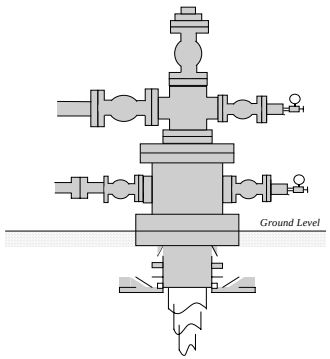
Alternative and Strategic Evaluation and Approaches for Injection Well Development for Western Kentucky CO_2 Storage



Presentation
to
Kentucky Consortium for Carbon Storage (KYCCS)

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Items for Discussion

- Project Goals and Strategic Approaches
- Drill new Well approach
- Re-entry Well Approach- single or multiple wells
- Project Efficiencies-Allocations
- Risk Assessment & Chance of Success, Measuring Success
- Estimated Costs
- Public Visibility, Partner Goals, Organization Goals
- Summary

Project Goals and Strategic Approaches

- **Goal:**
  - Prove injection intervals and storage reservoirs to develop a CO_2 sequestration storage industry
    - Prove capability of Knox Ls and/or Mt. Simon as Injection Intervals

- **Objectives**:
  - acquire and integrate new geologic data on deep reservoirs and interval capability
    - Challenge of Limited Geologic borehole data and knowledge across large areas of KY; Carbonate terrain is complex

- **Funds constraint – drives an Innovative Assessment:**
  - Drill new Well vs. Well Re-entry Approach

- **Alternative Plan**
  - Consider 2 geographically separated re-entry wells of equal risk/chance of success. There is more potential offering a better overall project chance of success with considerably more risk management incorporated.

Drill new Well approach

- Advantages/Disadvantages
  - Home Run – Excellent Interval, --*generally rare*
  - Risk of limited or no success, no injection interval present
  - Seismic based location, or offset geology twin, *helpful, not magic*
  - Assume 8,000 ft TD to get to Knox and Mt. Simon

- **Total of $ 5.745 MM (w/10% contingency)—Conservative Estimate**
  - 42 days drilling, $ 4.36 MM drill 8,000'
  - + completion, $ 0.488 MM; set 5-1/2 casing, equipment
  - + testing, $ 0.770 MM

- Risk is all ' eggs in one basket' philosophy
  - Need detailed geology, offset twin geology, seismic evaluation to minimize risk present – *we do not have pure quality of exploration data to warrant this approach—pwp & Sandia personal opinion*
- Game over if no interval or success or limited success
- Funds not Present for this approach

Re-entry Well Approach

- Advantages/Disadvantages
  - Candidate Parameters
    - Single Re-entry or Multiple Well Re-entries
    - Help Manage risk via multiple wellbore evaluation approachs, integrated information, leverage from offset or remote boreholes
    - Based on key offset detailed geologic assessment, or direct correlation of candidate injection intervals with porosity
    - Based on wellbore condition, target depth and size of casing
    - Assumes Multiple (2) work overs, re-entry, drill deeper combination
    - Assumes open-hole test, logging, DST, coring
    - Set casing only if favorable for extended injection testing or future CO_2
  - Estimated costs of $ 0.6 MM per well re-entry to pre-existing depth, assumes depth of ~ 4,000 ft, log and prepare to drill new borehole
  - Est. Incremental Costs + < $ 0.7 - 1.0 MM drilling deeper from 4,000 to 8,000' TD, log, openhole test
    - If interval favorable -- + casing $ 0.2 MM
  - Est. Totals for Re-entry, drill deeper, completion, test = $ 1.8 MM per well Candidate
  - If new deeper interval(s) not favorable -- Risk only $ 0.7 - 1.0 MM total; however a shallower interval maybe identified in < 4,000' borehole

Re-entry Well Approach (cont'd)

- Advantages/Disadvantages
  - Primary Risk is in initial Borehole Re-entry due to Junk and potential Obstructions, collapsed casing, cement plugs, etc.
    - Can cut losses if well cannot be re-entered, apply unused funds to other Candidates
  - Secondary Risk is in Drilling New Borehole; acquiring data, testing, etc.
    - If drilled deeper interval not favorable -- Risk only $ 1.0 MM total
- Efficient Allocation of funds allow re-entry, drill deeper, testing of 1-2 wells with various data gathered
- Consider up to 2 well Re-entries, select Candidates that meet criteria and may be within a geologic fairway for Knox, Mt. Simon porosity-permeability development
- Scalable testing, can perform as little basic data acquisition to as much as evaluation as funds allow

Project Efficiencies-Allocations

- A single New Well is good for a larger budget, can prove an interval using managed data and acquisition (seismic, geology integration), with selection of favorable location to narrow risk.
  - Sparse data yields essentially a Wildcat to TD
  - May take more than one well for success

- Drilling; Logging; Testing (up to 2 re-entry wells)
  - Selection of favorable location(s) via subsurface geology, interval correlation, seismic, and all available integrated data sets
  - Wildcat from original well TD to new drilled well TD

- Tubular & Services purchases (multiple wells, i.e. 2) offer discounts

- Work over vs. Drilling Costs
  - Day rate $ 10-12,000 vs. $ 20,000 (e.g. 7 days workover ~ 3.5 days drilling)
  - Pricing is efficient, competitive for 2 + wells
  - Can buy more testing with workover Re-entry approach vs. New Well Drilling approach

Risk Assessment & Chance of Success

Re-entry

- Low-hanging fruit -- Secure gains or success in proving candidate injection interval as identified from original re-entry well(s); logs, offset well data
- Incremental risk of drilling deeper is managed with successful test of pre-existing upper openhole interval
  - re-entry and deepening of original well to a TD sufficient to see basal Knox Ls and upper Mt. Simon offers new data, evaluation
- Can collect new information via existing wellbores
  - New logs, cores, data, DST, injection test, pressure data
  - Supplements known universe of data, adds to knowledge set
- Options to test 1 or both wells – openhole fashion to reduce costs
  - No casing, openhole testing philosophy, casing only to be set if interval good off log, or DST or cores, or if injection test warranted it – extended testing
- 2 well Re-entry provides 2 new data points, acquisition of geologic, interval and formation data, tie-in to offset well(s)

Estimated Costs

- New Well= $ 5.745 MM vs. 2 Re-entry Wells = $ 3.6 MM

- 1 Well Re-entry *(separate location or county)*
  - Assumes re-entry of ~ 4000' borehole into Knox Ls
  - Test existing original drilled hole if log indicates favorable interval(s)
  - Drill and Deepen new hole from 4000' to 8000' ~ Knox to Mt. Simon
  - Logging, coring, testing *(if warranted)*
    - Estimated Costs = $ 0.6 + $ 1.0 + $ 0.2 MM = $ 1.8 MM

- 2nd Well Re-entry *(separate location or county)*
  - Assumes re-entry of ~ 4000' borehole into Knox Ls
  - Test existing original drilled hole if log indicates favorable interval(s)
  - Drill and Deepen new hole from 4000' to 8000' ~ Knox to Mt. Simon
  - Logging, coring, testing *(if warranted)*
    - Estimated Costs = $ 0.6 + $ 1.0 + $ 0.2 MM = $ 1.8 MM

- Can have options to limit testing to Knox, with no Mt. Simon but not recommended; must assess the Mt Simon, since data may attract funding from DOE, operators in the area.
- Can hold interval(s) open, deferred for later extensive testing with CO_2

Public Visibility, Partner & Organization Goals

- High Visibility, typically have 1 – shot to make it work; limited funds
- There is corporate pressure, lots of public visibility to show success by finding a suitable injection interval
  - Geology does not always cooperate….
  - Hetereogeneity Rules!!
- Consider dedicating and using limited funds toward re-entry of up to 2 wells, testing, evaluation, etc.
  - Base well locations on key offset detailed geologic assessment, correlation of candidate injection intervals with porosity
- Re-entry gives data population, adds 2 wells to integrate into subsurface geologic assessment, identify favorable fairways
  - may offer 1 or 2 favorable locations or 1 or 2 favorable intervals

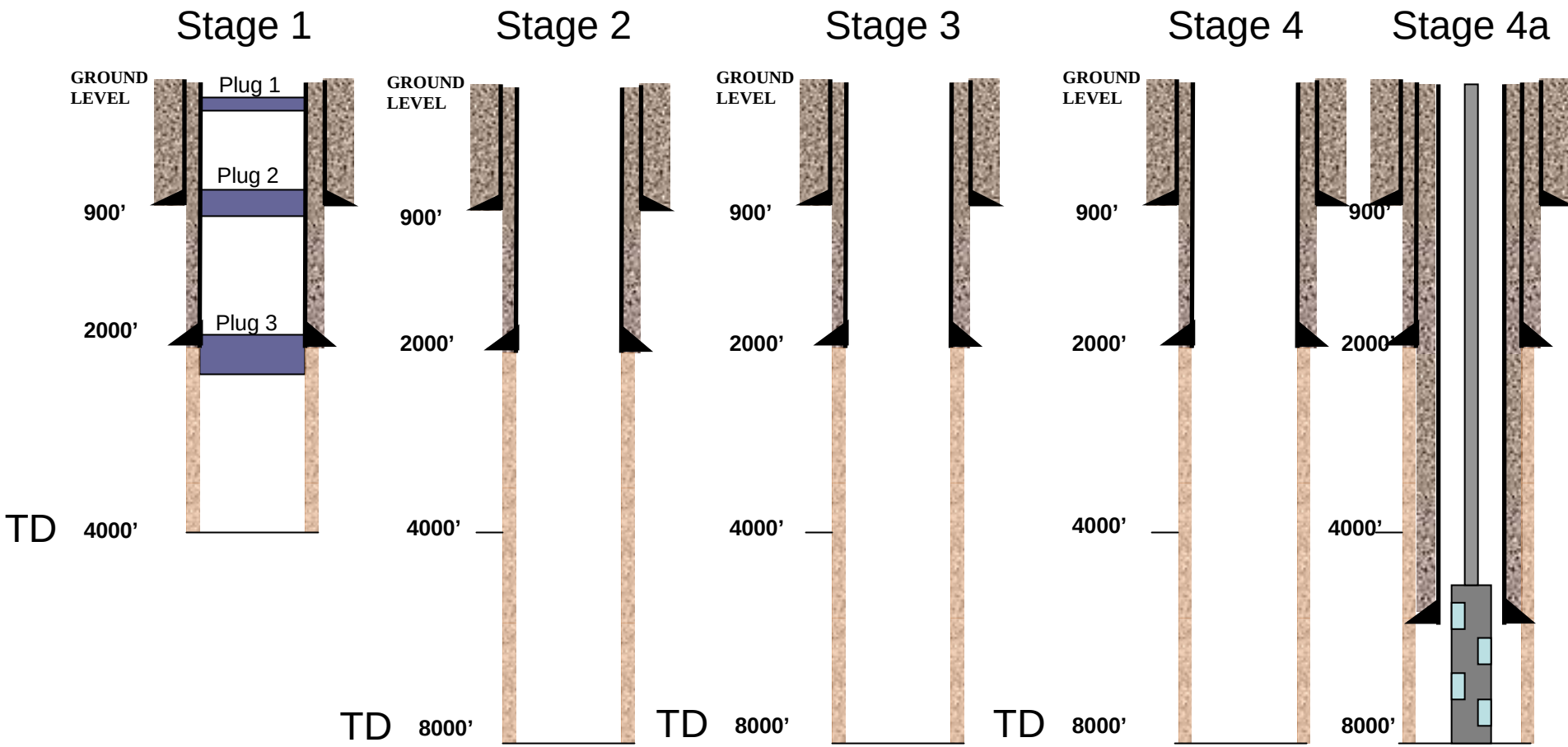
Suggested Steps for Re-entry Candidates

- Select County-Counties
  - Identify all Knox & Mt. Simon penetration wells
  - Identify all wells ~ 3 to 4,000 feet for Re-entry with suitable casing size, depth, etc.
- Perform Detailed Geology
  - Structure, Isopach, Cross Sections-regional/local
  - Correlatable intervals, net porosity, permeability, core data
  - Predict depths, tops of Knox, Mt. Simon
    - Base location on favorable Knox Ls intervals originally logged in re-entry well
    - Integrate DST data, logs, carbonate textures, features, breccias, fractures, etc.
    - Integrate all geologic data
- Integrate Available Seismic data
  - Check Seismic lines, for formations, basement, tie in well(s)
- Search data for DSTs, cores, logs, porosity sections

Summary

- Re-entries offer more ‘Bang for the Testing Buck’ $$$
- Spread or hedge risk with 2 wells, geographically separated, evaluating multiple formations—Knox, Mt. Simon
- Data Collection, Acquisition critical to assessment
- ‘Piggy back’ on known leads -- geologic porosity or interval leads, identifying favorable areas, fairways
- Utilize all area data, with an integrated approach

Potential Re-entry Test Plan



Re-enter & re-Log interval

Re-entry & Drill Deeper

Logging New Openhole 4000 – 8000’

DSTs, Logs, Cores

Openhole Testing

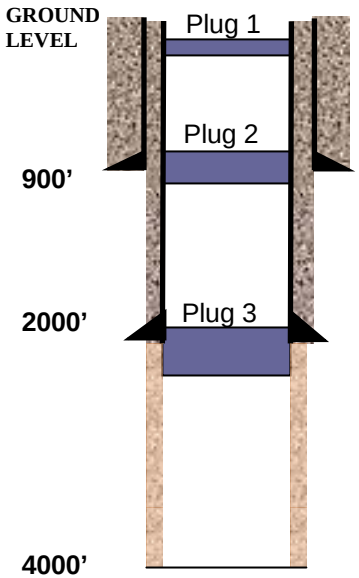
Packer, short term Injection tests

Set Casing Extended Testing

Openhole slotted liner Completion Injection tests

Potential Re-entry Test Plan

Stage 1



Require 8-5/8-inch Surface or Intermediate Casing

Drill out Cement Plugs

Wash to bottom, 4000’

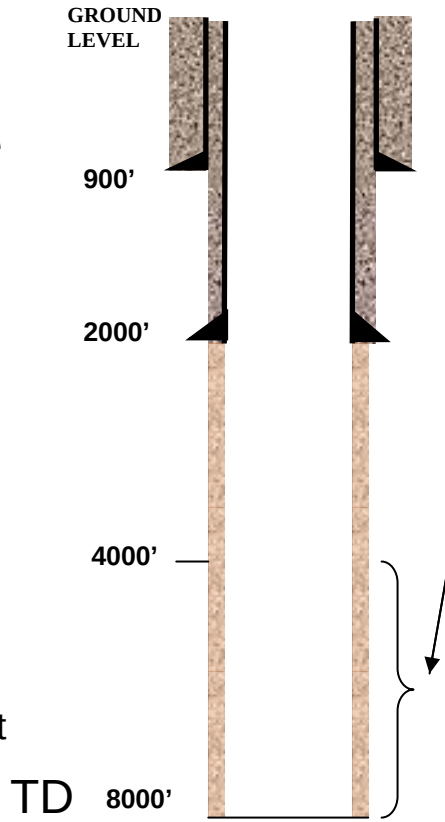
Re-Log Well if original Log not acceptable

Test intervals if present
DST, Horiz Cores,

Openhole Injection Test

Re-enter & re-Log interval

Stage 2



Require 8-5/8-inch Surface or Intermediate Casing

Drill new borehole (Air)
Using 8-1/2; 8 or 7-7/8-inch
To TD of ~ 8,000 ft
Thru Knox Ls, top 2-300’
Mt. Simon

Log Well, Platform Express
Add DSSI
Horizontal Cores
DSTs
MDT
Openhole Injection Test

Re-entry & Drill Deeper

Summary Criteria for a Suitable Injection Interval

Injection Interval

- Favorable Primary Reservoir Porosity & Permeability in Sandstone Clastic Matrix.
- Favorable Primary & Secondary Reservoir Porosity & Permeability in Limestone-Dolomite formations, with associated fractures, oolites, biohermal features,etc.
- Combination of suitable primary and Secondary porosity and permeability development.
- Connected Fracture networks, dolomitization processes in carbonate rocks.
- Presence of Karstification, collapse breccias, erosional surfaces, weathering features in formations. Prevalent in Knox and Cambro-Ordovician formations.
- Distance to major faulting may affect the fracture potential of the formations.
- Horizontal Wellbore may enhance kh and injectivity of the interval