APPALACHIAN STORAGE HUB (ASH) STUDY

Summary, Conclusions and Recommendations

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ASH STUDY – OUR GOAL

- Complete a geologic study of all potential options for subsurface storage of NGLs
- Required a stratigraphic correlation of key units
- Mapping thickness and structure of key units
- Studies of reservoir character
- Developing ranking criteria

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)

Gas Reservoirs

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

OBJECTIVE AND OUTCOME

- **Objective**
  - Identify, characterize, evaluate and rank the subsurface storage resources of the AOI as potential options for storage of NGLs
- **Major Outcome**
  - Multiple options are present along the Ohio and Kanawha rivers where storage could be constructed in three different types of storage containers

THREE MAIN PRODUCTS

- Regional subsurface study with correlations, cross sections, thickness and structure maps
- Criteria with which to rate and eventually rank candidate formations and reservoirs as safe and secure storage containers
- A project database and website in which all of the data and research findings ae located and can be accessed by the public and potential storage companies

GREENBRIER MINED-ROCK CAVERNS

- Identified three main facies; mapped net thickness of each
  - Upper grainstone (top seal)
  - Lime mudstone (mine)
  - Lower grainstone (bottom seal)

SALINA SALT CAVERNS

- Mapped net thickness of upper F4 salt (conservative approach)
- Identified four areas where upper F4 salt >100 ft
- However, due to the presence of a 20-25 ft lower salt, most areas in the middle of the north-south salt trend have good potential
- Salt thickness changes abruptly to the east and west of the main trend
- Important to leave a buffer zone between the caverns and edge of the salt basin

DRILLING DOWN – 2,700+ GAS FIELDS

- Only 1,500 deeper than 2,000 ft
- Preliminary rating effort resulted in 12 natural gas storage fields and 113 depleted gas fields to be studied further
- 2nd round used a series of detailed rating criteria; this reduced list of candidates to 24 depleted gas fields (production or storage)
- Detailed rating criteria applied to mined-rock caverns and salt caverns added 6 more opportunities to create a short list of 30 candidates

"THE BEST OF THE BEST"

- Ratings for top 30 NGL storage candidates were normalized using only criteria common to each type of container
- Candidates had comparable rating values for distance to infrastructure, acreage, net thickness and well penetrations
- Distinguishing criteria were average depth, favorable trap integrity and presence of stacked opportunities
- The top 9 received rankings of 1, 2 or 3
- The top 15 that emerged include all types of containers: mined-rock caverns, solution cavities, depleted gas fields and gas storage fields

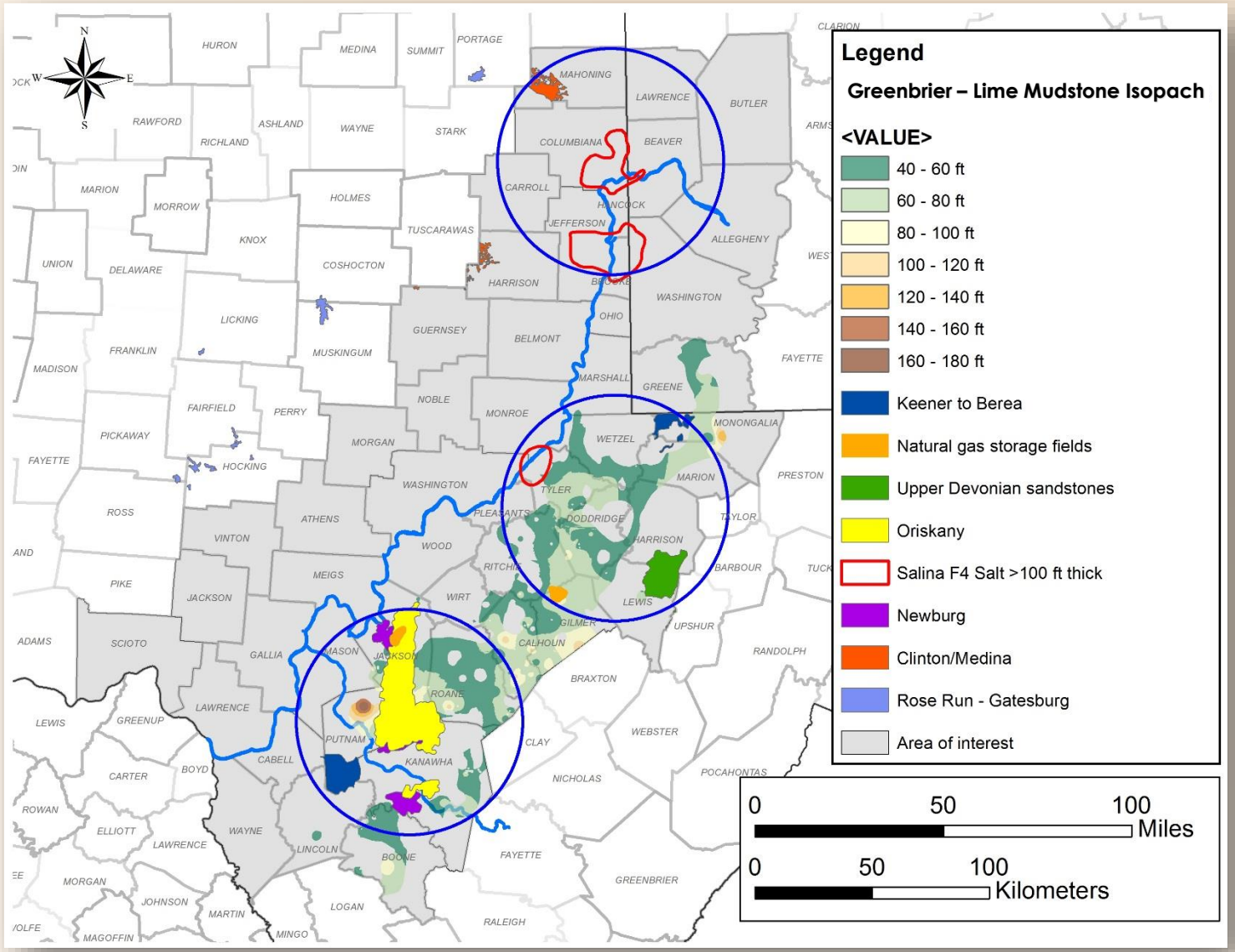
THE TOP 30 INCLUDED…

- Three Greenbrier mine-rock cavern options in top 7
- Two F4 Salt cavern options in top 10
- Three Newburg depleted gas fields in top 5
- One Oriskany gas storage field at #13

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

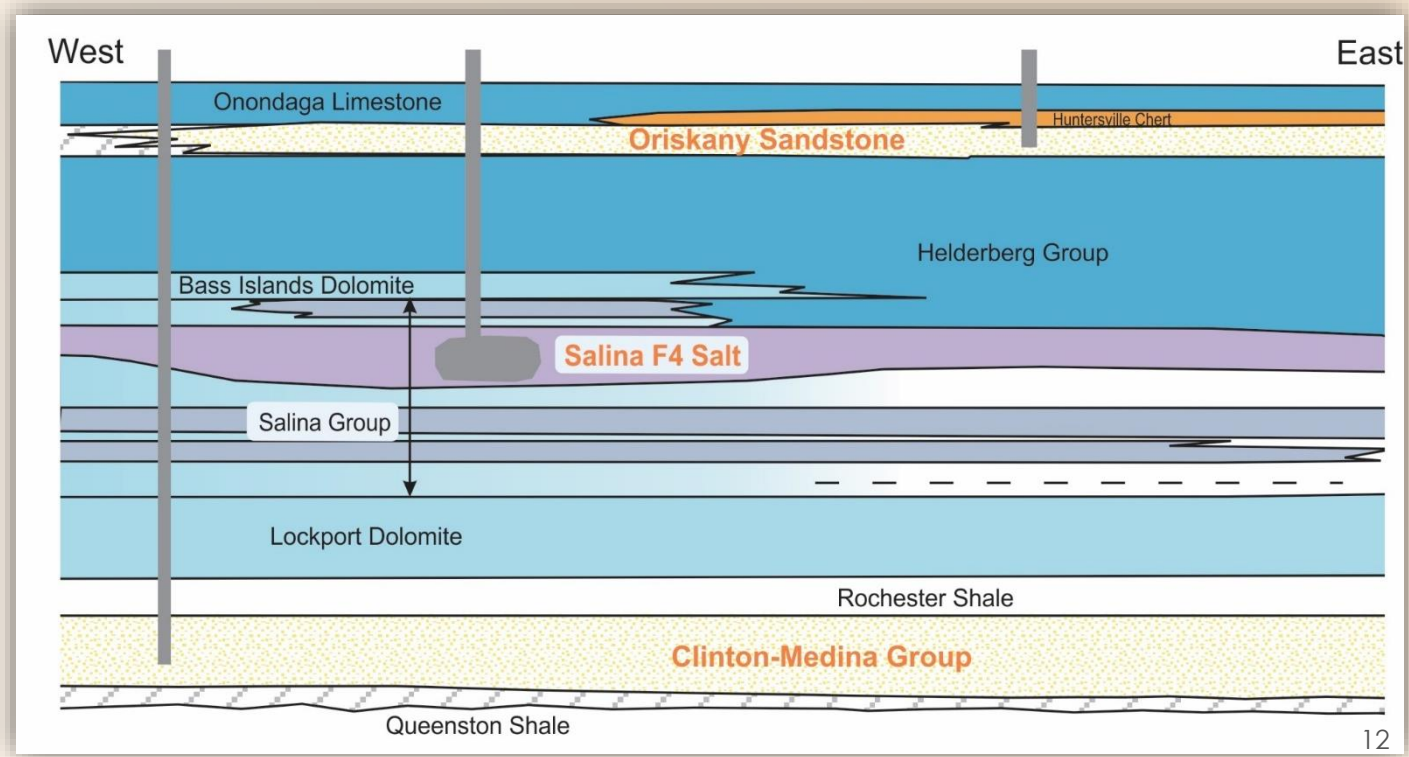
THREE PROSPECT AREAS

- Each prospect differs in number and type of opportunities
- Demonstrate how this Study's geologic data can be applied in underground storage siting work
- Stacked storage is important



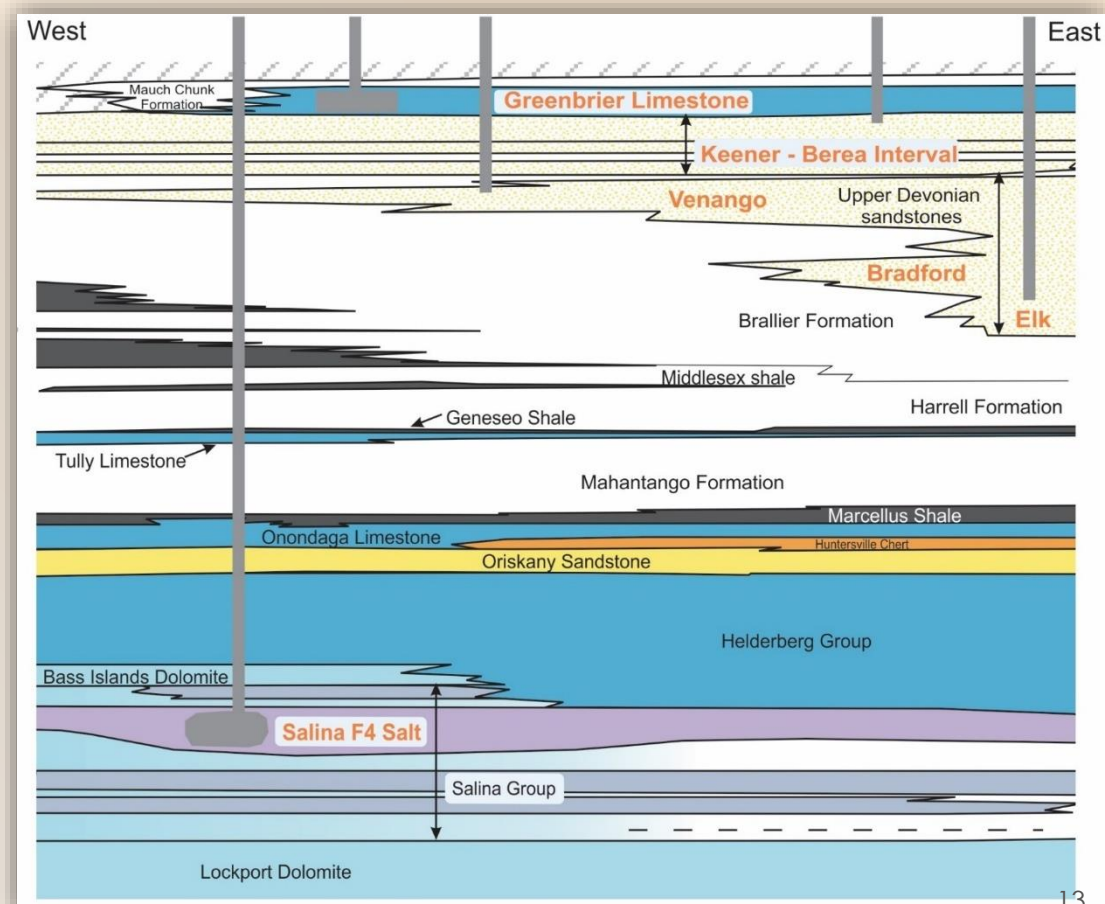
NORTHERN PROSPECT AREA

- Clinton/Medina sandstones in Ohio's Ravenna-Best Consolidated Field
- Two Salina F4 Salt cavern opportunities on both sides of the Ohio River
- Oriskany core data indicates another opportunity; suggests stacked potential



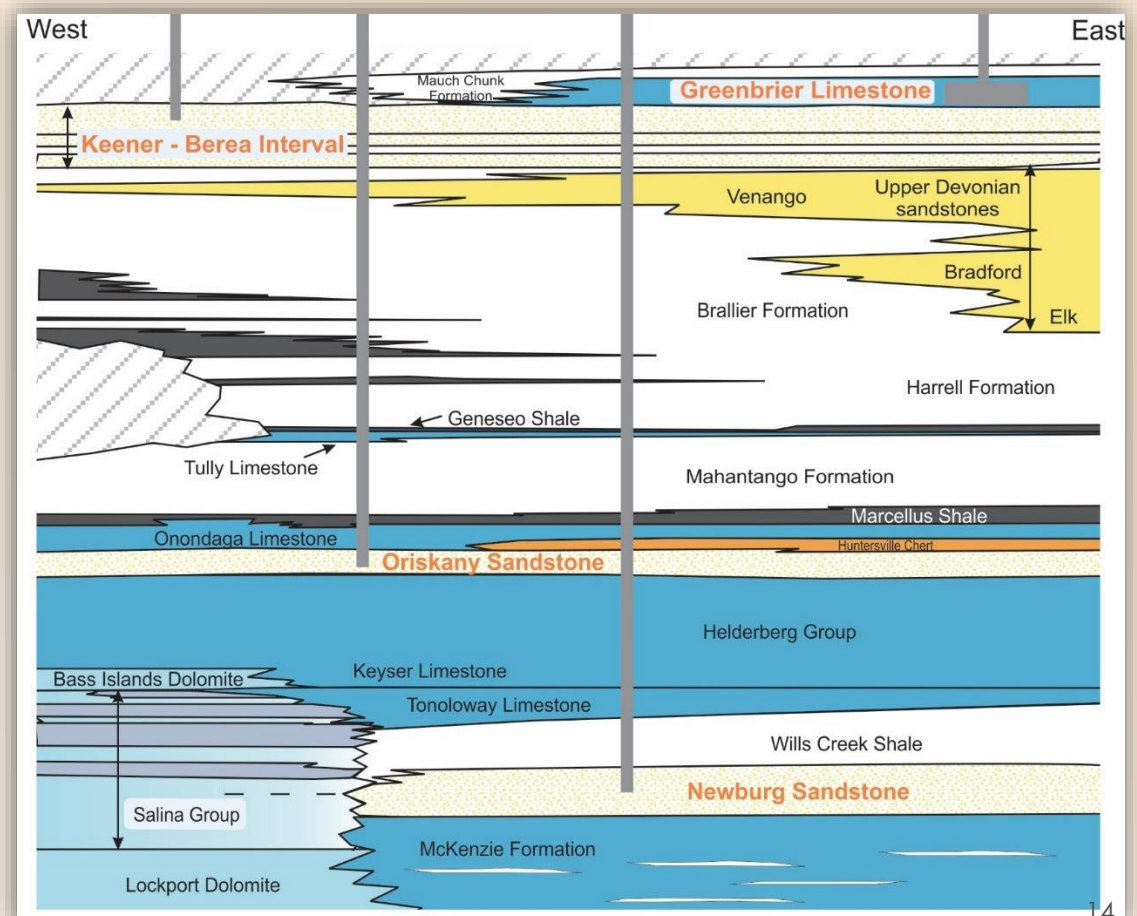
CENTRAL PROSPECT AREA

- Greenbrier Limestone mines throughout the area; key facies, thickness and depth
- Keener to Berea Interval depleted gas field
- Venango Group inactive gas storage field
- Upper Devonian depleted gas field to the east
- Salina F4 Salt near Ben's Run



SOUTHERN PROSPECT AREA

- Greenbrier Limestone mined-rock storage
- Depleted gas fields in the Keener to Berea Interval
- Oriskany gas storage in part of Elk-Poca field
- Newburg fields(North Ripley, Rocky Fork, Cooper Creek and Kanawha Forest) are among the very best of all depleted gas fields



WHAT WE DID NOT CONSIDER

- Who owns or operates a depleted gas field or gas storage field that was rated highly
- Or if this operator would be interested in NGL storage
- Who owns the rights to the Greenbrier Limestone or Salina Salt
- And again, if the owner might be interested in NGL storage
- If a candidate is in an area of future Marcellus or Utica drilling
- Surficial activities, other than towns or cities
- Cost implications for storage and pipelines (next step)
- Focus was entirely on subsurface geology

ADDRESSING STATE REGULATORY ISSUES RELATED TO A STORAGE HUB

- Workshop held last week (8/22) in Morgantown
- Speakers did address the ownership issue
- Summary of current laws, rules and regulations in three states
- Heard from speakers in TX and KS who have gone through the process of developing regulations related to subsurface storage of NGLs

AND, IN THE REPORT APPENDIX…

- Jessica discussed mined-rock caverns, solution-mined caverns and porous reservoirs
- Addressed infrastructure requirements, timelines and cost estimates of each
- Considered three scenarios for volume to be stored
- Listed the advantages/disadvantages of each of the three storage options

OTHER FACTORS TO BE CONSIDERED

- Follow up site-specific engineering and geological studies
- Design & construction parameters
- On-site drilling, coring and logging of potential storage unit
- Core tests for porosity, permeability, mechanical strength, etc
- Core and sample thin section descriptions (porosity, salt purity)
- Thickness and homogeneity of the desired limestone facies
- Descriptions and testing of upper, lower & lateral seals
- Result – detailed feasibility and economic evaluation of site

THANK YOU!

…from all the members of the Appalachian Storage Hub Research Team