Big Creek Research and Extension Team

University of Arkansas System Division of Agriculture

Quarterly Report - October 2013 to December 2013

DEMONSTRATING AND 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

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

Executive Summary

This first Quarterly Report of the U of A Division of Agriculture's Big Creek Research and Extension Team, documents our activities and progress in establishing a research and monitoring program on the C&H Farm and in Big Creek Watershed, compliant with State funding received on October 1, 2013. Our work and progress during the first three months has focused on gaining a better understanding of the C&H Farm within the context of the Big Creek Watershed. We have undertaken a systematic approach to getting information on soils, underlying substrata, and background water quality information. To this end, during the first quarter we have: acquired landowner permission to conduct research and monitoring on three fields permitted to receive manure; better characterized the soils, topography, and underlying shallow layers of these fields including: 1) a Ground Penetrating Radar (GPR) assessment provided by NRCS, to determine if this non-invasive technology could help us identify subsurface features that could influence the fate and transport of surface applied nutrients, 2) fine (0.25 acre) grid-soil sampling of these fields to examine the spatial variability of nutrients within fields; 3) conducted a preliminary water quality monitoring of Big Creek upstream and downstream of the C&H Farm and of a spring on the property to determine baseline chemical, composition of these waters, and 4) initiated discussions with C&H Farms to identify manure and nutrient management options for evaluation by the project

Collecting this information will guide future efforts to monitor surface and subsurface movement on the farm in the most reliable and rigorous manner possible. This is needed to assess potential impacts of the C&H Farm on water quality and to respond to the farm's request for assistance in responding to identified concerns. Our findings to date are summarized below.

GPR Survey

Results from the GPR survey two fields showed that this technique / tool holds promise in defining features in the strata underlying the application fields in a non-invasive manner, which warrants further, more detailed characterization. While the survey indicated changes in subsurface strata, interpretations such as gravel lenses and dissolution cavities, are only indications at the present time, as actual ground truthing with invasive observational coring has not been conducted yet.

The GPR survey did demonstrate that soil properties such as soil depth to bedrock, were consistent with NRCS soil mapping unit description already available, which shows the soil depth being greater on Creek-side Field 5 than Field 1. Fields 12 is still to be completed, but so far GPR results indicate that at least 49 inches of soil overlies any bedrock which is consistent with soil pedons described in the NRCS soil survey.

A more detailed and exhaustive survey of the application fields, coupled with other soil tests, such as hydraulic conductivity and infiltration measurements, will be conducted in the coming year to make reliable conclusions on the underlying geology and presence of karst features.

Grid Soil Sampling

Fields 1 (80 samples) and 5 (270 samples) were sampled for soil nutrients by a grid pattern representing 0.25 acre blocks of each field. The concentration of phosphorus in the surface soil varied across these fields, as is typical of grazed pastures and is consistent with previous surveys of soil phosphorus variability across pastures in Northwest Arkansas and Eastern Oklahoma.

To help put soil phosphorus levels in perspective, the mean soil phosphorus in the top 4 inches for all grid samples was 41 mg/kg for Field 1 and 54 mg/kg for Field 5. Based on the U of A Division of Agriculture's fertility guidelines for a mixture of cool and warm season grasses, Field 1 would require additional phosphorus for a typical hay production yield of 3 tons/acre. Field 5 is in the optimal range of soil phosphorus levels (i.e., 50 - 60 mg/kg) for warm season grasses such as Bermudagrass.

Water Quality Monitoring

Water quality monitoring of Big Creek and a spring since September 2013, showed concentrations of nitrogen and phosphorus were only slightly greater than detection limits. This is expected for nutrient flows in a watershed that has historically had minimal land use disturbance and is still predominantly forested. Water sample collection was primarily during baseflow (flow derived from groundwater and in the absence of surface runoff contributions or storm flow) conditions in Big Creek and reflect the general impact of the landscape within the watershed on Big Creek water chemistry. E. Coli and total Coliform amounts were more highly variable reflecting periodic inputs from several potential sources in the Big Creek Watershed.

Manure Sampling

Analysis of holding pond manure samples exhibited typical holding pond trends with nutrient concentrations (phosphorus and nitrogen) increasing with pond depth. However, as the relative increase in nitrogen was greater than phosphorus, the nitrogen/phosphorus ratio of manure slurry in the top 6 inches of the pond, more closely matches manure nutrients to crop nutrient needs. Land applying this slurry is more likely to meet crop nitrogen needs with acceptable phosphorus applications, while bottom slurries are suitable for a manure banking approach, where the slurry would be applied to more distant fields on alternate years. Preliminary assessment of pond slurry composition demonstrates that, without the addition of mechanical and/or chemical separation approaches, natural gravity separation provides nutrient management opportunities to more closely match applied manure nutrients to crop nutrient needs.

Future Plans

During the second quarter, installation of surface and subsurface monitoring equipment will take place, along with continuous flow and water quality sampling equipment on springs, ephemeral streams, and Big Creek within the confines of the C&H Farm operation. In addition, manure chemical treatment field testing and analysis will take place to guide manure/nutrient management options identification and evaluation. Finally, progress has been made to establish an independent and unbiased review of our work plan by a panel of international experts in the areas of karst hydro-geochemistry and dye-tracer studies, watershed hydrology, soil and water quality monitoring, and farm nutrient management. This should occur in late spring/early summer, 2014.

Big Creek Research Team

Media Contact

Mary Hightower, Assistant Director of Communications and Marketing, Cooperative Extension Service

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

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

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., Associate 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

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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Introduction

This research project will evaluate the sustainable management of nutrients from the C&H Farm operation (subsequently referred to as C&H, to include animal facilities and permitted land application fields). The study includes the following major tasks:

1. Monitor the fate and transport of nutrients and bacteria from land-applied swine effluent to pastures.
2. Assess the impact of farming operations (effluent holding ponds and land-application of effluent) on the quality of critical water features on and surrounding the farm including springs, ephemeral streams, creeks and ground water.
3. Determine the effectiveness and sustainability of alternative manure management techniques, including solid separation, which may enhance transport and export of nutrients out of the watershed.

To address the long-term sustainability of C&H, the project will measure soil fertility levels of all permitted fields at frequent intervals. This combined with nutrient levels in monitored wells will guide adaptive manure management decisions to address field and environmental sustainability concerns. The project will also assess the feasibility of manure treatment, which is regarded as addressing nutrient imbalance concerns and has the potential to provide the farm with cost-beneficial alternatives for the sustainable use and export of treated manures.

The plan of research meets the level of funding currently available. Other important methods of investigation, such as the use of dye-tracer tests, will provide valuable information on possible rapid by-pass flow pathways common in karst dominated areas and will be included in years 2 and 3, when water flows on the operation will be better understood. See Figure 1 for a conceptual description of the karst watershed. With additional funding, dye-tracer tests would be conducted at sites identified from year 1 studies. Finally, a broad pool of expertise from the partner organizations will be brought together for work plan implementation and periodic review.

This information will be a short-term assessment and it must be noted that funds allocated below will not cover long-term monitoring, sample analysis, and assessment of land use impacts on area waters. Additional funds would be needed for sample collection and labor to continue monitoring for a minimum of five years. This time frame is recognized by NRCS, EPA, and general scientific community to be the minimum required to accurately assess any impacts and overcome annual weather fluctuations.

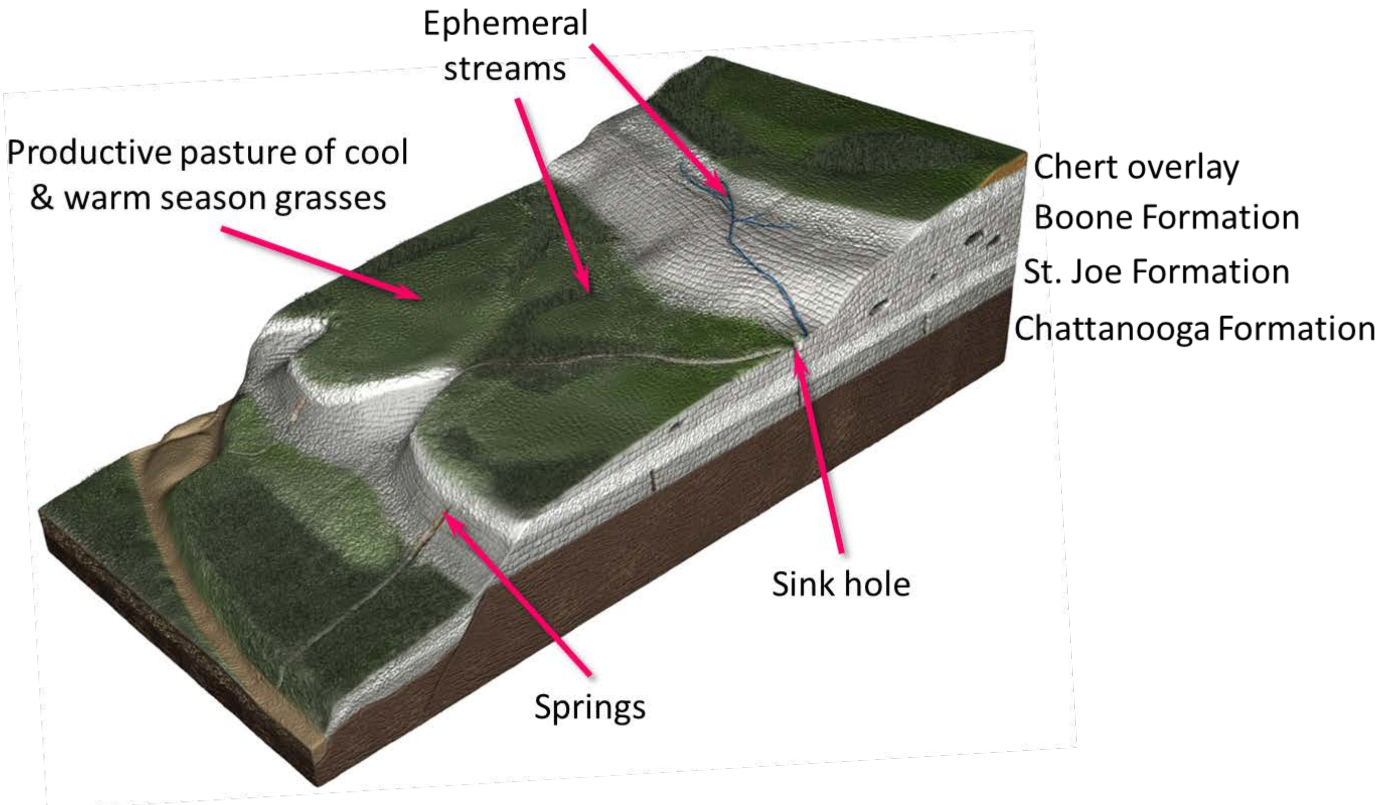
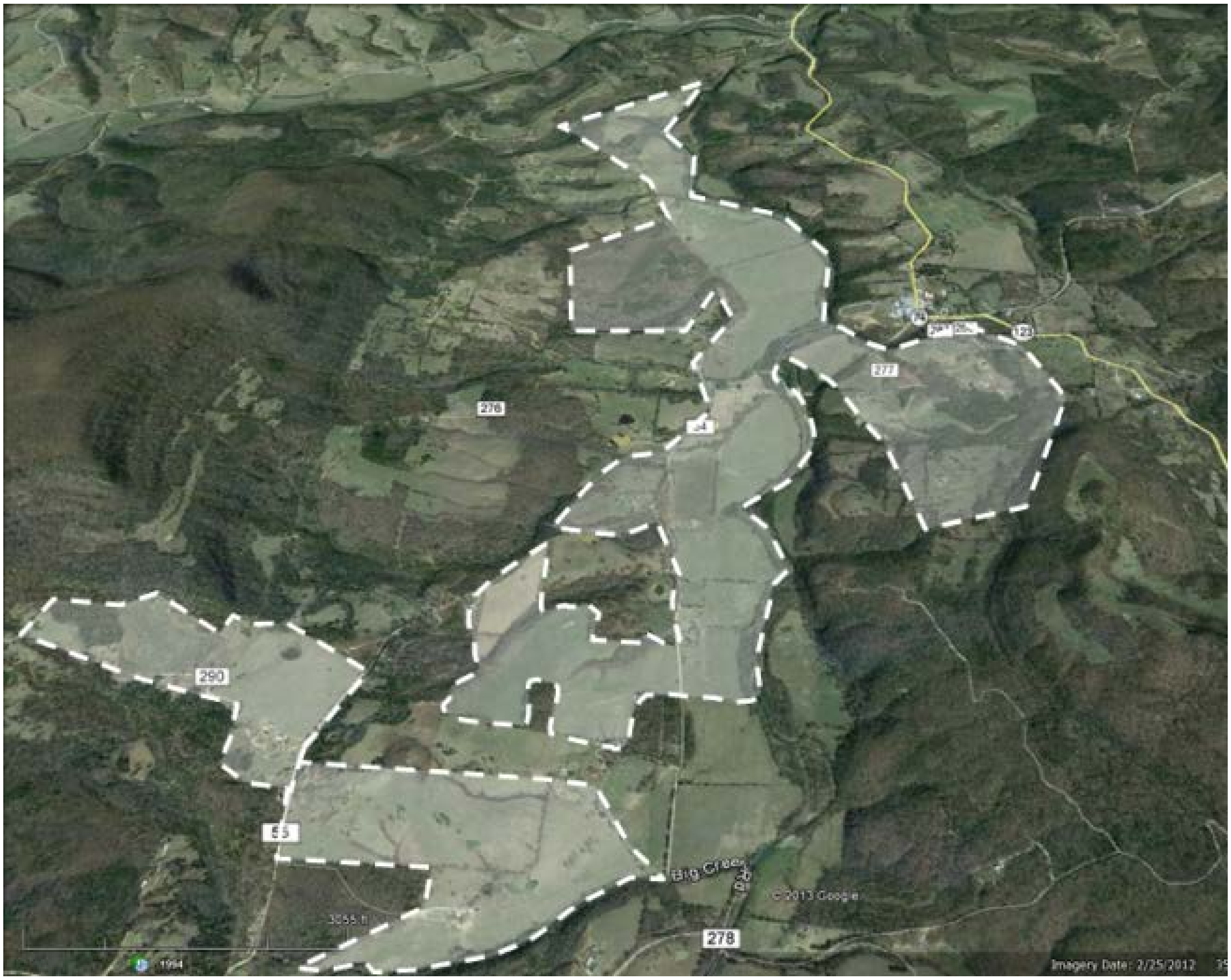


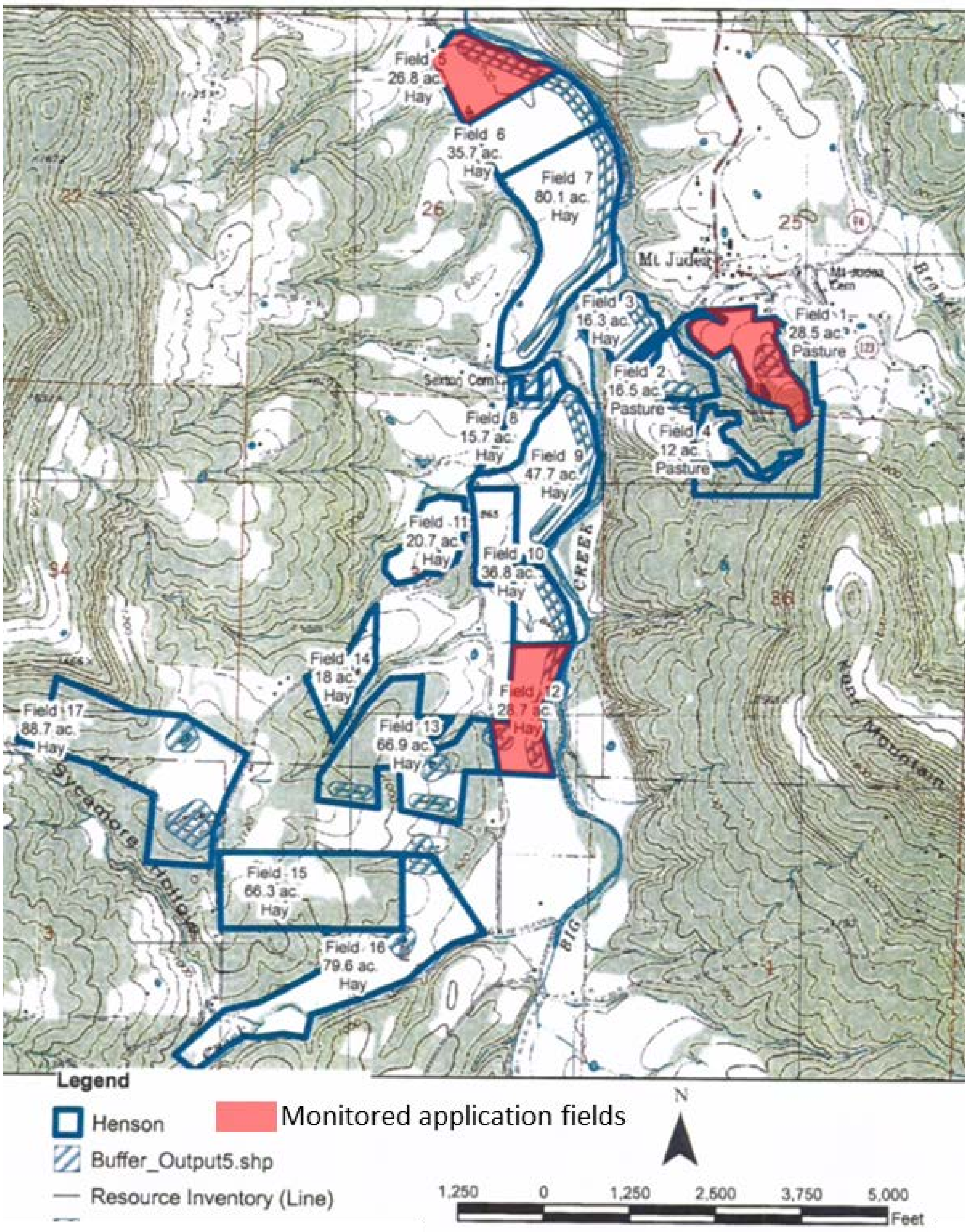
Figure 1. Simple conceptual description of the Karst features in in the Ozark Highlands.

The C&H Farm location

The C&H Farm and permitted fields are located in Mt. Judea, Newton County, AR as shown on Maps 1 and 2. This research project will focus on three permitted application fields, which give a range in landscape position, topography, and soil fertility levels representative of the overall operation (Maps 1 and 2, and Photo 1). A topographic map of the site is presented in Map 3. The soils mapped by NRCS, Newton County on the C&H operation are shown in Map 4, and Table 1. A description of the soils made by NRCS, Newton County is provided in Appendix 1. The physical properties and dimensions of the fields where surface and subsurface flow will be determined are given in Table 2, along with Maps 2 and 5. Water quality assessment of Big Creek above and below the farm will provide baseline information (Map 6).

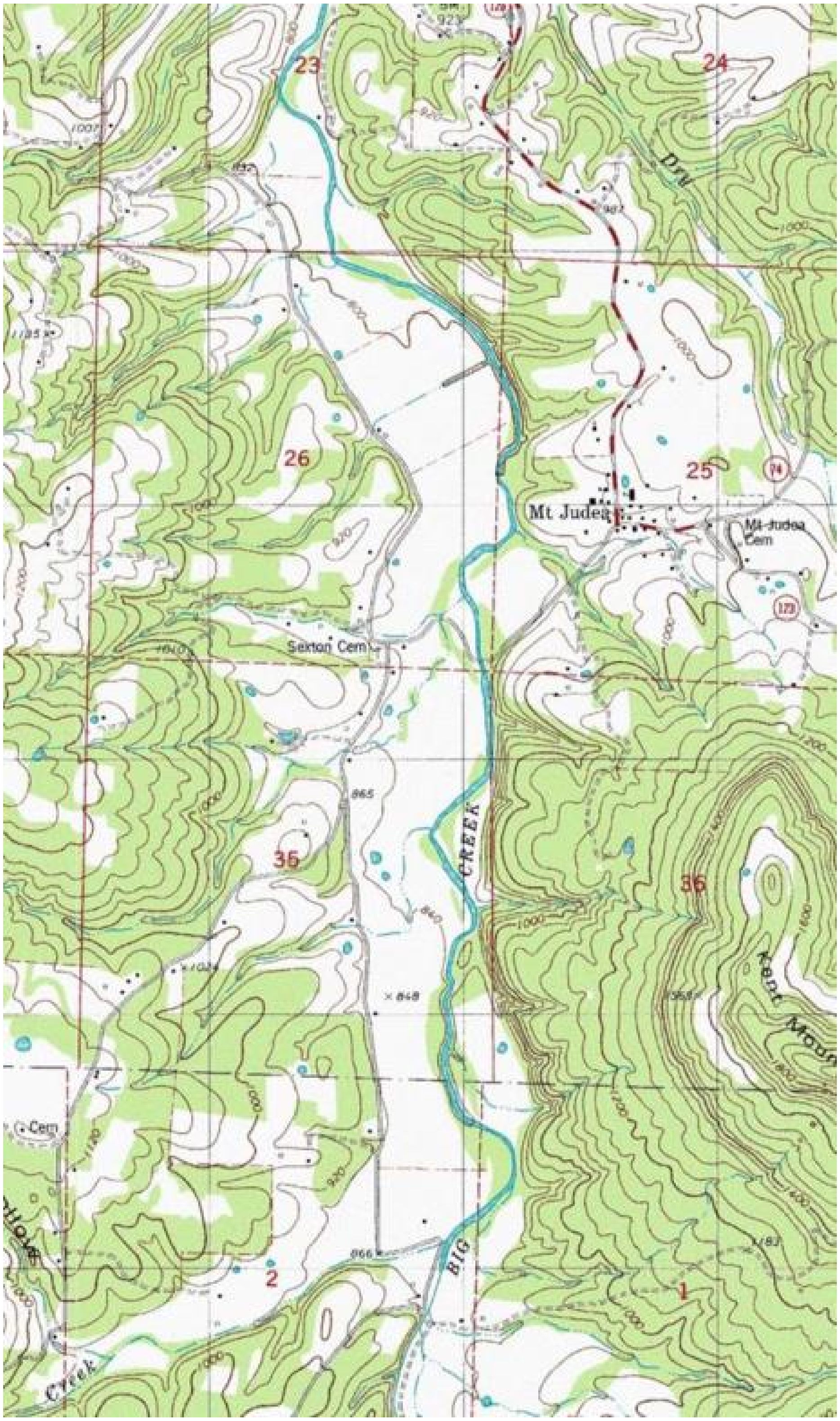


Map 1. Location of the C&H Farm operation, Mt. Judea, Newton County, AR.



Map 2. Location of monitored fields on the C&H operation Mt. Judea, Newton County, AR.

Photo 1. Recent aerial photo of the Mt. Judea, Newton County, AR region.



Map 3. Topographic map of Mt. Judea, Newton County, AR region.

Map 4. Soil type distribution in the vicinity of the C&H Farm operation Mt. Judea, Newton County, AR.

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Newton County, Arkansas
Survey Area Data: Version 12, Dec 19, 2013

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 5, 2010—Jun 30, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

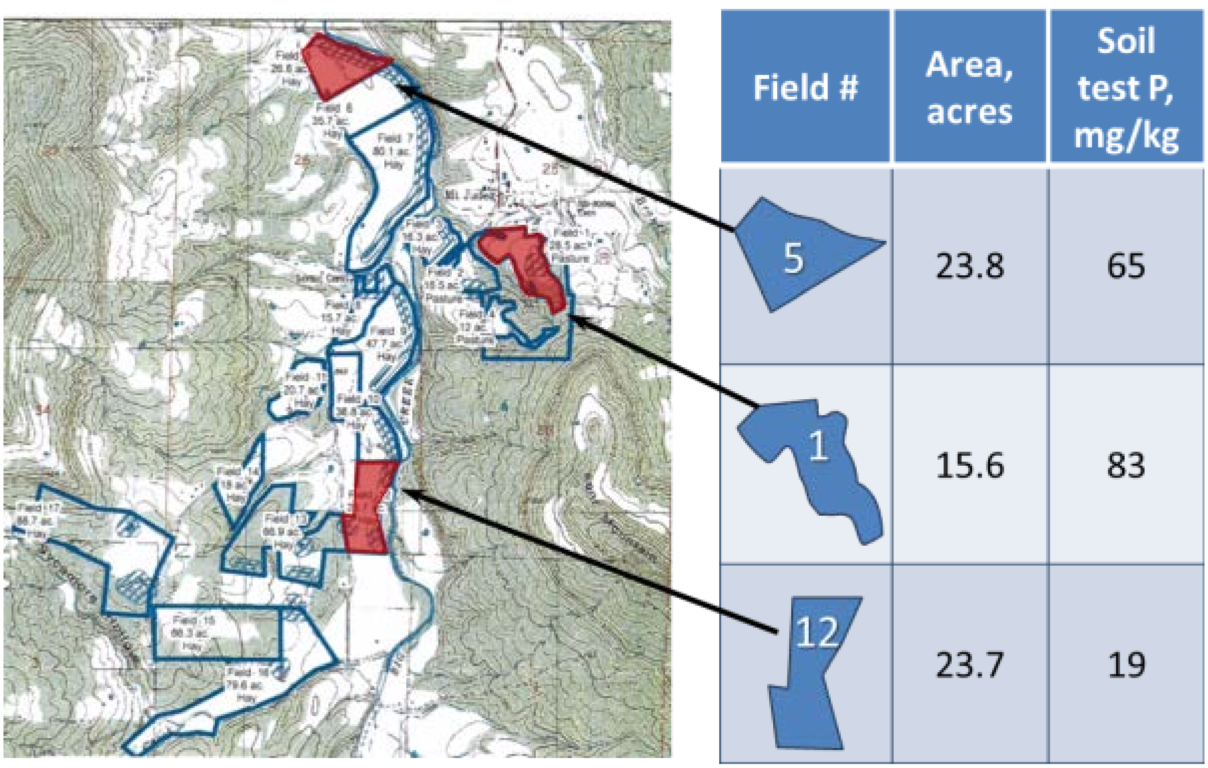
USDA Natural Resources Conservation Service — Web Soil Survey, National Cooperative Soil Survey — 1/21/2014, Page 2 of 4

Table 1. Key for the soil distribution Map 4.

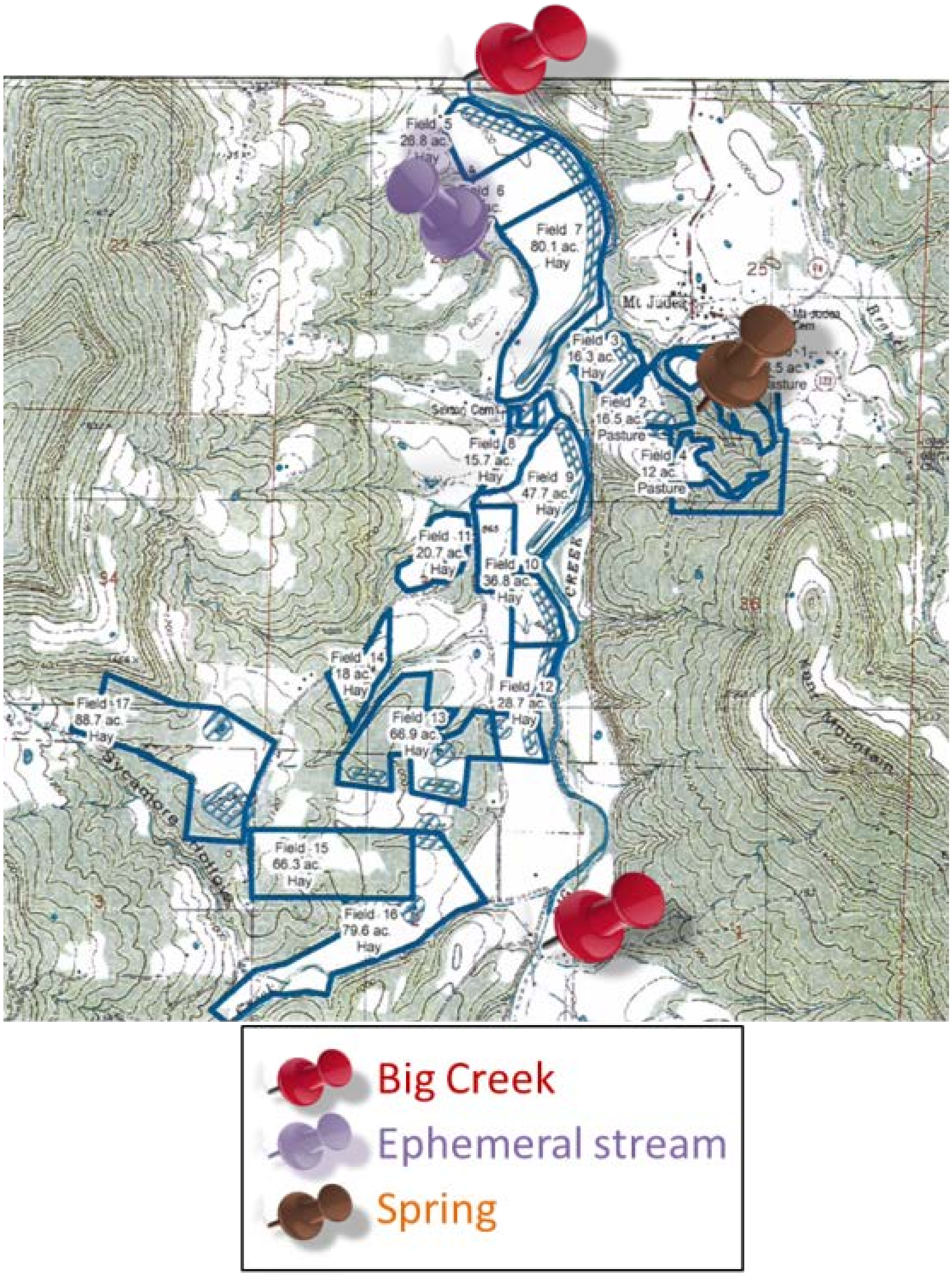
Table 2. Properties of fields where surface and subsurface flow will be determined.

	Field 1	Field 5	Field 12
¼ section	SW	NE	SE
Section	25	26	35
Township	15N	15N	15N
Range	20W	20W	20W
Latitude	35.917	35.928	35.901
Longitude	-93.058	-93.071	-93.069
Available acres	15.6	23.8	23.7
Soil type	Noark very cherty slit loam	Razort loam	Spadra loam
Soil test P, ppm	83	65	19
Field slope, %	5.3	0.2	2.0
Erosion, tons/acre [a]	0.12	0.05	0.05

[a] Erosion estimated by RUSLE 1.



Map 5. Location of monitored fields and soil test P levels on the C&H Farm operation Mt. Judea, Newton County, AR.



Map 6. Location of water sampling locations on and adjacent to the C&H Farm operation Mt. Judea, Newton County, AR.

United States Department of Agriculture
Natural Resources Conservation Service

Ground Penetrating Radar (GPR) Survey Report, November, 2013

Purpose and Overview:

A series of ground penetrating radar surveys were conducted near Mount Judea, AR on November 7th and 8th, 2013, on two different fields to investigate soil properties.

Participants:

Lawrence Berry	(University of AR, Crop, Soil and Environmental Sciences Department)
Dr. Kris Brye	(Professor of Applied Soil Physics and Pedology, University of Arkansas)
Dr. Mike Daniels	(Professor, Extension Water Quality, University of AR Division of Agriculture)
Cory Halmark	(University of AR Extension)
Josh Hesselbein	(University of AR Extension)
Wes Tuttle	(Geophysical Soil Scientist, NRCS)
Richard Vaught	(Soils Scientist and GPR operator, NRCS)

Activities, Field 1:

1. A SIR-3000 Ground-Penetrating Radar (GPR) system (Geophysical Survey Systems Inc) with 200-Mhz antenna was used at this site (Photos 1 and 2).
2. A metal plate was buried at the site at a depth of 50-cm to calibrate the instrument and to ground-truth soil conditions. A second hole was hand dug to 50-cm to further ground-truth soil conditions.
3. Conditions were too rocky at the site to successfully use a Giddings soil probe to a depth of deeper than 20-cm.
4. Two 90-m transects were laid out. The transects were flagged at 10-m intervals.
5. Transect/GPR survey #18 proceeded in a generally north easterly direction, up hill, where slopes ranged from 3 to 15 % or greater (Figure 2).
6. Transect/GPR survey #20 ran at a right angle to transect #18, and traveled in a north westerly direction, where slopes ranged from 3-5% (Figure 2).

Photo 2. Preparing a transect for the Ground Penetrating Radar assessment at C&H Farm.

Photo 3. Conducting the Ground Penetrating Radar assessment at C&H Farm.

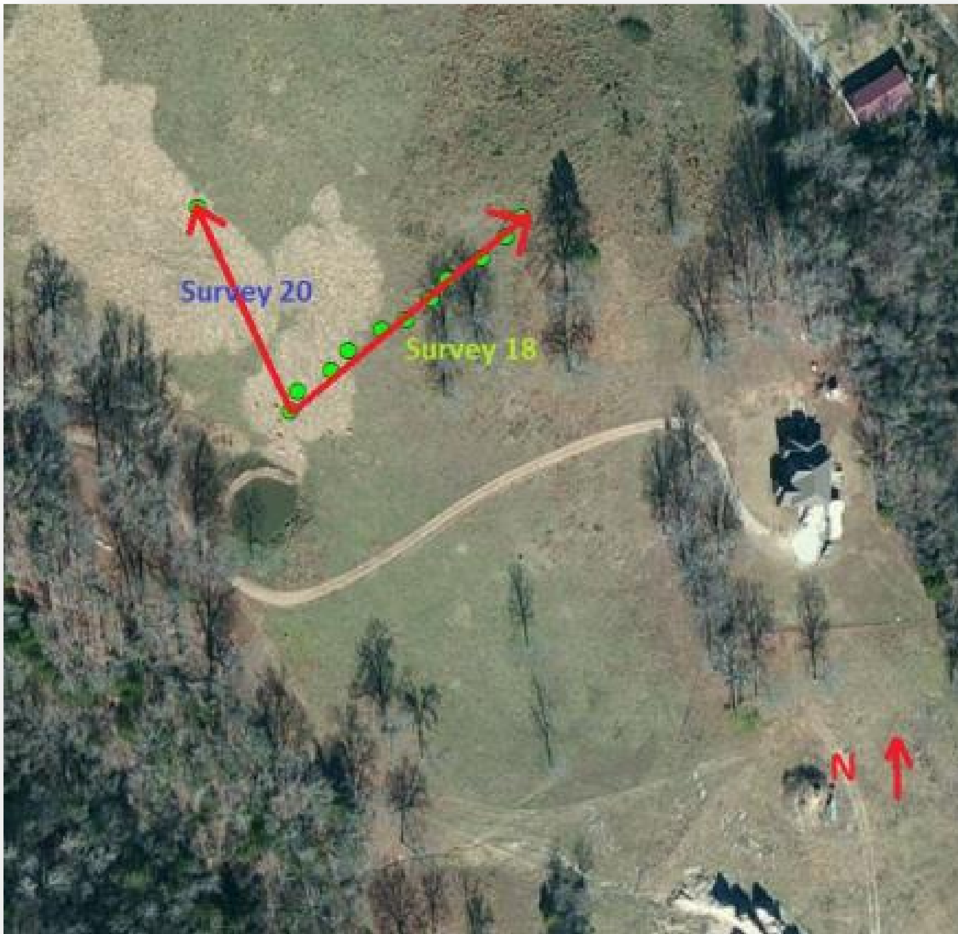


Figure 2. Location of ground penetrating radar surveys at field 1 near Mount Judea, AR. Surveys were 90-m in length.

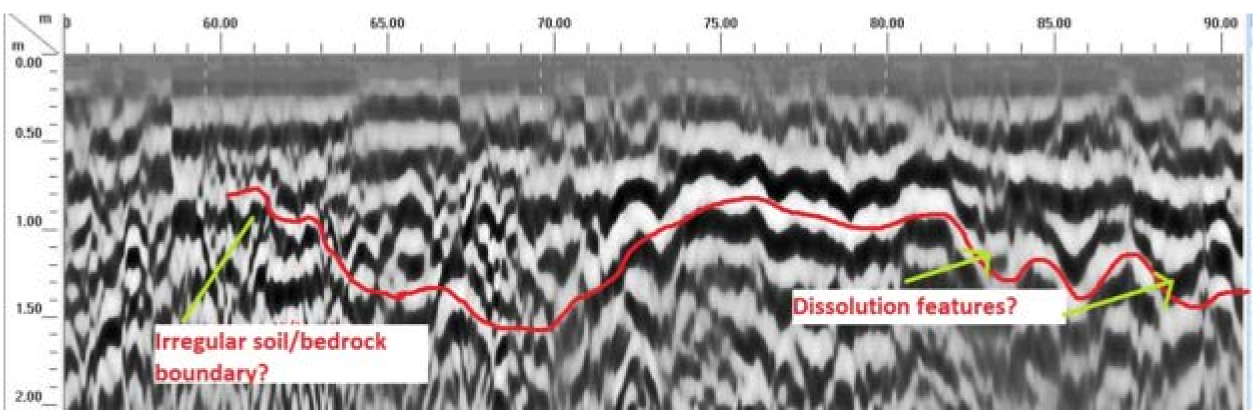


Figure 3. Possible solution features on the end sections of survey 18.

Summary, Field 1, Transect 18

1. Soils observed at the site seemed to agree with the Newton county soil survey, and resembled the Noark series, which is formed in residuum and colluvium of clayey limestone.
2. The radar records from this site are of good interpretative quality. Several features that were not readily evident in the field became more noticeable after processing the data.
3. Excavation to identify many of the subsurface features was not feasible due to rocky conditions. Thus, it should be noted that most features “observed” in the radar record have not been verified in the field.
4. The radar record indicates that soil features across survey 18 are not homogenous, which is not surprising, since the landform changed across the survey.
5. The data suggests that there could be an irregularly shaped boundary between soil and bedrock across the survey (Figures 4 and 5). This apparent contact is wavy in nature, and resembles the dissolution features that are manifested in cutter and pinnacle karst.
6. Depth to bedrock and karst features appear to be more shallow near the top of the hill surveyed, which would conform to standard soil landscape models for the area.

Summary, Field 1, Transect 20

1. The radar record suggests (as was verified at both test holes) that there is a horizon boundary that is mostly located in the vicinity of 50-cm. This horizon was observed to be a BC horizon, heavy silt loam or silty clay loam, with approximately 60% coarse fragments.
2. The radar record suggests an irregularly shaped boundary between soil and bedrock across the survey (Figure 5). This apparent contact is wavy in nature, and resembles the dissolution features that are manifested in cutter and pinnacle karst.

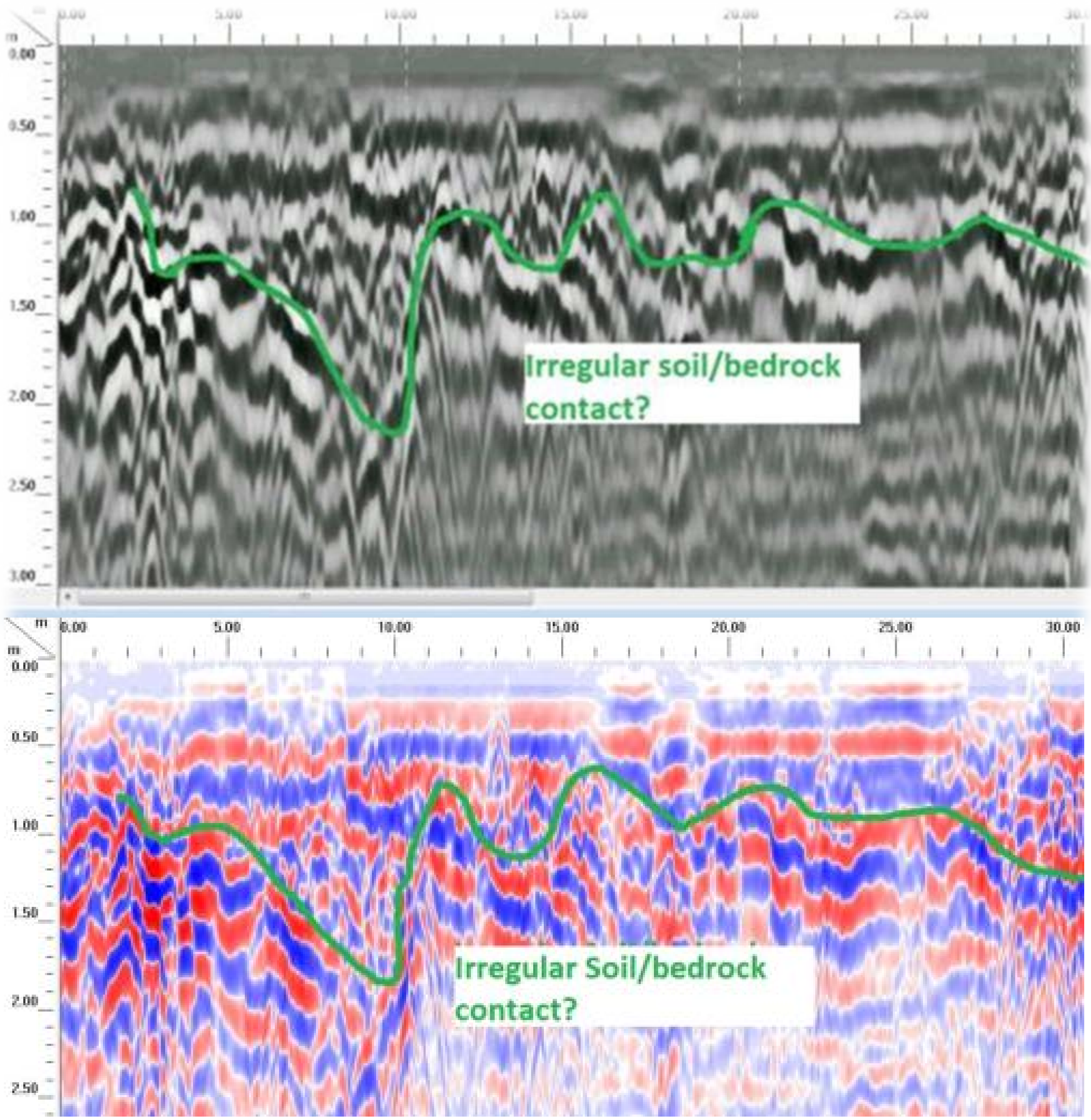


Figure 4. Two different representations of possible soil/bedrock interface at the beginning of survey 18.

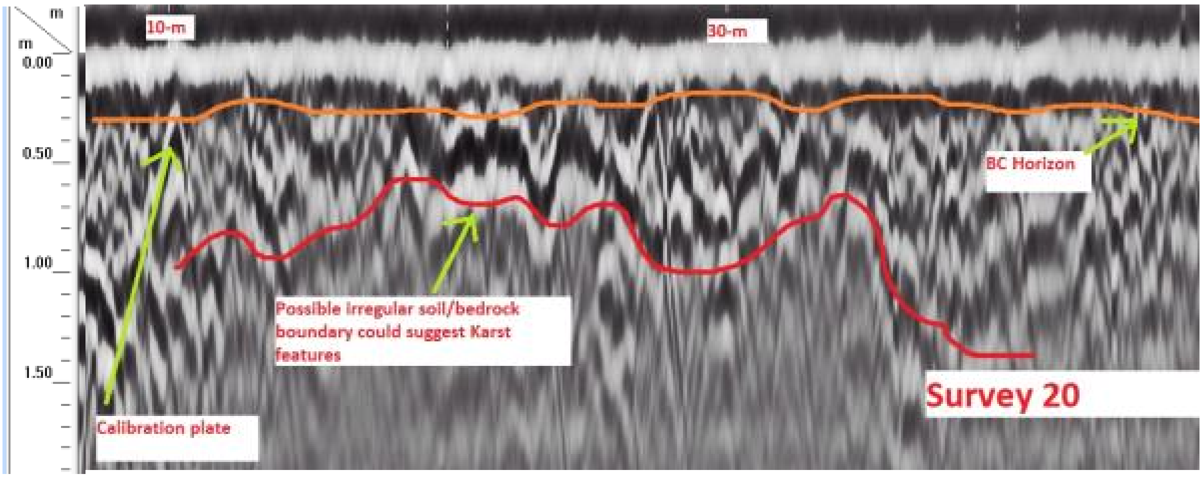


Figure 5. The apparent soil/bedrock contact was wavy in nature across survey 20.

Field Number 5, Surveys 27, 28 and 29

Activities, Field 5

1. A SIR-3000 Ground-Penetrating Radar (GPR) system (Geophysical Survey Systems Inc.) with 400-mhz antenna was used at this site.
2. A metal plate was buried at the site at a depth of 50-cm to calibrate the instrument and to ground-truth soil conditions.
3. A series of three transects were laid out and flagged at 10-m increments perpendicular to Big Creek, progressing from a portion of a toe slope, over a terrace to the flood plain. The bulk of the transects were located on the terrace (Figure 6).
4. Three holes were hand dug on survey 27 to observe soil conditions.
5. Four holes were bored with a Giddings soil probe to a depth of around 80-cm along each of the transects to collect samples and to ground-truth the radar survey.

Figure 6. Field 5.

Summary, Transect 27

1. The radar record and field observations indicated an argillic layer beginning in the vicinity of 25-cm over much of the transect. Field textures for this layer were mostly silt loam.
2. The radar record shows a contrasting layer at a depth near 50 to 60-cm over much of the transect. Field observations found that clay content increased near this depth consistently, changing from silt loam or fine sandy loam to clay, clay loam, or silty clay loam at greater depths.
3. Coarse fragment content observed in most of the borings was less than 10%. The Giddings probe worked well due to lack of fragments.
4. An anomaly was noted on the radar record near the end of survey 27, near the 160-m mark. Boring with the Giddings probe was not possible at this location, due to coarse fragment content. Further digging with a spade showed that coarse fragment content was 40-60% at a depth of 30-cm. Heavy coarse fragment content made further digging unfeasible due to time constraints.
5. Based on the radar records, field observation, and proximity to the creek, the area with an increase in coarse fragment content could be a gravel lens.

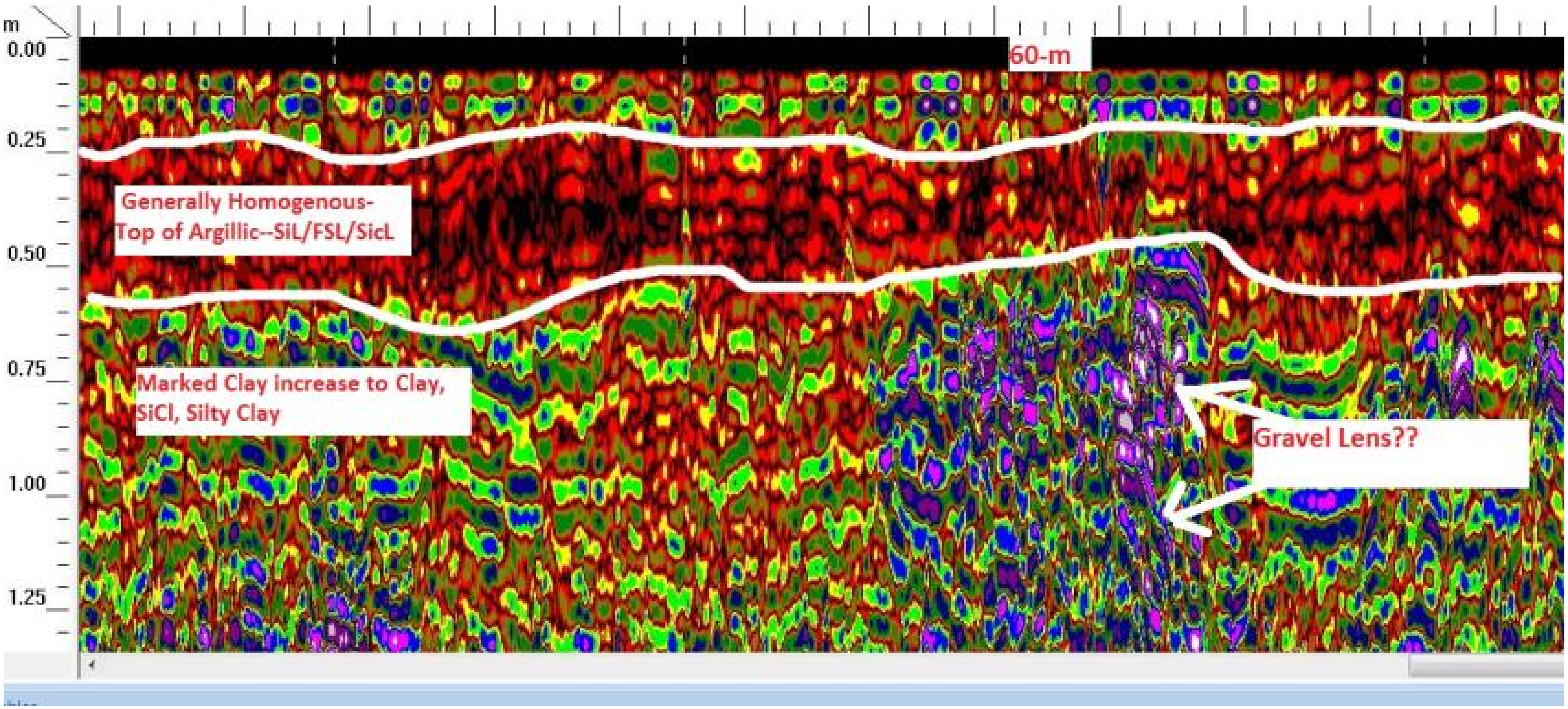


Figure 7. A marked increase in coarse fragments was observed in the field at the 60-m mark of survey 27.

Summary, Transect 28

1. Much like survey 27, the radar record and field observations indicated an argillic layer beginning at around 25-cm over much of the transect. Field textures for this layer were mostly silt loam.
2. The beginning portion of the transect occurred on a toe-slope. The radar record suggests that the soil-bedrock interface could be wavy in nature, which may suggest cutter and pinnacle karst (Figure 8).
3. The radar record shows a contrasting layer at a depth of around 50 to 60-cm over much of the transect. Field observations found that clay content increased near this depth consistently, changing from silt loam or fine sandy loam to clay, clay loam, or silty clay loam at greater depths (Figure 9).
4. Signatures from portions of this radar record resembled the area from transect 27 where coarse fragment content greatly increased. These areas could contain gravel lenses in the subsurface (Figure 9).
5. Based on field observations, soils near the end of the survey (closer to the creek) were younger and less developed.

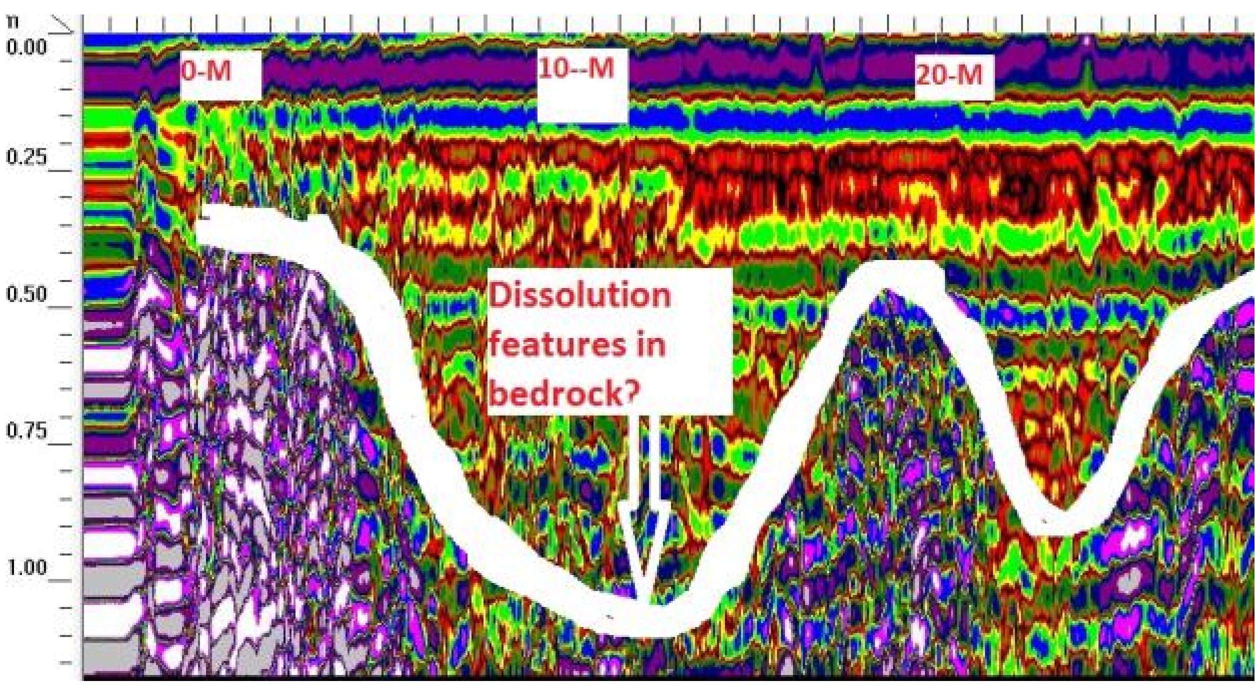


Figure 8. The first portion of transects 27-28 began on a toe-slope. The transect then dropped down onto a terrace. The toe-slope portion (above) may be underlain by dissolution features.

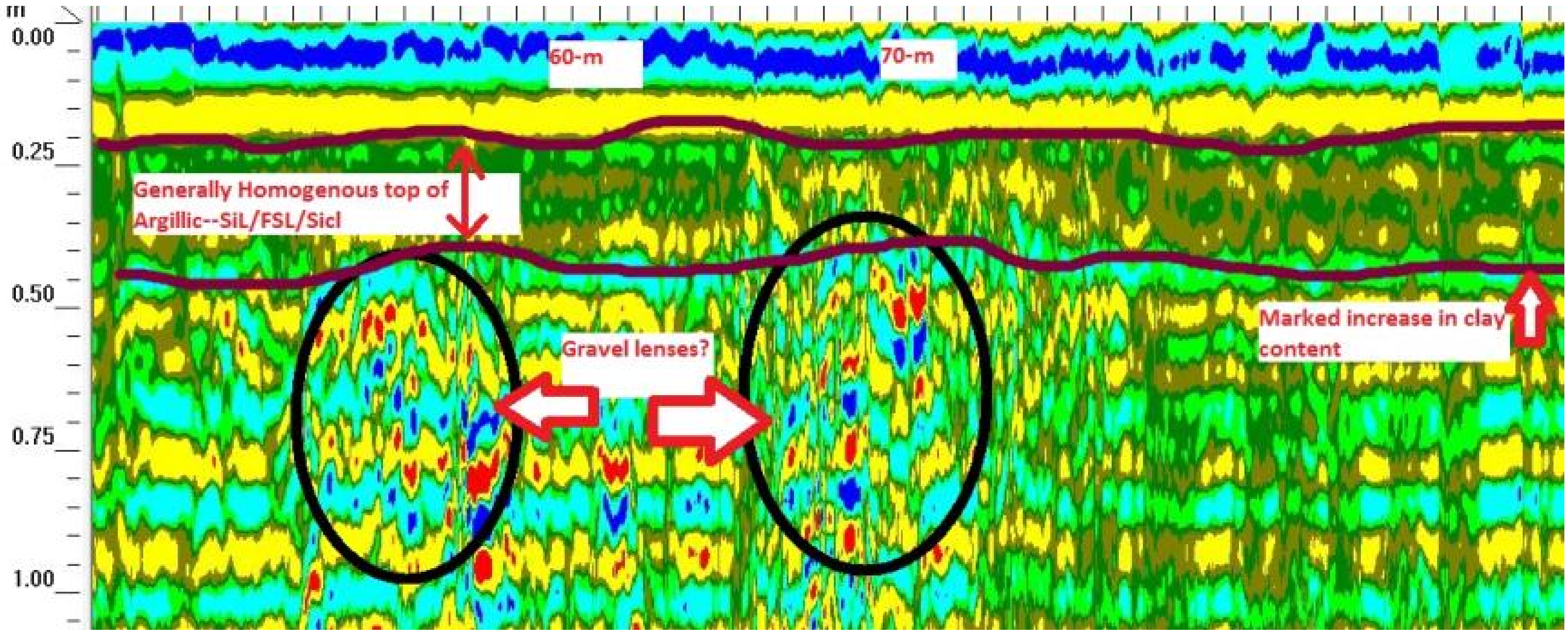


Figure 9. From survey 28. The right hand portion of the radar record seems to exemplify the overall nature of the field: a layer of silt loam or fine sandy loam, which transitions to clay or silty clay at around 50-cm. Possible gravel lenses were detected between 50-m and 70-m on the transect.

Summary, Transect 29

1. Much like surveys 27 and 28, the radar record and field observations indicated an argillic layer beginning at around 25-cm over much of the transect. Field textures for this layer were mostly silt loam.
2. The beginning portion of the transect occurred on a toe-slope. The radar record suggests that the soil-bedrock interface could be wavy in nature, which would be indicative of cutter and pinnacle karst.
3. The radar record shows a contrasting layer at a depth of around 50 to 60-cm over much of the transect. Field observations found that clay content increased near this depth consistently, changing from silt loam or fine sandy loam to clay, clay loam, or silty clay loam at greater depths (Figure 10).
4. There were no potential gravel lenses observed on this radar record.
5. Based on field observations, soils near the end of the survey (closer to the creek) were younger and less developed.

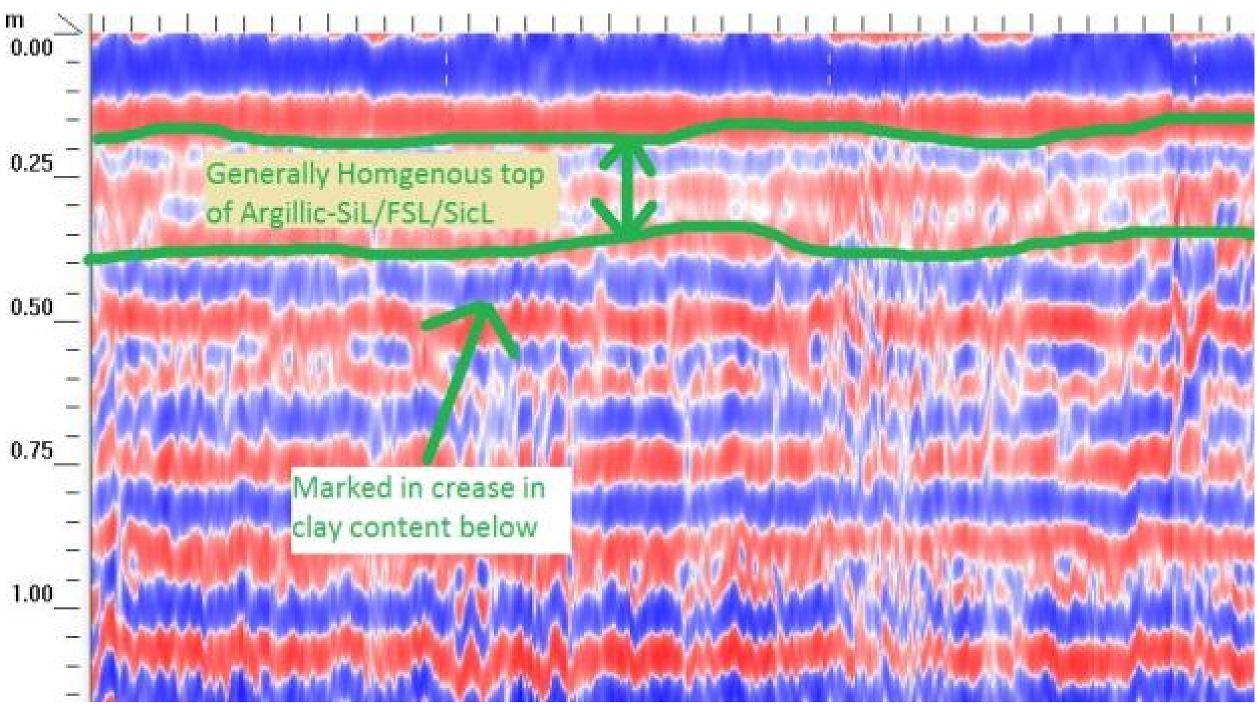


Figure 10. Typical portion of the radar record from survey 29, along the terrace/flood plain NRCS report and brief interpretation.

Summary of GPR Analysis of Fields 1 and 5

Results from this preliminary GPR survey along several transects in application fields showed that this methodology can be useful for evaluating variability and/or uniformity in the top 1 to 2 m of underlying soil/geologic material and holds promise for helping define other unique features in the strata underlying the application fields in a non-invasive manner. Although results are strictly preliminary at this point, additional, more detailed characterization and investigation of the application fields with the GPR technology are warranted and planned. While the survey indicated changes in subsurface strata along numerous preliminary transects, interpretations of these changes as being gravel lenses and/or dissolution features, are inconclusive at the present time, as actual ground truthing with invasive observational coring has not been conducted yet.

The preliminary GPR survey demonstrated that the apparent soil depth to bedrock was consistent with NRCS soil mapping unit descriptions already available, which show the soil depth being greater on the Big Creek side of Field 5 than in Field 1. In all transects conducted, GPR results indicated that at least 49 inches of soil overlies any bedrock, which is consistent with soil pedons described in the NRCS soil survey of this area in the watershed.

A more detailed and exhaustive survey of the application fields, coupled with other soil tests and characterizations, such as hydraulic conductivity and infiltration measurements, will be conducted in the coming year to make reliable conclusions on the underlying geology and presence of karst features.

Soil Sampling and Analyses

Each of the application fields were are monitoring were grid soil sampled prior to any manure application from the new operation. The grid size is approximately 0.25 acres and seven soil-depths increments will be collected to include 0 to 4", 4 to 8", 8 to 12", 12 to 18", 18 to 24", 24 to 30", and 30 to 36" where possible with a Giddings soil probe. Combining the three fields and sampling increments, we will eventually collect approximately 2800 soil samples that will be used to construct detailed soil nutrient, texture, pH, organic matter, and potassium concentration maps by depth. A grid network was overlain on each field to determine the point of sampling, which was noted by GPS. Each sample-hole remaining after the soil core was removed was carefully back-filled with commercial top soil (see Map 5). Where rock stopped the core penetrating below a specific layer, no sample was taken.

All soil samples were shipped to the University of Arkansas, Marianna Soil Test Laboratory for analysis (http://www.uark.edu/depts/soiltest/NewSoilTest/index.htm). This Laboratory serves Arkansas and provides accurate and timely soil analyses and unbiased nutrient management guidelines that are based on the best available science. In terms of quality control and assurance, the Laboratory is a member of The North American Proficiency Testing Program (a program of the Soil Science Society of America), which assists soil, plant and water testing laboratories in their performance through inter-laboratory sample exchanges and a statistical evaluation of the analytical data. The program guidelines have been developed for the agricultural laboratory industry by representatives from groups familiar with and involved in standardizing methods and developing nutrient recommendations for soil and plant analysis methods within the U.S. and Canada.

A complete description of the nationally standardized methods for soil handling, preparation, and analysis used for all samples collected in this project, can be found at http://www.uark.edu/depts/soiltest/NewSoilTest/lab_methods.htm

As of December 31, 2013, Fields 1 and 5 had been soil sampled and initial routine soil test analyses conducted at the Division of Agriculture University of Arkansas Soil Testing Laboratory. We used the same sample packaging and analyses that farmers in Arkansas use to test for soil fertility levels that guide fertilizer recommendations. Field 12 has not been grid sampled due to the cold and wet weather limiting access to the fields, without the probe equipment damaging the pasture.

The measured nutrient concentrations of all individual soil analyses are listed in the Appendix 2 (Tables 4, 5, 6, 7, 8, 9, 10, 11, and 12). Average, minimum, and maximum values are given below in Table 3, along with the original values from the C&H NMP. The distribution of soil test phosphorus (measured as Mehlich-3 extractable soil phosphorus) in the surface 4 inches of soil are graphically represented in Map 8 for Field 1 and Map 9 for Field 5. As expected, soil test phosphorus is not evenly distributed across these grazed fields.

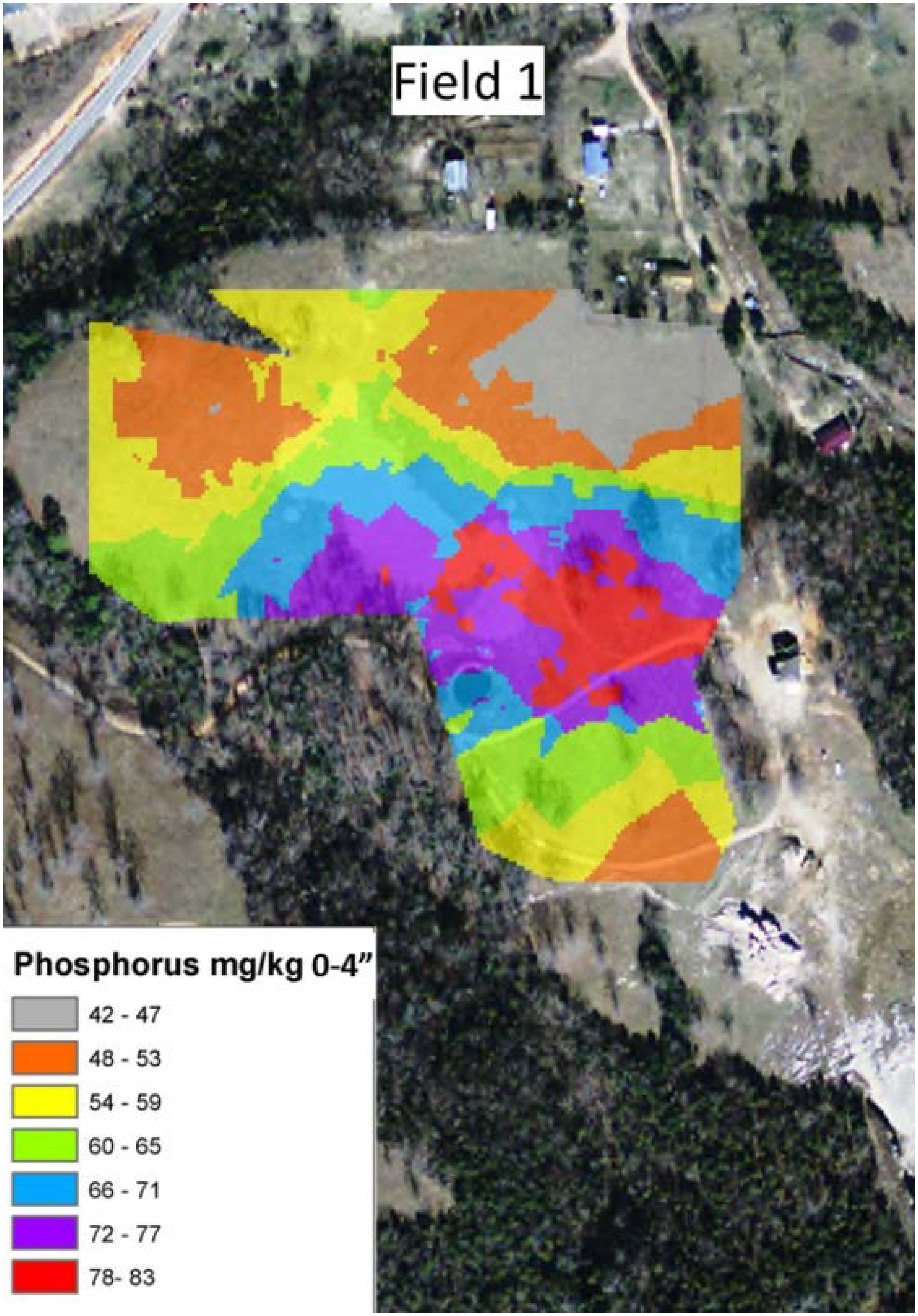
To help put soil phosphorus levels in perspective, the mean soil phosphorus in the top 4 inches for all grid samples was 41 mg/kg for Field 1 and 54 mg/kg for Field 5. Based on the U of A Division of Agriculture's fertility guidelines for a mixture of cool and warm season grasses, Field 1 would require additional phosphorus for a typical hay production yield of 3 tons/acre. Field 5 is in the optimal range of soil phosphorus levels (i.e., 50 - 60 mg/kg) for a warm season grass, such as Bermudagrass.

Table 3. Average soil test phosphorus concentrations in the surface 0 to 4 inches of each field and when sampled during the Comprehensive Nutrient Management Plan (CNMP) development.

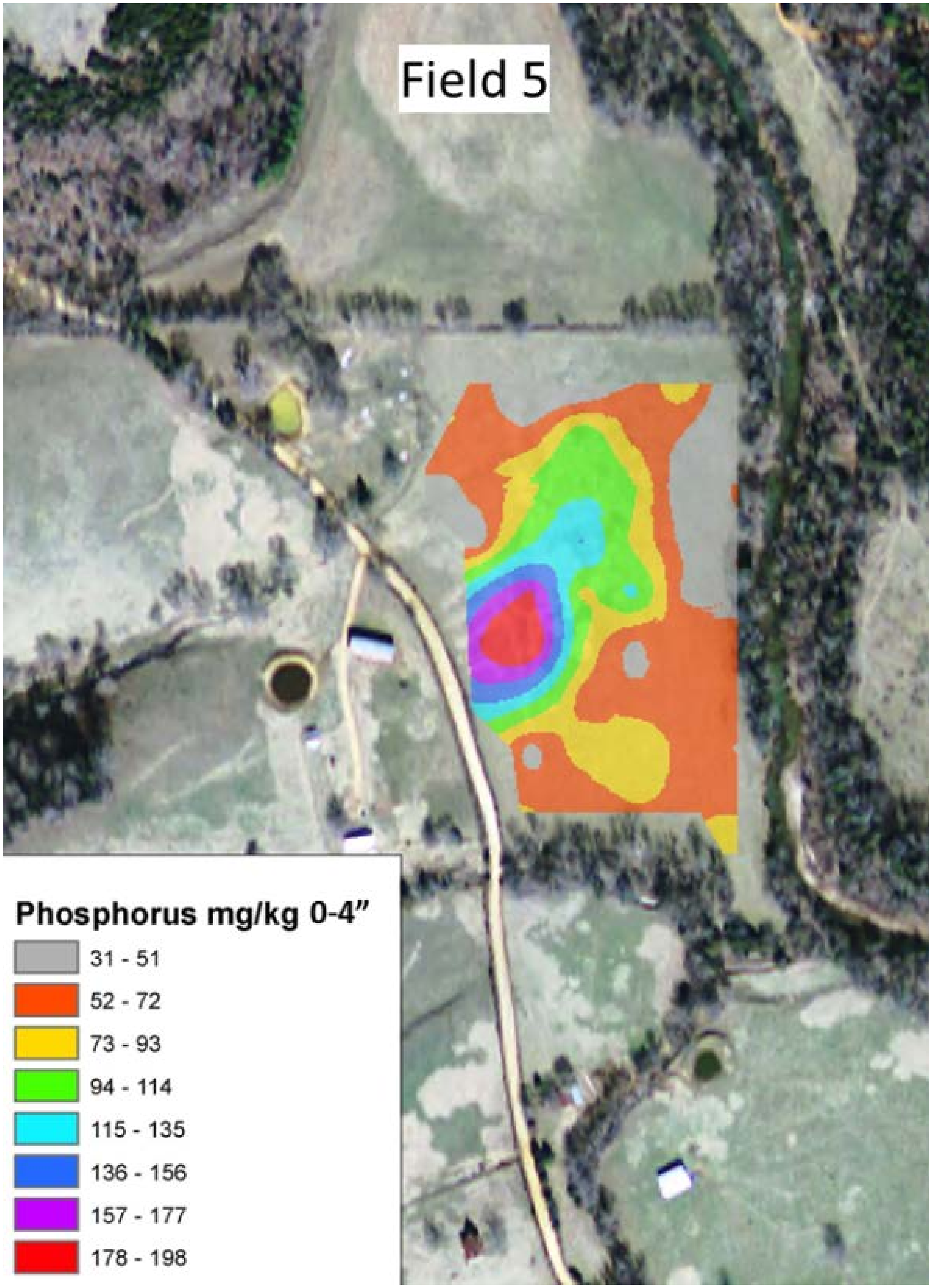
Soil depth, inches	Field 1	Field 5	Field 12
	- - - - - - - - -	mg/kg	- - - - - - - - - -
Original NMP	83	65	19
0 - 4	41	54	NS
4 – 8	17	32	NS
8 – 12	10	28	NS
12 – 18	NS	34	NS
18 – 24	NS	6	NS
24 – 30	NS	19	NS

NS – Not sampled.

Map 7. Gridded layout of the sampled fields on the C&H Farm operation Mt. Judea, Newton County, AR.



Map 8. Soil phosphorus distribution of the 0 to 4 inch depth for Field 1.



Map 9. Soil phosphorus distribution of the 0 to 4 inch depth for Field 5.

Manure Slurry Sampling and Analysis

To help guide initial adaptive manure management decisions samples of the manure slurry from the C&H lagoon were collected on September 24, 2013 for chemical analysis. A foot valve liquid manure sampler was used to collect samples of slurry from the top 6 inches of slurry, the bottom of the lagoon, and from the entire depth profile of the lagoon (Photo 4). Additional information on manure sampling is given in Appendix 3. Results of this slurry sampling are given in Table 4 and the distribution of chemical constituents with lagoon depth is given in Figure 11. This information was shared with C&H's owners as part of the adaptive manure management discussions.

Photo 4. Foot valve manure sampler as used to collect samples from the C&H lagoon.

Table 4. Chemical properties of manure slurry taken from the C&H lagoon on 09/24/2013.

Parameter	0 – 6"	Bottom	Profile
pH	7.8	7.6	7.7
Electrical conductivity µmohos/cm	10020	9880	10060
Solids. %	0.63	2.99	2.56
Concentration on a mg/L as-is basis			
Total N	763.0	1565.0	1514.0
Total P	134.7	1139.3	527.5
Water extractable P	88.4	162.6	137.7
Total K	1080.4	158.8	1054.3
Total Ca	35.0	925.3	379.6
Ammonium-N	731.0	758.0	875.0
Nitrate-N	<0.7	<0.7	<0.7
Total Mg	12.3	556.5	228.8
Total S	35.0	214.6	106.8
Total Fe	12.9	346.8	156.6
Total Mn	6.6	24.2	10.1
Total Zn	1.95	46.9	19.7
Total Cu	0.28	5.2	2.3
Content on a lbs/1000 gallon as-is basis			
Total N	6.36	13.04	12.61
Total P as P_2O_5	2.57	21.73	10.06
Water extractable P	0.74	1.35	1.15
Total K as K_2O	10.80	11.58	10.54
Total Ca	0.29	7.71	3.16
Ammonium-N	6.09	6.31	7.29
Nitrate-N	<0.0006	<0.0006	<0.0006

Parameter	0 – 6“	Bottom	Profile
Total Mg	0.10	4.64	1.91
Total S	0.29	1.79	0.89
Total Fe	0.11	2.89	1.30
Total Mn	0.05	0.20	0.08
Total Zn	0.02	0.39	0.16
Total Cu	0.002	0.04	0.02

* lbs/1000gal P2O5 = mg/l Total P on "as-is" basis multiplied by 2.29*0.00833

* lbs/1000gal K2O = mg/l Total K on "as-is" basis multiplied by 1.2*0.00833

* Water Extractable P: 1:100 solids to H2O ratio, I hour shake, centrifuged, filtered, acidified, analysis by ICP.

Collection and analysis of manure samples from the holding pond / lagoon on the C&H Farm, representing the top water, bottom slurry, and entire profile, generated chemical profiles typical of other holding ponds associated with hog production. That is, nitrogen and phosphorus concentrations of the manure increased with water depth (Table 4 and Figure 11). However, phosphorus concentrations increased at a greater rate than did concentrations of nitrogen. The result of the relatively greater phosphorus increase than nitrogen increase with pond depth is that the nitrogen / phosphorus ratio is greater for surface liquid than bottom slurries. As a consequence, the higher nitrogen / phosphorus ratio of the surface water is closer to the ratio of these nutrients required by pastures on the C&H Farm. Thus, land application of top water from the pond to farm pastures will more likely meet both the nitrogen and phosphorus needs of the pasture and avoid application of phosphorus surplus to plant needs. The higher concentration and lower nitrogen / phosphorus ratio of bottom slurries will lend application of that slurry on a manure banking approach, where the slurry would be applied on alternate years to fields more distant from Big Creek. Even without the addition of mechanical and/or chemical separation approaches, the observed natural gravity separation of slurry and its constituents, provides farm nutrient management opportunities to closely match manure nutrients to crop nutrient needs.

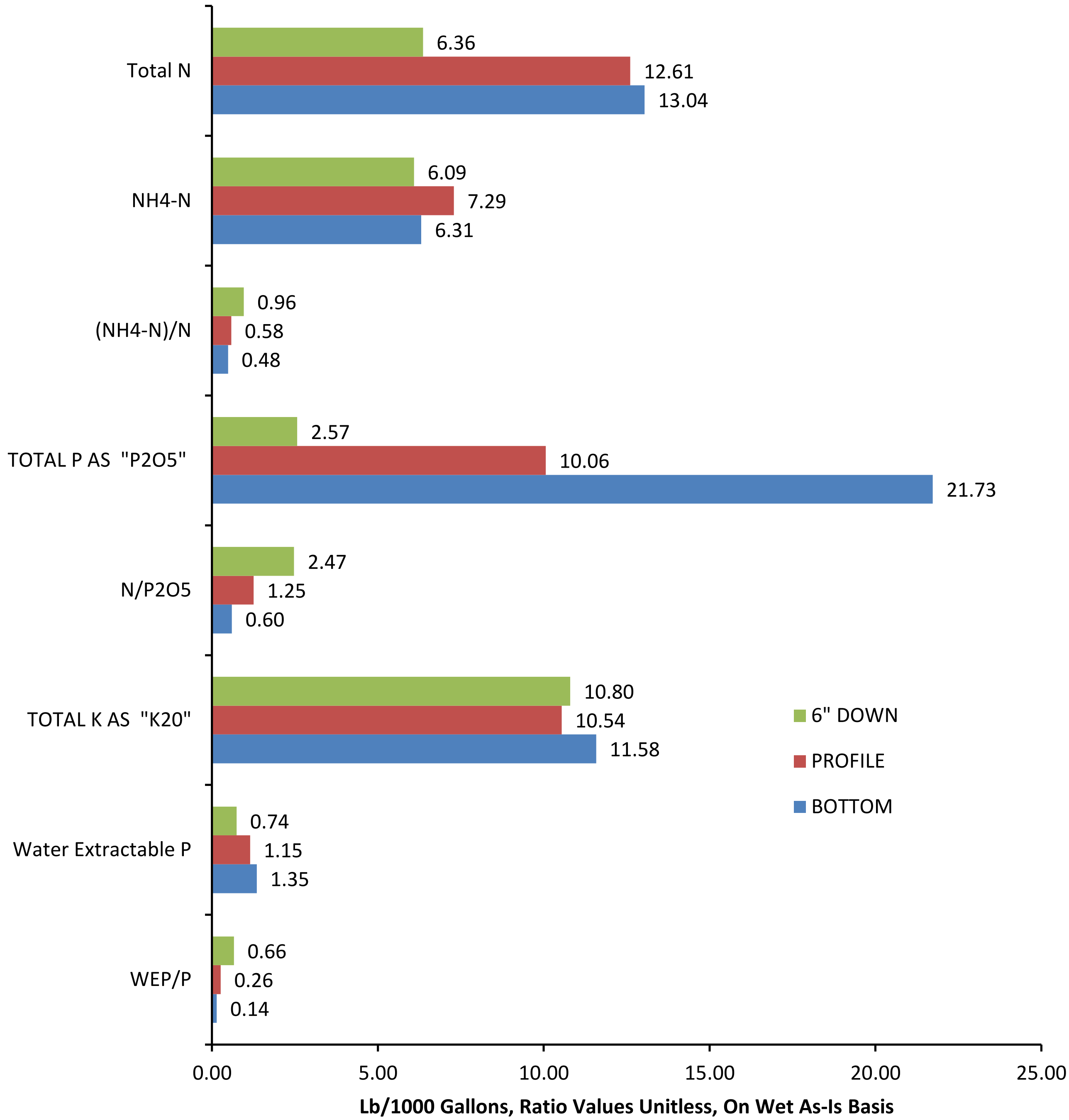


Figure 11. Distribution of nitrogen, phosphorus and potassium with depth in the manure lagoon, sampled on September 24, 2013.

Water Sampling and Analyses

Sampling Locations

Water quality sampling was initiated on September 24th, 2013, prior to the formal start of the project at five locations (Map 10). These sites were;

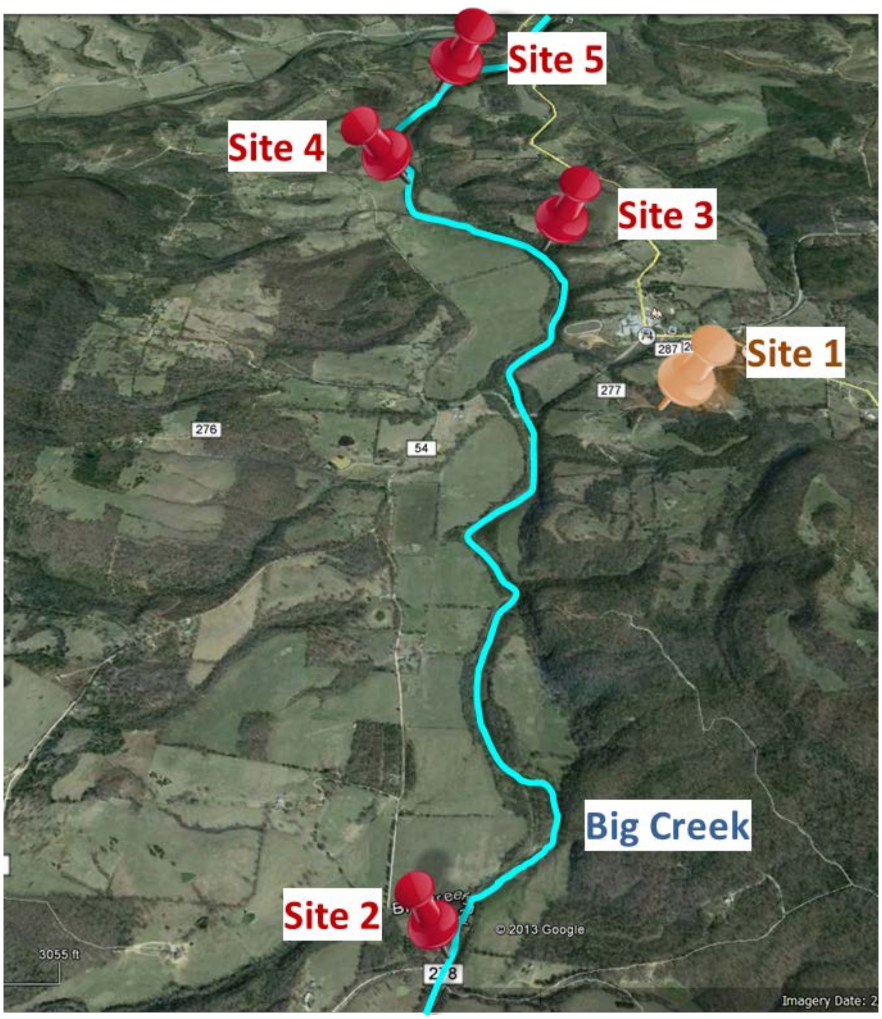
Site 1. A spring below application field 1 – Photo 4,

Site 2. Big Creek upstream of the C&H Farm operation – Photo 5,

Site 3. Big Creek upstream of the barn – Photo 6,

Site 4. Big Creek downstream of the barn – Photo 7, and

Site 5. Big Creak downstream of the C&H Farm operation Photo 8.



Map 10. Location of water quality sampling sites on Big Creek and spring below application Field 1.

Photo 5. The spring sampled adjacent to Big Creek on the C&H Farm.

Photo 6. The Big Creek sampling site upstream of the C&H Farm during baseflow.

Photo 7. The Big Creek sampling site upstream of the C&H Farm barn during baseflow.

Photo 8. The Big Creek sampling site downstream of the C&H Farm barn during baseflow.

Photo 9. The Big Creek sampling site downstream of the C&H Farm during baseflow.

Sampling Protocols and Analyses

The chemical composition of water samples collected prior to December 31, 2013 is given in Table 5. The following procedure was 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.
6. 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.
7. Analyses included Dissolved Phosphorus (EPA 365.2), Total Phosphorus (APHA 4500-P), Ammonia (EPA 351.2), Nitrate (EPA 300.0), Total Nitrogen (APHA 4500-P), Total Suspended Solids (EPA 160.2), E. Coli (APHA 9223, B) and Total Coliforms (APHA 9223, B).

Table 5. Water quality analyses at each sample site. Coliform units are Most Probable Number (MPN) per 100 mL of water.

Date & time sample collected	Date & time received @ laboratory	Sample location	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
			- mg/L -						- - - MPN/100 mL - - -	
9/12/2013	**9/12/2013**	**Base flow**								
10:45	15:30	Upstream farm	0.016	0.030	0.06	0.367	0.50	3.0	6.3	>2420
11:15	15:30	Upstream barn	0.010	0.022	0.05	0.356	0.54	5.8	4.1	4040.0
10:50	15:30	Downstream barn	0.019	0.026	0.05	0.632	0.78	1.2	1.0	488.4
13:00	15:30	Downstream farm	0.010	0.022	0.04	0.396	0.62	1.7	16.0	>2420
9/20/2013	**9/20/2013**	**Base flow**								
10:50	16:08	Spring	0.006	0.020	0.03	0.384	0.50	4.7	72.7	5040
11:15	16:08	Upstream farm	0.009	0.022	0.03	0.247	0.36	1.1	80.9	9870
11:20	16:08	Upstream barn	0.015	0.024	0.04	0.356	0.42	1.2	1203	26130
12:20	16:08	Downstream barn	0.024	0.032	0.06	0.757	0.85	1.3	218.7	2430
12:50	16:08	Downstream farm	0.013	0.022	0.05	0.442	0.53	1.1	548	17230
9/24/2013	**9/24/2013**	**Base flow**								
10:55	16:15	Spring	0.004	0.024	0.00	0.122	0.35	50.0	8.5	>2420

Date & time sample collected	Date & time received @ laboratory	Sample location	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
11:40	16:15	Upstream farm	0.011	0.014	0.03	0.444	2.20	17.9	39	1120
11:15	16:15	Upstream barn	0.007	0.024	0.00	0.330	0.41	1.6	42	>2419
11:20	16:15	Downstream barn	0.017	0.032	1.77	0.790	0.76	0.7	42	816
12:40	16:15	Downstream farm	0.007	0.028	0.01	0.511	0.58	1.5	5	>2420
10/1/2013	**10/1/2013**	**Base flow**								
9:45	14:42	Spring	0.001	0.162	0.00	0.108	0.41	89.2	4	920
10:00	14:42	Upstream farm	0.011	0.038	0.02	0.236	0.34	2.2	8	1300
10:15	14:42	Upstream barn	0.006	0.032	0.03	0.235	0.40	6.7	82	5200
10:35	14:42	Downstream barn	0.018	0.032	0.00	0.837	0.80	1.1	19	649
10:55	14:42	Downstream farm	0.009	0.034	0.02	0.514	0.65	3.6	2620	10810
10/9/2013	**10/9/2013**	**Base flow**								
9:00	13:52	Spring	0.011	0.054	0.00	0.088	0.28	29.1	3	1413
9:30	13:52	Upstream farm	0.016	0.034	0.00	0.497	0.73	7.1	11	2419
9:45	13:52	Upstream barn	0.016	0.030	0.00	0.385	0.53	6.2	194	4730

Date & time sample collected	Date & time received @ laboratory	Sample location	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
10:00	13:52	Downstream barn	0.017	0.02	0.00	0.868	0.82	0.4	29	1986
10:20	13:52	Downstream farm	0.006	0.038	0.00	0.618	0.77	13.6	28	3450
10/15/2013	**10/15/2013**	**Storm flow**								
11:13	15:47	Spring	0.010	0.250	0.15	0.086	0.58	66.9	1401	19863
12:24	15:47	Upstream farm	0.018	0.026	0.00	1.041	0.96	1.1	759	>2419
12:47	15:47	Upstream barn	0.019	0.036	0.06	0.839	0.99	2.1	472	8664
13:13	15:47	Downstream barn	0.033	0.244	0.12	1.280	1.44	89.2	959	12997
13:34	15:47	Downstream farm	0.067	0.316	0.20	0.677	1.07	101.1	1334	19863
10/22/2013	**10/22/2013**	**Base flow**								
10:10	15:31	Spring	0.005	0.086	0.10	0.307	0.53	36.4	1733	>2419
10:30	15:31	Upstream farm	0.014	0.034	0.00	0.345	0.32	0.3	186	299
10:45	15:31	Upstream barn	0.016	0.024	0.03	0.575	0.60	1.2	411	11190
11:00	15:31	Downstream barn	0.016	0.022	0.00	0.786	0.77	0.1	150	2419
11:20	15:31	Downstream farm	0.012	0.020	0.04	0.723	0.76	0.7	87	292

Date & time sample collected	Date & time received @ laboratory	Sample location	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
10/31/2013	**10/31/2013**	**Base flow**								
11:00	15:15	Spring	0.003	0.404	0.14	0.321	1.02	400.9	91	32550
10:45	15:15	Upstream farm	0.012	0.032	0.00	0.242	0.32	1.1	66	1986
10:15	15:15	Upstream barn	0.007	0.044	0.04	0.246	0.38	2.3	261	6310
10:00	15:15	Downstream barn	0.018	0.022	0.11	0.519	0.53	0.9	14	218
10:30	15:15	Downstream farm	0.012	0.024	0.03	0.443	0.45	1.4	Leaked	Leaked
11/6/2013	**11/6/2013**	**Base flow**								
8:35	14:35	Spring	0.013	0.130	0.10	0.062	0.72	21.2	8570	34480
9:00	14:35	Upstream farm	0.032	0.074	0.03	0.432	0.61	4.7	4080	28510
9:10	14:35	Upstream barn	0.020	0.038	0.00	0.184	0.27	2.5	579	13330
9:45	14:35	Downstream barn	0.040	0.164	0.12	0.413	0.67	32.9	3180	36090
10:00	14:35	Downstream farm	0.041	0.154	0.12	0.286	0.60	28.4	3500	43520
11/12/2013	**11/12/2013**	**Base flow**								
10:56	16:28	Spring	0.006	0.022	0.05	2.449	2.39	8.9	48	2750

Date & time sample collected	Date & time received @ laboratory	Sample location	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
11:35	16:28	Upstream farm	0.011	0.010	0.00	0.169	0.22	1.0	45	1986
12:15	16:28	Upstream barn	0.012	0.014	0.09	0.221	0.33	1.4	36	1733
13:03	16:28	Downstream barn	0.012	0.012	0.00	0.295	0.34	0.5	21	1046
13:35	16:28	Downstream farm	0.011	0.010	0.00	0.242	0.31	0.0	24	>2419
11/19/2013	**11/19/2013**	**Base flow**								
9:20	14:35	Spring	0.007	0.022	0.02	3.063	3.06	4.4	579	9880
9:45	14:35	Upstream farm	0.010	0.026	0.00	0.123	0.22	0.7	435	2400
10:05	14:35	Upstream barn	0.011	0.028	0.00	0.175	0.32	0.3	172	>2419
10:35	14:35	Downstream barn	0.011	0.028	0.00	0.231	0.34	0.5	238	2419
10:55	14:35	Downstream farm	0.009	0.024	0.02	0.172	0.28	1.0	194	4410
11/26/2013	**11/26/2013**	**Base flow**								
10:35	14:40	Spring	0.007	0.018	0.00	1.69	1.70	4.5	86	1553
10:45	14:40	Upstream farm	0.013	0.018	0.00	0.135	0.14	0.4	77	1203
11:06	14:40	Upstream barn	0.014	0.016	0.00	0.19	0.20	0.7	249	1986

Date & time sample collected	Date & time received @ laboratory	Sample location	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
11:30	14:40	Downstream barn	0.014	0.018	0.03	0.3	0.33	1.3	40	613
11:45	14:40	Downstream farm	0.013	0.016	0.00	0.231	0.24	1.2	36	2419
12/3/2013	**12/3/2013**	**Base flow**								
8:30	13:23	Spring	0.007	0.046	0.04	1.048	1.37	26.9	25	1986
8:45	13:23	Upstream farm	0.007	0.012	0.00	0.152	0.25	0.5	27	435
9:00	13:23	Upstream barn	0.009	0.012	0.00	0.21	0.28	0.3	29	548
9:15	13:23	Downstream barn	0.010	0.018	0.00	0.295	0.35	0.6	248	687
9:35	13:23	Downstream farm	0.006	0.012	0.00	0.225	0.28	0.5	12	>2419

The water quality data in Table 4 for the monitored spring and Big Creek above and below the boundary of the permitted fields of the C&H Farm only is given in Table 6.

Table 6. Water quality analyses at the spring and in Big Creek upstream and downstream of the C&H Farm boundary of permitted land application fields (see Map 12).

Sample location relative to farm	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
	- - - - - - - - - - - -	- - - - - - - - - - - -	mg/L	- - - - - - - - - - - -	- - - - - - - - - - - -		- - - MPN/100 mL - - -	
9/12/2013 Base flow								
Upstream	0.016	0.030	0.06	0.367	0.50	3.0	6	>2420
Downstream	0.010	0.022	0.04	0.396	0.62	1.7	16	>2420
9/20/2013 Base flow								
Spring	0.006	0.020	0.03	0.384	0.50	4.7	73	5040
Upstream	0.009	0.022	0.03	0.247	0.36	1.1	81	9870
Downstream	0.013	0.022	0.05	0.442	0.53	1.1	548	17230
9/24/2013 Base flow								
Spring	0.004	0.024	0.00	0.122	0.35	50.0	9	>2420
Upstream	0.021	0.140	0.03	0.444	2.20	17.9	39	1120
Downstream	0.007	0.028	0.01	0.511	0.58	1.5	5	>2420
10/1/2013 Base flow								
Spring	0.001	0.162	0.00	0.108	0.41	89.2	4	920.8
Upstream	0.011	0.038	0.02	0.236	0.34	2.2	8	1300
Downstream	0.009	0.034	0.02	0.514	0.65	3.6	2620	10810
10/9/2013 Base flow								
Spring	0.011	0.054	0.00	0.088	0.28	29.1	3	1413.6

Sample location relative to farm	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
Upstream	0.016	0.034	0.00	0.497	0.73	7.1	11	2419.6
Downstream	0.006	0.038	0.00	0.618	0.77	13.6	28	3450.0
10/15/2013 Storm flow								
Spring	0.010	0.250	0.15	0.086	0.58	66.9	1401	19863.0
Upstream	0.018	0.026	0.00	1.041	0.96	1.1	759	>2419.6
Downstream	0.067	0.316	0.20	0.677	1.07	101.1	1334	19863.0
10/22/2013 Base flow								
Spring	0.005	0.086	0.10	0.307	0.53	36.4	1733	>2419.6
Upstream	0.014	0.034	0.00	0.345	0.32	0.3	186	299.0
Downstream	0.012	0.020	0.04	0.723	0.76	0.7	87	292.0
10/31/2013 Base flow								
Spring	0.003	0.404	0.14	0.321	1.02	400.9	91	32550.0
Upstream	0.012	0.032	0.00	0.242	0.32	1.1	66	1986.3
Downstream	0.012	0.024	0.03	0.443	0.45	1.4	Leaked	Leaked
11/6/2013 Base flow								
Spring	0.013	0.130	0.10	0.062	0.72	21.2	8570	34480.0
Upstream	0.032	0.074	0.03	0.432	0.61	4.7	4080	28510.0
Downstream	0.041	0.154	0.12	0.286	0.60	28.4	3500	43520.0
11/12/2013 Base flow								
Spring	0.006	0.022	0.05	2.449	2.39	8.90	48	2750.0
Upstream	0.011	0.010	0.00	0.169	0.22	1.00	45	1986.3

Sample location relative to farm	Dissolved phosphorus	Total phosphorus	Ammonia-nitrogen	Nitrate-nitrogen	Total nitrogen	Total suspended solids	E_ coli	Total coliform
Downstream	0.011	0.010	0.00	0.242	0.31	0.0	24	>2419.2
11/19/2013 Base flow								
Spring	0.007	0.022	0.02	3.063	3.06	4.4	579	9880.0
Upstream	0.010	0.026	0.00	0.123	0.22	0.7	435	2400.0
Downstream	0.009	0.024	0.02	0.172	0.28	1.0	194	4410.0
11/26/2013 Base flow								
Spring	0.007	0.018	0.00	1.69	1.70	4.5	86	1553.1
Upstream	0.013	0.018	0.00	0.135	0.14	0.4	77	1203.3
Downstream	0.013	0.016	0.00	0.231	0.24	1.2	36	2419.2
12/3/2013 Base flow								
Spring	0.007	0.046	0.04	1.048	1.37	26.9	25	1986.3
Upstream	0.007	0.012	0.00	0.152	0.25	0.5	27	435.2
Downstream	0.006	0.012	0.00	0.225	0.28	0.5	12	>2419.2

Future Plan of Work

Field Evaluation - Land Application Sites

Assess water flow directions and risk of nutrient and bacteria losses from three fields (Fields 1, 5, and 12) that will be used to land apply manure. On each field:

1. Complete the detailed topographic survey of the application fields to better understand surface water flow patterns and the most appropriate location for surface runoff collection and monitoring wells / piezometer devices.
2. Conduct annual grid soil sampling to develop dynamic soil nutrient maps for the monitored application fields (i.e., Fields 1, 5, and 12). Use results to develop a balanced/sustainable soil fertility strategic plan.

3. Conduct inventory of soil physical properties, to include but not limited to surface infiltration, subsurface hydraulic conductivity, bulk density, phosphorus sorption isotherms, and particle size analysis in the three application fields.
4. Install bermed surface runoff area (>2 acres) to collect and monitor surface runoff, with weather station (Maps 11, 12, and 13) as and where appropriate. Collect surface runoff and measure nitrogen, phosphorus, pH, sediment, and bacteria (E. coli) for one year.
5. Install two transects of piezometers across the two stream-side fields (i.e., #5 and 12) to automatically and continuously determine if subsurface water is moving to or away from the adjacent river (Maps 12 and 13). These will be installed according to standard NRCS protocols and described in more detail in Appendix 4 (see Figures 12 and 13). Piezometers will be installed so that there is minimal piping or equipment above ground that could interfere or influence with day to day farm operations on that field.
6. Periodically determine plant uptake by collecting plant and hay samples for tissue analysis and determine yield (dry matter mass for a pre-determined area.
7. Determine nutrient application rate by determining nutrient content of swine effluent before land application via manure application and determine volume of effluent being applied to known monitoring area.

Water Quality Assessment of Springs, Ephemeral Streams, and Creeks in the Operation

Measure nutrient, bacteria, and sediment concentrations in: a) an ephemeral stream that drains runoff from around the animal production facility and slurry holding ponds, b) springs connected to land application fields, and c) Big Creek at upstream and downstream of farm (see Map 11).

1. Continuously monitor flow and automatically collect water samples at a road culvert draining the subwatershed containing the animal houses and manure holding ponds.
2. Install a calibrated stream gauge for continuous flow measurement and collect Big Creek water samples on at least a biweekly basis above and below the C&H farm boundary. At the same sate, deploy an automatic water sampler in Big Creek that will collect storm flow samples.
3. Deploy sondes at the spring and Big Creek sampling locations to continuously determine dissolved oxygen (DO), excess partial pressure of carbon dioxide ($EpCO_2$), electrical conductivity (EC), and temperature of the water. Diurnal, seasonal, and storm event fluctuations of water $EpCO_2$, DO, EC, and temperature can be used to examine the rates of respiration and photosynthesis linked to changing nutrient status and organic matter loading and to also identify possible sources of new and old water at these locations. Similarly, a longitudinal survey downstream between upper and lower sampling points in Big Creek under baseflow, can locate potential sites where water is entering the Creek from the surrounding landscape. That is, $EpCO_2$ will increase (and pH will drop), with the input of spring water into Big Creek.

Manure Treatment via Solids and Chemical Separation: A Case Study to Evaluate Cost Benefits of Alternative Manure Management Options

Continue current discussions with the owners of the C&H Farm to explore potential long-term, economically viable, options to modify current manure management practices in the general areas of:

1. Separating manure liquids and solids along with their differential management;
2. Retaining sufficient nitrogen to meet crop needs;
3. Exporting excess phosphorus off the farm;
4. Mitigating off site odor;
5. Not exceeding the current physical, economic, labor, and management resources of the farm; and
6. Operating within the constraints of the appropriate environmental regulations.

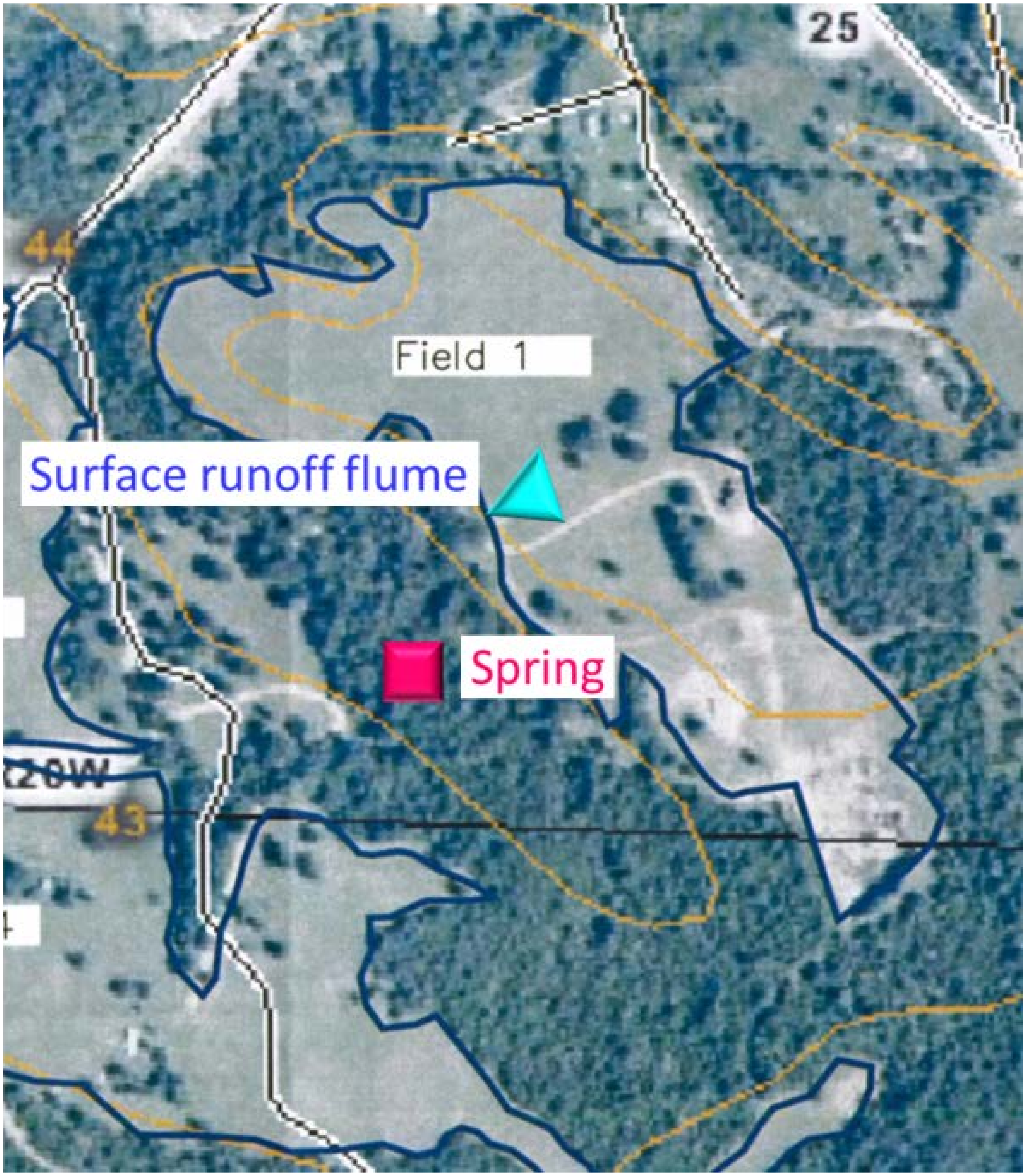
The project will identify management options to meet the above objectives. It is anticipated that the options will include but not be limited to:

- Mechanical separation manure solids from liquids with or without chemicals as a precursor for off-farm transport of separated solids; and
- Selective application of higher phosphorus content slurries and lower phosphorus content liquids to different fields that minimizes any loss of nutrient loss.

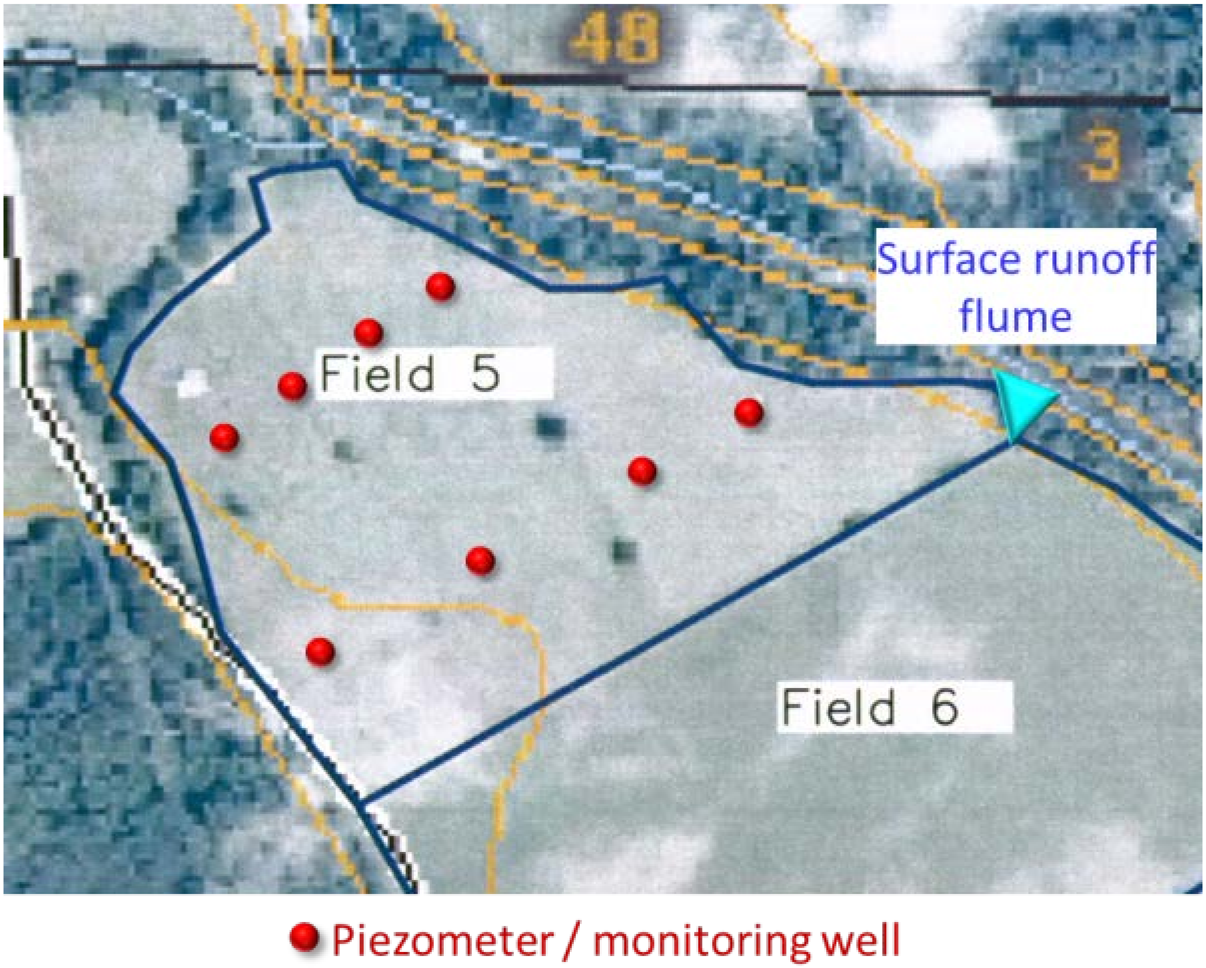
For the management options identified, their initial and long-term costs will be estimated and an assessment of their implementation impacts made. Available literature and other information resources will be utilized in this process. However, there will be a need for laboratory and onsite tests/trials. This is especially true when evaluating manure solid-liquid separation and/or chemical use. Based on current discussions development of field chemical tests and lab analysis will begin soon. The results of these tests will guide decisions that may lead to additional larger scale implementation trials.

Project Outcomes

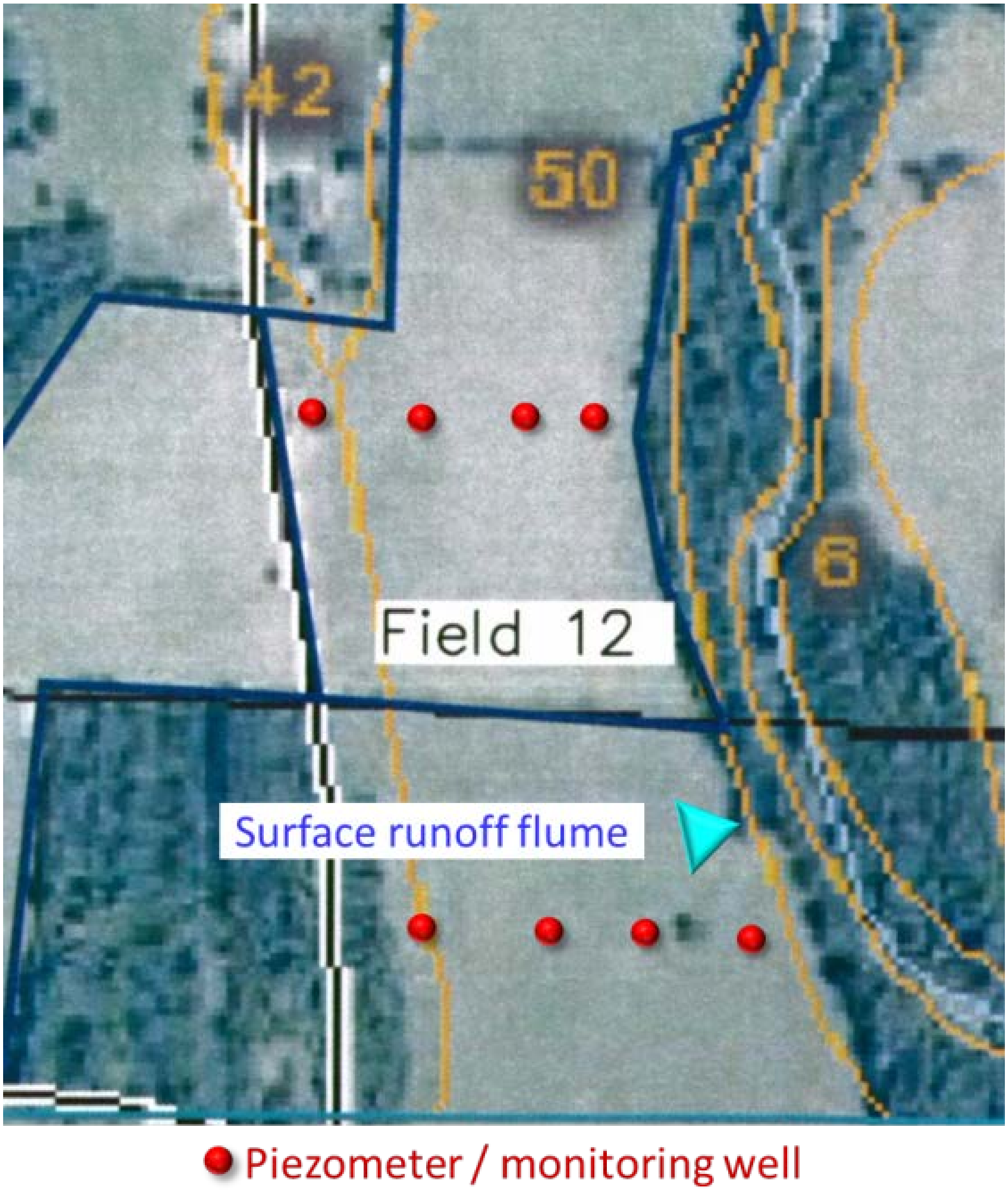
1. Research project documenting the field and manure management options evaluated and the details of their evaluation.
2. Will provide C&H Farm input for their decision on appropriate options to undertake manure treatment and export, in terms of cost and labor considerations.
3. A sustainable management blueprint for C&H Farm operation.
4. Documentation of any environmental impacts and details of actions taken to eliminate them.
5. A five-year assessment of C&H. If the majority of those five years are abnormal weather years, consideration should be given to extend the assessment in order to obtain a true representation of Operation impacts.



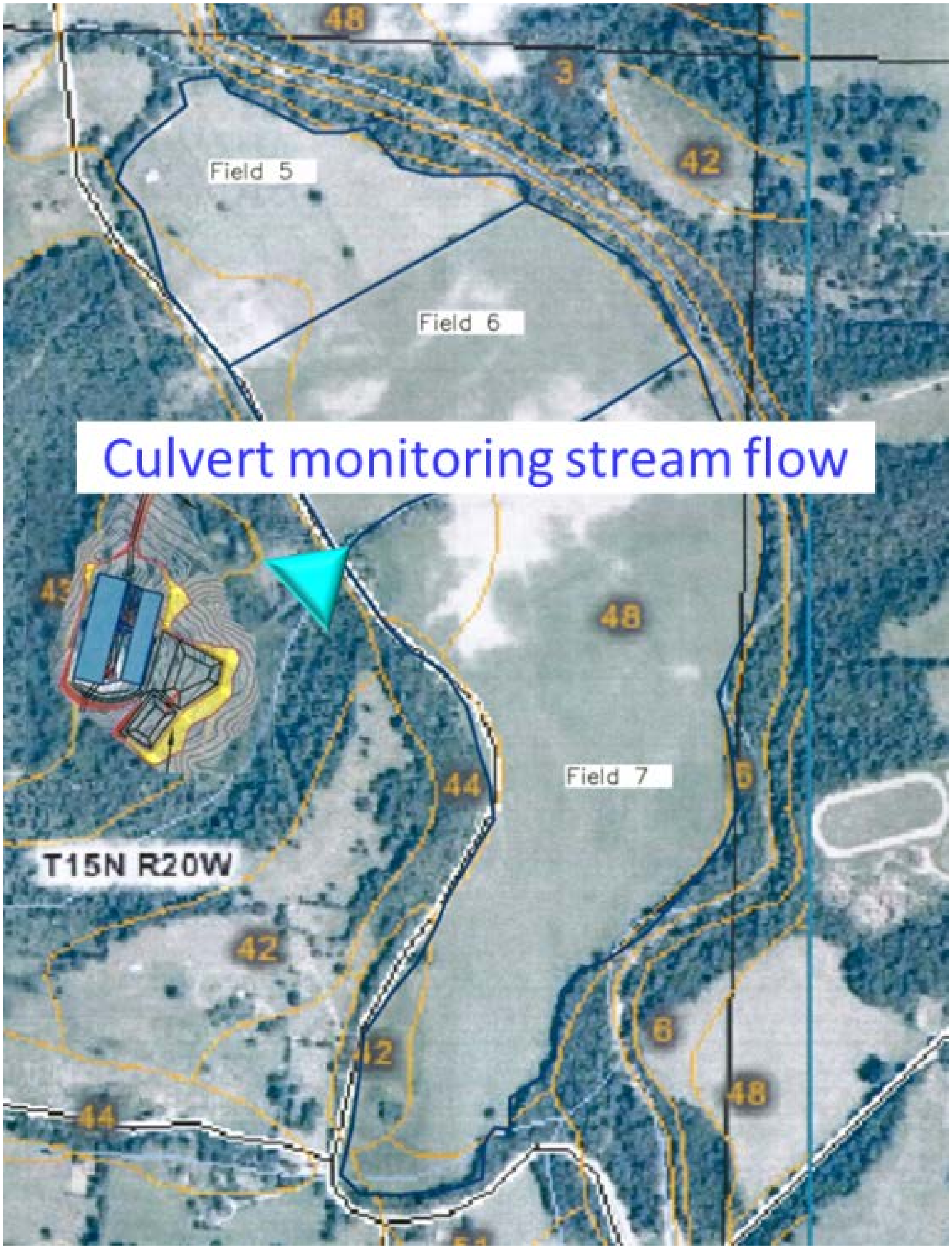
Map 11. Potential sampling locations for Field 1.



Map 12. Potential sampling locations for Field 5.



Map 13. Potential sampling locations for Field 12.



Map 14. Potential sampling locations for culvert monitoring.

Figure 12. Standard installations for soil studies of (1A) a piezometer and (1B) a water-table well (NRCS, 2008).

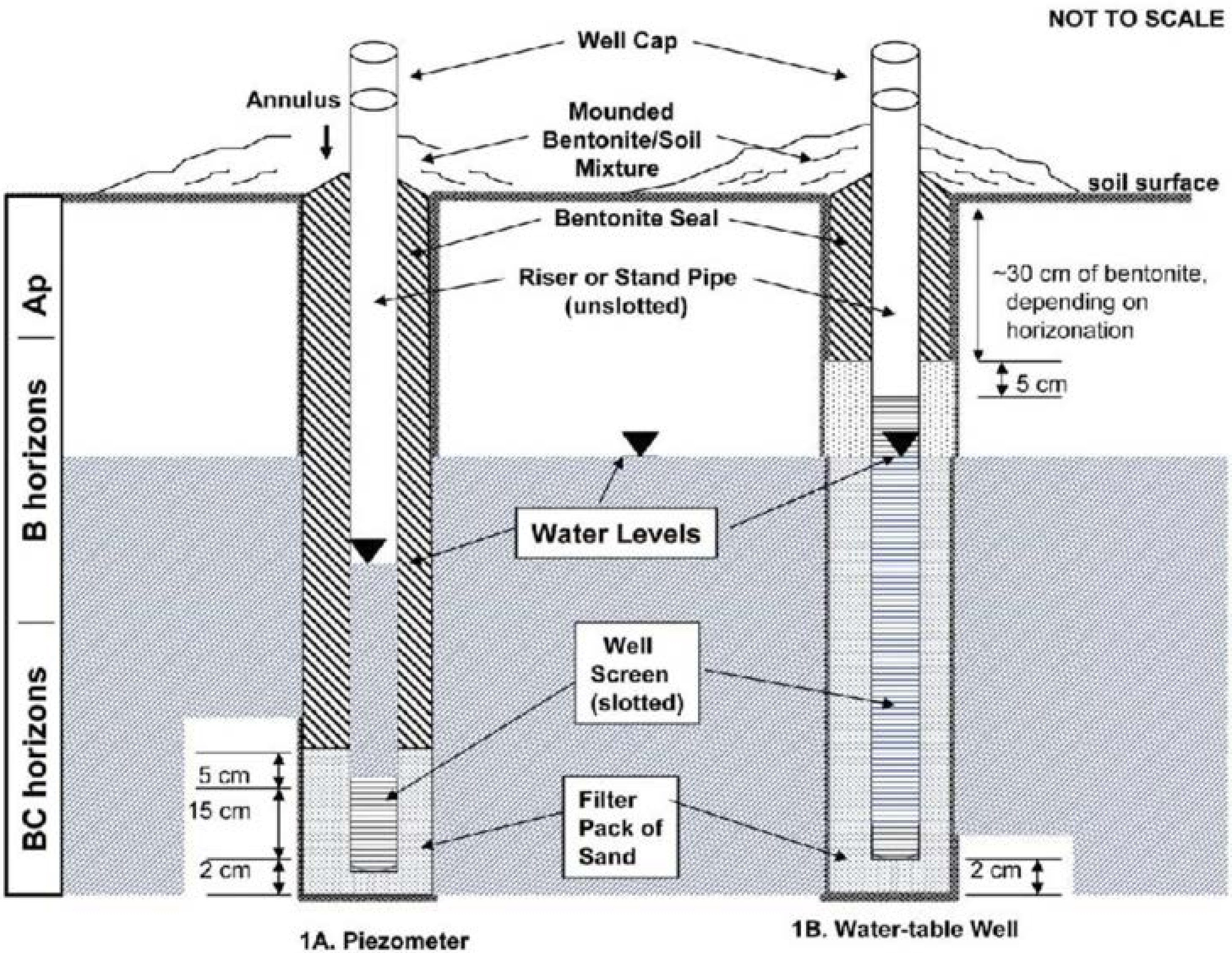
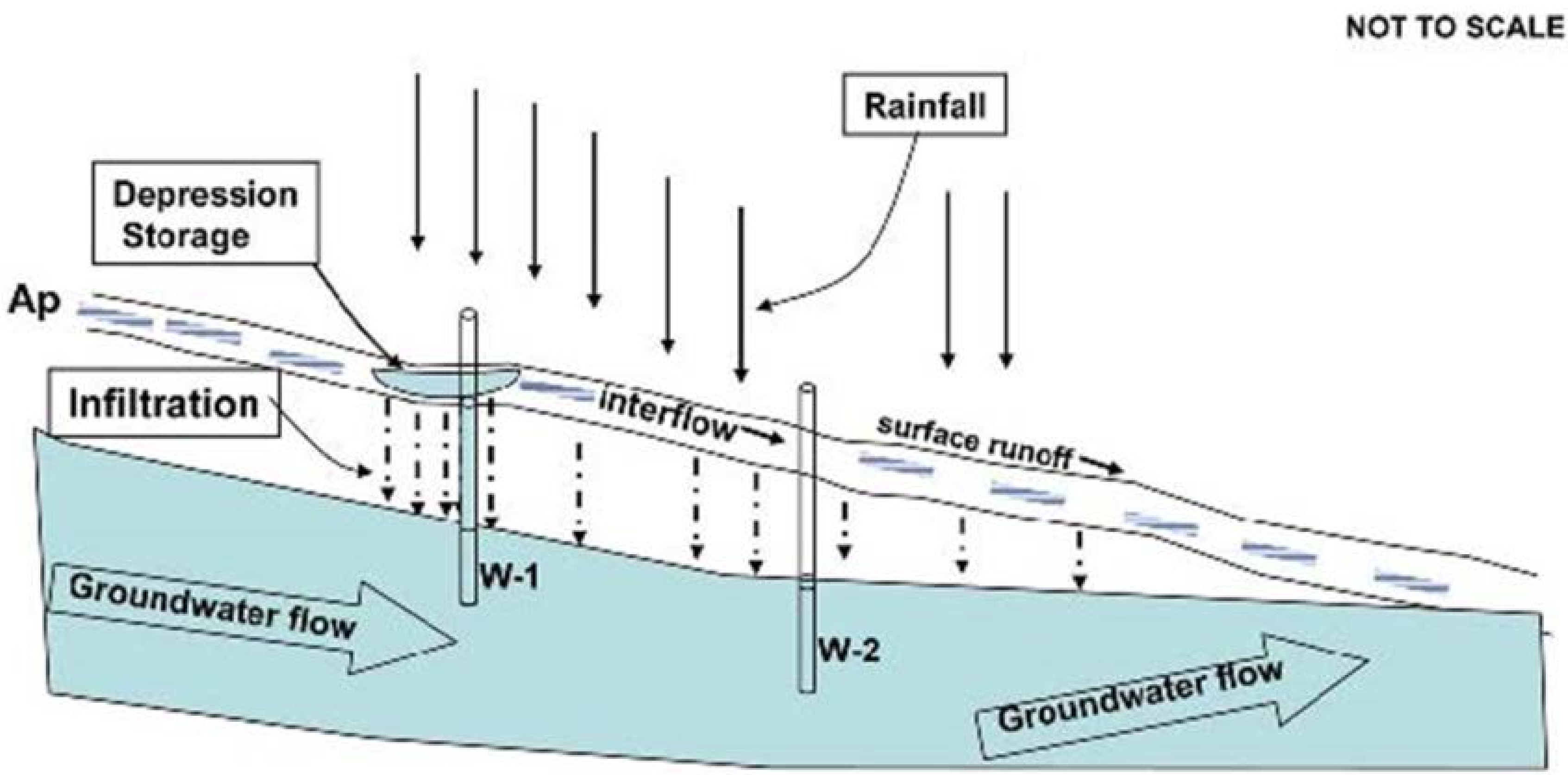


Figure 13. Schematic diagram of paths of water flow significant to shallow water monitoring studies in sloping landscapes. A combination of depression storage and interflow at small scales may be short-lived but can be significant enough to cause bypass flow down poorly protected well risers (W-1). Figure modified from Kirkby (1969).



Appendix 1 - Soil Mapping Unit Description from NRCS, Newton County, AR

[Minor map unit components are excluded from this report]

Map unit: 1 - Arkana very cherty silt loam, 3 to 8 percent slopes

Component: Arkana (100%)

The Arkana component makes up 100 percent of the map unit. Slopes are 3 to 8 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer, bedrock, lithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is very low. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria.

Map unit: 2 - Arkana-Moko complex, 8 to 20 percent slopes

Component: Arkana (50%)

The Arkana component makes up 50 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer, bedrock, lithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is very low. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria.

Component: Moko (35%)

The Moko component makes up 35 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillslopes and hills. The parent material consists of loamy residuum weathered from cherty limestone. Depth to a root restrictive layer, bedrock, lithic, is 6 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. This component is in the R116AY001AR Limestone Ledge ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 3 - Arkana-Moko complex, 20 to 40 percent slopes

Component: Arkana (45%)

The Arkana component makes up 45 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer, bedrock, lithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is very low. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 3 - Arkana-Moko complex, 20 to 40 percent slopes

Component: Moko (45%)

The Moko component makes up 45 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of loamy residuum weathered from cherty limestone. Depth to a root restrictive layer, bedrock, lithic, is 6 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. This component is in the R116AY001AR Limestone Ledge ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 6 - Ceda-Kenn complex, frequently flooded

Component: Ceda (55%)

The Ceda component makes up 55 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains and hills. The parent material consists of gravelly alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is frequently flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. Nonirrigated land capability classification is 7w. This soil does not meet hydric criteria.

Component: Kenn (30%)

The Kenn component makes up 30 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains and hills. The parent material consists of loamy alluvium derived from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is low. Shrink-swell potential is moderate. This soil is frequently flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. Nonirrigated land capability classification is 5w. This soil does not meet hydric criteria.

Map unit: 7 - Clarksville very cherty silt loam, 20 to 50 percent slopes

Component: Clarksville (100%)

The Clarksville component makes up 100 percent of the map unit. Slopes are 20 to 50 percent. This component is on hillsides and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is somewhat excessively drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 8 - Eden-Newnata complex, 8 to 20 percent slopes

Component: Eden (55%)

The Eden component makes up 55 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from limestone and shale. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria.

Component: Newnata (30%)

The Newnata component makes up 30 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillslopes and hills. The parent material consists of residuum weathered from limestone and shale. Depth to a root restrictive layer, bedrock, lithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Map unit: 9 - Eden-Newnata complex, 20 to 40 percent slopes

Component: Eden (50%)

The Eden component makes up 50 percent of the map unit. Slopes are 20 to 40 percent. This component is on mountain slopes and hills. The parent material consists of clayey residuum weathered from limestone and shale. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 7e. This soil does not meet hydric criteria.

Component: Newnata (40%)

The Newnata component makes up 40 percent of the map unit. Slopes are 20 to 40 percent. This component is on mountain slopes and hills. The parent material consists of residuum weathered from limestone and shale. Depth to a root restrictive layer, bedrock, lithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 11 - Enders gravelly loam, 3 to 8 percent slopes

Component: Enders (80%)

The Enders component makes up 80 percent of the map unit. Slopes are 3 to 8 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 4e. This soil does not meet hydric criteria.

Map unit: 12 - Enders gravelly loam, 8 to 15 percent slopes

Component: Enders (80%)

The Enders component makes up 80 percent of the map unit. Slopes are 8 to 15 percent. This component is on hillslopes on hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria.

Map unit: 13 - Enders stony loam, 3 to 15 percent slopes

Component: Enders (85%)

The Enders component makes up 85 percent of the map unit. Slopes are 3 to 15 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Map unit: 14 - Enders stony loam, 15 to 40 percent slopes

Component: Enders (80%)

The Enders component makes up 80 percent of the map unit. Slopes are 15 to 40 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 15 - Enders-Leesburg complex, 8 to 20 percent slopes

Component: Enders (60%)

The Enders component makes up 60 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Component: Leesburg (30%)

The Leesburg component makes up 30 percent of the map unit. Slopes are 8 to 20 percent. This component is on mountains. The parent material consists of loamy colluvium derived from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Map unit: 16 - Enders-Leesburg complex, 20 to 40 percent slopes

Component: Enders (50%)

The Enders component makes up 50 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Leesburg (40%)

The Leesburg component makes up 40 percent of the map unit. Slopes are 20 to 40 percent. The parent material consists of loamy colluvium derived from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 25 - Linker-Mountainburg complex, 8 to 20 percent slopes

Component: Linker (50%)

The Linker component makes up 50 percent of the map unit. Slopes are 8 to 20 percent. This component is on mountains and hills. The parent material consists of loamy residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, lithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria.

Component: Mountainburg (45%)

The Mountainburg component makes up 45 percent of the map unit. Slopes are 8 to 20 percent. This component is on mountains and hills. The parent material consists of gravelly and stony, loamy residuum weathered from sandstone and siltstone. Depth to a root restrictive layer, bedrock, lithic, is 12 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R117XY004AR Sandstone Ridge ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 26 - Moko-Rock outcrop complex, 15 to 50 percent slopes

Component: Moko (50%)

The Moko component makes up 50 percent of the map unit. Slopes are 15 to 50 percent. This component is on hillslopes and hills. The parent material consists of loamy residuum weathered from cherty limestone. Depth to a root restrictive layer, bedrock, lithic, is 6 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. This component is in the R116AY001AR Limestone Ledge ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Rock outcrop (40%)

Generated brief soil descriptions are created for major soil components. The Rock outcrop is a miscellaneous area.

Map unit: 35 - Nella-Enders stony loams, 8 to 20 percent slopes

Component: Nella (45%)

The Nella component makes up 45 percent of the map unit. Slopes are 8 to 20 percent. This component is on mountains and hills. The parent material consists of loamy colluvium derived from sandstone and shale and/or loamy residuum weathered from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Component: Enders (40%)

The Enders component makes up 40 percent of the map unit. Slopes are 8 to 20 percent. This component is on mountains and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Map unit: 36 - Nella-Enders stony loams, 20 to 40 percent slopes

Component: Nella (50%)

The Nella component makes up 50 percent of the map unit. Slopes are 20 to 40 percent. This component is on mountain slopes and hills. The parent material consists of loamy colluvium derived from sandstone and shale and/or loamy residuum weathered from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Enders (35%)

The Enders component makes up 35 percent of the map unit. Slopes are 20 to 40 percent. This component is on mountain slopes and hills. The parent material consists of clayey residuum weathered from acid shale. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 37 - Nella-Steprock complex, 8 to 20 percent slopes

Component: Nella (50%)

The Nella component makes up 50 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillsides and hills. The parent material consists of loamy colluvium derived from sandstone and shale and/or loamy residuum weathered from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Component: Steprock (35%)

The Steprock component makes up 35 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillsides and hills. The parent material consists of skeletal loamy residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria.

Map unit: 38 - Nella-Steprock-Mountainburg very stony loams, 20 to 40 percent slopes

Component: Nella (45%)

The Nella component makes up 45 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of loamy colluvium derived from sandstone and shale and/or loamy residuum weathered from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Steprock (25%)

The Steprock component makes up 25 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of skeletal loamy residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 38 - Nella-Steprock-Mountainburg very stony loams, 20 to 40 percent slopes

Component: Mountainburg (15%)

The Mountainburg component makes up 15 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of gravelly and stony, loamy residuum weathered from sandstone and siltstone. Depth to a root restrictive layer, bedrock, lithic, is 12 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R117XY004AR Sandstone Ridge ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 39 - Nella-Steprock-Mountainburg very stony loams, 40 to 60 percent slopes

Component: Nella (45%)

The Nella component makes up 45 percent of the map unit. Slopes are 40 to 60 percent. This component is on hillslopes and hills. The parent material consists of loamy colluvium derived from sandstone and shale and/or loamy residuum weathered from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Steprock (20%)

The Steprock component makes up 20 percent of the map unit. Slopes are 40 to 60 percent. This component is on hillslopes and hills. The parent material consists of skeletal loamy residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Mountainburg (10%)

The Mountainburg component makes up 10 percent of the map unit. Slopes are 40 to 60 percent. This component is on hillsides and hills. The parent material consists of loamy residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, lithic, is 12 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R117XY004AR Sandstone Ridge ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Map unit: 42 - Noark very cherty silt loam, 3 to 8 percent slopes

Component: Noark (100%)

The Noark component makes up 100 percent of the map unit. Slopes are 3 to 8 percent. This component is on hillsides and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 4e. This soil does not meet hydric criteria.

Map unit: 43 - Noark very cherty silt loam, 8 to 20 percent slopes

Component: Noark (100%)

The Noark component makes up 100 percent of the map unit. Slopes are 8 to 20 percent. This component is on hillsides and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria.

Map unit: 44 - Noark very cherty silt loam, 20 to 40 percent slopes

Component: Noark (100%)

The Noark component makes up 100 percent of the map unit. Slopes are 20 to 40 percent. This component is on hillslopes and hills. The parent material consists of clayey residuum weathered from cherty limestone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 7e. This soil does not meet hydric criteria.

Map unit: 48 - Razort loam, occasionally flooded

Component: Razort (95%)

The Razort component makes up 95 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains and hills. The parent material consists of loamy alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is low. This soil is occasionally flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 2w. This soil does not meet hydric criteria.

Map unit: 49 - Riverwash, frequently flooded

Component: Riverwash (95%)

Generated brief soil descriptions are created for major soil components. The Riverwash is a miscellaneous area.

Map unit: 50 - Spadra loam, occasionally flooded

Component: Spadra (95%)

The Spadra component makes up 95 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains and hills. The parent material consists of loamy alluvium derived from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is occasionally flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 2w. This soil does not meet hydric criteria.

Map unit: 51 - Spadra loam, 2 to 5 percent slopes

Component: Spadra (95%)

The Spadra component makes up 95 percent of the map unit. Slopes are 2 to 5 percent. This component is on stream terraces and hills. The parent material consists of loamy alluvium derived from sandstone and shale. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. Nonirrigated land capability classification is 3e. This soil does not meet hydric criteria.

Map unit: 54 - Water

Component: Water (100%)

A general description for water bodies.

Appendix 3 – Soil Profile Analyses from Grid Sampling of Application Fields

Table 7. Soil analyses of 0 to 4 inch samples collected from Field 1. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			----------	----------	----------	----------	----------	---------- mg/kg	----------	----------	----------	----------	----------
166760	126	7.3	30	183	8465	142	14	23	35	230	1	4.7	1.1
166776	142	7.8	32	104	5672	78	12	11	61	108	0.5	3.9	0.5
166702	143	6.7	99	571	1821	116	28	15	232	117	0.4	4	0.7
166703	144	7.8	18	123	7643	92	43	13	44	156	0.9	2.3	0.6
166752	145	6.5	28	80	2741	110	16	20	76	86	0.5	3	0.4
167144	162	6.1	83	706	1415	158	22	22	159	266	0.9	5.6	0.6
166704	163	6.3	98	597	2478	227	10	25	172	251	0.7	8	0.7
166694	180	6.5	22	144	1298	89	14	13	118	374	0.6	2.6	0.3
166715	181	7	100	329	2229	144	13	18	134	232	0.9	6.1	0.6
166716	182	6.6	59	469	2007	150	14	21	101	267	1	9.7	0.7
166698	198	6.6	82	405	2022	152	12	18	149	360	1.1	7.1	0.7
166699	199	6.9	50	84	1667	85	12	17	121	346	0.6	4.2	0.3
166714	200	6.1	57	151	1613	139	14	23	101	532	0.4	3	0.4
166713	201	6	44	107	1700	158	19	22	94	316	0.8	7.5	0.5
167143	212	4.4	49	53	456	53	16	17	188	31	0.2	2.2	0.2
166721	213	6	52	108	1398	96	10	17	70	50	0.2	1.8	0.2
166722	214	5.3	102	163	1072	122	9	21	107	97	0.3	3.5	0.2
166712	215	5.5	93	187	922	95	12	19	200	148	0.3	3.1	0.4
166710	216	6.6	50	84	1598	77	17	15	127	106	0.5	2.4	0.4
166711	217	6.2	67	191	1290	143	20	19	148	214	0.5	4.3	0.4
166708	218	7	77	245	1310	127	13	16	128	326	0.4	4	0.5
166707	219	6.3	169	771	2073	216	17	29	128	258	0.6	10.6	0.9
166706	221	5.5	100	90	1357	131	44	19	141	257	0.7	9.4	0.3

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
166728	231	6.6	80	189	1454	110	14	15	117	84	0.4	3.6	0.4
166723	232	7	48	277	1898	107	12	16	78	129	0.4	2.7	0.4
166724	233	6.8	56	223	1503	110	20	16	110	174	0.5	3.3	0.5
166727	234	6.4	41	61	1200	71	12	16	116	289	0.4	2.1	0.3
166725	235	6.3	109	707	1502	144	16	28	170	318	1	9.1	0.6
166726	236	6.5	56	420	1442	145	12	20	105	219	0.7	4.8	0.4
166718	237	6.8	82	366	2051	150	18	24	124	173	0.8	6.9	0.5
166720	238	6.4	55	93	1730	105	13	17	95	280	0.6	5	0.4
166736	240	5.4	60	88	889	69	10	17	119	171	0.2	3.3	0.2
166737	241	6.3	71	314	1638	94	9	17	97	193	0.3	5.3	0.4
166738	249	6.3	66	143	1247	84	8	17	114	122	0.3	3.3	0.4
166739	250	7.5	39	148	2056	62	7	13	84	238	0.4	2.1	0.4
166740	251	5.8	35	269	675	61	10	20	115	388	0.3	2.5	0.3
166732	252	6.5	63	208	1149	128	12	17	118	381	0.8	4.1	0.4
166733	253	6.7	90	251	1649	139	11	17	111	362	0.9	6.1	0.5
166734	254	5.9	54	238	1275	131	11	20	153	253	1.1	5.1	0.4
166735	255	7.3	77	675	4064	161	10	26	52	380	0.8	5.6	0.9
166730	256	6.6	52	231	1591	120	14	19	109	188	0.6	3.7	0.4
166745	257	5.5	54	174	955	107	17	18	124	190	0.7	6	0.2
166746	258	6	30	49	1299	44	12	13	89	244	0.3	2.1	0.2
166764	259	5.7	81	52	941	69	12	15	110	168	0.4	3.9	0.2
166763	260	6.7	37	121	3098	176	10	20	64	341	0.8	7.5	0.6
166759	268	5.2	58	44	641	47	12	16	166	130	0.5	2.5	0.2
166749	269	5.5	44	67	801	76	10	16	96	316	0.5	2.3	0.3
166750	270	5.7	53	67	1046	62	11	18	89	360	0.5	2.2	0.2
166747	271	6.4	33	127	1230	83	8	15	86	444	0.5	2.3	0.4
166748	272	7	62	172	1767	156	10	19	90	448	0.9	4.2	0.5
166768	273	7.4	52	473	2717	123	8	22	70	321	0.8	4.3	0.5

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
166742	274	6.4	56	373	4822	230	16	19	40	308	0.9	3.8	0.7
166743	275	6.3	28	66	1665	89	15	15	94	231	0.6	2.7	0.3
166751	276	6.2	46	51	1510	74	13	18	95	222	0.4	3.6	0.2
166772	278	6.6	32	88	2359	86	11	19	79	486	0.5	3.3	0.3
166691	287	5.9	65	63	1231	72	25	17	144	137	0.4	2.5	0.3
166692	288	6.2	55	78	1620	101	11	18	129	235	0.5	2.9	0.5
166775	289	5.6	36	62	1337	79	10	15	96	164	0.2	2	0.2
166754	291	6.1	40	161	1284	149	12	20	130	361	0.6	4.1	0.4
166761	292	7	42	109	2258	95	10	17	80	462	1	6.4	0.4
166762	293	7	45	224	3777	166	9	17	45	339	0.9	5.5	0.5
166755	294	6.7	40	136	2241	117	10	19	86	330	0.6	6.2	0.4
166757	295	6.9	36	248	2385	134	12	23	92	363	0.6	4.7	0.5
166758	296	5.3	49	48	736	63	11	18	169	309	0.4	3.1	0.2
166771	297	6.8	30	83	2047	59	10	14	79	269	0.3	3.3	0.3
166766	309	5.4	66	71	848	107	16	16	115	131	0.4	3.9	0.3
166767	310	5.4	72	73	605	92	10	20	128	326	0.4	4.1	0.2
166773	311	5.8	88	101	1181	96	11	21	124	346	0.5	3.2	0.3
166769	312	6.2	37	86	1835	126	11	19	83	511	0.8	4.3	0.3
166770	313	7.5	70	83	4550	127	19	18	50	311	0.9	6.1	0.5
166774	314	6.4	51	72	1430	99	11	17	79	311	0.6	3.3	0.3
Mean, mg/kg		6.85	41	128	4948	121	13	20	57	271	0.8	4.0	0.7
Minimum, mg/kg		4.4	18	44	456	44	7	11	35	31	0.2	1.8	0.2
Maximum, mg/kg		7.8	169	771	8465	230	44	29	232	532	1.1	10.6	1.1
Standard deviation, mg/kg		0.64	15	78	4974	30	2	4	31	57	0.3	1.0	0.6
Coefficient of variation, %		9.34	36	62	101	25	18	21	55	21	35.0	24.8	81.4

Table 8. Soil analyses of 4 to 8 inch samples collected from Field 1. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			----------------------------------- mg/kg -----------------------------										
166695	180	6.4	11	71	1002	75	17	10	108	354	0.6	2	0.3
166700	199	6.6	25	41	1024	62	14	9	104	310	0.4	1.6	0.2
166709	218	6.6	24	117	861	71	13	9	141	303	0.3	1.6	0.3
166731	256	6.6	22	112	1226	97	13	9	94	269	0.4	2.9	0.2
166744	275	6.6	14	51	1440	54	11	10	86	193	0.5	1.5	0.2
166756	294	6.9	22	68	1853	89	14	15	77	297	0.6	3.3	0.2
Mean, mg/kg		6.65	17	70	1428	82	16	13	93	326	0.6	2.7	0.3
Minimum, mg/kg		6.4	11	41	861	54	11	9	77	193	0.3	1.5	0.2
Maximum, mg/kg		6.9	25	117	1853	97	17	15	141	354	0.6	3.3	0.3
Standard deviation, mg/kg		0.35	8	2	602	10	2	4	22	40	0.0	0.9	0.1
Coefficient of variation, %		5.26	47	3	42	12	14	28	24	12	0.0	34.7	28.0

Table 9. Soil analyses of 8 to 12 inch samples collected from Field 1. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	Bo
							mg/kg						
166696	180	6.2	7	69	836	67	13	9	129	415	0.4	0.9	0.2
166701	199	6.5	12	45	936	70	11	6	114	322	0.3	1	0.2
166719	237	7	12	228	3587	139	25	8	59	102	0.4	0.6	0.3
Mean, mg/kg		6.60	10	149	2212	103	19	9	94	259	0.4	0.8	0.3
Minimum, mg/kg		6.2	7	45	836	67	11	6	59	102	0.3	0.6	0.2
Maximum, mg/kg		7	12	228	3587	139	25	9	129	415	0.4	1	0.3
Standard deviation, mg/kg		0.57	4	112	1945	51	8	1	49	221	0.0	0.2	0.1
Coefficient of variation, %		8.64	37	76	88	49	45	8	53	86	0.0	28.0	28.0

Table 10. Soil analyses of 0 to 4 inch samples collected from Field 5. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			------------------------------------ mg/kg ------------------------------------										
179511	25	6.2	76	322	2847	164	21	10	141	94	2.3	10.2	0.4
179516	34	6.6	64	100	1680	95	11	10	137	153	1.2	3.2	0.1
178394	35	6.8	54	109	3266	114	9	9	106	71	2.2	5.7	0.2
178398	36	6.5	66	179	3605	146	18	13	142	54	2.2	7.4	0.2
178403	37	6	61	145	2852	131	12	9	160	37	1.6	5.1	0.1
178408	47	6.6	48	104	1337	82	8	11	122	218	0.8	3.3	0.1
178413	48	6.2	76	162	2894	155	12	11	151	62	1.9	7.2	0.2
178415	49	6.4	78	207	3637	183	15	13	110	79	2.1	7.5	0.3
178421	50	6.1	61	110	2563	155	13	11	153	41	1.4	7.8	0.1
178425	51	6.2	52	146	2594	112	10	9	115	50	1.5	4.8	0
178431	59	6.2	122	251	1330	116	17	18	142	350	1	5.9	0.2
178436	61	5.9	58	133	2443	148	17	10	164	31	1.3	6.9	0.2
178442	62	6.1	57	120	2811	129	11	10	150	26	2	5.6	0.1
178447	73	6.5	179	344	1613	172	5	21	135	363	0.8	10.4	0.2
178451	74	6.2	82	365	1784	98	7	17	141	107	1.4	6.4	0.2
178456	75	6.4	49	166	2935	137	7	9	109	50	1.8	7.8	0.1
178460	76	5.8	65	144	2634	151	7	12	212	39	1.6	7.9	0.2
178466	85	6.4	118	119	1215	90	45	14	136	315	0.8	3.5	0.2
178470	86	6.1	156	529	889	104	15	20	162	276	0.7	5.8	0.2
178472	87	6.5	74	203	2651	164	5	10	129	63	1.5	7.5	0.2
178476	88	6.5	105	565	2744	213	9	21	149	47	1.7	7.9	0.4
178482	89	6.5	48	253	2515	132	6	11	122	88	1.5	5.3	0.3
178485	98	6.7	43	76	2853	104	8	12	74	119	1.7	4.2	0.1
178492	99	6.5	95	136	1950	142	56	15	119	146	1.4	6.4	0.2
178495	100	6.2	116	125	1129	86	43	10	133	158	1	3.7	0.1

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
178497	101	6.5	75	168	1709	101	12	12	120	157	1.4	5	0.2
178502	102	6.9	48	71	3078	106	9	13	119	170	2.1	6.4	0.6
178508	110	6.5	44	160	2711	151	9	13	96	113	2	7.6	0.3
178510	111	6.6	62	197	2708	135	12	16	99	100	1.9	5.2	0.3
178515	113	6.3	95	167	1854	122	15	15	126	106	1.1	5.8	0.3
178519	114	6.9	84	129	2647	134	16	17	135	123	1.4	9.3	0.7
178526	115	6.7	40	47	2129	79	11	14	143	157	1.2	5	0.6
178532	116	7.4	56	75	1698	88	8	9	105	132	0.7	3.9	0.3
178536	124	6.5	62	112	3003	128	15	15	103	154	1.9	7	0.4
178539	125	6.5	56	95	2281	110	29	15	100	139	2	6.4	0.5
178544	126	6.7	98	124	2398	136	17	16	132	162	1.7	7.4	0.6
178547	127	6.9	60	138	2446	105	10	15	143	186	1.5	6.5	0.7
178553	128	7.1	51	137	1864	76	10	13	117	166	1	9.7	0.5
178555	129	7.5	31	46	2118	48	26	8	114	147	0.9	3.4	0.4
178560	137	6.7	59	104	2892	154	16	17	85	143	2	7.3	0.6
178565	138	6.8	34	91	2755	95	12	13	82	178	2.1	4.2	0.4
178570	139	6.5	37	80	2224	100	9	14	102	162	1.6	4.6	0.5
178576	140	6.8	53	160	1839	70	9	13	125	175	1.1	4.5	0.6
178581	141	7	78	73	2205	121	22	15	130	196	1.3	6	0.7
178389	142	6.7	31	36	2190	68	23	10	117	159	1.2	5.2	0.3
Mean, mg/kg		6.45	54	179	2519	116	22	10	129	127	1.8	7.7	0.4
Minimum, mg/kg		5.8	31	36	889	48	5	8	74	26	0.7	3.2	0
Maximum, mg/kg		7.5	179	565	3637	213	56	21	212	363	2.3	10.4	0.7
Standard deviation, mg/kg		0.35	32	202	465	68	1	0	17	46	0.8	3.5	0.1
Coefficient of variation, %		5.43	59	113	18	59	6	0	13	36	44.6	46.0	20.0

Table 11. Soil analyses of 4 to 8 inch samples collected from Field 5. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			-------	-------	-------	-------	-------	mg/kg	-------	-------	-------	-------	-------
179512	25	6.4	42	192	2927	118	54	7	127	77	2.9	6.9	0.3
179517	34	6.6	45	41	1577	42	50	7	104	100	1.3	2	0
178395	35	6.4	33	92	2964	86	12	6	93	64	2.4	4.6	0.1
178399	36	6.1	36	114	3270	105	16	8	106	38	2.5	4	0
178404	37	5.8	49	129	2870	124	13	10	150	34	2.3	4.3	0
178409	47	6.3	22	71	1005	67	7	6	104	148	0.8	16.2	0
178416	49	6.7	41	131	4381	101	17	8	95	91	2.2	6.3	0.2
178422	50	6.1	30	98	2877	117	16	7	124	39	2	4.7	0
178426	51	5.9	33	119	2873	89	12	8	100	58	2	3.8	0
178432	59	6.3	49	144	921	48	6	10	113	243	1	4.1	0
178437	61	6	37	115	2754	126	11	8	143	36	2.3	4.9	0.1
178443	62	6.2	36	102	3093	109	11	7	111	35	2.6	5	0.1
178448	73	6.3	73	175	861	70	6	11	109	246	1.2	7	0
178452	74	6.2	67	176	2139	96	8	13	125	84	2.1	5.6	0.1
178457	75	6.4	28	143	3379	135	15	7	96	41	2.6	4.5	0
178461	76	5.6	42	111	2661	133	16	10	184	32	2.4	7.9	0.1
178467	85	6.4	57	80	981	44	27	8	122	233	0.8	2.2	0
178471	86	5.9	96	315	589	52	7	12	113	200	0.9	3.2	0
178473	87	6.4	41	169	2823	132	20	7	95	38	2	3.9	0
178478	88	6.1	36	127	2754	109	11	12	101	43	2.1	3.9	0
178483	89	6.7	50	151	2927	144	12	9	100	49	1.7	3.8	0.1
178486	98	6.8	17	59	2361	61	10	7	62	96	1.8	1.8	0
178493	99	6.4	46	55	1819	88	16	8	78	130	1.9	3.3	0
178496	100	6.3	98	67	1267	68	23	7	125	136	1.4	2.4	0

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
178498	101	6.6	43	82	1800	74	15	7	97	132	1.7	3.3	0
178503	102	6.8	23	63	2477	78	9	7	93	99	2	4.2	0.2
178509	110	6.3	15	104	3322	116	11	9	69	115	2.6	4.6	0.2
178511	111	6.3	14	116	3031	65	13	8	68	128	2.4	2.5	0.1
178516	113	6.4	70	94	1972	107	35	9	101	97	1.3	4.3	0.2
178520	114	6.8	46	82	1922	81	11	9	118	88	1.2	4.4	0.3
178527	115	6.8	20	38	2056	54	9	10	116	114	1.3	3.6	0.5
178533	116	7.2	28	46	1640	56	8	6	115	101	0.9	3	0.2
178538	124	6.6	17	73	2889	56	29	9	70	115	2.4	16.7	0.5
178540	125	6.8	25	80	2168	71	18	8	77	119	1.9	2.9	0.2
178545	126	6.8	50	79	2347	81	15	10	97	154	2.4	5.3	0.3
178548	127	7	30	50	1981	69	10	9	125	157	1.4	4.1	0.4
178554	128	7	21	74	1746	43	42	8	102	136	1.1	2.9	0.5
178556	129	7.1	21	35	1548	37	8	6	108	116	0.9	2.5	0.2
178562	137	6.6	17	68	2730	58	18	11	84	154	2.3	12.3	0.4
178566	138	6.7	11	81	2769	50	29	8	68	149	2.3	1.9	0.3
178571	139	6.7	14	67	2419	62	11	8	97	178	2.2	3.5	0.3
178577	140	7.1	33	62	1363	43	24	7	109	110	0.9	4.8	0.3
178582	141	7	34	38	1685	46	10	8	117	164	1.3	4.3	0.4
178390	142	6.8	21	28	1338	27	8	4	108	112	0.9	7.6	0
Mean, mg/kg		6.60	32	110	2133	73	31	6	118	95	1.9	7.3	0.2
Minimum, mg/kg		5.6	11	28	589	27	6	4	62	32	0.8	1.8	0
Maximum, mg/kg		7.2	98	315	4381	144	54	13	184	246	2.9	16.7	0.5
Standard deviation, mg/kg		0.28	15	116	1124	64	33	2	13	25	1.4	0.5	0.2
Coefficient of variation, %		4.24	46	105	53	89	105	39	11	26	74.2	6.8	140.0

Table 12. Soil analyses of 8 to 12 inch samples collected from Field 5. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			mg/kg										
179513	25	6.1	33	159	3411	124	26	5	99	55	2.6	4.5	0.1
179518	34	6.7	36	50	1445	34	11	5	93	64	1	1.2	0
178396	35	6.5	21	130	4104	95	15	6	95	52	2.9	3.6	0.1
178400	36	6.1	23	143	3790	104	17	8	98	42	2.4	3.4	0.1
178406	37	5.4	42	158	3067	125	18	12	129	27	2.3	3	0
178410	47	6.6	24	65	1162	100	24	3	113	93	0.8	0.9	0
178414	48	6.6	23	133	4357	110	40	7	116	67	2.1	3.9	0.2
178418	49	7.1	11	121	4154	57	16	5	74	105	2.3	4	0.3
178423	50	6.2	22	119	3375	95	16	6	96	32	2.3	2.8	0
178427	51	5.7	30	127	3330	93	21	9	94	30	2.1	3	0
178433	59	6.6	30	91	824	31	31	6	118	209	0.9	3.6	0
178438	61	5.8	21	119	3024	113	17	6	95	32	2.2	7.7	0
178444	62	6.3	26	122	3266	113	14	7	100	41	2.5	3.4	0.1
178449	73	6.5	59	144	765	43	5	8	123	236	1	0.9	0
178454	74	6.3	36	137	2919	121	16	9	102	83	2.4	4.9	0.2
178458	75	6.2	28	140	3769	148	14	7	93	36	2.9	3.1	0
178462	76	5.3	42	140	2727	123	20	12	193	25	2.2	4.4	0
178468	85	6.5	46	61	910	25	11	4	139	165	0.5	0.7	0
178474	87	6.3	30	123	3392	119	18	4	89	33	1.7	3.9	0
178479	88	5.9	22	93	2971	99	15	10	93	35	1.9	2.8	0
178484	89	6.4	37	152	3089	155	11	7	77	39	2.1	4	0
178487	98	6.7	10	69	2474	49	10	7	70	113	2	2.9	0
178494	99	6.5	23	61	1979	64	28	7	78	131	2	2.8	0
178499	101	6.5	25	68	2073	77	29	5	80	100	1.9	2.8	0

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
178504	102	6.7	24	92	2946	96	12	6	97	77	2.4	3.8	0.2
178512	111	6.4	5	86	3016	33	16	5	55	86	1.8	1.2	0
178517	113	6.4	57	123	2771	138	16	7	91	48	1.2	0.9	0.1
178521	114	6.7	34	102	2023	88	16	8	114	131	1.7	4.2	0.2
178528	115	6.9	14	55	2327	62	10	8	92	99	1.6	3	0.4
178534	116	7	20	42	1539	61	10	6	117	95	0.9	3.1	0.2
178541	125	6.9	15	114	2659	64	19	6	84	82	1.9	0.8	0.2
178546	126	6.8	19	93	2896	85	35	9	82	163	2.7	4.7	0.5
178550	127	7	27	56	1615	56	86	6	120	141	1.5	2.9	0.5
178557	129	7.3	21	36	1418	41	19	5	102	117	0.9	4.1	0.1
178563	137	6.6	7	104	2964	31	19	7	74	86	2.6	1	0.3
178567	138	6.7	5	103	3189	40	16	6	62	85	1.9	1.4	0.1
178572	139	6.7	10	87	2756	60	14	7	84	174	2.4	6.2	0.3
178578	140	7	30	40	1108	34	11	5	114	107	1.1	2.8	0.1
178583	141	7	48	51	1563	41	11	6	119	156	1.4	2.9	0.2
178391	142	6.4	22	45	1554	33	10	4	114	112	1.4	2	0
Mean, mg/kg		6.25	28	102	2483	79	18	5	107	84	2.0	3.3	0.1
Minimum, mg/kg		5.3	5	36	765	25	5	3	55	25	0.5	0.7	0
Maximum, mg/kg		7.3	59	159	4357	155	86	12	193	236	2.9	7.7	0.5
Standard deviation, mg/kg		0.21	8	81	1313	64	11	1	11	40	0.8	1.8	0.1
Coefficient of variation, %		3.36	27	79	53	82	63	16	10	48	42.5	54.5	140.0

Table 13. Soil analyses of 12 to 18 inch samples collected from Field 5. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			mg/kg										
179514	25	6.3	35	159	3619	127	73	5	98	38	2.3	5	0.1
179519	34	6.4	59	87	1896	83	17	3	92	24	0.7	0.5	0
178397	35	6.7	16	139	4601	95	18	7	94	74	2.8	4.3	0.4
178401	36	6.2	19	133	3892	79	30	6	83	43	2.3	3.4	0.1
178407	37	5.2	48	156	3048	115	19	11	132	40	2.2	2.6	0
178411	47	6.2	49	100	2014	133	15	2	108	46	0.7	1.2	0
178419	49	7	9	114	3998	52	42	4	68	106	2.3	7.3	0.3
178424	50	6.2	21	108	3248	79	20	6	93	33	2.2	2.3	0
178428	51	5.8	31	128	3272	81	30	8	105	36	2.3	3.3	0
178434	59	6.3	41	74	1027	50	44	4	143	149	0.6	1.3	0
178439	61	5.9	26	124	3258	104	23	8	108	32	2.5	2.6	0.1
178445	62	6	34	128	3110	113	20	8	141	19	2.1	2.9	0.1
178450	73	6.3	41	117	697	38	6	7	136	208	0.7	2	0
178455	74	6.4	19	122	3279	112	17	6	86	57	2	3.4	0
178459	75	6.1	39	137	3336	130	26	7	94	30	2.2	2.6	0
178463	76	5.2	45	148	2873	121	38	12	243	22	2.3	2.9	0.2
178469	85	6.6	53	53	707	19	12	2	139	98	0.3	1.1	0
178480	88	6	17	125	3590	114	22	8	95	44	2.5	4.1	0.2
178488	98	6.8	8	72	2268	32	15	4	79	110	1.9	1.2	0
178500	101	6.5	26	85	2595	84	15	4	85	98	2.4	3.6	0
178505	102	6.3	15	117	3586	114	17	6	92	58	2.4	3	0.3
178514	111	6.5	5	116	3373	26	22	7	79	105	1.8	5.8	0.2
178518	113	6.6	61	129	3098	121	20	6	110	48	0.9	3.2	0.1
178522	114	6.7	27	114	2957	112	24	8	92	93	2.4	4	0.4

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
178529	115	6.9	13	86	3115	90	15	7	84	100	2.1	2.5	0.4
178535	116	7	30	64	1769	62	9	6	106	101	1.3	2.8	0.1
178542	125	6.9	17	121	2889	61	30	5	75	74	1.7	0.7	0.2
178551	127	6.8	22	102	2950	99	16	6	89	114	1.9	2.3	0.4
178558	129	7.1	23	46	1505	47	9	5	106	124	1.1	1.8	0.1
178564	137	6.7	6	121	3263	35	30	6	75	66	2.4	1.1	0.3
178568	138	6.7	5	107	3158	27	18	5	66	69	1.8	1.5	0.1
178574	139	6.6	8	109	3303	65	18	8	86	160	2.5	3.1	0.4
178579	140	6.9	26	68	1853	65	21	6	101	199	1.7	3.3	0.3
178584	141	6.9	50	74	2094	61	17	5	133	136	1.6	2.1	0.2
178392	142	6.5	33	72	2250	46	10	5	145	127	2	2.7	0.1
Mean, mg/kg		6.40	34	116	2935	87	42	5	122	83	2.2	3.9	0.1
Minimum, mg/kg		5.2	5	46	697	19	6	2	66	19	0.3	0.5	0
Maximum, mg/kg		7.1	61	159	4601	133	73	12	243	208	2.8	7.3	0.4
Standard deviation, mg/kg		0.14	1	62	968	57	45	0	33	63	0.2	1.6	0.0
Coefficient of variation, %		2.19	4	53	33	66	107	0	27	76	9.8	42.3	0.0

Table 14. Soil analyses of 18 to 24 inch samples collected from Field 5. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			mg/kg										
179515	25	6.5	42	156	3756	136	78	3	118	37	2.3	3.8	0.2
179520	34	5.7	59	97	1401	111	21	4	106	15	0.6	0.8	0
178402	36	6.5	20	138	4317	74	25	6	88	51	2.2	10.1	0.2
178412	47	6.1	45	119	2011	180	20	3	95	27	0.6	1	0
178420	49	7	8	120	4131	42	40	4	70	99	2.1	4	0.5
178430	51	5.7	35	150	3653	79	23	7	107	47	2	5.9	0
178435	59	6.2	51	75	1011	63	24	3	125	93	0.3	2.8	0
178440	61	6.1	19	128	3450	97	25	8	108	43	2.6	5.1	0.1
178446	62	5.8	34	132	3376	108	24	11	118	26	2.5	3.2	0.2
178464	76	5.4	33	132	3240	113	36	9	169	32	2.2	3	0
178475	87	6.4	16	114	3252	76	22	4	86	62	1.9	3.4	0.2
178481	88	5.9	25	118	3288	102	23	6	110	47	2.2	3.4	0.1
178490	98	6.7	14	76	2148	25	20	2	61	62	1.5	0.6	0
178506	102	6.3	20	117	3861	127	21	6	83	43	2.1	3	0.2
178523	114	6.4	32	119	3326	123	22	8	95	60	2.3	3.5	0.3
178530	115	6.8	14	101	3450	102	13	8	88	90	2.2	6	0.4
178543	125	6.8	20	120	2928	61	28	5	76	58	1.4	0.7	0.1
178552	127	6.9	19	90	2525	85	32	5	85	82	1.4	1.4	0.3
178559	129	6.5	38	77	2050	55	14	6	115	133	1.8	2	0.2
178569	138	6.8	6	105	2975	20	19	4	72	68	1.6	0.8	0.1
178575	139	6.6	8	116	3433	64	18	8	79	153	2.7	3.2	0.4
178580	140	6.8	19	88	2870	88	16	7	97	176	2.3	4.7	0.6
Mean, mg/kg		6.65	31	122	3313	112	47	5	108	107	2.3	4.3	0.4

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
Minimum, mg/kg		5.4	6	75	1011	20	13	2	61	15	0.3	0.6	0
Maximum, mg/kg		7	59	156	4317	180	78	11	169	176	2.7	10.1	0.6
Standard deviation, mg/kg		0.21	16	48	626	34	44	3	15	98	0.0	0.6	0.3
Coefficient of variation, %		3.16	53	39	19	30	93	57	14	92	0.0	15.1	70.0

Table 15. Soil analyses of 24 to 30 inch samples collected from Field 5. P is phosphorus, K is potassium, Ca is calcium, Mg is magnesium, Na is sodium, Fe is iron, Cu is copper, Zn is zinc, and B is boron.

Lab Number	Point	pH	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			---------------------------------- mg/kg ----------------------------										
178491	98	6.5	21	100	2708	32	23	2	61	41	1.7	0.9	0
178507	102	6.2	23	114	3624	131	24	6	94	49	2.3	2.9	0.1
178524	114	6.6	35	140	3755	144	21	9	99	54	2.3	4.7	0.3
178531	115	6.6	16	88	2861	79	18	7	104	103	1.8	4.7	0.3
Mean, mg/kg		6.55	19	94	2785	56	21	5	83	72	1.8	2.8	0.2
Minimum, mg/kg		6.2	16	88	2708	32	18	2	61	41	1.7	0.9	0
Maximum, mg/kg		6.6	35	140	3755	144	24	9	104	103	2.3	4.7	0.3
Standard deviation, mg/kg		0.07	4	8	108	33	4	4	30	44	0.1	2.7	0.2
Coefficient of variation, %		1.07	19	9	4	60	17	79	37	61	4.0	96.1	140.0

Appendix 3 – Protocols for Sampling Liquid Manures

UNIVERSITY OF ARKANSAS DIVISION OF AGRICULTURE

Cooperative Extension Service

Sampling Liquid Manure

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Liquid animal manure sampling can be an important management tool. Proper sampling provides the producer with nutrient analysis results that can be used in a sound farm fertilization program. Nutrient analysis of manure, in conjunction with soil sampling, helps determine how much manure should be applied to fields to maintain adequate fertility while minimizing potential environmental problems such as ground and surface water pollution. However manure applications should not exceed the maximum application rates in a manure management plan until sufficient data can be collected to justify revising the plan.

When to Sample

Liquid animal manure should be sampled for nutrient analysis as close to land application time as possible. This helps ensure that the reported nutrient content accurately reflects what is being applied to the land. If the manure is sampled as it is being land applied, the results will not be available to govern present application rates. It does, however, provide information for future land applications of animal manure, if the manure management remains fairly constant over time.

How to Collect a Liquid Manure Sample

During Land Application

The easiest way to collect liquid animal manure samples is to collect the manure as it is being land applied. This approach ensures what is sample reflects what is applied. Randomly place catch pans in the field to collect the liquid manure as it is land applied by an irrigation system or honey wagon. Flexible rubber feed pans work well. Immediately after the manure has been applied, collect the manure from the catch pans, combine in a bucket to make one composite sample and mix well by stirring. This bucket will be the source of the manure sent for analysis.

From a Storage Facility

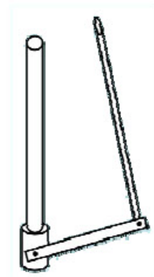
If collecting liquid animal manure samples during land application is not possible, collect the samples from the storage facility. Liquid animal manure storage facilities have a tendency for the manure to stratify with the solids settling to the bottom and the liquids remaining on top. It is also not uncommon for some solids to form a floating crust. This stratification affects the manure nutrient concentrations in the storage facility. The nitrogen and potassium will be more concentrated in the top liquid, while the phosphorus will be more concentrated in the settled solids. This stratification of nutrient concentrations increases the challenge of getting samples that represent what will be applied to a particular field. If the liquids from the top and middle of the profile will be applied, only this material should be sampled. If the settled solids will be applied, then they should be sampled. However, if the manure is to be agitated before pumping, as has been the traditional recommendation, the sample should contain representative proportions of manure from the top, middle, and bottom. The idea is to collect a sample of an entire column of manure to represent the manure after agitation.

If agitating the manure prior to sampling is not possible, an alternative approach is to make a sampler to collect the required sub-samples. The sub-samples are then mixed to represent the manure after agitation. The easiest to construct is simply a container such as a cup, attached to the end of a pole. Liquids from the manure surface can be simply scooped up. To collect liquids from the middle depths, or settled solids, the container is held up side down, trapping air, until the desired sampling depth is reached. Then the container is rotated, releasing the air and collecting the sample. When collecting a sample of the entire profile of the manure, sub-samples are collected and mixed in a bucket.

- over -

A sampler design that automatically collects a sample of the entire profile uses 10 foot, 1 ½ inch PVC pipe with a PVC ball valve at the bottom. The handle of the ball valve is replaces with a lever arm about 2 feet long. The free end of the lever arm is attached to the end of a 10 foot, 1 inch PVC pipe. The lever arm and smaller pipe allow the ball valve to be operated while holding to top of the sampler. To use the sampler the valve is opened and the sampler is inserted (in a line, not and arc) into the manure. When the foot of the valve is at the bottom of the settled solids, it is closed. Then the sample of the entire manure profile can be removed from the manure and placed in a bucket.

Sketch of Cup Sampler



Sketch of Foot Valve Sampler

Whichever sampler is used, at least 8 locations around the manure storage unit should be sampled and mixed in a bucket to serve as a final composite sample. This bucket will be the source of the manure sent for analysis

Getting the Sample Analyzed

After thoroughly mixing the final composite sample, fill a one liter plastic bottle half full. These bottles may be obtained from your county Extension office. Never fill the bottle more than half full to allow for gas expansion of the sample and to prevent the bottle from exploding. Keep the samples as cool as possible until you can take them to your county Extensions office for shipping to the University of Arkansas lab for analysis. There you will get assistance in filling out an information sheet on your manure sample. There is a fee to have the sample analyzed. While the sample can be sent to a private lab, the fees are often higher. If you are required by the Arkansas Department of Environmental Equality (ADEQ) to sample your liquid animal manure as part of your Regulation No. 5 permit, make sure that you inform the individual helping you with the paperwork so the correct set of analyses can be performed. In addition to the analyses to determine the fertilizer value of manure, it is recommended to analyze for the amount of phosphorus in the manure that is water soluble. Water soluble phosphorus is needed to evaluate the potential environmental risk associated with phosphorus application rates specified in manure management plans. Having good farm based information should help planners develop plans tailored to and individual farm.

Key Points to Remember

The important things to remember in collecting a liquid animal manure sample are:

- Collect a sample that best represents the nutrient content of the manure in that storage facility and what will be applied. If only the top water is to be applied it should be sampled. If the storage unit will be agitated prior to application the sample should contain material from the entire depth profile.
- Only fill the sample bottle ½ full.
- Keep the sample cool prior to shipping.
- Ship the sample to the lab as soon as possible.

Handout, April 27, 2010

Appendix 4 - Piezometer and Monitoring Well Installation

At each site, a series of three (3) piezometers will be installed. Piezometers containing water-level sensors (Water Logger WL-15 units from Global Water) will be installed near just below the root zone (about 12 inches deep), at approximately the bottom impermeable layer or groundwater level (about 15 feet or approximately at the Big Creek bed elevation), and equidistant from the first two piezometers. A bucket auger will used to describe the soil profile upon excavation to install the deepest piezometers. The piezometers containing the water-level sensors will consist of 5-cm (2-inch) diameter Schedule 40 PVC pipe, which will be slotted in the bottom 10 cm of the pipe to facilitate water flow. Sand will be placed in the bottom of the hole and along the outside of the PVC pipe up to the top level of the slots in the pipe. Bentonite chips will be placed above the sand along the outside of the PVC pipe to the soil surface to ensure no preferential movement of water along the well casing. Data will be downloaded from each WL-15 unit using a laptop computer once approximately every month. Water-table heights will be measured manually each time the datalogger is downloaded to confirm the sensors' accuracy.

NOTE - Piezometers will be installed so that there is minimal piping or equipment above ground that could interfere with day to day farm operations on that field.

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