Rating And Ranking Geologic Intervals for NGL Storage Applications

Methods of the Appalachian Storage Hub Study

Katherine Schmid, Senior Geologist
Kristin Carter, Assistant State Geologist
Pennsylvania Geological Survey (Pittsburgh, PA)

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- **Advisory Group**

BACKGROUND

- In 2015, the governors of Pennsylvania and West Virginia and the Lt. governor of Ohio signed a regional cooperation agreement
  - A commitment to cross-border promotion of the economic opportunities presented by the Marcellus and Utica shales to build a global petrochemical hub
- In response to this, the Appalachian Oil and Natural Gas Research Consortium was tasked with evaluating the storage potential of subsurface stratigraphic units along the proposed pipeline route

STUDY GOAL

- Complete a geologic study of all potential options for subsurface storage of NGLs along and adjacent to the Ohio River from southwestern Pennsylvania to eastern Kentucky, including a similar study along the Kanawha River in West Virginia
  - Stratigraphic correlation of key units
  - Mapping thickness and structure of key units
  - Reservoir characterization studies
  - **Development and application of rating and ranking criteria**

Area of Interest (AOI)

GEOLOGIC INTERVALS OF INTEREST

Mined-rock caverns

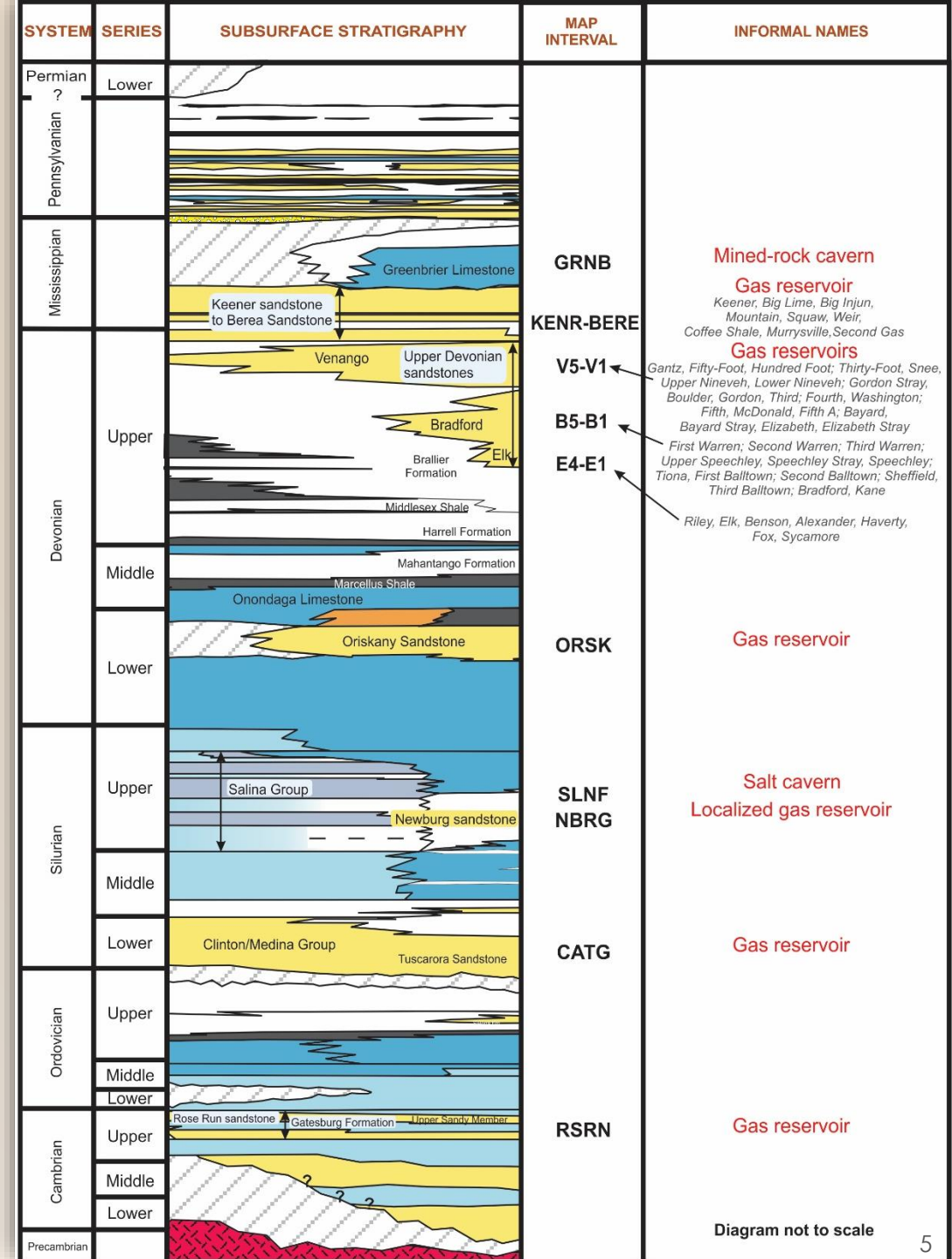
- Greenbrier Limestone (≥40 ft thick; depths of 1,800 – 2000 ft)

Salt caverns

- Salina Group salts (≥100 ft thick)

Depleted gas reservoirs or storage fields

- Keener to Berea sandstones
- Upper Devonian sandstones (Venango, Bradford, Elk)
- Oriskany Sandstone
- Newburg sandstone
- Clinton/Medina Group
- Rose Run-Gatesburg sandstones



DETAILED RATING CRITERIA

Mined-Rock Caverns	Salt Caverns	Depleted Gas Reservoirs	Gas Storage Fields
Distance to Infrastructure	Distance to Infrastructure	Distance to Infrastructure	Distance to Infrastructure
Acreage	Acreage	Acreage	Acreage
Average depth	Average depth	Average depth	Average depth
Net Thickness	Net Thickness	Net Thickness	Net Thickness
Trap integrity	Trap integrity	Trap integrity	Trap integrity
Legacy well penetrations	Legacy well penetrations	Legacy well penetrations	Legacy well penetrations
Stacked opportunity	Stacked opportunity	Stacked opportunity	Stacked opportunity
	Pressure	Pressure	Pressure
		Average Porosity	Average Porosity
		Permeability	Permeability
		Mode CO_2 storage	Mode CO_2 storage
		Estimated cumulative gas production	Working gas capacity

RATING DEPLETED GAS RESERVOIRS/FIELDS

Mined Rock Caverns	Salt Caverns	Depleted Gas Reservoirs	Gas Storage Fields
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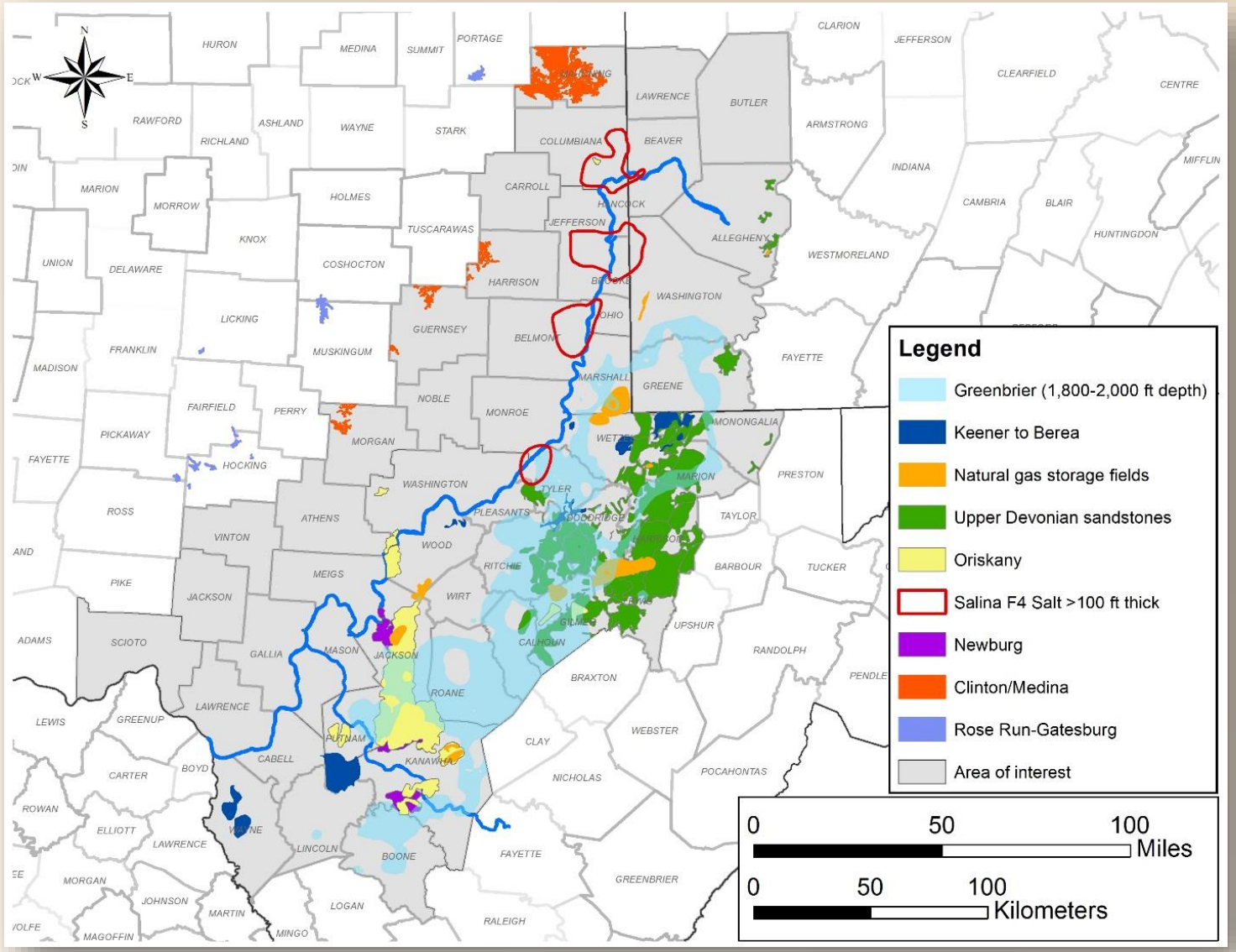
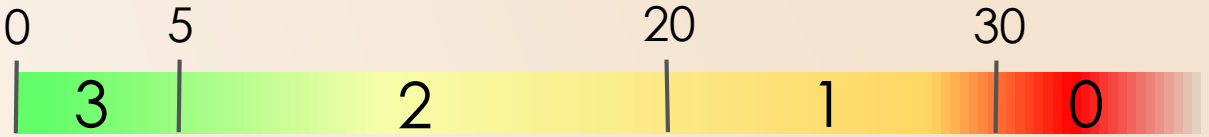
PRELIMINARY ASSESSMENT RESULTS

- 134 opportunities
  - ➢113 depleted gas fields
  - ➢12 natural gas storage fields
  - ➢5 limestone areas
  - ➢4 salt areas

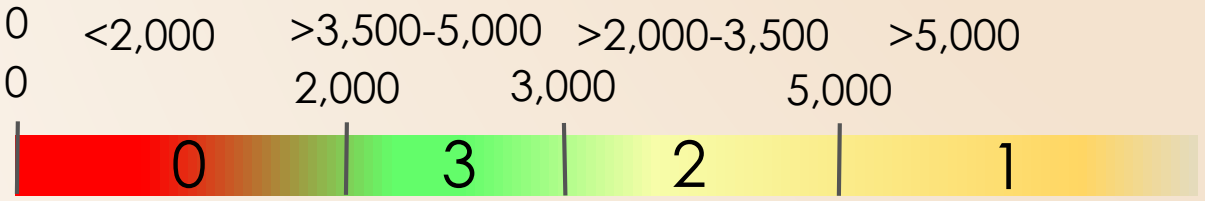


DETAILED RATING CRITERIA

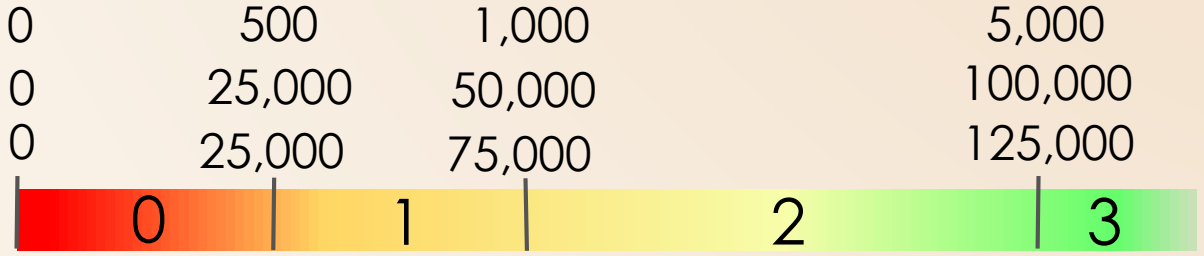
Distance to proposed or existing Infrastructure (mi):



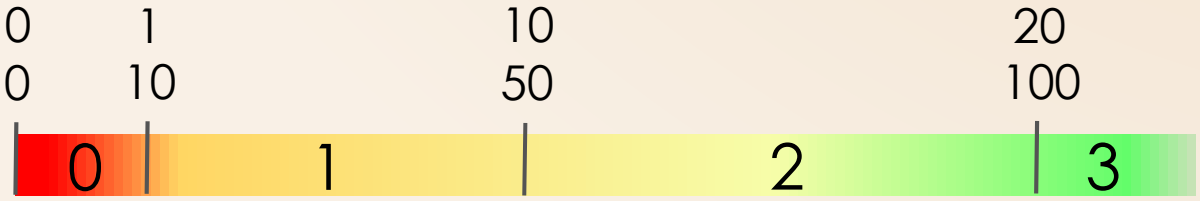
Average depth (ft) (gas fields):
(salt caverns):



Acreage (ac) (gas fields):
(salt caverns):
(mined-rock caverns):

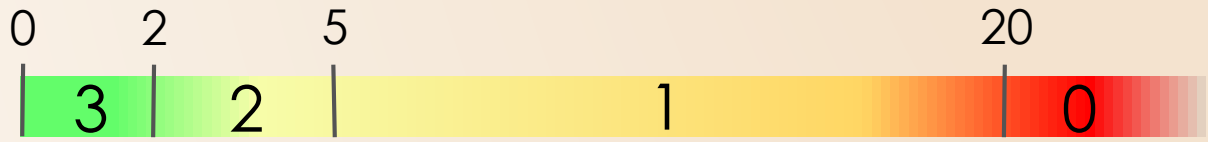


Net thickness (ft)(gas fields):
(salt caverns):

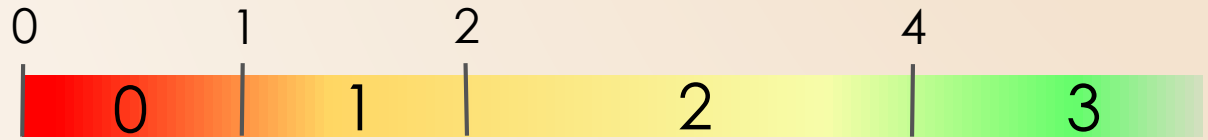


DETAILED RATING CRITERIA

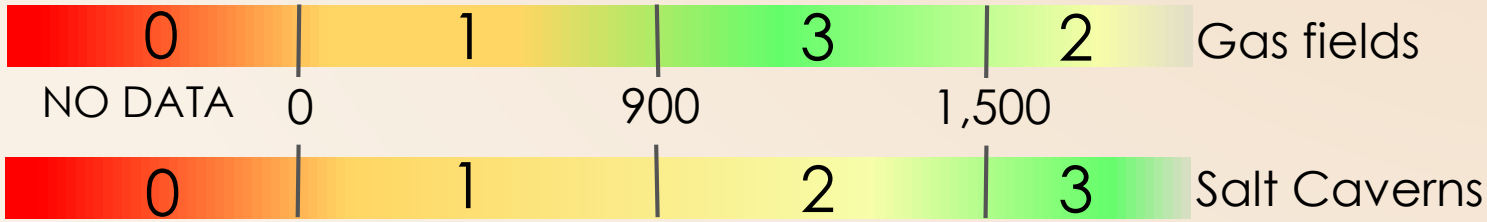
Legacy well penetrations (no. wells per 1,000 acres):



Stacked opportunity:



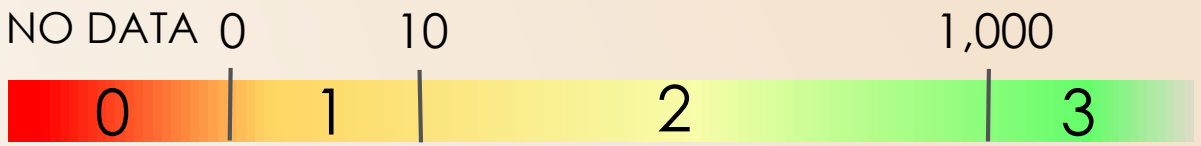
Pressure (psi):



Average porosity (%):

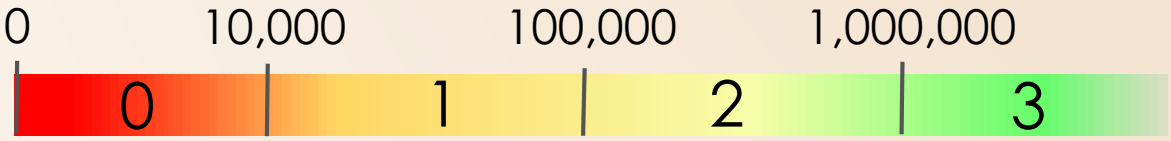
DETAILED RATING CRITERIA

Permeability (mD):



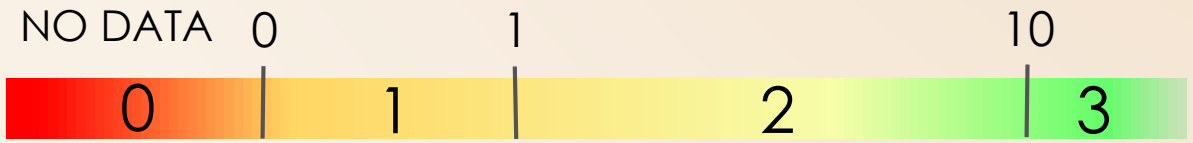
Gas fields

Mode CO_2 storage (tons):



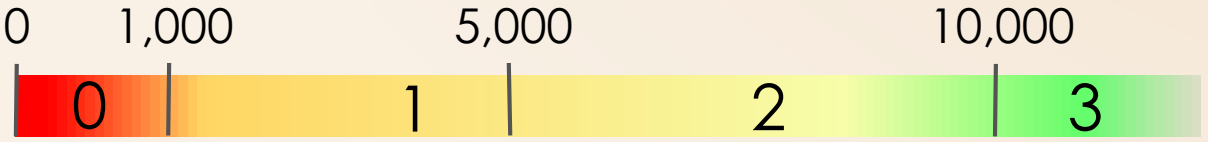
Gas fields

Estimated cumulative gas production (BCF) (gas fields):



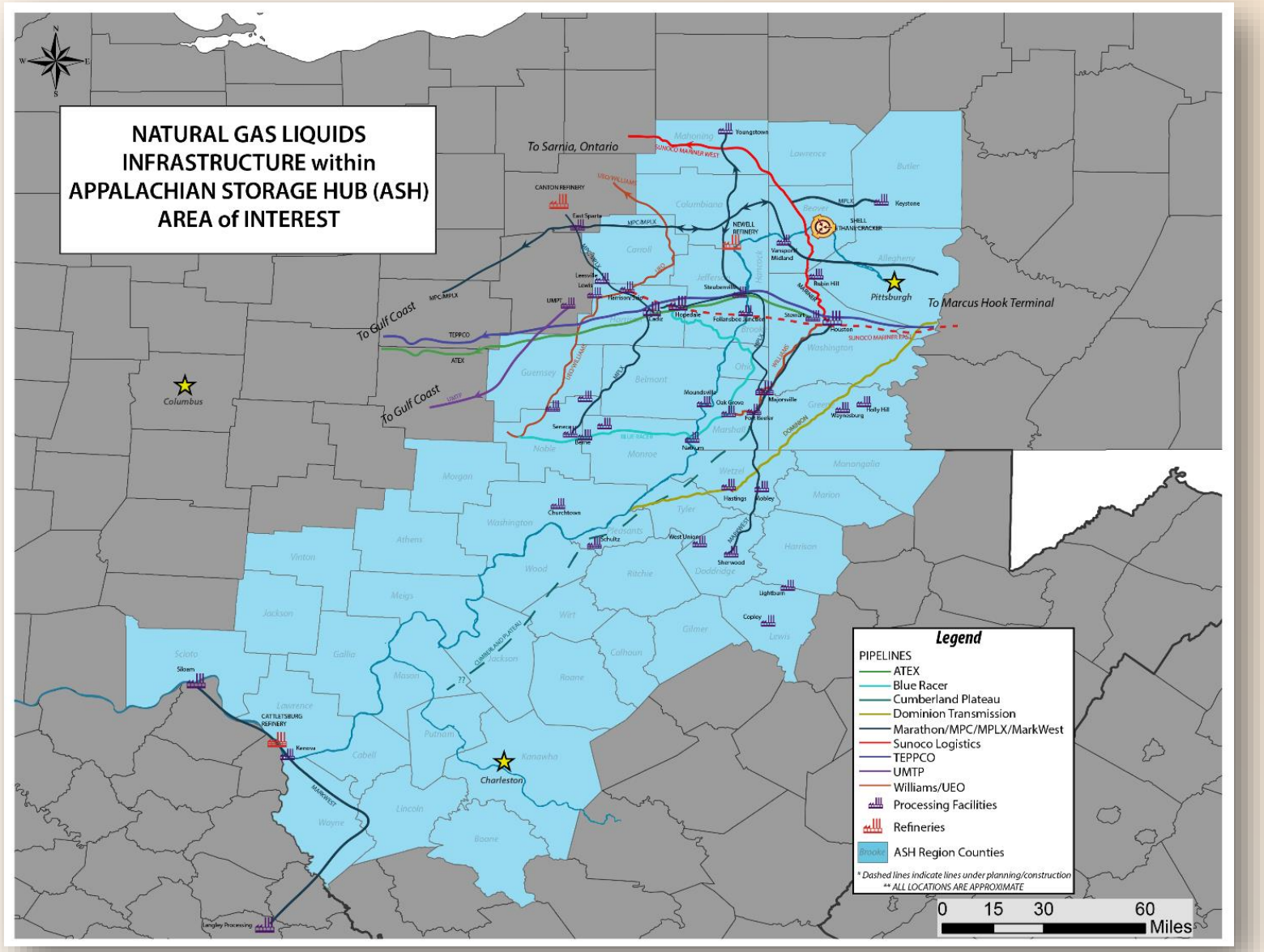
Gas fields

Working gas capacity (MMCF) (storage fields):

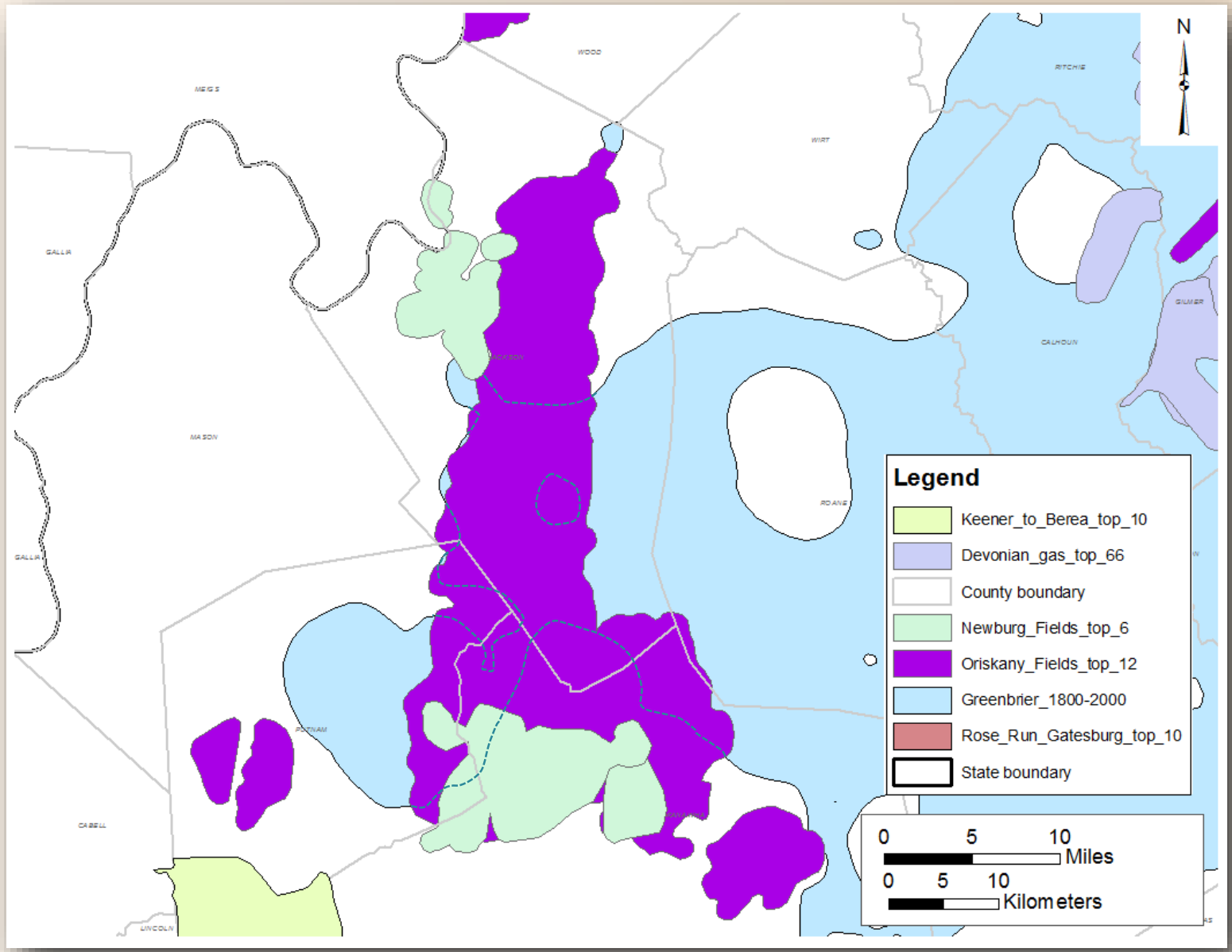


Gas fields

DISTANCE TO INFRASTRUCTURE

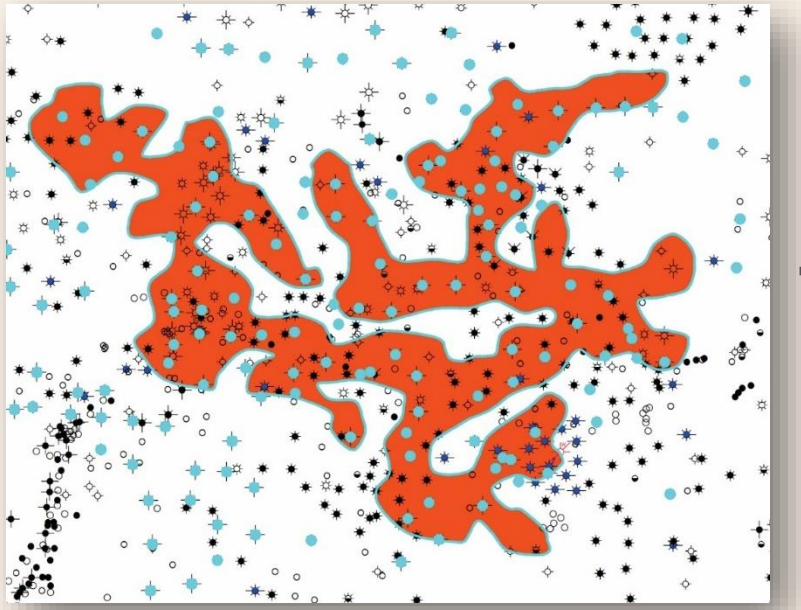


STACKED OPPORTUNITY RATINGS

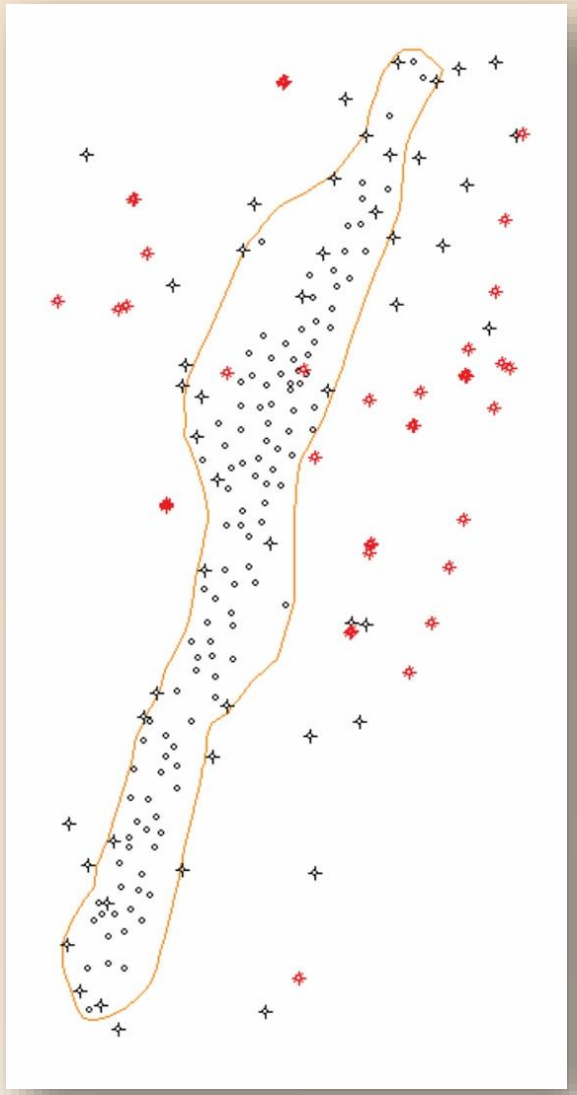


TRAP INTEGRITY RATING CRITERIA

- No data **0**
- Limited data on trap characteristics **1**
- Inferred lithologic and/or structural closure **2**
- Documented lithologic and/or structural closure **3**

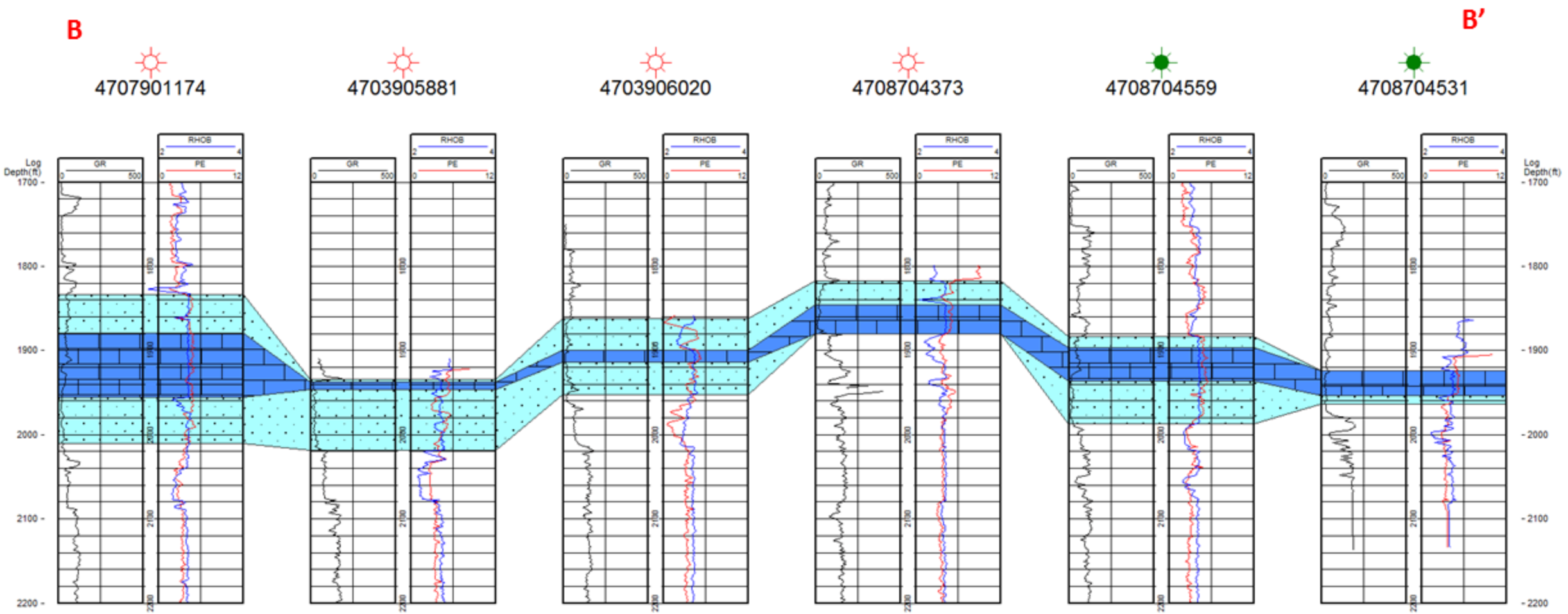


Trap integrity - 0



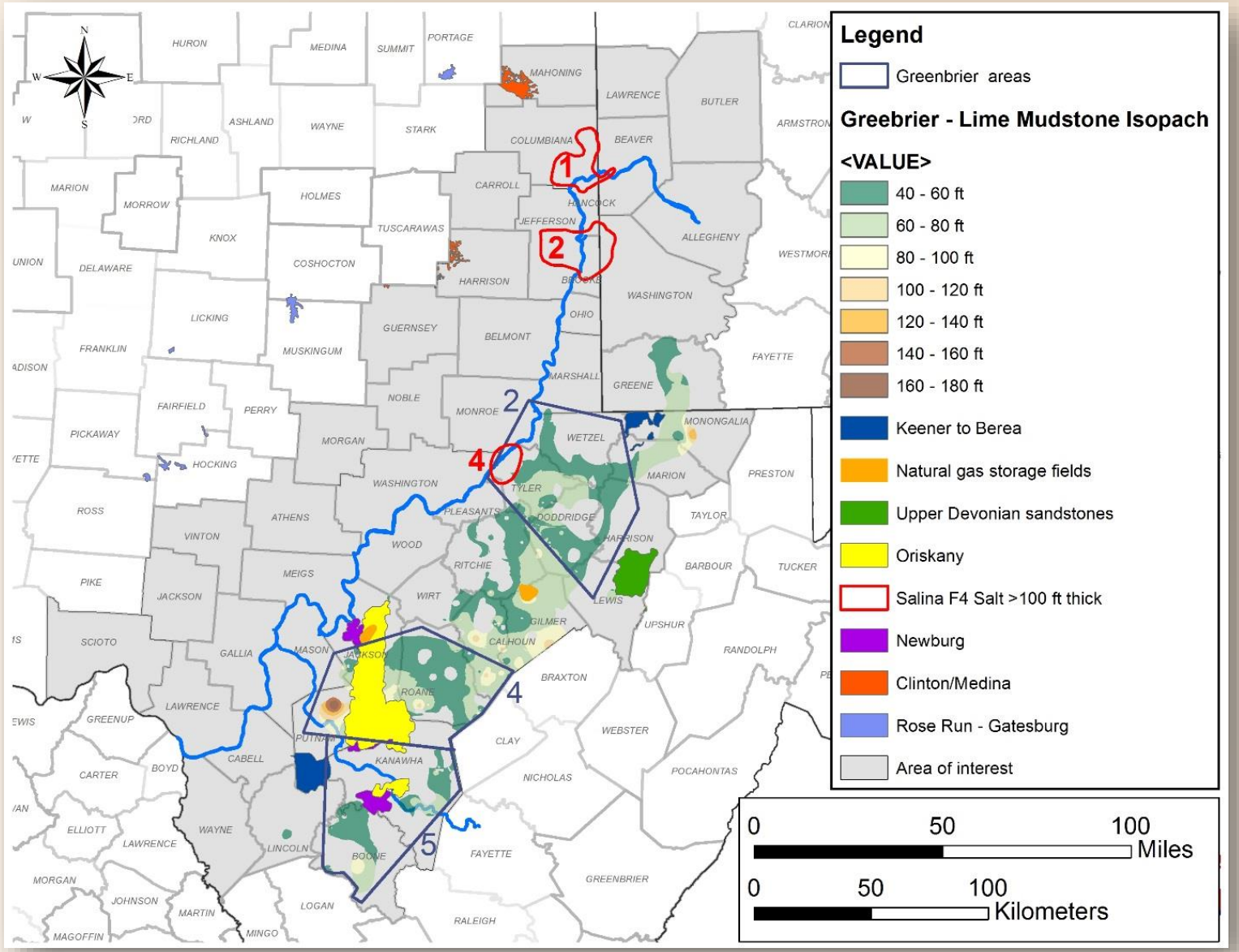
Trap integrity - 3

Trap integrities of Mined Rock Fields



DETAILED RATING RESULTS

- 30 opportunities
  - 22 depleted gas fields
  - 3 salt areas
  - 3 mined-rock areas
  - 2 natural gas storage fields



RELATIONSHIP BETWEEN RATING AND RANKING EFFORTS

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Stacked opportunity	Stacked opportunity	Stacked opportunity	Stacked opportunity

RANKING EXAMPLE:

Rating Criteria	Campbell Creek	Kanawha Forest	Red House
Distance to infrastructure	3	3	3
Average depth	3	3	3
Acreage	3	3	3
Net thickness	2	2	1
Trap integrity	2	2	1
Legacy well penetrations	1	1	1
Stacked opportunity	1	1	1
Pressure	*2*	*2*	*2*
Porosity	*2*	*2*	*2*
Permeability	*0*	*0*	*0*
Mode CO_2 storage (computed)	*3*	*3*	*3*
Estimated cumulative gas production (BCF)	*3*	*0*	*2*
Rating totals	25	22	22
Normalized totals	*15*	*15*	*13*

FINAL RANKING RESULTS

Ranking	Container Type	Field/Location	Geologic Interval	Normalized Rating
1	mined-rock cavern	5	Greenbrier	19
2	depleted gas reservoir	NORTH RIPLEY	Newburg	16
2	depleted gas reservoir	ROCKY FORK	Newburg	16
2	depleted gas reservoir	KANAWHA FOREST	Newburg	16
2	mined-rock cavern	4	Greenbrier	16
3	depleted gas reservoir	CAMPBELL CREEK	Oriskany	15
3	mined-rock cavern	2	Greenbrier	15
3	salt cavern	1	Salina F4 Salt	15
3	salt cavern	2	Salina F4 Salt	15

Ranking	Container Type	Field/Location	Geologic Interval	Normalized Rating
1	mined-rock cavern	5	Greenbrier	19
2	depleted gas reservoir	NORTH RIPLEY	Newburg	16
2	depleted gas reservoir	ROCKY FORK	Newburg	16
2	depleted gas reservoir	KANAWHA FOREST	Newburg	16
2	mined-rock cavern	4	Greenbrier	16
3	depleted gas reservoir	CAMPBELL CREEK	Oriskany	15
3	mined-rock cavern	2	Greenbrier	15
3	salt cavern	1	Salina F4 Salt	15
3	salt cavern	2	Salina F4 Salt	15
4	depleted gas reservoir	WESTON-JANE LEW	Elk	14
4	depleted gas reservoir	CANTON CONSOLIDATED	Clinton/Medina	14
4	depleted gas reservoir	COOPER CREEK	Newburg	14
4	depleted gas reservoir	ABBOTT-FRENCH CREEK	Venango	14
4	natural gas storage field	RIPLEY	Oriskany	14
5	depleted gas reservoir	MAPLE-WADESTOWN	Keener to Berea	13
5	depleted gas reservoir	ELK-POCA (SISSONVILLE)	Oriskany	13
5	gas storage field	RACKET-NEWBERNE (SINKING CREEK)	Venango	13
5	salt cavern	4	Salina F4 salt	13
4	depleted gas reservoir	CANTON CONSOLIDATED	Clinton/Medina	13
5	depleted gas reservoir	CANTON CONSOLIDATED	Clinton/Medina	13
5	depleted gas reservoir	RAVENNA-BEST CONSOLIDATED	Clinton/Medina	13
6	depleted gas reservoir	BURDETT-ST. ALBANS	Keener to Berea	12
6	depleted gas reservoir	CONDIT-RAGTOWN	Keener to Berea	12
7	depleted gas reservoir	DUMM RIDGE	Rose Run-Gatesburg	11
7	depleted gas reservoir	FRAZEYBURG	Rose Run-Gatesburg	11
8	depleted gas reservoir	KIRKERSVILLE	Rose Run-Gatesburg	10
8	depleted gas reservoir	DUMM RIDGE	Rose Run-Gatesburg	10
8	depleted gas reservoir	DUMM RIDGE	Rose Run-Gatesburg	10
8	depleted gas reservoir	ROCKBRIDGE	Rose Run-Gatesburg	10
8	depleted gas reservoir	RANDOLPH	Rose Run-Gatesburg	10

SUMMARY

- Preliminary rating methods were used to determine locations of potential storage caverns and to reduce the number of gas fields investigated in this study.
- The top nine ranked prospects include three Greenbrier areas, two Salina salt cavern areas and four depleted gas fields.
- The final report and project data are available online at: **http://www.wvgs.wvnet.edu/ash**

THANK YOU!

Katherine Schmid, PG
Senior Geologist
Pennsylvania Geological Survey (Pittsburgh, PA)
kschmid@pa.gov