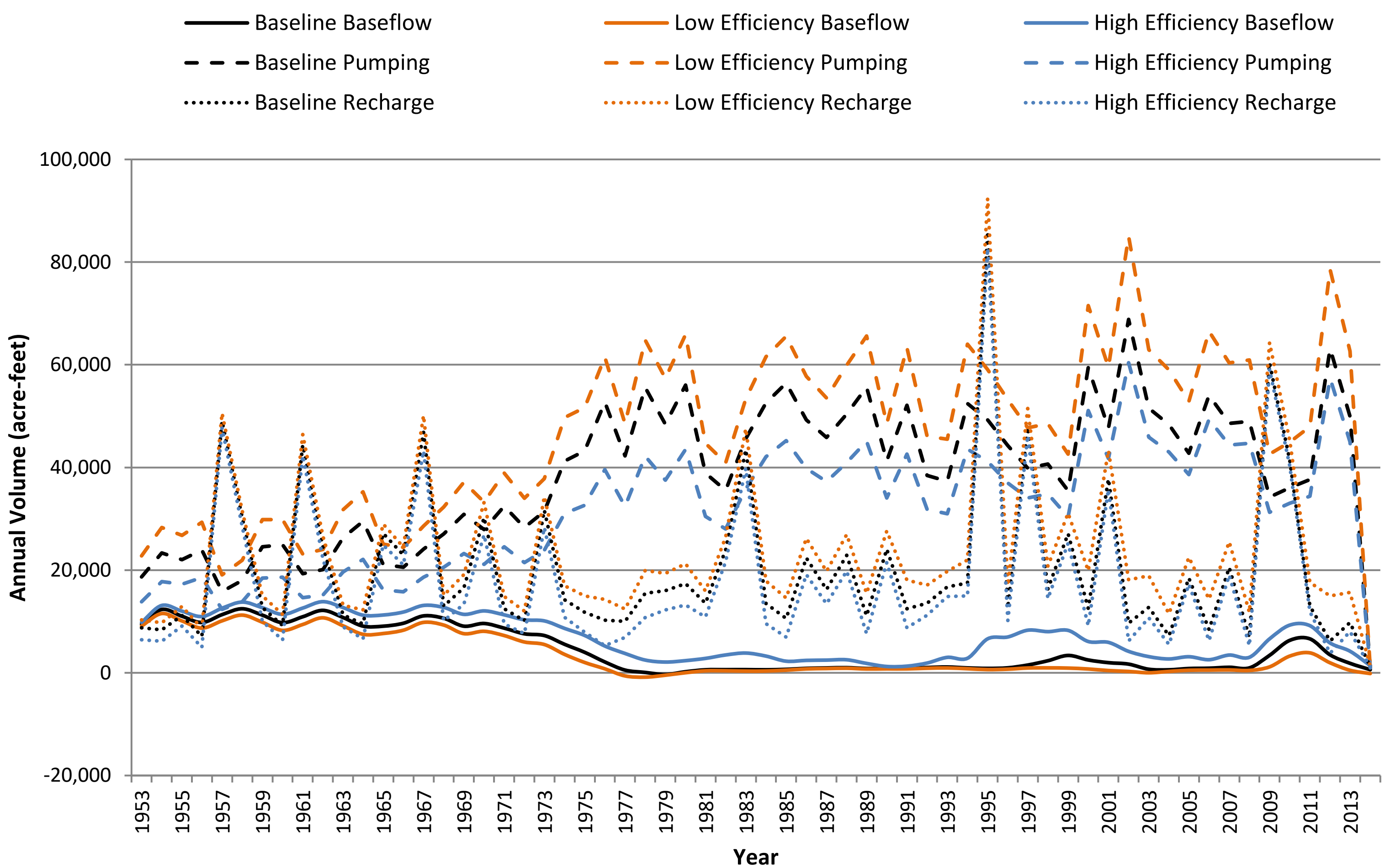


Figure 6 provides the annual change in stream baseflow for the North Platte River (and tributaries) in the NPNRD.

Figure 6 - Annual Change in Stream Baseflow in the South Platte River Only: Tillage Practices

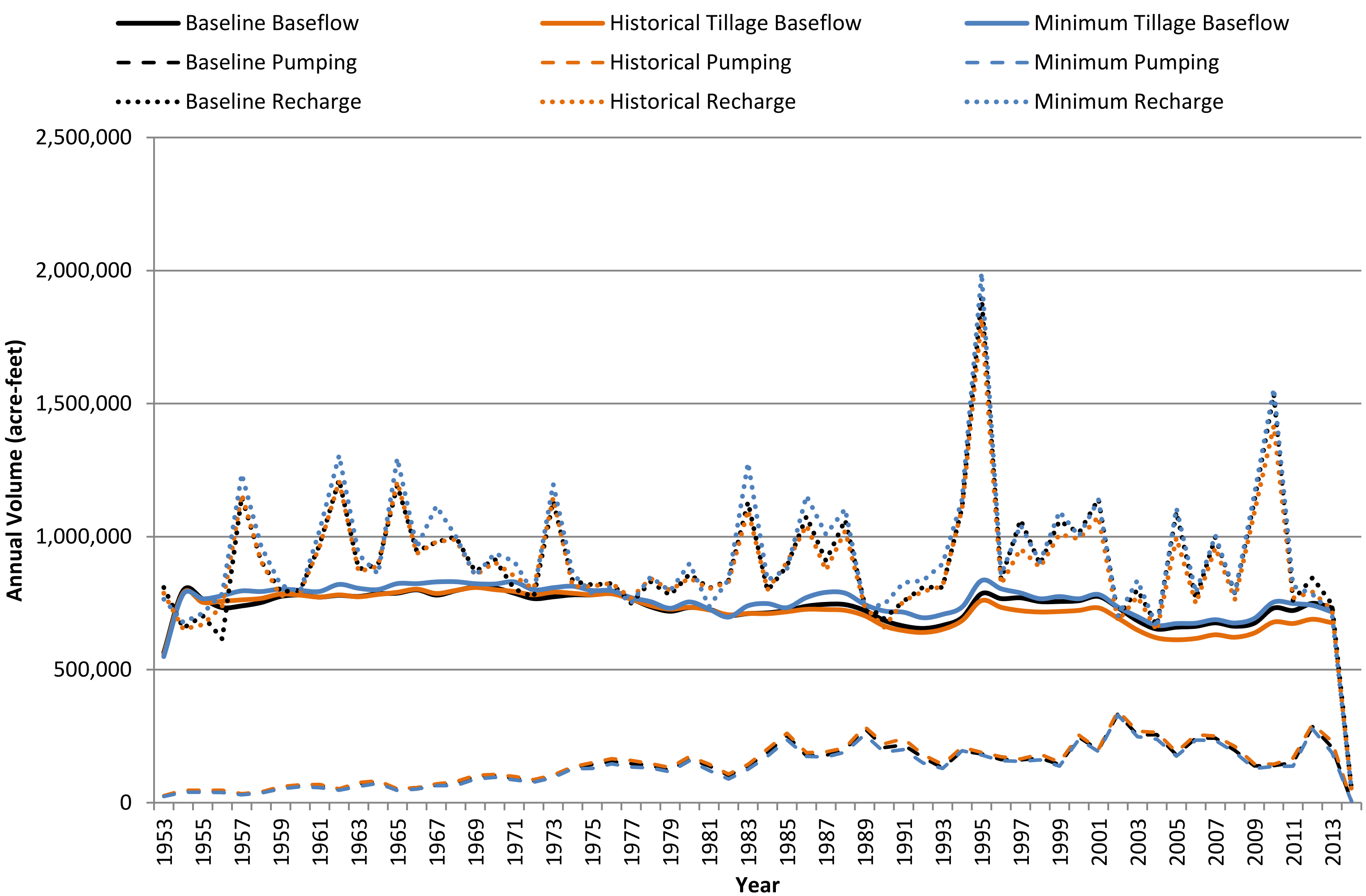


Figure 7 provides the annual change in stream baseflow for Lodgepole Creek and the South Platte River in SPNRD.

Figure 7 - Annual Change in Stream Baseflow SPNRD: Tillage Practices

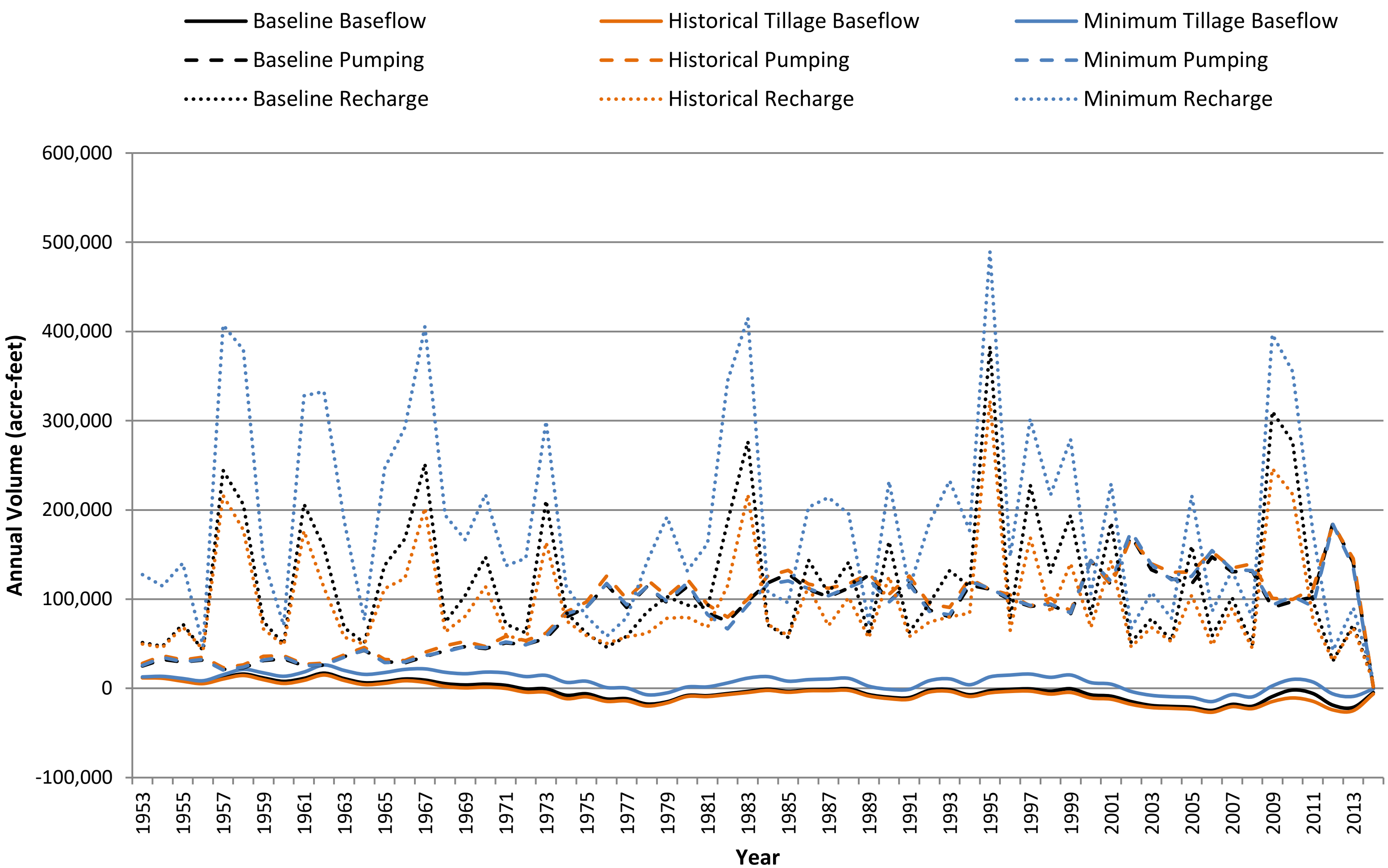


Figure 8 provides the annual change in stream baseflow for the South Platte River in the SPNRD.

Figure 8 - Annual Change in Stream Baseflow in Lodgepole Creek Only: Tillage Practices

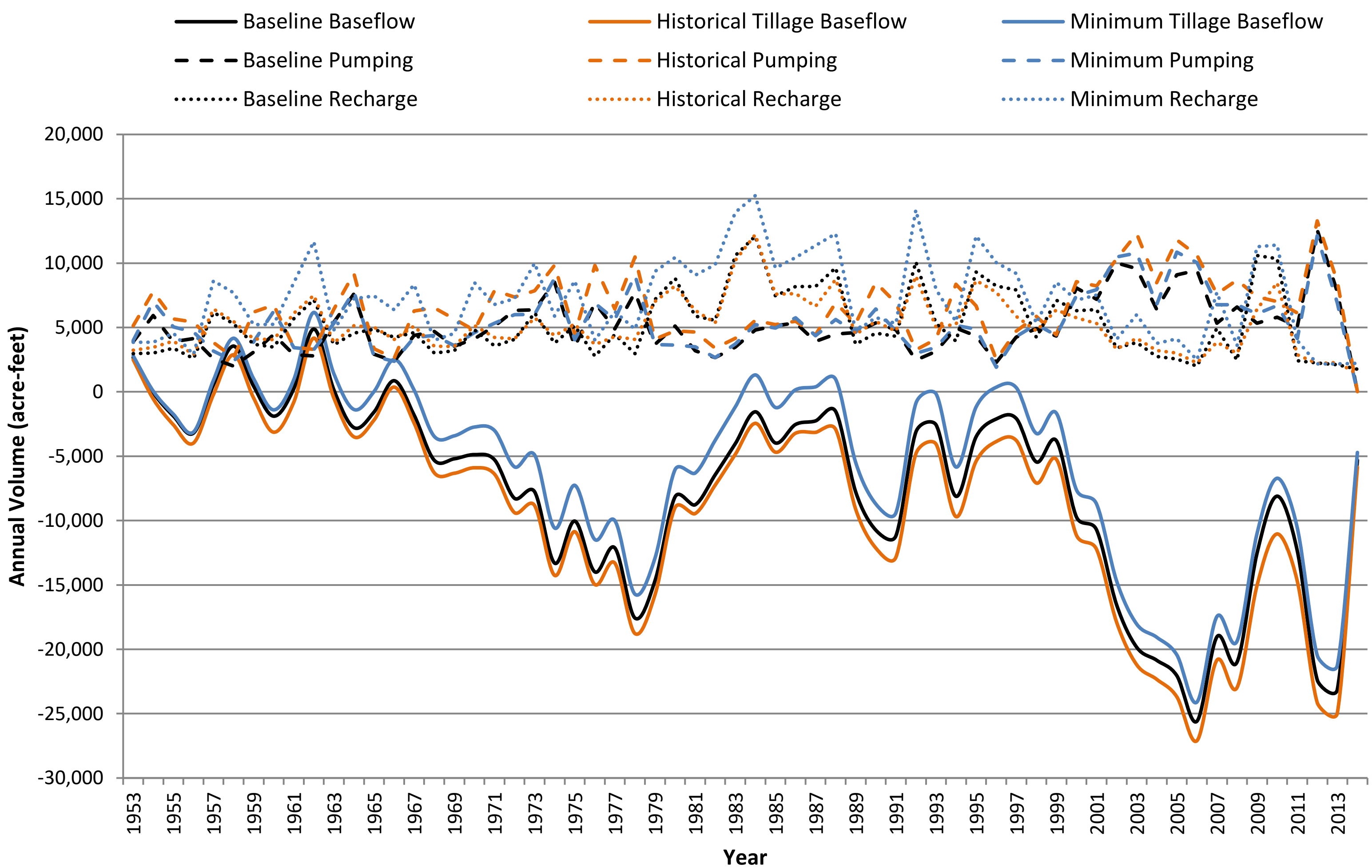
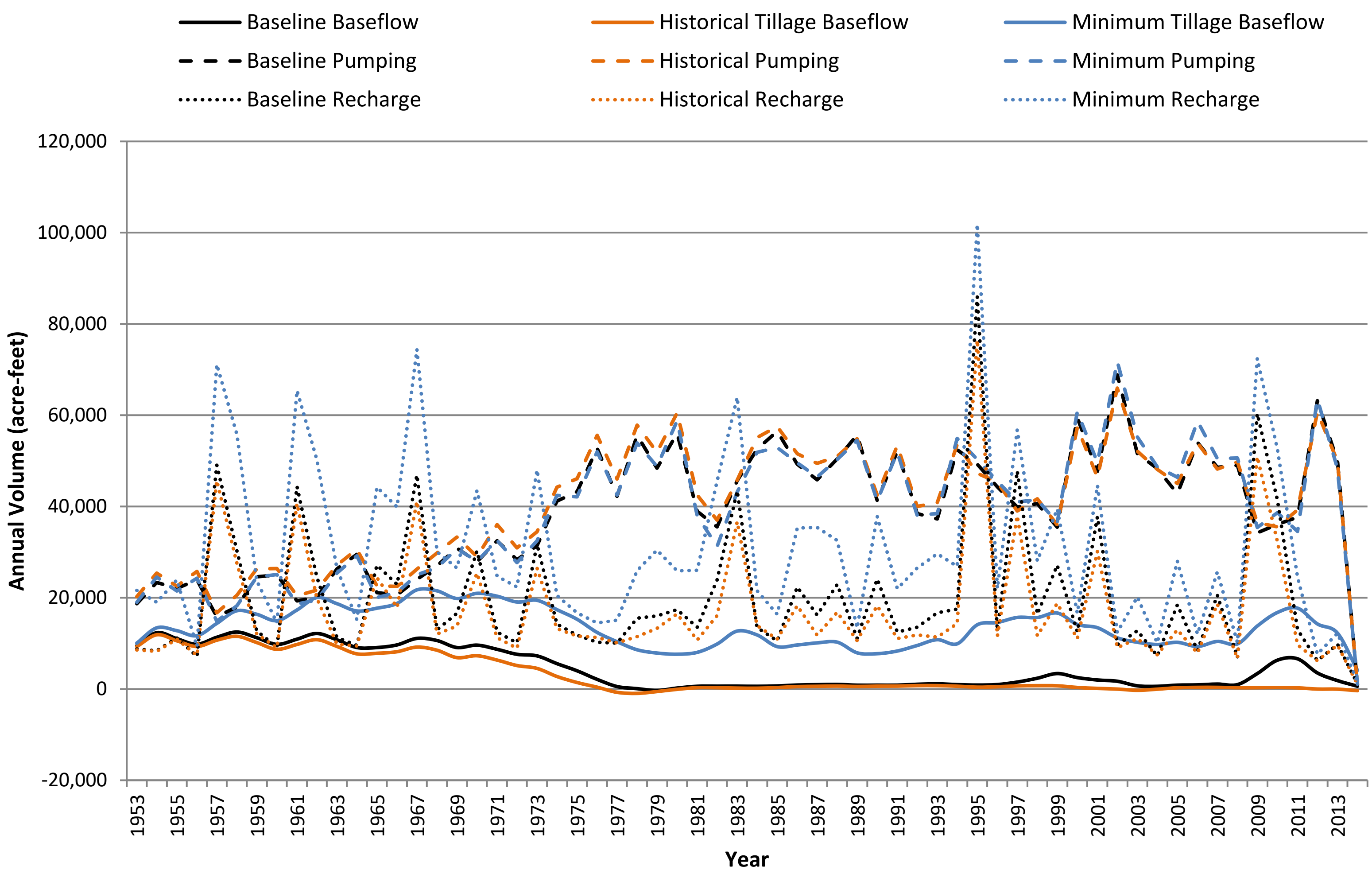


Figure 9 provides the annual change in stream baseflow for Lodgepole Creek in the SPNRD.

Figure 9 - Annual Change in Stream Baseflow in Lodgepole Creek Only: Tillage Practices



Conservation Study: Western Water Use Model
Efficiency Scenarios
December 19, 2017

Scenario Purpose:
The Conservation Study was initiated to evaluate and quantify within each NRD the impact that selected conservation practices have on stream flow. The Efficiency Scenarios explore how the system would respond to alternative means of applying irrigation water to the field throughout the simulation period. Two scenarios were investigated; a High Efficiency Scenario and a Low Efficiency Scenario.

Baseline Description:
The Baseline Scenario represents the standard from which to compare subsequent scenarios. For the Conservation Study, a modified version of the Historically Calibrated Model (Run028) was employed over the period: May 1953 through April 2014. The Baseline Scenario used the historical land use development, and on farm production practices and irrigation management techniques modeled over the simulation period with historic climate conditions. The following changes were made to the Historically Calibrated Model to create the Conservation Study baseline:

Watershed Model
- All groundwater irrigated land is simulated to meet a target NIR. No metered pumping is used

Surface Water Operations Model[1]
- All canals were converted to use a 'mutual ditch' approach for comingled irrigation volumes
- Additional upstream storage water could be made available if needed

Groundwater Model
-

High Efficiency Scenario Description:
The High Efficiency Scenario investigated the impact of converting all irrigated acres within the WWUM Region 1[2] to high efficiency application methods and its effect on diversions, pumping, recharge, aquifer levels, baseflow, and stream flow. The following changers were made to the baseline model to implement this scenario:

Watershed Model
- The irrigation application efficiency in Region 1 was changed to 95% for both sprinkler and flood irrigated parcels.

Surface Water Operations Model
*See attached report

No changes were made to the baseline Groundwater Model. Rather, scenario results reflect changes to inputs resulting from changes to the watershed model and surface water operations model.

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[1] This represents a summary of the major changes to the surface water operations model; further detail is available in the attached report.
[2] Region 1 consists of the NPNRD, SPNRD, and dryland pasture areas in Wyoming and Colorado.

Low Efficiency Scenario Description:
The Low Efficiency Scenario investigated the impact of converting all irrigated acres within the WWUM Region 1 to low efficiency application methods and its effect on diversions, pumping, recharge, aquifer levels, baseflow, and stream flow. The following changes were made to the baseline model to implement this scenario:

Watershed Model
- The irrigation application efficiency for sprinkler irrigated lands was changed to 60%
- The irrigation application efficiency for flood irrigated lands was changed to 50%

Surface Water Operations Model
*See attached report

No changes were made to the baseline Groundwater Model. Rather, the scenario results reflect changes to inputs resulting from changes to the watershed model and surface operations model.

Surface Water Model Results:
*See attached report

Watershed Model Results:

Table 1. Groundwater pumping by Natural Resources District – 1953-2013 (AF)

NRD	Baseline	Low Efficiency		High Efficiency	
	Volume	Volume	Change	Volume	Change
North Platte	8,961,000	13,282,000	4,321,000	6,599,000	(2,362,000)
South Platte	5,963,000	8,040,000	2,077,000	4,728,000	(1,235,000)

Table 2. Surface water deliveries by Natural Resources District – 1953-2013 (AF)

NRD	Baseline	Low Efficiency		High Efficiency	
	Volume	Volume	Change	Volume	Change
North Platte	32,001,000	34,613,000	2,612,000	24,761,000	(7,240,000)
South Platte	364,000	364,000	-	364,000	-

Table 3. Recharge by Natural Resources District – 1953-2013 (AF)

NRD	Baseline	Low Efficiency		High Efficiency	
	Volume	Volume	Change	Volume	Change
North Platte	26,903,000	29,959,000	3,056,000	22,974,000	(3,929,000)
South Platte	7,323,000	7,922,000	599,000	6,994,000	(329,000)

Groundwater Model Results:
**See attached report

Conservation Study: Western Water Use Model
Tillage Scenarios
December 19, 2017

Scenario Purpose:
The Conservation Study was initiated to evaluate and quantify within each NRD the impact that selected conservation practices have on stream flow. The Tillage Scenarios explore how the system would respond to alternative tillage practices being used exclusively throughout the simulation period. Two scenarios were investigated; a minimum Tillage Scenario and a Circa 1950's Tillage Scenario.

Baseline Description:
The Baseline Scenario represents the standard from which to compare subsequent scenarios. For the Conservation Study, a modified version of the Historically Calibrated Model (Run028) was employed over the period: May 1953 through April 2014. The Baseline Scenario used the historical land use development, and on farm production practices and irrigation management techniques modeled over the simulation period with historic climate conditions. The following changes were made to the Historically Calibrated Model to create the Conservation Study baseline:

Watershed Model
- All groundwater irrigated land is simulated to meet a target NIR. No metered pumping is used

Surface Water Operations Model[1]
- All canals were converted to use a 'mutual ditch' approach for comingled irrigation volumes
- Additional upstream storage water could be made available if needed

Groundwater Model
-

Minimum Tillage Scenario Description:
The Minimum Tillage Scenario investigated the impact of minimizing the number of tillage practices throughout the year. Minimum tillage was defined as limiting the operation to:

1. Only a planting operation for tilled crops
2. A planting operation preceded by a field cultivator operation 3 days prior (sugar beets, potatoes, and dry edible beans)
3. No changes on perennial forage crops

Limiting the tillage developed a new system response on agricultural fields. This response was applied to the historical land use and climate to investigate the effects on diversions, pumping, recharge, aquifer levels, base flow, and stream flow. The following changes were made to the baseline model to implement this scenario:

[1] This represents a summary of the major changes to the surface water operations model; further detail is available in the attached report.

Watershed Model

- Modifications were made to the soil water balance model CROPSIM
    + A new set of '*simfiles*' were created with minimum tillage practices (Tables 4-11)
    + CROPSIM was used to generate irrigated and dryland results for each crop on each soil at every WWUM weather station over the simulation period
- The CROPSIM results were spatially distributed to create a new set of Water Balance Parameters for the Regionalized Soil Water Balance model
    + This includes new parcel NIR values provided to the surface water operations model

No changes were made to the baseline Surface Water Operations Model or the Groundwater Model. Rather, the scenario results reflect changes to inputs resulting from changes to the watershed model.

<u>Circa 1950's Tillage Scenario Description:</u>

The Circa 1950s Tillage Scenario investigated the impact of implementing tillage practices common in the middle of the 20th century throughout the simulation period. Tillage practices during this time frequently turned the topsoil and destroyed much of the residue on the soil surface. The Circa 1950's Tillage developed a new system response on agricultural fields. This response was applied to the historic land use and climate to investigate the effect on diversions, pumping recharge, aquifer levels, base flow, and stream flow. The following changes were made to the baseline model to implement this scenario:

Watershed Model

- The results of the CROPSIM run using the '*49*' '*simfile*' data set (Tables 4-11) were expanded through 2014
- Temporal distribution of the CROPSIM results was omitted, rather the '*49*' results were spatially distributed to create a new set of Water Balance Parameters for the Regionalized Soil Water Balance model
    + This includes new parcel NIR values provided to the surface water operations model

<u>Surface Water Model Results:</u>

**See attached Report*

<u>Watershed Model Results:</u>

Table 1. Groundwater pumping by Natural Resources District – 1953-2013 (AF)

	Baseline	Circa 1950's Tillage Scenario		Minimum Tillage Scenario	
NRD	Volume	Volume	Change	Volume	Change
North Platte	8,961,000	9,610,000	649,000	8,269,000	(692,000)
South Platte	5,963,000	6,584,000	621,000	5,659,000	(304,000)

Table 2. Surface water deliveries by Natural Resources District – 1953-2013 (AF)

	Baseline	Circa 1950's Tillage Scenario		Minimum Tillage Scenario	
NRD	Volume	Volume	Change	Volume	Change
North Platte	32,001,000	32,179,000	178,000	28,967,000	(3,034,000)
South Platte	364,000	364,000	-	364,000	-

Table 3. Recharge by Natural Resources District – 1953-2013 (AF)

NRD	Baseline Volume	Circa 1950's Tillage Scenario Volume	Circa 1950's Tillage Scenario Change	Minimum Tillage Scenario Volume	Minimum Tillage Scenario Change
North Platte	26,903,000	26,000,000	(903,000)	31,345,000	4,442,000
South Platte	7,323,000	5,901,000	(1,422,000)	11,582,000	4,259,000

Groundwater Model Results:

**See attached Report*

<u>Summary of Tillage Practices:</u>

Table 4. Tillage practices for Corn

Circa 1949	
Tandem/Offset Disk - Secondary Tillage	-67
Tandem/Offset Disk - Secondary Tillage	-58
Moldboard Plow	-43
Harrow - Packer Roller	-36
Harrow - Spike Tooth	-22
Finishing - Disks, Shanks, Leveling	-6
Rowcrop Planter - Smooth Coulters	1
Rotary Hoe	18
Row Cultivator - Multiple Sweeps	34
Row Cultivator - Multiple Sweeps	55

Circa 1973	
Knife Applicator	-43
Moldboard Plow	-27
Harrow - Roller	-20
Rowcrop Planter - Ripple/Bubble Coulters	1
Row Cultivator - Multiple Sweeps	18
Row Cultivator - Multiple Sweeps	49

Circa 1998	
Stalk Chopper	-35
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Minimum Till	
Rowcrop Planter - Double-disk Openers	1

Table 5. Tillage practices for Dry Edible Beans

Circa 1949	
Tandem/Offset Disk - Secondary Tillage	-101
Tandem/Offset Disk - Secondary Tillage	-94
Moldboard Plow	-61
Harrow - Packer Roller	-56
Harrow - Spike Tooth	-26
Finishing - Disks, Shanks, Leveling	-9
Rowcrop Planter - Smooth Coulters	1
Row Cultivator - Multiple Sweeps	14
Row Cultivator - Multiple Sweeps	21
Rodweeder - Plain	(1)

Circa 1973	
Tandem/Offset Disk - Secondary Tillage	-92
Tandem/Offset Disk - Secondary Tillage	-85
Moldboard Plow	-61
Harrow - Roller	-47
Field Cultivator - Secondary Duckfoot Points	-17
Harrow - Roller	-12
Rowcrop Planter - Ripple/Bubble Coulters	1
Row Cultivator - Multiple Sweeps	19
Row Cultivator - Multiple Sweeps	29
Rodweeder - Plain	(1)

Circa 1998	
Tandem/Offset Disk - Primary Tillage	-30
Tandem Disk - Light	-10
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	20
Field Cultivator - Secondary 12-20inch Sweep	40
Undercutter Plow: V-Blade 20-30inch	(3)

Minimum Till	
Field Cultivator - Primary Duckfoot Points	-3
Rowcrop Planter - Double-disk Openers	1

Table 6. Tillage practices for Dry Sugar Beets

Circa 1949	
Tandem/Offset Disk - Primary Tillage	-20
Moldboard Plow	-14
Tandem Disk - Light	-3
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	35
Knife Applicator	50
Field Cultivator - Secondary 12-20inch Sweep	65
Rotary Tiller - 6inch deep - Similar to Lifter	(3)
Tandem/Offset Disk - Secondary Tillage	(7)

Circa 1973	
Tandem/Offset Disk - Primary Tillage	-20
Moldboard Plow	-14
Tandem Disk - Light	-3
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	35
Knife Applicator	50
Field Cultivator - Secondary 12-20inch Sweep	65
Rotary Tiller - 6inch deep - Similar to Lifter	(3)
Tandem/Offset Disk - Secondary Tillage	(7)

Circa 1998	
Tandem/Offset Disk - Primary Tillage	- 20
Moldboard Plow	- 14
Tandem Disk - Light	-3
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	35
Knife Applicator	50
Field Cultivator - Secondary 12-20inch Sweep	65
Rotary Tiller - 6inch deep - Similar to Lifter	(3)
Tandem/Offset Disk - Secondary Tillage	(7)

Minimum Till	
Field Cultivator - Primary Duckfoot Points	-3
Rowcrop Planter - Double-disk Openers	1

Table 7. Tillage practices for Irrigated Sugar Beets

Circa 1949	
Moldboard Plow	-31
Harrow - Packer Roller	-25
Harrow - Spike Tooth	-17
Finishing - Disks, Shanks, Leveling	-7
Rowcrop Planter - Smooth Coulters	1
Rotary Hoe	19
Row Cultivator - Multiple Sweeps	34
Row Cultivator - Multiple Sweeps	61
Row Cultivator - Multiple Sweeps	85
Rotary Tiller - Primary Tillage - 6" deep	(1)

Circa 1973	
Tandem Disk - Light	-31
Moldboard Plow	-27
Harrow - Packer Roller	-22
Harrow - Spike Tooth	-7
Harrow - Roller	-4
Rowcrop Planter - Smooth Coulters	1
Rotary Hoe	19
Row Cultivator - Multiple Sweeps	34
Row Cultivator - Multiple Sweeps	61
Rotary Tiller - Primary Tillage - 6" deep	(1)

Circa 1998	
Tandem/Offset Disk - Primary Tillage	-20
Moldboard Plow	-14
Tandem Disk - Light	-3
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	35
Knife Applicator	50
Field Cultivator - Secondary 12-20inch Sweep	65
Rotary Tiller - 6inch deep - Similar to Lifter	(3)
Tandem/Offset Disk - Secondary Tillage	(7)

Minimum Till	
Field Cultivator - Primary Duckfoot Points	-3
Rowcrop Planter - Double-disk Openers	1

Table 8. Tillage practices for Potatoes

Circa 1949	
Tandem/Offset Disk - Primary Tillage	-20
Moldboard Plow	-14
Tandem Disk - Light	-3
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	25
Knife Applicator	35
Field Cultivator - Secondary 12-20inch Sweep	50
Rotary Tiller - 6inch deep - Similar to Lifter	(2)
Tandem/Offset Disk - Secondary Tillage	(7)

Circa 1973	
Tandem/Offset Disk - Primary Tillage	-20
Moldboard Plow	-14
Tandem Disk - Light	-3
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	25
Knife Applicator	35
Field Cultivator - Secondary 12-20inch Sweep	50
Rotary Tiller - 6inch deep - Similar to Lifter	(2)
Tandem/Offset Disk - Secondary Tillage	(7)

Circa 1998	
Tandem/Offset Disk - Primary Tillage	-20
Moldboard Plow	-14
Tandem Disk - Light	-2
Harrow - Roller	-2
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	25
Knife Applicator	35
Field Cultivator - Secondary 12-20inch Sweep	50
Rotary Tiller - 6inch deep - Similar	(1)
Tandem/Offset Disk - Secondary Tillage	(7)

Minimum Till	
Field Cultivator - Primary Duckfoot Points	-3
Rowcrop Planter - Double-disk Openers	1

Table 9. Tillage practices for Small Spring Grains

Circa 1949	
Tandem/Offset Disk - Primary Tillage	-20
Knife Applicator	-15
Tandem/Offset Disk - Secondary Tillage	-5
Drill: Single Disk Opener	1
Undercutter Plow: V-Blade >30inch	(21)

Circa 1973	
Tandem/Offset Disk - Primary Tillage	-20
Knife Applicator	-15
Tandem/Offset Disk - Secondary Tillage	-5
Drill: Single Disk Opener	1
Undercutter Plow: V-Blade >30inch	(21)

Circa 1998	
Tandem/Offset Disk - Primary Tillage	-20
Knife Applicator	-15
Tandem/Offset Disk - Secondary Tillage	-5
Drill: Single Disk Opener	1
Undercutter Plow: V-Blade >30inch	(21)

Minimum Till	
Drill: Single Disk Opener	1

Table 10. Tillage practices for Sorghum

Circa 1949	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Circa 1973	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Circa 1998	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Minimum Till	
Rowcrop Planter - Double-disk Openers	1

Table 11. Tillage practices for Sunflower

Circa 1949	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Circa 1973	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Circa 1998	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Minimum Till	
Rowcrop Planter - Double-disk Openers	1

Conservation Study
Tillage Scenarios
December 19, 2017

Scenario Purpose:
The Conservation Study was initiated to evaluate and quantify within each NRD the impact that selected conservation practices have on stream flow. The Tillage Scenarios explored how the system would respond to alternative tillage practices being used exclusively throughout the simulation period. Two scenarios were investigated; a Minimum Tillage Scenario, and a Circa 1950s Tillage Scenario.

Baseline Description:
The Baseline Scenario represents the standard from which to compare subsequent scenarios. For the Conservation Study, the historical model (COHYST 2010_28_15_28) was extended backward to 1950 and forward to 2013. The Baseline Scenario used the historic land use development, production practices, and irrigation management techniques modeled over the simulation period with historic climate conditions. The following changes were made to the COHYST 2010 model to create the Conservation Study baseline:

Watershed Model
- Land use for the 1950-1984 period was obtained from the 2013 FAB analysis
- Land use for the 2011-2013 period was copied from 2010
    + 6 Mile Canal was shut off. Surface water only and comingled irrigated lands were converted to groundwater only irrigated lands.
- The climate dataset was updated to include the entirety of the 1950-2013 period

Surface Water Operation Model
- Historical gage data at Julesburg, CO and Lewellen, NE were used
- Three temporal diversion patterns were implemented
    + 1950-1990 used average 1985-1990 diversion patterns
    + 1991-2000 used average 1991-2000 diversion patterns
    + 2001-2013 used average 2001-2005 diversion patterns

Groundwater Model
- Initial heads were updated to January 1950 levels
- 1950-1984 High Water Evapotranspiration was set at 1985 levels
- 2011-2013 High Water Evapotranspiration was set at 2010 levels
- Lake McConaughy general head boundaries were set to surface water modeled end of month elevations for January 1950 to December 2013
- Harry Strunk Lake and Hugh Butler Lake general head boundaries were updated with elevations from the United States Bureau of Reclamation

Minimum Tillage Scenario Description:
The Minimum Tillage Scenario investigated the impact of minimizing the number of tillage practices throughout the year. Minimum tillage was defined as limiting operation to a planting operation for tilled crops; perennial forage crops were not changed. Limiting the tillage developed a new system response on agricultural fields. This response was applied to the historical land use and climate to investigate the effect on diversions, pumping, recharge, aquifer levels, base flow, and stream flow. The following changes were made to the baseline model to implement this scenario:

Watershed Model

- Modifications were made to the soil water balance model CROPSIM
  + A new set of '*simfiles*´ were created with minimum tillage practices (Tables 8-11)
  + CROPSIM was used to generate irrigated and dryland results for each crop on each soil at every COHYST weather station over the simulation period
- The CROPSIM results were spatially distributed to create a new set of Water Balance Parameters for the Regionalized Soil Water Balance model

No changes were made to the baseline Surface Water Operations Model or the Groundwater Model. Rather, the scenario results reflect changes to inputs resulting from changes to the watershed model during the integrated modeling sequence.

Circa 1950s Tillage Scenario Description:

The Circa 1950s Tillage Scenario investigated the impact of implementing tillage practices common in the middle of the 20th century throughout the simulation period. Tillage practices during this time frequently turned the topsoil and destroyed much of the residue on the soil surface. The circa 1950s tillage developed a new system response on agricultural fields. This response was applied to the historic land use and climate to investigate the effect on diversions, pumping, recharge, aquifer levels, base flow, and stream flow. The following changes were made to the baseline model to implement this scenario:

Watershed Model

- The results of the CROPSIM using the '*49*' '*simfile*' data set (Tables 8-11) were expanded though 2013
- Temporal distribution of the CROPSIM results was omitted, rather the '*49*' results were spatially distributed to create a new set of Water Balance Parameters for the Regionalized Soil Water Balance model

No changes were made to the baseline Surface Water Operations Model or the Groundwater Model. Rather, the scenario results reflect changes to inputs resulting from changes to the watershed model during the integrated modeling sequence.

Surface Water Model Results

Table 1. Platte River Gage Flow – 1950-2013 (AF)

	Baseline	Circa 1950s Tillage		Minimum Tillage	
Platte River Gages	Volume	Volume	Change	Volume	Change
Brady	23,543,000	23,823,000	280,000	22,712,000	(831,000)
Cozad	24,153,000	23,860,000	(293,000)	25,131,000	978,000
Overton	57,855,000	57,074,000	(781,000)	62,447,000	4,592,000
Odessa	59,653,000	59,493,000	(160,000)	63,996,000	4,343,000
Grand Island	62,635,000	62,402,000	(233,000)	69,852,000	7,217,000

Table 2. Platte River diversions and returns – 1950-2013 (AF)

Platte River Diversions and Returns	Baseline	Circa 1950s Tillage Scenario		Minimum Tillage Scenario	
	Volume	Volume	Change	Volume	Change
Keystone	45,265,000	45,007,000	(258,000)	46,751,000	1,486,000
North Platte Canals (Total)	6,912,000	7,055,000	143,000	6,449,000	(463,000)
Western	948,000	955,000	7,000	938,000	(10,000)
Korty	9,397,000	9,467,000	70,000	9,490,000	93,000
Sutherland Return	44,251,000	44,064,000	(187,000)	45,798,000	1,547,000
Tri-County	62,935,000	62,842,000	(93,000)	64,814,000	1,879,000
Jeffrey Return	3,520,000	3,452,000	(68,000)	3,720,000	200,000
Gothenburg	3,547,000	3,654,000	107,000	3,243,000	(304,000)
Thirty Mile	2,287,000	2,359,000	72,000	2,092,000	(195,000)
Cozad	2,006,000	2,083,000	77,000	1,753,000	(253,000)
Orchard Alfalfa	565,000	581,000	16,000	508,000	(57,000)
Dawson	4,299,000	4,420,000	121,000	3,907,000	(392,000)
J-2 Return	28,232,000	27,864,000	(368,000)	31,111,000	2,879,000
Kearney	4,989,000	4,969,000	(20,000)	5,033,000	44,000

Table 3. Platte River main canal recharge – 1950-2013 (AF)

Platte River Diversions and Returns	Baseline	Circa 1950s Tillage Scenario		Minimum Tillage Scenario	
	Volume	Volume	Change	Volume	Change
Keystone	1,013,000	1,013,000	-	1,013,000	-
North Platte Canals (Total)	2,778,000	2,778,000	-	2,778,000	-
Western	729,000	731,000	2,000	732,000	3,000
Korty	508,000	509,000	1,000	520,000	12,000
Sutherland Return	585,000	585,000	-	585,000	-
Tri-County	3,394,000	3,384,000	(10,000)	3,462,000	68,000
Jeffrey Return	4,000,000	4,001,000	1,000	4,015,000	15,000
Gothenburg	1,605,000	1,605,000	-	1,605,000	-
Thirty Mile	915,000	917,000	2,000	924,000	9,000
Cozad	476,000	476,000	-	476,000	-
Orchard Alfalfa	250,000	250,000	-	250,000	-
Dawson	963,000	963,000	-	963,000	-
J-2 Return	(834,000)	(834,000)	-	(834,000)	-
Kearney	8,000	8,000	-	8,000	-

Watershed Model

Table 4. Groundwater pumping by Natural Resources District – 1950-2013 (AF)

NRD	Baseline	Circa 1950s Tillage Scenario		Minimum Tillage Scenario	
	Volume	Volume	Change	Volume	Change
Twin Platte	13,474,000	14,167,000	693,000	11,984,000	(1,490,000)
Central Platte	35,094,000	36,767,000	1,673,000	28,771,000	(6,323,000)
Tri-Basin	16,185,000	17,248,000	1,063,000	12,659,000	(3,526,000)

Table 5. Surface water deliveries by Natural Resources District – 1950-2013 (AF)

NRD	Baseline	Circa 1950s Tillage Scenario		Minimum Tillage Scenario	
	Volume	Volume	Change	Volume	Change
Twin Platte	3,268,000	3,405,000	137,000	2,830,000	(438,000)
Central Platte	4,805,000	5,059,000	254,000	3,823,000	(982,000)
Tri-Basin	4,886,000	5,202,000	316,000	3,474,000	(1,412,000)

Table 6. Recharge by Natural Resources District – 1950-2013 (AF)

NRD	Baseline	Circa 1950s Tillage Scenario		Minimum Tillage Scenario	
	Volume	Volume	Change	Volume	Change
Twin Platte	25,943,000	25,418,000	(525,000)	27,622,000	1,679,000
Central Platte	37,785,000	36,022,000	(1,763,000)	46,274,000	8,489,000
Tri-Basin	15,765,000	15,061,000	(704,000)	20,611,000	4,846,000

Groundwater Model

Table 7. Baseflow by reach – 1950-2013 (AF)

Reach	Baseline	Circa 1950s Tillage Scenario		Minimum Tillage Scenario	
	Volume	Volume	Change	Volume	Change
PR - Brady to Cozad	8,285,000	7,943,000	(342,000)	8,887,000	602,000
PR - Cozad to Overton	3,032,000	2,657,000	(375,000)	4,008,000	976,000
PR - Overton to Odessa	(1,288,000)	(1,464,000)	(176,000)	(470,000)	818,000
PR - Odessa to GI	(6,047,000)	(6,513,000)	(466,000)	(3,063,000)	2,984,000

Summary of tillage practices

Table 8. Tillage practices for corn

Circa 1950	
Tandem/Offset Disk - Secondary Tillage	-67
Tandem/Offset Disk - Secondary Tillage	-58
Moldboard Plow	-43
Harrow - Packer Roller	-36
Harrow - Spike Tooth	-22
Finishing - Disks, Shanks, Leveling	-6
Rowcrop Planter - Smooth Coulters	1
Rotary Hoe	18
Row Cultivator - Multiple Sweeps	34
Row Cultivator - Multiple Sweeps	55

Circa 1975	
Knife Applicator	-43
Moldboard Plow	-27
Harrow	-20
Rowcrop Planter - Ripple/Bubble Coulters	1
Row Cultivator - Multiple Sweeps	18
Row Cultivator - Multiple Sweeps	49

Circa 2000	
Stalk Chopper	-35
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double Disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep	50

Minimum Till	
Rowcrop Planter - Double Disk Openers	1

Table 9. Tillage practices for soybeans

Circa 1950	
Tandem/Offset Disk - Secondary Tillage	-30
Tandem/Offset Disk - Secondary Tillage	-5
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Multiple Sweeps per Furrow	40

Circa 1975	
Tandem/Offset Disk - Secondary Tillage	- 30
Tandem/Offset Disk - Secondary Tillage	-5
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Multiple Sweeps per Furrow	40

Circa 2000	
Tandem/Offset Disk - Secondary Tillage	-30
Tandem/Offset Disk - Secondary Tillage	-5
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Multiple Sweeps per Furrow	40

Minimum Till	
Rowcrop Planter - Double Disk Openers	1

Table 10. Tillage practices for sorghum

Circa 1950	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep per Furrow	50

Circa 1975	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep per Furrow	50

Circa 2000	
Knife Applicator	-30
Tandem/Offset Disk - Secondary Tillage	-21
Tandem Disk - Light	-7
Rowcrop Planter - Double-disk Openers	1
Row Cultivator - Rolling Disc	30
Row Cultivator - Single Sweep per Furrow	50

Minimum Till	
Rowcrop Planter - Double Disk Openers	1

Table 11. Tillage practices for winter wheat

Circa 1950	
Moldboard Plow	-116
Tandem Disk - Light	-90
Field Cultivator - Secondary 6 - 12" Sweep	-60
Rodweeder - Plain	-30
Rodweeder - Plain	-17
Rodweeder - Plain	-5
Drill: Double Disk Opener	1

Circa 1975	
One-way Disc - 12-16" Blades	-123
Chilsel Plow with Spike Points	-109
Field Cultivator - Secondary 12-20" Sweep	-78
Rodweeder - Plain	-31
Rodweeder - Plain	-5
Drill: Hoe Opener	1

Circa 2000	
Tandem/Offset Disk - Primary Tillage	-130
Tandem/Offset Disk - Secondary Tillage	-100
Rodweeder - with Semi-chisels/Shovels	-50
Knife Applicator	-30
Rodweeder - with Semi-chisels/Shovels	-10
Drill: Single Disk Opener	1
Undercutter Plow-V Blade >30inch with Treader	(50)

Minimum Till	
Drill: Single Disk Opener	1

The values in Tables 8-11 represent the number of day relative to planting or maturity:

- Positive numbers represent tillage operations which occur after planting
- Negative number represent tillage operation which occur prior to planting
- Parenthetical numbers represent tillage operations which occur after the growing season is complete

Conservation Study
Efficiency Scenarios
December 19, 2017

Scenario Purpose:

The Conservation Study was initiated to evaluate and quantify within each NRD the impact that selected conservation practices have on stream flow. The Efficiency Scenarios explore how the system would respond to alternative means of applying irrigation water to the field throughout the simulation period. Two scenarios were investigated; a High Efficiency Scenario and a Low Efficiency Scenario.

Baseline Description:

The Baseline Scenario represents the standard from which to compare subsequent scenarios. For the Conservation Study, the historical model (COHYST 2010_28_15_28) was extended backward to 1950 and forward to 2013. The Baseline Scenario used the historic land use development, production practices, and irrigation management techniques modeled over the simulation period with historic climate conditions. The following changes were made to the COHYST 2010 model to create the Conservation Study baseline:

Watershed Model

- Land use for the 1950-1984 period was obtained from the 2013 FAB analysis
- Land use for the 2011-2013 period was copied from 2010
    + 6 Mile Canal was shut off. Surface water only and comingled irrigated lands were converted to groundwater only irrigated lands.
- The climate dataset was updated to include the entirety of the 1950-2013 period

Surface Water Operation Model

- Historical gage data at Julesburg, CO and Lewellen, NE were used
- Three temporal diversion patterns were implemented
    + 1950-1990 used average 1985-1990 diversion patterns
    + 1991-2000 used average 1991-2000 diversion patterns
    + 2001-2013 used average 2001-2005 diversion patterns

Groundwater Model

- Initial heads were updated to January 1950 levels
- 1950-1984 High Water Evapotranspiration was set at 1985 levels
- 2011-2013 High Water Evapotranspiration was set at 2010 levels
- Lake McConaughy general head boundaries were set to surface water modeled end of month elevations for January 1950 to December 2013
- Harry Strunk Lake and Hugh Butler Lake general head boundaries were updated with elevations from the United States Bureau of Reclamation

High Efficiency Scenario Description:

The High Efficiency Scenario investigated the impact of converting all irrigated acres within the model domain to high efficiency application methods and its effect on diversions, pumping, recharge, aquifer levels, baseflow, and stream flow. The following changes were made to the baseline model to implement this scenario:

Watershed Model

- The irrigation application efficiency in all coefficient zones was changed to 95% for both groundwater and surface water irrigated lands

No changes were made to the baseline Surface Water Operations Model or the Groundwater Model. Rather, the scenario results reflect changes to inputs resulting from changes to the watershed model during the integrated modeling sequence.

Low Efficiency Scenario Description:

The Low Efficiency Scenario investigated the impact of converting all irrigated acres within the model domain to low efficiency application methods and its effect on diversions, pumping, recharge, aquifer levels, baseflow, and stream flow. The following changes were made to the baseline model to implement this scenario:

Watershed Model

- The irrigation application efficiency for groundwater irrigated lands was changed to 60%
- The irrigation application efficiency for surface water irrigated lands was changed to 50%

No changes were made to the baseline Surface Water Operations Model or the Groundwater Model. Rather, the scenario results reflect changes to inputs resulting from changes to the watershed model during the integrated modeling sequence.

Surface Water Model Results

Table 1. Platte River Gage Flow – 1950-2013 (AF)

	Baseline	Low Efficiency		High Efficiency	
Platte River Gages	Volume	Volume	Change	Volume	Change
Brady	23,543,000	26,211,000	2,668,000	21,678,000	(1,865,000)
Cozad	24,153,000	24,533,000	380,000	24,597,000	444,000
Overton	57,855,000	55,594,000	(2,261,000)	60,931,000	3,076,000
Odessa	59,653,000	59,285,000	(368,000)	61,283,000	1,630,000
Grand Island	62,635,000	62,249,000	(386,000)	64,497,000	1,862,000

Table 2. Platte River diversions and returns – 1950-2013 (AF)

Platte River Diversions and Returns	Baseline	Low Efficiency		High Efficiency	
	Volume	Volume	Change	Volume	Change
Keystone	45,265,000	42,832,000	(2,433,000)	47,458,000	2,193,000
North Platte Canals (Total)	6,912,000	7,964,000	1,052,000	5,817,000	(1,095,000)
Western	948,000	989,000	41,000	908,000	(40,000)
Korty	9,397,000	9,417,000	20,000	9,194,000	(203,000)
Sutherland Return	44,251,000	41,871,000	(2,380,000)	46,210,000	1,959,000
Tri-County	62,935,000	60,768,000	(2,167,000)	64,765,000	1,830,000
Jeffrey Return	3,520,000	3,028,000	(492,000)	3,951,000	431,000
Gothenburg	3,547,000	4,031,000	484,000	3,026,000	(521,000)
Thirty Mile	2,287,000	2,616,000	329,000	1,952,000	(335,000)
Cozad	2,006,000	2,401,000	395,000	1,586,000	(420,000)
Orchard Alfalfa	565,000	654,000	89,000	471,000	(94,000)
Dawson	4,299,000	5,022,000	723,000	3,568,000	(731,000)
J-2 Return	28,232,000	25,253,000	(2,979,000)	31,148,000	2,916,000
Kearney	4,989,000	4,957,000	(32,000)	4,967,000	(22,000)

Table 3. Platte River main canal recharge – 1950-2013 (AF)

Platte River Diversions and Returns	Baseline	Low Efficiency		High Efficiency	
	Volume	Volume	Change	Volume	Change
Keystone	1,013,000	1,013,000	-	1,012,000	(1,000)
North Platte Canals (Total)	2,778,000	2,785,000	7,000	2,782,000	4,000
Western	729,000	739,000	10,000	722,000	(7,000)
Korty	508,000	506,000	(2,000)	512,000	4,000
Sutherland Return	585,000	585,000	-	585,000	-
Tri-County	3,394,000	3,324,000	(70,000)	3,471,000	77,000
Jeffrey Return	4,000,000	3,992,000	(8,000)	4,012,000	12,000
Gothenburg	1,605,000	1,605,000	-	1,605,000	-
Thirty Mile	915,000	914,000	(1,000)	921,000	6,000
Cozad	476,000	476,000	-	476,000	-
Orchard Alfalfa	250,000	250,000	-	250,000	-
Dawson	963,000	963,000	-	963,000	-
J-2 Return	(834,000)	(834,000)	-	(834,000)	-
Kearney	8,000	8,000	-	8,000	-

Watershed Model

Table 4. Groundwater pumping by Natural Resources District – 1950-2013 (AF)

	Baseline	Low Efficiency		High Efficiency	
NRD	Volume	Volume	Change	Volume	Change
Twin Platte	13,474,000	16,841,000	3,367,000	10,639,000	(2,835,000)
Central Platte	35,094,000	44,479,000	9,385,000	28,138,000	(6,956,000)
Tri-Basin	16,185,000	21,131,000	4,946,000	13,367,000	(2,818,000)

Table 5. Surface water deliveries by Natural Resources District – 1950-2013 (AF)

	Baseline	Low Efficiency		High Efficiency	
NRD	Volume	Volume	Change	Volume	Change
Twin Platte	3,268,000	4,254,000	986,000	2,223,000	(1,045,000)
Central Platte	4,805,000	6,208,000	1,403,000	3,209,000	(1,596,000)
Tri-Basin	4,886,000	6,314,000	1,428,000	3,239,000	(1,647,000)

Table 6. Recharge by Natural Resources District – 1950-2013 (AF)

	Baseline	Low Efficiency		High Efficiency	
NRD	Volume	Volume	Change	Volume	Change
Twin Platte	25,943,000	27,656,000	1,713,000	24,593,000	(1,350,000)
Central Platte	37,785,000	41,738,000	3,953,000	35,165,000	(2,620,000)
Tri-Basin	15,765,000	18,067,000	2,302,000	14,551,000	(1,214,000)

Groundwater Model

Table 7. Baseflow by reach – 1950-2013 (AF)

	Baseline	Low Efficiency		High Efficiency	
Reach	Volume	Volume	Change	Volume	Change
PR - Brady to Cozad	8,285,000	7,961,000	(324,000)	8,413,000	128,000
PR - Cozad to Overton	3,032,000	2,714,000	(318,000)	3,250,000	218,000
PR - Overton to Odessa	(1,288,000)	(1,530,000)	(242,000)	(1,061,000)	227,000
PR - Odessa to GI	(6,047,000)	(6,847,000)	(800,000)	(4,963,000)	1,084,000