Chapter 21

Little Bear River Watershed, Utah: National Institute of Food and Agriculture–Conservation Effects Assessment Project

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The Utah National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP), Investigation in the Changes in Water Quality in the Little Bear River Watershed in Response to the Implementation of Best Management Practices, was designed to evaluate whether adoption of several agricultural best management practices in a northern Utah Watershed have had a measurable impact on phosphorus (P) loadings into the Little Bear River. It was expected that the use of fine-grained data from throughout this watershed would enable determination of whether these changes are related to the implementation of management practices. The core research objectives to be addressed by this project included the following:

1. To determine whether publicly funded programs to promote the adoption of agricultural conservation best management practices were able to reduce P loadings into surface waters in the Little Bear Watershed
2. To critically examine the strengths and weaknesses of different water quality monitoring techniques
3. To make recommendations to policymakers, agricultural conservation field staff, and other interested parties to ensure that future management efforts are targeted towards the most effective and socioeconomically viable agricultural best management practices

The Little Bear River NIFA–CEAP, as originally proposed, was a retrospective study attempting to assess water quality impacts of conservation practices implemented as part of a Hydrologic Unit Area (HUA) Project in the 1990s. The NIFA–CEAP did not involve any new implementations of conservation practices or changes in land-use practices. The project was dependent on previously collected water quality and discharge data. Because the historical data ultimately proved inadequate for detecting changes in water quality in such a variable environment, the project shifted its water quality focus to investigating improved water quality monitoring techniques and approaches. A significant effort of the NIFA–CEAP involved an analysis of land-use and management changes in response to the HUA Project.

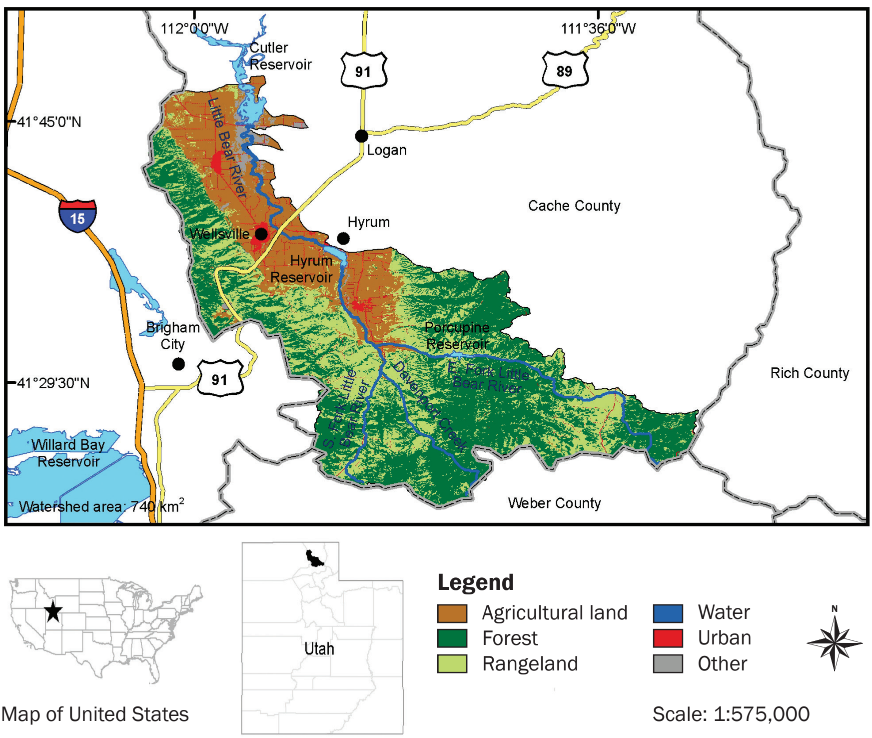
Watershed Information

The Little Bear River Watershed is located in northern Utah, encompassing approximately 74,000 ha (182,858 ac) of primarily agricultural lands. Land ownership is 88% private, 10% national forest, and 2% state land (figure 21.1). The area is experiencing rapid population growth, with a 32% increase in population between 1990 and 2000 and an even higher increase (47%) occurring in unincorporated areas.

Approximately 70% of the watershed area is devoted to grazingland and forest, 19% is irrigated cropland (small grain, corn, and miscellaneous crops), and 7% is dry cropland (alfalfa, small grain, and fallow). The national forest and state lands are used primarily for grazing and forest areas. Because of confidentiality issues, data were not available on intensity of distributed grazing on any of these lands. The area is home to over 50 dairies with an average herd size of 120 milk cows.

Elevations in the watershed range from 1,341 to over 2,743 m (4,400 to over 9,000 ft). The mountainous area above this elevation is characterized by steep slopes and soils derived from mixed parent materials. The lower portion of the watershed is within the footprint of the ancient

Figure 21.1
Little Bear Watershed, Utah, land use and stream networks.



Lake Bonneville, which reached its maximum elevation of 1,591 m (5,220 ft) about 16,800 years before present. Soils in these old lake bottoms are nearly level and consist of silt clay loams with much finer texture than soils in the upper portions of the watershed. Saline and sodic soils are also common in these ancient lake deposits.

Most of the precipitation in this watershed falls as snow, with the greatest accumulations at higher elevations. Summers are typically dry, with occasional summer convective storms. Rainfall ranges from 1,143 mm y^{-1} (45 in yr^{-1}) at the highest elevation to 483 mm y^{-1} (19 in yr^{-1}) at the lowest elevation.

The Little Bear Watershed has two main headwater drainages, the East Fork and the South Fork, which meet at the approximate midpoint of the watershed, several miles upstream of Hyrum Reservoir. The river discharges into Cutler Reservoir, a large shallow reservoir on the mainstem of the Bear River. Hyrum Reservoir divides the Little Bear Watershed into two distinct subwatersheds. The lower subwatershed is characterized by low gradients, depositional soils deposited by the ancient Lake Bonneville, and a highly modified hydrograph due to irrigation withdrawals and canal diversions. The upper watershed has narrower river valleys, steeper gradients, and less regulated streamflows.

Discharges in this region are highly variable and have been dominated by a drought cycle since 2000. The natural hydrograph of rivers in this part of the intermountain west includes a high spring runoff period as the snow melts, followed by low base flows from midsummer through early spring. Portions of the upper subwatershed, including most of the South Fork subdrainage, are unregulated. The Porcupine Reservoir traps much of runoff on the East Fork, diverting water via a feeder canal to agricultural lands to the east of the Little Bear Watershed. Some of the flows from this canal are ultimately discharged into the Blacksmith Fork River, draining lands to the north.

Flows in the lower basin are heavily affected by reservoir storage, releases, and canal diversions. As a result, flows in this portion of the river have relatively lower spring runoff flows and augmented summer flows due to reservoir releases for irrigation use. The effects of this complex hydrology on water quality are largely unknown, although cluster analysis of existing water quality data suggests that hydrology, in general, and irrigation, in particular, are major influences on observed water quality in the Little Bear River Watershed. These issues present serious challenges to modeling, and in some cases, require exclusion of parts of the watershed from loading analysis.

Water Quality Information

Historic Water Quality Information

Water quality data have been collected by the Utah Division of Water Quality since 1977. Utah water quality standards for dissolved oxygen and coliform bacteria have been periodically violated since 1985. Utah does not have a water quality standard for P or nitrogen, although pollution indicator concentrations for total P are exceeded regularly in the mainstem of the Little Bear Watershed, particularly in the lower portion of the watershed. Nitrogen exceedances have been infrequent. Hyrum and Cutler Reservoirs have impaired fisheries and recreation due to eutrophication.

During the 1990s, Little Bear River Watershed was designated as a USDA HUA Project. The water quality assessment at the start of this project was based largely on visually assessed water quality problems and focused on nonpoint source pollution from dairy, grazing, and riparian areas. The Little Bear River Project area was also designated as a state 319 Nonpoint Source Project Area. The Utah Department of Environmental Quality conducted detailed water quality assessments from 1990 through 1992 to provide information on use support, evaluate water quality trends, and determine critical water quality issues to be addressed. Primary water quality concerns were identified in the Little Bear River Watershed and included total suspended sediment (TSS), P, ammonium, biological oxygen demand, low dissolved oxygen, and fecal coliform bacteria. Based on these results, a total maximum daily load (TMDL) for P was established for the Little Bear River Watershed. Sediment and P were identified as the primary pollutants of concern, and the sources for these pollutants were identified as the following:

- Sheet, rill, and gully erosion from rangeland due to reduced vegetative cover caused by overgrazing of livestock and wildlife
- Stream bank and stream channel erosion

The TMDL included two goals:

- Improve the quality of the Little Bear River water to meet state standards for the designated uses by reducing the amount of nonpoint source pollutants entering the Little Bear River.
- Achieve long-term stability of stream channels, stream banks, and shorelines throughout the watershed, and restore a quality fishery.

One of the principal goals of the NIFA–CEAP was to evaluate the impacts of agricultural conservation practices that were implemented during the 1990s to reduce P loadings into the Little Bear River. Specific research questions in the original proposal included the following:

- Can a statistically significant association be demonstrated between the use of various types of conservation practices and changes in surface water quality within the watershed?
- Does an understanding of variability in the implementation and maintenance of conservation practices (and associated behaviors) help improve our ability to explain changes in P loadings?
- What is the time lag associated with observing a response from land management changes?
- How does spatial location within the watershed affect the timing and intensity of water quality responses to changes in producer behaviors?
- How well do load reductions predicted by the original models used to design conservation programs in the Little Bear Watershed correlate with the actual observed load reductions identified from our monitoring data?
- How well do alternative water quality indicators (such as macroinvertebrates) correlate with traditional grab sample approaches?

The NIFA–CEAP proposal assumed that the historic water quality data collected by the Utah Division of Water Quality (UDWQ) and discharge data at six different US Geological Survey (USGS) gaging stations were sufficient to identify changes in water quality over time and to correlate these changes to implementation of best management practices. Compared to many watershed-wide monitoring programs, the Little Bear River had a long record of water quality sampling and what appeared to be well-distributed sample locations. Two sites had been sampled continuously since 1977, and another 20 sites had been sampled at less frequent intervals during periods of intensive monitoring. Fourteen of these sites had at least five years of data collected since 1990. Typically sites were visited between 4 to 10 times per year. During intensive monitoring activities conducted from 1992 through 1994 and from 1999 through 2001, samples were collected biweekly during runoff periods and monthly during baseflow. Water quality data were collected at least monthly and biweekly during runoff periods at 9 sites throughout the basin from 1990 through 1993 and at 10 stations from 1999 through 2004. In addition, two sites in the watershed were sampled continuously since 1977 and were visited between 4 to 10 times per year.

Since 1938, discharge has been measured by the USGS at eight different gaging stations. One of these stations, the Little Bear River at Paradise (10105900), was installed in 1991 and is still active, but the record from the other gaging stations are intermittent with little overlap between sites. There has never been a USGS station at the outlet of the watershed above Cutler Reservoir, so the historic record consisted only of discharge measurements collected when water quality samples were taken during low-flow periods.

The NIFA–CEAP proposal used information from the UDWQ that suggested that there was a reduction in P concentration of about 50% from 1980 to the early 2000s, as well as a reduction in P loads. Several problems in this original loading analysis by UDWQ were subsequently identified. The pre-1991 data were lumped, resulting in very high loads associated with high flows during the mid-1980s. A drought cycle began in 2000, resulting in low loads associated with lower flows. Finally, improvements in the management of a wastewater treatment facility in the lower watershed resulted in reduced P concentration discharges and thus lower loads in the river. While this last factor represented a true improvement in water quality in the river, it could not be attributed to agricultural best management practices.

While the raw water quality and discharge data initially appeared to be adequate for meeting project goals, NIFA–CEAP staff concluded that the data were of limited use for assessing changes in P concentration or load in response to conservation practices. The frequency of monitoring events in the historic water quality dataset and the incomplete coverage of the watershed by the USGS gaging stations limited the ability to use these data for a meaningful understanding of dynamics of P loads in the Little Bear River and its tributaries.

Investigation of Water Quality Monitoring Techniques

In recognition that the historic water quality data in the Little Bear River Watershed were inadequate for detecting impacts of best management practices implementation, the NIFA–CEAP redirected some of its efforts toward an investigation of improved water quality monitoring techniques. Much of the work during the first two years of the NIFA–CEAP focused on identifying and filling data gaps, particularly in water quality monitoring data and in understanding of modified river flows as a result of irrigation diversions and return flows.

Continuous monitoring of flow and turbidity was initiated at two sites in the watershed: an upper site was located in the mainstem of the Little Bear River below the confluence of the south and east forks of the Little Bear River and above Hyrum Reservoir, and a lower site was located just above the Cutler Reservoir. Water quality data were collected by the UDWQ at both these sites, providing some limited continuity with historic data. Grab samples were also collected at these sites and were analyzed for total and dissolved P, nitrate, nitrite, and TSS.

An analysis of these high frequency data established site-specific relationships for total P and TSS as a function of turbidity (Spackman Jones et al. 2011). Inclusion of baseflow and runoff flows improved the predictive value of these relationships. Spackman Jones et al. (2009) also evaluated loading estimates based on water quality data collected at varying frequencies measurements, verifying that the frequency of data collection in the historic dataset was inadequate in the face of concentration and flow variability to establish meaningful load estimates.

The NIFA–CEAP also focused on the need for better understanding of hydrology in this highly modified system. Two reservoirs in the watershed capture runoff and release flows to canals or the river channel for irrigation use. In addition, a number of diversions from the river itself move river flow to the irrigation canal system. Water from Porcupine Reservoir in the upper watershed is diverted to a series of canals that feed the eastern portion of the upper watershed. Unused water in the main channel diversion eventually is released into the Blacksmith Fork Watershed to the north of the Little Bear Watershed. Water diverted from the south fork of the Little Bear diverts water to the west of the main channel. Water stored in Hyrum Reservoir is released into several canals that deliver water to both the east and west of the main river channel in the lower watershed.

In addition, the NIFA–CEAP used historic (1992) and recently collected (2007) multispectral imagery to compare changes in riparian areas and river geomorphology over time. The 1992 analog data were transformed in order to compare them to the 2007 digital data. A subset of control and treatment reaches were identified, and metrics were chosen for comparison, including extent (width and continuity) of riparian community, width, sinuosity and slope of the river, and location and extent of erosional and depositional regions. The imagery demonstrated increased vegetation growth and changes in stream morphology, but the comparison of treatment and control reaches has not been completed.

Water quality and streamflow data were stored (http://water.usu.edu/littlebearriver), and the data were compiled within a central database. Through work done using the funding from this NIFA–CEAP grant and a watershed initiative project funded by the USEPA and a National Science Foundation Testbed Project, the network of monitoring stations has been expanded, a watershed based water quality model has been developed, and an environmental information system has been built (http://www.bearriverinfo.org). All of the monitoring data are included in this system, which includes the sensors in the field, the central database that stores the data, and Internet-based applications that publish the data. Linkages were made through the combination of an Internet Map Server, which shows the locations of our monitoring sites, and a Time Series Analyst application, which is launched when users click on one of the sites on the map and choose to visualize the data. Both of these applications are linked to the Little Bear River Web site at http://water.usu.edu/littlebearriver/applications/.

In addition to these public interface tools, several data management tools that automate the process of loading the data into the central database have been developed. These allow more detailed data management and manipulation tasks that were not available through the Internet-based tools listed above.

Land Treatment

The need for conservation practices in the original Little Bear River Watershed USDA HUA Project was based largely on visual assessment of water quality problems, addressing mostly dairy, grazing, and riparian land uses. Objectives of the HUA Project were determined by the USDA Natural Resources Conservation Service (NRCS) staff who conducted the initial screening and assessment that resulted in the 1992 Watershed Plan. Emphasis was on manure management, stream bank and channel stabilization, reestablishment of riparian buffer areas, and upland grazing management. A ranking system was established to treat 70% of the rangeland and 21 km (13 mi) of stream bank restoration; afterward, a focus on animal waste management was added. Originally, the plan was to start conservation practice implementation in the upper watershed and move to the lower watershed.

During the implementation of the HUA Project, a P TMDL was established, giving target load reductions of 12 kg d^{-1} (26.5 lb day^{-1}) above Cutler Reservoir and 2.4 kg d^{-1} (5.3 lb day^{-1}) above Hyrum Reservoir. This TMDL also defined targets and endpoints for land treatment:

- 14 animal waste management systems
- 25% reduction of cropland runoff
- 16 km (10 mi) of stream bank restoration
- Conservation practices installed on 3,035 ha (7,500 ac) designated as critical
- Total P concentrations not exceeding 0.05 mg L^{-1} in the stream

For the USDA HUA Project, several modeling efforts using the Pacific Southwest Interagency Committee, AGricultural Non-Point Source Pollution (AGNPS), and Environmental Policy Integrated Climate (EPIC) models were made to characterize pollutant loads and sources. Identification of critical areas was very basic, with distance to surface water as the main consideration. For the NIFA–CEAP, a geographic analysis of the watershed indicated that approximately 13% of the watershed area was in the highest nonpoint source risk categories. About 26% of these identified critical areas had received some previous land treatment, suggesting that a degree of targeting had occurred during the HUA Project. However, 75% of conservation practices were applied to fields with low water quality impacts.

The criteria and processes to select conservation practices in the Little Bear River Watershed changed over time but concentrated on waste management structures. The original plan for starting at the top of the watershed and moving toward the outlet changed because of the signup procedures wherein producers were accepted in the order in which they signed up.

Extension marketed the conservation practices to producers through direct personal contact. Project staff indicated that cost share (75%) was the primary determinant enabling producers to establish practices. The signup process determined which conservation practices were used. Present-day assessment of the signup process indicates that personal, one-to-one visits between producers and project staff were critically important in securing participation by landowners. Survey data suggest that outreach had little overall impact on conservation practice adoption in the Little Bear River Watershed.

The USDA NRCS focused on structural practices for the poorest managers because management practices were hardest to implement and demanded the greatest management capability. It appeared that landowners selected practices based on their farming operations. Farmers with livestock used waste management structures. Landowners could make some choices, for instance, the capacity of manure structure and how to manage the riparian corridor. This was based on land availability and perceived management capability. Most conservation practice priorities, however, were set by federal or state programs (Environmental Quality Incentives Program [EQIP] or the US Environmental Protection Agency [USEPA] Section 319) that paid for the conservation practices. In addition, local agricultural preference changed from flood to sprinkler irrigation in the mid-1990s. This was a popular conservation practice but probably had limited impact on water quality.

No quantitative land treatment objectives were set for the HUA Project. From 1992 through 1996, over 90 individual landowners and small groups installed conservation practices in the Little Bear River Watershed. These conservation practices included the following: 36 manure management systems for animal feeding operations, 7,300 m (23,950 ft) of stream bank fenced and another 4,000 m (13,123 ft) stabilized, approximately 10 ha (25 ac) of riparian buffer, and 8,499 ha (21,002 ac) of improved grazing management on range and pasture land. The USDA NRCS staff believed that, according to the knowledge at the time, treatment of the highest priority sites in the watershed was achieved during the HUA Project. The project estimated that these activities resulted in a reduced nitrogen load of 417,000 kg y^{-1} (919,328 lb yr^{-1}) and P load reductions of 64,900 kg y^{-1} (143,080 lb yr^{-1}) from the proper containment and application of over 69,853 Mg (77,000 tn) of the manure. The Pacific Southwest Interagency Committee modeling predicted that grazing management would reduce gross erosion and sediment loads by 37,500 kg ha^{-1} (33,375 lb ac^{-1}). Numeric loading responses to increased stream bank stability were not estimated by the project. However, contemporary analysis by NIFA–CEAP staff indicated that due to type of practice and location, 11% of the conservation practices had a strong impact on water quality, 18% had some impact, 27% had a possible small impact, and 44% had no impact. Thus, the majority of the practices installed or implemented probably had little or no impact on water quality.

The HUA Project did not monitor land use or implementation of conservation practices during its lifetime. This information was determined later during the NIFA–CEAP. Based on survey and other data, it was suggested that management-based practices had the highest frequency of nonimplementation; 47% of the supposedly implemented practices were actually not implemented. Structural practices had a better rate of implementation, with only 35% nonimplementation.

Following completion of the HUA Project, work within the watershed continued as directed by the TMDL implementation plan. The EQIP funds and additional USEPA Section 319 funds continue to be used for implementation in the watershed. Although actual implementation under the TMDL is unknown in detail, it appears that conservation objectives for the TMDL were exceeded, at least for some practices. Some additional farmers participated for a total of 100 farmers installing conservation practices through HUA, EQIP, or USEPA Section 319 funds. An additional nine waste structures were built, 8 km (5 mi) of stream banks were restored, and about 3,602 ha (8,900 ac) of rangeland were restored with this new funding. In order to meet the TMDL goal, the land treatment objectives were 14 waste structures, and 16 km (10 mi) of stream and 3,035 ha (7,500 ac) of grazing land were restored; thus practices exceeded the TMDL goals.

Water Quality Response

To achieve the objective of the NIFA–CEAP to relate water quality response to land-use changes, NIFA–CEAP staff attempted to use water quality data collected by the UDWQ in the Little Bear River Watershed. However, project staff stated clearly that HUA–era water quality data, which appeared to be quite robust at first, were not adequate to support extensive analysis. Recent monitoring efforts determined that data collected at much higher frequency (intervals of days during runoff periods) would have been necessary to detect change in this highly variable environment (Spackman Jones 2009). The network of high frequency monitoring stations currently established in the Little Bear River Watershed should be useful for tracking future changes in P loads from the Little Bear River Watershed. Based on the monitoring results from the Little Bear River Watershed sites, similar high frequency stations are now being established in several other watersheds in northern Utah and southern Idaho.

In 2004, the Upper Little Bear River Watershed was taken off of the Utah Section 303(d) of the Clean Water Act (USEPA 2011) list and was identified as fully supporting its beneficial uses. However, as noted, historical data were not sufficient to effectively tie this change to the HUA land treatment. Total P loads calculated for samples collected at the lowest site in the river from the 1980s through 2002 suggested that water quality may be improving; P loads appear to have changed over this time, unrelated to average annual flows. However, rigorous trend analysis was not possible given the quality of the historic data, and the monitoring design cannot rule out other factors, such as weather or land-use change.

The NIFA–CEAP conducted some additional statistical analysis on the Little Bear River Watershed dataset. Cluster analysis was used to understand seasonal patterns in water quality data. Results suggested that observed water quality was more related to hydrology than strictly to season, with irrigation being a major influence on water quality. Bayesian Network Analysis was used to understand what was happening in the Little Bear River Watershed and results were used to improve contemporary monitoring. However, neither of these techniques was capable of relating conservation practice implementation to land treatment at the watershed level using currently available data. With the exception of very limited bacteria analysis above and below several farms conducted early in the HUA Project, no farm-level or best management practices–level monitoring has been conducted. Existing water quality data did not allow this analysis, especially given the confounding influence of irrigation on watershed hydrology. In addition, the irrigation system profoundly complicated water quality interpretation, and because irrigation ditches were not monitored and irrigation ditches were sometimes not even represented in any maps, such analysis was essentially impossible.

The current NIFA–CEAP used stream bank and stream channel condition assessment as an alternative indicator of response to conservation practices. This process compared 1992 to 2007 aerial video imagery to analyze for changes in riparian zones. Areas of dense implementation of river-based conservation practices (installed stream channel structures, stream access control for livestock, and riparian vegetation) were identified from HUA data and interviews, focusing on a 30 m (100 ft) buffer from streams. Interim results noted significant vegetation growth and changes in stream morphology associated with reaches treated with conservation practices. Analysis to determine causes and to document differences between treatment and control reaches is in progress. Although this approach does not directly address some of the original project objectives (e.g., achievement of in-streamwater quality standards), the analysis offers much promise for quantifying the success of riparian restoration efforts.

Model Application

Modeling was not a major component of the Utah NIFA–CEAP. The NIFA–CEAP staff has used multivariate regression modeling to evaluate water quality trends. In addition, Bayesian Decision Networks, standard analysis of variance, and principal component analysis were used. Because the water quality data were inadequate, it was not possible to model the relationship between conservation practice implementation and water quality changes as had been hoped when the NIFA–CEAP began.

Socioeconomic Analysis

To assess implementation, NIFA–CEAP staff conducted a series of field visits and extended structured interviews with approximately 90 landowners who participated in official Little Bear River Watershed protection projects since 1990. The interview instrument was modeled on the Farm Practices Inventory, which was successfully implemented on almost 2,000 farms across 20 watersheds between 1990 and 1998 with response rates of over 75%. The Farm Practice Inventory instrument collects basic information about farmland and livestock inventories, cropping and manure management practices, as well as demographic information about the farm household. The interviews evaluated both direct and indirect implementation of prescribed agricultural conservation practices. The dataset obtained from this work was very rich and insightful.

Some 55 of the 90 landowners were interviewed, a 61% interview rate. The majority of the producers initially identified who were not interviewed were deceased or could not be located. Among the conservation practices adopted by respondents, 35% were structural (e.g., fences, waste storage, sprinklers), 47% were management (e.g., irrigation, nutrient management, waste utilization), 16% were planting (e.g., grasses, filter strips, trees), and 2% were clearing (e.g., clearing and snagging, land clearing).

Survey results indicated that not all practices were fully implemented—75% of management conservation practices, 13% of planting conservation practices, and 4% of structural conservation practices were not fully implemented, even though the producers thought they were doing a very good job. Reasons cited for not fully implementing practices ranged from did not remember (46%), to ignored full implementation (15%), to practice failed (9%). Overall, the survey results revealed the following:

- 27% fully implemented all contractual practices
- 39% fully implemented 75% to 99% of the contractual practices
- 22% fully implemented 59% to 74% of contractual practices
- 1% fully implemented less than 50% of contractual practices
- 73% of the producers had at least one practice that was not fully implemented

The survey asked about maintenance of practices. Results indicated the following:

- 61% of management practices were not maintained
- 4% of planting practices were not maintained
- 35% of structural practices were not maintained

Reasons for discontinuation of practices included that the practice was designed to be temporary, the practice was undone by natural events, new structures replaced old structure, the producer no longer wanted to follow the management practices, or the farm system changed.

Overall, management practices had lower rates of maintenance than did structural or planting practices. Both USDA NRCS staff and key informants confirmed that cost share was the biggest factor in practice adoption in the Little Bear River Watershed. Without the cost share, producers would not have had financial resources to implement the conservation practices. Utility in farm operation was a more important factor in adoption than was water quality or other environmental concerns. Implementation occurred because the USDA NRCS had a program in place, not because attitudes or behaviors changed in major ways.

Outreach

One objective of the HUA Program was to educate the community and public. Consequently, the HUA Project conducted an extensive outreach effort from 1992 through 1997 to six target audiences: landowners, general public, public schools, civic groups, Utah State University personnel, and others. Utah State University Water Quality Extension personnel made over 100 visits per year to the watershed. Extension used newsletters, field trips, workshops, seminars, and visits to landowners to reach watershed residents.

The NIFA–CEAP evaluated the program and found that the three primary reasons producers participated were cost share, desire for the specific project, and/or desire to improve farm operations; thus, the USDA NRCS had the greatest effect on producer participation. For the most part, farmers did not influence each other, and 60% did not attend field days. Demonstrations seemed to have had no effect on participation. Producers did understand that there was a water quality problem and that the program was trying to improve water quality.

Outreach in the NIFA–CEAP was aimed at two different target audiences. One audience was composed of watershed managers and coordinators, agency personnel, decision makers, and county extension agents who need current information on how best to prioritize spending on implementations and how best to monitor the effectiveness of these efforts. To this end, outreach targeted this audience in the following ways:

- The NIFA–CEAP staff developed two-page fact sheets of the project findings and the implications of these for monitoring programs, expectations of watershed-level response to implementation, and TMDL targets.
- Detailed training opportunities were presented in the form of workshops, and a detailed training manual designed to transfer lessons learned from this and other NIFA–CEAP watershed studies to watershed managers and agency personnel concerning alternative water quality monitoring approaches, realistic expectations of the effectiveness of implementation, expected time lags, and how to deal with natural variability. A final version of a guide to designing water quality monitoring programs was completed and published in late 2010 by Nancy Mesner and was coauthored by water quality program coordinators from other USEPA Region 8 states.
- The outcomes of the Utah NIFA–CEAP and all fact sheets have been made available on Utah State University Extension's Web site (http://extension.usu.edu) and are linked to other relevant Web sites in the state.
- Real-time data on water quality monitoring conditions are available online at http://littlebearriver.usu.edu.

A second audience included producers in this and other watersheds who have or who may implement agricultural conservation practices on their properties. Information transferred to this audience included lessons learned about the effectiveness and necessity of correct operation and maintenance of these conservation practices. The NIFA–CEAP team presented their work to various local and state audiences, including high-profile presentations to the leadership teams at the Utah Department of Agriculture and the Utah Department of Environmental Quality. These presentations led to extensive informal conversations about possible programmatic changes to improve the effectiveness of nonpoint source water quality programs in the state and a recently awarded contract to the Utah NIFA–CEAP team to extend their work as part of an evaluation of Utah's nonpoint source watershed conservation programs.

Other Observations

The Little Bear River Watershed NIFA–CEAP staff offered a number of important observations concerning their project:

- Land treatment success in the Little Bear River Watershed was based on cooperative relationships, not on a heavy-handed regulatory approach. Success in the watershed has led to greater acceptance of land treatment watershed projects elsewhere in the Cache Valley of Utah.
- The USDA NRCS and other agencies involved in implementation of conservation practices need to follow up on land treatments after the contract period to ensure that conservation practices are completely installed and maintained.
- The water quality database that looked robust when the NIFA–CEAP was conceived was inadequate to evaluate the effects of conservation practices on water quality. Monitoring must be designed specifically to answer the questions that are being asked.
- There is a lag time in water quality response to land treatment; degraded land (especially riparian zones) takes a long time to heal.
- The Little Bear River USDA HUA Project represented a kick-off for watershed and water quality programs in the state of Utah. Landowners, scientists, managers, and other stakeholders need to be able to continue the conversation about agriculture, environment, water quality, and conservation practices after this—or any other—project is officially completed.

Little Bear River Watershed National Institute of Food and Agriculture–Conservation Effects Assessment Project Publications

This project's results have been published in numerous journal articles and other publications and have been presented at many conferences. The complete list is provided below.

Publications

Horsburgh, J.S., A. Spackman Jones, D.K. Stevens, D.G. Tarboton, and N.O. Mesner. 2010. A study of high frequency water quality observations in the Little Bear River Utah, USA. Environmental Modelling & Software 25:1031-1044.

Horsburgh, J.S., A. Spackman Jones, D.G. Tarboton, D.K. Stevens, and N.O. Mesner. 2009. A sensor network for high frequency estimation of water quality constituent fluxes using surrogates. Environmental Modelling & Software 25:1031-1044, doi:10.1016/j.envsoft.2009.10.012.

Jackson-Smith, D., E. de la Hoz, M. Halling, J. McEvoy, and J. Horsburgh. 2010. Measuring conservation program BMP implementation and maintenance at the watershed scale. Journal of Soil and Water Conservation 65(6):363-373, doi:10.2489/jswc65.6.413.

Jackson-Smith, D., and J. McEvoy. 2011. Assessing the long-term impacts of water quality outreach and education efforts on landowners in the Little Bear River Watershed in northern Utah. Journal of Agricultural Education and Extension 17(4):341-354.

Spackman Jones, A., D.K. Stevens, J.S. Horsburgh, and N.O. Mesner. 2011. Surrogate measures for providing high frequency estimates of total suspended solids and total phosphorus concentrations. Journal of the American Water Resources Association 47:239-253, doi:10.1111/j.1752-1688.2010.00505.x.

Presentations

De la Hoz, E., and D. Jackson-Smith. 2008. Assessing the spatial distribution of conservation practices implemented along a northern Utah watershed: Did practices target critical areas? USDA National Water Quality Conference, Reno, NV, February 4-7, 2008.

Halling, M., and D. Jackson-Smith. 2006. Questioning the "nature" of biophysical processes: Evidence from the irrigated west. Junior-author of paper presented at the Annual Meetings of the Rural Sociological Society, Louisville, KY, August 10-13, 2006.

Horsburgh, J.S., and D. Stevens. 2006. Integrating historical and real-time monitoring data into an Internet-based watershed information system for the Bear River Basin. National Water Quality Monitoring Association, Bi-Annual Conference, San Jose, CA, May 12-16, 2006.

Horsburgh, J.S., D. Stevens, D.L. Sorensen, N. Mesner, D. Jackson-Smith, and R. Ryel. 2006. A real-time water quality monitoring network for investigating the strengths and weaknesses of existing monitoring techniques. Little Bear River Basin. 2006 Annual Conference, Water Environment Association of Utah, St. George, UT, March 2006.

Horsburgh, J.S., D.K. Stevens, D.G. Tarboton, N.O. Mesner, and A. Spackman Jones. 2008. Sensors, cyberinfrastructure, and examination of hydrologic and hydrochemical response in the Little Bear River Observatory Test Bed. Abstract H43K-04. Eos, Transactions, American Geophysical Union 89(53), Fall Meeting Supplement.

Jackson-Smith, D. 2006. Understanding human dimensions of hydrologic systems as a scientific project. 2006. 12th International Symposium on Society and Resource Management, Vancouver, BC (Canada), June 4-8, 2006.

Jackson-Smith, D., M. Halling, L. Belton, E. de la Hoz, N. Messner, and D. Stevens. 2007. Integrating social science methods into an assessment of conservation programs. USDA Cooperative State Research, Education, and Extension Service National Water Conference, Savannah, GA, January 28-February 1, 2007.

Jackson-Smith, D., E. de la Hoz, M. Halling, and J. McEvoy. 2007. Implementation and maintenance of water quality BMPs: A sociological study of cooperator behavior in the Little Bear River Watershed. Bear River Symposium, Utah State University, Logan, UT, September 6, 2007.

Jackson-Smith, D., N. Mesner, and D. Stevens. 2010. Little Bear River NIFA–CEAP Project highlights. Invited presentation to Utah Department of Agriculture and Foods and Utah Division of Water Quality, May 17, 2010.

Jackson-Smith, D., N. Mesner, D. Stevens, J. Horsburgh, and D. Sorensen. 2010. The effectiveness of conservation efforts in the Little Bear River Watershed. 2010. Utah Nonpoint Source Conference, Richfield, UT, September 2010.

McEvoy, J., and D. Jackson-Smith. 2008. Assessing the long term impacts of water quality outreach and education efforts on landowners. USDA National Water Quality Conference, Reno, NV, February 4-7, 2008.

Mesner, N., and G. Paige. 2010. Approaches and tools for effective water quality monitoring programs: Focus on BMP assessment for stream systems. Invited presentation: USDA NIFA Land Grant and Sea Grant National Water Quality Conference, Hilton Head, SC, February 21-25, 2010.

Mesner, N., G. Paige, D. Stevens, J. Horsburgh, D. Jackson-Smith, D. Sorensen, and R. Ryel. 2008. Designing monitoring programs to evaluate BMP effectiveness. USDA Cooperative State Research, Education, and Extension Service National Water Conference. Reno, NV, February 2008.

Mesner, N., G. Paige, and A. Walker. 2008. Designing monitoring programs to evaluate BMP effectiveness. Utah Nonpoint Conference, Cedar City, UT, September 17, 2008.

Mesner, N., R. Ryel, D. Stevens, J. Horsburgh, C. Allen, and D. Sorenson. 2007. Monitoring for BMP Effectiveness. Bear River Symposium and Annual Utah NPS Conference, Logan, UT, September 2007.

Mesner, N.O., J.S. Horsburgh, D. Jackson-Smith, R. Ryel, D.L. Sorensen, and D. Stevens. 2007. Strengths and weaknesses of water quality monitoring techniques in the Little Bear River

Basin. USDA Cooperative State Research, Education, and Extension Service National Water Conference, Savannah, GA, February 2007.

Mesner, N.O., J.S. Horsburgh, D.K. Stevens, D.L. Sorenson, R. Ryel, and D. Jackson-Smith. 2007. Comparison of water quality monitoring techniques: Detecting change in a variable environment. Presented at the Bear River Symposium, Utah State University, Logan, UT, September 5-7, 2007.

Sorensen, D., N. Mesner, D. Stevens, J. Horsburgh, R. Ryel, and D. Jackson-Smith. 2007. Monitoring lessons learned from conservation effectiveness project on the Little Bear. Spring Runoff Conference, Logan, UT, March 2007.

Spackman, A., D.K. Stevens, D.G. Tarboton, N.O. Mesner, and J.S. Horsburgh. 2007. Surrogate measures for providing high frequency estimates of total suspended solids and phosphorus concentrations in the Little Bear River. Presented at the Bear River Symposium, Utah State University, Logan, UT, September 5-7. 2007.

Spackman Jones, A., J.S. Horsburgh, and N.O. Mesner. 2009. Impact of sampling frequency on annual load estimation of total phosphorus and total suspended solids. Spring Runoff Conference, Utah State University, April 2-3, 2009.

Spackman Jones, A., N. Mesner, J.S. Horsburgh, R. Ryel, and D.K. Stevens. 2009. Impact of sampling frequency on annual load estimation. Presented at the USDA Cooperative State Research, Education, and Extension Service National Water Conference, St. Louis, MO, February 8-12, 2009.

Stevens, D. 2009. Experiences in USDA CSREES proposal writing. USDA Grantsmanship Workshop, Las Vegas, NV, March 9,10. 2009.

Stevens, D., and J.S. Horsburgh. 2006. A real-time water quality monitoring network for investigating the strengths and weaknesses of existing monitoring techniques. National Water Quality Monitoring Assoc, Bi-Annual Conference. San Jose, CA, May 12-16, 2006.

Stevens, D., and J.S. Horsburgh. 2009. Monitoring needs in support of waste load allocation. Invited talk. Western Governors Association - Western States Water Consortium: Water Information Needs & Strategies Symposium.

Stevens, D., J.S. Horsburgh, D.L. Sorensen, N. Mesner, D. Jackson-Smith, R. Ryel, M. Allred, and J. Hardman. 2006. Investigation of the changes in water quality in The Little Bear River Watershed in response to the implementation of best management practices. 2006 Annual Conference, Water Environment Association of Utah, St. George, UT, March 2006.

Stevens, D., and J.S. Horsburgh, D.L. Sorensen, N. Mesner, D. Jackson-Smith, R. Ryel, M. Allred, and J. Hardman. 2006. Investigation of the changes in water quality in the Little Bear River Watershed in response to the implementation of best management practices. Utah State University, Spring Runoff Conference, March 2006.

Stevens, D., J.H. Lee, J.S. Horsburgh, and A. Spackman. 2007. Bayesian network approach to estimating total phosphorus loading in the Little Bear River. Bear River Symposium, Logan UT, September 5-6, 2007.

Stevens, D., N. Mesner, J.S. Horsburgh, A. Spackman, R. Ryel, D. Jackson-Smith, and J.H. Lee. 2008. High frequency monitoring system to assess water quality constituent loading. USDA Cooperative State Research, Education, and Extension Service National Water Conference, Reno, NV, February 2008.

Stevens, D., A. Spackman, D.G. Tarboton, N.O. Mesner, and J.S. Horsburgh. 2007. Surrogate measures for providing high frequency estimates of total suspended solids and phosphorus concentrations in the Little Bear River. INRA Environmental Monitoring Symposium, Boise, ID, October 26-27, 2007.

Stevens, D.K., and J.S. Horsburgh. 2008. Monitoring needs in support of waste load allocation. Western Governors Association/Western States Water Council Water Information Needs & Strategies Symposium, Salt Lake City, UT, November 19-21, 2008.

Theses and Dissertations

De la Hoz, E. Forthcoming. Targeting of Agricultural BMPs to High Risk Landscapes. MS thesis. Utah State University, Logan, UT.

Halling, M. 2007. Factors Influencing BMP Implementation and Maintenance within the Constraints of a Voluntary Participatory Conservation Program: An Analysis of the Little Bear River Project in Logan, Utah. MS thesis. Utah State University, Logan, UT.

Horsburgh, J.S. 2008. Hydrologic Information Systems: Advancing Cyberinfrastructure for Environmental Observatories. PhD dissertation. Utah State University, Logan, UT.

Spackman Jones, A. 2008. Estimating Total Phosphorus and Total Suspended Solids Loads from High Frequency Data. MS thesis. Utah State University, Logan, UT.

Peer-Reviewed Extension Publication

Mesner, N., and G. Paige. 2011. Best Management Practices Monitoring Guide for Stream Systems. University of Wyoming B-213.

Project Web Site

Utah State University Cooperative Extension. CEAP Web Site–Little Bear. http://extension.usu.edu/waterquality/htm/wqlinks/ceap-project-little-bear.

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Project Personnel

All project personnel were affiliated with Utah State University. David Stevens (environmental engineer) was the project investigator. Coproject investigators included Nancy Mesner (limnologist and environmental engineer), Doug Jackson-Smith (sociologist), Darwin Sorensen (environmental microbiologist), and Jeffery Horsburgh (water resources engineer).

References

Spackman Jones, A., N. Mesner, J.S. Horsburgh, R. Ryel, and D.K. Stevens. 2009. Impact of sampling frequency on annual load estimation. Presented at the USDA Cooperative State Research, Education, and Extension Service National Water Conference, St. Louis, MO, February 8-12, 2009.

Spackman Jones, A., D.K. Stevens, J.S. Horsburgh, and N.O. Mesner. 2011. Surrogate measures for providing high frequency estimates of total suspended solids and total phosphorus concentrations. Journal of the American Water Resources Association 47:239-253, doi:10.1111/j.1752-1688.2010.00505.x.

USEPA (United States Environmental Protection Agency). 2011. Clean Water Act Section 303. Water Quality Standards and Implementation Plans. http://water.epa.gov/lawsregs/guidance/303.cfm.