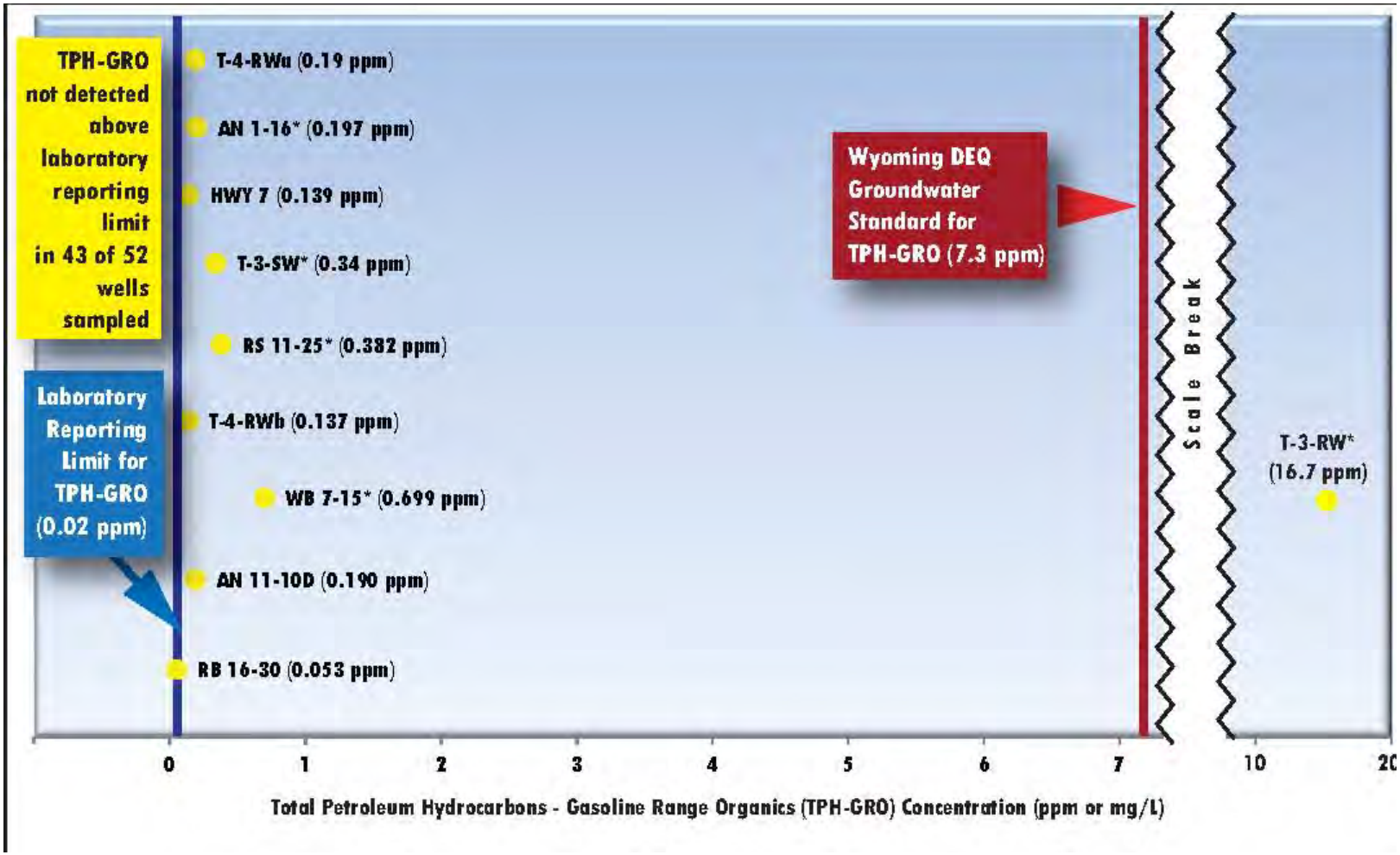
Results of LLPHC Study

Pinedale Anticline Project Area

Sublette County, Wyoming

Overview
Low-Levels



Overview
Contrast in Chemical Signatures

Potential Sources*

- Volatile/Semivolatile Organics/TICs
  - Multiple detections
  - Complimentary detections
  - Fractions: both detected and complimentary; one may be dominant
- Inorganic Constituents
  - Elevated concentrations
- Gas Composition
  - Thermogenic
  - Unaltered
- Chromatographic Profiles
  - Diagnostic
  - Relatively high response

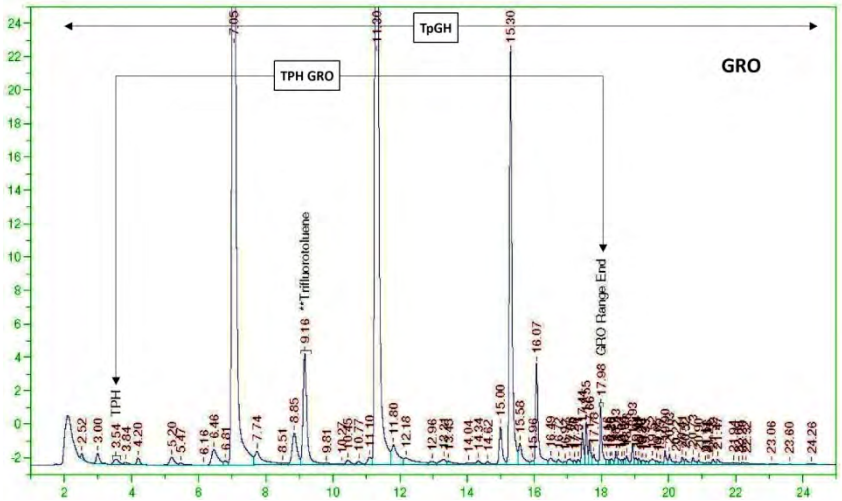
Low-Level Wells

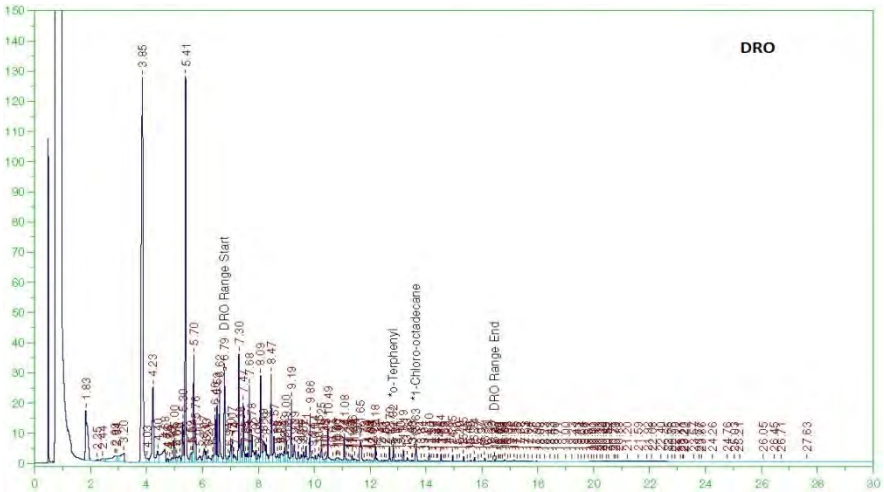
- Volatile/Semivolatile Organics/TICs
  - Few to no detections
  - Few to no complimentary detections
  - Fractions do not appear to be related
- Inorganic Constituents
  - Concentrations in range of typical groundwater
- Gas Composition
  - Thermogenic, Intermediate, Microbial
  - Altered
- Chromatographic Profiles
  - Non-diagnostic
  - Low response

***Includes condensate, produced water, flowback fluid, drill mud, natural gas**

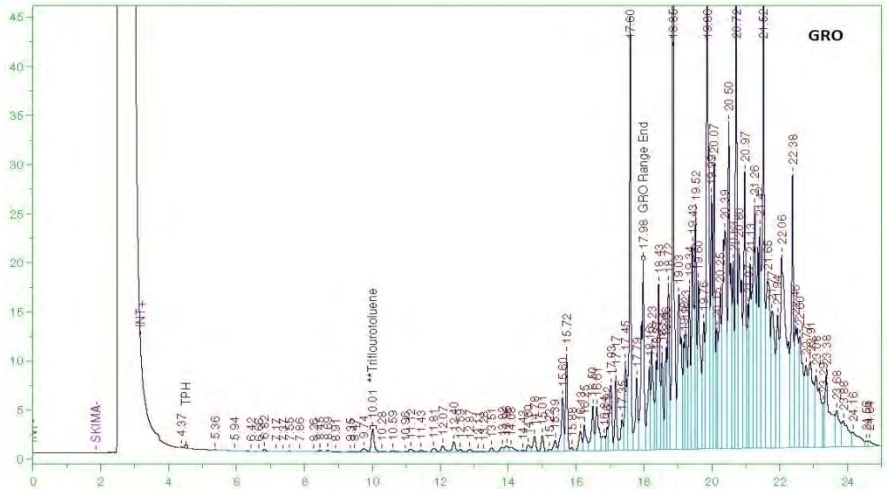
Overview
Typical Chromatographic Profiles: Sources

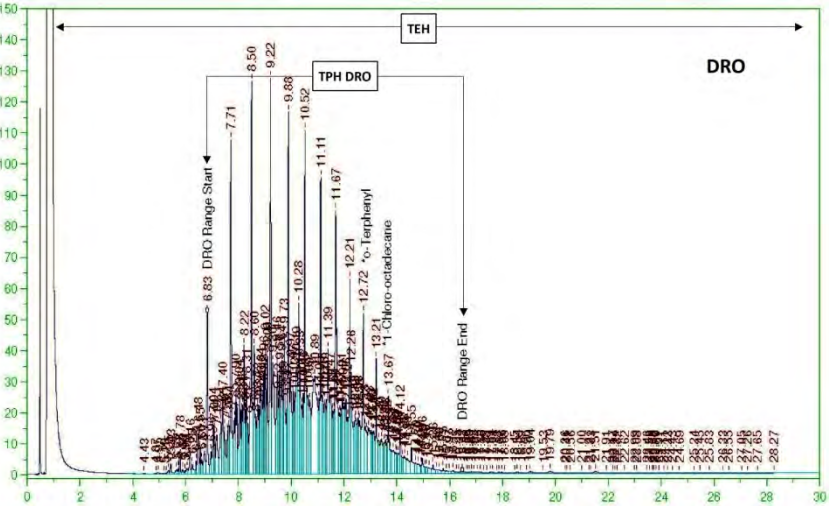
Produced Water





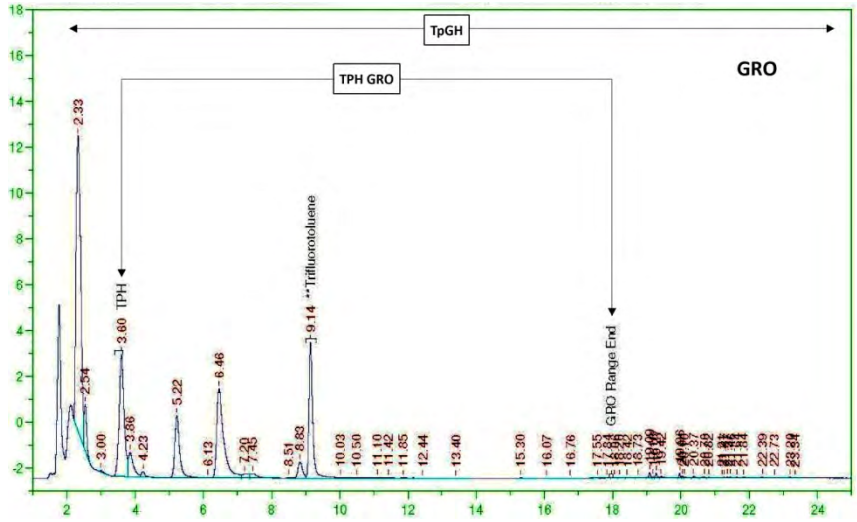
Drill Mud

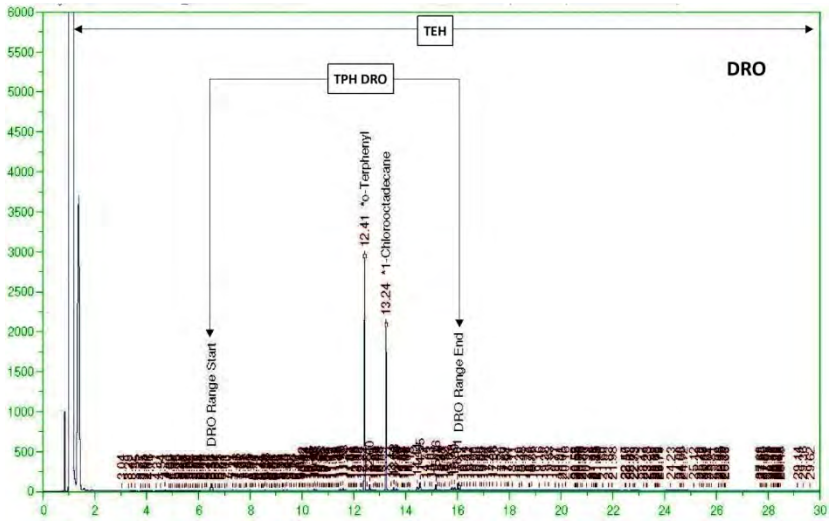




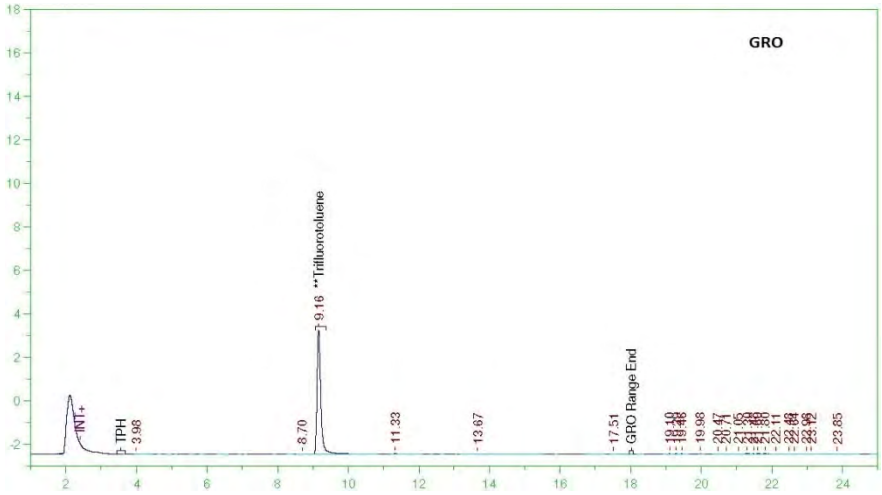
Overview
Typical Chromatographic Profiles: Low-Level Wells

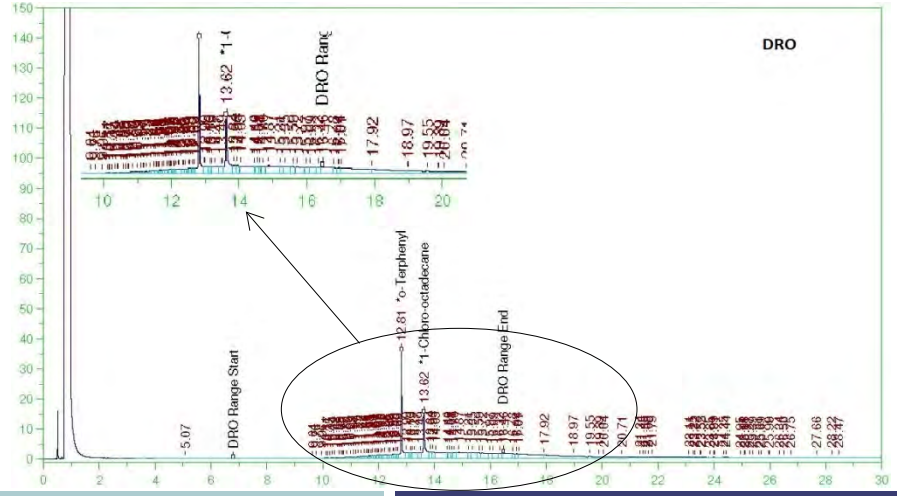
Groundwater – AN 11-10D





Groundwater – AN 15-23





Overview
Volatile versus Semivolatile Organics

- Results reported for study separated by volatile and semivolatile fraction; however, both fractions were considered when assessing source.

- The volatile organic constituents detected in low-level wells do not appear to be related to semivolatile organic constituents detected in low-level wells.

- The source of chemical signatures in low level wells, particularly for the semivolatile fraction, is not readily apparent. It is more difficult to connect the low-level detections to their likely source.

Four Conclusions

amec

Conclusion #1

Source of Low-Level Volatile Organic Constituents

- Largely attributable to upward seepage of natural gas
  - Gas likely originated from Lance Pool, but has been subsequently altered
  - Upward seepage likely occurs over geologic time
  - Seepage of gas is driven by natural processes

Conclusion #2

Source of Low-Level Semivolatile Organic Constituents

- Not readily apparent
- Likely originates from either:
  - Substances introduced during the drilling, installation, and operation of wells, and/or
  - Naturally-occurring organic matter

Four Conclusions

amec

Conclusion #3

No Widespread Impact from E&P Activities

- Chemical signatures of potential source materials are not present in low-level wells
- Migration of organic constituents would be of limited extent based on:
  - Hydrogeology
  - Modelling studies
- High-level detections not the source of low-level detections
- Several sources evaluated for study not likely due to:
  - Temporal factors
  - Spatial factors
- Current E&P best practices minimize risk of impacts to groundwater

Conclusion #4

No Additional Mitigations Needed

- The presence of gas in near-surface groundwater due to natural processes can be expected and cannot be mitigated
- Best practices now in place to minimize the introduction of substances to water wells
- Naturally occurring organic matter in groundwater cannot be mitigated

Conclusion #1:
Source of Low-Level Volatile Organic Constituents

- Largely attributable to the upward seepage of natural gas from the Lance Pool over geologic time by natural processes.
  - Hydrocarbon gases in low-level wells are not the same as natural gas produced in the PAPA.
  - Natural gas likely migrates to the ground surface over geologic time in the PAPA.

Conclusion #1:
Low-Level Volatile Organic Constituents Characteristics of Detections

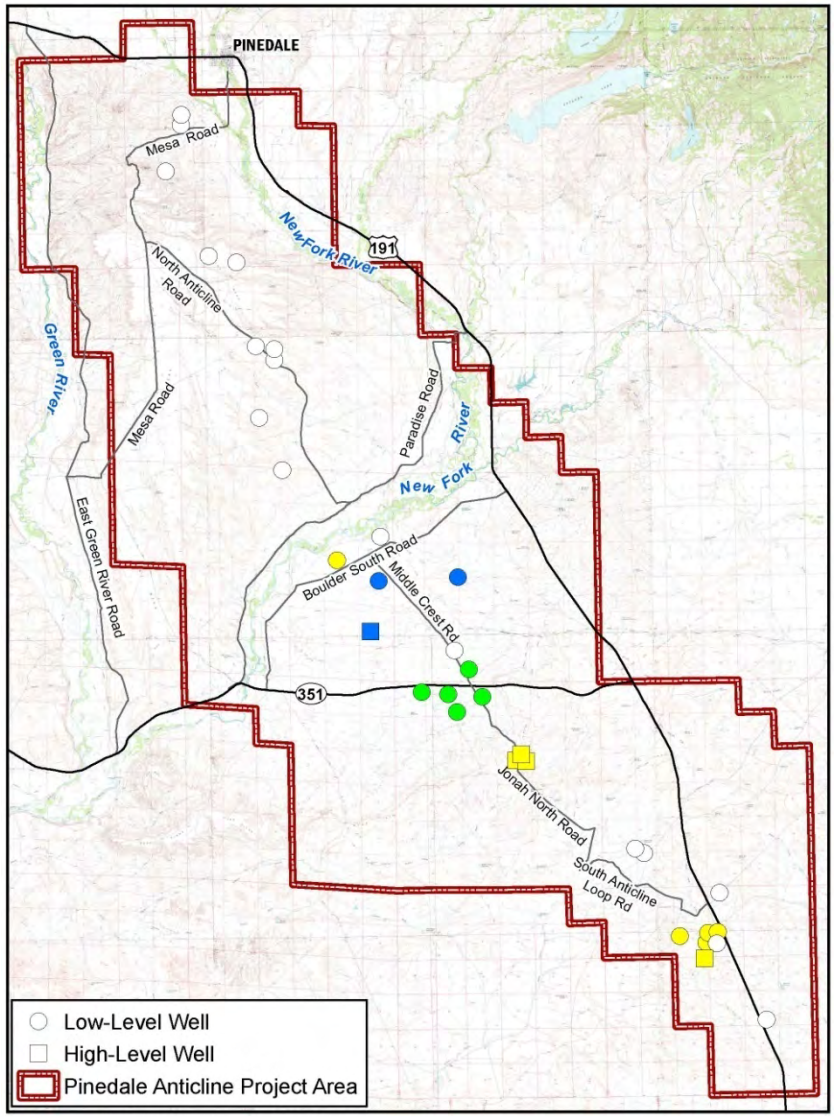
- All low-level wells sampled contained methane; roughly ½ of these wells contained higher molecular weight (C_{2+}) hydrocarbon gases (*dissolved gas analysis*).

- Volatile organic fractions (TPgH and TPH-GRO) were detected in less than ½ of these wells at low concentrations (*Method 8015*).

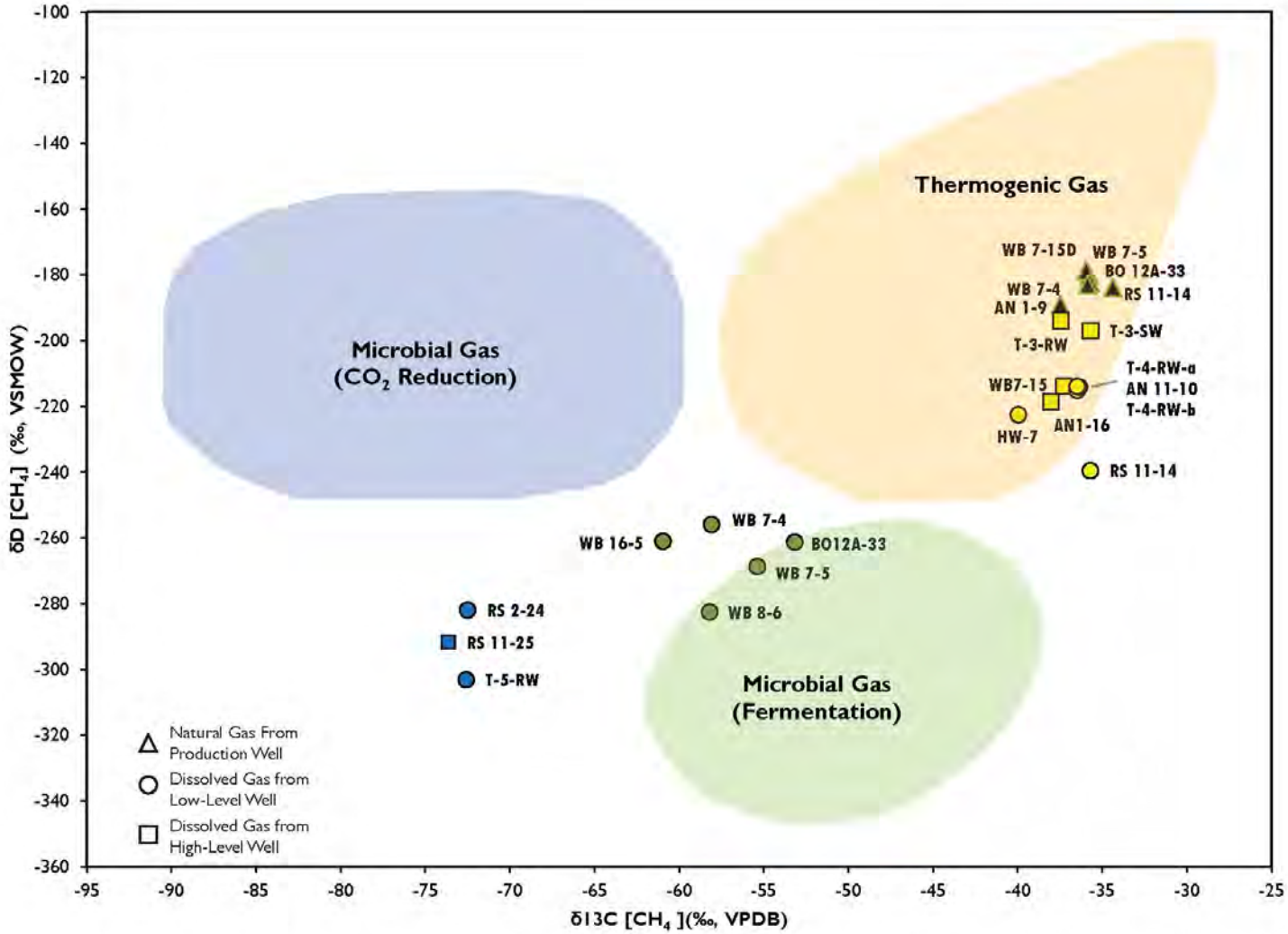
- Detection of specific volatile organic compounds (i.e., BTEX) and tentatively-identified compounds (TICs) that are not gases is generally limited (*Method 8260*).

Conclusion #1:
Low-Level Volatile Organic Constituents Distribution of Dissolved Hydrocarbon Gas

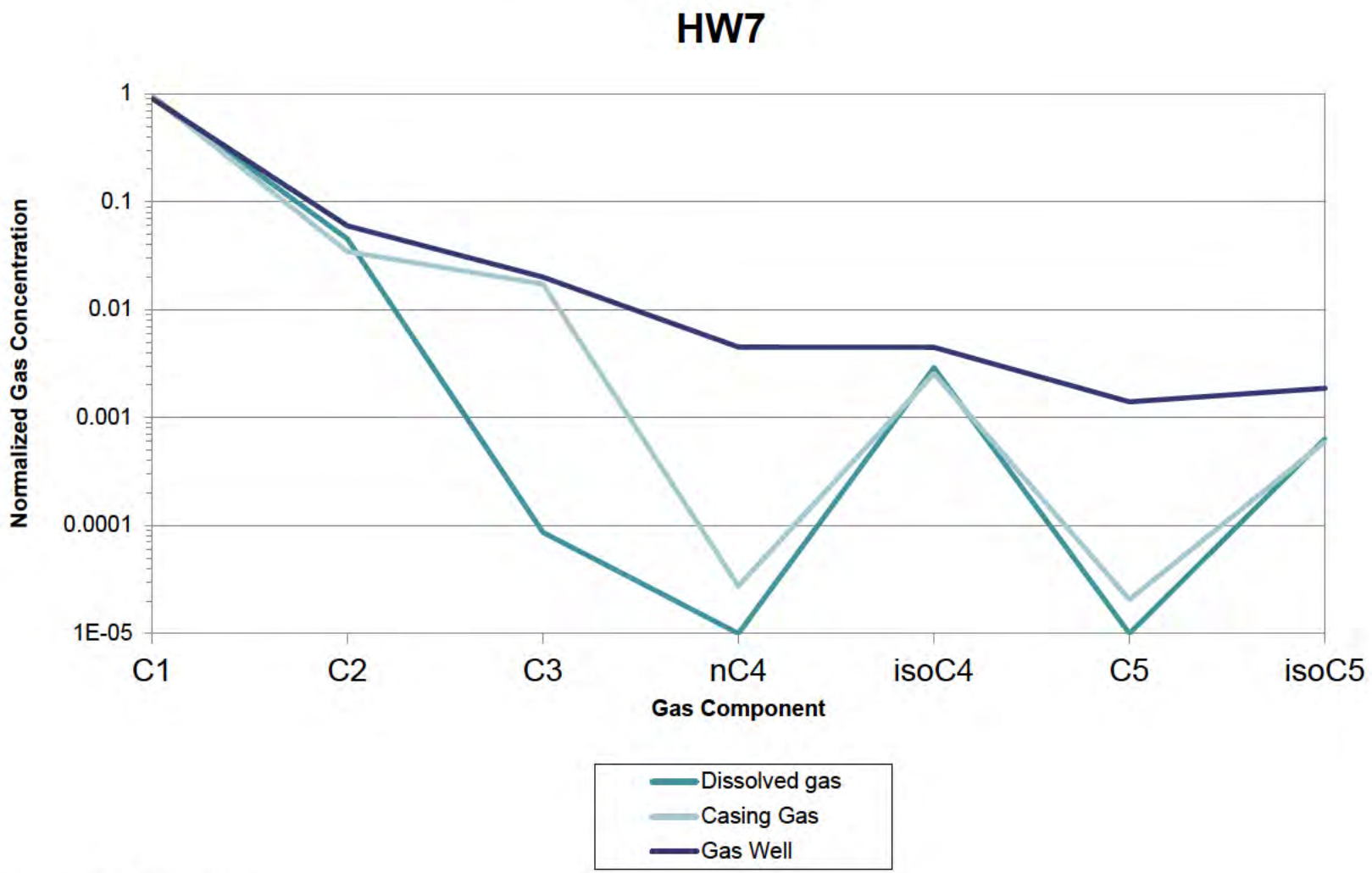
- Wells north of New Fork River; some wells south of New Fork River
  - Low methane concentrations
  - Methane and ethane only
- Wells immediately south of New Fork River
  - Moderate methane concentrations
  - Methane, ethane, propane
- Wells in vicinity of Hwy 351
  - Moderate methane concentrations
  - Methane through butane, some up through hexane
- Wells in south end of PAPA
  - Highest methane concentrations
  - Methane through hexane



Conclusion #1:
Low-Level Volatile Organic Constituents Isotopic Composition of Methane



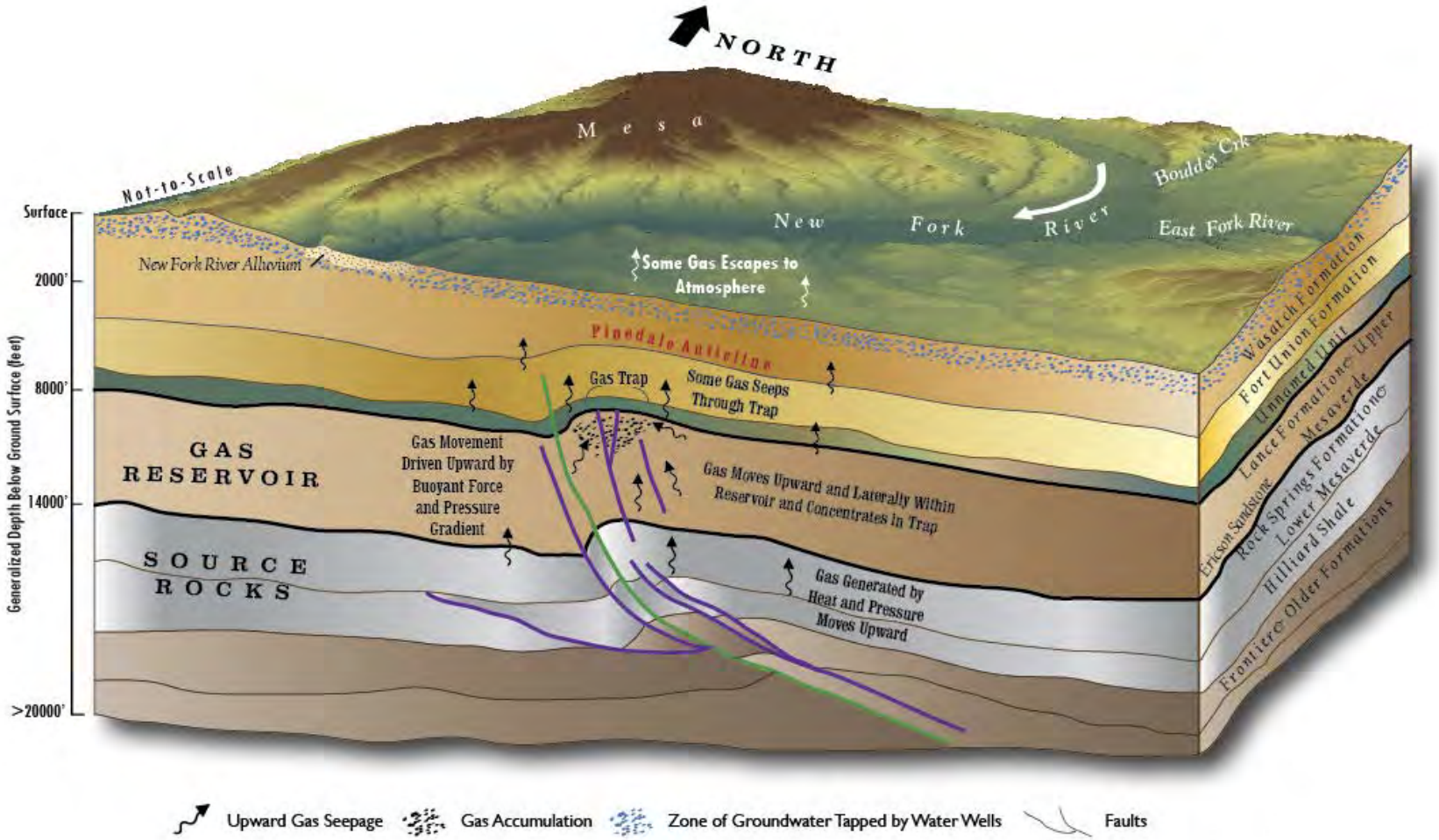
Conclusion #1:
Low-Level Volatile Organic Constituents: Gas Component Ratios Exhibiting Alteration



* Gas well data from Antelope 1-9

Conclusion #1:
Low-Level Volatile Organic Constituents: Observations of Gas in PAPA

Conclusion #1:
Low-Level Volatile Organic Constituents Gas Generation and Seepage

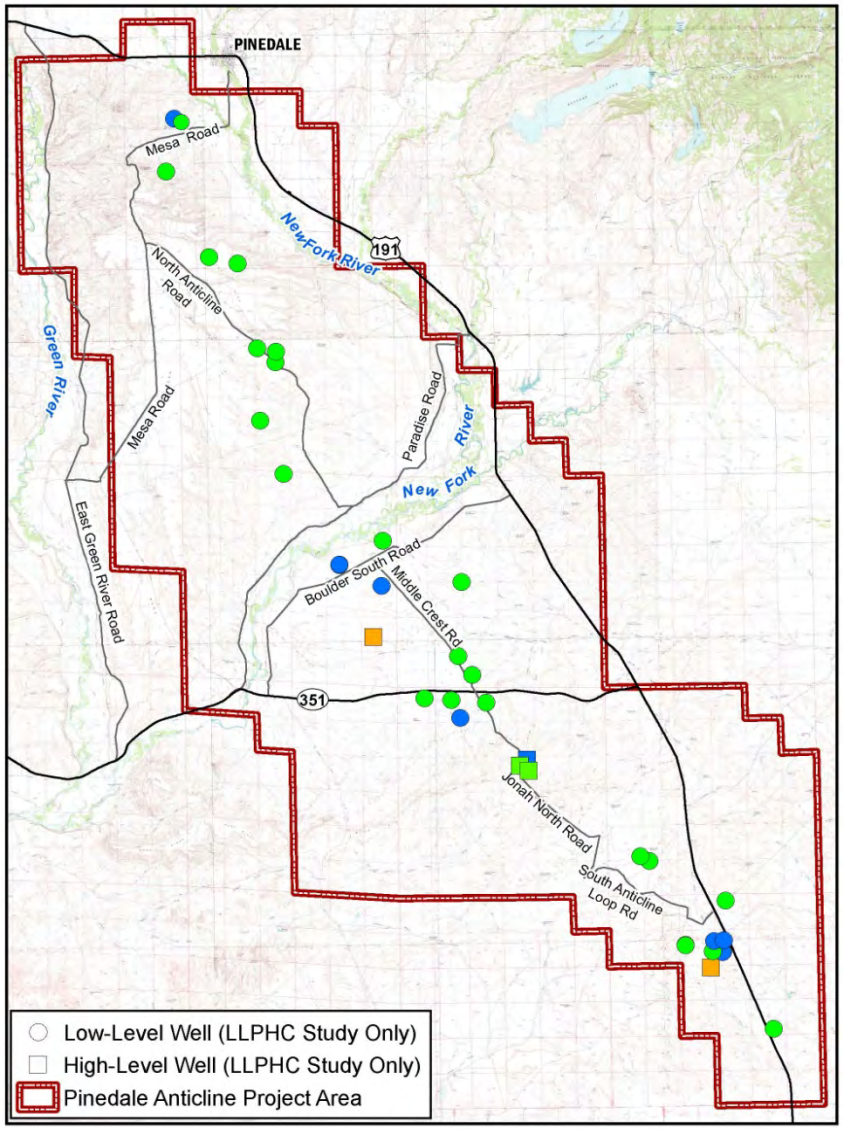


Conclusion #2:
Source of Low-Level Semivolatile Organic Constituents

- Not readily apparent
- Likely originates from substances introduced during the drilling, installation, and operation of wells and/or from naturally-occurring organic matter.
  - In general, the chemical signature of most low-level wells most closely resembles the chemical signature for pump installation materials.
  - Low-level detections in some wells may be attributable to naturally occurring organic matter.
  - Low-level detections in some wells may be attributable to well drilling and installation materials.

Conclusion #2:
Low-Level Semivolatile Organic Constituents Distribution of Detections

- Wells with No Detections of Semivolatile Organics
- Wells with Low-Level Detections of Semivolatile Organics
- Wells with High Level Detections of Semivolatile Organic Constituents



Conclusion #2:
Low-Level Semivolatile Organic Constituents Characteristics of Detections

- Most low-level wells sampled contained total extractable hydrocarbons (TEH); roughly ½ of these wells contained total petroleum hydrocarbons – diesel range organics (TPH-DRO)(*Method 8015*).

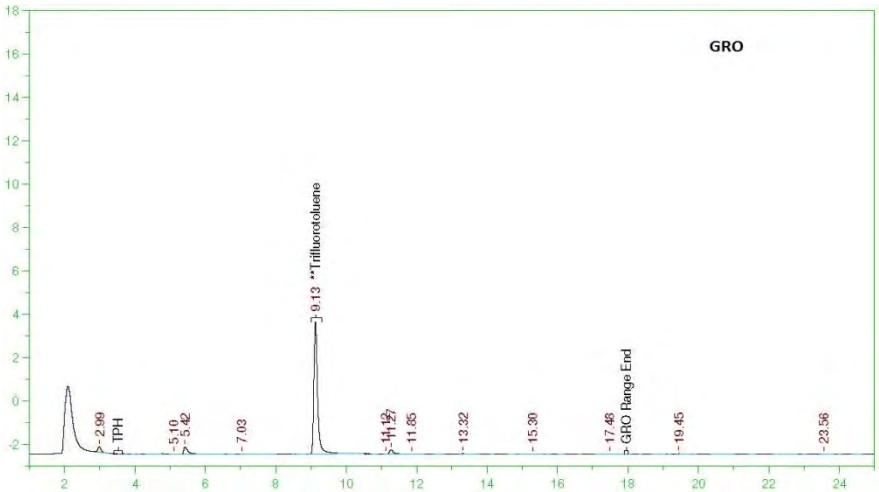
- No complimentary detections of semivolatile organic compounds (*Method 8270*).

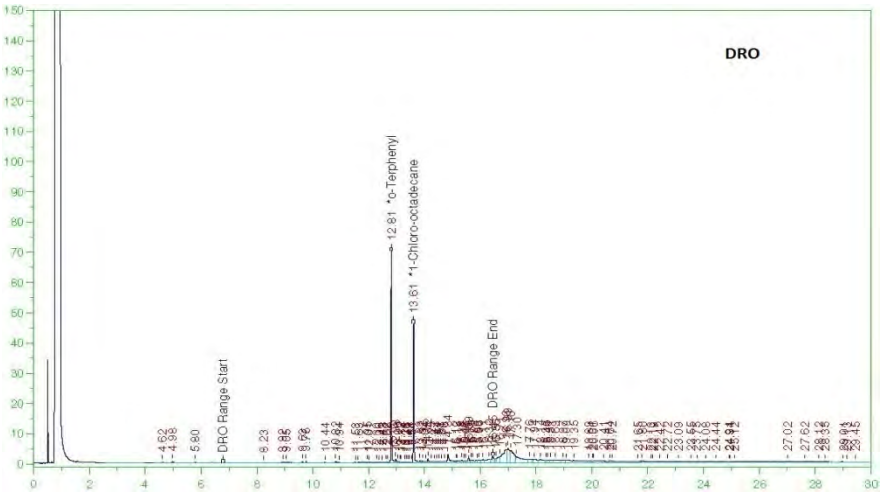
- Few reported tentatively-identified compounds (TICs), most of which are not characteristic of potential sources sampled for this study or typically associated with petroleum substances (*Method 8270*).

- Profiles in DRO chromatograms that are mostly non-characteristic and/or characterized by unresolved complex mixtures (*Method 8015*). One exception to this rule is low-level well RS 15-12.

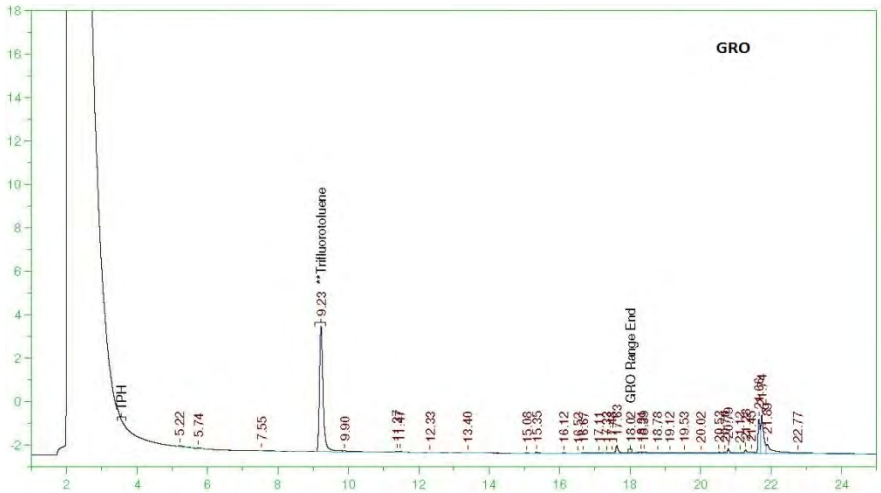
Conclusion #2:
Low-Level Semivolatile Organic Constituents Chromatographic Comparison

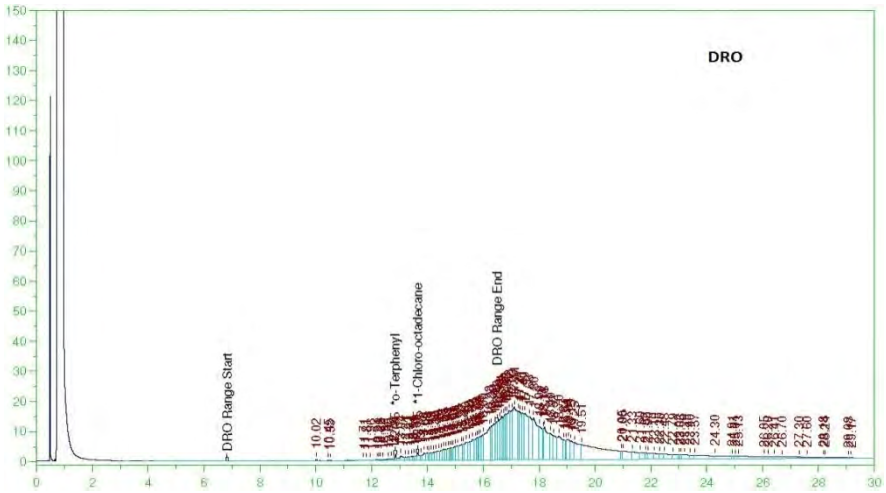
Groundwater – MS 14-16





Pipe Dope – MS 14-16

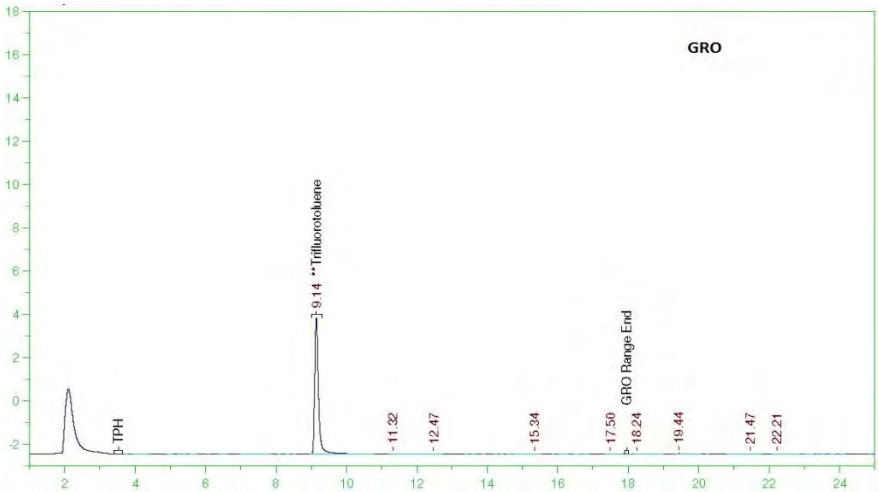


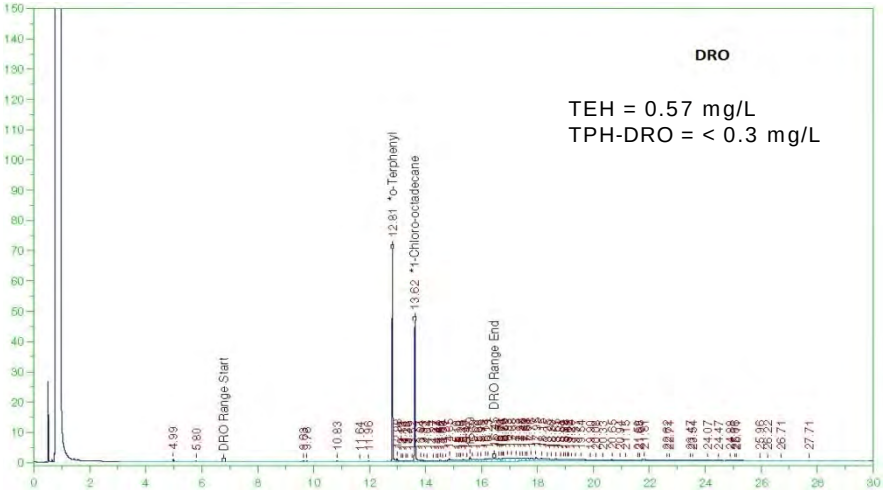


Conclusion #2:

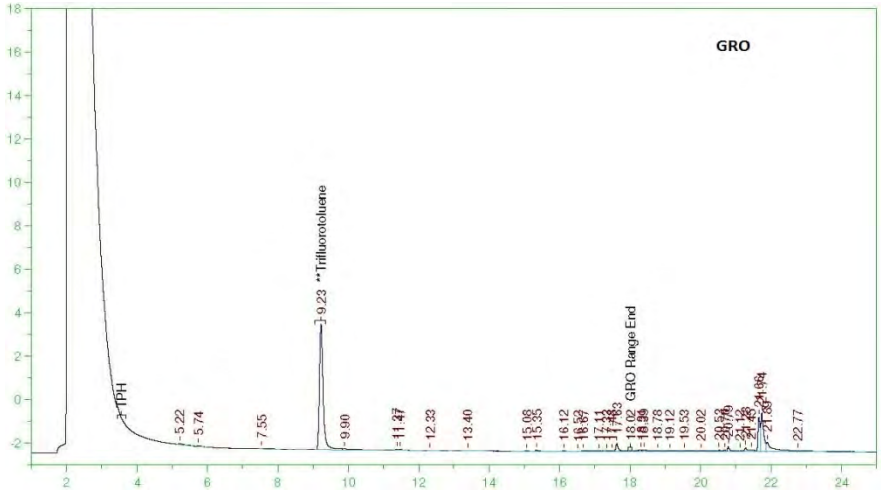
Low-Level Semivolatile Organic Constituents Chromatographic Comparison

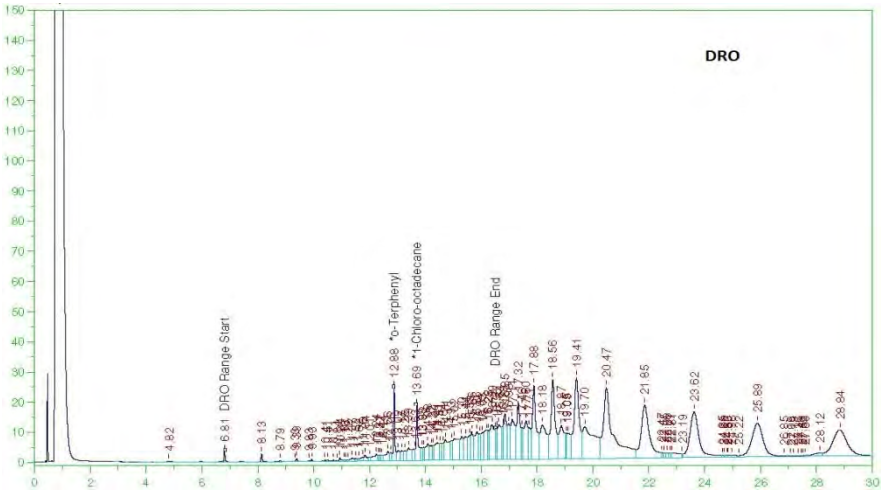
Groundwater – SP 11-33





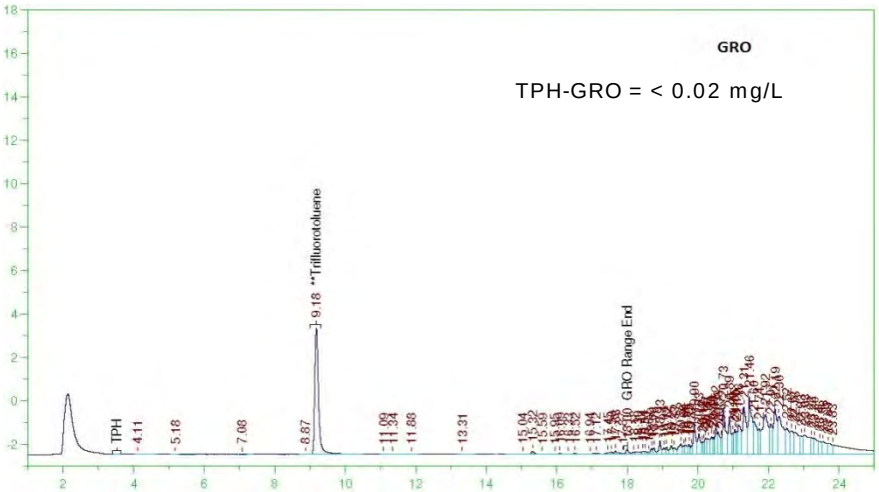
Pipe Dope – Unused, Silicone Based

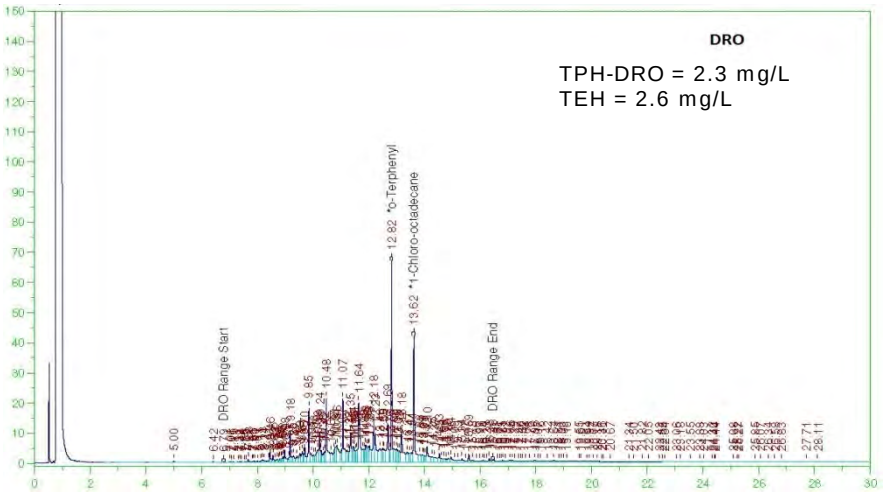




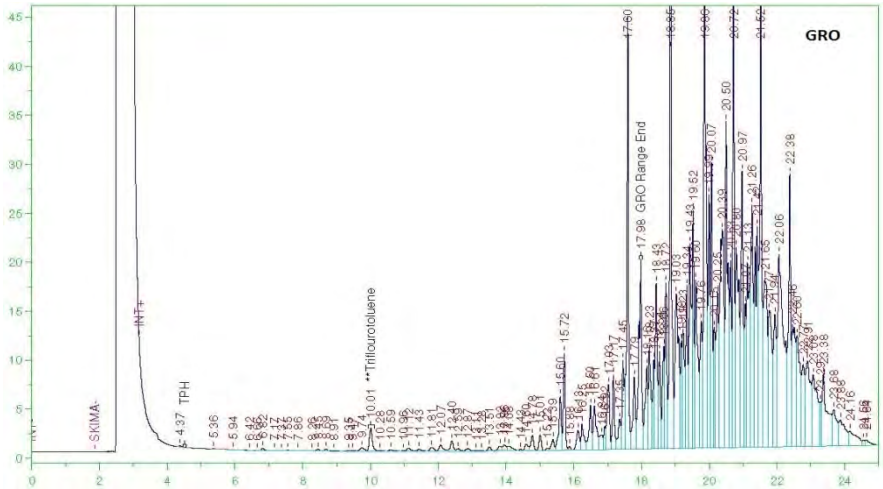
Conclusion #2:
Low-Level Semivolatile Organic Constituents Chromatographic Comparison

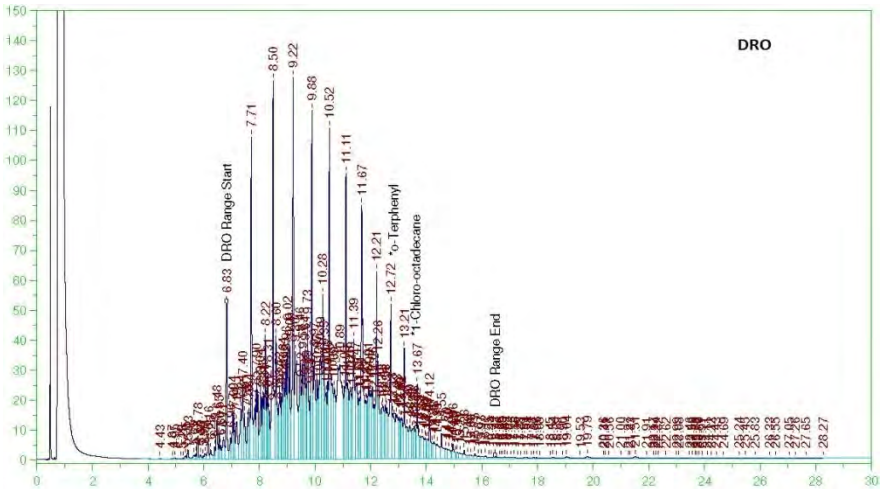
Groundwater – RS 15-12





Drill Mud



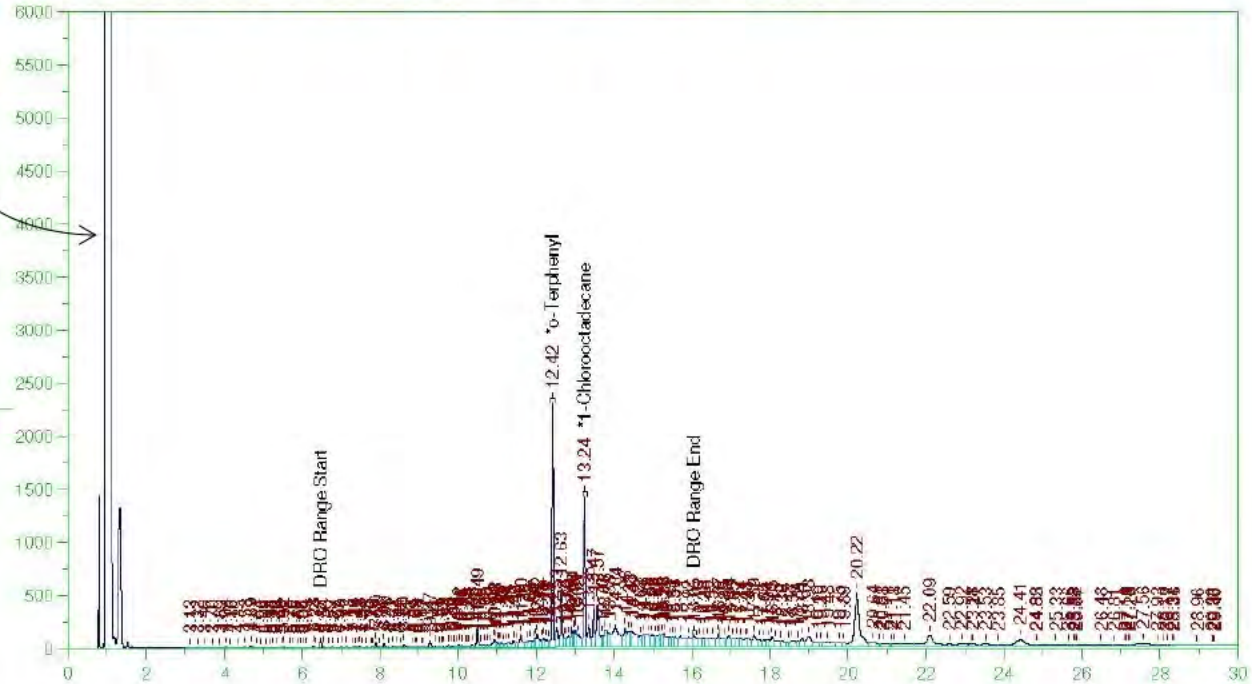


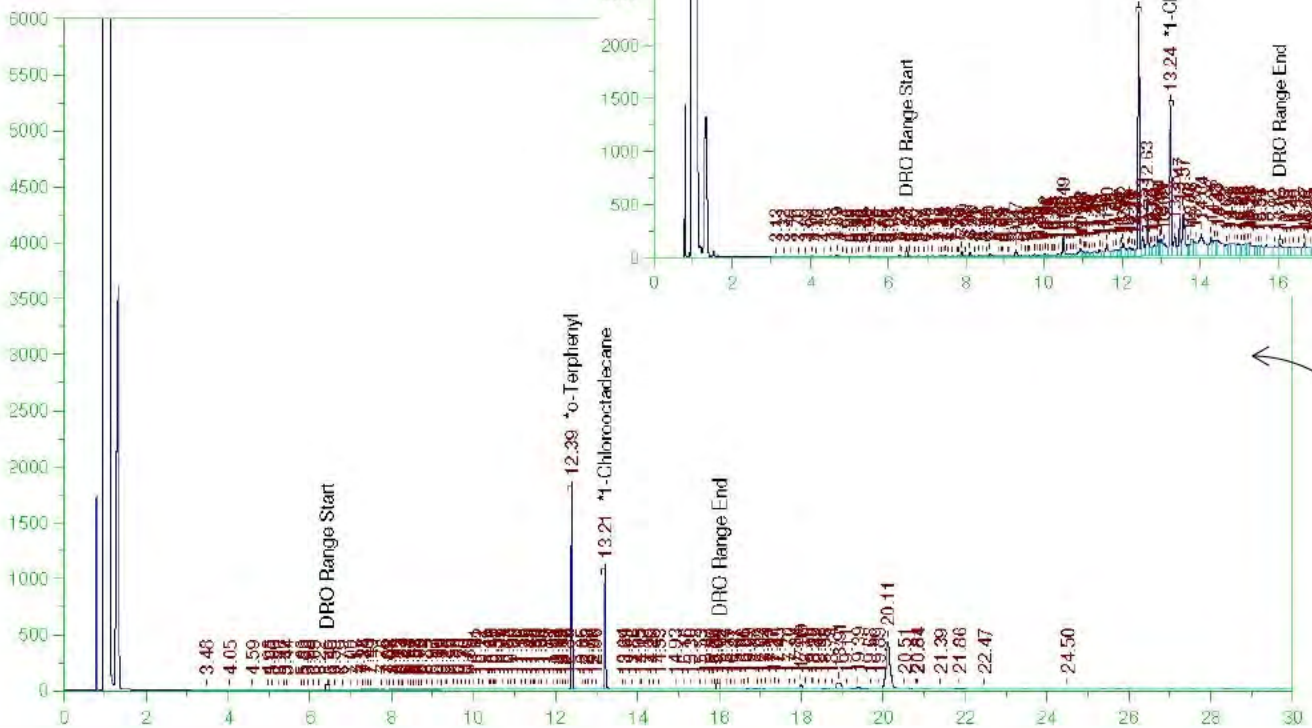
Conclusion #2:
Low-Level Semivolatile Organic Constituents: Naturally Occurring Organic Matter as Source

Conclusion #2:

Low-Level Semivolatile Organic Constituents Chromatographic Response from Silica Gel Treatment

DRO analysis of groundwater sample ***without*** treatment of sample extract using silica gel

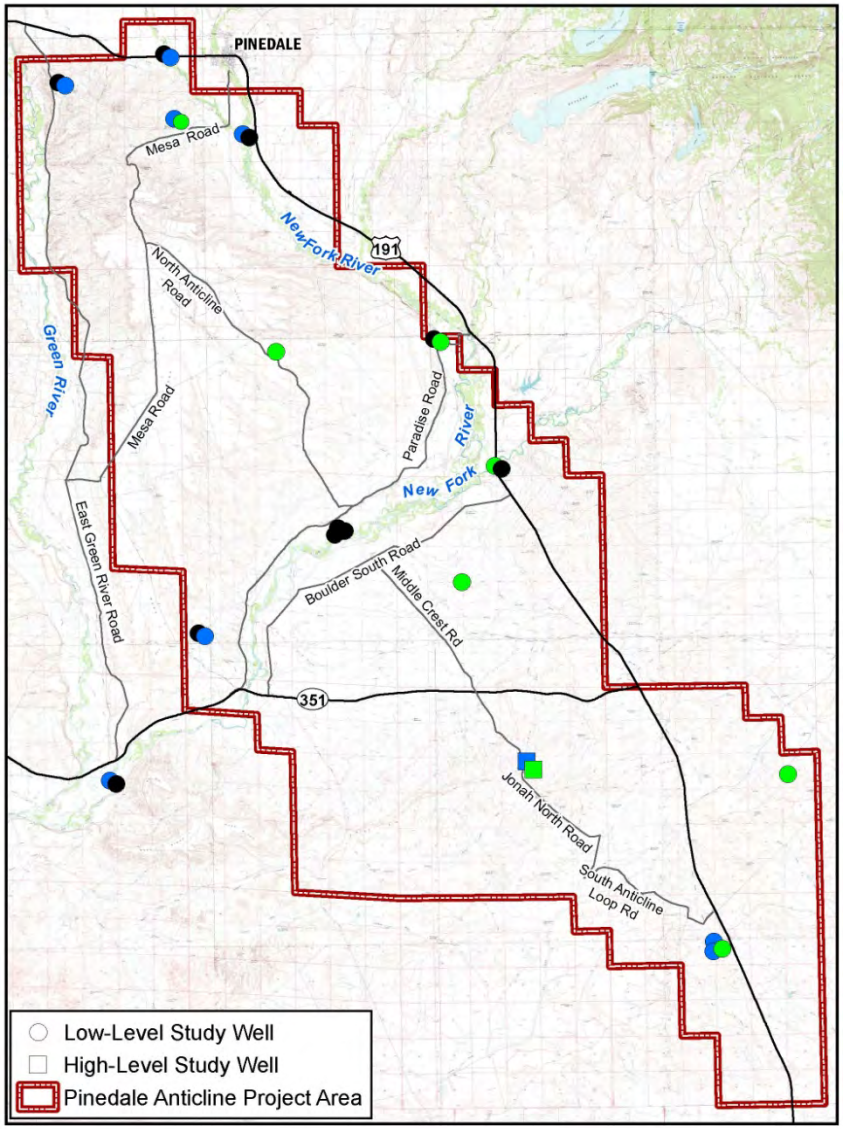




DRO analysis of groundwater sample ***with*** treatment of sample extract using silica gel

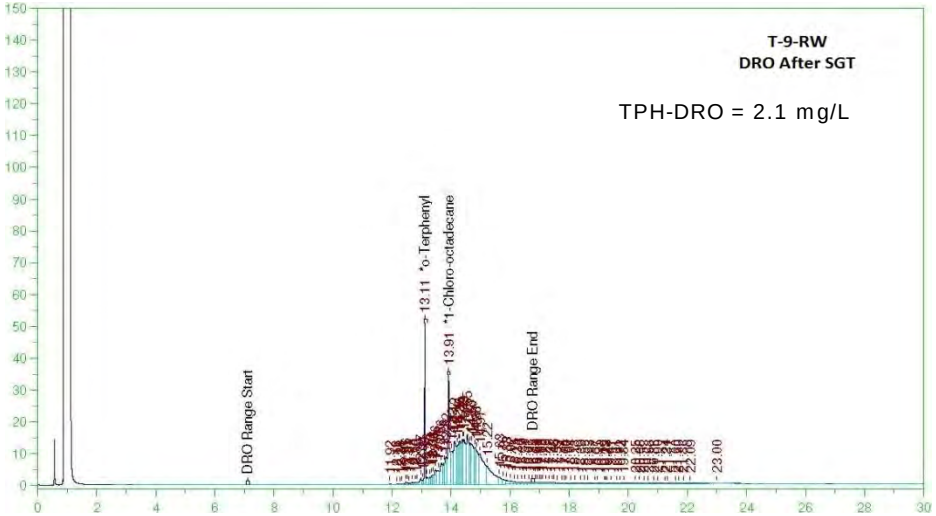
Conclusion #2:
Low-Level Semivolatile Organic Constituents: Effect of Silica Gel Treatment

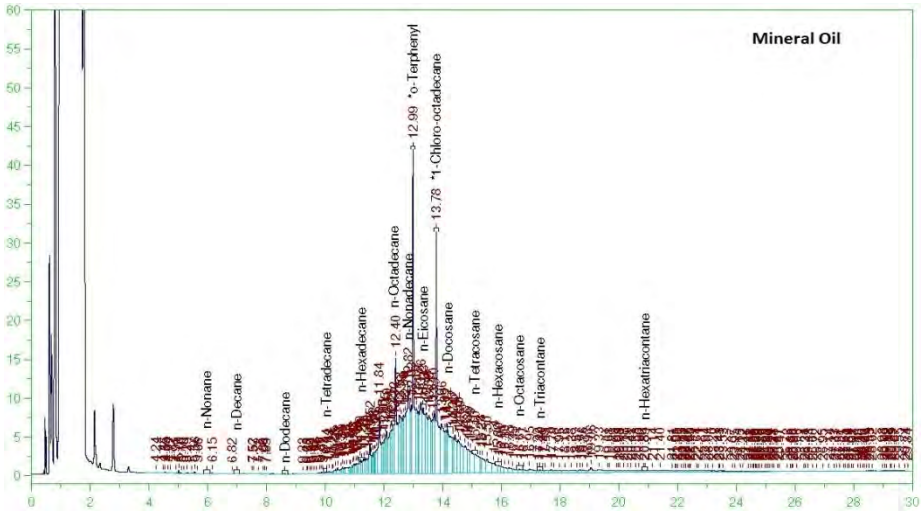
- Effect of silica gel treatment (SGT) of sample extracts upon analysis
  - ● Semivolatile organic fraction *not* detected
  - ● Semivolatile organic fraction *not* detected after SGT
  - ● Semivolatile organic fraction detected after SGT
- Trend in Semivolatile Organic Detections
  - Shallower study wells tended to have no detections of semivolatile organics ● or semivolatile organics removed after SGT ●
  - Deeper study wells tended to have semivolatile organics detected after SGT ● particularly those along the crest of the Pinedale Anticline, as well as east of the crest of the Anticline, which is outside the area of concentrated E&P activity.

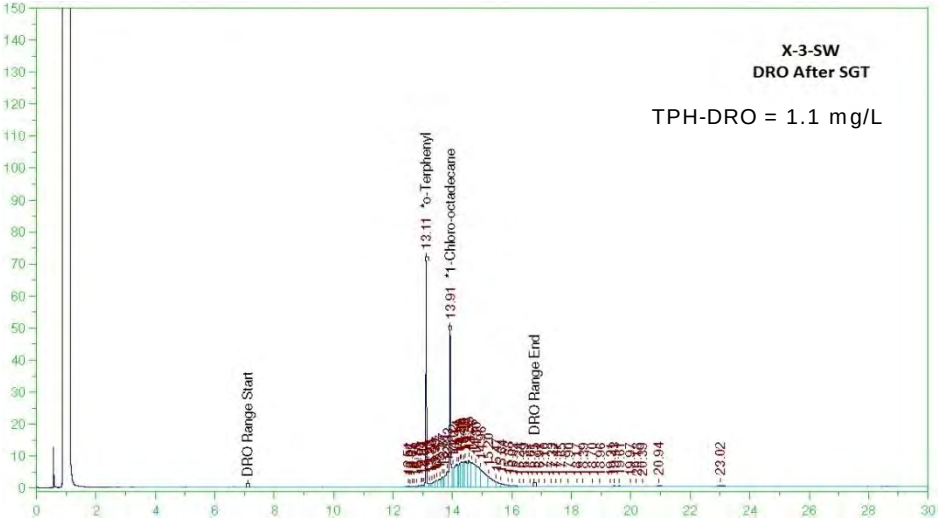


Conclusion #2:
Low-Level Semivolatile Organic Constituents Study Wells with Possible Refined Source

- TPH-DRO detected and not removed upon SGT
- Chromatographic profiles from wells exhibited a narrow, symmetrical response in DRO chromatogram, which is consistent with a refined substance
- Study wells share a common history of well installation and are located upgradient of E&P activities.
- Use of petroleum substances during drilling and well installation may introduce semivolatile organics







Conclusion #2:
Source of Low-Level Semivolatile Organic Constituents

- Not readily apparent
- Likely originates from substances introduced during the drilling, installation, and operation of wells and/or from naturally-occurring organic matter.
  - In general, the chemical signature of most low-level wells most closely resembles the chemical signature for pump installation materials.
  - Low-level detections in some wells may be attributable to naturally occurring organic matter.
  - Low-level detections in some wells may be attributable to well drilling and installation materials.

Conclusion #3:
No Widespread Impact from E&P Activities

- The chemical signatures of produced water, condensate, drill mud, natural gas and flowback fluid are not present in low-level wells
- Migration of organic constituents, if released, would be of limited extent in the subsurface
- Constituents in high-level wells are not the source of low-level detections
- Spatial and temporal factors suggest that several potential sources are not likely sources of low-level detections
- Current best practices for exploration and production (E&P) minimize the risk of impacts to groundwater

Conclusion #3:
No Widespread Impact from E&P Activities
Chemical Signatures of Most Potential Source Materials Absent

Potential Sources*

- Volatile/Semivolatile Organics/TICs
  - Multiple detections
  - Complimentary detections
  - Fractions: both detected and complimentary; one may be dominant
- Inorganic Constituents
  - Elevated concentrations
- Gas Composition
  - Thermogenic
  - Unaltered
- Chromatographic Profiles
  - Diagnostic
  - Relatively high response

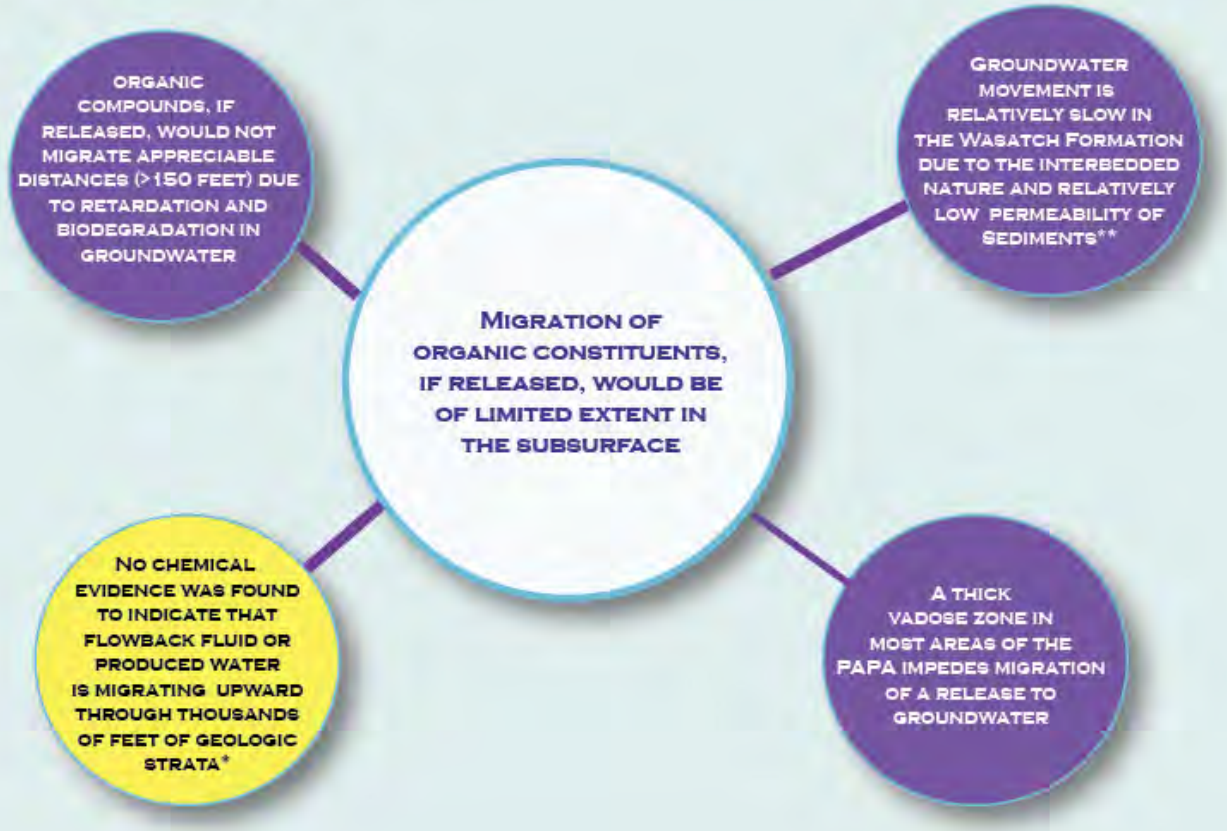
Low-Level Wells

- Volatile/Semivolatile Organics/TICs
  - Few to no detections
  - Few to no complimentary detections
  - Fractions do not appear to be related
- Inorganic Constituents
  - Concentrations in range of typical groundwater
- Gas Composition
  - Thermogenic, Intermediate, Microbial
  - Altered
- Chromatographic Profiles
  - Non-diagnostic
  - Low response

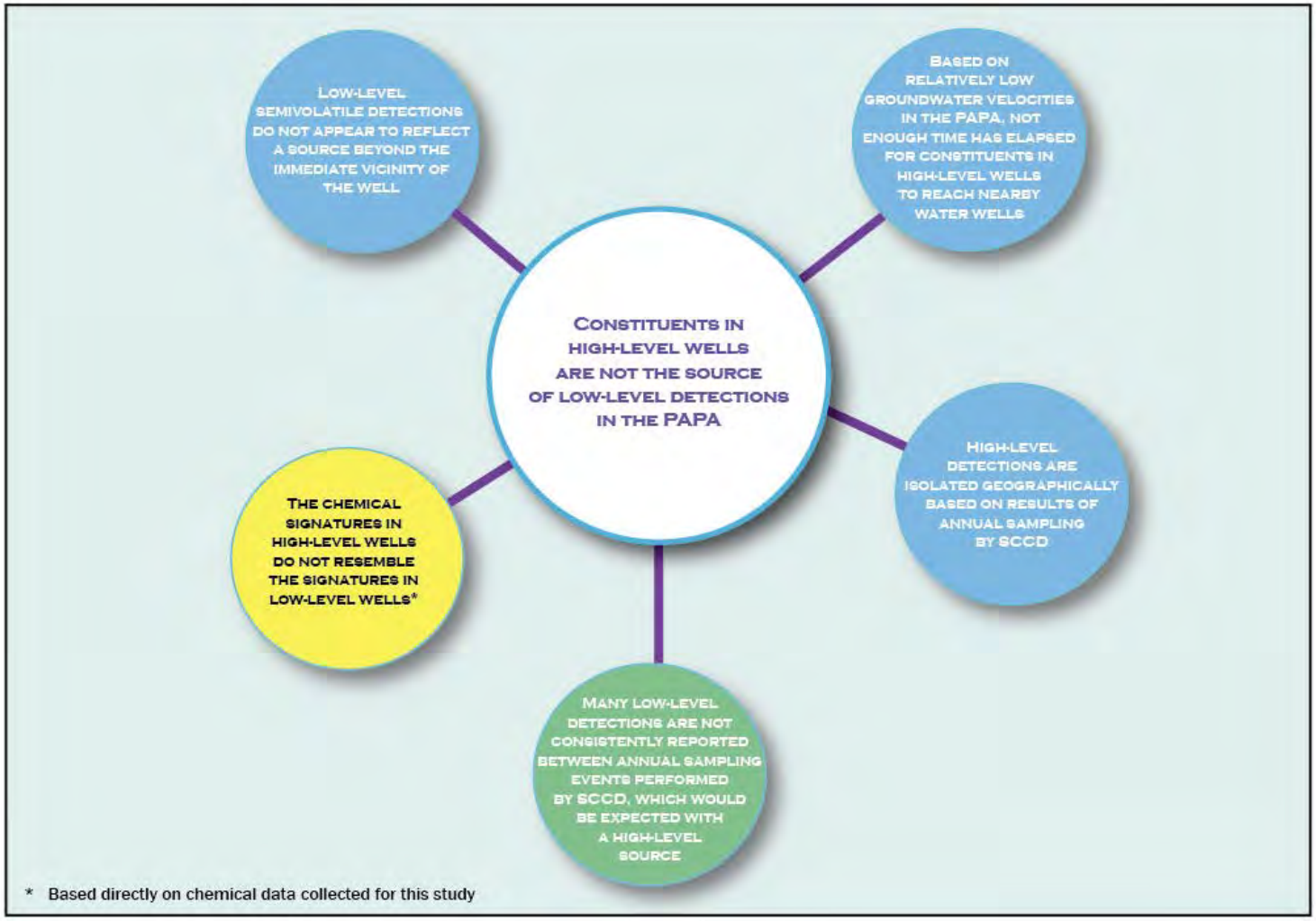
***Includes condensate, produced water, flowback fluid, drill mud, natural gas**

Conclusion #3:
No Widespread Impact from E&P Activities Migration of Organic Constituents Limited

* Based directly on chemical data collected for this study
** Based directly on hydrogeological data collected for the Hydrogeologic Data Gaps Investigation (AMEC, 2012)



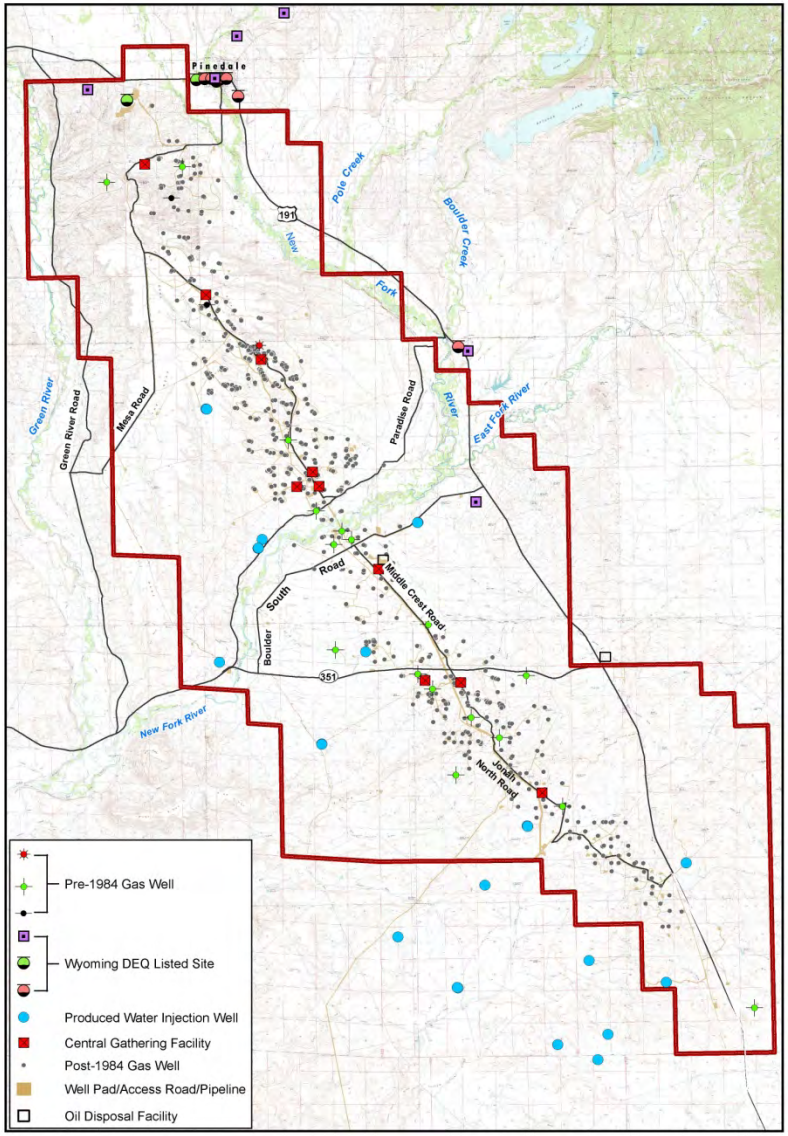
Conclusion #3:
No Widespread Impact from E&P Activities
High-Levels Not Source of Low-Levels



Conclusion #3:
No Widespread Impact from E&P Activities
Spatial Factors Related to Potential Sources

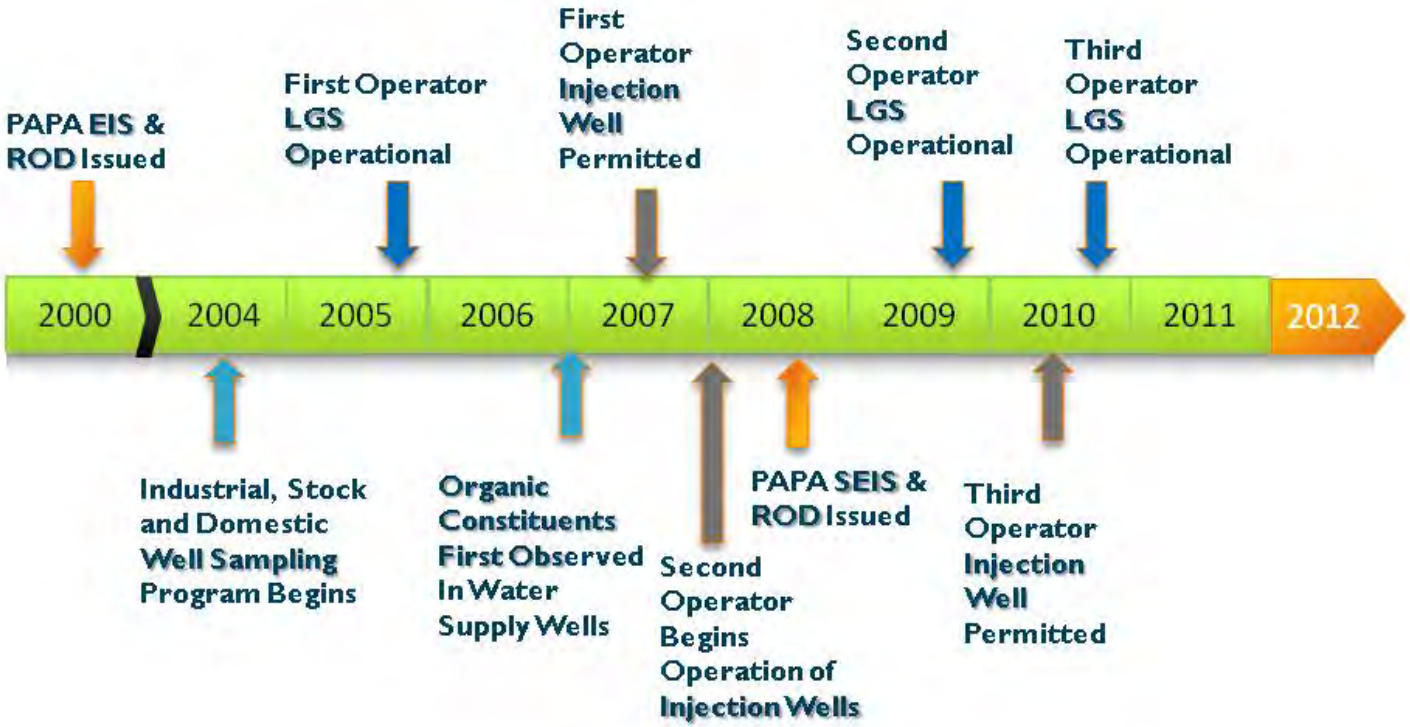
- Most produced water injection wells located downgradient of water wells

- Most Wyoming DEQ listed sites (landfills, underground storage tank sites, hazardous waste sites) are located away from main E&P area.



Conclusion #3:
No Widespread Impact from E&P Activities
Temporal Factors Related to Potential Sources

- Low-level detections in water wells occurred prior to construction and/or operation of most produced water injection wells, liquid gathering systems (LGS) or central gathering facilities.



Conclusion #3:
No Widespread Impact from E&P Activities
Current Best Practices Minimize Risk

Conclusion #4:
No Additional Mitigations Needed

Low-Levels of Volatile Organic Constituents

- Largely Attributable to Upward Seepage of Natural Gas
- Presence of the gas in the near-surface is expected based on geologic conditions
- Gas that is seeping upward by natural processes cannot be mitigated

Low-Levels of Semivolatile Organic Constituents

- Most likely originates from substances introduced during the drilling, installation, and/or operation of wells
- Operators have implemented best practices including:
  - Using hydrocarbon-free pipe dope compounds
  - Decontamination of pumps between installations
  - Backflow prevention at wellhead
- Naturally occurring organic matter in groundwater cannot be mitigated