Contribution of Irrigation Seepage to Groundwater-Surface Water Interactions on the Eastern Snake River Plain

Rob Van Kirk, HSU Department of Mathematics
http://www.humboldt.edu/henrysfork/
Collaborators and funders

Current USDA-funded Project
Brian Apple, Humboldt State University
Dr. J. Mark Baker, Humboldt State University
Dr. Yvonne Everett, Humboldt State University
Dr. Brad Finney, Humboldt State University
Lora Liegel, Humboldt State University
Kimberly Peterson, Humboldt State University
Dr. Steve Steinberg, Humboldt State University
Dale Swenson, Fremont-Madison Irrigation District
Kim Ragotzkie, Henry’s Fork Foundation
Amy Verbeten, Friends of the Teton River

Other Collaborators
Kevin Boggs, University of Idaho
Dr. Gary Johnson, University of Idaho

Funders
National Science Foundation
U.S. Department of Agriculture
Outline

• Study areas and hierarchy of nested spatial scales
  1. Teton Valley—tributary basin (400 km²)
  2. Henry’s Fork—upper part of Plain (8,000 km²)
  3. Upper Snake R.—entire aquifer (93,000 km²)
• Hydrogeology of Snake River Plain
• Statement of problem
• Research approach
• Results
• Ecological consequences
• Conclusions and recommendations
Eastern Snake River Plain and Study Basins
Elevation-precipitation relationship across the hotspot.
Upper Snake River Water System

- Drainage area: 35,800 mi$^2$ (93,130 km$^2$)
- Irrigated area: 2.4 M acres (9750 km$^2$)
- 9 major storage reservoirs; capacity 4 M a-f (5 x 10$^9$ m$^3$)
Eastern Snake Plain Aquifer (ESPA)

Water budget and water rights accounting close below Thousand Springs.
Problem 1: Decline in Groundwater Levels

Groundwater level in a monitoring well on the ESPA.
Problem 2: Decline in Aquifer Discharge

Thousand Springs Discharge
Research Approach

• Model flow through linked surface-ground system, including:
  ▪ Diversions from streams into canal system
  ▪ Seepage from canals
  ▪ Seepage from stream channels
  ▪ Seepage due to irrigation application in excess of crop ET
  ▪ Surface return from irrigation system
  ▪ Returns to surface system from aquifers
• Analyze changes in irrigation practices
• Estimate water budgets
• Conduct analyses at multiple spatial scales:
  ▪ Small tributary basins (Teton Valley)
  ▪ Intermediate-scale watershed (Henry’s Fork)
  ▪ Entire system (Upper Snake River/Eastern Snake Plain Aquifer)
• Mean ann. precip.: 28.2 inches
• Min. elevation: 4,820 ft.
• Max. elevation: 11,400 ft.
• Canal-irrigated area: 250,000 ac.
• Canal length: 475 miles
• Annual water supply: 2.5 M a-f
• Annual diversion: 1.2 M a-f
Surface lithology of Henry’s Fork

- **Precambrian**
- **Paleozoic and Mesozoic sedimentary**
- Cenozoic silicic volcanics from Yellowstone hotspot explosive eruptions
- **Quaternary basalts**
- **Quaternary alluvium and glacial drift**

Source: Bayrd 2006 M.S. Thesis, Idaho State University
Field work to measure canal and stream channel loss rates and geometry for model parameterization.
Changes in Irrigation Practices

Flood irrigation

Sprinkler irrigation
But, almost all conveyance still occurs in unlined canals.
Groundwater pumping began in 1950s

Annual volume of groundwater pumped by A&B Irrigation District

But, GW pumping does not occur in all locations.
30-year Mean Canal Hydrograph—Teton Valley

![Graph showing diversion flow over time with labels for Application Seepage, Crop ET, Canal Seepage, Canal/Sprinkler ET, and Surface Return.](image)

- **Diversion (cfs)**
- **Date**
  - 1-Oct
  - 1-Nov
  - 1-Dec
  - 1-Jan
  - 1-Feb
  - 1-Mar
  - 1-Apr
  - 1-May
  - 1-Jun
  - 1-Jul
  - 1-Aug
  - 1-Sep
30-year Mean Canal Hydrograph—HF

- **Application Seepage**
- **Crop ET**
- **Canal Seepage**
- **Canal/Sprinkler ET**
- **Surface Return**

**Diversion (cfs)**

**Date**

1-Oct to 1-Sep
# Canal Budget by Year—Henry’s Fork

<table>
<thead>
<tr>
<th>Year</th>
<th>Application Seepage</th>
<th>Crop ET</th>
<th>Canal Seepage</th>
<th>Canal/Sprinkler ET</th>
<th>Surface Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reach gains depend strongly on irrigation recharge, which depends on diversion
GW recharge under modeled scenarios, Teton Valley
“Pipeline” scenario assumes 100% irrigation efficiency
Effect on GW elevations: Teton Valley
Does this scale up to entire Upper Snake?

Teton Valley: 0.92 M a-f/yr
Henry's Fork: 1.2 M a-f/yr
Upper Snake: 8.7 M a-f/yr

Water budget for surface water withdrawals
Does this scale up to entire Upper Snake?

Distribution of Recharge Sources to Valley Aquifers

- Teton Valley: 0.95 M a-f/yr
- Henry's Fork: 1.2 M a-f/yr
- Upper Snake: 9.0 M a-f/yr

Distribution of Recharge Sources:
- Direct Precipitation
- Stream Seepage/Tributary Underflow
- Irrigation Seepage
Prediction of Thousand Springs discharge from irrigation seepage

Modeling efficiency: 75%
Boggs et al. 2010, JAWRA
Ecological Consequences: hydrologic alteration

Modeled Teton River flow: irrigation has decreased peak flow and increased base flow
Ecological Consequences: hydrologic alteration

Modeled Teton River flow, dimensionless hydrographs
Measure GW influence by maximum/minimum ratio
Teton R. Maximum/minimum discharge ratio
Stream channel complexity increases with hydrograph max/min ratio (Bayrd 2006)
Nonnative rainbow trout displace native cutthroat when max/min ratio is low.
BUT, irrigation seepage maintains...
Some conclusions and recommendations

• Irrigation patterns have driven groundwater-surface water interactions in upper Snake Basin since late 19th century.
• Irrigation has transformed upper Snake hydrologic regimes from snowmelt-dominated to GW-dominated.
• Native species and ecosystems have been replaced by nonnatives, but...
• Ecosystem services provided by irrigation-dependent groundwater and wetlands are valued, if poorly understood and under-appreciated.
• Increases in irrigation efficiency have reduced GW-associated resources, including water supply for downstream users.
• Irrigation remains single largest source of aquifer recharge.
• Water management for all uses and values must account for groundwater-surface water interactions and treat both components equally.
• Beware of unintended down-gradient and downstream consequences of well-intentioned water conservation measures.