[PS]Facilitating Shale Play Development in Pennsylvania - Meeting the Need for Nearby Brine Disposal Wells*

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Abstract

Marcellus Shale exploration and production operations in Pennsylvania generate large quantities of flowback and produced water. Although there is a strong increasing trend in recycling, not all flowback and produced waters can be cost-effectively recycled due to water chemistry, lack of a nearby new well at which the water can be recycled and other factors. Brine disposal wells have an important role to play in managing such waters in a cost-effective and environmentally protective manner. The need for brine disposal wells in Pennsylvania is expected to increase as the Marcellus and Utica Shale Plays mature and tens of thousands of new wells begin generating produced water on a daily basis. Although currently there are only five permitted brine disposal wells operating in Pennsylvania and no commercial wells, there is potential to develop many additional brine disposal wells within or near Marcellus and Utica Shale producing areas.

The presentation will provide an overview of the status of currently permitted brine disposal wells in Pennsylvania and nearby states, most of which have substantially more wells than Pennsylvania. Potential target formations for brine disposal in Pennsylvania will be discussed along with procedures for identifying and evaluating specific candidate injection well sites. An overview of EPA brine disposal well permit application procedures will also be presented along with a summary of well construction and operating requirements. Ranges in capital and Operation and Maintenance (O&M) costs and the economics of utilizing brine disposal wells relative to other available options (e.g., water treatment plants) will also be discussed.

Facilitating Shale Play Development in Pennsylvania - Meeting The Need for Nearby Brine Disposal Wells

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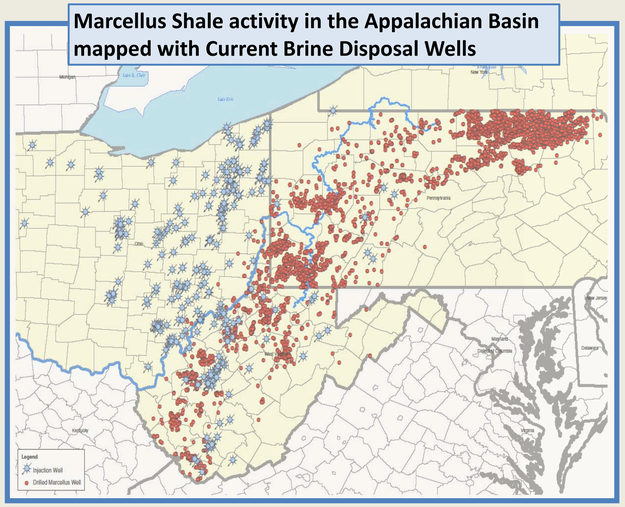
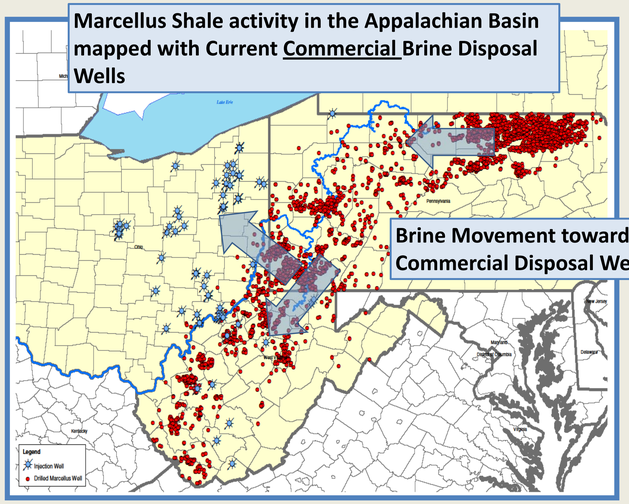
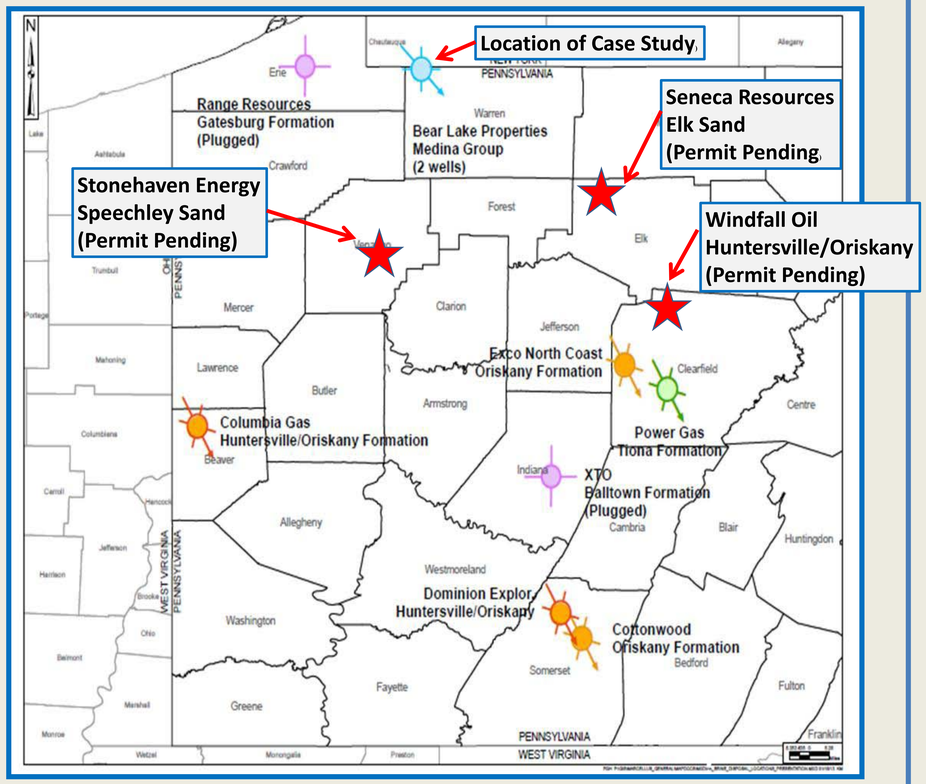
Marcellus Shale activity in the Appalachian Basin mapped with Current Brine Disposal Wells



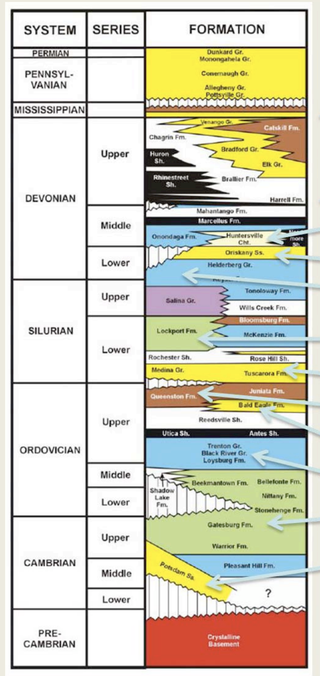
Marcellus Shale activity in the Appalachian Basin mapped with Current Commercial Brine Disposal Wells



Current Brine Disposal Wells in Pennsylvania



Possible Formations for Brine Disposal Wells in Pennsylvania

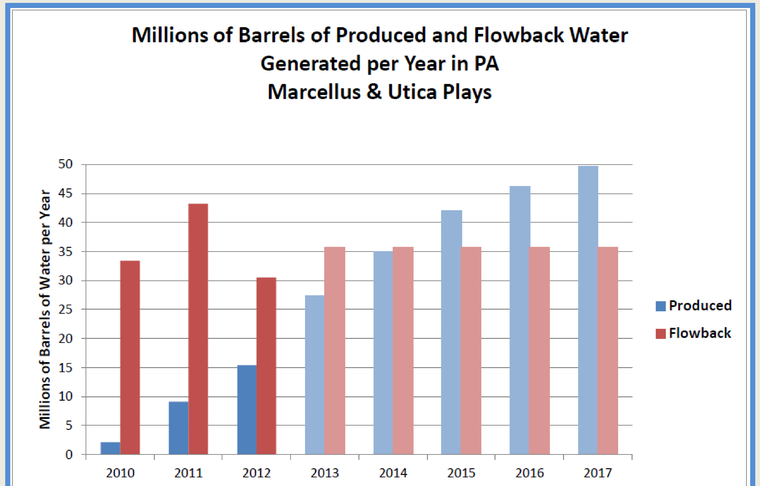


Upper Devonian Sandstones*
Huntersville Chert*
Oriskany Sandstone*
Bass Islands
Lockport Dolomite
Medina – Tuscarora Sandstones*
Queenston Shale
Bald Eagle Sandstone
Trenton – Black River
Gatesburg Formation*
Basal Cambrian Sandstones (e.g. Potsdam)

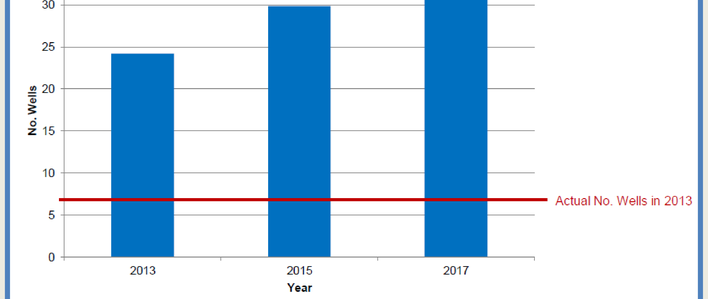
*Existing injection well in PA

Source: Stratigraphic Column from PADCNR

Need for Brine Disposal Wells in Pennsylvania Forecast of Flowback and Produced Water



Sources: PADEP website (actual data); Barclays Research Report - Marcellus : Promised Land (projected data). Flowback water volumes estimated based on wells developed (actual or projected) x 23,800 barrels.



*Assumes 10% of flowback and produced water will not be recycled and each injection well has 1,000 bbl/well/d capacity.

Identifying Target Areas and Formations

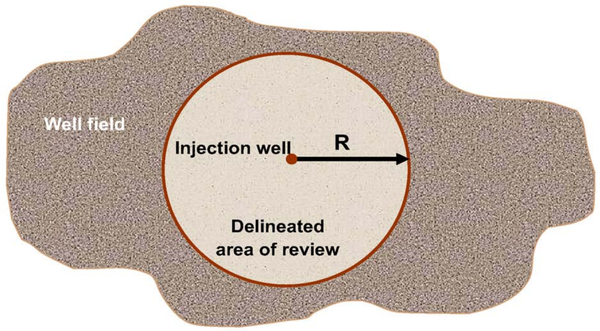
- Determine Viable Transportation Distances (via truck, rail, barge or pipeline) from Your Water Sources.
- Identify Potential Target Formations.
  - -- Existing brine disposal wells in the area?
  - -- Depleted oil and gas wells / fields in the area?
  - -- Drilling depths, Disposal depths and Cost considerations?
- Identify Existing Production. Or, Avoidance of Watering Out Existing Production
- Injectivity Testing to Confirm Viability.

EPA UIC Well Permit Application

- Define Area of Review/Zone of Endangerment
- USDW Description
- Injection well construction
- Well operation including maximum injection pressure and rates
- Plugging and abandonment
- Financial Responsibility

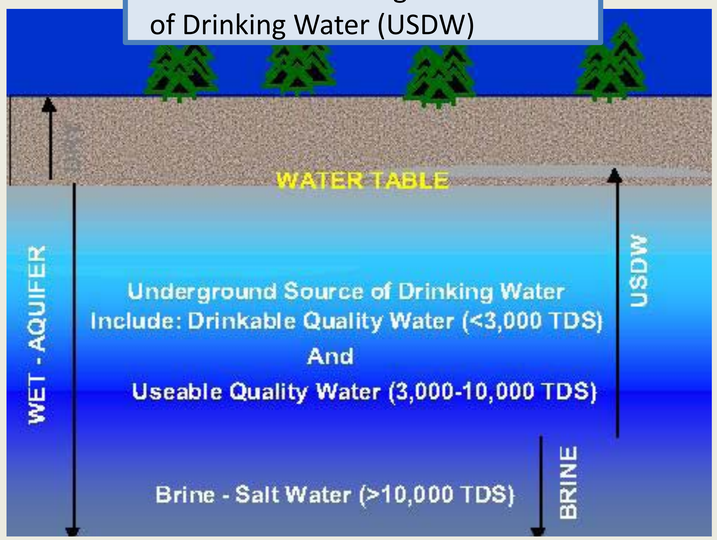
UIC Permit - Area of Review

Plan View of Area of Review

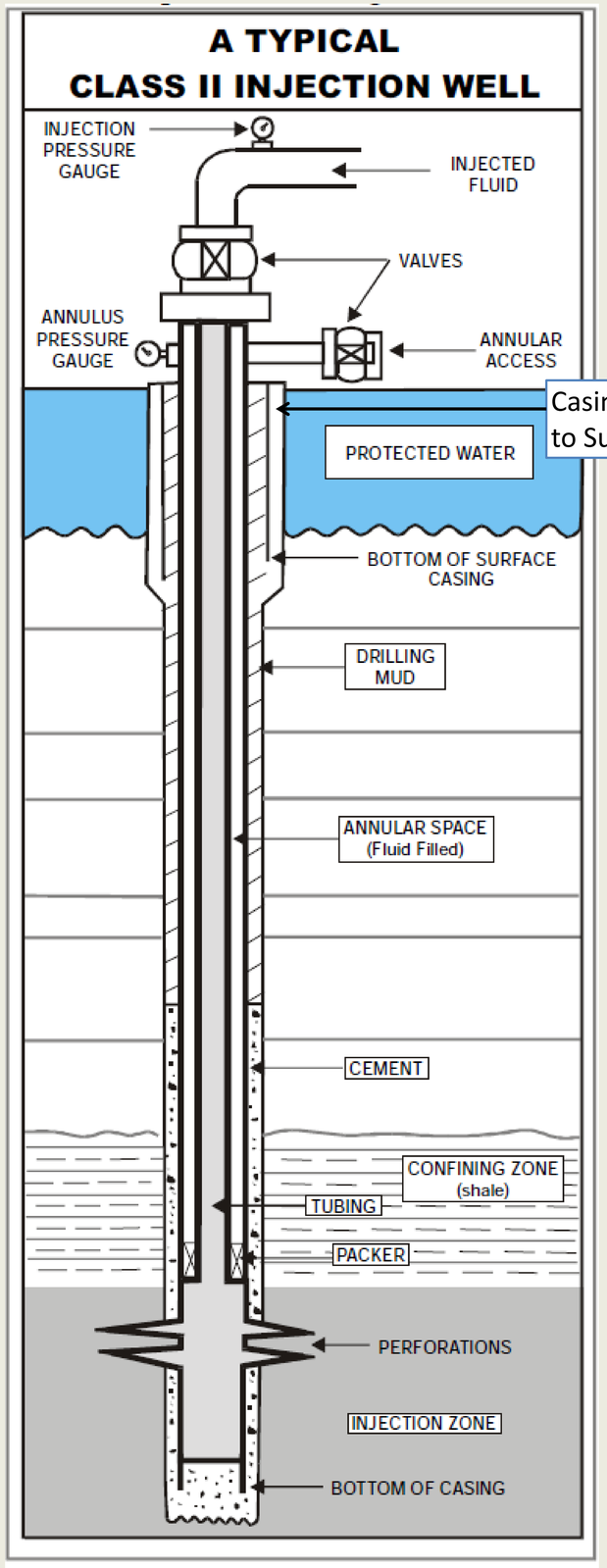


Source: EPA January 2009

Lowest Most Underground Source of Drinking Water (USDW)



Source: EPA April 2002



Typical UIC Class II Well Construction

Casing Cemented to Surface

Modified from graphic from New Mexico UIC Well Website

Comparison of PA, OH and WV UIC Class IID Well Permitting

State	Primacy	Area of Review (AOR)	Maximum Injection Pressure (MIP) Basis	Seismicity Evaluation	Approx. Timeframe*
PA	EPA	Calculated based on 10 year injection scenario. Default 1/4 mi.	ISIP From Frac; consider SG of brine; Frac gradient of 0.733 if no ISIP	Considered in EPA review.	8 months to 16 months
OH	State	<200 bbl/d - 1/4 mi; >200 bbl/d - 1/2 mi	Frac gradient of 0.75 psi/ft	Yes	2 to 3 months
WV	State	1/4 mi	Frac gradient of 0.8 psi/ft; 90% of breakdown pressure may be approved	Yes	2 to 3 months

*From application submittal to final permit

INJECTIVITY TESTING

- Step-Rate Test
  -- Establish optimal rate for constant rate test
  -- ISIP data can help regarding Maximum Injection Pressure (MIP)
- Constant Rate Test
  -- Injection – establish radial flow
  -- Pressure Falloff monitoring
  -- Data Evaluation - permeability, injection pressures, rates, AOR, boundaries, etc.
- Valuable tool but may have limitations in predicting long term performance

Brine Disposal Wells - $/Bbl Cost

Capital Cost ($1000s)	O&M ($1000s)	Total Cost 15 years ($1000s)	Approx. $/Bbl by Injection Rate*		
			500 Bbl/d	1000 Bbl/d	2000 Bbl/d
1000	150	3250	$1.67	$0.83	$0.42
1500	150	3750	$1.92	$0.96	$0.48
2000	150	4250	$2.18	$1.09	$0.54

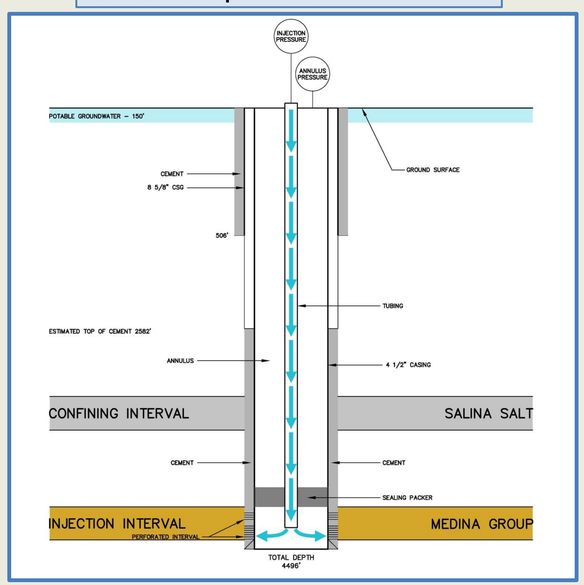
*Assumes 260 operating days per year

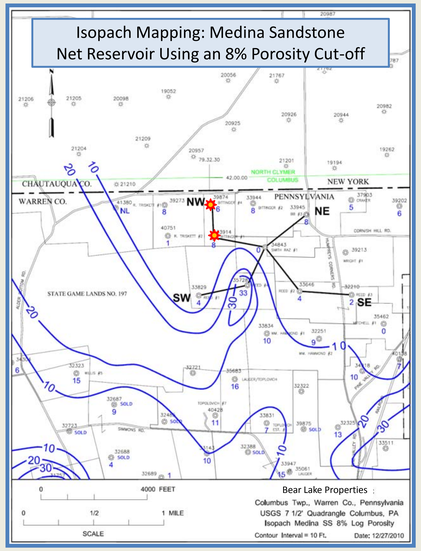
Case Study: Bear Lake Properties Brine Disposal Permits Warren County, Pennsylvania

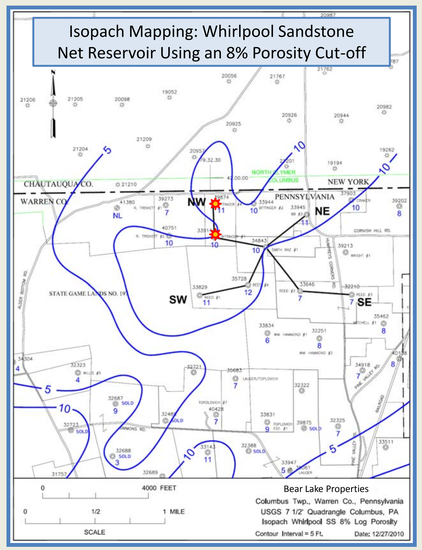
Summary of Bear Lake Brine Disposal Properties

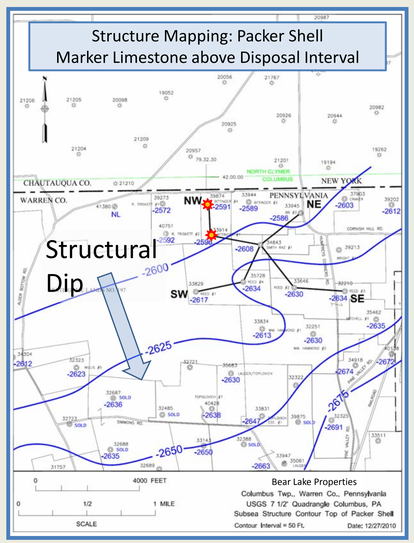
- Depleted Medina gas well field
- Over 11,000 acres
- 2 Commercial UIC Well permits, currently accepting brine for disposal
- 30,000 bbl/mo/well
- Approx. 20 wells could potentially be converted to injection
- Est. 300 million bbls. capacity within the potential injection field

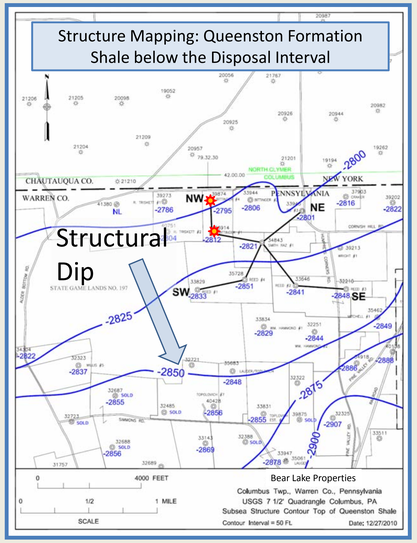
Bear Lake Properties – Well Construction

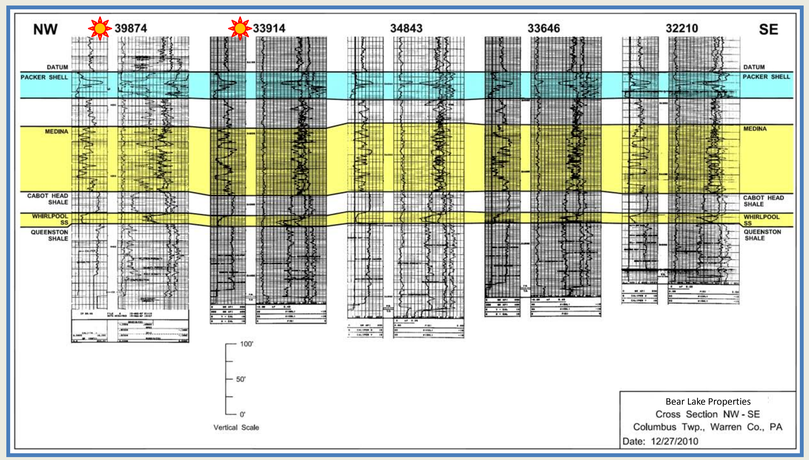


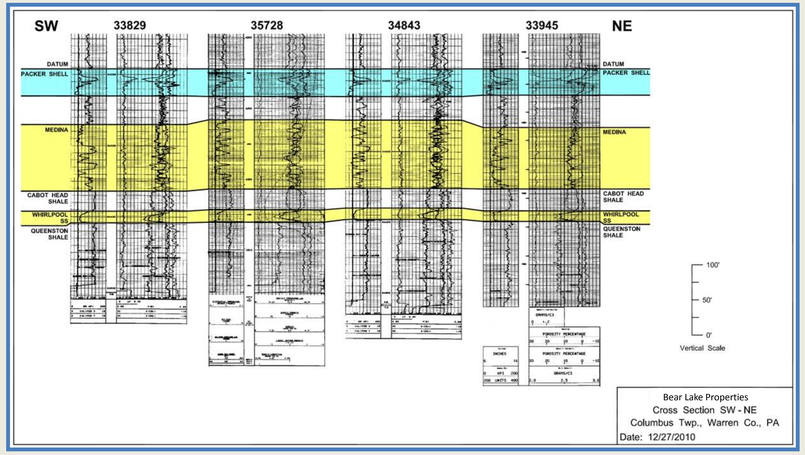












SUMMARY OF BEAR LAKE SWD FIELD

- The two-well field is conveniently located within the Marcellus and Utica Shale fields.
- Injection interval includes the Medina and Whirlpool Sandstones.
- The Silurian Salina Group (salts and anhydrites) serve as a confining interval for disposal.
- The field is currently in operation, taking flowback and produced brines from local operators.

CONCLUSIONS

- Strong understanding of the reservoir system is key to geologic siting of a possible SWD project.
- Can be a very cost-effective and safe option for brine disposal management
- Underutilized in PA – only 7 wells permitted with many additional wells needed
- There are various potential injection targets which may vary locally/regionally
- Depleted oil or gas wells/fields can be “low hanging fruit”
- Siting and public education strategies may help in addressing public opposition issues

THANKS

- Thanks to Bear Lakes Properties and Karl Kimmich for allowing us to use their data as our case study
- Special thanks to Suzanne Paxton and Steve Hughes of Tetra Tech