Monitoring of Egin, Idaho Recharge Experiment, Fall 2008

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INTRODUCTION

The Egin Lakes are ponds located near a Bureau of Land Management recreational site at the end of the Recharge Canal in southwestern Fremont County, approximately 11 miles west of the town of St. Anthony. A canal extends west of Egin Lakes approximately two more miles to a series of ephemeral ponds referred to in this report as the "West Recharge Area." Tibbitts Lake is located approximately one mile south of the West Recharge Area. Davis Lake is east of Egin Lakes near the confluence of the Last Chance Canal and the Recharge Canal. The subject area for the 2008 Recharge Experiment and the associated Monitoring Project includes all these locations, and in this report the collective area will be referred to as the "Egin Lakes area." Figure 1 indicates the location of the study area.

The study area has historically been considered a potential groundwater recharge site. Previous investigations, including a pilot recharge project, concluded that more detailed investigations needed to be conducted to determine recharge feasibility and benefit to the Eastern Snake Plain Aquifer (ESPA).

Previous Recharge Studies

A recharge project in this area was first proposed by the U. S. Bureau of Reclamation in 1962 (White, 1962; Mundorff, 1962). The St. Anthony Pilot Recharge Project was initiated by the Idaho Water Resource Board (IWRB) in late 1970 in response to public interest concerning utilization and storage of excess spring runoff in the Snake River Basin. A 1975 report (Anderson) concluded that recharge was feasible at an average infiltration rate of approximately 0.5 acre-foot per acre per day (0.5 ft/day). The report also recommended increased monitoring and extending the duration of testing. Because of the unavailability of sophisticated computer modeling capabilities at the time, questions regarding the effects that Egin Lakes area recharge has upon the Mud Lake area (approximately 25 miles west of Egin Lakes) as well as the overall Eastern Snake Plain Aquifer were not addressed.

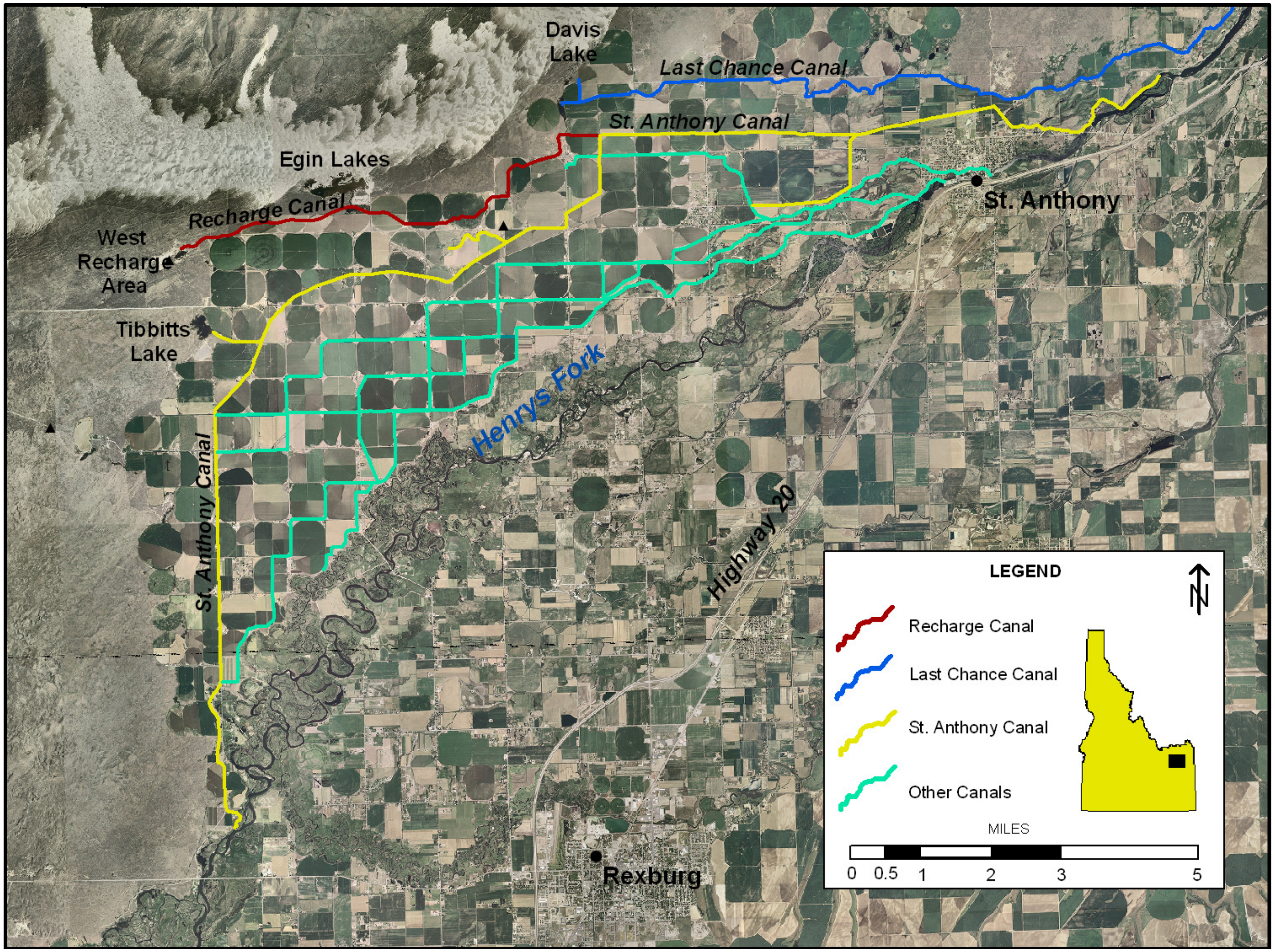

Figure 1. – Location of Egin Lakes Study Area

Fall 2008 Recharge Experiment

Between October and December 2008 Fremont-Madison Irrigation District (FMID) diverted storage water from the Henry's Fork of the Snake River through the St. Anthony, Last Chance and Recharge Canals to the Egin Lakes for a late-season recharge project. In this pilot project, approximately 4,860 acre-feet were recharged at Egin Lakes, the West Recharge Area, Tibbitts Lake, and the canals solely devoted to the recharge experiment. During the period of the experiment, additional water entered the aquifer in association with canal leakage from diversions for stockwater rights via the St. Anthony and Last Chance Canals. The IWRB provided funding to compensate FMID for the cost of the storage water and related maintenance and operation costs of the project. In February 2009, a memorandum of understanding was signed between the Idaho Department of Water Resources (IDWR) and the Eastern Idaho Water Rights Coalition (EIWRC) to provide funding for the University of Idaho, acting through the Idaho Water Resources Research Institute (IWRRI) to provide technical assistance for conducting and evaluating recharge monitoring through spring 2009. It is likely this monitoring will continue either through a renewed agreement with IWRRI or involvement of IDWR personnel.

Continued Recharge Activity

The Egin Lakes area was included in the IWRB's Early Season Recharge Program in 2009. Through the end of May 2009, nearly 17,000 acre-feet were recharged via the Egin Lakes area and supply canals. On-going monitoring and analysis will provide further details on the extent of ESPA and Snake River benefits.

GOALS OF MONITORING PROJECT

An important component of managing aquifer recharge is to quantify the timing and location of benefits that accrue to springs and surface water reaches, as a result of recharge activities. The monitoring project described in this report was performed in conjunction with the 2008 recharge experiment described above. The purpose of the monitoring project was to assess the potential for monitoring activities to quantify the benefits of aquifer recharge, independent of aquifer modeling.

A regional aquifer model (ESPAM1.1) has been constructed for the Eastern Snake Plain Aquifer, designed specifically to address the impacts of activities such as pumping or recharge on springs and reaches of the Snake River. The Egin recharge area is included within the aquifer model, and may be used to estimate the timing and location of benefits that recharge generates.

Because ESPAM 1.1 is a regional model, stakeholders sometimes express concerns about the ability of the model to correctly apportion the benefits of recharge to springs and Snake River reaches. An alternate way of phrasing the goal of this monitoring project is: "Can monitoring independently evaluate the appropriateness of the aquifer model's apportioning of recharge benefits, in time and space?" Three specific questions are:

1. Does recharge generate more benefit to the Henrys Fork than indicated by ESPAM1.1?
2. Does recharge generate more benefit to the regional system (and therefore to distant springs and river reaches) than indicated by ESPAM1.1?
3. Does ESPAM1.1 accurately represent the timing of the arrival of benefits to various springs and river reaches?

An important topic that can be addressed neither by the aquifer model alone nor by monitoring is: "Recharge that increases reach gains to the Henrys Fork positively affects downstream diversions and storage. This may facilitate additional recharge in other locations and reduce supplemental groundwater pumping. What are the benefits to river, spring and aquifer users from these secondary impacts?" Additional information on this important question is available on the following Websites:

1. http://www.idwr.idaho.gov/WaterInformation/projects/espam/meetings/2008_ESHMC/10-28&29-2008/D_Blew.PDF
2. http://www.idwr.idaho.gov/WaterInformation/projects/espam/meetings/2008_ESHMC/10-28&29-2008/CAMP_Environmental_Model_Summary-1.doc

DATA GATHERED AND SUMMARY RESULTS

Data gathered in the monitoring project include aquifer water levels, estimates of the timing and location of recharge (both experiment recharge and other recharge), a reconnaissance of seeps and springs on the face of the Egin Bench bluff, a literature search, and application of the Transfer Tool realization of the ESPAM1.1 aquifer model.

Photos of fieldwork are available at:[1]

1. http://picasaweb.google.com/bryce.contor/ShorelineMeasurementPointsForEginLakesRechargeProject?authkey=Gv1sRgCIH2zuuUpKmpaA#
2. http://picasaweb.google.com/bryce.contor/EginBench20081018?authkey=Gv1sRgCIDf6-Th6Y3r6AE#

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[1] Note that starting a slide show is the most convenient way to view photos, but clicking on individual photos allows viewing of comments posted at the bottom of the slides. Users may have to drag the slider bar on the right of the screen to see the comments. High-resolution copies may be downloaded by clicking "download" above the photo. Low-resolution copies may be obtained by right clicking on the photo itself and selecting "save picture as."

3. http://picasaweb.google.com/bryce.contor/EGIN_Spring_2009?authkey=Gv1sRgCN_A0pTVsrKtaA#.

A slideshow presented in 2008 may be viewed at:
http://picasaweb.google.com/bryce.contor/SlidesFromMeeting17DecemberAtFMIDOffice?authkey=Gv1sRgCLLBoeawibHnsAE#

Aquifer Water Levels

Impacts of recharge on aquifer water levels are best assessed when compared to aquifer conditions prior to the beginning of the recharge process. This background information allows for comparison of previous water level measurements to measurements acquired during the recharge process. Early in October 2008, the recharge experiment began and water was released from Egin Lakes to the West Recharge Area. However, prior background information had not been collected; as a result, data are limited. The following is a timeline of events that occurred during the 2008 recharge experiment in Egin:

- 30 October 2008: Water that was delivered by the canal out of the lower Egin Lake reached the largest pond at the West Recharge Area.
- 31 October 2008: The irrigation season ended and all canals were off except for the canals associated with the recharge experiment.
- 13 December 2008: The headgate at the Henrys Fork was closed allowing no additional water to enter recharge site or canals from the river.
- 16 December 2008: The canals continued to drain.
- 22 December 2008: Canals were found essentially empty.

Aquifer water levels were measured manually by hand using electric water level sounder devices or steel tape, whichever was most appropriate for a specific well. Aquifer water levels were collected at 13 different sites in the Egin vicinity starting in the middle of October 2008 as shown in Figure 2. Several of the sites included wells with multiple wells or piezometers with different completion depths. Water level measurements were collected weekly at most sites except for those that were inaccessible in the winter. Four IDWR LevelTROLL transducers and two IWRRI miniTROLL transducers were placed in the wells to monitor water level twice daily. Since water levels were recorded in these wells by transducers, they were only visited once a month.

Figure 3 is a hydrograph of the wells measured during the recharge experiment. The lines represent data collected from the transducers and the points represent data collected from manual hand measurements. Since monitoring was initiated as the recharge process was beginning, it is difficult to distinguish a change in water levels relative to the recharge experiment. One well in particular, 7N 39E 7BDA1, had an obvious increase in water level. This well will be discussed in more detail in a later section (DISCUSSION). Most of the wells in Figure 3 show a decrease in water level after the irrigation season ended and no more water was released to the recharge site.

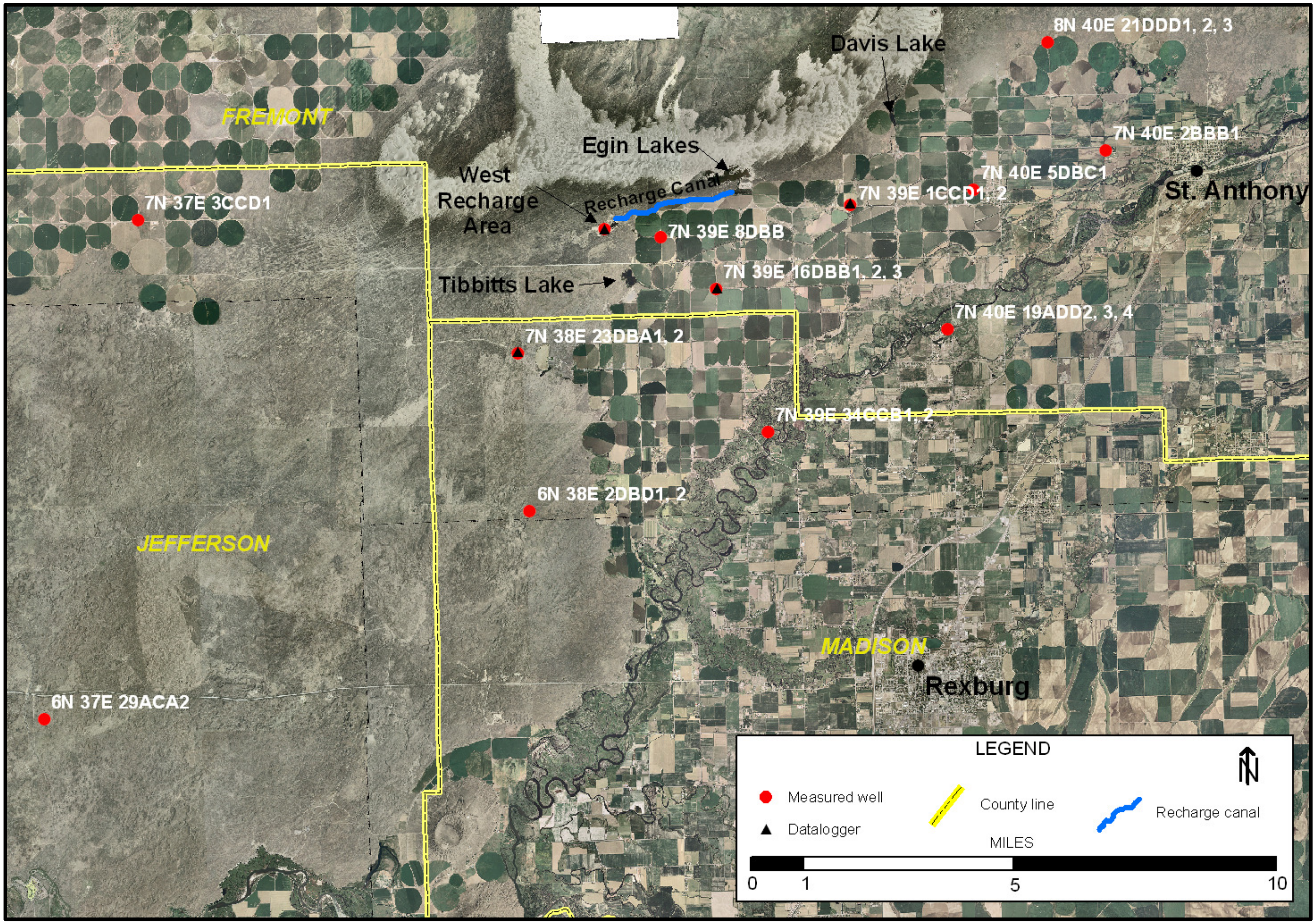

Figure 2. Aquifer sites monitored during the recharge experiment.

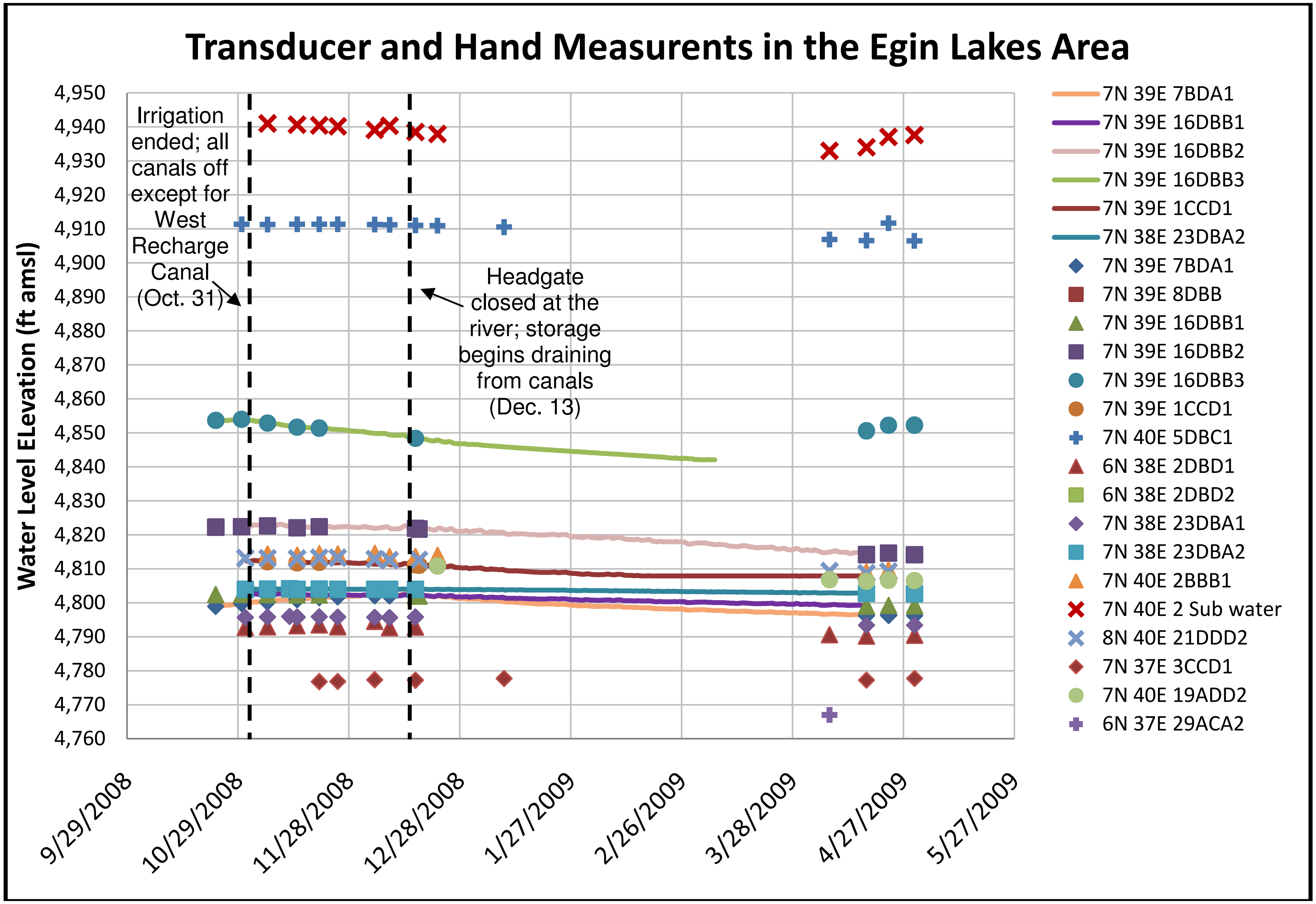

Figure 3. Hydrograph of all wells measured during the recharge experiment.

Perched Aquifer Systems

Several previous investigations indicate aquifer perching in the Egin area, in which there is an unsaturated zone below a saturated zone. Analysis of sites with multiple piezometers or wells may suggest otherwise; there are strong vertical gradients in the area, but none high enough to indicate actual perching. The following formula can be used to determine perching or non-perching aquifer systems:

$$\frac{(H_{shallow} - H_{deep})}{(Ctop_{shallow} - Ctop_{deep})} ,$$

> 1 indicates perched system

< 1 indicates non-perched system (i.e. fully saturated even if multiple aquifer layers and strong gradients exist)

where $H_{shallow}$ is the measured aquifer head elevation in the shallow well of a group of wells/piezometers, H_{deep} is the measured aquifer head elevation in the deep well of a group of wells/piezometers, $Ctop_{shallow}$ is the elevation of the top of the completion zone or the open interval of a well in the shallow well, and $Ctop_{deep}$ is the top of the completion zone or open interval of a well in the deep well. When a value is greater than one, this indicates that the aquifer is perched and a value less than one indicates that there is a non-perched system (i.e. the saturation is continuous in depth zones between the well completion depths).

Several sites have multiple wells or piezometers completed at varying depths (see Figure 2). Table 1 displays a list of sites in which multiple completions are located. When calculating the value to estimate whether the aquifer system is

Table 1.

Aquifer Water Level Measurement Sites in the Egin Area with Mulitiple Wells or Piezometers.

Well Location	Calculated Vertical Gradient (ft/ft)	Perched?	Not Perched?
7N 39E 16DBB1, 2, 3	0.17		X
7N 39E 34CCB1, 2	0.18		X
7N 40E 19ADD2, 3, 4	0.16		X
7N 38E 23DBA1, 2, 3	0.07		X
8N 40E 21DDD1, 2, 3[2]	0.0002		X
6N 38E 2DBD1, 2[2]	-0.01[3]		X

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[2] These sites include multiple piezometers with different completion intervals.

[3] Piezometers may be damaged since water levels were approximately the same during the 2008-2009 experiment despite different completion depths. Negative value indicates an upward gradient which is not expected for this location.

perched or not, data from several dates were compared in order to calculate an average. All six of the sites with multiple wells were not perched and it is assumed there is continuous saturation at these sites.

Timing, Amount and Location of Recharge

Measurement and calculation of recharge volumes for purposes of IWRB recharge accounting was performed by IDWR, Water District 01 and St. Anthony Canal personnel. This included adjustments for deliveries that are accounted as part of other water uses such as irrigation or stockwater diversions, although they physically resulted in aquifer recharge. This accounting is beyond the scope of the report.

For purposes of understanding and interpreting depth-to-water measurements and the reconnaissance of seepage, an attempt was made at a rough accounting of all aquifer recharge and discharge for the summer and fall of 2008. Table 2 lists recharge and discharge components considered, regardless of water-right accounting status. Figure 1 shows the spatial location of all components except neglected domestic and municipal pumping.

Table 2.
Approximate Aquifer Recharge and Discharge
in the Egin Bench, Idaho, Area, Summer and Fall 2008

Component	**Rech/Disch**	**Estimation Method**
Net impact, domestic GW uses	Discharge	Neglected
Net impact, municipal GW use	Discharge	Neglected
Net impact of GW irrigation (incl. mixed-source parcels)	Discharge	County-wide crop mix from National Ag Statistics (2006), ET from Agrimet, acreage from ESPAM1.1 data (2008). Assume irrigation supports full crop production.
St. Anthony, Last Chance and Recharge Canal seepage	Recharge	Based on IDWR and IWRRI flow measurements November 2008
Other canal seepage	Recharge	Extrapolated from per-mile seepage on St. Anthony Canal measured Nov. 2008

Component	Rech/Disch	Estimation Method
Net recharge from SW irrigation	Recharge	Crop mix from National Ag Statistics, ET from Agrimet (2008), acreage from ESPAM1.1 data, diversions and returns from ESPAM1.1 data (2006), canal seepage as above. Assume irrigation supports full crop production, calculate percolation as residual.
Seepage from Egin Lakes	Recharge	IWRRI & IDWR field measurements fall 2008
Seepage from Tibbitts Lake	Recharge	IWRRI field measurements fall 2008
Seepage, West Recharge Area	Recharge	IWRRI field measurements fall 2008

Approximate time series of recharge and discharge for various components are illustrated in Figures 4 through 6. Note the differences in scale of the vertical axes of the graphs. The average Tibbitts Lake seepage rate during the 2008 monitoring activity was approximately 0.6 feet/day.[4] The Egin Lakes rate was about 0.2 ft/day and the West Recharge Area rate was approximately 1.1 feet/day. Davis Lake appears to have a bottom sealed with mud and algae, with very little seepage.

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[4] This is calculated at the IWRRI-observed rate of 10 cfs. Per Bob Davis of St. Anthony Canal Co., the lake's full recharge capacity is nearer 15 cfs, which would be a seepage rate of 0.9 ft/day.

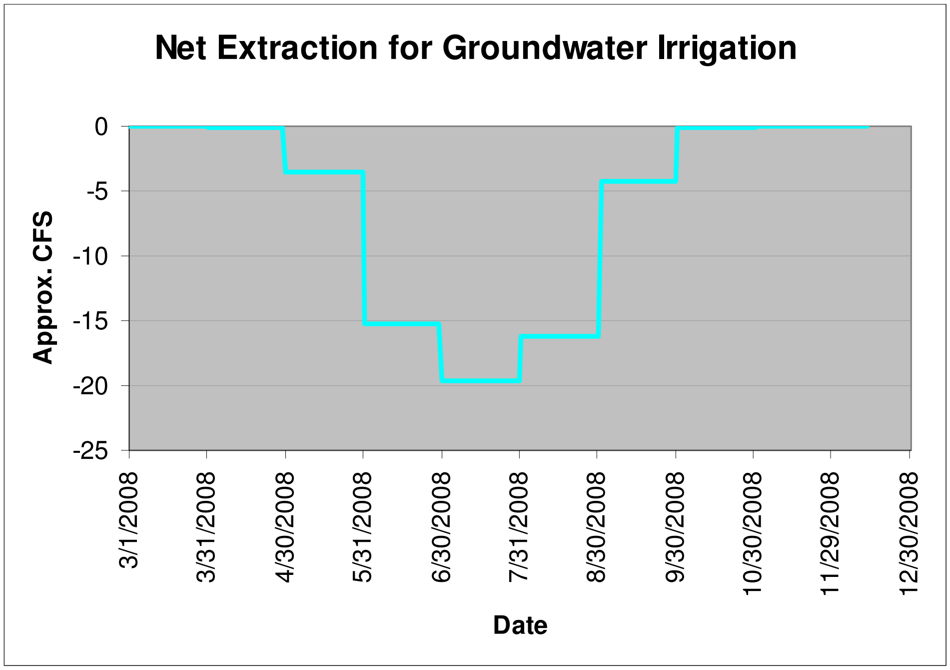

Figure 4. Approximate net extraction for groundwater irrigation in Egin Bench, including estimates of groundwater extraction for mixed-source lands.

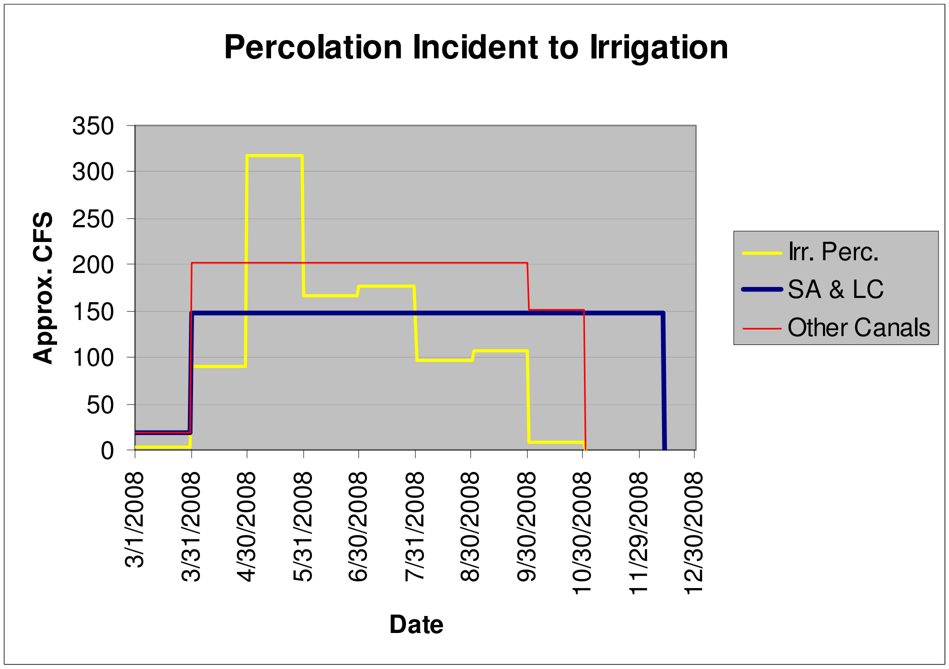

Figure 5. Approximate percolation incident to irrigation in the Egin Bench area, including effects of surface water delivered to mixed-source lands. "SA & LC" refers to the St. Anthony Canal and Last Chance Canal, including the part of the St. Anthony Canal known as the Recharge Canal.

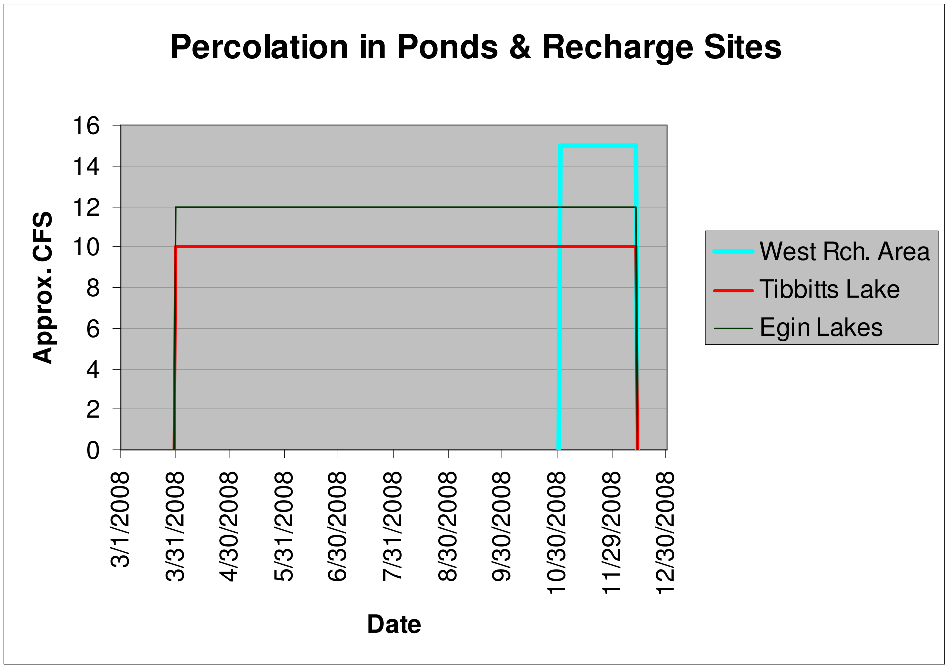

Figure 6. Approximate percolation in ponds and recharge sites, Egin Bench area.

Reconnaissance of Seeps and Springs

In order to improve assessment of migration of recharge and percolation to the Henrys Fork, a reconnaissance of seeps and springs was performed in the fall of 2008 and repeated in the spring of 2009. Photos may be viewed at the websites referenced above. Figure 7 is a map of the reconnaissance path. This is reconnaissance-level work, and more detailed study could refine the results and conclusions. Tentative findings are:

1. Seeps from the face of the Egin Bench are small in magnitude relative to total recharge.
    a. The ditch at Waypoint 18 (see Figure 7) drains approximately 1.2 miles of bench face, with estimated flow 1.5 to 6 cfs. Extrapolating this to the 13-mile face of the bench suggests that surface-expressed seepage and springs sum to approximately 20 to 80 cfs.
    b. At Waypoints 25 and 28 bridges cross large, unnamed side channels in the Henrys Fork bottoms. It appears that hyporheic flows (flows within the flood-plain gravels) or surface connections to the Henrys Fork dominate flow in these channels, overwhelming any seepage from the face of the bench. This is assumed based on observation of little change in flow from fall to spring, followed by a marked increase in flow over the course of just a few weeks as flow in the Henrys Fork increased in the spring of 2009. See Figure 8, 9 and 10. All photos are of the same location.

2. Seeps and springs respond to canal seepage and incidental recharge from irrigation. This is based on observation that ponds, wetlands and ditch discharges decreased significantly from fall to spring.
3. There is significant temporal dampening in response. Water was in the canals by the time of the first springtime observation on 4 April 2009, but had not appeared in seeps as of 12 May 2009.
4. Definitively quantifying seeps and springs from the face of Egin Bench would be technically challenging.
    a. Trees and vegetation interfere with aerial photo interpretation.
    b. Private land interferes with field inspection.
    c. Slow flows and wide channels make quantification of flow difficult.
    d. Presence of river gravels, side channels and oxbows make it difficult to separate seepage from hyporheic flows.
    e. Mingling of surface returns with seepage flows may confound quantification of seepage flows.

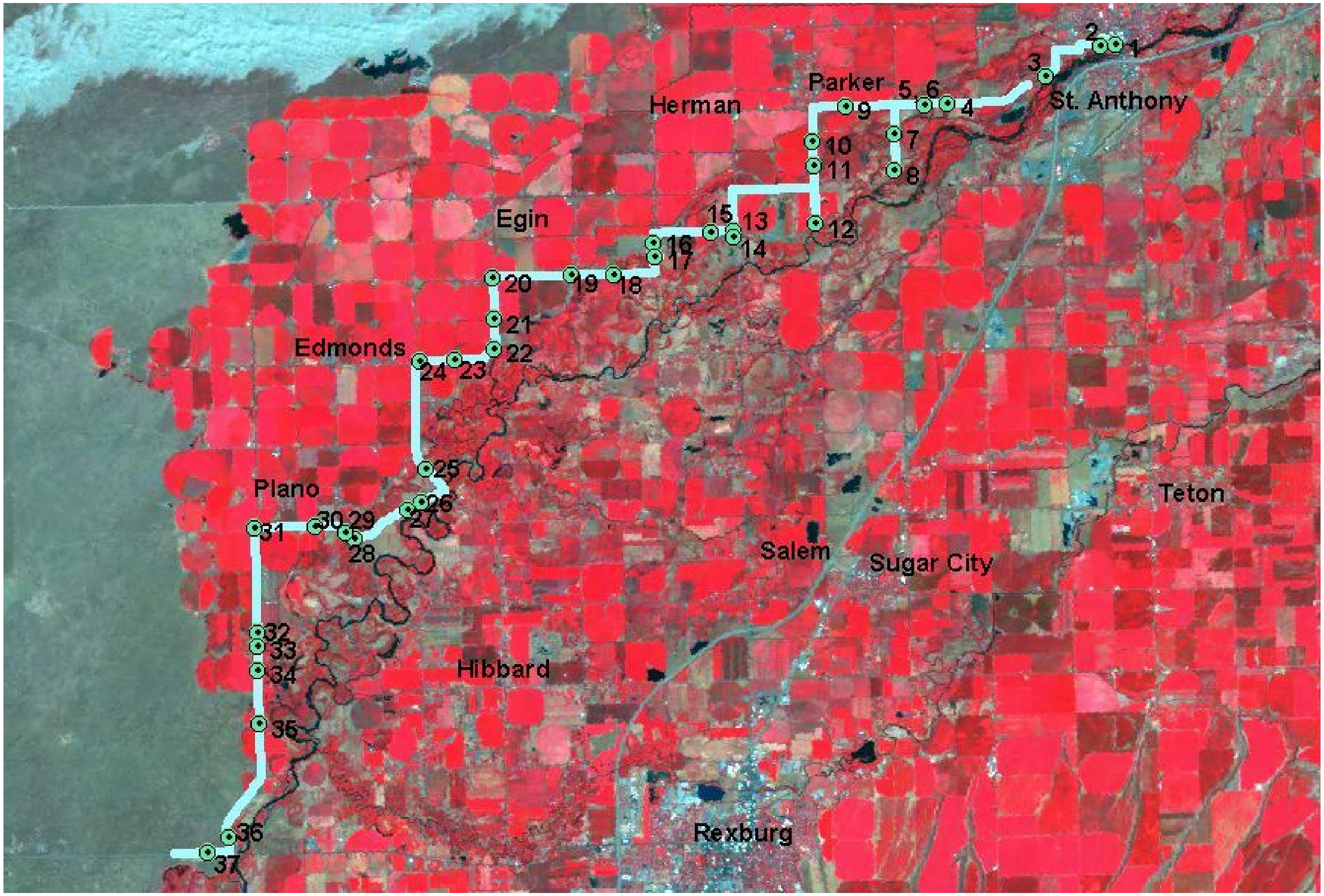

Figure 7. Map of seepage reconnaissance with Global Positioning System (GPS) waypoint numbers, fall 2008.

Figure 8. Looking SW at Waypoint 28, 18 October 2008

Figure 9. Looking SW at Waypoint 28, 6 April 2009.

Figure 10. Looking SW at Waypoint 28, 25 April 2009.

Literature Search

Stearns, Bryan and Crandall (1939) report on the effect that irrigation of Egin Bench had upon the regional aquifer system, and the Mud Lake area in particular. Important points include:

1. Pre-irrigation aquifer water levels in Parker were more than 100 feet below land surface.
2. By the 1920s, water levels had risen to within a few feet to a few tens of feet of surface.
3. The post-irrigation water levels may be associated with a perched aquifer.
4. Shallow wells showed a typical surface-water-irrigation dominated hydrograph with highs in summer to fall and lows in springtime. Seasonal variations of two to 20 feet were shown in various wells. Note that this is consistent with present trends.
5. Water recharging in Egin Bench has three fates:
   a. Seepage back to Henrys Fork
   b. Seepage northwest to Mud Lake and tributaries
   c. Seepage southwestward towards Roberts
6. Significant delay of impact to the Mud Lake area was reported: "Nearly 5 years was required for the water from the Egin Bench to have any visible effect on the Mud Lake Basin, and about 23 years more for it to produce the maximum effect."

7. Approximately half the recharge on the Egin Bench goes "into ground storage beyond the borders" of the bench. We interpret this to be the investigators' indication of the fraction of recharge that reaches the regional system rather than the local aquifer or the Henrys Fork.

The White (1962) and Mundorff (circa 1962) reports detail an extensive investigation in the 1950s and 1960s that included construction of dedicated monitoring wells, engineering studies of recharge sites, and recharge experiments at various locations. They include cost-benefit studies and find that recharge has positive net effects on irrigation, flood-control and power-generation. Projected lost hydropower revenues during times of recharge (typically high-flow periods when hydropower production is capacity limited) are more than offset by projected increased revenues during low-flow periods when recharge sustains base flow and capacity exists to utilize any additional flow.

Highlights from the White (1962) and Mundorff (circa 1962) investigations with relevance to the 2008 Egin recharge experiment include:

1. Relative to other locations in the Eastern Snake River Plain, recharge in the northeast (i.e. near St. Anthony) offers the potential of "greatest benefit to present and future water use."
2. Seepage rates from experiments in the Egin Lakes area were in the range of 0.3 to 0.5 feet/day.
3. About 35% of St. Anthony-area recharge would return to the Snake River above Milner and the balance would return to springs and river reaches between Milner and Bliss.
4. The water-supply benefits of recharge flow in all hydraulically-connected direction and not just down-gradient.
5. The reports include test data that possibly could be re-analyzed to obtain localized estimates of aquifer properties.
6. Though recharge will provide significant benefits, it cannot be the sole solution: "Groundwater withdrawals undoubtedly will continue to increase and the water table will continue to decline. Artificial recharge will not reverse that trend, not enough water is available for that.... [However] there is no question but that large quantities of water can be successfully added to the groundwater supply."

As discussed in the introduction, Anderson (1975) reported on a pilot recharge project that occurred at the same location as the 2008 recharge experiment. Relevant findings include:

1. With construction of dikes, the West Recharge Area could be enlarged to a ponded area of 320 acres, with capacity of 1,640 acre feet.
2. Observed seepage rates were in the range of 0.5 ft/day.
3. The recharge had "no measurable effect on the regional groundwater table beyond the mounding effect directly below the recharge pond." This was attributed to the small magnitude of the recharge experiment relative to other stresses on the system.

4. Computer modeling "may represent a better tool to determine the effects of a long term, large scale recharge project" than a physical pilot experiment. "In order to determine the impacts from the project [using physical measurements] a highly sophisticated monitoring network would have to be established."

Wytzes.(1980) developed a numerical groundwater model that included the Egin Bench area. Key results include:

1. A local perched aquifer exists in the Egin Bench area. The Henrys Fork is hydraulically connected to the perched aquifer, rather than to the underlying regional system.
2. The Egin Bench perched aquifer has little communication with groundwater southeast of the Henrys Fork.
3. A large amount of water percolates downward from the Egin Bench aquifer to the regional aquifer.
4. The Henrys Fork from St. Anthony to Rexburg is at times a net gaining reach and at times a net losing reach. Wytzes estimated 12-month gains of 91,600 acre feet and losses of 8,000 acre feet. This is an annual average gain of 115 cfs, which Wytzes compared to 1938 estimates of 400 cfs. The difference was attributed to drought and reduced water supplies.
5. Groundwater impact on the Henrys Fork varied from 6,460 acre feet gain the last two weeks of August 1977 (217 cfs) to 2,260 acre feet loss the last two weeks of April 1978 (-81 cfs).

The 1987 report on sprinkler conversion on the Egin Bench (V.G. King) analyzes the expected impacts to local irrigation, flows in the Henrys Fork, and water supply at Mud Lake from conversion. Elements important for the current recharge experiment include:

1. King's conceptual model is that there is a local perched aquifer system maintained by lower-permeability basalt underlying sand.
2. As of 1987, "Over 80 percent of the water diverted infiltrates into the soil and 60 percent of that diverted enters the regional aquifer."
3. There is no explicit discussion of contributions to the Henrys Fork, and especially no indication whether some of the contributions to the regional aquifer may contribute to Henrys Fork gains.
4. Measured infiltration rates at seven sites range from 0.5 to 2.7 ft/day.
5. Effects upon water supply in Mud Lake and flows in the Henrys Fork are addressed qualitatively, but not quantified.
6. About 371 acres of additional infiltration would be needed to offset the reduced infiltration from the "Condition III" scenario, which was defined as follows: "All the area converts to sprinklers, winter diversions are discontinued and spring diversions are delayed two weeks (to the middle of April)." Note that this scenario closely parallels what has actually occurred.

Hortness and Vidmar (2003) estimated reach gains in the Henrys Fork using mass-balance calculations based on measured flows in the river, measured outflows and measured inflows. Work was conducted in the fall of 2001, and spring, summer and fall of 2002. Relevant findings for the recharge experiment are:

1. Any "extensive trend analysis with respect to time would likely require additional data."
2. The Henrys Fork between St. Anthony and Rexburg includes alternating gaining and losing reaches. Overall gain and loss patterns vary seasonally, as shown in Table 3.

Table 3.
Henrys Fork Gains and Losses between St. Anthony and Rexburg, Idaho Power and USGS Seepage Study 2001-2002
(Positive numbers indicated river gains from the aquifer; negative numbers indicate river losses to the aquifer.)

Reach	**Fall 2001 (cfs, 29-31 October)**	**Spring 2002 (cfs, 8-9 April)**	**Summer 2002 (cfs, 22-23 July)**	**Fall 2002 (cfs, 4-5 November)**
St. Anthony - Near Parker	-42	112	95	-44
Near Parker - Near Hibbard	-93	-156	-196	-60
Near Hibbard - Near Rexburg	55	93	200	-18
Total St. Anthony - Rexburg	-80	49	99	-122

3. Between St. Anthony and Rexburg, no major inflows were noted on the northwest (Egin Bench) side of the Henrys Fork, except for an end-of-canal spill between Waypoint 35 and Waypoint 36 on Figure 1.[5] .

The ESPAM1.1 final report (Cosgrove and others, 2006) describes the most recent numerical computer model of the aquifer. Its representation of the Egin Bench area includes the following:

1. The aquifer is represented as a single-layer system with time-constant transmissivity. Aquifer properties (transmissivity and storage coefficient) are smoothly interpolated between pilot points. Relative to the Egin Bench, pilot points are widely spaced. The effect is that locally, the aquifer is represented as a uniform porous medium.

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[5] Gains calculations are adjusted for this inflow, which ranged from zero to 49 cfs on the measurement dates. Repeated measurements in the fall of 2008 and spring of 2009 range from five to 60 cfs.

2. The Henrys Fork is modeled as hydraulically connected with the aquifer whenever aquifer water levels are higher than the elevation of the representation of the bottom of riverbed sediments.
3. The model was calibrated to match aquifer water level observations and observed reach gains. Reach gains were calculated based on measured flows in river reaches, measured or estimated tributary inflows, measured diversions, and estimated irrigation return flows. Confidence is high for all values except estimated irrigation return flows.
4. Figure 11 shows filtered (temporally smoothed) measured and modeled river gains. Figure 12 shows monthly modeled and measured gains.

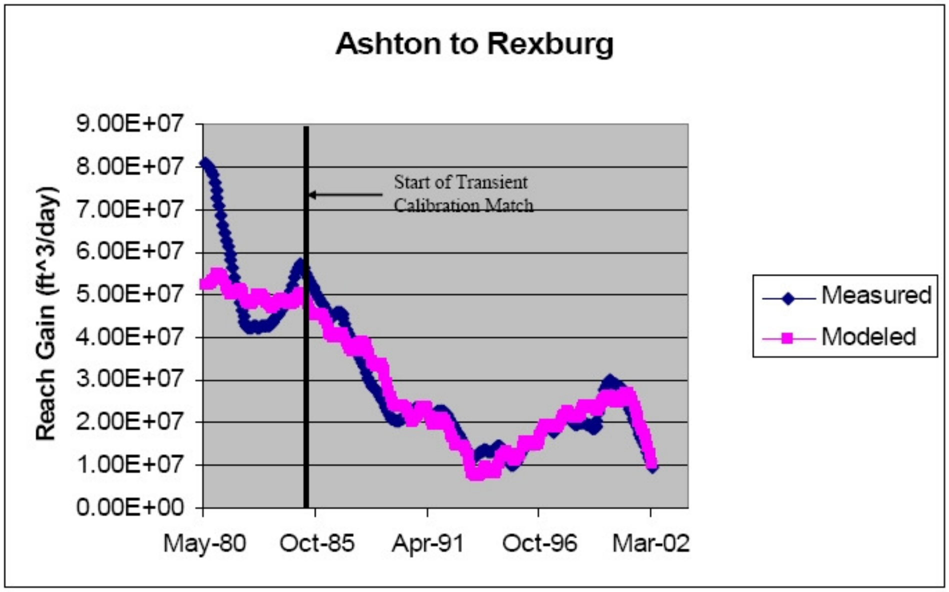

Figure 11. Smoothed reach gains from ESPAM1.1 model calibration. This is Figure 66 from Cosgrove at others (2006). For scale comparison, 6.00E+07 ft^3/day is equivalent to 694 cfs.

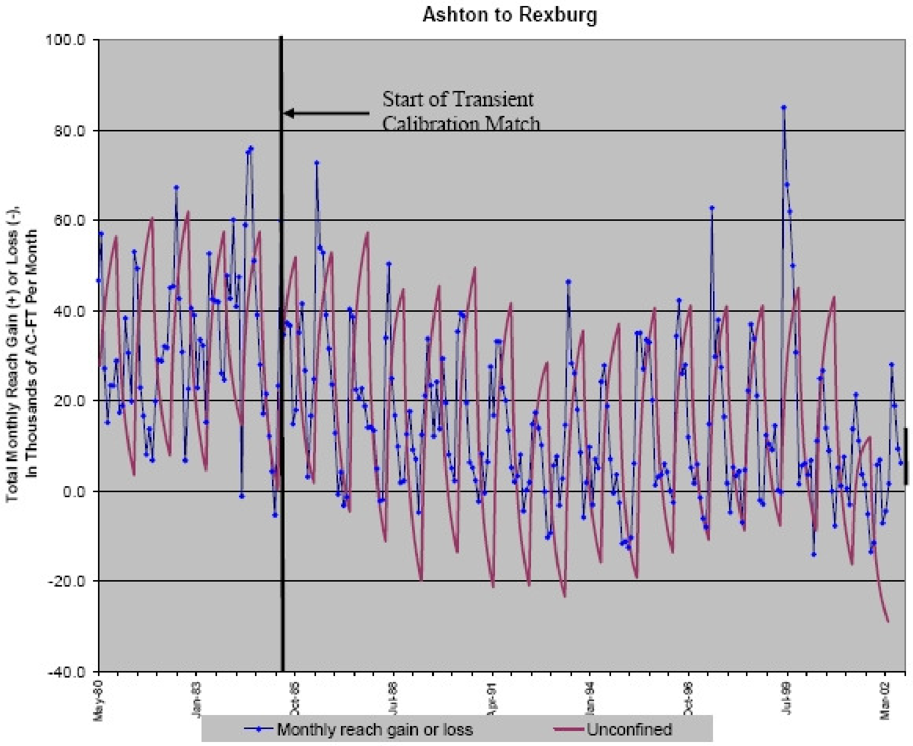

Figure 12. Monthly reach gains from ESPAM1.1 calibration. "Monthly Reach Gain or Loss" is measured, "Unconfined" is modeled. This is Figure 71 in Cosgrove and others (2006). A value of "40.0" on the vertical scale represents 40,000 acre feet/month, equivalent to 663 cfs.

Transfer Tool Analysis

One of the realizations of ESPAM1.1 is a water-rights transfer tool, which allows users to quickly obtain model results for a hypothetical recharge or discharge event applied at a single model cell. The tool and documentation may be downloaded at http://www.if.uidaho.edu/%7Ejohnson/ifiwrri/projects.html. Figure 13 illustrates the model's final allocation of benefits to spring and river reaches, using the tool with recharge applied at the West Recharge Area for a single four-month period. Figure 14 shows the model's representation of timing of benefits to the Henrys Fork.

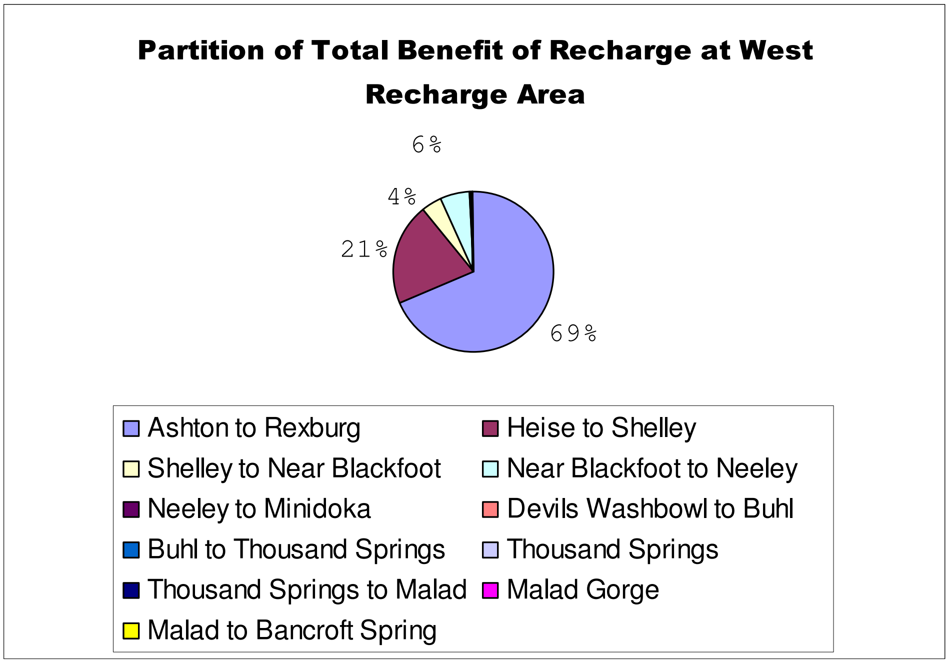

Figure 13. ESPAM1.1 spatial distribution of recharge applied at the West Recharge Area.

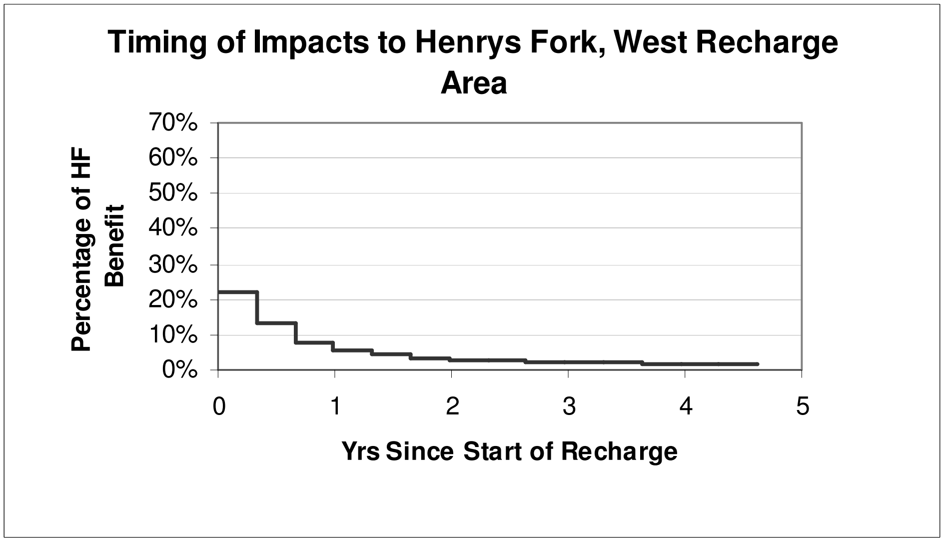

Figure 14. ESPAM1.1 indication of timing of impacts to the Henrys Fork, from recharge applied at the West Recharge Area.

The model indicates over 30% of recharge that occurs at the West Recharge Area will benefit reaches beyond the Henrys Fork reach, as illustrated in Figure 13. Even benefits to the nearby Henrys Fork are significantly delayed in the model; over 75% of the benefit to that reach is represented in trimesters beyond the one in which recharge occurred, as shown in Figure 14.

DISCUSSION

Apportioning of Benefits of Recharge, Independent of Aquifer Modeling

While it is difficult to allocate the recharge benefit independently of aquifer modeling, response in the regional aquifer system can be qualitatively shown.

Observed water-level responses. The greatest water level change was found in two wells close to the ponds in the West Recharge Area. Figure 15 shows the location of these two wells relative to the ponds. Figure 16 shows the response in well 7N 39E 7BDA1 as recorded by a transducer. The blue points are data recorded by the transducer while the red points are data collected manually during the course of the experiment. This well is located approximately 100 feet from the ponds and is completed at 340 ft. On 30 October 2008, water had reached the ponds at the West Recharge Area and on 31 October 2008, irrigation season had ended and water was continually delivered to the West Recharge Area by the recharge canal. Figure 16 shows the water level in the well increasing from approximately 4799 ft up to about 4802 ft. On 13 December 2008, no more additional water from the Henrys Fork was delivered to the canal system and water levels in well 7N 39E 7BDA1 began to decline.

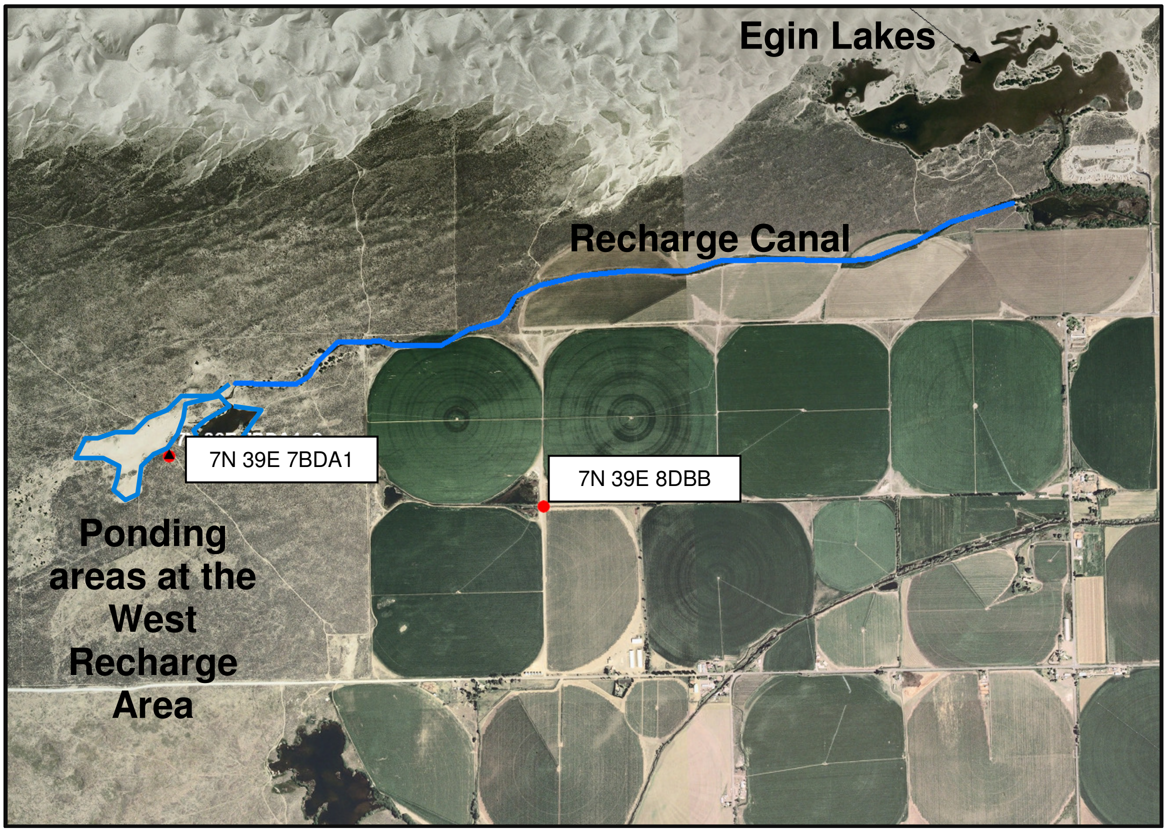

Figure 15. Wells closest to the West Recharge Area.

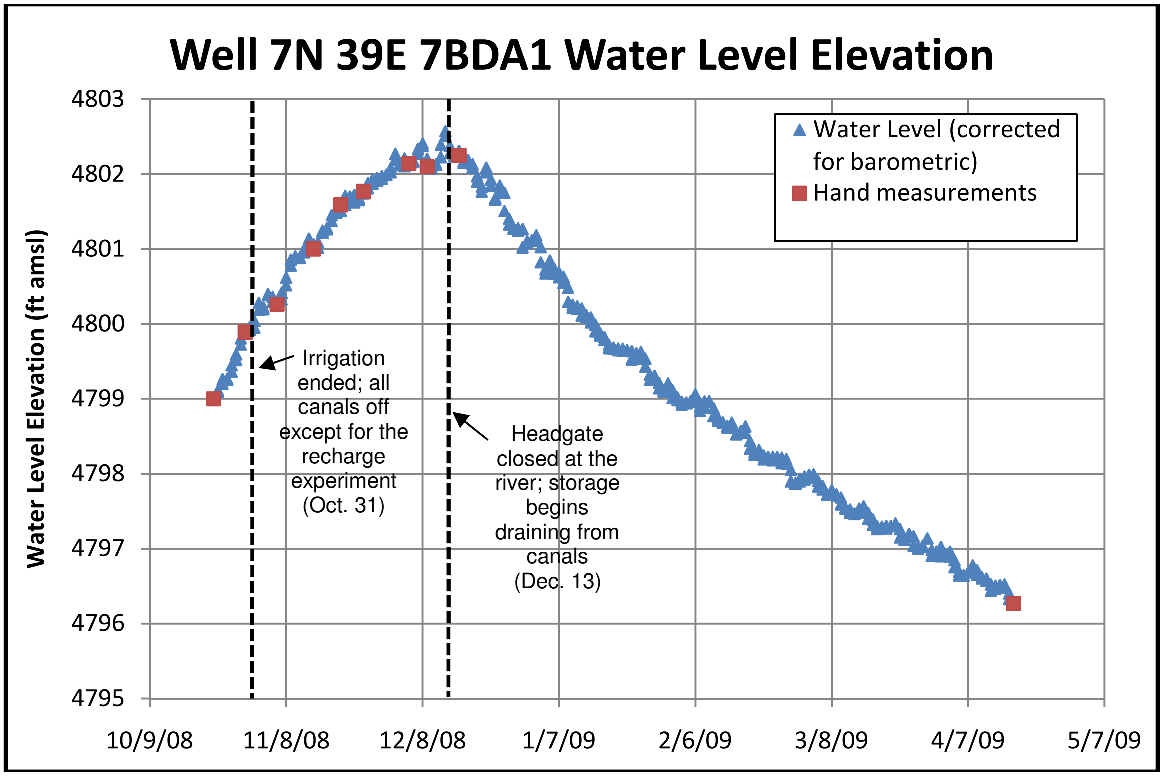

Figure 16. Aquifer water levels recorded by transducer in well 7N 39E 7BDA1.

The shape of the hydrograph in Figure 16 shows a classic response and recovery pattern. While the rising limb might be consistent with either a recharge response or a response to cessation of groundwater pumping, the falling limb is too early to be associated with resumption of pumping for irrigation. This well (7N 39E 7BDA1) is completed in the deep aquifer system (340 ft). Another well (7N 39E 7BDA2) located approximately 20 ft from 7N 39E 7BDA1 was characteristically dry throughout the recharge experiment. This well is 55 ft deep. Not enough recharge accumulated in the shallow system (if such a system exists) to reach the 55-foot level. However, enough recharge appeared to reach the deeper part of the system to noticeably raise the potentiometric surface.

Manual water level measurements were collected in a private irrigation well (7N 39E 8DBB) southeast of the ponds in the West Recharge Area. These measurements are shown in Figure 17. When water began entering the canal to the West Recharge Area, a rise in water level occurred. This well water level began dropping after 22 December 2008.

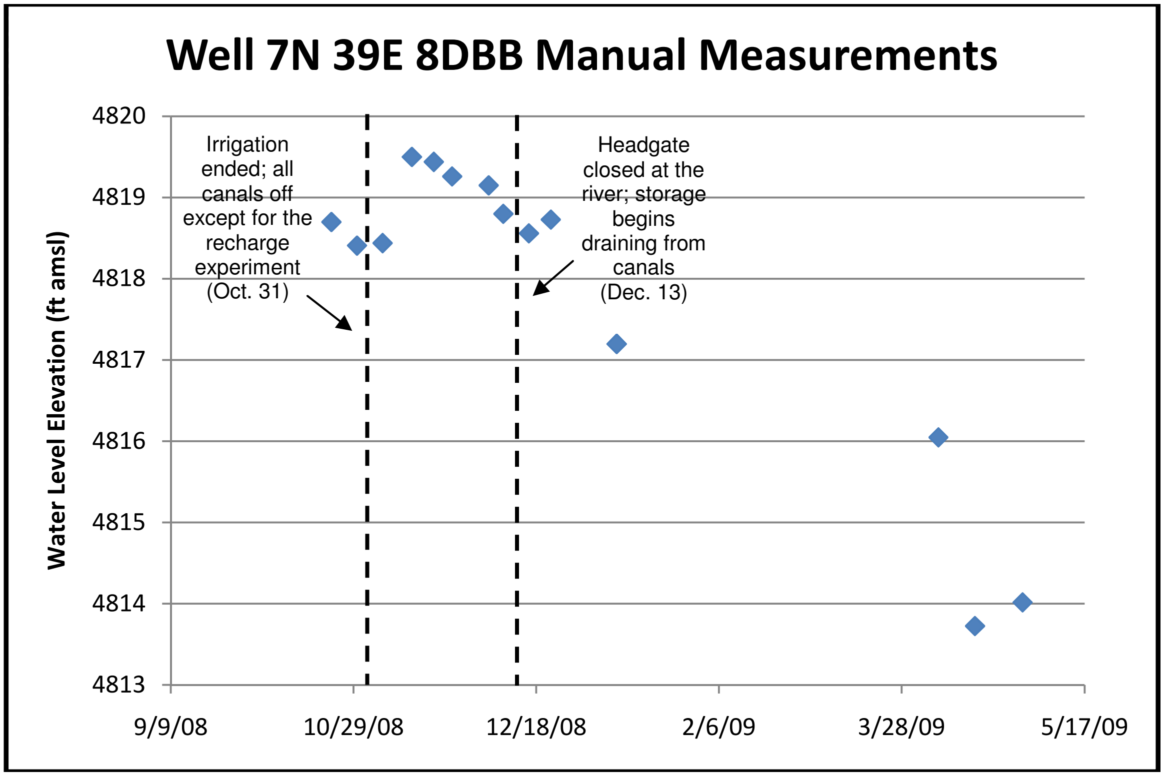

Figure 17. Aquifer water levels recorded manually in well 7N 39E 8DBB.

Transducer data were collected for well 7N 38E 23DBA2 located approximately 2.5 miles southwest of the ponds at the West Recharge Area (see Figure 2). This well is about 110 ft deep; therefore, it is not quite as deep as the well (7N 39E 7BDA1) directly south of the ponds at the recharge site. The recorded measurements are shown in Figure 18. The transducer recording was initiated at this site on 31 October 2008. After 31 October 2008, the water level in the well experienced an increase of about one tenth of a foot. At the end of November, the water level stabilized until the end of December in which the water level then declined.

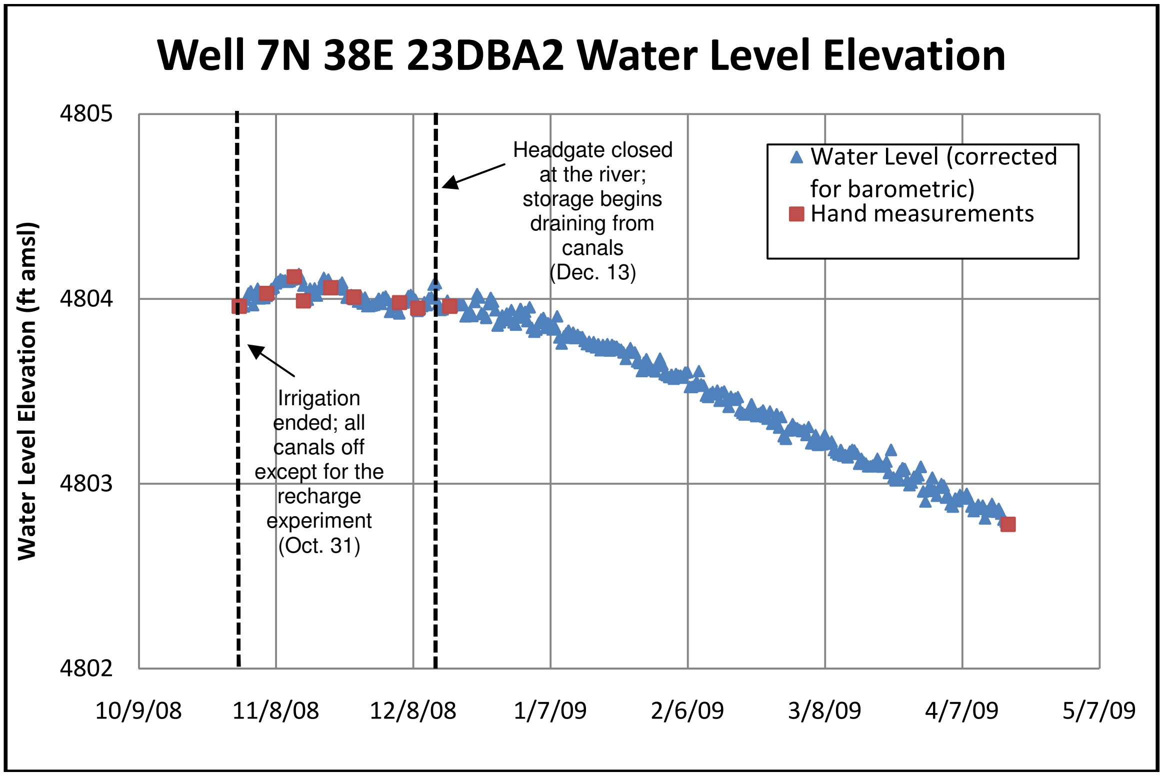

Figure 18. Aquifer water levels recorded by transducer in well 7N 38E 23DBA2.

In section 16 of township 7 north range 39 east, three wells were monitored with transducers. Each well is completed at a different depth. Figure 19 shows the transducer data for a well (7N 39E 16DBB1) that is approximately 444 ft deep. After data collection was initiated at the end of October in this well, the water level slowly declined, possibly due to the end of irrigation season. After the middle of December, which is also when the recharge canal was turned off, the declining water level slope became steeper as shown by the lines in Figure 19. This same change is visible in another well (7N 39E 16DBB2) located about 10 feet south and is completed at a depth of 107 ft. Figure 20 shows the results of data recorded by a transducer in this well (7N 39E 16DBB2). Like the well in Figure 19, this well also appears to experience a change in slope shortly after water is shut off to the recharge canal. Figure 21 shows a shallow well in section 16 of township 7 north range 39 east. This well (7N 39E 16DBB3) is about 38 ft deep. It shows several changes in water level, which are likely due to the water in the canal nearby. Although this is a shallow well, it is difficult to visibly find any changes in water level related to the recharge experiment.

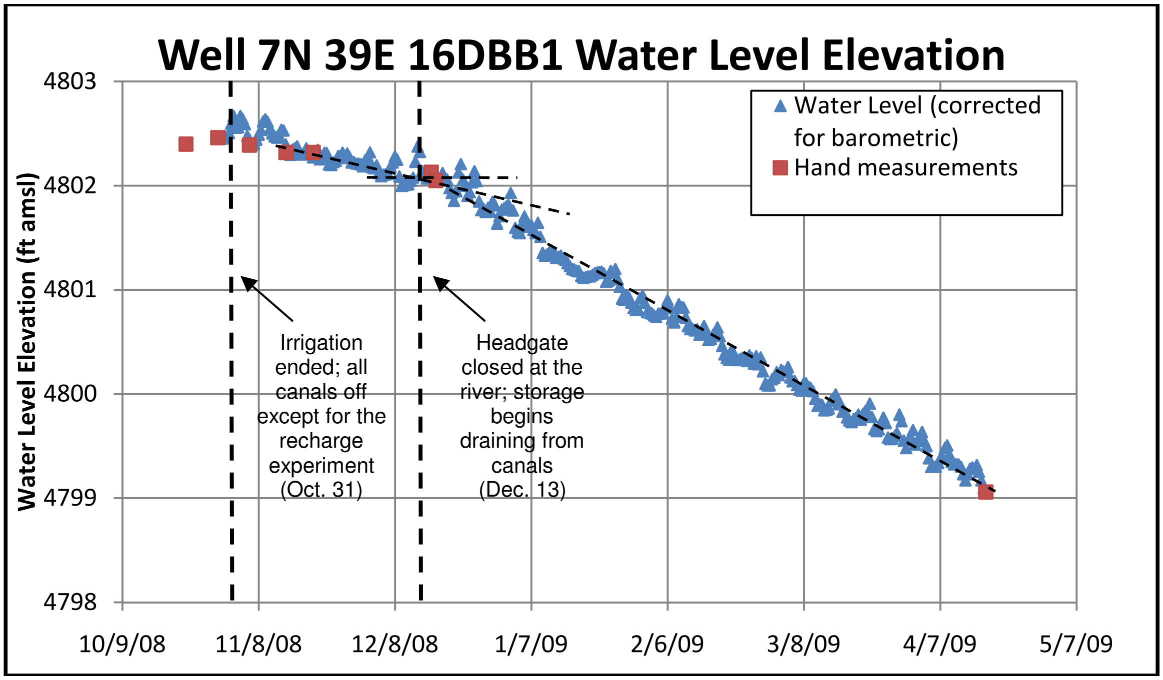

Figure 19. Aquifer water levels recorded by a transducer in well 7N 39E 16DBB1 (completion depth 444 feet)

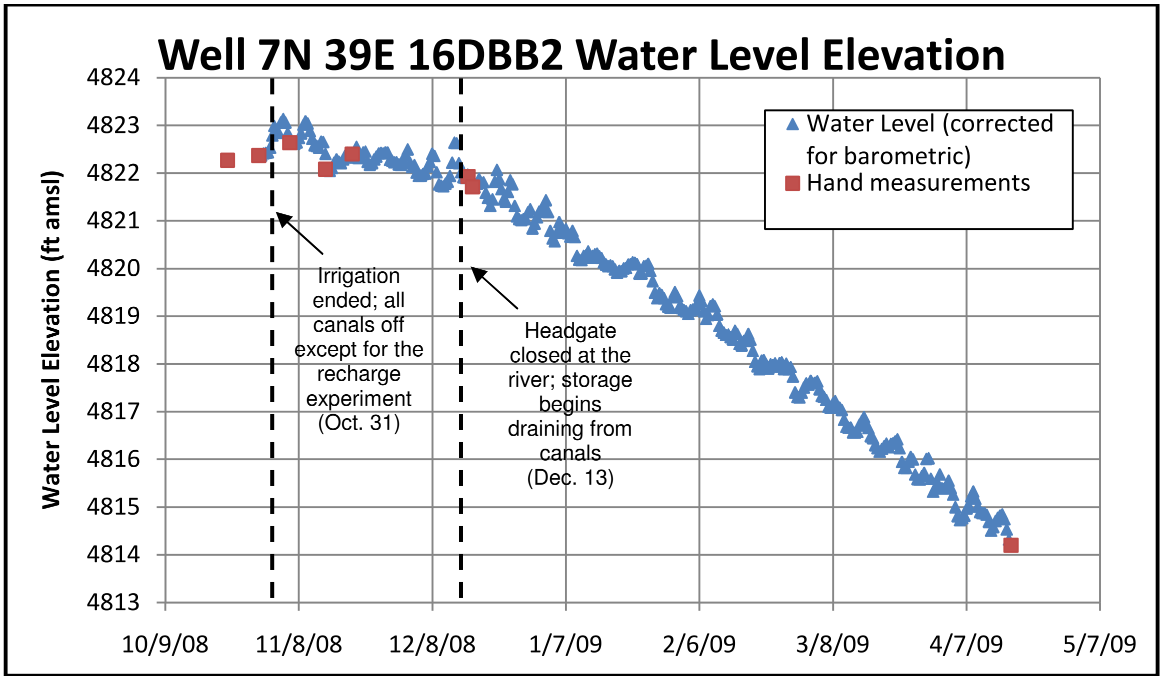

Figure 20. Aquifer water levels recorded by a transducer in well 7N 39E 16DBB2. This well is located about 10 feet south of the well in Figure 19. (completion depth 107 feet)

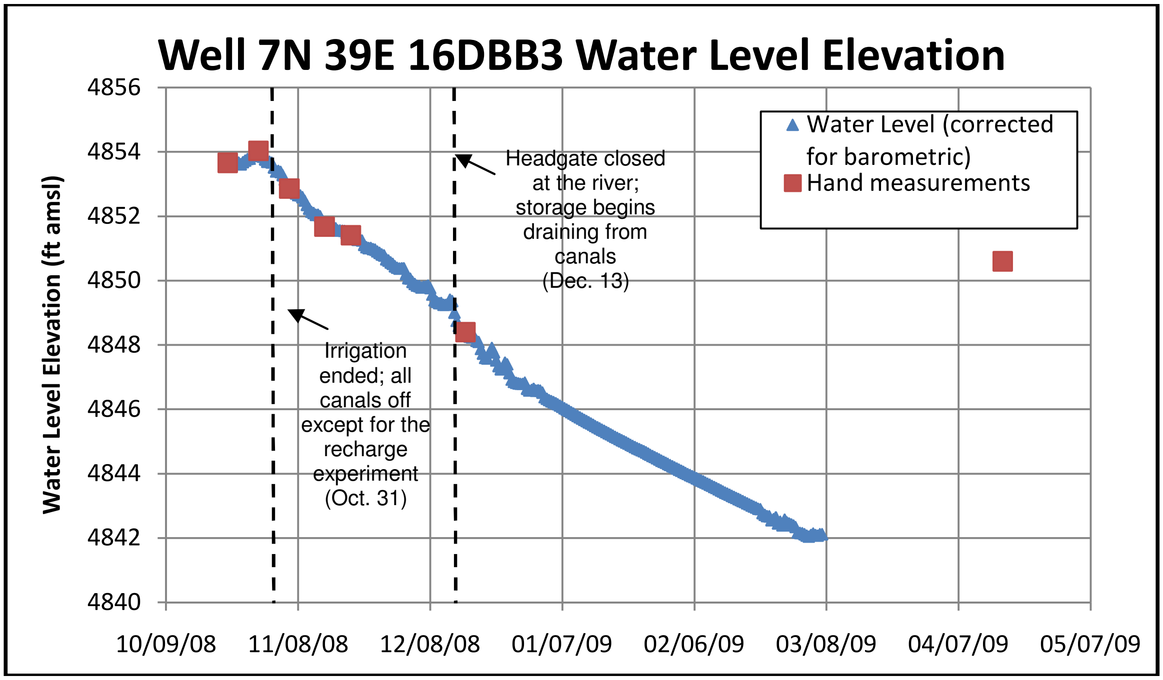

Figure 21. Aquifer water levels recorded by a transducer in well 7N 39E 16DBB3. (completion depth 38 feet)

<u>Seepage Reconnaissance.</u> Due to the measurement difficulties described above in the section "Reconnaissance of Seeps and Springs", it is difficult to use seeps monitoring to draw definitive conclusions about partitioning of recharge benefits.

Ability of Monitoring to Confirm or Contradict Aquifer Model

The ESPAM1.1 aquifer model was specifically developed for administrative analysis of questions of surface-water/groundwater interaction. It is a regional model designed for exactly the type of question presented by managed recharge at Egin. The model can be used to estimate the distribution of impacts of recharge in space and time, to 11 spring reaches and Snake River reaches.

A primary purpose of the monitoring project is to assess the ability of monitoring to confirm or contradict the model's apportionment of benefits and indications of timing of benefits. To fulfill this purpose, this section of the report compares and contrasts the findings of the literature search, data gathered in the monitoring project, and the representation of ESPAM1.1.

In the context of confirming or contradicting results of the ESPAM1.1 model, three questions are important:

1. Does more benefit of recharge accrue to the regional system than represented by ESPAM1.1?
2. Does more benefit of recharge accrue to the Henrys Fork than represented by ESPAM1.1?

3. Does ESPAM1.1 appropriately represent temporal delay of benefits?

Conceptual Models. ESPAM1.1 simplifies the aquifer as a locally-uniform porous medium in hydraulic connection with the Henrys Fork of the Snake River.[6] This is not necessarily in conflict with Stearns and others' (1939) representation, though it does not explicitly include the perched system they indicated. Stearns and others indicated that about half the recharge at Egin Bench is stored "beyond the borders" of the bench. This is mildly contradictory with the ESPAM1.1 representation that about 70% of recharge benefits the Henrys Fork and 30% benefits other reaches. King's (1987) estimate that 60% of diversions reach the regional system is more contradictory of ESPAM1.1.

The ESPAM1.1 conceptual model is in conflict with Wytzes' (1980) assertion that the Henrys Fork is in communication with the perched system but not the regional system. However, Wytzes' conceptual model includes significant downward movement of water from the Egin Bench perched system to the regional aquifer. There is at least theoretically room for the Wytzes conceptual model to accommodate the ESPAM1.1 apportionment of benefits of recharge, even with the difference in hypothesized physical structures.

White (1962) estimated that only 35% of St. Anthony-area recharge would accrue above Milner. This is in strong contrast to the ESPAM1.1 representation, where virtually all benefits are represented as benefiting the Snake River above Milner, and most above Rexburg.

No other strong contradictions of ESPAM1.1 are noted in the literature.

Data. Stearns and others (1939), White and Mundorff (1962) and Wytzes (1980) all present groundwater levels and hydrographs generally consistent with data gathered in the project. Vertical gradients are consistent with a multi-layer or reduced-vertical-conductivity conceptual model, and not contradictory (though not explicitly confirming) of the ESPAM1.1 uniform porous medium conceptual model. Vertical gradients are less than 1.0 ft/ft and therefore contradict Wytzes' conceptual model of a truly perched aquifer.

White (1962) reports of short-term reach gains ranging from -80 to 217 cfs and average gains ranging from 115 to 400 cfs are consistent with both the data and simulation results of ESPAM1.1. Hortness and Vidmar's data (2003) are also consistent with the ESPAM1.1 data. As shown in Figure 13 and Figure 14, ESPAM1.1 calibration simulation gains were reasonably consistent with target data.

End-of-canal spills reported by Hortness and Vidmar (2003) are consistent with those measured in the 2008 monitoring project. This project's reconnaissance estimate of 20 to 80 cfs of seepage from the bench face is inconsistent with

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[6] Hydraulically-connected when aquifer water levels are in an appropriate range.

Hortness and Vidmar's report of no other major inflows on the northwest side of the Henrys Fork. Possible explanations include:

1. This projects' seepage reconnaissance estimates probably have higher uncertainty than Hortness and Vidmar's observations.
2. Seepage could have entered the river in small channels difficult to identify.
3. Seepage could have percolated into the flood plain before reaching the stream as surface flows.

Recharge-site seepage rates in literature were reasonably consistent with one another and with the 2008 monitoring study.

ESPAM1.1 vs. Data and Literature Summary. Table 4 summarizes the discussion in terms of the ESPAM1.1 representation of the spatial and temporal partitioning of benefits of recharge. This is a practical test; a conflict noted above between the Wytzes (1980) and ESPAM1.1 conceptual models is not noted in the table, since the Wytzes model is not necessarily contradictory to the ESPAM1.1 partitioning of benefits. The regional system is the larger Eastern Snake Plain Aquifer (ESPA). The fact that response was seen in a 340 ft well in such a short period of time indicates that not all the recharge was captured by a shallow system. Therefore this observation supports both the ESPAM1.1 representation or a representation that attributes even more benefit to the regional aquifer.

Table 4.
Consistency of Data and Literature Search
with ESPAM1.1 Representation of Spatial and
Temporal Partitioning of Benefits of Recharge

Observation or Literature Assertion	**More Benefit to Regional System Than ESPAM1.1**	**Less Benefit to Regional System Than ESPAM1.1**	**Partitioning of Benefit Consistent with ESPAM1.1**	**Timing of Benefits Consistent with ESPAM1.1**
Deep-well response, 2008 monitoring	Supports	Contradicts	Supports	
Seepage reconnaissance				Supports
Wytzes (1980) discussion of Henrys Fork reach gains			Supports	

Observation or Literature Assertion	More Benefit to Regional System Than ESPAM1.1	Less Benefit to Regional System Than ESPAM1.1	Partitioning of Benefit Consistent with ESPAM1.1	Timing of Benefits Consistent with ESPAM1.1
Hortness and Vidmar (2003) gain/loss study			Supports	Supports
Stearns and others (1939) partitioning of benefits	Supports	Contradicts	(not strongly contradictory)	
White (1962) partitioning of benefits	Supports	Contradicts	Contradicts	
King (1975) partitioning of benefits	Supports	Contradicts	Contradicts	
Calibration target reach gains data			Supports	Supports

The general indication of data and literature is that the benefit of recharge to the regional system is at least as great as ESPAM1.1 represents and possibly greater, but not less. Data and literature tend to support in a general way the model's timing of benefits to the Henrys Fork.

Secondary Effects

Early-spring recharge in the Egin Bench area could sustain summertime reach gains lower down the river, reducing supplemental groundwater pumping and thereby positively affecting spring discharges. Delivery to recharge could capture spring runoff that otherwise might have been spilled for flood control purposes. The result of this recharge may be to sustain fall and winter baseflows that become storage in American Falls Reservoir. It may even facilitate additional aquifer recharge at other sites, via increasing reservoir carryover or sustaising natural flow. Neither monitoring nor aquifer modeling alone can appropriately describe the cascading benefits that can result from these kinds of secondary effects.

FUTURE WORK

A number of activities could be carried out to refine the findings of this project, improve the estimates of partitioning of benefits of recharge, and provide input to future refinements of the aquifer model. These include:

1. Ongoing monitoring of aquifer water levels. This is probably the single most valuable activity that could be undertaken in the near future. It has two benefits:
    a. Provides input to future calibration of aquifer model.
    b. Allows for normalization of water levels to compare different years.

    IDWR conducted a recharge experiment in October 2007 using the Northside Canal in collaboration with the Idaho Groundwater Appropriators, Idaho Dairyman's Association, and the Northside Canal Company (Wylie et al, 2008). Water-level records prior to the recharge event were available to compare to the data recorded during the 2007 recharge event. Figure 22 is a hydrograph of a well monitored during the experiment. Figure 23 was produced from Figure 22 in which part of the data were normalized by dividing the observed water level with the average water level (H/H_avg). This technique allows qualitative comparison of hydrographs from different years. The 2007 data were recorded after the irrigation season. The typical recession of water levels is noticeably dampened; the recession is not as steep in 2007 as it was in previous years. This qualitatively suggests the benefit of the recharge experiment.

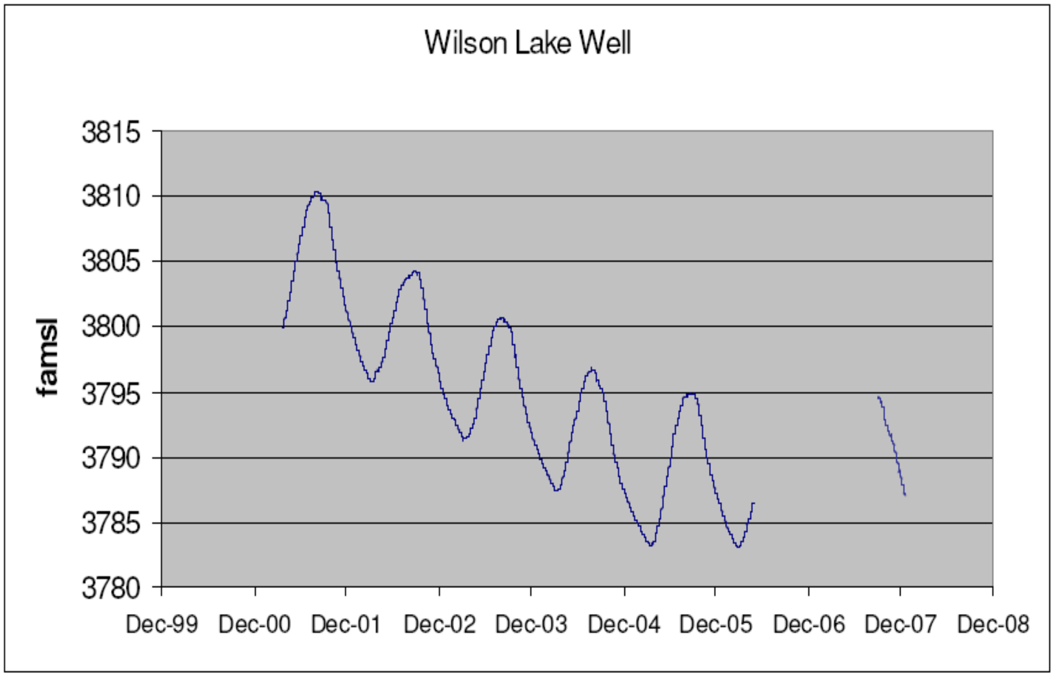

Figure 22. Wilson Lake well hydrograph before and during the Northside Canal recharge experiment. (Courtesy Allan Wylie)

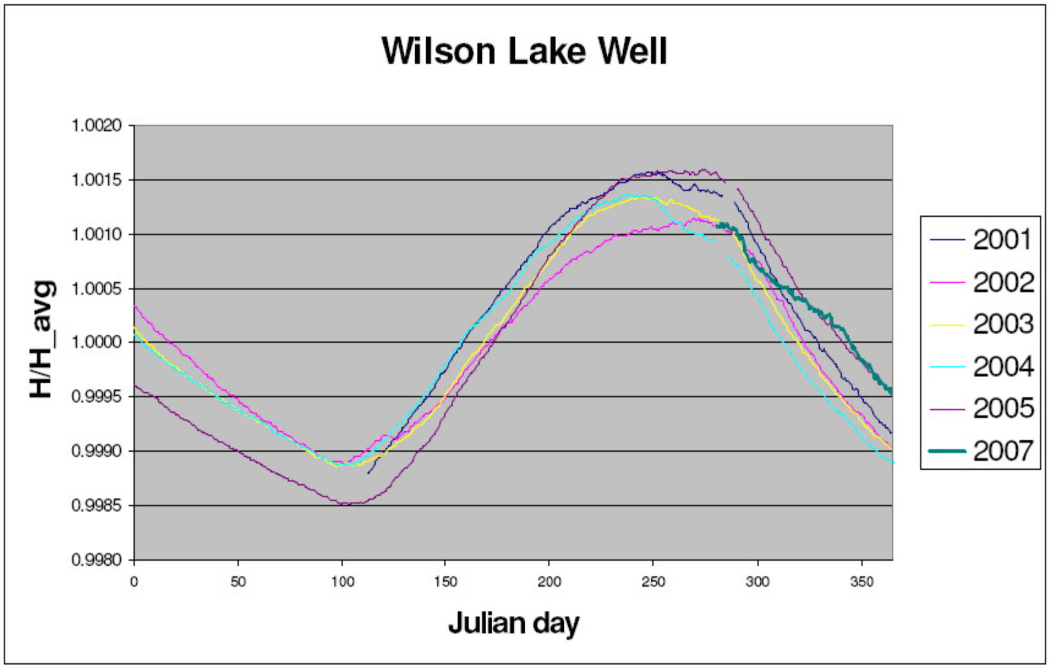

Figure 23. Normalized water levels in the Wilson Lake well. (Courtesy Allan Wylie)

2. Better accounting of movement of water on land surface. Personnel of the St. Anthony Canal were very willing to participate in data gathering, and the project relied heavily on their observations. However, they have responsibility for a large system with many headgates, water users, and reporting needs. Weirs, flumes or structures with recording devices at the Recharge Canal heading, entrance and exit to Egin Lakes, and the entrance to Tibbitts Lake could reduce the burden on the canal company and provide finer temporal resolution of data. IDWR Eastern Region personnel and canal company managers should be consulted if this effort is contemplated.
3. Better understanding of seeps and return flows. This would provide additional qualitative information on timing and partitioning of benefits of recharge, and would provide useful information to future aquifer modeling efforts. Monitoring return flow and end-of-canal spills would be necessary.
4. Geologic framework studies. A detailed review of well logs would be beneficial in better understanding the hydrogeologic units in the area. Definition of the horizontal and vertical extents of the clay layers in the area would be aid understanding of the hydrologic units. Geophysical studies may be helpful in defining such units as well. Additional literature research would also be essential.
5. Acquire additional wells in the monitoring network. Several wells have been drilled for the purpose of monitoring in the Egin area for previous studies. Some of these were not located until early spring 2009 and consequently were not included in the fall-2008 measurement activities. Additional wells that may be considered are found in T7N R40E of

sections 8, 16, 18, and 20 of Fremont County. These wells have not been measured for quite some time and it is not known if all are appropriate sites to monitor.

6. Pumping tests. Pumping tests can allow estimation of local hydraulic properties of aquifer materials. Two locations (7N 39E 16 and 7N 40E 19) include a large production well in close proximity to monitoring wells at three different depths. These provide an excellent opportunity to conduct pump tests to refine understanding of vertical connections in the aquifer. This would aid in resolving the conflict between the Wytzes and ESPAM1.1 conceptual models.
7. Tracer tests. Tracer tests can provide insight into flow rate and direction, as well as preferential flow paths. One benefit of tracer tests is to provide data relating to water-quality concerns for domestic or municipal wells in the vicinity of recharge activities. They may also aid in understanding conceptual models and resolving conflicts.

   Tracer tests indicate movement of individual molecules of water but do not indicate the propagation of water-supply benefits. A hazard is that readers may not understand this distinction and may misinterpret results.

SUMMARY AND CONCLUSIONS

Potential for Monitoring to Quantify Benefits of Recharge

From the 2008 recharge experiment at Egin Lakes and the associated monitoring project, it appears that monitoring of aquifer water levels and seepage can provide qualitative information regarding the partition of the benefits of recharge and the timing of benefits. Monitoring can also confirm or contradict conceptual models that underlie computerized aquifer models, and can provide important data for calibration. As shown by the Northside Canal recharge experiment (Wylie et al, 2008), long term monitoring provides beneficial information for distinguishing between the benefits of recharge relative to recovering water levels in the aquifer. As pointed out by Anderson (1975), quantitative partitioning of recharge benefits would be very difficult to obtain from monitoring alone, without the use of computerized aquifer modeling.

Indications from this monitoring project include the following:

1. Transducer data suggest the recharge experiment benefitted the deeper aquifer system.
2. Data and literature support the general ESPAM1.1 indication of the timing of benefits to the Henrys Fork.
3. Data and literature tend to either support the ESPAM1.1 partitioning of benefits or indicate that more benefit accrues to the regional system and less to the Henrys Fork than indicated by ESPAM1.1.

Developing Public Policy for Future Management of the Eastern Snake Plain Aquifer

Recharge is a recognized beneficial use of water in Idaho and the public interest is served by recharge projects benefiting the Eastern Snake Plain Aquifer and the Snake River. The cooperation between the Idaho Department of Water Resources, the Eastern Idaho Water Rights Coalition, the Idaho Water Resources Board and the Fremont-Madison Irrigation District in supporting Egin Lakes recharge and continued monitoring and analysis serves as a model of state agencies and local groups working together to obtain mutual benefits to the public.

Future recharge projects at Egin Lakes will conform with the Eastern Snake Plain Aquifer Comprehensive Management Plan (ESPA – CAMP) which was approved by the Idaho Legislature and signed into law on April 23, 2009. CAMP establishes a long-term program for managing water supply and demand in the ESPA through a phased approach to implementation and an adaptive management process to allow for adjustments in management techniques as implementation proceeds. The goal of the Plan is to: “Sustain the economic viability and social and environmental health of the Eastern Snake Plain by adaptively managing a balance between water uses and supplies.” The Plan sets forth actions, which include aquifer recharge, that stabilize and improve spring flows, aquifer levels, and river flows across the Eastern Snake Plain.

ACKNOWLEDGEMENTS

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1. US Bureau of Reclamation, US Bureau of Land Management, USGS and local landowners, for providing access to sites and monitoring wells.
2. Annette Campbell of USGS, for providing site schedules and information about individual sites.
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4. Fremont Madison Irrigation District, for providing background information and access to sites.
5. Representative Jack Barraclough (Eastern Idaho Water Rights Coalition), for referring us to the King publication and providing background information and insight to the White and Mundorff publications.
6. Neal Farmer, Allan Wylie and Rick Raymondi of IDWR, for technical input and insights.

7. Eastern Idaho Water Rights Coalition and Idaho Water Resource Board, for funding the monitoring project.

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