Report for 2003WY13B: Conveyance Losses and Travel Times of Reservoir Releases Along the Bear River from Woodruff Narrows Reservoir to Cokeville Wyoming

Publications

- Articles in Refereed Scientific Journals:
  - Kunz, B.G., Johnson, D. W. and Kerr, G., “Return Flows, Re-Diversion, and Irrigation Performance Measures for Water Taken from the Bear River in Wyoming and Utah”, Kunz, W., Johnson, D. W. and Kerr, G. , Journal of Irrigation and Drainage Engineering, Submitted for Publication August 2005, notified revisions are required before publication.
- Dissertations:
  - Franz, T., 2005. A Water Budget Analysis for Predicting Return Flow on the Bear River in Wyoming and Utah, MCE Plan B Paper, Department of Civil & Architectural Engineering, University of Wyoming, Laramie WY.
  - Kunz, W., 2005. Return Flows, Re-Diversion, and Losses Associated With the Bear River In Wyoming and Utah, M.S. Thesis, Department of Civil & Architectural Engineering, University of Wyoming, Laramie WY.

Report Follows

Problem and Research Objectives:

The Bear River is the longest river in the United States without an ocean outlet. It originates in the Uinta Mountains of Utah and flows north to Wyoming, Idaho, and back to Utah and releases its water into the Great Salt Lake. With the extreme drought experienced in the late 90's and early part of the new millennium, the accuracy to which water is allocated has become increasingly important. The Bear River is a vital lifeline to farmers, ranchers, industry and municipalities in Utah, Wyoming, and Idaho; therefore, knowledge of its water losses, gains and general fluctuations are of vital importance. The Bear River between Woodruff Narrows reservoir and Pixley diversion dam is a reach with 17 irrigation diversions that cause enormous amounts of return flow in the system. This study examined many factors that may be of interest to the irrigators in the Bear River region. Estimates for conveyance losses were developed over two irrigation seasons as were approximations of gains, seasonal losses, and re-diversion proportions. Also included in the study are estimates of travel time and return flow timing to aid irrigators in approximating the time that water may become available to them.

Methodology:

Gage Installation

Analyzing years of historical data made it evident that it would not provide the information needed for this study. The data obtained from the USGS and state water agencies only allowed the region to be sectioned in to one large reach, and did not allow the prediction of return flows that may occur in Utah and prior to the Wyoming state line. More detailed analysis was needed to determine gaining and losing reaches, and what river sections contributed most of the return flows. Historical data only showed that the system experienced large return flow and overall seasonal loss, but could not provide the insight required for a thorough study including the detail necessary for conveyance loss estimates. Due to the lack of data, three new gaging sites were established. The new gages installed on April 27, 2004 allowed the breakdown of the river into four reaches from Woodruff Narrows to Pixley Dam. The new gaging sites were chosen based on the input of Kevin Wilde of Wyoming and Ron Hoffman of Utah, both of which are hydrographers for their respective states. The Cornia, Thornock, and Weston bridges along the Utah section of the Bear River were chosen as the new gaging sites. Bridges were chosen because they allow easy gage access and a solid anchor for the new gages. Also, the bridges were spread out in a way that allowed data collection on the Utah section which would provide the most useful data for determining return flow and loss before the Wyoming state line.

Gains and System Losses

A water balance was used to determine total loss, return flows, and re-diversion proportions over irrigation seasons. The system was analyzed on a cumulative basis which allowed the irrigation seasons to be viewed as the reservoir release of one large slug of water from May 1 until July 15, when the majority of diverted flow ceases for the summer. As the slug becomes cumulatively larger on a daily basis, the effects of outflow are incorporated to determine if the slug is losing, gaining, or experiencing re-diverted proportions. Cumulative values were calculated based on two river gages and seventeen diversion gages. Historical data for 1988, and 1993-2003 was analyzed based on the two river gages operated by the USGS that accounted for flow entering and leaving the system. The two USGS river gages that exist on the reach are gage 10020300 located below the dam at Woodruff Narrows, and gage 1028500 located below Pixley Dam. Flow data for the USGS gage below Pixley are available from the 1940's to present, while historic data for the gage below the dam at Woodruff Narrows dates back to 1961. For the separate analysis done for 2004 and 2005, three additional gages were installed in the Utah section of the river. Wyoming diversion data was obtained from Wyoming Division IV Hydrographer's Annual reports. Although this data was available from as far back as the 1970's, some diversions were missing from several years. Utah diversion data was acquired from the water rights website www.waterrights.utah.gov. The final historical data set included the USGS flow records for both gages on the reach along with all diversion flow for 1988, and1993-2004.

Consumed water

Consumptive irrigation requirements (CIR) were calculated over the study period and compared to system loss values in an attempt to estimate how well diverted water was being utilized. CIR values can be calculated as precipitation subtracted from the crop's evapotranspiration (ET) values. The SCS Blaney-Criddle approach was used to calculate the crop's ET values. Effective precipitation to the area was determined from weather stations and applying the effective precipitation coefficient of 0.8 provided by the Wyoming State Water Plan for the Bear River Basin.

Conveyance losses and travel times

Conveyance losses were calculated based on hydrographs. New hydrographs were developed from the three new gages and allowed the entire reach to be sectioned into shorter reaches that were not as heavily influenced by return flows as the overall system. An incremental approach was used to measure conveyance losses because it helped eliminate the confusion associated with any re-diverted flow that occurred in a reach. The conveyance losses were calculate from difference in the change in inflow and outflow, including diversions, for a given reservoir release for each reach.

Travel times were important to three parts of the study: matching hydrologic events for conveyance loss estimates, estimating reservoir release lag times, and return flow lag times. A graphical approach was used for travel time estimates that involved the matching of increased flow periods that correspond to the same hydrologic event. Typically, the time lag between the maximums on the inflow and outflow hydrographs is estimated by observing the time difference between the visible maximums on the hydrographs. In this particular study, maximums were believed to be shortened by high amounts of diverted flow; therefore instead of comparing lag time to peaks, the difference between the rising limbs in flow were observed and used as the travel time.

Diversion Efficiencies

With the installation of the three gages, it was possible to estimate the diversion efficiency of each canal, return flow lag times and return flow quantities for each reach. A GIS analysis was used to find irrigated areas for each canal based on surface runoff by gravity. This allowed an estimate of where return flows entered the system. A water budget analysis was used to estimate volumes of return flow and predict outflow for each reach. The diversion efficiencies were calculated based upon the constraint that total return flows generated by the diversions must match the measured return flows for the connected reaches and in the analysis and timing of return flows generated was assumed to vary with inversely with diversion distance away from the reaches.

Principal Findings and Significance:

The re-diversion proportion for wet, average, and dry years was estimated as 84%, 111%, and 153% of inflow, respectively. These proportions were based on cumulative plots that spanned the time period of May 1 – July 15 which is the main period of irrigation. Gains are the amount of positive imbalance to the system that can be mostly attributed to return flows.

The gains for wet, average, and dry years for the historical data examined in this study were 72%, 62% and 44% of diverted flow, respectively. On average, 62% of all diverted flow returns to the main channel of the river. For 2004 Wyoming showed gains of 105% proportional to diverted flow while Utah showed 41% gains. The high gain proportion in Wyoming is likely due to Wyoming's dependency on Utah return flows, which enter the Wyoming section without being gaged; therefore, making the amount of diverted flow in Wyoming high proportional to inflow.

System losses were calculated for the historical data (1988, 1993-2004) and for wet, average, and dry years were 22%, 41%, and 86% of inflow, respectively. For 2004 system loss by state was determined for Wyoming and Utah as 62%, and 63%, respectively as a proportion of diverted flow. Diverted flow was used to relate the reaches as opposed to inflow because inflow is not a good representation of available water to the Wyoming reach because it is thought that Wyoming uses a great deal of Utah return flows.

Based upon the suitability of the hydrographs for analysis, conveyance losses were determined for two reaches. Reach 3 (Between the Thornock, and Weston bridges) showed conveyance losses of 0.68% and 0.56% per km (1.1% and 0.9% per mile) for first and second releases respectively; therefore, yielding an average loss of 0.62% per km (1.0% per mile). Reach 4 (Between Weston Bridge and Pixley Diversion Dam) exhibited losses of nearly zero which does not agree with the two loss measurements in Reach 3. Due to the repeatability of the loss estimates in Reach 3, and the idealistic nature of its system, the average conveyance loss of 1.0% per mile found in Reach 3 is thought to be the most representative and accurate estimate for conveyance losses in the entire system for 2004. For the 2005 data, the analysis was repeated. However, 2005 was a very wet year; in the analysis for 2005 each reach was found to be a gaining reach with unstable return flows being generated throughout the irrigation season and not enough data was available to make an accurate estimate of conveyance losses. This is most likely explained because of the considerable difference in available water and the increased flow of water in the Bear River during 2005. During the period of May 1 through September 30 the peak flow for 2005 was 1,185 cubic feet per second while in 2004 experienced only 869 cubic feet per second, a difference of over 300 cubic feet per second. Between May 1 and July 14, 2005, 145.3 MCM (118,118 acre feet) of water flowed past the Woodruff Narrows gage, but only 55.7 MCM (45,275 acre feet) flowed past the same gage during the same time period in 2004.

Travel times within the channel in 2004 were estimated for the sections of river from Woodruff Narrows Reservoir to Cornia, Thornock, and Weston bridges, and BQ and Pixley diversion dams; the graphical estimates were 1, 2, 3, 3.8, 4, and 5 days respectively. Return flow lag times were approximated and help show Wyoming's dependency on Utah's returns. Although it is believed that Wyoming receives Utah's returns throughout the irrigation season, the Wyoming reach during 2004 received the majority of returns from Utah after June 23. The lag time was approximately 53 days, or the time from May 1 to June 23. An analysis of 2005 data confirmed this estimate.

The modeling results of the 2004 data resulted in diversion efficiencies (D_{eff}) of around 30%, for all canals which matched the historical values reviewed. Modeling with 2005 data resulted in lower diversion efficiencies of approximately 20% for the larger canals. The wet hydrologic conditions of 2005 resulted in significant gains from the system and the large contributing areas of these larger canals magnified the gains, which lowered the diversion efficiency considerably.   Modeling results indicated that return flows occurred primarily within two months in for the drier 2004 data year. The wetter 2005 data year indicated approximately 10% of return flow occurred in the third month after diversion. Further data should be used to verify the model and the capabilities of the model.

Students Supported:

Nicholas Charles, MS Civil Engineering, University of Wyoming, Current
Trenton Franz, M. Civil Engineering, University of Wyoming, Fall 2005
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Meetings and Presentations:

"Re-diversion Proportions on the Bear River", Bear River Advisory Group, Cokeville Wyoming, October 2004.

"Bear Lake Eco Symposium and Annual Meeting of Bear River affiliates" September 2004

"Conveyance Losses on the Bear River" Wyoming State Engineers office, Utah State Engineers Office, Cokeville Wyoming, January 2004.

"Conveyance Losses on the Bear River", Bear River Advisory Group, Kemmer Wyoming, July 2003.