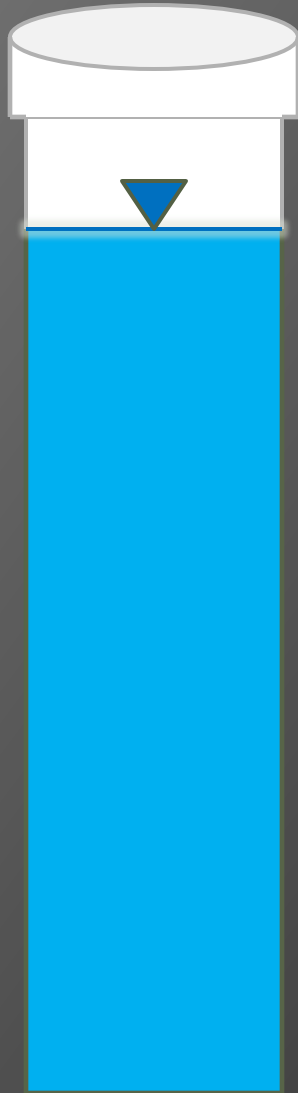


Moody and Associates, Inc.
Meadville, PA, Houston, PA, Waverly, NY
Burt A. Waite
Senior Geologist

**STRAY GAS IN
PENNSYLVANIA
OCTOBER 18, 2011**

Methane

- CH₄ 74.87% carbon and 25.13% hydrogen
- Ethane C₂H₆
- Propane C₃H₈
- American natural gas is 85% methane
- Colorless, odorless
- Density = 0.554 Air = 1 (**lighter than air**) at 1 atmosphere
- Soluble in water at normal temp and pressure is 21-35 mg/l.
- Solubility increases with increasing pressure
- Explosive from 5 to 15% in atmosphere



Methane Solubility with Depth

20' of 6" casing

50' (0' of Head)

100' (50' of Head)

150' (100' of Head)

200' (150' of Head)

250' (200' of Head)

Methane Solubility

28 mg/L

69 mg/L

110 mg/L

151 mg/L

192 mg/L

20' of 6" casing	
50' (0' of Head)	28 mg/L
100' (50' of Head)	69 mg/L
150' (100' of Head)	110 mg/L
200' (150' of Head)	151 mg/L
250' (200' of Head)	192 mg/L

Methane in Water

- ⦿ **No drinking water standard**
- ⦿ Not recognized as a toxic substance
- ⦿ Recognized as a safety issue – it burns and/or explodes
- ⦿ There have been a number of cases where homes have exploded and people have been killed due to fugitive gas in fresh ground water aquifers.

Laboratory Testing for Methane in Water

- ⦿ **No universally accepted laboratory method**
- ⦿ No EPA protocol
- ⦿ Some labs use head space, some don't
- ⦿ Can not compare concentrations in water between labs
- ⦿ Can not be sure of reproducibility of lab results
- ⦿ Can be seen to effervesce when brought to atmospheric pressure (alka seltzer like)

Sources of Methane

- Landfills (decay of organic material)
- Manure digestion
- Coal mines and coal
- Natural gas (Thermogenic and Thermogenic)

Identifying sources of stray gas

- Geochemical and isotopic fingerprinting
- Can differentiate between microbial origin (landfill and marsh gas) and thermogenic gas and thermogenic gases from different sources

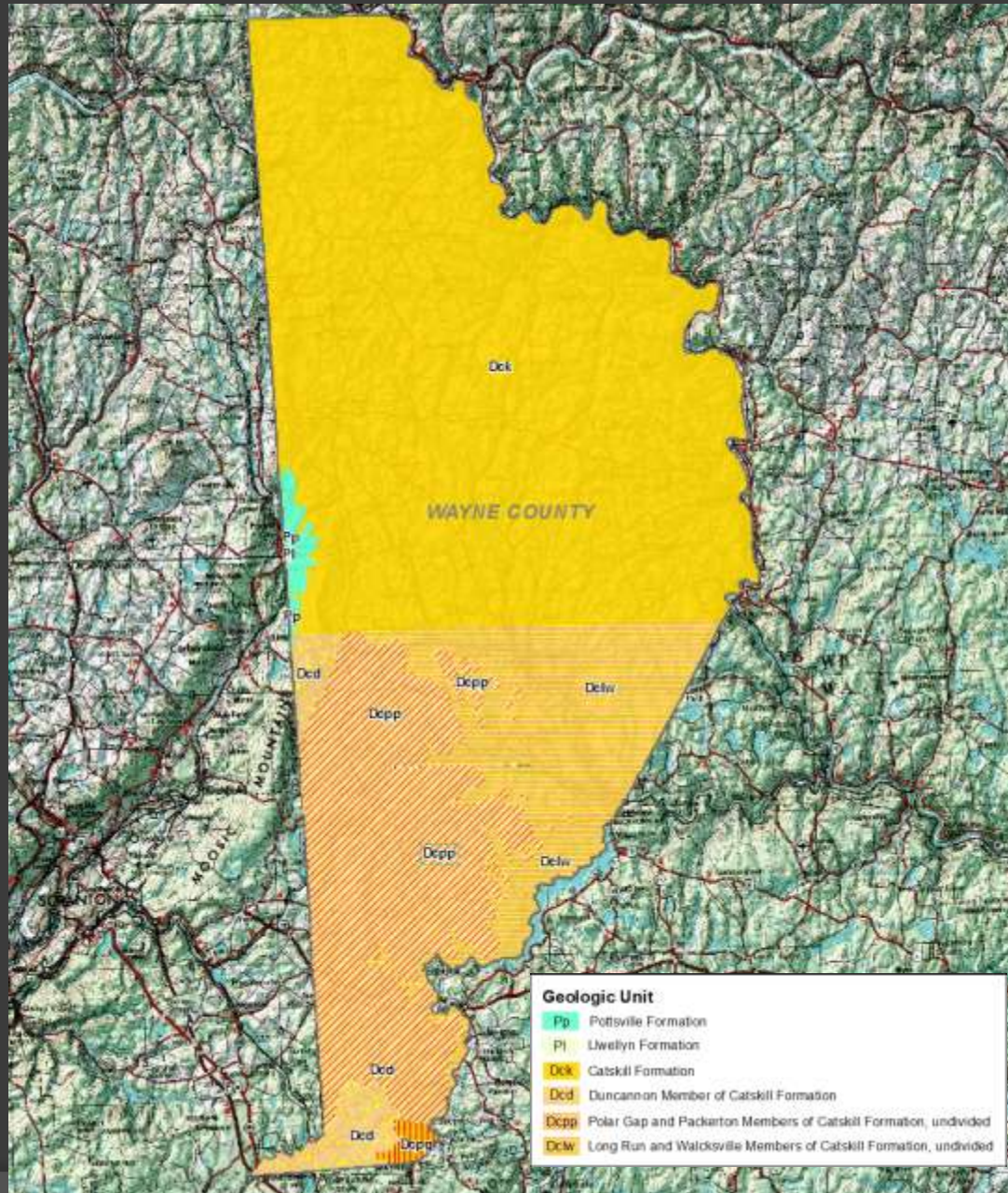
Hydrostatic pressure of water:

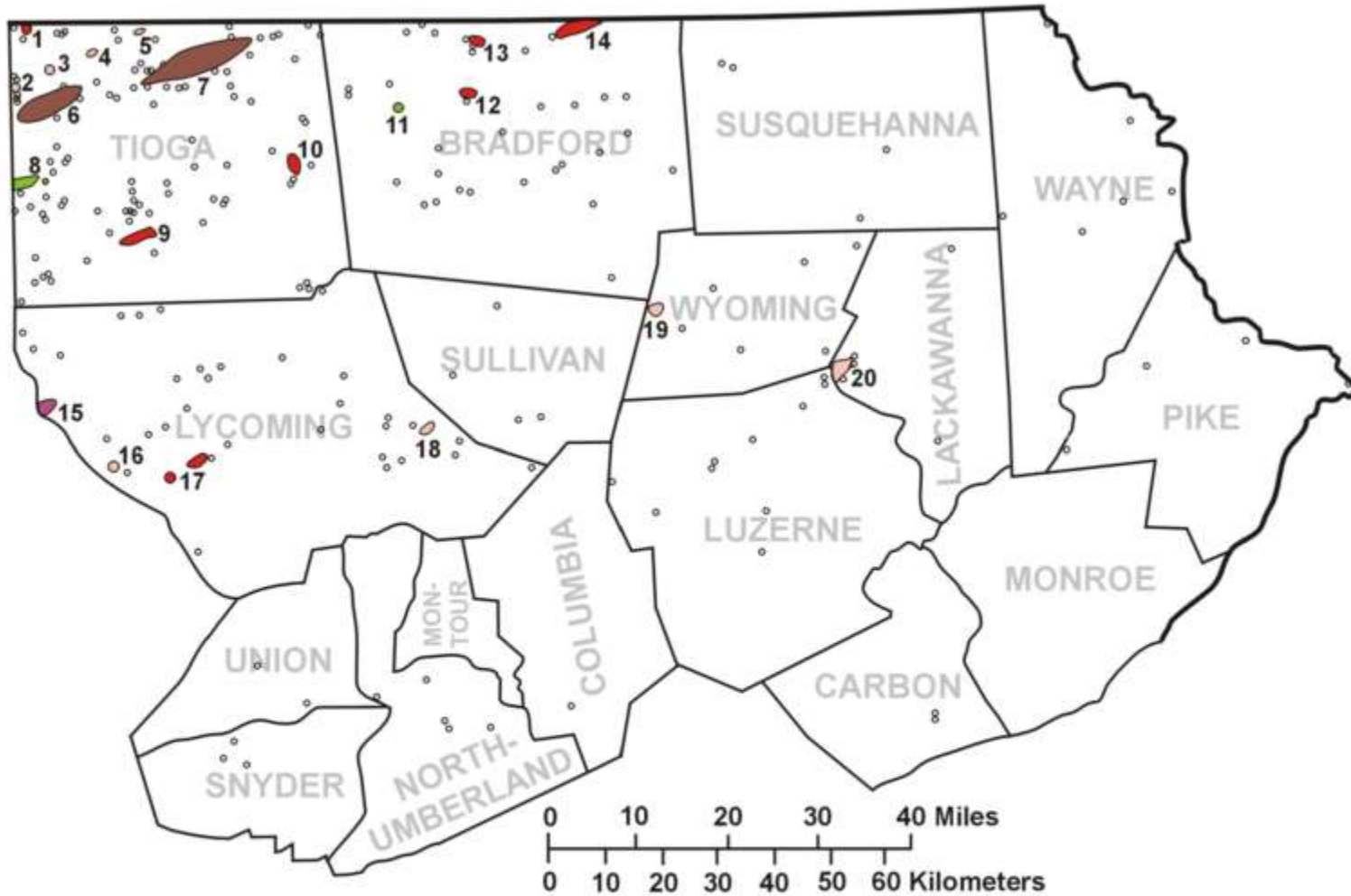
- ① 1 psi = 2.3 feet of head
- ① 1 foot of head = 0.433 psi
- ① 80 % Rule
- ① $0.80 * 0.433 * \text{Casing length in feet}$
 $0.80 * 0.433 * 300' = 104 \text{psi}$





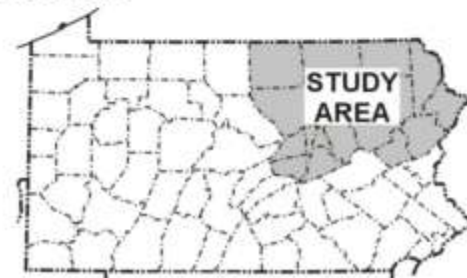


Wayne County, Pennsylvania





- | | |
|--|--|
|  Lock Haven oil field |  Lock Haven gas field |
|  Oriskany gas field |  Oriskany gas storage field |
|  Bald Eagle gas field |  Dry hole |



Natural Gas/Stray Gas

Recognized as major issue

DEP has investigated 119 stray gas incidents since 1987
(16 related to Marcellus Shale Wells)

Some very high profile

Some very destructive

Some with injuries and some with fatalities

Natural gas is part of the issue concerning casing off fresh water

Naturally occurring in fresh water aquifers

Literature review

As early of 1939 recognized as being present(Lohman)

Wells in glaciated valleys contain methane and highly saline water

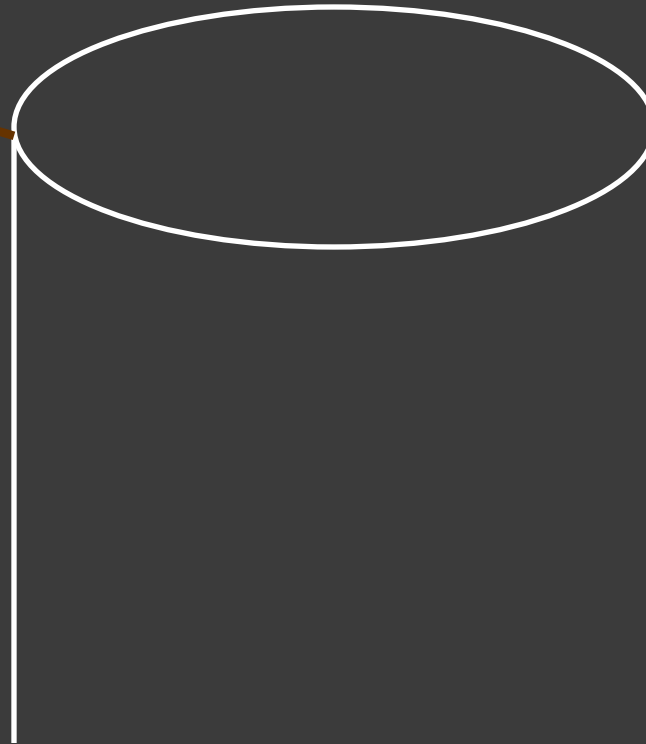
New York regulators recognize natural gas in fresh water aquifers

Pre-Drill data

5 to 80% of the wells exhibit some level of methane

MARCELLUS WELL

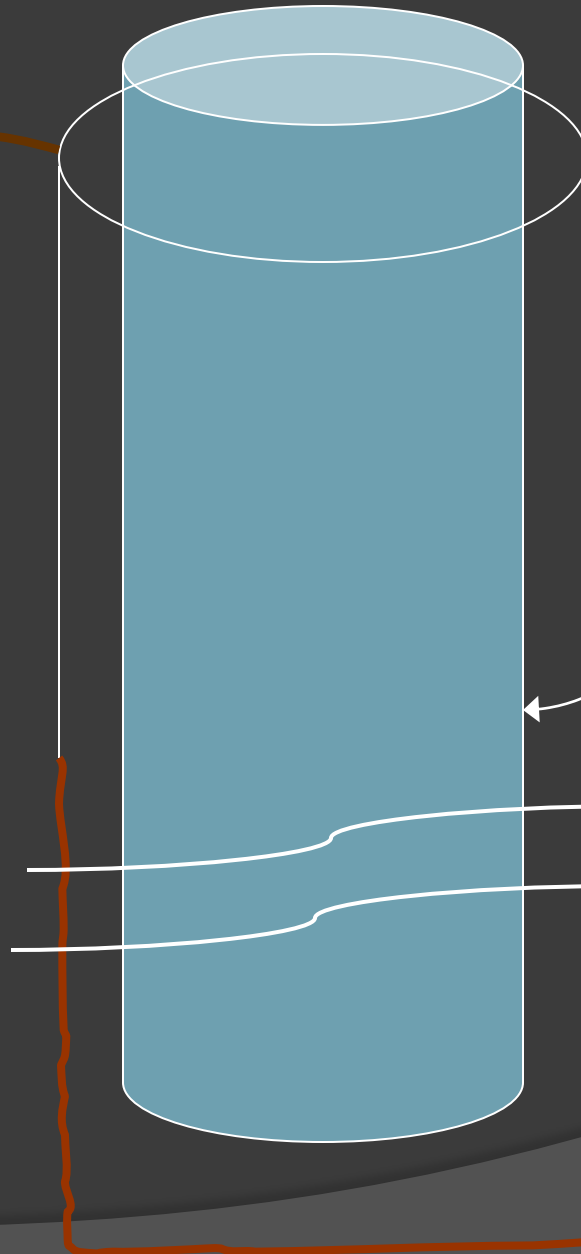
Ground Level



20" Conductor
Casing to 20" ±

MARCELLUS WELL SURFACE CASING

Ground Level

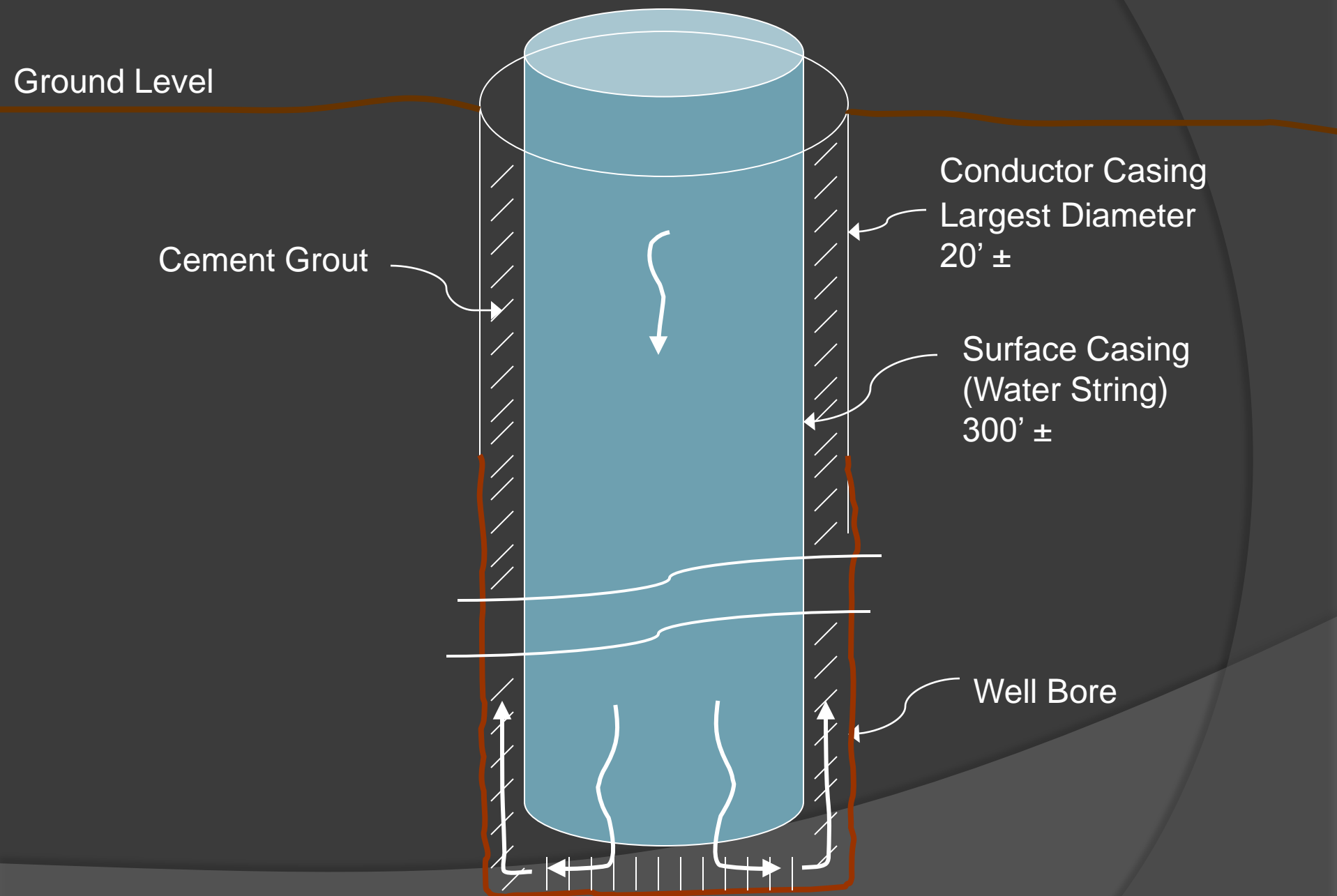


Conductor Casing
Largest Diameter 20" ±

Surface Casing
(Water String)
13 3/8" Casing
300' ±

Well Bore

MARCELLUS WELL - SURFACE CASING CEMENT



MARCELLUS WELL INTERMEDIATE CASING #1

Ground Level

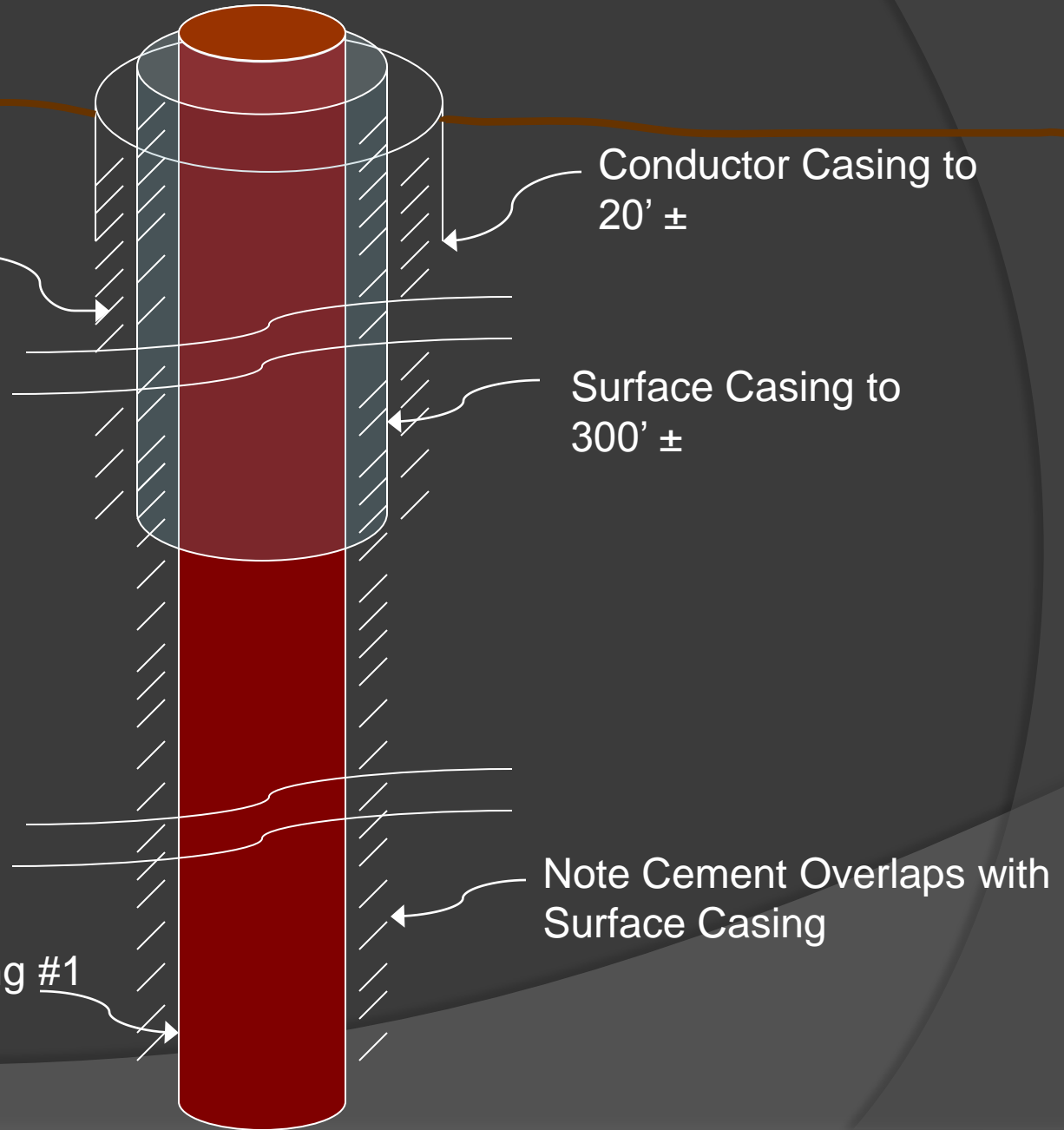
Cement Grout

Conductor Casing to
20' ±

Surface Casing to
300' ±

Note Cement Overlaps with
Surface Casing

Intermediate Casing #1
9 5/8" set to 1000'



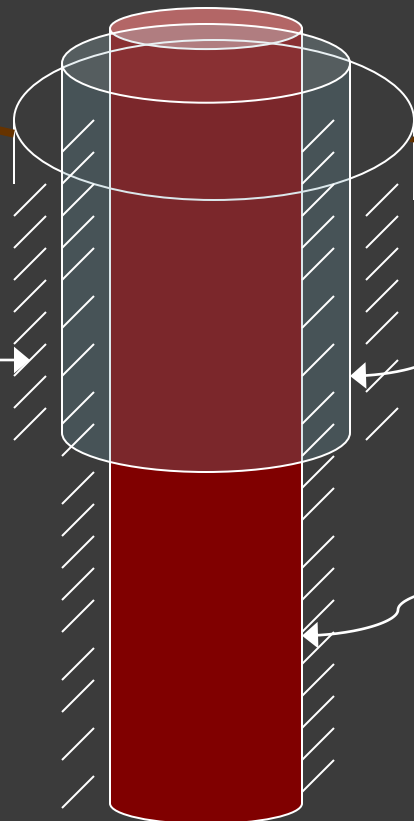
MARCELLUS WELL INTERMEDIATE CASING #2

Ground Level

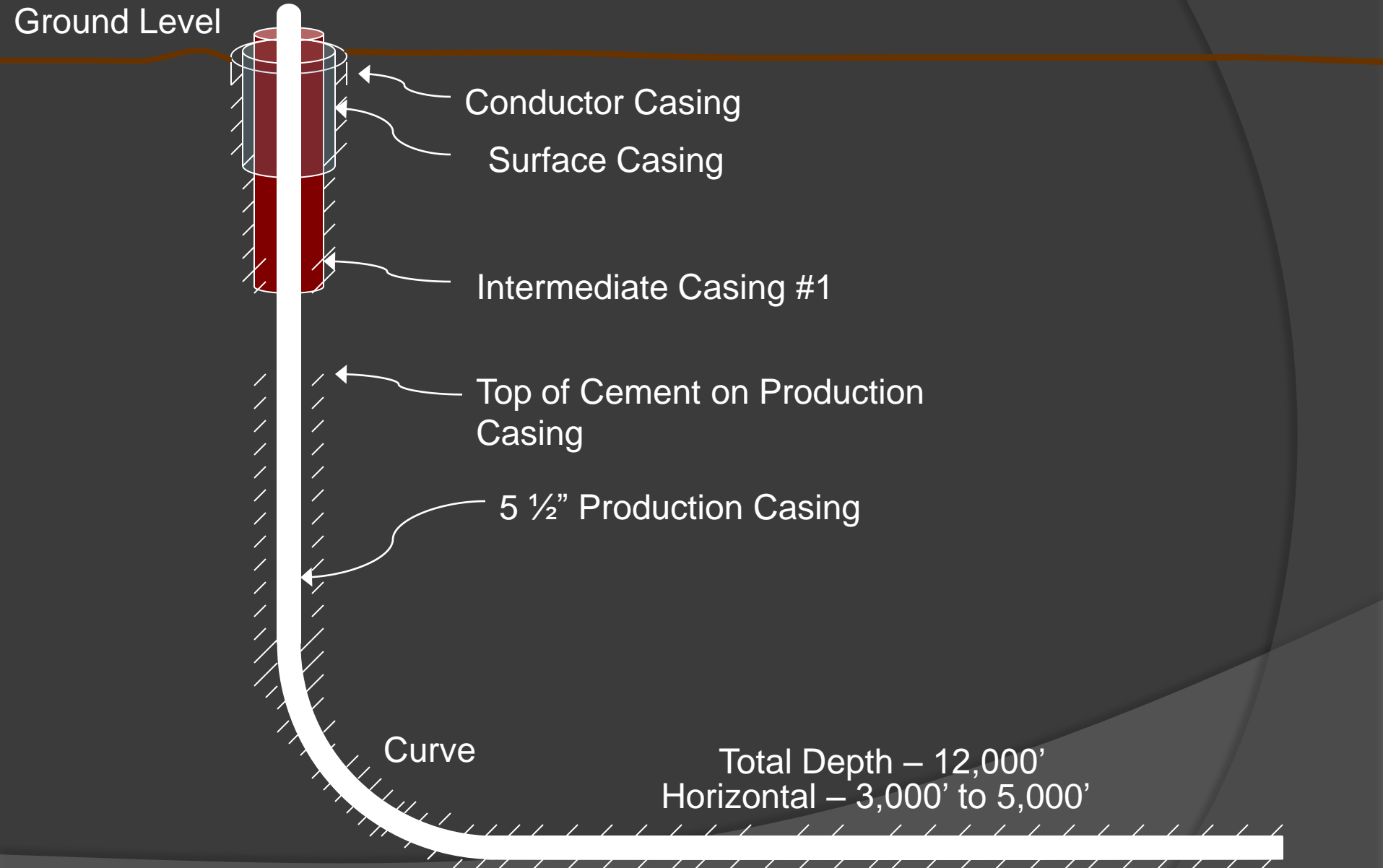
Cement Grout

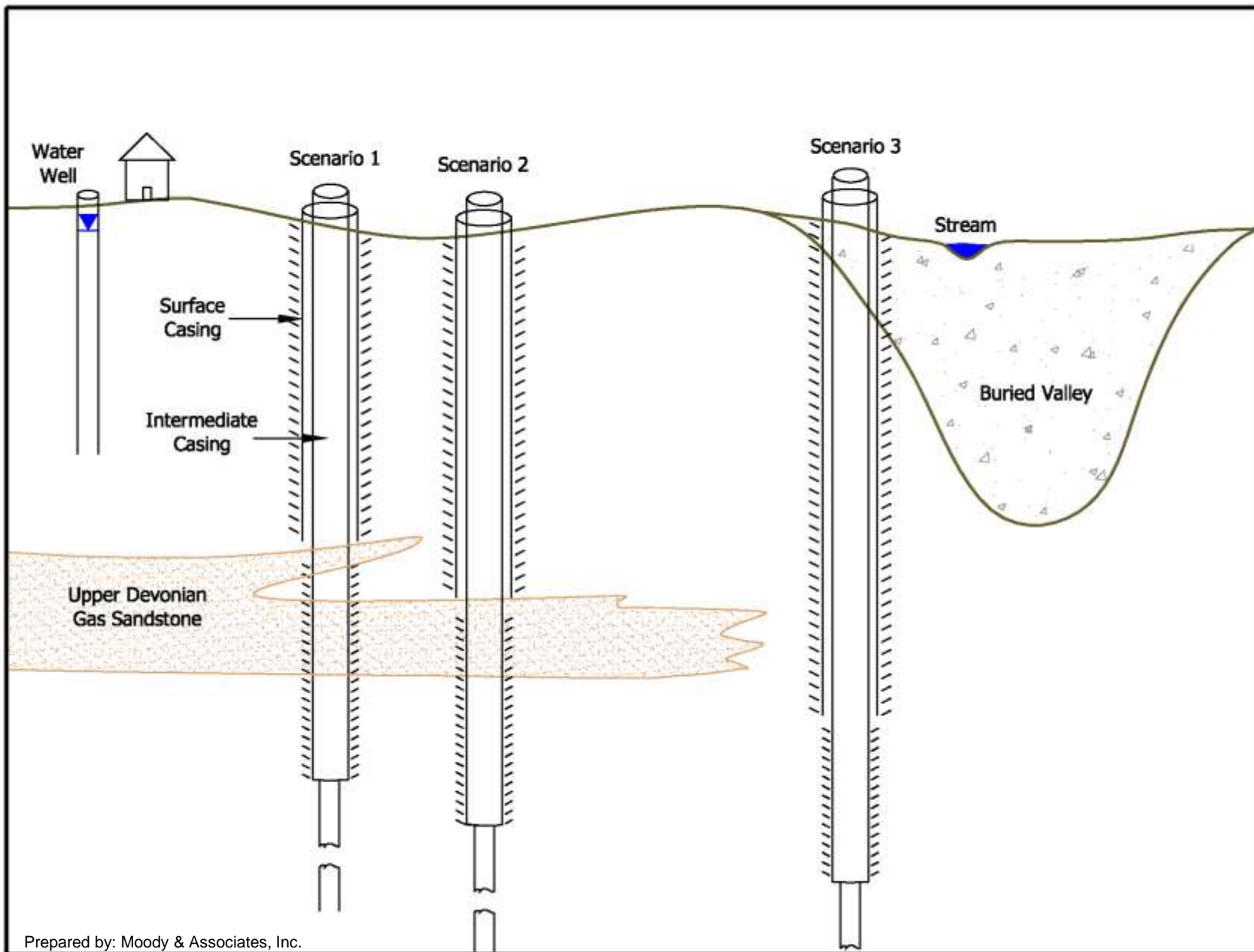
Conductor Casing to 20' ±
Surface Casing to 300' ±

Intermediate Casing #1
9 5/8" set to 2,000'



MARCELLUS WELL PRODUCTION CASING





§78.89 Gas Migration Response

- ⦿ (a) When an operator or owner is notified of or otherwise made aware of a **POTENTIAL** natural gas migration incident, the operator shall immediately conduct an investigation of the incident. The purpose of the investigation is to determine the nature of the incident, assess the potential for hazards to public health and safety, and mitigate any hazard posed by the **CONCENTRATIONS OF STRAY NATURAL GAS.**

Pre-drill
considerations

§78.89 Gas Migration Response

- ⦿ **When notified of a POTENTIAL natural gas migration incident – immediately conduct an investigation.**
 - **Site visit and interviews**
 - **Field survey of the presence of gas, concentrations and aerial extent**
 - **Establish monitoring locations at potential sources, impacted structures and subsurface**

§78.89 Gas Migration Response

- (c) **IF COMBUSTIBLE GAS IS DETECTED INSIDE A BUILDING OR STRUCTURE AT CONCENTRATIONS EQUAL TO OR GREATER THAN 10% OF THE LOWER EXPLOSIVE LIMIT (L.E.L.), THE OPERATOR SHALL:**
 - 1) IMMEDIATELY NOTIFY THE DEPARTMENT, LOCAL EMERGENCY RESPONSE AGENCY, GAS AND ELECTRIC UTILITY COMPANIES, POLICE AND FIRE DEPARTMENTS AND, IN CONJUNCTION WITH THE DEPARTMENT AND LOCAL EMERGENCY RESPONSE AGENCIES, TAKE MEASURES NECESSARY TO ENSURE PUBLIC HEALTH AND SAFETY;
 - 2) INITIATE MITIGATION MEASURES NECESSARY TO CONTROL AND PREVENT FURTHER MIGRATION;
 - 3) IMPLEMENT THE ADDITIONAL INVESTIGATION AND MITIGATION MEASURES AS PROVIDED IN SUBSECTION (E)(1)-(5).

§78.89 Gas Migration Response

More discussions
to come on soil
gas

- (d) THE OPERATOR SHALL NOTIFY THE DEPARTMENT AND, IN CONJUNCTION WITH THE DEPARTMENT, TAKE MEASURES NECESSARY TO ENSURE PUBLIC HEALTH AND SAFETY, IF SUSTAINED DETECTABLE CONCENTRATIONS OF COMBUSTIBLE GAS SATISFY ANY OF THE FOLLOWING:
 - 1) GREATER THAN 1% AND LESS THAN 10% OF THE L.E.L., IN A BUILDING OR STRUCTURE;
 - 2) EQUAL TO OR GREATER THAN 25% OF THE L.E.L. IN A WATER WELL HEAD SPACE
 - 3) DETECTABLE IN THE SOILS; OR
 - 4) EQUAL TO OR GREATER THAN 7 MG/L DISSOLVED METHANE IN WATER

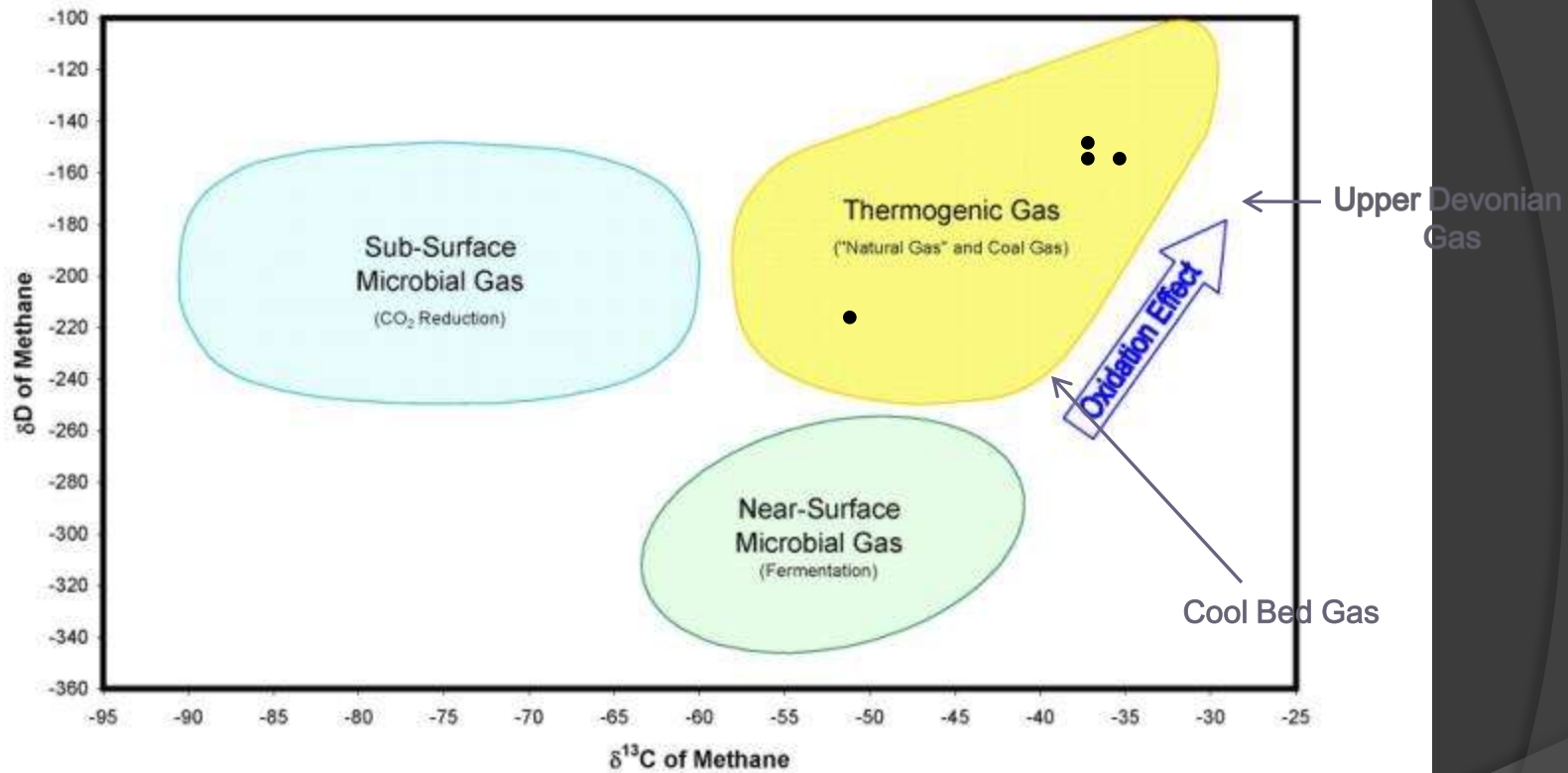
§78.89 Gas Migration Response

- ⦿ **(E) THE DEPARTMENT MAY REQUIRE THE OPERATOR TO TAKE THE FOLLOWING ADDITIONAL ACTIONS:**
 - 1) CONDUCT A FIELD SURVEY TO ASSESS THE PRESENCE GAS IN:**
 - **SOILS**
 - **SURFACE WATER BODIES**
 - **WATER WELLS**
 - **OTHER POTENTIAL MIGRATION PATHWAYS**

§78.89 Gas Migration Response

- 2) COLLECT GAS AND/OR WATER SAMPLES AT A MINIMUM FOR MOLECULAR AND STABLE CARBON AND HYDROGEN ISOTOPE ANALYSES FROM THE IMPACTED LOCATIONS SUCH AS WATER WELLS, AND FROM POTENTIAL SOURCES OF THE MIGRATION SUCH AS GAS WELLS;

Typical Compositional Ranges of Methanes from Different Sources



§78.89 Gas Migration Response

3) CONDUCT AN IMMEDIATE EVALUATION OF THE OPERATOR'S ADJACENT OIL OR GAS WELLS

- INITIAL SEARCH WITHIN 2,500 FEET
- DETERMINE WELL CEMENT INTEGRITY
- DETERMINE CASING INTEGRITY
- DETERMINE ANNULAR PRESSURES

§78.89 Gas Migration Response – Reporting Requirements

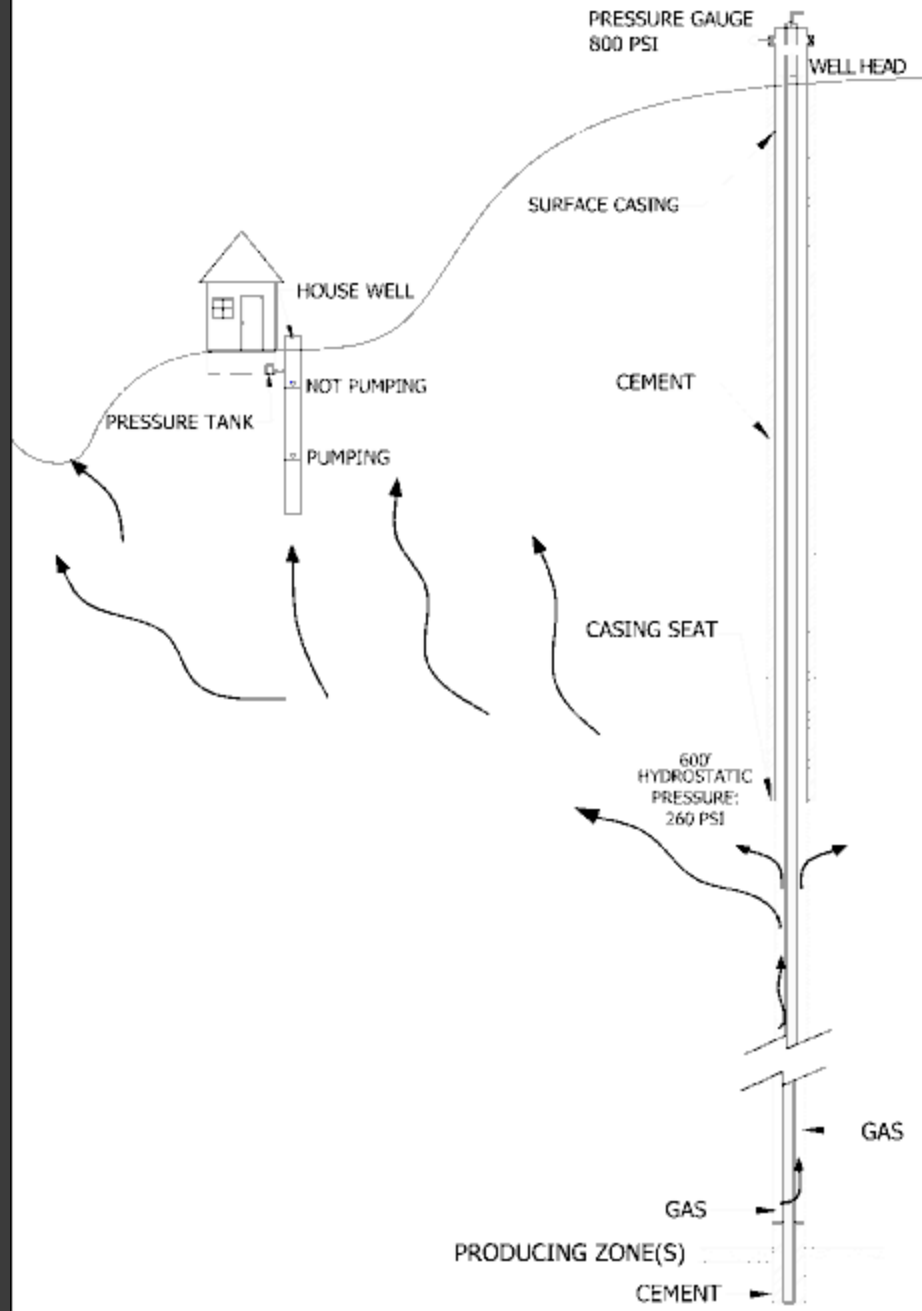
- **C) *REPORTING REQUIREMENTS* - IF CONCENTRATIONS OF STRAY NATURAL GAS ARE DETECTED INSIDE A BUILDING OR STRUCTURE AT CONCENTRATIONS EQUAL TO OR GREATER THAN 10% OF THE L.E.L., THE OPERATOR AND OWNER SHALL FILE A REPORT WITH THE DEPARTMENT BY PHONE AND EMAIL WITHIN 24 HOURS.**

§78.89 Gas Migration Response– Reporting Requirements

- ⦿ (D) FOR ALL STRAY NATURAL GAS MIGRATION INCIDENTS, A FINAL WRITTEN REPORT DOCUMENTING:
 - 1) ALL RESULTS OF THE INVESTIGATION, INCLUDING ANALYTICAL DATA, MONITORING RESULTS
 - 2) OPERATIONAL CHANGES ESTABLISHED AT THE OPERATOR'S OIL AND GAS WELLS IN PENNSYLVANIA
 - 3) MEASURES TAKEN BY THE OPERATOR TO REPAIR ANY DEFECTS AT ANY OF THE INVESTIGATED OIL AND GAS WELLS.
- ⦿ (E) ALL REPORTS TO BE SIGNED BY A PENNSYLVANIA LICENSED GEOLOGIST (PG) OR ENGINEER(PE).

Pre-Drill Gas

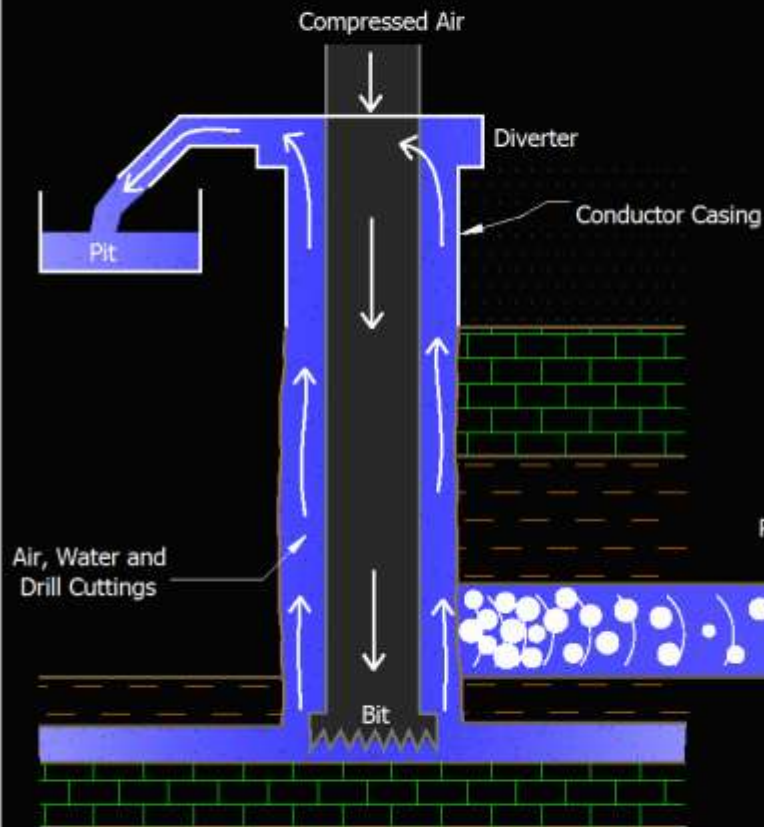
- ◎ The new regulations require operators to provide the Department with their pre-drill survey data within 10 days of receipt from the lab. The operator is not required to call the Department's attention to "anomalous" occurrences of methane. Further, there is no obligation for the operator to conduct any kind of further investigation envisioned by Section 78.89 if they discover "anomalous" gas readings during the pre-drill survey. If, however, the operator receives a complaint about gas in a water well, they must respond and cannot use the pre-drill survey as a defense regarding the obligations imposed by Section 78.89. To the extent Department staff are available and aware of "anomalous" occurrences of methane, they will investigate the possible sources of the gas.



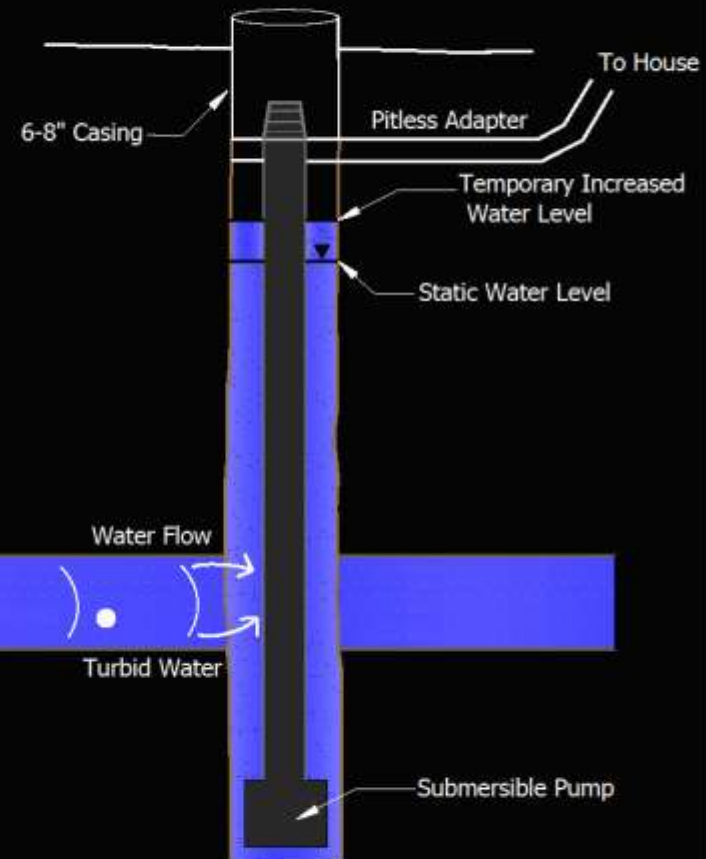
METHANE MIGRATION

DRILLING AIR IMPACTS ON WATER WELLS

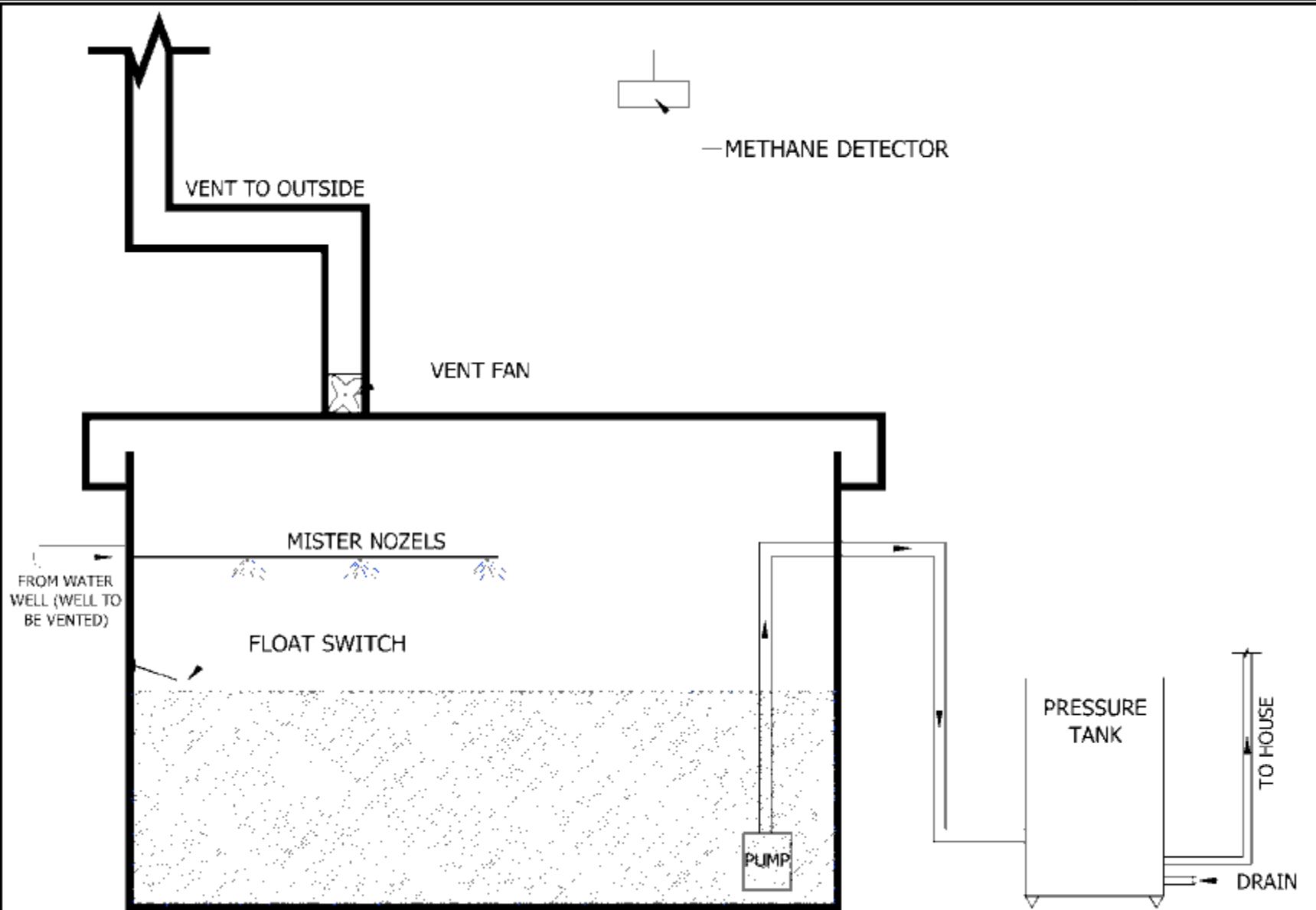
Drilling Air



Water Well







METHANE TREATMENT SYSTEM