Environmental Assessment
for 47-039-05714, Raymond City #11,
Kanawha County, West Virginia

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Description of Site

The site is immediately off of Harmon's Creek Road on the Kanawha County side of the Putnam and Kanawha County lines, north of Charleston. The well was drilled in 2005 to the Marcellus formation and that and two other Devonian shale formations were fractured according to the operator's completion report filed with the state.[1]

George originally visited the site in November 2008 but because of construction equipment parked on the pad (for a waterline being installed along Harmon's Creek Road) his observations were limited to the perimeter of the pad and the production equipment.[2]

We returned to the site with one of the surface owners on 20 July 2009. Our objective at that time was to try to determine the location of the pit and possible location of the land application of drill waste. What we found was a large area on the pad, north of the wellhead, where sections of thick black plastic were sticking up out of the ground. The exposed plastic surrounded an area that was bare of vegetation in some places, sparsely vegetated in others. The owner told us that this was where the pit had been located when the well was drilled. He also indicated north of the pad where he and his wife had observed a powdery "cement colored" substance on leaves and vegetation. This was the presumed land application area.

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[1] The well completion report is available online at http://downloads.wvgs.wvnet.edu/BatchInfo/kanawha/4703905714compO.tif.

[2] Photographs of the site taken in November 2008 are on the *Gas Well Study, 2008* portion of our website: http://members.citynet.net/sootypaws/Woods/gaswell/comments/otherwells/5714.html. A secondary containment dike for the condensate storage tank was constructed in October 2009.

We received permission from the surface owners and began to assess the site.[3]

Description of Pad and Surroundings

The cleared area for the pad was about 100 by 200 feet, oriented roughly west to east with the wellhead more or less in the center. There seems to have been little required in the leveling of the site as there was not a cut into a hillside. The fill slope was short and the sedimentation control along the northern edge of the site consisted of a branch and log barrier. A pipeline to a nearby compressor station passed along the northern edge of the site.

The pad had a slant and depressions. The highest part of the pad was at the southeast corner, above the paved Harmon's Creek Road. From south to north there was a slight downward slope with the lowest portion of the pad being where the pit had been. It was in this area where we observed standing water in the form of shallow puddles.

Vegetation coverage on the fill slope and the southeastern corner was the best on the site. There were areas not related to the exposed plastic perimeter where coverage was sparse, similar to what we've seen at other sites reclaimed at about the same time by this operator.

A steep hillside at the north of the pad drops to a hollow. About 326 feet from the well, according to our GPS, is a spring-fed cistern on the surface owners' property.

Exposed Plastic Perimeter

Exposed black plastic created a perimeter that was roughly 15 feet wide and 100 long. At the western end within this perimeter there was no vegetation at all. Vegetation became progressively less sparse towards the east.[4] There was a portion of thick steel cable emerging from approximately the center of the space within the perimeter of exposed plastic.

Soil in this area was a fine, tan colored clay. There were small patches of darker material showing and next to one of the exposed pieces of plastic this darker material had the appearance of drill waste -- dark gray, cement-like in appearance.

When the chloride test sample for S5 was collected, less than 2 inches below the surface a dark gray horizon was encountered, similar to the

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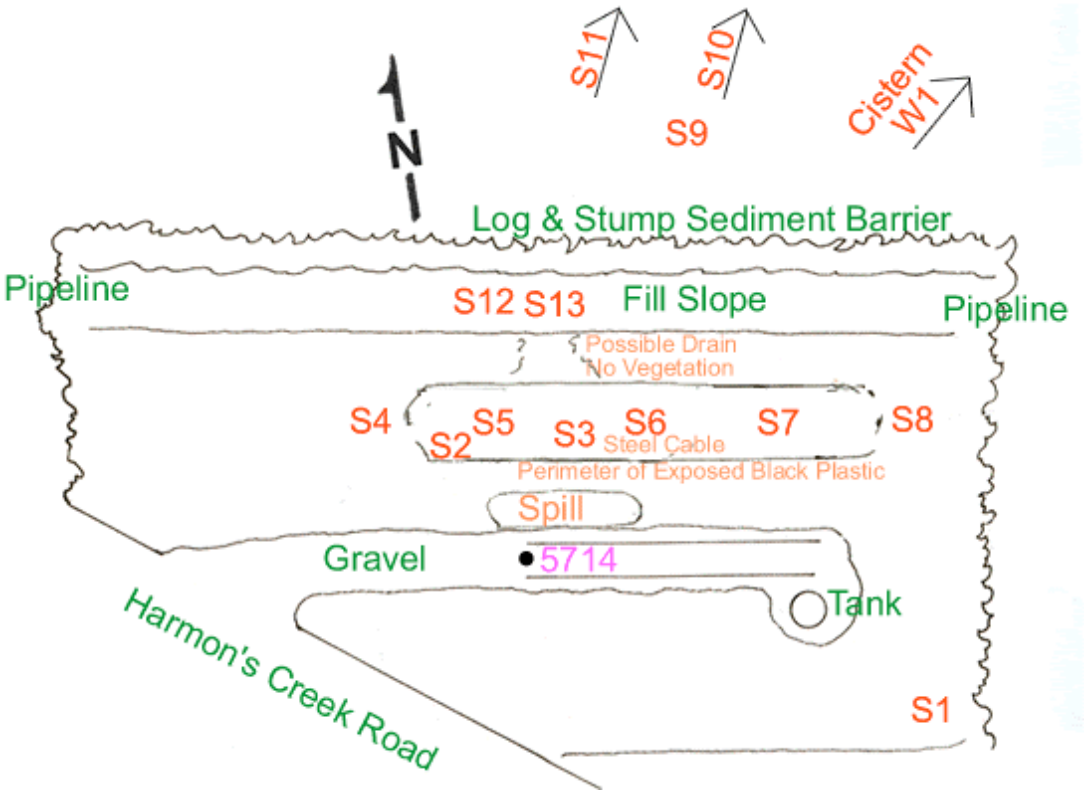
[3] The surface owners had a verbal agreement with the operator that all drill waste was to be disposed of off site. This was also the understanding of neighboring surface owners.

[4] The predominate form of vegetation on the pad is tall fescue grass. At least one variety of tall fescue is vulnerable to high chloride in soil which prohibits germination. See David A. Munn and Raymond Stewart, 1989, "Effect of Oil Well Brine on Germination and Seedling Growth of Several Crops," *Ohio Journal of Science*.

cement-like material. When the laboratory sample was collected at the same location as S5, the dark gray horizon extended from about 2 inches below the surface to as far was we excavated during sample collection, 6 inches. About a foot east of this location, there was dark gray colored soil on the surface. The only place when collecting samples where we encountered what we believe to be drill waste was within the exposed plastic perimeter.



Soil Testing

For preliminary soil and water testing we used Hach Quantab low range chloride test strips with an effective range of concentrations between 30 and 650 mg/l.[5] For lower concentration tests we consider Quantab 0.2 and 0.4 as trace and 0.6 and 0.8 as <30 mg/l chloride.

All but one of the samples collected were soil samples and were taken to try to assess two different issues. On the pad itself, soil samples were taken to try to determine the extent and nature of soil contamination in the pit area. Away from the pit area, soil samples were taken on the hillside below the pad on the north side to try to determine if this was the application area for liquid drill waste. All soil samples, except 5714-A for laboratory analysis, were taken from the surface.

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[5] A description of how we use the Quantab test strips is available on our website, George Monk and Molly Schaffnit, *Environmental Assessment -- Chloride Testing*, Sootypaws website.

One water grab sample was taken from the spring-fed cistern on the hillside below the pad to test the water for chloride.

Hach Quantab Soil Test Locations

During our initial visit to the site (20 July 2009) we tested the cistern's water (<30 mg/l chloride, sample W1) and took two soil samples from the pad within the exposed plastic perimeter where there was no vegetation. Those samples (S2 and S3) showed the presence of chloride at >650 mg/l.

A second visit to the site (on 26 July 2009) was made. After measuring the extent of the black plastic and bare and sparsely vegetated area, we created a traverse line through the length of this affected area, with markers set 28 feet apart. Five markers were set, with the central marker next to a piece of thick steel cable that projected from the soil's surface.[6] These are samples S4-S8 on the map. Samples S4 and S8 were taken outside the perimeter of exposed black plastic.

North of the pad, on the hillside below, three locations were tested (S9 - S11). According to our GPS these were roughly 116 to 216 feet from the wellhead.

On a third visit (6 August 2009) we tested two spots located on the fill slope of the pad (samples S12 and S13) to the north of the perimeter of exposed plastic, where we believed drainage from the pit area possibly was taking place. We also took samples for laboratory analysis in the same location at S5.

High Chloride Locations

The only soil locations that tested greater than a trace concentration of chloride were within the perimeter of exposed black plastic: the two initial soil tests S2 and S3 (>650 mg/l) and the later tests S5 (>650 mg/l), S6 (331 mg/l) and S7 (136 mg/l) along the traverse. One soil test, the easternmost sample on the traverse, S8, showed less than 30 mg/l (Quantab 0.6).

Low Chloride Locations

Soil tests carried out beyond the black plastic perimeter all showed just a trace of chloride or, at the eastern end of the traverse at S8, < 30 mg/l. The water grab sample from the cistern below the site tested at less than 30 mg/l (Quantab 0.8 on the scale of the test strip).

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[6] We have assumed that this is close to the center of the closed pit. We believe the piece of steel cable was used to puncture and hold the folded ends of pit liner while the pit contents were buried. We observed a similar piece of steel projecting above the surface of the closed pit of 47-079-01492, a well operated by a different company.

Table 1. Sample Locations and Chloride Concentrations

ID	Sample Location	Chloride
S1	Soil test sample from southeast corner of pad.	trace
S2	Soil test sample from north of well in area bare of vegetation, inside of exposed black plastic perimeter.	>650 mg/l
S3	Soil test sample from north of well in area bare of vegetation, inside of exposed black plastic perimeter.	>650 mg/l
S4	Soil test sample from westernmost point of traverse, outside of exposed black plastic perimeter.	trace
S5	Soil test sample 28 feet east of S4 on traverse, inside exposed black plastic perimeter.	>650 mg/l
S6	Soil test sample 28 feet east of S5 on traverse, inside exposed black plastic perimeter, next to piece of steel cable.	331 mg/l
S7	Soil test sample 28 feet east of S6 on traverse, inside exposed black plastic perimeter.	136 mg/l
S8	Soil test sample 28 feet east of S7 on traverse, outside exposed black plastic perimeter, at the easternmost end of the traverse.	<30 mg/l
S9	Soil test sample from wooded slope below pad.	trace
S10	Soil test sample from wooded slope below pad, further down slope than S9.	trace
S11	Soil test sample from wooded slope below pad, further down slope than S10.	trace
S12	Soil test sample from fill slope below northern edge of pad.	trace
S13	Soil test sample from fill slope below northern edge of pad, northeast of S12.	trace
5714-A	Soil sample for laboratory analysis, the same location as S5 but from 4-5 inches below the surface.	2,550 mg/l
W1	Water grab sample from spring-fed cistern downhill from pad.	<30 mg/l
Note: Samples taken from surface except where noted. Locations shown on map.		

Laboratory Analysis

We collected two samples of the pit material on 6 August 2009 and sent one to Pace Analytical Laboratories for analysis. The sample submitted to Pace (5714-A) was collected at between 4 and 5 inches below the surface,

where the material appeared to be entirely pit waste by its color and consistency. The sample was collected exactly from the same location as S5.

Table 2. Laboratory Analysis for 5714-A

	Concentration	CAS Number
Chloride	2550 mg/kg	16887-00-6
Arsenic	16 mg/kg	7440-38-2
Barium	203 mg/kg	7440-39-3
Cadmium	Not Detected	7440-43-9
Calcium	37100 mg/kg	7440-70-2
Chromium	27.9 mg/kg	7440-47-3
Lead	23.4 mg/kg	7439-92-1
Magnesium	6400 mg/kg	7439-95-4
Sodium	1230 mg/kg	7440-23-5
Radium 226	1.57 pCi/g	13982-63-3
Radium 228	1.35 pCi/g	15262-20-1

Site Assessment

The following assessment is based only on the concentrations of arsenic and lead found by the laboratory in the sample 5714-A, from within the perimeter of exposed plastic. Three of the metals are not considered a concern -- calcium, magnesium and sodium -- even though their concentrations were high.[7] Radium 226 and Radium 228 had concentrations within the normal background range.

The other five metals tested for were selected because they tend to appear in high concentrations in drill waste. Comparison with state soil background levels shows that the arsenic and lead concentrations were higher than the maximum.[8] Our assessment is based on these two metals, though we are also concerned with the high concentration of chloride in the sample. We believe chloride is directly impacting vegetation on the surface. As mobilizer and transporter of metals of concern, a high chloride concentration also has an influence on how we must assess the site.

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[7] The Sodium Adsorption Ratio (SAR) for the sample was 1.55.

[8] West Virginia soil background concentration levels are found in Table 2-3 of West Virginia Department of Environmental Protection, 2001, *West Virginia Voluntary Remediation and Redevelopment Act: Guidance Manual Version 2.1.*

The conceptual model for this site includes a number of factors, some already mentioned such as the presence of a spring-fed cistern down hill.[9] This cistern marks a point where nearby ground and surface water are hydrologically connected.

The Tolley residence and vegetable garden is about 200 feet from the laboratory sample location.[10] The spring-fed cistern is located about 300 feet in the opposite direction. City water has recently become available to residents, but some may still use similar cisterns.

The operator's well completion report notes fresh water 92 feet below the surface, though it is possible that a perched aquifer also exists much closer to the surface as is found elsewhere on this ridge. A mile away, the seasonal high water table is just a few feet from the surface.

After the well has finished production and equipment has been removed, the pad would make an ideal homesite because of its location next to the paved road and easy access to utilities. For this reason, and also because of the existing Tolley residence, we consider this a residential site.

We noted deer hoof prints in the vicinity of the hot spot and believe that deer are attracted to this location because of the salts in the soil which they ingest.[11]

Our assessment concerns are, as derived from the site description: possible effects to surface and ground water; possible effects to humans as they live, play and garden nearby (and possibly in the future, on the site); and possible ecological effects to wildlife and vegetation.

Table 3. Screening Levels for Soil to Ground Water

	Concentration mg/kg	EPA Soil to Groundwater mg/kg	WV Soil to Groundwater mg/kg
Arsenic	16	0.292	5.8
Lead	23.4	13.5	270

EPA's soil to groundwater screening levels shows there should be a concern for both arsenic and lead's concentrations in the sample. The EPA

[9] At this time the cistern is not being used for domestic or agricultural water supply.

[10] According to Annette Tolley, the well is 185 feet from her home and the vegetable garden is approximately 100 feet from the well.

[11] Taylor Campbell et al, 2004, "Unusual white-tailed deer movements to a gas well in the central Appalachians," *Wildlife Society Bulletin*. This study found deer traveling up to 6 km to visit a spot contaminated by gas well brine.

has two default Dilution-Attenuation Factors (DAF), a factor of 1 and a factor of 20.[12] The state's soil screening levels (taken from the de minimis soil screening levels in 60CSR3) use a DAF of 20 and still arsenic's concentration is almost 3 times higher.

There is a possibility that groundwater is being negatively affected by pit waste.

Table 4. Screening Levels for Residential Soil

	Concentration mg/kg	EPA Residential Soil mg/kg
Arsenic	16	0.389
Lead	23.4	400

Residential soil screening levels show that the arsenic concentration is 41 times the EPA's soil screening level. There is a strong possibility that current residents living nearby are being negatively affected by exposure to arsenic, and a similarly strong possibility that future residents on the site would be affected.

Table 5. Ecological Soil Screening Levels

	Concentration mg/kg	NOAA SQuiRTs Eco-SSL mg/kg	EPA Eco-SSL mg/kg
Arsenic	16	5.7 (mammals)	43 (avian) 2000 (mammals)
Lead	23.4	0.0537 (mammals)	11 (avian) 56 (mammals)

The NOAA ecological soil screening levels are much more protective than the EPA's and are based on recent research. There are no overriding reasons to use Eco-SSLs (such as endangered species or climax habitat), but we believe they need to be taken in consideration. Vegetation has been adversely affected and wildlife is attracted to the site by the presence of salts in the soil. Wildlife, such as deer, which is hunted and consumed by humans,

[12] The DAF is a mathematical expression of the diminution of a contaminant's concentration upon entering a large aquifer. See [New Jersey Department of Environment Protection], 2008, *Guidance for the Determination of the Dilution-Attenuation Factor for the Impact to Ground Water Quality*.

provides an additional pathway of exposure for the chemicals of concern on the site.

Conclusions

Soil testing for chloride was not able to show whether or not land application of liquid pit waste occurred on the hillside to the north of the site. Land application, if it occurred, happened in 2005 and chloride doesn't reside in soil for long periods of time. Other types of soil testing, such as for elevated sodium or heavy metals, should be used in a situation of this sort.

Soil testing was able to show the extent of surface contamination from the contents of the pit but did not seem to show migration of the contamination to elsewhere on the site or to off the site. We were not able to visit the site during a heavy rain to see how the pad's drainage worked. It is possible that the pit area drains west, toward the Tolley residence across Harmon's Creek Road, instead of north. Diminishing surface chloride concentrations on the eastern segments of the traverse suggest that the pit's liner bottom may not be intact.

Heavy equipment and pipe parked on the pit area in 2008 and early 2009 while a water line was being installed along Harmon's Creek Road may have been a factor toward the disturbance of pit material and liner. The primary factor was the shallow and improper burial of the pit's contents. The shallow burial of pit waste and destruction of pit liner cover occurred earlier, during reclamation of the site by the operator after completion of the well. The highest point on the pad, where sample S1 was taken, was constructed of soil scraped from other parts of the pad as bits of torn black plastic and orange plastic fencing, used around the pit, attest. The state's regulations do not offer guidance, though other states require encapsulation of the pit's contents and a soil cover of at least 18 inches.[13] The Argonne National Laboratory recommends a minimum of 3 feet cover.[14]

Site assessment based on laboratory results from a single sample indicate that further assessment is required if the operator wishes to defer remediation. Screening levels for arsenic show that there's a concern for groundwater contamination and for the health of current nearby residents and potential future residents on the site.

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[13] Commonwealth of Pennsylvania, *Pennsylvania Code, Chapter 78.62*, subsections (A)17 and (A)18.

[14] Argonne National Laboratory, *Fact Sheet - Onsite Burial (Pits, Landfills). Drilling Waste Management.*

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Photograph 1. View of the pit area showing perimeter of exposed black plastic (indicated by red circles). Molly is standing at easternmost edge of perimeter about 100 feet away. Sparsely vegetated area with highest chloride tests is in foreground. Photograph was taken looking east.

Photograph 2. Portion of exposed black plastic. Deer tracks are visible in foreground.

Photograph 3. Taken in October 2009, this photograph shows extensive deer activity at the location where samples S2, S3 and S5 were taken. The location for sample S5 and laboratory sample 5714-A is indicated by the green shotgun shell.

Photograph 4. Piece of steel cable emerging from surface. This is the approximate center of the perimeter of exposed black plastic and is the location of soil test S6.

Photograph 5. Traverse through pit area with locations of soil samples. Residence is on other side of Harmon's Creek Road. Photograph taken looking west.

Photograph 6. Looking up hillside below the well toward the northern edge of the pad. The hillside grade is approximately 36%. This photograph was taken from the cistern area.

Photograph 7. The spring-fed cistern below the well pad. The cement block cistern is covered with sheets of metal roofing and its overflow drainage is visible in the foreground.