Honey Creek
Watershed Implementation Project
Final Report

FY 2006 §319(h), EPA Grant # C9-996100-13, Project 9, Task 9.5.5
FY 2007 §319(h), EPA Grant # C9-996100-14, Project 5, Task 5.5

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Introduction

The Honey Creek watershed was chosen for an implementation project due to its historic problems with nutrient and bacteria impairments. In 1995, the Clean Lakes Study determined that excess phosphorus in Grand Lake resulted in low dissolved oxygen and algal blooms. Then, in 2000, the USGS study discovered fecal bacteria in both surface and groundwater in the Honey Creek watershed. According to the study, the majority of the fecal bacteria originated from cattle and horses, but human traces were also present. In 2002, Grand Lake and several streams in the Honey Creek watershed (Honey Creek, Cave Springs Branch of Honey Creek, and Whitewater Creek) were placed on the Oklahoma 2002 Integrated Report Category V list of impaired waters for pathogens, low dissolved oxygen, sulfate, TDS, and chloride. In addition to these problems, the 2002 OWRB Beneficial Use Monitoring Program (BUMP) report found that Grand Lake was hypereutrophic during the growing season, as determined by high turbidity and chlorophyll-*a* values.

In October 2006, the Oklahoma Conservation Commission (OCC) began an implementation project in the Honey Creek watershed to reduce nonpoint source (NPS) pollution due to nutrients, sediment, and bacteria by installing best management practices (BMPs) on a voluntary, cost-share basis. The following year, the OCC initiated a second project in the Honey Creek watershed, the Northeastern Oklahoma Demonstration Farm Project. The “demo farm” project’s objective was to showcase all BMPs that were offered through the Honey Creek Project and to maintain records of the effects of these BMPs on the farmer’s bottom line. In addition, this second project included more funding to implement BMPs in the watershed due to high interest from landowners. A third round of funding for BMP implementation in this watershed was obtained in 2011, which will allow landowners to install additional BMPs through 2012. The long-range goals of the Honey Creek Watershed projects are to restore beneficial uses to the waterbodies within the Honey Creek watershed and to prevent future degradation of water quality in Grand Lake.

This report will summarize: 1) the education efforts in the watershed, especially those which were possible through the demonstration farm, 2) the BMPs installed in the watershed so far, 3) the meetings which were necessary for the continuation of watershed activities, and 4) the results of monitoring data, specifically, the amount of pollutant loading and load reductions and the change in land use / land cover achieved through the 319 projects so far.

This project involved the collaboration of numerous agencies and 86 local landowners, with approximately 1.7 million dollars spent in BMP implementation. Data was collected by the Oklahoma Conservation Commission (OCC) from three stream sites using a paired watershed design in order to determine the effects of the implementation project on water quality.

Project Location

The Honey Creek watershed is a subwatershed of Grand Lake O' the Cherokees, one of Oklahoma's premier recreational reservoirs. The majority of the 79,000 acre Honey Creek watershed is located in northeastern Oklahoma (approximately 70%); however, portions of the watershed are located in Arkansas and Missouri (Figure 1). Honey Creek flows from Benton County, Arkansas, and McDonald County, Missouri, into Delaware County in northern Oklahoma. It drains into Grand Lake O' The Cherokees, which is a public water supply for the surrounding communities of Grove, Langley, Afton, Ketchum, and Vinita.

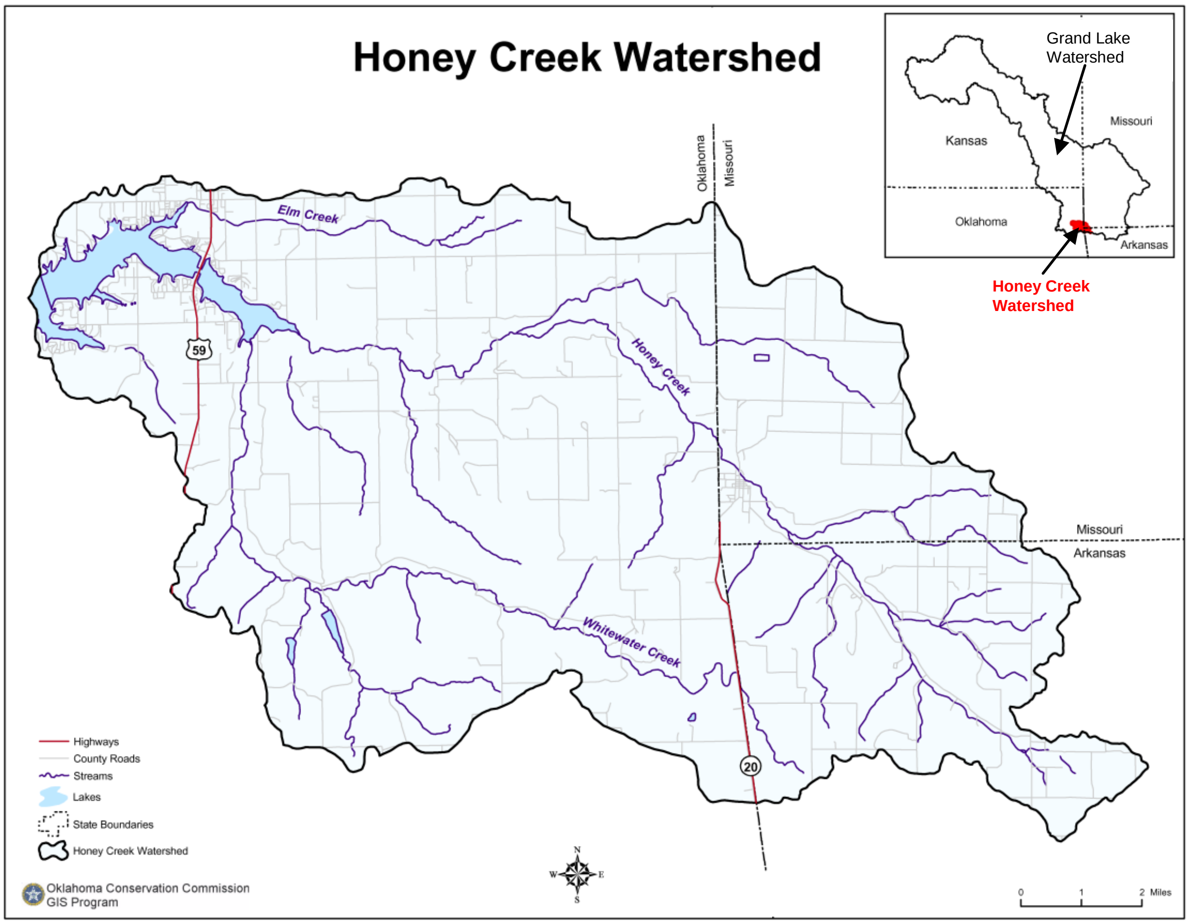


Figure 1. Honey Creek Watershed location.

Honey Creek is located in the Ozark Highlands and Central Irregular Plains Ecoregions in northeastern Oklahoma, southwestern Missouri, and northeastern Arkansas. Landuse in the watershed is primarily pasture (57% of total) and forest (33%), with approximately 7% cropland. As depicted in the land use map (Figure 2), many of the stream miles run through pasturelands, which may lack protected riparian zones. Approximately 70% of stream miles in the watershed in Oklahoma and 78% of miles in the total watershed run through pastureland (Figure 2).

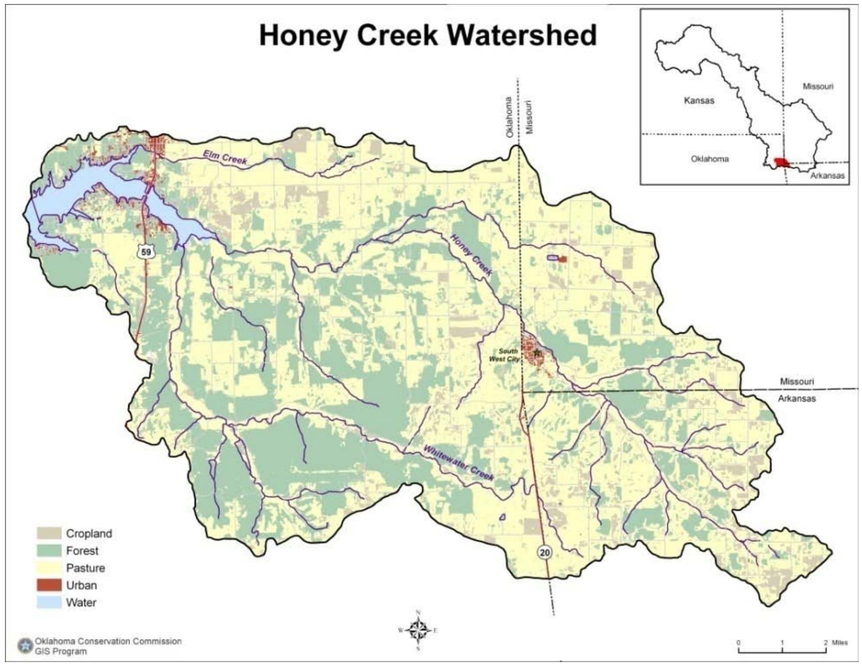


Figure 2. Land use in the Honey Creek Watershed.

The designated beneficial uses for Grand Lake and Honey Creek include public and private water supply (PPWS), fish and wildlife propagation--warm water aquatic community (WWAC), agriculture, primary body contact recreation (PBCR), and aesthetics. In addition, Honey Creek has a “high quality water” (HQW) designation, which indicates water quality that exceeds that necessary to support the propagation of fish and other aquatic life. This designation prohibits any new point source discharge or increased load or concentration from an existing point source which would lower water quality.

Problem Statement

The Honey Creek Watershed is located in a poultry and cattle producing area. As a subwatershed of the Grand Lake Watershed that includes an arm of the lake, Honey Creek is also affected by NPS pollution from residential and development sources. Honey Creek and Grand Lake are of concern because both waterbodies are on the State’s 303(d) list of impaired waters, along with a tributary to Honey Creek (Cave Springs Branch). Grand Lake is on the state’s 2008 303(d) list for low dissolved oxygen values and high turbidity, and Honey Creek is on the 2008 list for bacteria (*Enterococcus*) impairment. Both the lake and the creek have been on the 303(d) list since 2002, and OWRB BUMP monitoring has indicated that Grand Lake is hypereutrophic, as supported by high turbidity and chlorophyll-*a* values during the growing season.

Riparian areas in this region are frequently compromised, either through removal of protective vegetation or through uncontrolled livestock access. The result is streambank erosion, habitat loss, and increased sediment and nutrient transport into streams. The large percentage of pastureland along stream channels suggests that a significant portion of NPS-derived loading of sediment and nutrients originates in the pastureland of the watershed; however, as residential development continues and the population increases around the lake, point sources and development-related pollution will contribute increasingly to the pollution loads in the watershed.

The elevated bacteria levels in the watershed have similarly been attributed to a combination of agricultural activities and residential issues. A 1999-2000 USGS reconnaissance study (Schlottmann et al. 2000) in the Cave Springs Branch watershed of Honey Creek found that bacteria in groundwater and surface water in the basin were from bird, cow, horse, dog, deer, and human sources. Sampling at the state line suggested that much of the bacteria were from cows and horses. Sampling in well water indicated human and dog feces as bacteria sources, suggesting that onsite wastewater treatment (septic tanks) may not always be adequate in the region's highly permeable soils. Also, groundwater sampling for nitrogen suggested nitrogen sources other than Cave Springs Branch, indicating that animal waste, fertilizer, and/or human waste is likely contributing to high levels in groundwater. Surface water sampling suggested that the poultry processing plant on Cave Springs Branch contributes significantly to nitrogen[1] loading in the watershed.

NPS-derived phosphorus loading to Honey Creek can be estimated using the unit area loadings from the Honey Creek area predicted through the 1995 Grand Lake Basin Management Plan report (OCC 1995). These estimates (Table 1) suggest that the highest load to the watershed is from pastureland. These values may underestimate the loading from urban and residential development (primarily in forested areas of the watershed) because significant development has occurred in the watershed since the 1995 report.

Table 1. Sources of NPS Phosphorus Loading to Honey Creek.

	Annual P Load in Oklahoma (kg/yr)	Annual P Load from outside OK	Total Annual P Load to Honey Creek
Cropland	1,144	954	2,098
Pasture	3,106	1,861	4,967
Urban	52	17	69
Forest	1,868	406	2,274
Total	6,170	3,238	9,408
% of Total Load	66%	34%	

A Watershed Based Plan (WBP) has been drafted for the entire Grand Lake Watershed, and a series of Total Maximum Daily Loads (TMDLs) are in the early stages of development, under contract with Tetra Tech through the EPA. The TMDLs and future

[1] The USGS study did not sample for phosphorus; however, additional sampling conducted by the ODEQ suggests that the poultry processing plant also contributes significantly to the phosphorus loading in Cave Springs Branch and Honey Creek.

evolutions of the WBP may further define the water quality problems and identify additional measures needed to achieve water quality improvements in the Honey Creek Watershed. The current Honey Creek projects are focused on the nonpoint source (NPS) water quality problems identified to date, namely, agricultural and residential development activities.

The draft WBP establishes an initial load reduction goal for phosphorus, sediment, and fecal bacteria of 20% within five years, working towards an ultimate goal of an 80% reduction in phosphorus and sediment, and at least a 50% reduction in fecal bacteria. To reach those goals, phosphorus loading in Honey Creek would need to drop to approximately 7,526 kg P/year within five years, and ultimately be only 1,881 kg P/year.

The objectives of this 2007 Honey Creek Watershed project were 1) to establish and maintain a Demonstration Farm to enhance the education and understanding of citizens in the watershed about the benefits of BMPs and 2) to continue and expand the implementation of practices and programs necessary to reduce NPS loading in Honey Creek. Water quality monitoring data is summarized in this report to assess the load reductions due to BMP implementation in the watershed. In addition, examples of photodocumentation of BMPs and GIS evaluation of land use / land cover changes are included in this report.

Program Partners and Management

Considerable efforts have been made to identify the causes, extent, and sources of water quality threats and impairments in the basin, and extensive remedial efforts have been carried out and will continue into the future. The Oklahoma Conservation Commission (OCC), as the state's technical lead nonpoint source agency, managed the project, providing administrative support and technical guidance. A local project coordinator, Marti Mefford, was hired to set cost-share rates and oversee the implementation of best management practices. At the beginning of the 2006 Honey Creek project, citizens representing multiple interests in the watershed were invited to attend a meeting to establish a Watershed Advisory Group (WAG). The Honey Creek WAG convened for the first time on September 26, 2006. The WAG suggested BMPs and cost-share rates for the project and then decided on the prioritization of BMPs, as discussed later in this report. The OCC's board of commissioners had to approve all BMP cost-share rates and helped to oversee all expenditures in the project on a monthly basis. The WAG had a public meeting to encourage sign-up in the program on January 9, 2007.

The OCC worked with local agency partners to educate the residents of the watershed to reduce nonpoint source pollution. The primary partner agencies in the Honey Creek Watershed Project include:

- **Delaware County Conservation District and Natural Resources Conservation Service (NRCS)**
These agencies were critical in ensuring participation of local landowners in water quality improvement programs and in accounting for local cost-share funds. The Delaware County Conservation District and local NRCS offices tracked program progress and promoted local education events and demonstrations. The district, the NRCS, and the project coordinator worked one-on-one with citizens of the watershed to reduce pollution and educate about the importance of protecting water resources. The district and NRCS also organized or participated in seminars, training sessions, and BMP tours to interact with local people and provide technical assistance and information. Use of the NRCS Toolkit and computer programs has been instrumental in the development of maps, plans, and training for OCC personnel. Additionally, members of the conservation district board chaired or served on the WAG committee, assisted in obtaining WAG members, and actively promoted the 319 project.

- **Oklahoma State University Cooperative Extension Service (OCES)**
The OCES worked closely with the Delaware County Conservation District and the NRCS to promote water quality awareness through numerous educational programs in the watershed. OCES provided technical assistance to landowners and assisted at educational events to educate producers about the effectiveness of certain best management practices. The OCES also assisted with youth educational events at the demonstration farm.

- **Oklahoma Department of Wildlife Conservation**—Partnered with OCC on a streambank restoration project in Honey Creek. Hosted two tours of the restoration site.

- **Oklahoma Department of Agriculture, Food and Forestry**—Assisted with educational programs at the demonstration farm.

- **Grand Lake Visitors Center, Greenwood Recycling in Grove, the Grand River Dam Authority (GRDA), Ottawa County CD, Bernice State Park, Lendonwood Gardens, and the Delaware County Master Gardeners**—Partnered to present Earth Day activities.

- **United Keetoowah Band**--Assisted a landowner with his cost-share for a replacement septic tank installation.

Demonstration Farm and Education Activities

Based in part on the results from a watershed model (discussed in a later section) and also on the practices that have been successfully adopted in similar projects, a suite of BMPs were promoted throughout the Honey Creek watershed. One important mechanism for demonstrating BMPs was the establishment of a demonstration farm which allowed viewing of all of the regional BMPs on one property, including cross-fencing and alternative water supplies for rotational grazing, a waste storage/feeding facility, riparian buffer establishment, and heavy use area protection (see Figure 3). The demonstration farm, which was initiated as part of the previous Honey Creek grant, was maintained through the 2007 grant in order to provide a hands-on approach to education about the benefits of the BMPs installed in this watershed.

The owner of this 265 acre farm, Jerry Davis, allowed access to his property for data collection and public tours. Numerous organized tours for students, watershed groups, and landowners have occurred on this farm, in addition to one-on-one informal tours for interested producers.


Jerry Davis (right), owner of Demonstration Farm


Winter Feeding / Waste Storage Facility and Cross-Fencing


Heavy Use Area Protection around Tank


Winter Feeding / Waste Storage Facility


Alternative Water Supply (tank)


Riparian Area Protection (exclusion)


Heavy Use Area Protection

Some of the BMPs installed on the Demonstration Farm

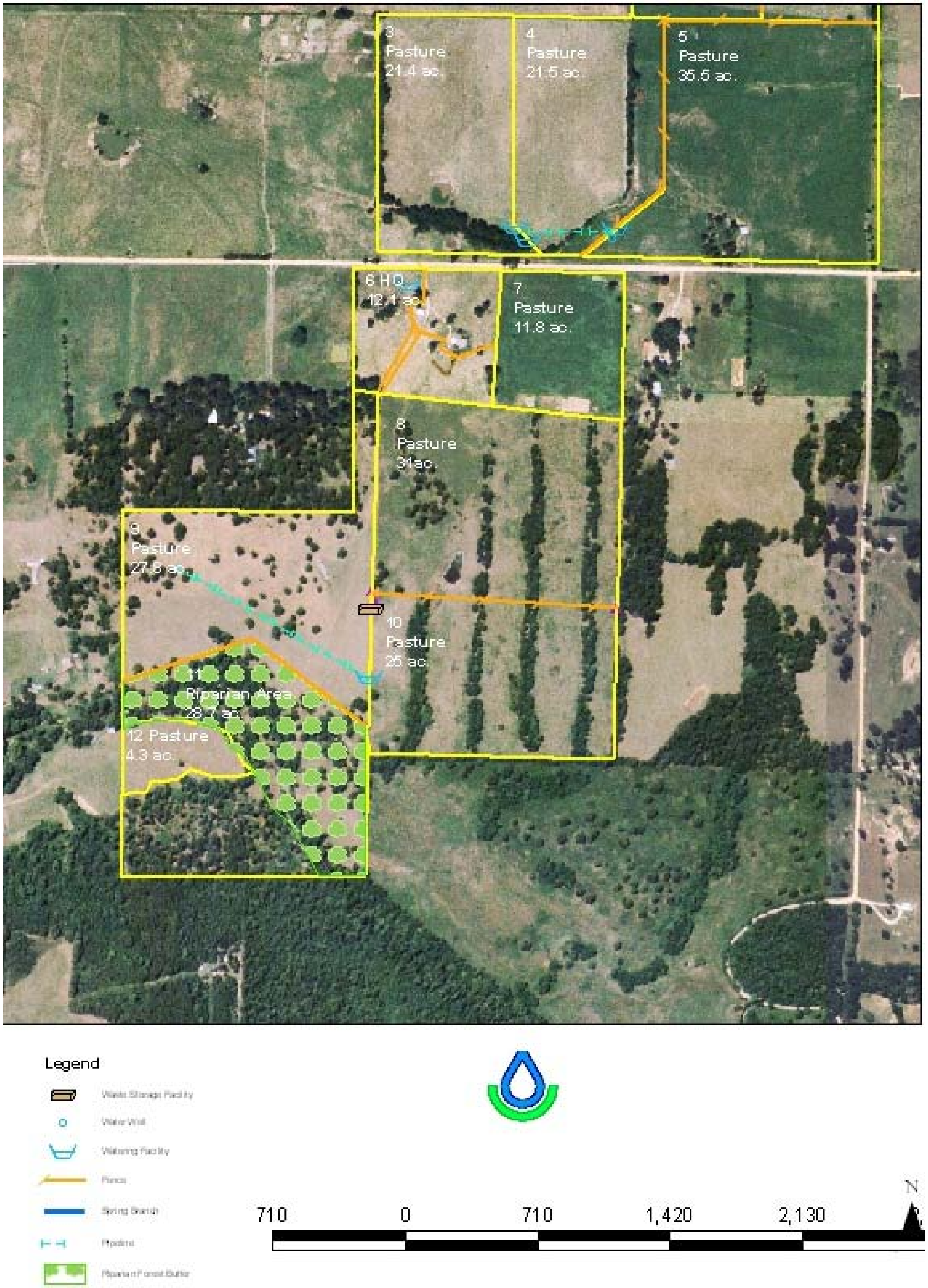
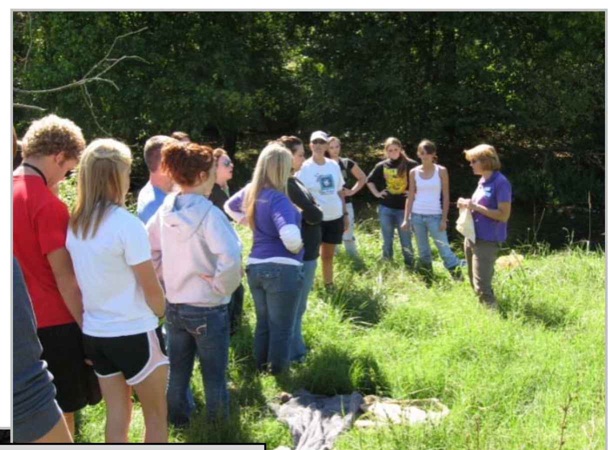


Figure 3. Aerial photo of Honey Creek Demonstration Farm with installed BMPs highlighted.

The agency partners listed previously in this report were instrumental in providing education to a wide audience throughout the project period, both on the demonstration farm and at other locations in the watershed. Some of the events included seminars on waste management, tree planting and pruning, composting, fertilizer usage, and water quality.

Producer Education Events

Youth education was a significant effort pursued by OCC, OCES, NRCS, and the conservation district. Most youth education activities focused on general water quality maintenance and improvement. A youth water camp was offered several times during the project period. The OCC's volunteer stream monitoring program, **Blue Thumb**, provided two trainings in the area over the project period, as well as numerous educational tours at the demonstration farm and natural resource day events.



High School and College Education Events

Table 2 lists the formal events at the demonstration farm, as well as other educational activities associated with the project. Hard copies of flyers and newspaper articles describing each event have been included in the submission of the report to EPA Region 6 and may be viewed upon request to either the OCC Water Quality Division or to EPA Region 6.

Table 2. Summary of Honey Creek educational events held from 2007-2011.

Date	Event	# Attending
10/26-10/27/06	Blue Thumb Training	
04/21/07	Display at "Clear Grand Earth Day" Event	
08/07/07	Display for Public Outreach and Program Availability Meeting	21
08/25/07	Riparian Tour - Berry restoration site	5
09/06/07	Display for Delaware County Fair	
09/11/07	Honey Creek Streambank Restoration Tour for Agencies	28
11/01/07	Farm Demo: Composting, Fertilizer, Water Quality	6
04/19/08	Display at "Clear Grand Earth Day" Event	
04/21/08	Poultry Waste Training with OSU Extension @ Fairgrounds	
06/06-06/07/2008	Blue Thumb Training in Grove	
07/12/08	Tour for the DC Cattlemen's Assoc. and Beefmasters	75
09/06/08	Display at Jay Farm Fest	
11/20/08	Display for Poultry Waste Management Continuing Ed Class	
01/22/09	Presentation and display for Delaware Co. Cattlemen's Assoc.	100
04/05/09	OSU Tulsa Environmental Education Outreach tour	7
04/14/09	Executive Committee of the Grand Lake Watershed Alliance Foundation tour	10
09/29/09	Student tour and open house at demo farm	43
10/15/09	Presentation made to Delaware Co. Cattlemen's Assoc.	86
10/27/09	Cooperator Appreciation Dinner	77
03/04/10 - 03/05/10	Conservation Fair	70 children & 15 adults
03/16/10	Spring Outing at Demo Farm	17 adults & 7 students
03/27/10	OSU-Tulsa Watershed Management Course Tour	10
04/29/10	Presentation and display for Delaware Co. Cattlemen's Assoc.	75
07/03/10	Presentation to Ozark Heartland of America Beefmaster Assoc. and Delaware Co. Cattlemen's Assoc. at Demo Farm	60
07/19/10	Presentation and display to Kiwanis Group in Grove	14
08/23/10	Cooperator interviews	4
09/01/10	Environmental Science Class - Berry stream restoration site	8
11/09/10	Display at Poultry Waste Management Training	76
09/24-09/25/10	Exhibit booth with Blue Thumb at Grove Pelican Festival	100s
09/27/10	Display and Activities at Pelican Festival	100s
09/29/10	Display for the SE Asian Poultry Producers meeting	22
01/25/11	Presentation to the Delaware Co. Commissioners	12
04/19/11	Eastern Shawnee Tribe of Oklahoma tour	3
05/11/11	Earth Day event	
07/14/11	WQ camp for 4-H members	30
07/22/11	Presentation made to Summer Beef Forum	60+
07/09/08 -- 06/30/09	Individual tours hosted by Jerry Davis	8

Summaries of a few of the events, as written for the monthly newsletter, are presented below:

Spring Outing at Demonstration Farm (March 16, 2010)

The Spring Outing was designed to attract a variety of groups—homeowners, ranchers, students on spring break, and landowners with forest land. Attendees included five envirothon students and their teacher from Owasso High School, two envirothon students and their teacher from Memorial High School in Tulsa, and seventeen other adults.

The first presentation, by Bill Berry of Honey Creek Nursery, covered tree planting and pruning. Berry, a cooperator in the 319 project and former Blue Thumb volunteer, demonstrated the correct way to prune hardwoods and fruit trees. He graciously donated a Black Gum and a maple tree to the Demonstration Farm/Davis family as he demonstrated the correct depth and method of planting trees. Berry answered numerous questions from participants throughout his presentation.

Page Belcher, OK Forestry Services, discussed forestry management, agroforestry, prescribed burning, forest pests, and problem pests heading toward Oklahoma from other states. Then, Cheryl Cheadle and Jean Lemmon (Blue Thumb) were assisted by the teachers and students as they studied the fish, bugs, and instream habitat of the stream at the demo farm, Cave Springs Branch of Honey Creek. The students enjoyed learning about the abundance of aquatic life found. While seining, the students found darters, a central stone roller, and a madtom. Macroinvertebrates collected from the kicknet included caddisflies, craneflies, stoneflies, mayfly nymphs, a few crayfish, and a salamander.

Beefmaster/Delaware County Cattlemen's Association Meeting (July 3, 2010)

Jerry Davis hosted a joint meeting of the Ozark Heartland of America Beefmaster Association and the Delaware County Cattlemen's Association at the D&D Ranch. Approximately 60 visitors from a four-state area attended. Some participants took their cattle for a rib-eye ultrasound procedure and for cattle judging. Dr. Tommy Perkins provided information for Beefmaster breeders on updates and plans for their association.

Beef Cattle Forum (July 22, 2011)
A Summer Beef Forum took place at the Demonstration Farm. After a cookout with lots of homemade ice cream, OSU and Conservation personnel made presentations. Programs available through NRCS, the three priority 319 watershed programs in the area, and the Conservation District were explained by Marti Mefford, Honey Creek Project Coordinator. Other presenters for the program were Dr. Bob Kropp, OSU Nutritionist; Dr. Dave Sparks, OSU District Veterinarian; Doug McKinney, OSU Beef Cattle Value Enhancement Specialist; and Jeff Jaronek, Oklahoma Beef Council Director of Industry Relations. Over 60 people attended the event.

4-H Water Camp (July 14, 2011)
4-H kids enjoyed an educational and fun-filled day on Cave Springs. They tested the water quality using handmade secchi dishes. An Enviroscape© model was used by Marti Mefford to demonstrate the effects of everyday activities on our watersheds. Kids and adults greatly enjoyed seining and fish / macroinvertebrate identification led by Cheryl Cheadle, Blue Thumb Coordinator. In addition to 20 4-H kids, 9 OSU and OCC employees, landowner Jerry Davis and Susan Hylton with The Tulsa World attended the event.

As shown in Table 2, many people were given information about the Honey Creek Project and participated in hands-on activities. Newspaper ads were published to encourage participation in many of the events listed, and public service announcements were occasionally run on a local radio station about the Honey Creek project. In addition to holding educational events, the project coordinator cooperated with the Delaware County Conservation District to put articles in a monthly newsletter which was distributed throughout the county and other surrounding areas. The Delaware County newsletter was changed from monthly to bimonthly in 2011. Copies of all newsletters have been submitted to EPA Region 6 with this report and can be viewed upon request to either EPA or OCC Water Quality Division.

Youth Education

Targeting NPS Pollution

As part of an earlier Honey Creek Watershed project, a Soil and Water Assessment Tool (SWAT) model was used to target regions in the watershed most likely to contribute phosphorus via nonpoint source mechanisms in the Oklahoma portion of the watershed. Targeting was completed and maps were generated to determine the prioritization of ranking implementation projects. Figure 4, below, indicates the areas contributing the greatest phosphorus loading in the watershed. Red areas contribute 35-40% of the total phosphorus load, dark orange areas provide an additional 5-10% of the phosphorus load, and light orange areas supply another 5% of the total load. Specifics of the SWAT modeling are found in a report by AMEC (AMEC 2007).

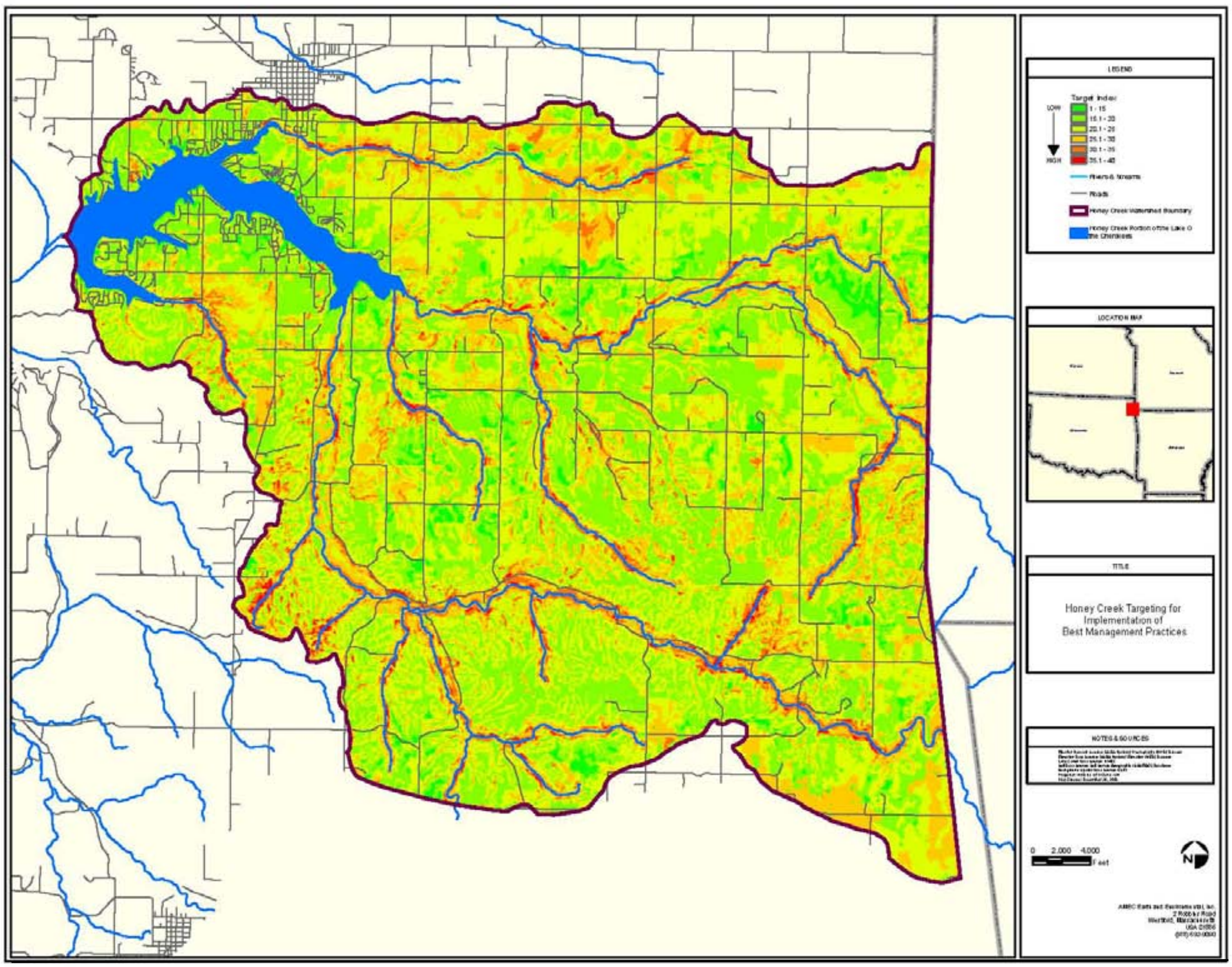


Figure 4. SWAT model targeting map showing areas in the Honey Creek Watershed most likely to contribute high phosphorus loads.

Those individuals desiring to participate in the program received a preliminary site visit from the Honey Creek Project coordinator. The coordinator determined the extent to which the particular landowner contributes to the water quality problems in the watershed and assigned a ranking index based on the practices that would need to be implemented, the cost for implementation, and the expected impact on water quality improvement. This prioritization ranking process allowed the greatest environmental improvements with the project's limited monetary resources. A concerted effort was made to identify the areas that were contributing the larger amounts of nutrients such that the remediation cost per unit mass of pollutant was minimized.

The Priority Ranking System was developed based on the following criteria:

- High, medium and low potential phosphorus loss as identified on the target map;
- Usage of a comprehensive Nutrient Management Plan;
- Distance from a confined livestock facility to a USGS blue line stream or other water body;
- Topography between a confined livestock facility to a USGS blue line stream or other water body;
- Development of filter strips;
- Percentage of grazing lands planned for prescribed grazing;
- Improvement of grazing distribution;
- Number of pastures to be utilized for rotational grazing; and,
- Replacement of existing septic systems.

Figure 5, below, is the worksheet that was developed and used to rank the participants of the implementation project. Individuals were given priority in BMP sign-up based on their resulting rank.

HONEY CREEK 319 NON-POINT PRIORITY WATERSHED
PRIORITY RANKING SYSTEM 2006

Producer: ____________________ Total Acres:

Legal: Section ______ Township _____ Range ______ **Total Points:**

Water Quality- High Potential Phosphorus Loss on Targeted Riparian Area and Grazing Lands (Maximum Total: 100 pts)	
Poor Condition Pastures as identified on Target Maps (20 pts)	
High Potential Phosphorus Loss areas identified on Target Maps (20 pts)	
Medium Potential Phosphorus Loss areas identified on Target Maps (15 pts)	
Low Potential Phosphorus Loss areas identified on Target Maps (10 pts)	
Land offered will apply a Comprehensive Nutrient Management Plan if applying poultry litter according to an animal waste management plan. (20 pts)	
Distance from confined livestock facility to USGS Blue Line Stream or other water body. Adjacent (15pts) <1/4 mile (10pts) 1/4-1/2 mile (5pts) >1/2 mile (0pts)	
General topography between confined livestock facility and USGS Blue line or Water Body. >8% slope (10pts) 3% - 8% slope (5pts) 0% - 3% slope (0pts)	
319 Project application will develop filter strips for the entire length of land that is adjacent to streams and lakes in offered land units (15pts)	

Plant Condition- Productivity, Health and Vigor (Maximum Total: 20 pts)	
Offer includes implementation of Prescribed Grazing (528A) system that balances forage production with livestock numbers for the period of the contract.	
% of the grazing lands in the operating unit planned for implementation of Prescribed Grazing according to the (528A) standard during the contract period. 100% (10pts) 50%-99% (5pts) <49% (0pts)	
Practice(s) will facilitate improved grazing distribution. (382, 614, 642, 378) (5pts)	
Grazing system rotates through 3 or more pastures per grazing season. 3-5 (1pts) 6/7 (3pts) 8 or more (5pts)	

Rural Waste On-site Disposal Systems - Rural Septic System Concerns (Total: 100 pts)	
Offer includes replacement of existing septic system by installation of 1,000 gallon tank, lateral lines, percolation test, and DEQ permit (100pts)	
Total Evaluation Points:	

This form will be used to determine priorities for planning and fund distribution. The applicants with the highest number of points, as determined by the planner, will be the first priority for planning and fund allocation.

Figure 5. Worksheet used to rank participants in the Honey Creek Implementation Project.

Implementation of Best Management Practices

To facilitate the demonstration of BMPs throughout the watershed, the OCC partnered with the Delaware County Conservation District and local Natural Resources Conservation Service (NRCS). The OCC employed a local project coordinator, who was responsible for working with the individual landowners to develop conservation plans and agreements to participate in the program, then verifying whether the practices had been implemented and maintained. The specific practices and cost-share rates offered to individual producers through the Honey Creek project were based on the recommendations of the Honey Creek Watershed Advisory Group (WAG). The WAG met for the first time on September 26, 2006 and suggested BMPs and cost-share rates for the project and then decided on the prioritization of BMPs. The OCC's board of commissioners then approved the suggested rates and practices.

All residents of the Honey Creek Watershed were eligible for cost-share assistance regardless of size of land ownership. Using the targeting results discussed above, individuals who lived in a critical area were contacted by the project coordinator and the conservation district and encouraged to participate in the program. The coordinator then developed a conservation plan and assigned a priority rank based on the proximity of their property to streams, whether the property was in the targeted area (Figure 4), and the practices that would be implemented. Landowners with the highest rankings were funded first to ensure that the greatest water quality benefit was derived for each dollar spent.

Planning efforts were coordinated with the NRCS and the Delaware Conservation District to allow leveraging of funds for mutual benefit. For example, the NRCS Environmental Quality Incentives Program (EQIP) provides funding for some practices that the 319 program does not. If a landowner could not participate in the 319 program, they were informed about EQIP possibilities so that both agencies benefited from the relationship and worked toward mutual goals.

The maximum cost-share assistance to any one participant in Honey Creek was $25,000, unless special approval was granted by the Delaware Co. Conservation District Board, and cost share rates were generally set at 75-80%, requiring a 20-25% match from the landowner (see below). The approved list of BMPs to be implemented is shown below. The following practices were offered to landowners in the watershed and were prioritized in this order:

	Cost-Share Practices		Cost-Share Rate
Priority #1	**Riparian Area Establishment and Management**		
	Components:	(1) Incentive payments	100%
		(2) Off-site watering	80%
Priority #2	**Buffer Strip Establishment and Streambank Protection**		
	Components:	(1) Incentive payments	100%
		(2) Fencing	90%

		(3) Vegetative planting	80%
		(4) Critical area improvements	80%
		(5) Special BMPs, as determined by OCC representatives	
Priority #3	**Animal Waste**		
	Components:	(1) Composter	75%
		(2) Composter with dry waste storage	75%
		(3) Cake out storage	75%
		(4) Full clean out storage	75%
		(5) Waste storage/animal feeding structure	60%
Priority #4	**Pasture Establishment and Management**		
	Components:	(1) Vegetative establishment	80%
		(2) Cross fencing	80%
		(3) Watering facilities	80%
Priority #5	**Proper Waste Utilization (Poultry Waste Producers) Incentive Payments for Proper Utilization**		
	Components:	(1) Poultry waste used on producer's farm	6¢/lb P
		(2) Poultry waste off farm but in the Honey Creek Watershed	8¢/lb P
		(3) Poultry waste moved out of the Honey Creek Watershed into a non-phosphorus threatened or NLW watershed (cannot be moved into Eucha/Spavinaw, Grand Lake, Wister, or Illinois Watersheds)	15¢/lb P
Priority #6	**Heavy Use Areas**		
	Components:	(1) Concrete pads	75%
		(2) Gravel	75%
		(3) Geotextile fabric	75%
		(4) Grading and shaping	75%
		(5) Terracells	75%
Priority #7	**Rural Waste Septic Systems (Human Waste)**		
	Components:	(1) Septic systems with tank; pump out (when needed); installation; percolation test; lateral lines	80%
		(2) Soil profiling	90%

Eighty-six landowners installed BMPs through the Honey Creek Watershed project, resulting in **about 49% of the land in the Oklahoma portion of the watershed having some sort of BMP** (Figure 7). Participants in the program were given signs to place on their property to recognize their participation (photo at left). This also provided an additional way to reach interested landowners.

A total of **$1,686,914** was spent on BMP implementation, of which landowners provided $658,320 (approximately 40% of the total) and the rest was a combination of federal and state funding.

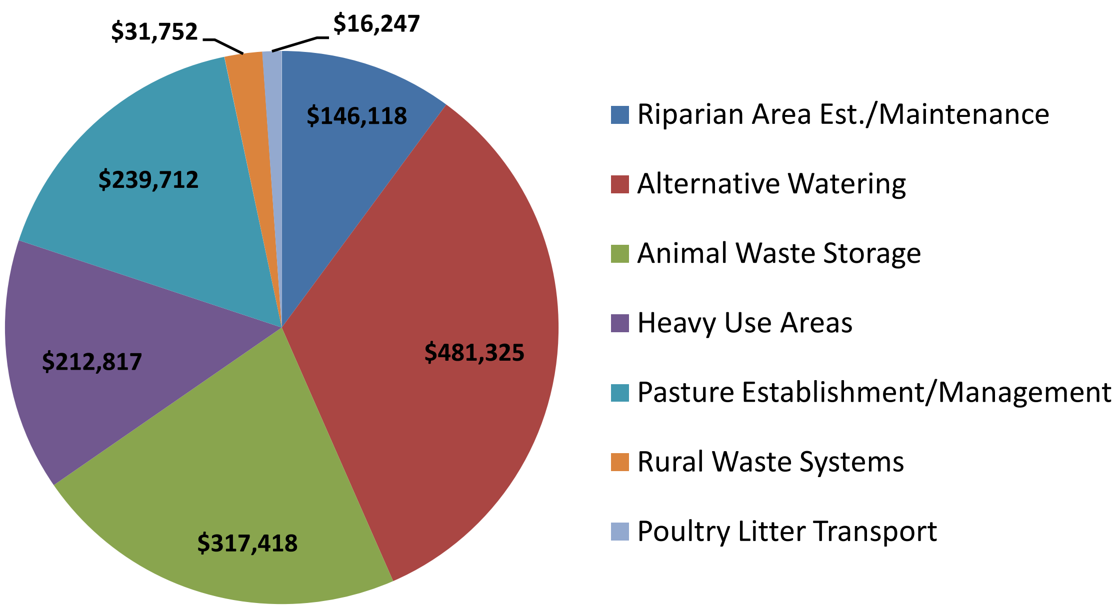


Figure 6. Summary of funds spent on implementation for each BMP category.

As shown in Figure 6, approximately 33% of the funding was to establish alternative water supplies, which includes pond construction, drilling wells, water tanks, solar pumps, and pipeline to convey water to ponds or tanks. Alternative water supplies are an important component of both riparian buffer establishment/maintenance and pasture management. Animal waste management components comprised approximately 22% of the BMP funding and included both cake out storage for poultry waste and winter feeding/waste storage facilities for cattle. The locations of BMP implementation across the watershed are shown in Figure 7.

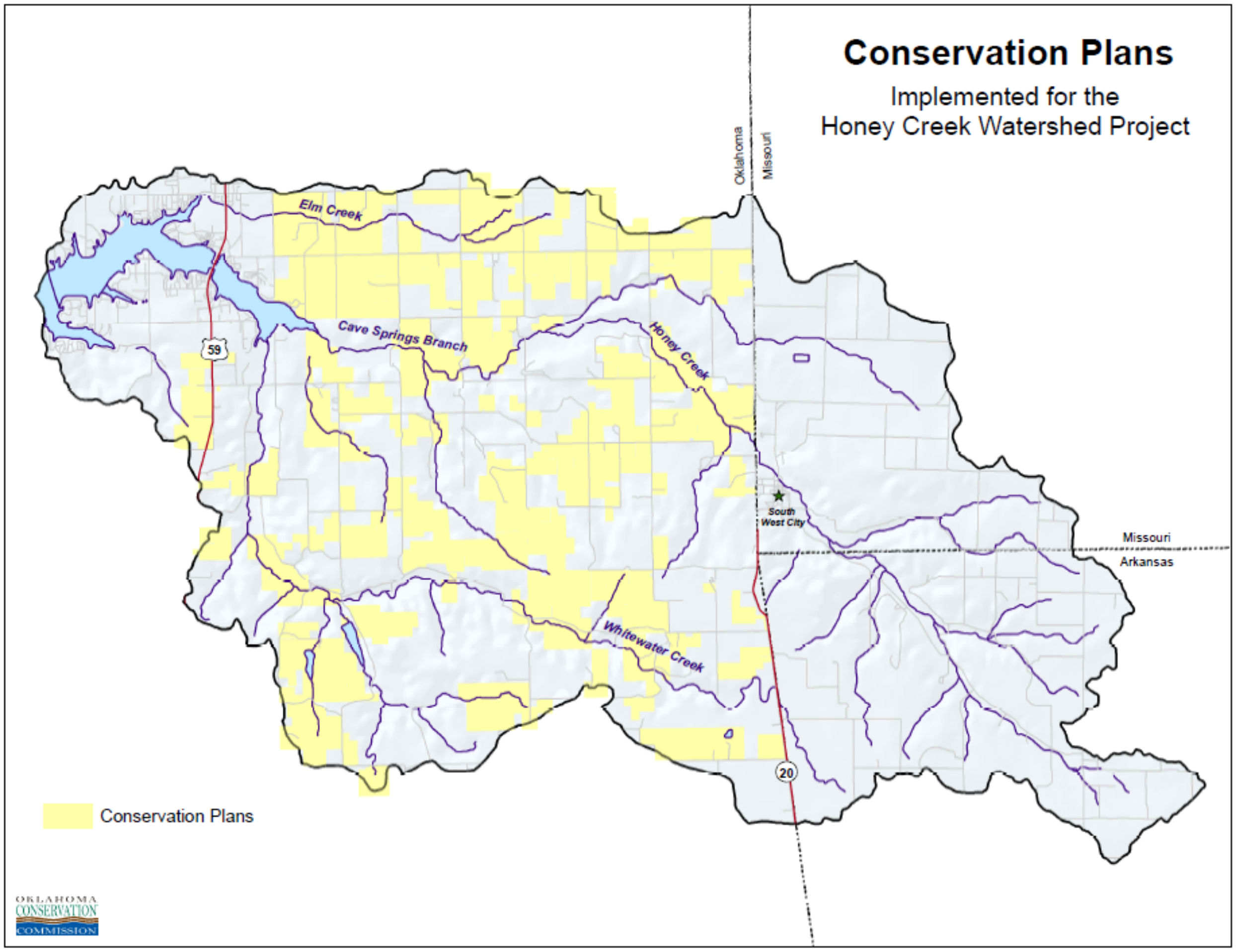


Figure 7. Honey Creek Project Cooperators.

The SWAT model estimated that the top 45-55% of phosphorus loading was coming from 27% (14,760 acres) of the watershed in Oklahoma (Figure 4). Prioritizing BMP implementation using the targeting map produced from SWAT allowed a high percentage of implementation to occur in "hotspot" regions of the watershed. **Forty-two percent of the targeted, high phosphorus yield areas were included in BMP implementation through this project,** as shown in Figure 8.

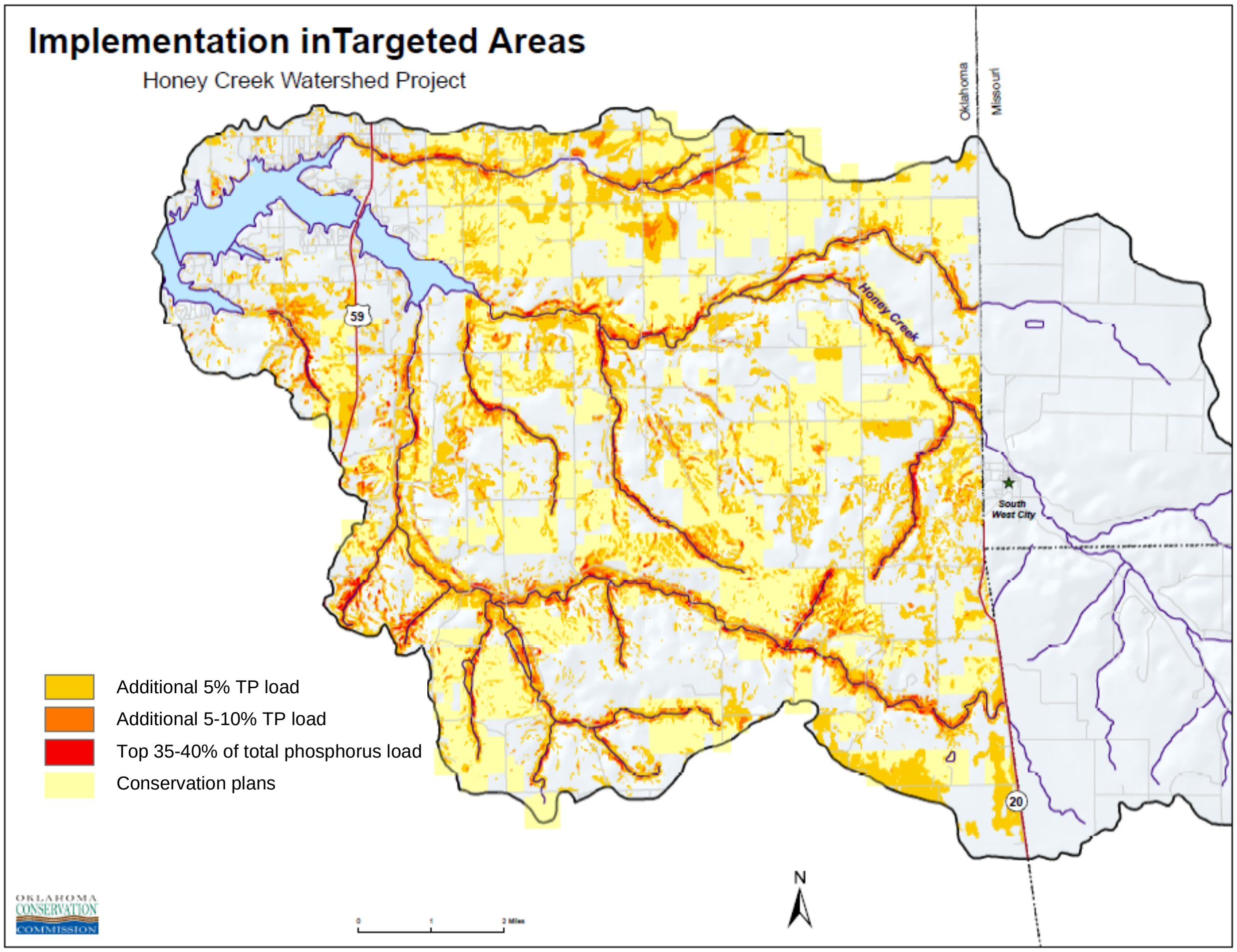


Figure 8. GIS analysis of BMP implementation in relation to high phosphorus load areas. Red areas contribute 35-40% of the total phosphorus (TP) load, dark orange areas provide an additional 5-10% of the load, and light orange areas supply another 5% of the total load.

Riparian Area Establishment and Management

Cultivated fields, pastures, and farmsteads have the potential to contribute large amounts of nutrients and sediment that pollute nearby waterbodies during runoff events. The establishment of vegetated riparian zones and buffer zones / filter strips around these areas helps to reduce the nonpoint source pollution from these sources. The demonstration of the cumulative benefit of comprehensive buffer and riparian management incentives was a top priority. The following practices were implemented in order to reduce the nutrient and sediment load:

1) Fencing for Riparian Management

Landowners look upon the riparian areas as critically needed, highly productive pasture. However, heavily grazed riparian areas function poorly as nutrient traps, and cattle trails become channels for direct transport of nutrients to the stream. Fencing to exclude cattle from a certain area along a stream was recommended to control these problems.

Incentives were offered to establish a buffer of 150 feet, maximum, on each side of the stream (average width). In order to take advantage of existing fences, the buffer widths occasionally varied slightly. Fences were built above the flood prone area elevation to lower maintenance costs.

Landowners were given the option of riparian protection with total livestock exclusion for a $50/acre incentive payment, riparian protection with limited hay production (with haying allowed only in vegetative zone of the buffer and only during a time of the year to allow sufficient regrowth prior to the end of the growing season) for a $45/acre incentive payment, or riparian protection with limited grazing for a $40/acre incentive payment. Limited grazing or flash grazing would allow landowners to grant livestock access to the riparian zone for a brief period in summer when streambanks were most stable (due to lack of rain) and with sufficient time for regrowth before the end of the growing season. In addition, during limited grazing, landowners agreed to pull livestock out of the area prior to the point where it became overgrazed.

The acreage that was converted to riparian buffer zones is given in Table 3, below, along with the other riparian protection BMPs. Five landowners (total of 115 acres) used the limited grazing/haying option, while the rest of the riparian area was total exclusion. As shown in the photos below, the riparian area (side of the fence with trees in photos 1 and 2) can be quite wide, and vegetation will quickly grow to the height of the fence or more once cattle are excluded.

Table 3. Riparian buffer establishment/management BMPs implemented.

Best Management Practice	Number of Landowners	Amount	Unit
Riparian area total exclusion	18	300	acres
Riparian area/limited haying/limited grazing	5	115	acres
Riparian fence	18	40,329	feet
Water tanks	4	5	tanks
Pond	2	2	ponds

Photo 1a: March 2010
Photo 1b: August 2011

2) Off Stream Watering

Pastures where the stream is the primary or sole source of water for livestock were provided with an alternate water source to allow riparian management. Studies have shown that off-stream water sources can substantially reduce the impact of cattle even without fencing the stream. Off-stream watering was budgeted only for the perennial sections of the stream because the landowners already had provided water supplies for livestock where the stream does not supply permanent water. Watering options included pond excavation (example photos below) and freeze-proof water tanks (see photos in pasture management section). Table 3, above, indicates the number of alternative water supplies installed through this project to replace stream access.

Pond excavation

New pond

Figure 9 shows the locations of the riparian areas which were protected as well as the alternative water supplies that were established. Two ponds and five water tanks were installed as part of the riparian management practices. In addition, 40,329 feet of fencing was built along riparian areas.

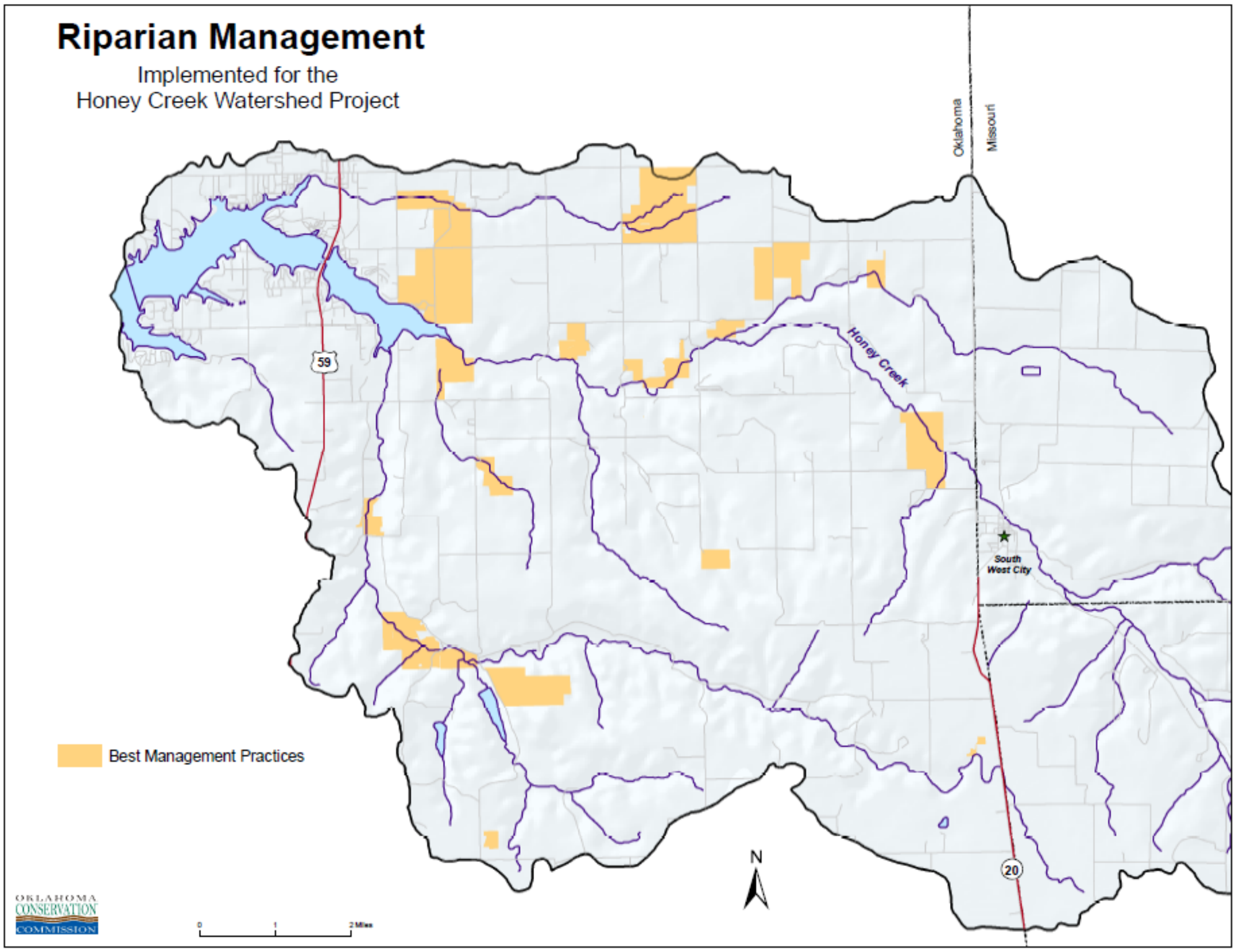


Figure 9. Location of riparian management practices implemented.

Animal Waste Storage

1) Poultry Composters / Cake-out Houses

There are many poultry operations in northeast Oklahoma, including the Honey Creek watershed. Many producers are forced to clean out their poultry houses when weather and soil conditions are not acceptable for application of animal waste as fertilizer. Cost-sharing was used to provide waste storage facilities, example photos to the right, to poultry producers. This enabled the producers to clean out their houses regardless of weather and time of year and store the waste out of the elements until it could be transported off of the farm or applied properly. As Table 4, below, indicates, two producers participated in this BMP.

Table 4. Animal Waste Storage Facilities installed.

Best Management Practice	Number of Landowners	Amount	Unit
Cakeout/litter storage facility	2	2	facilities
Waste storage/animal feeding facility	24	25	facilities

2) Cattle Feeding / Waste Storage Facilities

Cattle feeding / waste storage facilities (example photo below) are structures which are designed to reduce runoff of nutrients, bacteria, and sediment from cattle supplemental feeding areas. Landowners typically overwinter and often feed cattle in the certain areas of a pasture, areas that are chosen because they are easy to get to and provide a reliable source of shelter and water for overwintering stock. This often means they are close to the creek or a ravine or dry channel where shelter from the wind is available, and the running water in the creek generally insures that it does not freeze often. Unfortunately, these areas become trampled, overgrazed, and laden with waste, and, hence, are susceptible to runoff. By providing a sheltered feeding area away from the stream, feeding facilities reduce this problem. The structure has a concrete floor with a lip all around to contain waste. In addition, the back 1/3 of the structure is devoted to dry manure storage, sized sufficiently to store up to 3 months worth of manure until such a time as it can be properly land applied.

Pasture Establishment / Management

Pastures that have been overgrazed or degraded can be improved through the regeneration of a proper stand of grass. Vegetative planting, cross fencing, nutrient management, watering facilities, and heavy use area protection are BMPs which may be utilized on these pastures.

1) Vegetative Plantings

Over-grazed and poorly grassed fields and pastures can be significant sources of erosion in the watershed. Since the phosphorus levels in the soil in this watershed are high, soil entering streams could be contributing to the high phosphorus load in the watershed. Fertilization or lime application on 270 acres of poor pastureland in the watershed allowed for the establishment of better quality and quantity of vegetative cover. As indicated in Table 5, below, approximately 90 acres of Bermuda grass and 56 acres of fescue were planted to create healthy pastures which will reduce the amounts of nutrients and sediment which enter streams due to runoff. Figure 10 shows the locations of pasture BMPs in the watershed, and photos 2 and 3 below show before (a) and after (b) images of pastures where plantings occurred.

Photo 2a: July 2009

Photo 2b: June 2010

Photo 3a: July 2009

Photo 3b: Sept. 2009

2) Cross-Fencing

In order to keep pastures in optimal condition, as seen in photos 2b and 3b above, overgrazing must be avoided. Landowners may use cross-fencing to rotate cattle to various pastures and, thus, prevent overgrazing. Additionally, rotating herds to various fields lessens the bare soil, erodible areas associated with loafing in certain spots of a pasture (as seen in photos 4a and 5a). 235,037 linear feet of fence was erected to allow rotation of livestock

Healthy pasture with cross-fencing, August 2011

across pastures at certain times. The before (a) and after (b) photos below show additional examples of cross-fencing.

Photo 4a: December 2010

Photo 4b: August 2011

Photo 5a: May 2010

Photo 5b: Aug. 2011

Table 5. Pasture establishment/management BMPs implemented.

Best Management Practice	Number of Landowners	Amount	Unit
Cross-fence	59	235,037	feet
Pasture planting (bermuda, fescue)	9	146	acres
Watering facilities and pipeline	59	162	tanks
Ponds	16	22	ponds
Wells	43	54	wells
Lime	4	105	acres
Fertilizer	10	165.7	acres

3) Water Facilities

To successfully cross-fence livestock, water must be available in each pasture. As part of the pasture management BMPs, 162 water tanks (example photos below) and 22 ponds were installed in the watershed. The water for some of these tanks was supplied by new wells.

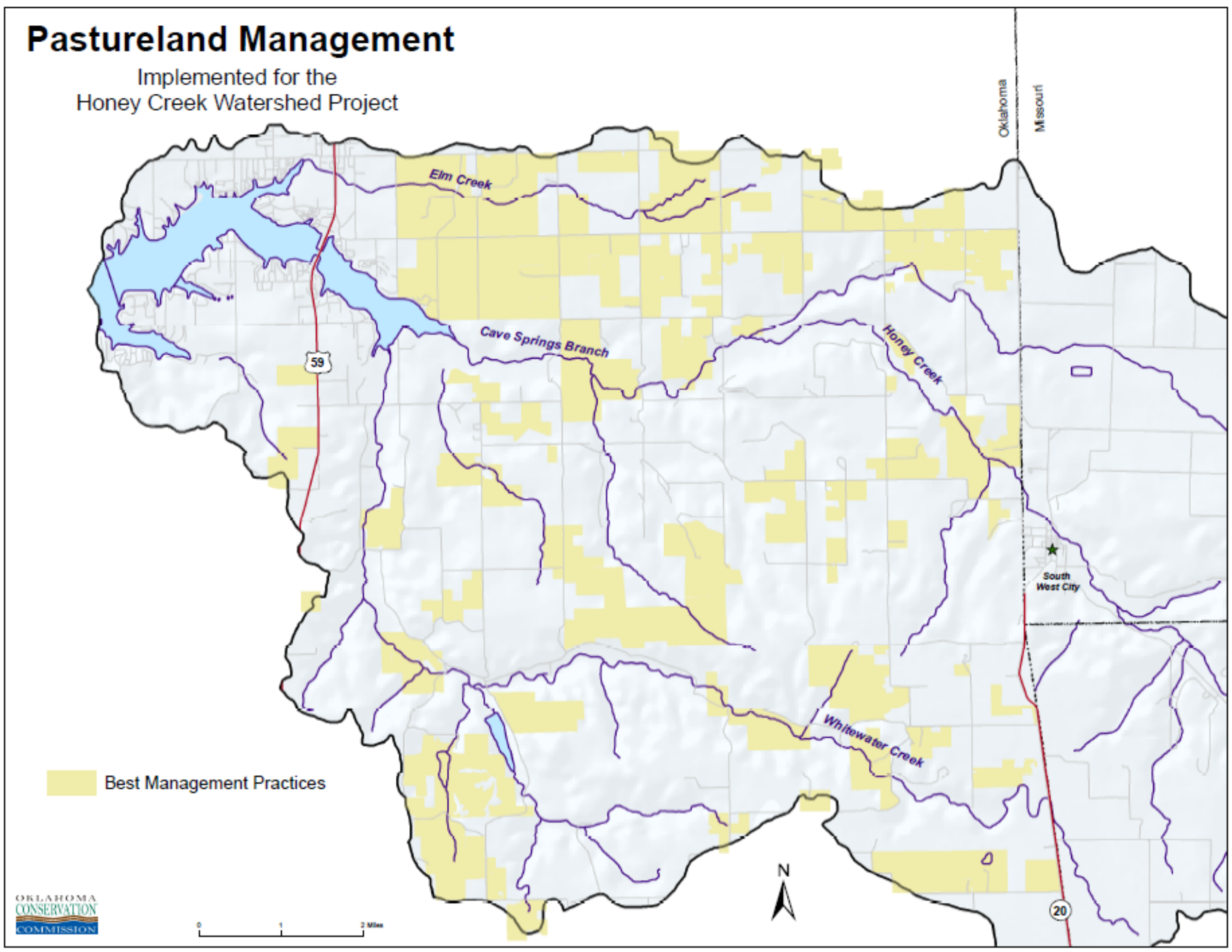


Figure 10. Location of pasture establishment / management BMPs implemented.

Poultry Waste Utilization

There are a large number of poultry farms in northeastern Oklahoma. Periodically, poultry houses must be cleaned out, and the contents of the houses, termed "poultry litter," is often used on adjacent fields as fertilizer. Poultry litter is a mixture of manure and bedding material which is high in phosphorus. The timing of litter application, as well as the amount applied, can have a large impact on water quality in the area. Many of the soils in this part of the state are already very high in nutrients, particularly phosphorus, due to years of litter application. Grasses can only take up and utilize phosphorus to a certain point, and then the phosphorus remains in the soil and continues to build up. Adding additional phosphorus to already saturated soils only contributes to this problem.

To ensure that animal waste is properly applied to fields and to halt the continued increase of phosphorus in soils, participants in the Honey Creek Watershed Project were required to have an animal waste management plan, along with soil and litter analyses. The NRCS has established soil phosphorus values for various regions of the state, and participants were not allowed to apply litter if their soil phosphorus was above this value. One producer had 26,626.76 lbs of his 41,069 lbs of litter moved out of the watershed and was paid a higher rate for removal of that litter. Three other producers in the watershed moved an additional 134,888 lbs of phosphorus off their farms to areas that could utilize it properly but were still in the Honey Creek watershed (in Missouri).

Heavy Use Areas

Erosion-prone heavy use area

Heavy use area protected by concrete, geotextile, and gravel

As large animals, cattle can severely impact areas around feeding or watering facilities where heavy traffic compacts soil and destroys stabilizing vegetative cover, increasing soil erosion from the area. In addition, heavy traffic is usually accompanied by increased waste deposition, which can lead to increased nutrients and bacteria in runoff from these areas. Installation of concrete feeding pads for round hay bale feeding or gravel and grading in loafing areas are modifications that can reduce runoff of soil, nutrients, and bacteria from these heavy use areas. In some instances, only geotextile and gravel are necessary to prevent degradation around feeding/watering areas.

Fifty-eight landowners installed 173 heavy use areas as part of this project. Most areas consisted of a combination of concrete surrounded by geotextile and gravel, but a few opted for the geotextile/gravel area only. Photos 6 - 10 show the improvement in the area around water tanks, feeding troughs, barns, travel lanes, etc. after installation of geotextile and gravel. Similar improvement is observed in other heavy use areas.

Photo 6a: October 2010

Photo 6b: August 2011

Photo 7a: October 2010

Photo 7b: August 2011

Photo 8a: Sept 2008

Photo 8b: June 2009

Photo 9a: Sept 2009

Photo 9b: Oct 2009

Photo 10a: Sept 2009

Photo 10b: Oct 2009

Rural Waste Systems

Rural residents within the Honey Creek watershed may not have septic tanks, or they may be in bad repair. To decrease the amount of residential sewer pollution entering the streams and lakes in the watershed, septic systems were installed by 14 landowners. Figure 11 shows the locations of septic systems installed as well as animal waste BMPs.

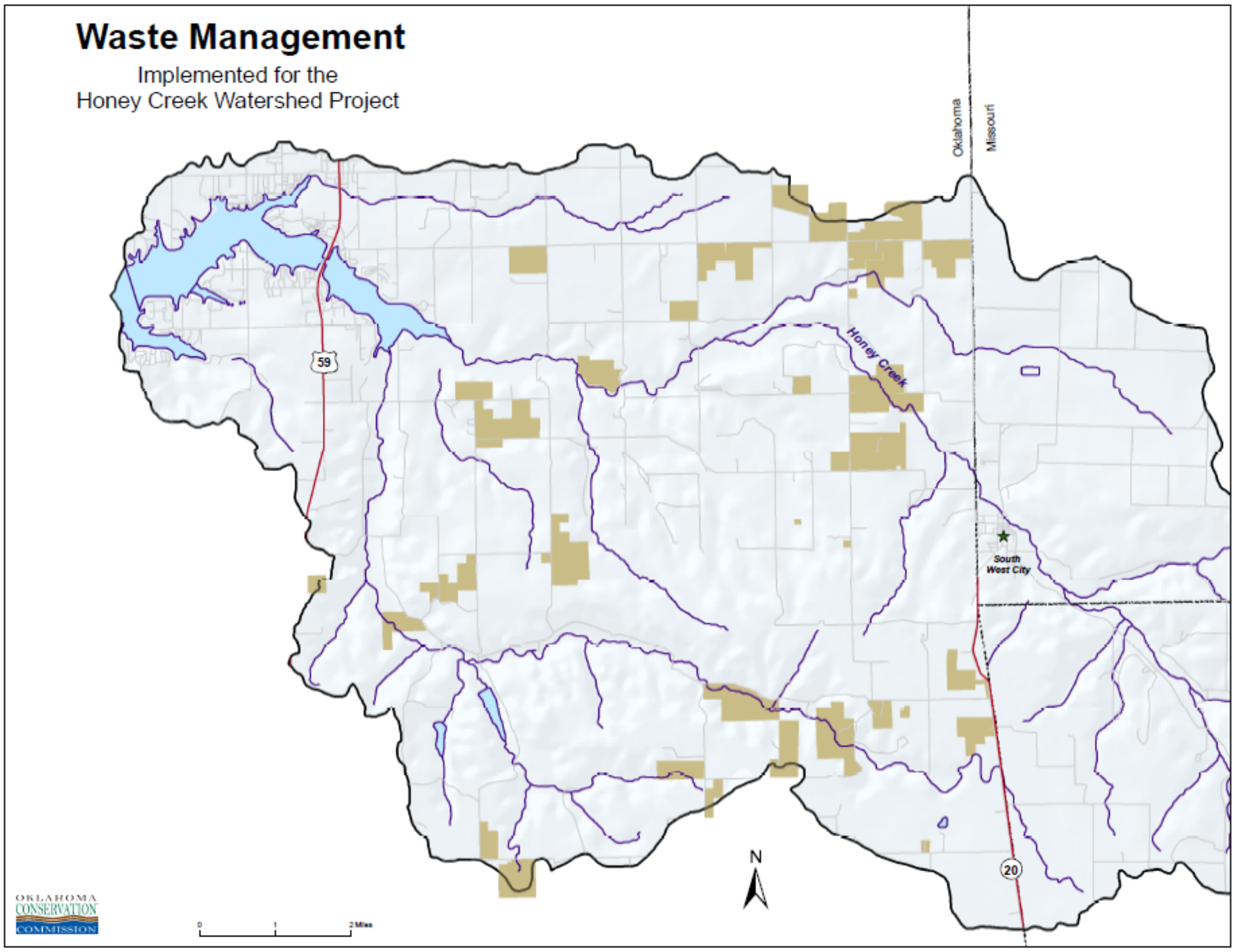


Figure 11. Location of human and animal waste BMPs installed.

Water Quality Assessment

Water quality monitoring is critical to the project for purposes of determining the causes and sources of NPS derived pollution in the watershed and ascertaining whether or not project efforts have had an effect on water quality. A considerable amount of water quality monitoring has occurred since 2007 in the Honey Creek watershed and the Saline Creek control watershed. All monitoring followed the protocols detailed in the project QAPP, with data collected at the locations indicated in Table 6 and Figure 12.

Table 6. OCC monitoring sites.

Site Name	WBID	Latitude	Longitude	County
Honey Creek: Lower	OK121600-03-0445L	36.54783	-94.72053	Delaware
Honey Creek: Upper	OK121600-03-0445Y	36.52689	-94.61970	Delaware
Saline Creek	OK121600-02-0030D	36.28225	-95.09280	Mayes

The Honey Creek Watershed Project was set up using a paired watershed design, developed in accordance with requirements outlined in Clausen and Spooner (1993). This project allowed analysis of two different paired designs: the Honey Upper / Honey Lower pairing is an upstream (control) and downstream (treatment) "paired site" design, while the Saline / Honey Lower comparison is a control / treatment "paired watershed" design. Data is collected over two definable periods of study, calibration (pre-implementation) and treatment (post-implementation).

The control/upstream watershed/site is chosen to account for environmental variability, which may otherwise mask the overall effect of BMPs on NPS pollutant loads in the treatment watershed, over the periods of study. The control watershed must be located near the treatment watershed in order to experience the same weather and seasonally induced changes. The difference in quality of runoff between the control and treatment watersheds is not the issue of concern; rather, it is most important that the relationship between paired observations between the two remains the same through time, except for the effects of the BMPs (EPA 1993). Differences in water quality between the two sites are expected, but it is the predictable response of the two watersheds/sites together that is the foundation of the paired watershed method.

Monitoring was conducted at each site in an identical fashion for both the treatment (Honey Lower) and the control (Honey Upper and Saline) watersheds, and through the calibration and treatment periods, as required in the paired watershed design. A total of three automated samplers were set up (see Figure 9) to obtain continuous, flow-weighted samples from the sites. These samples were collected at least weekly (more often if rain had occurred). If the autosampler had malfunctioned, a grab sample was obtained and submitted to the lab.

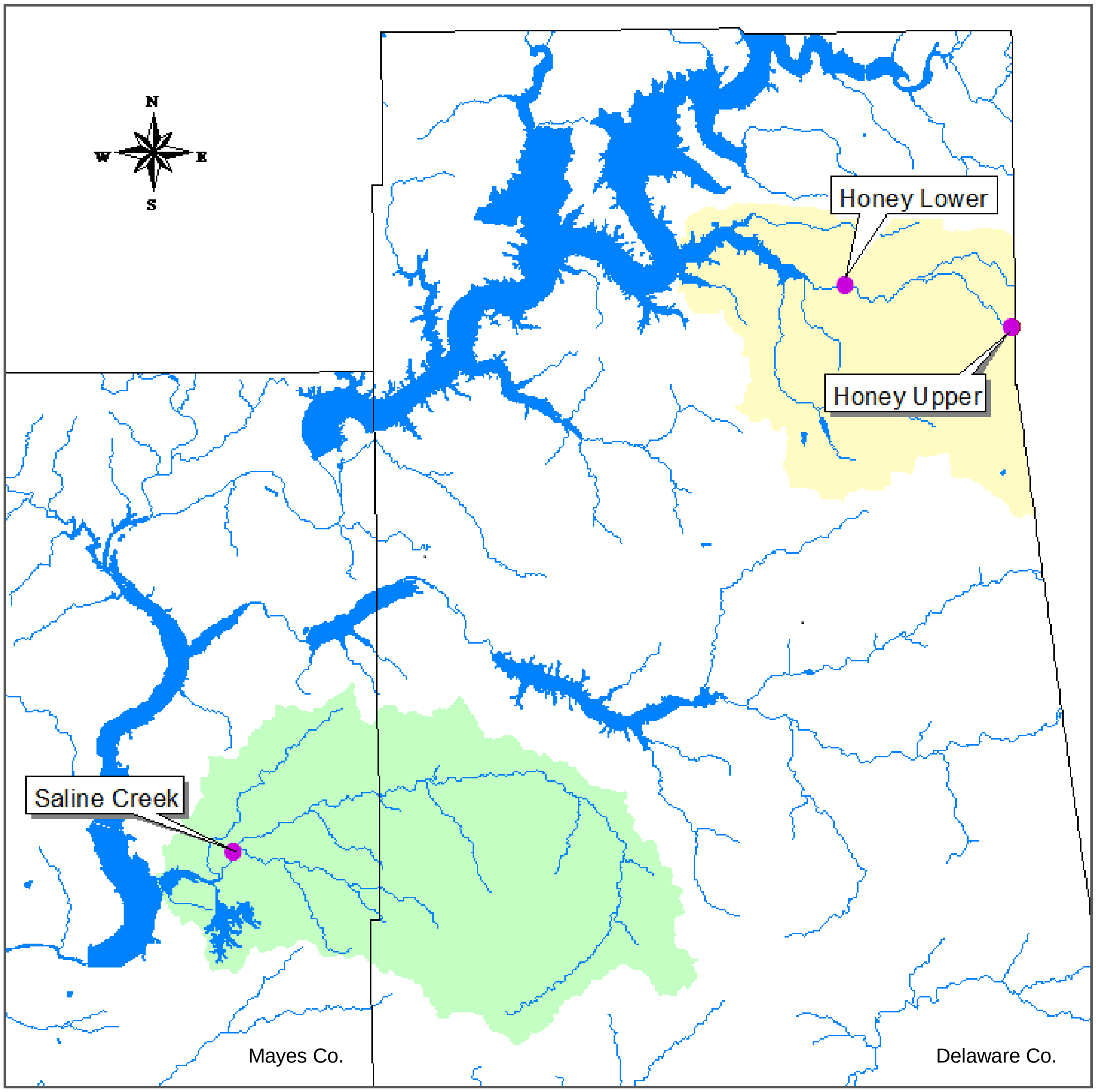


Figure 12. Map of the project watersheds with monitoring sites indicated by the purple dots.

Water quality samples were analyzed for ortho-phosphorus, total phosphorus, nitrate-nitrogen, ammonium nitrogen, and total Kjeldahl nitrogen (TKN). *Escherichia coli* and *Enterococcus* bacteria were assessed weekly during the recreation season only (May 1-September 30). The OCC also conducted routine physico-chemical monitoring at each site on a weekly basis throughout the length of the project. This included the following field parameters: dissolved oxygen, pH, temperature, turbidity, conductivity, instantaneous discharge, hardness, and alkalinity. Monthly grab samples were analyzed for total suspended solids (TSS), chloride, and sulfate. Additionally, benthic macroinvertebrates were collected twice a year throughout the project, and fish and habitat data was collected twice total for each site.

Nutrient Load Reduction Analysis

Monitoring began in April 2007 and is ongoing. The data analyzed for this report includes collections made April 2007 through June 2010. The results presented in this report are considered preliminary, since only one year of implementation data has been examined, and in actuality, implementation has continued throughout this period and beyond. It is expected that further load reductions will be observed in future years since the effect of some BMPs is not immediate but rather takes time to have a significant impact in a watershed. Additional data collected will be analyzed in future reports.

Data analysis was conducted according to procedures outlined in Clausen and Spooner (1993). The relationship between water quality variables from the treatment (Honey Creek Lower) and control sites (Honey Creek Upper and Saline Creek) was determined by simple linear regression during the calibration/pre-implementation phase of the project. Both a one year calibration period and a two year calibration period were considered. The two year period resulted in a higher r^2 value, indicating a stronger relationship than with the one year period. Hence, the period from April 2007-April 2009 is considered the calibration period, and from May 2009-June 2010 is the implementation period assessed in this report.

Total weekly loads were determined by multiplying concentrations from weekly integrated samples by the total flow for that week. The first step in the analysis was to determine the relationship, if any, between the watersheds for both the calibration and treatment phases. To better meet assumptions necessary to utilize certain statistical methods, weekly loads were converted to log base ten values before analysis. These log transformed load values were paired between the watersheds by date of collection and analyzed by linear regression to determine relationship for each parameter analyzed.

The two-year calibration regression equations provided a baseline relationship for each parameter between Honey Lower (the treatment watershed) and Honey Upper and Saline (the control sites). The paired watershed/site model was then used to assess implementation effectiveness based on one year of monitoring subsequent to the calibration period. The significance of the regression of paired observations between the treatment and controls was tested using an analysis of variance (ANOVA). The probability (p) value associated with the resulting F statistic indicates whether the regression explained a significant amount of the variation in the paired data ($p \leq 0.05$). The coefficient of determination (r^2) indicates the quality of the regression (i.e., its utility in predicting y from x).

At the end of the treatment period, the significance of the effect of the BMPs on each nutrient parameter was determined using analysis of covariance (ANCOVA). Specifically, the analysis determined:

1. the significance of the treatment regression equation,
2. the significance of the overall regression which combines the calibration and treatment period data,
3. the difference between the slopes of the calibration and treatment regressions, and

4. the difference between the intercepts of the calibration and treatment regressions. Item 1 was determined through an ANCOVA for the treatment period regression. Items 2 – 4 were determined through an ANCOVA comparing the treatment and calibration period regressions.

Honey Creek Lower versus Honey Creek Upper:

Total Phosphorus (T-P): Figure 13 indicates strong, statistically significant (P<0.000) linear relationships between the Honey Upper and Honey Lower sites for both the calibration and post-implementation periods. The resulting regression equations for each treatment-control pair for both calibration and implementation periods are given in Figure 13, below.

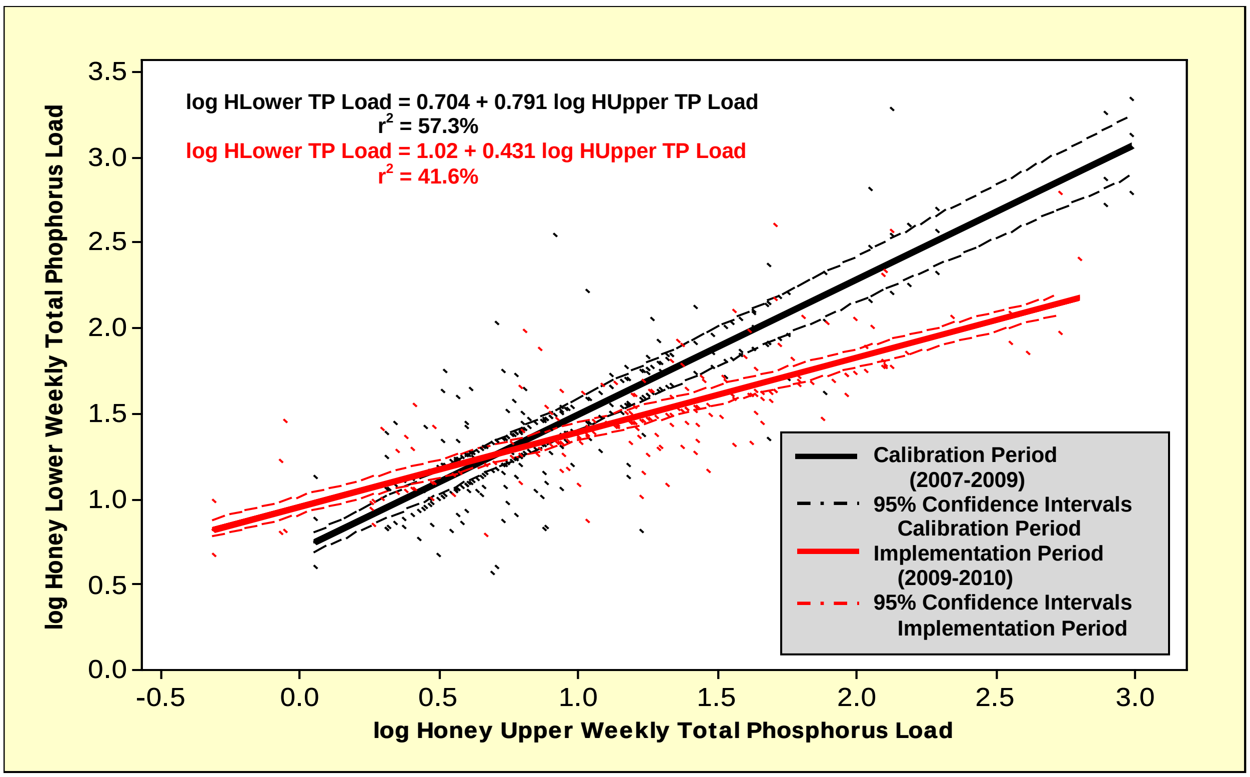


Figure 13. Regressions of log-transformed weekly total phosphorus (TP) load. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting one year of implementation.

An analysis of covariance (ANCOVA) was performed to determine the effect of the BMP implementation on weekly T-P load in the Honey Creek watershed. This type of analysis allows the determination of difference between the calibration and treatment periods despite whatever difference might have occurred because of environmental variability (e.g., wet year vs. dry year). The statistical software package Minitab, V. 14 was employed to conduct the analysis. The results of the ANCOVA analysis are shown in Table 7 (below). The p value of >0.05 for “period” indicates that the regression equations are not significantly different.

Table 7. Minitab results of the ANCOVA for calibration and implementation T-P data (log transformed) for Honey Lower and Upper sites.

Factor:	**Type:**	**Levels:**	**Values:**
Period	Fixed	2	Calibration, Implementation

Analysis of Variance for logT-P Load, using Adjusted SS for Tests:

Source	DF	Seq SS	Adj SS	Adj MS	F	P
logT-P Load	1	21.070	21.220	21.220	162.15	0.000
period	1	0.196	0.196	0.196	1.50	0.223
Error	168	21.985	21.985	0.131		
Total	170	43.251				

The significance of the regression lines was also evaluated using a regression analysis to examine both slope and intercept together (whole regression equation), slope only, and intercept only. Both the slopes (represented by the interaction term) and the intercepts (indicated by the "period" term) of the regression lines were significantly different ($p \leq 0.05$), as shown in Table 8.

Table 8. Minitab results of the regression analysis for the combined calibration and implementation T-P data (log transformed) for Honey Upper and Honey Lower sites.

The regression equation is:
logHonLowT-P Load = 0.704 + 0.791 logHonUpT-P Load + 0.313 period - 0.360 TP interaction

Predictor	Coef	SE Coef	T	P
Constant	0.7035	0.0714	9.86	0.000
logLST-P Load	0.7910	0.0644	12.26	0.000
period	0.3125	0.1148	2.72	0.007
TP interaction	-0.3597	0.0944	-3.81	0.000
r^2 = 29.7%	r^2 (adj) = 29.0%			

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	23.023	7.675	63.36	0.000
Residual Error	167	20.227	0.121		
Total	170	43.251			

In order to quantify the reduction in total phosphorus load, expected loads are calculated for Honey Lower using the calibration and implementation regression equations and the observed implementation period loads in Honey Upper. Then, the percent reduction was calculated in terms of the average of the difference between the calibration and implementation weekly loads relative to the calibration load:

*% reduction = (calibration – implementation) / calibration * 100*

Using this method (*"average % reduction" method*), it was calculated that a **9% reduction in total phosphorus loading** has been achieved at Honey Lower relative to Honey Upper during just one year of the implementation period.

Examining the regressions with a slightly different analysis method, comparing the least squares means calculated in the ANCOVA between the two regression lines (*"least squares means" method*), indicated that a **15% reduction in total phosphorus loading** was achieved. Both methods are valid approaches to determining load reductions, so the T-P load reduction can be considered to be between 9% and 15%.

As shown in Table 10, below, reductions in average total phosphorus concentration and in average weekly total phosphorus load were observed for Honey Lower in the treatment period relative to the calibration period, although these reductions are not statistically significant ($p<0.10$). Analysis of variance showed that the increase in T-P concentration at the Honey Upper site is marginally significant ($0.05<p<0.10$).

Table 9. Average nutrient concentrations and loads for the calibration period (2007-2009) and the first year of the implementation period (2009-2010). Asterisks indicate significant changes between the calibration and implementation periods at that site, and the number in parentheses following the asterisk denotes the p value that resulted from the analysis of variance comparing the calibration and implementation periods for each site for that parameter (*p<0.10; **p<0.05).

	Parameter	Honey Lower Calib	Honey Lower Implem.	Honey Lower Change	Honey Upper Calib	Honey Upper Implem	Honey Upper Change
Concentration (mg/L)	TotPhosphorus	0.1417	0.1244	⇓	0.0837	0.1139	⇑ *(0.084)
	Ortho-Phosphorus	0.0648	0.0465	⇓ *(0.072)	0.0431	0.0349	⇓
	Ammonia	0.0413	0.0603	⇑ *(0.093)	0.0659	0.0529	⇓
	Nitrate	2.3150	2.2205	⇓	2.3170	1.9812	⇓ *(0.078)
	TKN	0.3403	0.5974	⇑ **(0.007)	0.1992	0.5211	⇑ **(0.000)
Load (lbs)	TotPhosphorus	96.30	59.11	⇓	33.60	39.50	⇑
	Ortho-Phosphorus	46.20	23.99	⇓	18.43	13.67	⇓
	Ammonia	18.40	25.15	⇑	9.97	14.78	⇑
	Nitrate	968	1046	⇑	670	637	⇓
	TKN	209.1	295.8	⇑	67.5	185.8	⇑ **(0.032)

Figure 14 shows the T-P load in the two Honey Creek sites through time. The Lower site has a slight downward trend while the Upper site has a slight increase over time. Since these are paired watersheds experiencing approximately the same environmental conditions, the observed differences are assumed to be due to the BMP implementation in the watershed versus relatively no implementation in the Missouri and Arkansas portion of the watershed upstream of the Honey Upper site (a small amount may have been implemented through the NRCS EQIP program).

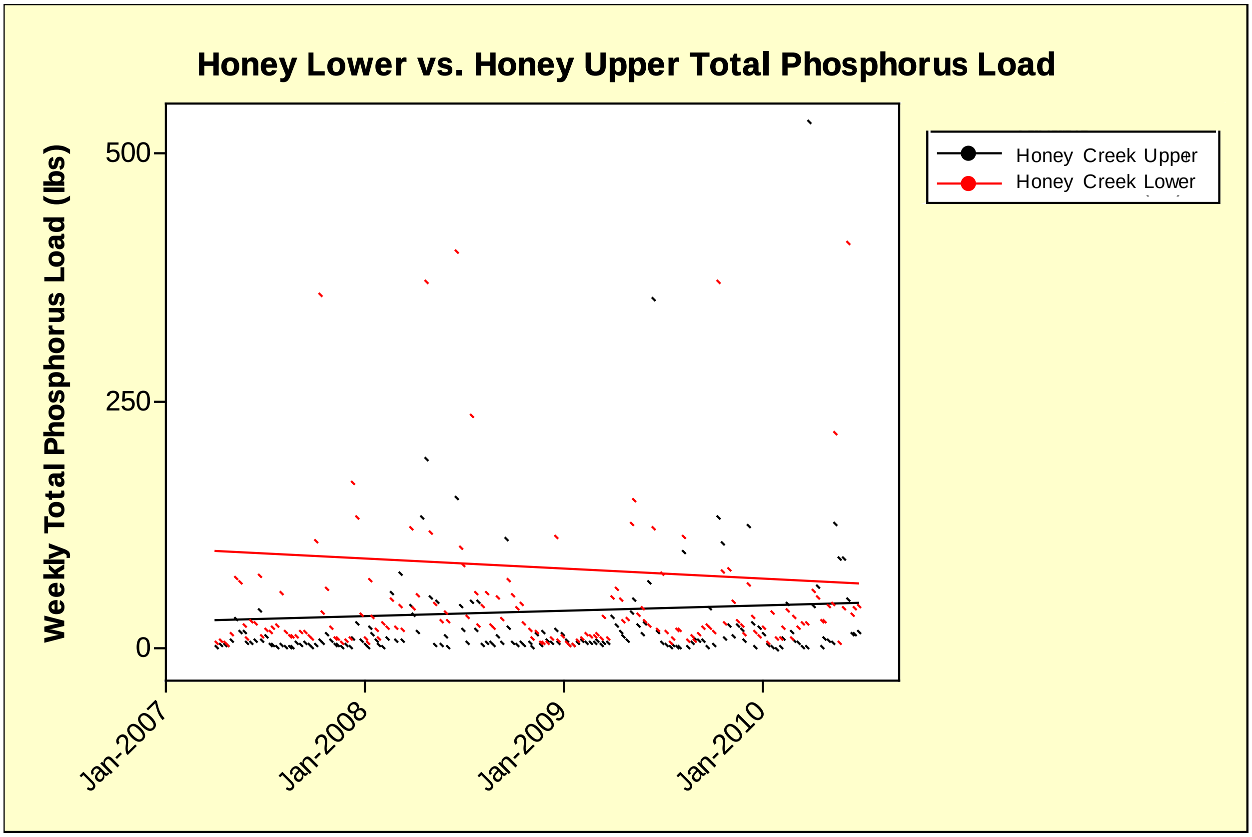


Figure 14. Comparison of weekly total phosphorus load over time. Honey Creek Lower (red line) shows a slight *reduction* in TP over time, while Honey Creek Upper (black line) shows a slight increase over time. Neither trend is statistically significant, however.

All other nutrient parameters were analyzed using the methods just described. The results for each parameter are presented in the following pages, but the details of the analysis methods will not be repeated, so the reader is encouraged to refer back to this section if questions arise.

OrthoPhosphorus (OP): Performing an ANCOVA and comparing the least squares means between the two regression lines (Figure 15) indicated that a **7% reduction in orthophosphorus loading** was achieved in the implementation period relative to the calibration period; however, using the "average % reduction" method to calculate load reductions (average of the difference between the calibration and implementation weekly loads relative to the calibration load), a slight increase in OP loading was noted. As indicated in Table 10, above, the OP concentration decreased significantly (p=0.072) at the Honey Lower site during the treatment period as compared to the calibration period. The OP loading also decreased but the change was not statistically significant.

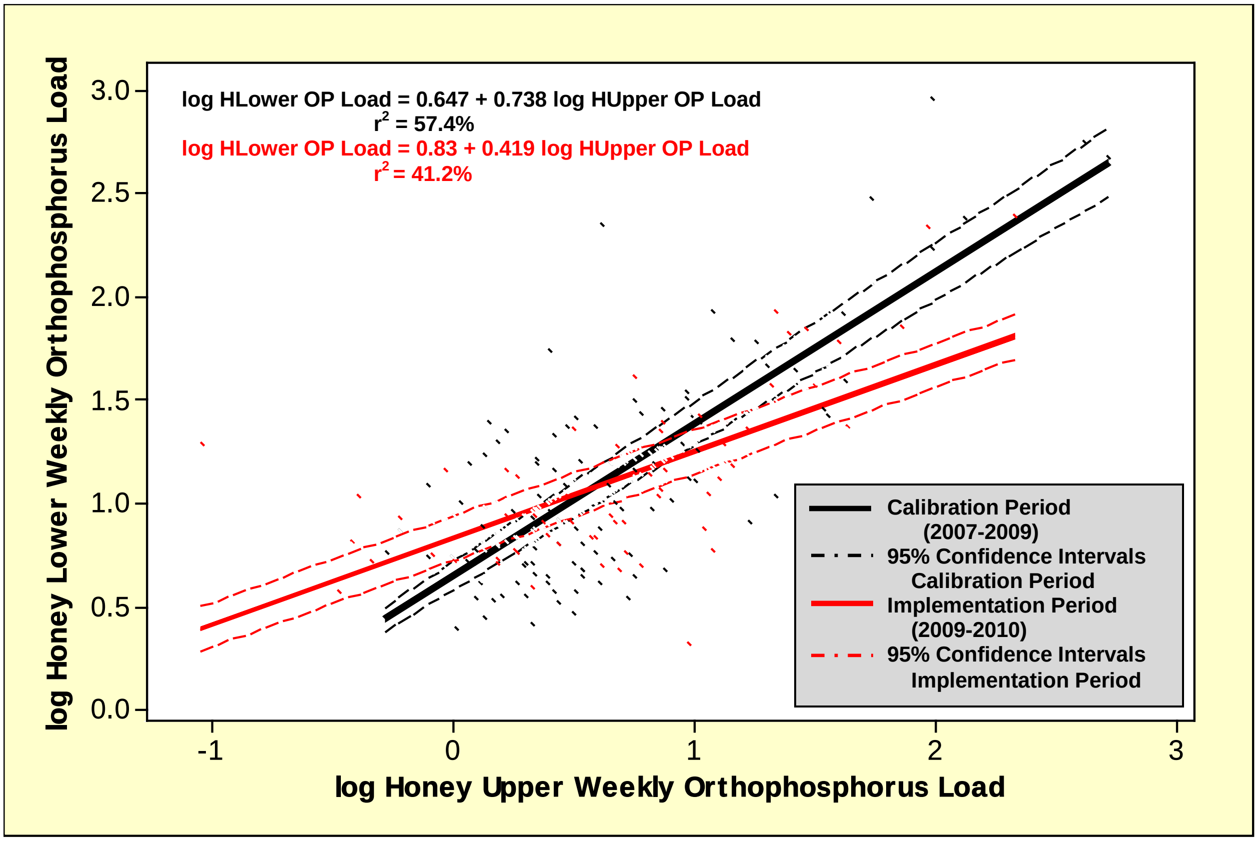


Figure 15. Regressions of log-transformed orthophosphorus (OP) data. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting post-implementation.

The p value of 0.582 in Table 10 indicates that the regression equations are not significantly different. Both the slopes (represented by the interaction term) and the intercepts (indicated by the "period" term) of the regression lines were significantly different ($p \leq 0.05$), as shown in Table 14. Figure 16 shows the weekly OP loading over time for each site. Both sites had slight decreases in OP loading over time, with a steeper decrease exhibited at the Honey Lower site.

Table 10. Minitab results of the regression analysis for the combined calibration and implementation OP data (log transformed) for Honey Upper and Honey Lower sites.

Factor:	**Type:**	**Levels:**	**Values:**
Period	Fixed	2	Calibration, Implementation

Analysis of Variance for logOPLoad, using Adjusted SS for Tests:

Source	DF	Seq SS	Adj SS	Adj MS	F	P
logOPLoad	1	21.437	21.458	21.458	166.56	0.000
period	1	0.039	0.039	0.039	0.30	0.582
Error	168	21.643	21.643	0.129		
Total	170	43.119				

Table 11. Minitab results of the regression analysis for the combined calibration and implementation OP data (log transformed) for Honey Upper and Honey Lower sites.

The regression equation is:
logHonLowOP Load = 0.647 + 0.738 logHonUpOP Load + 0.183 period - 0.319 interaction

Predictor	Coef	SE Coef	T	P
Constant	0.6468	0.0520	12.44	0.000
logOP Load	0. 7379	0.0598	12.35	0.000
period	0.1828	0.0819	2.23	0.027
OP interaction	-0.3189	0.0908	-3.51	0.001

r^2 = 53.3% r^2 (adj) = 52.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	22.9651	7.6550	63.43	0.000
Residual Error	167	20.1544	0.1207		
Total	170	43.1195			

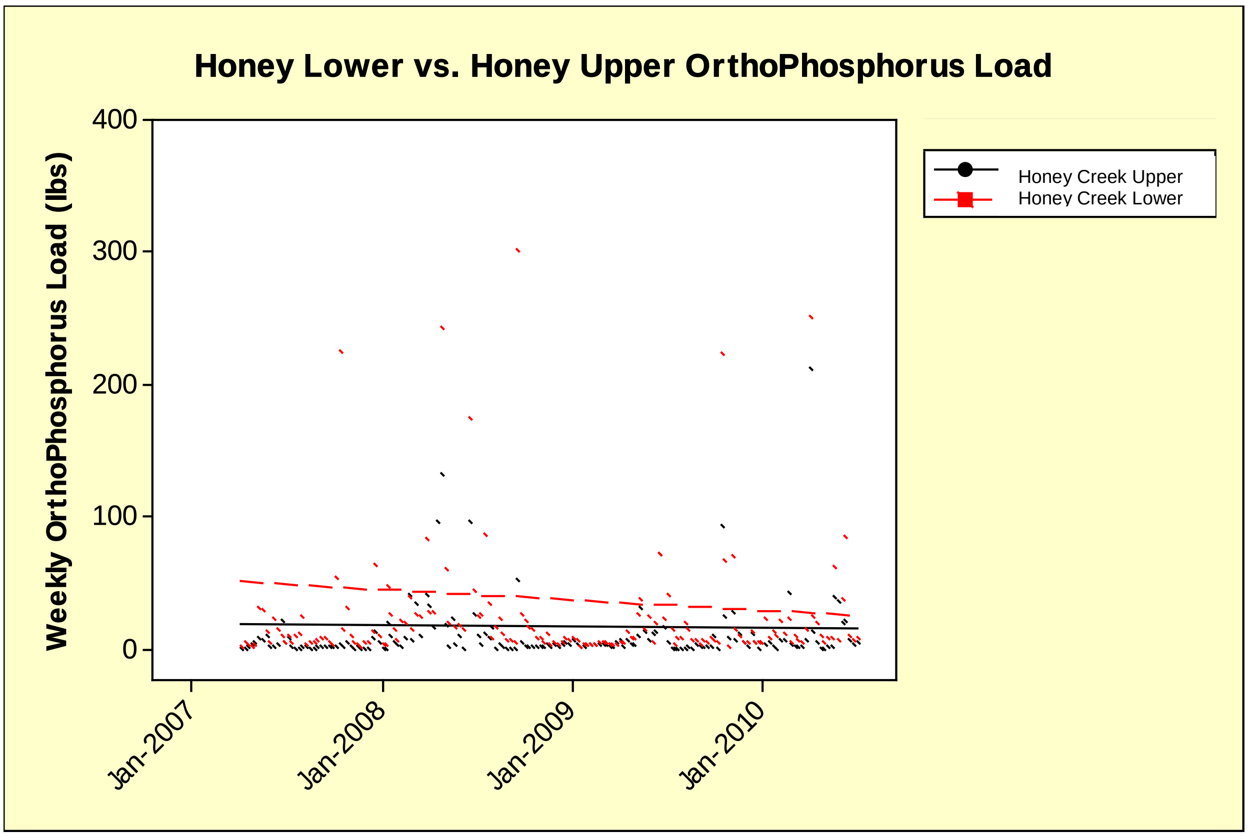


Figure 16. Comparison of orthophosphorus load over time. Both Honey Creek Upper (black line) and Honey Creek Lower (red line) show a decrease over time. Although neither trend is statistically significant, Honey Lower has a greater decrease than Honey Upper.

Nitrogen Parameters--Total Kjeldahl Nitrogen (TKN), Ammonia, Nitrate:
None of the nitrogen parameters showed significantly decreased loading using either of the paired watershed methods of analysis (least squares means or average % reduction); in fact, slight increases in loading for TKN, ammonia, and nitrate were generally observed. When comparing between the calibration and treatment periods, TKN concentrations increased significantly at both Honey Creek sites, and TKN weekly loading increased significantly at the Honey Upper site (Table 9, above). This was not surprising since a recently completed TMDL by the state of Missouri found that much of the nitrogen loading in the Cave Springs Branch of Honey Creek is due to point source discharges, particularly from the Simmons poultry processing plant just across the border in Missouri (MDNR 2010). The regulatory actions presented in the TMDL may result in eventual improvements in nitrogen loading in the watershed.

Figure 17 shows the regressions of the calibration versus treatment periods for TKN, and Figure 18 shows the TKN load over time for the control (Honey Upper) and treatment (Honey Lower) sites. Tables 12 and 13 show the supporting statistical analyses for determining the significance due to implementation. The regression equations are not significantly different (Table 12: p=0.226), while the slopes and intercepts are significantly different (Table 13: p=0.074; p=0.034).

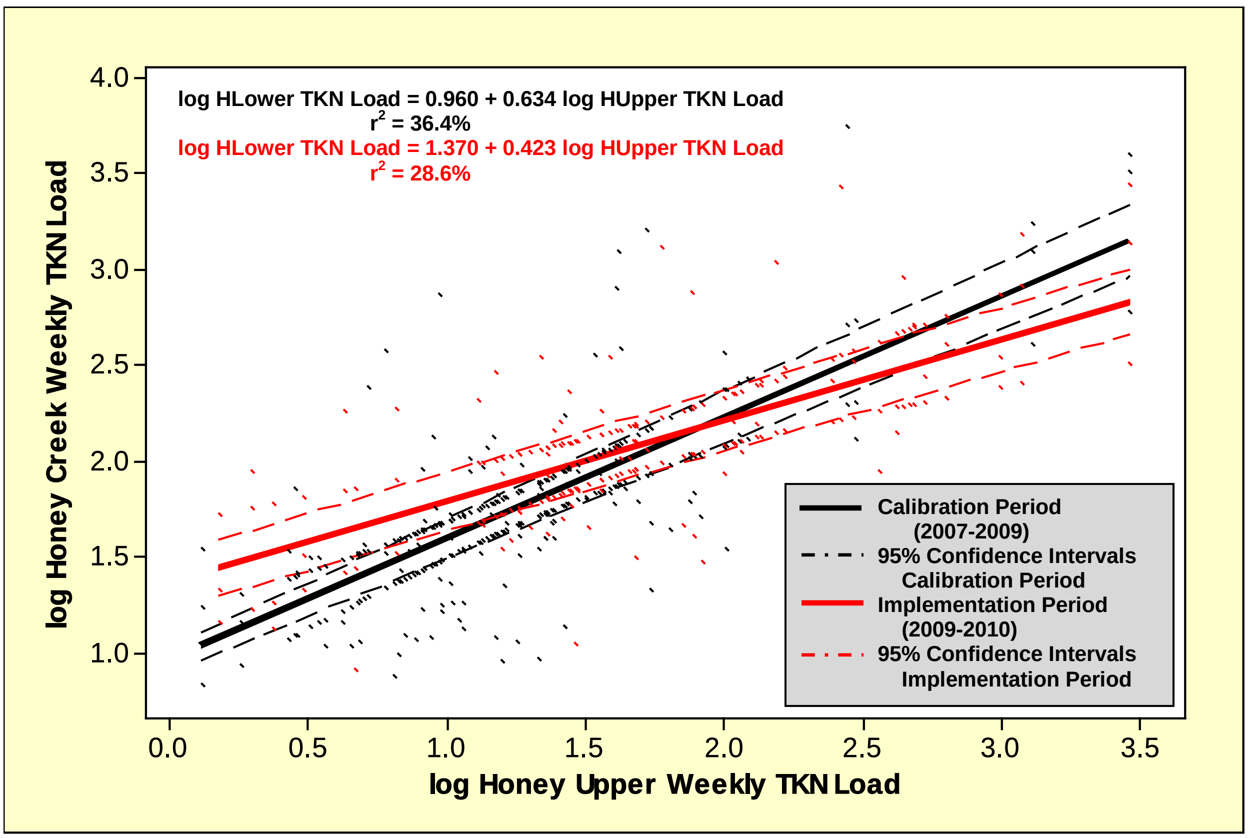


Figure 17. Regressions of log-transformed TKN data. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting implementation.

Table 12. Minitab results of the ANCOVA for the calibration and implementation TKN data (log transformed) for Honey Lower and Honey Upper.

Factor:	**Type:**	**Levels:**	**Values:**
Period	Fixed	2	Calibration, Implementation

Analysis of Variance for logHonLowTKN Load, using Adjusted SS for Tests:

Source	DF	Seq SS	Adj SS	Adj MS	F	P
logHonUpTKN Load	1	20.992	16.637	16.637	79.54	0.000
period	1	0.308	0.308	0.308	1.47	0.226
Error	168	35.142	35.142	0.209		
Total	170	56.443				

Table 13. Minitab results of the regression analysis for the combined calibration and implementation TKN data (log transformed) for Honey Upper and Honey Lower.

The regression equation is:

logHonLowTKN Load = 0.960 + 0.634 logHonUpperTKN Load + 0.405 period - 0.211 interaction

Predictor	Coef	SE Coef	T	P
Constant	0.9604	0.1142	8.41	0.000
logLSTKN Load	0.6337	0.0842	7.53	0.000
period	0.4051	0.1891	2.14	0.034
TKN interaction	-0.2106	0.1170	-1.80	0.074

r^2 = 38.9% r^2 (adj) = 37.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	21.970	7.323	35.48	0.000
Residual Error	167	34.473	0.206		
Total	170	56.443			

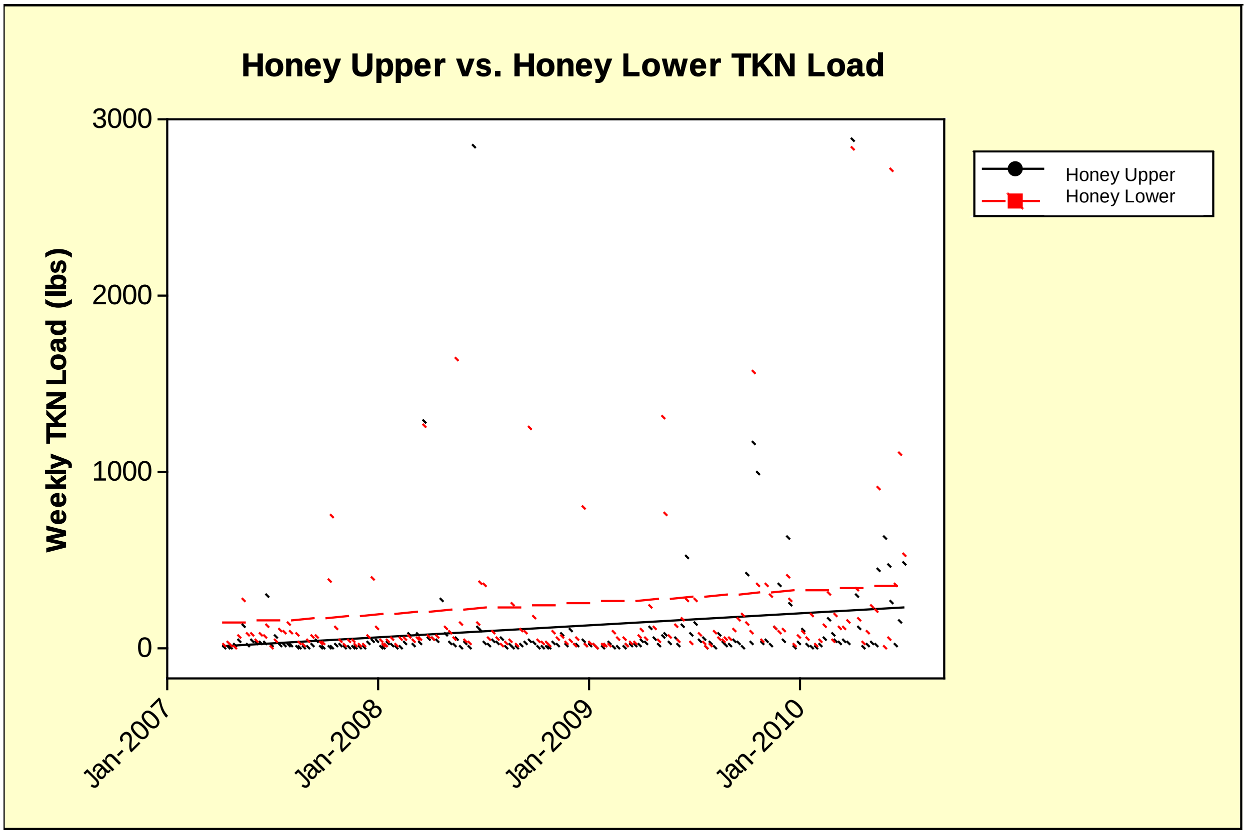


Figure 18. Comparison of TKN load over time. Both Honey Upper (black line) and Honey Lower (red line) show an increase over time, but the increase is only significant (p=0.02) for the Honey Upper site.

Figure 19 shows the regressions of the calibration versus treatment periods for ammonia, and Figure 20 shows the ammonia load over time for the control (Honey Upper) and treatment (Honey Lower) sites. Tables 14 and 15 show the supporting statistical analyses for determining the significance due to implementation. The regression equations are not significantly different (Table 14: p=0.307), while the slopes and intercepts are significantly different (Table 15: p=0.035; p=0.023).

Table 14. Minitab results of the ANCOVA for the combined calibration and implementation ammonia data (log transformed) for Honey Upper and Honey Lower.

Factor:	Type:	Levels:	Values:
Period	Fixed	2	Calibration, Implementation

Analysis of Variance for logHonLow Ammonia Load, using Adjusted SS for Tests:

Source	DF	Seq SS	Adj SS	Adj MS	F	P
logHonUp Ammon Load	1	14.664	13.063	13.063	60.66	0.000
period	1	0.2263	0.2263	0.2263	1.05	0.307
Error	168	36.181	36.181	0.2154		
Total	170	51.072				

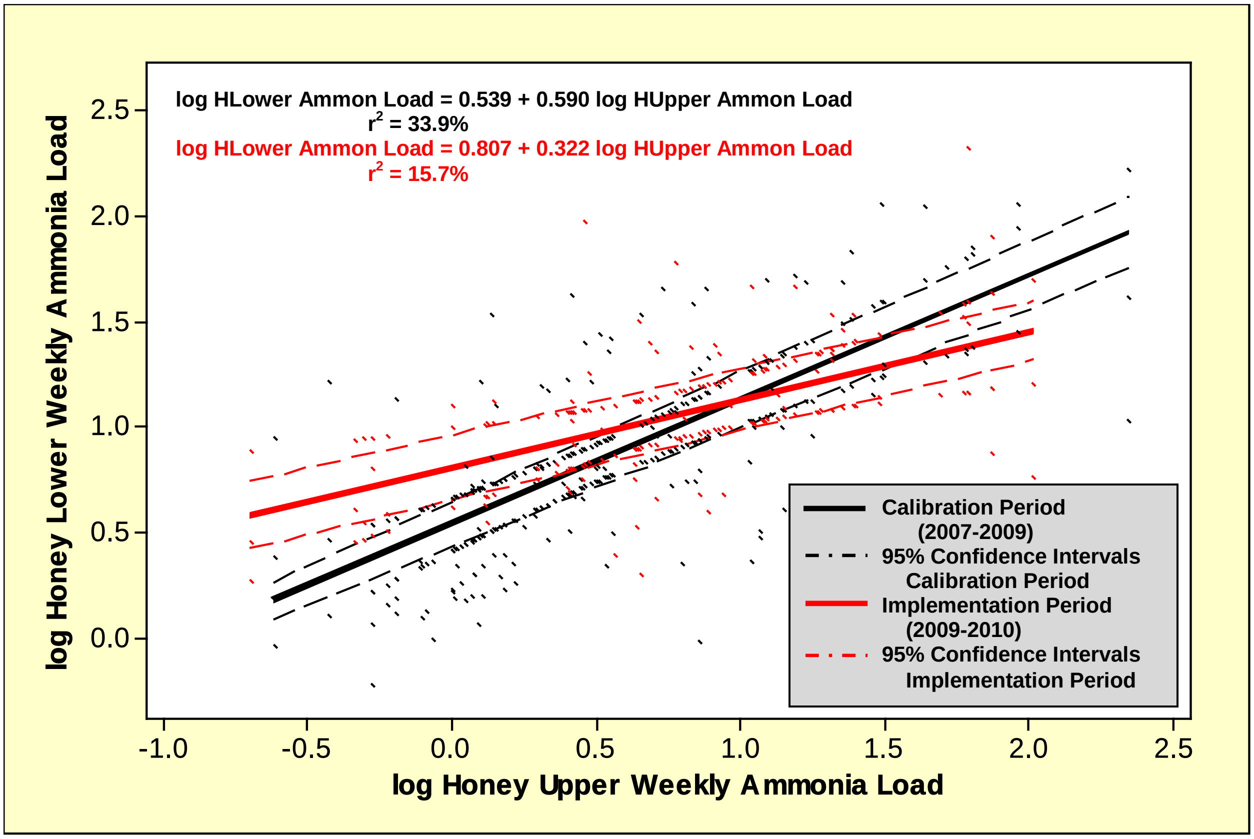


Figure 19. Regressions of log-transformed ammonia data. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting implementation.

Table 15. Minitab results of the regression analysis for the combined calibration and implementation ammonia data (log transformed) for Honey Upper and Honey Lower.

The regression equation is:

logHonLow Ammon Load = -0.044 + 0.644 logHonUpper Ammon Load – 0.097 period - 0.720 Ammonia interaction

Predictor	Coef	SE Coef	T	P
Constant	0.5389	0.0618	8.71	0.000
logHUAmmonLoad	0.5903	0.0791	7.46	0.000
period	0.2676	0.1164	2.30	0.023
Ammon interaction	-0.2681	0.1259	-2.13	0.035

r^2 = 31.0% r^2 (adj) = 29.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	15.848	5.283	25.05	0.000
Residual Error	167	35.224	0.211		
Total	170	51.072			

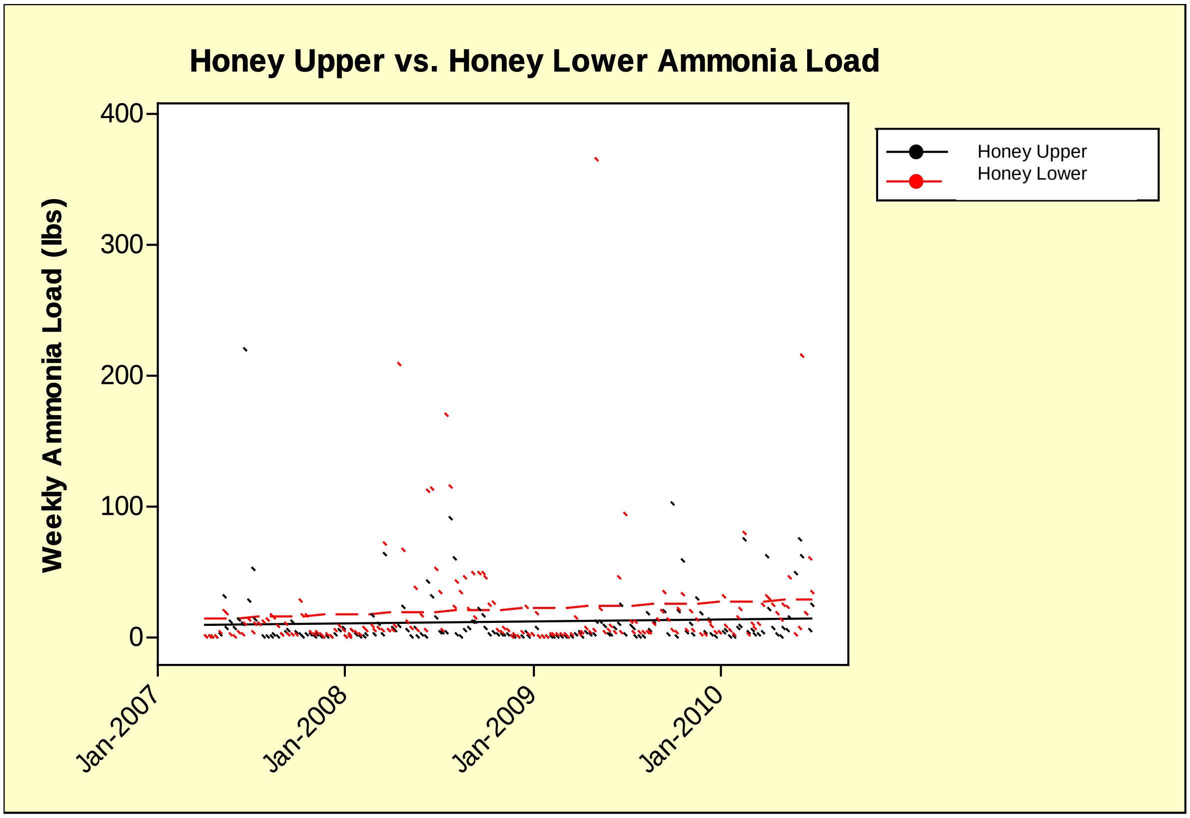


Figure 20. Comparison of ammonia load over time. Both Honey Upper (black line) and Honey Lower (red line) show an increase over time, but neither is statistically significant.

Figure 21 shows the regressions of the calibration versus treatment periods for nitrate, and Figure 22 shows the nitrate load over time for the control (Honey Upper) and treatment (Honey Lower) sites. Tables 16 and 17 show the supporting statistical analyses for determining the significance due to implementation. The regression equations are not significantly different (Table 16: p=0.194 while the slopes and intercepts are significantly different (Table 17: p<0.000; p<0.000).

Table 16. Minitab results of the ANCOVA for the combined calibration and implementation nitrate data (log transformed) for Honey Upper and Honey Lower.

Factor:	Type:	Levels:	Values:
Period	Fixed	2	Calibration, Implementation

Analysis of Variance for logHonLow Nitrate Load, using Adjusted SS for Tests:

Source	DF	Seq SS	Adj SS	Adj MS	F	P
logHU Nitrate Load	1	19.405	19.272	19.272	210.92	0.000
period	1	0.155	0.155	0.155	1.700	0.194
Error	168	15.350	15.350	0.091		
Total	170	34.911				

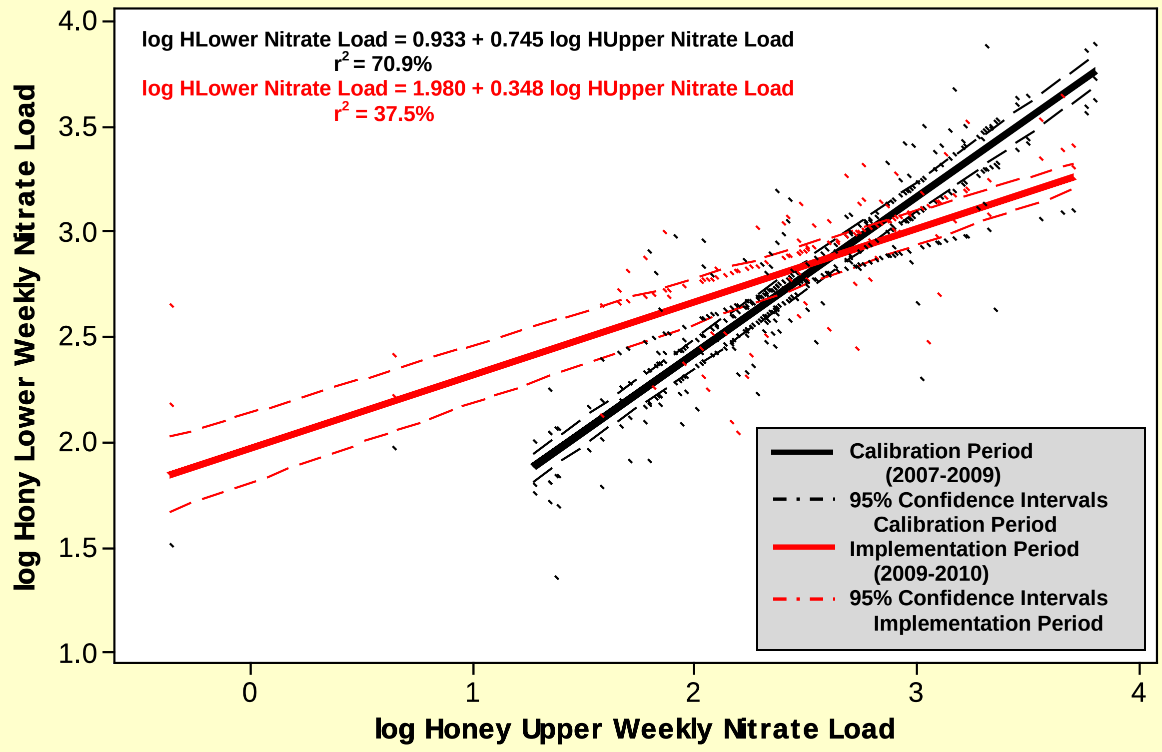


Figure 21. Regressions of log-transformed nitrate data. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting implementation.

Table 17. Minitab results of the regression analysis for the combined calibration and implementation nitrate data (log transformed) for Honey Upper and Honey Lower.

The regression equation is:
logHonLowNitrate Load = 0.851 + 0.627 logHonUpperNitrate Load – 0.233 period + 0.225 Nitrate interaction

Predictor	Coef	SE Coef	T	P
Constant	0.9334	0.1219	7.66	0.000
logHUNitrate Load	0.7448	0.0485	15.34	0.000
period	1.0420	0.1839	5.67	0.000
Nitrate interaction	-0.3967	0.0723	-5.49	0.000

r^2 = 62.7% r^2 (adj) = 62.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	21.905	7.302	93.76	0.000
Residual Error	167	13.005	0.078		
Total	170	34.911			

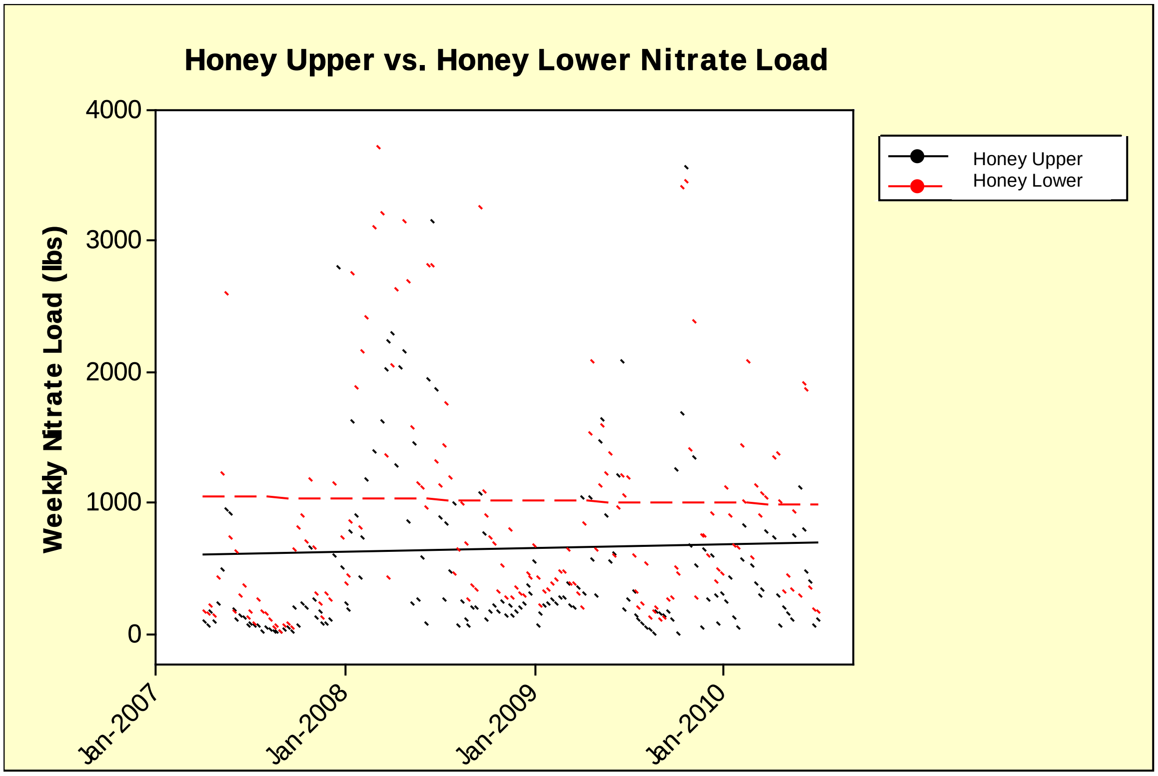


Figure 22. Comparison of nitrate load over time. Honey Upper (black line) shows a slight increase over time while Honey Lower (red line) shows a slight decrease, but neither change is statistically significant.

<u>Honey Creek Lower versus Saline Creek:</u>
The Saline Creek site was included as a potential control site for Honey Lower since it was already being monitored as a control site for two other projects in the area. It is potentially a good control for the Honey Lower site since it is relatively close geographically and similar in size; however, several heavy rain events resulted in damage to the Saline autosampler, so the data from some of the most important periods for comparison was unavailable. The relationship between the Honey Creek Lower and Saline Creek sites is not as strong as the relationship between the Upper and Lower Honey Creek sites. The r^2 values for the relationship for total phosphorus was 11% for the implementation phase and 31% for the calibration phase (Figure 23), much lower than the 41% and 58% observed between Honey Lower and Honey Upper. Figure 24 shows the TP load through time for Honey Lower and Saline.

The preliminary analyses using Saline Creek as a control for Honey Lower did not result in significant differences between the calibration and treatment periods, as shown in Tables 18 and 19 below, although slight reductions were observed in total phosphorus and ortho-phosphorus loads when assessed using the least squares means method: a **1.8% reduction in total phosphorus load was calculated**. None of the other parameters resulted in load reductions using either the least squares method or the average % reduction method, so the results are not presented in this report. Saline Creek will continue to be monitored and will be compared against Honey Lower in future analyses, since it is possible the relationship will be strengthened and significant load reductions detected after a longer implementation/post-implementation period.

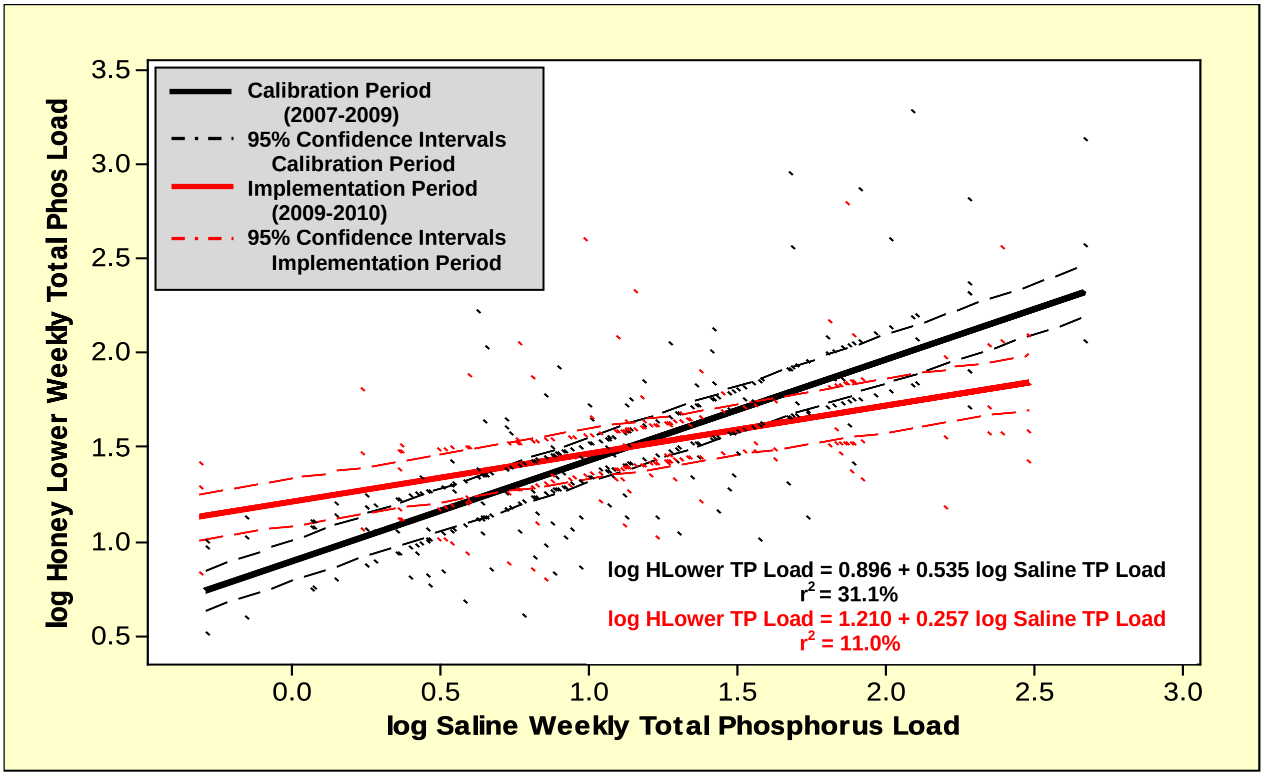


Figure 23. Regressions of log-transformed weekly total phosphorus (TP) load. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting one year of implementation.

Table 18. Minitab results of the ANCOVA for the combined calibration and implementation total phosphorus data (log transformed) for Saline and Honey Lower.

Factor:	Type:	Levels:	Values:
Period	Fixed	2	Calibration, Implementation

Analysis of Variance for logHonLow TP Load, using Adjusted SS for Tests:

Source	DF	Seq SS	Adj SS	Adj MS	F	P
logSaline TPLoad	1	10.261	10.217	10.217	52.04	0.000
period	1	0.003	0.003	0.003	0.02	0.902
Error	168	32.987	32.987	0.196		
Total	170	43.251				

Table 19. Minitab results of the regression analysis for the combined calibration and implementation total phosphorus data (log transformed) for Saline and Honey Lower.

The regression equation is:

logHonLowTP Load = 0.896 + 0.535 logSal TP Load + 0.310 period – 0.278 TP interaction

Predictor	Coef	SE Coef	T	P
Constant	0.8964	0.0910	9.85	0.000
logSalTP Load	0.5347	0.0744	7.19	0.000
period	0.3098	0.1591	1.95	0.053
TP interaction	-0.2780	0.1251	-2.22	0.028

r^2 = 25.9% r^2 (adj) = 24.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	11.211	3.737	19.48	0.000
Residual Error	167	32.039	0.192		
Total	170	43.251			

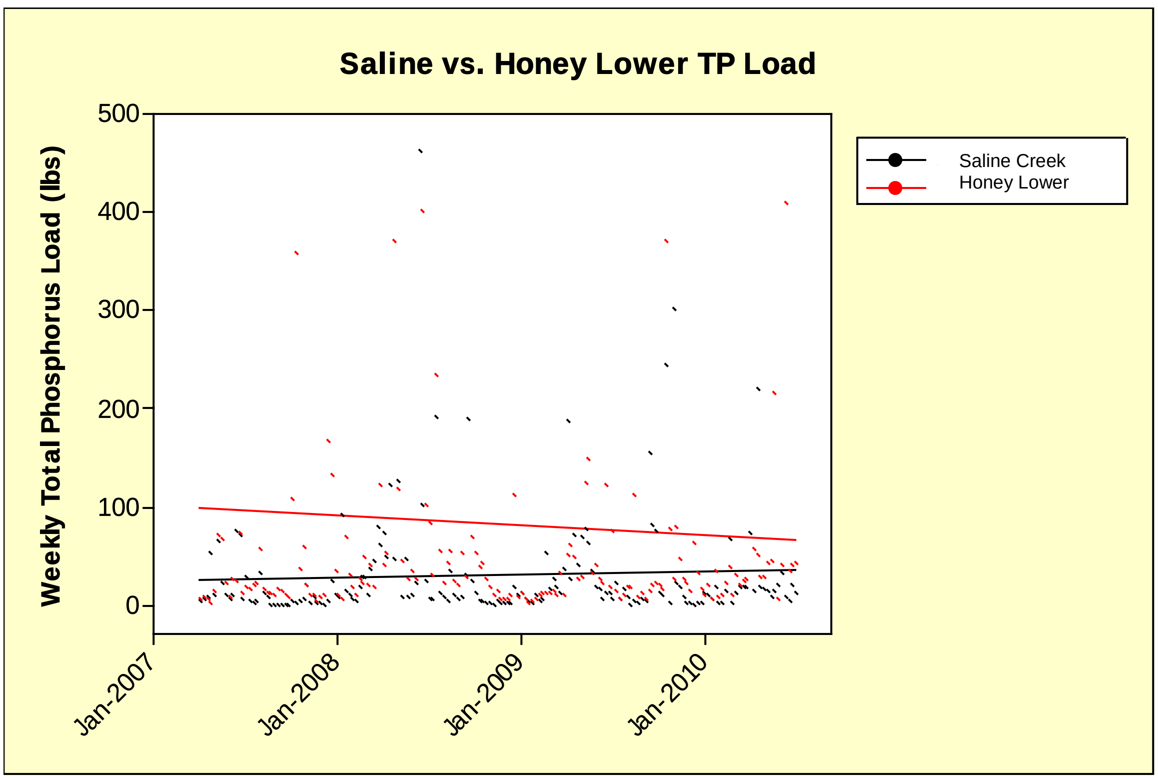


Figure 24. Comparison of total phosphorus load over time. Saline Creek (black line) showed a slight increase over time, while Honey Lower decreased.

Grab Sample Data

Table 20, below, shows the means for chloride and sulfate analyzed from monthly grab sample data. All total suspended solids (TSS) analyses were below the detection limit (<10). No significant differences were observed between the calibration and treatment periods for chloride, TSS, or sulfate.

Table 20. Mean values for chloride and sulfate. N indicates the sample size.

SiteName	period	N	Chloride	Sulfate
Honey Lower	calibration	21	32.8	27.1
	treatment	11	26.3	20.5
Honey Upper	calibration	21	11.6	16.9
	treatment	11	11.0	9.0
Saline	calibration	41	8.6	6.5
	treatment	16	7.9	7.9

In-situ Data

Figure 25, below, shows the *in-situ* data that was collected for the three monitoring sites. The data has been divided into calibration (2007-2009) and implementation (2009-2010) periods. There was no discernible change between the two monitoring periods for the physico-chemical parameters.

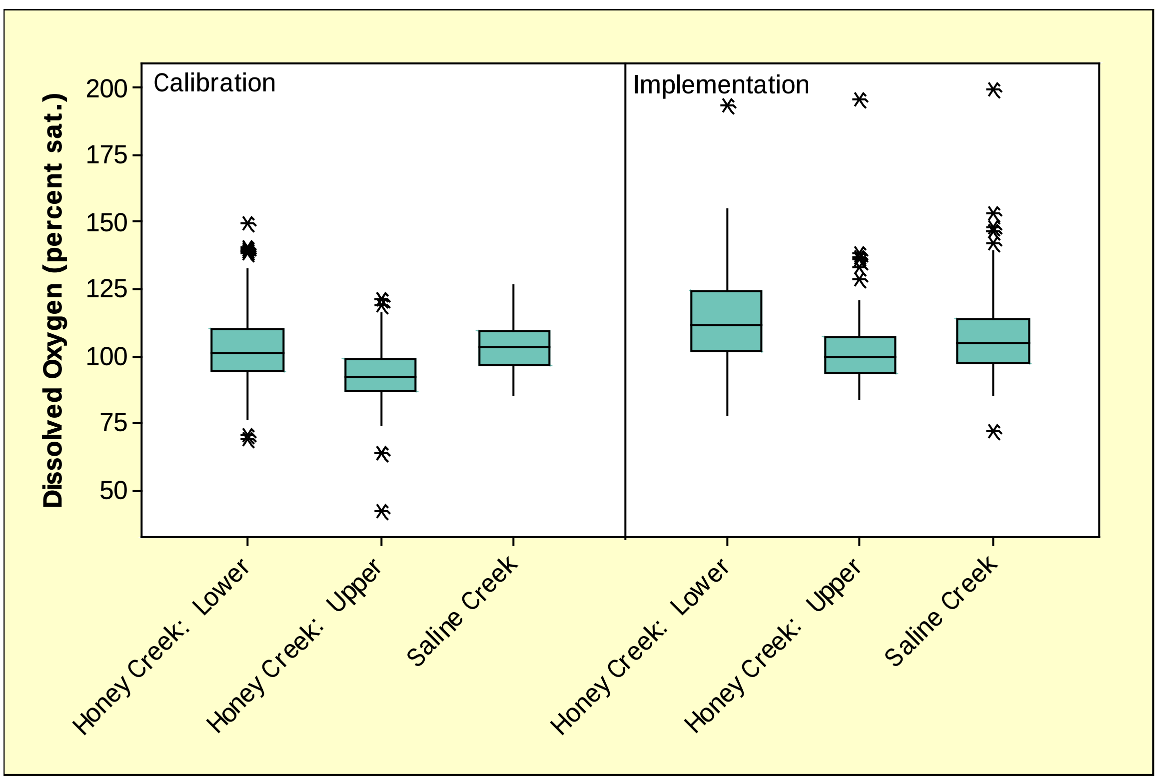


Figure 25. Boxplots of *in-situ* data collected during calibration (2007-2009) and implementation (2009-2010) periods. The solid line within each box is the median value, and the box represents the interquartile range (25th -75th quartile) of the data. Asterisks indicate outliers.

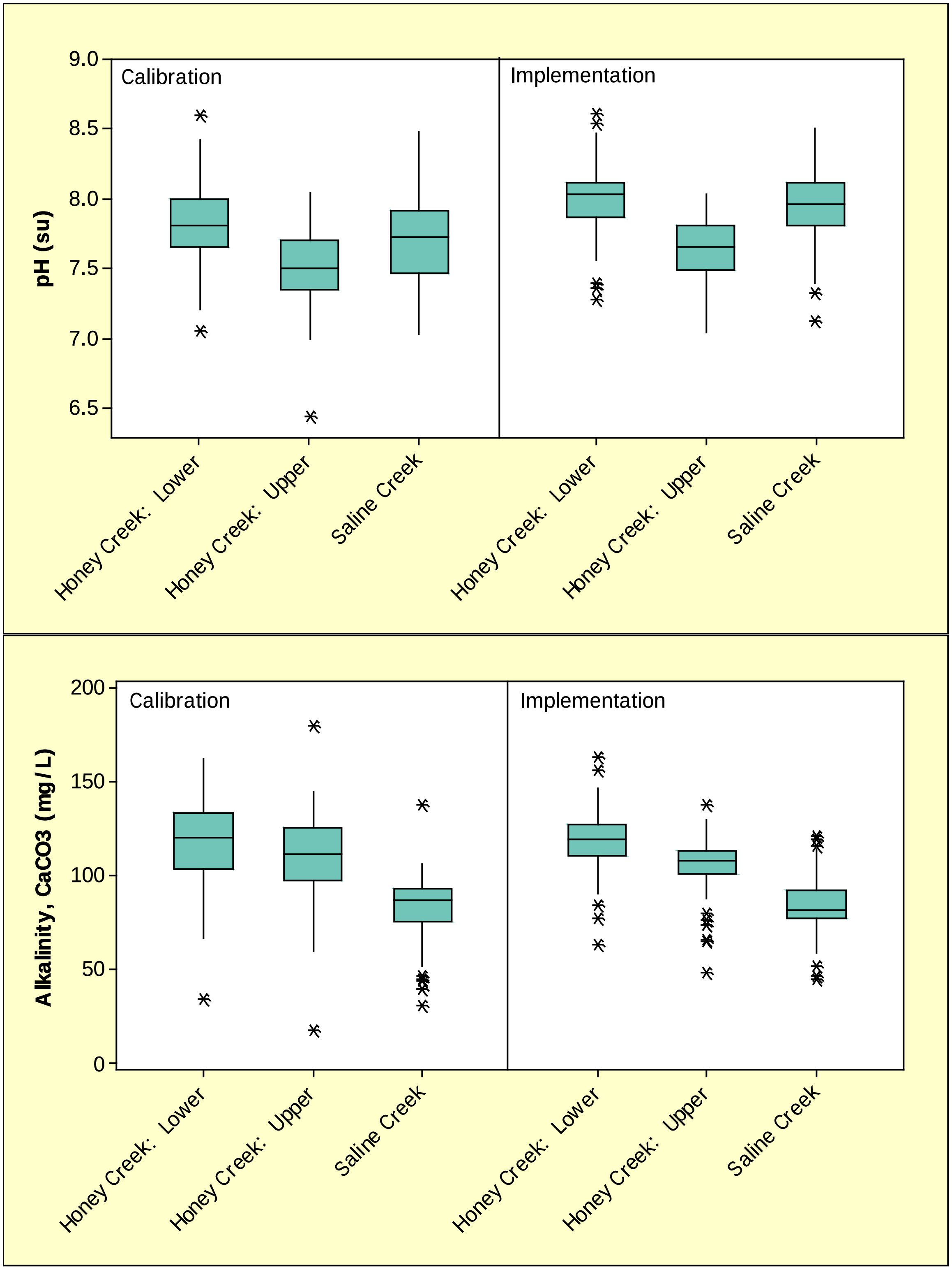
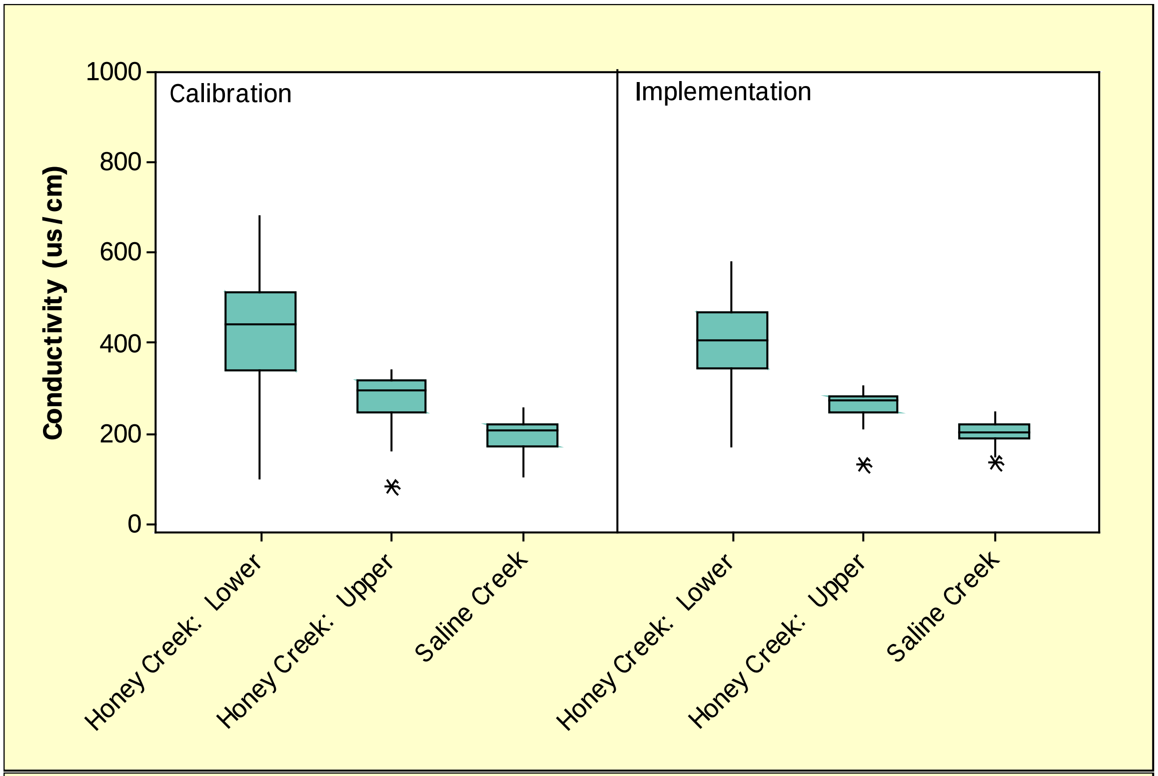


Figure 25, continued.



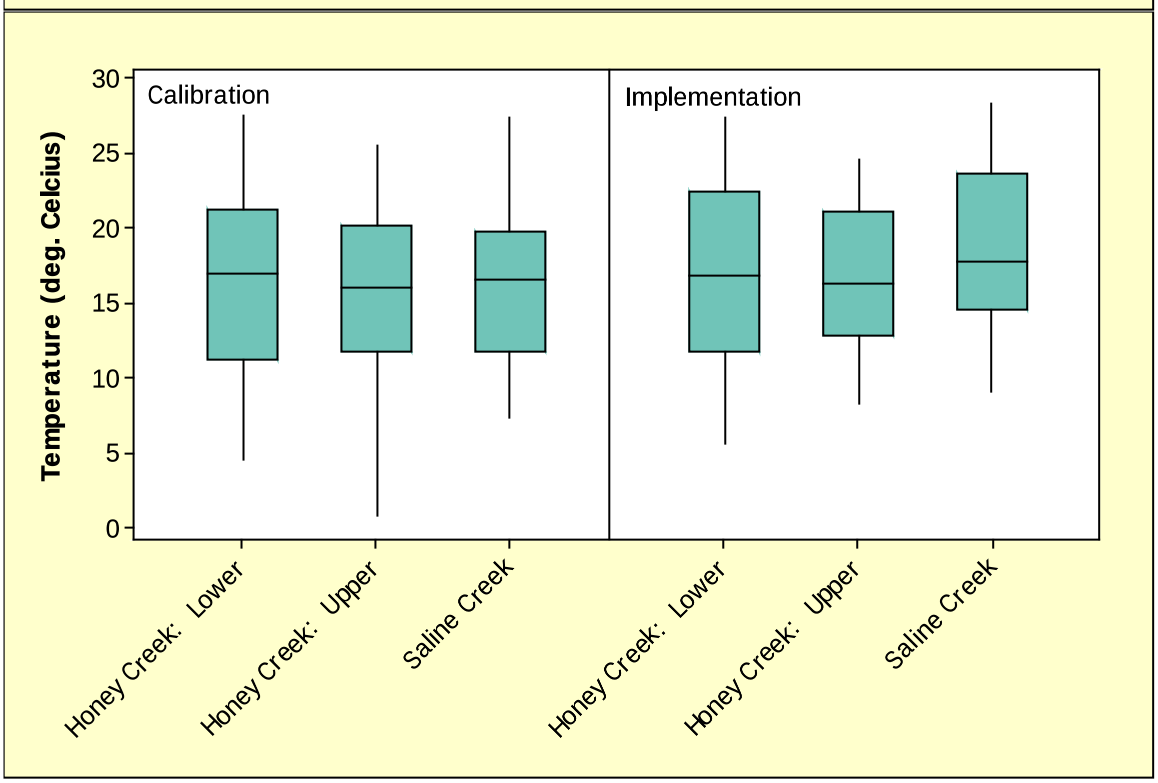


Figure 25, continued.

Biological Data Analysis

Fish

Fish collections were obtained in 2006, 2008, and 2009 for both Honey Creek sites and in 2006 and 2009 for the Saline site. In addition, fish data was available from 1998 and 2001 for Saline Creek and from 1999 for Honey Lower. Fish were collected from a 400 meter reach at each site using a combination of seining and electroshocking according to procedures outlined in OCC SOP (2010). The collection of fish follows a modified version of the EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989) supplemented by other documents. The fish data was analyzed using a modified Rapid Bioassessment Protocol to calculate an "Index of Biological Integrity" (IBI) score. Table 21, below, shows the metrics used to calculate the scores. Details of this method for calculating IBIs are found in the latest OCC Rotating Basin report (OCC 2011).

Both Honey and Saline Creeks are designated as "Cool Water Aquatic Communities." Analysis of fish collection data resulted in "excellent" fish community scores for all collections relative to cool water aquatic community (CWAC) high quality sites in the Ozark Highlands ecoregion. As seen in Table 21, all sites had an IBI score that was at least 94% of the reference IBI. Honey Lower showed an increase in the percentage of tolerant species and a decrease in the percentage of lithophilic spawners over the decade examined, which resulted in a lower IBI score. Honey Upper and Saline remained relatively stable in most metric values and overall IBI scores.

Table 21. Fish metrics used for calculation of IBI score and resulting IBI and percent of reference.

Site	Date	Total Species	# Darters	# Sunfish Species	# Intolerant Species	% Tolerant Species	% Insectivorous Cyprinids	% Lithophilic Spawners	OCC IBI	% Reference IBI
Honey Creek: Lower	10/21/1999	20	4	6	11	1.86%	22.53%	98.07%	33	1.00
	8/17/2006	19	2	6	9	4.37%	52.08%	93.35%	31	0.94
	7/24/2008	26	3	7	11	12.82%	38.33%	84.01%	31	0.94
	7/29/2009	22	3	7	10	10.04%	34.50%	88.10%	31	0.94
Honey Creek: Upper	9/20/2006	18	3	4	12	0.42%	35.37%	99.58%	33	1.00
	7/31/2008	19	3	5	12	1.74%	50.52%	98.26%	35	1.06
	7/29/2009	19	3	6	11	1.31%	42.24%	98.69%	33	1.00
Saline Creek	8/12/1998	17	5	3	11	0.57%	34.57%	98.57%	33	1.00
	8/2/2001	21	5	6	12	0.70%	25.99%	99.12%	33	1.00
	7/13/2006	19	5	5	12	2.22%	23.33%	96.11%	33	1.00
	8/3/2009	22	5	6	12	1.90%	25.51%	95.92%	33	1.00

Instream and riparian habitat assessments were conducted at sites concurrent with fish collections. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2010). The OCC's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (as described in the SOP) and is designed to assess in-stream habitat quality in relation to its ability to support biological communities in the stream. Detailed field records are taken every 20 meters over a 400 meter transect. This data is then condensed into 11 primary parameters in order to assess micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate makeup, stable cover, canopy, depth, and velocity. Macro scale assesses the channel morphology, sediment deposits, and other parameters. Riparian/bank structure includes riparian zone quality, width, and general makeup (trees, shrubs, vines, and grasses) as well as bank features, including bank erosion and streamside vegetative cover. Table 22, below, shows the scores of the 11 parameters used to determine habitat quality relative to high quality sites in the ecoregion. At least three habitat assessments were performed at each site over the last decade.

Table 22. Habitat assessment metrics, total habitat score, and site total score relative to reference site score for this ecoregion.

Site Name	Date	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points	% of Reference
Honey Creek: Lower	10/21/1999	19.3	19.0	19.0	9.9	14.7	20.0	0.4	1.5	7.0	5.2	9.9	125.8	1.05
	8/17/2006	19.5	15.8	20.2	0.8	14.1	13.3	2.3	1.7	9.9	8.4	9.2	115.2	0.96
	7/24/2008	19.0	12.8	14.6	3.8	16.1	20.0	0.4	1.2	8.8	7.0	9.5	113.2	0.94
	7/29/2009	17.3	14.6	20.2	5.7	16.3	20.0	2.3	1.2	9.0	6.0	6.4	119.0	0.99
Honey Creek: Upper	9/20/2006	19.6	18.5	13.0	14.1	15.9	11.9	0.4	0.6	7.2	3.4	3.6	108.2	0.90
	7/31/2008	19.4	17.5	18.8	19.1	15.2	19.3	0.4	1.3	5.8	3.1	9.5	129.4	1.08
	7/29/2009	18.5	16.0	15.0	14.1	16.1	20.0	0.4	0.8	6.7	4.7	8.0	120.3	1.00
Saline Creek	8/12/1998	19.0	18.9	19.3	2.2	16.3	15.8	0.4	0.0	6.6	2.8	9.1	110.3	0.92
	8/2/2001	18.0	16.2	17.2	7.7	15.2	15.0	0.4	0.0	5.1	1.6	8.4	104.7	0.87
	7/13/2006	13.0	17.2	0.0	2.7	16.3	17.0	1.4	0.0	3.1	1.8	8.9	81.3	0.68
	8/3/2009	14.6	14.8	17.2	3.0	16.1	20.0	0.4	0.0	4.4	1.0	8.9	100.3	0.84

In general, Honey Creek in-stream habitat is excellent. Saline Creek had a low habitat score in 2006 and had rebounded somewhat by 2009. It is possible that in-stream activities such as gravel mining contributed to this result.

Macroinvertebrates

Macroinvertebrate collections were attempted at all sites twice a year, once in the winter period (January 1 to March 20) and once in the summer period (July 1 to September 15). Macroinvertebrates were only collected if there was flowing water, so in dry periods, no samples were obtained. Macroinvertebrates were collected only from rocky riffles in this project, using methods adapted from the EPA Rapid Bioassessment Protocols (Plafkin et al. 1989). The sampling effort consisted of three, one meter squared kicknet samples in areas of rocky substrate reflecting the breadth of the velocity regime at a site. Riffles with substrates of bedrock or tight clay were not sampled. Each sample was preserved in quart mason jars with ethanol, labeled, and sent to a professional taxonomist for subsampling and identification.

Table 23. Macroinvertebrate metrics used to calculate an IBI score, score percent of reference, and biological condition of sites. In the "Season" column, "S" denotes the summer index period and "W" indicates the winter period.

Season	Collection Type	Date	Site	Total Species	# EPT Taxa	Percent EPT Taxa	Shannon Diversity	HBI	Percent Dominant 2 Taxa	Total IBI Score	% of Ref. Total Score	Condition
S	riffle	17-Aug-06	Honey Creek: Lower	24	6	0.23	2.83	4.29	0.29	26	0.95	non-impaired
S	riffle	10-Jul-07	Honey Creek: Lower	20	8	0.36	2.41	4.55	0.37	28	1.02	non-impaired
S	riffle	22-Jul-08	Honey Creek: Lower	25	9	0.32	2.53	3.94	0.39	30	1.10	non-impaired
S	riffle	05-Aug-09	Honey Creek: Lower	25	13	0.45	2.60	4.49	0.23	32	1.17	non-impaired
W	riffle	07-Feb-07	Honey Creek: Lower	19	11	0.33	2.33	5.48	0.46	22	0.72	slightly impaired
W	riffle	04-Mar-09	Honey Creek: Lower	28	10	0.29	2.67	3.33	0.39	24	0.78	slightly impaired
S	riffle	20-Sep-06	Honey Creek: Upper	19	9	0.35	2.37	3.79	0.45	26	0.95	non-impaired
S	riffle	10-Jul-07	Honey Creek: Upper	21	9	0.40	2.30	5.80	0.46	24	0.88	non-impaired
S	riffle	22-Jul-08	Honey Creek: Upper	25	9	0.33	1.96	4.67	0.00	32	1.17	non-impaired
S	riffle	05-Aug-09	Honey Creek: Upper	21	9	0.26	2.19	4.60	0.53	24	0.88	non-impaired
W	riffle	07-Feb-07	Honey Creek: Upper	24	6	0.08	2.21	6.36	0.02	16	0.52	moderately impaired
W	riffle	04-Mar-09	Honey Creek: Upper	20	11	0.27	2.06	2.36	0.56	22	0.72	slightly impaired
S	riffle	26-Jun-06	Saline Creek	14	3	0.13	2.04	4.54	0.54	14	0.51	moderately impaired
S	riffle	10-Jul-07	Saline Creek	19	7	0.28	2.13	5.46	0.51	20	0.73	slightly impaired
S	riffle	02-Aug-07	Saline Creek	16	6	0.05	1.40	4.08	0.76	14	0.51	moderately impaired
S	riffle	05-Aug-08	Saline Creek	22	9	0.21	2.20	5.68	0.50	22	0.80	slightly impaired
S	riffle	16-Jul-09	Saline Creek	17	4	0.10	1.72	5.47	0.69	14	0.51	moderately impaired
W	riffle	06-Feb-07	Saline Creek	20	8	0.15	1.58	4.60	0.71	16	0.52	moderately impaired
W	riffle	17-Mar-09	Saline Creek	18	11	0.17	1.66	4.99	0.77	18	0.59	slightly impaired

Data was collated by year and season. As with the fish collections, the method used to determine the condition of the macroinvertebrate communities at each site is based on and modified from methods outlined in the EPA Rapid Bioassessment Protocols (Plafkin et al. 1989). The biological data was compared relative to data from high quality cool water aquatic community (CWAC) sites in the Ozark Highlands ecoregion following the method described in the latest Rotating Basin report (OCC 2011). A total IBI score was calculated from six metrics and compared to high quality sites in the ecoregion to determine overall macroinvertebrate health. Table 32 shows summarized results for each collection and how the overall IBI compares to high quality streams in the ecoregion.

As observed in Table 23, all summer collections at both Honey Lower and Upper were "non-impaired." Winter collections at Honey Lower were "slightly impaired" relative to high quality sites in the ecoregion, while at Honey Upper, one winter collection was moderately impaired and the other was slightly impaired. All collections at Saline Creek were either slightly or moderately impaired. Gravel mining has been reported on that stream, so that type of activity could be impairing the macroinvertebrate community by contributing to channel instability and dewatering upstream. Figure 26, below, indicates that Honey Lower had improved macroinvertebrate communities over time, trending upwards of the average high quality IBI score, while the IBI scores for Honey Upper and Saline remained approximately stable over time.

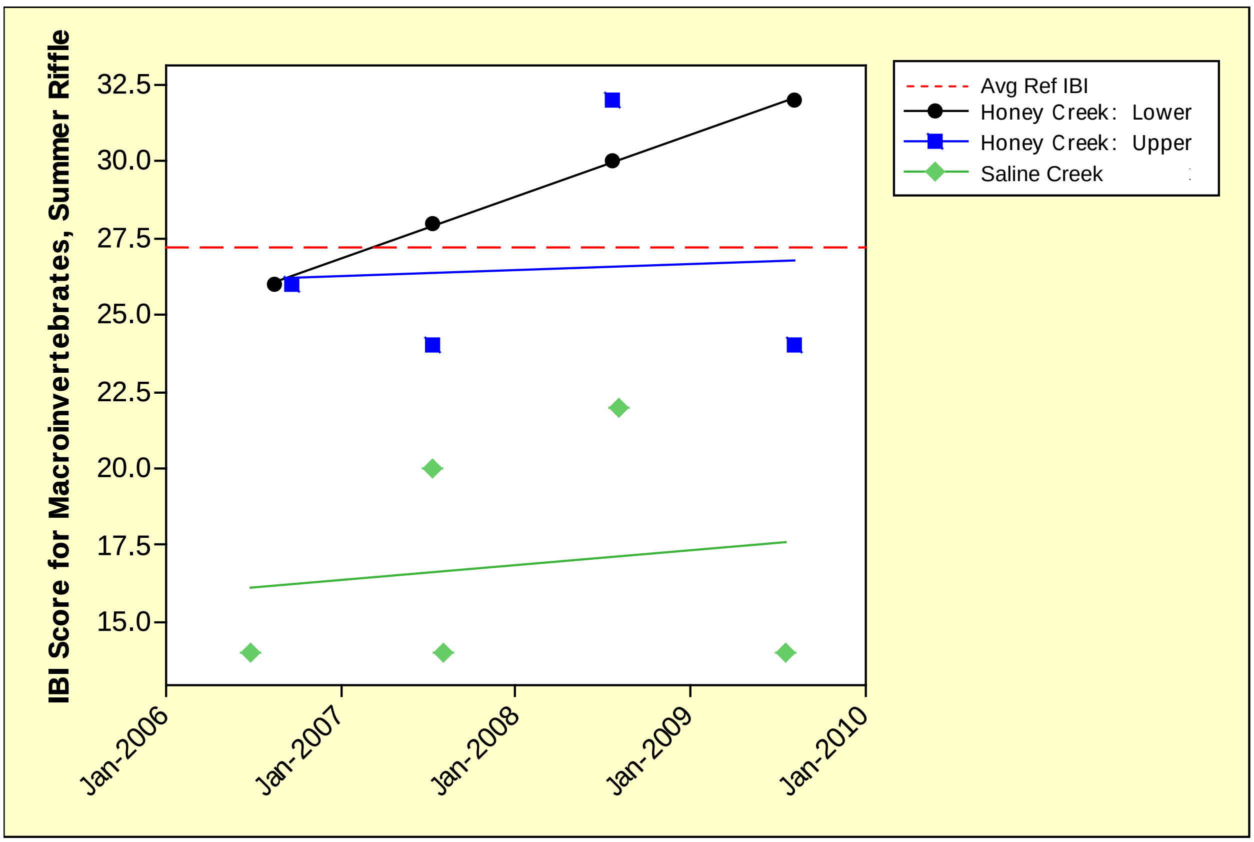


Figure 26. Macroinvertebrate IBI scores for summer riffle collections. The red dashed line represents the average summer riffle IBI score for high quality sites in the Ozark Highlands ecoregion

Bacteria

Honey Creek Upper was added to the 2010 303(d) list as not attaining the designated Primary Body Contact Recreation (PBCR) use due to impairment by *Enterococcus* and *E. coli* bacteria. The criteria for being placed on the 303(d) list of impaired waters are described in the Oklahoma State Standards (OWRB 2009). Bacteria concentrations are only assessed during the warm weather recreational period, defined as May 1 through September 30 of every year. Both Honey Creek sites and the Saline Creek site exhibited lower bacteria levels in the treatment period than in the calibration period (Figure 27, below). This could be as least in part a result of wetter years in 2007-2009 as compared to 2009-2010, but the BMPs installed through the project are expected to reduce both runoff and direct contribution of animal wastes into the stream.

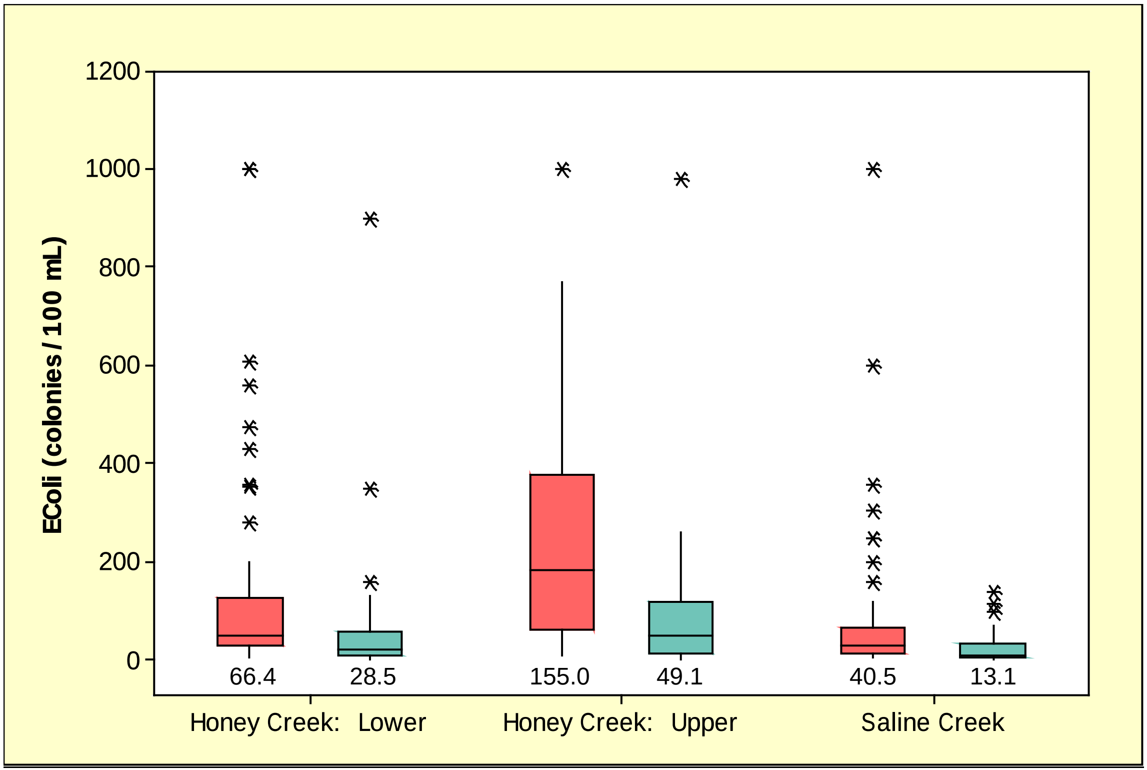


Figure 27. Boxplots of the bacteria data for Honey Lower, Honey Upper, and Saline Creek. The calibration period data, 2007-2009, is shown in red, while the implementation period data, 2009-2010, is shown in blue. The numbers below each boxplot are the geometric means of the data for that period.

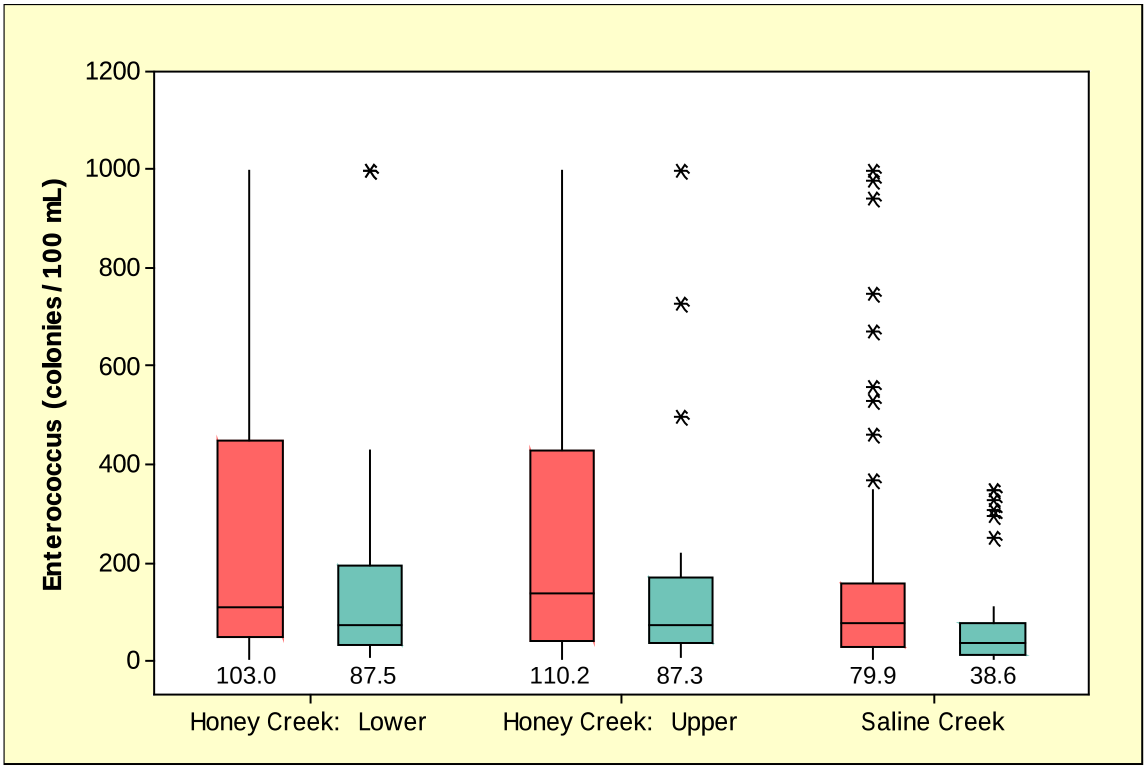


Figure 27, continued. Boxplots of the bacteria data for Honey Lower, Honey Upper, and Saline Creek. The calibration period data, 2007-2009, is shown in red, while the implementation period data, 2009-2010, is shown in blue. The numbers below each boxplot are the geometric means of the data for that period.

To examine the effects of BMP implementation while accounting for any predominant environmental effects, such as less rain during the treatment period, the paired watershed analysis method was used to calculate the change in bacteria levels in the treatment period relative to the expected bacteria levels based on the calibration period relationship between the treatment and control sites. Instantaneous loads were calculated for both *E. coli* and *Enterococcus* for each sampling event. Since the bacteria analyses were based on grab samples representing a single point in time, the instantaneous load (expressed as colony forming units per second; "cfu/sec") was calculated by multiplying the bacteria concentration (colony forming units per 100 mL; "cfu/100 mL") from each grab sample by the instantaneous discharge (cubic feet per second; "cfs") measured at the time of sample collection and then adjusting for the volume of water at that time. **Load reductions of nearly 40% were observed for both *E. coli* (34.7%-37.8% reduction) and *Enterococcus* (37.6%-38.2% reduction) in the treatment period relative to the calibration period.** Figure 28 below shows the regression equations from the paired sites analysis.

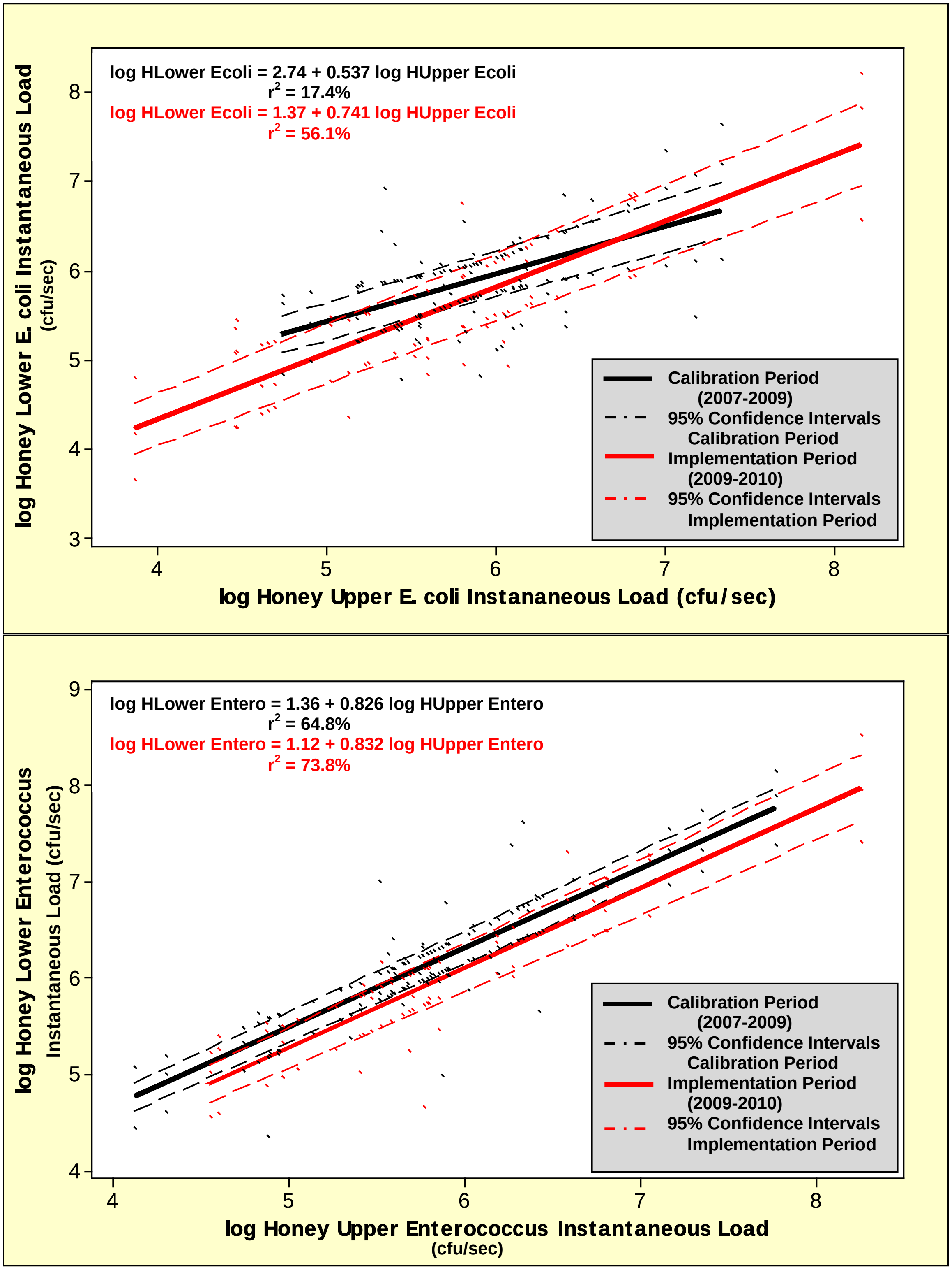


Figure 28. Regressions of log-transformed *E. coli* and *Entercoccus* bacteria instantaneous load. 95% confidence intervals for each regression line are indicated by dashed lines. The equations for the regression lines are given at the top of the graph, with black lines and font representing the calibration period and red lines and font depicting one year of implementation.

Conclusion

The Honey Creek Watershed Implementation Project and the Northeastern Oklahoma Demonstration Farm Project enabled successful implementation of approximately 1.7 million dollars of best management practices (BMPs). Prioritizing implementation based on SWAT model results enabled best use of funds to install BMPs where they would have the most impact on reducing total phosphorus loads. In all, nearly 50% of the Oklahoma portion of the Honey Creek watershed was included in BMP implementation of some sort through this project, and 42% of the land in high phosphorus load areas had some form of BMP installed on it. This level of participation was outstanding, especially since this is a voluntary program, and other programs such as EQIP are available in the area.

The installation of BMPs on this scale has resulted in decreasing phosphorus and bacteria loads, evident even only a very short time after implementation. Total phosphorus loading was reduced by between 9 and 15% over what was expected, while bacteria loading was reduced by nearly 40%. It is expected that the load reductions discussed in this report will increase over time, since some BMPs were just recently installed and the effects may not have been captured yet by the data presented here.

None of the nitrogen parameters showed significantly decreased loading, most likely due to the major point source discharge into Cave Springs Branch, a significant tributary of Honey Creek, in Missouri. A Cave Springs Branch TMDL document produced by the Missouri Department of Natural Resources stated that “surface water discharges from the Simmons Foods, Inc. facility influenced nitrogen concentrations as measured at the state line [in Cave Springs Branch], while phosphorus and bacteria at the state line and downstream appear to be most influenced by nonpoint sources” (MDNR 2010). The MDNR has recommended a phased implementation approach to reduce the wasteload allocations from the Simmons plant into Cave Springs Branch. The Simmons facility has made significant improvements in recent years, including upgrades and operational improvements, closing old lagoons, and transporting poultry litter off site, and further actions should result in significantly reduced nitrogen loading into Honey Creek.

Another benefit of BMP implementation on water quality was evident in the steady increase in macroinvertebrate health at the Honey Creek Lower site. The Honey Upper site had “non-impaired” macroinvertebrate collections throughout the project, but the scores varied over time, sometimes being higher and sometimes lower. The Saline macroinvertebrate scores similarly fluctuated throughout the project. The linear improvement at the Honey Lower site, going from 95% of the reference score to 117% of the reference score, indicates excellent water quality, improved and protected by the BMPs that were installed during this project.

Participants often convey the positive effects that they have seen on their land as a result of implementation, and this encourages others to try out the program. The project coordinator tracked how participants (or potential participants) learned about the Honey Creek project and found that 55 applicants were told about it by a friend or neighbor, 16 saw information about the project in the local newspaper or the district newsletter, and 30 had been contacted by OCC or NRCS personnel. OCC staff conducted interviews with a few participants in the Honey Creek watershed, and here are a few of the quotes that resulted:

- *"I can raise more pounds of beef per acre than what I could have before, primarily because of the ability to rotate my pastures."*
- *"If we can manage our land better and build a seed bank of native grasses and a better, more stable river bank, then that flood—if it happens, it won't be as catastrophic."*
- *"[Some OCC people] came out and was in the stream with the seine, and they were pulling fish and different things out of there that theoretically had gone, had not been there for a few years. And now they're back."*
- *"It helps the bottom line because you're utilizing more of your acreage than before."*
- *"We can actually run more animals than what we previously could….Now we rotate them every 30 days. We have a lot better grass."*

Landowner interest in the 319 program in Honey Creek continues. Additional funding has been granted through special 319 funds in order to expand the implementation achieved so far. Data will continue to be collected at least until the end of the special project funding, and then the paired watershed method will be used to redo the analysis presented in this report with the expectation that even greater load reductions will be observed. It is expected that with the additional implementation of BMPs, water quality in the Honey Creek watershed will steadily improve.

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