Qualities of spring-waters of Clarke County where biosolid materials were applied as fertilizer to karst landscapes.

2014
Report No. 0001-2014 2nd Edition
Friends of the Shenandoah River. 92 pp.

Webb, W., R. Marzolf, K. Andersen, B. Sawyer, A. Teetor

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Abstract

Here we examine the nitrogen and phosphorus yields of 10 springs in the karst areas of the northern Shenandoah Valley. We document the nutrient yield at base flow and report the yield differences from springs proximal to and distant from the application of biosolids applied as fertilizer to agricultural land. The objective was to gain perspective on the ground water contribution of nutrients to the spring creeks of the northern Shenandoah Valley. Springs were selected to sample rather than wells because the water flowing from springs represents conditions from a larger area than most wells could represent, usually yield the youngest water in the aquifer, and comprise the water that is the source of flow in surface streams.

We observed as many parameters characterizing water qualities as time and resources could allow; thus sacrificing numbers of samples for possible effects on spring-water's nutrient yields. The results of these preliminary observations and comparisons suggest that the concentration of nutrients in the flow of individual springs did not vary with time, though there were differences among springs with different proximities to biosolids application and the fraction of the spring-watershed underlain by karst.

Introduction

In recent decades with the growth in population and the consequent intensification of agriculture, the increased production of waste products has emerged as a source of several troublesome issues. The pollution of surface waters by nitrogen and phosphorus has led to eutrophication of freshwater lakes and reservoirs. With the transport of nutrients downstream, coastal estuaries such as Chesapeake Bay have been damaged severely to the extent that citizen concern has begun to call for corrective action that includes management activity in watersheds far inland. Sewage treatment, i.e., composting and microbial decomposition of various manures result in the production of a residue called "sludge" or "biosolids. The application of biosolids from these digestive processes to agricultural lands as fertilizer has been a promising potential innovation. Biosolids are rich in organic matter and nutrients yielding potential soil building capabilities. The downside risk of applying nutrients centers on its effects on water resources. The central purpose of this study was to examine some of these effects in karst geological situations where the interaction of ground water and surface water underpins much of the hydrological complexity.

The Spout Run example

Spout Run is a type example of a karst watershed in Clarke County in the Shenandoah Valley. Its drainage basin of 21.4 square miles is entirely karst (carbonate); with characteristic fracture zones, frequent sinks and springs and fewer surface streams than the adjacent less permeable metamorphic and siliciclastic formations. Flow from springs is nearly a direct connection to the ground water; that is, ground water, emerging to the surface in spring flow, accounts for up to ca. 80% of the stream flow. Precipitation infiltrates rapidly with only 2- 4% of rainfall appearing as runoff, and, depending on vegetation and season, up to 70% of rainfall is returned to the atmosphere by evapotranspiration. The upshot of this hydrogeological configuration is that base flow is sustained and flood peaks are muted. The central purpose of the study was to examine the role of ground-water transport of nutrient constituents of biosolids when they were applied to lands near springs. A general finding of the chemical analyses was that changes through time were minor in any one spring; while the differences were observed to be among the various springs. Generally the nitrogen concentration was higher in spring flow from springs proximal to biosolid application areas. Total Kjeldahl nitrogen (organic), ammonia and nitrite concentrations were below the limit of detection.

Methods

Application of biosolids to the landscape.

The transport of nutrients from biosolids applied to the land is mediated by the infiltration flow of water to ground-water aquifers and, subsequently, to springs in karst areas. Detailed description of such flow patterns are not understood. Using GIS techniques the land area surrounding the springs of interest was represented by concentric circles of one, two, or three square miles per cfs with the spring at the center (see Appendices 3.41 – 3.123)

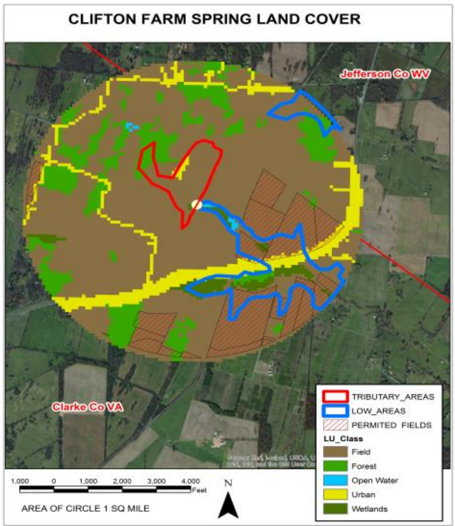


Figure 1. Example map of land uses in the springshed of one of the springs in this study. Additional maps are shown in the appendices; A3.4 to A3.13

Descriptions of the parcels of land that received biosolid treatment were retrieved from the records of Clarke County's permitting process (see appendix A3.3). These data were used in GIS analyses of maps of the land uses in the Clarke County area of the Shenandoah Valley.

The lands that received biosolid amendment were chosen according to this permitting process and overlaid other land use categories. (See appendix A6.2) for criteria and for the rules that govern the application process. This was not a precise manipulation in any experimental sense; furthermore, there could be no designed controls in the statistical sense. Thus, while we attempted to achieve a quantitative comparison of nutrient yield by measuring the land areas defined by a few independent variables, i.e., geology (karst or non-karst), biosolids application (applied or unapplied), vegetation, (forest or fields) and land use (urban or fields), unfortunately, the attempt was compromised by small sample sizes, uncertain independence of the measured variables, and heterogeneous permeability. This is candidly an attempt to make use of available data to sort out the complexity of nutrient loading in this tributary setting. Conclusions are preliminary.

Field sampling methods

Each of ten springs was sampled 6 times between February and October in 2013. Spring locations are shown on Map 1. and sampling dates are indicated by vertical bars on the time axis of the Spout Run hydrograph in Fig 2

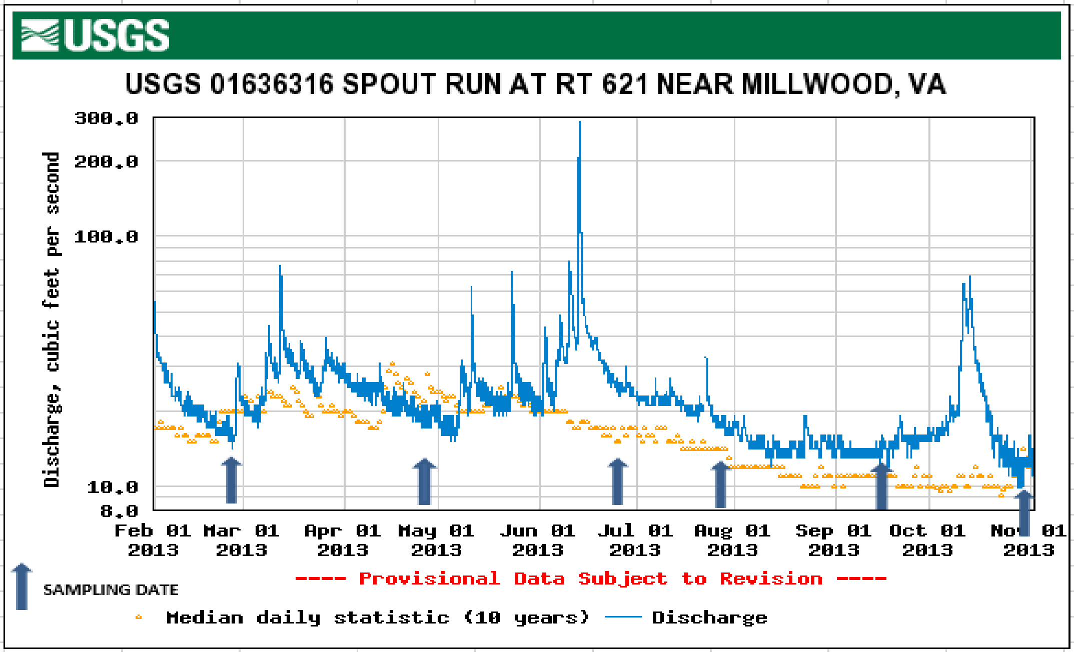
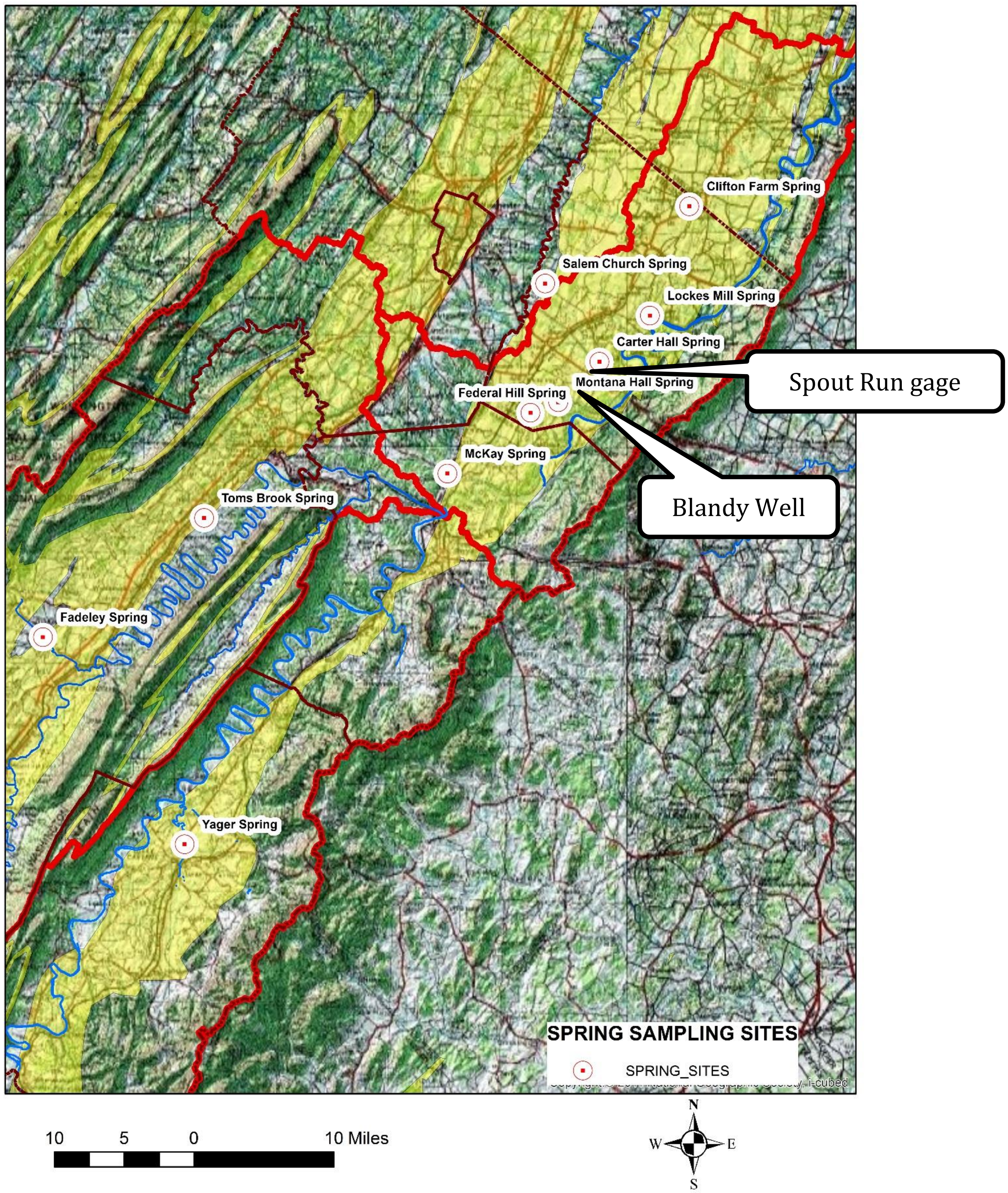


Figure 2. Graph of sampling dates and flow of Spout Run. Samples were collected during periods of no overland flow.



Map1. Map of the location of 10 springs measured this project Blandy well and Spout Run gage. Yellow over lay illustrates karst lands. Heavy red outlines are North Fork, South Fork and main stem Shenandoah River

Two of the study springs, a USGS observation well, and a USGS stream gage are located in the Spout Run drainage. The sampling dates were chosen to approximate a monthly frequency and a base flow hydrologic status. Each spring was sampled six times at base flow over a seven-month period from February 25, 2 2013 to October 28 2013. The sampling sites are shown on Map 1. The sampling dates are plotted in figure 1 along with the flow of Spout Run (USGS 01636316 SPOUT RUN AT RT 621 NEAR MILLWOOD, VA) to show that the samples were collected during periods of base flow. Grab samples for chemical analysis of the springs' waters were collected at the centroid of the spring as it emerged at the land surface before the formation of a channel or spring run. The objective was to minimize the effects of surficial or in-channel processes on the sample; that is, to attempt to focus the sample on the ground water emerging from the spring. Samples were iced immediately and analyses were performed with 24 hours. Temperature, oxygen and pH measurements were made in the field as parallel checks on the laboratory analyses. Discharge measurements, on the other hand, were made below the spring "boil" as soon as a definite channel-cross section was discernable and the flow cross-section was controlled.

The similarity between water level in the Blandy observation well (USGS 390348078035501 46W175 well site) and flow at the Spout Run gage is evidence that the springs were responding to similar concurrent rainfall and recharge events. Water level in the Blandy observation well and the average of the flows of the 10 springs are plotted in figure 3. As the water level in the Blandy observation well rose the flow of the springs increased.

The rainfall amounts during the 7 and 14 day periods preceding the sampling days along with the flow of Spout run and the water level in Blandy observation well are in table 1.

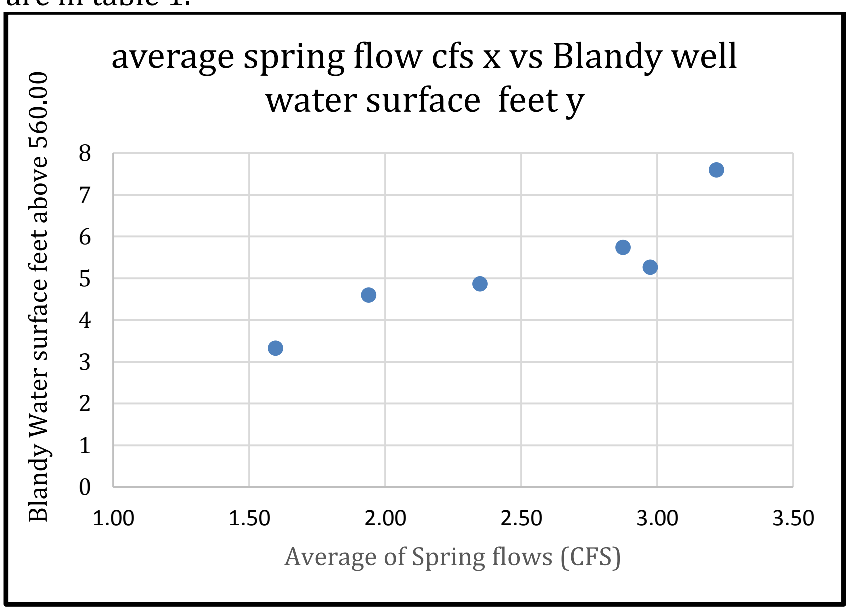


Figure 3. Blandy Well (USGS 390348078035501 46W175) water level above 560 foot elevation versus the average flow of the project springs on the project sampling dates

sampling date	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Spout Run flow (cfs)	16	20	27	17	12	25
Spout Run historic median for day	20	26	18	14	11	12
prior 14 day rain inches	0.37	1.26	2.36	1.6	0.06	0.10
prior 7 day rain inches	0.05	0.78	0.41	1.44	0.01	0.00
average of spring flows	2.35	2.97	3.22	2.88	1.60	1.94
Blandy well water level above 560 ft	4.87	5.27	7.6	5.74	3.33	4.6

Table 1.Rain fall amounts during the 7 and 14 day periods preceding the sampling days along with the flow of Spout Run and the water level in Blandy observation well

Aquatic chemistry methods

Nitrogen, phosphorus, oxygen, conductance, pH, and temperature

The measurements made include nitrogen (N as NO_3, $N0_2$, and NH_3) phosphorus (P as soluble reactive phosphate), conductivity, temperature, pH, dissolved oxygen, *Escherichia coli*, (*E. coli*) and turbidity. Methods used to make these measurements are standard and described in the Standard Methods for the Examination of Water and Waste Water as used by the Friends of the Shenandoah River (FOSR) laboratory in an application for a segmented flow auto analyzer. More detailed results of analyses are reported graphically below and the data that support them are presented in the Appendices.

Coliform bacterial enumeration

Enumeration of *E. coli* was performed using the "*COLISCAN* "method to provide an index to pathogenic microbial contamination. This is a health-related parameter to help determine the safety of the water for drinking and water contact recreation. *E. coli* most probable number (mpn) are shown in in the Appendices A2. Montana Hall Spring was the only spring that never had an mpn above the drinking water standard of none. *E. coli* mpn changed substantially between samplings and between springs. *E. coli* mpn per 100ml ranged from 0 to 387 and for any individual spring the lowest count was less than 1/10 highest count. In only one case was the mpn above the Virginia level for water contact recreation. The mpn numbers were generally low but the highest counts were for springs with the lowest biosolids application and percent area in fields.

Spring-flow methods

Flow of the springs was measured so that the yield of nitrogen and phosphorus could be calculated. Flow and nitrate yield of the springs are shown in tables A2.311, and A2.312 in Appendix A2 The Flow ranged from 0.04 to 11.7 cubic feet per second (cfs) between springs and for any individual spring the lowest flow was less than half and often only 1/3 the highest observed flow. The yield of the springs was directly related to the flow because the nitrate concentration was almost constant.

Summary of results: conclusions

Nitrogen

Nitrogen in its bioavailable forms is of interest since it is one of the 3 constituents that the Chesapeake Bay TMDL is working to have controlled to improve the Bay quality and when ammonia and nitrate concentrations exceed certain limits they can be detrimental. However these limits were only exceeded in this study in the nitrate concentrations in the Montana Hall spring that averaged 10.9 mg/L. The drinking water standard is less than 10 mg/L.

Generally the nitrogen concentration is higher in spring flow from springs near biosolids application areas. Nitrogen data are in appendices A2. Nitrate concentration is higher in springs with a higher percent of the springshed covered by fields. Nitrate concentration is also higher in springs with a higher percent of karst springshed. Because biosolids are applied on fields, most the fields in the springsheds are on karst lands and adjoining fields may have had other nitrogen fertilizer applied it is not clear that application of biosolids is the sole reason for elevated nitrate concentrations. Total Kjeldahl nitrogen (organic), ammonia and nitrite concentrations were below the limit of detection.

Phosphorus

Phosphorus is of interest since it is one of the 3 constituents that the Chesapeake Bay TMDL is working to have controlled to improve the Bay quality Total phosphorus and ortho phosphorus data are shown in the Appendices A2. Total phosphorus and ortho-phosphorus concentrations were usually below the reporting limits of 0.05 and 0.01 mg/L . Total phosphorus was not measured in the samples collected on September 16 and on October 28, 2013.

Dissolved Oxygen

Dissolved oxygen and it's percent saturation are shown in Tables 4a and 4b. Dissolved oxygen concentrations are an indication of the dissolved organic matter condition of the springshed ground water and in the interpretation of reduced nitrogen compounds such as nitrite and ammonia. Oxygen concentrations less than 1 mg/L would indicate organic the presence of organic carbon and bacterial decomposers. The substantial oxygen concentrations measured in this study indicate little organic contamination and nitrogen should be, as it is, in the form of nitrate. Dissolved oxygen and percent saturation of dissolved oxygen are shown in tables Appendix 2. These measurements were similar from one sampling date to the next with 2 exceptions. The measurements of dissolved oxygen on October 28 at all 10 springs were the highest observed during the study with one exception, Yager Spring on February 25. The situation at Yager spring on that occasion was comprised of (1) an algal bloom in the spring pond, (2) a bright sunny day, (3) a sampling time late in the day and (4) a measurement made at the pond outflow; …a "perfect storm" for photosynthetic oxygen production. The dissolved oxygen in the springs' water was always lower than 100% saturation and relatively consistent from one sampling time to the next generally about 2/3 saturation.

Specific Conductance

Specific conductance in the absence of contamination indicates the solubility of the aquifer. Specific conductance results are shown in appendices A2. Specific conductance measurements changed little from one sampling time to the next. The specific conductance measurements are typical of the bicarbonate water in limestone aquifers. The specific conductance of Yager spring is a little less than half of that of the other springs suggesting that this spring may be receiving some or all of its groundwater flow from other than carbonate rocks.

Water Temperature

The temperature of the spring water is about the long term average air temperature of the study area. The fact that the temperature is near the long-term environmental temperature indicates that the source of the water is not from extremely deep circulation patterns and is another clue that we are measuring recent local water inputs. The temperature of the spring water was relatively constant with all measurements for any spring within a 2 degree Celsius range and all the temperature measurement between 11.3 and 13.8 degrees Celsius. Temperature measurements are shown in appendices A2

pH

Measurements of pH are shown in table 7. pH values were almost constant and very close between springs ranging from 7.0 to 7.7 (excluding the Yager spring measurement on 2/25). For any specific spring the pH measurements ranged less than 0.2 pH units.

Summary of results: implications N and *E. coli*

Nitrate-N concentration and mpn of *E. coli* per 100ml are the measurements that were different among springs. The discussion that follows examines the relation of these measurements to land use and geology.

The springs all yielded water with concentrations of nitrate nitrogen that is similar to the concentrations observed in nearby streams that originate in the karst areas of the Shenandoah Valley. Most of the flow in the karst streams is ground water and much of that flow issues from springs (Nelms and Moberg. 2010). It follows that the source of a substantial amount of the nitrate transported by the karst streams originates in the ground water. The nitrate concentration in Spout Run and other karst streams decreases with increasing stream flow (Figure 4.) Decreasing concentrations of a dissolved constituent such as nitrate with increasing stream flow is typical if the source is a point source. The sewage treatment plant for the town of Boyce is the only point source in the Spout Run drainage. Thus the decreasing concentrations in the other streams and the constant concentration from the springs is evidence that much of the nitrate in the streams is from ground water.

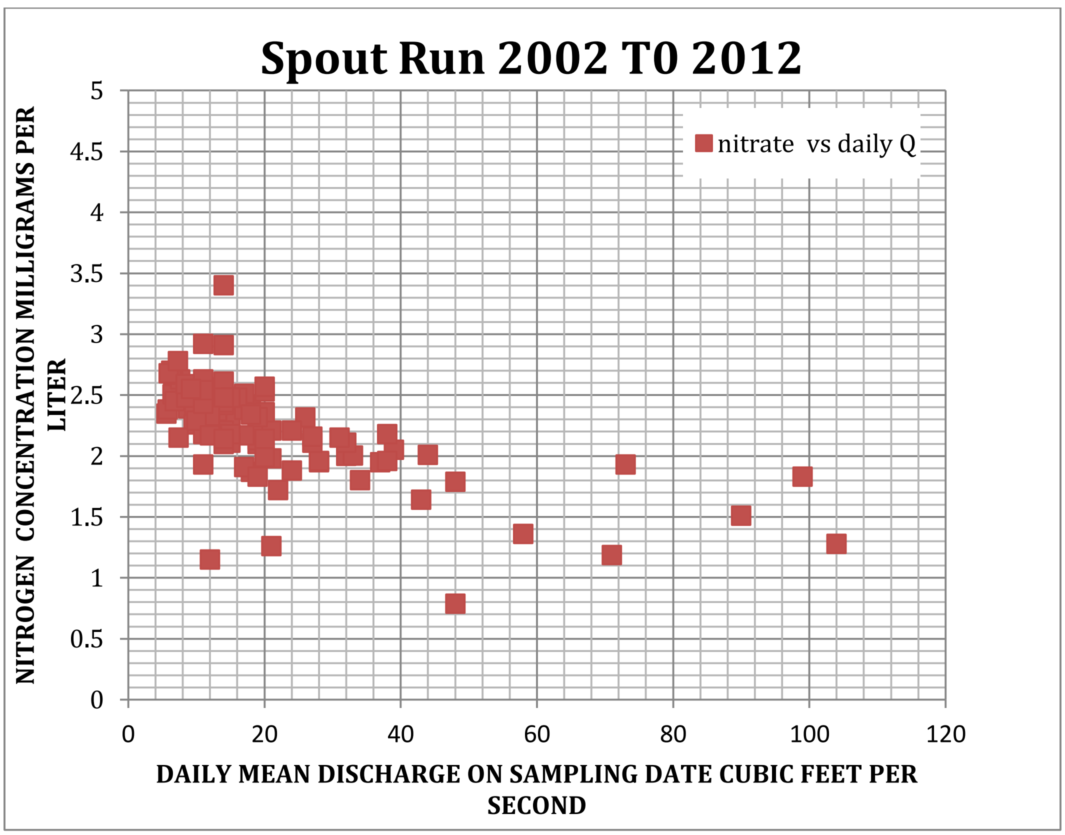


Figure 4. Nitrate concentrations in Spout Run near the gage versus stream flow for the period 2002 to 2012

The nitrate-N concentrations are higher in the springs near biosolids application areas. Land use data in the Appendices tables A3.11, A3.12 A3.13 list various land use types near the springs. Stream flow records show that the long-term average stream flow in the Shenandoah River is about 1 cubic foot per second per square mile of drainage area. For each spring the land use was measured for 1, 2 and 3 square mile area for approximately each cfs of spring flow with the spring at the center of the area. Figure 5 is a plot of the rate of biosolids application in the springsheds and the spring average nitrate concentration. Figure 5 indicates that springs with the highest average nitrate concentration have the highest rate of biosolids application within the springshed over the period of biosolids record of application (2000 to Sept. 2013). When the nitrate concentration is compared to the rate of biosolids application since January 2010 however there appears to be no relation between application rate and nitrate concentration. The lack of a relation maybe because there were no applications in 2013 and no applications at all in two of the springsheds permitted for application. The disparity between the short term and long term effect of biosolids application on nitrate concentrations suggests that if there is an effect it is long term.

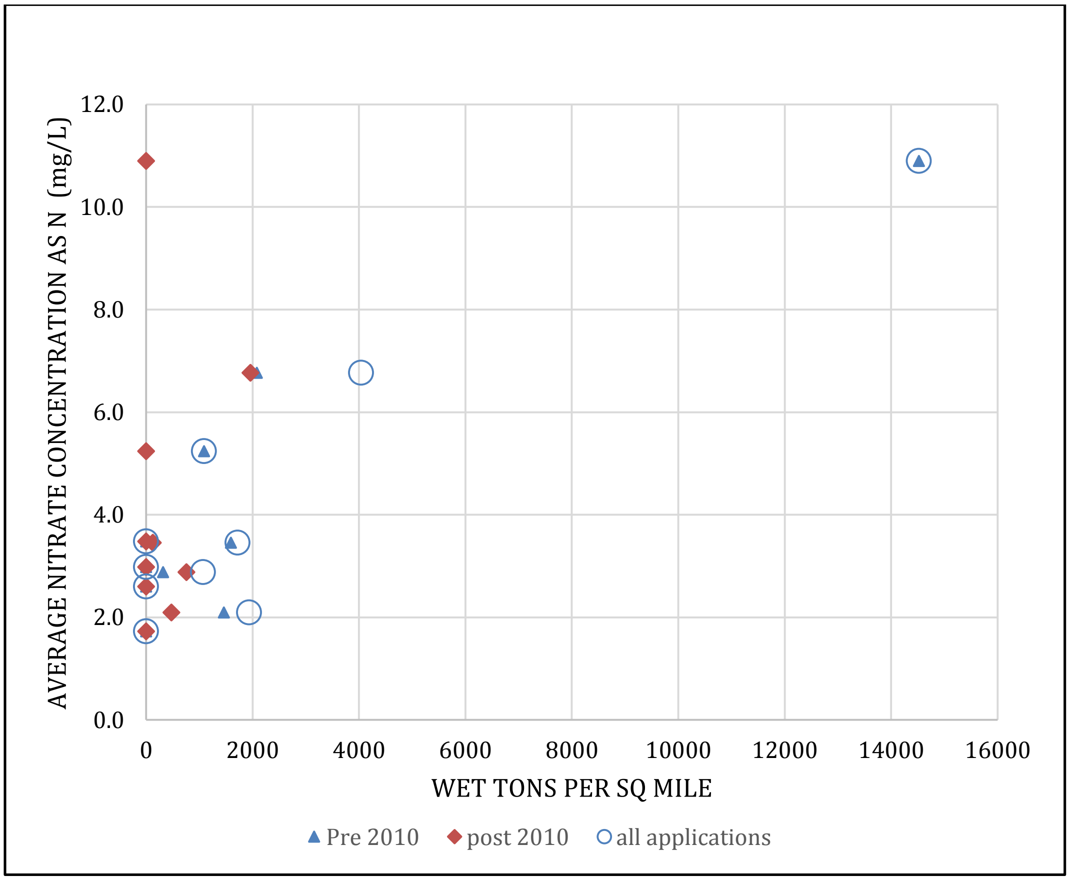


Figure 5. average nitrate concentration compared to biosolids application rate within the springshed.

	spring shed area sq mi	BIOSOLIDS APPLIED Wet tons /sq mi pre 2010	post 2010	total	AVERAGE NITRATE mg/L	
FHS	2.8	2078	1960	4038	6.8	Federal Hill Spring
CHS	17.6	1596	126	1721	3.5	Carter Hall Spring
MHS	0.4	14523	0	14523	10.9	Montana Hall Spring
CS	2.8	1087	0	1087	5.2	Clifton Farm Spring
LMS	6.3	316	756	1072	2.9	Lockes Mill Spring
SCS	6.3	1459	477	1936	2.1	Salem Church Spring
TBS	2.8	0	0	0	3.5	Toms Brook Spring
YS	30.7	0	0	0	1.7	Yager Spring
FS	9.1	0	0	0	3.0	Fadeley Spring
MS	9.1	0	0	0	2.6	McKay Spring

Table 2. Biosolids application rate by date and springshed including spring average nitrate concentration

A map[2] that shows some of the areas that contribute to McKay spring is reproduced in Map 2. This map was developed as part of a dye tracing study that included McKay spring. An area, if the circle were complete, of about 9 square miles is super imposed on that map. As shown on the map the areas that contribute to a spring in a karst area are difficult to define and are not necessarily the topographic areas that appear to be tributary to a spring. The blue lines in Map 2 connect McKay spring with sink holes from which dye appeared in McKay spring. The land uses listed for the measured springs can be considered a first cut approximation of the land uses that contribute to the quality of the spring water.

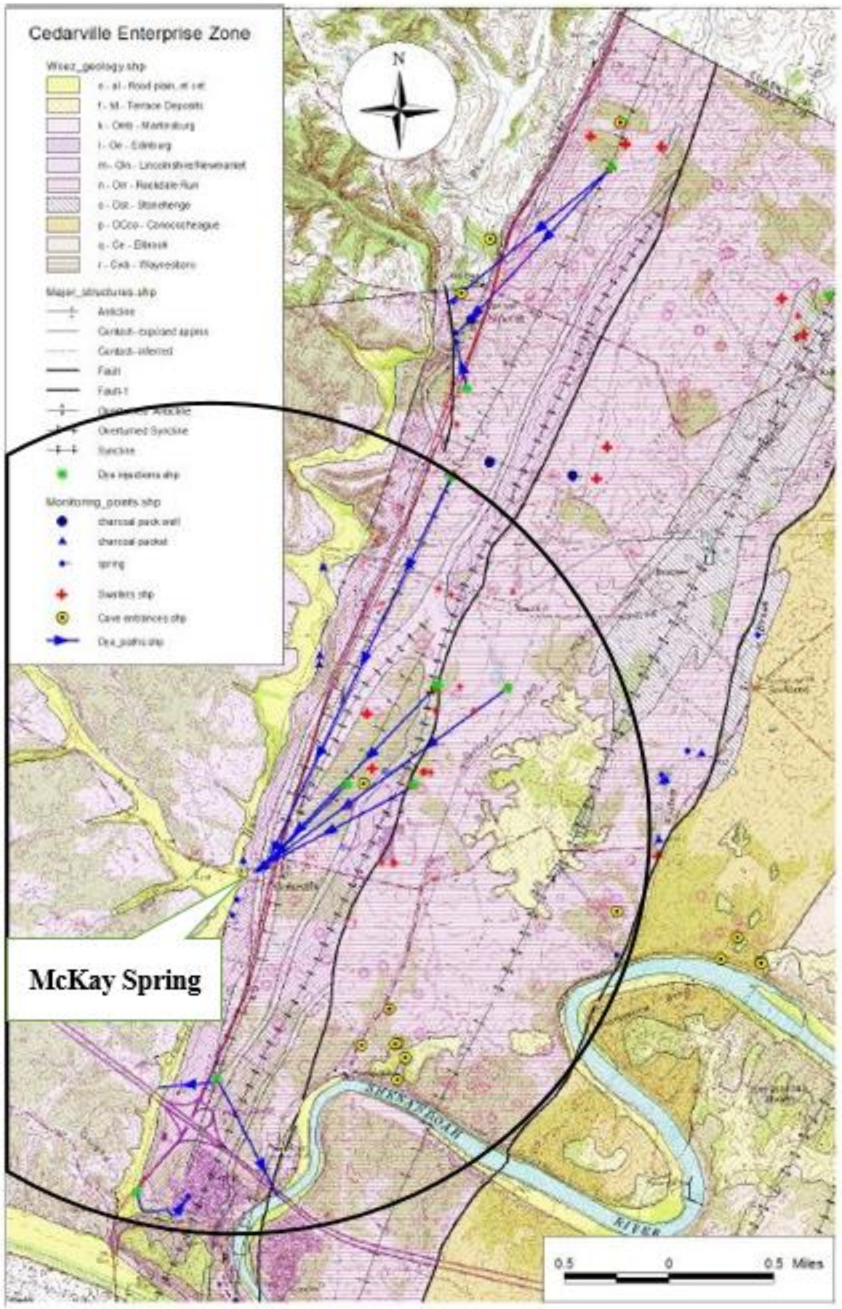


Figure 2. Geology of Cedarville Enterprise Zone

Map 2 of McKay Spring springshed outlined in black...Adapted from Cedarville Enterprise Zone study.

The original intent of the study design was to sample springs in karst land only. We were unable to achieve that distribution and maintain the sampling scale comparable to the scale of biosolid application. Salem Church Spring and McKay Spring are both near the edge of the karst area and are no more than 10 to 40 % karst. Fadeley and Toms Brook Spring are about 2/3 karst. The fact that the contributing area was not entirely karst added a new dimension to the study.

Plotting nitrate concentrations versus "% of contributing area in fields (Figure 6), "% of contributing area that is karst" (Figure 7), and "% of contributing area that is permitted for biosolids application"(figure 8) shows that for this sampling set nitrate concentrations are generally higher in springs that have a larger fraction of their contributing area in fields. Nitrate concentrations are generally higher in springs that have a larger fraction of karst area in their contributing area. Nitrate concentrations are generally higher in springs that have a larger fraction of area permitted for biosolids application in their contributing area.

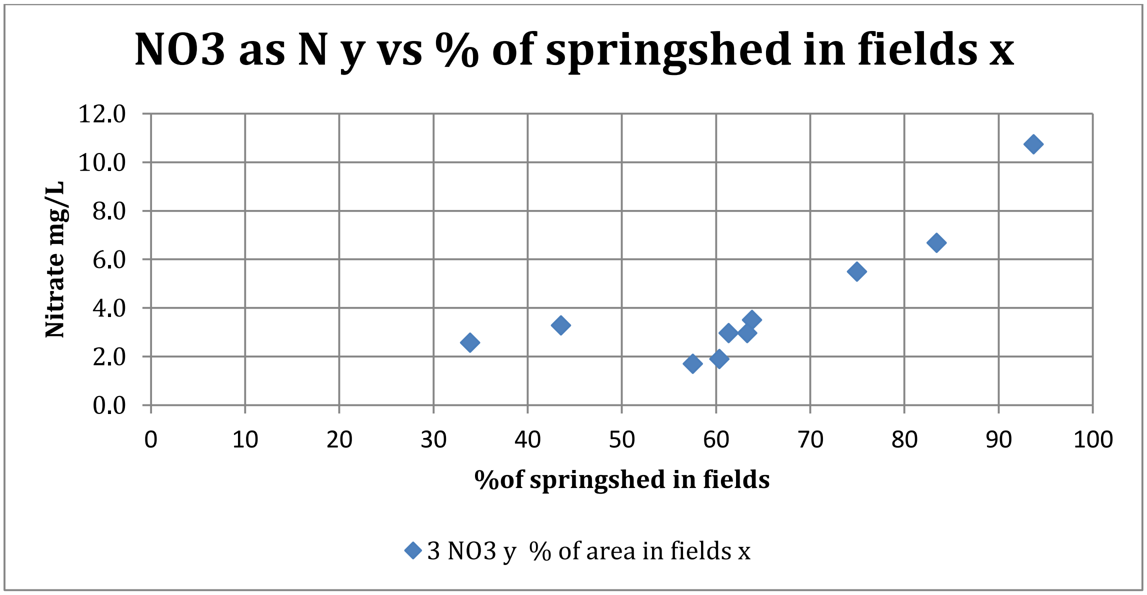


Figure 6. Average observed nitrate concentration in spring water compared to the % of springshed that is covered in fields

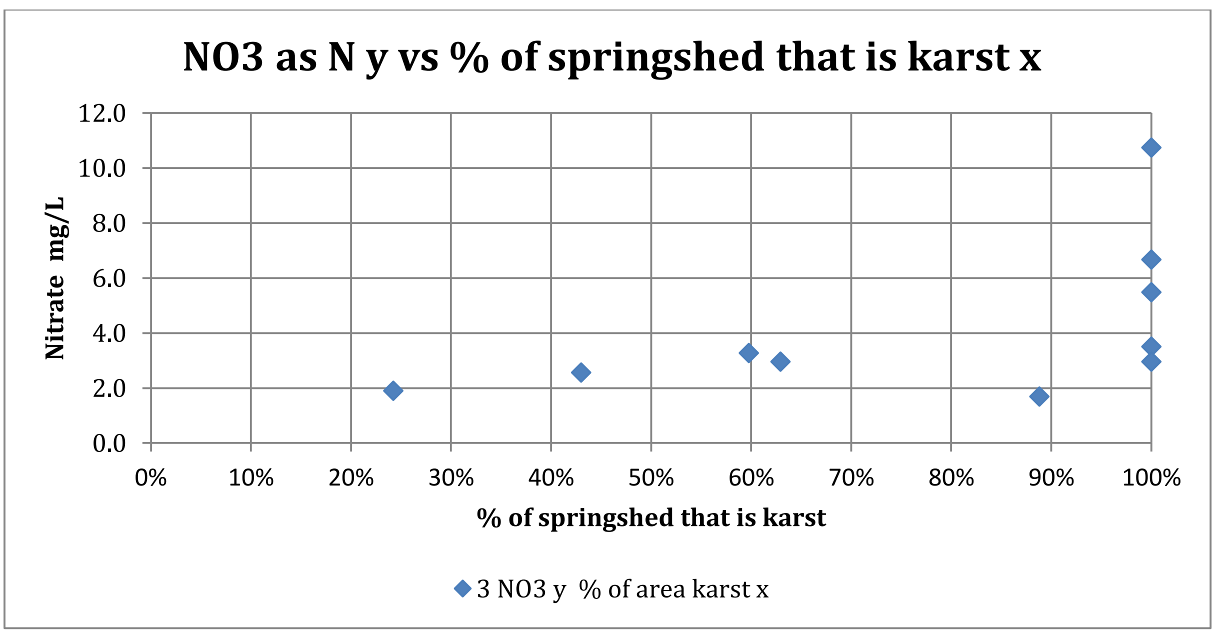


Figure 7. Average observed nitrate concentration in spring water compared to the % of springshed that is karst.

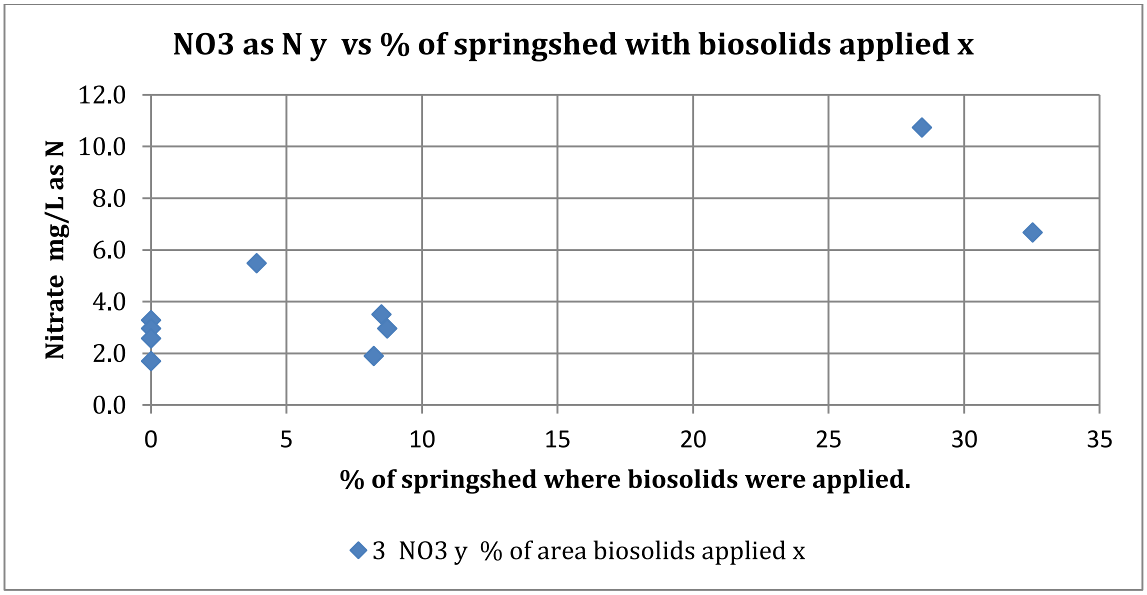


Figure 8. Average observed nitrate concentration in spring water compared to the % of springshed that had biosolids applied

Fecal coliform counts changed at each site during the study. The median *E. coli* densities decreased with increasing % of area with biosolids application, (Figure 9), % of area in fields(Figure 10), % of area karst(figure 11), The *E. coli* densities results are puzzling.

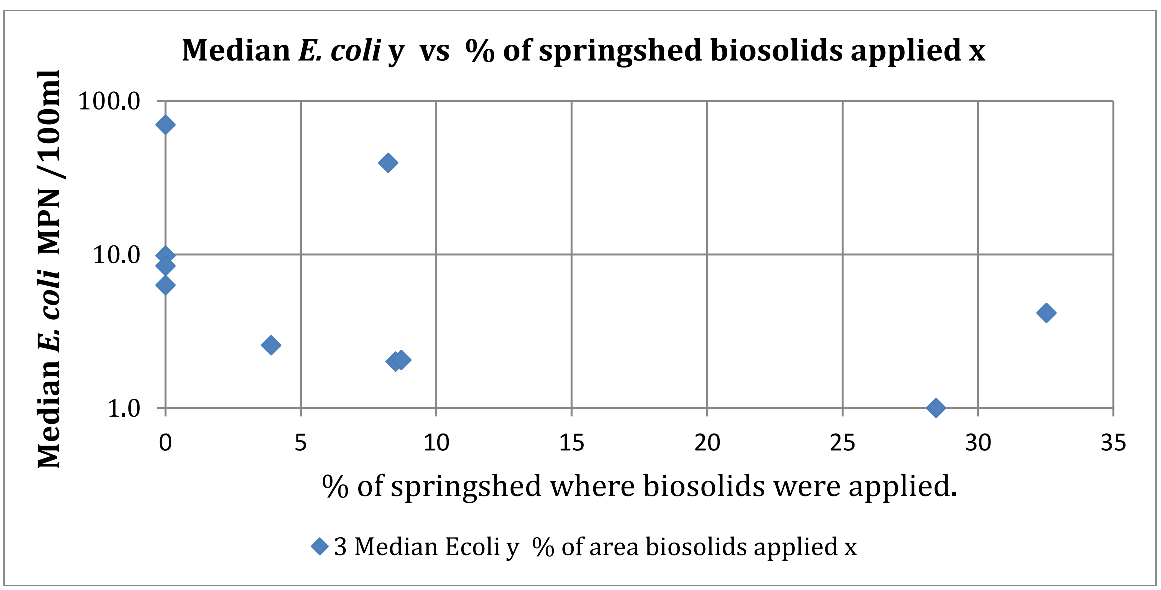


Figure 9. Median *E. coli* mpn in spring water compared to the % of springshed that had biosolids applied

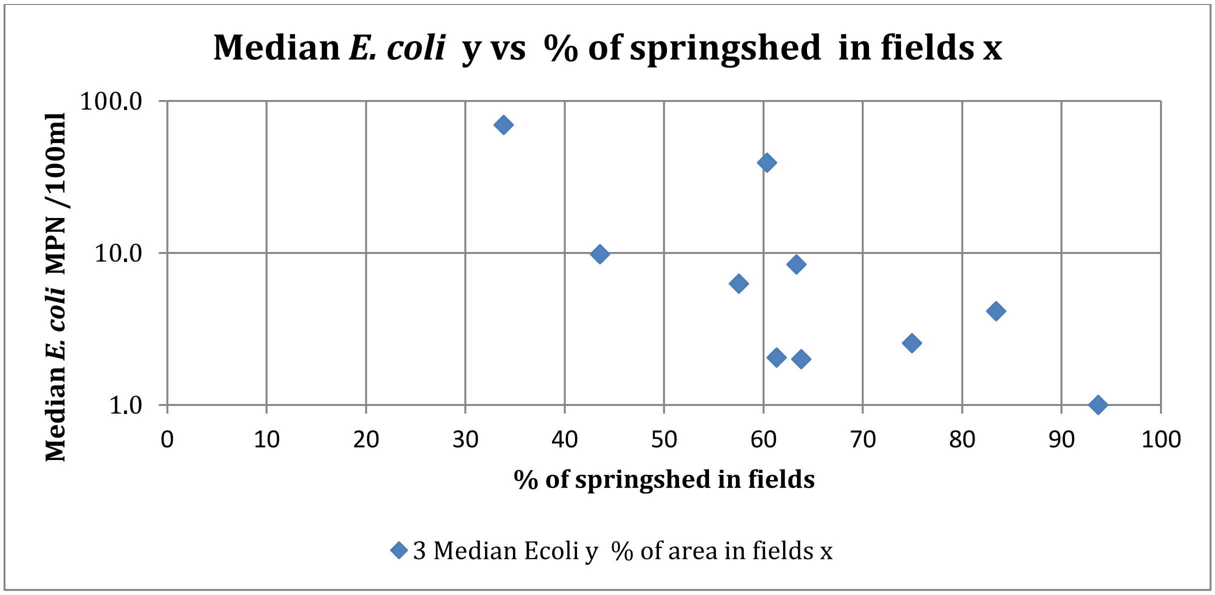


Figure 10. Median *E. coli* mpn in spring water compared to the % of springshed that is covered in fields

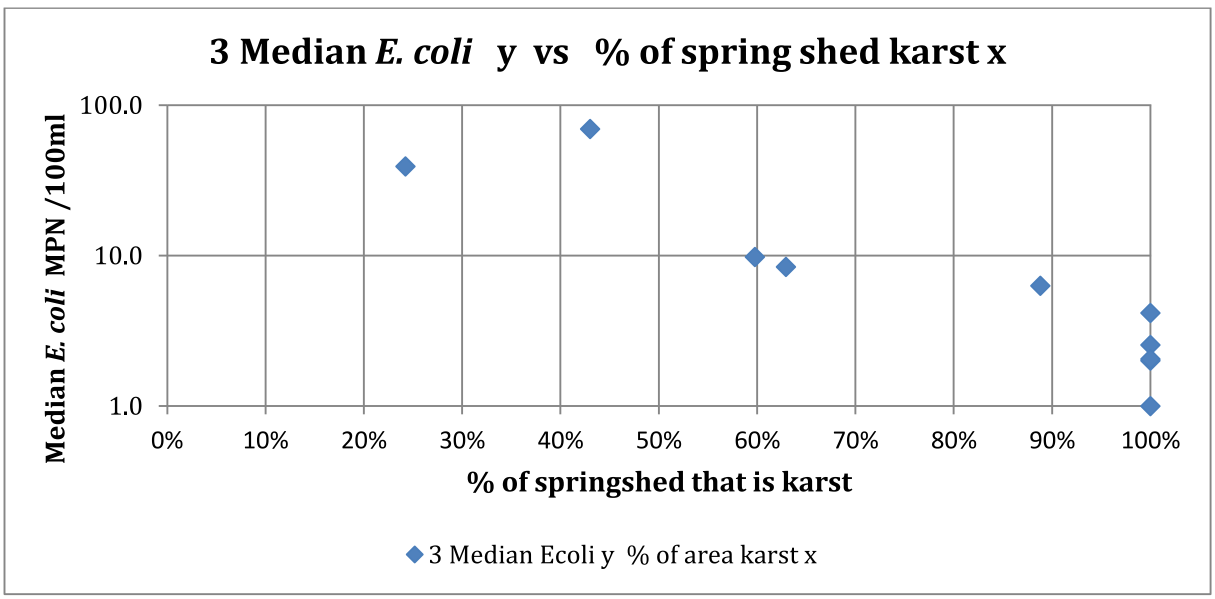


Figure 11. Median *E. coli* mpn in spring water compared to the % of springshed that is karst

Recent biosolids application have been on pasture land. In this study pasture land, un-grazed meadow and tilled land were measured as fields. In the Shenandoah Valley fields are most often on karst land. The relations between nitrate and land use, and *E. coli* and land use are similar in each of the three land uses. Thus increased nitrate or decreased *E. coli* densities cannot be ascribed solely to the application of biosolids.

Based on this admittedly small and preliminary study there are nitrate concentrations in the ground water of the Shenandoah Valley that range from 2 to 10 mg/L Because the water in the streams in the karst area of the Valley is mostly ground water then the nitrates in the stream are also transported to the streams by ground water.

Acknowledgements

This study was conducted by Friends of the Shenandoah River with cooperation of Clarke County and the willingness of landowners who gave access to the springs. Funds for the study were granted to Alison Teetor by the 2013 Citizen Water Quality Monitoring Grant Program, from the Virginia Department of Environmental Quality, and from the Chesapeake Bay Restoration Fund. Chemical analyses were conducted by Karen Andersen and Molly Smith. Ben Sawyer performed GIS measurements and helped with hydrologic analyses. John Young USGS Leetown, WV loaned a stream flow meter. Richard Marzolf helped write this report.

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APPENDICES

A1 General Information

SPRINGSHED AREAS AND RADII

	1 sq mi	1 r ft	2 sq mi	2 r ft	3 sq mi	3 r ft	
FHS	1.0	3000	1.8	4000	2.8	5000	Federal Hill Spring
CHS	6.3	7500	12.4	10500	17.6	12500	Carter Hall Spring
MHS	0.1	1000	0.2	1350	0.4	1900	Montana Hall Spring
CS	1.0	3000	1.8	4000	2.8	5000	Clifton Farm Spring
LMS	1.8	4000	4.1	6000	6.3	7500	Lockes Mill Spring
SCS	1.8	4000	4.1	6000	6.3	7500	Salem Church Spring
TBS	1.0	3000	1.8	4000	2.8	5000	Toms Brook Spring
YS	10.2	9500	20.5	13500	30.7	16500	Yager Spring
FS	2.8	5000	6.3	7500	9.1	9000	Fadeley Spring
MS	2.8	5000	6.3	7500	9.1	9000	McKay Spring

USGS NUMBER	FOSR SITE NUMBER	these data are from the USGS
46WS 1	CARTER HALL SPRING CHS	USGS 390405078014201 46WS 1 Latitude 39°04'06.02", Longitude 78°01'41.18" NAD83 Land-surface elevation 511.72 feet above NAVD88 Clarke County, Virginia Site Type: Spring Spring discharges from Conococheague Group (371CCCG) local aquifer
47XS 6	CLIFTON FARM SPRING CF	USGS 391136077560701 47XS 6 Latitude 39°11'34.62", Longitude 77°56'06.12" NAD83 Land surface altitude: 530.93 feet above NAVD88. Clarke County, Virginia , Hydrologic Unit 02070007
46WS 7	FEDERAL HILL SPRING FHS	USGS 390147078055401 46WS 7 Latitude 39°01'38.60", Longitude 78°05'57.73" NAD83 Land surface altitude: 580.00 feet above NGVD29. Clarke County, Virginia , Hydrologic Unit 02070007 Spring discharges from "Conococheague Group" (371CCCG) local aquifer

USGS NUMBER	FOSR SITE NUMBER	these data are from the USGS
	FADELEY SPRING FS	Latitude 38°50' 48.9", Longitude 78°36' 14.3" NAD27 Land surface altitude: 780 feet above NAVD88. Shenandoah County, Virginia
47WS 2	LOCKES MILL SPRING LMS	USGS 390618077583301 47WS 2 Latitude 39°06'19.17",Longitude 77°58'32.82" NAD83 Land-surface elevation 440.93 feet above NAVD88 Clarke County, Virginia Site Type: Spring
46WS 10	MONTANA HALL MHS	USGS 390211078042501 46WS 10 Latitude 39°02'09.21", Longitude 78°04'14.34" NAD83 Land surface altitude: 578.09 feet above NAVD88. Clarke County, Virginia , Hydrologic Unit 02070007 Spring discharges from "Conococheague Group" (371CCCG) local aquifer
45VS 2	MCKAY SPRING MS	USGS 385843078110701 45VS 2 Latitude 38°58'42.59", Longitude 78°11'07.06" NAD83 Land-surface altitude 500 ft. above NGVD29 Warren County, Virginia Hydrologic Unit Code 02070007
46XS 9	SALEM CHURCH SPRING SCS	USGS 390751078050301 46XS 9 Latitude 39°07'51.42", Longitude 78°05'02.74" NAD83 Land surface altitude: 590.90 feet above NAVD88. Clarke County, Virginia , Hydrologic Unit 02070004
	TOMS BROOK SPRING TBS	Latitude 38°56' 33", Longitude 78°26'13" NAD27 Land surface altitude: 650 feet above NAVD88. Shenandoah County, Virginia
	YAGER SPRING YS	USGS 01629990 YAGERS SPRING NEAR LURAY, VA Latitude 38°40'55", Longitude 78°27'33" NAD27 Page County, Virginia , Hydrologic Unit 02070005

Note: All nitrogen species are reported as N
All phosphorus reported as P

A2 Laboratory and field analyses A2.1 Results by sampling date

Station	Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia (NH_3)$^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
FHS	2/25/2013	1500	29.19	544	0.8	7.06	7.27	12.6	13	6.57	0.01	0.01	0.01	1.0	<0.5	0.13	6.3	0.010	NA	NR	NR	68	29.0
CHS	2/25/2013	1545	29.33	618	4.5	7.30	7.18	12.7	11	3.55	0.01	0.01	0.01	2.0	<0.5	0.10	3.4	0.005	NA	NR	NR	70	86.7
MHS	2/25/2013	1430	29.18	618	0.1	6.87	7.27	11.9	8	10.31	0.01	0.01	0.01	<1	<0.5	0.07	7.9	0.009	NA	NR	NR	65	5.0
CS	2/26/2013	0800	29.22	600	0.5	6.56	7.06	12.4	-4	5.77	0.01	0.01	0.01	<1	<0.5	0.11	3.6	0.008	NA	NR	NR	63	14.6
LMS	2/26/2013	0915	29.34	650	1.8	5.77	7.05	12.2	8	3.05	0.01	0.01	0.01	<1	<0.5	0.12	2.4	0.008	NA	NR	NR	55	29.0
SCS	2/26/2013	0850	29.17	602	1.3	4.95	7.00	12.6	8	1.89	0.01	0.01	0.01	1.0	<0.5	0.11	2.1	0.005	NA	NR	NR	48	13.2
TBS	2/25/2013	1039	29.17	733	0.8	6.00	7.17	12.9	2	3.46	0.01	0.01	0.01	6.3	<0.5	0.07	2.4	<0.005	NA	NR	NR	57	15.1
YS	2/25/2013	1254	29.02	246	8.2	10.56	7.99	12.2	10	1.99	0.01	0.01	0.01	4.1	<0.5	0.09	1.8	0.008	NA	NR	NR	100	87.2
FS	2/25/2013	1114	29.32	542	2.2	6.82	7.33	13.1	7	3.02	0.01	0.01	0.01	5.2	<0.5	0.07	2.8	0.005	NA	NR	NR	66	36.3
MS	2/25/2013	0933	29.37	736	2.7	4.44	7.21	13.3	5	2.89	0.01	0.02	0.01	5.2	<0.5	0.05	2.4	0.010	NA	NR	NR	43	42.2

Station	Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia (NH_3)$^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
FHS	4/22/2013	1033	29.62	NR	0.9	6.41	NR	12.9	9	6.74	NR	0.01	0.01	<1	<0.5	0.14	7.2	0.005	NA	NR	NR	61	32.0
CHS	4/22/2013	0925	29.77	NR	6.0	7.41	NR	12.9	9	3.55	NR	0.01	0.01	<1	<0.5	<0.05	4.3	0.006	NA	NR	NR	71	114.8
MHS	4/22/2013	1005	29.62	NR	0.0	6.17	NR	12.0	13	10.96	NR	0.01	0.01	<1	<0.5	0.09	11.0	0.007	NA	NR	NR	58	1.8
CS	4/22/2013	0730	29.67	NR	0.2	7.94	NR	12.5	3	5.11	NR	0.01	0.01	<1	<0.5	0.12	5.8	>0.005	NA	NR	NR	75	5.8
LMS	4/22/2013	0845	29.82	NR	2.2	6.80	NR	12.3	11	2.98	NR	0.01	0.01	<1	<0.5	0.10	3.3	0.006	NA	NR	NR	64	35.2
SCS	4/22/2013	0810	29.62	NR	1.5	5.05	NR	12.6	9	1.99	NR	0.01	0.01	1	<0.5	0.12	2.5	0.006	NA	NR	NR	48	16.5
TBS	4/22/2013	1235	29.47	NR	1.4	5.33	NR	13.1	15	3.08	NR	0.01	0.01	71.1	<0.5	<0.05	3.6	0.006	NA	NR	NR	52	22.9
YS	4/22/2013	1450	29.27	NR	9.4	6.83	NR	11.9	16	1.58	NR	0.01	0.01	4.1	<0.5	0.06	2.3	0.006	NA	NR	NR	65	80.0
FS	4/22/2013	1325	29.66	NR	4.0	6.74	NR	13.4	13	2.99	NR	0.01	0.01	5.2	<0.5	<0.05	3.6	0.007	NA	NR	NR	65	63.8
MS	4/22/2013	1115	29.70	NR	3.4	4.04	NR	13.2	13	2.58	NR	0.01	0.01	14.1	<0.5	0.09	2.9	0.007	NA	NR	NR	39	47.3

Station	Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia (NH_3)$^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
FHS	6/23/2013	1038	29.19	543	1.3	6.42	7.19	12.9	24	6.72	0.01	0.01	0.01	3.10	<0.5	<0.05	6.0	<0.005	G	<0.5	<0.05	62	46.7
CHS	6/24/2013	0937	29.30	628	8.1	7.12	7.00	12.9	25	3.42	0.01	0.01	0.01	8.50	<0.5	<0.05	3.2	0.009	H	<0.5	<0.05	69	149.2
MHS	6/24/2013	1019	29.19	620	0.2	5.67	7.11	12.9	25	10.95	0.01	0.01	0.01	<1	<0.5	<0.05	10.1	0.005	C	<0.5	<0.05	55	11.8
CS	6/24/2013	0811	29.20	601	0.3	7.28	7.12	12.6	23	5.58	0.01	0.01	0.01	2.0	<0.5	<0.05	4.3	0.019	J	<0.5	<0.05	70	10.2
LMS	6/24/2013	0850	29.32	635	2.8	6.84	7.03	12.4	23	2.85	0.01	0.01	0.01	12.2	<0.5	<0.05	2.6	0.006	D	<0.5	<0.05	66	43.2
SCS	6/24/2013	0731	29.13	627	1.5	4.19	7.00	12.9	22	1.81	0.01	0.01	0.01	14.8	0.6	<0.05	1.7	<0.005	A	<0.5	<0.05	41	33.8
TBS	6/24/2013	1245	29.05	739	1.3	4.55	7.08	13.3	28	3.29	0.01	0.01	0.01	46.4	<0.5	<0.05	2.9	<0.005	B	<0.5	<0.05	45	22.5
YS	6/24/2013	1422	28.99	248	8.4	5.95	7.34	12.4	26	1.52	0.01	0.01	0.01	32.7	<0.5	<0.05	1.7	0.017	I	<0.5	0.08	58	69.0
FS	6/24/2013	1321	28.99	546	4.0	6.22	7.18	13.2	25	2.86	0.01	0.01	0.01	12.2	<0.5	<0.05	2.5	0.011	E	0.7	<0.05	61	61.0
MS	6/24/2013	1124	29.30	692	3.5	3.32	7.04	13.5	25	2.25	0.01	0.01	0.01	47.1	<0.5	<0.05	2.0	0.013	F	0.6	<0.05	33	42.0

A2 Laboratory and field analyses   A2.1 Results by sampling date

Station	Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
FHS	7/29/2013	1105	*29.24*	546	0.8	6.48	7.20	12.1	*24*	6.79	0.01	0.01	0.01	33.2	<0.5	<0.05	NR	NR	NA	NR	NR	62	29.3
CHS	7/29/2013	1010	*29.32*	615	6.4	7.06	7.16	12.2	*22*	3.45	0.01	0.01	0.01	2.0	<0.5	<0.05	NR	NR	NA	NR	NR	67	119.0
MHS	7/29/2013	1045	*29.23*	625	0.1	5.82	7.14	12.5	*23*	11.00	0.01	0.01	0.01	0.0	<0.5	<0.05	NR	NR	NA	NR	NR	56	5.9
CS	7/29/2013	0817	*29.24*	603	0.4	7.21	7.04	12.6	*17*	5.18	0.01	0.01	0.01	3.1	<0.5	<0.05	NR	NR	NA	NR	NR	70	11.7
LMS	7/29/2013	0848	*29.32*	640	2.0	6.39	7.06	12.1	*22*	2.75	0.01	0.01	0.01	3.1	<0.5	<0.05	NR	NR	NA	NR	NR	61	29.8
SCS	7/29/2013	0940	*29.18*	635	0.9	3.64	7.02	12.3	*25*	2.06	0.01	0.01	0.01	39.3	<0.5	<0.05	NR	NR	NA	NR	NR	35	10.4
TBS	7/29/2013	1300	*29.11*	739	0.4	4.85	7.09	11.9	*24*	3.59	0.01	0.01	0.01	8.6	<0.5	<0.05	NR	NR	NA	NR	NR	46	7.4
YS	7/29/2013	1530	*29.02*	262	11.3	5.04	7.53	11.3	*27*	1.54	0.01	0.01	0.01	20.1	<0.5	<0.05	NR	NR	NA	NR	NR	48	94.1
FS	7/29/2013	1340	*28.89*	549	3.9	6.10	7.20	12.1	*25*	2.96	0.01	0.01	0.01	8.4	<0.5	<0.05	NR	NR	NA	NR	NR	59	62.2
MS	7/29/2013	1045	*29.31*	690	1.8	2.97	7.10	12.6	*23*	2.46	0.01	0.01	0.01	101.7	<0.5	<0.05	NR	NR	NA	NR	NR	29	23.3

Station	Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
FHS	9/16/2013	1030	*29.23*	546	0.7	6.49	7.24	12.7	*17*	6.90	NR	0.01	0.01	5.2	<0.5	<0.05	NR	NR	NA	NR	NR	63	27.2
CHS	9/16/2013	0936	*29.33*	601	5.1	6.94	7.18	12.8	*15*	3.42	NR	0.01	0.01	1.0	0.5	<0.05	NR	NR	NA	NR	NR	67	93.3
MHS	9/16/2013	1006	*29.27*	622	0.0	6.13	7.18	13.6	*16*	11.18	NR	0.01	0.01	1.0	<0.5	<0.05	NR	NR	NA	NR	NR	60	2.5
CS	9/16/2013	0823	*29.22*	604	0.1	7.17	7.13	12.9	*12*	5.00	NR	0.01	0.01	37.9	<0.5	<0.05	NR	NR	NA	NR	NR	70	3.0
LMS	9/16/2013	0856	*29.36*	642	1.5	6.07	7.10	12.6	*15*	2.80	NR	0.01	0.01	1.0	0.5	<0.05	NR	NR	NA	NR	NR	58	23.2
SCS	9/16/2013	0747	*29.17*	631	0.2	3.85	7.07	13.1	*18*	2.36	NR	0.01	0.01	387.3	0.6	<0.05	NR	NR	NA	NR	NR	38	2.8
TBS	9/16/2013	1214	*29.17*	732	0.8	4.70	7.14	13.5	*19*	3.70	NR	0.01	0.01	8.4	<0.5	<0.05	NR	NR	NA	NR	NR	46	15.1
YS	9/16/2013	1417	*29.07*	312	4.3	5.79	7.65	12.7	*21*	2.02	NR	0.01	0.01	2.0	0.6	<0.05	NR	NR	NA	NR	NR	56	47.2
FS	9/16/2013	1257	*28.97*	548	2.1	6.18	7.31	13.1	*18*	3.01	NR	0.01	0.01	2.0	<0.5	<0.05	NR	NR	NA	NR	NR	61	34.1
MS	9/16/2013	1058	*29.42*	705	1.1	3.15	7.18	13.5	*16*	2.94	NR	0.02	0.01	69.7	<0.5	<0.05	NR	NR	NA	NR	NR	31	16.8

Station	Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
FHS	10/28/2013	1002	*29.36*	548	1.5	7.74	7.28	12.8	*10*	6.89	NR	0.01	0.01	0.0	NR	NR	NR	NR	NA	NR	NR	75	55.0
CHS	10/28/2013	0913	*29.45*	616	4.8	8.39	7.09	12.8	1	3.35	NR	0.01	0.01	2.0	NR	NR	NR	NR	NA	NR	NR	81	86.1
MHS	10/28/2013	0937	*29.31*	635	0.1	7.76	7.17	13.3	5	10.99	NR	0.01	0.01	1.0	NR	NR	NR	NR	NA	NR	NR	76	4.4
CS	10/28/2013	0805	*29.32*	605	0.2	7.93	7.03	12.6	0	4.82	NR	0.01	0.01	0.0	NR	NR	NR	NR	NA	NR	NR	76	4.0
LMS	10/28/2013	0839	*29.45*	648	1.3	7.27	7.03	12.5	2	2.87	NR	0.01	0.01	0.0	NR	NR	NR	NR	NA	NR	NR	70	20.6
SCS	10/28/2013	0728	*29.22*	647	0.5	6.07	6.94	13.2	2	2.48	NR	0.01	0.01	63.7	NR	NR	NR	NR	NA	NR	NR	59	6.4
TBS	10/28/2013	1148	*29.22*	744	0.7	5.71	7.07	13.6	14	3.78	NR	0.01	0.01	9.8	NR	NR	NR	NR	NA	NR	NR	56	13.2
YS	10/28/2013	1308	*29.09*	263	7.2	6.29	7.53	13.0	14	1.73	NR	0.01	0.01	6.3	NR	NR	NR	NR	NA	NR	NR	62	66.9
FS	10/28/2013	1220	*29.00*	547	1.5	5.97	7.38	13.3	13	3.06	NR	0.01	0.01	20.3	NR	NR	NR	NR	NA	NR	NR	59	24.9
MS	10/28/2013	1038	*29.12*	707	1.8	4.96	7.06	13.8	9	2.51	NR	0.02	0.01	579.4	NR	NR	NR	NR	NA	NR	NR	49	24.1

Laboratory and field analyses A2.2 Results by spring

Carter Hall Spring CHS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	1545	29.33	618	4.53	7.30	7.18	12.7	11	3.55	0.01	0.01	0.01	2.0	<0.5	0.10	3.4	0.005	NA	NR	NR	70	86.7
4/22/2013	0925	29.77	NR	6.00	7.41	NR	12.9	9	3.55	NR	0.01	0.01	<1	<0.5	<0.05	4.3	0.006	NA	NR	NR	71	114.8
6/24/2013	0937	29.30	628	8.10	7.12	7.00	12.9	25	3.42	0.01	0.01	0.01	8.5	<0.5	<0.05	3.2	0.009	H	<0.5	<0.05	69	149.2
7/29/2013	1010	29.32	615	6.40	7.06	7.16	12.2	22	3.45	0.01	0.01	0.01	2	<0.5	<0.05	NR	NR	NA	NR	NR	67	119.0
9/16/2013	0936	29.33	601	5.06	6.94	7.18	12.8	15	3.42	NR	0.01	0.01	1	<0.5	<0.05	NR	NR	NA	NR	NR	67	93.3
10/28/2013	0913	29.45	616	4.77	8.39	7.09	12.8	1	3.35	NR	0.01	0.01	2	NR	NR	NR	NR	NA	NR	NR	81	86.1

Clifton Farm Spring CS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/26/2013	0800	29.22	600	0.47	6.56	7.06	12.4	-4	5.77	0.01	0.01	0.01	<1	<0.5	0.11	3.6	0.008	NA	NR	NR	63	14.6
4/22/2013	0730	29.67	NR	0.21	7.94	NR	12.5	3	5.11	NR	0.01	0.01	<1	<0.5	0.12	5.8	>0.005	NA	NR	NR	75	5.8
6/24/2013	0811	29.20	601	0.34	7.28	7.12	12.6	23	5.58	0.01	0.01	0.01	2	<0.5	<0.05	4.3	0.019	J	<0.5	<0.05	70	10.2
7/29/2013	0817	29.24	603	0.42	7.21	7.04	12.6	17	5.18	0.01	0.01	0.01	3.1	<0.5	<0.05	NR	NR	NA	NR	NR	70	11.7
9/16/2013	0823	29.22	604	0.11	7.17	7.13	12.9	12	5.00	NR	0.01	0.01	37.9	<0.5	<0.05	NR	NR	NA	NR	NR	70	3.0
10/28/2013	0805	29.32	605	0.15	7.93	7.03	12.6	0	4.82	NR	0.01	0.01	0	NR	NR	NR	NR	NA	NR	NR	76	4.0

Federal Hill Spring FHS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	1500	29.19	544	0.82	7.06	7.27	12.6	13	6.57	0.01	0.01	0.01	1.0	<0.5	0.13	6.3	0.010	NA	NR	NR	68	29.0
4/22/2013	1033	29.62	NR	0.88	6.41	NR	12.9	9	6.74	NR	0.01	0.01	<1	<0.5	0.14	7.2	0.005	NA	NR	NR	61	32.0
6/23/2013	1038	29.19	543	1.29	6.42	7.19	12.9	24	6.72	0.01	0.01	0.01	3.1	<0.5	<0.05	6.0	<0.005	G	<0.5	<0.05	62	46.7
7/29/2013	1105	29.24	546	0.80	6.48	7.20	12.1	24	6.79	0.01	0.01	0.01	33.2	<0.5	<0.05	NR	NR	NA	NR	NR	62	29.3
9/16/2013	1030	29.23	546	0.73	6.49	7.24	12.7	17	6.90	NR	0.01	0.01	5.2	<0.5	<0.05	NR	NR	NA	NR	NR	63	27.2
10/28/2013	1002	29.36	548	1.48	7.74	7.28	12.8	10	6.89	NR	0.01	0.01	0	NR	NR	NR	NR	NA	NR	NR	75	55.0

Laboratory and field analyses   A2.2 Results by spring cont.

Fadeley Spring FS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	1114	29.32	542	2.23	6.82	7.33	13.1	7	3.02	0.01	0.01	0.01	5.2	<0.5	0.07	2.8	0.005	NA	NR	NR	66	36.3
4/22/2013	1325	29.66	NR	3.96	6.74	NR	13.4	13	2.99	NR	0.01	0.01	5.2	<0.5	<0.05	3.6	0.007	NA	NR	NR	65	63.8
6/24/2013	1321	28.99	546	3.96	6.22	7.18	13.2	25	2.86	0.01	0.01	0.01	12.2	<0.5	<0.05	2.5	0.011	E	0.7	<0.05	61	61.0
7/29/2013	1340	28.89	549	3.90	6.10	7.20	12.1	25	2.96	0.01	0.01	0.01	8.4	<0.5	<0.05	NR	NR	NA	NR	NR	59	62.2
9/16/2013	1257	28.97	548	2.10	6.18	7.31	13.1	18	3.01	NR	0.01	0.01	2	<0.5	<0.05	NR	NR	NA	NR	NR	61	34.1
10/28/2013	1220	29.00	547	1.51	5.97	7.38	13.3	13	3.06	NR	0.01	0.01	20.3	NR	NR	NR	NR	NA	NR	NR	59	24.9

Lockes Mill Spring LMS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/26/2013	0915	29.34	650	1.76	5.77	7.05	12.2	8	3.05	0.01	0.01	0.01	<1	<0.5	0.12	2.4	0.008	NA	NR	NR	55	29.0
4/22/2013	0845	29.82	NR	2.19	6.80	NR	12.3	11	2.98	NR	0.01	0.01	<1	<0.5	0.10	3.3	0.006	NA	NR	NR	64	35.2
6/24/2013	0850	29.32	635	2.81	6.84	7.03	12.4	23	2.85	0.01	0.01	0.01	12.2	<0.5	<0.05	2.6	0.006	D	<0.5	<0.05	66	43.2
7/29/2013	0848	29.32	640	2.01	6.39	7.06	12.1	22	2.75	0.01	0.01	0.01	3.1	<0.5	<0.05	NR	NR	NA	NR	NR	61	29.8
9/16/2013	0856	29.36	642	1.54	6.07	7.10	12.6	15	2.80	NR	0.01	0.01	1	0.5	<0.05	NR	NR	NA	NR	NR	58	23.2
10/28/2013	0839	29.45	648	1.33	7.27	7.03	12.5	2	2.87	NR	0.01	0.01	0	NR	NR	NR	NR	NA	NR	NR	70	20.6

Montana Hall Spring MHS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	1430	29.18	618	0.09	6.87	7.27	11.9	8	10.31	0.01	0.01	0.01	<1	<0.5	0.07	7.9	0.009	NA	NR	NR	65	5.0
4/22/2013	1005	29.62	NR	0.03	6.17	NR	12.0	13	10.96	NR	0.01	0.01	<1	<0.5	0.09	11.0	0.007	NA	NR	NR	58	1.8
6/24/2013	1019	29.19	620	0.20	5.67	7.11	12.9	25	10.95	0.01	0.01	0.01	<1	<0.5	<0.05	10.1	0.005	C	<0.5	<0.05	55	11.8
7/29/2013	1045	29.23	625	0.10	5.82	7.14	12.5	23	11.00	0.01	0.01	0.01	0	<0.5	<0.05	NR	NR	NA	NR	NR	56	5.9
9/16/2013	1006	29.27	622	0.04	6.13	7.18	13.6	16	11.18	NR	0.01	0.01	1	<0.5	<0.05	NR	NR	NA	NR	NR	60	2.5
10/28/2013	0937	29.31	635	0.08	7.76	7.17	13.3	5	10.99	NR	0.01	0.01	1	NR	NR	NR	NR	NA	NR	NR	76	4.4

Laboratory and field analyses A2.2 Results by spring cont.

McKay Spring MS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	0933	29.37	736	2.71	4.44	7.21	13.3	5	2.89	0.01	0.02	0.01	5.2	<0.5	0.05	2.4	0.010	NA	NR	NR	43	42.2
4/22/2013	1115	29.70	NR	3.40	4.04	NR	13.2	13	2.58	NR	0.01	0.01	14.1	<0.5	0.09	2.9	0.007	NA	NR	NR	39	47.3
6/24/2013	1124	29.30	692	3.47	3.32	7.04	13.5	25	2.25	0.01	0.01	0.01	47.1	<0.5	<0.05	2.0	0.013	F	0.6	<0.05	33	42.0
7/29/2013	1045	29.31	690	1.75	2.97	7.10	12.6	23	2.46	0.01	0.01	0.01	101.7	<0.5	<0.05	NR	NR	NA	NR	NR	29	23.3
9/16/2013	1058	29.42	705	1.06	3.15	7.18	13.5	16	2.94	NR	0.02	0.01	69.7	<0.5	<0.05	NR	NR	NA	NR	NR	31	16.8
10/28/2013	1038	29.12	707	1.78	4.96	7.06	13.8	9	2.51	NR	0.02	0.01	579.4	NR	NR	NR	NR	NA	NR	NR	49	24.1

Salem Church Spring SCS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/26/2013	0850	29.17	602	1.29	4.95	7.00	12.6	8	1.89	0.01	0.01	0.01	1.0	<0.5	0.11	2.1	0.005	NA	NR	NR	48	13.2
4/22/2013	0810	29.62	NR	1.54	5.05	NR	12.6	9	1.99	NR	0.01	0.01	1	<0.5	0.12	2.5	0.006	NA	NR	NR	48	16.5
6/24/2013	0731	29.13	627	1.47	4.19	7.00	12.9	22	1.81	0.01	0.01	0.01	14.8	0.6	<0.05	1.7	<0.005	A	<0.5	<0.05	41	33.8
7/29/2013	0940	29.18	635	0.94	3.64	7.02	12.3	25	2.06	0.01	0.01	0.01	39.3	<0.5	<0.05	NR	NR	NA	NR	NR	35	10.4
9/16/2013	0747	29.17	631	0.22	3.85	7.07	13.1	18	2.36	NR	0.01	0.01	387.3	0.6	<0.05	NR	NR	NA	NR	NR	38	2.8
10/28/2013	0728	29.22	647	0.48	6.07	6.94	13.2	2	2.48	NR	0.01	0.01	63.7	NR	NR	NR	NR	NA	NR	NR	59	6.4

Toms Brook Spring TBS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia $(NH_3)^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	1039	29.17	733	0.81	6.00	7.17	12.9	2	3.46	0.01	0.01	0.01	6.3	<0.5	0.07	2.4	<0.005	NA	NR	NR	57	15.1
4/22/2013	1235	29.47	NR	1.38	5.33	NR	13.1	15	3.08	NR	0.01	0.01	71.1	<0.5	<0.05	3.6	0.006	NA	NR	NR	52	22.9
6/24/2013	1245	29.05	739	1.27	4.55	7.08	13.3	28	3.29	0.01	0.01	0.01	46.4	<0.5	<0.05	2.9	<0.005	B	<0.5	<0.05	45	22.5
7/29/2013	1300	29.11	739	0.38	4.85	7.09	11.9	24	3.59	0.01	0.01	0.01	8.6	<0.5	<0.05	NR	NR	NA	NR	NR	46	7.4
9/16/2013	1214	29.17	732	0.76	4.70	7.14	13.5	19	3.70	NR	0.01	0.01	8.4	<0.5	<0.05	NR	NR	NA	NR	NR	46	15.1
10/28/2013	1148	29.22	744	0.65	5.71	7.07	13.6	14	3.78	NR	0.01	0.01	9.8	NR	NR	NR	NR	NA	NR	NR	56	13.2

Laboratory and field analyses — A2.2 Results by spring cont.

Yager Spring YS

Date	Time of Sample Collection	Barometric pressure inches Hg	Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C	Air Temperature °C	Nitrate (NO_3) as N mg/L	Nitrite (NO_2) as N mg/L	Ortho Phosphate as P mg/L	Ammonia (NH_3)$^+$ as N mg/L	*E. coli* Enumeration MPN	IES TKN N as N mg/L	IES Total P as P mg/L	IES Nitrate (NO_3) as N mg/L	IES Nitrite (NO_2) as N mg/L	field rep ID	IES Field Rep. TKN N as N mg/L	IES Field Rep. Total P as P mg/l	Dissolved Oxygen % saturation	Nitrate Load Lbs./Day
2/25/2013	1254	29.02	246	8.15	10.56	7.99	12.2	10	1.99	0.01	0.01	0.01	4.1	<0.5	0.09	1.8	0.008	NR	NR	NR	100	87.2
4/22/2013	1450	29.27	NR	9.39	6.83	NR	11.9	16	1.58	NR	0.01	0.01	4.1	<0.5	0.06	2.3	0.006	NR	NR	NR	65	80.0
6/24/2013	1422	28.99	248	8.43	5.95	7.34	12.4	26	1.52	0.01	0.01	0.01	32.7	<0.5	<0.05	1.7	0.017	I	<0.5	0.08	58	69.0
7/29/2013	1530	29.02	262	11.30	5.04	7.53	11.3	27	1.54	0.01	0.01	0.01	20.1	<0.5	<0.05	NR	NR	NA	NR	NR	48	94.1
9/16/2013	1417	29.07	312	4.34	5.79	7.65	12.7	21	2.02	NR	0.01	0.01	2	0.6	<0.05	NR	NR	NA	NR	NR	56	47.2
10/28/2013	1308	29.09	263	7.16	6.29	7.53	13.0	14	1.73	NR	0.01	0.01	6.3	NR	NR	NR	NR	NA	NR	NR	62	66.9

A2.31 Nitrate (NO_3) as N mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	6.57	6.74	6.72	6.79	6.90	6.89
Carter Hall Spring	3.55	3.55	3.42	3.45	3.42	3.35
Montana Hall Spring	10.31	10.96	10.95	11.00	11.18	10.99
Clifton Farm Spring	5.77	5.11	5.58	5.18	5.00	4.82
Lockes Mill Spring	3.05	2.98	2.85	2.75	2.80	2.87
Salem Church Spring	1.89	1.99	1.81	2.06	2.36	2.48
Toms Brook Spring	3.46	3.08	3.29	3.59	3.70	3.78
Yager Spring	1.99	1.58	1.52	1.54	2.02	1.73
Fadeley Spring	3.02	2.99	2.86	2.96	3.01	3.06
McKay Spring	2.89	2.58	2.25	2.46	2.94	2.51

A2.32 Total Kjeldahl Nitrogen as N mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	<0.5	<0.5	<0.5	<0.5	-	-
Carter Hall Spring	<0.5	<0.5	<0.5	<0.5	-	-
Montana Hall Spring	<0.5	<0.5	<0.5	<0.5	-	-
Clifton Farm Spring	<0.5	<0.5	<0.5	<0.5	-	-
Lockes Mill Spring	<0.5	<0.5	<0.5	<0.5	-	-
Salem Church Spring	<0.5	<0.5	0.60	<0.5	-	-
Toms Brook Spring	<0.5	<0.5	<0.5	<0.5	-	-
Yager Spring	<0.5	<0.5	<0.5	<0.5	-	-
Fadeley Spring	<0.5	<0.5	<0.5	<0.5	-	-
McKay Spring	<0.5	<0.5	<0.5	<0.5	-	-

A2.33 Ammonia $(NH_3)^+$ as N mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	0.01	0.01	0.01	0.01	0.01	0.01
Carter Hall Spring	0.01	0.01	0.01	0.01	0.01	0.01
Montana Hall Spring	0.01	0.01	0.01	0.01	0.01	0.01
Clifton Farm Spring	0.01	0.01	0.01	0.01	0.01	0.01
Lockes Mill Spring	0.01	0.01	0.01	0.01	0.01	0.01
Salem Church Spring	0.01	0.01	0.01	0.01	0.01	0.01
Toms Brook Spring	0.01	0.01	0.01	0.01	0.01	0.01
Yager Spring	0.01	0.01	0.01	0.01	0.01	0.01
Fadeley Spring	0.01	0.01	0.01	0.01	0.01	0.01
McKay Spring	0.01	0.01	0.01	0.01	0.01	0.01

A2.34 Nitrite (NO2) as N mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	0.01	-	0.01	0.01	-	-
Carter Hall Spring	0.01	-	0.01	0.01	-	-
Montana Hall Spring	0.01	-	0.01	0.01	-	-
Clifton Farm Spring	0.01	-	0.01	0.01	-	-
Lockes Mill Spring	0.01	-	0.01	0.01	-	-
Salem Church Spring	0.01	-	0.01	0.01	-	-
Toms Brook Spring	0.01	-	0.01	0.01	-	-
Yager Spring	0.01	-	0.01	0.01	-	-
Fadeley Spring	0.01	-	0.01	0.01	-	-
McKay Spring	0.01	-	0.01	0.01	-	-

A2.35 Ortho Phosphorus as P mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	0.01	0.01	0.01	0.01	0.01	0.01
Carter Hall Spring	0.01	0.01	0.01	0.01	0.01	0.01
Montana Hall Spring	0.01	0.01	0.01	0.01	0.01	0.01
Clifton Farm Spring	0.01	0.01	0.01	0.01	0.01	0.01
Lockes Mill Spring	0.01	0.01	0.01	0.01	0.01	0.01
Salem Church Spring	0.01	0.01	0.01	0.01	0.01	0.01
Toms Brook Spring	0.01	0.01	0.01	0.01	0.01	0.01
Yager Spring	0.01	0.01	0.01	0.01	0.01	0.01
Fadeley Spring	0.01	0.01	0.01	0.01	0.01	0.01
McKay Spring	0.02	0.01	0.01	0.01	0.02	0.02

A2.36 Total Phosphorus as P mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	0.13	0.14	<0.05	<0.05	-	-
Carter Hall Spring	0.10	<0.05	<0.05	<0.05	-	-
Montana Hall Spring	0.07	0.09	<0.05	<0.05	-	-
Clifton Farm Spring	0.11	0.12	<0.05	<0.05	-	-
Lockes Mill Spring	0.12	0.10	<0.05	<0.05	-	-
Salem Church Spring	0.11	0.12	<0.05	<0.05	-	-
Toms Brook Spring	0.07	<0.05	<0.05	<0.05	-	-
Yager Spring	0.09	0.06	<0.05	<0.05	-	-
Fadeley Spring	0.07	<0.05	<0.05	<0.05	-	-
McKay Spring	0.05	0.09	<0.05	<0.05	-	-

A2.37 Dissolved Oxygen mg/L

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	7.06	6.41	6.42	6.48	6.49	7.74
Carter Hall Spring	7.30	7.41	7.12	7.06	6.94	8.39
Montana Hall Spring	6.87	6.17	5.67	5.82	6.13	7.76
Clifton Farm Spring	6.56	7.94	7.28	7.21	7.17	7.93
Lockes Mill Spring	5.77	6.80	6.84	6.39	6.07	7.27
Salem Church Spring	4.95	5.05	4.19	3.64	3.85	6.07
Toms Brook Spring	6.00	5.33	4.55	4.85	4.70	5.71
Yager Spring	10.56	6.83	5.95	5.04	5.79	6.29
Fadeley Spring	6.82	6.74	6.22	6.10	6.18	5.97
McKay Spring	4.44	4.04	3.32	2.97	3.15	4.96

A2.38 Dissolved Oxygen % saturation

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	68.20	61.40	62.40	61.83	62.80	74.70
Carter Hall Spring	70.40	70.70	69.00	67.30	67.05	80.75
Montana Hall Spring	65.40	58.00	55.20	56.10	60.40	75.90
Clifton Farm Spring	63.10	75.30	70.30	69.60	69.70	76.30
Lockes Mill Spring	55.00	63.90	65.50	60.80	58.30	69.50
Salem Church Spring	47.90	48.10	40.90	35.00	37.70	59.40
Toms Brook Spring	57.30	51.60	44.90	46.30	46.40	56.40
Yager Spring	99.60	64.70	57.60	47.50	56.30	61.50
Fadeley Spring	66.30	65.20	61.30	58.90	60.90	59.00
McKay Spring	43.40	38.90	32.60	28.60	30.80	49.30

A2.39 Specific Conductance µS @ 25 °C

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	544.00	meter	543.00	546.00	546.00	548.00
Carter Hall Spring	618.00	failure	628.00	615.00	601.00	616.00
Montana Hall Spring	618.00		620.00	625.00	622.00	635.00
Clifton Farm Spring	600.00		601.00	603.00	604.00	605.00
Lockes Mill Spring	650.00		635.00	640.00	642.00	648.00
Salem Church Spring	602.00		627.00	635.00	631.00	647.00
Toms Brook Spring	733.00		739.00	739.00	732.00	744.00
Yager Spring	246.00		248.00	262.00	312.00	263.00
Fadeley Spring	542.00		546.00	549.00	548.00	547.00
McKay Spring	736.00		692.00	690.00	705.00	707.00

A2.310 Water Temperature °C

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	12.60	12.90	12.90	12.10	12.70	12.80
Carter Hall Spring	12.70	12.90	12.90	12.20	12.80	12.80
Montana Hall Spring	11.90	12.00	12.90	12.50	13.60	13.30
Clifton Farm Spring	12.40	12.50	12.60	12.60	12.90	12.60
Lockes Mill Spring	12.20	12.30	12.40	12.10	12.60	12.50
Salem Church Spring	12.60	12.60	12.90	12.30	13.10	13.20
Toms Brook Spring	12.90	13.10	13.30	11.90	13.50	13.60
Yager Spring	12.20	11.90	12.40	11.30	12.70	13.00
Fadeley Spring	13.10	13.40	13.20	12.10	13.10	13.30
McKay Spring	13.30	13.20	13.50	12.60	13.50	13.80

A2.311 Discharge cubic feet per second (cfs)

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	0.85	0.91	1.34	0.80	0.73	1.48
Carter Hall Spring	4.70	6.21	8.40	6.63	5.06	4.77
Montana Hall Spring	0.09	0.04	0.20	0.10	0.04	0.08
Clifton Farm Spring	0.49	0.22	0.36	0.44	0.11	0.15
Lockes Mill Spring	1.83	2.28	2.92	2.09	1.54	1.33
Salem Church Spring	1.29	1.54	1.47	0.94	0.22	0.48
Toms Brook Spring	0.85	1.44	1.32	0.40	0.76	0.65
Yager Spring	8.45	9.74	8.74	11.70	4.34	7.16
Fadeley Spring	2.23	3.96	3.96	3.90	2.10	1.51
McKay Spring	2.71	3.40	3.47	1.75	1.06	1.78

A2.312 Nitrate discharge in pounds per day as N

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	29.03	31.98	46.71	29.30	27.18	54.97
Carter Hall Spring	86.74	114.85	149.15	118.95	93.31	86.06
Montana Hall Spring	5.00	1.77	11.81	5.93	2.53	4.44
Clifton Farm Spring	14.63	5.79	10.23	11.73	2.97	4.00
Lockes Mill Spring	28.97	35.19	43.18	29.80	23.22	20.60
Salem Church Spring	13.17	16.52	33.81	10.44	2.79	6.41
Toms Brook Spring	15.10	22.92	22.54	7.35	15.14	13.24
Yager Spring	87.23	80.00	69.00	94.08	47.20	66.94
Fadeley Spring	36.35	63.84	61.05	62.18	34.13	24.95
McKay Spring	42.17	47.30	42.04	23.25	16.79	24.13

A2.313 *E. coli MPN most probable number per 100 mL*

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	1.0	<1	3.10	33.20	5.20	0.00
Carter Hall Spring	2.0	<1	8.50	2.00	1.00	2.00
Montana Hall Spring	<1	<1	<1	0.00	1.00	1.00
Clifton Farm Spring	<1	<1	2.00	3.10	37.90	0.00
Lockes Mill Spring	<1	<1	12.20	3.10	1.00	0.00
Salem Church Spring	1.0	1.00	14.80	39.30	387.30	63.70
Toms Brook Spring	6.3	71.10	46.40	8.60	8.40	9.80
Yager Spring	4.1	4.10	32.70	20.10	2.00	6.30
Fadeley Spring	5.2	5.20	12.20	8.40	2.00	20.30
McKay Spring	5.2	14.10	47.10	101.70	69.70	579.40

A2.314 pH Standard units

	25-Feb	22-Apr	24-Jun	29-Jul	16-Sep	28-Oct
Federal Hill Spring	7.27	meter	7.19	7.20	7.24	7.28
Carter Hall Spring	7.18	failure	7.00	7.16	7.18	7.09
Montana Hall Spring	7.27		7.11	7.14	7.18	7.17
Clifton Farm Spring	7.06		7.12	7.04	7.13	7.03
Lockes Mill Spring	7.05		7.03	7.06	7.10	7.03
Salem Church Spring	7.00		7.00	7.02	7.07	6.94
Toms Brook Spring	7.17		7.08	7.09	7.14	7.07
Yager Spring	7.99		7.34	7.53	7.65	7.53
Fadeley Spring	7.33		7.18	7.20	7.31	7.38
McKay Spring	7.21		7.04	7.10	7.18	7.06

A3 Land use information

Table 3.11 1 sq mi per cfs	Total Acreage in radius	Acres of Fields	Acres of Forest	Acres of Urban	Acres of Open Water	Acres of Wetlands	Acres of Grassland	Acres of Barren Land	Acres of Biosolids Application	Permitted acres	Acres of Karst	% karst	fields %of total	biosolids %of total	biosolids %of total fields
Federal Hill Spring	648	589	31	28	1	0	0	0	240	333	648	100%	90.8	37.1	40.8
Carter Hall Spring	4054	2467	1178	364	22	10	18	0	124	365	4054	100%	60.8	3.0	5.0
Montana Hall Spring	64	59	2	2	0	0	0	0	5	43	64	100%	92.9	8.0	8.6
Clifton Farm Spring	648	513	50	54	4	26	0	0	0	75	648	100%	79.1	0.0	0.0
Lockes Mill Spring	1153	597	437	58	60	1	0	0	0	24	1153	100%	51.8	0.0	0.0
Salem Church Spring	1153	762	347	39	3	2	0	0	80	86	129	11%	66.1	6.9	10.5
Toms Brook Spring	648	156	299	192	2	0	0	0	0	0	438	68%	24.1	0.0	0.0
Yager Spring	6505	3340	1076	2091	1	0	0	0	0	0	6506	100%	51.3	0.0	0.0
Fadeley Spring	1801	1066	543	194	0	0	0	0	0	0	938	52%	59.2	0.0	0.0
McKay Spring	1801	679	647	435	0	3	4	34	0	0	666	37%	37.7	0.0	0.0

Table 3.12 2 sq mi per cfs	Total Acreage in radius	Acres of Fields	Acres of Forest	Acres of Urban	Acres of Open Water	Acres of Wetlands	Acres of Grassland	Acres of Barren Land	Acres of Biosolids Application	Permitted acres	Acres of Karst	% karst	fields %of total	biosolids %of total	biosolids %of total fields
Federal Hill Spring	1153	1047	57	49	1	0	0	0	478	599	1153	100%	90.9	41.5	45.6
Carter Hall Spring	7948	5092	2127	618	78	18	22	0	630	1031	7948	100%	64.1	7.9	12.4
Montana Hall Spring	128	121	3	3	0	0	0	0	26	101	128	100%	94.4	20.5	21.7
Clifton Farm Spring	1153	911	122	81	5	37	0	0	4	164	1153	100%	79.0	0.4	0.5
Lockes Mill Spring	2594	1510	871	118	95	5	0	0	119	212	2594	100%	58.2	4.6	7.9
Salem Church Spring	2594	1649	834	88	9	18	0	0	180	240	523	20%	63.5	6.9	10.9
Toms Brook Spring	1153	388	455	308	2	0	0	0	0	0	723	63%	33.7	0.0	0.0
Yager Spring	13138	7374	2365	3212	191	0	0	0	0	0	12672	96%	56.1	0.0	0.0
Fadeley Spring	4054	2574	1102	370	6	0	0	3	0	0	2284	56%	63.5	0.0	0.0
McKay Spring	4054	1470	1579	885	24	4	80	15	0	0	1680	41%	36.3	0.0	0.0

Table 3.13 3 sq mi per cfs	Total Acreage in radius	Acres of Fields	Acres of Forest	Acres of Urban	Acres of Open Water	Acres of Wetlands	Acres of Grassland	Acres of Barren Land	Acres of Biosolids Application	Permitted acres	Acres of Karst	% karst	fields %of total	biosolids %of total	biosolids %of total fields	ave NO3	median E_coli
Federal Hill Spring	1801	1502	209	76	7	6	0	0	586	812	1801	100%	83.4	32.5	39.0	6.7	4.2
Carter Hall Spring	11265	7187	3004	897	131	21	31	0	957	1615	11265	100%	63.8	8.5	13.3	3.5	2.0
Montana Hall Spring	256	240	12	5	0	0	0	0	73	207	256	100%	93.7	28.4	30.4	10.7	1.0
Clifton Farm Spring	1801	1350	236	166	5	43	0	0	70	301	1801	100%	75.0	3.9	5.2	5.5	2.6
Lockes Mill Spring	4054	2487	1247	173	140	10	0	0	353	468	4054	100%	61.3	8.7	14.2	3.0	2.1
Salem Church Spring	4054	2447	1398	179	10	23	0	2	334	394	982	24%	60.4	8.2	13.6	1.9	39.3
Toms Brook Spring	1801	784	650	366	2	0	0	0	0	0	1077	60%	43.5	0.0	0.0	3.3	9.8
Yager Spring	19628	11290	3949	4051	346	0	0	0	0	0	17430	89%	57.5	0.0	0.0	1.7	6.3
Fadeley Spring	5838	3697	1619	518	6	0	0	3	0	0	3675	63%	63.3	0.0	0.0	3.0	8.4
McKay Spring	5839	1978	2504	1164	76	5	80	37	0	0	2511	43%	33.9	0.0	0.0	2.6	69.7

A3 Land use information

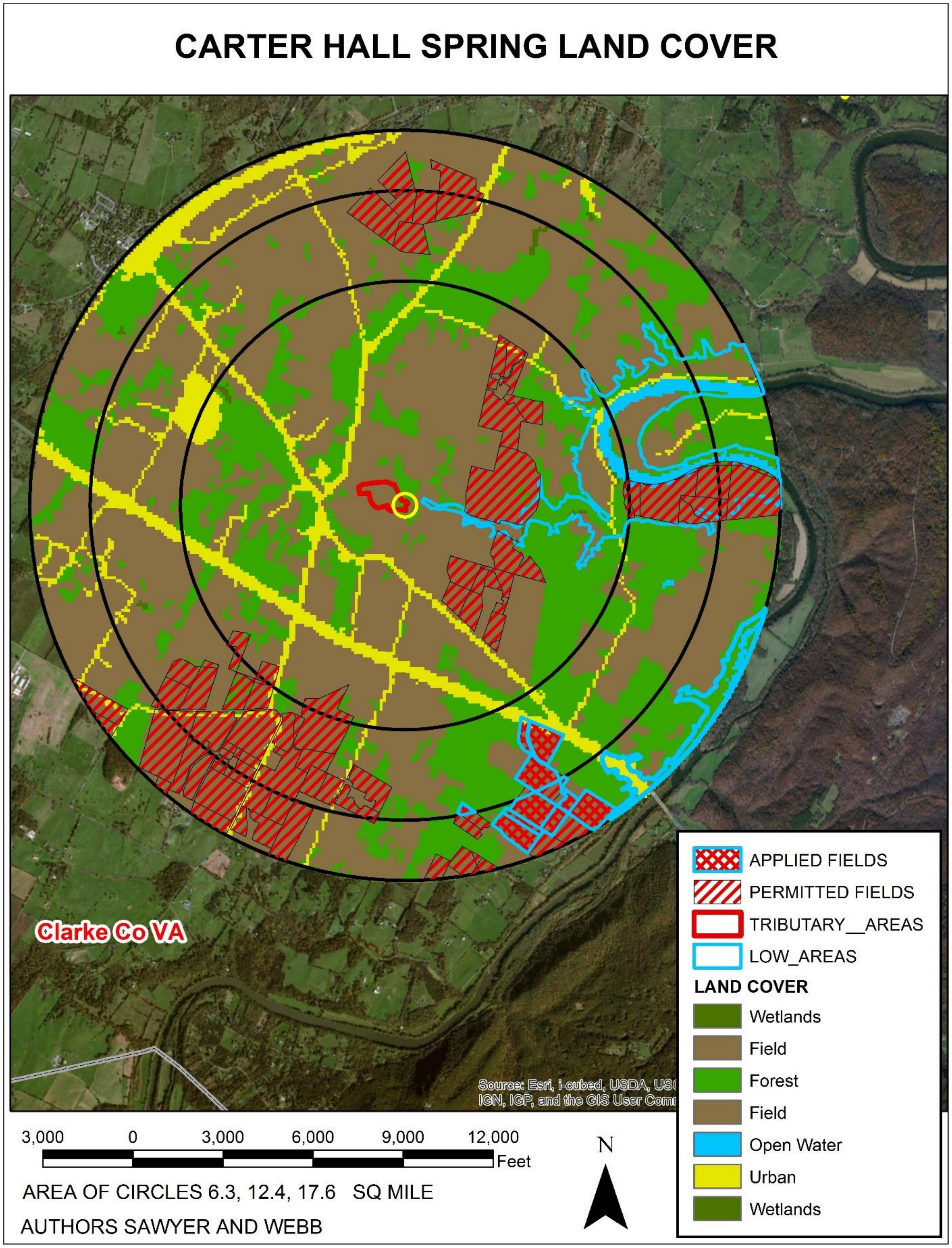
A3.2 Wet tons of biosolids applied by date and 3 sq mi / cfs springshed

	PRE 10		2010		2011		2012		2013		2010 TO 2013		TOTAL
	TONS	AC	tons	ac	tons	ac	tons	ac	tons	ac	tons	ac	TONS
Federal Hill Spring	5818	289	1654	170	3023	2141	812	84	0		5489	2395	4038
Carter Hall Spring	28082	1520	1928	122	213	29	73	7	0		2213	158	1721
Montana Hall Spring	5809	307	0		0		0		0		0	0	14523
Clifton Farm Spring	3044	220	0		0		0		0		0	0	1087
Lockes Mill Spring	1992	148	1823	125	1537	183	1404	178	0		4764	486	1072
Salem Church Spring	9191	618	3008	230	0		0		0		3008	230	1936
Toms Brook Spring	0										0		0
Yager Spring	0										0		0
Fadeley Spring	0										0		0
McKay Spring	0										0		0

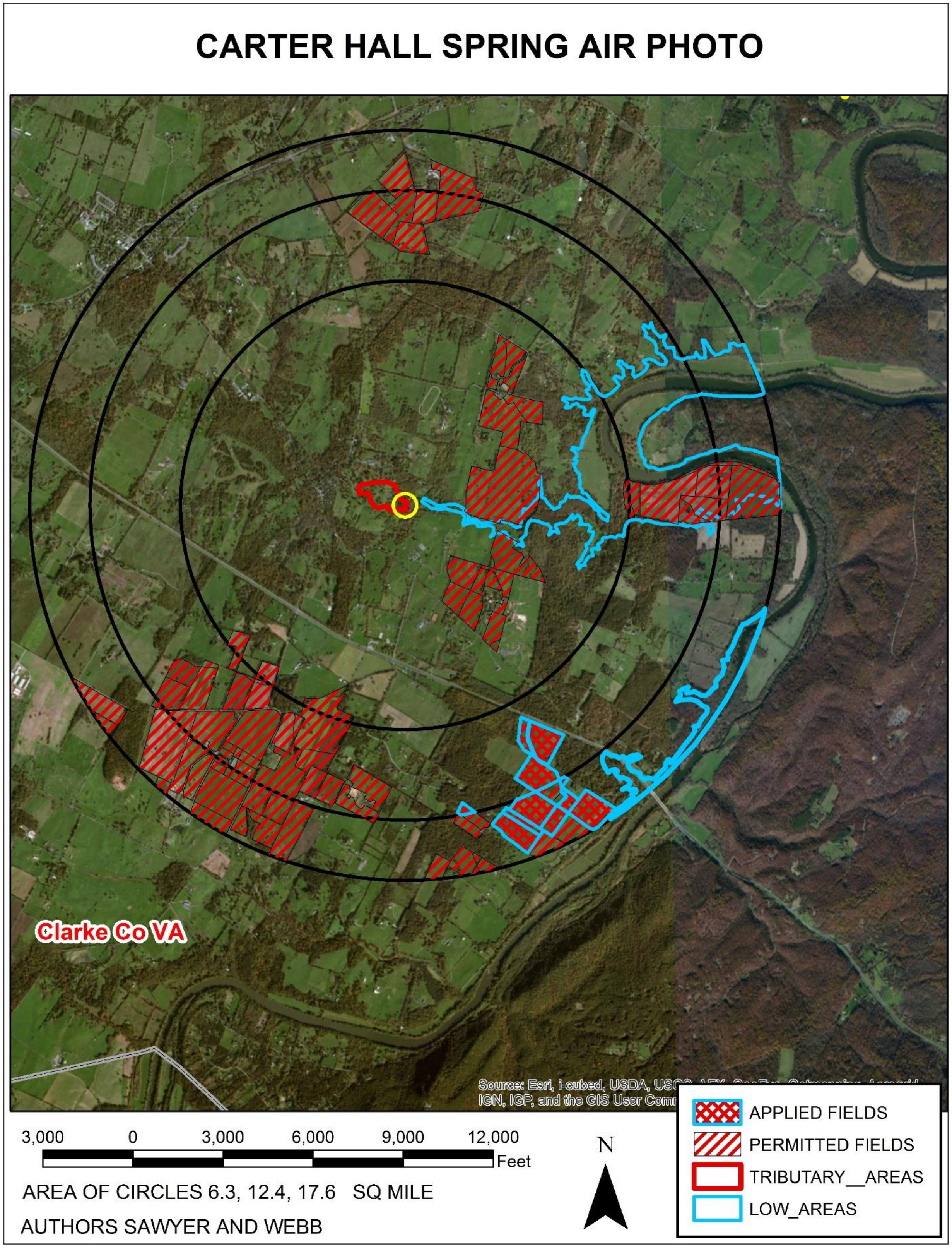
A3.3 BIOSOLIDS APPLICATION ,NO3 CONCENTRATION FLOW AND *E_coli* MPN

	spring shed area sq mi	BIOSOLIDS APPLIED tons /sq mi pre 2010	post 2010	total	AVERAGE NITRATE mg/L	ave FLOW CFS	median E_coli
Federal Hill Spring	2.8	2078	1960	4038	6.8	1.0	4.2
Carter Hall Spring	17.6	1596	126	1721	3.5	5.8	2.0
Montana Hall Spring	0.4	14523	0	14523	10.9	0.1	1.0
Clifton Farm Spring	2.8	1087	0	1087	5.2	0.3	2.6
Lockes Mill Spring	6.3	316	756	1072	2.9	1.9	2.1
Salem Church Spring	6.3	1459	477	1936	2.1	1.0	39.3
Toms Brook Spring	2.8	0	0	0	3.5	0.9	9.8
Yager Spring	30.7	0	0	0	1.7	8.1	6.3
Fadeley Spring	9.1	0	0	0	3.0	2.9	8.4
McKay Spring	9.1	0	0	0	2.6	2.4	69.7

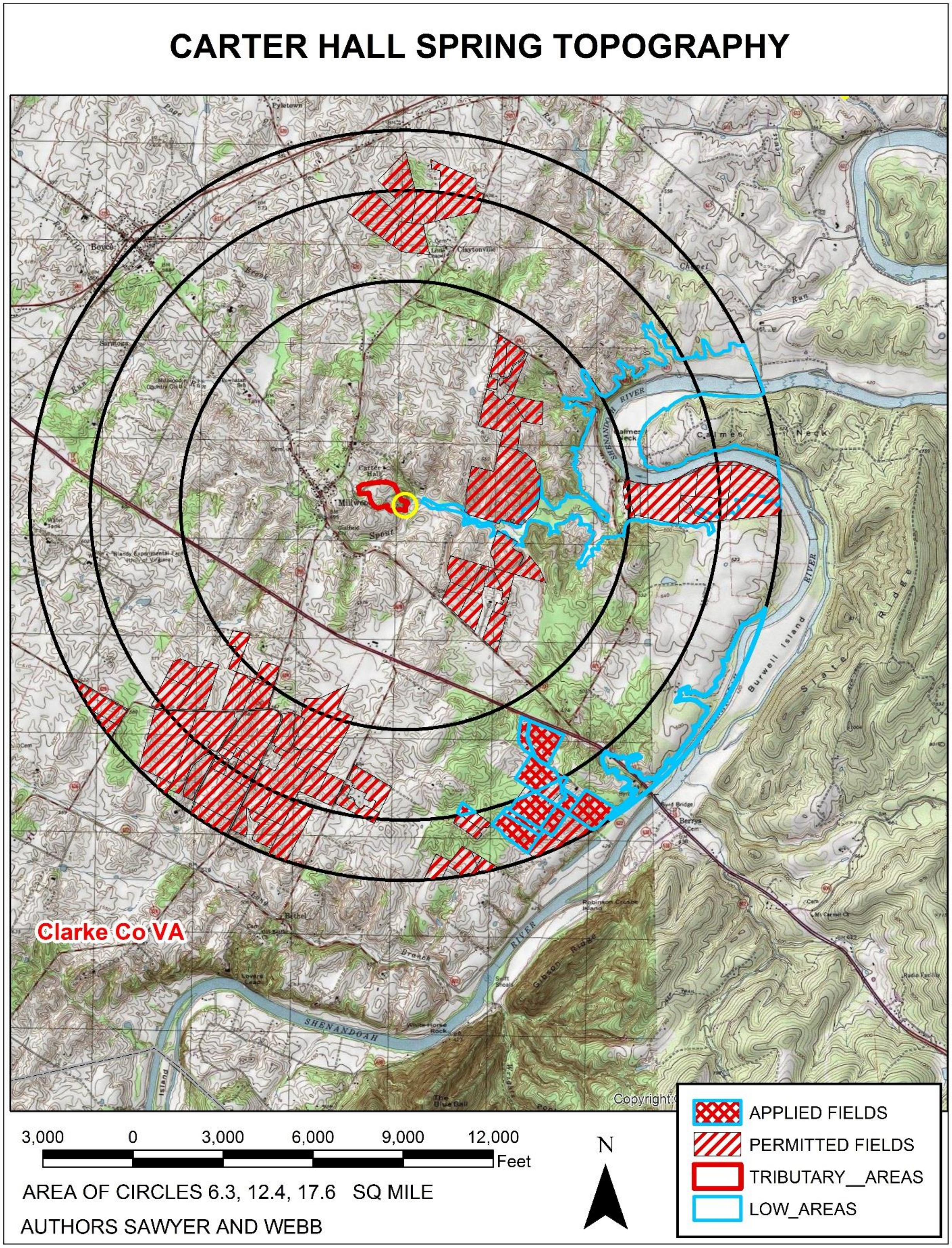
A3.41 Carter Hall Spring Land Cover



A3.42 Carter Hall Spring Air Photo

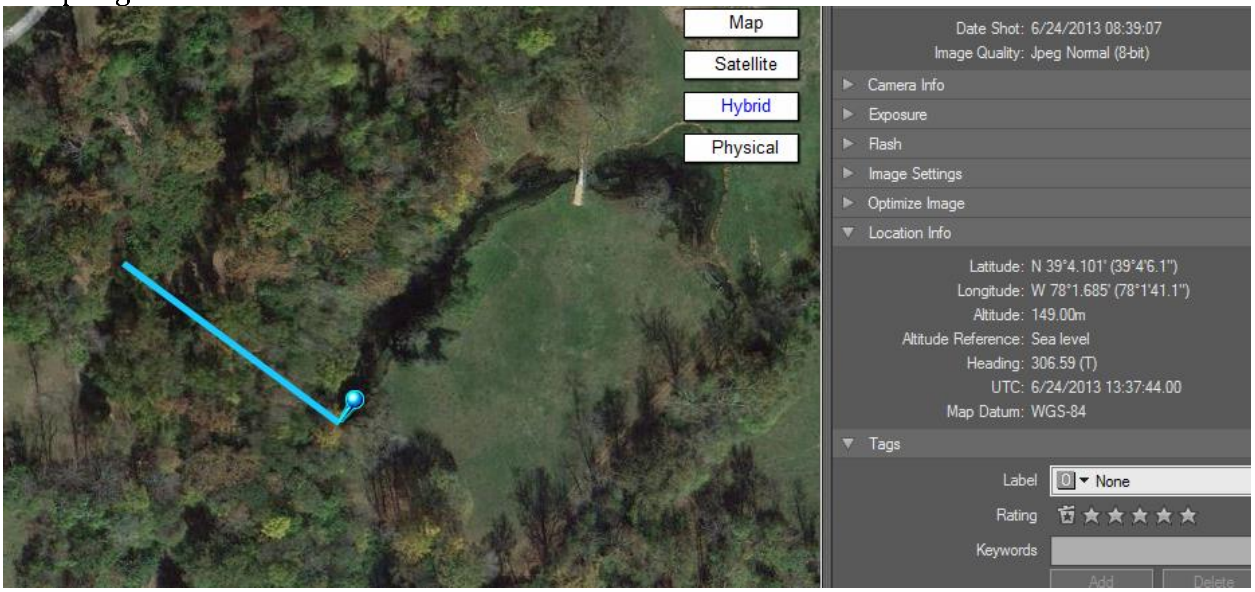


A3.43 Carter Hall Spring Topography

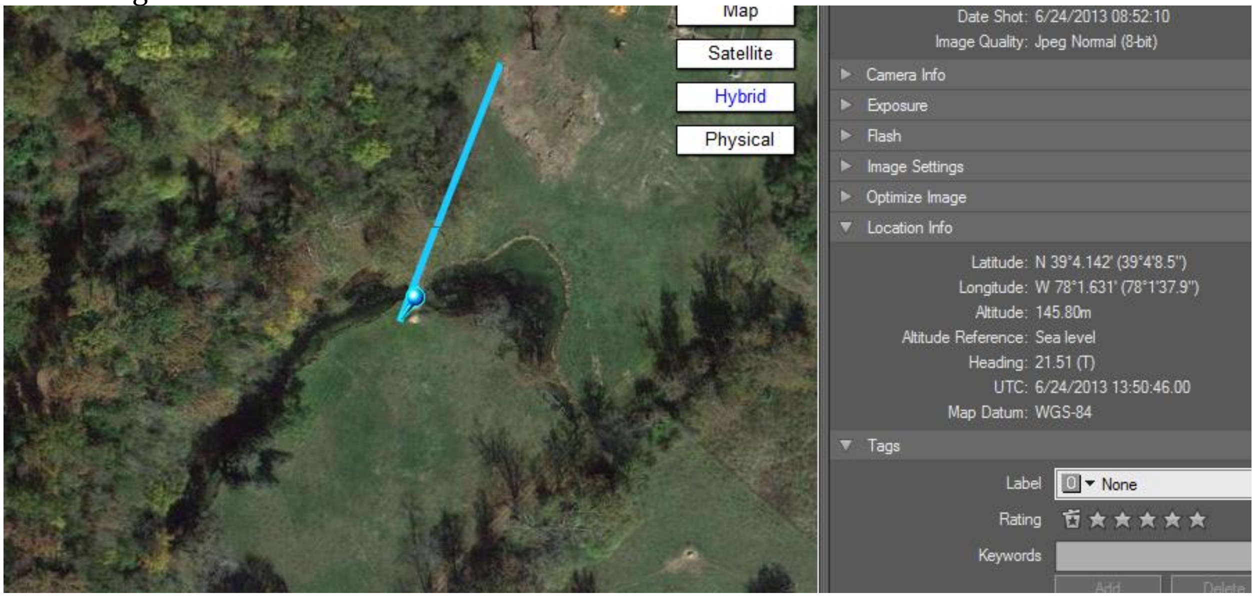


A3.44 Carter Hall Spring Sampling location 6 24 2013

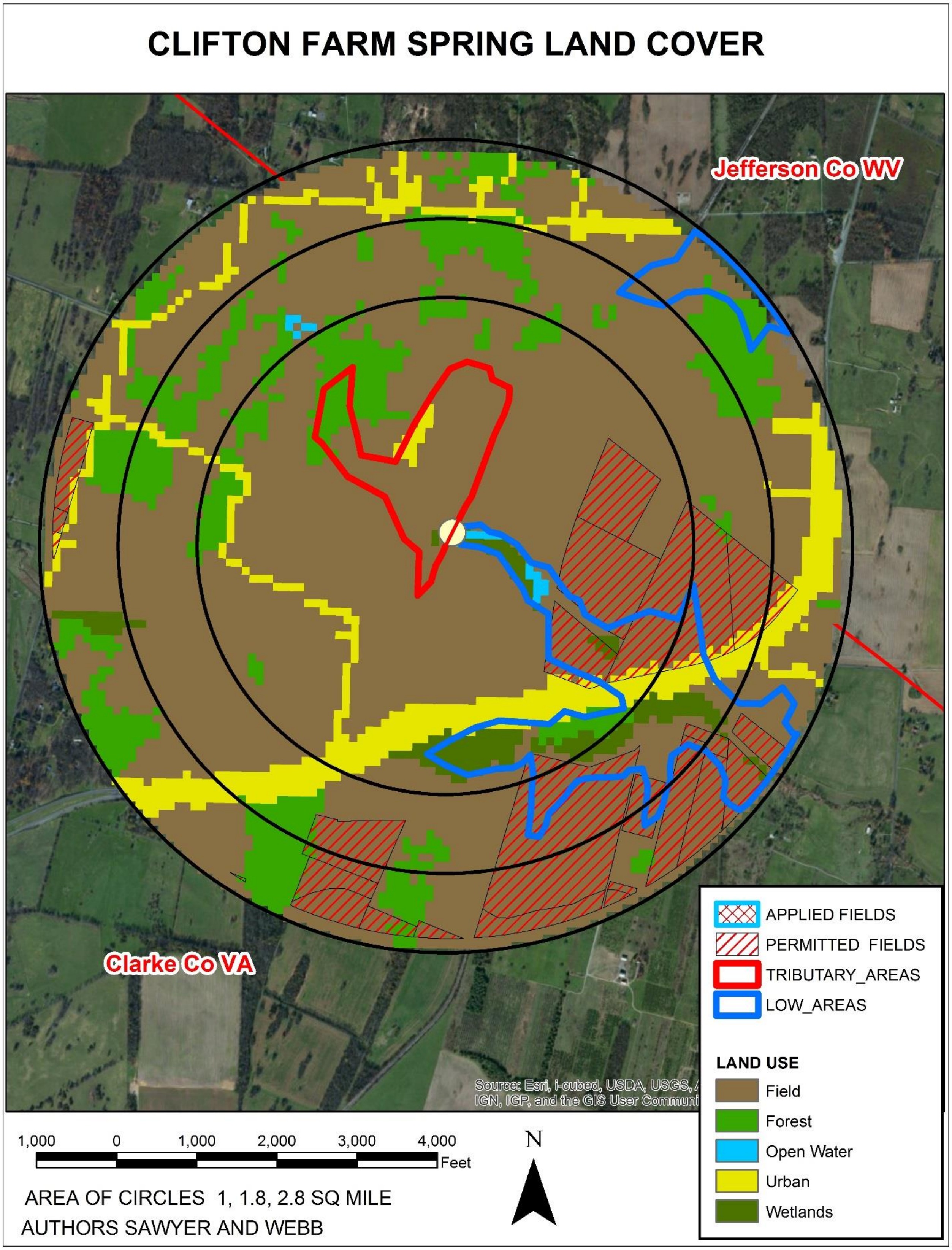
Sampling location



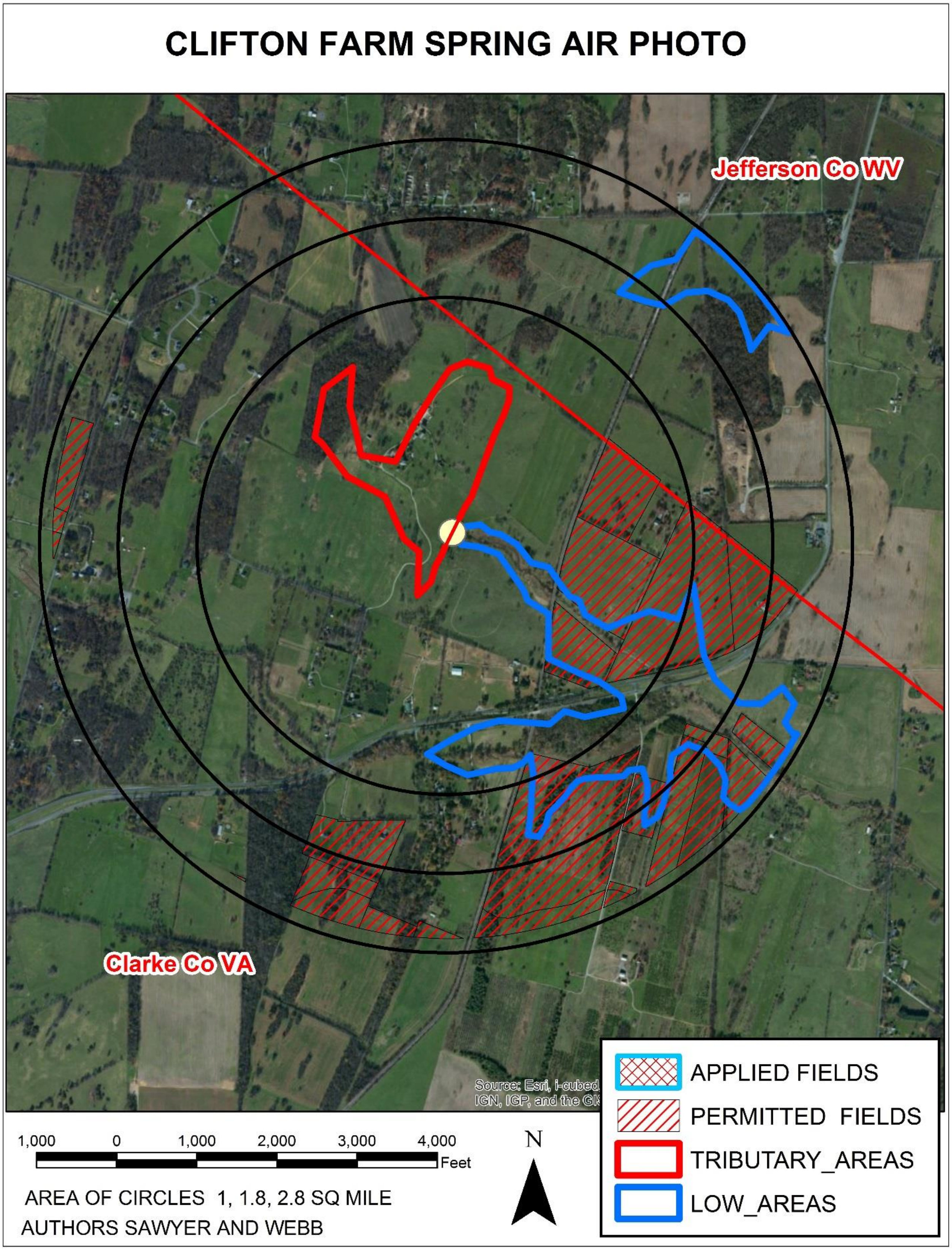
A3.45 Carter Hall Spring Sampling Measuring section 6 24 2013
Measuring section



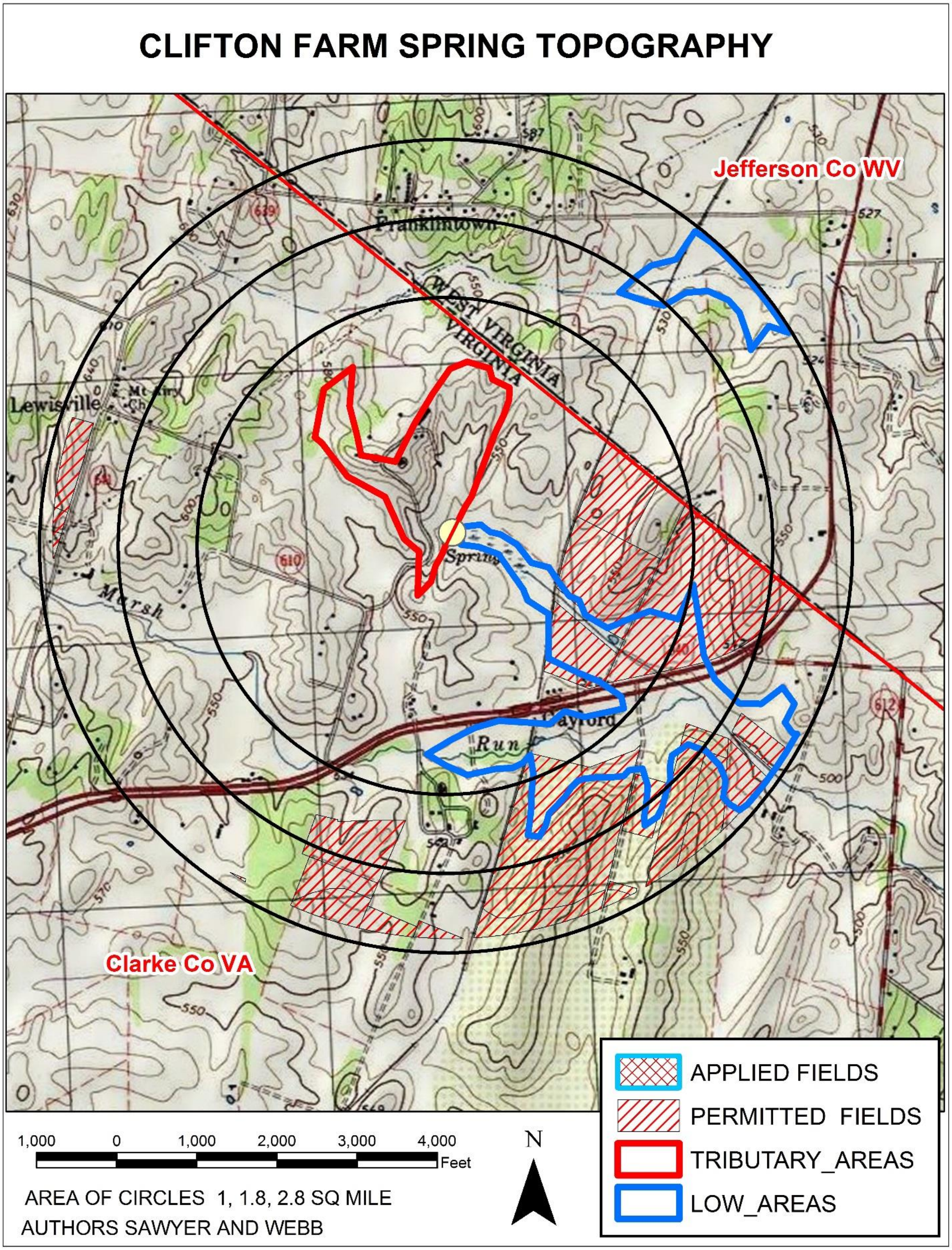
A3.51 Clifton Farm Spring Land Cover



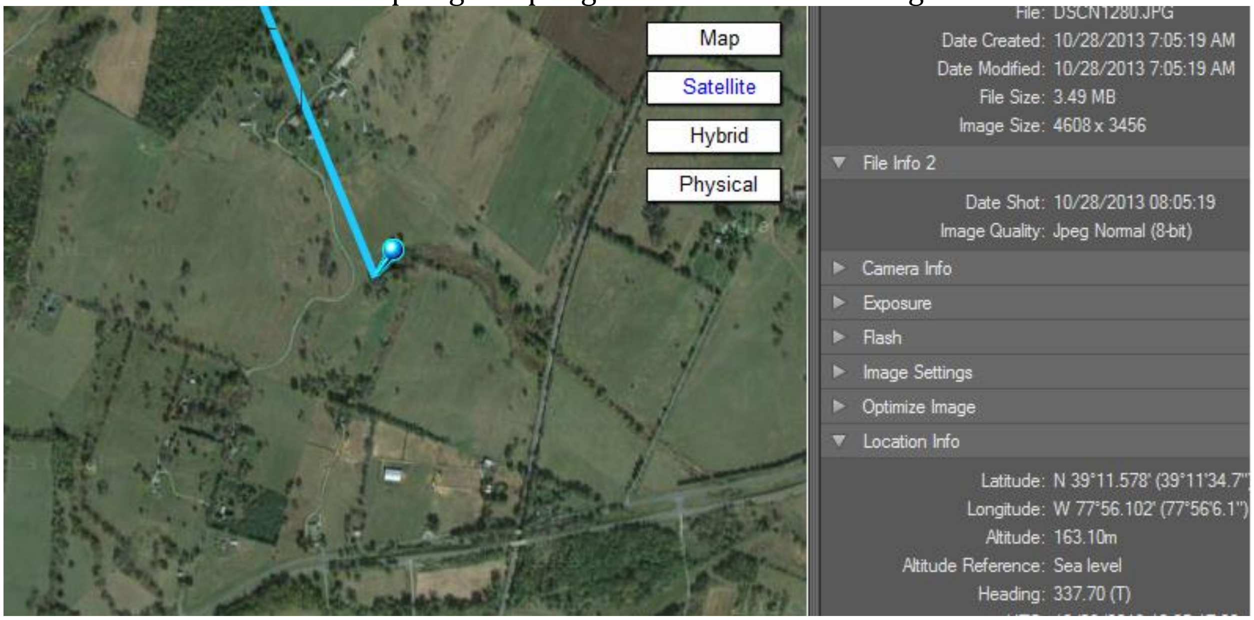
A3.52 Clifton Farm Spring Air Photo



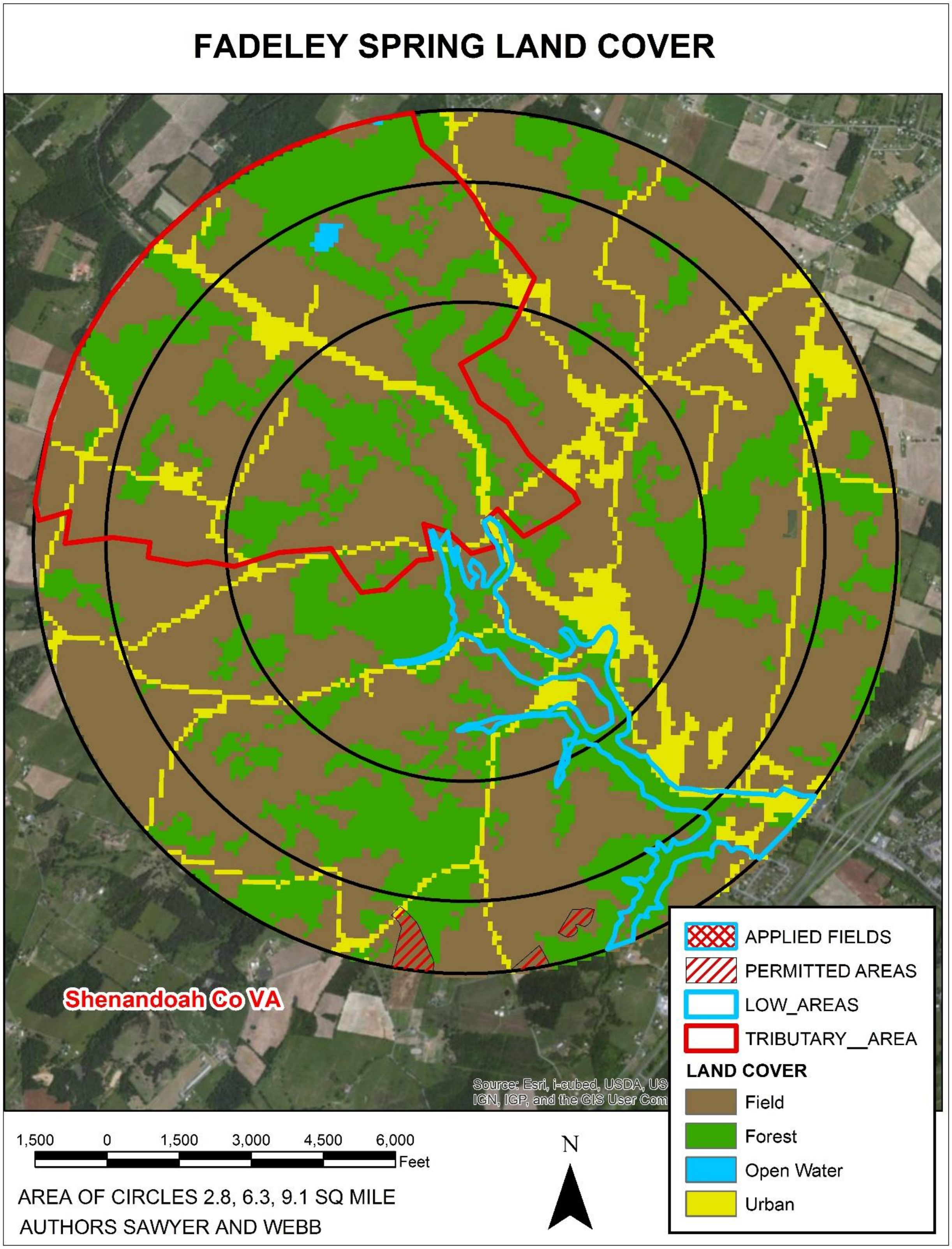
A3.53 Clifton Farm Spring Topography



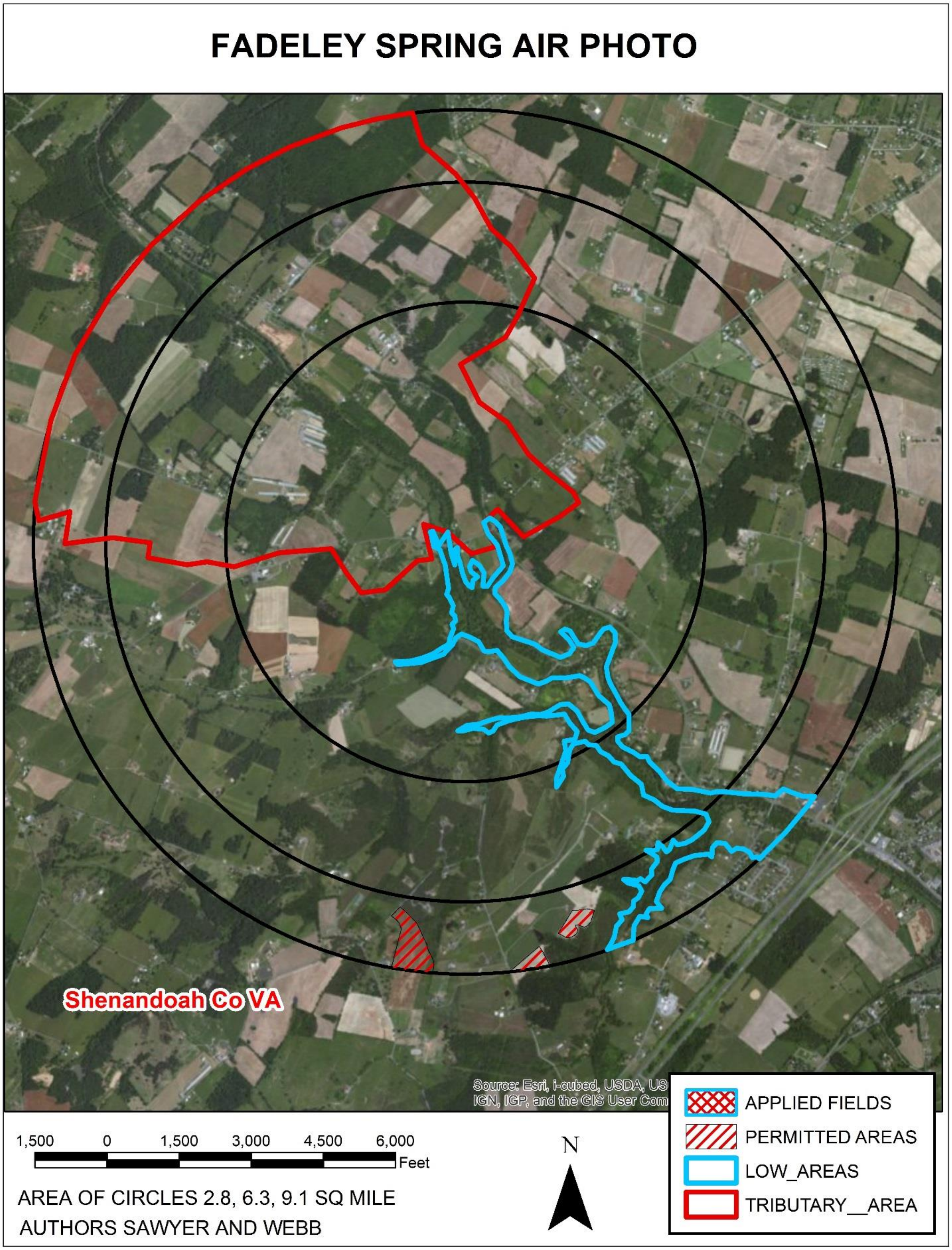
A3.54 + A3.55 Clifton Farm Spring sampling location and measuring section



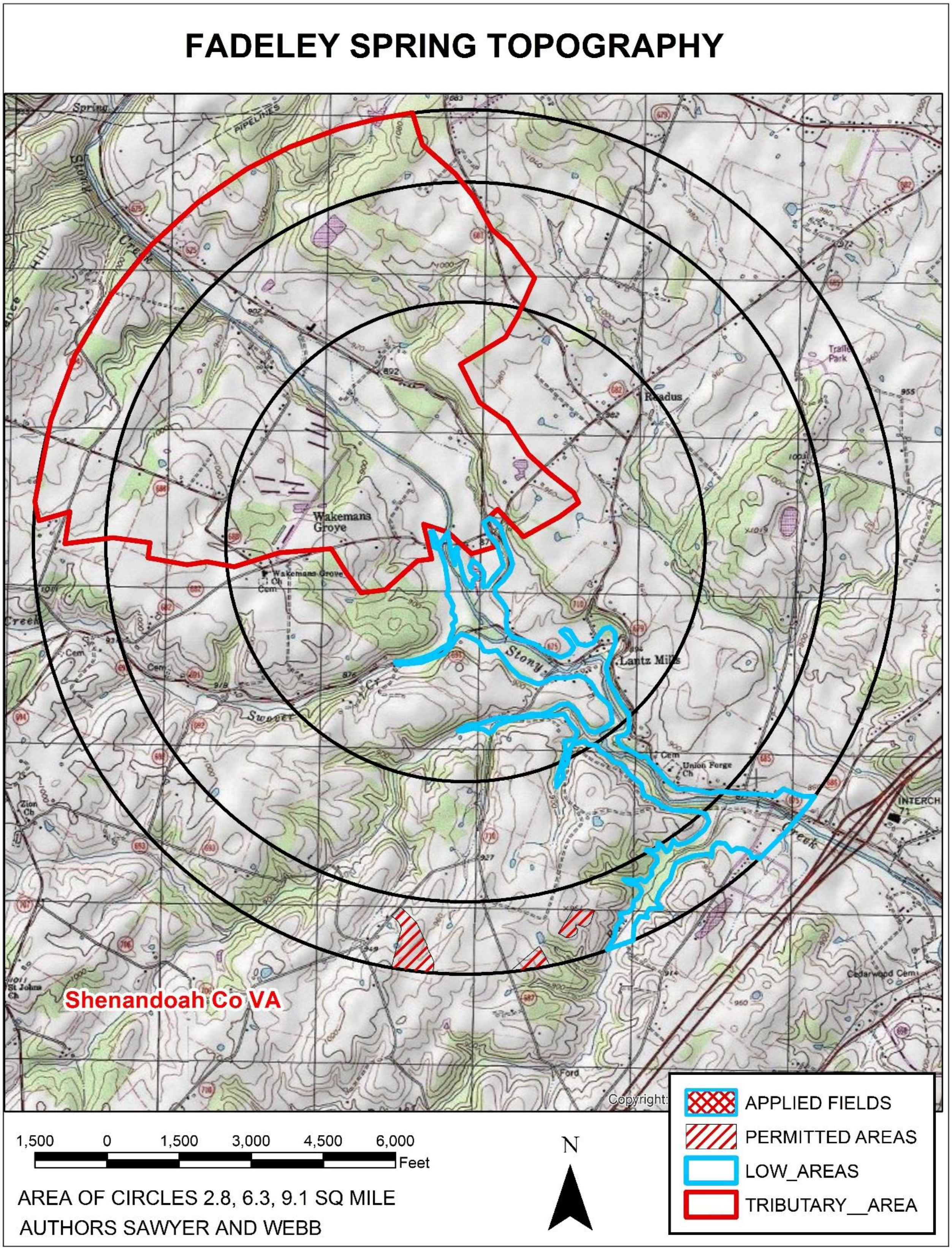
A3.61 Fadeley Spring Land Cover



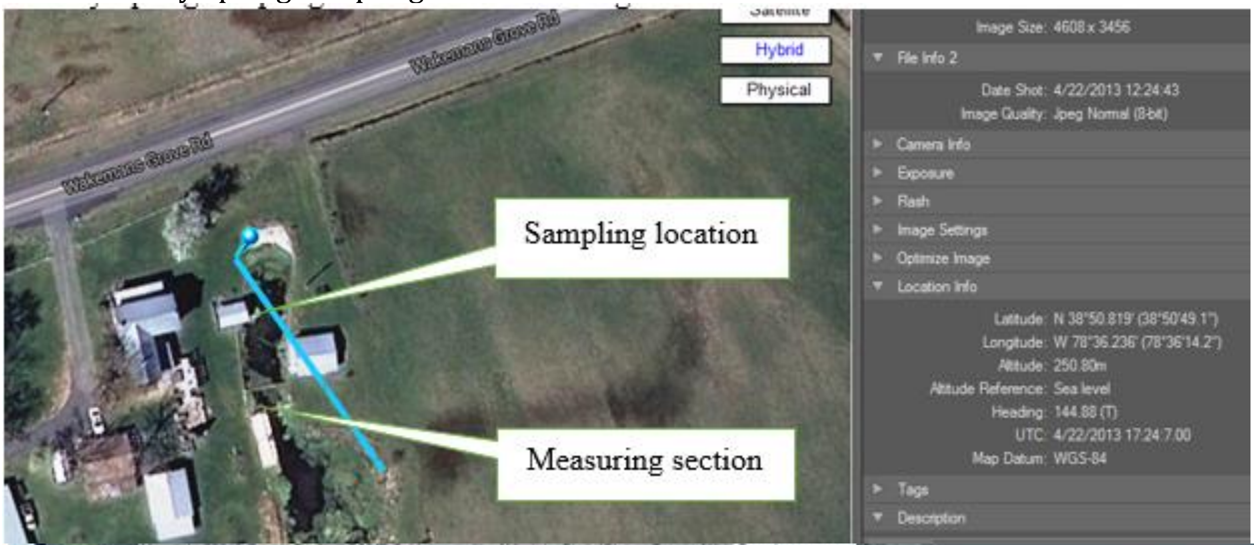
A3.62 Fadeley Spring Air Photo



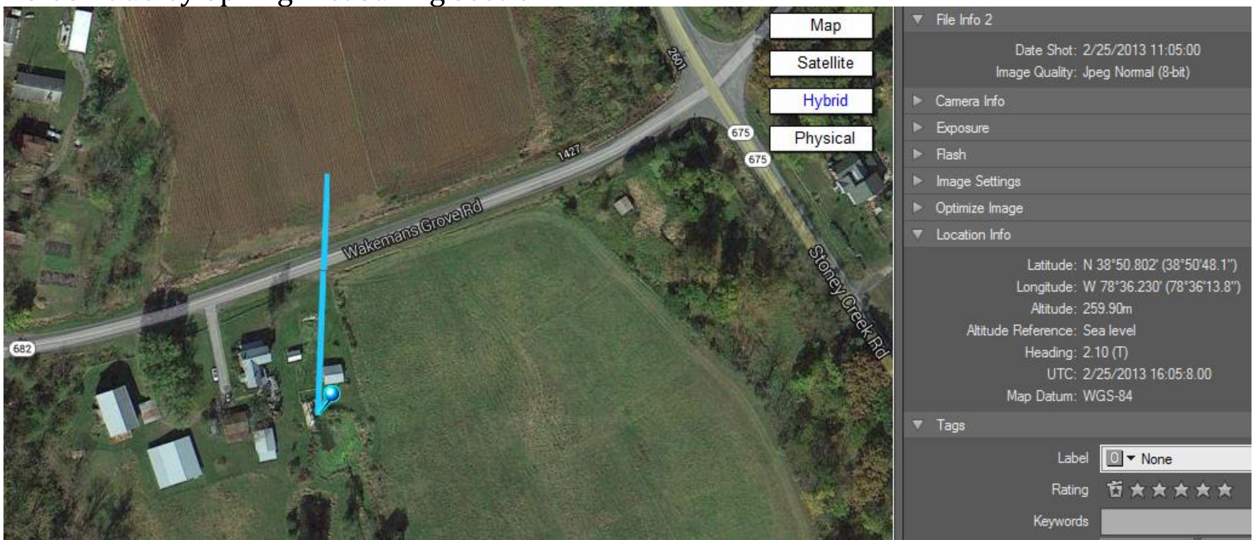
3.63 Fadeley Spring topography

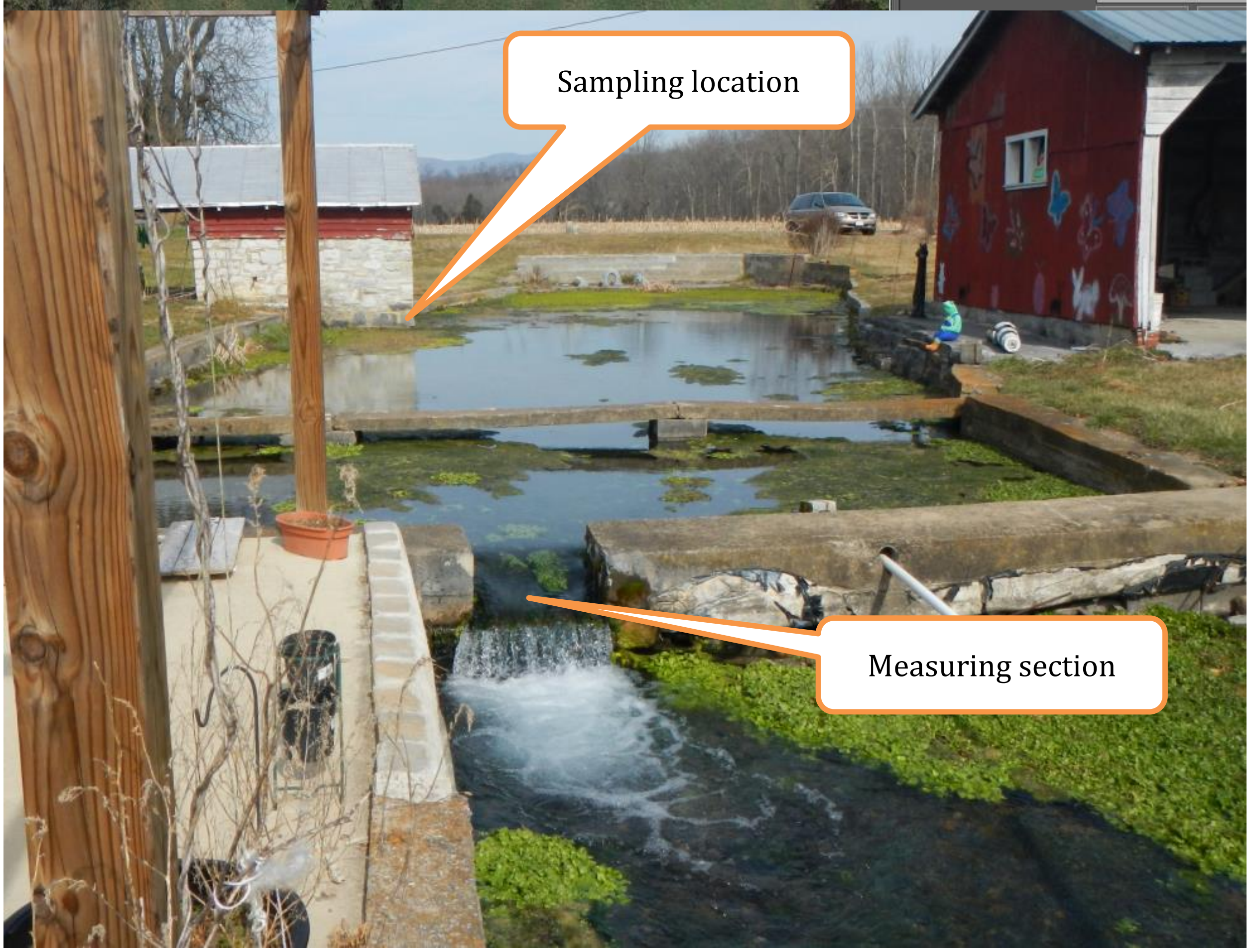


A3.64 Fadeley Spring sampling location

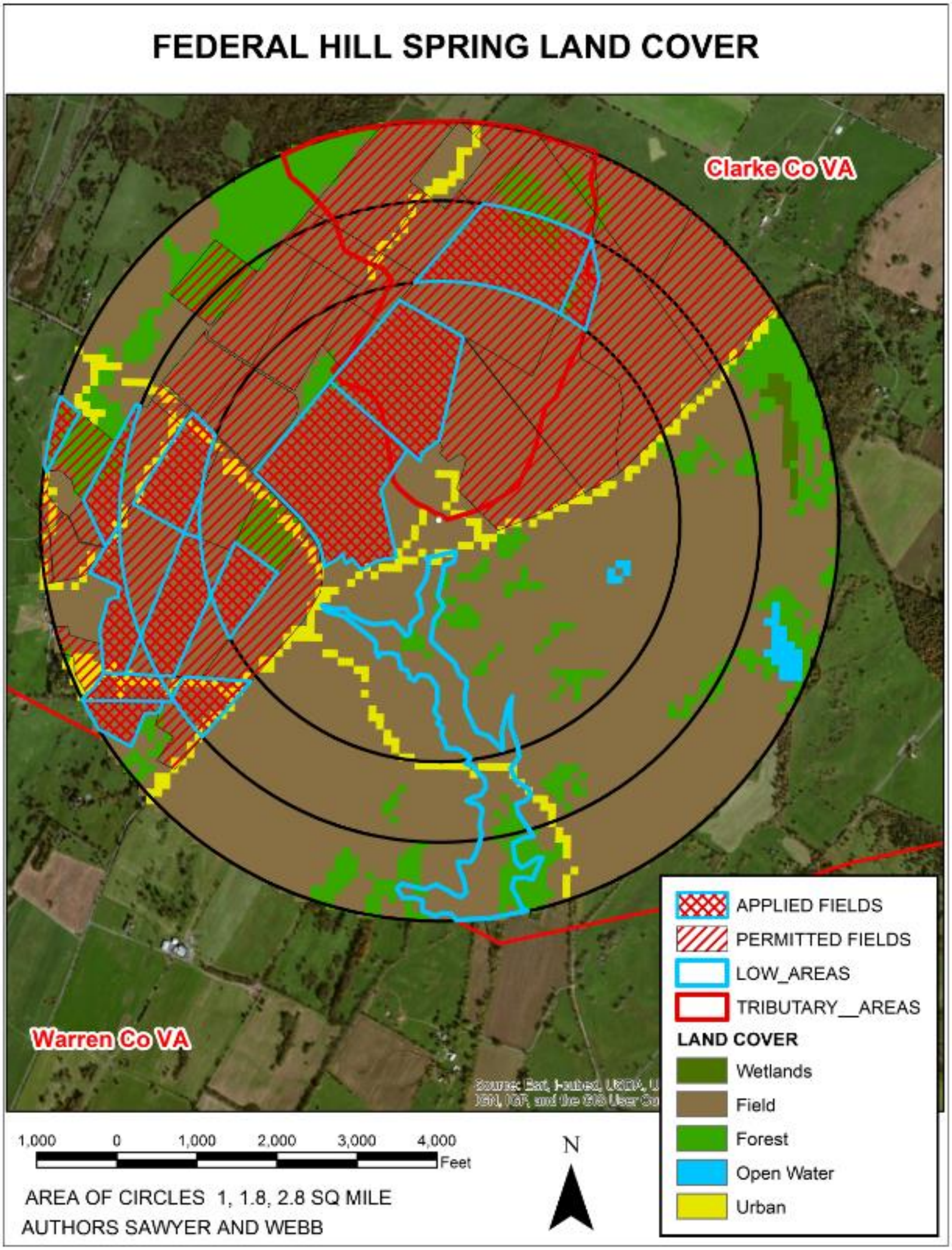


A3.65 Fadeley Spring measuring section

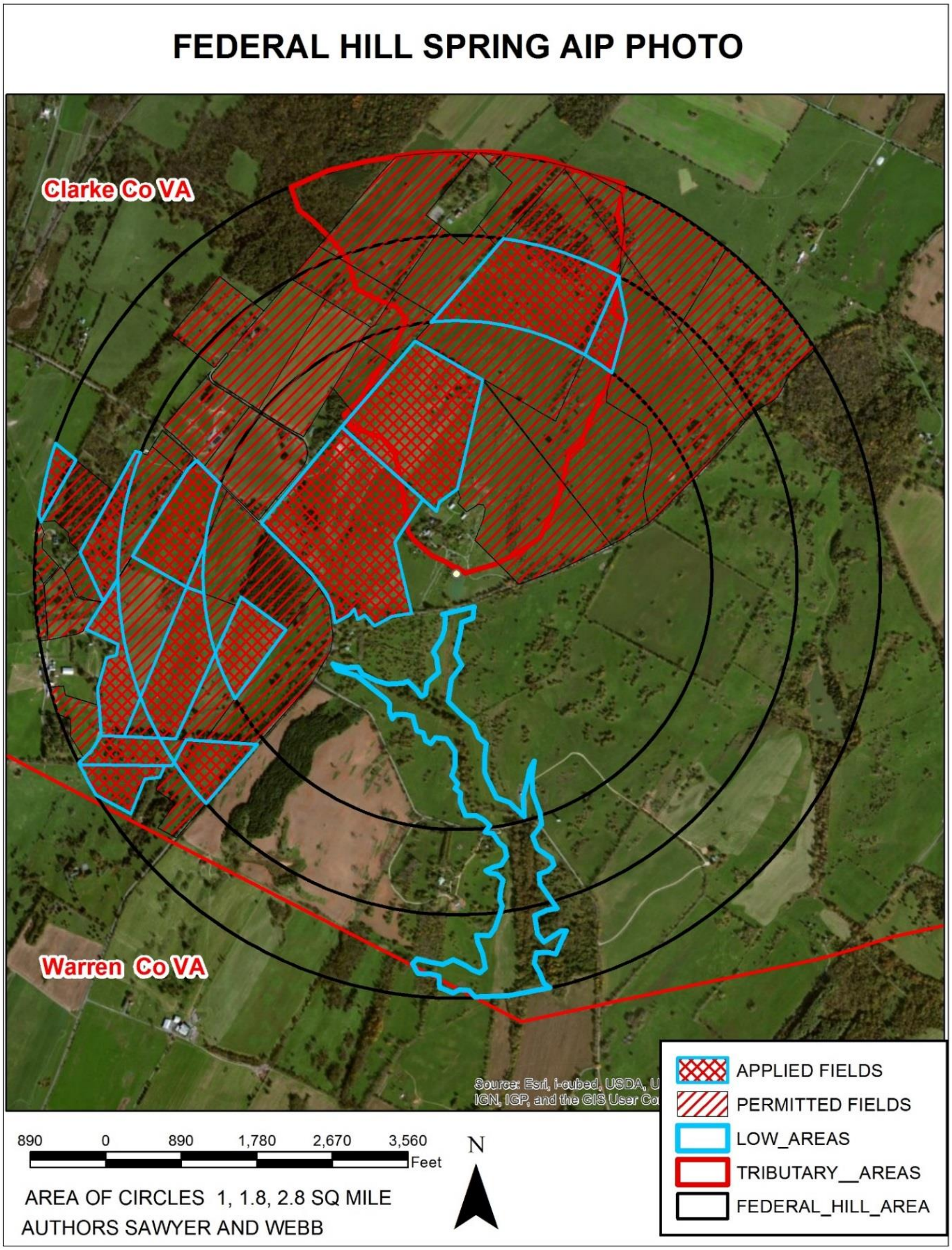




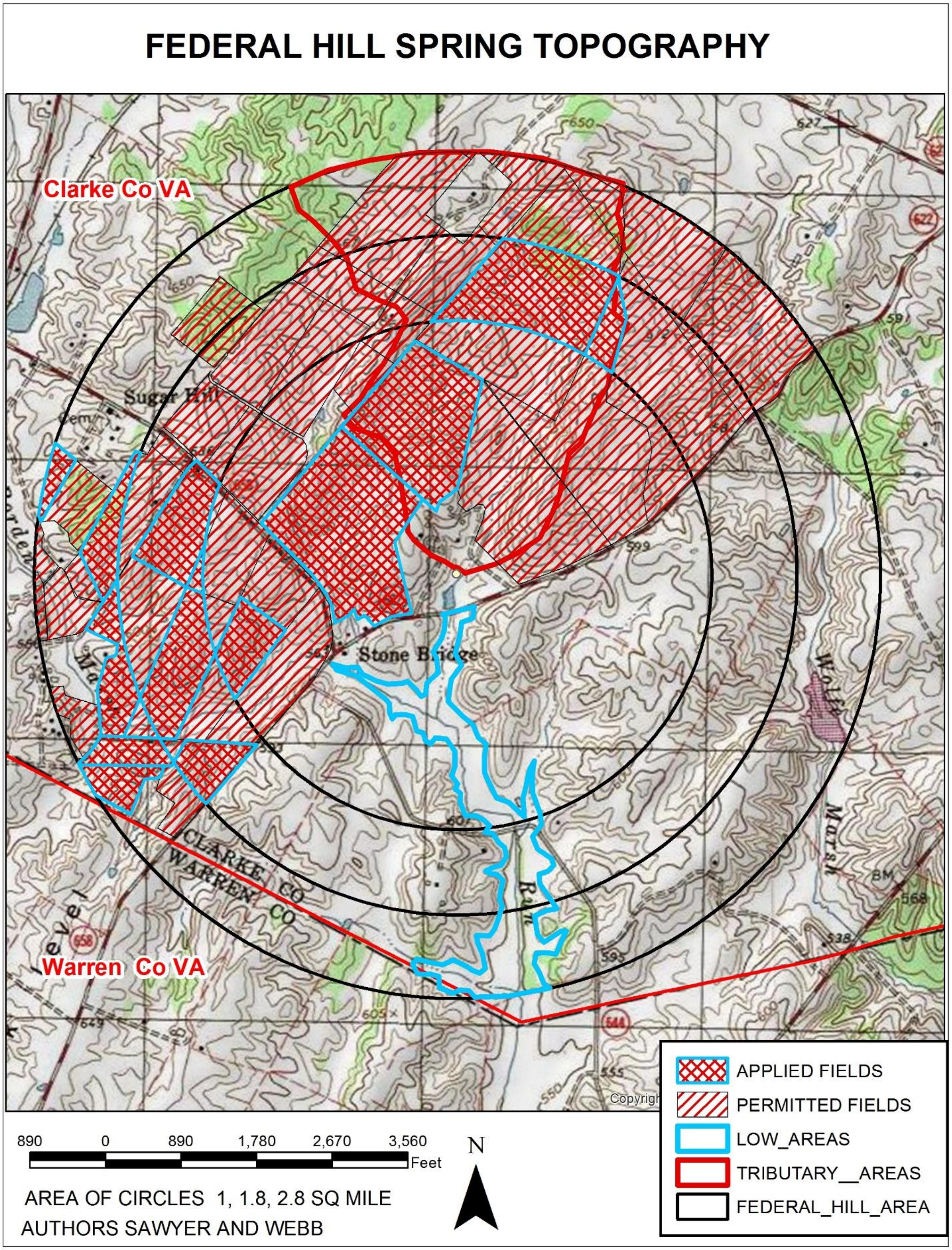
A3.71 Federal Hill Spring Land Cover



A3.72 Federal Hill Spring Air Photo

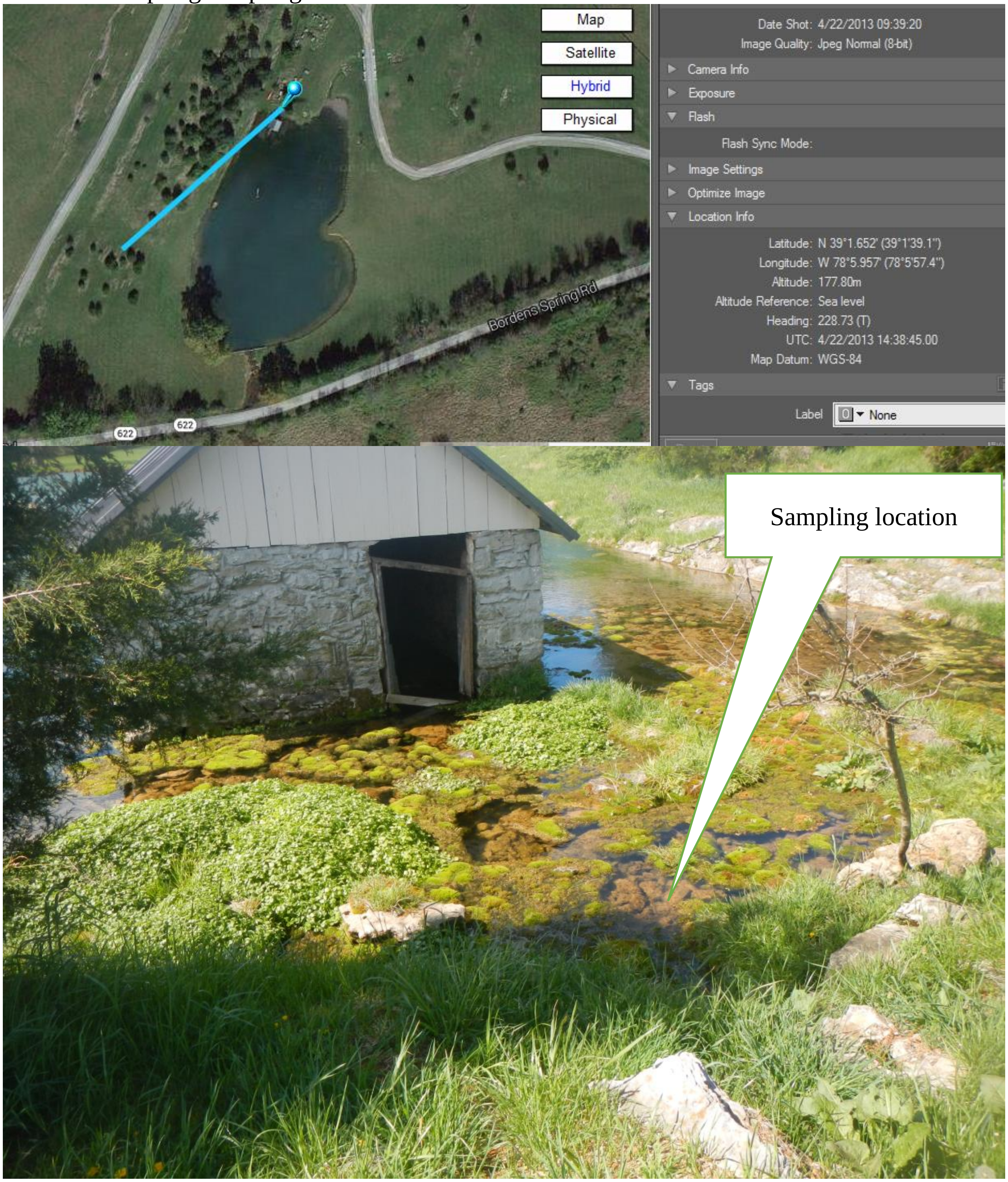


A3.73 Federal Hill Spring Topography

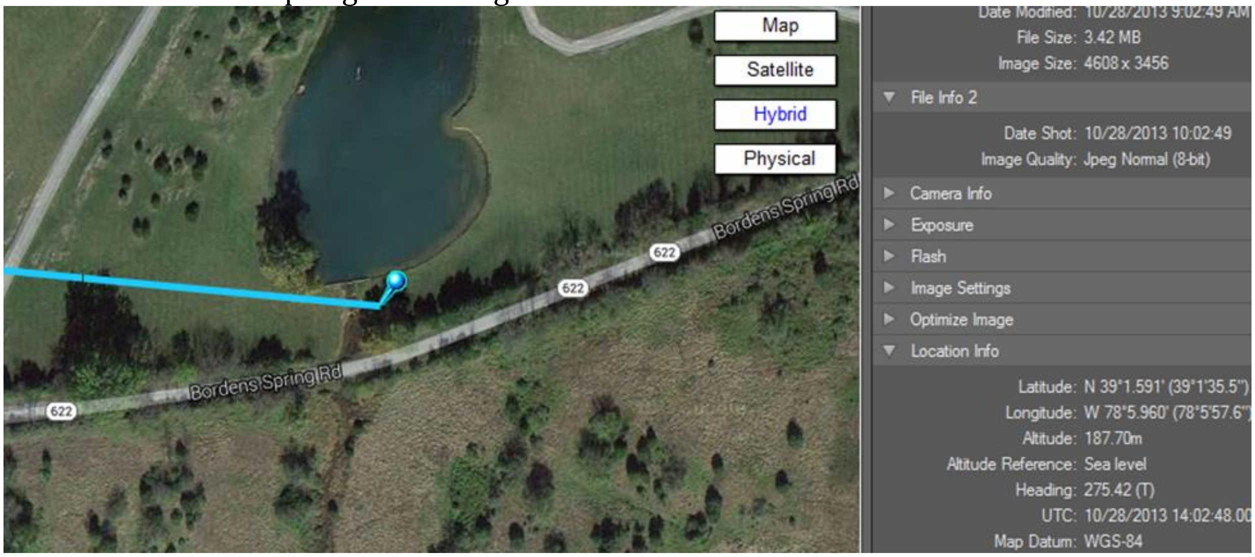


A3.74 Federal Hill Spring Sampling location

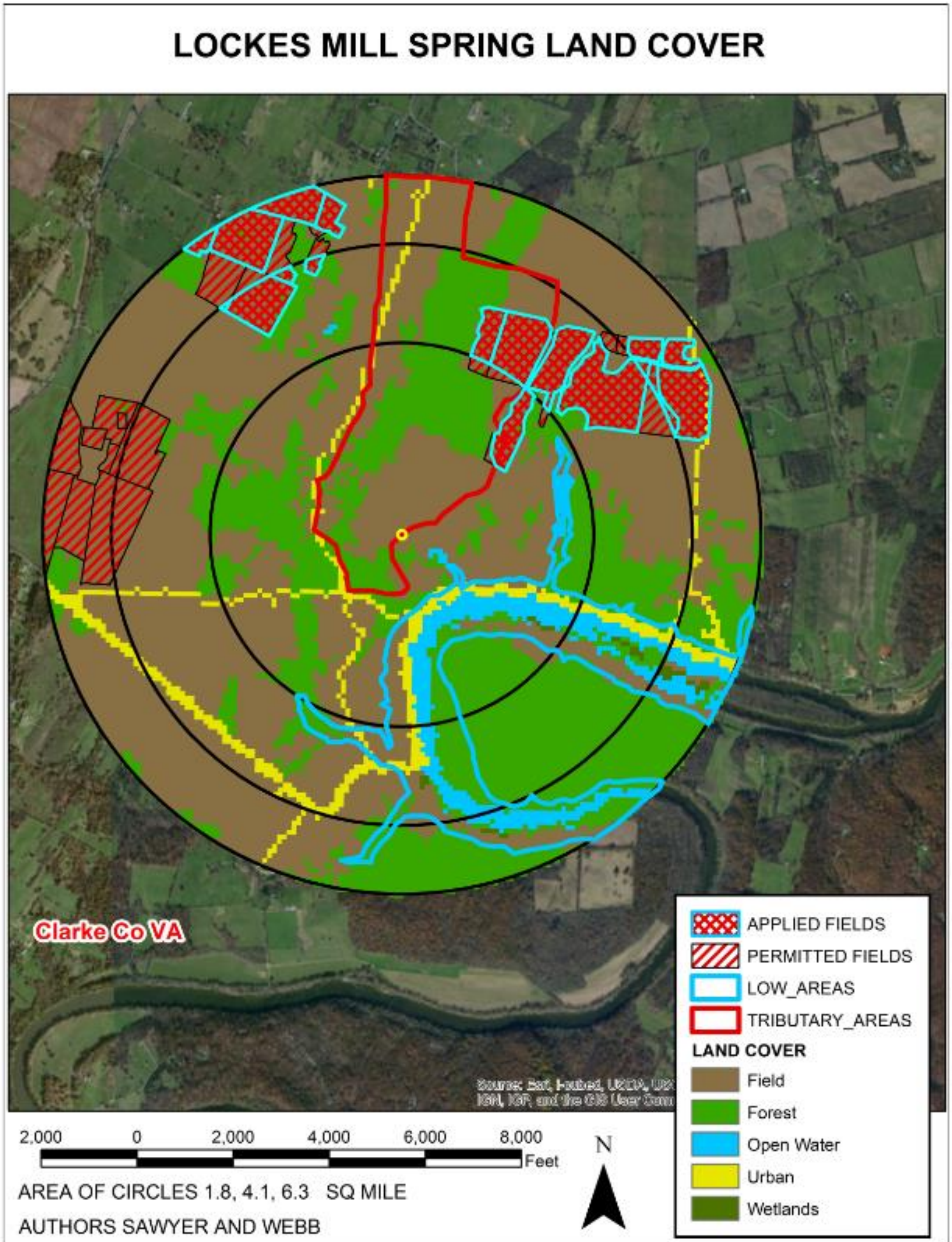
Federal Hill Spring sampling location 422 2013



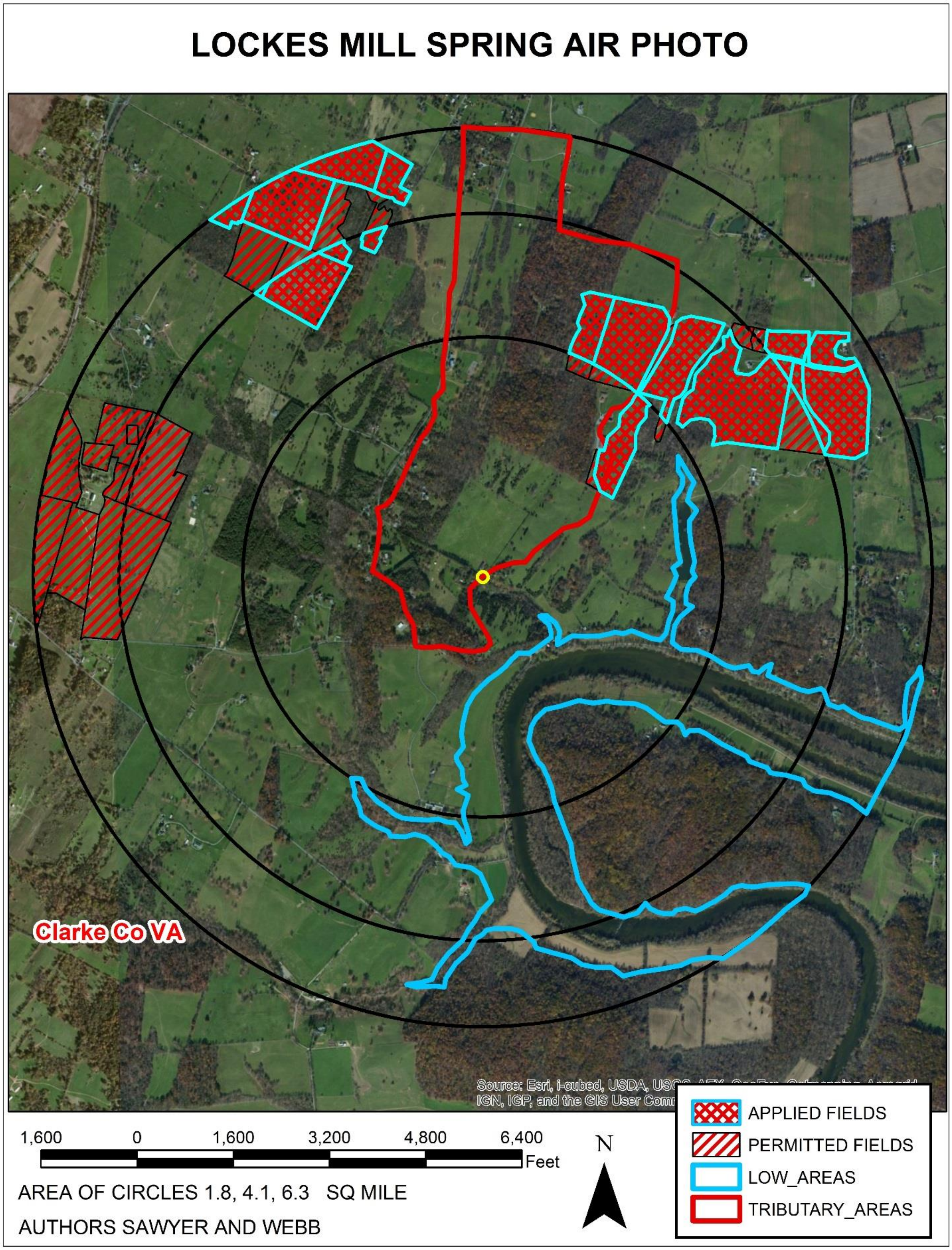
A3.75 Federal Hill Spring Measuring section



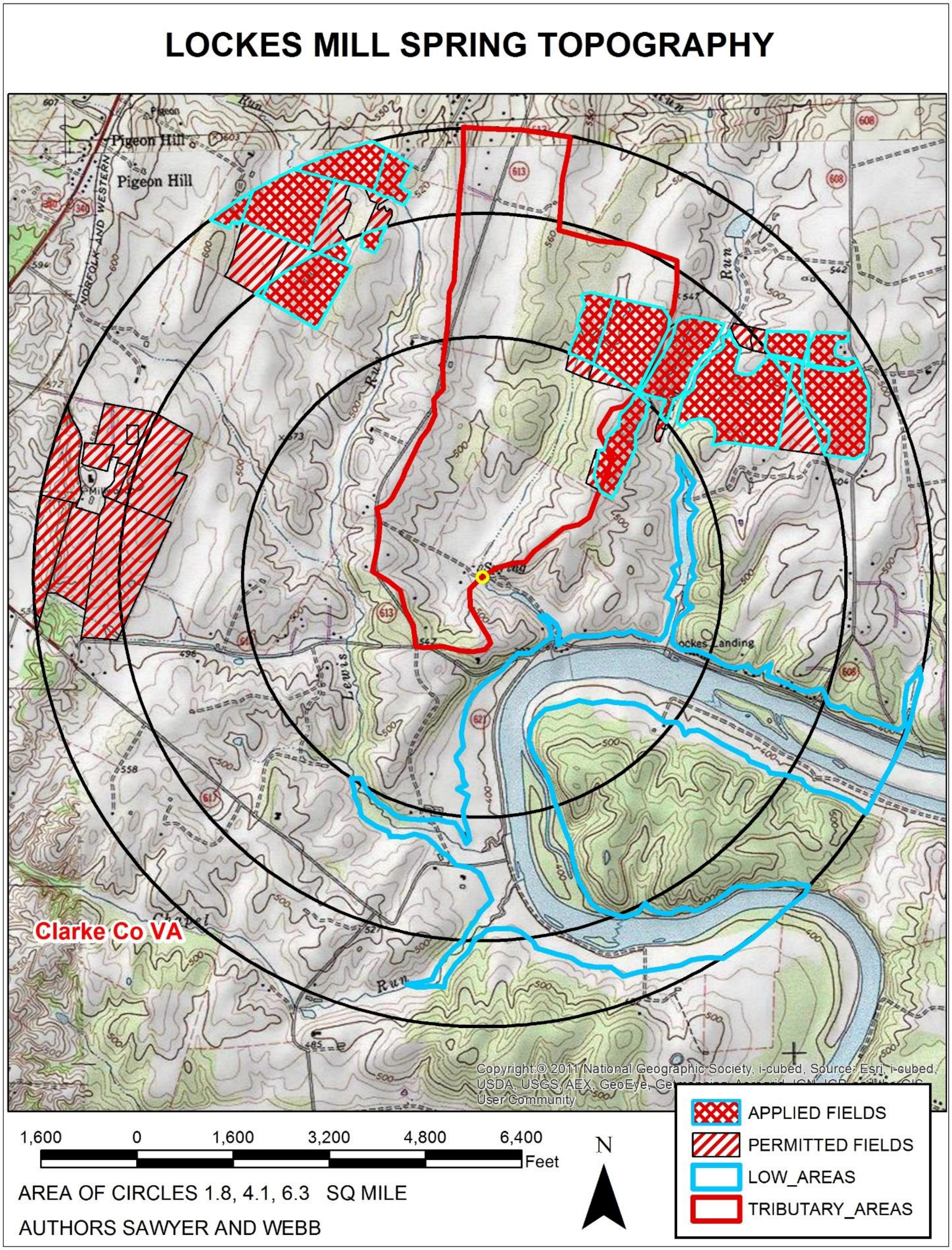
A3.81 Lockes Mill Spring Land Cover



A3.82 Lockes Mill Spring Air Photo

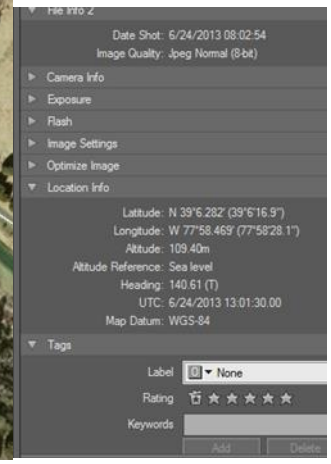


A3.83 Lockes Mill Spring Topography

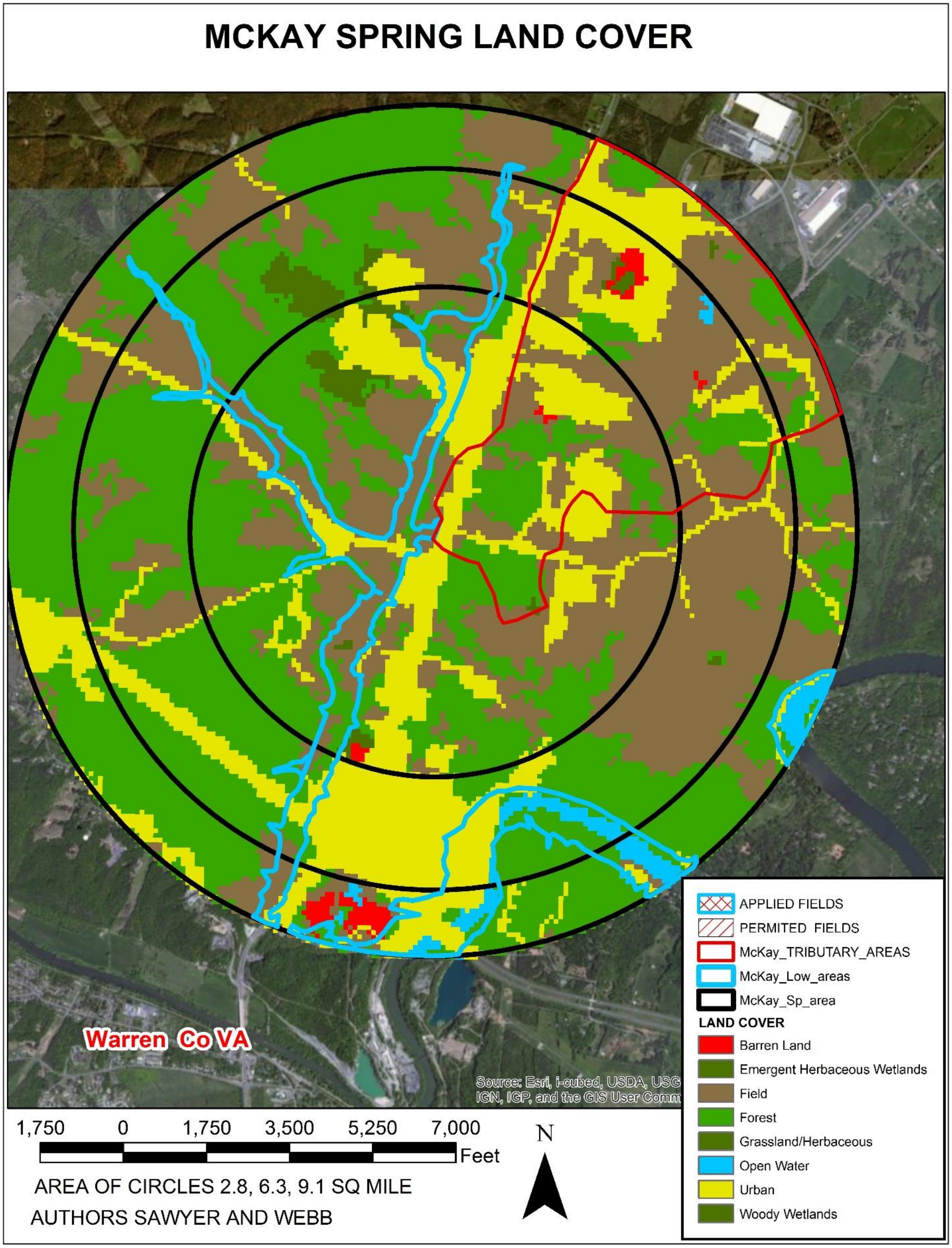


A3.84 Lockes Mill Spring Sampling location

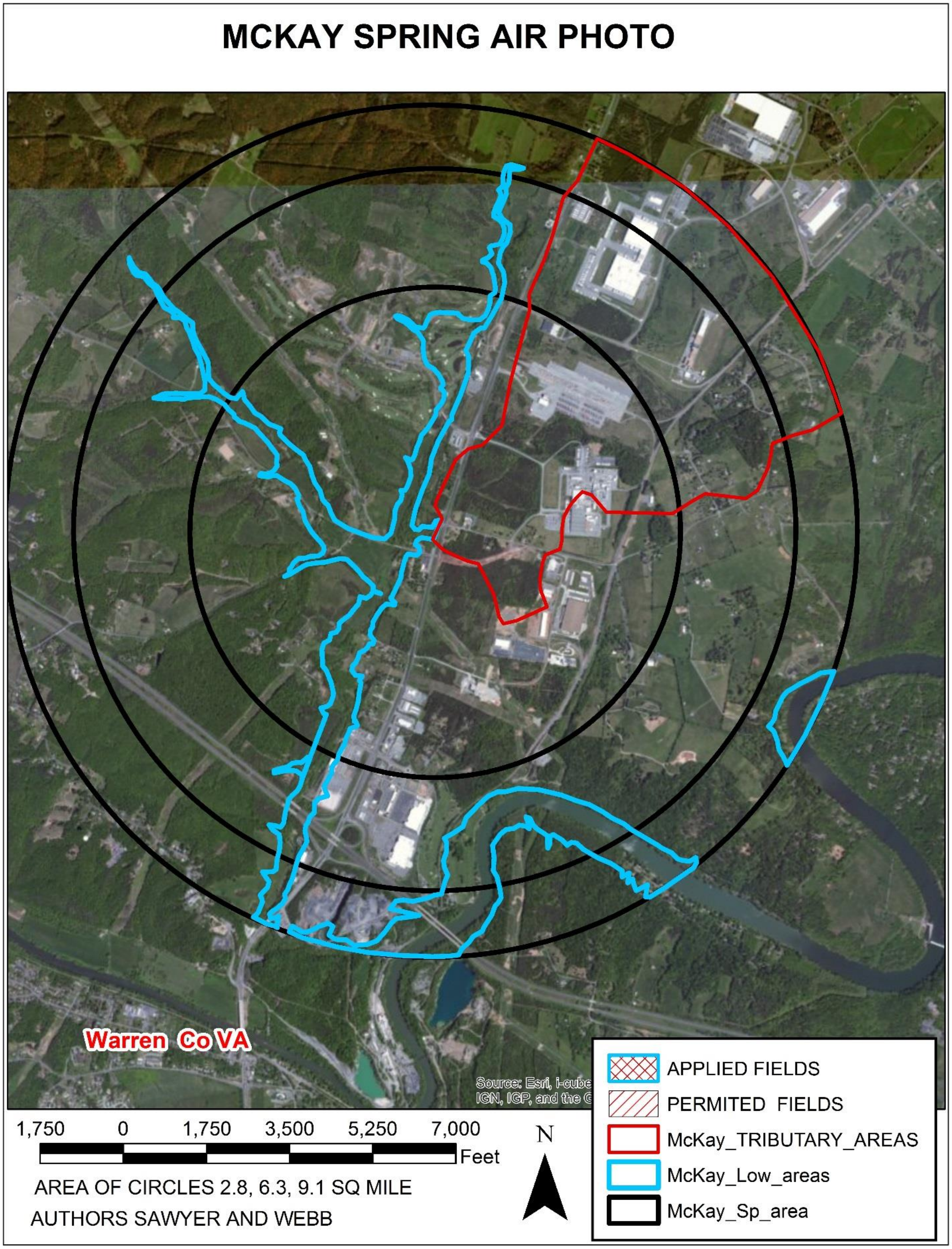
A3.85 Lockes Mill Spring Measuring section



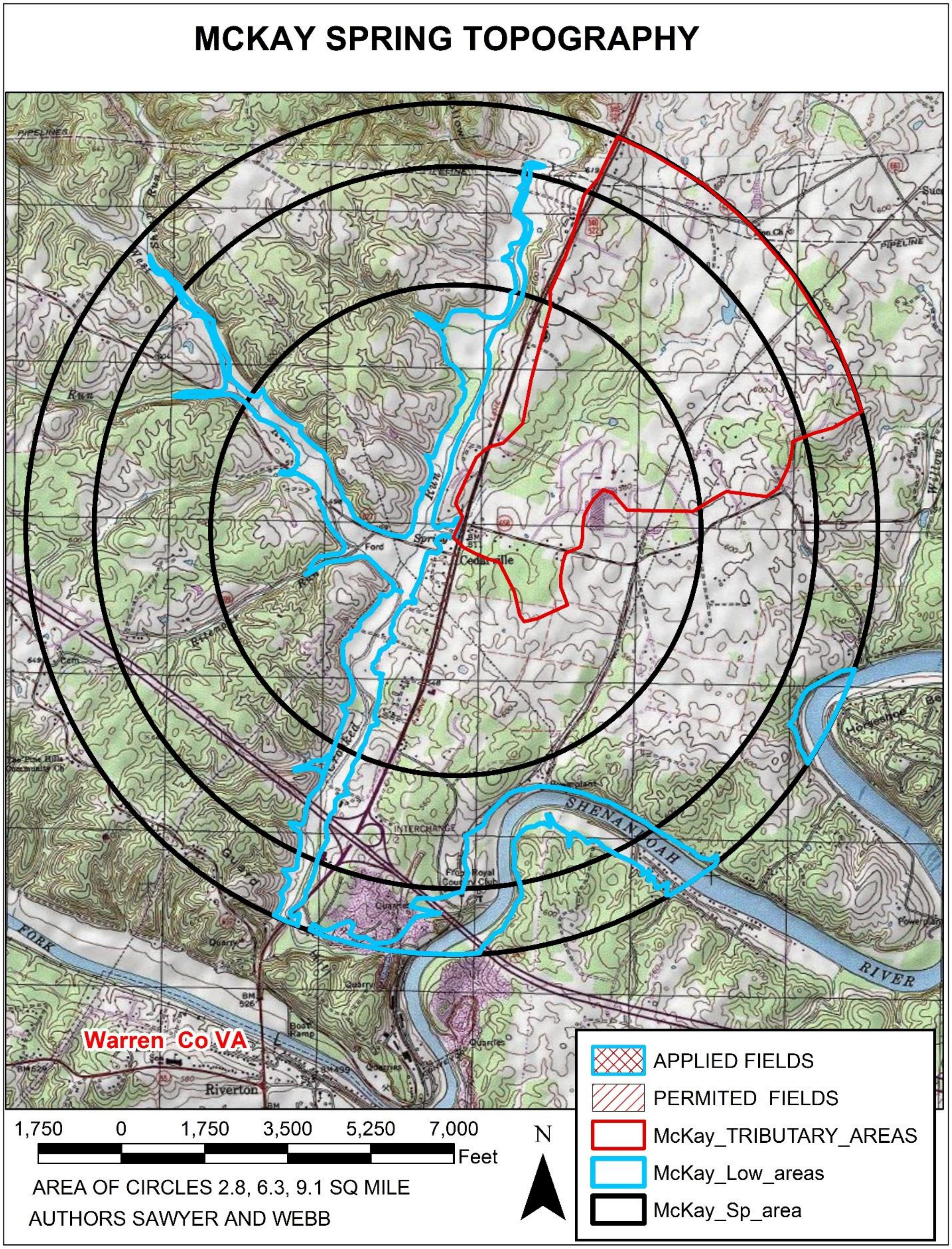
A3.91 McKay Spring Land Cover



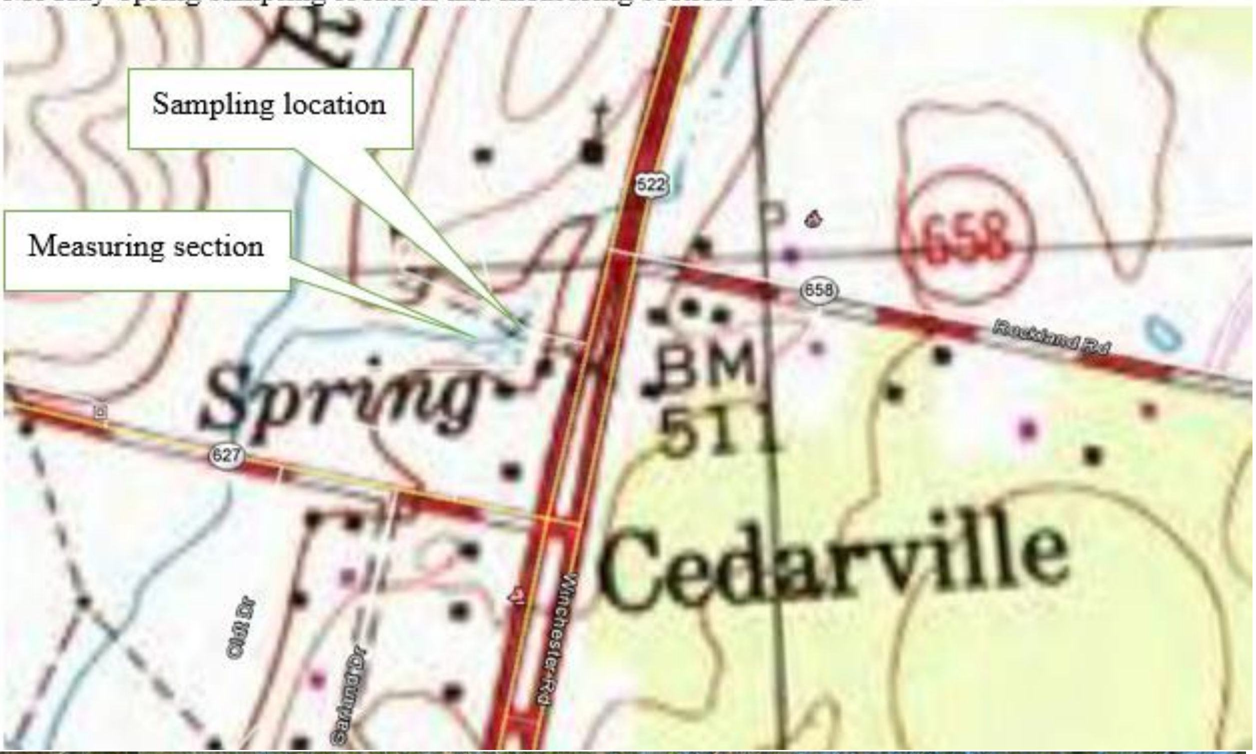
A3.92 McKay Spring Air Photo

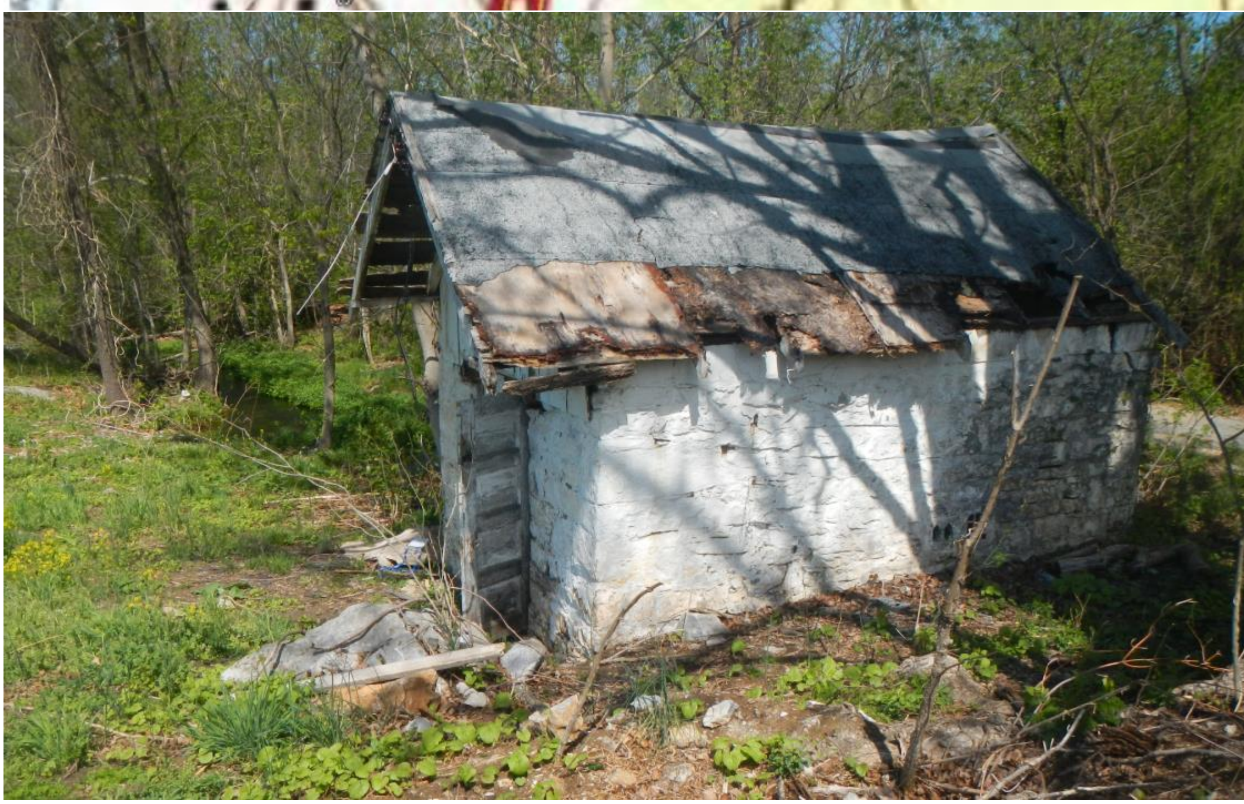


A3.93 McKay Spring Topography

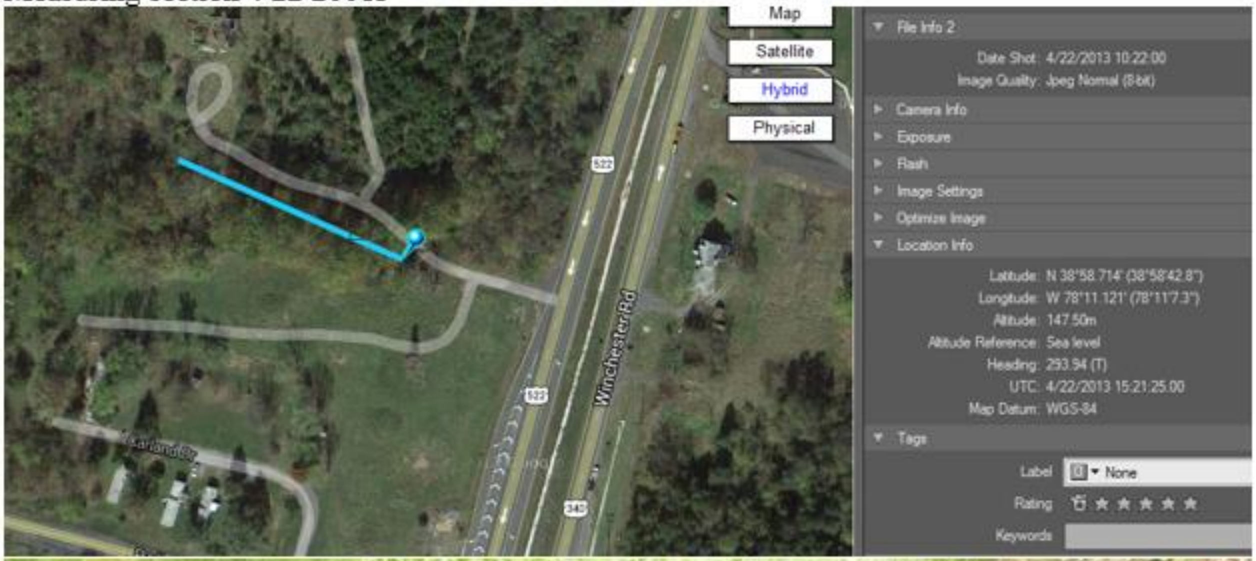


A3.94 McKay Spring Sampling location

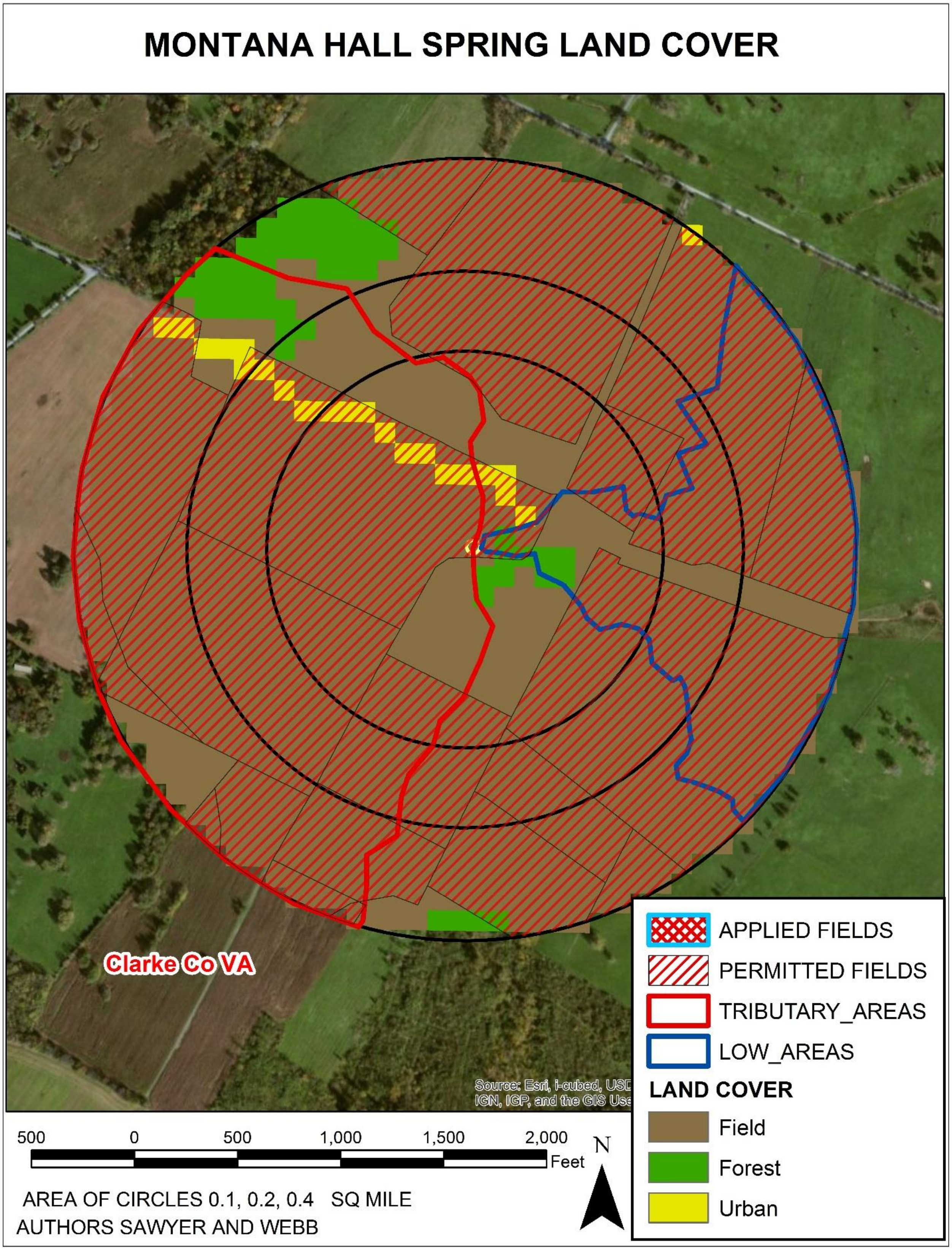




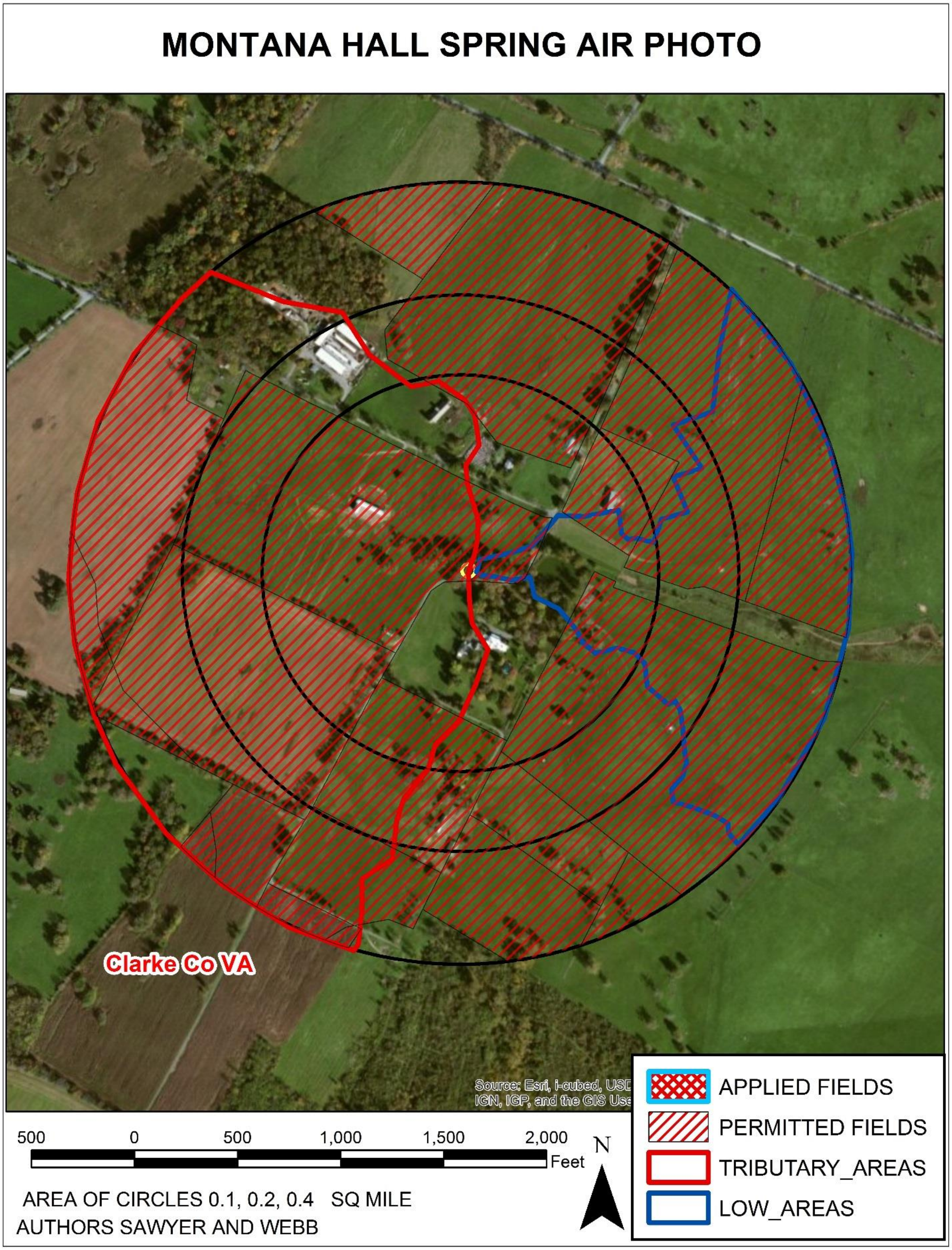
A3.94 McKay Spring Measuring section



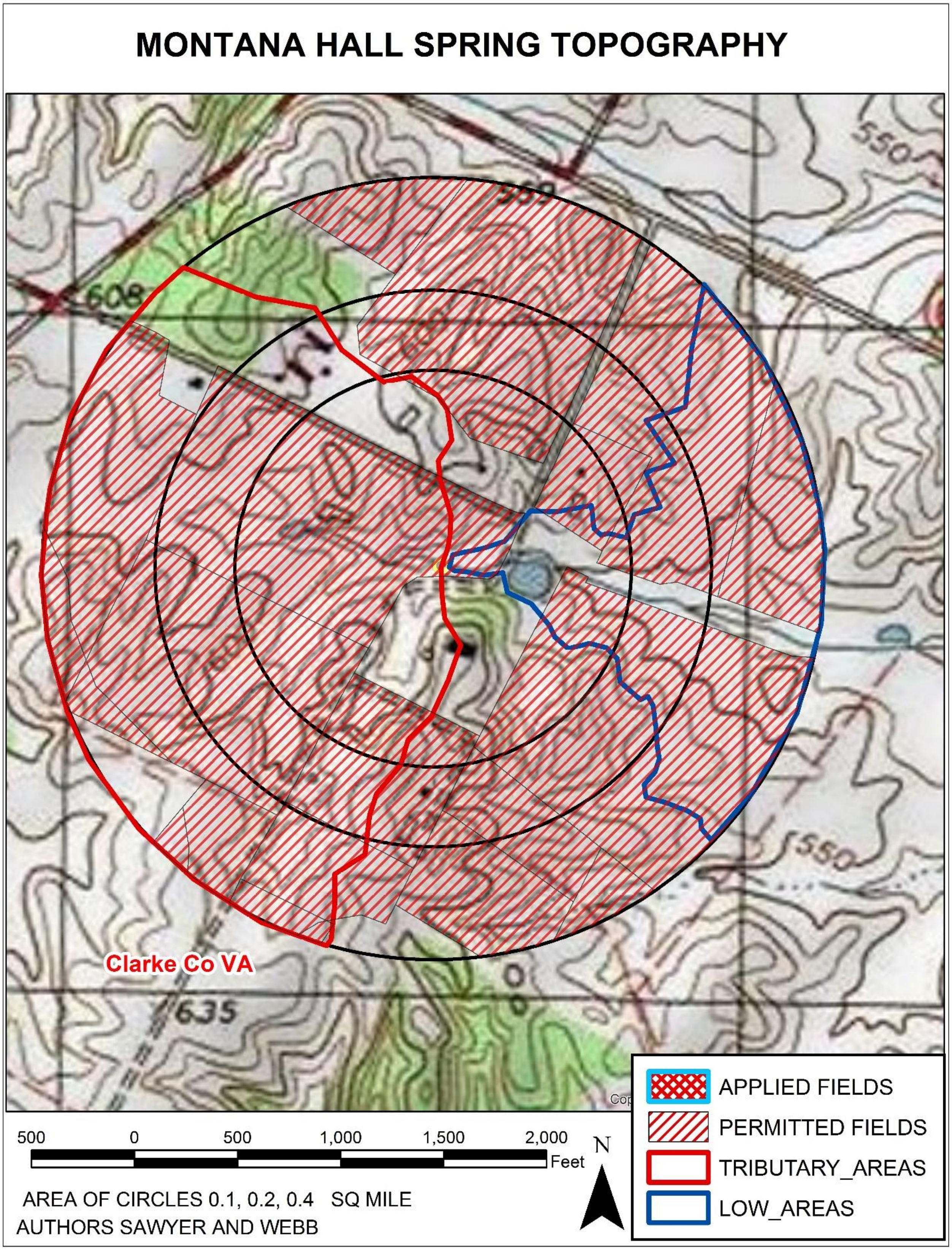
A3.101 Montana Hall Spring Land Cover



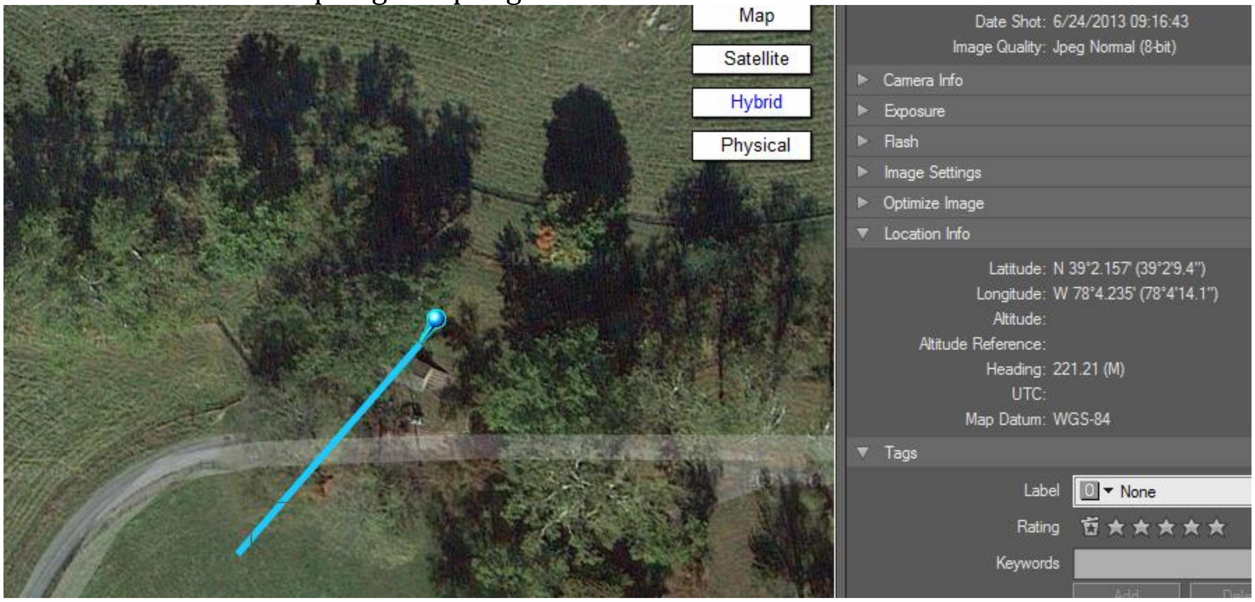
A3.102 Montana Hall Spring Air Photo



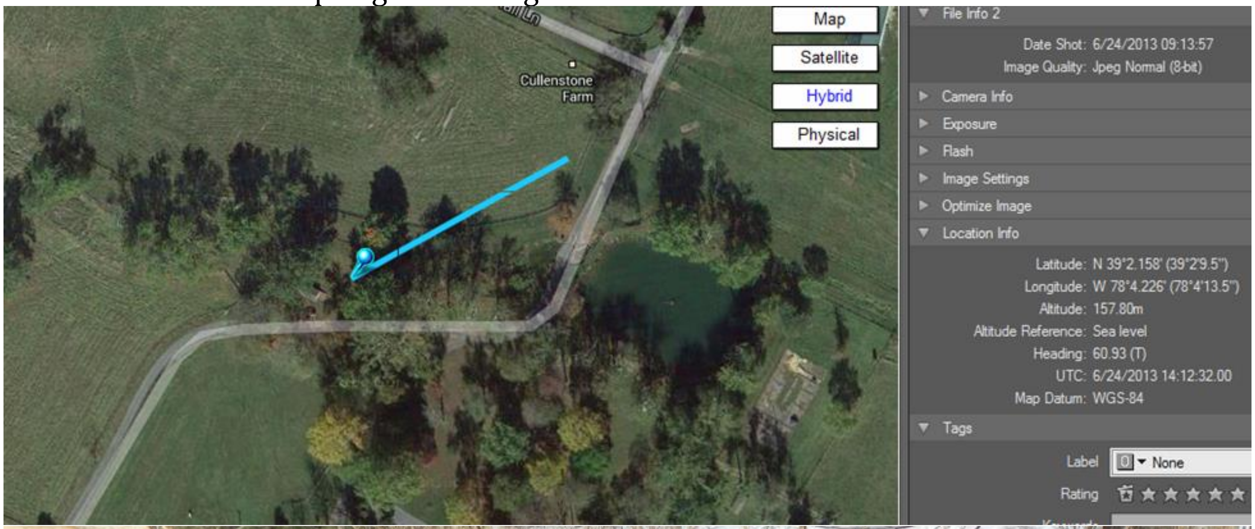
A3.103 Montana Hall Spring Topography



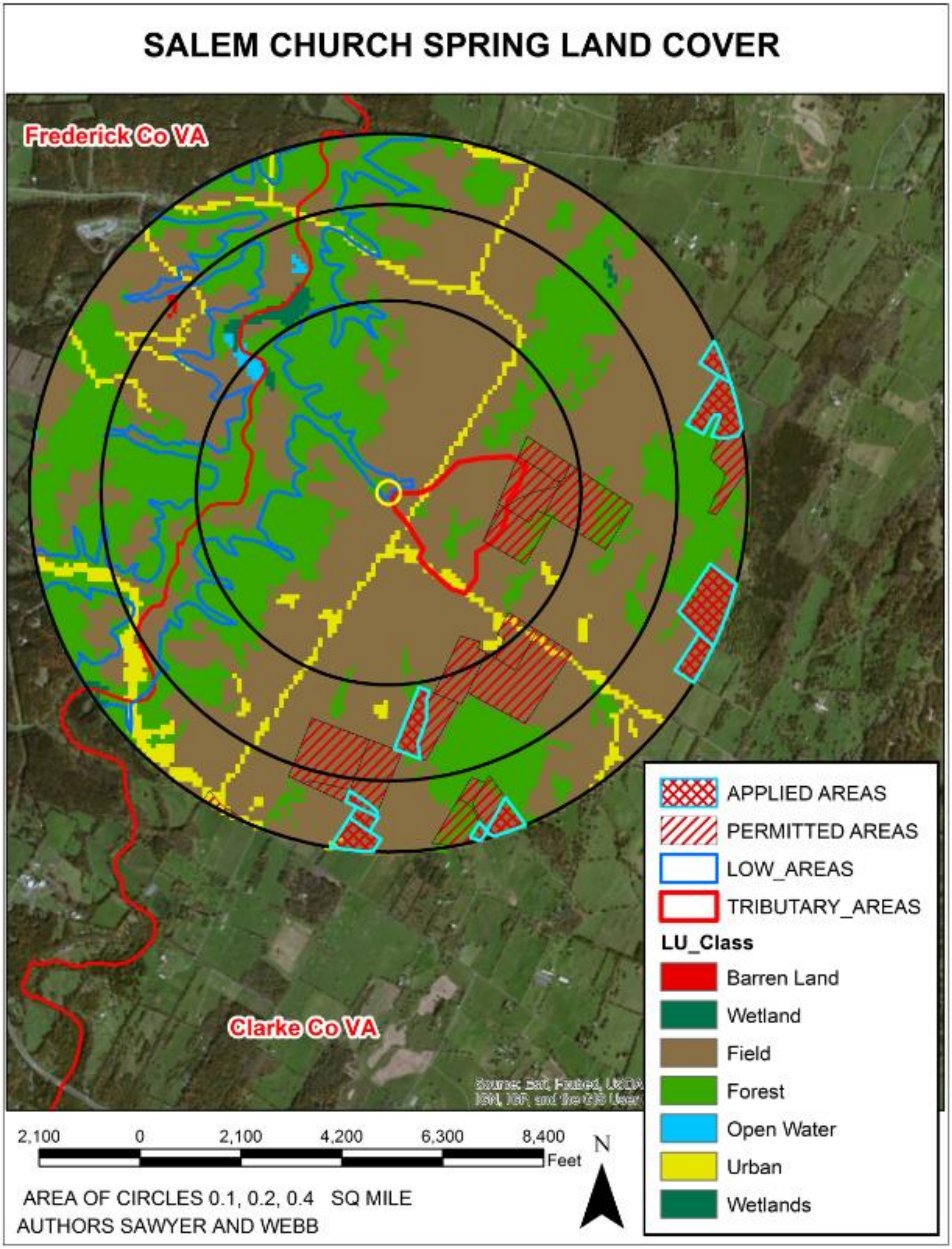
A3.104 Montana Hall Spring Sampling location



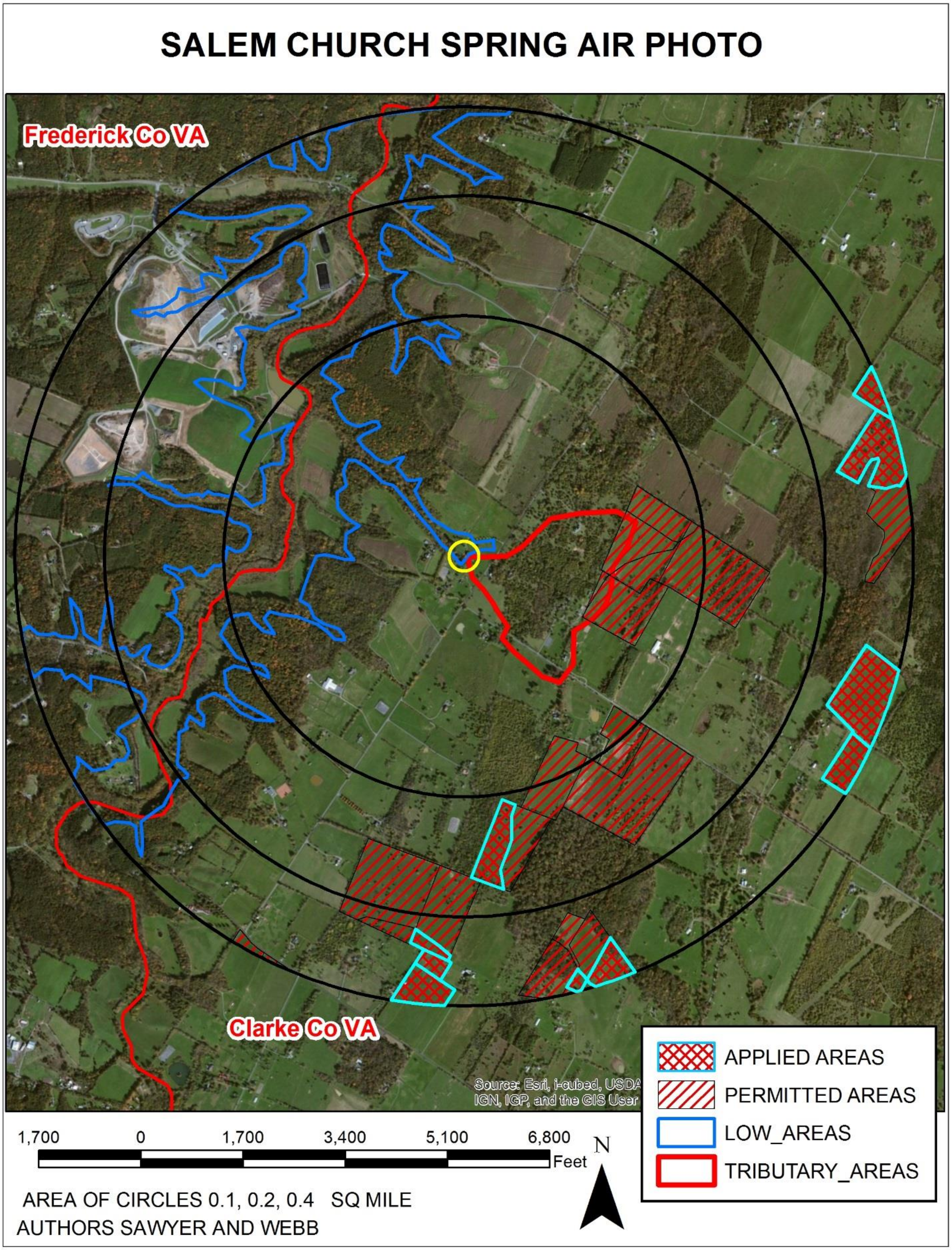
A3.105 Montana Hall Spring Measuring reach



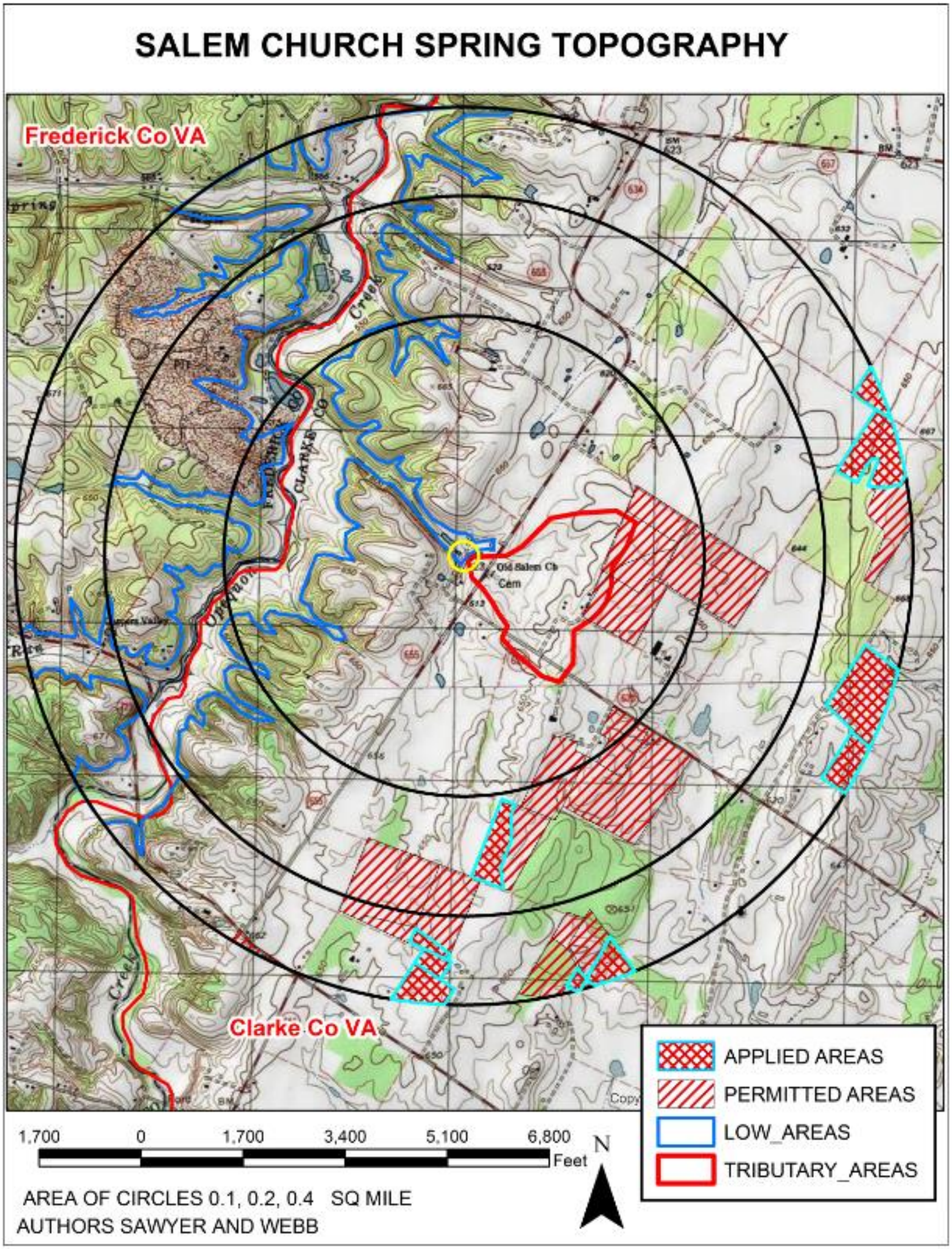
A3.111 Salem Church Spring Land Cover



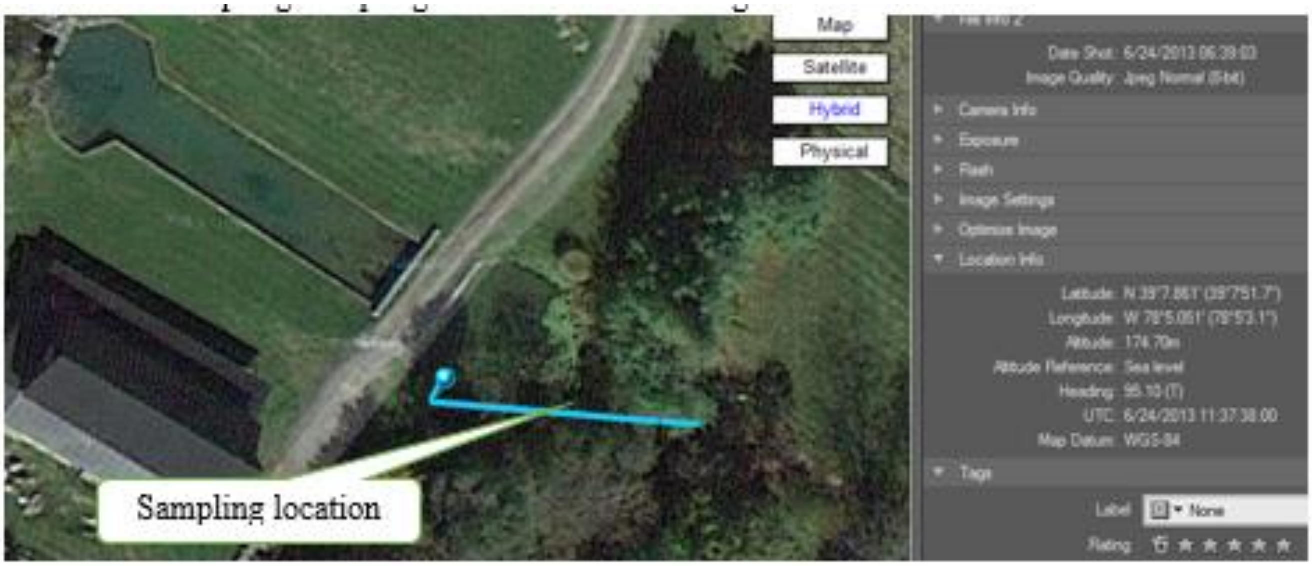
A3.112 Salem Church Spring Air Photo



A3.113 Salem Church Spring Topography



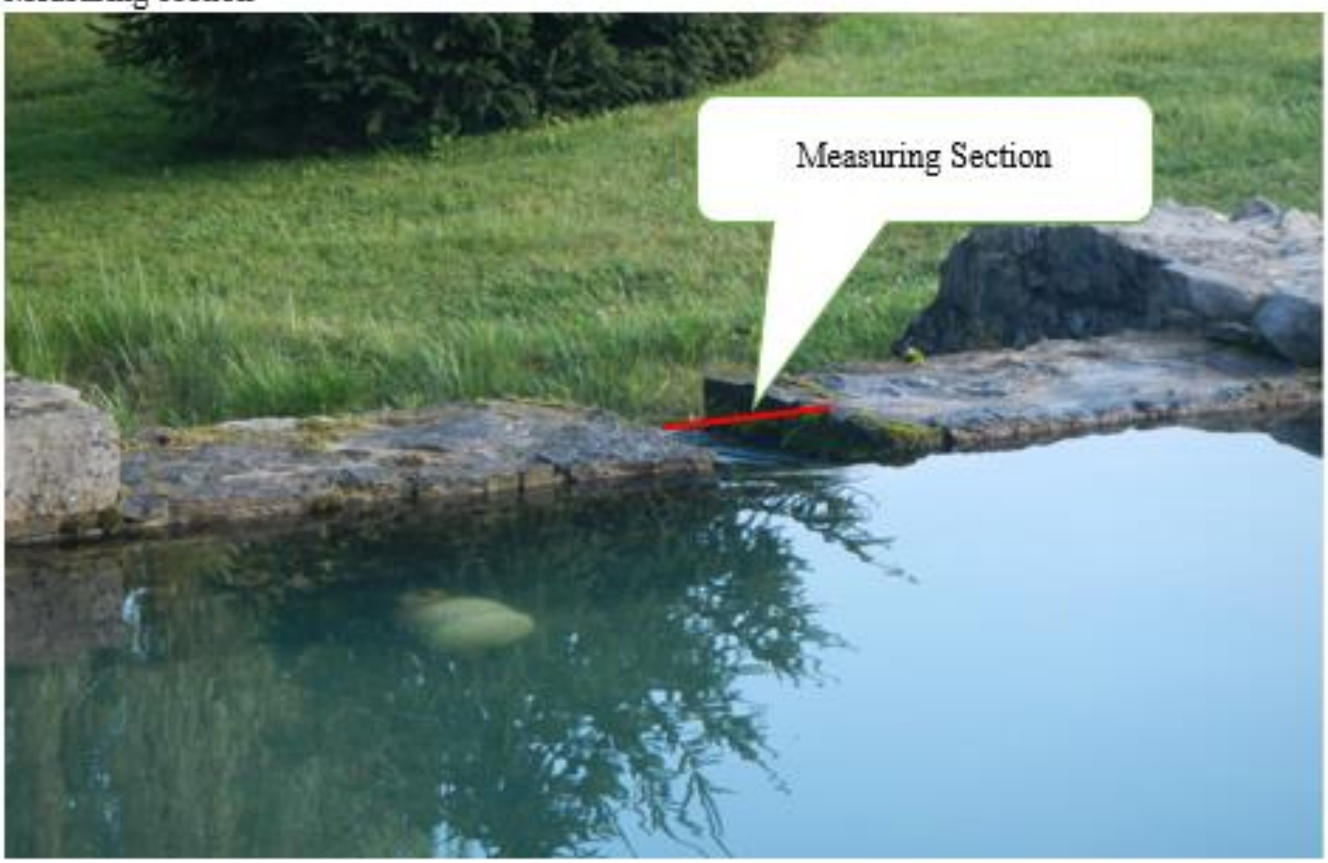
A3.114 Salem Church Spring Sampling Location



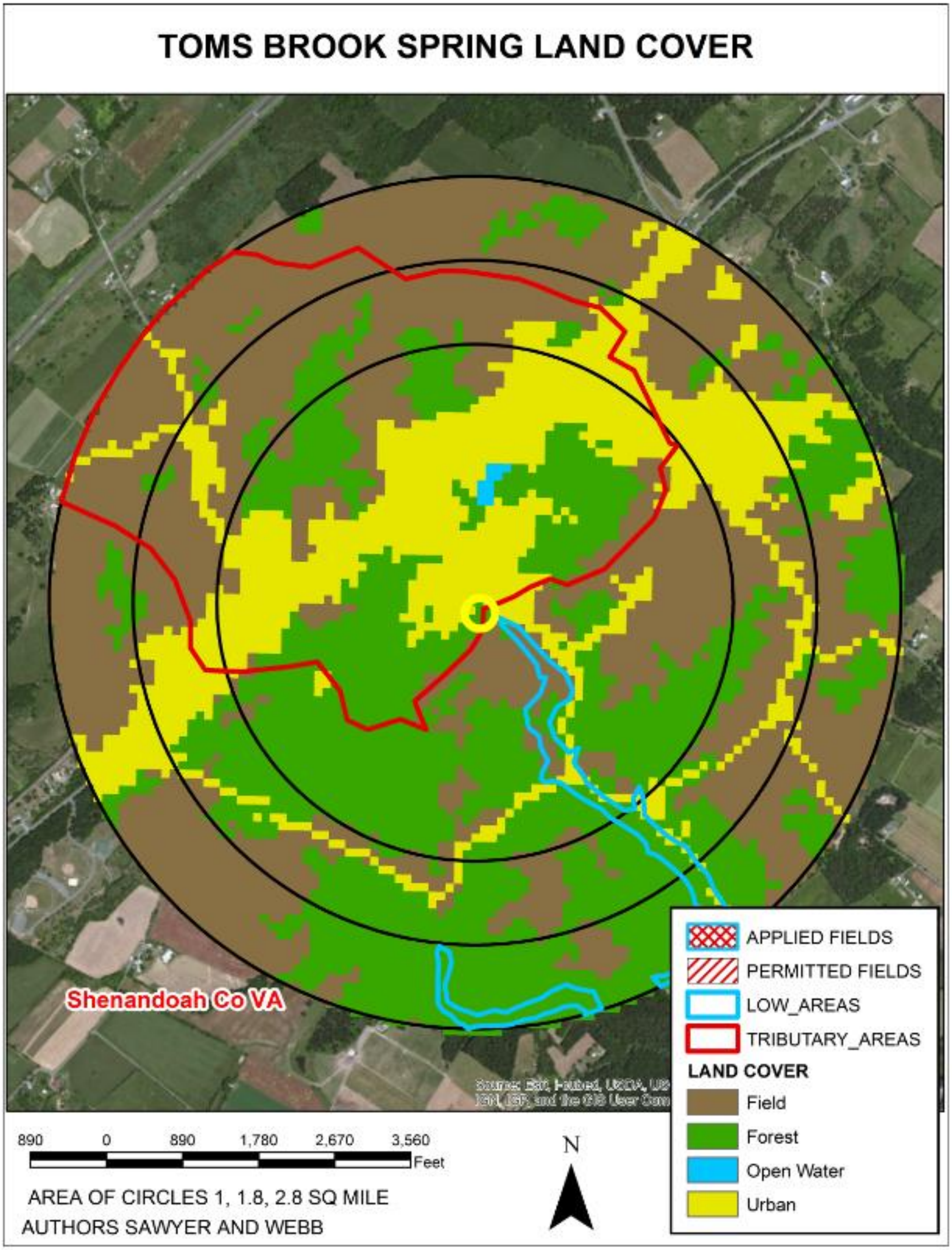
Sampling location

A3.115 Salem Church Spring Measuring section

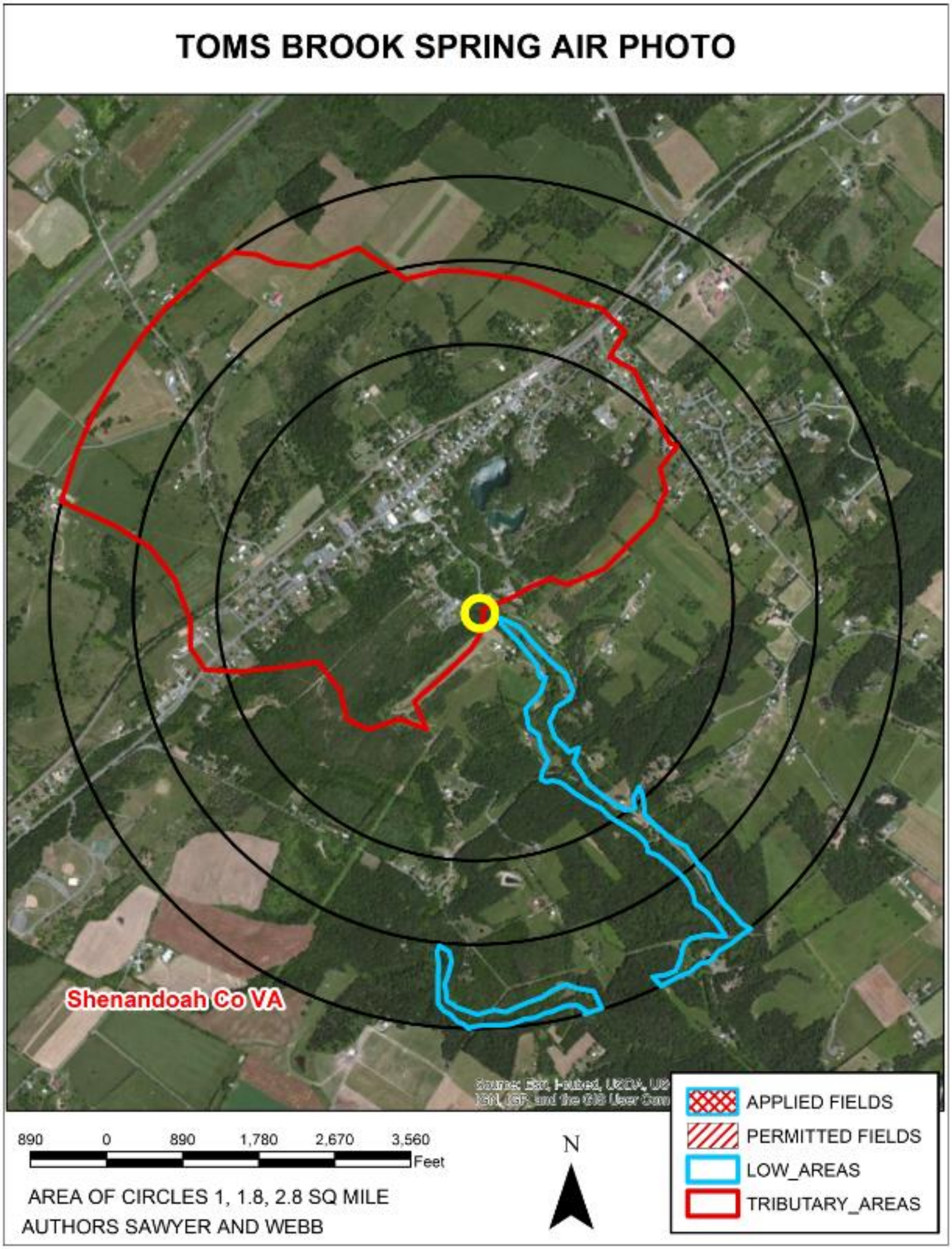
Measuring section



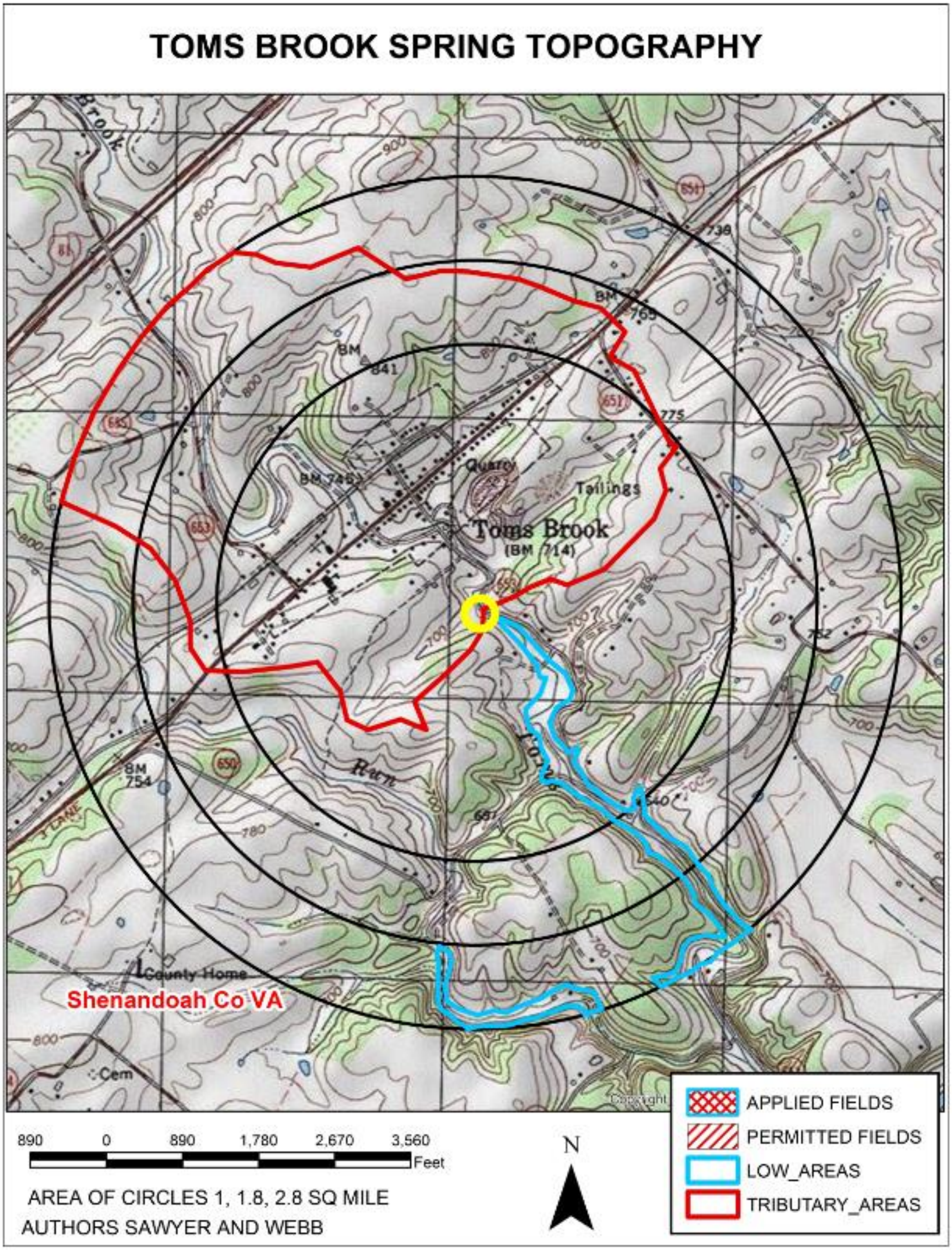
A3.121 Toms Brook Spring Land Cover



A3.122 Toms Brook Spring Air Photo



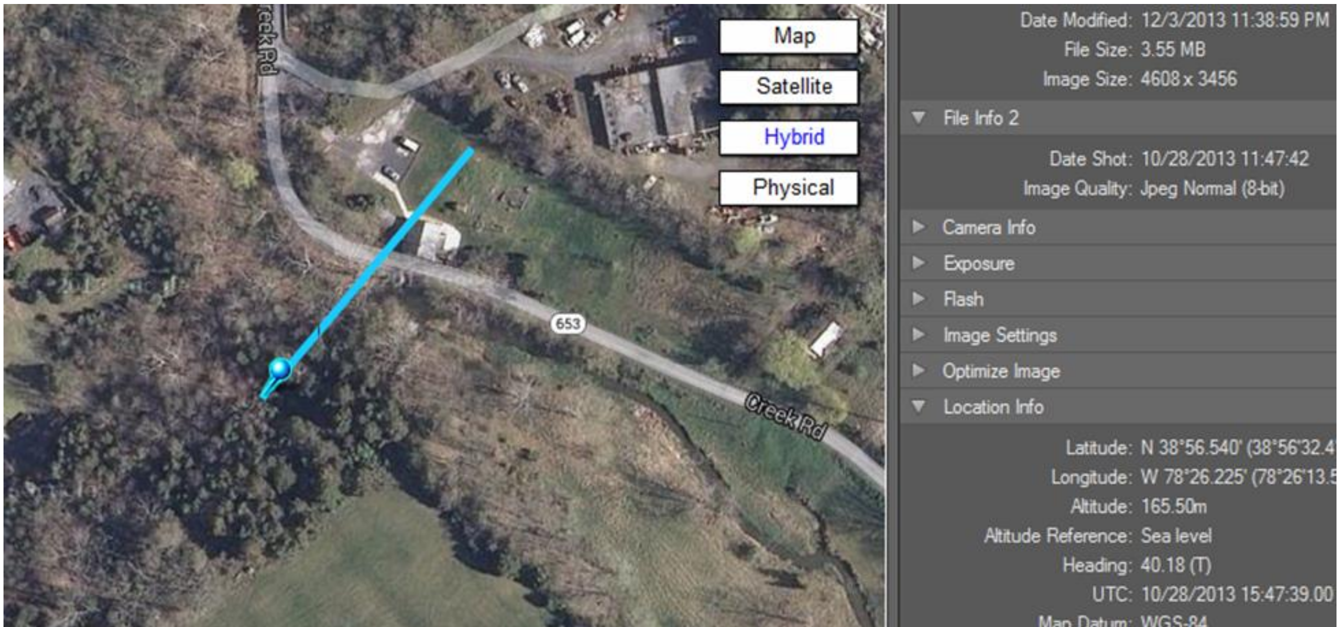
A3.123 Toms Brook Spring Topography



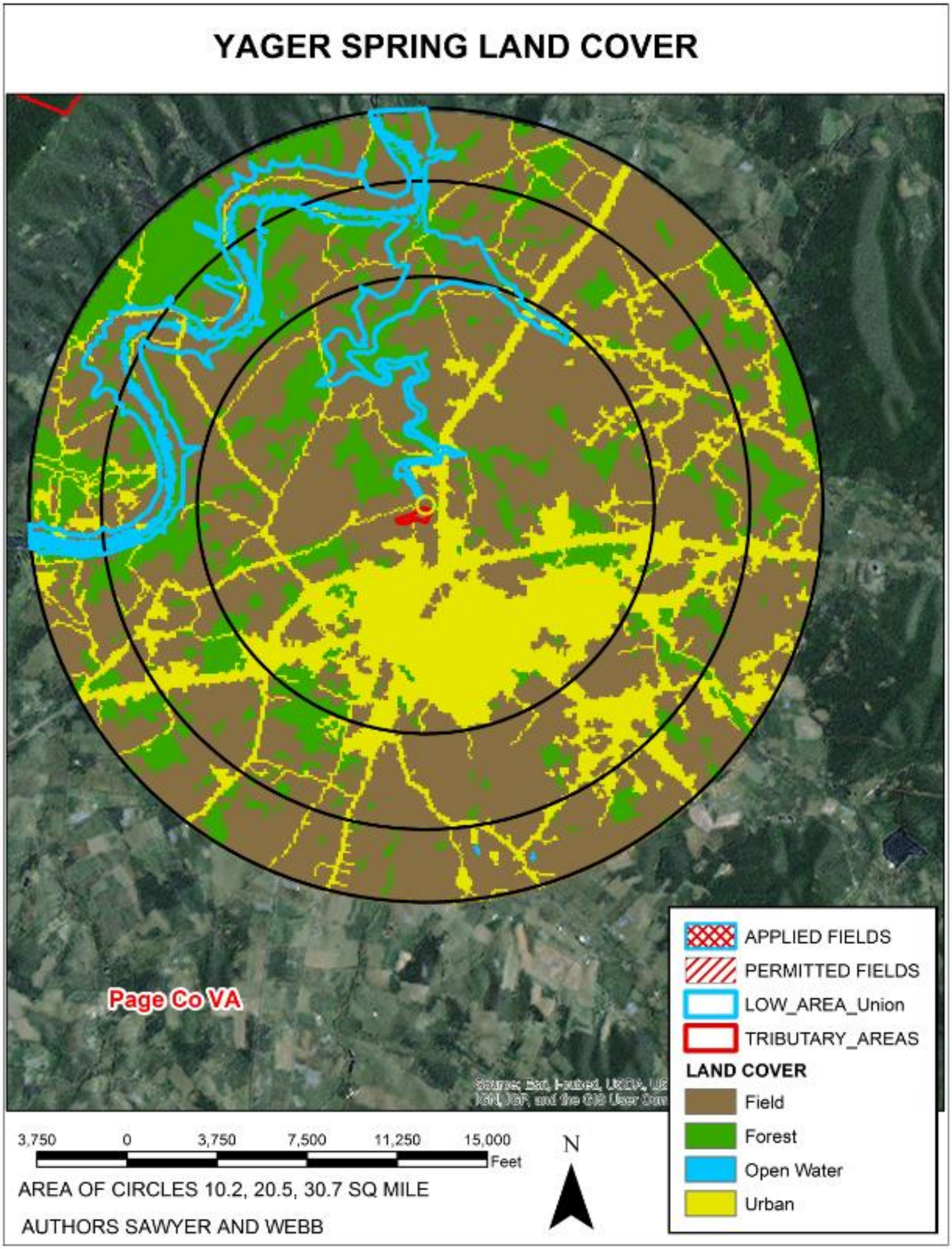
A3.124 Toms Brook Spring Sampling location

Toms Brook sampling location 6 24 2013

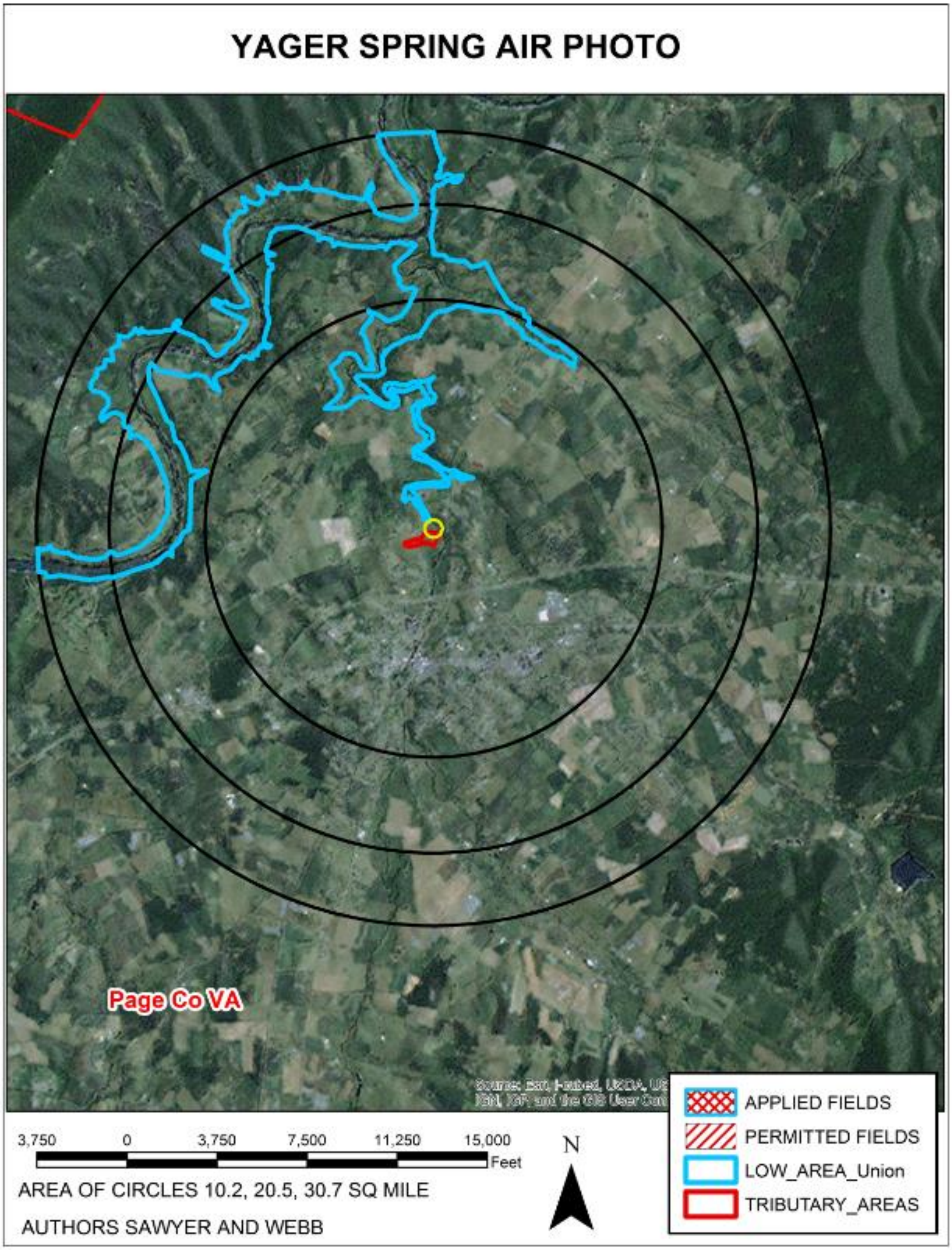
A3.125 Toms Brook Spring Measuring section



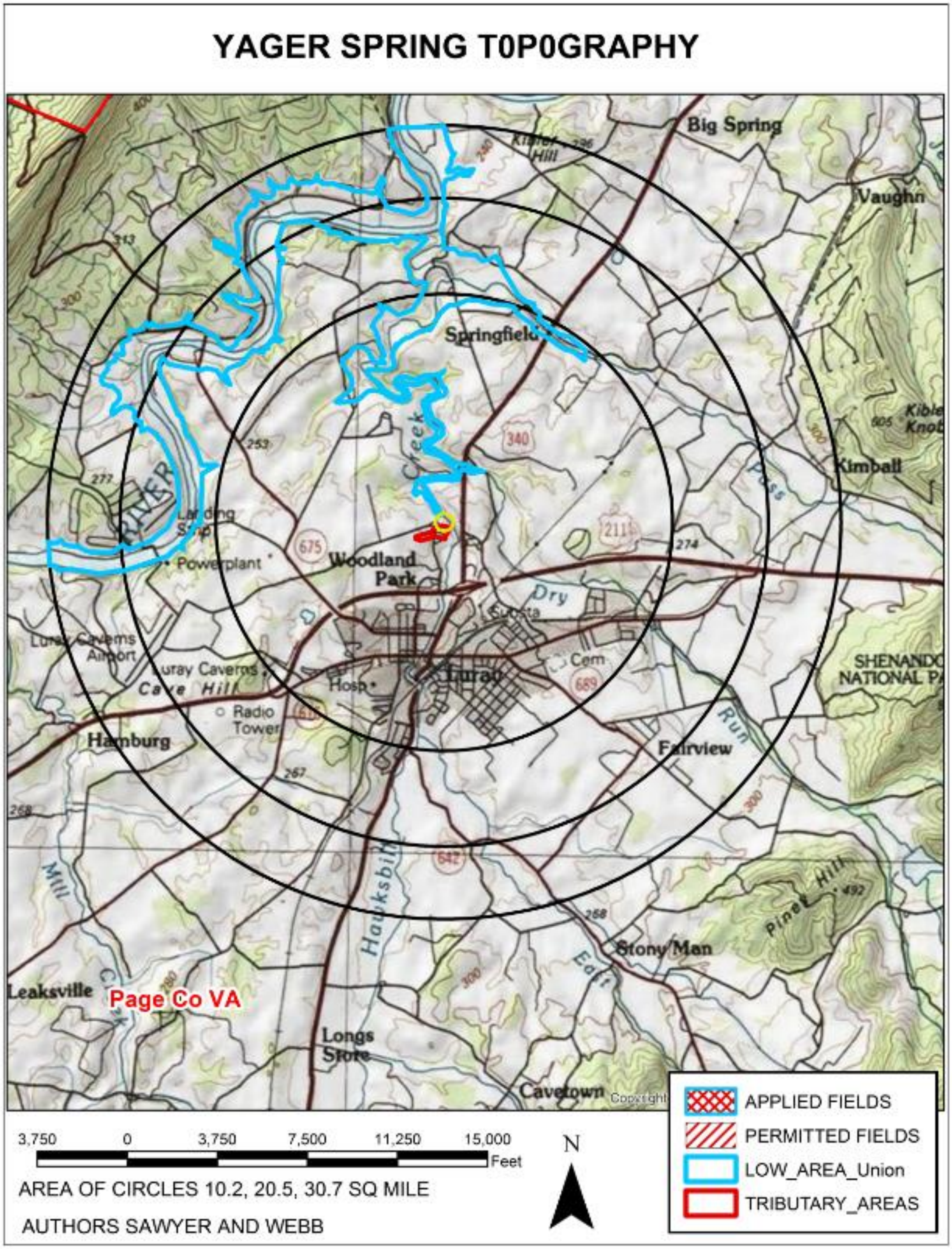
A3.131 Yager Spring Land Cover



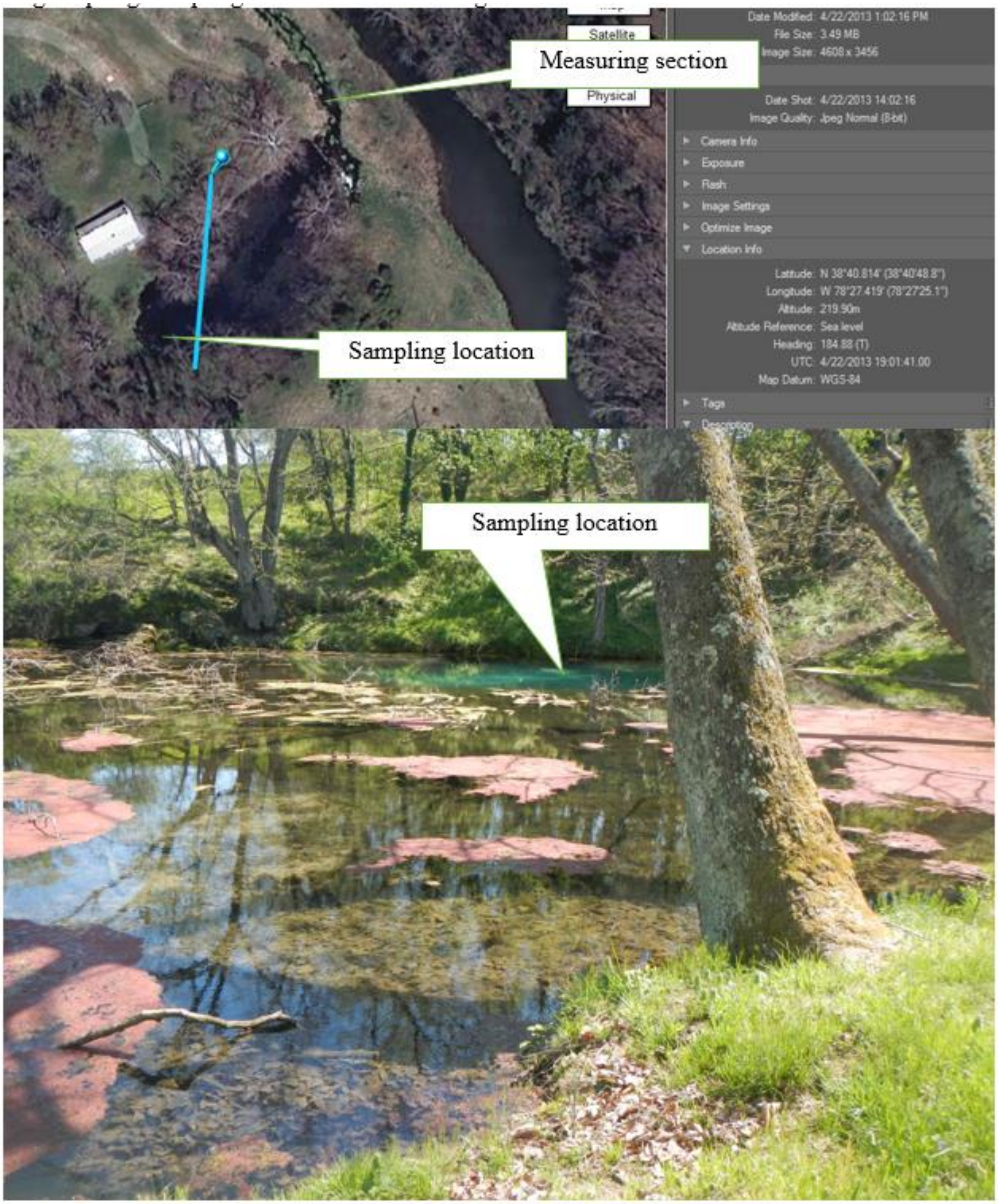
A3.132 Yager Spring Air Photo



A3.133 Yager Spring Topography



A3.134 Yager Spring Sampling location



A3.135 Yager Spring Measuring section

A4 Quality assurance information

A4.1 Laboratory and field QAPP

Quality assurance for the biosolids project included the written laboratory and field procedures of the Friends of the Shenandoah River (FOSR). The Friends procedures are available by contacting

Friends of the Shenandoah River Laboratory
Attention: Karen Andersen
1460 University Drive/ Gregory Hall
Winchester, VA 22601

And by email at
friendsofshenandoahriver@gmail.com

The FOSR procedures have been reviewed and approved by Virginia DEQ and the laboratory is a Virginia DEQ class 3 laboratory. The procedures include field sample collection, field meter calibration, sample preservation and laboratory procedures that include meter calibration, equipment cleaning.

A4.2 MEASUREMENT QUALITY ASSURANCE DATA

Measurement quality assurance for the project included: blind duplicate concurrently collected samples sent to both the FOSR and the contract laboratory Inboden Environmental Services Inc.(IES); spiked samples sent to the contract laboratory IES. ;comparison of field analyses with results from USGS sampling most of the same springs 5 to 10 years prior to this study; and comparison of results with data from other studies.

A4.21 FOSR LABORATORY BLIND DUPLICATE CONCURRENTLY COLLECTED SAMPLES

The 5 blind duplicate concurrently collected samples one for all but the first sample round were sent to the FOSR laboratory and are listed below. The results of the analysis show very close agreement between the blind samples with a site ID that includes FRB and the concurrently collected environmental sample. The analysis date shows that the samples were analyzed within 24 hours of collection. Part of the sampling protocol is to bury the samples in crushed ice within 10 minutes of collection and keep them chilled until analysis.

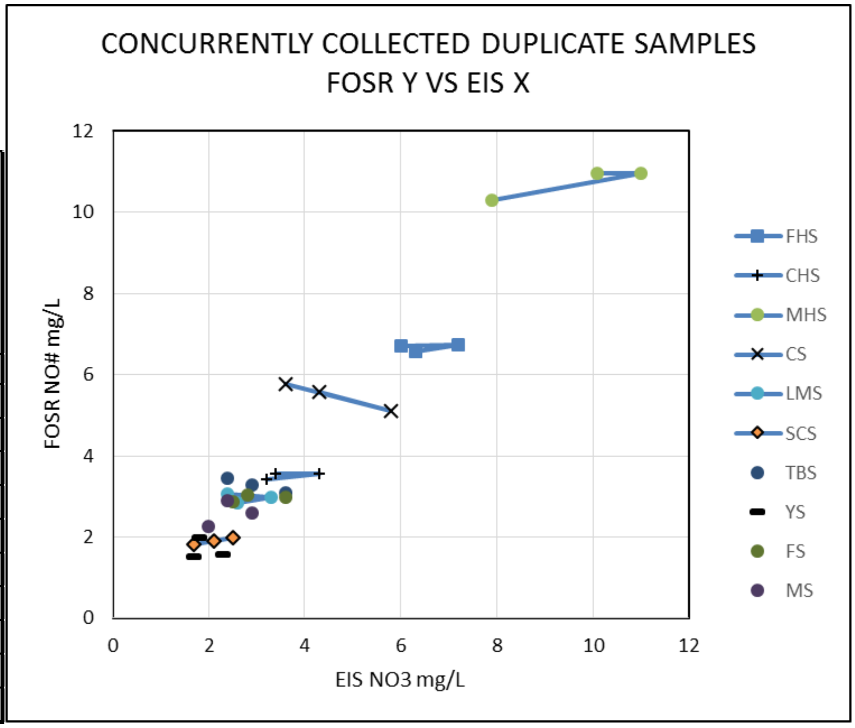
Friends of the Shenandoah River laboratory (FOSR)
Results of concurently collected "blind" samples

Site ID	Analysis Date	Date Collected	Time Collected	Split #	Nitrate mg/L as N	Nitrite (NO2) mg/L as N	Ortho Phos mg/L as P	Ammonia mg/L as N	MPN *E-coli* per 100ml
FHS: FEDERAL HILL SPRING	4/22/2013	4/22/2013	10:33	1	6.74		0.01	0.01	<1
FRB: FIELD REPLICATE BLIND	4/22/2013	4/22/2013		1	6.73		0.01	0.01	<1
FHS: FEDERAL HILL SPRING	6/24/2013	6/24/2013	10:38	1	6.72	0.01	0.01	0.01	3.10
FRB: FIELD REPLICATE BLIND K	6/24/2013	6/24/2013		1	6.75	0.01	0.01	0.01	5.20
YS YAGER SPRING	7/29/2013	7/29/2013	15:30	1	1.54	0.01	0.01	0.01	20.1
FRB: FIELD REPLICATE BLIND	7/29/2013	7/29/2013	15:30	1	1.54	0.01	0.01	0.01	19.9
CHS CARTER HALL SPRING	9/17/2013	9/16/2013	9:36	1	3.42		0.01	0.01	1.0
FRB: FIELD REPLICATE BLIND	9/17/2013	9/16/2013	9:39	1	3.42		0.01	0.01	1.0
MHS MONTANA HALL SPRING	10/28/2013	10/28/2013	9:37	1	10.99		0.01	0.01	1.0
FRB: FIELD REPLICATE BLIND	10/28/2013	10/28/2013		1	10.91		0.01	0.01	8.6

A4.22 NITRATE AND NITRITE DUPLICATE CONCURRENTLY COLLECTED SAMPLES ANALYZED BY BOTH FOSR AND IES

Results of analyses for nitrate and nitrite performed in both FOSR and the contract laboratory, Inboden Environmental Services Inc. (IES) on concurrently collected samples for the first 3 sampling rounds. The agreement between laboratories is very good When FOSR reports nitrite as 0.01 mg/L the concentration is equal to or less than 0.01mg/L. FOSR did not report nitrite results for the 4/22/2013 sampling round. The plot below of the nitrate results shows very good agreement between laboratories. It should be noted that the IES method for nitrate is for sewage and an operational range of 0.14 to 1400 mg/L. For methods with a wide range of applicability the accuracy/precision near the 2 mg/l is less than for the FOSR method that is designed to test for concentrations from 0.01 to 2 mg/L. The FOSR method required dilution of the samples where the nitrate concentration exceeded 2 mg/l. The results indicate nitrate values below 2 mg/L are probably well within 0.5 mg/L of the true value and values above 2 mg/L are well within 1 mg/L of the true value. Thus an examination of the FOSR data for each of the sites shows nitrate values are very similar from one sampling to the next. And the quality assurance data suggest that interpretations from one sampling date to the next for any site are tenuous but that the differences between sites are real and a comparison of the averages between sites is on solid ground.

IES ave Nitrate (NO3) mg/L as N	FOSR ave Nitrate (NO3) mg/L as N	IES Nitrate range (NO3) mg/L as N	FOSR Nitrate range (NO3) mg/L as N
6.5	6.7	1.2	0.2
3.6	3.5	1.1	0.1
9.7	10.7	3.1	0.7
4.6	5.5	2.2	0.7
2.8	3.0	0.9	0.2
2.1	1.9	0.8	0.2
3.0	3.3	1.2	0.4
1.9	1.7	0.6	0.5
3.0	3.0	1.1	0.2
2.4	2.6	0.9	0.6



Results of concurently collected "blind" samples compaired to FOSR data

	IES Nitrate (NO3) mg/L as N	FOSR Nitrate (NO3) mg/L as N	IES Nitrite (NO2) mg/L as N	FOSR Nitrite (NO2) mg/L as N
date of collection 2/26/2013				
Federal Hill Spring	6.3	6.57	0.01	0.01
Carter Hall Spring	3.4	3.55	0.005	0.01
Montana Hall Spring	7.9	10.31	0.009	0.01
Clifton Farm Spring	3.6	5.77	0.008	0.01
Lockes Mill Spring	2.4	3.05	0.008	0.01
Salem Church Spring	2.1	1.89	0.005	0.01
Toms Brook Spring	2.4	3.46	<0.005	0.01
Yager Spring	1.8	1.99	0.008	0.01
Fadeley Spring	2.8	3.02	0.005	0.01
McKay Spring	2.4	2.89	0.01	0.01
date of collection 4/22/2013				
Federal Hill Spring	7.2	6.74	0.005	NR
Carter Hall Spring	4.3	3.55	0.006	NR
Montana Hall Spring	11	10.96	0.007	NR
Clifton Farm Spring	5.8	5.11	>0.005	NR
Lockes Mill Spring	3.3	2.98	0.006	NR
Salem Church Spring	2.5	1.99	0.006	NR
Toms Brook Spring	3.6	3.08	0.006	NR
Yager Spring	2.3	1.58	0.006	NR
Fadeley Spring	3.6	2.99	0.007	NR
McKay Spring	2.9	2.58	0.007	NR
not reported =NR				
date of collection 6/24/2013				
Federal Hill Spring	6.0	6.72	<0.005	0.01
Carter Hall Spring	3.2	3.42	0.009	0.01
Montana Hall Spring	10.1	10.95	0.005	0.01
Clifton Farm Spring	4.3	5.58	0.019	0.01
Lockes Mill Spring	2.6	2.85	0.006	0.01
Salem Church Spring	1.7	1.81	<0.005	0.01
Toms Brook Spring	2.9	3.29	<0.005	0.01
Yager Spring	1.7	1.52	0.017	0.01
Fadeley Spring	2.5	2.86	0.011	0.01
McKay Spring	2.0	2.25	0.013	0.01

A4.23 RESULTS OF TKN and TP QA SAMPLES SUBMITTED TO THE IES LABORATORY

The results of the spikes submitted blind on 7/29/2013 to Inboden Environmental Services Inc. (IES) show that IES had difficulty in measuring TKN nitrogen less than 2 mg/L but were able to measure total phosphorus within 0.10 mg/l of the spiked value. Additional spiked samples submitted on 9/16/2013 demonstrated that had there been TKN nitrogen in the environmental samples in the 3 to 6 mg/L range that IES would have reported a concentration within 1 mg/l of the true value. And the total phosphorus reported values were within 0.1 mg/L of the spiked value. It should be noted that the spikes were made with water collected from Fadeley Spring and that water probably contained some TKN nitrogen and total phosphorus so that the reported concentrations should be above the spike concentrations. Thus the values for TKN nitrogen and total phosphorus reported for the environmental samples of generally less than 0.5 mg/L TKN N and less than 0.05 mg/L total phosphorus can be interpreted with confidence to say that the TKN N was never more than 1mg/L and was probably less than 0.5mg/L in any Spring during the 6 sampling events and that the total phosphorus was never more than 0.2 mg/L and was probably less than 0.05mg/l during the sampling events.

Results of spiked samples submitted blind to Imboden Environmental Services Inc. (IES)

SPIKED QA SAMPLES					
all made with spiking Fadeley Spring water		Reported values		spiked concentration	
9/16/2013	all values in mg/L	TKN	Tot P	TKN	Tot P
Saratoga Spring		6.9	0.35	6.0	0.30
Providence Spring		2.6	0.65	3.0	0.60
Ninavi Spring		6.5	0.20	6.0	0.30
Buck Marsh Spring		3.4	0.67	3.0	0.60
Fadeley Spring		<0.5	<0.05		

SPIKED QA SAMPLES					
all made with spiking Fadeley Spring water		Reported values		spiked concentration	
7/29/2013	all values in mg/L	TKN	Tot P	TKN	Tot P
HPS		<0.5	<0.05	2.0	0.00
BMS		<0.5	0.1	1.0	0.10
NVS		<0.5	0.21	0.0	0.20
LS		<0.5	<0.05	1.0	0.00
STS		<0.5	0.12	0.0	0.10
PVS		0.8	0.32	2.0	0.20
Fadeley Spring		<0.5	<0.05		

DUPLICATE QA SAMPLES submitted blind to Imboden Environmental Services Inc. (IES)

Sample ID	IES TKN N	IES Tot P	field REP ID	FIELD REP IES TKN N	FIELD REP IES Tot P
6/24/2013 all values in mg/L					
Federal Hill Spring	<0.5	<0.05	G	<0.5	<0.05
Carter Hall Spring	<0.5	<0.05	H	<0.5	<0.05
Montana Hall Spring	<0.5	<0.05	C	<0.5	<0.05
Clifton Farm Spring	<0.5	<0.05	J	<0.5	<0.05
Lockes Mill Spring	<0.5	<0.05	D	<0.5	<0.05
Salem Church Spring	0.6	<0.05	A	<0.5	<0.05
Toms Brook Spring	<0.5	<0.05	B	<0.5	<0.05
Yager Spring	<0.5	<0.05	I	<0.5	0.08
Fadeley Spring	<0.5	<0.05	E	0.7	<0.05
McKay Spring	<0.5	<0.05	F	0.6	<0.05

A4.24 CONCURRENTLY COLLECTED BLIND DUPLICATE SAMPLES SUBMITTED TO THE IES LABORATORY

On 6/24/2013 concurrently collected blind duplicate samples from each site were submitted to the IES laboratory. The results of the comparison of the blind samples with the environmental samples as shown in the table above supports the statements developed by examining the results of the spiked samples.

A4.25 COMPARISON WITH PAST DATA

During March 2013 Montana Hall spring was sampled 3 times the results of those samples are very close to the average of the 6 project samples. Except for bacteria which are elevated possibly because of a 20000 gallon manure spill up gradient a few days prior to sample collection.

Seven of the springs sampled for this study were sampled over a 6 to 8 year period 25 to 50 times by the USGS. The average of the USGS results are very close to the results of this study. There are some interesting comparisons. The specific conductance is about 30 to 40 µS higher in the samples from this project than for the average of the previous samples. The average discharges and discharge ranges are very close. The average dissolved oxygen is lower in all but 2 of the springs. The water temperature and pH are virtually unchanged. The good comparison of field measurements provides assurance that the field measurements from the springs with and without direct comparison can be used with confidence.

Results of sampling for other projects FOSR data

Site ID	Date	Date Collected	Time Collected	Split #	Nitrate mg/L (NO_3) as N	Nitrite mg/L (NO_2) as N	Ortho Phosphate PPM	Ammonia mg/L as N	*E. coli MPN/100 ml	Total Coliform MPN/100 ml	Specific Conductance @ 25°C	Stream pH	Stream T(C)	Stream DO mg/L
Montana Hall Spring	3/12/2013	3/12/2013	15:22	1	10.31		0.01	0.01	14.6	108.6-116.2	612	7.10	11.9	6.60
Montana Hall Spring	3/23/2013	3/22/2013	10:00	1	10.60		0.01		>200.5	>200.5	610	7.16	11.8	6.55
Montana Hall Spring	5/20/2013	5/20/2013	12:47	1	10.92	0.01	0.01	0.01	0.0	>200.5	616	7.05	12.5	5.83
Montana Hall Spring	average of project samples				*10.61*	*0.01*	*0.01*	*0.01*	*7.30*		*613*	*7.10*	*12.07*	*6.33*

Comparison to previous USGS data

Carter Hall Spring CHS	Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
	2/25/2013			618	4.5	7.30	7.18	12.7
	4/22/2013			NR	6.0	7.41	NR	12.9
	6/24/2013			628	8.1	7.12	7.00	12.9
	7/29/2013			615	6.4	7.06	7.16	12.2
	9/16/2013			601	5.1	6.94	7.18	12.8
	10/28/2013			616	4.8	8.39	7.09	12.8
		max		628	8.1	8.39	7.18	12.9
		min		601	4.5	6.94	7.00	12.2
		ave		616	5.8	7.37	7.12	12.7
46WS 1	USGS data 57 samples		31 flow measurements					
	4/14/2009	max		723	9.6	9.80	7.50	13.0
	4/23/2003	min		543	3.5	6.60	6.80	12.3
	2/10/2006	ave		577	5.4	7.48	7.07	12.7

Clifton Farm Spring CS	Sampling Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
	2/26/2013			600	0.5	6.56	7.06	12.4
	4/22/2013			NR	0.2	7.94	NR	12.5
	6/24/2013			601	0.3	7.28	7.12	12.6
	7/29/2013			603	0.4	7.21	7.04	12.6
	9/16/2013			604	0.1	7.17	7.13	12.9
	10/28/2013			605	0.2	7.93	7.03	12.6
		max		605	0.4	7.94	7.13	12.9
		min		600	0.1	6.56	7.03	12.4
		ave		603	0.3	7.35	7.08	12.6
47XS 6	USGS data 24 samples		24 flow measurements					
	4/14/2009	max		590	1.9	9.30	7.60	12.7
	4/23/2003	min		510	0.0	6.10	6.50	9.4
	2/10/2006	ave		560	0.5	7.13	7.00	12.3

Federal Hill Spring	Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
				uS	cfs	mg/l	units	water C
	2/25/2013			544	0.8	7.06	7.27	12.6
	4/22/2013			NR	0.9	6.41	NR	12.9
	6/23/2013			543	1.3	6.42	7.19	12.9
	7/29/2013			546	0.8	6.48	7.20	12.1
	9/16/2013			546	0.7	6.49	7.24	12.7
	10/28/2013			548	1.5	7.74	7.28	12.8
		max		548	1.5	7.74	7.28	12.9
		min		543	0.7	6.41	7.19	12.1
		ave		545	1.0	6.77	7.24	12.7
46WS 7	USGS data 24 samples		10 flow measurements					
	4/15/2009	max		542	1.3	8.70	7.40	12.8
	8/11/2005	min		493	0.7	6.60	7.00	12.5
	3/9/2007	ave		511	1.1	7.06	7.15	12.7

Lockes Mill Spring	Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
	2/26/2013			650	1.8	5.77	7.05	12.2
	4/22/2013			NR	2.2	6.80	NR	12.3
	6/24/2013			635	2.8	6.84	7.03	12.4
	7/29/2013			640	2.0	6.39	7.06	12.1
	9/16/2013			642	1.5	6.07	7.10	12.6
	10/28/2013			648	1.3	7.27	7.03	12.5
		max		650	2.8	7.27	7.10	12.6
		min		635	1.3	5.77	7.03	12.1
		ave		643	1.9	6.52	7.05	12.4
47WS 2	USGS data 24 samples		10 flow measurements					
	4/14/2009	max		635	2.0	9.40	7.70	12.6
	12/11/1986	min		540	1.0	6.10	6.60	11.2
	6/19/2005	ave		599	1.4	7.10	7.06	12.2

McKay Spring MS	Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
	2/25/2013			736	2.7	4.44	7.21	13.3
	4/22/2013			NR	3.4	4.04	NR	13.2
	6/24/2013			692	3.5	3.32	7.04	13.5
	7/29/2013			690	1.8	2.97	7.10	12.6
	9/16/2013			705	1.1	3.15	7.18	13.5
	10/28/2013			707	1.8	4.96	7.06	13.8
		max		736	3.5	4.96	7.18	13.8
		min		690	1.1	2.97	7.04	12.6
		ave		706	2.4	3.81	7.12	13.3
45VS 2	USGS data 1 sample		no flow measurements					
	8/21/2003			560		5.00	6.30	13.3

Montana Hall Spring	Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
	2/25/2013			618	0.09	6.87	7.27	11.9
	4/22/2013			NR	0.03	6.17	NR	12.0
	6/24/2013			620	0.20	5.67	7.11	12.9
	7/29/2013			625	0.10	5.82	7.14	12.5
	9/16/2013			622	0.04	6.13	7.18	13.6
	10/28/2013			635	0.08	7.76	7.17	13.3
		max		635	0.20	7.76	7.18	13.6
		min		618	0.03	5.67	7.11	11.9
		ave		624	0.09	6.40	7.17	12.7
46WS 10	USGS data 25 samples		23 flow measurements					
	4/15/2009	max		644	0.144	7.10	7.70	14.2
	4/21/2003	min		508	0.002	3.30	6.60	10.1
	3/3/2006	ave		587	0.051	5.61	7.05	12.4

Salem Church Spring SCS	Date	FOSR data		Specific Conductance µS @25 °C	Discharge cubic feet per second	Dissolved Oxygen mg/L	pH standard units	Water Temperature °C
	2/26/2013			602	1.3	4.95	7.00	12.6
	4/22/2013			NR	1.5	5.05	NR	12.6
	6/24/2013			627	1.5	4.19	7.00	12.9
	7/29/2013			635	0.9	3.64	7.02	12.3
	9/16/2013			631	0.2	3.85	7.07	13.1
	10/28/2013			647	0.5	6.07	6.94	13.2
		max		647	1.5	6.07	7.07	13.2
		min		602	0.2	3.64	6.94	12.3
		ave		628	1.0	4.63	7.01	12.8
46XS 9	USGS data 50 samples		24 flow measurements					
	10/28/2010	max		640	2.4	8.00	7.40	13.2
	5/13/2003	min		510	0.1	2.40	6.80	11.9
	2/2/2008	ave		596	0.7	5.09	6.96	12.7

A5 Land use Designations Used in this report.

Sources of land use information included 30 meter resolution land-use and land-cover from the USGS; Preliminary Map of Potentially Karstic Carbonate Rocks in the Central and Southern Appalachian States U.S. Geological Survey Open-File Report 2008-1154 By D. J. Weary; and coverage of field and tracts based on NRCS mapping, that were permitted for biosolids application. The tract and field data were provided by Clarke County and DEQ

The NLCD 92 Land Cover Class Definitions were used for this project are a modification of the Anderson land-use and land-cover classification system. They are described in detail at: http://landcover.usgs.gov/classes.php#wet by the USGS Land Cover Institute (LCI)
The coverage used is the 30 meter NLCD 2006 data published in 2011 02 16 by U.S. Geological Survey

The land use classes were aggregated into 7 classes for the land cover maps of the springsheds.
Fields which included primarily NLCD1992 classes 81, 82, 83, 84
Forest which included primarily NLCD1992 classes 41, 42, 43
Urban which included primarily NLCD1992 classes 21, 22, 23
Open water which included NLCD1992 class 11
Wetlands which included primarily NLCD1992 classes 91, 92
Grassland which included primarily NLCD1992 class 71
Barren which included primarily NLCD1992 classes

Fields and forest were the vast majority of the land cover for the spring sites. For each springshed the area of each of the classes was measured for 3 concentric areas with the spring at the center. The areas were based on the flow of the spring. The inner area is 1 square mile (sq mi) for each cubic feet per second (cfs) of spring flow. The next was larger area was 2 sq mi for each cfs and the largest was 3 or 4 sq mi for each cfs. The rational of selecting those areas was that in this area of Virginia the annual average stream flow is approximately 1 cfs per sq mi. Thus land within the inner circle has may be the source of water for the spring. Lands outside the larger circle probably do not contribute water to the spring. The area land contributing water to the springs is controlled by the geology of the karst rocks from which the spring emanates. The area of contribution may have only a vague resemblance to the topographic drainage area of the spring.

NLCD1992 land use class description from The USGS Land Cover Institute (LCI) include:
Water - All areas of open water
11. Open Water - all areas of open water, generally with less than 25% cover of vegetation/land cover
Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.
31. Bare Rock/Sand/Clay - Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.
32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.
33. Transitional - Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities.

Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.
41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
42. Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species `maintain their leaves all year. Canopy is never without green foliage.
43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Herbaceous Upland - Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.
71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.
81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.
84. Fallow - Areas used for the production of crops that do not exhibit visible vegetation as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.
85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al.
91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

A6 Biosolids application information.

A6.1 Land cover map development

The maps of biosolids permitted areas and applied areas show all the areas permitted for biosolids application. The applied areas show the areas that received biosolids since January 2010. The table of land use shows the acres of land on which biosolids have been applied during the period of record that started in 2001 for each of the 3 concentric areas around the spring.
The areas that can be permitted for biosolids application in Clarke were defined in 1997 by a text amendment to the County code that establishing standards for the application of Biosolids. In 2004, State law repealed Counties ability to regulate biosolid application beyond testing and monitoring. The change permits Counties to request reimbursement for expenses relating to monitoring and testing but eliminates increased setback standards that Clarke County had adopted to protect ground and surface water resources in sensitive karst areas. The County maintains the ordinance and requests applicators to comply.The areas excluded from biosolids application included areas near homes, streams, and soils less than 30 inches, steep slopes, shallow water table and sink holes etc. a copy of excerpts from the Clarke County ordinance application restrictions is included below.

A6.2 Biosolids application rules

Current application rules and Excerpts from Clarke County biosolids ordinance, listing past application restrictions

On July 15, 1997 the Board of Supervisors approved the adoption of a text amendment establishing standards for the application of Biosolids.

Beginning in 1998, two companies, Bio Gro and Recyc Systems applied biosolids in the County. Currently Synagro (formally Bio-Gro) and Wright Trucking spread on area farms.

In 2004, State law repealed Counties ability to regulate biosolid application beyond testing and monitoring. The change permits Counties to request reimbursement for expenses relating to monitoring and testing but eliminates increased setback standards that Clarke County had adopted to protect ground and surface water resources in sensitive karst areas. The County maintains the ordinance and requests applicators to comply.

All applications have been closely monitored by County and State representatives and have been in compliance with all requirements. In accordance with State Regulations, Counties may be reimbursed for the testing and monitoring expenses.

Beginning January 1, 2008 the Virginia Department of Environmental Quality (DEQ) assumed regulatory oversight of all land application of treated sewage sludge, commonly referred to as biosolids.

This action, which moves oversight of the Biosolids Use Regulations from the Virginia Department of Health to DEQ, was at the direction of the 2007 General Assembly, which voted to consolidate the regulatory programs so that all persons land applying biosolids would be subject to uniform requirements, and to take advantage of the existing compliance and enforcement structure at DEQ. DEQ has established an Office of Land Application Programs within the Water Quality Division to manage the biosolids program, as well as land application of industrial sludges, septage, livestock and poultry waste, and water reclamation and reuse. The Virginia Department of Health will continue to consult with DEQ and advise the public on health issues related to biosolids applications. State Web Site

Current new State regulations require:

· Nutrient Management Plan to be submitted with application

· Posting of property 48 hours prior to application

· No spreading on snow

Excerpts from Clarke County code on biosolids:
3-C-2-b **Bio-Solids Land Application**

(3) Bio-Solids Land Application shall be conducted in accord with the following standards:

(a) Bio-solids shall not be applied in areas with a slope exceeding 15% or where bedrock is shallow or the water table is high.

1) Depth to Bedrock: Biosolids may not be applied to soil types with a depth to bedrock of less than 30 inches as identified in Table 16 of the Soil Survey of Clarke County, Virginia (USDA, 1982). These include the following soil types: 1B, 1C, 5B, 5C, 7D, 8D, 9D, 12D, 12E, 13D, 13E, 14C, 15B, 15C, 17B, 28B, 28C, 29C, 32B, 58D.

2) Depth to High Water Table: Biosolids may not be applied to soil types with a depth to high water table of less than 30 inches as identified in Table 16 of the Soil Survey of Clarke County, Virginia (USDA, 1982). These include the following soil types: 1B, 1C, 24, 25B, 26B, 26C, 27B, 30B, 56. 3) If an applicator believes the Soil Survey is inaccurate, the applicator shall demonstrate to the Zoning Administrator that a minimum depth of 30 inches to bedrock or ground water exists. Demonstrating adequate depth shall be determined by auger borings. Auger borings shall be collected in the following manner:

a) To determine depth of bedrock, there shall be at least one boring for each soil type in question with a minimum of one boring per 10,000 square feet.

b) To determine depth to high water table there shall be at least one boring for each soil type in question with a minimum of one boring per 10,000 square feet. Borings shall be placed in the lowest areas of the soil type. Borings shall be exactly 30 inches deep. Groundwater may be assumed to be within two feet of the soil surface if any water appears in the bottom of the hole after 30 minutes (one hour if the soil is "heavy textured", i.e., high in clay content).

(b) Bio-Solids shall not be applied within the EPA designated Sole Source Aquifer of Prospect Hill Spring. This encompasses the surface water drainage area of Page Brook, and the Natural Resource Overlay District.

(c) In addition to the setback requirements established by the Virginia Department of Health, as listed in items one through six below, the additional setbacks, listed in items seven through seventeen below, shall be complied with:

1) occupied dwellings 200 feet (unless waived in writing by the owner and occupant of the dwelling)
2) Property line 100 feet (unless waived in writing by the owner of the adjacent property)
3) Public rights of way 10 feet
4) Rock outcrop 25 feet
5) Agricultural drainage ditches with slopes < 2% 10 feet
6) Private wells 100 feet
7) Intermittent Streams or drainage swales 50 feet
8) Perennial Stream 100 feet
9) Parcels containing public water sources 1000 feet (including wells, springs, or surface water intakes)
10) Shenandoah River 100 year flood plain
11) Sinkholes 100 feet (sinkholes as defined in the Clarke Co. Soil Survey)
12) Springs-perennial -above spring 500 feet -below spring 200 feet
13) Incorporated town limits 1000 feet

14) The Berryville Annexation Area 1000 feet
15) Residential zoning districts 1000 feet
16) Parcels containing public or private schools, authorized by the Commonwealth of Virginia, providing instruction at any grade(s) from K through 12, with at least 50 students 1000 feet
17) Other human created, animal created, 100 feet or natural features that could allow bio-solids to migrate to surface water or ground water to be identified by the applicator and the Zoning Administrator (including but not limited to perc. holes, old foundations, pulled up trees, animal holes on slopes, etc.)

GLOSSARY

APPLIED FIELDS	Are fields within the springshed that have had biosolids applied since January 1, 2010
cfs	In this study cubic feet per second are units used to describe the flow of water .
E-coli	Are bacteria that are present in the feces of warm-blooded mammals and do not occur naturally in soil and vegetation thus the presence of which are an indicator of recent contamination.
FOSR	Friends of the Shenandoah River friendsofshenandoahriver@gmail.com http://fosr.org
IES	Imboden Environmental Services Inc. The laboratory that provided total phosphorus and total Kjeldahl nitrogen analyses and quality assurance nitrate and nitrite analyses
LOW AREAS	Are areas within the springshed that are lower than the surface of the spring.
mpn	MPN stands for 'Most Probable Number' and in the past referred to a method that uses dilution cultures and a probability calculation to determine the approximate number of viable cells in a given volume of sample. The Colilert® method used to enumerate *E-coli* in this study has been developed to express the results as as a concentration of *E-coli* bacteria in the sample (expressed as the number of bacteria per 100 mL of sample)
nitrogen	In this report all forms of nitrogen are reported as N
phosphorus	In this report all forms of phosphorus are reported as P.
PERMITTED FIELDS	Are fields within the springshed that have been permitted for biosolids application. All the APPLIED FIELDS are also permitted fields. Most the premitted fields have had biosolids applied since 2000.
QA	Quality assurance
QAPP	Quality assurance plan. Documents developed by FOSR to describe collection and analyses methods used in the conduct of FOSR projects. These documents are submitted to Virginia DEQ as part of the laboratory certification process.
springshed	Springshed is used in this report to designate the area of land around a spring that may contribute water to the flow of the spring. The springshed is a circle of land with the spring at the center. The springshed has 3 concentric sub areas. The smallest is approximately 1 square mile for each cubic foot per second of spring flow. The next subarea is 2 square miles for each cubic foot per second The largest subarea is 3 or 4 square miles per cubic foot per second of spring flow, Springshed when used without qualifiers refers to the area defined by 3 square miles per cubic foot per second of spring flow.
TKN	Total Kjeldahl nitrogen or TKN is the sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+) in the chemical analysis of soil, water, or wastewater (e.g. sewage treatment plant effluent). The Kjeldahl method is a method for the quantitative determination of nitrogen in chemical substances developed by Johan Kjeldahl in 1883. The Kjeldahl method's universality, waters, fertilizers. precision and reproducibility have made it the internationally-recognized method for estimating the protein content in foods and it is the standard method against which all other methods are judged. It is also used to assay soils, waste waters, fertilizers. In this report all TKN values are reported as N
TRIBUTARY AREAS	Are areas within the springshed that are topographically postioned so that surface runoff would flow to the spring.