Irrigation Return Flows and Snake River Reach Gains for Calibration of Eastern Snake Plain Aquifer Model Version 2

Idaho Department of Water Resources
Jennifer Sukow
Michelle Richman
Sudhir Goyal
October 1, 2012

ESPAM2 Design Document DDW-V2-15

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DESIGN DOCUMENT OVERVIEW

During calibration of the Eastern Snake Plain Aquifer Model Version 1.1 (ESPAM1.1), a series of Design Documents were produced to document data sources, conceptual model decisions and calculation methods. These documents served two important purposes: they provided a vehicle to communicate decisions and solicit input from members of the Eastern Snake Hydrologic Modeling Committee (ESHMC) and other interested parties, and they provided far greater detail of particular aspects of the modeling process than would have been possible in a single final report. Many of the Design Documents were presented first in a draft form, then in revised form following input and discussion, and finally in an "as-built" form describing the actual implementation.

This report is a Design Document for the calibration of the Eastern Snake Plain Aquifer Model Version 2 (ESPAM2). Its goals are similar to the goals of Design Documents for ESPAM1.1: to provide full transparency of modeling data, decisions and calibration; and to seek input from representatives of various stakeholders so that the resulting product can be the best possible technical representation of the physical system (given constraints of time, funding and personnel). It is anticipated that for some topics, a single Design Document will serve these purposes prior to issuance of a final report. For other topics, a draft document will be followed by one or more revisions and a final "as-built" Design Document. Superseded Design Documents will be maintained in a "superseded" file folder on the project Website, and successive versions will be maintained in a "current" folder. This will provide additional documentation of project history and the development of ideas.

INTRODUCTION

Irrigation return flows and Snake River reach gains were used as calibration targets for ESPAM2.0. Irrigation return flows were used as calibration targets to constrain the adjustment of parameters D_{pin} and D_{pex} for some surface water entities. These parameters are used in the MKMOD On-Farm Algorithm to calculate how surface water diversions not consumptively used are partitioned between recharge and return flow. Measured irrigation return flows were available for a limited number of years for ten of the ESPAM2.0 surface water entities. Data collection at most of the measured return flow sites began in 2002 or later. For years without measured return flow data, estimates are used in reach gain calculations, but are not included in the return flow calibration targets used to constrain adjustment of D_{pin} and D_{pex}

Reach gains were used to calibrate modeled aquifer recharge and discharge in cells representing five reaches of the Snake River above Minidoka. Reach gains used for calibration of ESPAM2.0 are the best estimate of river gains or losses from or to the Eastern Snake Plain Aquifer (ESPA), and may differ from reach gains used in other applications (i.e. water allocation) that include surface water contributions to natural flow.

Reach gains in three reaches of the Snake River between Kimberly and King Hill were also used to calibrate modeled spring discharge. Groundwater contribution from the south side of the Snake River (outside of the ESPAM model domain) was deducted from the Kimberly to King Hill reach gains. Calculation of reach gains between Kimberly and King Hill is described in detail in Design Document DDW-V2-14 and is not covered in this document.

This Design Document describes the irrigation return flow monitoring network, analysis of irrigation return flow data, assignment of return flows to ESPAM2 irrigation entities and Snake River reaches, and calculation of reach gains for five modeled reaches of the Snake River upstream of Minidoka.

This Design Document incorporates ESHMC meeting discussions in May and June 2011, and supporting data analyses completed by IDWR staff.

IRRIGATION RETURN FLOW MONITORING

Background

For use in calibration of ESPAM2.0, return flow sites were grouped based on ESPAM irrigation entity (Contor, 2010). Return flow groups and corresponding irrigation entities are listed in Table 1.

Return Flow Group	ESPAM2 Entity	ESPAM2 Entity Name	Measured Data	Data Source
7	IESW016	Egin	12/1988 - 6/1990	USGS
9	IESW036	Liberty	4/2002 - 10/2008	IPCO
10	IESW009 IESW020 IESW055	Burgess Harrison Labelle	4/2002 -10/2008	IPCO
8	IESW011	Butte Market Lake	4/2002 - 10/2003	IPCO
5	IESW002	Aberdeen Springfield	4/1989 - 10/1994 4/2001- 10/2001 4/2002 - 10/2004 10/2004 - 5/2008 5/2008 - 10/2008	ASCC ASCC IPCO BOR IDWR
2	IESW028	Minidoka	4/2002 - 10/2004 10/2004 - 5/2008 5/2008 - 10/2008	IPCO BOR IDWR
3	IESW010	Burley	4/1996 - 8/2001 4/2002 - 10/2004 10/2004 - 5/2008 5/2008 - 10/2008	BID IPCO BOR IDWR
1	IESW032	Northside	4/2002 - 10/2008	NSCC
4	IESW041	Twin Falls Canal Co	4/2002 - 10/2004 11/2004 - 10/2008 6/2005 - 10/2008 3/2002 - 10/2008	IPCO IDWR ARS TFCC

Table 1. Return flow data used in calibration of ESPAM2.0.

In 2002, the Idaho Department of Water Resources (IDWR) and cooperating agencies began efforts to expand monitoring of irrigation return flows for calibration of the ESPAM. Beginning in 2002, IDWR contracted with Idaho Power Company (IPCO) to monitor return flow sites within most of the grouped irrigation entities listed in Table 1. IPCO has continued to conduct monitoring work for the return flow sites within Groups 9 and 10. In late 2004, the Bureau of Reclamation (BOR) took over monitoring of return flows in the mid-Snake region (Groups 2, 3, and 5), encompassing the Burley Irrigation District (BID), Minidoka Irrigation District (MID), and Aberdeen Springfield Canal Company (ASCC) irrigation entities. IDWR subsequently took over the monitoring work from the BOR for the mid-Snake sites in 2008. ASCC, MID, and BID have assisted with installation of new monitoring sites and have performed most of the maintenance for the return flow sites in their respective areas. ASCC and BID have also provided historic data collected prior to 2002.

In 2005, IDWR took over the monitoring work from IPCO for the return flow sites within the Twin Fall Canal Company (TFCC) irrigation entity, which comprises Group 4. Meanwhile, the Agricultural Research Service (ARS) monitored and maintained six additional sites within the TFCC irrigation tract from 2005 to 2010. IDWR took over the monitoring and maintenance of these sites from the ARS in 2011. ARS monitors streamflow at the Rock Creek Highline gage which is used in processing data from the Rock Creek Poleline return flow site. The TFCC maintains one other return flow site (Perrine Coulee) and reports the corresponding data to IDWR annually.

The North Side Canal Company (NSCC) maintains the return flow sites within Group 1 and reports the daily average flow for each site to IDWR on an annual basis.

Historic data for return flow group 7 were obtained from the USGS. This site was not monitored between 1991 and 2009. Return flow group 8 is not currently monitored, only historic data measured by IDWR are available for this site.

The return flow sites that IDWR monitors within Groups 2, 3, 4, and 5 are equipped with data loggers, water level sensors, and fixed staff gages. IDWR makes regular site visits year-round to observe perennial and seasonal sites and to check for tracking between the logged water levels and the observed staff gage readings. For notable discrepancies, the logged water level is reset to match the staff gage value when the difference cannot be attributed to equipment issues or physical site conditions.

A majority of the sites have measurement devices, such as weirs, in place; however, for those stations with rated sections, periodic flow measurements are made to establish and maintain rating equations for computation of flow. All stations are programmed to record 15-minute water level data, which are downloaded during site visits.

Return Flow Locations

Locations of return flow sites used in calibration of ESPAM2.0 are shown in Figure 1 through Figure 10. Measured return flows were available for ten surface water irrigation entities within the model boundary. Measured return flow data were unavailable for eleven other surface water irrigation entities with return flow to the Snake River (Figure 11). Sixteen surface water irrigation entities and IESW000 were assumed to have no surface return flow to the Snake River (Figure 12).

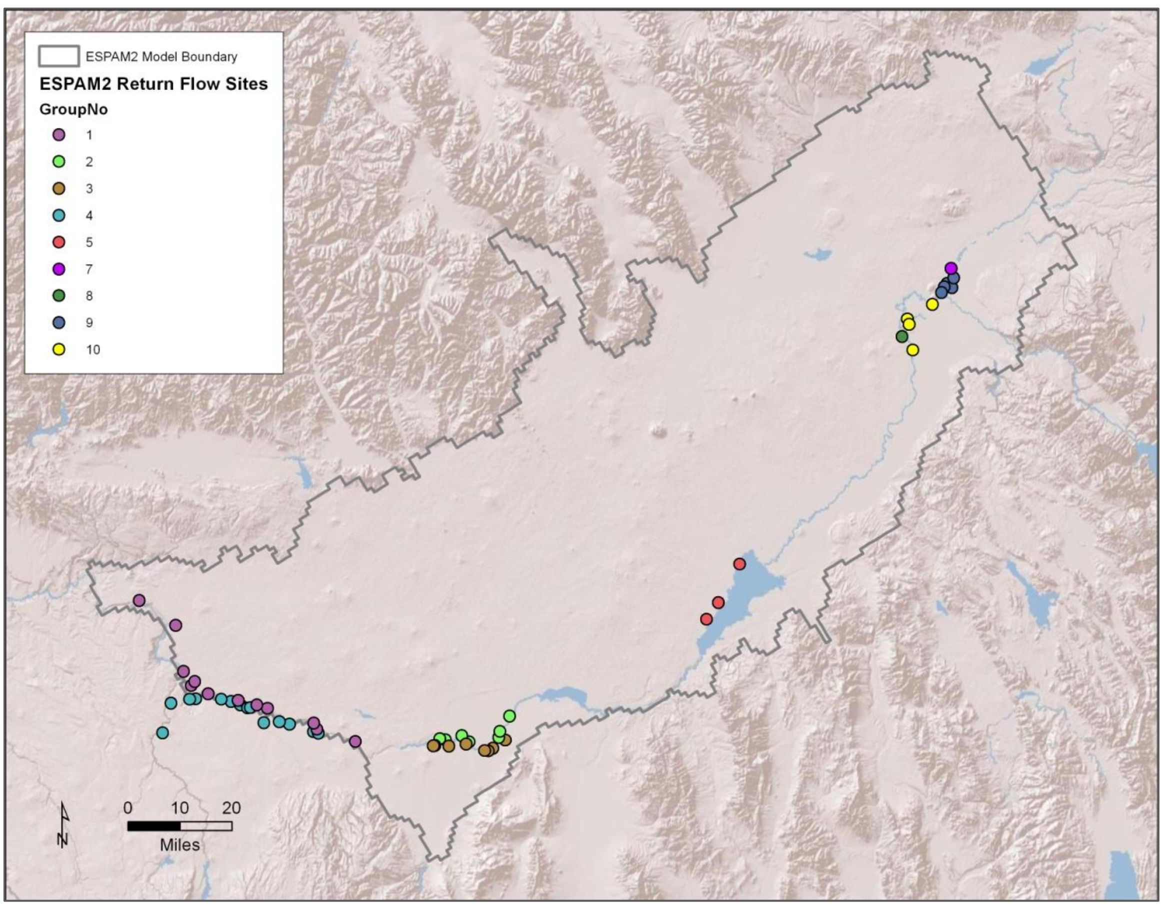

Figure 1. Return flow sites used in calibration of ESPAM2.0.

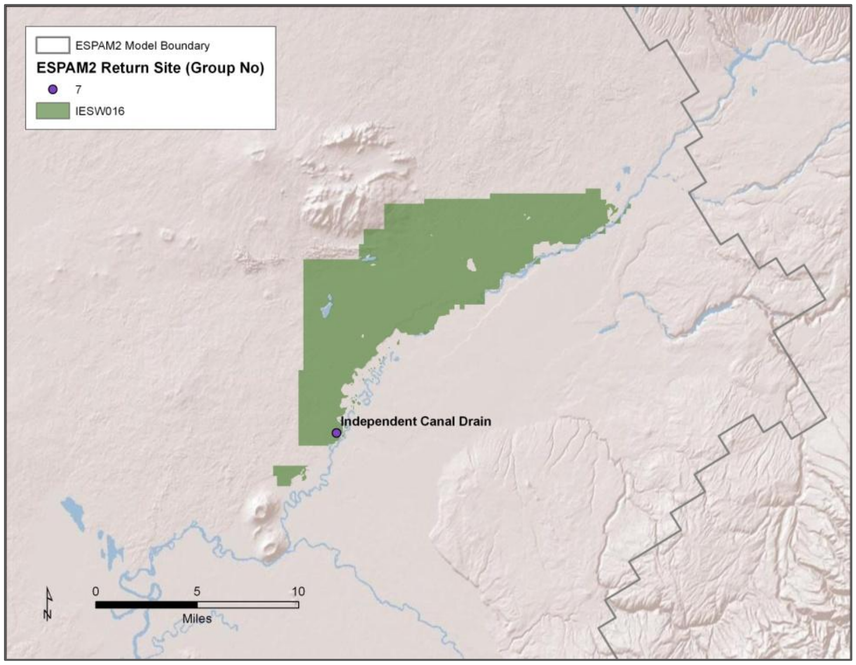

Figure 2. Return flow site used in calibration of ESPAM2.0, Egin entity.

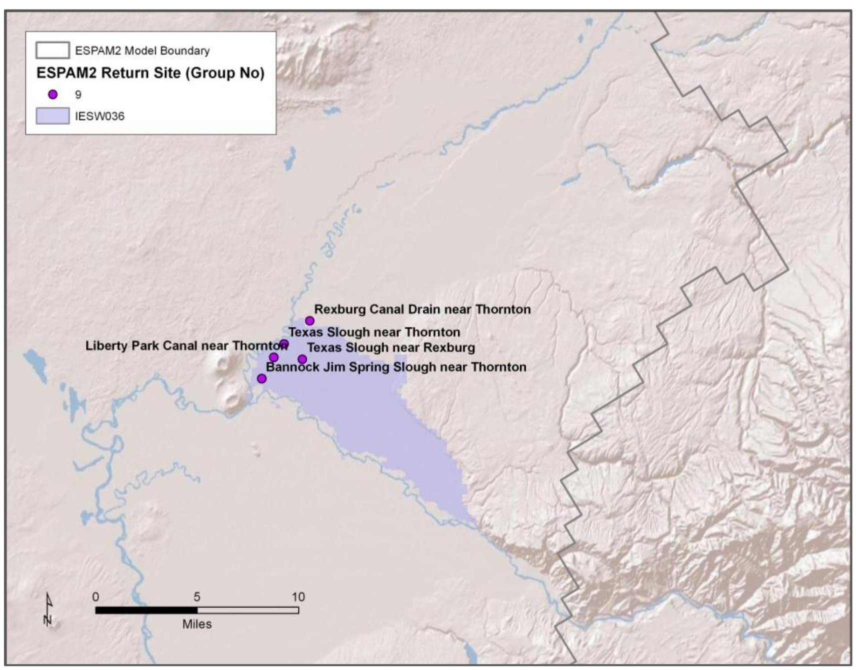

Figure 3. Return flow sites used in calibration of ESPAM2.0, Liberty entity.

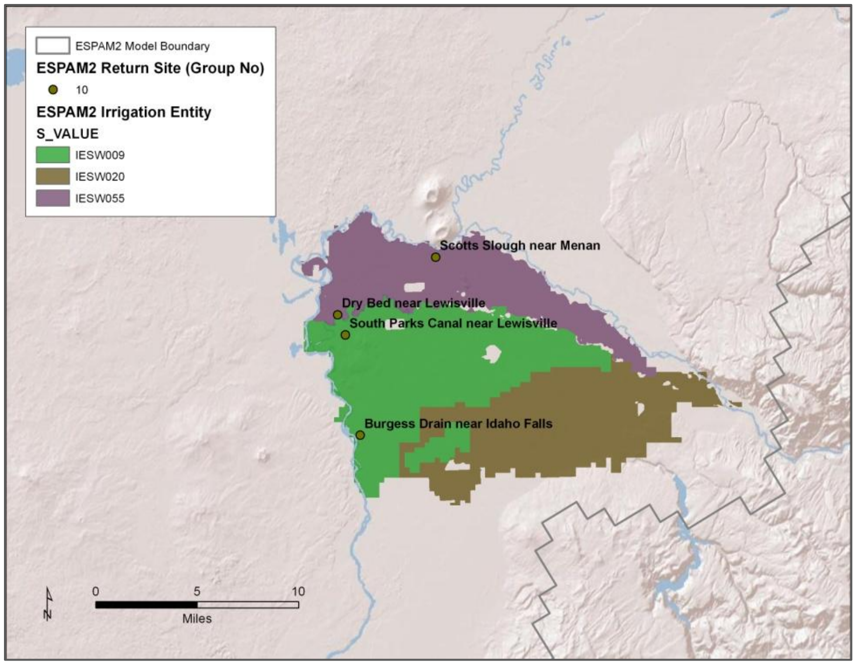

Figure 4. Return flow sites used in calibration of ESPAM2.0, Burgess, Harrison, and Labelle enitities.

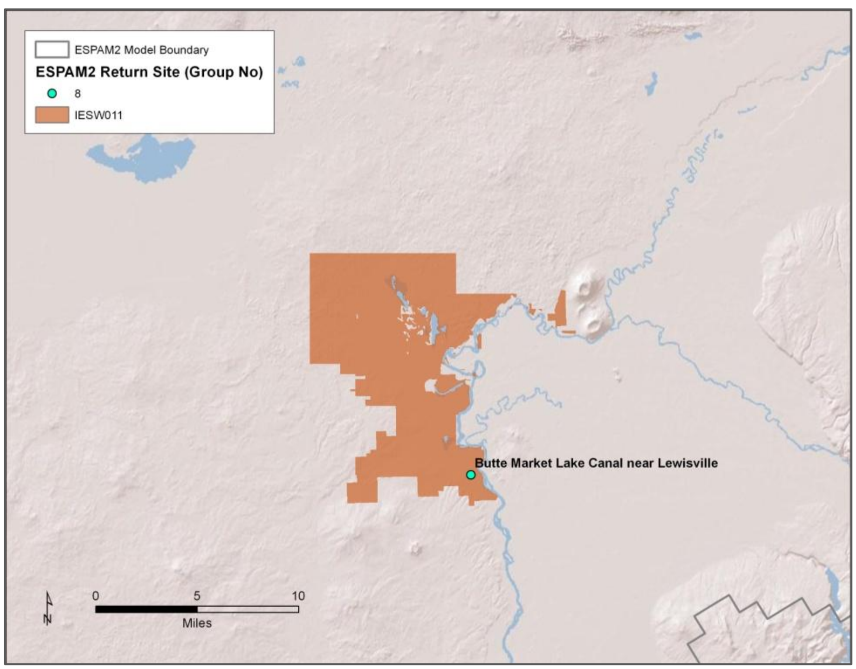

Figure 5. Return flow sites used in calibration of ESPAM2.0, Butte-Market Lake entity.

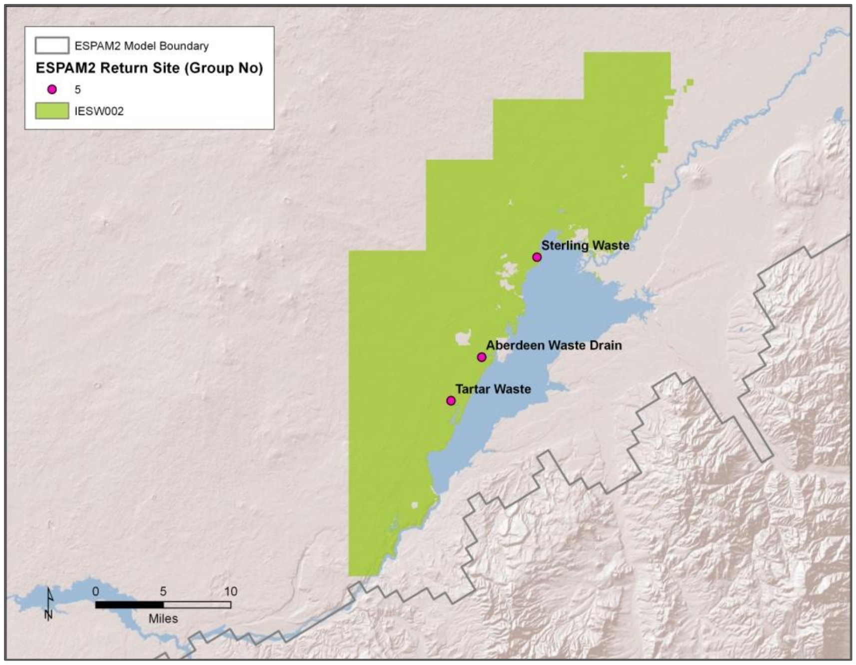

Figure 6. Return flow sites used in calibration of ESPAM2.0, Aberdeen Springfield entity.

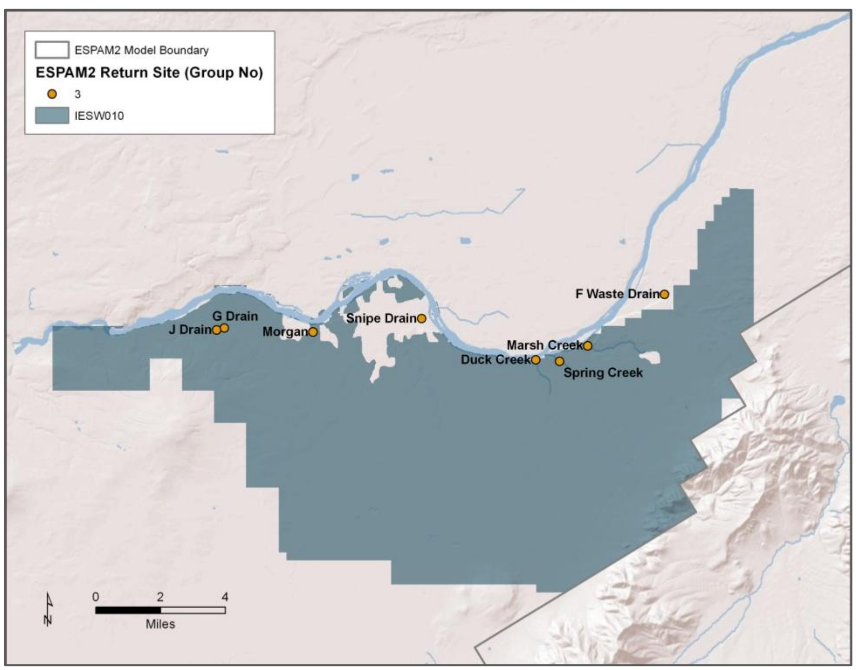

Figure 7. Return flow sites used in calibration of ESPAM2.0, Burley entity.

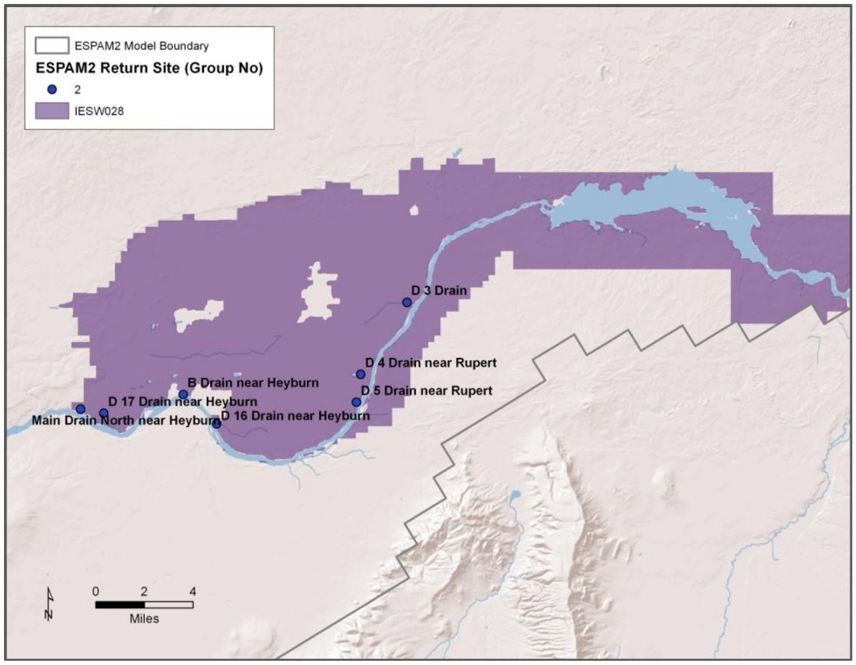

Figure 8. Return flow sites used in calibration of ESPAM2.0, Minidoka entity.

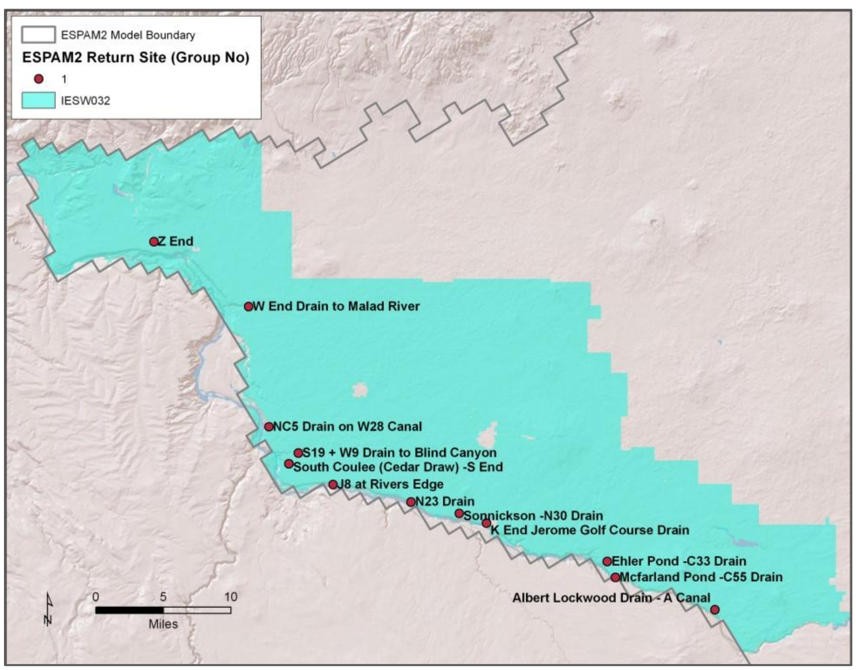

Figure 9. Return flow sites used in calibration of ESPAM2.0, Northside entity.

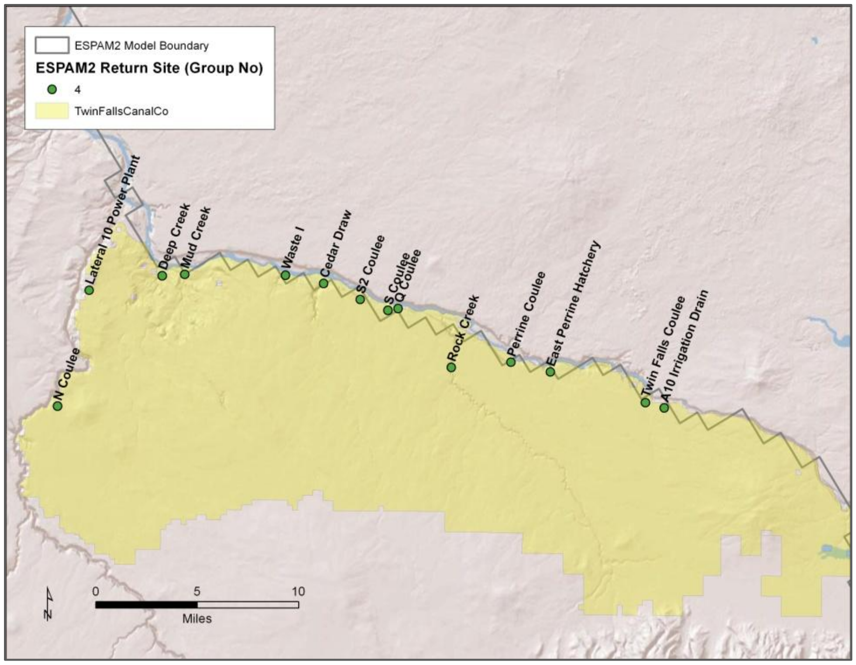

Figure 10. Return flow sites used in calibration of ESPAM2.0, Twin Falls entity.

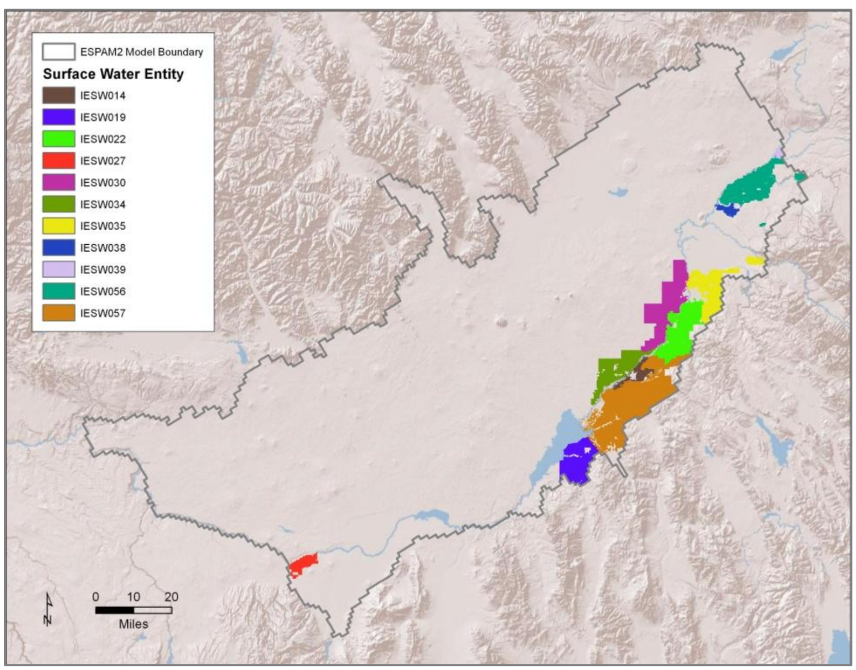

Figure 11. Entities without measured return flow data for calibration of ESPAM2.0.

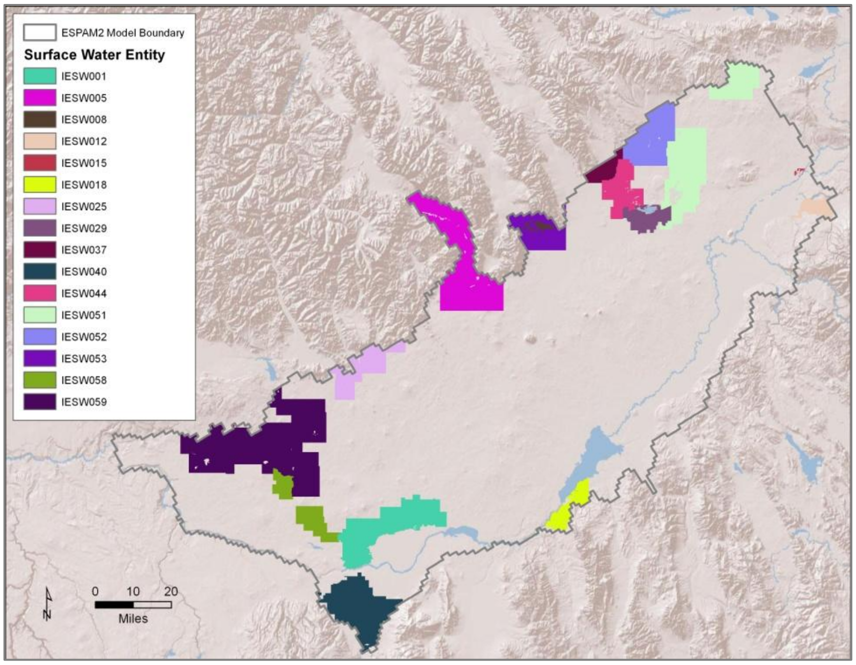

Figure 12. Surface water irrigation entities without significant surface return flow to Snake River.

New Irrigation Return Flow Sites Added After 2008

Return flow sites added after 2008 are listed in Table 2. Data were not available during the ESPAM2.0 calibration period, which ended October 2008, but will be available for use in future calibrations of ESPAM.

The new site at Egin End-of-Canal was established in cooperation with the Idaho Water Resources Research Institute (IWRRI). IWRRI conducts site visits and supplies data to IDWR. This site measures the same return flow measured by the United States Geological Survey (USGS) at the Independent Canal Drain site between 1988 and 1990.

MID and BID assisted with the creation of five new stations within their areas. One of the five new sites was a rediversion project established with cooperation between BID, the Southwest Irrigation District, and Water District 1. This site more accurately reflects return flow for the G & J drains (which IDWR currently monitors at an alternate location) and captures return flow from the G19 drain (which was not previously monitored).

Return Flow Group	ESPAM2 Entity	ESPAM2 Entity Name	# Sites Added	Date	Data Source
--	IESW057	Blackfoot Chubbock	3 5	7/2009 5/2011	TWRD
--	IESW057	Blackfoot Chubbock (Pocatello Creek)	1	4/2010	IDWR
--	IESW030	New Sweden	3	7/2012	New Sweden Irrigation District
2	IESW028	Minidoka	2	7/2011	IDWR
3	IESW010	Burley	1 2	4/2010 7/2011	IDWR
5	IESW002	Aberdeen Springfield	5	4/2010	ASCC
7	IESW016	Egin	1	7/2010	IWRRI

Table 2. Return flow monitoring sites added after 2008.

The ASCC helped establish the new return flow sites in its service area, and ASCC staff members monitor these sites for which they supply site visit data to IDWR.

Fort Hall return flow monitoring sites were installed in cooperation with the Shoshone-Bannock Tribes' Water Resources Department (TWRD), which monitors the sites and supplies site visit data to IDWR. An additional site is planned for installation in cooperation with TWRD in 2013. IDWR established a site at Pocatello Creek that also measures returns from the Fort Hall irrigation entity.

Three sites were established in cooperation with the New Sweden Irrigation District to measure return flow from its service area. New Sweden Irrigation District assisted in the installation of equipment, monitors the sites, and provides data to IDWR. Two additional sites are planned for installation in cooperation with the New Sweden Irrigation District in 2013.

IRRIGATION RETURN FLOW DATA ANALYSIS

Data analysis and quality control

Regarding the field data obtained directly by IDWR for Groups 2 through 5, the 15-minute time-stamped downloads over the course of a year are compiled for each site. For those sites with measurement devices, discharge is calculated for the 15-minute data using standard equations for the device published by the Bureau of Reclamation. Other sites have no measurement device, and flow is computed using a rating equation developed from field discharge and stage measurements. Rating equations are created using Aquarius rating curve development software. Periodic flow measurements are taken to validate or update the rating equations. The 15-minute water level and computed flow data are then converted to daily average values, which are used to populate multi-year water level and flow hydrographs. Field values for staff gage readings and flow measurements are also plotted on the hydrographs.

Creation of the hydrographs helps highlight corrections that will improve the quality of the data. Small data gaps are filled using linear interpolation. For those sites that are seasonal, data gaps and erroneous spikes in winter are replaced with zero flow after first confirming with site visit data that there was, in fact, no flow at the approximate time in question. Erroneous spikes throughout the year are also clipped so values fall within the allowable freeboard for the site. Extended data gaps due to station downtime are filled by replicating a similar year's data for the same site using field staff gage readings and flow measurements as a point of reference. When major discrepancies exist between the logged water level or flow and the field observed staff reading or measured flow, an offset correction may be applied to a specific time frame of the logged data. This would be necessary, for example, if a sensor had swung out of position and was subsequently returned to the original position.

As mentioned previously, data for Groups 1, 7, 8, 9, and 10 were measured by other agencies and supplied to IDWR. Minimal data correction for data in these groups includes filling of data gaps and elimination of erroneous spikes.

Separation of baseflow

It is important to note that the initial flow hydrograph may include precipitation runoff and base flow. For the perennial return sites, the estimated base flow is removed from the total flow. To do so, the minimum value of the daily average flow for each calendar year is identified, and this minimum value is subtracted from all daily average values for the year. This results in a new base flow for each calendar year for each site. Once the baseflow has been removed, the remaining flow is considered the return flow for that site, and that value is reported for modeling purposes.

Within the TFCC area (Group 4), the Rock Creek site near Poleline Road is treated differently from the other perennial sites. First, South Hills runoff is removed by subtracting flow for Rock Creek at Highline as well as estimated flow for McMullen and Cottonwood Creeks to obtain an adjusted daily average flow. A 30-day moving average is then computed for the adjusted daily average flow values, and the minimum of those values is considered the baseflow. This baseflow is subtracted from the adjusted daily average flow values to determine the reported return flow for Rock Creek near Poleline Road.

Scaling return flow group data

After separation of baseflow, irrigation return flows are summed by group. A few groups (Group 1, Group 3, and Group 4) had only a portion of the returns measured during part of the period of record. Group totals for these years were scaled up to account for the missing return measurements, based on the average monthly proportion of the returns during the period when all returns were measured.

NSCC began measuring eight return flow sites in their service area (Group 1, IESW032) in 2002. NSCC added five return flow sites in 2008. The additional sites accounted for approximately 9% of the Group 1 return flow measured between 2008 and 2010. For 2002 through 2007, the monthly irrigation return flow volumes for Group 1 were scaled up based on average monthly proportions observed in 2008 through 2010.

IDWR contracted with IPCO to begin measuring irrigation return flow sites in the BID area (Group 3, IESW010) in 2002. Additional return flow data measured between 1996 and 2001 were obtained from the BID. The data provided did not include measurements of the F Waste site, which comprised approximately 31% of the Group 3 return flow between 2002 and 2009. For 1996 through 2001, the monthly irrigation return flow volumes for Group 3 were scaled up based on average monthly proportions observed in 2002 through 2009. IDWR may be able to obtain measured F Waste data from BID for 1996 through 2001 for use in future versions of the ESPAM model.

IDWR contracted with IPCO to begin measuring ten return flow sites in the Twin Falls Canal Company area (Group 4) on the south side of the Snake River in 2002. Two of these sites were discontinued after 2005 because return flows were not significant. The Agricultural Research Service (ARS) began measuring five previously unmeasured return flow sites in 2005 and provided these data to IDWR through 2010. The five previously unmeasured return flow sites added in 2005 include Rock Creek, Deep Creek, and the L10 Power site. The ARS sites comprised approximately 55% of the measured return flow for Group 4 between 2005 and 2010. For 2002 through 2004, the monthly irrigation return flow volumes for Group 4 were scaled up based on average monthly proportions observed in 2005 through 2010.

RETURN FLOW LAG FACTORS

Irrigation return flow may return to the Snake River days or months after diversion, depending on the location and properties of the delivery system and irrigated lands. For calculation of monthly reach gains, the Snake River Planning Model uses return flow lag factors to represent the percentage of diversions that return to the Snake River each month. Where measured return flow data are available, lag factors were calculated for surface water entities as described by Lutz (2003). Monthly lag factors represent the percent returned the same month diverted, the percent returned one month after diverted, the percent returned two months after diverted, etc. An example calculation of return flow lag factors is shown in Figure 13.

Where measured return flow data are not available, lag factors are based on canal manager intuition or on data from nearby irrigation entities. Lag factors based on canal manager intuition are also used for most entities in the years preceding data collection (1980 through 2001 for most entities).

In the Snake River Planning Model, return flows are calculated by applying the monthly lag factors to measured diversion data. Calculated return flows are then deducted from reach gains. Appendix A shows the return flow lag factors applied from 1980 through 2010 for ESPAM2 irrigation entities with measured return flows.

REACH GAIN CALCULATIONS (ABOVE MINIDOKA)

ESPAM2.0 models gains and losses resulting from ESPA discharge and recharge at five river reaches upstream of Minidoka (Figure 14). The ground water contribution to reach gain is generally calculated as follows. A negative reach gain indicates the aquifer received recharge from the river. A positive reach gain indicates aquifer discharge to the river.

> Reach gain = Surface outflows – surface inflows = Downstream gage + diversions – upstream gage – tributary streamflow – irrigation return flow

Streamflows, diversions, and irrigation return flows were obtained from the Snake River Planning Model and include both measured and estimated data.

Reach gain calculations for ESPA discharge to the Snake River between Kimberly and King Hill are described in ESPAM2 Design Document DDW-V2-14.

Calculating Lag Factors using Measured Returns - Preliminary Data

Water Year 2004	**Group 5: Irrigation Entity: IESW002**	**Total Annual Returned (%) =>**	**6.1**				
		Month =>	**1**	**2**	**3**	**4**	**5**
		Lag. Ret. (%) =>	**5**	**0.7**	**0.38**	**0**	**0**

Recorded Diversions: Aberdeen Springfield Canal [Ac-Ft] Ratio Returned = 0.0608

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	Total
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	
2004	0	0	0	0	0	0	18300	62500	65100	62300	50000	36200	294400	
2005	0	0	0										0	294400
Time Lag(months)	0	1	2	3	4	5	6	7	8	9	10	11		
Return Lags Factor	0.050	0.007	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.061

Calculated Returns [Ac-Ft]

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	Total
2004		0	0	0	0	0	915	3253.1	3762.04	3808.2	3183.48	2396.74	17318.56	
2005	443	138	0	0	0	0	0	0	0	0	0	0	581	17900
plot	443	138	0	0	0	0	915	3253.1	3762.04	3808.2	3183.48	2396.74		

Measured Return Flows: [Ac-Ft]

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	Total
2004	0	0	0	457.0361	314.476	424.586	1624	3318	3200	3174	3253	2772	18537	
2005	385	184	290.1322	0	0	0	0	0	0	0	0	0	859	17910
plot	385	184	290.1322	457.0361	314.476	424.586	1624	3318	3200	3174	3253	2772		

Figure 13. Example calculation of return flow lag factors for Snake River Planning Model.

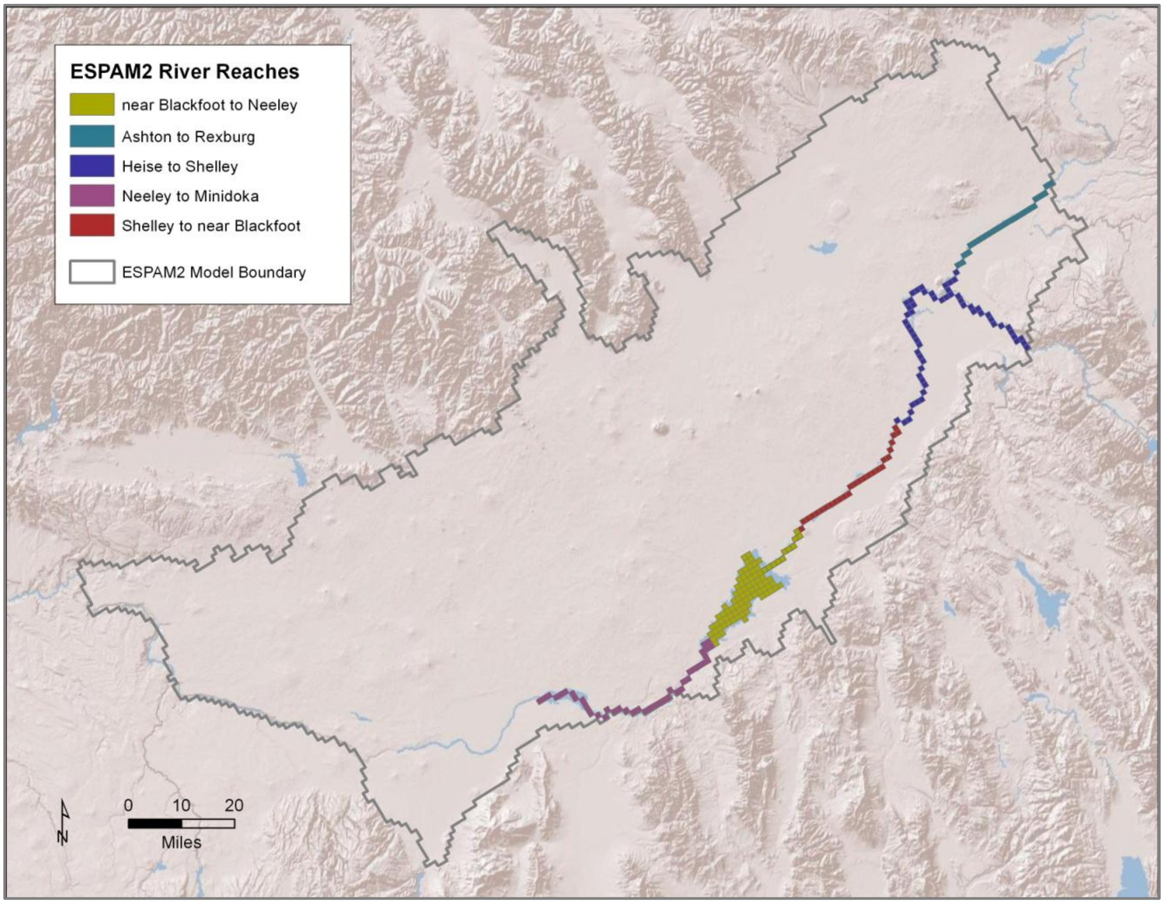

Figure 14. River reach calibration targets for ESPAM2.0.

ESPAM2.0 CALIBRATION TARGETS

Irrigation Return Flows

Irrigation return flows were used as calibration targets to constrain the adjustment of parameters D_{pin} and D_{pex}. These parameters are used in the MKMOD On-Farm Algorithm to calculate how surface water diversions not consumptively used are partitioned between recharge and return flow. Measured irrigation return flows were available for a limited number of years for ten of the ESPAM2.0 surface water entities. Data availability is summarized in Table 1.

Data collection at most of the measured return flow sites began in 2002 or later. For years without measured return flow data, estimates are used in reach gain calculations, but are not included in the return flow calibration targets used to constrain adjustment of D_{pin} and D_{pex}.

Irrigation return flows used for ESPAM2.0 calibration targets are shown in Figure 15 through Figure 22.

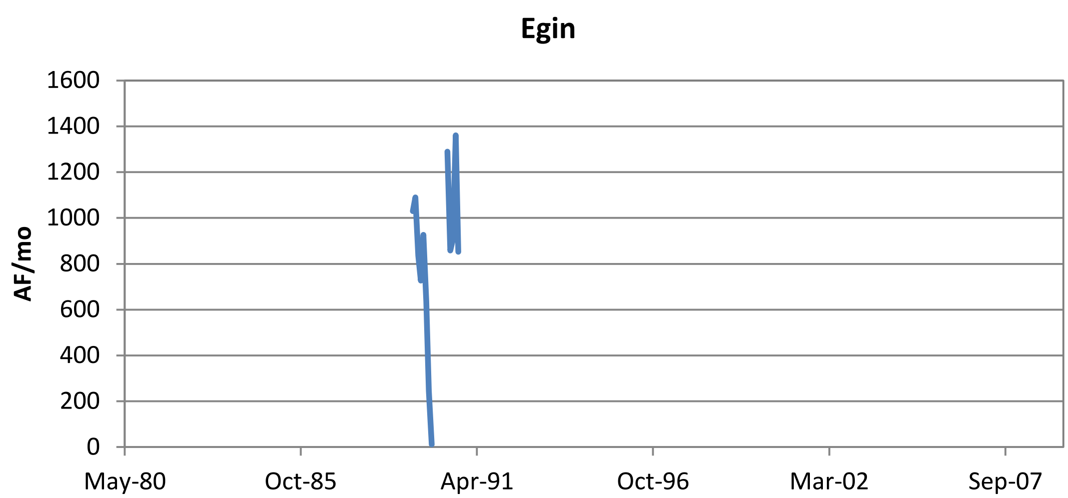

Figure 15. IESW016 return flow calibration target.

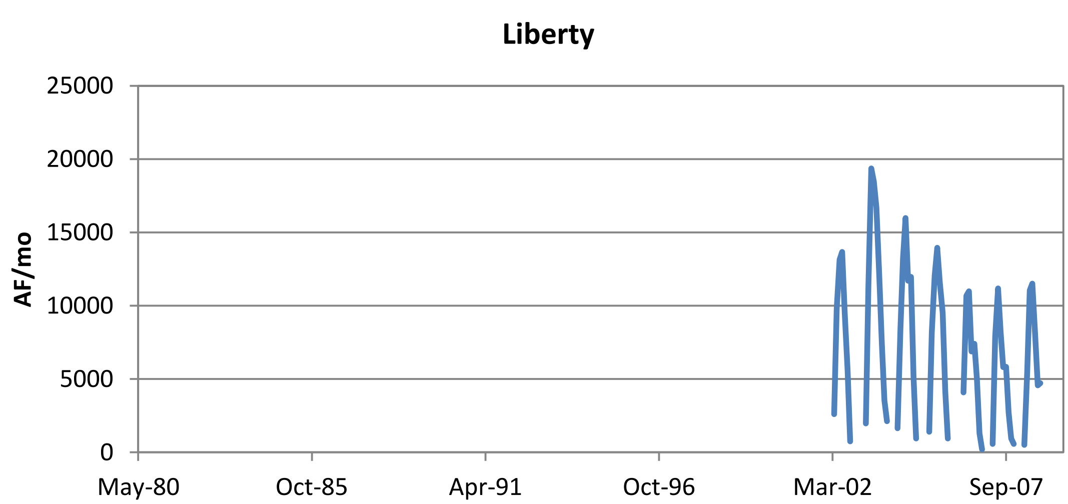

Figure 16. IESW036 return flow calibration target.

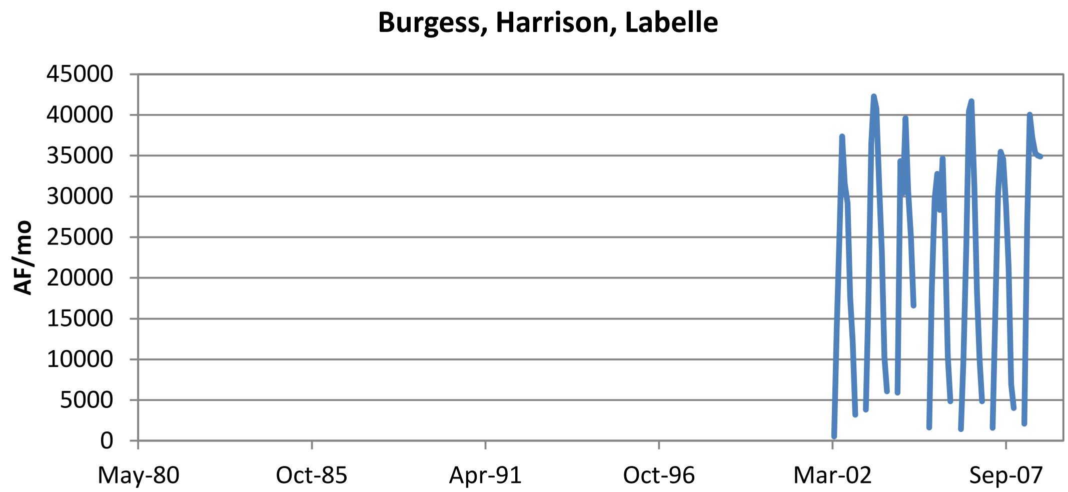

Figure 17. IESW009, IESW020, and IESW055 return flow calibration target.

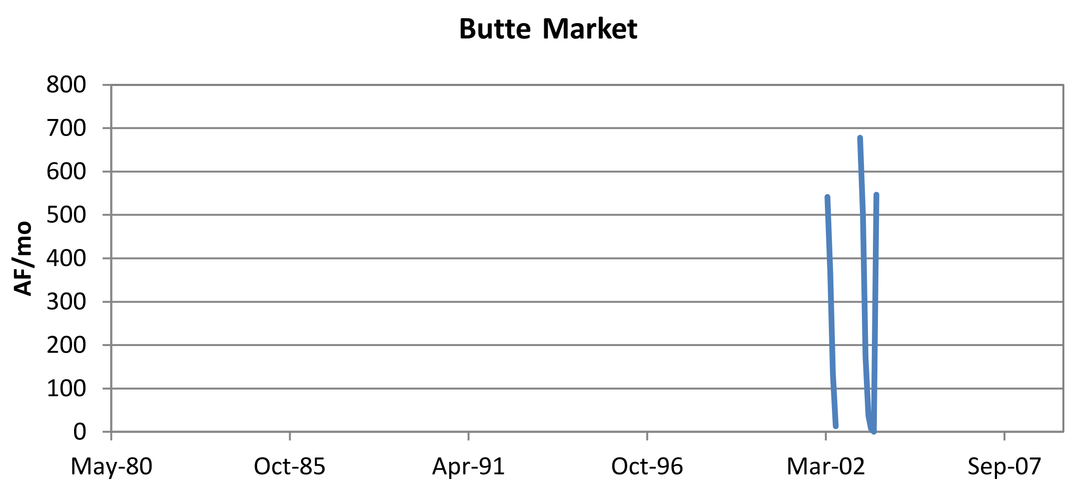

Figure 18. IESW011 return flow calibration target.

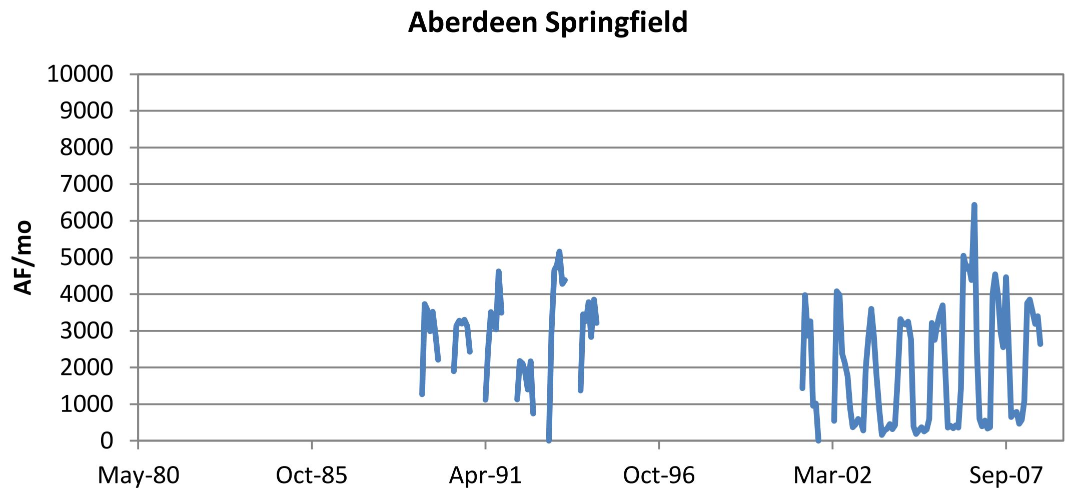

Figure 19. IESW002 return flow calibration target.

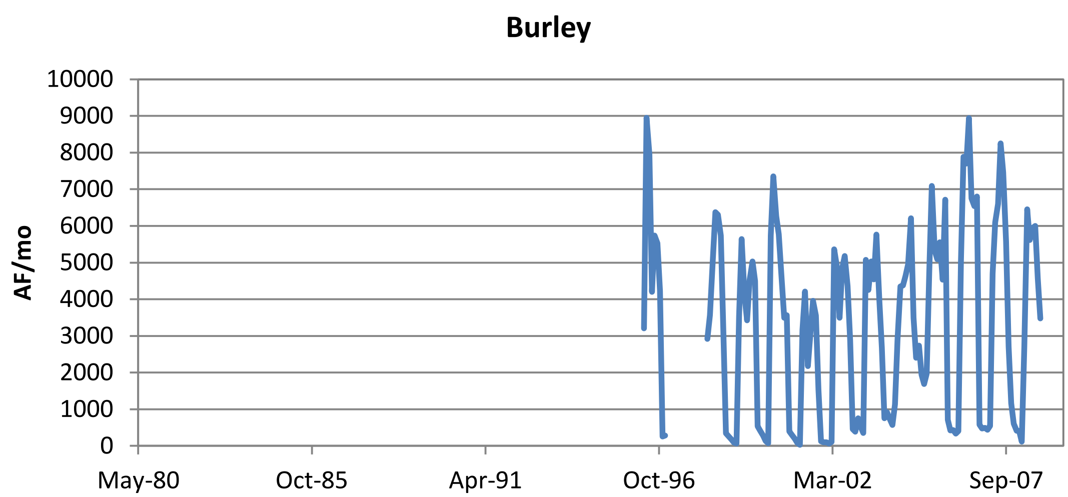

Figure 20. IESW010 return flow calibration target.

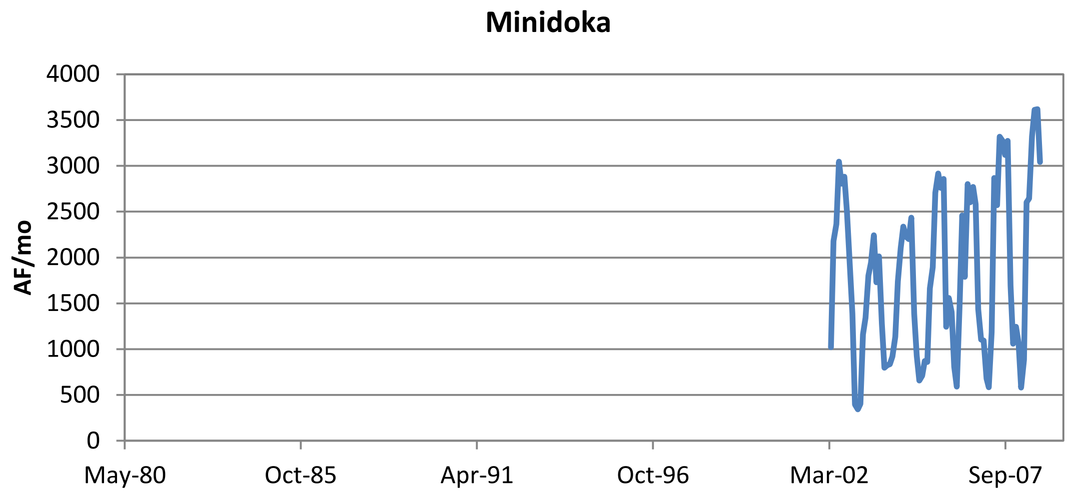

Figure 21. IESW028 return flow calibration target.

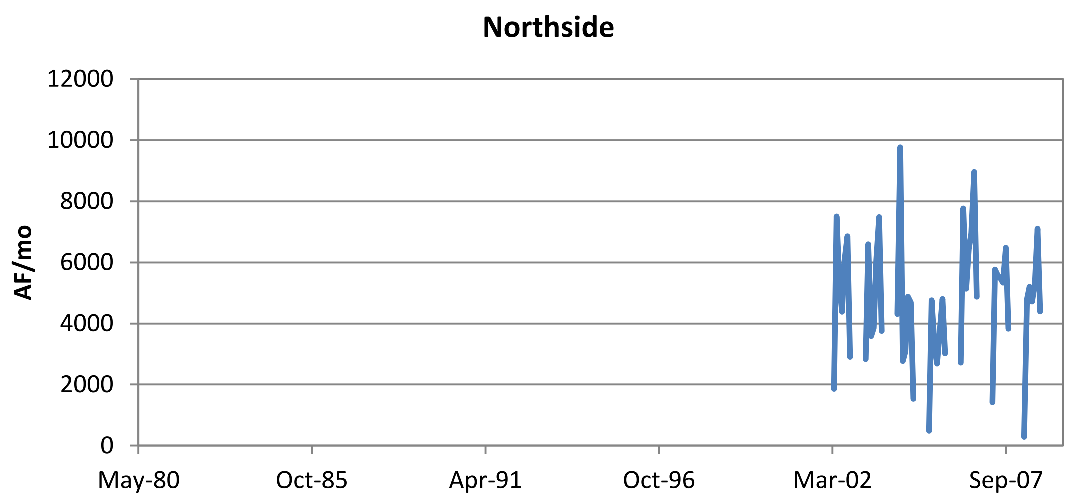

Figure 22. IESW032 return flow calibration target.

Reach Gains

Reach gains were used to calibrate modeled aquifer recharge and discharge in cells representing five reaches of the Snake River above Minidoka. Reach gains used for calibration of ESPAM2.0 are the best estimate of river gains or losses from or to the ESPA, and will differ from reach gains used in other applications (i.e. water allocation) that include surface water contributions to natural flow. Reach gains used as model calibration targets are shown in Figure 23 through Figure 27.

Reach gains in three reaches of the Snake River between Kimberly and King Hill were also used to calibrate the total modeled spring discharge. Groundwater contribution from the south side of the Snake River (outside of the ESPAM model domain) was deducted from the Kimberly to King Hill reach gains, as described in Design Document DDW-V2-14.

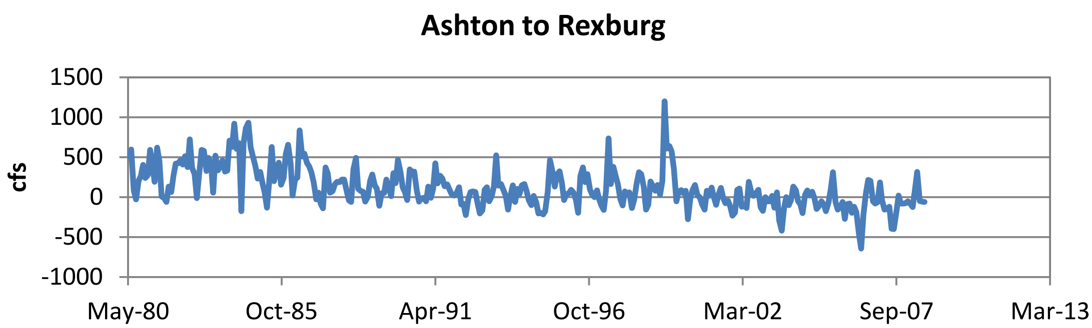

Figure 23. Reach gain calibration target, Ashton to Rexburg.

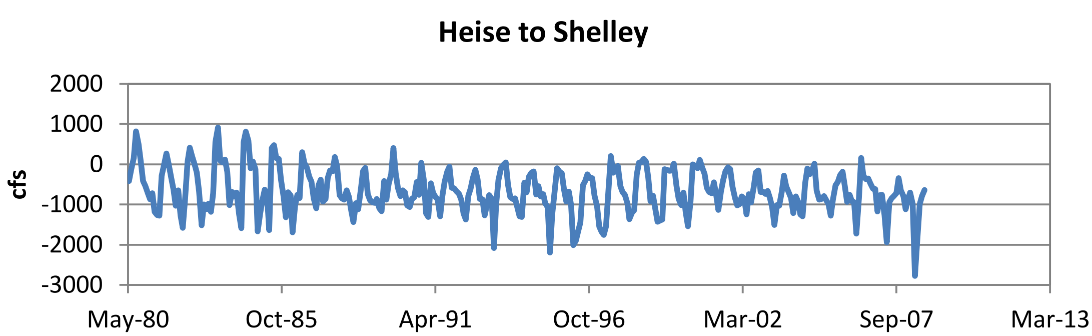

Figure 24. Reach gain calibration target, Heise to Shelley.

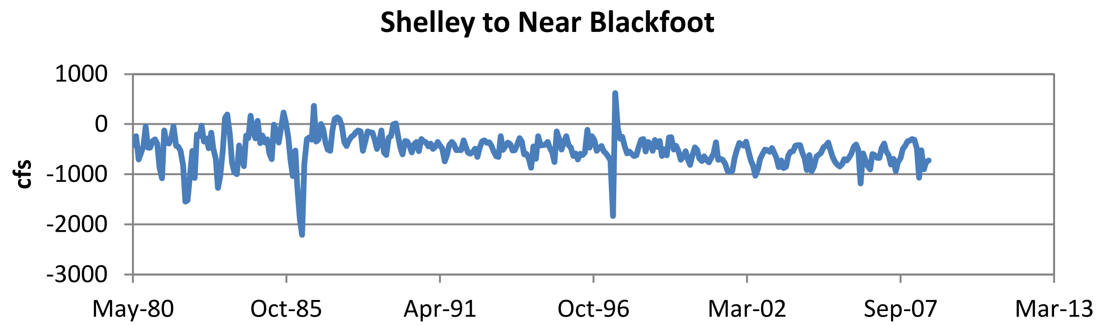

Figure 25. Reach gain calibration target, Shelley to near Blackfoot.

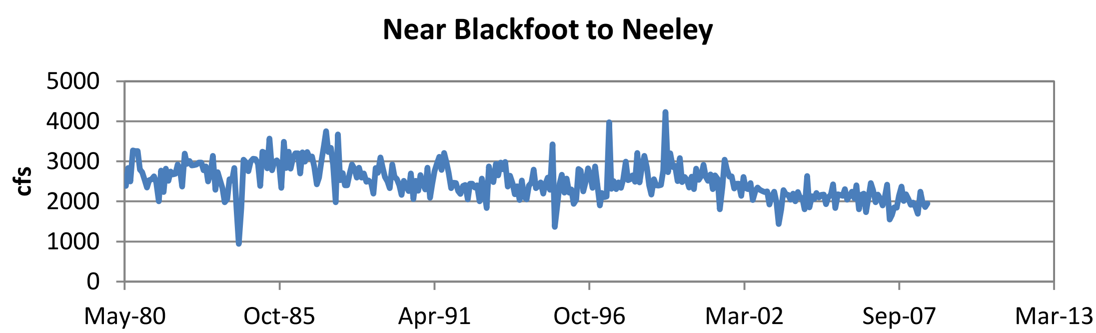

Figure 26. Reach gain calibration target, near Blackfoot to Neeley.

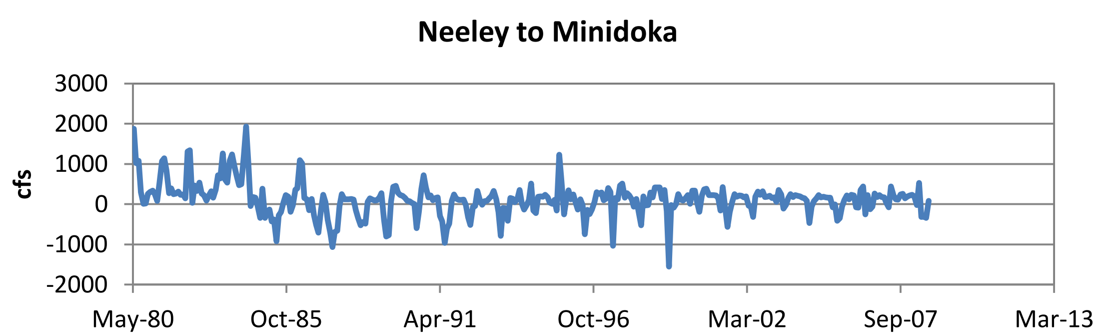

Figure 27. Reach gain calibration target, Neeley to Minidoka.

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