# Bear River Basin

**From:** Bear River Basin Planning Team

**Subject:** **APPENDIX H - Spreadsheet Modeling Support - Efficiencies and Return Flow Patterns**

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## Introduction

The spreadsheet model determines the mass balance at locations along the river. Therefore, historic or estimated river headgate diversions are used as the demands that drive the model. However, only a portion of the headgate diversion is actually available to satisfy crop consumptive use requirements, municipal demands, or industrial demands. The unused portion of the headgate diversions is either lost in route to the farm or treatment plant (conveyance loss) or lost during crop application (application or on-farm loss).

## Efficiencies and Return Flow Patterns

This unused portion of headgate diversion either returns to the river as surface runoff during the month it is diverted, or "deep percolates" into the alluvial aquifer. The deep percolation portion returns to the river through the aquifer but generally lags the time of diversion by several months, or even years. It is important for the model to simulate both the percent of headgate diversions that return to the river, and the timing of which this unused portion returns. In the Bear River Basin, water from the river is reused many times from the headwaters to the Great Salt Lake.

Diversion efficiency for agricultural use is the common measure of the portion of headgate diversion that is consumed, and therefore not returned to the river. Diversion efficiency for municipal and industrial use is the percent of headgate diversion that makes it to the treatment plant or industrial site. The remaining percent is lost during conveyance, and returns to the river as surface runoff or deep percolation. Diversions for agricultural use experience both conveyance losses and application losses, and both these loss percents return to the river as surface runoff or deep percolation.

Conveyance Efficiency

Factors that affect conveyance efficiencies include:

- Frequency and duration of diversion. More losses occur during the first month of the irrigation season due to canal "wetting".
- Underlying soil characteristics. More permeable soil will experience greater conveyance losses.
- Canal capacity and length. Larger canals generally serve more lands and have more opportunity to "lose" water in route to the farm.
- Location of water table relative to the canal. Canals running through areas with high water tables can actually "gain" water in route to the farm.
- Canal evaporation. Water evaporates from the surface of canals. The amount of is generally small and depends on the width and length of canals.
- Phreatophyte occurance. Phreatophytes, such as willows and cottonwood trees that grow unchecked along canals, can use a portion of diverted water.

The report "Irrigation Conveyance Systems - Working Paper for the Bear River Basin Type IV Study", USDA and SCS, April 1976, estimated conveyance efficiencies throughout the Bear River Basin. The conveyance efficiencies for the Unita County irrigation systems ranged from 30 percent to 75 percent. The conveyance efficiencies for Lincoln County ranged from 50 percent to 85 percent. Tables are provided in that report showing conveyance efficiencies by major ditch system, however, there is no documentation provided on how these estimates were developed. Therefore, we estimated conveyance efficiencies based on main canal length and the proximity of irrigated acreage to the main canal. The maps provided in the Type IV Study report were used to measure canal lengths. In most cases, our estimated conveyance efficiencies were consistent with the efficiencies summarized in the Type IV Study report. Note that the ditch systems in the Bear River basin in Wyoming have changed very little since 1976.

Table 1 shows the conveyance efficiencies estimated for the key ditch systems represented in the modeling effort for the upper division. The upper division aggregate ditch systems were assigned a conveyance efficiency of 60 percent, because they represent smaller ditches generally irrigating lands close to the river.

Table 2 shows the conveyance efficiencies estimated for the key ditch systems represented in the modeling effort for the central division. The central division aggregate ditch systems were assigned a conveyance efficiency of 65 percent, again because they represent smaller ditches generally irrigating lands close to the river. The exception is the aggregate diversion representing the irrigated lands in Utah between Woodruff Narrows and Pixley Dam. These lands are dependent on each other's return flows for diversion supply, but because of the aggregation, all diversion will be modeled at one location. A conveyance efficiency of 45 percent was used to represent these diversions.

Application (on-farm) Efficiencies

Factors that affect application efficiencies include:

- Irrigation practice. Flood irrigation techniques require more water to be applied than the crops require. Flood irrigation causes much more runoff and deep percolation than sprinkler irrigation. Sprinkler irrigation is generally applied more frequently and directly to the crops.
- Crop types. Row crops generally cause more runoff than field crops, such as irrigated meadow.

Ranges of irrigation application efficiencies are widely published. For this study, we used efficiency percents presented by Duane D. Klamm and John S. Brenner in the 1995 Evapotranspiration and Irrigation Efficiency Seminar sponsored by the American Consulting Engineers Council of Colorado and the Colorado Division of Water Resources. Flood irrigation application efficiencies were estimated to be 55 percent basin wide for the modeling effort. Center pivot and side-roll sprinkler application efficiencies were estimated at 85 percent, and hand-line sprinklers were estimated at 80 percent.

Most crop acreage in the upper division of the Bear River basin is irrigated using flood application techniques. There is only one sprinkler irrigated quarter-section shown in the 1993 irrigated acreage assessment. The local water administrator further verified that all other farms use flood irrigation in the upper division.

The central division is also mostly flood irrigated, however, there has been a greater trend towards sprinkler irrigation. Through interviews with water administrators and users, we have estimated the percent of acreage under the key ditch systems that apply water through sprinklers. Center pivot and side-roll sprinklers are most common; however there are a few hand-line sprinklers.

In addition to conveyance efficiencies, Table 1 shows the suggested application efficiency for the key ditch systems in the upper division. Because lands in the upper division are flood irrigated, the application efficiencies are all 55 percent. An application efficiency of 55 percent is also used for aggregated ditch systems.

Table 2 shows the suggested application efficiency for the key ditch systems in the central division. An application efficiency of 65 percent was used for aggregated ditch systems in the central division, which represents an average of key ditch system efficiencies.

The model uses a diversion efficiency that represents the actual amount of headgate diversion used to satisfy crop consumptive use demands. It is calculated as the product of conveyance efficiency and application efficiency. The diversion efficiency is also provided in Tables 1 and 2.

**Table 1**
**Upper Division Diversion Efficiencies**

| Model Node ID | Diversion Name | Conveyance Efficiency | Application Efficiency | Diversion Efficiency | Irrigation Methods |
|---|---|---|---|---|---|
| 1.01 | Lannon and Lone Mountain | 45 % | 55 % | 25 % | 100 % Flood |
| 1.02 | Hilliard West Side | 40 % | 55 % | 22 % | 100 % Flood |
| 1.03 | Bear Canal | 40 % | 55 % | 22 % | 100 % Flood |
| 1.04 | Crown and Pine Grove | 50 % | 55 % | 27 % | 100 % Flood |
| 1.05 | McGraw (and Big Bend) | 55 % | 55 % | 30 % | 100 % Flood |
| 1.06 | Lewis | 55 % | 55 % | 30 % | 100 % Flood |
| 1.07 | Myers No 2 | 50 % | 55 % | 27 % | 100 % Flood |
| 1.08 | Myers No 1 | 50 % | 55 % | 27 % | 100 % Flood |
| 1.09 | Myers Irrigation | 55 % | 55 % | 30 % | 100 % Flood |
| 1.11 | Booth | 50 % | 55 % | 27 % | 100 % Flood |
| 1.12 | Anel | 55 % | 55 % | 30 % | 100 % Flood |
| 1.13 | Evanston Water Supply | 50 % | 55 % | 27 % | 100 % Flood |
| 3.01 | Evanston Water Ditch | 65 % | 55 % | 36 % | 100 % Flood |
| 3.02 | Rocky Mountain Blythe | 65 % | 55 % | 36 % | 100 % Flood |
| 4.01 | John Simms | 65 % | 55 % | 36 % | 100 % Flood |
| 4.02 | SP Ramsey | 60 % | 55 % | 33 % | 100 % Flood |
| 5.01 | Chapman (WY portion) | 50 % | 55 % | 27 % | 100 % Flood |
| 5.02 | Morris Brothers | 65 % | 55 % | 36 % | 100 % Flood |
| 5.04 | Tunnel | 65 % | 55 % | 36 % | 100 % Flood |
| 7.01 | Francis Lee | 60 % | 55 % | 33 % | 100 % Flood |
| 7.02 | Bear River Canal | 60 % | 55 % | 33 % | 100 % Flood |
| 7.03 | Utah Aggregate Ditches | 45 % | 65 % | 30 % | 67 % Flood<br>33 % Center Pivot |
| 8.00 | BQ Dam Diversions | 55 % | 60 % | 33 % | 90 % Flood<br>10 % Center Pivot |
| 8.01 | Pixley Dam | 55 % | 60 % | 33 % | 90 % Flood<br>10 % Center Pivot S |
| Varies | Aggregate Systems | 60 % | 55 % | 33 % | 100 % Flood |

**Table 2**
**Central Division Diversion Efficiencies**

| Model Node ID | Diversion Name | Conveyance Efficiency | Application Efficiency | Diversion Efficiency | Irrigation Methods |
|---|---|---|---|---|---|
| 10.02 | Button Flat | 65 % | 55 % | 36 % | 100 % Flood |
| 10.03 | Emelle | 65 % | 55 % | 36 % | 100 % Hand-line Sprinkler |
| 10.04 | Cooper | 65 % | 55 % | 36 % | 100 % Flood |
| 10.05 | Covey | 45 % | 65 % | 30 % | 70 % Flood<br>30 % Center Pivot Sprinkler |
| 10.06 | VH Canal | 55 % | 85 % | 47 % | 100 % Center Pivot Sprinkler |
| 10.07 | Goodell | 55 % | 85 % | 47 % | 100 % Center Pivot Sprinkler |
| 10.08 | Whites Water | 60 % | 65 % | 40 % | 60 % Flood<br>40 % Hand-line Sprinkler |
| 10.09 | S. Branch Irrigating | 60 % | 70 % | 42 % | 40 % Flood<br>60 % Hand-line Sprinkler |
| 11.02 | Alonzo F. Sights | 60 % | 65 % | 40 % | 60 % Flood<br>40 % Hand-line Sprinkler |
| 11.03 | Oscar E. Snyder | 73 % | 55 % | 40 % | 100 % Flood |
| 11.04 | Cook Brothers | 73 % | 55 % | 40 % | 100 % Flood |
| Varies | Aggregate Systems | 65 % | 65 % | 42 % | 67 % Flood<br>33 % Center Pivot Sprinkler |

## Return Flow Patterns

As discussed above, the unused, or inefficient, portion of diversions are returned to the river either by direct surface runoff, or through the alluvial aquifer. For modeling purposes, an estimate must be made of both:

- the location or locations on the river where the unused portion of diversions will return, and
- the timing of those returns.

Again, this information becomes very important in water supply-limited systems, such as the Bear River basin, because return flows are often re-diverted many times by downstream users.

The location where unused water is returned to the river is based on the location of irrigated lands. Unless a "drain" has been constructed to remove excess water from lands with high water tables, return flows do not generally return to a specific point on the river. However, for modeling purposes, it needs to be returned to a specific node in the network. The return flows can be re-diverted at the return flow location node and any nodes downstream. For the larger ditch systems, unused water may return at more than one location. The irrigated acreage GIS theme was used to estimate these locations, shown in Table 3 for the upper division and Table 4 for the central division.

Return flow patterns represent the timing of return flows back to the river. Generally, the surface runoff portion of unused diversion returns to the river the same month as diversions, whereas the deep percolation portion may take much longer. The timing of return flows can be determined using standard Glover equations, basin water budgets, or more detailed ground water modeling techniques. Return flow patterns were estimated in the publication "Water Budget Studies - Utah, Bear River Study Area", State of Utah Natural Resources, September 1994. Return flow patterns were developed for several river reaches, including both the upper and central portion of the Bear River Basin in Wyoming. The following return flow patterns were adopted from this study for the modeling effort, and represent the timing of the return of unused diversions. Note that month 0 is the month of diversion, month 1 is the 1st month after diversion, etc.

Return Pattern 1 = 50 % month 0, 25 % month 1, 15 % month 2, 10 % month 3

Return Pattern 2 = 70 % month 0, 20 % month 1, 10 % month 2

Return Pattern 3 = 100 % month 0

Return flow pattern 1 is used to represent larger ditch systems that serve lands further from the river. Return flow pattern 2 is used to represent smaller ditch systems that serve lands adjacent to the river. Return flow pattern 3 is used to represent municipal and industrial nodes, where water is returned to the river from treatment plants or industrial processes directly. In addition to the return flow node location in the river, Tables 3 and 4 show the return flow pattern used to represent each ditch system.

**Table 3**
**Upper Division Return Flow Locations and Patterns**

| Model Node ID | Diversion Name | Return Nodes | Return Pattern |
|---|---|---|---|
| 1.01 | Lannon and Lone Mountain | 30 % Lewis Ditch<br>70 % Confluence with Mill Ck | 1 |
| 1.02 | Hilliard West Side | 100 % Sulphur Creek Reservoir | 1 |
| 1.03 | Bear Canal | 60 % Sulphur Creek Reservoir<br>40 % Ag-Sulphur Creek bl Reservoir | 1 |
| 1.04 | Crown and Pine Grove | 25 % Lewis<br>25 % Confluence with Mill Ck<br>50 % Myers No 2 | 2 |
| 1.05 | McGraw (and Big Bend) | 100 % Lewis | 2 |
| 1.06 | Lewis | 100 % Myers No 1 | 2 |
| 1.07 | Myers No 2 | 100 % Myers No 1 | 2 |
| 1.08 | Myers No 1 | 50 % Booth<br>50 % Ag-Sulphur Creek bl Reservoir | 2 |
| 1.09 | Myers Irrigation | 100 % Anel | 2 |
| 1.11 | Booth | 100 %Evanston Water Ditch | 2 |
| 1.12 | Anel | 100 % Ag-Bear River between Mill Creek and Sulphur Creek | 2 |
| 1.13 | Evanston Water Supply | 50 % Rocky Mountain Blythe<br>50 % John Simms | 2 |
| 1.15 | Ag-Bear River between Mill Creek and Sulphur Creek | 100 % Confluence Bear and Sulphur Creek | 2 |
| 2.01 | Ag-Sulphur Creek Above Res | 100 % Sulphur Creek Res. | 2 |
| 2.03 | Ag-Sulphur Creek Below Reservoir | 100 % Confluence Bear and Sulphur Creek | 2 |
| 3.01 | Evanston Water Ditch | 100 % Rocky Mountain Blythe | 2 |
| 3.02 | Rocky Mountain Blythe | 70 % John Simms<br>30 % SP Ramsey | 2 |
| 4.01 | John Simms | 50 % SP Ramsey<br>50 % Ag-Bear River between Sulphur and Yellow Creeks | 2 |
| 4.02 | SP Ramsey (also called Adin Brown) | 50 % Ag-Bear River between Sulphur and Yellow Creeks<br>50 % Chapman | 2 |
| 4.03 | Ag-Bear River between Sulphur and Yellow Creeks | 100 % Chapman | 2 |
| 5.01 | Chapman | 100 % Ag-Bear River between Yellow Creek and Woodruff | 2 |
| 5.02 | Morris Brothers | 30 % Ag-Bear River between Yellow Creek and Woodruff<br>70 % Woodruff Narrows | 2 |
| 5.03 | Ag-Bear River between Yellow Creek and Woodruff Narrows | 100 % Tunnel | 2 |
| 5.04 | Tunnel | 100 % Woodruff Narrows | 2 |
| 7.01 | Francis Lee | 100 % Ag- Utah Diversions | 1 |
| 7.02 | Bear River Canal | 100 % Ag-Utah Diversion | 1 |
| 7.03 | Ag-Utah diversion | 70 % USGS Gage 10026500<br>5 % Pixley<br>25 % Return Flow Node 7.04 | 2 |
| 8.02 | BQ Dam Diversions | 100 % Pixley | 2 |
| 8.01 | Pixley Dam | 100 % Confluence with Smiths Fork | 2 |

**Table 4**
**Central Division Return Flow Locations and Patterns**

| Model Node ID | Diversion Name | Return Nodes | Return Pattern |
|---|---|---|---|
| 9.02 | Ag-Bear River between Twin Fork and Smiths Fork | 100 % Confluence with Smiths Fork | 2 |
| 10.01 | Quinn Bourne | 100 % Button Flat | 2 |
| 10.02 | Button Flat | 100 %Emelle | 2 |
| 10.03 | Emelle | 50 % Cooper Ditch<br>50 % Covey | 2 |
| 10.04 | Cooper | 100% Covey | 2 |
| 10.05 | Covey | 10 % White Water<br>90 % Ag-Bear River below Smiths Fork | 1 |
| 10.06 | VH Canal | 100 % White Water | 1 |
| 10.07 | Goodell | 100 % White Water | 1 |
| 10.08 | Whites Water | 100 % Ag-Bear River below Smiths Fork | 2 |
| 10.09 | S. Branch Irrigating | 100 % Ag-Bear River below Smiths Fork | 2 |
| 10.10 | Ag-Smiths Fork | 100 % Confluene Bear and Smiths Fork | 2 |
| 11.01 | Ag-Bear River below Smiths Fork | 40 % Alonzo F. Sights<br>40 % Oscar E. Snyder<br>20 % Cook Brothers | 2 |
| 11.02 | Alonzo F. Sights | 50 % Oscar E. Snyder<br>50 % Cook Brothers | 2 |
| 11.03 | Oscar E. Snyder | 50 % Cook Brothers<br>50 % Bear River at Border Gage (1003950) | 2 |
| 11.04 | Cook Brothers | 50 % Bear River at Border Gage<br>50% Ag-Idaho Diversions | 2 |

## Sources


*USDA and SCS, Irrigation Conveyance Systems - Working Paper for the Bear River Basin Type IV Study, April 1976,*

*State of Utah Natural Resources, Water Budget Studies - Utah, Bear River Study Area, September 1994.*

*Duane D. Klamm and John S. Brenner, excerpts from the 1995 Evapotranspiration and Irrigation Efficiency Seminar sponsored by the American Consulting Engineers Council of Colorado and the Colorado Division of Water Resources.*