DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Big Creek Research and Extension Team

University of Arkansas System Division of Agriculture

Quarterly Report – July 1 to September 30, 2014

MONITORING THE SUSTAINABLE MANAGEMENT OF NUTRIENTS ON C&H FARM IN BIG CREEK WATERSHED

Mission of the University of Arkansas System Division of Agriculture

The mission of the **Division of Agriculture** is to advance the stewardship of natural resources and the environment, cultivate the improvement of agriculture and agribusiness, develop leadership skills and productive citizenship among youth and adults, enhance economic security and financial responsibility among the citizens of the state, ensure a safe, nutritious food supply, improve the quality of life in communities across Arkansas, and strengthen Arkansas families.

Dr. Mark J. Cochran
Vice President for Agriculture

MONITORING THE SUSTAINABLE MANAGEMENT OF NUTRIENTS ON C&H FARM IN BIG CREEK WATERSHED

Executive Summary

This is the fourth Quarterly Report of the Big Creek Research and Extension Team that details the following progress made from July 1 through September 30, 2014.

1. Comments of the Expert Review Panel that took place in late spring were received and a response to their comments developed.
2. A Big Creek Summit was held on September 11, 2014, at the Pauline Whitaker Center, University of Arkansas. All involved in research and monitoring on the Big Creek were present including Dr. Van Brahana – retired Geosciences University of Arkansas, Faron Usrey – Park Service, Victor Roland – Geosciences University of Arkansas, USGS scientists, and BCRET Division of Agriculture members.
3. A trench was installed downslope of the manure holding ponds to monitor potential leakage from the holding ponds.
4. Sampling of Big Creek continued every week above and below the C&H Farm, a well adjacent to the production houses, a subwatershed draining the production area, surface runoff from Fields 1, 5a, and 12, and a spring below Field 1.
5. Continuous flow and storm sampling at the upstream and downstream sites continued during the quarter, in collaboration with USGS. The downstream site is providing real-time, on-line stream discharge, nitrate concentrations, water temperature, and rainfall data.
6. Hog barn wash-water contribution to manure volume was calculated as background information for the potential manure management options. A topographic elevation survey of the holding ponds and surrounding drainage area was conducted to determine the as-built volumes of the holding ponds and the precipitation catchment area of the ponds.

Big Creek Research Team

Faculty

Andrew Sharpley, Ph.D., TEAM LEADER – Distinguished Professor - Soil science, water quality, soil phosphorus chemistry, agricultural management

Kris Brye, Ph.D., Professor - Effects of land application of poultry litter on in-situ nutrient leaching, effects of land use and management practices on soil physical, chemical, and biological properties related to soil quality and sustainability

Rick Cartwright, Ph.D., Professor – Associate Director of Extension for Agriculture and Natural Resources

Mark Cochran, Ph.D., – Vice President, University of Arkansas System Division of Agriculture.

Mike Daniels, Ph.D., Professor – Extension water quality and nutrient management specialist

Ed Gbur, Ph.D., Professor and Director, Agricultural Statistics Laboratory - Experimental design, linear and generalized linear mixed models, regression, agricultural applications of statistics.

Brian Haggard, Ph.D., Professor - Ecological engineering, environmental soil and water sciences, water quality chemistry, water quality monitoring and modeling, algal nutrient limitation, pollutant transport in aquatic systems

Phil Hays, Ph.D. Ground Water Specialist, U.S. Geological Survey and Research Professor with Geosciences Dept., University of Arkansas, application of stable isotopes and other geochemical indicators in delineating movement and behavior of contaminants in ground-water systems

Tim Kresse, M.Sc., Water Quality Specialist, U.S. Geological Survey, natural geochemical evolution of groundwater and separating these processes from anthropogenic sources of contamination

Nathan McKinney, Ph.D., – Assistant Director, Agriculture Experiment Station

Mary Savin, Ph.D. - Structure and function of microbial communities in natural and managed ecosystems, microorganisms in nutrient cycling, contaminant degradation

Thad Scott, Ph.D., Assistant Professor - Water quality, transport of contaminants to and within water bodies

Karl VanDevender, Ph.D. and P.E., Professor - Extension Engineer, Livestock and poultry manure and mortality management, nutrient management planning

Jun Zhu, PhD., Professor - Biological and agricultural engineering, agricultural sustainability, manure treatment technologies

Adam Willis, M.Sc., Newton County Extension Agent - Agriculture

Field Technicians

The Big Creek Research and Extension Team are ably supported by several excellent Program Technicians based in Little Rock and Fayetteville.

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Expert Panel Review of BCRET Project

Memoranda

Date: – May 19, 2014

From: – **Dr. Carl Bolster**, Agricultural Research Service, U.S. Department of Agriculture, Bowling Green, KY
– **Dr. Lee J. Florea, P.G.**, Department of Geological Sciences, Ball State University, Muncie, IN
– **Dr. Martin J. Shipitalo**, Agricultural Research Service, U.S. Department of Agriculture, Ames, IA
– **Mr. Mark Rice**, Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC

To: – **Dr. Mark J. Cochran**, Vice President for Agriculture, University of Arkansas, Little Rock, AR

Re: – Report from Expert Panel – C&H Farms Research Project

Dear Dr. Cochran,

It was our pleasure to meet you and spend a few days in Fayetteville at the end of April. We certainly hope that our visit was productive for your team and that the report below provides a constructive review of the research underway at C&H Farms and the surrounding environs of Mt. Judea in Newton County, AR. We are cognizant of the important and sensitive nature of this research to the University, the State, stakeholder agencies and organizations, and the citizens of Newton County including the owners of C&H Farms. Therefore, the scope of the Panel and the content of this report do not include opinion or endorsement for or against the operation of the farm, the permitting process, or the origin of funding for this research. Rather, this report includes the recommendations and opinions of the Panel with regard to the strengths and challenges of current and planned activities associated with this research project.

Scope of investigations

On April 28 to May 1, 2014 the four-member Panel met to review the current and planned monitoring program associated with the C&H Hog Farm operation in Mt. Judea, Arkansas. Panel members were selected for their expertise in surface hydrology and groundwater hydrogeology (Bolster), cave and karst science (Florea), soil use and management (Shipitalo), and swine animal and manure management (Rice). The Panel met with members of the Big Creek Research Team (herein referred to as the 'Team'), University of Arkansas Administration, the manager of C&H Farms, and spent one day touring the farm and the proposed and current monitoring locations.

The Panel spent April 29 in the field and visited key sites such as the swine waste ponds at the C&H facility, ephemeral and perennial surface waterways draining into Big Creek, and several karst features in the watershed including sinkholes and springs. Panel members also visited instrumented sites surrounding the facility that are currently part of the Team's monitoring efforts. On the second day, Panel members met with members of the Team and Administration to go over aspects of the monitoring plan.

Summary of Findings

The complexity of the landscape and the farming operation presents a challenging task for the Team. However, the unfettered access of the Team to facilities and some of the application sites surrounding of Mt Judea in the Big Creek watershed is a strong benefit. Overall, the Panel was pleased with the collaborative nature of the Team, which included a wide range of experts suited to study the impacts of agriculture upon water quality. The Panel was also encouraged by the Team's openness to suggestions for improving the research and monitoring plan. The decision to hire a full-time technician to oversee the monitoring locations and the samples collected from those locations was appropriate and a good use of available resources. Both the Team and Panel, however, recognized the need for the addition of a karst hydrogeologist to the Team. The Panel was encouraged to learn that additional resources, both in equipment and personnel (including a scientist trained in karst hydrogeology), were being solicited from other agencies such as the U.S. Geological Survey. The Panel recognizes that this monitoring plan will require a substantial effort from the Team, and may place a considerable strain on untenured faculty and other scientists with significant commitments to other projects.

A key aspect of the Panel's charge was to identify limitations of the current research and monitoring plan and to provide input on possible solutions or augmentations within budget and time limitations. Even with the best monitoring system there can be considerable lag time between a change in management and system response. Thus, it is highly unlikely that a one-year study will provide sufficient information to conclusively determine the impact that the farming operations at C&H farms have on the water draining into the Big Creek. This is compounded by the fact that limited data on water quality are available prior to the onset of the farming operations. Additionally, within the Big Creek watershed there are a number of other ongoing land management and land use activities that can impact water quality. This includes other farming operations, domestic and wild livestock, and residential and municipal sewage systems. Securing resources, perhaps from multiple sources, to continue the monitoring efforts beyond the initial year should be a priority for the Team leaders. Finally, extreme events are often the driver of hydrologic responses to environmental stressors and we recommend that more effort be directed at sample collection during high-flow events.

Within this context, the Panel recognized three major potential threats to water quality associated with C&H Farms. These include: 1) leakage from the two onsite waste storage ponds, 2) contamination of surface and subsurface water due to land application of the wastes, and 3) potential long-term buildup of soil nutrient levels (primarily soil phosphorus) due to application in excess of crop needs and removal. These are each described below. Included are challenges the Panel identified along with recommended solutions.

Potential leakage from the waste storage ponds. Currently a single surface water monitoring station is positioned down gradient from the ponds that is capable of sampling intermittent flow events. This should be kept in place. In addition, water usage is being measured in the confinement buildings. The Panel recommends that a short-term, detailed water balance study be conducted to determine the actual seepage rate of the storage ponds. This more robust approach would include a measure of all liquid inputs to the ponds, withdrawals from the ponds, the liquid levels of the ponds and evaporative losses. The results would allow for the calculation of actual seepage rate (within certain bounds) from the storage ponds for comparison to design specifications and standards. In addition, a total water balance approach will identify other potential losses of liquid in excess of that which can be attributable to evaporation and planned withdrawals, either for land application or barn flushing.

Adjacent to the housing complex there is a single water supply well. Given the information provided on well design, depth, and construction, combined with the available information on nearby soil borings, it is unlikely that the water in this well will be adversely affected by leakage from the storage ponds. Nevertheless, the Panel recommends that water quality samples continue to be collected from this well on a routine basis. In addition, the Panel recommends that the detailed well driller's log be obtained and that a slug test, pump test, or both be conducted on this well to determine characteristics of the aquifer from which water is drawn.

Team members should conduct a detailed walking survey of the slope down gradient from the waste ponds to identify potential seeps and springs from perched aquifers. These have some potential for impact by leakage from the ponds. If perched aquifers are noted based on the driller's log or by the identification of hillside seeps, one or more shallow monitoring wells should be installed to the depth of the perched aquifer within as short a distance as feasible from the storage ponds. If springs or seeps are noted on the hillside, these should be monitored on a routine basis to establish baselines and trends in water quality.

Effects of Land Application. The current plan has two components: 1) automated sampling and gauging of Big Creek at two sites—one upstream from all permitted C&H Farm activities and a second site downstream from all permitted activities, and 2) sampling of surface runoff and soil water within three fields where land application of wastes are currently planned. The Panel recognizes that the selection of monitoring sites is dictated in part by accessibility and landowner permission and thus may be less than ideal. We suggest the following be conducted as soon as possible.

- An inventory of the entire reach of Big Creek between the upstream and downstream sampling points with georeferenced notes made on any significant changes in water flow due to tributaries or major springs. This inventory should include karst features located within the contributing area.
- A detailed land use map that identifies all land uses within the contributing area of the watershed. This should include surveys of farmers to gauge land management practices,

with particular emphasis on animal stocking practices, fertilization, and manure applications.

- A seepage survey to include stream profile measurements and estimations of discharge. The stream survey should be repeated under high (if feasible), medium, and low flow conditions to capture the potential variability in groundwater recharge and discharge to the riparian zone, valley alluvium, and karst features (if present).
- Develop rating curves between water level and discharge at both the upstream and downstream sites.
- Conduct traces with multiple dyes. The first set of traces should be qualitative to identify the potential connections between points of recharge and discharge. Once established, quantitative traces should be conducted with both conservative and non-conservative dyes to establish travel times and dispersion characteristics. Results of the traces, for example from the sinkhole in Field #1 to the spring downslope, may help revise the area for manure application.

During our tour of the watershed the Panel took particular note of a significant tributary known as Dry Creek located shortly downstream of the upstream Big Creek monitoring site. The Dry Creek watershed includes an estimated 1/3 of the proposed land area approved for manure application from C&H Farms. An automated sampling and gauging station should be installed as close to the confluence with Big Creek if landowner permission can be secured. Monitoring of this additional site should help reduce some of the confounding influences of non-C&H land management practices that may contribute to loadings at the larger downstream sampling location.

Currently, surface runoff flumes have been or are being installed in three fields designated for manure application. Given the geomorphology of these sites, the composition of the soils, and the current land management practices (e.g., permanent grass cover) surface runoff may not be a major contributor to water quality concerns under normal rainfall conditions. Nevertheless, the Panel recognizes the need to monitor surface runoff and recommends that more emphasis be placed on a sampling protocol to better capture flow-weighted samples during runoff events. The potential for movement of contaminants to groundwater at these sites is currently being assessed using piezometers and shallow monitoring wells. Additionally, ground penetrating radar (GPR) transects were made to characterize the subsurface conditions that could potentially contribute to preferential flow of water and contaminants in these fields. While GPR may provide useful information on shallow subsurface characteristics, this technique does not provide meaningful information on potentially deeper flow paths. The Panel recommends that more sophisticated geophysical surveys (such as terrain conductivity and electrical resistivity tomography) be conducted, if feasible, to more fully characterize the subsurface environment in these fields in lieu of further GPR studies. If these procedures document significant subsurface features that can affect water flow, subsurface investigations (i.e., drilling) should be conducted to confirm these observations. Depending on the results of these studies, relocation of existing piezometers and shallow monitoring wells or installation of additional equipment should be considered so that the potential impact of these features on subsurface water quality can be assessed.

Nutrient buildup. Detailed soil sampling has been conducted on a grid basis to characterize available soil P levels in the monitored manure application fields. This has provided useful information and should be repeated post-manure application. If buildup of soil P levels is noted, the results of the manure solids and liquid separation trials that are being conducted as part of the project may offer an opportunity to better match waste applications to specific crop and soil fertility needs. In general, the manure solids will have a lower N:P ratio than the liquid fraction. Ideally, the dryer solid fraction could be applied to fields where soil P levels are low or transported out of the watershed altogether. In light of C&H Farm's use of additives to enhance the function of the waste storage ponds, a regular sampling of storage ponds is important to understand the effects of the additives and to determine variability in nutrient concentrations.

Additional Analyses

As part of the review, the Panel considered whether the existing sampling protocol undertaken by the Team would sufficiently answer their primary monitoring and research goals. Depending on results from initial sample collections, interpretations of those data by the Team, and available funding, we recommend the Team consider adopting some or all of the following:

Source tracking of nutrients and bacteria. While this is time consuming and can be prohibitively expensive to conduct on a routine basis, if elevated contaminant levels are noted at the downstream site relative to the upstream monitoring locations, source tracking using isotopic or PCR methods may provide additional information needed to establish whether activities associated with C&H are a contributing factor.

Supplemental chemical parameters. Studying watershed hydrology and geochemistry is regularly enhanced by combining a multi-parameter approach. For example, the use of multiple water quality parameters may provide additional information on flow paths, residence times, and sources that may otherwise be difficult to interpret on limited sources of data. Therefore, the Panel recommends that the Team consider, if practical, the following additional analytes:

- Principal ions
- Alkalinity
- Appropriate trace metals
- Environmental isotopes (including C/N ratios)
- Ammonia, Nitrite, and Nitrate fractions of total N
- Emerging contaminants (caffeine, hormones, antibiotics, etc.)

Storm event sampling. Wide-ranging studies of watershed processes and contaminant transport demonstrate the importance of storm events. In this particular investigation, the transport of waste offsite may be strongly correlated to periods of overland flow on application fields. While the Panel is encouraged to see instrumentation specifically designed to capture this overland flow, it would be beneficial to capture more than a single composite sample, particularly for long lasting storms.

In summary, the Panel was impressed with the progress made thus far and was encouraged by the collaborative environment fostered by the Team leaders. Monitoring activities thus far are important, but perhaps not fully adequate in scope and duration to address the long-term potential for impacts to the quality of surface and groundwater resources. It is our hope that the above recommendations in this report may be of benefit to you and your team when developing future monitoring and research activities. We submit this report in the spirit of helpfulness, and thank you for providing us the opportunity to review the project.

Sincerely,

- Carl Bolster

- Lee Florea

- Mark Rice

- Martin Shipitalo

Panel members

cc: Andrew Sharpley
Nathan McKinney

Expert Panel Review Response

Response to the Expert Panel Review of the BCRET Project

We greatly appreciate the Review Panel's time and effort spent reviewing our Big Creek Research and Extension Team's Project at Mt. Judea. Your visit to the sites, meeting with Project personnel, and preparing a detailed report has been very helpful to our project. A response to the comments and suggestions raised in your report is given below detailing how the Team will address them.

A. **Potential Leakage from the Waste Storage Ponds:** We agree that the potential for leakage of manure from the storage ponds needs to be closely monitored. To address this we will install a trench downslope of the storage ponds that will intercept any subsurface flow of leakage moving along a restricting or less permeable layer. See Figure 1 for site plans. Initial soil coring reveals a natural cherty layer about 48 inches deep in the profile. Digging a trench below this depth will enable more precise characterization of this, and any other relevant low-permeability features. Once identified, a metal plate will be positioned on the profile just below the preferential flow layer to ensure water is intercepted and collected in a perforated pipe, taking flow to a downslope sampling point. Depending on site conditions, it is envisaged that this trench will be approximately 30' to 40' long and 6' deep. The perforated pipe will be embedded in pea-sized gravel and the top foot of the trench backfilled with soil. This trench collection system has been widely used to monitor shallow subsurface flows in karst systems and USGS have successfully installed one locally in the past to monitor leakage from a swine lagoon. We feel this approach is more technically rigorous to detect and collect seepage than installing single-point wells downslope of the waste storage ponds. Installation will be complete by the end of July. An inventory of karst seeps or springs immediately down slope of the storage ponds will be conducted. These karst features represent natural emergence points where integration of flow occurs and will offer additional sampling points for detecting potential leakage.

B. **Pond Water Balance:** The panel recommended conducting a short-term detailed water balance of the storage ponds. Given precision limits for the various direct and indirect measurements needed to estimate the seepage loses and the fact that the ADEQ's design criteria is 5000 gal/ac/day which is the same as 0.0013 in/day, we are concerned that a detailed water balance determination is not appropriate at this time. Rather the trench collection system will be used to test soil water for indications that it is seeping from the ponds. If these results indicate the need they and a rough water balance based on precipitation and pumping records will be used to reassess the feasibility of a detailed measured water balance for the storage ponds.

C. **Effects of Land Application:**

(i) We plan to conduct a water quality inventory along the reach of Big Creek between up and downstream sampling points this summer and fall with sondes continually determining water temperature, pH, dissolved oxygen, and turbidity. At the same time, USGS Hydrogeologists will conduct a visual survey for any obvious springs along the near stream areas of Big Creek.

(ii) While a detailed land use surveys to determine field management practices in the Big Creek Watershed is a laudable recommendation, it is outside the scope of our "charge." Voluntary

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participation in such as survey by farmers in the watershed would likely be minimal given the public scrutiny of the project and Arkansas's Freedom of Information requirements. However, an aerial land-use survey will be conducted in the main watershed to determine the areas under pasture and forest.

(iii) Seepage survey: we plan to conduct such a survey, led by the USGS Hydrogeologists on the Team and recruited University of Arkansas Geology students.

(iv) Rating curves for both up and downstream monitoring and water sampling locations are in development. This has been contracted to USGS.

(v) Tracer studies with multiple dyes will be conducted on known sink holes on permitted monitoring fields (i.e., Fields 1, 5a, and 12) and on the losing reach of Big Creek, while this will identify surface and subsurface flow connectivity, it does not relate to current manure management practices, which broadcast slurry to pastures.

D. **Dry Creek Monitoring:** Plans are underway to monitor flow and collect base and stream flow samples where Dry Creek enters Big Creek. Installation should be completed by the end of July. Dry Creek contains approximately 1/3 of the fields permitted to receive manure that are more distant from Big Creek but drain into Dry Creek and ultimately to Big Creek.

E. **Electrical Resistivity Measurements:** We do plan to contract with experts to conduct electrical resistivity measurements that can identify subsurface flow pathways with minimal surface disturbance, more accurately than ground penetrating radar already conducted. This is planned for before and after a manure application; ideally in the fall or spring when forage height is minimal.

F. **Nutrient Buildup:** The detailed grid-soil sampling (0.25 acre grid) will be conducted annually in late fall or early winter for each monitored permitted field (i.e., Fields 1, 5a, and 12).

G. **Bacterial Source, Isotope or PCR Tracking:** We agree that these methods are time consuming and prohibitively expensive, as well as being research tools that might qualify but not quantify sources, and we will consider them, along with the measurement of antibiotics and hormones, if and when elevated contaminant levels are found at a specific location.

H. **Supplemental Chemical Parameter Measurement:** Will be considered on an as-needed basis and with funding availability. A Master's Student has been enlisted to conduct a survey of the biological and nutrient status of several waters in the Buffalo River Watershed, including Big Creek at the downstream sampling station.

I. Storm-Event Sampling: Is now occurring at all water quality monitoring sites; Big Creek up and downstream of the C&H Farm, surface runoff from Fields 1, 5a, and 12, culvert draining the subwatershed draining the production houses and manure storage ponds. We collaborated with USGS to continuously monitor nitrate concentrations in Big Creek downstream of the C&H Farm.

Figure 1. Plan of possible site of seepage monitoring trench.

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BCRET Summit

A meeting was held September 11th, 2014, at the Pauline Whitaker Center for everyone conducting monitoring and research in Big Creek and Buffalo River Watersheds. Those present included Dr. Van Brahana – retired Geosciences University of Arkansas; Victor Roland – Geosciences University of Arkansas; Faron Usrey – Park Service; USGS scientists Jaysson Funkhouser, Tim Kresse, Phil Hays, and Billy Justus; and several BCRET Division of Agriculture members.

The meeting agenda included;

11:00 Welcome and Introductions

11:05 Presentations by each group active in the Big Creek Watershed

11:10 BCRET update – Andrew Sharpley and team

11:35 Dye-tracer studies - Van Brahana

12:30 Park Service – Faron Usrey

12 50 Discussion of monitoring efforts presented

13:30 Stream biology – Thad Scott and Ashley Rodman

13:50 Microcosm studies - Victor Roland

14:10 Discussion of biological assessment studies

14:30 USGS efforts: Biology – Billy Justus (15 minutes)

14:45 USGS efforts: Hydrology – Tim Kresse (15 minutes)

15:00 Open discussion

16:00 Future plans and collaborative efforts

16:30 Adjourn

The meeting adhered to the above agenda and everyone had sufficient time to present the results of their ongoing effort in the Big Creek and Buffalo River Watersheds. In addition, there was ample discussion of the information presented and how the combined efforts of the researchers complimented to larger goal of identifying and measuring any impacts of the C&H Farm operation on area water quality. All attendees agreed that the meeting was productive and would be interested in being involved in subsequent research meetings.

Manure Holding Pond Interceptor Trench Installation

To determine potential leaching of liquid from the manure holding ponds, an interceptor trench 200 feet in length was constructed approximately 150 feet downslope of the holding ponds. Any leakage from the ponds would initially move vertically, but horizontal flow will be induced at any permeability contrast in the subsurface. The trench was designed to intercept horizontal flow that would be induced over a low-permeability restricting layer existing at a soil depth of 4 feet that was identified during site evaluation. The trench was excavated to about 10 feet below the base of the holding ponds. The trench was designed to drain to outlets at both ends, with a minimum design gradient of 0.25 inch/foot maintained from the high midpoint of the trench to each of the two outlets to ensure unimpeded flow.

The base of the interceptor trench was lined with impermeable plastic sheeting to capture all flow moving through trench walls into the trench. A 4-inch perforated pipe was laid on top of the plastic sheet and the trench filled with washed gravel to a depth of 2-3 feet below the soil surface. The remaining trench was then backfilled with compacted soil and seed and hay placed on the surface to encourage surface vegetation regrowth. The design will capture any flow moving horizontally into the trench, and direct flow for collection and transmittal to the outlets where flow rate can be measured and samples can be collected for water-quality analyses.

The trench approach was selected over a three-dimensional network of shallow observation and sampling wells located below the holding ponds due to the greater probability of the trench intercepting any seepage from the ponds. The continuous interception provided by the trench offers a greater probability of capturing any subsurface seepage as compared to a three dimensional grid of discontinuous point observations. Thus, the trench reduces the probability of by-pass flow of any seepage down slope of the ponds. Water exiting the interceptor trench pipe outlets is currently sampled by hand. We plan to instrument both pipes with flow monitoring and sonde to collect continuous flow and water-quality data.

Figure 1. Trench location adjacent to the manure holding ponds at the C&H Farm, Mt. Judea, Newton County.

Similar interceptor trenches have been installed worldwide and information can be found in the following publications;

Hobza, C.M. 2006. ground-water quality near a swine waste lagoon in a mantled karst terrane in Northwestern Arkansas. Master's Thesis. Geology, University of Arkansas, Fayetteville, AR. 81 pages.

Pilgrim, D.H., and D.D. Huff. 1978. A field evaluation of subsurface and surface runoff: I. Tracer studies. Journal of Hydrology, 38:29-318.

Pilgrim, D.H., and D.D. Huff. 1978. A field evaluation of subsurface and surface runoff: II. Runoff processes. Journal of Hydrology, 38:319-341.

Smettem, K.R.J., D.J. Chittleborough, B.G. Rishards, and F.W. Leaney. 1991. The influence of macropores on runoff generation from a hillslope soil with a contrasting textural class. Journal of Hydrology, 122:235-252.

Trudgill, S.T., A.M. Pickles, K.R.J. Smettem, and R.W. Crabtree. 1983. Soil water residence time and solute uptake: I. Dye tracing and rainfall events. Journal of Hydrology, 60:257-279.

Wagner, D. 2005. Applications of δ15N, δ18O of nitrate to waste storage effectiveness in mantled karst terrain, Northwestern Arkansas. Master's Thesis. Geology, University of Arkansas, Fayetteville, AR. 109 pages.

Weyman, D.R. 1974. Runoff processes, contributing area and streamflow in a small upland catchment. *In*: K.J. Gregory and D.E. Walling (Editors), Fluvial Processes in Instrumented Watersheds. British Institute of Geography, London, Spec. Publ., 6:33-43. London, United Kingdom.

Figure 2. Trench construction and interceptor pipe installation adjacent to the manure holding ponds at the C&H Farm, Mt. Judea, Newton County.

Water Sampling and Analyses

Sampling Locations

Since July 1 and reported in the 3rd Quarterly Report, installation of a trench below the manure holding pond was completed (Site 8) and samples of trench water discharge collected for analysis. Water quality monitoring sites are shown in Figure 3 and are;

Site 1. Edge-of-field monitoring on Field 1 permitted to receive slurry.

Site 2. Edge-of-field monitoring on Field 5a.

Site 3. Edge-of-field monitoring on Field 12 permitted to receive slurry.

Site 4. Ephemeral stream flow draining a subwatershed containing the production facilities.

Site 5. Spring below Field 1.

Site 6. Big Creek upstream of the C&H Farm operation.

Site 7. Big Creak downstream of the C&H Farm operation.

Site 8. Manure holding pond trench – Figures 1 and 2.

Sampling Protocols and Analyses

The following protocols were used to collect, prepare, and analyze all water samples;

1. One-liter acid-washed bottles were used to collect the stream samples for nutrient analyses.
2. Water was collected from just beneath the surface where the stream was actively moving and well-mixed.
3. The bottle was rinsed with stream water before collecting the sample.
4. Sterilized specimen cups were used to collect samples for bacterial evaluation.
5. Time of collection was noted and samples were placed in a cooler on ice to preserve them until processed and were submitted to the Arkansas Water Resources Center Water Quality Lab on the day of collection for analyses.
6. Analyses included Dissolved Phosphorus (EPA 365.2), Total Phosphorus (APHA 4500-P), Ammonia (EPA 351.2), Nitrate (EPA 300.0), Total Nitrogen (APHA 4500-N), Total Suspended Solids (EPA 160.2), E. coli (APHA 9223, B) and Total Coliforms (APHA 9223, B). APHA is American Public Health Association from the Wadeable Streams Assessment, Water Chemistry Laboratory Manual http://www.epa.gov/owow/monitoring/wsa/WRS_lab_manual.pdf
7. The minimum detection limits (MDLs) for each chemical and biological constituent measured are listed in Table 1.

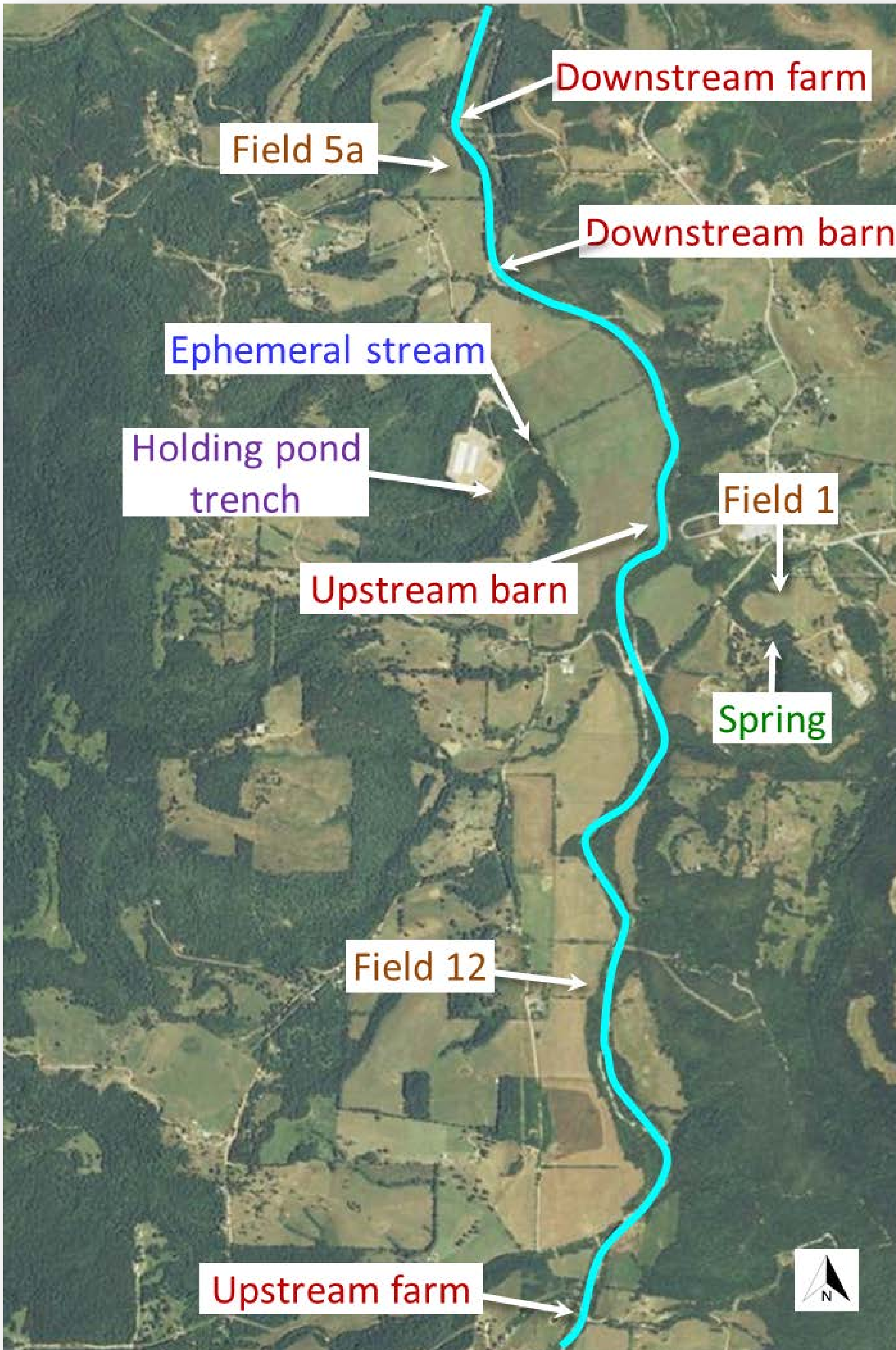

Figure 3. Location of water quality sampling sites on Big Creek and the C&H Farm.

The chemical composition of water samples collected prior to June 30, 2014, is listed in Tables 2, 3, and 4.

Table 1. Minimum detection limits (MDLs) for each chemical and biological constituent measured.

Constituent	Minimum detection limit
Dissolved P, mg L^{-1}	0.002
Total P, mg L^{-1}	0.012
Nitrate-N, mg L^{-1}	0.004
Ammonium-N, mg L^{-1}	0.027
Total N, mg L^{-1}	0.006
Total suspended solids, mg L^{-1}	6.58
Dissolved organic carbon, mg L^{-1}	0.18
E. coli, MPN 100 mL^{-1}	1
Total coliform, MPN 100 mL^{-1}	1

USGS Stations

Big Creek Continuous Flow

We are collaborating with USGS, Big Creek at the downstream site of prior water sample collection was instrumented with continuous flow gaging equipment and a nitrate sensor, which provides real-time flow, water temperature, water nitrate and precipitation data. These data are available on-line at the following site. Flow and nitrate for from the USGS downstream site is given in Figures 4 and 5.

USGS 07055790 Big Creek near Mt. Judea, AR

http://nwis.waterdata.usgs.gov/ar/nwis/uv/?site_no=07055790&agency_cd=USGS

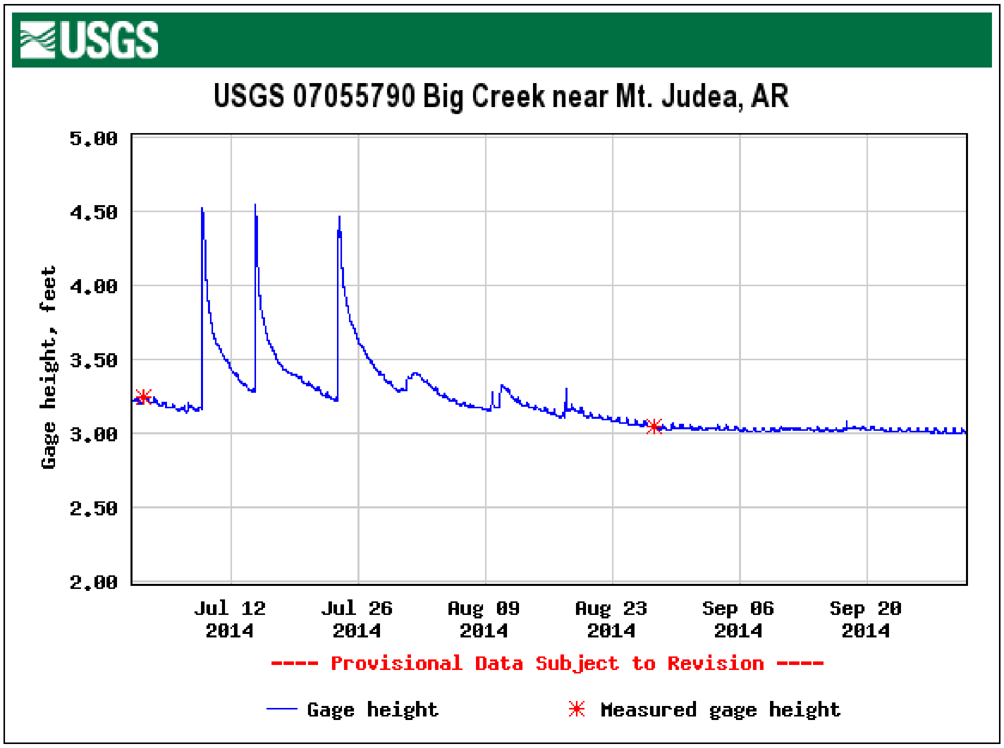

Figure 4. Big Creek flow at the monitoring site downstream of the C&H Farm during the 4th quarter.

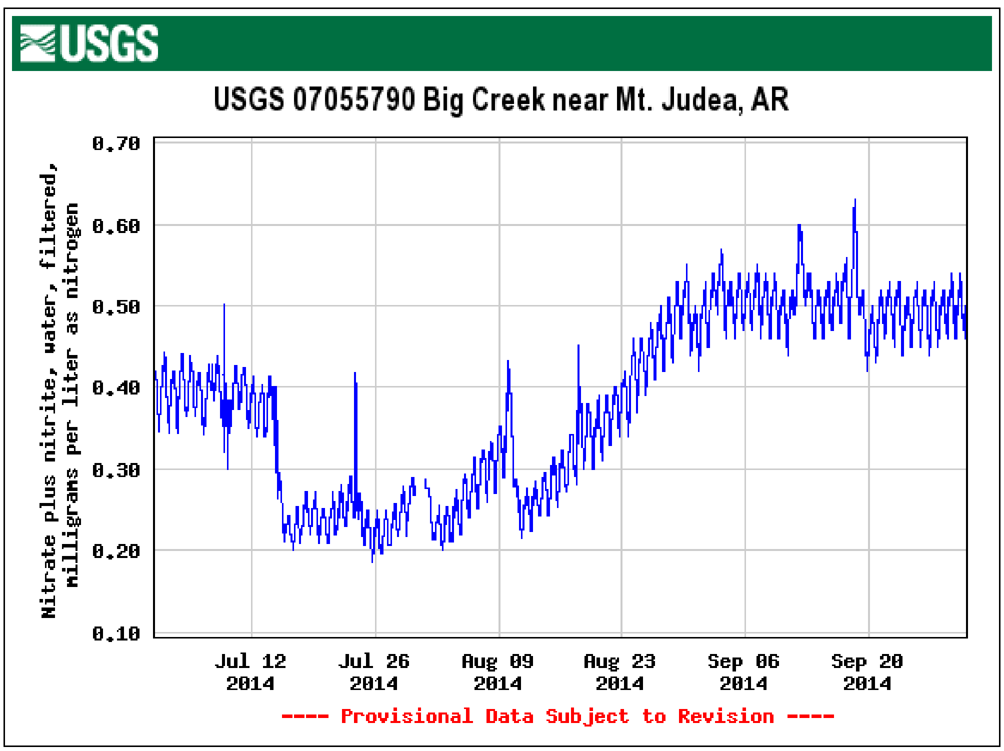

Figure 5. Nitrate concentration in Big Creek at the monitoring site downstream of the C&H Farm during the 4th quarter.

Table 2. Water quality analyses at each sample site. Coliform units are Most Probable Number (MPN) per 100 mL of water.

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
			- - - - - - - -	- - - - - - - -	- - - - - - - -	mg/L	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - MPN/100 mL - -	
5/1/2014	**5/1/2014**	**Base flow**									
10:09	13:05	Spring	0.007	0.012	0.00	0.505	0.57	1.4	1.0	52.1	1986.3
10:29	13:05	Upstream farm	0.006	0.018	0.00	0.070	0.09	1.9	1.0	96.0	3050.0
10:19	13:05	Upstream barn	0.007	0.014	0.04	0.096	0.10	2.2	0.4	73.8	4310.0
9:58	13:05	Downstream farm	0.007	0.008	0.05	0.119	0.11	1.5	0.9	62.4	3990.0
10:49	13:05	House well	0.012	0.012	0.08	0.467	0.52	0.7	0.5	<1	116.9
10:44	13:05	Culvert	0.005	0.010	0.00	0.448	0.50	1.5	0.6	90.5	4790.0
5/8/2014	**5/8/2014**	**Base flow**									
13:00	15:32	Spring	0.009	0.020	0.00	0.386	0.48	11.1	1.0	8.6	5560.0
12:45	15:32	Upstream farm	0.013	0.020	0.06	0.087	0.09	1.2	0.9	57.3	5120.0
12:53	15:32	Upstream barn	0.008	0.016	0.01	0.121	0.14	1.4	0.9	34.1	5760.0
13:13	15:32	Downstream farm	0.008	0.028	0.03	0.163	0.55	4.7	1.0	19.9	14760.0
12:34	15:32	House well	0.008	0.010	0.18	0.440	0.68	0.3	1.4	<1	<1

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
5/9/2014	**5/9/2014**	**Storm flow**									
10:05	13:54	Spring	0.009	0.030	0.02	0.161	0.36	5.8	4.0	N.D.	N.D.
10:42	13:54	Upstream farm	0.008	0.030	0.00	0.072	0.10	1.5	0.7	N.D.	N.D.
11:22	13:54	Upstream barn	0.008	0.020	0.06	0.102	0.10	2.0	0.7	N.D.	N.D.
9:52	13:54	Downstream farm	0.008	0.018	0.00	0.152	0.17	2.1	0.6	N.D.	N.D.
5/8/2014, 13:54	13:54	Field 1	0.079	0.312	0.17	0.209	1.63	125.9	9.6	N.D.	N.D.
5/13/2014	**5/13/2014**	**Storm flow**									
9:33	13:15	Spring	0.008	0.062	0.06	0.249	0.45	3.8	4.3	435.2	7280.0
10:38	13:15	Upstream farm	0.008	0.062	0.00	0.096	0.23	10.1	2.9	920.8	13130.0
10:05	13:15	Upstream barn	0.008	0.074	0.06	0.113	0.30	11.8	5.7	1046.2	15290.0
9:22	13:15	Downstream farm	0.010	0.086	0.07	0.133	0.38	19.4	5.6	1553.1	29090.0
10:13	13:15	House well	0.008	0.020	0.06	0.458	0.49	0.5	0.5	<1	18.9
10:20	13:15	Culvert	0.007	0.060	0.12	0.509	0.70	5.1	2.6	307.6	10760.0
5/12/2014, 16:26	13:15	Field 1	0.190	0.366	0.10	0.126	1.33	42.1	10.2	N.D.	N.D.

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
5/19/2014	**5/19/2014**	**Base flow**									
13:17	15:38	Spring	0.007	0.018	0.00	0.639	0.70	3.7	0.8	27.5	2419.2
12:11	15:38	Upstream farm	0.006	0.024	0.05	0.103	0.16	1.9	0.5	133.3	2419.2
13:10	15:38	Upstream barn	0.008	0.020	0.00	0.000	0.10	1.5	0.5	95.9	4710.0
13:30	15:38	Downstream farm	0.008	0.018	0.00	0.111	0.14	2.0	0.3	53.7	4220.0
12:46	15:38	House well	0.011	0.016	0.03	0.489	0.49	0.2	0.4	11.0	123.6
12:41	15:38	Culvert	0.008	0.020	0.08	0.522	0.55	0.8	0.3	204.6	5940
5/28/2014	**5/28/2014**	**Storm flow**									
9:34	14:00	Spring	0.010	0.036	0.00	0.353	0.58	7.3	2.8	1986.3	16740.0
11:06	14:00	Upstream farm	0.007	0.022	0.00	0.124	0.10	2.1	0.7	290.9	15760.0
10:13	14:00	Upstream barn	0.007	0.020	0.03	0.154	0.14	1.9	0.7	198.9	12660.0
9:16	14:00	Downstream farm	0.008	0.020	0.03	0.221	0.21	1.9	0.7	209.8	8390.0
10:35	14:00	House well	0.009	0.012	0.06	0.495	0.51	0.1	0.3	<1	<1
10:28	14:00	Culvert	0.011	0.020	0.10	0.799	0.85	1.7	0.2	517.2	14830.0
9:55	14:00	Field 1	0.235	0.310	N.D.	N.D.	N.D.	56.1	164.7	N.D.	N.D.

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
6/5/2014	**6/5/2014**	**Base flow**									
13:03	15:37	Spring	0.022	0.030	0.08	0.350	0.46	4.5	0.9	33.2	4280.0
12:50	15:37	Upstream farm	0.012	0.022	0.01	0.136	0.14	1.2	1.0	307.6	18500.0
13:16	15:37	Downstream farm	0.012	0.026	0.05	0.219	0.28	4.3	0.8	201.4	13330.0
11:37	15:37	House well	0.008	0.028	0.12	0.444	0.59	0.0	1.4	<1	<1
6/9/2014	**6/9/2014**	**Storm flow**									
9:06	13:02	Spring	0.009	0.048	0.15	0.163	0.39	7.2	5.15	770.1	173290.0
10:22	13:02	Upstream farm	0.006	0.030	0.00	0.176	0.19	3.3	1.95	410.6	2419.2
9:34	13:02	Upstream barn	0.006	0.034	0.00	0.213	0.31	3.9	2.66	1119.9	29870.0
8:51	13:02	Downstream farm	0.006	0.026	0.02	0.256	0.26	4.3	1.33	517.2	11690.0
9:54	13:02	House well	0.005	0.016	0.14	0.501	0.57	0.2	0.90	<1	<1
6/19/2014	**6/19/2014**	**Base flow**									
9:10	13:27	Spring	0.008	0.024	0.06	0.320	0.43	3.7	0.20	28.8	2419.2
9:55	13:27	Upstream farm	0.008	0.028	0.09	0.154	0.22	0.3	0.3	36.4	3790.0
9:24	13:27	Upstream barn	0.009	0.026	0.10	0.180	0.25	0.1	0.40	49.6	5120.0

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
8:55	13:27	Downstream farm	0.010	0.020	0.03	0.246	0.32	0.9	0.33	61.3	4960.0
9:32	13:27	House well	0.009	0.028	0.06	0.442	0.57	0.0	0.33	<1	<1
6/24/2014	**6/24/2014**	**Storm flow**									
9:46	14:56	Spring	0.007	0.046	0.04	0.201	0.38	4.8	5.14	10810.0	275.5
12:17	14:56	Upstream farm	0.014	0.056	0.03	0.219	0.27	4.3	2.63	28510.0	980.4
10:17	14:56	Upstream barn	0.010	0.052	0.04	0.228	0.30	30.1	2.45	17270.0	1046.2
9:27	14:56	Downstream farm	0.009	0.068	0.05	0.245	0.35	7.2	3.81	24950.0	1046.2
10:47	14:56	House well	0.006	0.036	0.03	0.504	0.53	0.2	0.61	<1	<1
6/22/14, 8:02	14:56	Culvert, ISCO	0.005	0.090	0.68	4.562	7.16	2096	4.09	N.D.	N.D.
6/20/14, 14:31	14:56	Field 1	0.228	0.498	0.18	0.114	2.39	23.2	20.15	N.D.	N.D.
6/27/2014	**6/27/2014**	**Storm flow**									
10:03	14:25	Spring	0.012	0.010	0.00	0.378	0.51	3.3	3.86	N.D.	N.D.
6/26/14, 4:52	14:25	Upstream farm, ISCO	0.007	0.014	0.01	0.117	0.14	5.1	3.34	N.D.	N.D.
10:10	14:25	Upstream barn	0.017	0.026	0.02	0.248	0.29	3.5	0.54	N.D.	N.D.

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
12:17	14:25	Downstream farm	0.017	0.022	0.01	0.379	0.42	5.5	1.26	N.D.	N.D.
11:00	14:25	Culvert	0.017	0.022	0.00	0.550	0.60	1.7	0.83	N.D.	N.D.
6/25/14, 14:29	14:25	Field 1	1.166	1.374	0.10	0.333	1.18	12.3	7.80	N.D.	N.D.
6/25/14, 15:29	14:25	Field 5a	0.506	0.656	0.06	0.000	0.53	39.7	5.82	N.D.	N.D.
7/7/2014	**7/7/2014**	**Storm flow**									
9:28	15:15	Spring	0.009	0.132	0.33	0.352	0.66	18.7	2.97	10190.0	111990.0
11:00	15:15	Upstream farm	0.009	0.040	0.00	0.266	0.28	3.9	1.08	1732.9	69100.0
9:38	15:15	Upstream barn	0.013	0.040	0.00	0.322	0.33	3.7	0.67	2419.2	48840.0
9:12	15:15	Downstream farm	0.010	0.034	0.00	0.398	0.40	3.5	0.67	649.8	15760.0
9:51	15:15	House well	0.007	0.020	0.11	0.483	0.57	0.2	0.50	<1	<1
7/8/2014	**7/10/2014**	**Storm flow**									
17:10	**8:38**	Culvert, ISCO	0.023	0.054	0.37	0.759	2.89	1252.1	6.96	N.D.	N.D.
7/15/2014	**7/15/2014**	**Base flow**									
9:33	14:38	Spring	0.005	0.014	0.01	0.353	0.43	2.7	1.39	129.6	2810.0
10:20	14:38	Upstream	0.010	0.046	0.04	0.215	0.30	5.2	1.73	686.7	26130.0

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
		farm									
10:10	14:38	Upstream barn	0.013	0.048	0.04	0.245	0.34	7.8	1.98	1119.9	26130.0
11:32	14:38	Downstream farm	0.009	0.050	0.03	0.270	0.40	9.1	1.92	816.4	27550.0
10:46	14:38	House well	0.009	0.012	0.08	0.476	0.60	0.4	0.70	<1	<1
7/18/2014	**7/18/2014**	**Storm flow**									
12:34	15:00	Spring	0.012	0.022	0.07	0.410	0.49	1.9	0.83	N.D.	N.D.
7/15/14, 18:52	15:00	Upstream farm, ISCO	0.006	0.032	0.04	0.004	0.20	4.4	1.83	N.D.	N.D.
12:13	15:00	Upstream farm	0.012	0.028	0.00	0.200	0.19	1.5	0.66	N.D.	N.D.
12:42	15:00	Upstream barn	0.013	0.028	0.03	0.249	0.25	2.1	0.68	N.D.	N.D.
10:45	15:00	Downstream farm	0.014	0.030	0.09	0.292	0.30	2.6	0.77	N.D.	N.D.
7/16/14, 12:18	15:00	Culvert, ISCO	0.006	0.032	0.06	0.601	0.67	16.8	0.56	N.D.	N.D.
7/23/2014	**7/23/2014**	**Base flow**									
10:27	13:11	Spring	0.015	0.024	0.05	0.342	0.37	2.5	1.42	14.6	1413.6
12:21	13:11	Upstream farm	0.021	0.020	0.05	0.103	0.11	1.3	1.13	142.1	2419.2

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
10:53	13:11	Upstream barn	0.018	0.026	0.04	0.217	0.21	1.8	1.08	344.8	5540.0
10:09	13:11	Downstream farm	0.019	0.032	0.09	0.280	0.31	3.7	1.12	95.9	6010.0
11:19	13:11	House well	0.013	0.016	0.26	0.469	0.67	0.2	0.70	<1	<1
7/25/2014	**7/25/2014**	**Storm flow**									
7/23/14, 15:41	15:59	Upstream farm, ISCO	0.081	0.476	0.09	0.004	0.86	447.1	5.55	N.D.	N.D.
11:33	15:59	Upstream farm	0.010	0.036	0.05	0.087	0.11	2.6	1.21	N.D.	N.D.
10:39	15:59	Upstream barn	0.012	0.034	0.04	0.134	0.19	2.7	1.31	N.D.	N.D.
9:55	15:59	Downstream farm	0.013	0.040	0.00	0.196	0.29	5.9	1.30	N.D.	N.D.
7/23/14, 14:42	15:59	Culvert, ISCO	0.016	1.018	0.98	0.875	2.69	2642.0	5.09	N.D.	N.D.
7/23/14, 15:06	15:59	Field 1	0.648	0.794	0.16	0.388	1.65	5.6	8.84	N.D.	N.D.
7/23/14, 16:09	15:59	Field 5a	0.625	0.754	0.09	0.004	0.61	9.0	5.81	N.D.	N.D.
7/31/2014	**7/31/2014**	**Storm flow**									
10:56	13:32	Upstream farm	0.015	0.022	0.00	0.116	0.13	1.2	0.76	275.5	6370.0
9:32	13:32	Downstream farm	0.018	0.030	0.00	0.250	0.30	3.3	0.77	224.7	23590.0

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
10:38	13:32	Culvert	0.017	0.042	0.20	1.204	1.23	4.9	1.03	1732.9	30760.0
8/12/2014	**8/12/2014**	**Base flow**									
10:09	13:23	Spring	0.009	0.032	0.03	0.217	0.26	7.0	0.56	40.4	2419.2
10:52	13:23	Upstream farm	0.012	0.026	0.00	0.108	0.13	1.7	0.30	98.8	1986.3
10:21	13:23	Upstream barn	0.015	0.024	0.01	0.162	0.18	1.5	0.28	83.0	2419.2
9:54	13:23	Downstream farm	0.012	0.036	0.04	0.232	0.23	8.3	0.40	125.0	9870.0
10:37	13:23	House well	0.009	0.020	0.20	0.418	0.62	0.5	0.35	<1	<1
8/20/2014	**8/20/2014**	**Base flow**									
10:28	14:05	Spring	0.010	0.036	0.00	0.285	0.45	7.5	1.09	307.6	40830.0
11:23	14:05	Upstream farm	0.014	0.040	0.00	0.214	0.32	8.3	0.52	88.4	3000.0
10:39	14:05	Upstream barn	0.015	0.030	0.00	0.229	0.22	3.5	0.32	12.1	2310.0
10:14	14:05	Downstream farm	0.011	0.032	0.01	0.319	0.37	3.4	0.44	69.7	7380.0
10:53	14:05	House well	0.010	0.020	0.15	0.412	0.61	0.3	0.28	<1	<1
8/22/2014	**8/25/2014**	**Base flow**									
14:06	9:25	Trench, South	0.007	0.008	0.00	0.523	0.69	5.7	1.79	N.D.	N.D.

Time sample collected	Time received @ laboratory	Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic Carbon	E. coli	Total coliform
8/26/2014	**8/26/2014**	**Base flow**									
11:38	14:23	Spring	0.007	0.078	0.05	0.256	0.42	38.6	0.35	51.2	4650.0
12:08	14:23	Upstream farm	0.005	0.064	0.09	0.075	0.42	6.5	1.21	3.1	4370.0
11:14	14:23	Downstream farm	0.013	0.018	0.01	0.398	0.46	1.4	0.22	19.7	5120.0
11:56	14:23	House well	0.008	0.022	0.26	0.378	0.66	0.4	0.18	<1	<1

N.D. is No Data.

Table 3. Water quality analyses at the spring and in Big Creek upstream and downstream of the C&H Farm boundary of permitted land application fields.

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
	- mg/L					- -		- - - MPN/100 mL - - -	
5/8/2014 Base flow									
Spring	0.009	0.020	0.00	0.386	0.48	11.1	1.0	8.6	5560.0
Upstream	0.013	0.020	0.06	0.087	0.09	1.2	0.9	57.3	5120.0
Downstream	0.008	0.028	0.03	0.163	0.55	4.7	1.0	19.9	14760.0
5/9/2014 Storm flow									
Spring	0.009	0.030	0.02	0.161	0.36	5.8	4.0	N.D.	N.D.
Upstream	0.008	0.030	0.00	0.072	0.10	1.5	0.7	N.D.	N.D.
Downstream	0.008	0.018	0.00	0.152	0.17	2.1	0.6	N.D.	N.D.
5/13/2014 Storm flow									
Spring	0.008	0.062	0.06	0.249	0.45	3.8	4.3	435.2	7280.0
Upstream	0.008	0.062	0.00	0.096	0.23	10.1	2.9	920.8	13130.0
Downstream	0.010	0.086	0.07	0.133	0.38	19.4	5.6	1553.1	29090.0
5/28/2014 Storm flow									

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Spring	0.010	0.036	0.00	0.353	0.58	7.3	2.8	1986.3	16740.0
Upstream	0.007	0.022	0.00	0.124	0.10	2.1	0.7	290.9	15760.0
Downstream	0.008	0.020	0.03	0.221	0.21	1.9	0.7	209.8	8390.0
6/5/2014 Base flow									
Spring	0.022	0.030	0.08	0.350	0.46	4.5	0.9	33.2	4280.0
Upstream	0.012	0.022	0.01	0.136	0.14	1.2	1.0	307.6	18500.0
Downstream	0.012	0.026	0.05	0.219	0.28	4.3	0.8	201.4	13330.0
6/9/2014 Storm flow									
Spring	0.009	0.048	0.15	0.163	0.39	7.2	5.15	770.1	173290.0
Upstream	0.006	0.030	0.00	0.176	0.19	3.3	1.95	410.6	2419.2
Downstream	0.006	0.026	0.02	0.256	0.26	4.3	1.33	517.2	11690.0
6/19/2014 Base flow									
Spring	0.008	0.024	0.06	0.320	0.43	3.7	0.20	28.8	2419.2
Upstream	0.008	0.028	0.09	0.154	0.22	0.3	0.3	36.4	3790.0
Downstream	0.010	0.020	0.03	0.246	0.32	0.9	0.33	61.3	4960.0

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
6/24/2014 Storm flow									
Spring	0.007	0.046	0.04	0.201	0.38	4.8	5.14	10810.0	275.5
Upstream	0.014	0.056	0.03	0.219	0.27	4.3	2.63	28510.0	980.4
Downstream	0.009	0.068	0.05	0.245	0.35	7.2	3.81	24950.0	1046.2
6/27/2014 Storm flow									
Spring	0.012	0.010	0.00	0.378	0.51	3.3	3.86	N.D.	N.D.
Upstream	0.007	0.014	0.01	0.117	0.14	5.1	3.34	N.D.	N.D.
Downstream	0.017	0.022	0.01	0.379	0.42	5.5	1.26	N.D.	N.D.
7/7/2014 Storm flow									
Spring	0.009	0.132	0.33	0.352	0.66	18.7	2.97	10190.0	111990.0
Upstream	0.009	0.040	0.00	0.266	0.28	3.9	1.08	1732.9	69100.0
Downstream	0.010	0.034	0.00	0.398	0.40	3.5	0.67	649.8	15760.0
7/15/2014 Base flow									
Spring	0.005	0.014	0.01	0.353	0.43	2.7	1.39	129.6	2810.0
Upstream	0.010	0.046	0.04	0.215	0.30	5.2	1.73	686.7	26130.0

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Downstream	0.009	0.050	0.03	0.270	0.40	9.1	1.92	816.4	27550.0
7/18/2014 Storm flow									
Spring	0.012	0.022	0.07	0.410	0.49	1.9	0.83	N.D.	N.D.
Upstream, ISCO	0.006	0.032	0.04	0.000	0.20	4.4	1.83	N.D.	N.D.
Upstream	0.012	0.028	0.00	0.200	0.19	1.5	0.66	N.D.	N.D.
Downstream	0.014	0.030	0.09	0.292	0.30	2.6	0.77	N.D.	N.D.
7/23/2014 Base flow									
Spring	0.015	0.024	0.05	0.342	0.37	2.5	1.42	14.6	1413.6
Upstream	0.021	0.020	0.05	0.103	0.11	1.3	1.13	142.1	2419.2
Downstream	0.019	0.032	0.09	0.280	0.31	3.7	1.12	95.9	6010.0
7/25/2014 Storm flow									
Upstream farm, ISCO	0.081	0.476	0.09	0.000	0.86	447.1	5.55	N.D.	N.D.
Upstream	0.010	0.036	0.05	0.087	0.11	2.6	1.21	N.D.	N.D.
Downstream	0.013	0.040	0.00	0.196	0.29	5.9	1.30	N.D.	N.D.
7/31/2014 Storm flow									

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Upstream	0.015	0.022	0.00	0.116	0.13	1.2	0.76	275.5	6370.0
Downstream	0.018	0.030	0.00	0.250	0.30	3.3	0.77	224.7	23590.0
8/12/2014 Base flow									
Spring	0.009	0.032	0.03	0.217	0.26	7.0	0.56	40.4	2419.2
Upstream	0.012	0.026	0.00	0.108	0.13	1.7	0.30	98.8	1986.3
Downstream	0.012	0.036	0.04	0.232	0.23	8.3	0.40	125.0	9870
8/20/2014 Base flow									
Spring	0.010	0.036	0.00	0.285	0.45	7.5	1.09	307.6	40830.0
Upstream	0.014	0.040	0.00	0.214	0.32	8.3	0.52	88.4	3000.0
Downstream	0.011	0.032	0.01	0.319	0.37	3.4	0.44	69.7	7380.0
8/26/2014 Base flow									
Spring	0.007	0.078	0.05	0.256	0.42	38.6	0.35	51.2	4650.0
Upstream	0.005	0.064	0.09	0.075	0.42	6.5	1.21	3.1	4370.0
Downstream	0.013	0.018	0.01	0.398	0.46	1.4	0.22	19.7	5120.0

N.D. is No Data.

Table 4. Water quality analyses at the culvert draining the subwatershed containing the production houses and manure holding ponds, the well adjacent to the ponds, and surface runoff from Field 1 (see Figure 3).

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
	- -			mg/L	- -			- - - MPN/100 mL - - -	
Culvert									
5/1/2014	0.005	0.010	0.00	0.448	0.50	1.5	0.6	90.5	4790.0
5/12/2014	0.010	0.290	0.61	0.939	2.33	847.6	4.7	N.D.	N.D.
5/13/2014	0.007	0.060	0.12	0.509	0.70	5.1	2.6	307.6	10760.0
5/19/2014	0.008	0.020	0.08	0.522	0.55	0.8	0.3	204.6	5940
5/28/2014	0.011	0.020	0.10	0.799	0.85	1.7	0.2	517.2	14830.0
6/22/2014	0.005	0.090	0.68	4.562	7.16	2096.3	4.09	N.D.	N.D.
6/27/2014	0.017	0.022	0.00	0.550	0.60	1.7	0.83	N.D.	N.D.
7/8/2014	0.023	0.054	0.37	0.759	2.89	1252.1	6.96	N.D.	N.D.
7/16/2014	0.006	0.032	0.06	0.601	0.67	16.8	0.56	N.D.	N.D.
7/23/2014	0.016	1.018	0.98	0.875	2.69	2642.0	5.09	N.D.	N.D.
7/31/2014	0.017	0.042	0.20	1.204	1.23	4.9	1.03	1732.9	30760.0
House well									

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
5/1/2014	0.012	0.012	0.08	0.467	0.52	0.7	0.5	<1	116.9
5/8/2014	0.008	0.010	0.18	0.440	0.68	0.3	1.4	<1	<1
5/13/2014	0.008	0.020	0.06	0.458	0.49	0.5	0.5	<1	18.9
5/19/2014	0.011	0.016	0.03	0.489	0.49	0.2	0.4	11.0	123.6
5/28/2014	0.009	0.012	0.06	0.495	0.51	0.1	0.3	<1	<1
6/5/2014	0.008	0.028	0.12	0.444	0.59	0.0	1.4	<1	<1
6/9/2014	0.005	0.016	0.14	0.501	0.57	0.2	0.90	<1	<1
6/19/2014	0.009	0.028	0.06	0.442	0.57	0.0	0.33	<1	<1
6/24/2014	0.006	0.036	0.03	0.504	0.53	0.2	0.61	<1	<1
7/7/2014	0.007	0.020	0.11	0.483	0.57	0.2	0.50	<1	<1
7/15/2014	0.009	0.012	0.08	0.476	0.60	0.4	0.70	<1	<1
7/23/2014	0.013	0.016	0.26	0.469	0.67	0.2	0.70	<1	<1
8/12/2014	0.009	0.020	0.20	0.418	0.62	0.5	0.35	<1	<1
8/20/2014	0.010	0.020	0.15	0.412	0.61	0.3	0.28	<1	<1
8/26/2014	0.008	0.022	0.26	0.378	0.66	0.4	0.18	<1	<1

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Field 1									
5/8/2014	0.079	0.312	0.17	0.209	1.63	125.9	9.6	N.D.	N.D.
5/12/2014	0.190	0.366	0.10	0.126	1.33	42.1	10.2	N.D.	N.D.
5/28/2014	0.235	0.310	N.D.	N.D.	N.D.	56.1	164.7	N.D.	N.D.
6/20/2014	0.228	0.498	0.18	0.114	2.39	23.2	20.15	N.D.	N.D.
6/25/2014	1.166	1.374	0.10	0.333	1.18	12.3	7.80	N.D.	N.D.
7/23/2014	0.648	0.794	0.16	0.388	1.65	5.6	8.84	N.D.	N.D.
Field 5a									
6/25/2014	0.506	0.656	0.06	0.004	0.53	39.7	5.82	N.D.	N.D.
7/23/2014	0.625	0.754	0.09	0.004	0.61	9.0	5.81	N.D.	N.D.
Interceptor Trench (South)									
8/22/2014	0.007	0.008	0.00	0.523	0.69	5.7	1.79	N.D.	N.D.

N.D. is No Data. E. coli and total coliform were not measured on surface runoff samples collected by ISCO samplers when sample holding time exceeded the required 8-hour threshold.

The mean, minimum, maximum, geometric mean, and standard deviations of concentrations of P, N, suspended sediment, dissolved organic C, E. coli, and total coliform measured in Big Creek above and below the C&H Farm presented in Table 5. Concentrations presented in all Tables are those measured at the site and do not include an estimate of flow. Thus, it is dangerous to compare concentrations among sites, especially those measuring different flow pathways for example, streams, culvert, springs, wells, and surface runoff from fields. Such comparisons are only valid on a mass flow basis. When flow is obtained from equipment at each site, concentration data will be converted to mass loading or flow-weighted values that allow a more informed interpretation of site data. Until this conversion is completed and flow considered, conclusions and interpretations should not be made on differences among site concentrations.

Table 5. Minimum, maximum, average, Geometric mean and standard deviation of concentrations of analytes measured in Big Creek above and below the C&H Farm, Newton County during the monitoring period. There were a total of 52 samples collected at each site.

Location & metric	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
	- - - - - - - -	- - - - - -	- - - - - -	mg/L	- - - - - -	- - - - - -	- - - - - - - -	MPN/100 mL	
Upstream of farm									
Minimum	0.005	0.010	0.01	0.004	0.09	0.3	0.3	3	210
Maximum	0.074	0.074	0.09	1.024	2.20	17.9	3.3	28510	69100
Average	0.012	0.030	0.03	0.179	0.28	2.7	1.3	936	5622
Geomean	0.010	0.027	0.03	0.137	0.21	1.7	1.1	111	1884
St. Dev.	0.010	0.014	0.02	0.156	0.32	3.1	0.8	4256	11617
Downstream of farm									
Minimum	0.004	0.008	0.01	0.108	0.11	0.2	0.2	1	272
Maximum	0.067	0.316	0.20	0.723	1.07	101.1	5.6	24950	43520
Average	0.012	0.037	0.04	0.283	0.37	5.9	1.3	917	7376
Geomean	0.011	0.028	0.03	0.250	0.33	2.5	1.0	90	3180
St. Dev.	0.009	0.045	0.03	0.147	0.18	14.3	1.2	3773	9348

Hourly Rainfall at the Manure Holding Lagoons

Rainfall at the manure holding lagoons was measured at hourly intervals and while all information is available, only the daily rainfall amounts are presented in Figure 6.

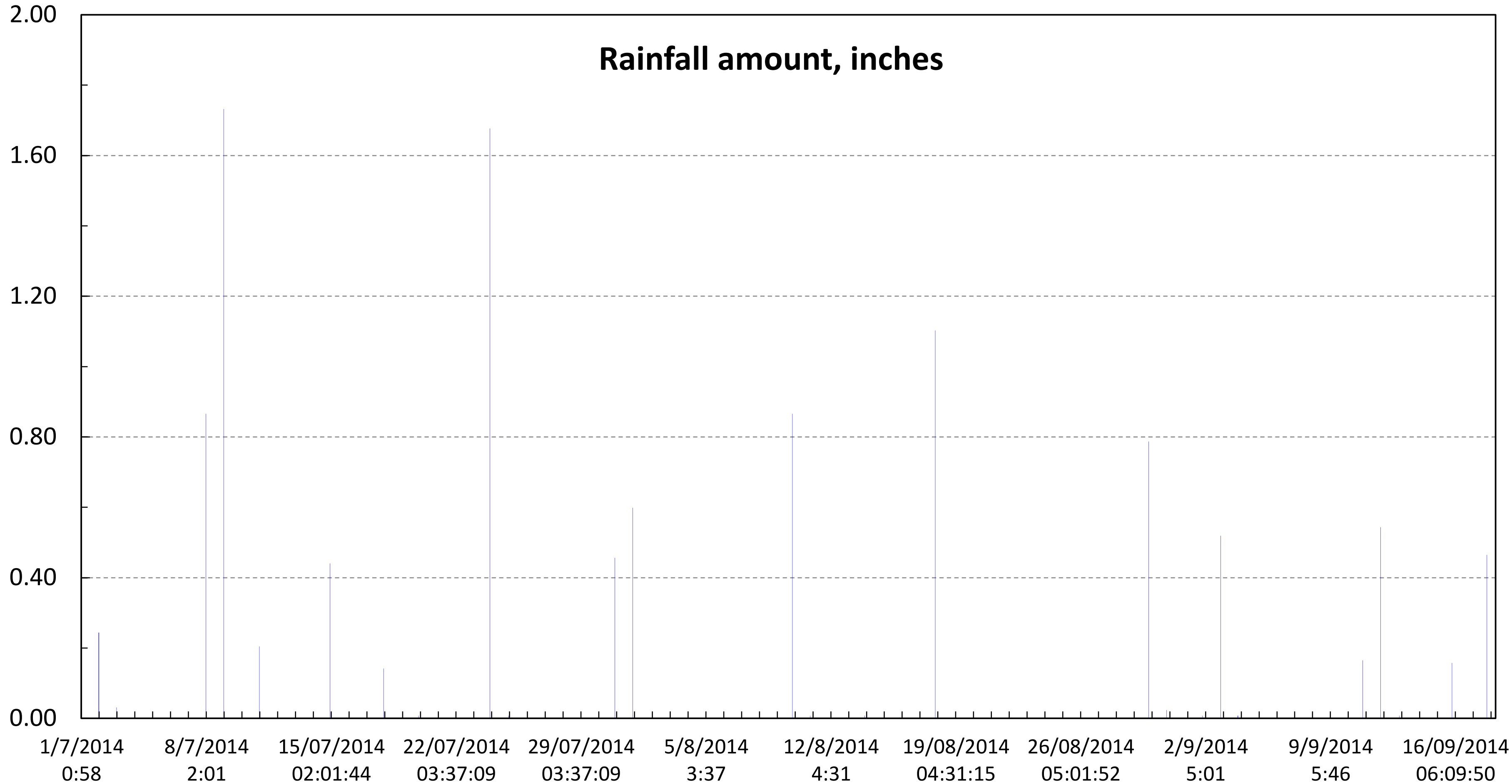

Figure 6. Rainfall amount in inches at the holding pond at the CH Farm for July 1 through September 18, 2014.

Manure Management Options

The volume of manure produced by a livestock is largely determined by the average animal population characteristics, fresh water additions, spilled drinking water, and pen wash-down water. Any precipitation directly into manure storages or via surface runoff will also increase manure volume.

Wash-water volume determination

Discussions with C&H management revealed that the farm used “wet/dry” feeders so that any animal drinking water spillage would fall into feed troughs to be consumed with the feed. As a result, there is effectively no spilled drinking water adding to manure volume. Estimates for pen wash-down water were provided in the form of the number of pressure washers, the flow rates in gallons per minute, and the average time spent washing each day. As a more direct determination of pen wash-water addition to the manure was desired, two standard water meters were installed to measure all water used by two pressure washers used in the barns (Figure 7). Pictures of the meters were taken and submitted to provide date and meter readings, from which accurate daily and cumulative wash-water volumes were calculated. From March 20 to September 9, 2014 a total of 161,722 gallons of water was used to wash the pens, with the water then draining into the manure pits. The average daily water use over these 174 days was 929 gallons/day (Table 6; Figures 8 and 9).

Table 6 Pen wash water meter readings and water volumes.

Reading Date	Days	Meter 1			Meter 2			Total	
		Reading	Cumulative	Daily average	Reading	Cumulative	Daily average	Cumulative	Daily average
		------------------------------ gallons ------------------------------							
3/20/2014		126.5			80.2				
9/10/2014	174	96,609.6	96,483.1	555	65,319.3	65,239.1	374.9	161,722	929

Figure 7. Standard water meter with hose adapters and mounting base installed to measure water use during pressure washing to clean animal pens.

Figure 8. Two water meters purchased and installed on March 20th, 2014 to measure pen wash down water additions to manure volume. Initial meters readings were 126.6 and 80.2 gallons for meter 1 and 2.

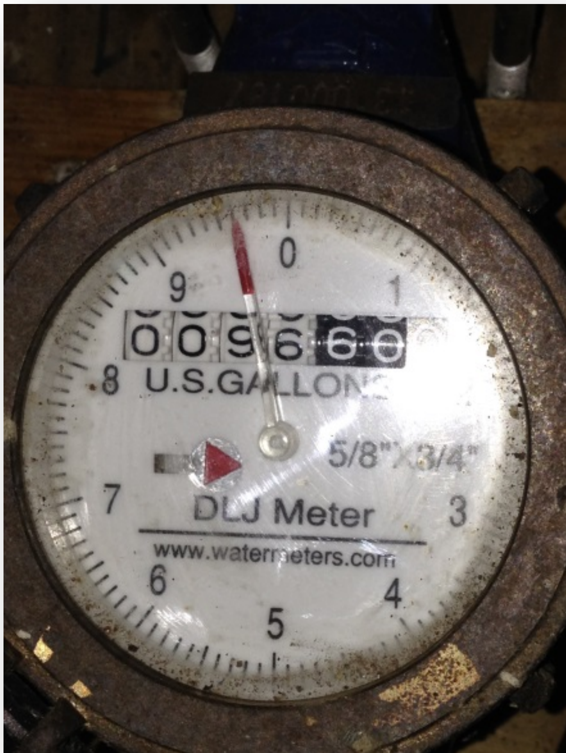

Figure 9. Two water meters purchased and installed on March 20th, 2014 to measure pen wash down water additions to manure volume. Meters readings were 96,609.6 and 65,319.3 gallons for meter 1 and 2 on September 10th, 2014.

Topographic Elevation Survey of Holding Ponds

To quantify potential precipitation additions to the volume of manure in the holding ponds, a topographic elevation survey of land adjacent to the ponds was conducted using total station survey equipment. A second elevation survey of land surrounding the holding ponds was conducted to determine the area of land draining to the ponds (Figure 10). Visual inspections and photographs provided additional inputs. This information is being used to build a Graphical Information System (GIS) surface model that will provide both the precipitation capture area of the holding ponds and storage volume at various holding-pond depths. This information and historical rainfall information will be included in the information used to estimate potential precipitation additions to the manure volume.

Figure 10. General area included in the topographic elevation survey delineated by yellow boundary line and holding pond 1 (smaller) and holding pond 2 (larger) delineated by red boundary lines.

Future Plan of Work

1. Conduct electrical resistivity analysis on application fields to determine the potential for subsurface areas of preferential flow pathways.
2. Continue to collect surface runoff, spring, and stream samples after each rainfall event from the autosamplers and manually collect baseflow samples every two weeks from the well, spring, and streams, for analysis of N, P, sediment, and bacteria (E. coli and total coliform from baseflow grab samples).
3. Collect water samples from the piezometers installed in Fields 5a and 12.
4. Install equipment to monitor flow, nutrients and sediment in Dry Creek entering Big Creek, after land owner permission and MOUs are obtained.
5. Continue to periodically determine plant uptake by collecting plant and hay samples for tissue analysis and determine yield (dry-matter mass for a pre-determined area).
6. Develop a Memorandum of Understanding with Oklahoma State University to conduct an Electrical Resistivity assessment of water movement below Fields 5a and 12 in the fall / early winter of 2014.
7. Finalize determination of holding pond volumes, precipitation capture area of holding ponds and surrounding area. Precipitation inputs, average daily wash-down water, and manure holding pond volumes will be used to estimate annual manure and nutrient production values. These values, coupled with chemical treatment trial results, will form the basis for investigating manure management alternatives.

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RESEARCH & EXTENSION
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