Typical Production Sequence for Marcellus Shale Gas Operations

1. Site preparation: clearing, road, grading, gravel, drainage
2. Drill rig move, set up; Drilling operations; remove rig
3. Hydraulic fracturing; sand kings, frac pumps, sand cans
4. Completions; condensate and brine tanks
5. Gas processing on well pads
6. Pipelines and Compressor
7. Compressors and Gas Processing Plants

What we see on the roads tells us what is occurring on the well pads.

Index to Photographs Displaying the Exploration and Production process at Shale Gas well sites and on road equipment required.

Section Number

1. Introduction—Typical Production Sequence of Shale Gas
2. Well pad site preparation and earth moving equipment
3. Drilling vertical and horizontal well sections
4. Well casing installation; cementing during drilling
5. Completions: Hydraulic fracturing process; general overviews
6. Frack tanks; AKA—500 barrel wheelies; water storage tanks; water impoundments
7. Hydraulic fracturing pumps; mixers; examples from different sub-contractors
8. Sand delivery and storage; sand kings; sand cans; sand castles
9. Fracturing chemicals; delivery, trucks and totes
10. Wells put into production; flaring; well heads; storage tanks on well pads
11. Well pad completed; gas & liquid separators; Vapor recovery units; gas processing
12. Miscellaneous and multipurpose trucks and equipment
13. Pipelines and compressors
14. Waste disposal process and trucks

Assembled by Bill Hughes, Wetzel County, WV ----- Feb. 16, 2015 3 score + ten

SITE PREPARATION

- Years before any dirt is moved to construct a well pad, a great deal of courthouse research has occurred to lease mineral rights, locate surface owners, survey a well pad and access road, and negotiate terms of surface damages.
- Arrangements will be made to acquire and store the huge amounts of water. This storage must be convenient and close by.
- Well pad areas might range between 4 and 25 acres disturbed.
- Timber will be cut and pushed out of the way; stumps removed.
- It is only for site prep that large earth-moving equipment is needed.
- Once the site is leveled, hundreds of dump trucks will bring the rocks that will provide the foundation for the well pad.

Notice size for comparison in next few slides

Heavy Equipment for Well Pad Work

NOTE:
A Red circle ◯ will surround some of this big equipment on some of the following well pad site prep photographs


D8T
CAT
08/16/2012 2:45 pm


01/04/2012 12:03 pm


DEERE
Hertz Equipment Rental
Talbert
01/04/2012 12:05 pm


Stone Energy Howell Well Pad Site Preparation
Wetzel County, WV
Photo by Skytruth

NOTES:

THE NEXT GROUP OF SLIDES SHOWS THE BEFORE AND AFTER OF WELL PAD CONSTRUCTION SITE PREPARATIONS AND THEN WHAT IT LOOKS LIKE AFTER THE WELL PAD IS COMPLETE.

1. Slide **10 + 11** are the Gastar pad in Wetzel County.

2. Slides **12 + 13 + 14**, show the Triad Hunter Ormet 2 well pad in Monroe County, in Eastern Ohio. Slide **11** is site prep; **12** is pad done; **13** shows drilling on the pad.

3. Slide **15 + 16 + 17** show same before and after and in use for Stone Energy Pad 3, in Lewis Wetzel Wildlife Management Area.

4. Slides **18 + 19**, same for Stone Energy Bowyers pad in western Wetzel county.

Beginning site preparation for small Gastar well pad

See next slide


Almost Finished Gastar
well pad in Wetzel County
09.28.2014 13:56

Site construction for Triad Hunter Ormet pad in Eastern Ohio—see next two photos

Triad Hunter Ormet pad done

Triad Ormet pad drilling

Drill Pad Site Clearing

Stone Energy Pad 3 LWWMA

Stone Energy Pad 3 LWWMA

Stone Energy Pad 3

Photo by Sky Truth


Wetzel County Stone Energy Bowyers Pad

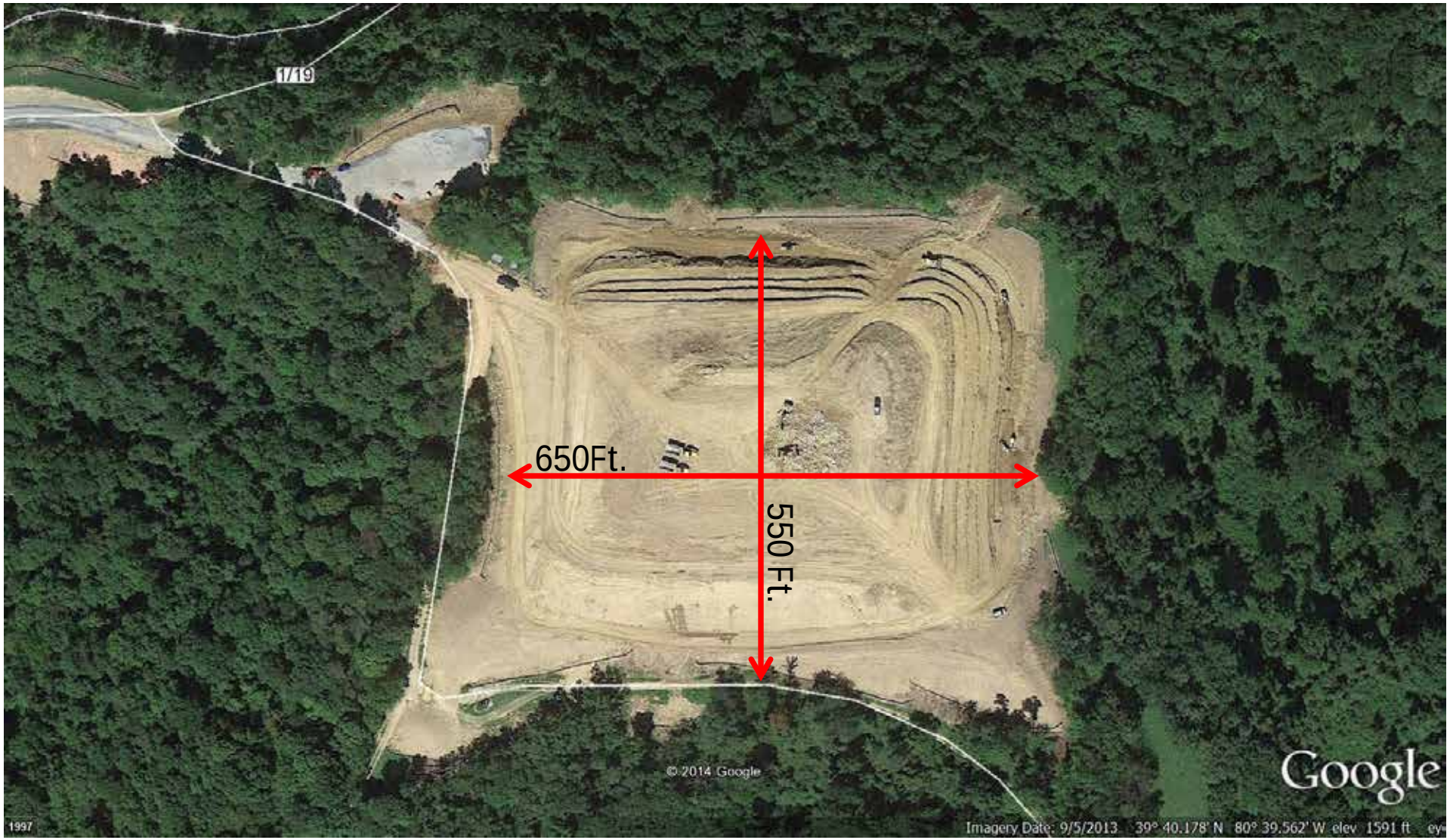
Wetzel County Stone Energy Bowyers Pad

Assorted Dump Trucks Hauling Gravel to Well Pads

More Gravel to Well Sites

Google Earth Photo of site preparation in Wetzel Co.

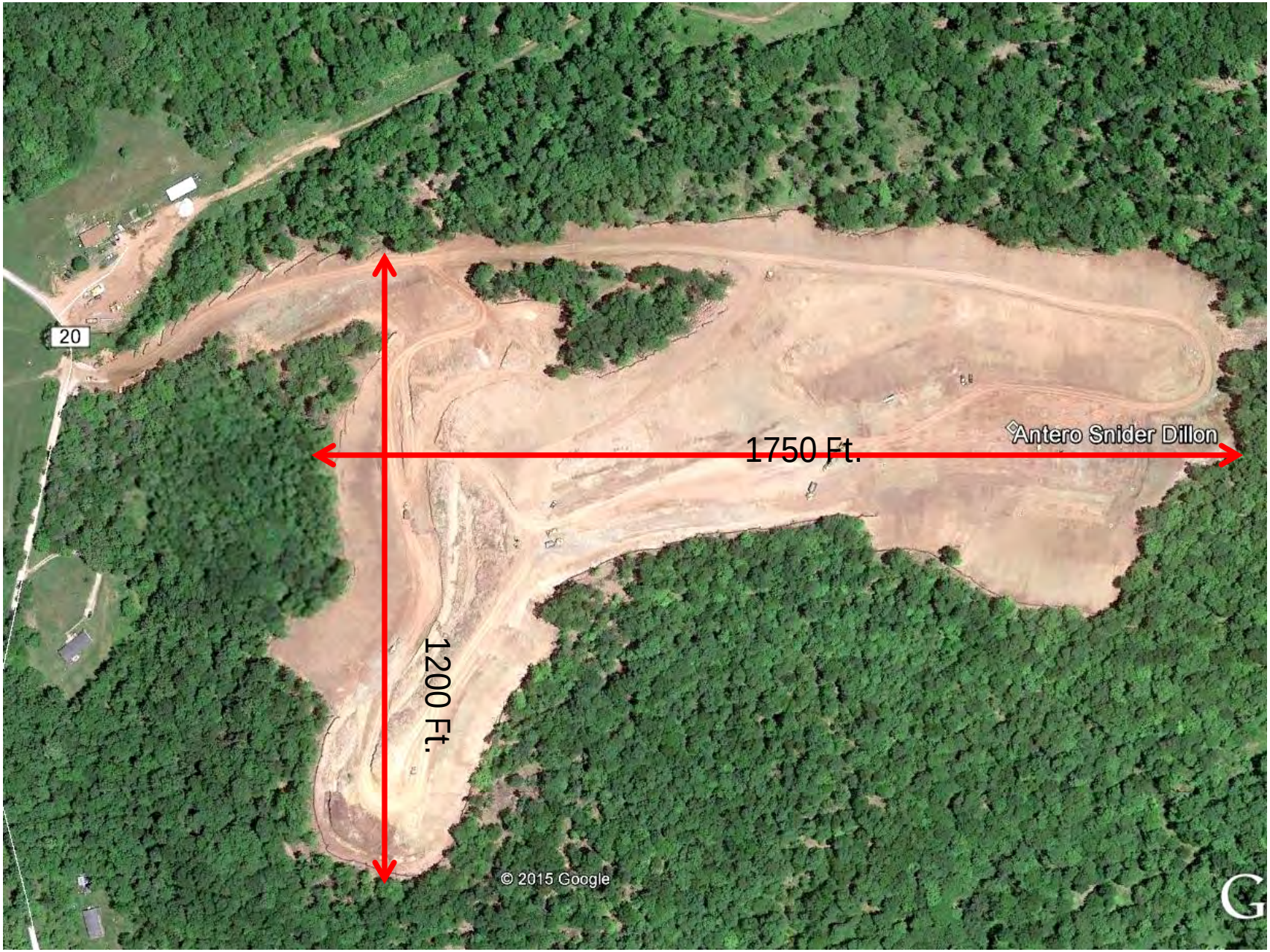
Total min. disturbed area = 8.2 acre of land



Antero Well pad in Doddridge County, WV

By Google Earth

Antero Pad in Tyler County WV by Google Earth



Typical Well Pad Appearance Ready for drill Rig

This Equipment is used to drill the large diameter hole needed to set the conductor pipe on the well pad

Mar -04-2010

Dec 17, 2010

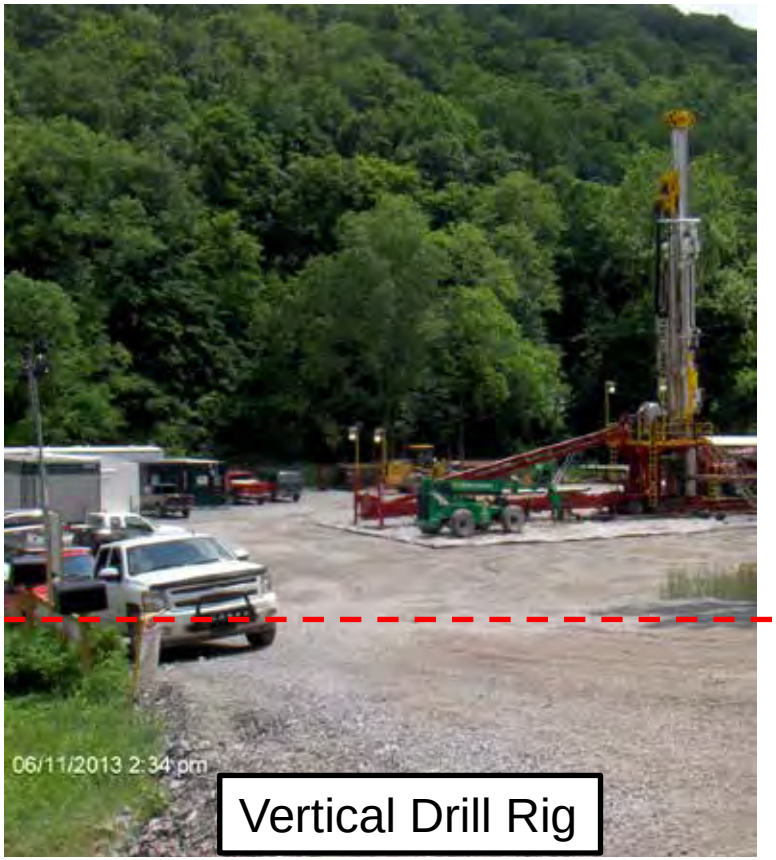
Vertical and Horizontal Drilling

There are a number of options for drilling on a shale gas well pad. These include:

- Just drill enough (one well) to lock in the lease and move on to your next well pad
- Drill just the vertical portions of all proposed wells first with a smaller drill rig, drilling down to the KOP—kick-off-point—where the curved section will begin
- Then follow up with a much larger drill rig capable of drilling the turn to horizontal and the full length of the horizontal bore
- Bring in a big drill rig to begin with and drill every well complete , vertical and horizontal
- With every strategy, there is always the option to come back on the well pad later and drill more wells, if the lease-hold (acreage) is large enough, either into the same formation, or drill into deeper formations—all from the same well pad.

Comparison of Vertical Drilling Rig and Horizontal Drilling Rig

The photos here were taken 6 weeks apart from approximately the same location. Perspective is not exact. However, using the red line under the mail boxes for reference, the size difference between the two types of drill rigs is obvious.



Vertical Drill Rig

Horizontal Drill Rig

Drill Rig at Work

Drill Rig at Work

Drill Rig at Work


Drilling---large rig
04/23/2013 5:26 pm
DEERE

Stone Pad 3 Drilling in Progress

Bowyers Pad in Western Wetzel County, WV

20 inch well casing being installed

24 Inch Drill bit for 20 Inch well casing for Utica Well, in Wetzel County WV


Flaring During Drilling
Monroe County, Ohio
10.24.2014 18:13

Drilling in Monroe County, Eastern Ohio

Part of Savanna Drill Rig 654 going to well pad

Drill Rig Parts

Drill Rig Parts Leaving a Chesapeake Well Pad

Drill Rig Parts Leaving a Chesapeake Well Pad

Set up of Savanna 654 Drill Rig on EQT Well Pad, Wetzel County

Centrifuge separation technology used on Drill Pad

Separation of Drill cuttings into red tub

Roll-off boxes hauling drill cuttings to the landfill

Portable Crane used to set up drill rig on well pad

Well Casing and Cementing

Considerations on the Cementing of Well Casings.

- The reassuring statements by the shale gas industry about multiple layers of steel and cement being used in and around well casings is actually a **TRUE** statement.
- The problem is the extremely long distance of a very thin layer of cement. At most 1.5 inches and thousands of feet deep and it must be perfectly centered in the well bore for the entire length.
- Very difficult to inspect later and repair. Steel will eventually rust. Cement will crack.
- Permanent bonding of cement to both well bore and casing is extremely critical.

Keep this sidewalk in mind. The thick concrete here was more that likely poured in good weather; good visibility; reinforcing mesh or re-bar likely was used; allowed to cure for many days or longer. Even under good conditions---

CEMENT CRACKS

Well Casing Pipes for Drilling Process

Photo by Ed Wade Jr.

13 inch Well Casing and Drill Rod

20 inch well casing

This **20 inch** well casing is for a new Utica formation well in Wetzel County WV. 1275 feet of it will be installed into the well bore.


Twenty Inch
Well Casing
11.07.2014 16:24


Well Casing
04/11/2010 12:54 pm


Drill Rod
Not Well Casing
08/23/2010 6:10 pm

Cement trucks for well casing

The leading truck is a cement pumping truck

Schlumberger Cement Trucks going to Drilling site

Schlumberger Cement Trucks going to Drilling site

Halliburton Cement Trucks going to Drilling site

Halliburton “Red Tiger” cement mixing and pumping truck

Cementing Casing on Drill pad in Wetzel County, WV

Baker Hughes Cement Truck

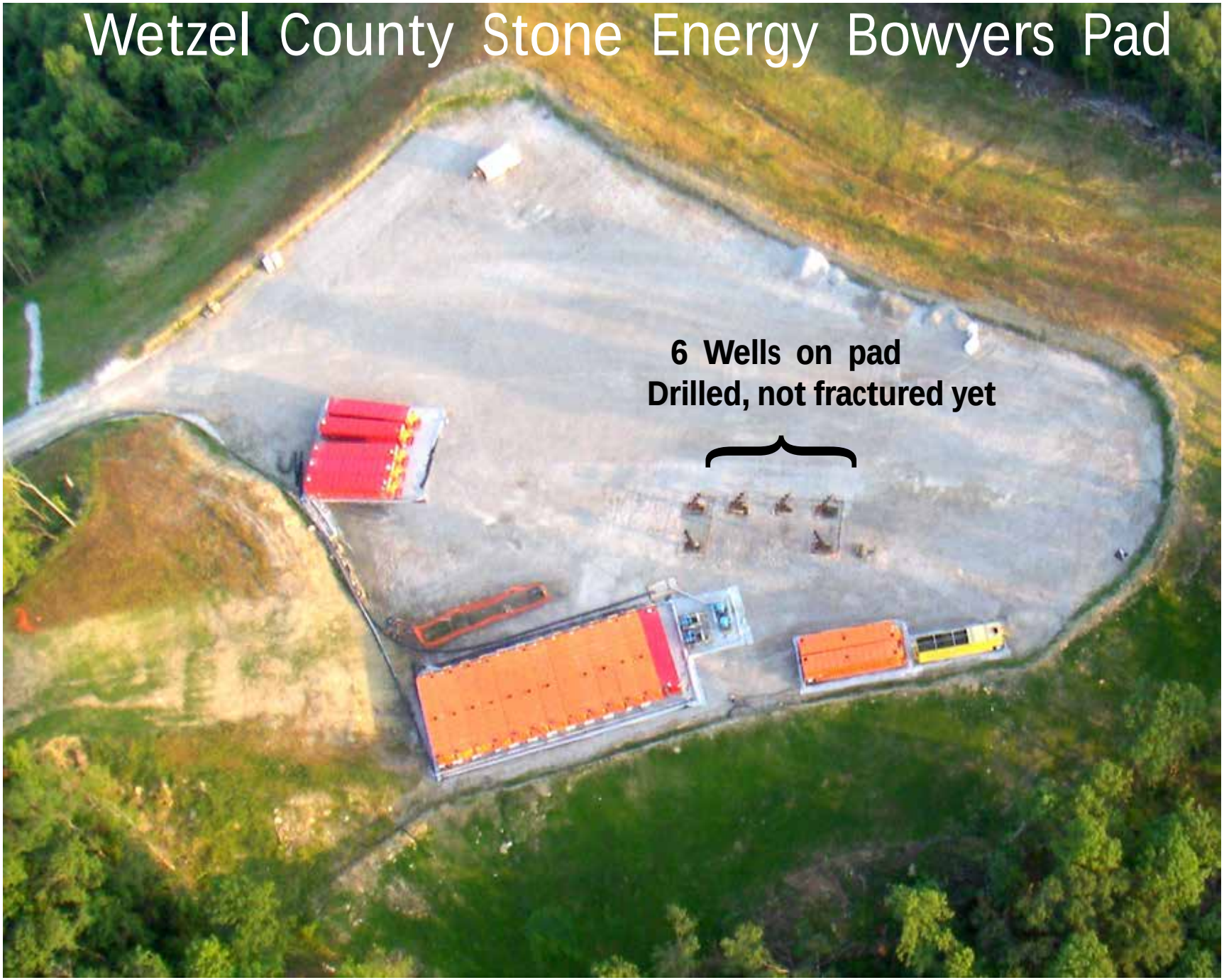
Baker Hughes Cement Pumper

Baker Hughes Cementing casing on Wetzel County Well

Hydraulic Fracturing Equipment

- After drilling is done the well pad is cleared off
- Some fluid storage tanks might be left on pad
- Well heads prepared to accept frack hardware
- Sand kings put in place to store sand
- 12-18 Fracturing pumps are moved onto the pad
- Fracturing chemical tanks arranged
- Crane used to hold perforation gun
- Start running sand cans to deliver sand

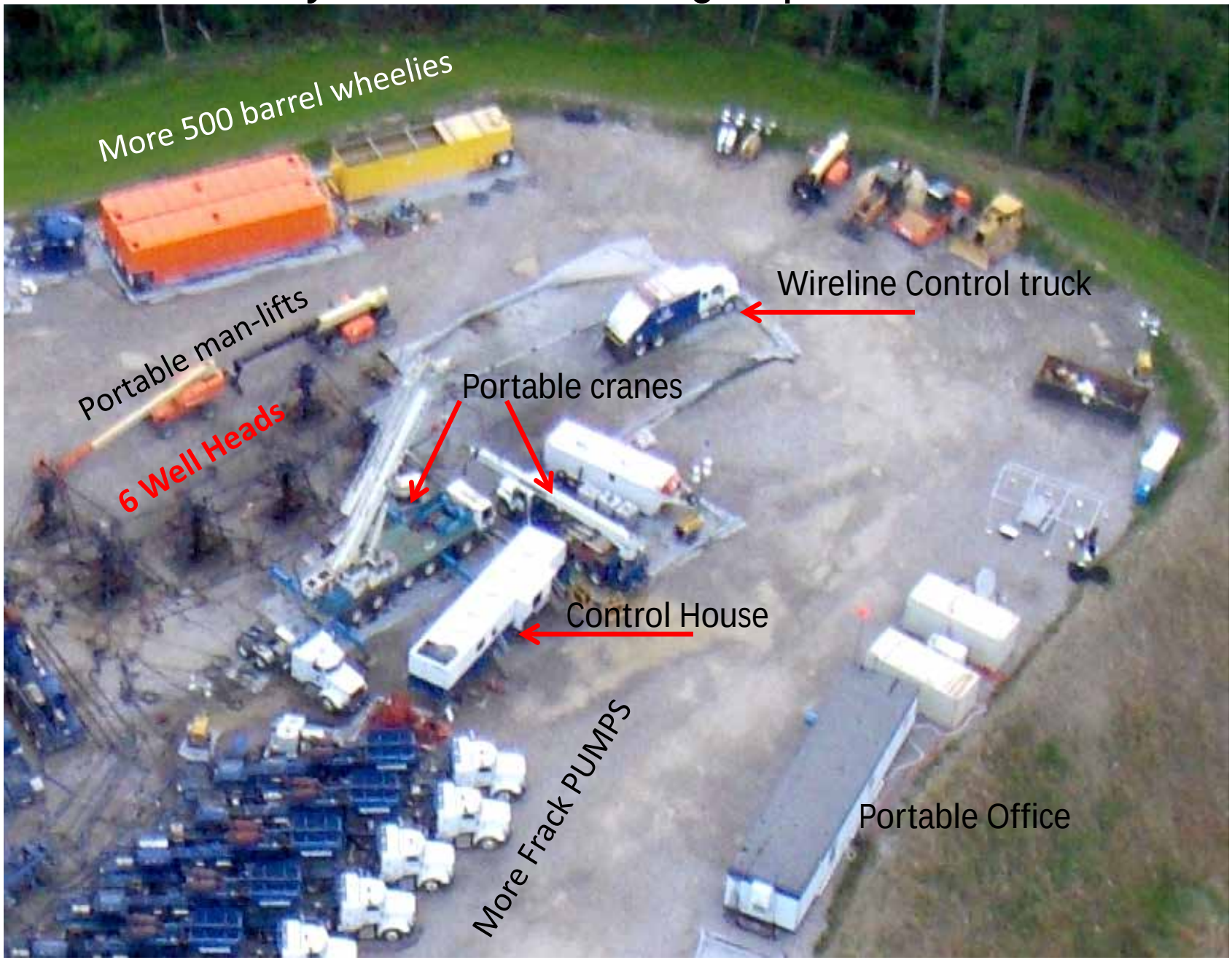
Wetzel County Stone Energy Bowyers Pad



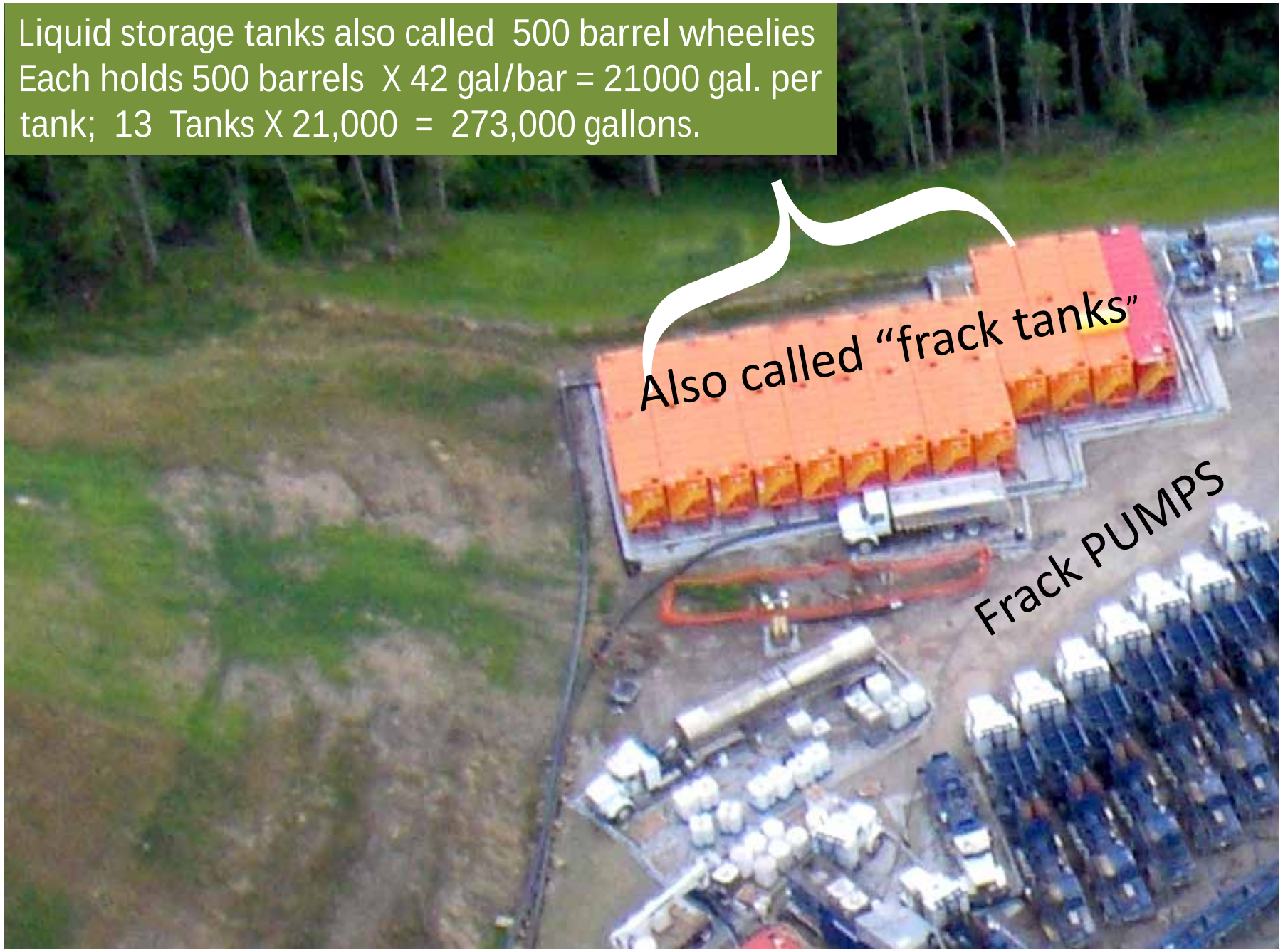

Wetzel County Stone Energy Bowyers Pad
07/05/2013 7:50 pm
Hydraulic Fracturing in process

Wetzel County Stone Energy Bowyers Pad

Hydraulic Fracturing in process

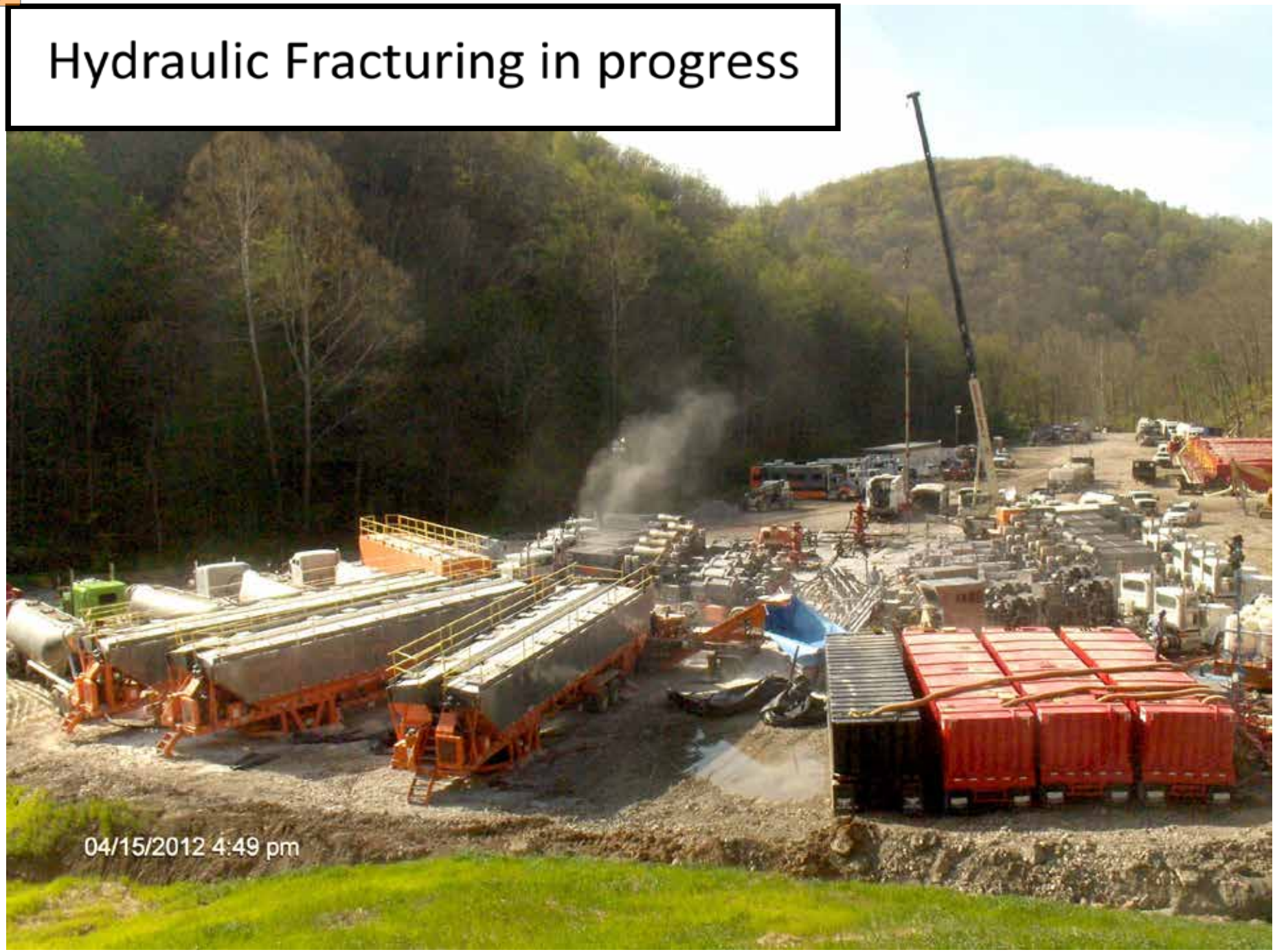


Top Left


Liquid storage tanks also called 500 barrel wheelies
Each holds 500 barrels X 42 gal/bar = 21000 gal. per tank; 13 Tanks X 21,000 = 273,000 gallons.
Also called “frack tanks”
Frack PUMPS

Hydraulic Fracturing in progress

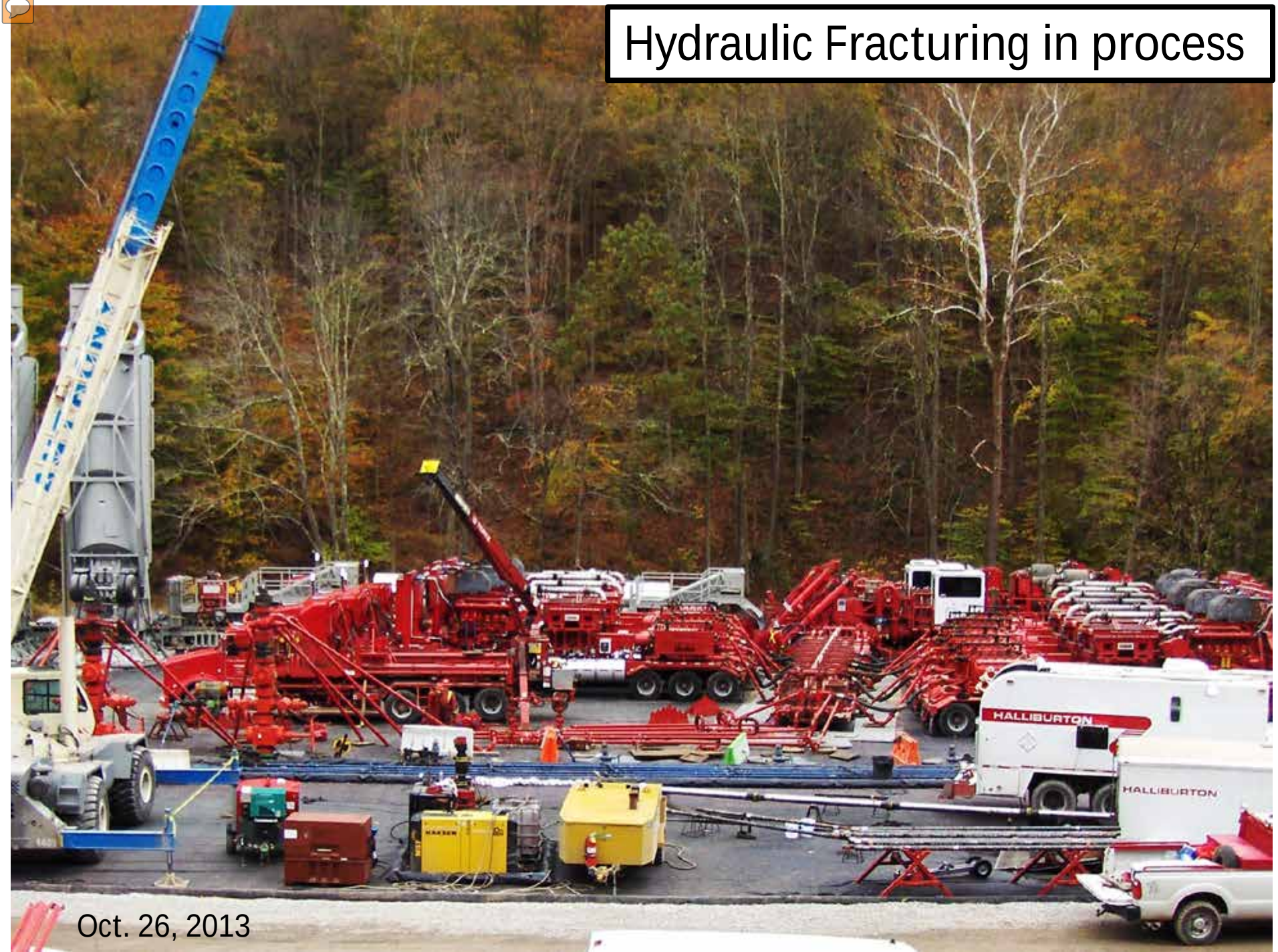
Hydraulic Fracturing in progress




Hydraulic Fracturing in process
Using 15 Fracturing Pumps
02.08.2015 14:46

Hydraulic Fracturing in process

Hydraulic Fracturing in process

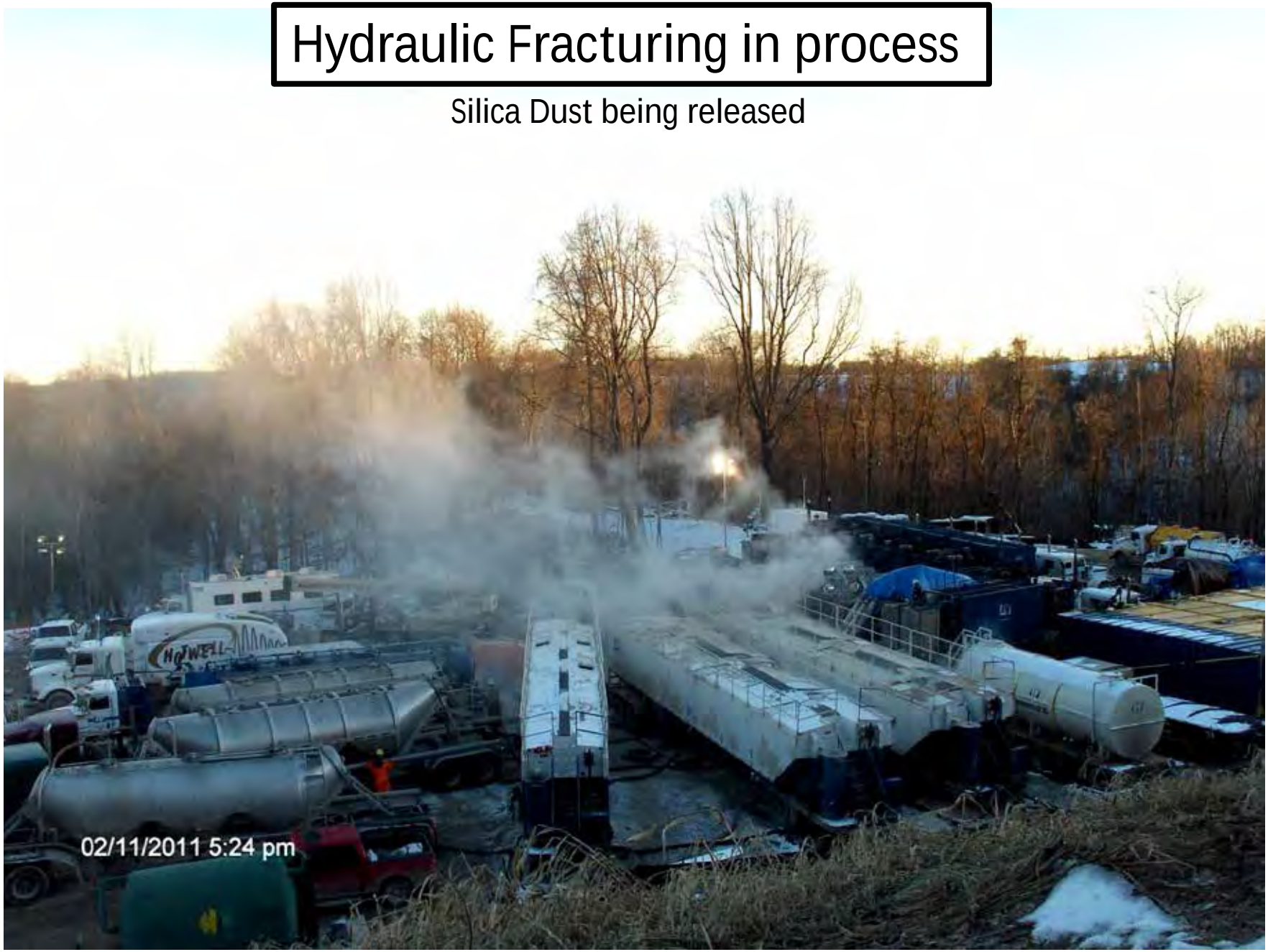


Oct. 26, 2013


Diesel fumes continually released during
Hydraulic fracturing process at Marcellus well

Hydraulic Fracturing in process

Silica Dust being released



Wireline Control Truck

Water Storage and Delivery for Fracturing

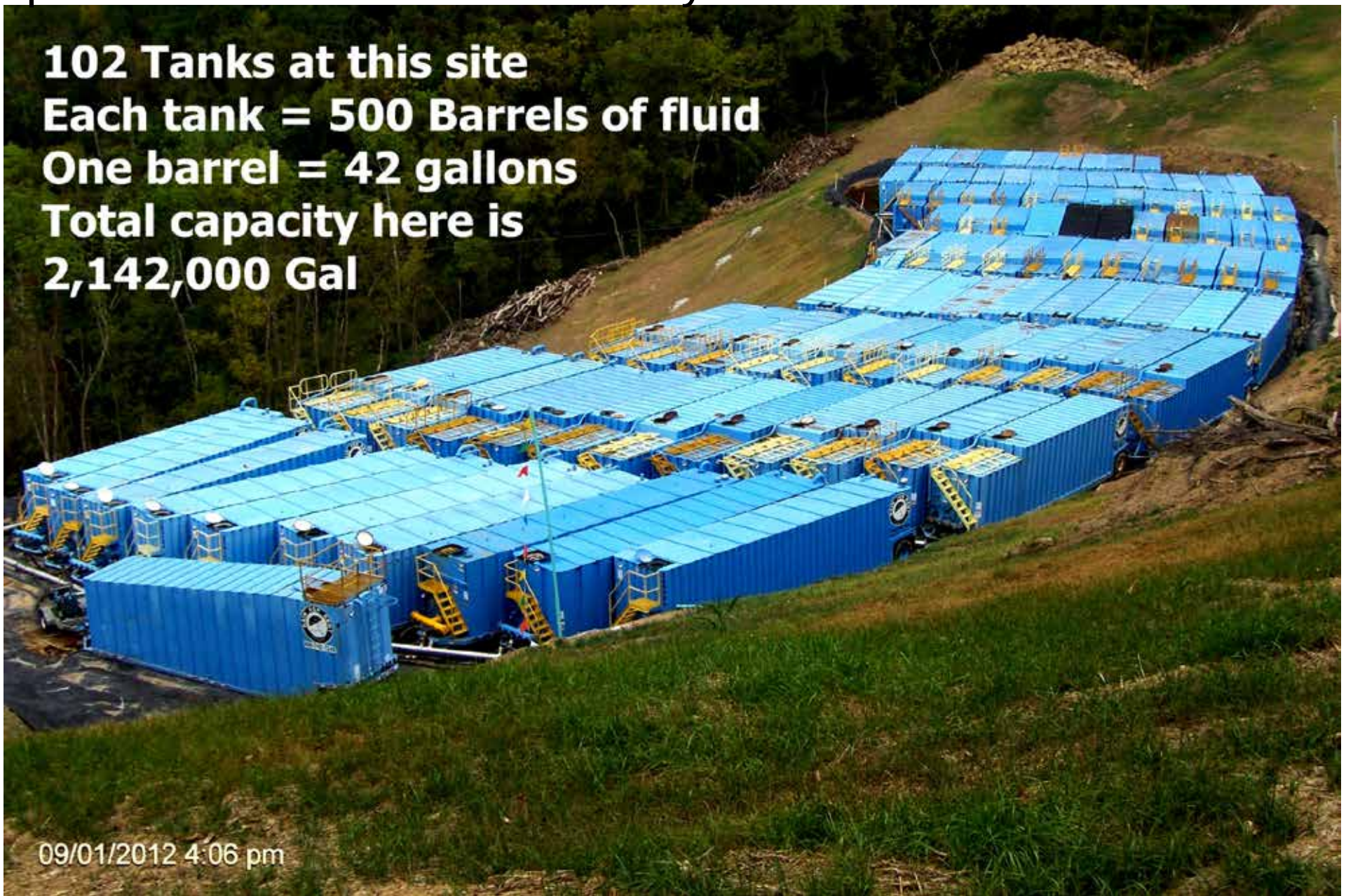
The largest need for water is during the actual hydraulic fracturing stage. There are at least three ways for drillers to get the required amount of water-- 4-6 million gallons

- 1. Pipe it in from a large, high-volume nearby source
- 2. Construct a freshwater holding pond near the well pad
- 3. Or use Temporary or semi-permanent storage tanks. The tanks might be the common “frac” tanks, aka 500 barrel wheelies; or round, shark tanks. All these tanks are shown in the next few slides.

Temporary transfer pumps will withdraw any water possible from any small stream or creek, and miles of plastic piping will be run to fill every holding pond and tank.

Shown is one, typical, 500 barrel “wheelie”, going to a well pad. These are always moved empty. They are not made to carry any weight. Best to refer to them as liquid storage tanks. When seen in use, on a well pad, it is difficult to know what might be in them. A common label is also, “frack tanks” They can be used for fresh water; brine; condensate; flowback; drill mud; fracturing fluids; or a witch’s brew of everything. Companies pay extra to get “certified clean” to use for just fresh water.

These tanks were part of a centralized water management plan. Much of the water initially came from the Ohio River.



Water storage tanks for high pressure testing of pipelines

Thirty or more 500 barrel tanks

Frac Tanks---500 Barrel Wheelies

NOTE: This type of tanks will never have much liquid in them when being moved on the road. The small wheels are only capable of carrying the empty weight of the metal box. When full and in use, they will be resting on the ground as shown above.

Frac Tanks---500 Barrel Wheelies


Frac Tanks---500 Barrel Wheelies
DRAGON
GP53396
PELIGRO
10/18/2010 5:49 pm
Very Clean--new


Frac Tanks---500 Barrel Wheelies
03/28/2011 11:31 am
Very Dirty on Well Pad

Frac Tanks---500 Barrel Wheelies


SCHOOL BUS
DRAGON
37521
BRAKES
FOR
RAILROAD
CROSSINGS
WIDE RIGHT
TURNS

Frac Tanks---500 Barrel Wheelies at an EQT Well Pad

Only about 6 of these tanks were put here for the drilling operations.

Above is the ground-level, side view of two round “shark” tanks for holding fresh water within a larger, lower containment tank. An aerial view of the two taller “shark” tanks within the containment tank is shown to the left.

More permanent water storage tank for a centralized water system.

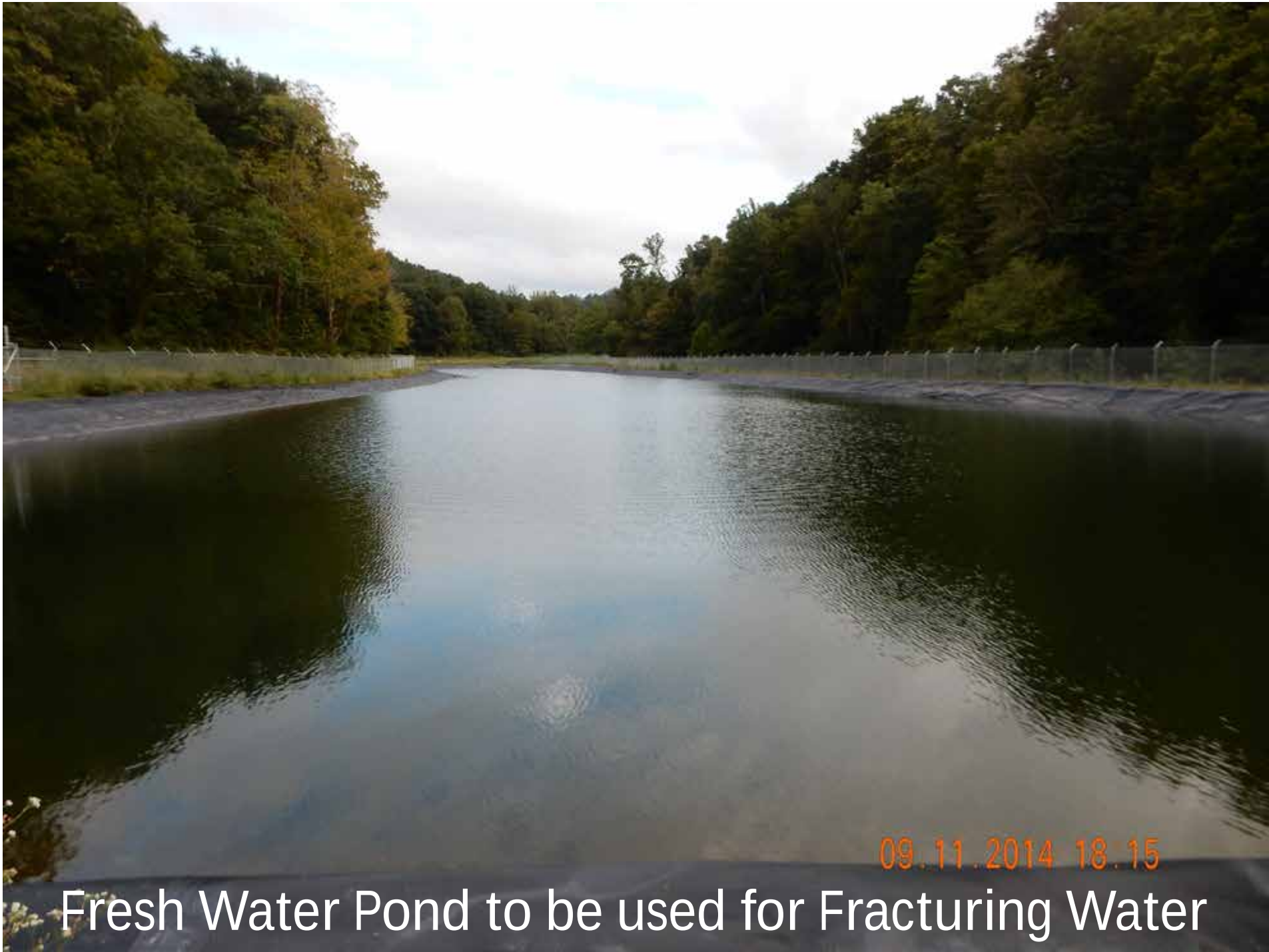
Temporary Fresh Water Storage for pipeline pressure test

Empty tanks being stored on well pad

Temporary Water Transfer Pumps

Construction of Large Fresh Water Holding Pond

Same holding pond as seen above



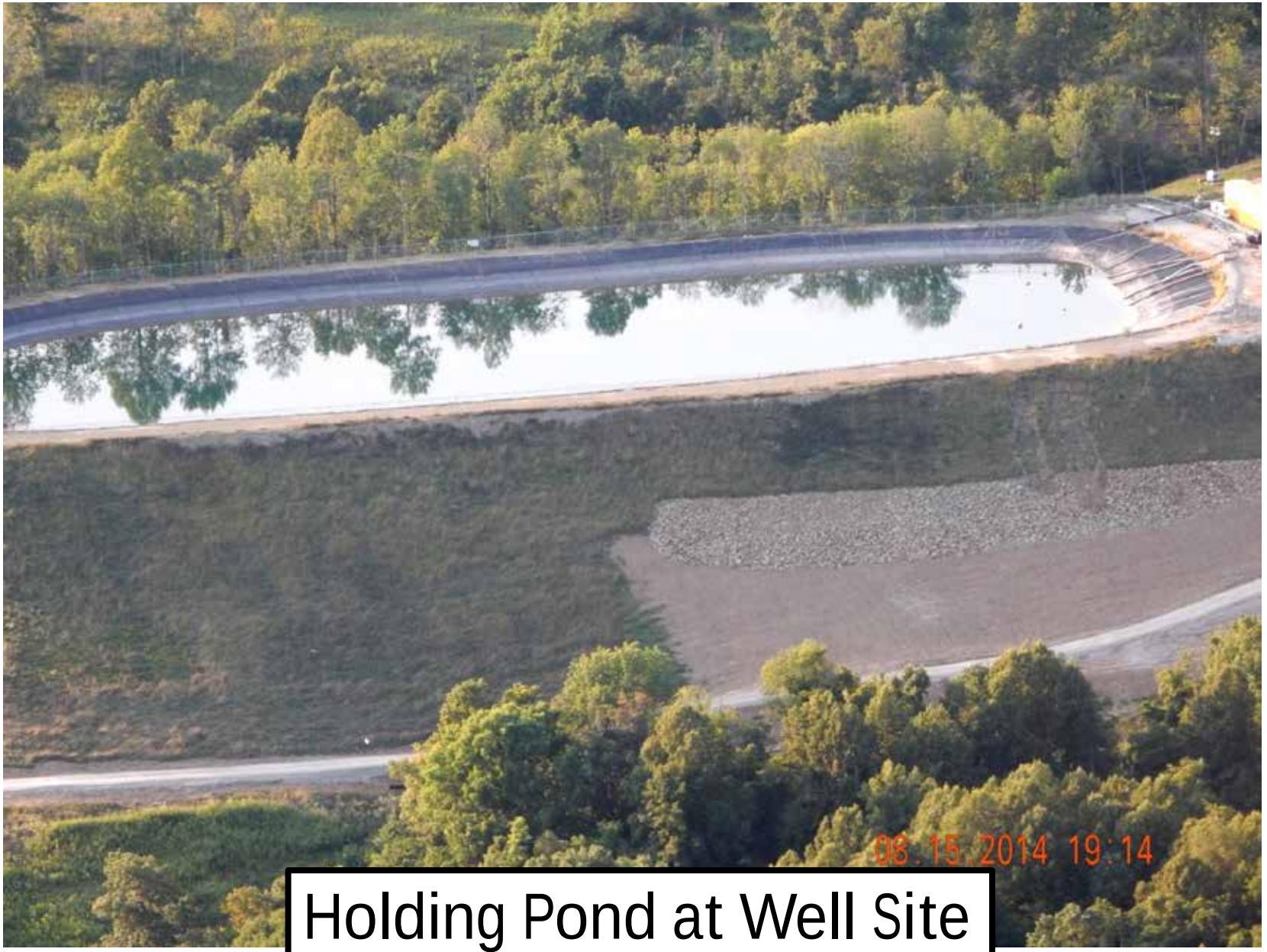
Fresh Water Pond to be used for Fracturing Water

Holding Pond, adjacent to a well pad, for a witch's brew of unknown, mixed fluids.


Most likely a fresh water holding pond

Well pad with holding pond. It had been fresh. Now very contaminated after **Statoil Fire**

For additional information on Statoil Fire see FracTracker's web site.



Holding Pond at Well Site

Hydraulic Fracturing Equipment

- Some hydraulic fracturing contractors include: Halliburton; Baker-Hughes; Schlumberger; Weatherford; Frac-Tech Services; GoFrac; US Well Services; Nabors Well Service; PumpCo; Keane; among others.
- Each fracturing contractor will also provide most of the other equipment required for the frack job, such as sand kings; mixers, wireline truck; and control center.

Halliburton Fracturing Pumps on site

Halliburton Blenders

Halliburton Q-10 Fracturing Pumps

Halliburton Q-10 pumps in use

Fracturing valves and piping assembly mounted on top of well head ready for the high-pressure fracturing plumbing

Fracturing valves and piping assembly mounted on top of well head ready for the high-pressure fracturing plumbing

The frack head is wrapped to keep heat in. Notice the portable heater to the right. This was being done in winter. The nylon wrap is to keep the pieces from flying off in case a pipe bursts .

Weatherford Mixer-blender


15 Fracturing Pumps at work
02 08 2015 14:43

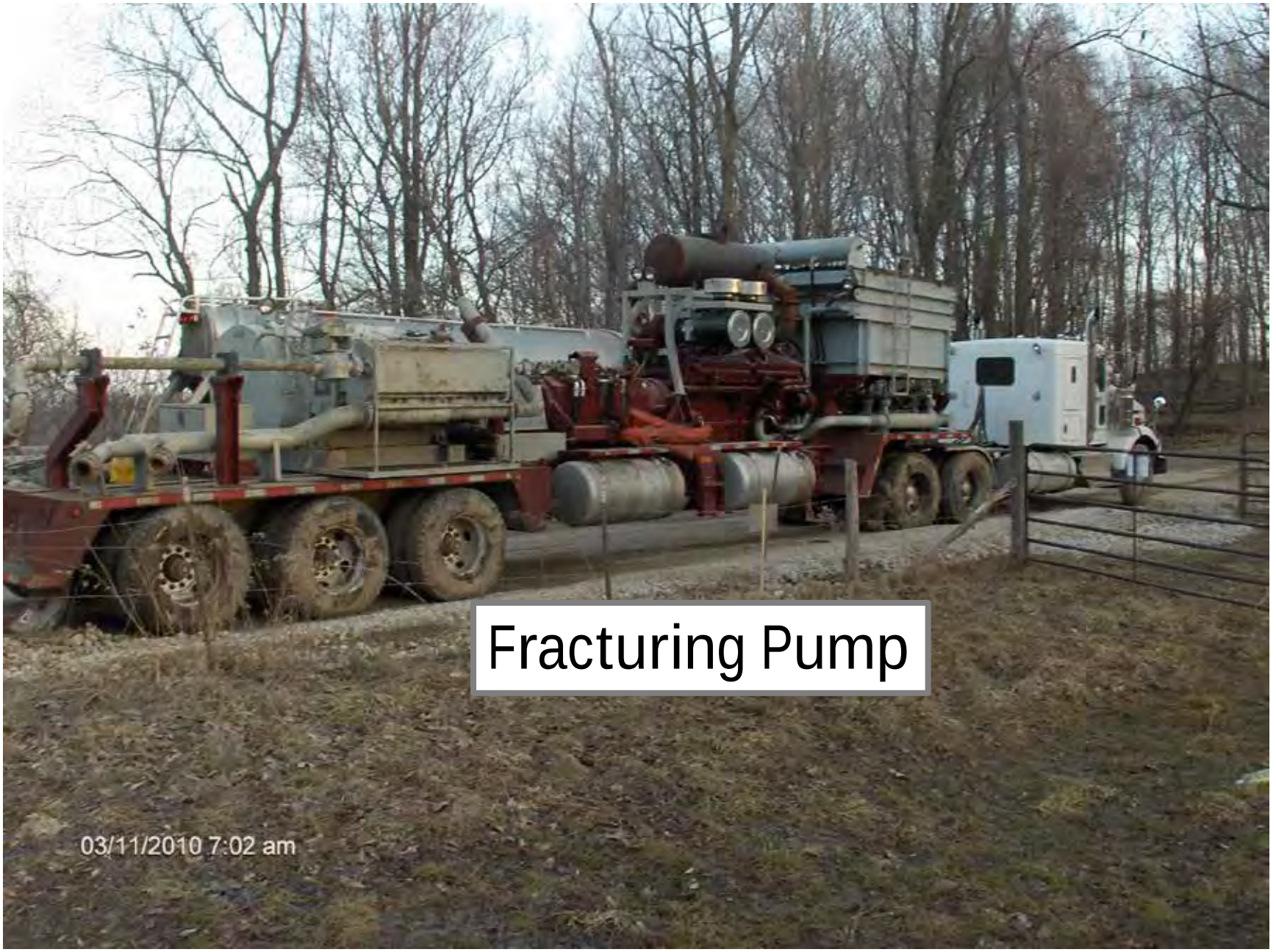
14 Schlumberger Fracturing Pumps

Halliburton Auxiliary Support Trucks

Pipe hardware for a frack job

Fracturing Pumps


Fracturing Pump
08/28/2013 1:49 pm


Fracturing Pump
03/11/2010 7:02 am

Fracturing Pump: stuck in neighbor's front yard

Fracturing Pumps and support equipment and hardware crane truck

Fracturing Pumps

- This section will show the tractor-trailer trucks used to transport sand to the Hydraulic Fracturing site well pad. They are called **Sand Cans**; many look very similar.
- Also shown will be the very large **Sand Kings** which are used to store sand while on site.
- Special, solar-powered, vertical sand storage containers made and used by Halliburton, called **Sand Castles** are also shown.

Typical Sand Can delivering sand to a well pad.

Typical Sand Can delivering sand to a well pad.

Sand Can on ice and snow with no chains on tires

Typical Sand Can returning from a well pad.

A day's worth of sand trucks waiting to go to the well pad

Sand Cans at Chesapeake Staging Area

Sand Cans at Stone Energy Staging Area

Sand Kings

Stored or parked Sand King---not in use. When in use, the tires will not be on the ground. The large pads in front and rear will be hydraulically lowered to hold the huge weight of the stored sand.

Four Sand Kings in use

Sand King on the road en route to Hydraulic Fracturing Site

NOTE: The numbered compartments are divided internally to identify what grain size of sand is available and which needs to be replenished

Sand King


4
3
2
1
03/10/2010 7:00 am
Sand King

Sand Castles are vertical sand storage tanks made by Halliburton.

And, yes, they are solar powered. These are in use on **EQT** site in Wetzel Co. WV

Sand Kings on Hydraulic Fracturing Site

NOTE: The diesel fumes are from frac pumps running behind the sand kings.

Silica dust from **Sand Kings** being filled up during a fracturing project


4
3
2
1
Weatherford
Fracturing Technologies
OVERSIZE LOAD
03/26/2011 4:26 pm

Fracturing Chemicals

- Tanker trucks with Hydrochloric Acid **DOT 1789**
- Fracturing chemicals in single plastic totes
- Tractor trailers filled with fracturing chemicals

Hydrochloric Acid Tanker

Being pulled up hill

Hydrochloric Acid Tanker

Hydrochloric Acid Tanker

Hydrochloric Acid Tanker

Truckloads of Fracturing Chemicals


1993


SCHÜTZ TICKET SERVICE FORM
KROFF
WFR-5
08/06/2010 3:41 pm


SUPERMAX
1993
3
08/06/2010 3:41 pm

Completed Well Pad, Ready for Production

- After flowback and flaring is complete, the well pad is cleaned off.
- Storage tanks are provided for **Condensate**, also called **NGL** or **N**atural **G**as **L**iquids. This is a very explosive, volatile liquid.
- Tanks are also placed on the well pad for **Brine**, also called **produced water**.
- The well heads are finished and connected to the separators, gas processing units, and the storage tanks.
- Sometimes wireless sensors and telemetry is used to monitor pressure at well head and on tanks.

Flaring after Fracturing is done


New Dominion gas plant along the Ohio River in SW Marshall Co. WV
06/20/2013 2:27 pm


12/10/2010 3:24 pm

Storage Tank on way to well pad

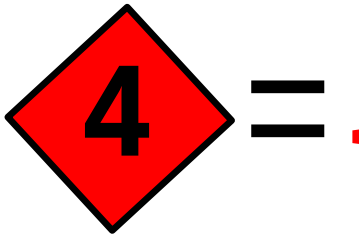
Storage Tank on way to well pad

Very Antique storage tanks on well pad

These tanks were actually still in use July, 2014; Tyler County, WV*

*However their warranty had expired

The Dangers of Condensate Storage Tanks



=

Materials that will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or that are readily dispersed in air and that will burn readily. By *NFPA*

Condensate and Brine Storage Tanks on Well Pad

Condensate and Brine Storage Tanks on Well Pad


Wireless Pressure Transmitters
Storage Tanks Marked Brine Only on Well Pad

Condensate and Brine Storage Tanks on Well Pad

Condensate and Brine Storage Tanks

Well Pad Storage Tanks

Using White Plastic Pipes to Capture the Explosive, Flammable Vapors

Tyler County, WV

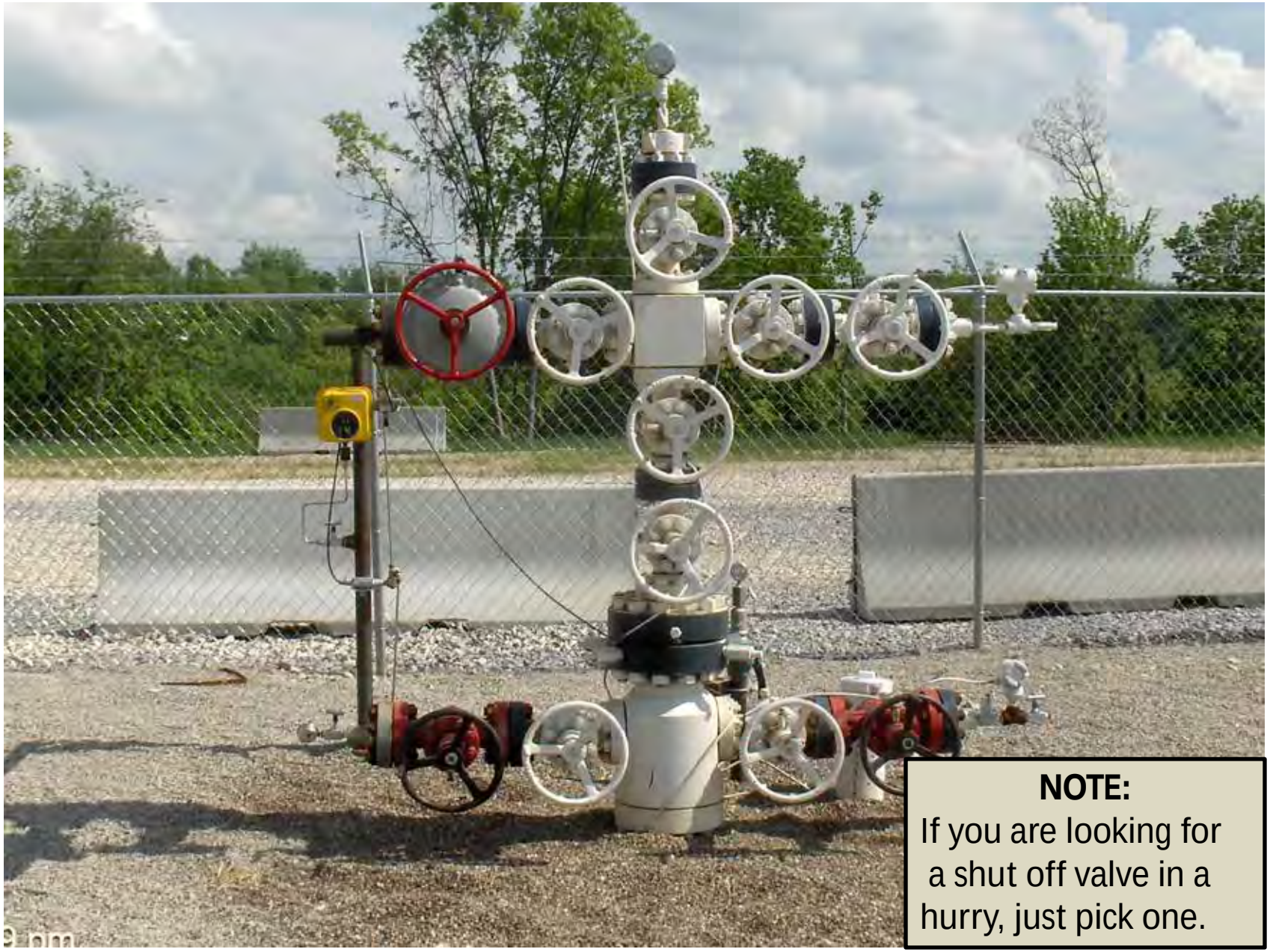
Condensate and Brine Storage Tanks on Well Pads

Condensate and Brine Storage Tanks on Well Pad

Well Heads with wireless pressure transmitters mounted on top

Well Heads in Production

Well Head in production

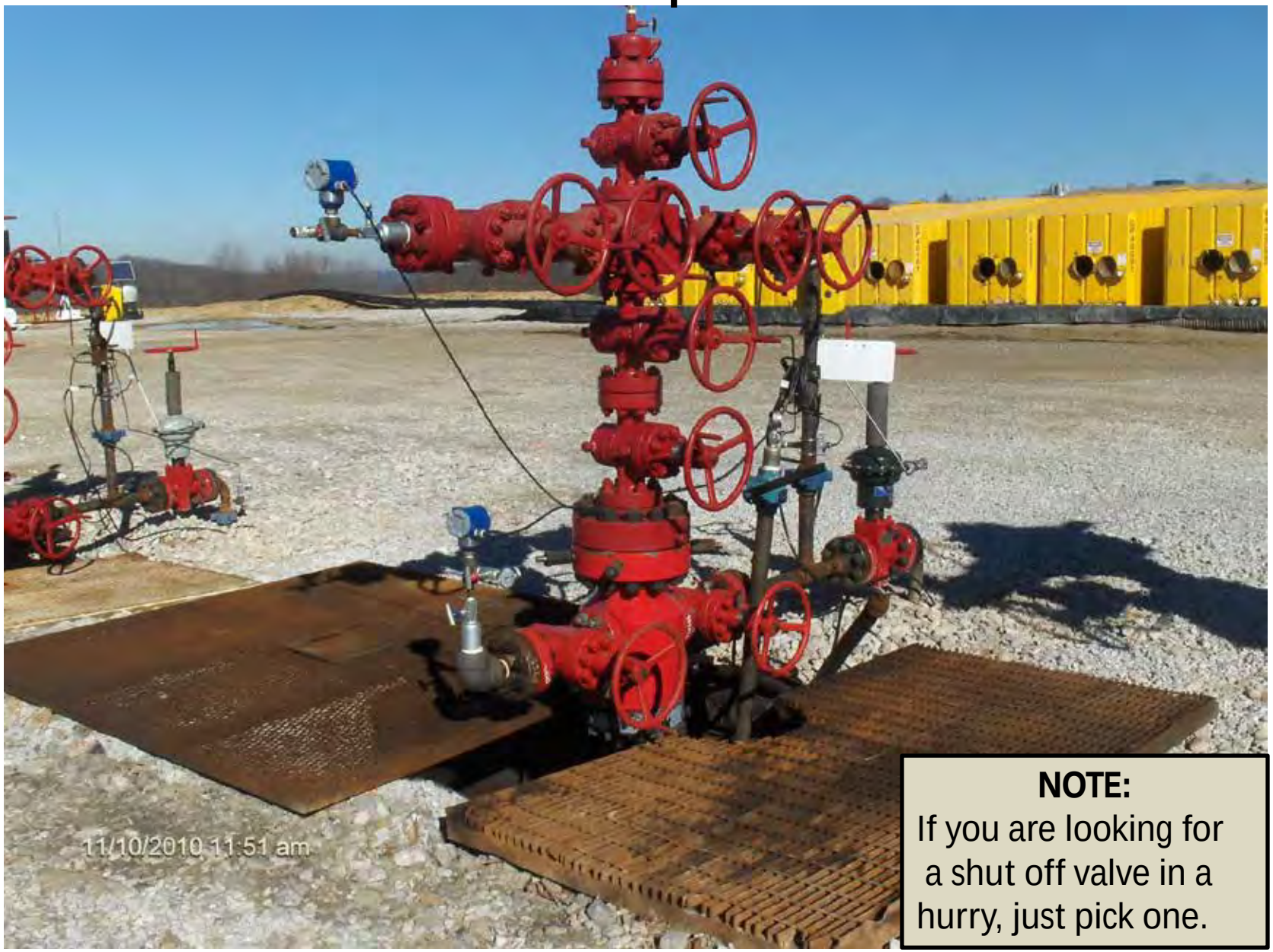


NOTE:
If you are looking for a shut off valve in a hurry, just pick one.

Well Head in production

Newly painted Well Head

Well Head in production



NOTE:
If you are looking for a shut off valve in a hurry, just pick one.

- After the fracturing head is removed and the production head is placed on the well head, then storage tanks are put on the well pad. These will hold produced water (brine) and condensate (natural gas liquids—NGL's). Gas Processing Units-- GPU's are then connected by pipes into the well heads.
- These GPU's are separators to separate the raw gas into Brine, Condensate, and somewhat dryer, Natural Gas.

One single separator and one dual separator.

Three wells on the pad.

Three Phase Separators

Two separators—one for each well on the pad.

Dual Three Phase Separators—for two wells

Two separators—one for each well on the pad.

Eight Gas Processing Units on completed well pad

Well pad compressor engine

Small compressor for Vapor Recovery Unit---Used to draw gas vapors from storage tanks

Gas Processing Unit on well pad

Four Gas Processing Units on well pad

There are four vertical sand separators in front of the GPU's

Triethylene Glycol (TEG) Dehydration Unit on well pad

Typical Gas Production Units Left on All Well Pads

Solar Panels Can Be Seen on all Well pads

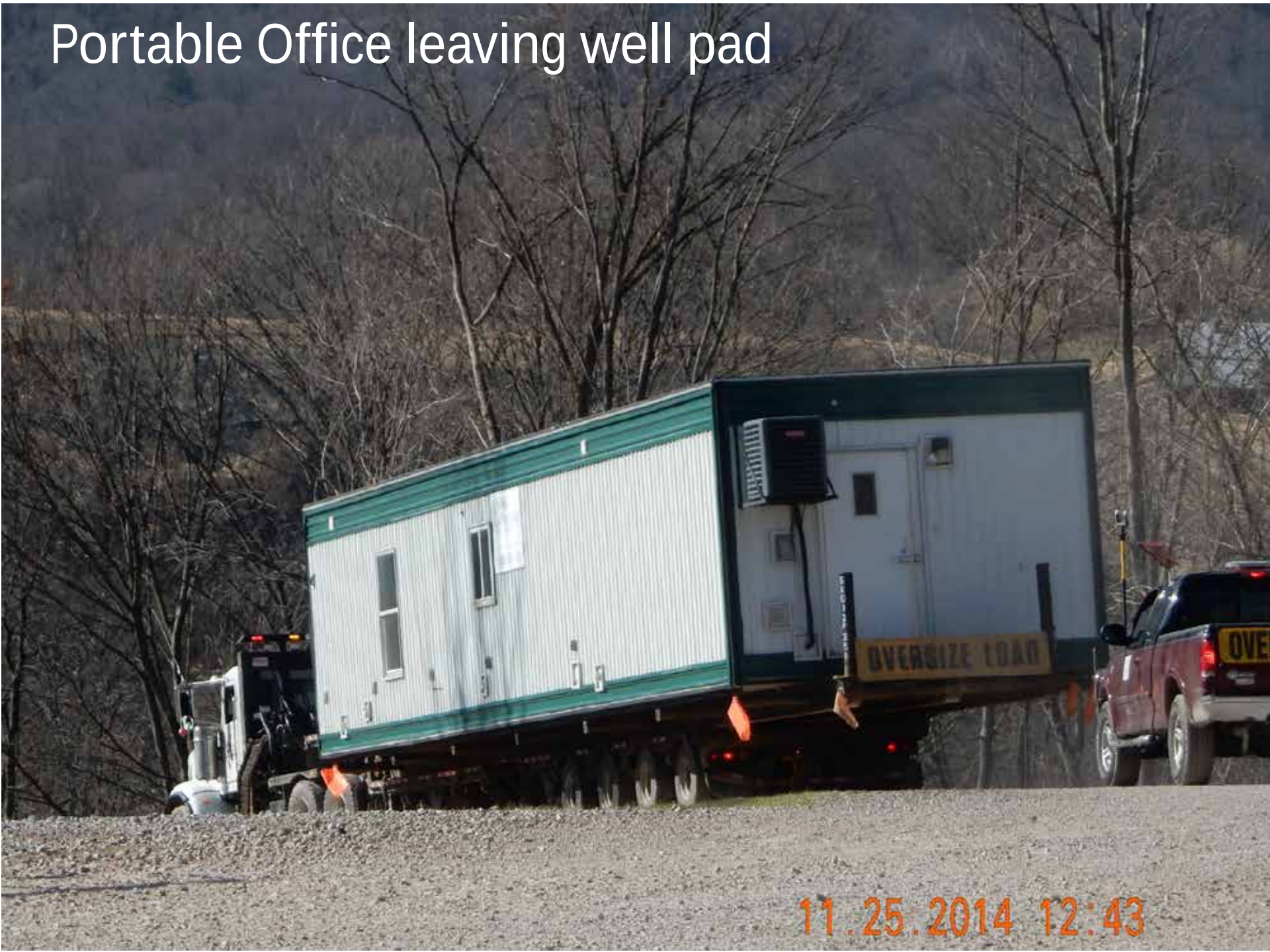
- **Miscellaneous Trucks Include**

- Throughout the complete shale gas horizontal exploration and production process, dozens of pieces of equipment and hundreds of trucks are used for many of the distinct steps.
- These include: tanker trucks for fresh water, brine, condensate, and diesel fuel; trucks for gravel; pipe
- Mobile offices; dump-trucks; portable cranes; coil-tubing trucks

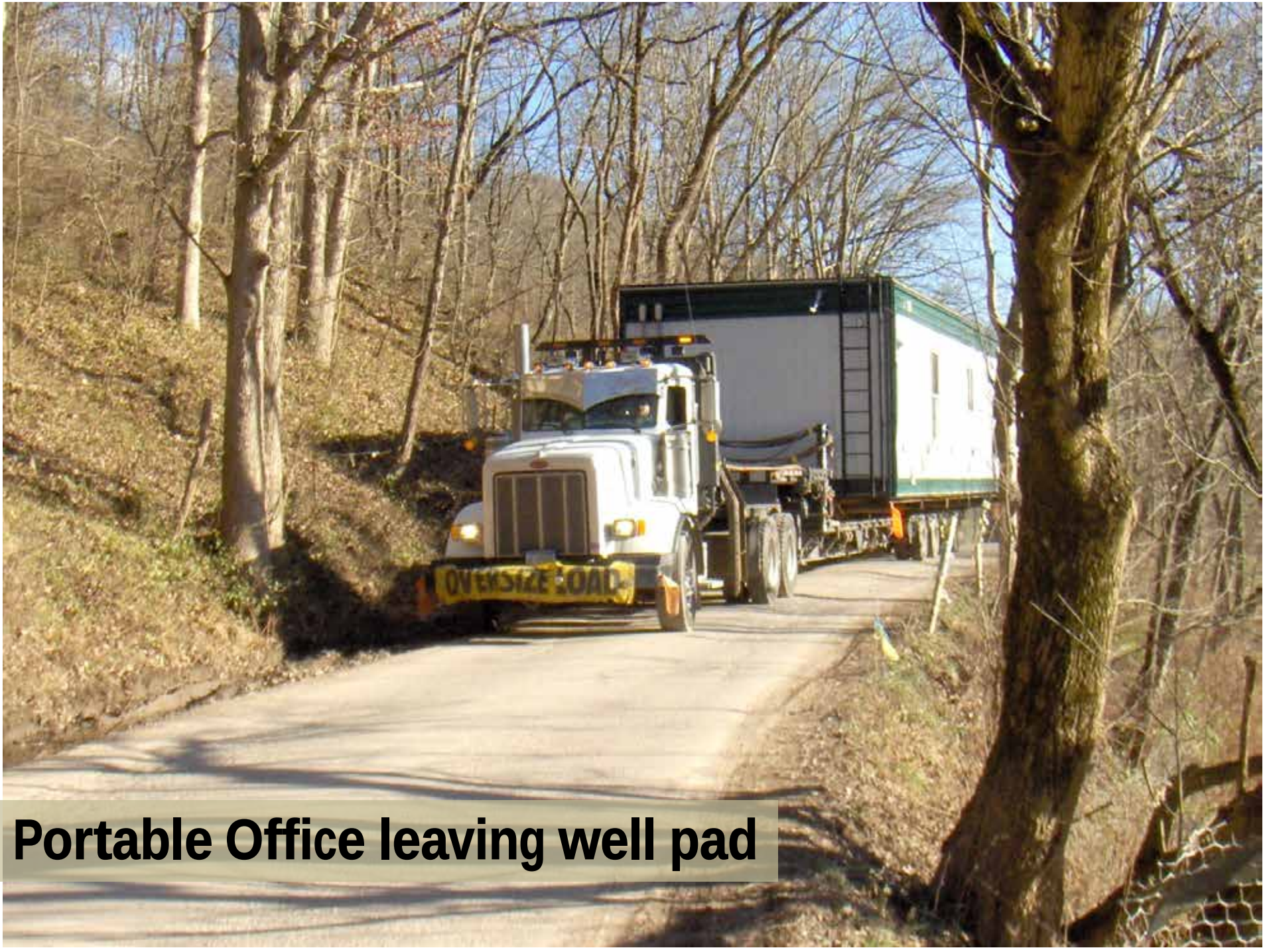

OVERSIZE LOAD


STONE

Portable Office leaving well pad




OVERSIZE LOAD
03/20/2013 12:39 pm



Portable Office leaving well pad

Portable Crane used to set up Drill Rig

Portable Crane used to set up Drill Rig

Not--So--Portable Crane

Coil Tubing Trucks

12-21-2010

Nitrogen Tanker Supply Truck used with Coil Tubing Service

Coil Tubing Truck

Coil Tubing Truck

Service Rig

Brine
tank
Truck
Watering Road--? or not

More Diesel Fuel Supply Tanker Trucks

More Diesel Fuel—for Fracturing Pumps

Diesel Fuel Supply Tanker

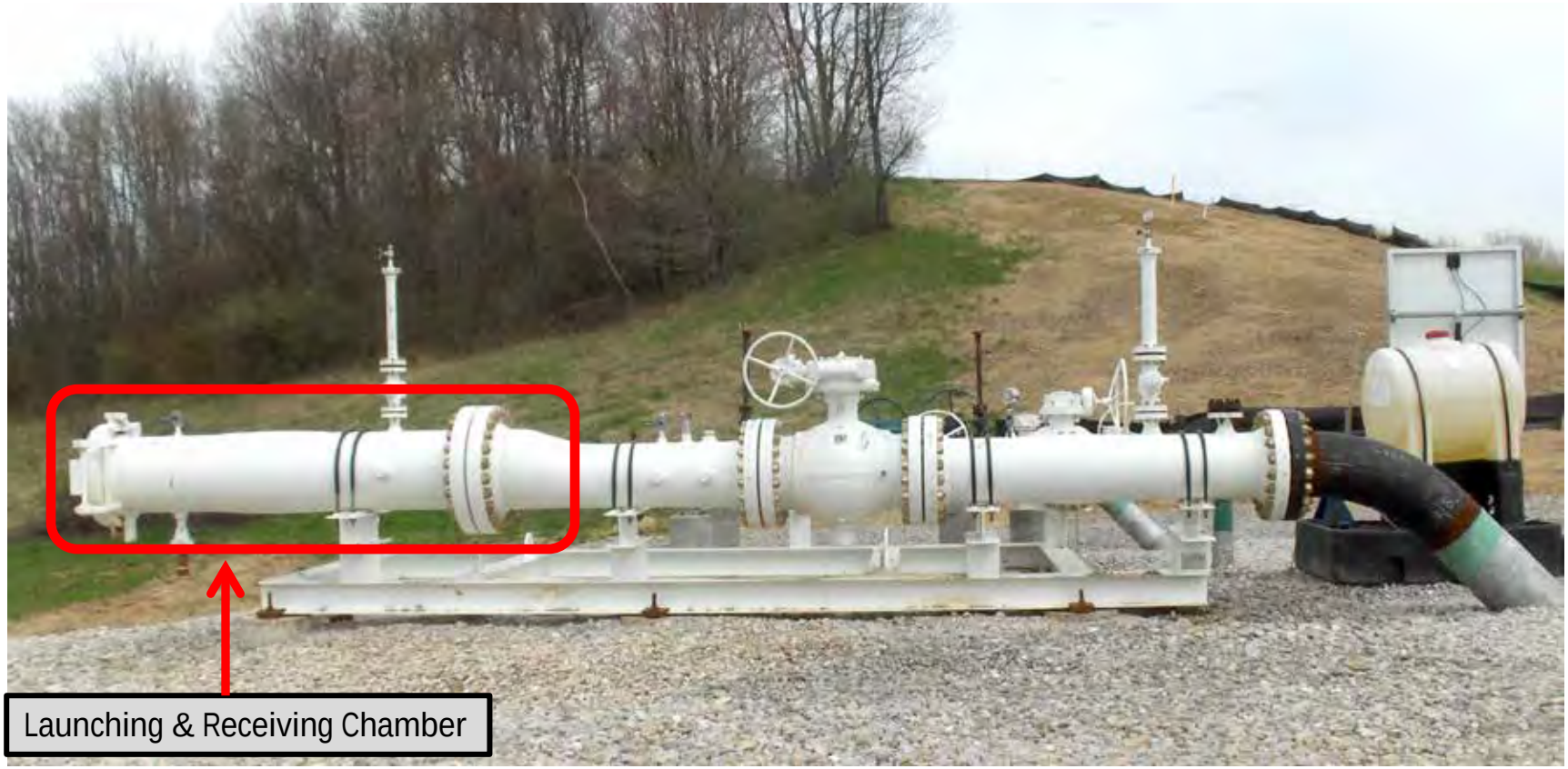
Tanker Truck Hauling
Natural Gas Liquids or Condensate

Condensate or NGL's are a very valuable product, not waste. These trucks are required to have a DOT placard on them to provide a general idea of the product category. Therefore the **1267** label.

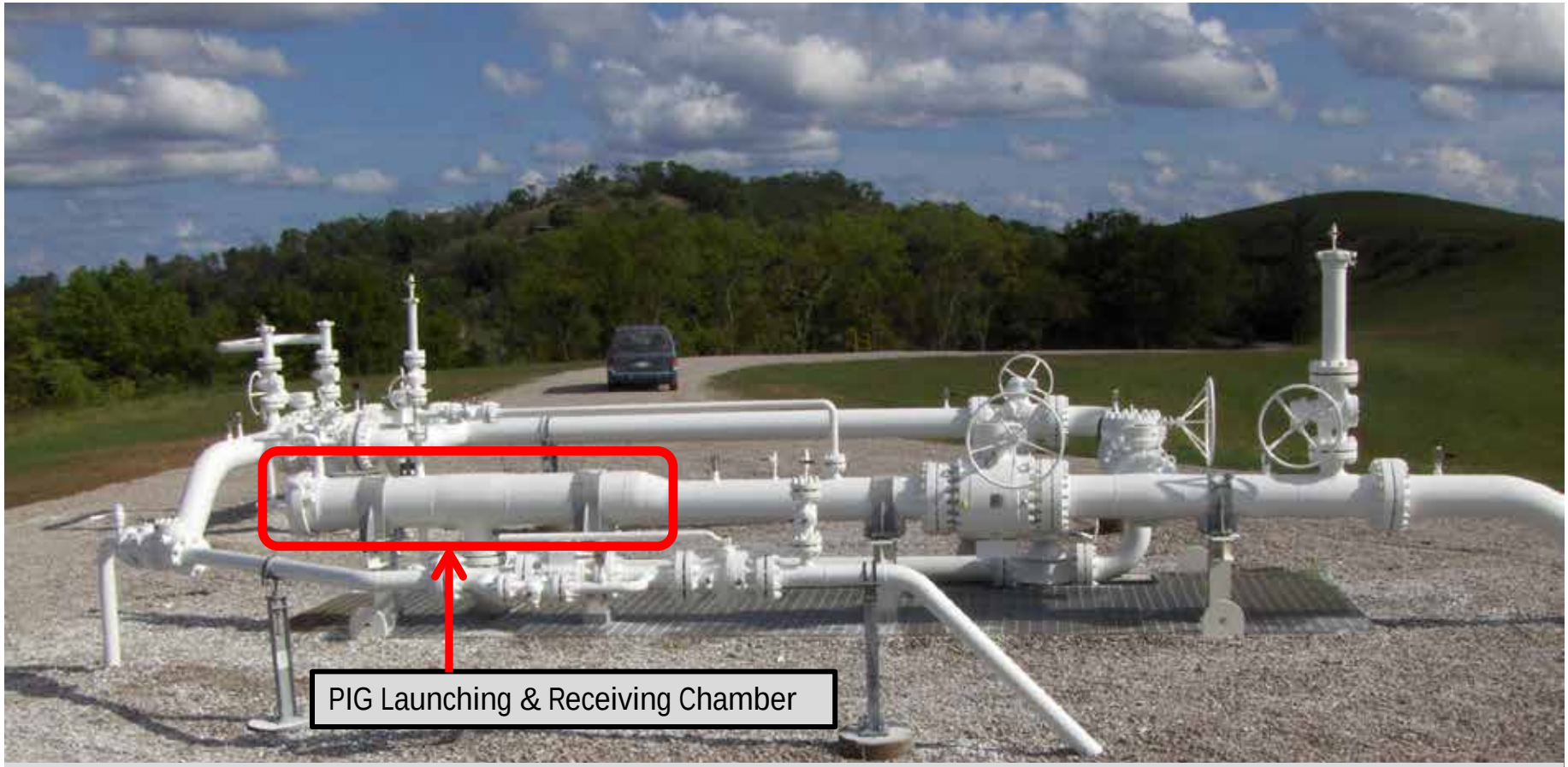
This section will cover:

- Pipe manifolds and assemblies on well pads; pig launchers & receivers;
- Installations on Pipeline rights-of-way
- Compressor moves
- Compressor stations
- Gas processing facilities

Pig Launchers & Receivers



The above chamber is designed to accept tubular, torpedo shaped devices which can be inserted into or removed from the pipeline at either end point. Gas pressure is used to push it thru the pipe. They have been called “pigs” for decades. A simple **PIG** will be used to cleanout debris, unwanted liquids or loose scale. A **“Smart Pig”**, will carry on-board electronic sensors and data storage which will measure wall thickness, distance and record everything for later analysis. It will look for defects like scale and corrosion and pitting. The pipe layout and design must only use large radius elbows to allow unrestricted pig travel.



The above pipe manifold and valve assembly and **PIG** station is midway along a gas pipeline run. These assemblies are also placed on some gas well pads and frequently at compressor stations and gas processing locations.

Assorted valve groups on small diameter gas gathering lines

Miles of Cross Country Pipeline

Pipeline Installations

Pipe for Pipeline Installation

Pipe for Pipeline Installation


10/02/2012 4:14 pm


08/19/2012 3:31 pm

Pipeline Installations

Pipeline Installations

Pipeline Installations

Pipeline Installations

Pipeline Installations

42 Inch Pipeline Installation

42 Inch Pipeline Installation

Compressor move in Wetzel County

Small Compressor Station and Glycol Dehydration Location

Temporary Compressor Installation in Mobley, Wetzel County, WV

Two 4,700 HP compressors here

Small Compressor on Well Pad

Compressor move in Wetzel County

1,380 HP Compressor Engine

Compressor Move Second Half

Compressor move in Wetzel County

Natural Gas Compressors in Wetzel County, WV

CHK Pleasants Compressor Station

Marcellus Drilling Waste Products

Waste Products from Shale Gas Operations

- Liquid waste such as produced water, (brine) and flowback
- Sludges and semi-solids like tank bottoms
- Concentrated (TENORM) material such as filter cake; filter socks and media
- Solid (mostly) waste like drill cuttings

For over three decades geologists have known and routinely referred to the relatively **high radioactive** content of the Marcellus Shale formation. It did not present a problem or threat to us where it had been safety stored out of harms way for millions of years. We are now challenged to dispose of this waste material since we have intentionally brought it to the surface…...

NOW IT IS OUR PROBLEM

In the next few pages this very simplified overview of waste disposal issues will show some examples of the equipment used to transport some of the waste products. All the waste is categorized as **"RESIDUAL".** It is left to the reader to define that term.

- First, the liquids, moved by tanker trucks
- Then, the solid types as in drill cuttings, via dump trucks or roll-off boxes.

No waste products whether liquid or solids from **ANY** shale gas operations, are ever required to be labeled as toxic or hazardous or dangerous or harmful. Except for the Ohio BRINE and UIC number, **NO LABEL** of **ANY** type is required when being transported on public roadways. Therefore we have **RESIDUAL + BRINE.**

The Marcellus Shale

IS

Known to be Radioactive

BUT

We Do Not

WANT TO

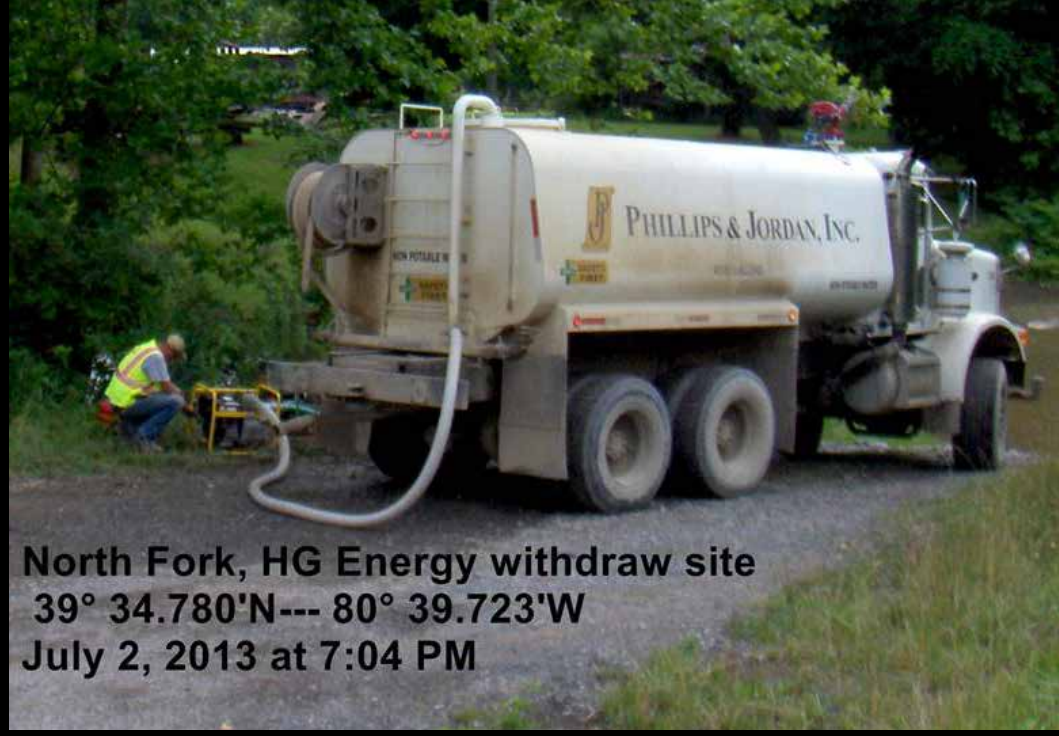
Know How Much

? Brine--Fresh--Residual ?

UIC Refers to the **U**nderground **I**njection **C**ontrol number for the deep well injection of liquid waste in the State of Ohio

Residual ? ? Waste

Residual ? ? Waste



Brine
tank
Truck
Watering Road--? or not

?

?

Fresh—or—Brine—or—Fresh—or Brine

?

?

Tanker Trucks Removing Produced Water from Well operations

The terms “Produced Water” or “Brine” are used interchangeably. Ohio requires the truck to have **BRINE** and the **UIC** number on the waste truck.

Tanker Truck at stream bank ? ?

Drill Cuttings on Drill Pad

Rich, black drill cuttings from the horizontal bore in the Marcellus Shale formation.

On the way to Landfill

Drill Cuttings on Well Pad—going to landfill

Drill Cuttings on Well Pad—ready for landfill

Rich, black drill cuttings from the horizontal bore in the Marcellus Shale formation.

Roll-off box of drill waste going to landfill

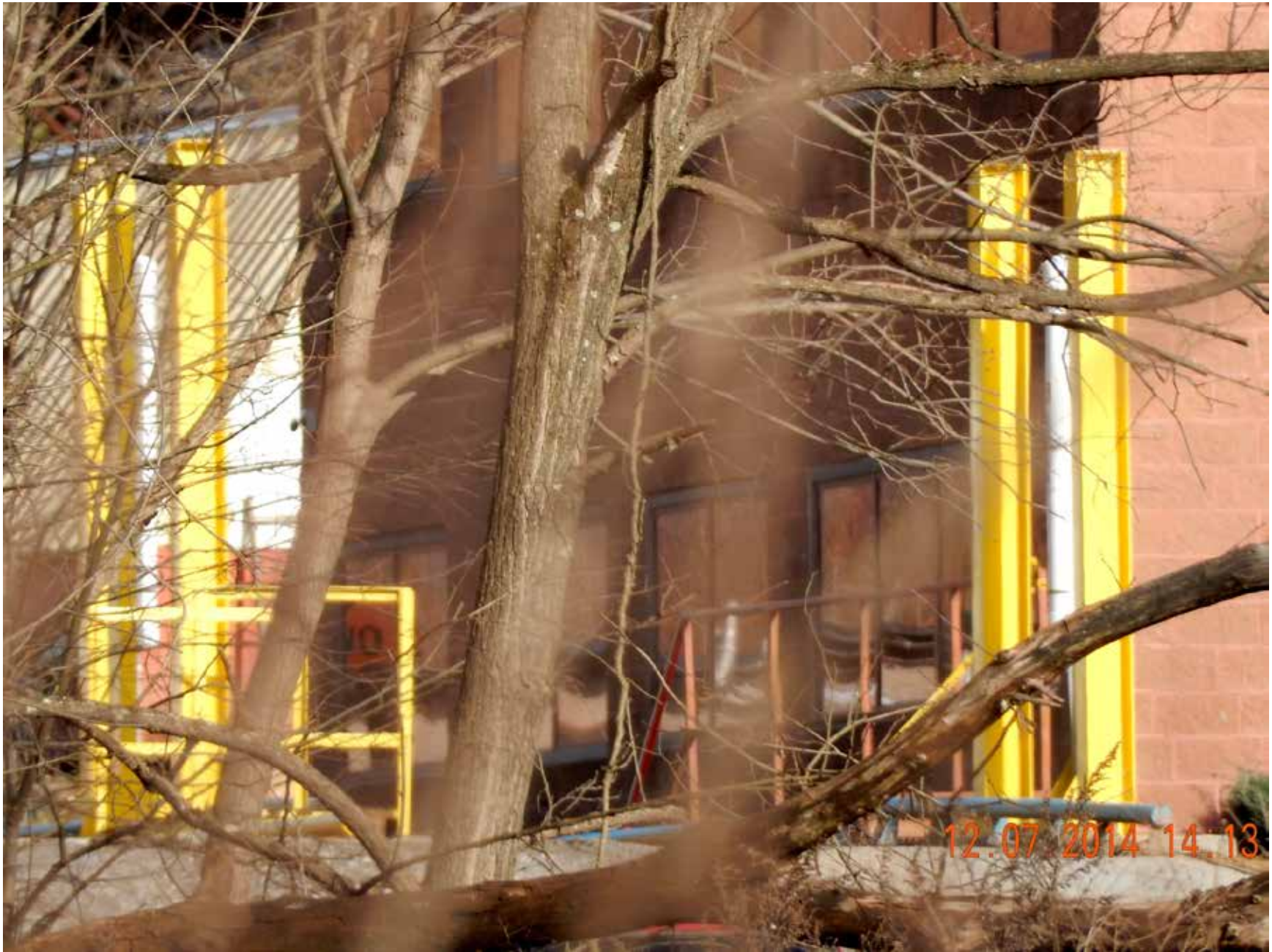
Roll-off boxes of drill waste going to landfill

Dump trucks are also used to haul drill cutting

Drill Cuttings on Well Pad—going to landfill

Drill cuttings deposited at landfill

Radiation Detectors at Landfill Entrance



West Virginia Landfills in Ohio River Valley

Process Flow

1. Well pad drill rig à Drill cuttings à Landfills
2. à Moisture drains out becomes à **Leachate**
3. **Leachate shows radioactive levels of concern**
4. **Radioactivity** cannot be filtered out à
5. **Leachate** goes to water treatment plant à
6. Effluent from water treatment plant goes into **Surface Streams and Rivers**
7. Surface waters à water intake à **Drinking Water**