

Analyzing Bear River Canal Company's Use of Water

By

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Introduction:

As an employee of the State of Utah, Division of Water Rights (UDWRi) in Northern Utah, our office plays an integral role in the distribution of the Bear River, along with Pacificorp, and the States of Idaho and Wyoming. This involves modeling and distributing the river below Bear Lake. The single-largest diverter of water on the Lower Bear River Distribution System is Bear River Canal Company (BRCC). The intent of this project is to analyze what factors influence the amount of water diverted each year. This project focuses on the service area and diversions of Bear River Canal Company.

Objectives:

The objectives of the project are to quantify water use by BRCC, to identify and quantify the factors that influence their diversion of water, and to use geographical information systems (GIS) as a tool to collect and process this data.

Methods:

The first step taken to meet the objectives of this project, was to determine factors that might influence the quantity of water diverted by BRCC. These were determined to be: land use (number of acres irrigated and crop type irrigated), temperature, precipitation, and water availability (both natural flow and storage). It was determined that data for all of these contributing factors was available to collect and analyze.

Next, the project area was identified. This could have been a difficult task because the canal company recently filed a change application to define a larger service area than has been irrigated heretofore. So the company's service area is changing. The service area was assumed to be the outline of the historic areas irrigated by the company.

Areas irrigated by BRCC were identified by the UDWRi during the adjudication of the Bear River, and indicated on their hydrographic survey maps. The hydrographic survey maps have been digitized for this area and can be seen on the UDWRi's webpage (www.waterrights.utah.gov), using the ESRI Mapview tool¹. This digitized area (shown in Figure 1) served as the basis for BRCC's service area, and hence the project area.

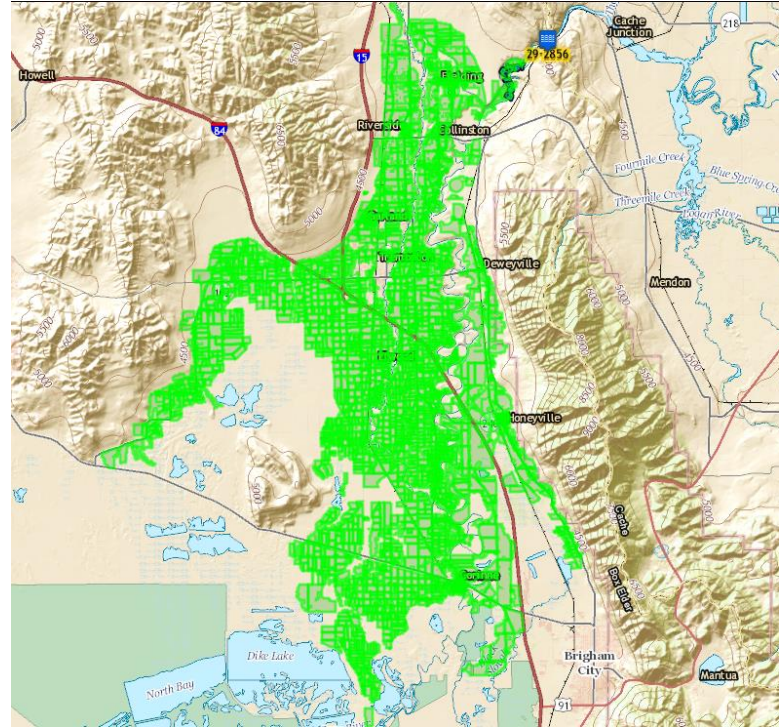


Figure 1. BRCC Service Area

BRCC has two main points of diversion from the Bear River; The Hammond Canal, and the Westside Canal. These two canals and their branches have been digitized, and a map of the canal system was accessed from UDWRi's website². The canal system, shown in Figure 2, is an integral part of the project area. It is shown in part, to help substantiate the irrigation service area and project area.

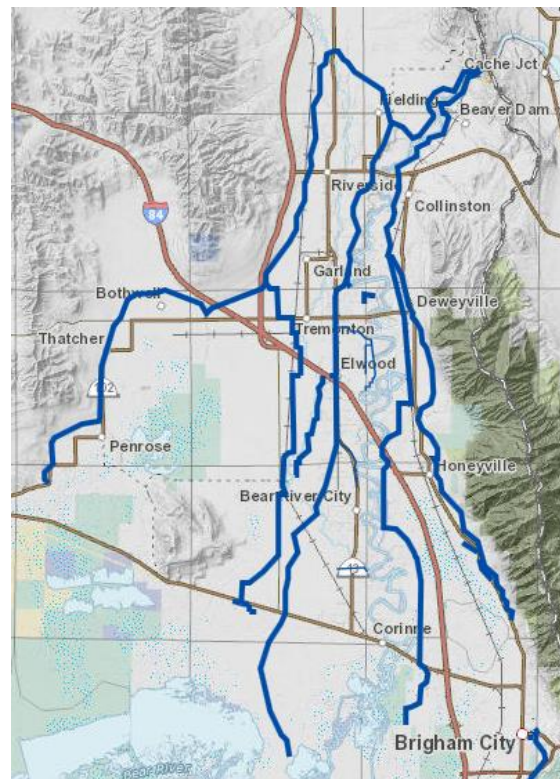


Figure 2. BRCC Canal System

Once the project area was defined, data was collected for each facet of the project, starting with diversion data from the Hammond and Westside canals. Once again, the UDWRi is the source of the diversion data³. They distribute the Lower Bear River in Utah, and maintain their own measuring devices. Monthly volumes in acre-feet were collected for the months of April thru October (the legal period of use for irrigation), for the years 1989 to 2014. Measuring the canal diversions began in 1989 and 2015 data was available, but not used, because the USGS streamgage for the Bear River near Corinne, Utah was discontinued in early 2015. Thus there could be no comparison data between the river gage and the canal gages for 2015.

It is important to note that the volumes of water recorded as diverted from BRCC's two canals are composed of both natural stream flow and storage water released from Bear Lake. The canal gages do not distinguish between storage water and natural flow. The UDWRi uses an accounting and distribution model to distribute Lower Bear River and Bear Lake water amongst the different diversions, according to priority. This model divides up the diversions into storage and natural flow components.

After the irrigation season is over, volume records for both natural flow and storage water are recorded in the Lower Bear River Distribution System Annual Report⁴, which is prepared by the Lower Bear River Water Commissioner, an employee of the UDWRi. The distribution system was setup beginning in 1989, and the breakdown of diversion quantities for storage and natural flow was taken from these reports for 1989 to 2014. The first three reports (1989 to 1991) didn't list a breakdown, only totals. Therefore, the storage portion of these three totals was assumed to be BRCC's portion of the total storage allocation release, which is 51.8 %⁵.

Total diversion data and storage data taken from the UDWRi sources were input into columns for each year in an Excel spreadsheet and an additional column of data was created for natural flow by subtracting the storage column from the total flow column. A graph was created for the resulting table of values. The graph can be seen in Figure 3 under the results section of this report.

The first data that was collected for the factors that influence irrigation use, was very specific land use data from the Utah Division of Water Resources (UDWRi)⁶. These were GIS shapefiles for the entire Bear River Basin for the years: 1986, 1996, 2003, and 2009. Datasets for these years were the only datasets of this type available. The shapefiles detail all valley floor land use covered by any vegetation or water body, including crop types, method of irrigation (flood or sprinkle) as available, irrigated, sub-irrigated, or non-irrigated land, riparian land, and urban land. These shapefiles were added to the GIS basemap as layers.

There were in each dataset, approximately 36,000 + polygons to filter through. Only polygons of irrigated parcels within Bear River Canal Company's historic service area were needed. ArcMap 10.1 was used to filter out all unnecessary parcels. This was done by opening the attribute table and selecting the land use attribute of all parcels that had a value of "IR" or irrigated. This selected only those polygons in the dataset that were actually irrigated by flood or sprinkler, and all other polygons were excluded.

Next, a polygon was carefully drawn around the service area of Bear River Canal Company, such that only irrigated polygons within BRCC's place of use were selected. These selected polygons were then copied and pasted into Excel where they were organized into their various crop types. Because each polygon has an "acres" attribute,

crop type total acreages and total irrigated acreages were calculated. This process was repeated for each of the four datasets.

Once the crop types were organized and quantities determined for each dataset, the mapping needed to reflect only the applicable polygons of the shapefiles. This was accomplished by using the Joins and Relates function in ArcMap, and selecting “Join”. This joined the selected polygons to the entire shapefile along a common attribute. Then, by selecting “keep only matching records”, only the desired polygons appear on the map. To further improve the mapping, it was desirable to show each land use or crop type as a distinct color. This would give a very good visual perception of the land use. This was accomplished by manipulating the value fields for the “LUID” (Land Use Identification) attribute in the “Symbology” tab under “Layer Properties”. Each LUID corresponded to a specific crop type. The five most common crop types; pasture, grass hay, alfalfa, corn, and grain were assigned specific unique colors. The remaining crop types were lumped together and shown in a dark blue color. The color scheme remained constant for each of the four datasets, in order to visualize the land use changes.

Next, temperature and precipitation data were collected from PRISM Climate Group, Oregon State University⁷. On their website they have a “Data Explorer: Time Series Values for Individual Locations” tool. This tool was used to produce .csv files for average monthly values of precipitation and temperature for Tremonton, Utah for the months of April 1989 to October 2014. The .csv files were turned into Excel (.xlsx) spreadsheets for manipulation, and tabular/graphical viewing of the data. It was desirable to only consider precipitation and temperature data for the irrigation season. Therefore,

the months of November through March were removed from the resulting data tables, and the results were graphed. See Figures 6 and 7 in the results section.

Water availability was the last factor to be considered. This meant water availability for both Bear Lake storage water and natural stream flow. For natural stream flow, data was taken from USGS Streamgage # 10126000, Bear River Near Corinne, UT. This site is downstream from the BRCC diversions, and is the closest streamgage location. A table of monthly mean flow in cfs (cubic feet per second) was generated from the USGS website⁸ for April 1989 through October 2014. This table was brought into Excel, the months of November thru March were deleted, and the monthly flow in cfs was changed to a monthly volume in acre-feet. See Figure 8 for results.

Data for water availability for storage was not widely available, and Pacificorp, the company owning storage contracts for Bear Lake, was generous enough to provide a spreadsheet⁹ listing the allotted storage allocation for the years 1981 to 2015. For this project, only allocations for the years 1989 to 2014 were used. The allocation is determined by Pacificorp each year based on current and projected lake levels, as specified by the Revised Bear River Compact and the Bear Lake Settlement Agreement. Bear Lake storage and allocation data can be seen in Figure 4.

Results:

Figure 3 shows a graph of the results for the combined diversions from both canals. The total diversions are shown in blue, with natural flow shown in green and storage shown in chartreuse. The green and chartreuse quantities add up to the blue quantity. Quantities vary greatly from year to year, but the ideal diversion would be zero storage water used and minimal natural flow used. This would suggest the crops are receiving all of their water from precipitation. Actually, in 2011, there was abundant natural flow available and zero storage water was used.

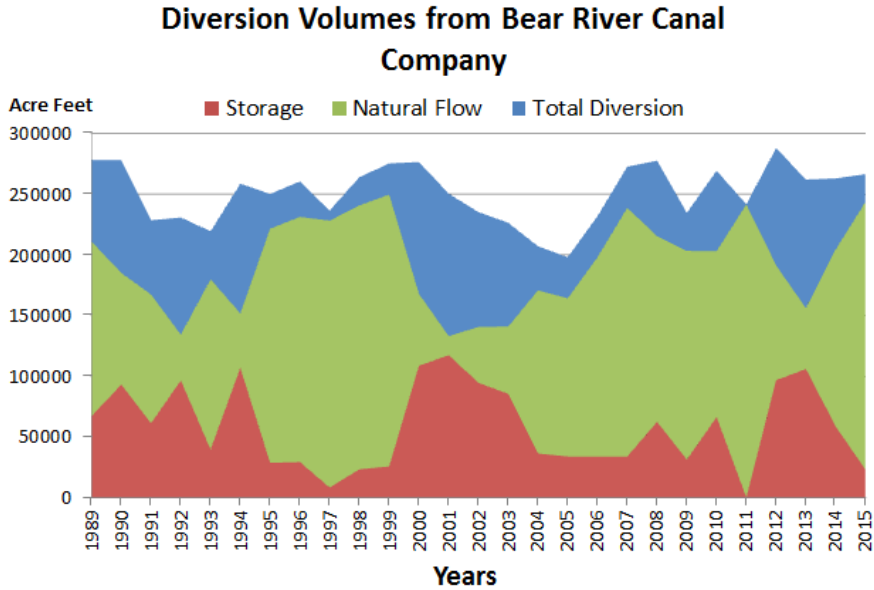


Figure 3. Bear River Canal Company Diversions

Figure 4 shows the results for Bear Lake storage. The green graph is the allocation, which is set prior to the irrigation season. The blue graph is the total storage release, and the magenta colored graph is the quantity used by BRCC. The optimal condition would be to have a high allocation, and low total release, such as in 1997 and 2011. A full allocation is 245,000 acre-feet.

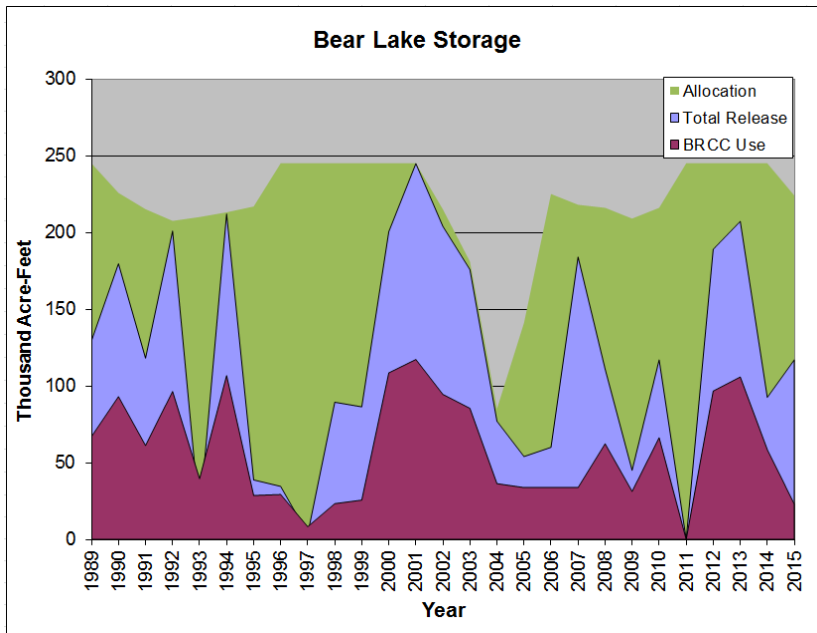


Figure 4. Bear Lake Storage

Land use results for this project are interesting. However, more recent data is needed. In 1986, 70,666 acres were irrigated, with corn, grain and alfalfa being the three major crops of choice. In 1996, 78,673 acres were irrigated, with similar results to 1986, but with a noticeable increase in acreage, primarily in grass hay and pasture. In 2003, 77,958 acres were irrigated, which is a similar quantity to the 1996 value. Of the 77,958 acres irrigated in 2003, 8758 acres were irrigated by sprinklers (11.2 %) and 69,200 acres were flood-irrigated (88.8 %).

An interesting land use trend shows up in 2003, where there is a decrease in the number of acres of grain and an increase in the number of acres of alfalfa. This trend continues in the 2009 data as well. However, in 2009, only 70,207 acres were irrigated. Of the 70,207 acres, 8261 acres were irrigated by sprinklers (11.8 %) and 61,946 acres were flood-irrigated (88.2 %). It appears that for the two data sets with higher acreage (1996 and 2003), the increases were primarily due to an increase in pastures being irrigated, with some other crops being irrigated as well. These trends can be seen in Figures 5a and 5b below.

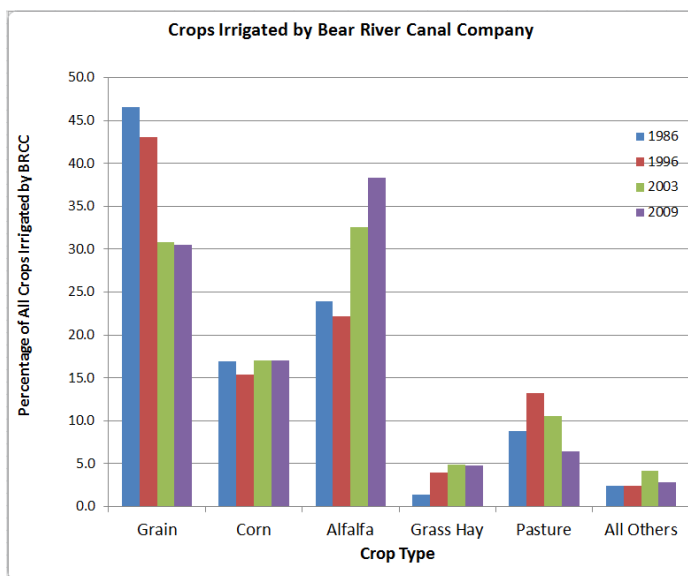


Figure 5a. Land Use by Percentage

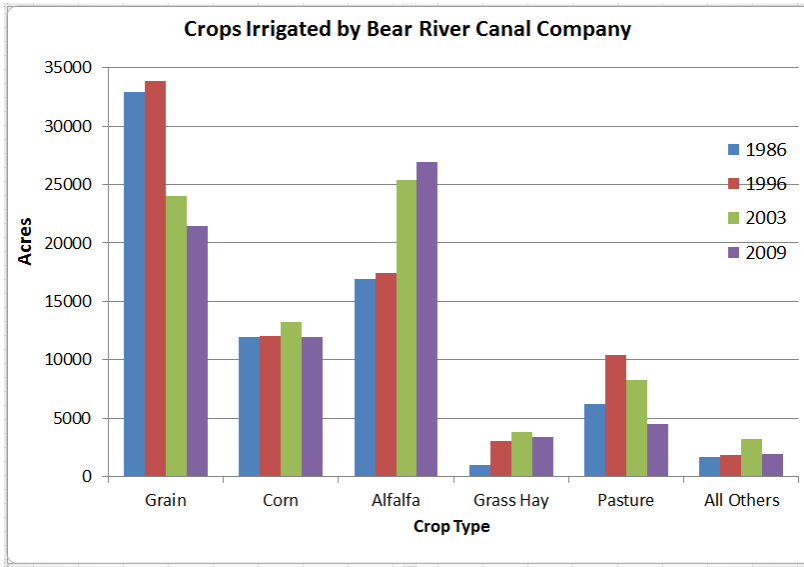


Figure 5b. Land Use by Acreage

Figure 6 shows temperature data results for the average of the irrigation season temperature for Tremonton, Utah during the months of April to October. Tremonton was selected because it is located in the center area of the project, and there was weather data for that site. The average temperature varies from a low of 59 degrees Fahrenheit, to a high of nearly 65 degrees Fahrenheit. It is difficult to quantify or measure the impact that temperature data at this level has on water use.

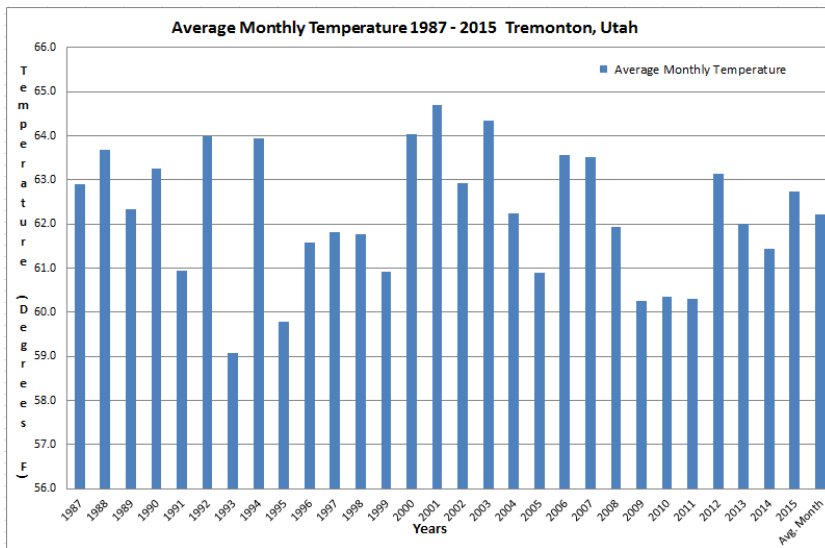


Figure 6. Temperature Data

Precipitation received during the irrigation season varies from about five inches to about 14 inches, as shown in Figure 7. When a precipitation event hits, the irrigation company reduces the amount of water it diverts from the river. Thus, precipitation received during irrigation season has a direct effect on the quantity of water diverted by BRCC. A measure of this can be seen and correlated between Figures 3 and 7.

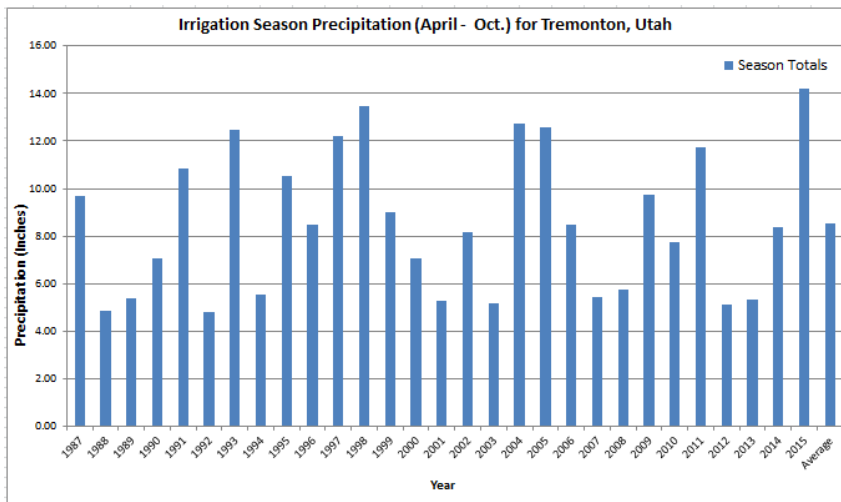


Figure 7. Precipitation Data

Discharge of the Bear River can be seen in Figure 8. It could be said that the river was high during irrigation season for the years 1993, 1995 to 1999, 2005/2006, 2009, and 2011. The remainder of the years, the river was pretty low. Discharge is a measure of water availability.

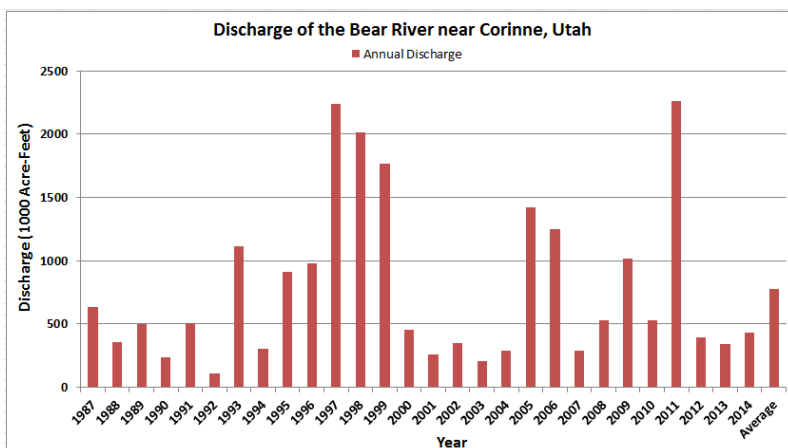


Figure 8. USGS Streamgage Near Corinne, UT

Figure 9 shows a scoring and ranking system for each year from 1989 to 2014, which is 26 years in all. Each year was ranked 1-26, or lower if there were any ties, for the following seven criteria; low temperature, high precipitation, high natural flow in the river, high storage allocation for Bear Lake, low quantity of natural flow diverted by BRCC, and low quantity of storage water diverted by BRCC. The scores were summed for each year, and averaged by dividing by the number of criteria. The lower the score, the higher the ranking. This method was meant to be a visual representation of the overall water use picture for each year.

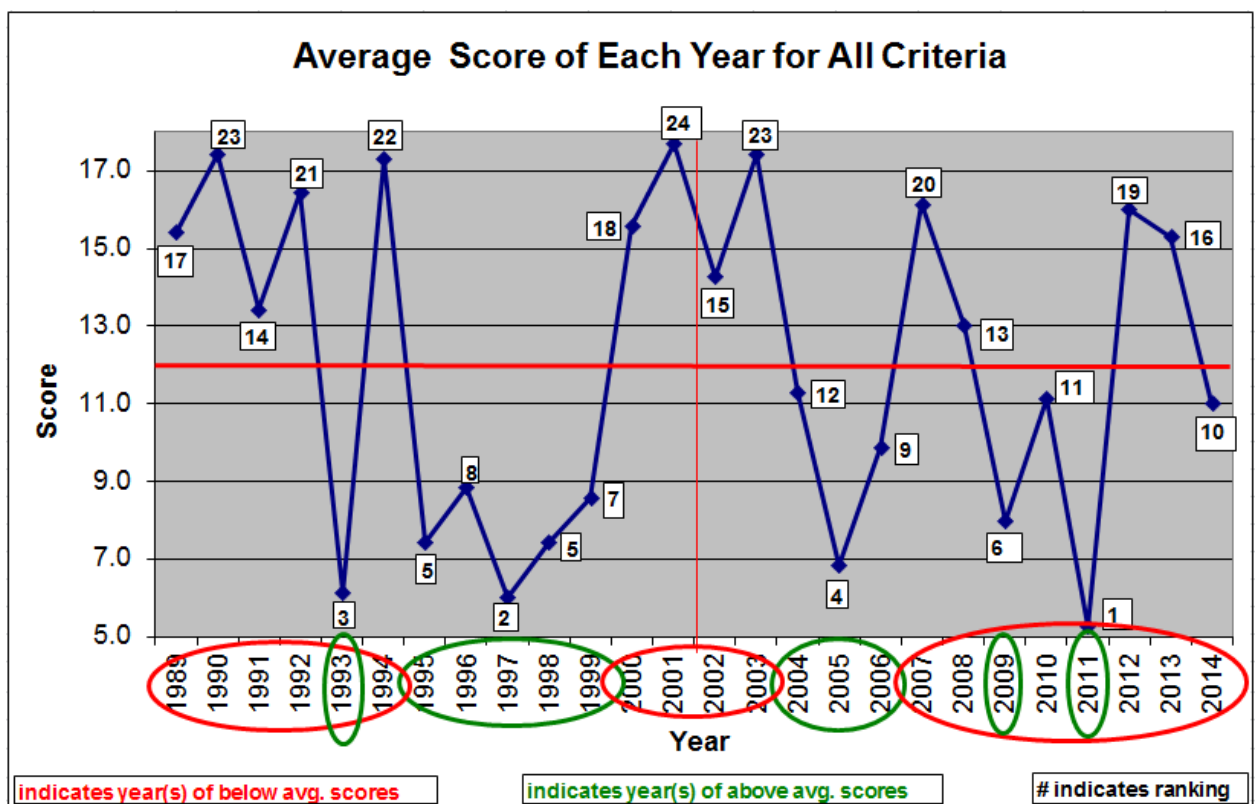


Figure 9. Scores and Ranking of all Years

Discussion:

Precipitation, whether received during the irrigation season, or prior to it, is the largest determiner of water availability and diversion use. Wet years such as: 1993, 1997 –

1999, 2004/2005, and 2011 can be seen in both Figures 7 and 8. These years are characterized in Figure 3 by low storage, and high natural flow, leaving a large gap between the two. Dry years, such as: 1990, 1992, 1994, 2000 to 2003, and 2012/2013 are characterized in Figure 9 by high storage peaks and low natural flow troughs, with a short gap in between.

It is interesting to note that water availability can fluctuate extremely from year to year, for example 1992 to 1993 and 2011 to 2012/2013. What may be more intriguing; is to observe trends in the diversion quantity over a longer period of time. This might be visualized by determining what the crop’s water use is over time, such as shown in Figure 10. The crop use was calculated by dividing the irrigated acreage of each year by the volume of water diverted from BRCC, and adding the precipitation. Linear interpolation was used for all years between datasets, while it was assumed that the irrigated acreage has remained constant since 2009.

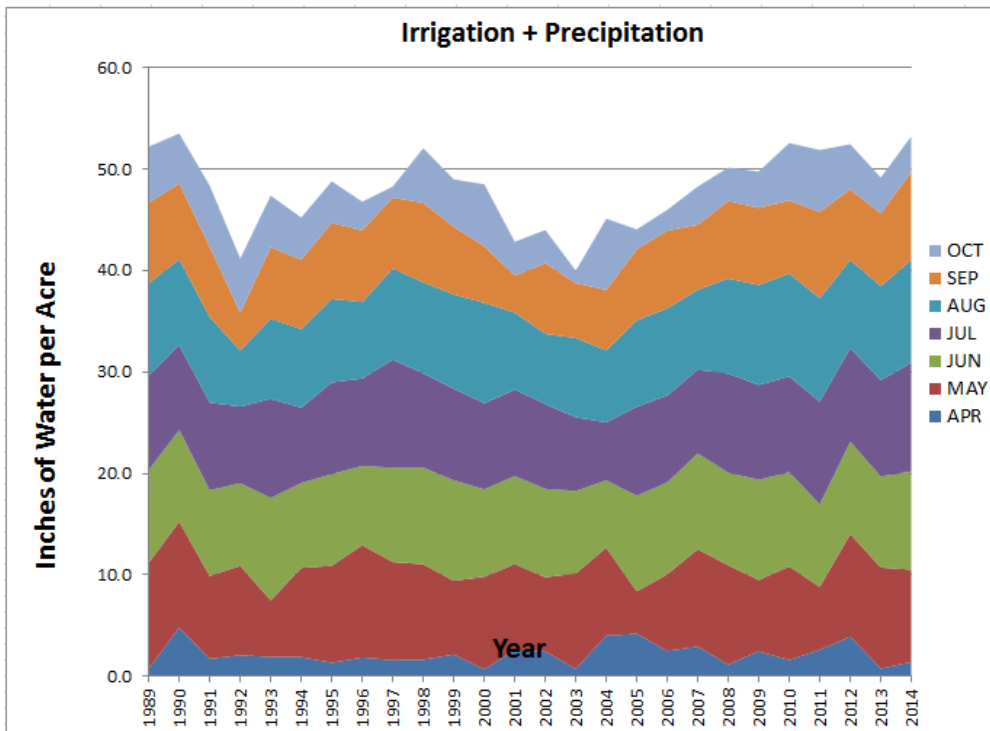


Figure 10. Crop Use (Irrigation + Precipitation)

Analyzing the crop use trends (land use) from Figures 4 and 5, and comparing them to Figure 10, some conclusions may be drawn regarding land use trends. Figure 10 shows that initially (1989/1990), a lot of water was used by crops, followed by a sharp decrease in 1991, and then a steady increase until 1997, followed by a decrease until 2002, and then a steady increase again until 2014. You would expect from looking at Figure 5, that the crop use would mimic the increase in number of acres from 1986 to 1996, remain fairly constant from 1996 to 2003, and then decrease from 2003 to 2009, however this is not quite the case.

What appears puzzling is the large crop use for the first two years and the decrease from 1997 to 2002. However, the steady increase in crop use from 2002 to 2014 may be a direct reflection of changes in crop type from decreased grain production and increased alfalfa production. Farmers in the Bear River Valley in Box Elder County strive to harvest four crops of alfalfa each irrigation season, whereas grain produces only one crop per season. More water is used to irrigate four crops of alfalfa than a single crop of grain. This appears to be reflected in the increased water use from 2002 to 2014. The increase from 1991 to 1997 might be attributed to an increase in the number of acres irrigated. Perhaps the hardest conclusion to arrive at or the hardest factor to quantify is the correlation between temperature and water use. Two of the years with the highest temperatures are 2000 and 2003, yet the difference in quantity of water diverted for those two years is 50,000 acre-feet. Two of the years with similar, lower temperatures are 1999 and 2005. The difference in quantity of water diverted for those two years is 77,000 acre-feet. Thus, while temperature may have a minor influence on quantity of water diverted,

it is the precipitation, or lack thereof that is coupled with it, which is the driving influence on weather-related water use.

Conclusion:

Analyzing the factors that may influence the quantity of water diverted by Bear River Canal Company is tricky. Hydrologic and weather-related data fluctuate drastically, making it somewhat difficult to quantify the factors that influence water diversions.

Precipitation is the driving factor, while temperature plays a very minimal role. Land use (crop type and area irrigated) also contributes to longer term water use trends. It would have been impossible to complete this project, while considering land use, without the use of GIS. More data and longer term data appear to be necessary to describe water use trends of the Bear River Canal Company, and other such water users, and to quantify the results.

References:

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