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**NO - DIG**  
FLORENCE 2019

Fortezza da Basso • FLORENCE (Italy)

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# CRITICAL ANALYSIS OF PIPE RAMMING BEHAVIOR AND FACTORS THAT IMPACT PREDICTIVE MODELS

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# PRESENTATION OUTLINE



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- Purpose of the Study
- Pipe Ramming Project
- Geotechnical Conditions
- Project Layout and Instrumentation
- Analysis of Results
- Conclusions

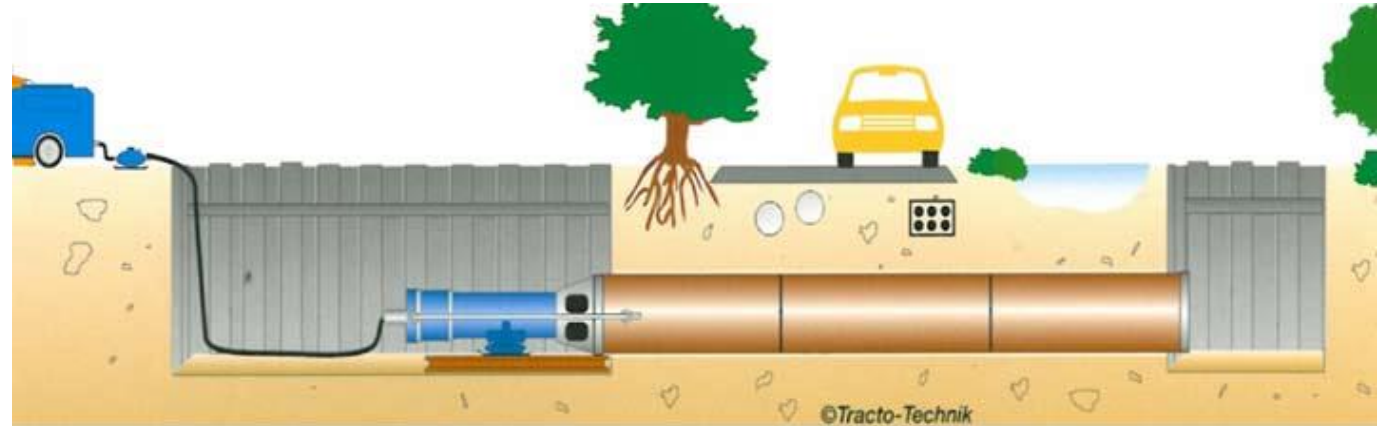
# WHY PIPE RAMMING?



- Project was previously bid as a microtunneling project.
- 610mm (30-inch) and 915mm (36- inch) diameter microtunneling
- Microtunneling Machines Stuck on Cobbles and gravel
- Project terminated for convenience

# PIPE RAMMING

- Pneumatic or Hydraulic Hammer
- Open-Ended Pipe
- Repeated Percussive Blows
- Soil Engulfed
- Non-Steerable



Typical Pipe Ramming Uses  
Diagrams by courtesy of TTUK Ltd.

# OLYMPUS MEADOWS TRUNK PIPE RAMMING

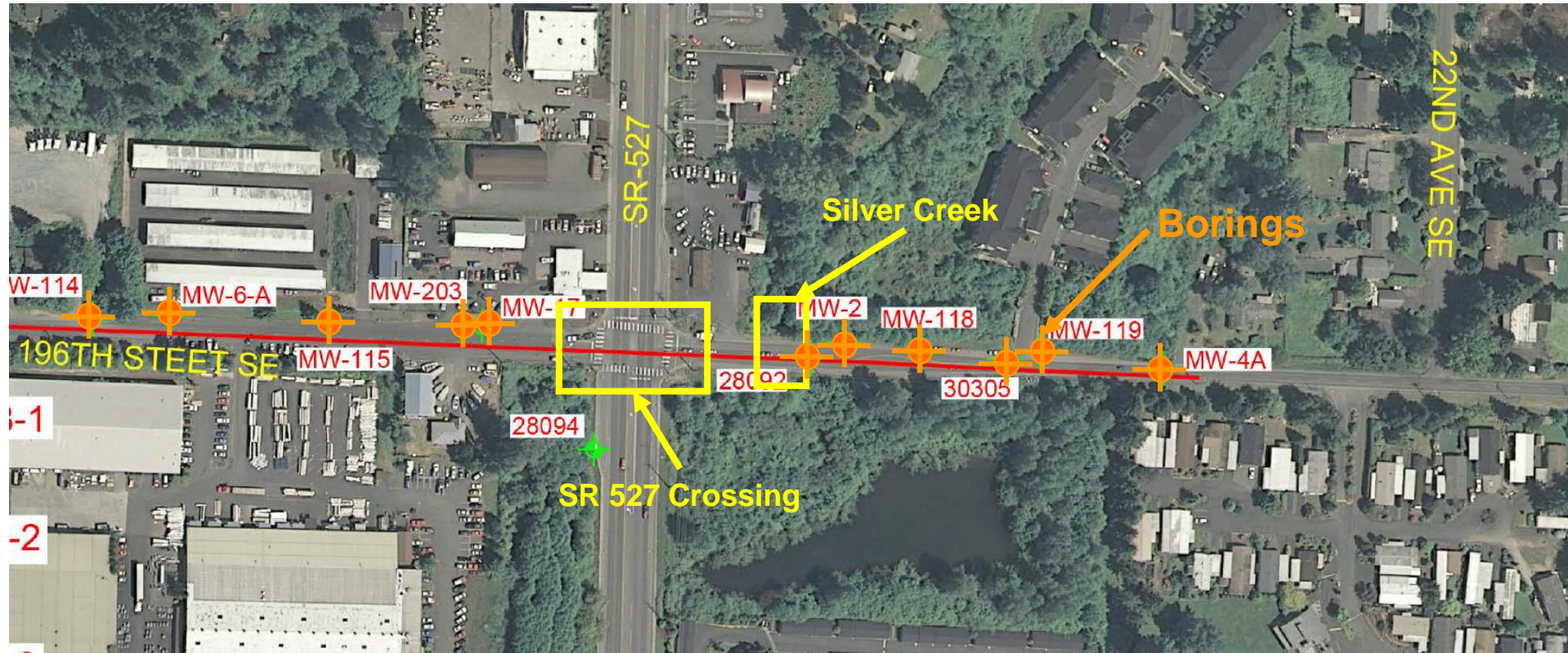


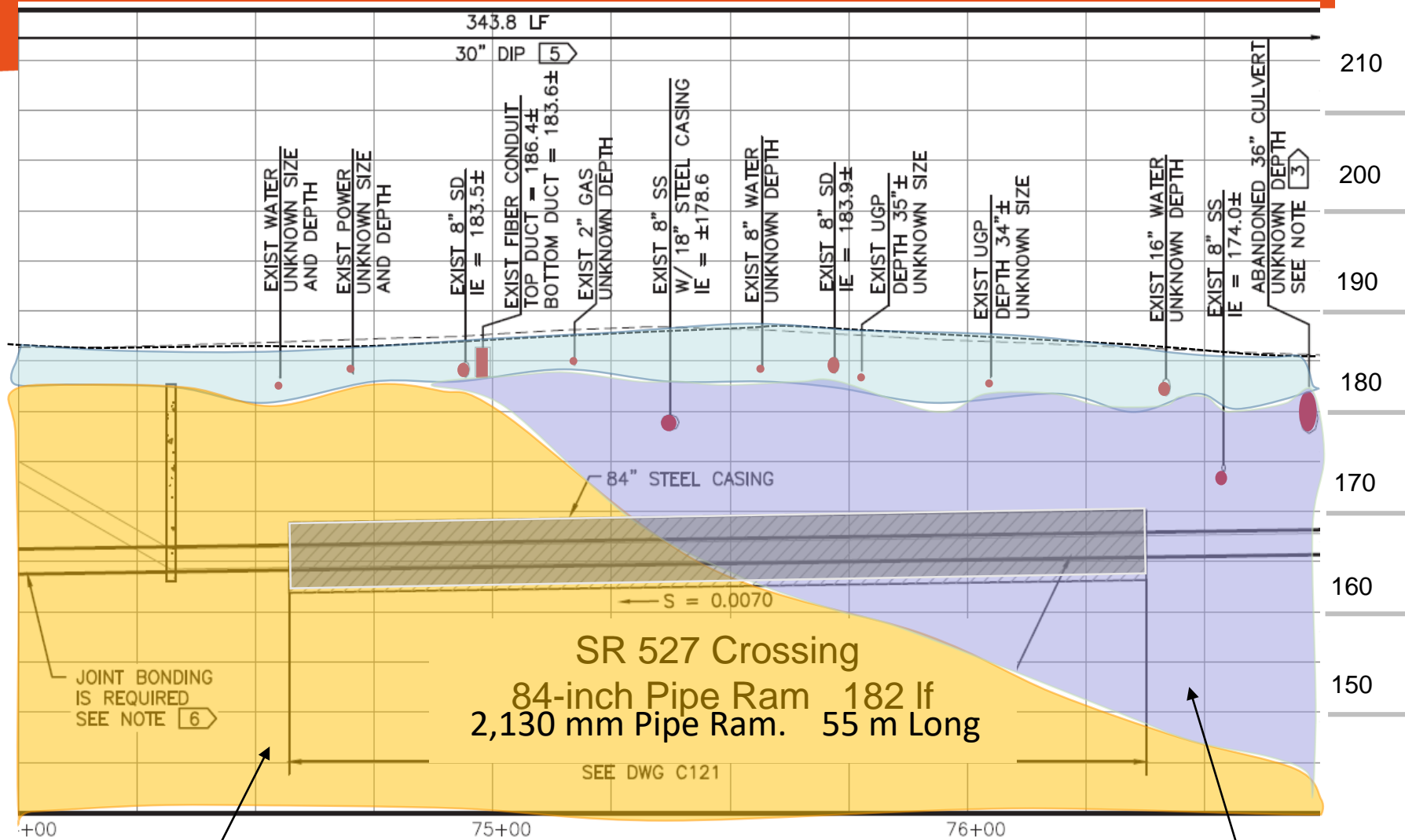
- Two 2,130mm (84-inch) Pipe Rams
- Crossings:
  - Highway 527
  - Silver Creek
- 760mm (30-inch) Gravity Sewer
- 610mm (24-inch) Water Line- (Force Main)



# WHERE IN THE WORLD???

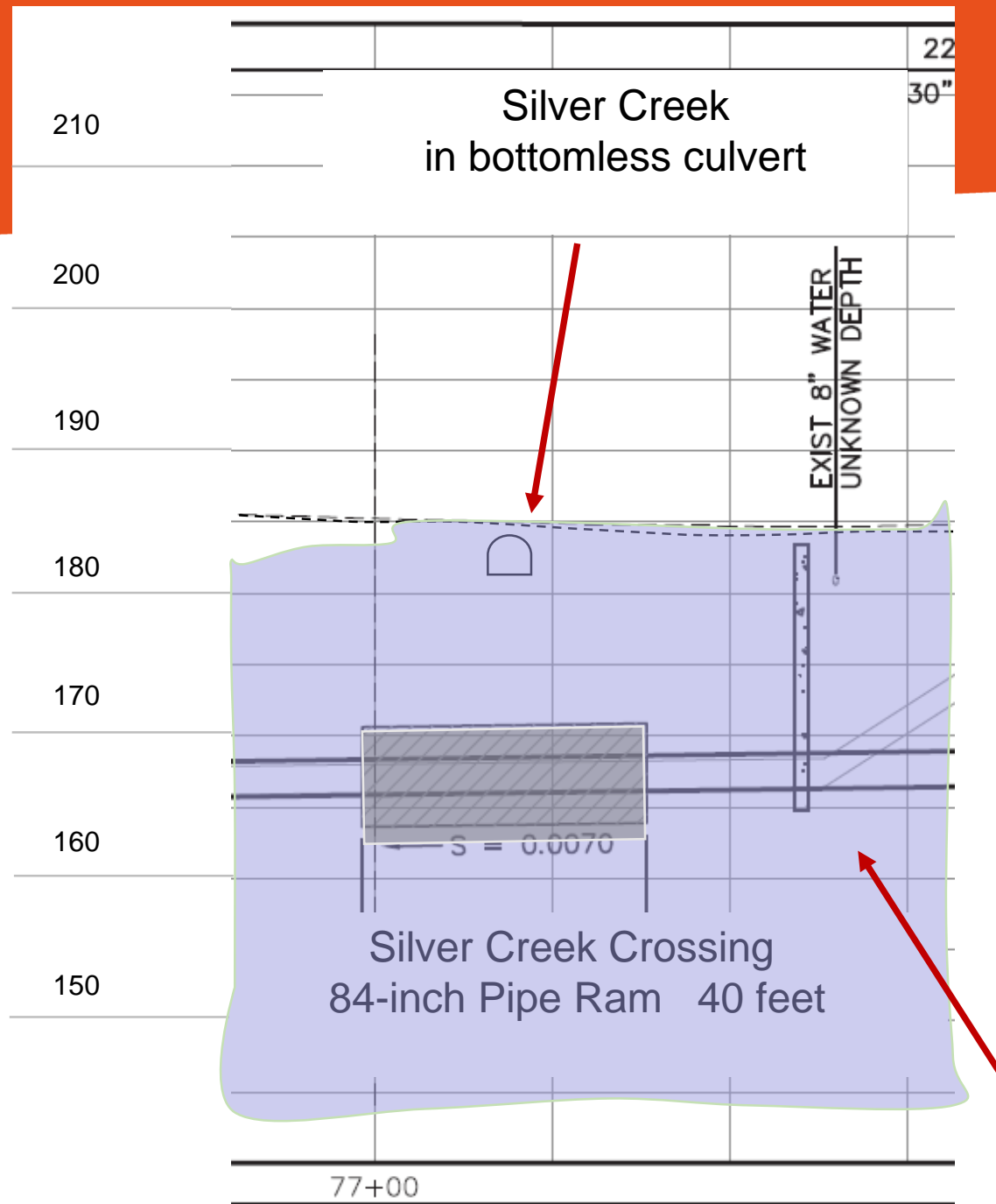






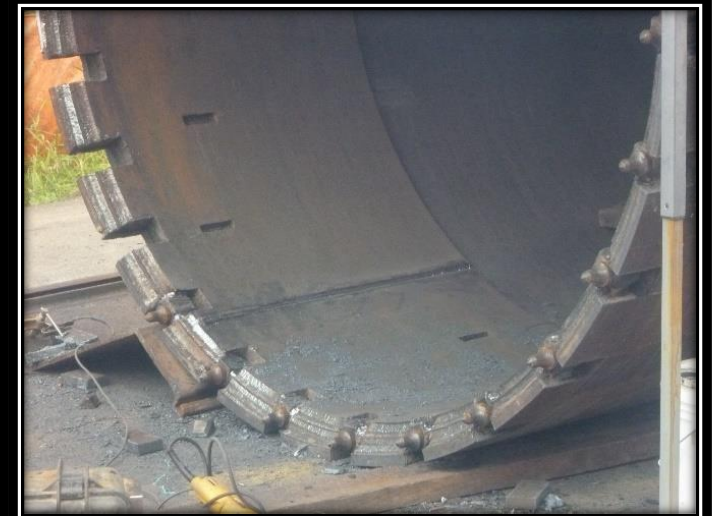
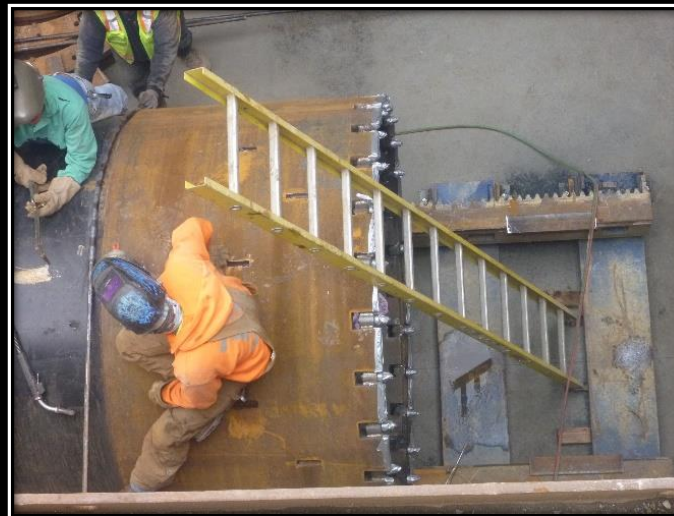
**“Dense Glacial Deposits”**

**“Alluvium and Recessional Outwash Deposits”**



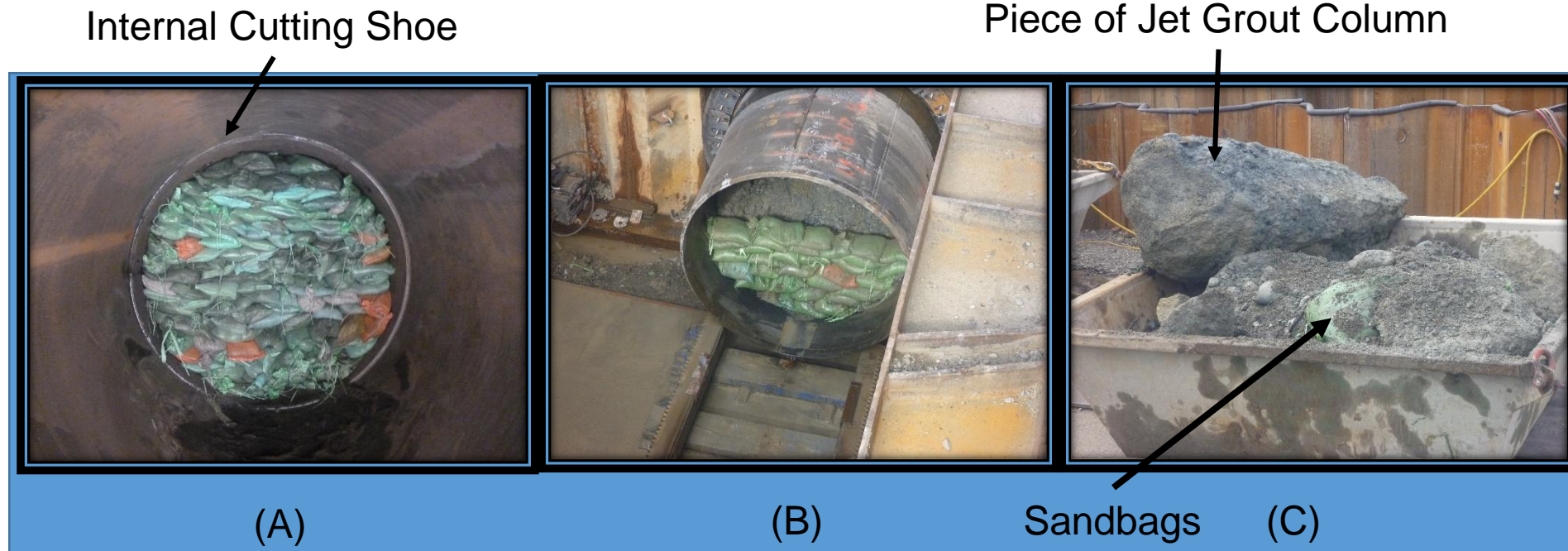
**“Alluvium and Recessional Outwash Deposits”**

- Cutting Shoe
  - D:t Ratio – Diameter to Shoe Thickness
    - Minimum 30
    - 2,130 mm (84-inch): 32mm (1.25-inch) thick steel pipe;  
89mm (3.5-inch) shoe thickness
  - Kennametal Bullet Bits nested in Shoe



# RAMMING BENEATH WATER TABLE

- Sandbags
- Alternating Sandbags and Gravel
- Use of Jet Grout Columns at Face



# ENSURE HAMMER IS LEVEL (TO GRADE)



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- Use of Sled
- Rails surveyed to design grade





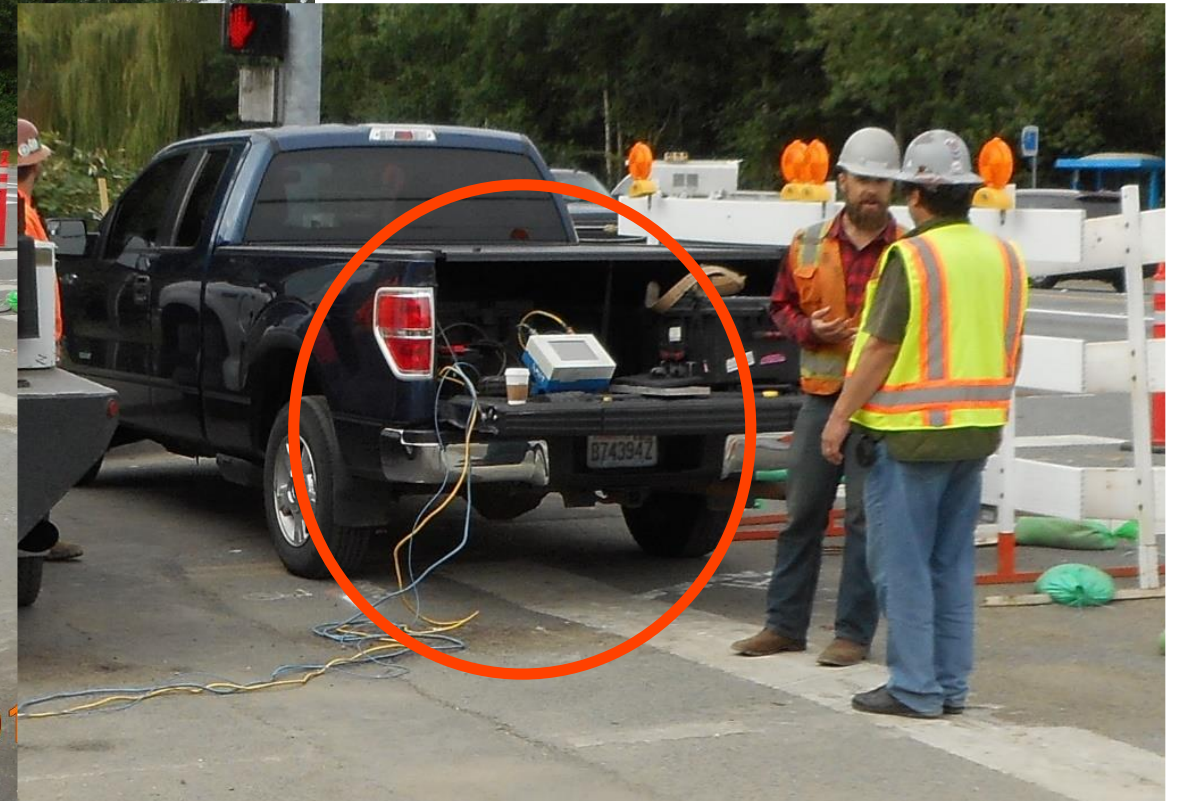
- Instrumentation of the Ram
- Strain Gages and Accelerometers
- Goal: Collect Valuable Information
  - Determine cause of high ramming forces
  - Provide real-time feedback on ram behavior
  - Understand Performance Parameters
  - Learn from one ram to the next



**Ramming Direction**

**Strain Gages  
and  
Accelerometers**

07.25.2016 09:24



# PARAMETERS MEASURED

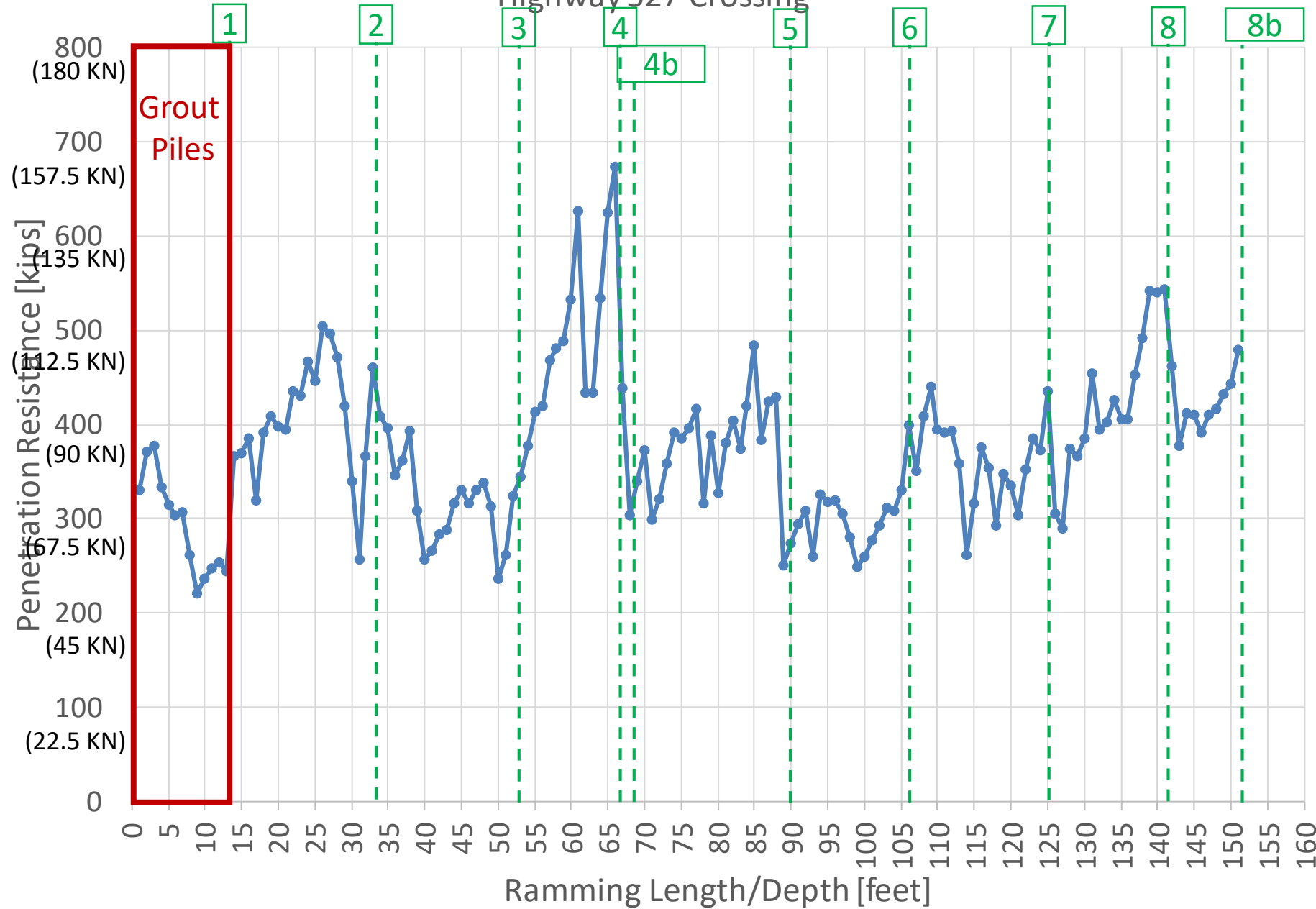


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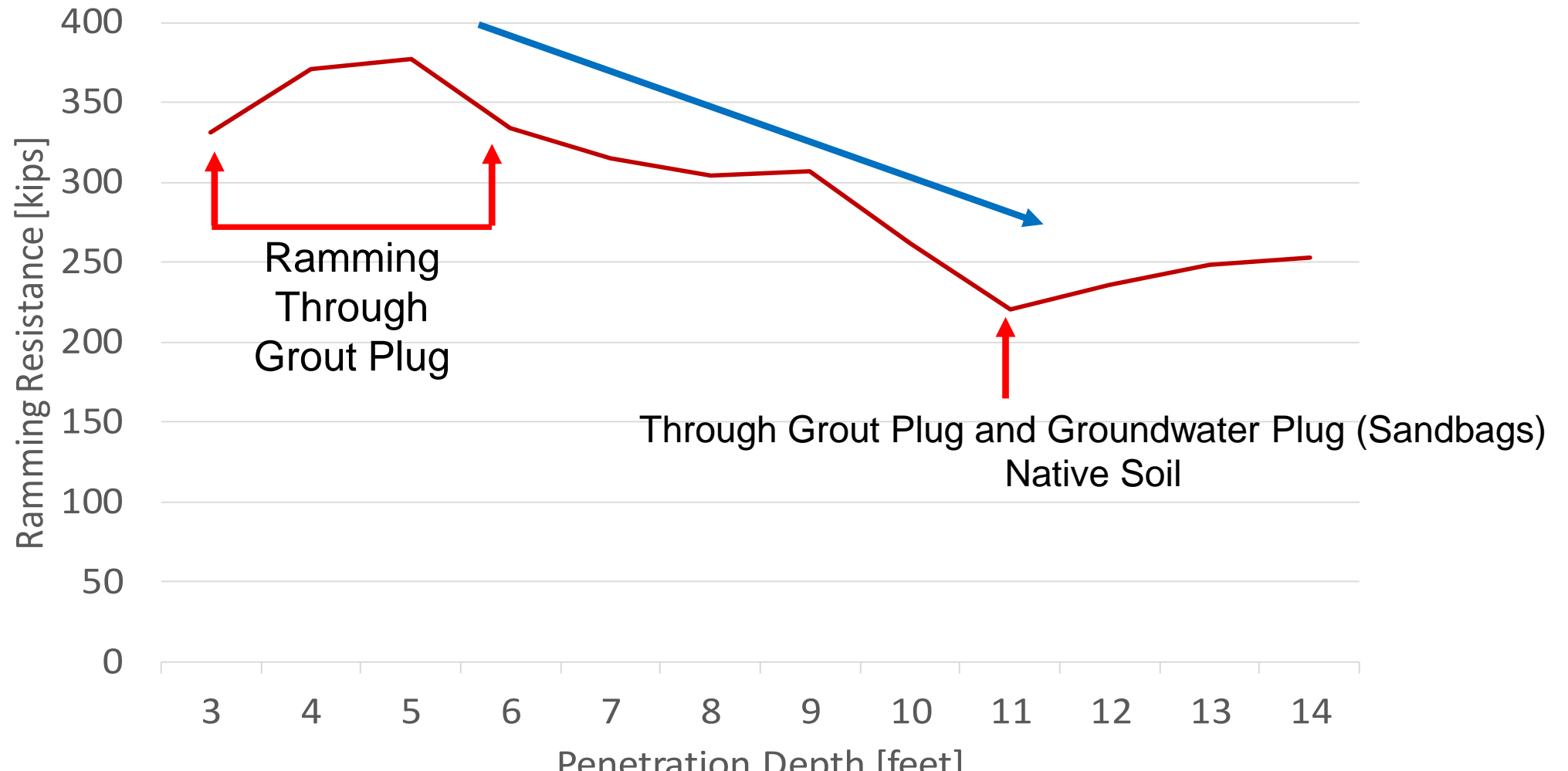
- Driving Resistance – kips
- Penetration Resistance – blows/ft
- Average Transfer Energy – kip-ft
- Average Transfer Efficiency %
  - Based on rating of the hammer
- Average Compressive Stress-- ksi
- Ramming Duration – per 20-foot pipe segment



# Highway 527 Crossing

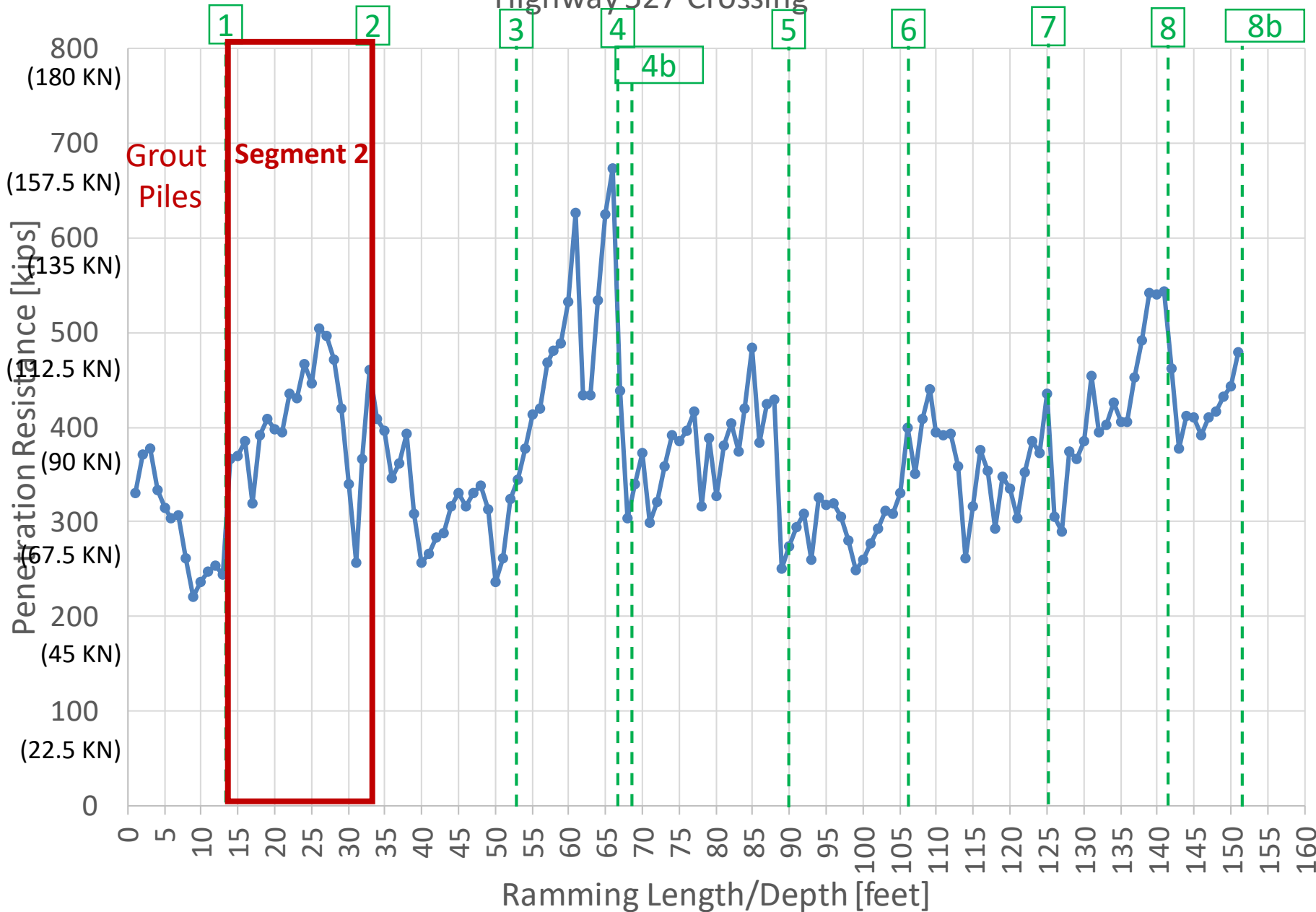


## SR 527 Crossing Segment 1

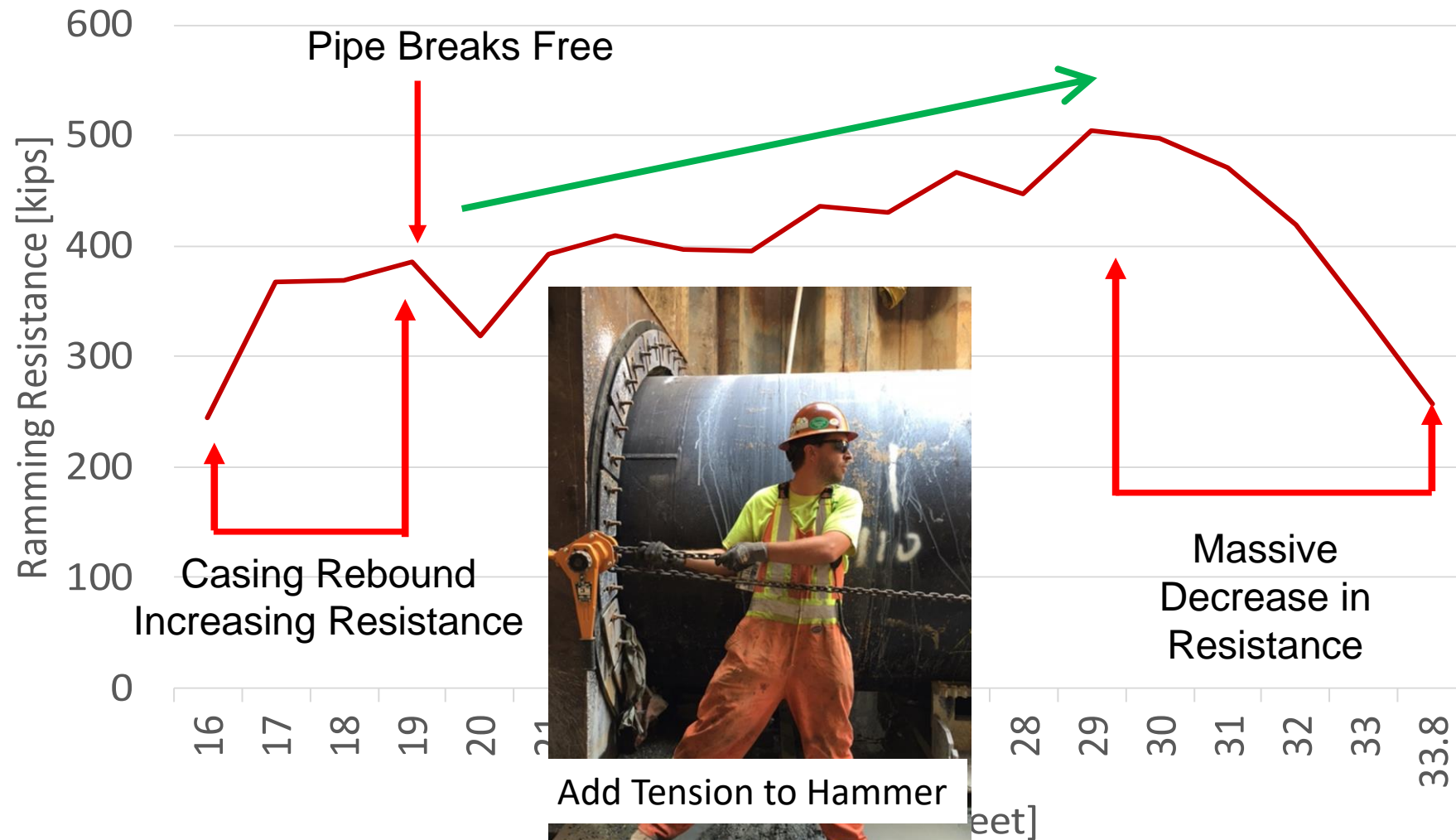




# Highway 527 Crossing



## SR 527 Crossing Segment 2





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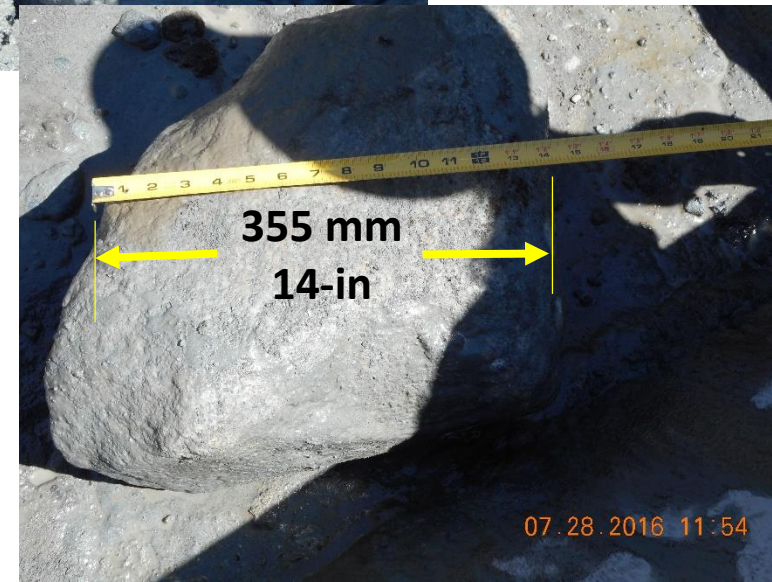
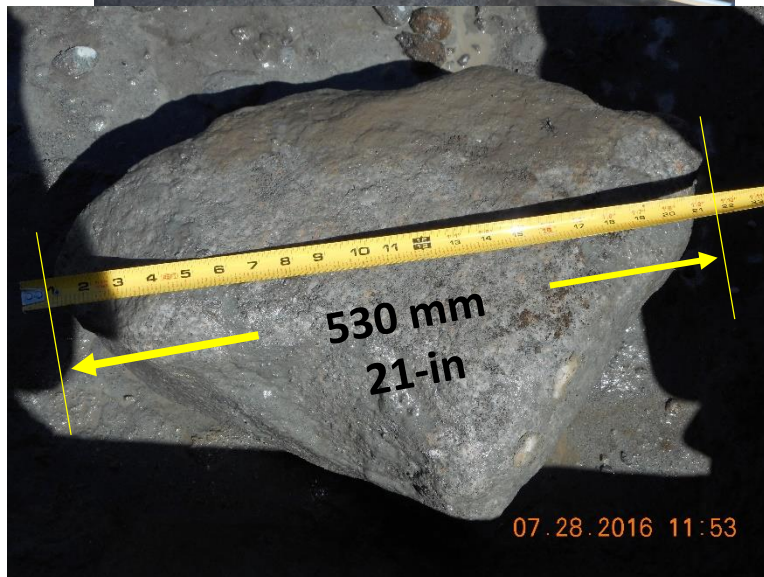
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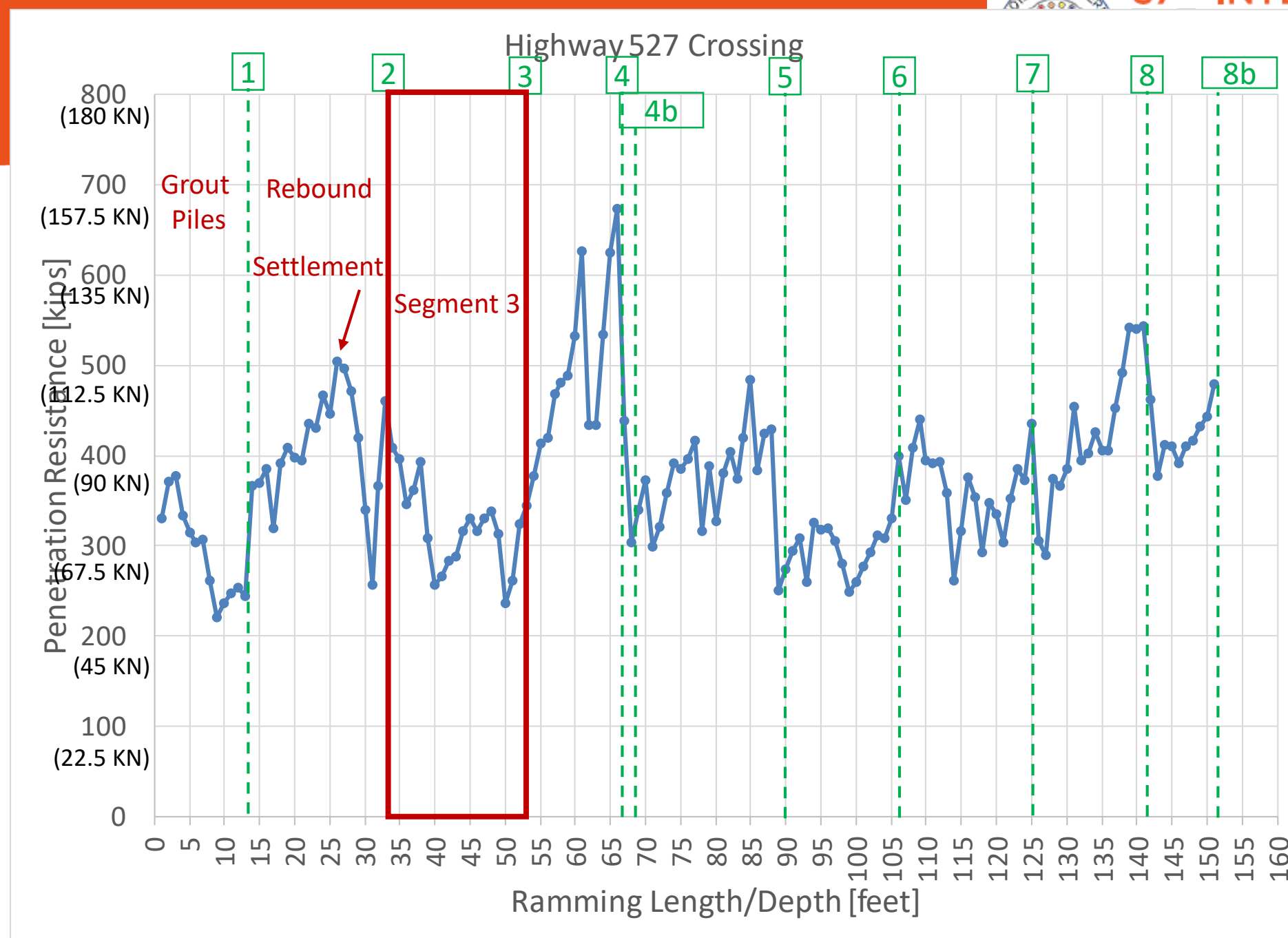


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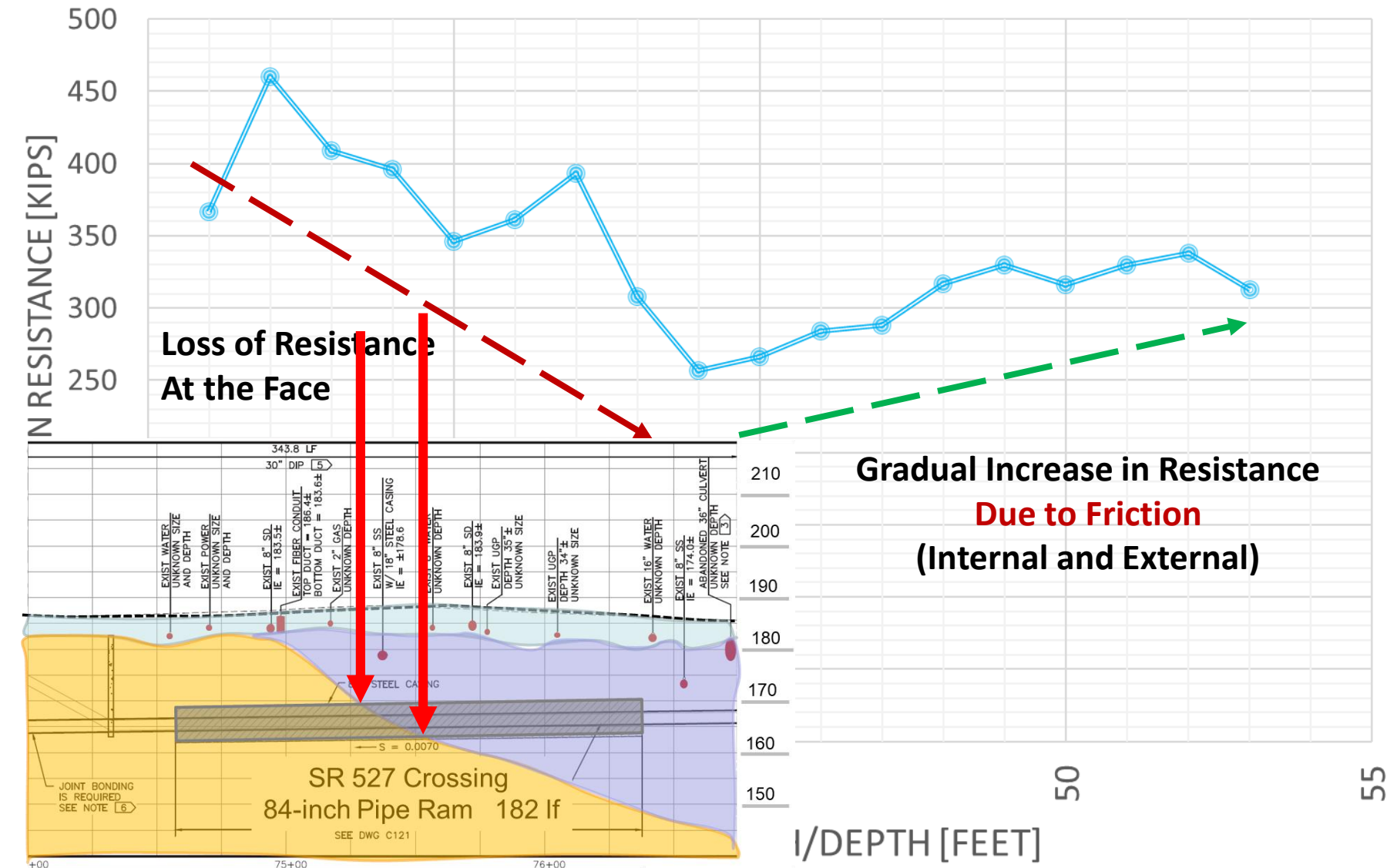
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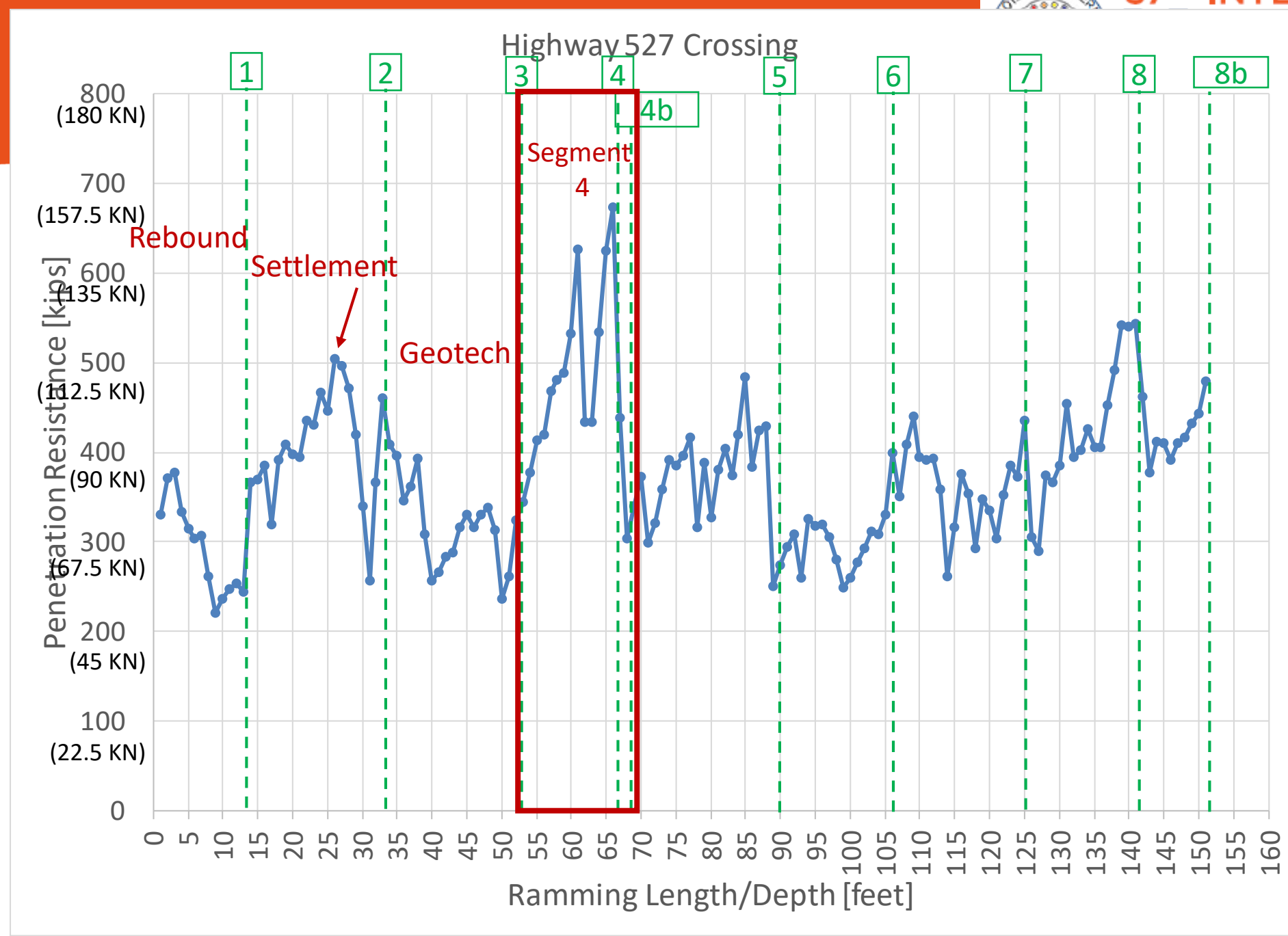
## Highway 527 Crossing Segment 3



**Alluvial and Recessional Deposits**



**Glacial Deposits**



# WHAT HAPPENED ON SEGMENT 4

- Forces Very High
- Ramming Very Slow
- Efficiency Very Low
- Hammer Very Hot





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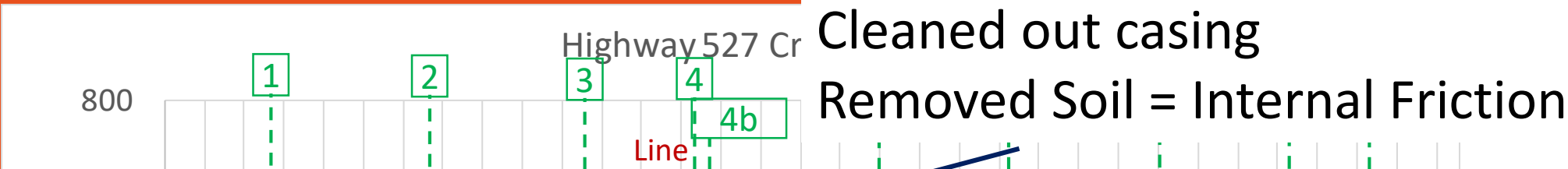
## Significant Deviation

5 mm (14 inches) and trending

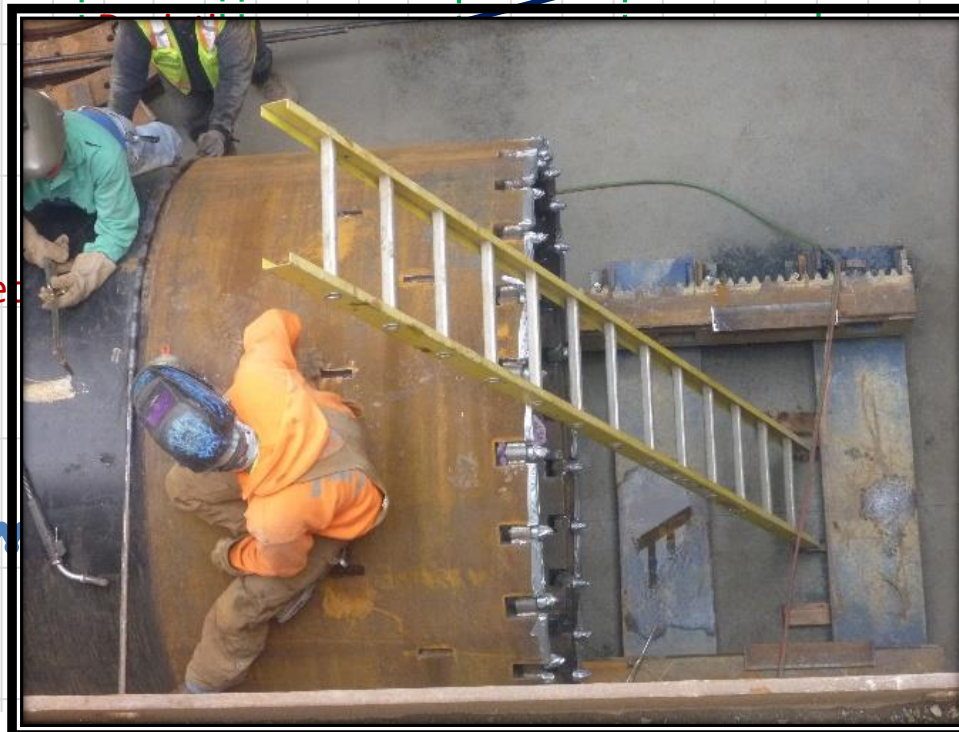
## Maintained Grade

adele?

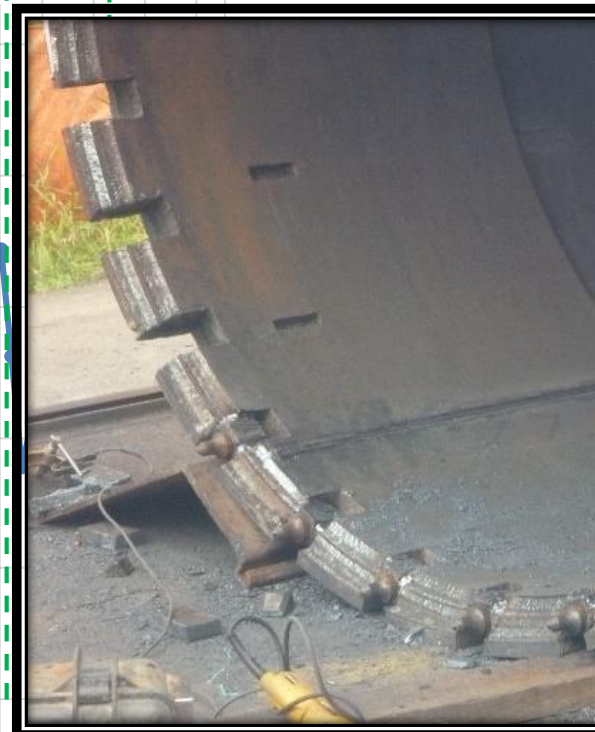
y losing line?



A.



B.

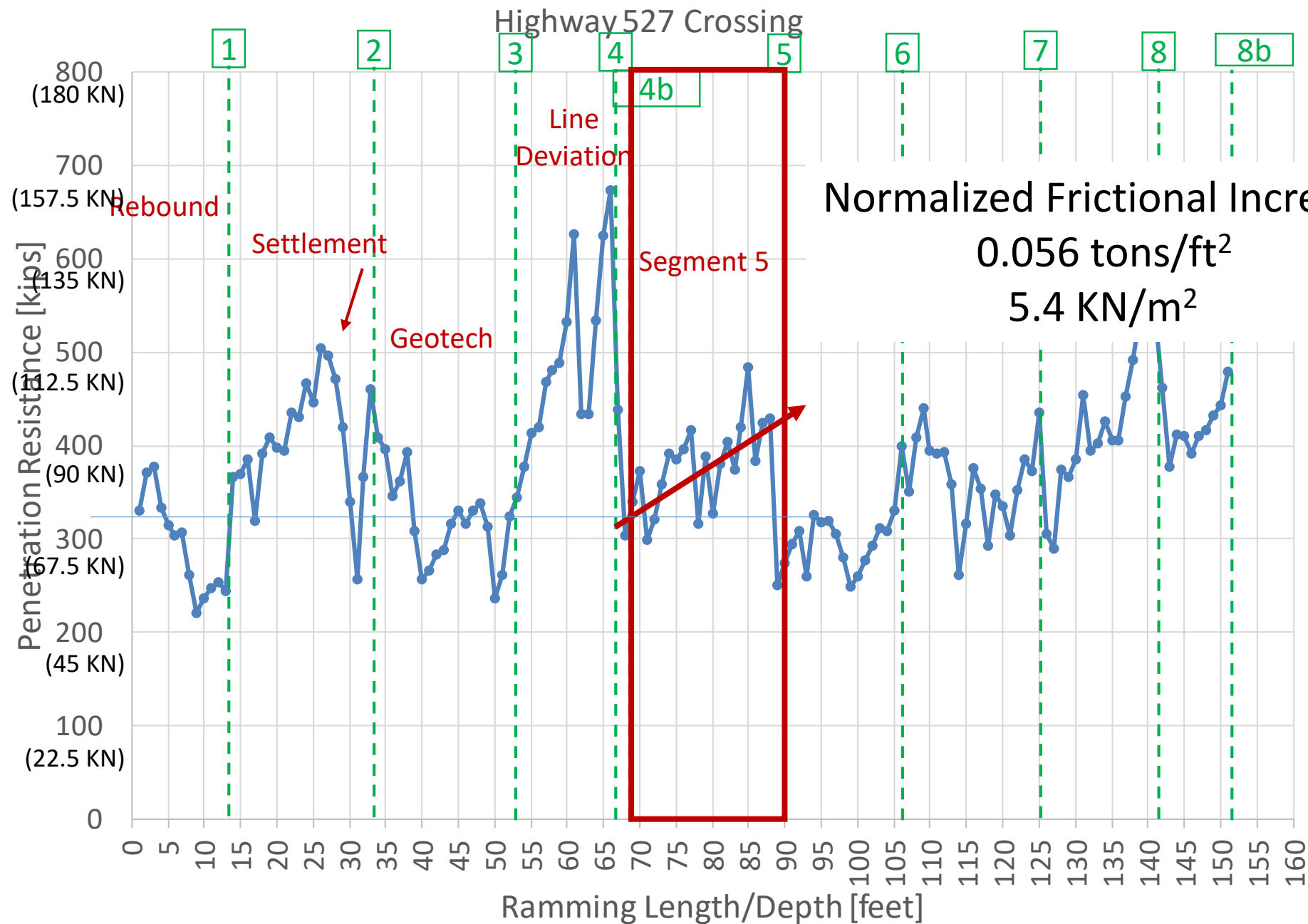


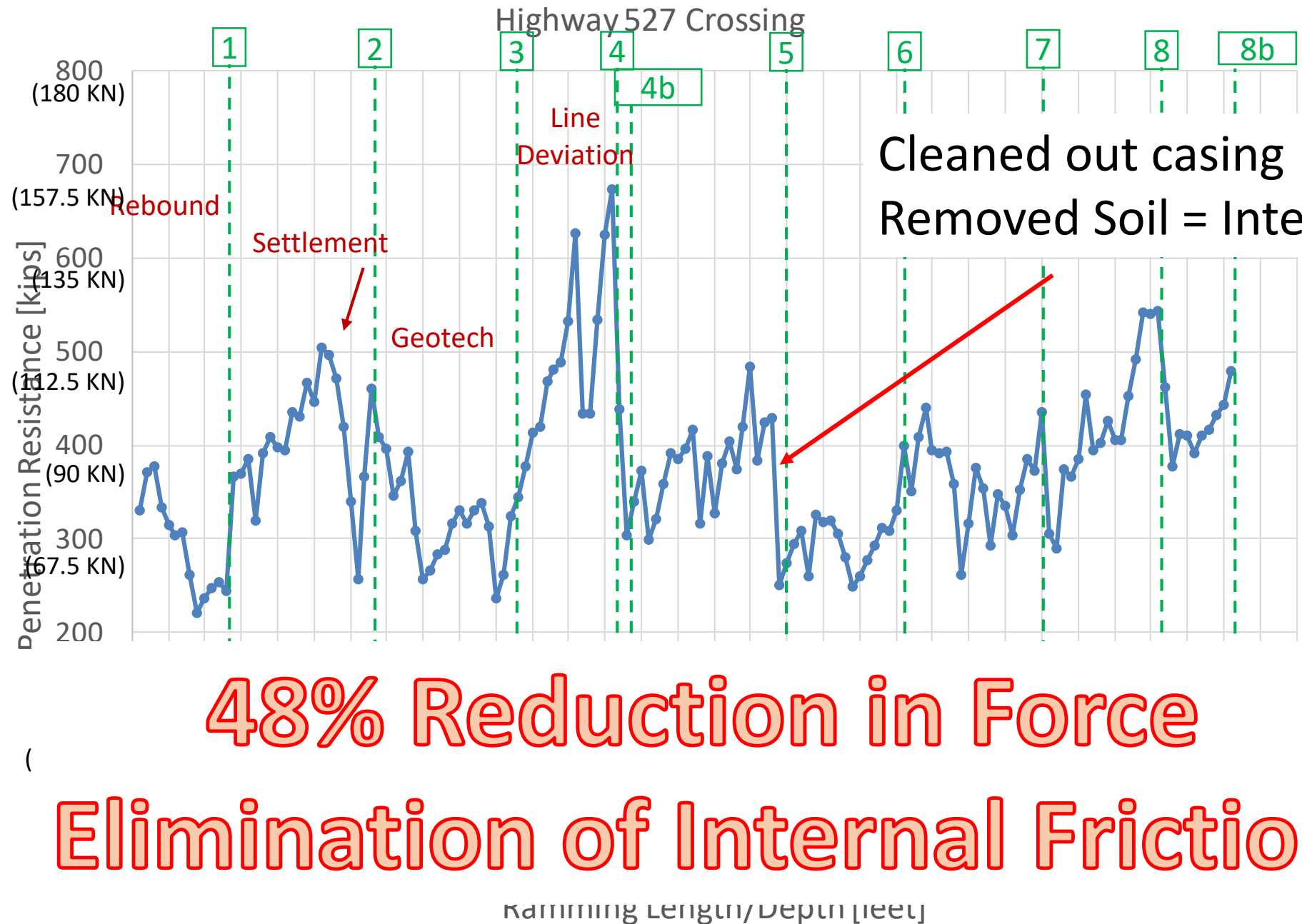
C.

**56% Reduction in Force**

**Elimination of Internal Friction**

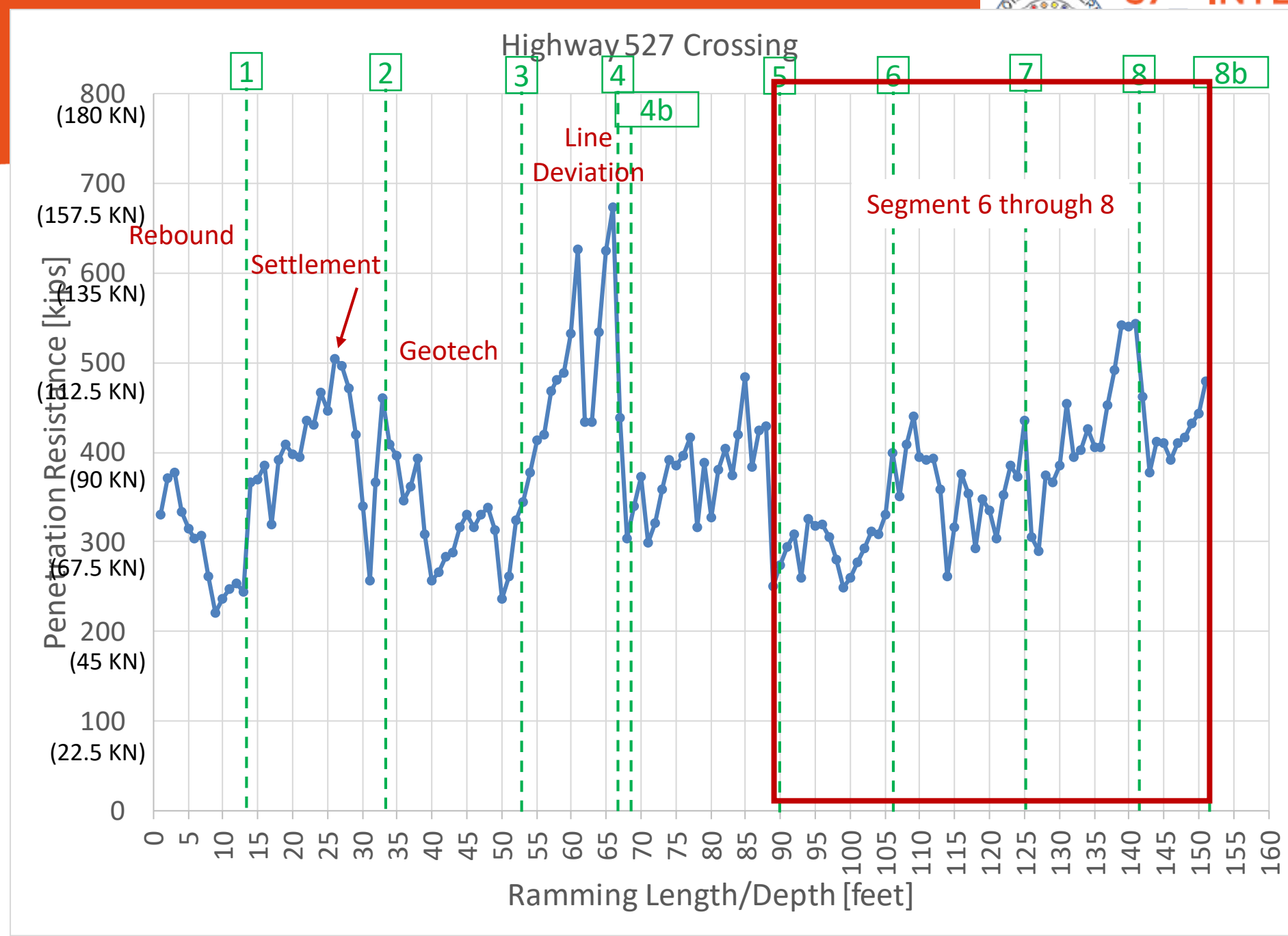
Ramming Length/Depth [feet]

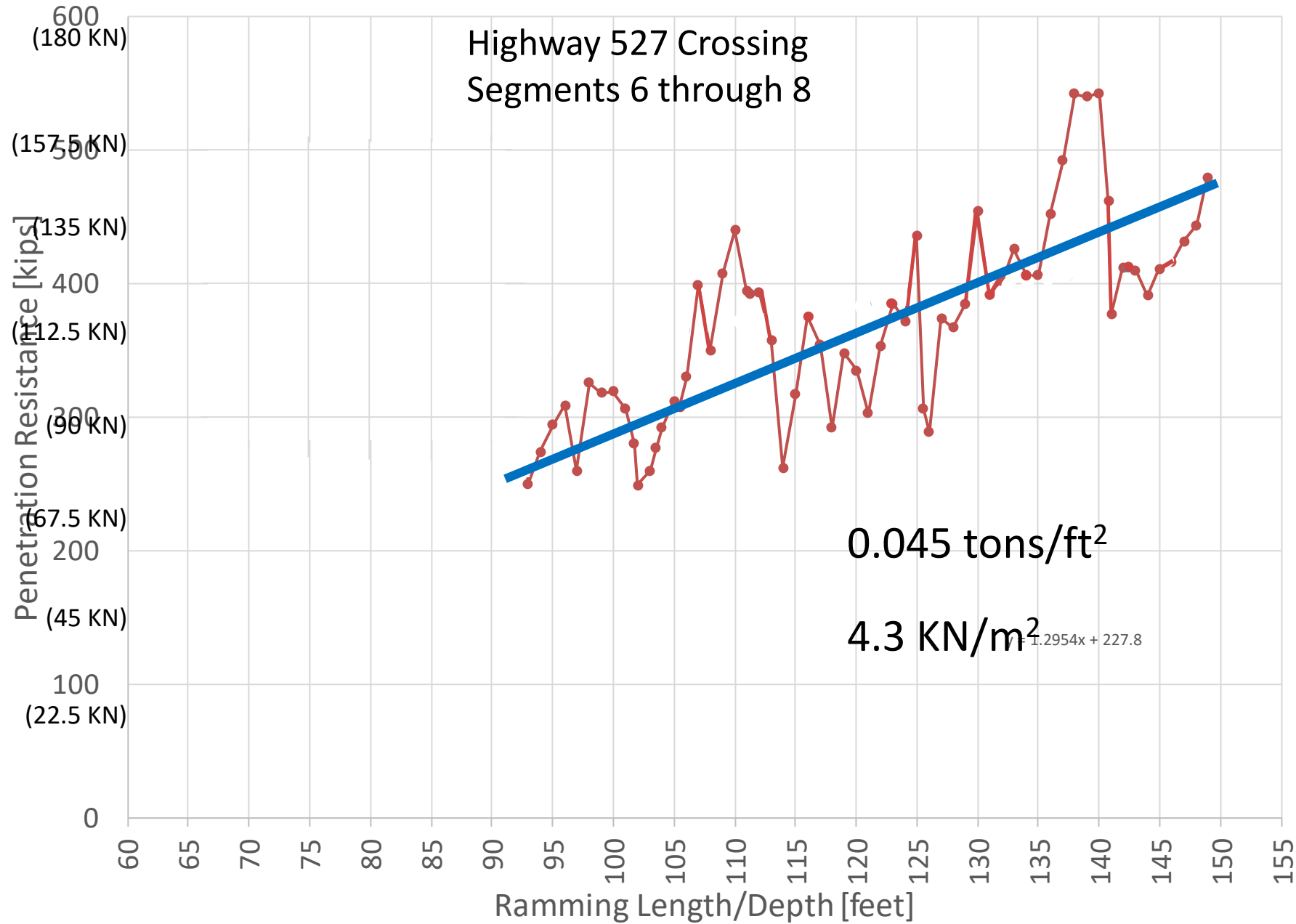




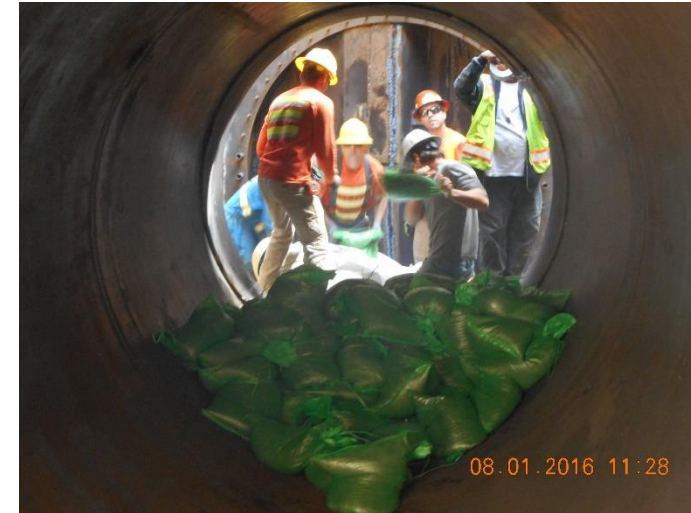
48% Reduction in Force

Elimination of Internal Friction





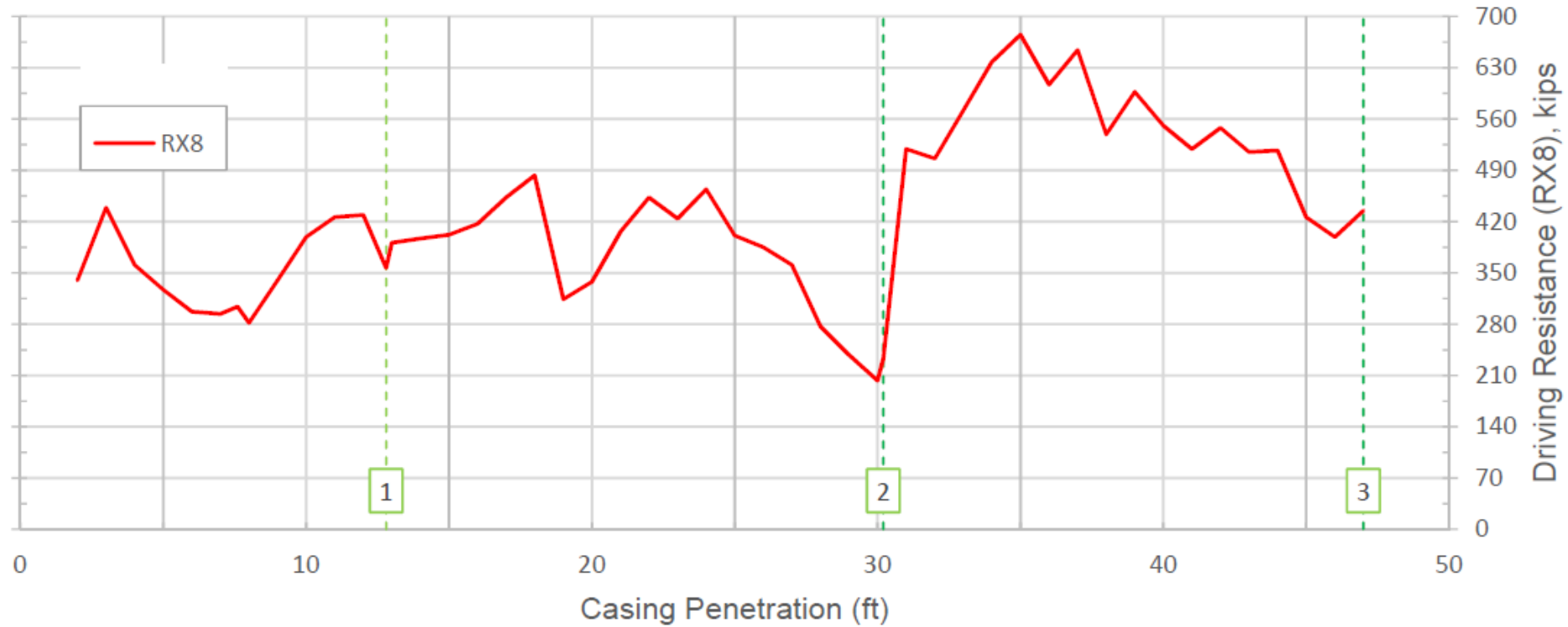
# SILVER CREEK CROSSING



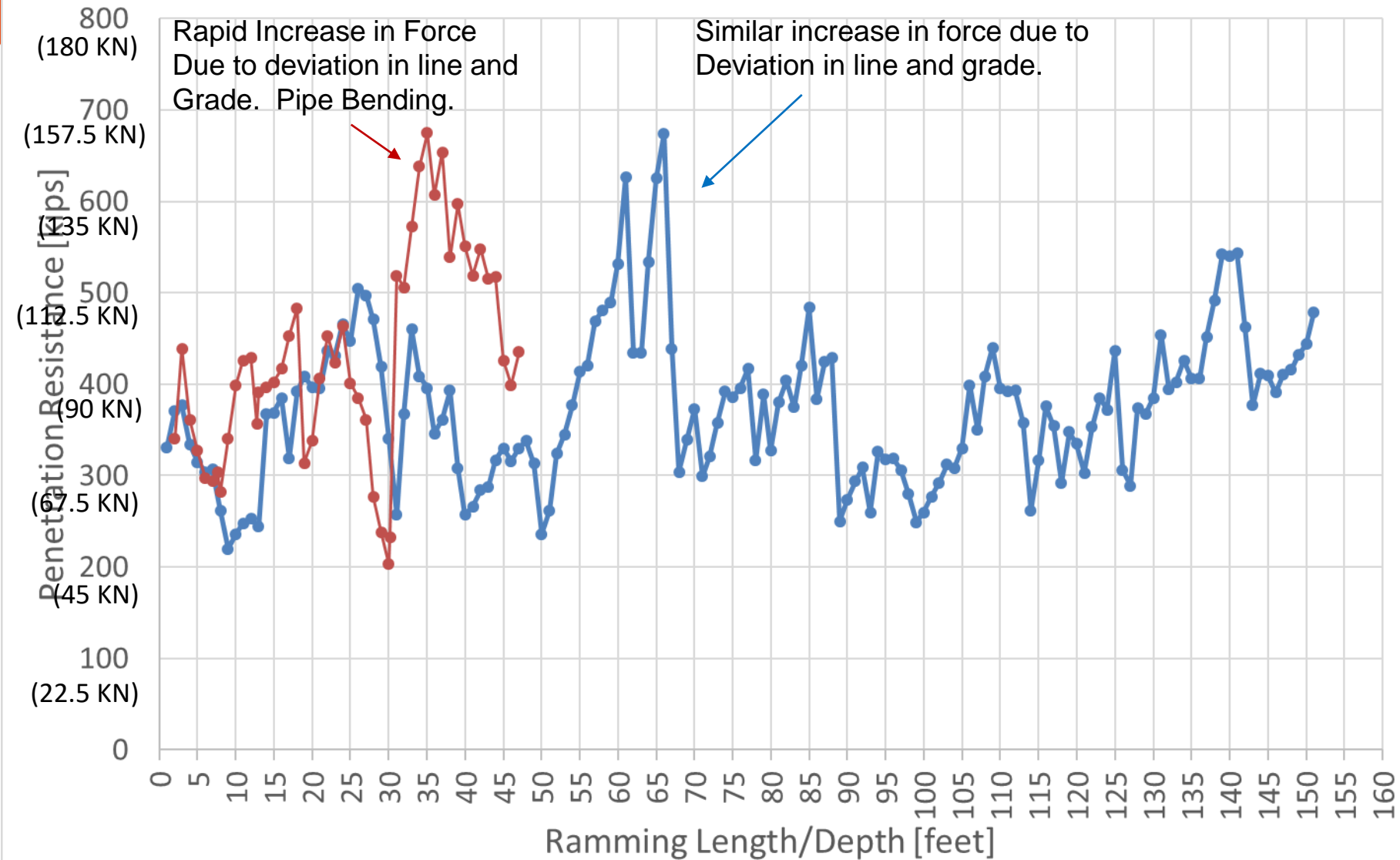
# SILVER CREEK CROSSING DRIVING RESISTANCE V. CASING PENETRATION



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## SR 527 and Silver Creek Crossings Ramming Length v. Penetration Resistance



- Beginning to Understand Mechanisms Governing Pipe Ramming Behavior
- Interface Friction for Pipe
  - Very different for Ramming and Jacking
- Instrumentation reveals tremendous amount about ramming behavior
- More data analysis in process

# MORE CONCLUSIONS...



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- Change in efficiency v. force at the shoe
  - Boulder v. Line/Grade Deviation
- Operator valued the information
  - Talk to instrumentation specialist during/after each pipe segment
- Instrumentation did NOT add to construction time but provided a lot of information for small cost
- Line and Grade Deviations???

# THANK YOU

- Alderwood Water and Wastewater District
  - Seeing the Light
  - Trusting STC
  - Vision with Risk Management
- Kamloops Auger Boring
- ISTT

