Concrete Integrity Anomalies above the Mudline in River Bridge Drilled Shafts

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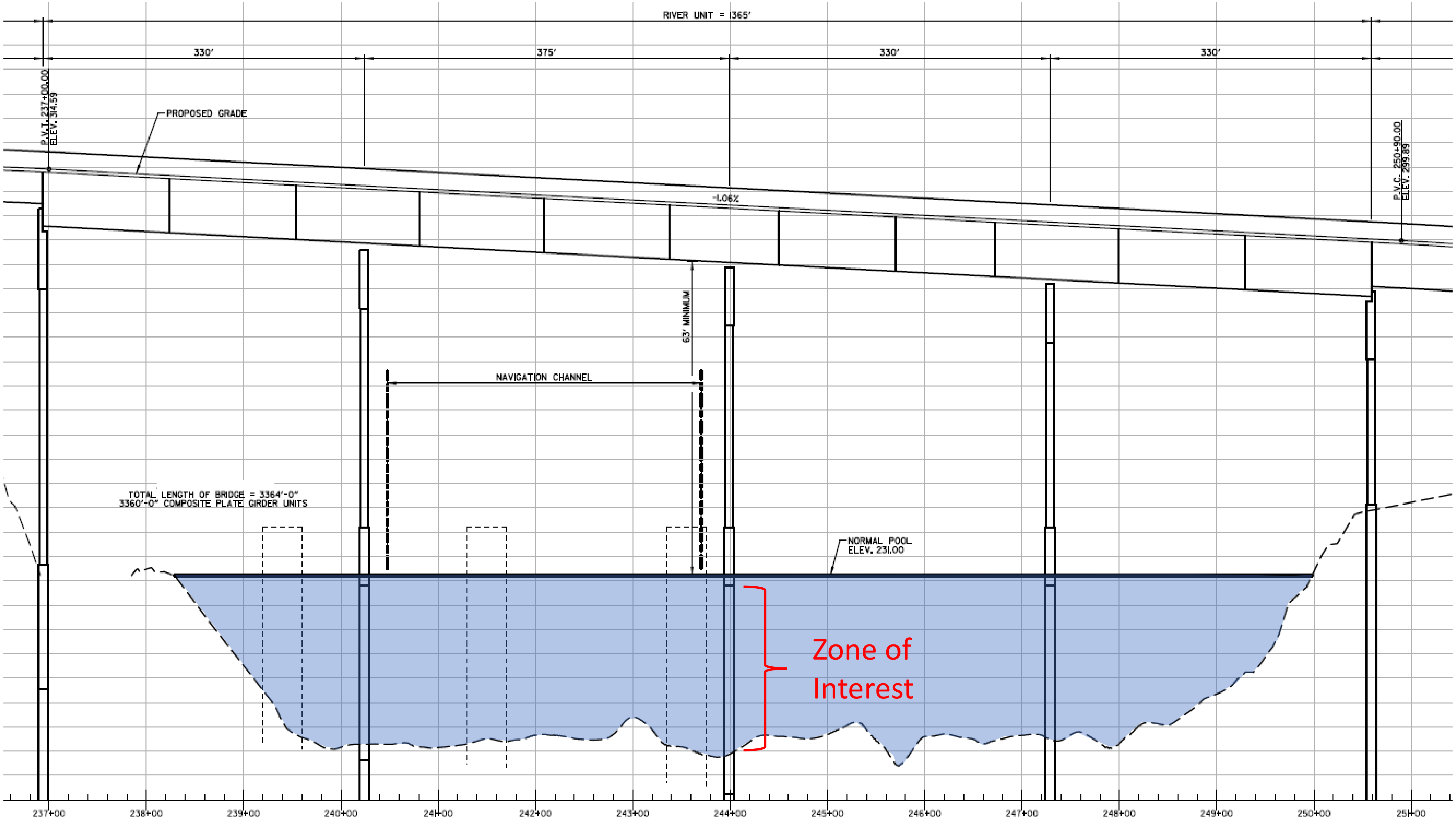
Drilled Shafts Above the Mudline



Concrete Integrity Testing

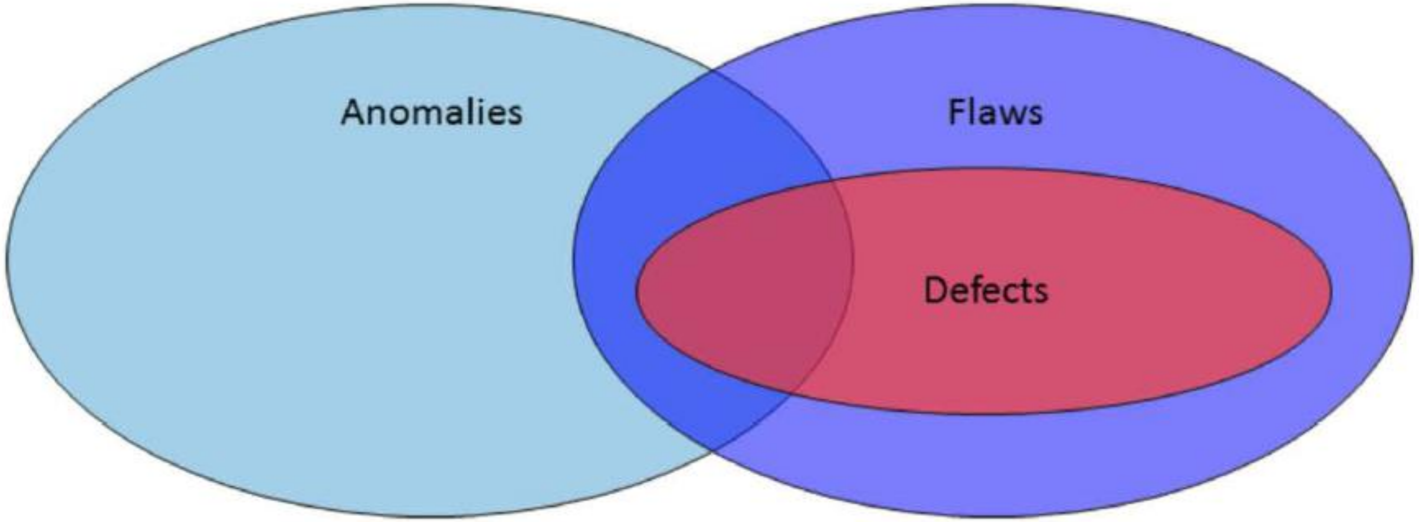
- Most common integrity methods:
  - Crosshole Sonic Logging (CSL), ASTM D6760
  - Thermal Integrity Profiling (TIP), ASTM D7949
- Bridge projects typically require one or both methods
- Each method has limitations
- Each methods requires semi-subjective interpretation of results
- Coring is typically the next investigative step when CSL or TIP raise concerns
- Coring has its own limitations

Terminology (DFI 2018)

Anomaly – Abnormal data that deviates from expectations, and may indicate a flaw or defect.

Flaw – Any imperfection in the planned shape or material of the foundation that may not necessarily affect its performance.

Defect – Any flaw that, because of size, location and inferred concrete properties, will have a significant adverse effect on the performance of the foundation.

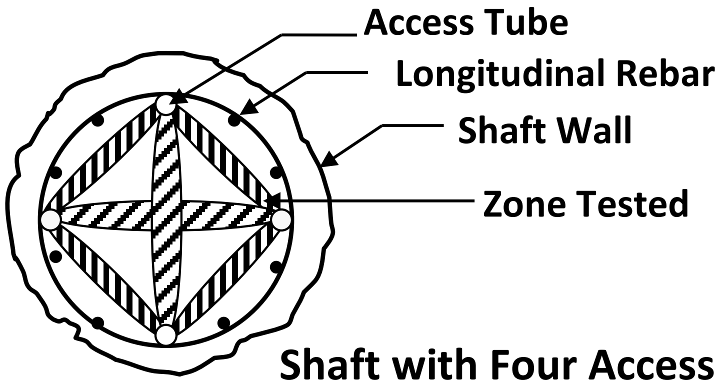


CSL

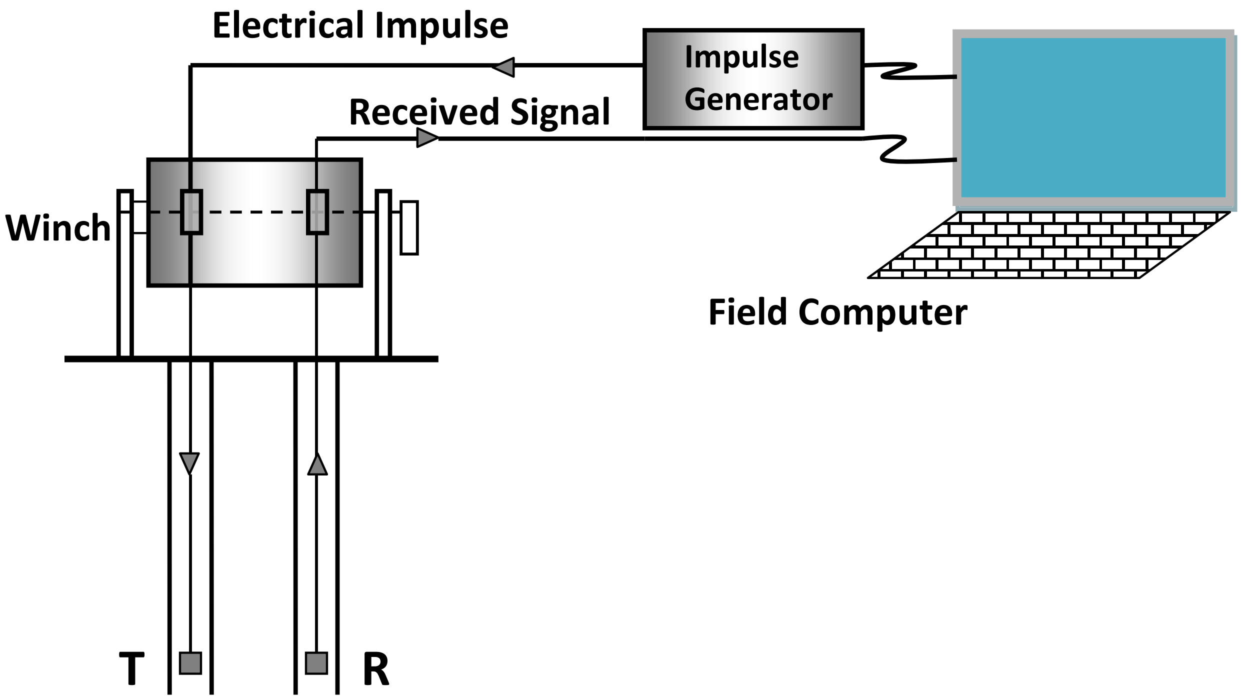
- Measure the travel time of acoustic signal pulses between tubes (Transmitter and Receiver)

- Signal velocity is a function of modulus and density:

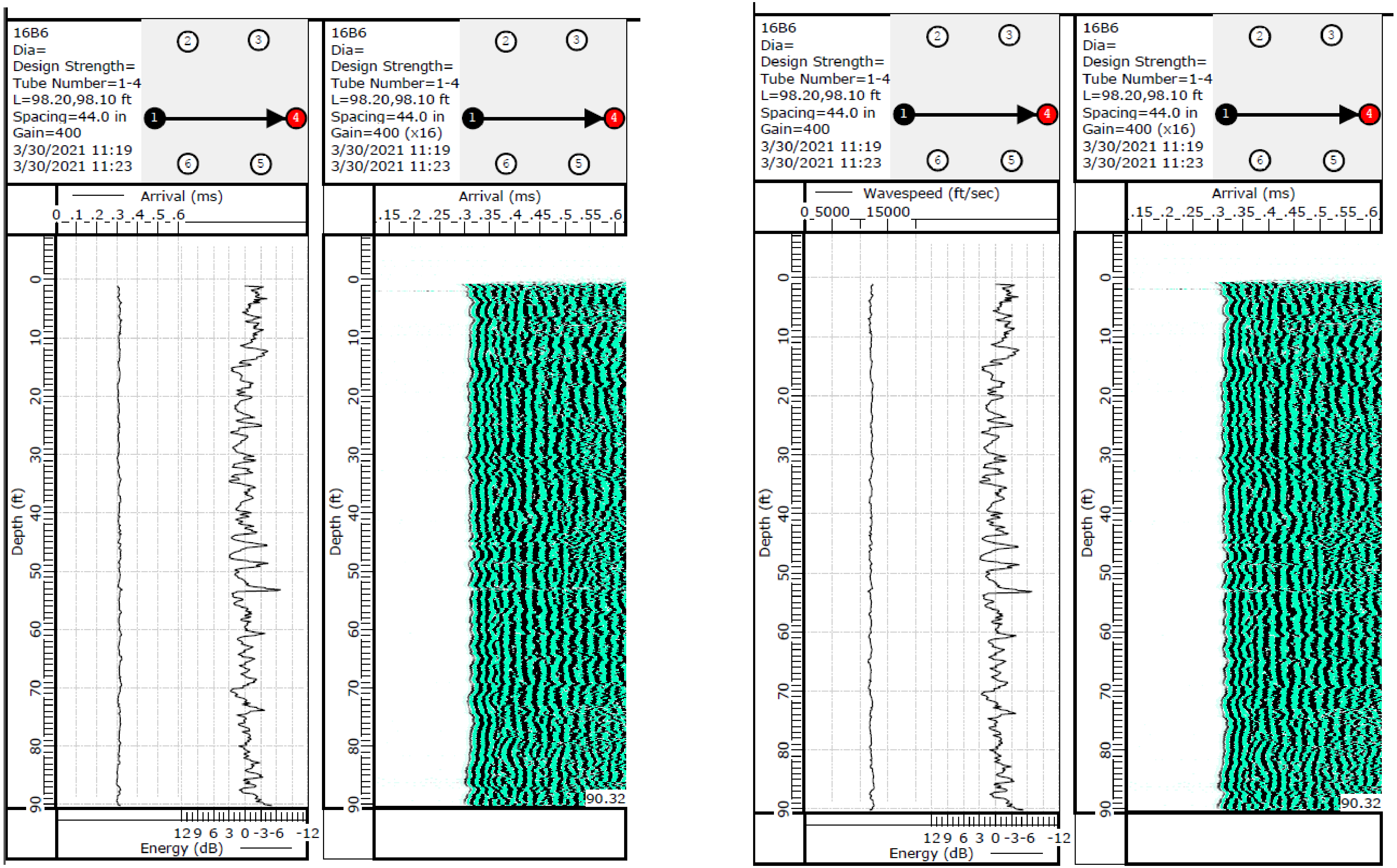
$$Velocity = \sqrt{\frac{Modulus}{Density}}$$



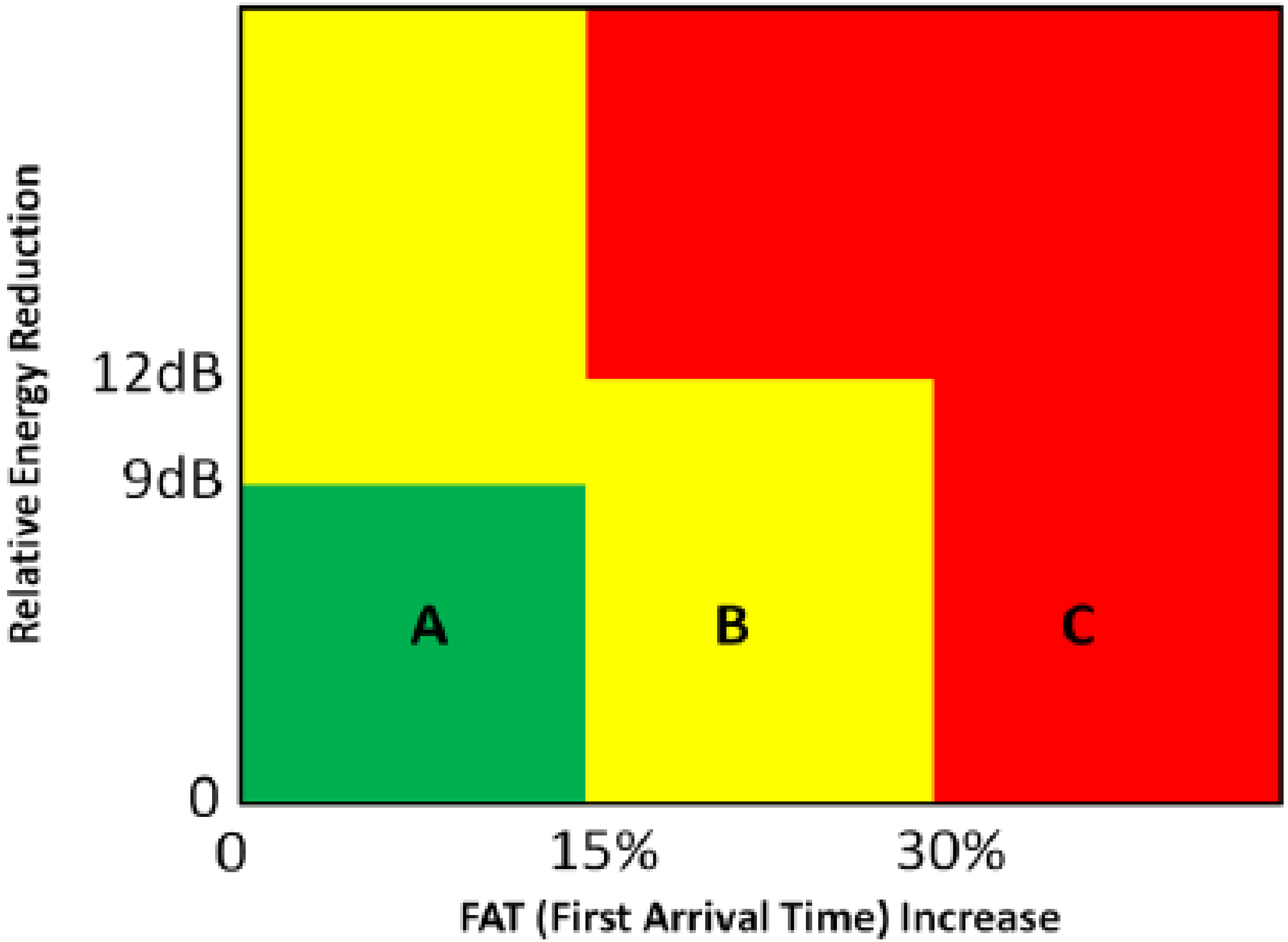
Shaft with Four Access Tubes



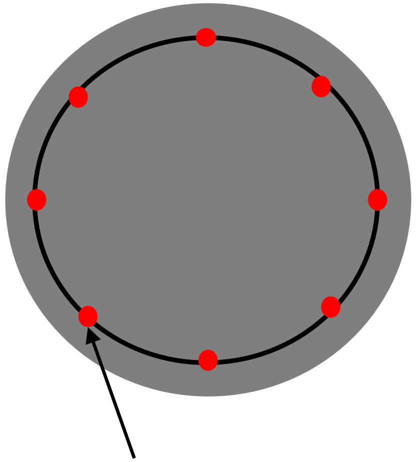
Typical CSL Software Output



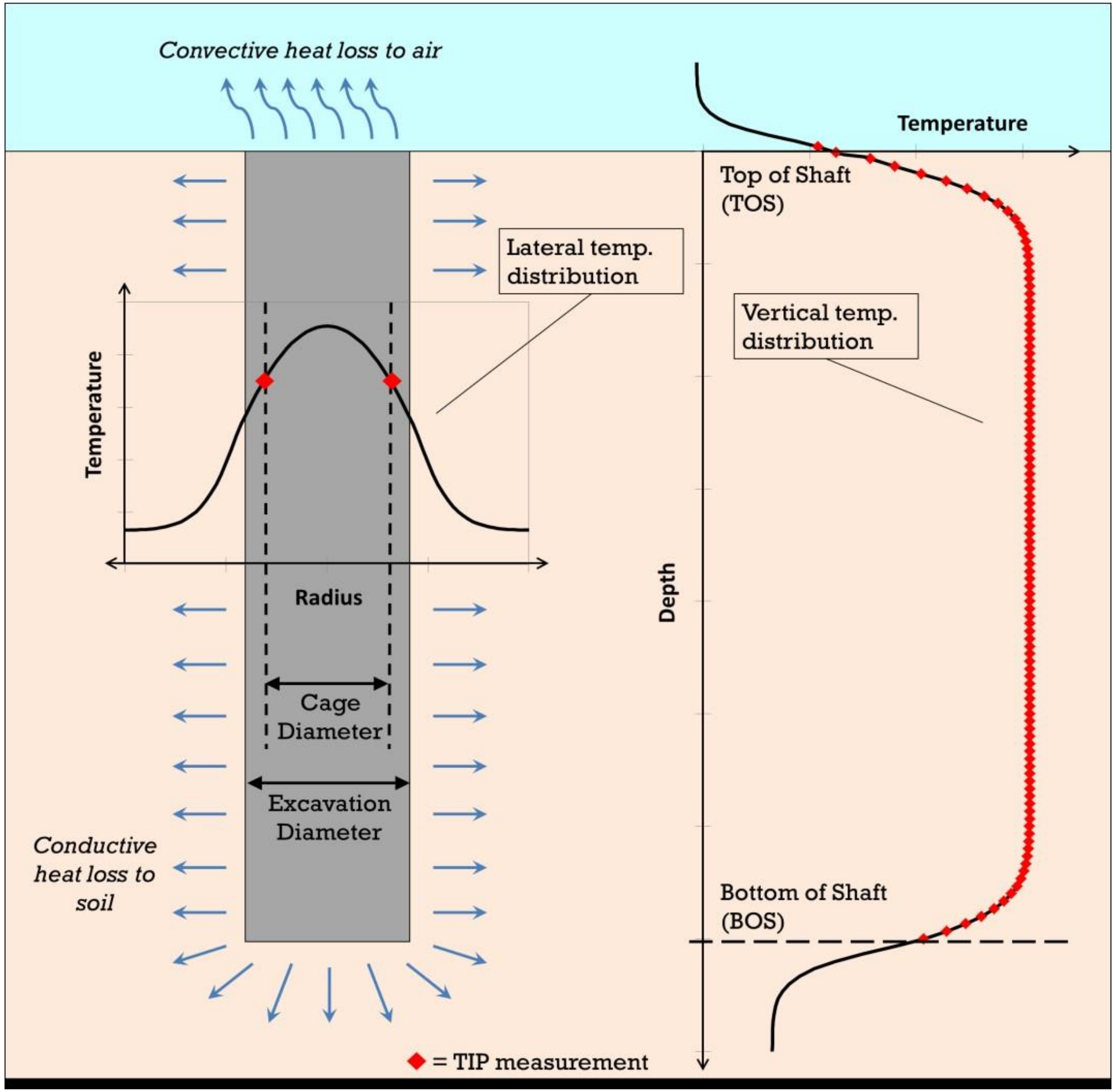
CSL Concrete Rating Criteria (DFI 2018)



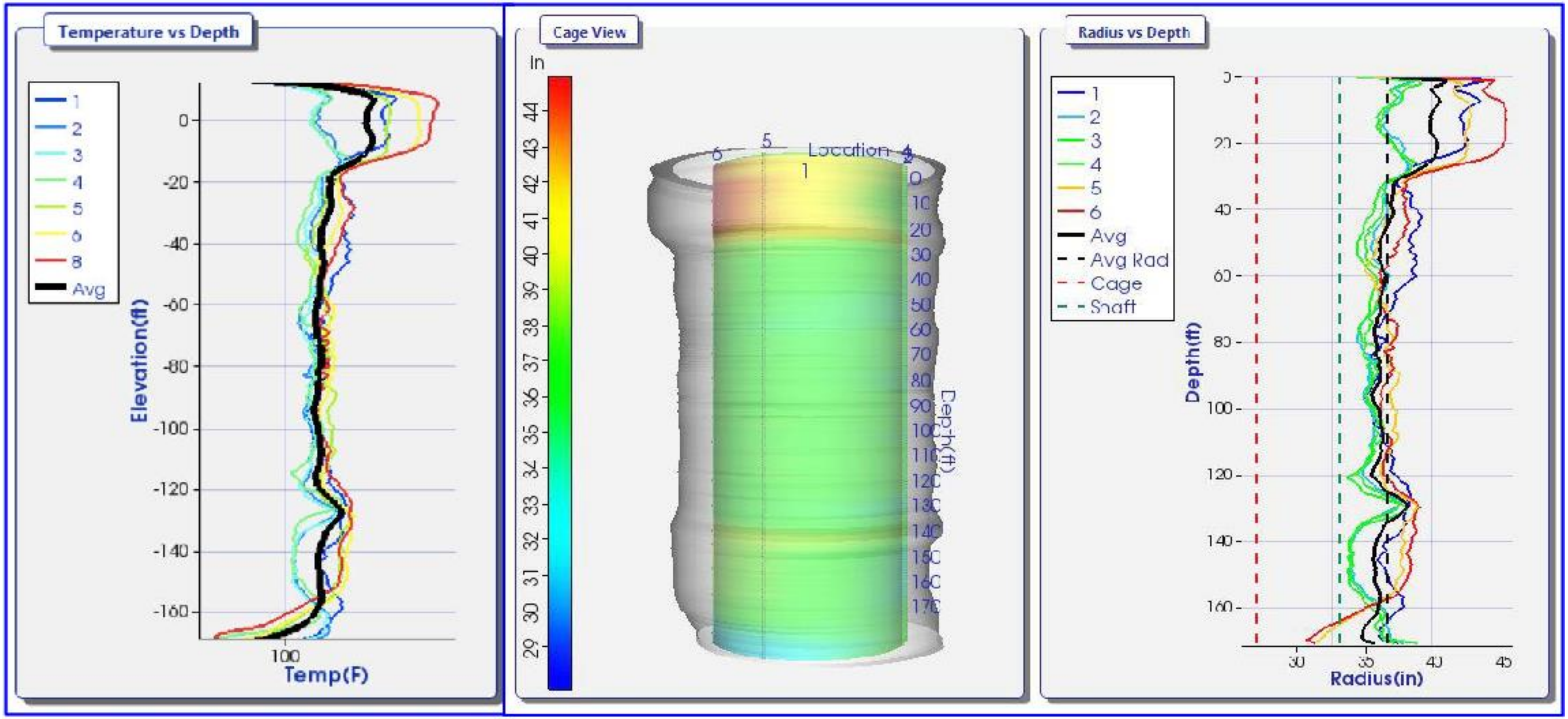
TIP



- Measure concrete temperatures during curing with TIP wires tied to the cage (or probe method)
- Data must be collected during hydration period

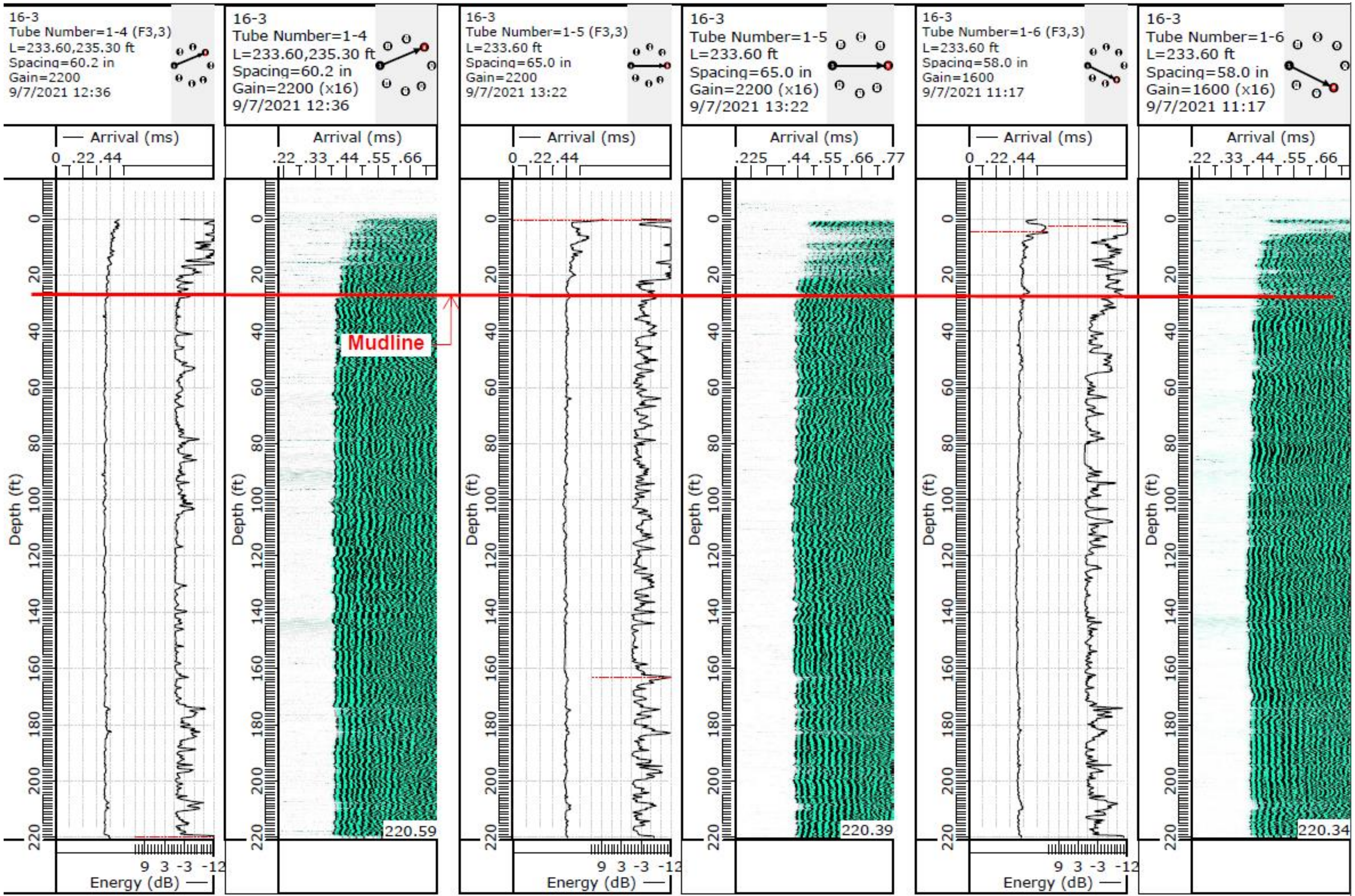


Typical TIP Software Output

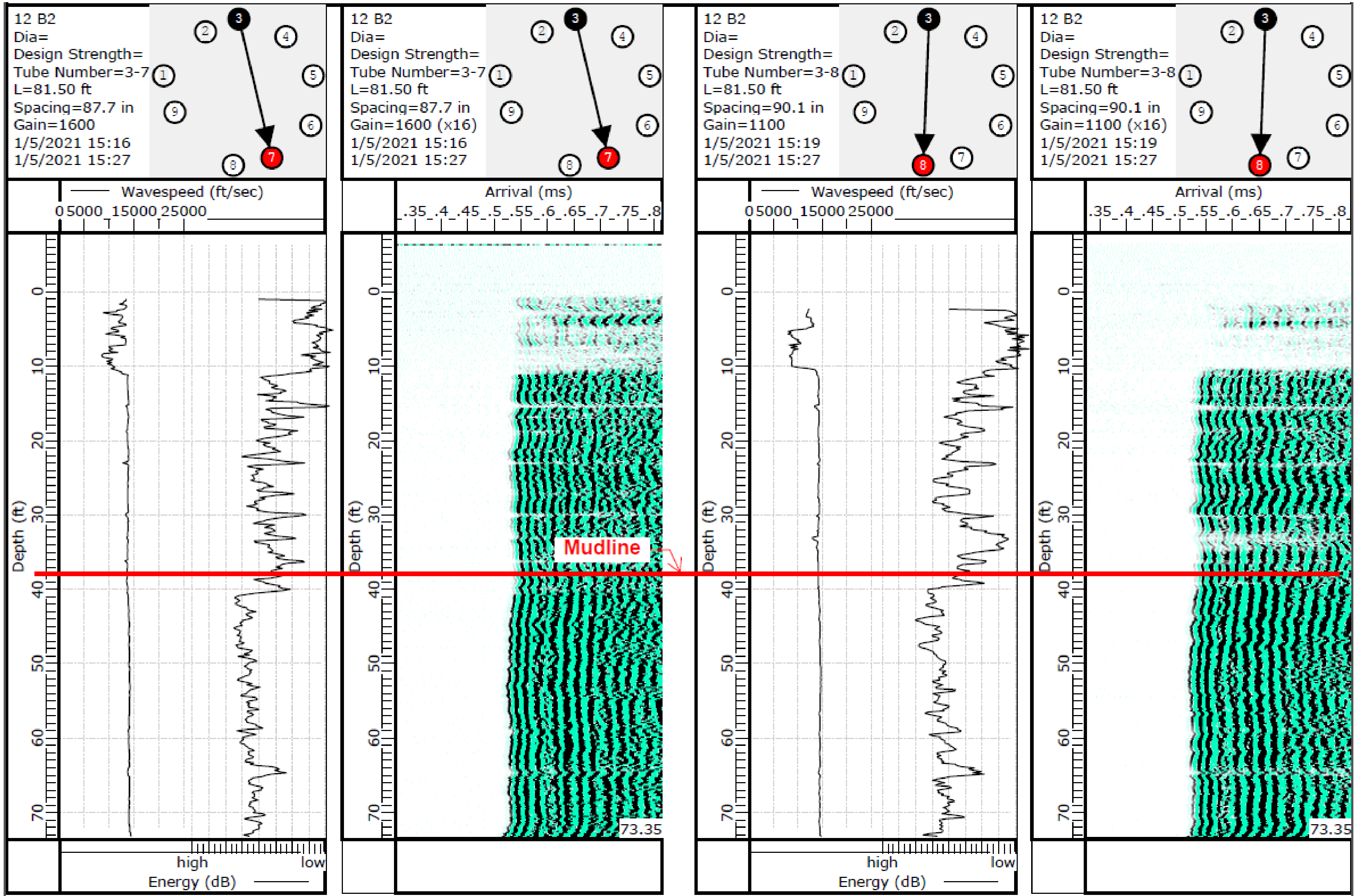


(From Martinello 2017)

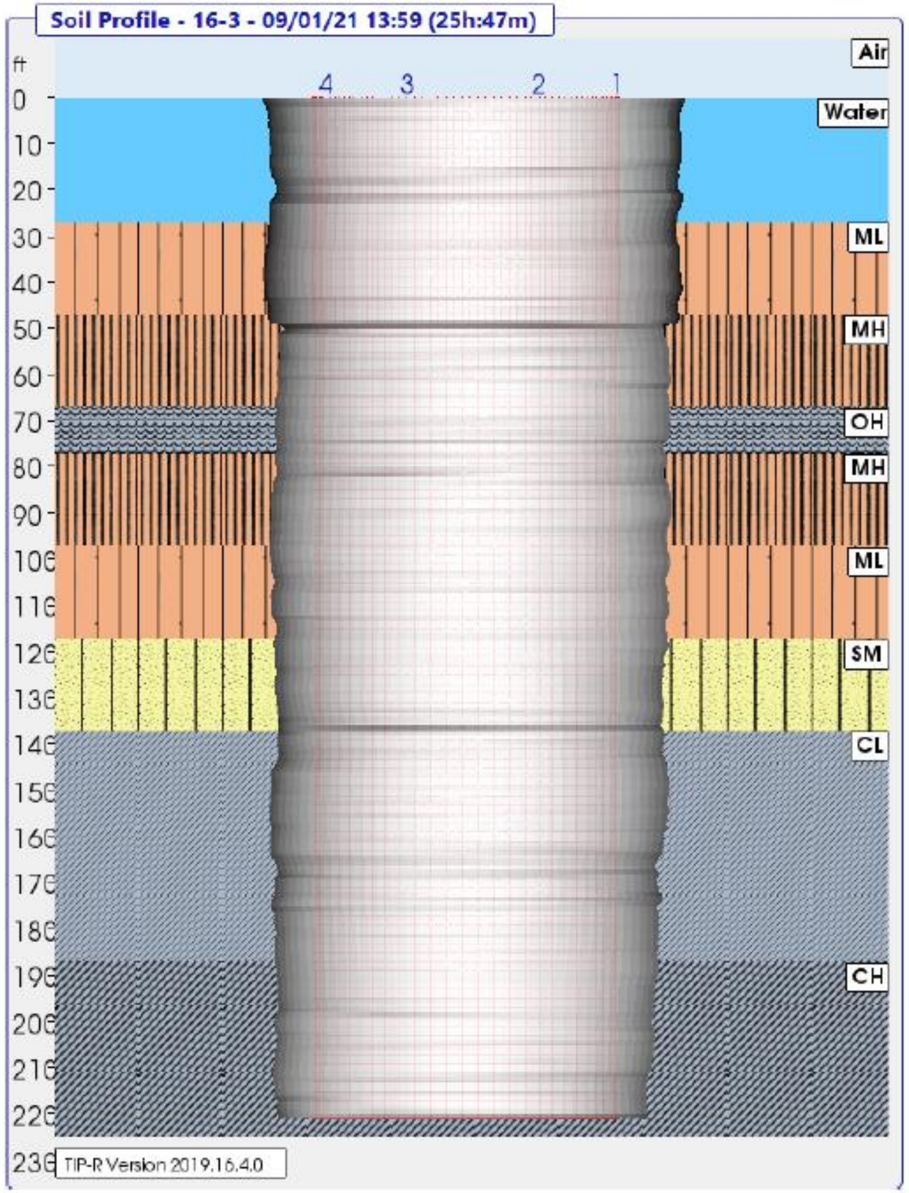
CSL Example: 8.5-ft Shaft in 27 ft of Water

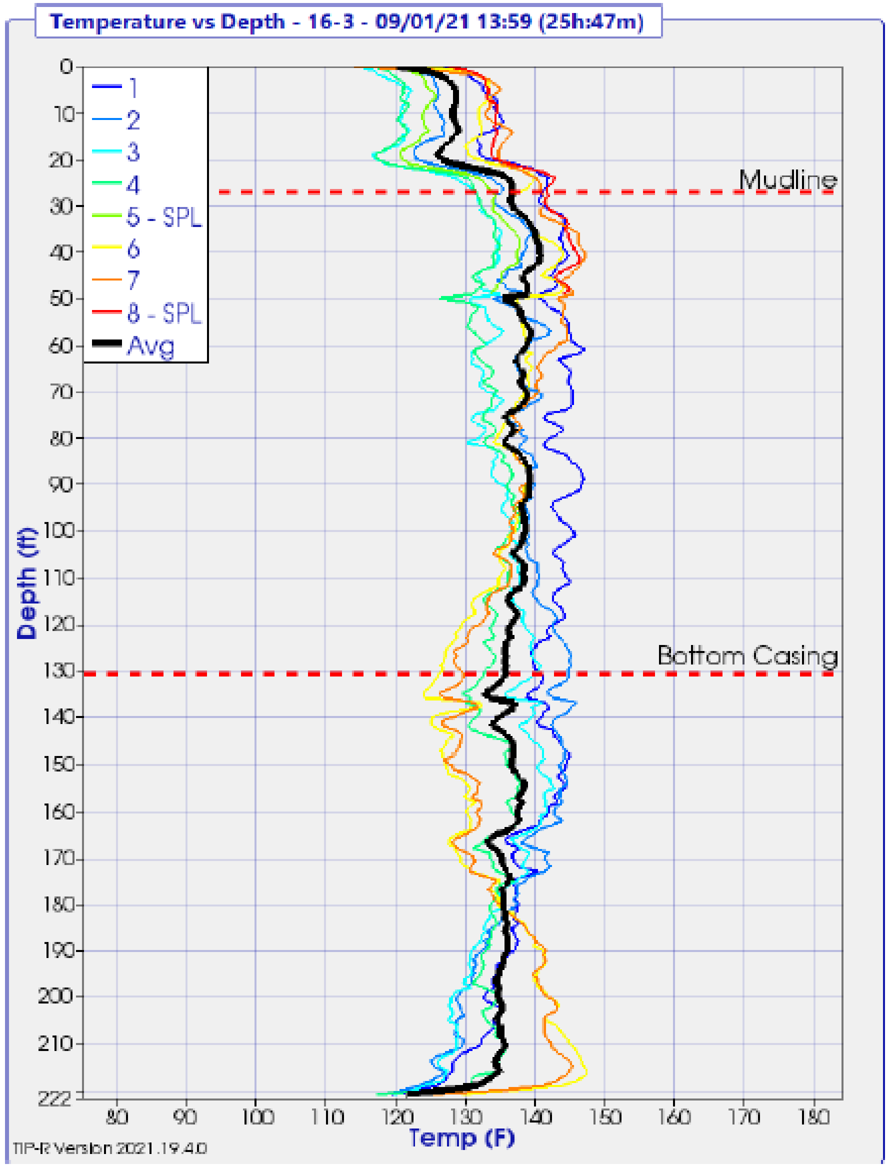


CSL Example: 10-ft Shaft in 38 ft of Water

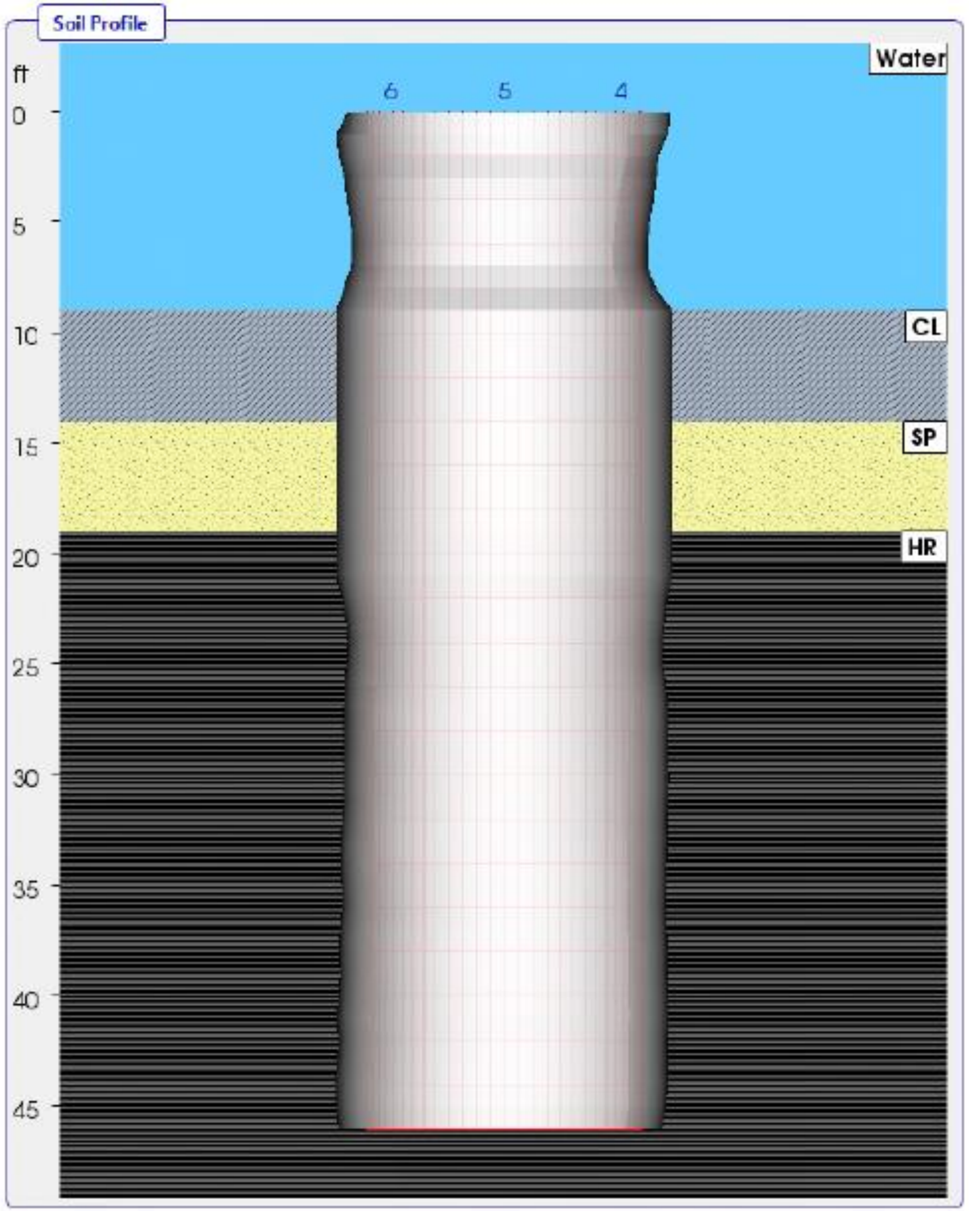


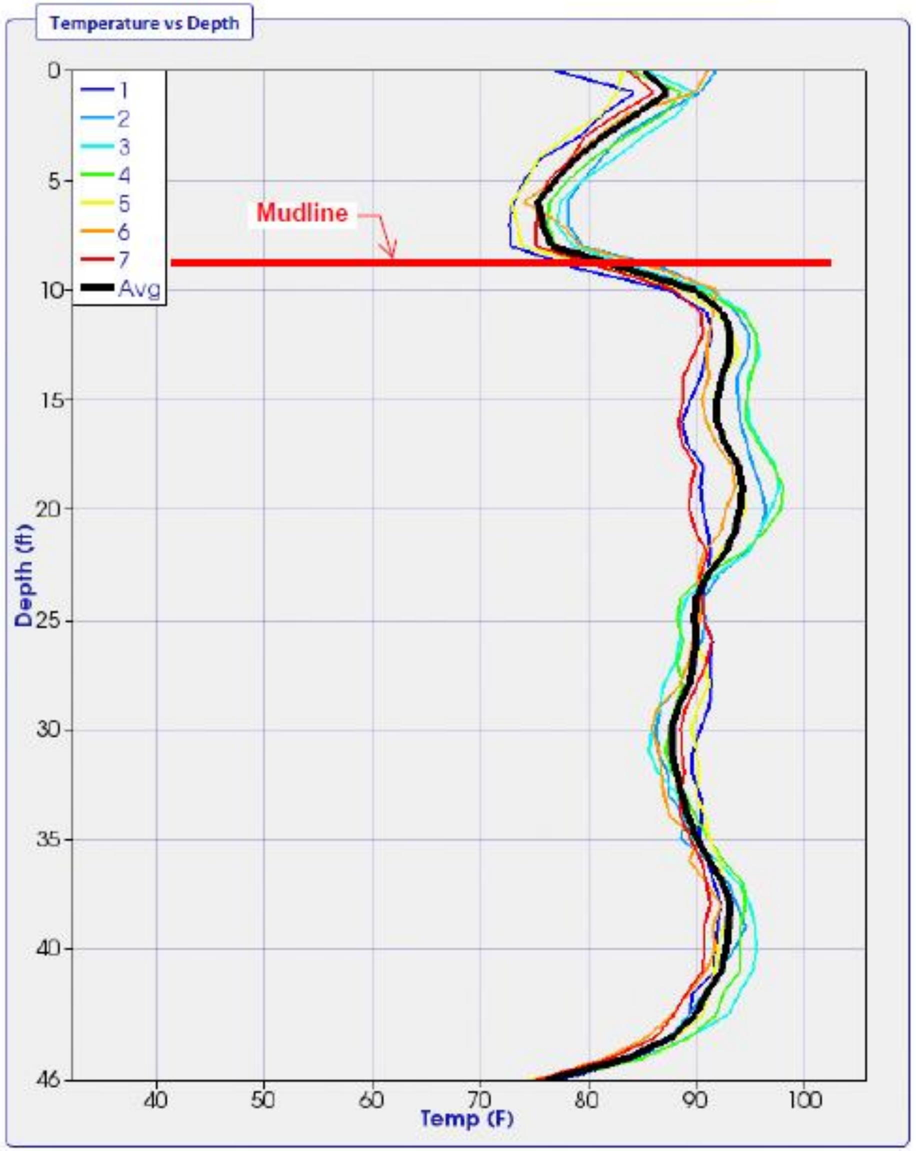
TIP Example: 8.5-ft Shaft in 27 ft of Water





TIP Example: 6-ft Shaft in 8 ft of Water





The Cause?

- Thermal conditions above the mudline are significantly different
  - Flowing water
  - Surface water is often colder than groundwater

- Thermal conditions have a direct effect on TIP measurements

- Thermal conditions have an indirect effect on CSL measurements
  - Tube debonding
  - Rate of concrete curing
  - Concrete bleeding

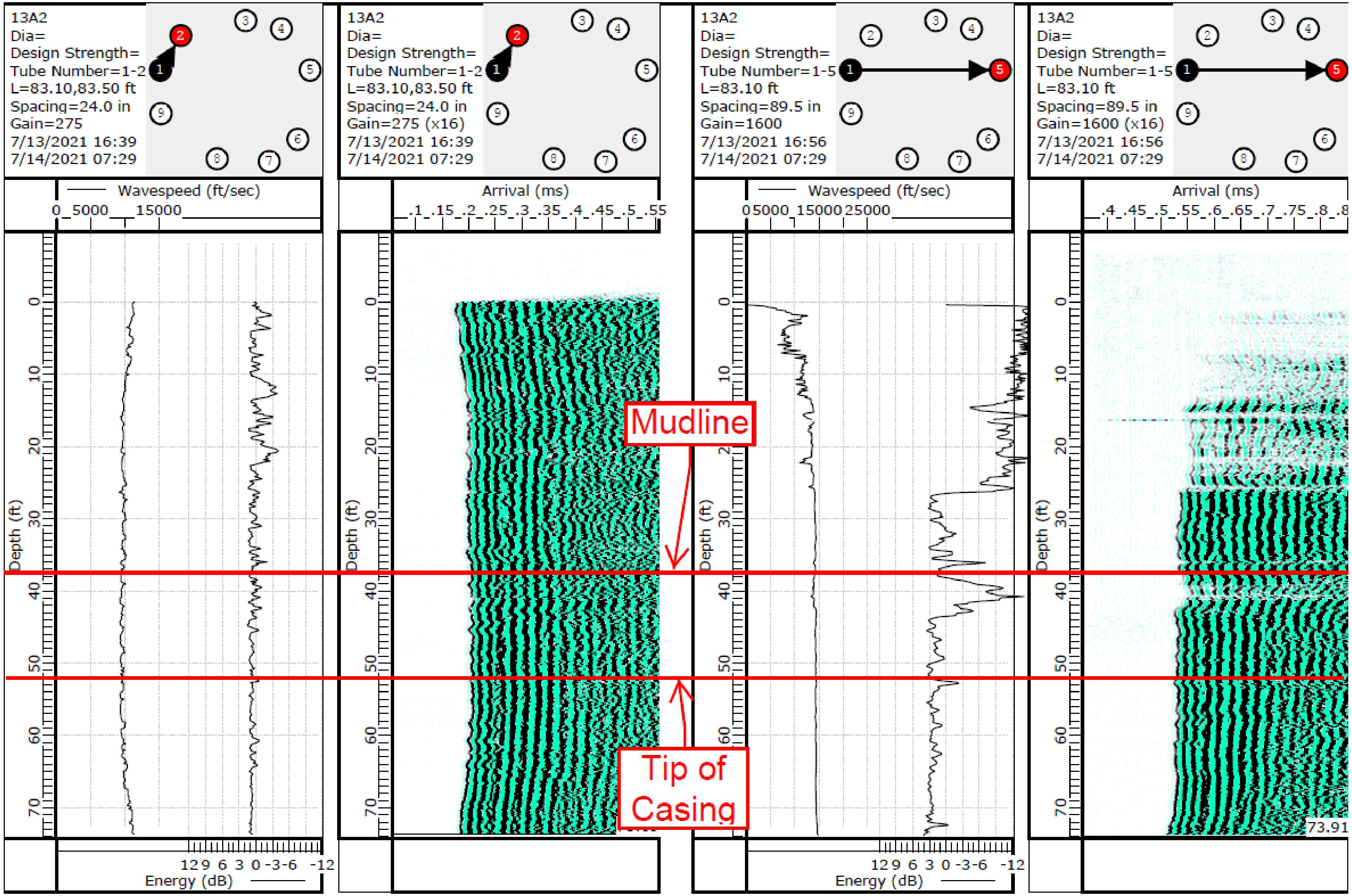
- Mix design

Case Study 1: South Central U.S. River Crossing

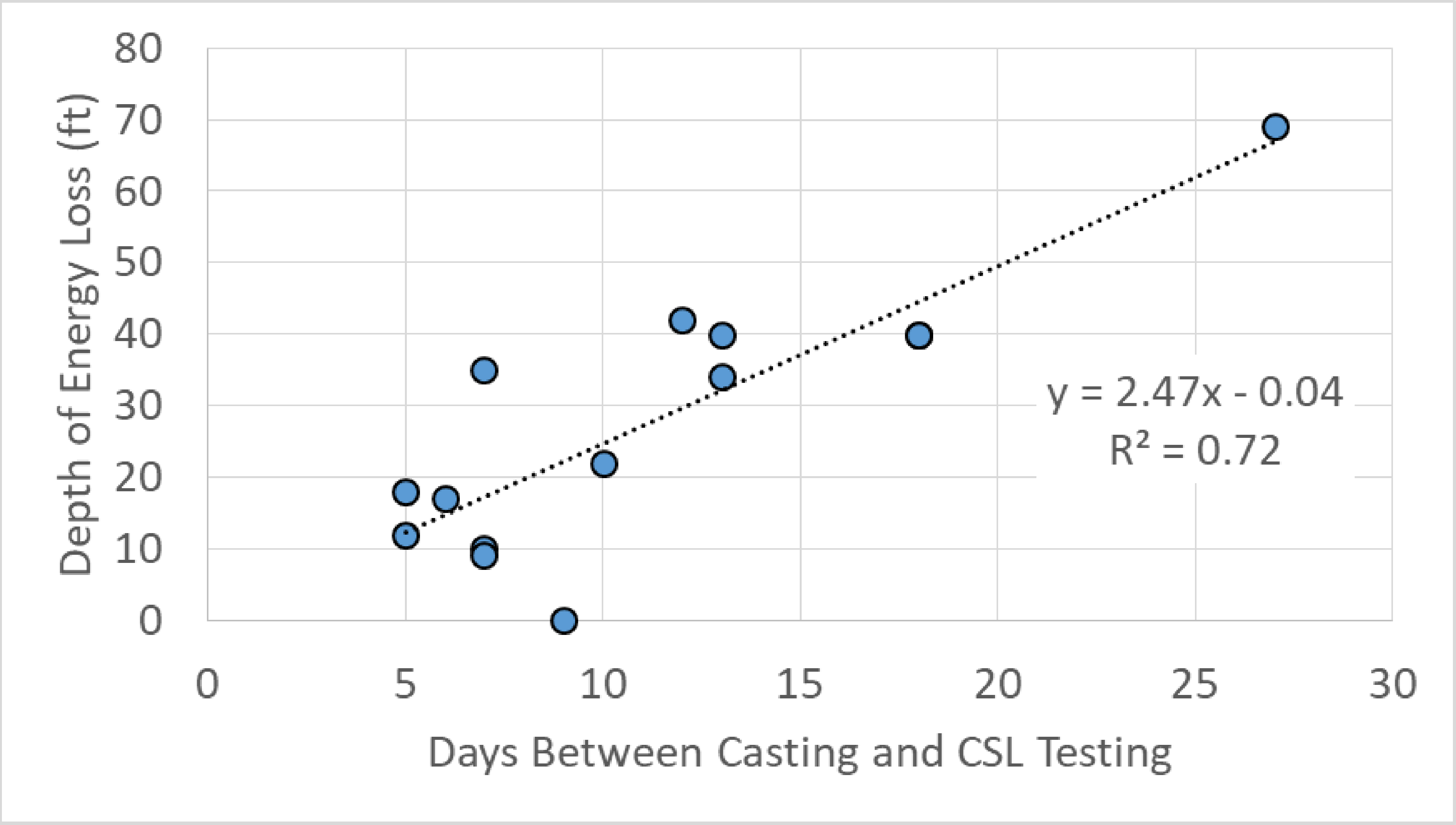
- 10-ft diameter shafts, permanently cased to rock
- CSL, no TIP
- Conventional tremie concrete mix (8-inch slump)
- Variety of ambient temperature conditions including some very hot
- Consistent CSL issues above the mudline with river shafts (17 of 18)
- Concrete bleed observed at some shafts
- No similar anomalies with land-based shafts of the same diameter, depth, and concrete mix
- Cored two shafts with bleed water channels encountered in one of the shafts
- Compressive strengths of core samples were above design strength

CSL Anomaly Signature

- Anomalies are significantly more pronounced in cross-shaft shots than perimeter shots
- Anomalies primarily consist of signal energy loss
- Longer time between concrete placement and CSL testing usually exacerbates the issue

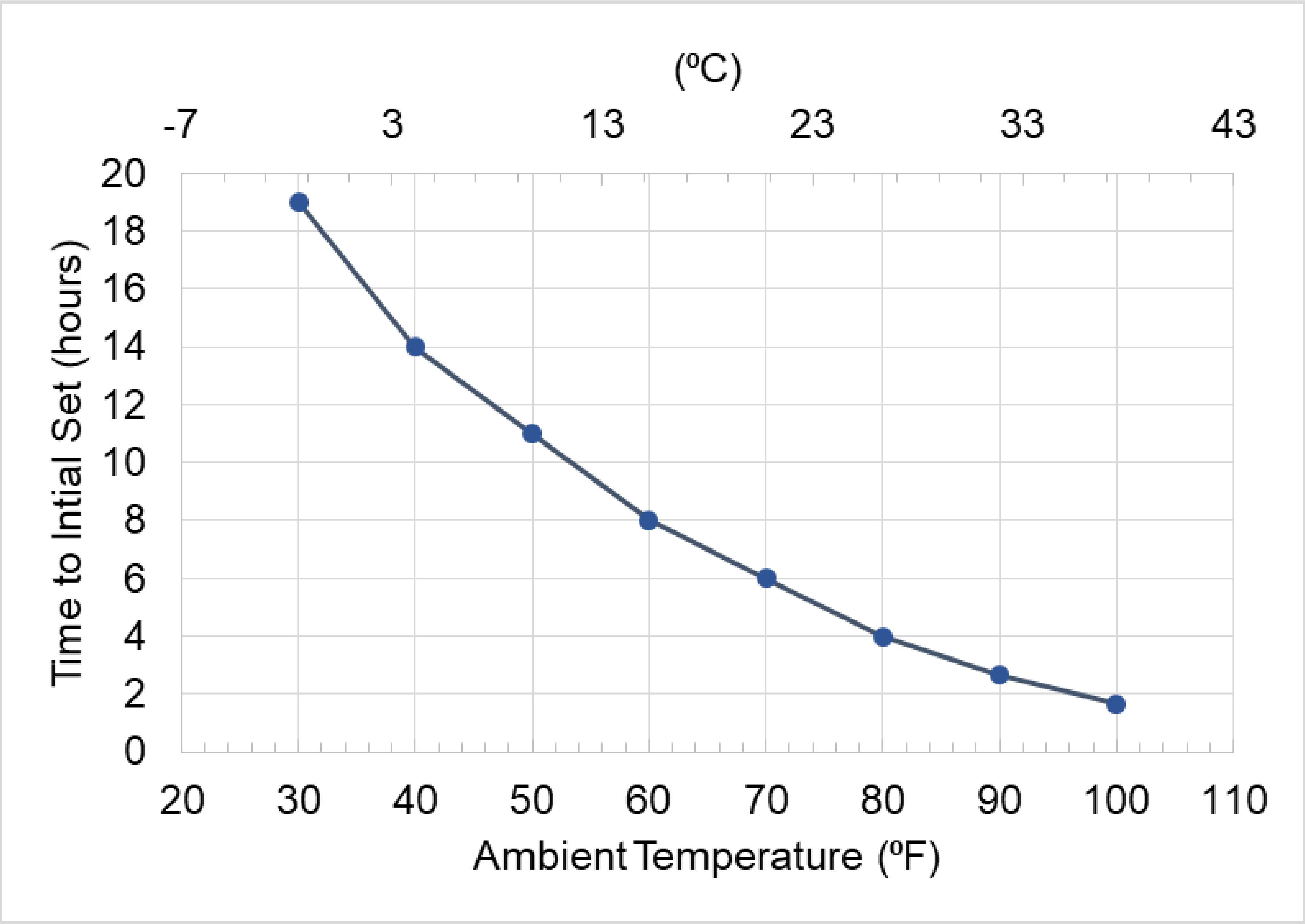


Depth of CSL Anomalies as a Function of Time



Bleed Water Channels

Time to Initial Set versus Ambient Temperature

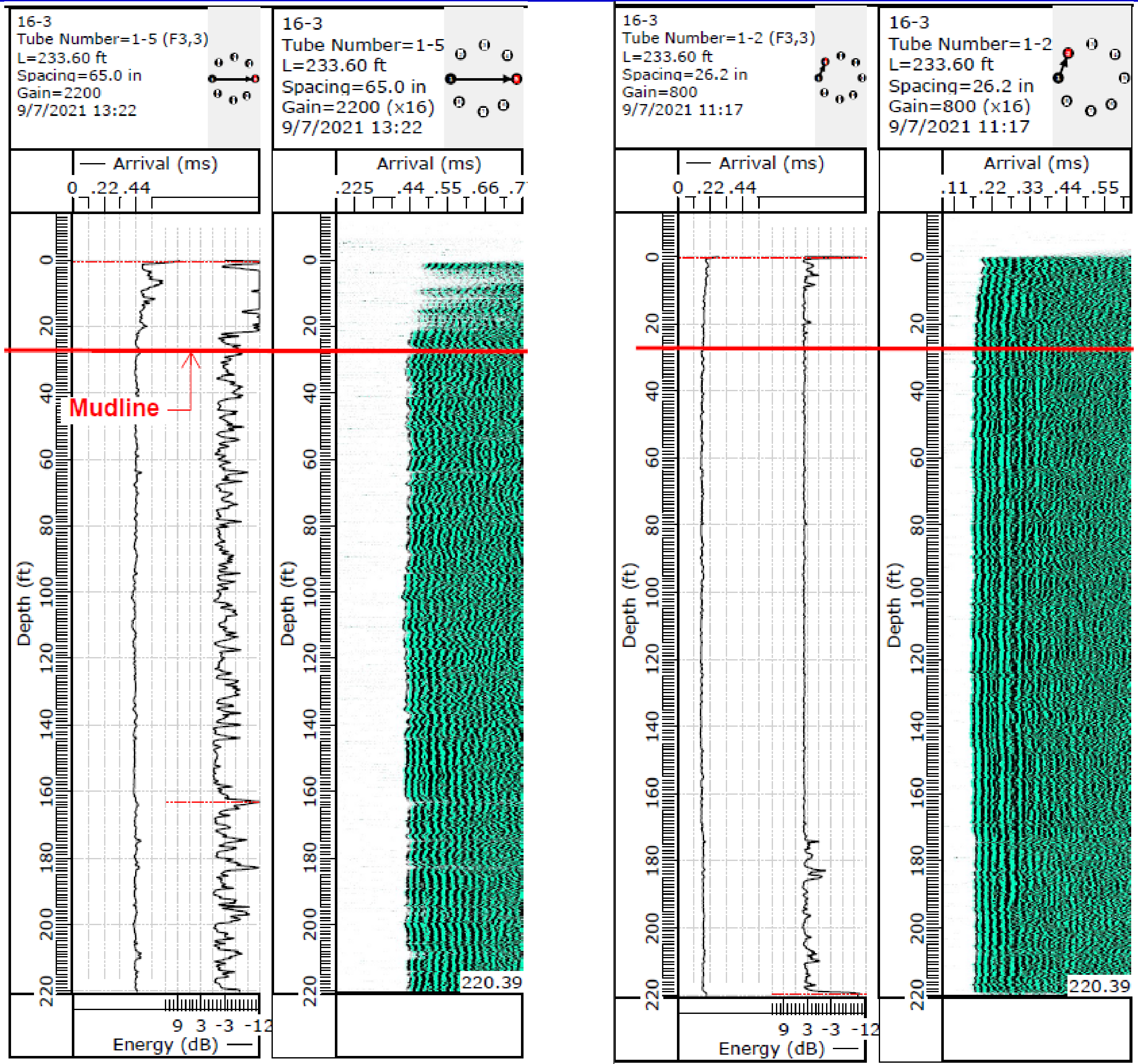


Case Study 2: Raritan River New Jersey

- 8-ft diameter shafts, permanently cased
- CSL
- TIP performed on one shaft in addition to CSL
- High-flow, self-consolidating concrete mix
- Variety of ambient temperature conditions including some very cold
- Concrete bleed observed at some shafts
- Consistent CSL issues above the mudline with all river shafts (86 shafts)
- Cored six shafts with some bleed water channels encountered
- Compressive strengths of core samples were above design strength

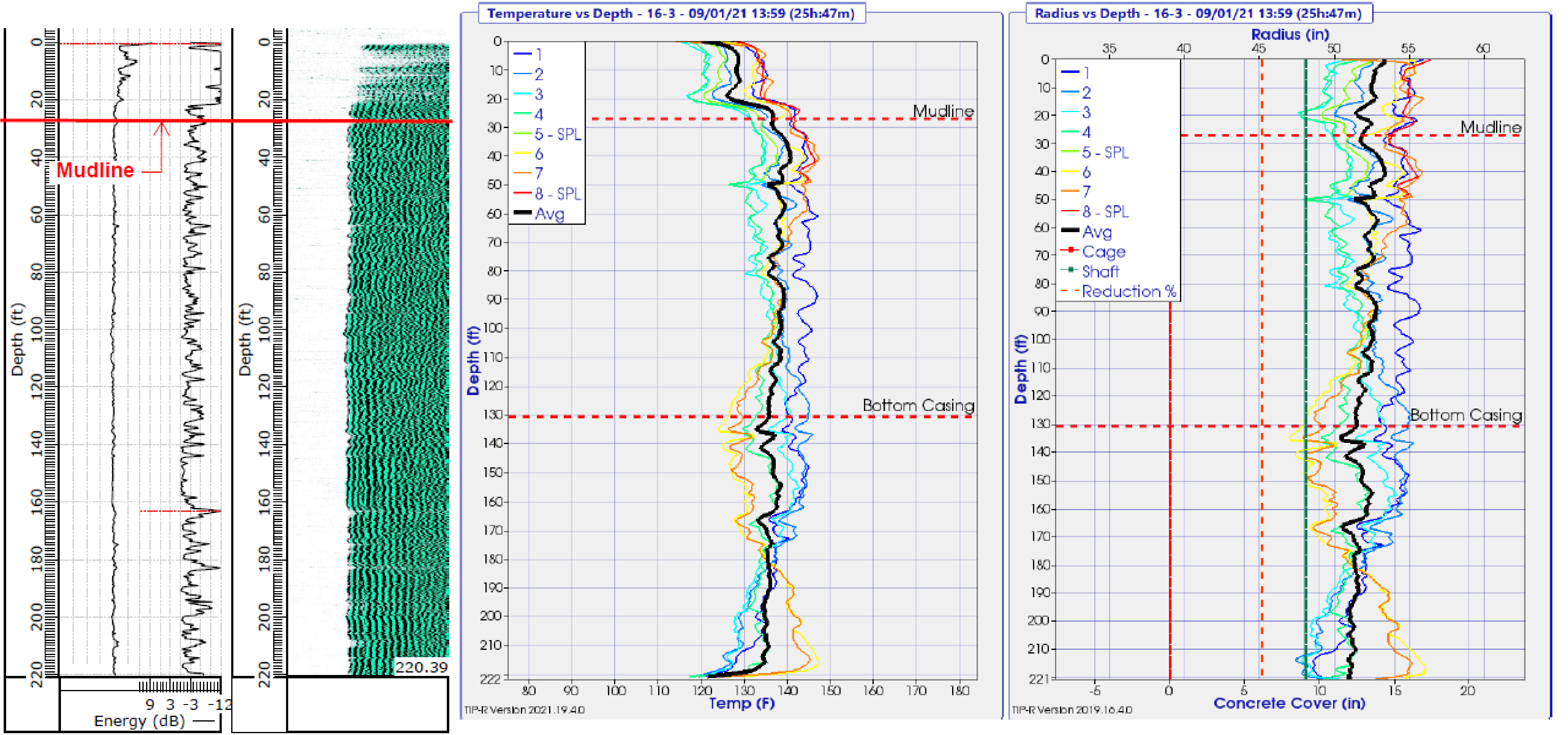
CSL Anomaly Signature

- Anomalies are significantly more pronounced in cross-shaft shots than perimeter shots
- Anomalies primarily consist of signal energy loss



Bleed Water Channels

Comparison of TIP and CSL



Summary and Closing Remarks

- Different thermal conditions above the mudline can influence TIP and CSL results.
- Influence on CSL results is possibly attributed to tube debonding and/or concrete bleed.
- TIP interpretation is difficult in the zone above the mudline, especially when CSL results show anomalies in the same zone.
- The examples presented are not defective shafts, but rather shafts with anomalous data due to the thermal conditions.
- Evaluation of CSL and TIP results must be considered in the context of what is known about the concrete placement.

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Thank you for listening.

Questions?

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