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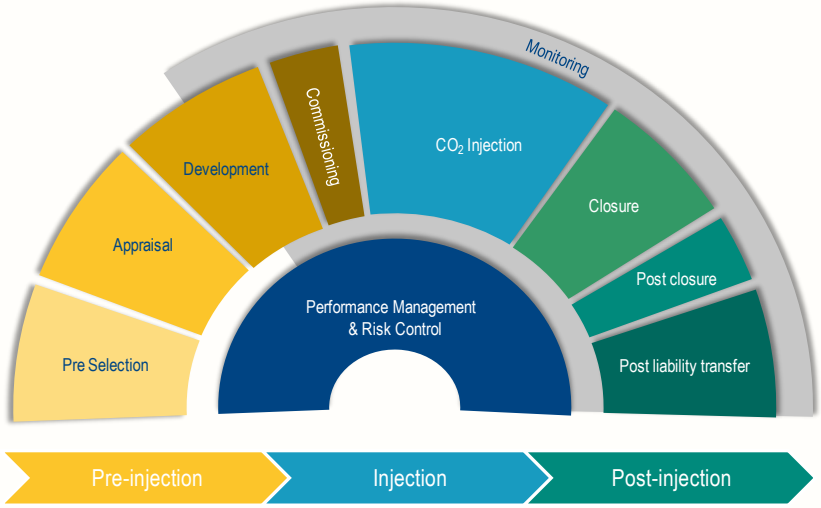

Costs and Experience with CO_2 Storage Monitoring and Verification

John Tombari

March 2012

Monitoring and verification

Schlumberger Carbon Services

- Operational monitoring
  - short term, alarms
- Verification monitoring
  - keeps the project within the acceptable risk framework of stakeholders
- Environmental monitoring
  - monitoring of last resort (no news is good news)

Operational monitoring

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- High frequency
  - pressure
  - temperature
  - volume
  - rate

Verification monitoring

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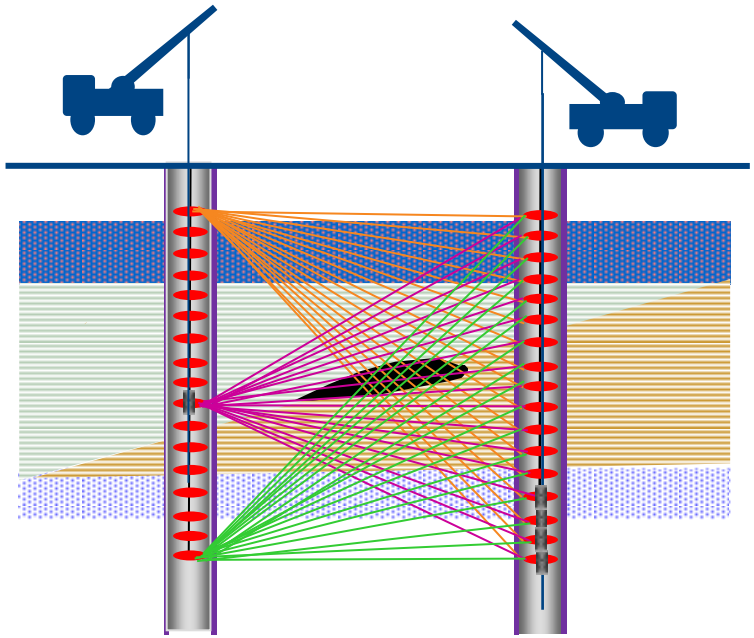
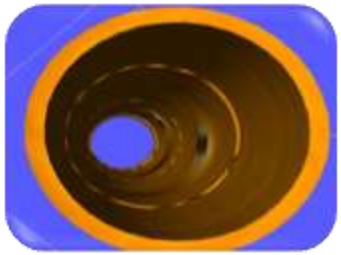
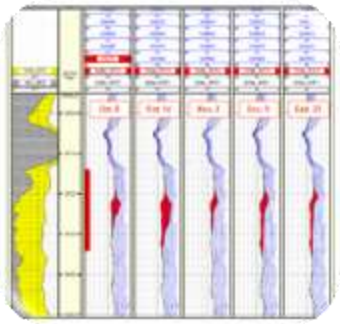
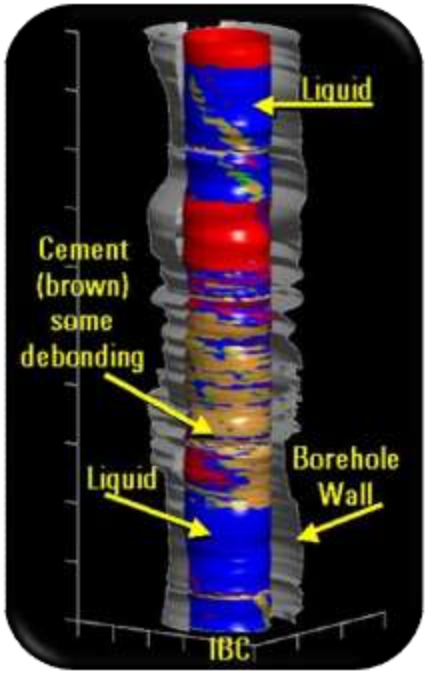
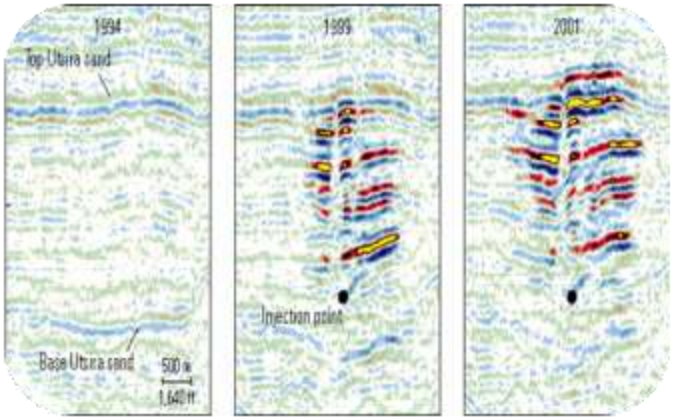
- Plume monitoring
- Storage integrity monitoring:
  - caprock
  - wells











Verification monitoring

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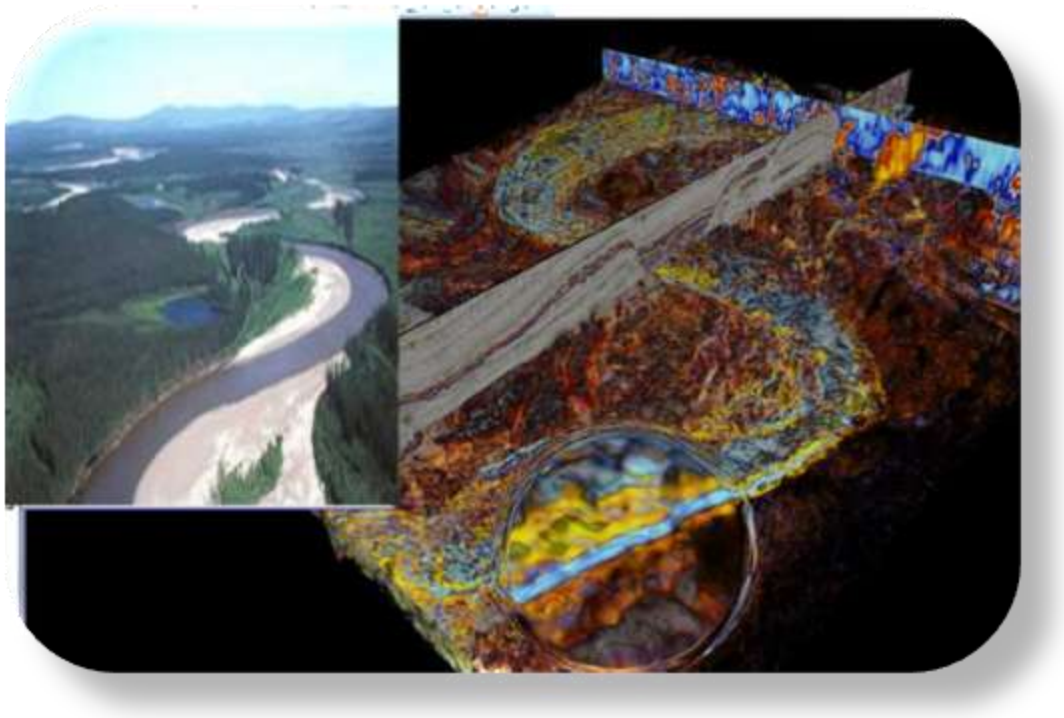
- Requires baseline data for comparison
  - static models (original state)
  - dynamic models (make predictions about future))



Verification monitoring

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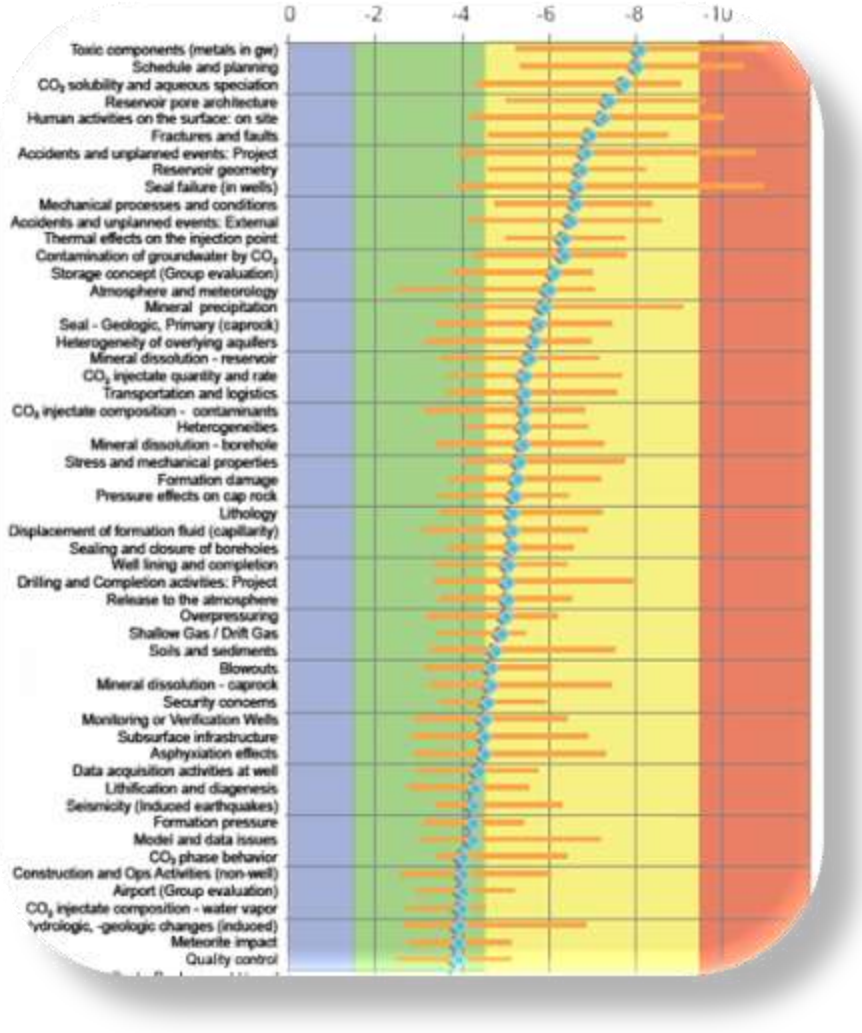
- Stakeholders must agree on an acceptable risk framework
- Over time, verification ensures that the project stays within the framework



Risk framework

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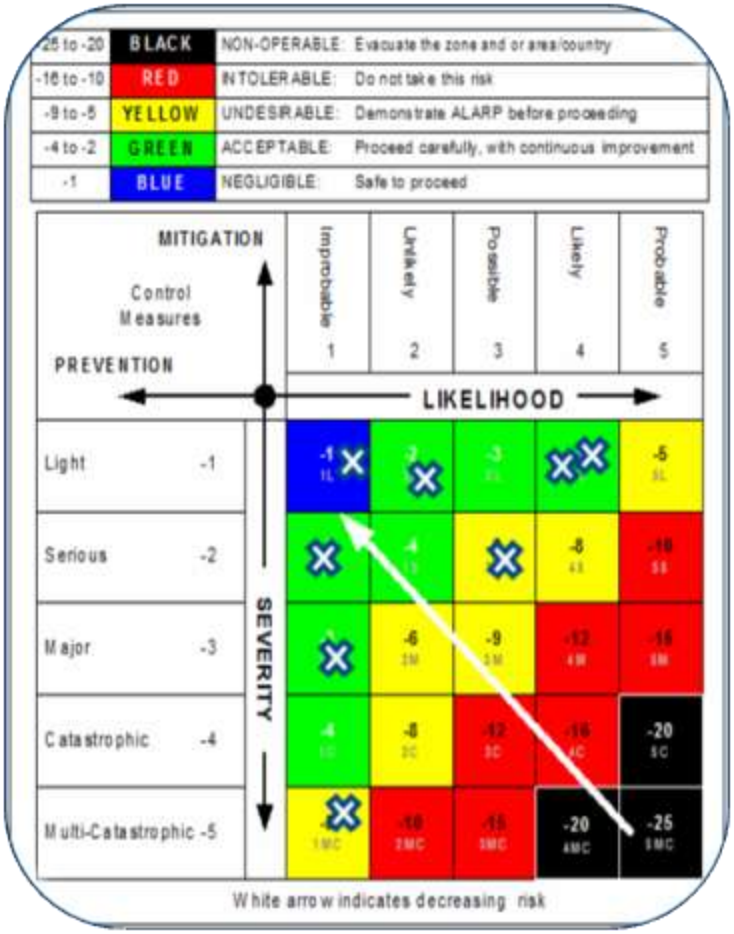

Hazard Analysis and Risk Control
Standard SLB-QHSE-S020

Risk informed action

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- Collect more data to reduce uncertainty (likelihood of a negative event)
- Create an operational plan that can be adapted over time, includes:
  - which measurements (site related)
  - what resolution (level of detail)
  - when (time interval: short, medium, long)
  - where (3-D placement)
- Change plan based on new information (must history match)

Monitoring quality - resolution

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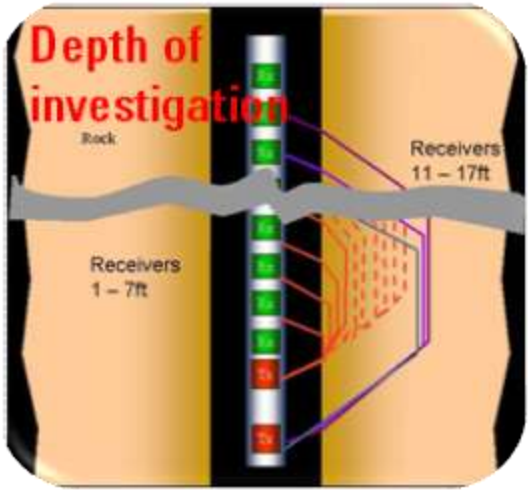

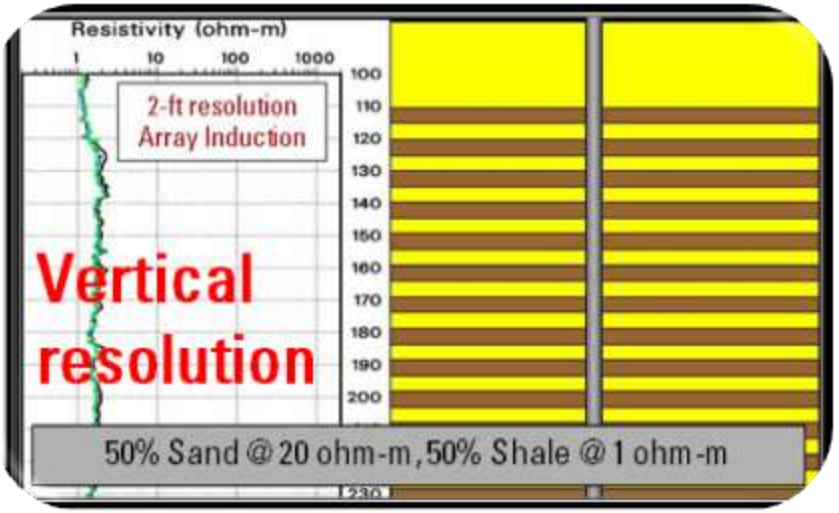

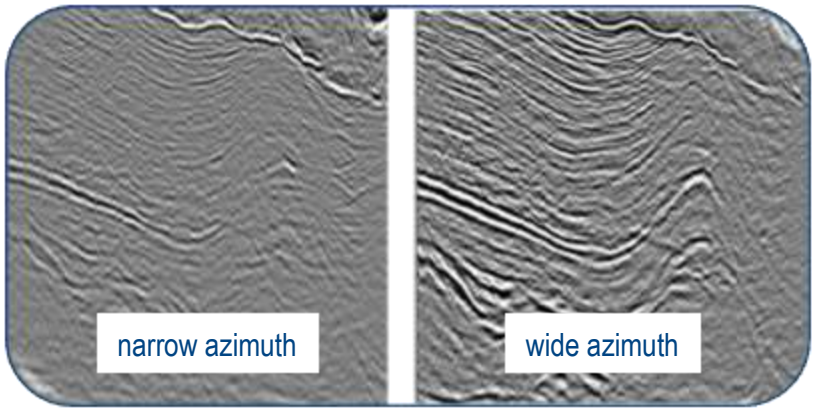

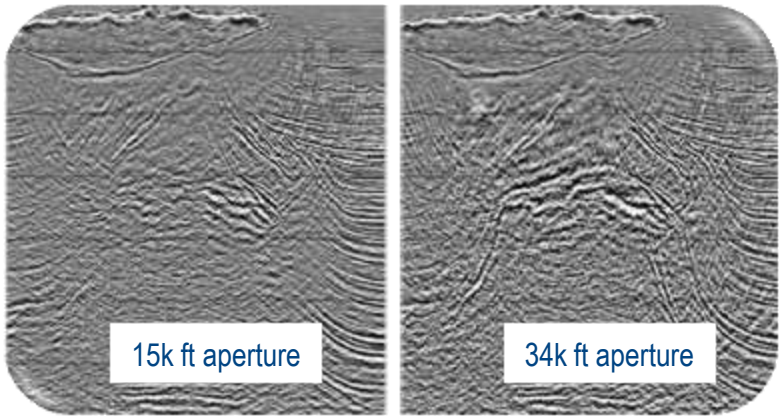

Environmental monitoring

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- Requires baseline data
- Looking for impacts. (no anomaly is good news yet subject to interpretation - uncertainty)
- Types:
  - soil sampling
  - water sampling
  - atmospheric monitoring
  - cement sampling

Costs

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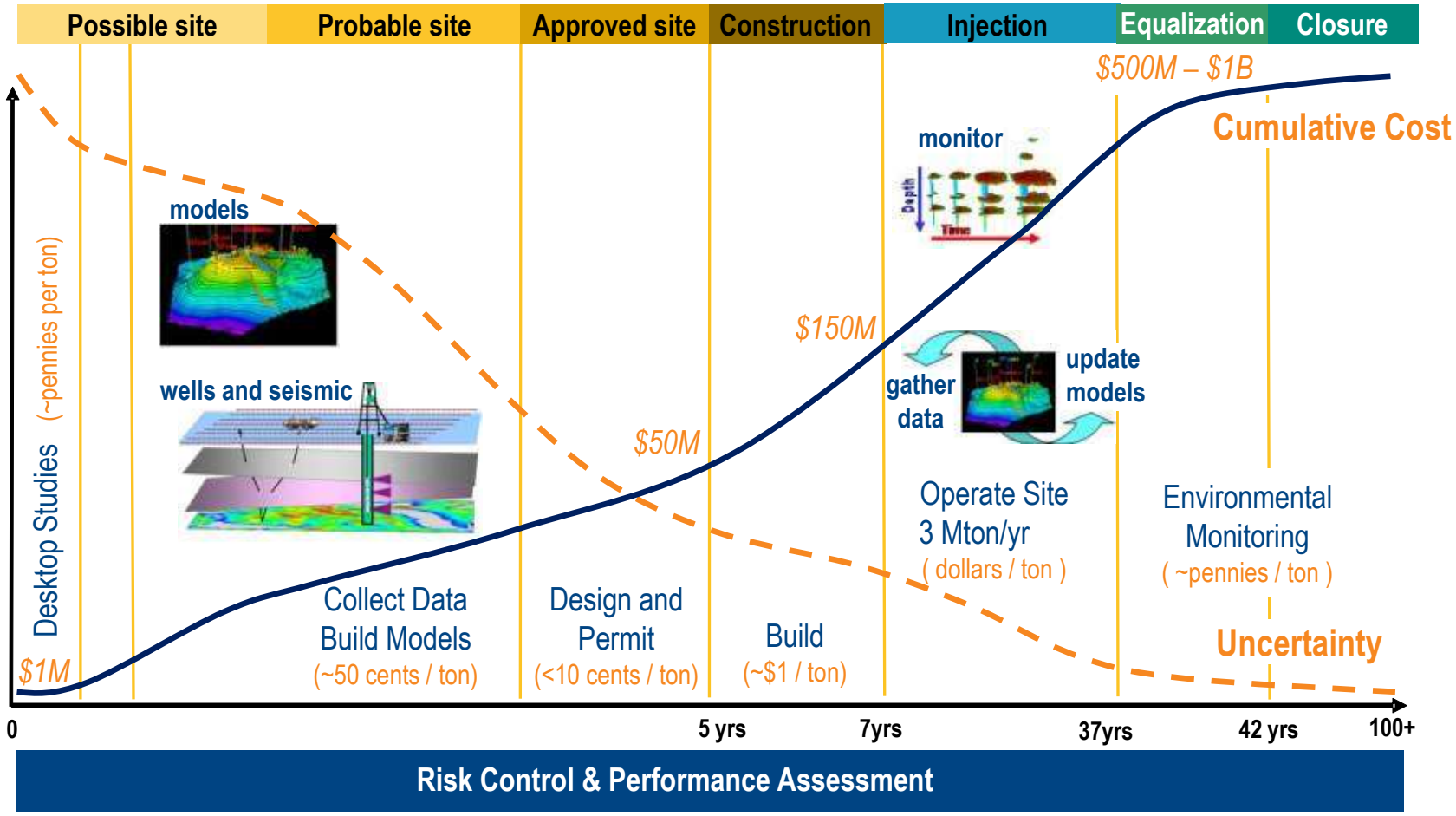
- Operational monitoring (very small – pennies per ton)
- Environmental monitoring (very small – pennies per ton)
- Verification monitoring (small relative to CCS - dollars per ton ?)
  - depends on site
  - driven by risk tolerance -“risk informed decisions”
  - overlaps with characterization and operational costs (baselines needed)

Commercialization timeline, costs and uncertainty

Schlumberger Carbon Services



** Per ton estimates and total costs (in current day $USD) are based on 100Mton lifetime storage volume)*

Conclusions

Schlumberger Carbon Services

- The costs of monitoring and verification are small relative to the overall cost of CCS
- Monitoring and verification costs depend on the level of risk stakeholders are willing to take
- The key to keeping monitoring and verification costs low is selecting a good site