IPLOCA Novel Construction Initiative Spring 2023 Session

Pipe-in-Pipe Construction and Preheating of Pipelines

Joseph Gilmartin
Pipeline Engineer

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Agenda

- Overview of the Pipe-in-Pipe (PIP) Project
- Details of PIP solution
  - Bulkheads
  - Insulation
  - Preheating
- PIP Construction Planning
- Thermal expansion theory & importance of Installation Temperature
- Examples from the Analysis
- Site Photos

Fluor Corporate Overview

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SOLUTIONS

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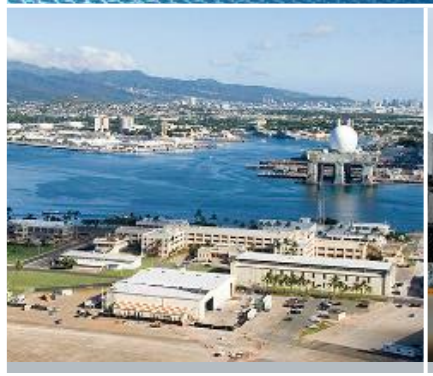

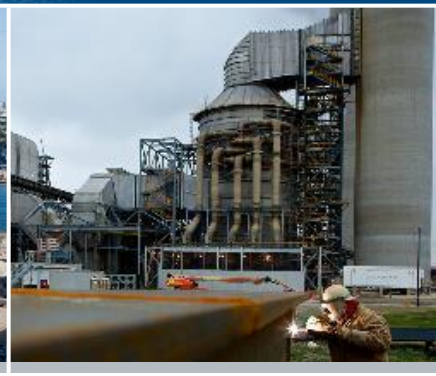

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Core Values

Fluor's core values act as our behavioral compass. They guide our actions, advance our objectives and power our performance. We live our core values without compromise.

Overview of PIP Project

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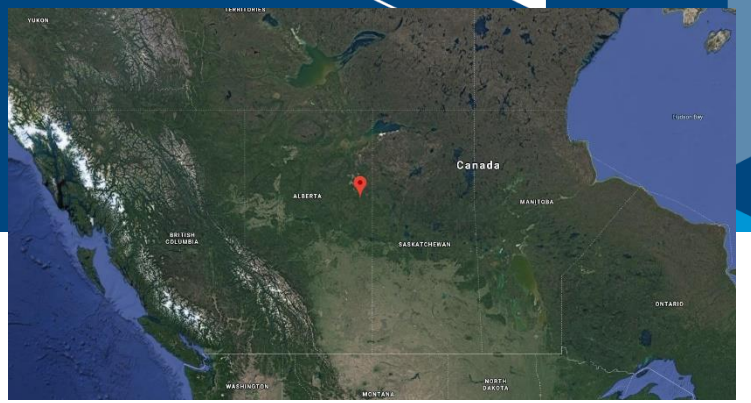
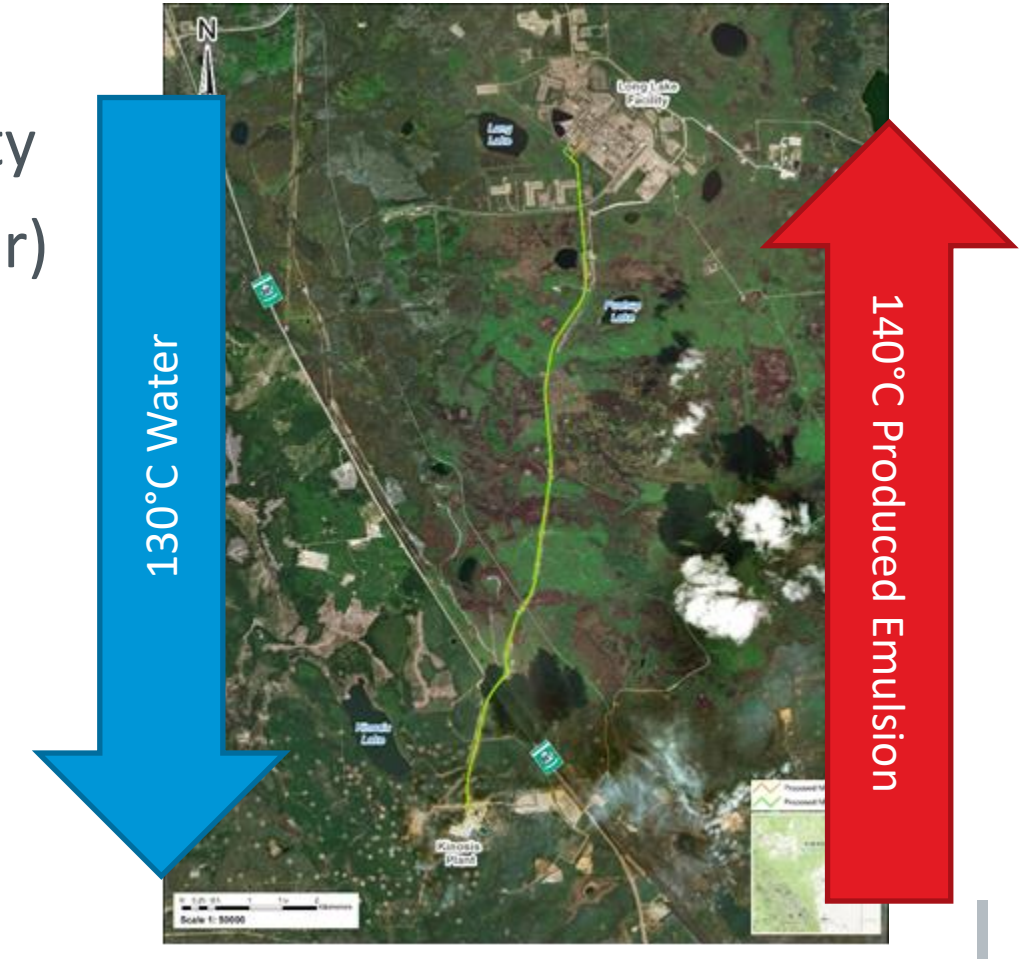
Pipe-in-Pipe Project Overview



- Northern Alberta, Canada
- Two 10km pipeline replacements
  - 130°C water from boilers in northern facility
  - 140°C produced emulsion (bitumen + water) from southern facility
- Challenging Terrain
  - Congested Right of Way
  - Major road and railway crossings
  - Wet ‘muskeg’ (peat bog) terrain



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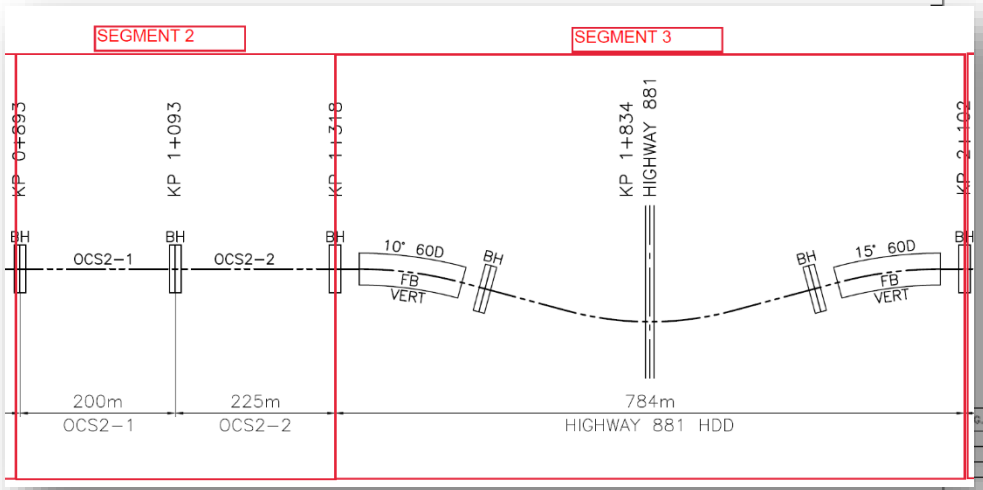
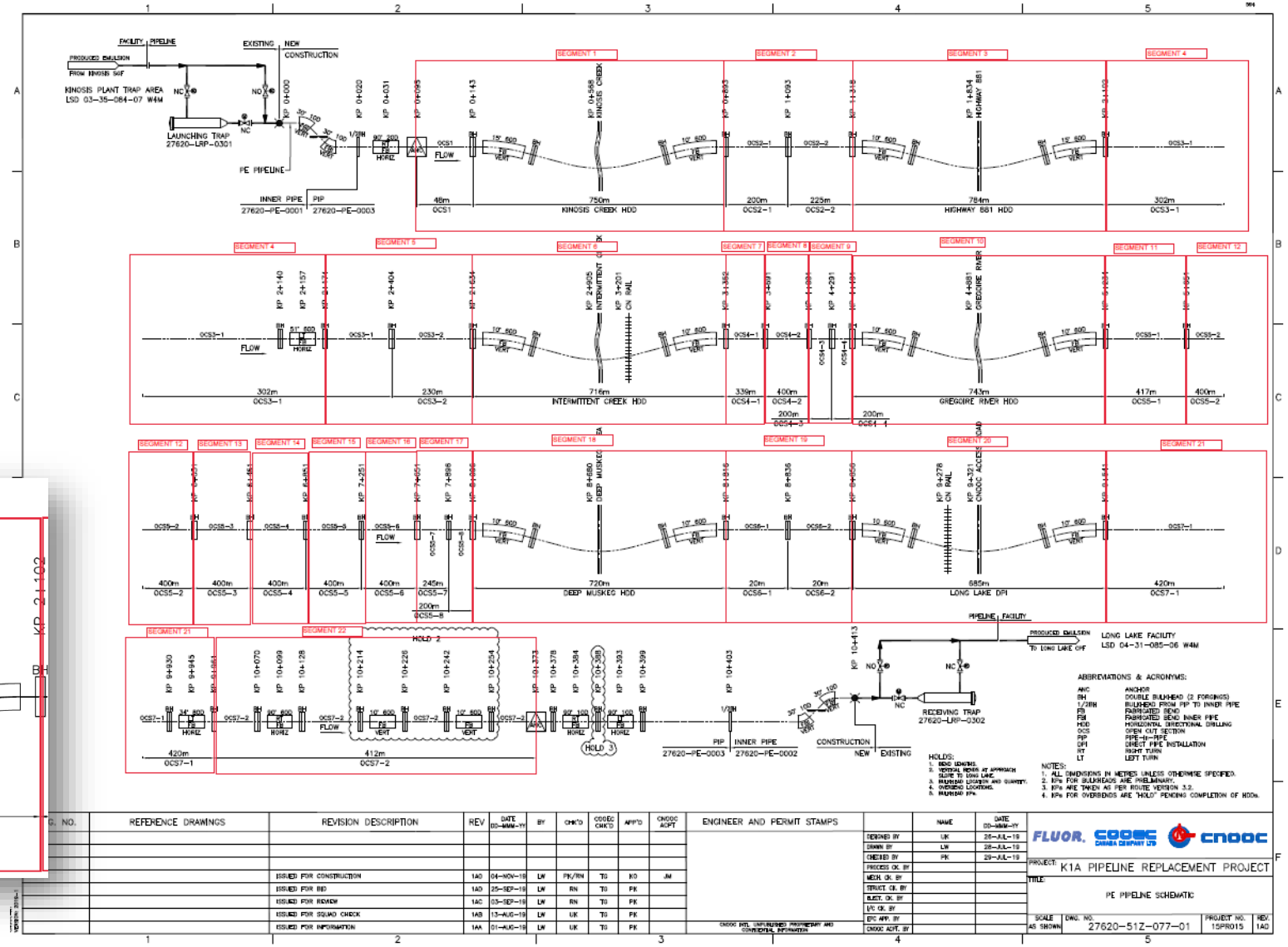
Schematic – each pipeline has:

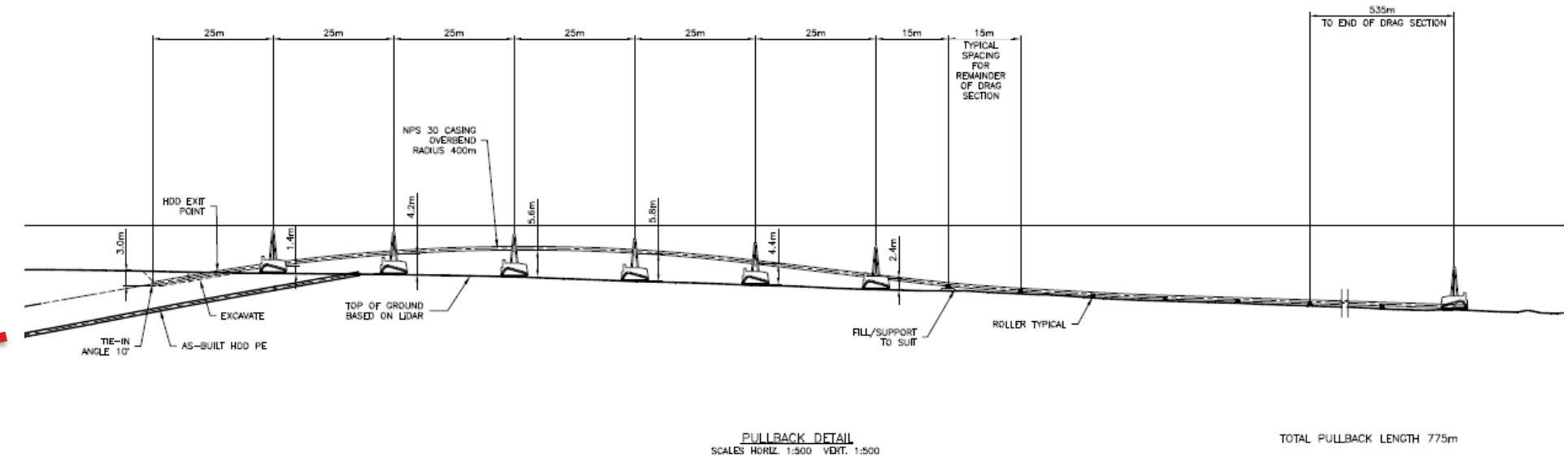
- 52 bulkheads
- 6 HDDs
- 7 Open Cut Sections
- 22 segments





Horizontal Directional Drill (HDD) Sections

- HDD casings pre-installed (early 2019)
- PIP strings pull-back into casing
- Low friction centralisers between PIP and Casing
- Grouting lines, Fibre optic cable strapped to PIP



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Technical Details

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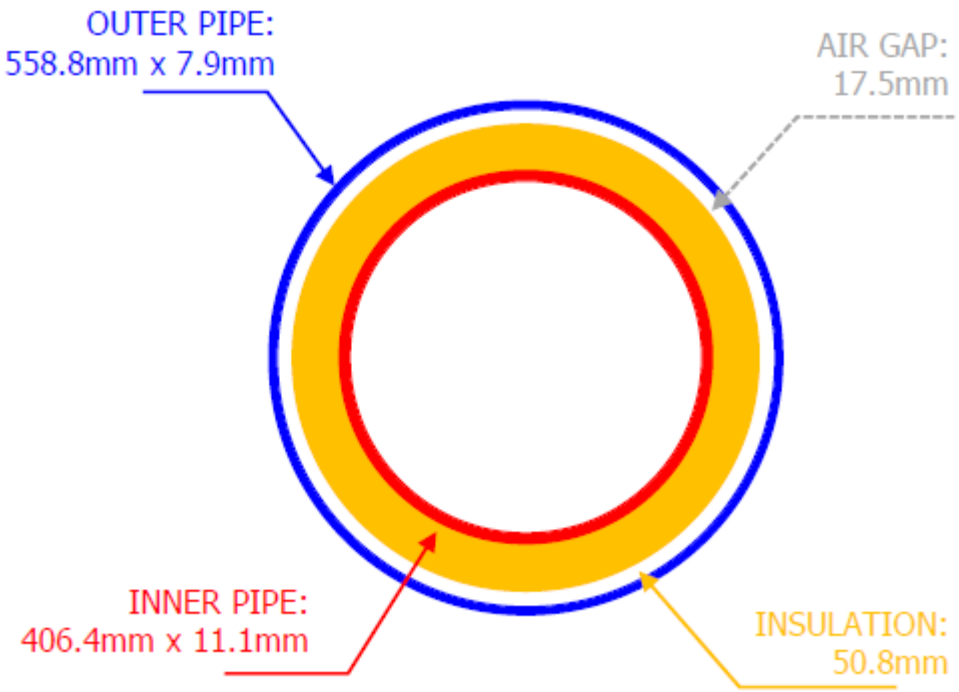
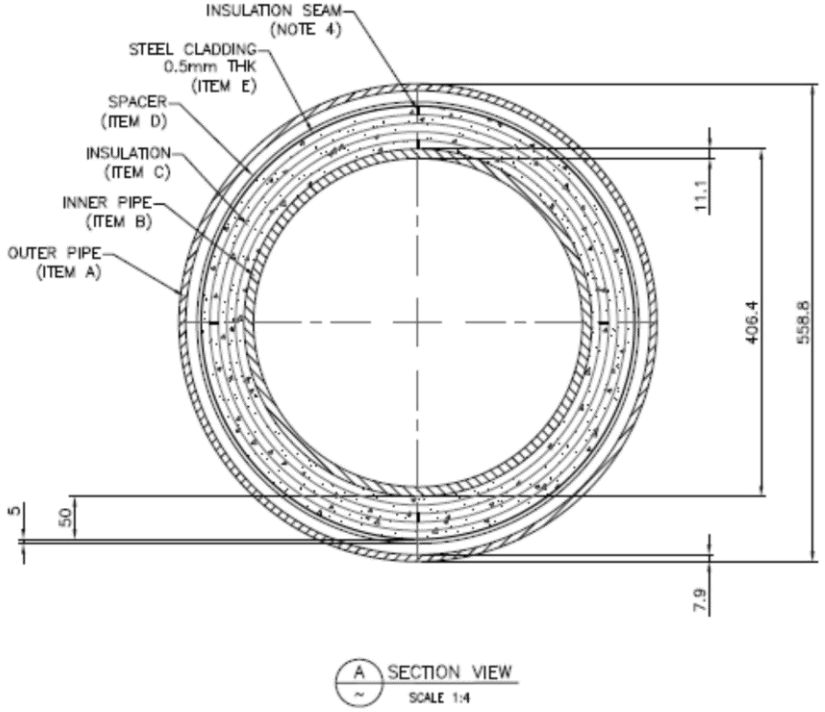
Pipe-in-Pipe (PIP) Concept

- 130-150 °C design temp, 60-90 barg design pressure
- Spacers to maintain gap between pipes





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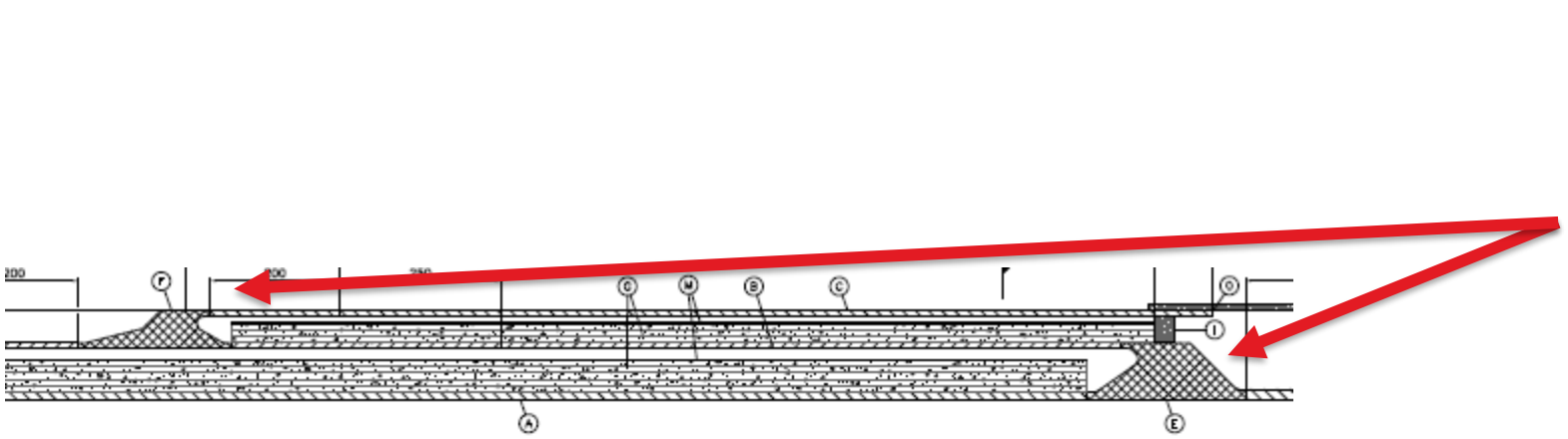
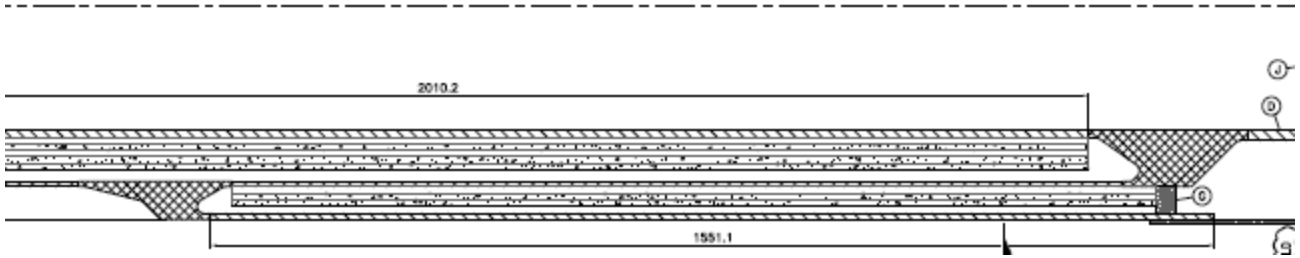
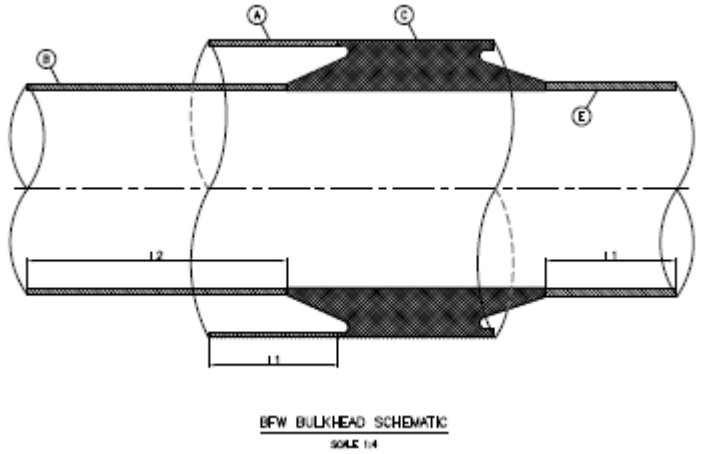
Intermediate Bulkheads

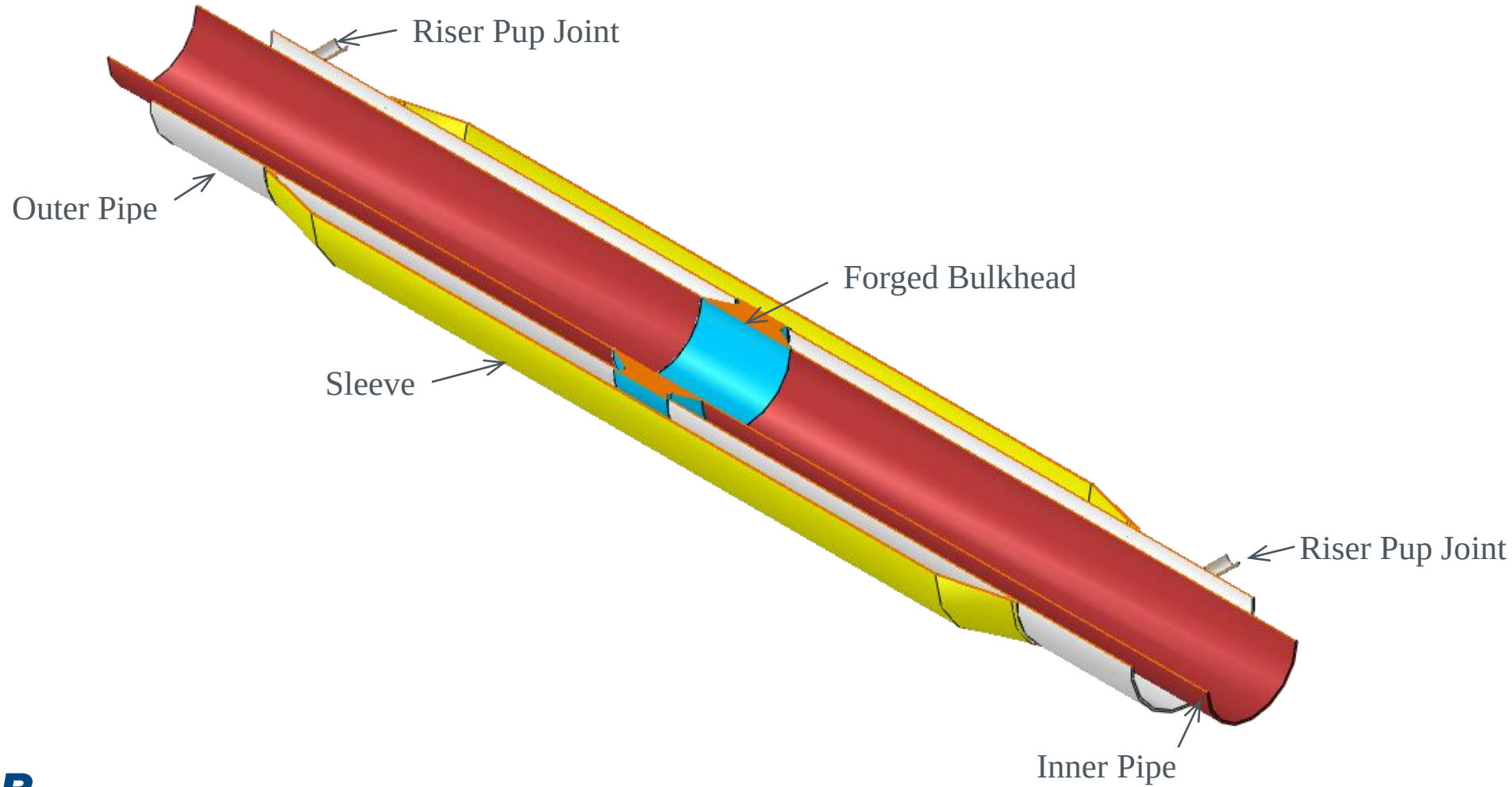
- Forged item, connecting inner and outer pipe
- Spaced every 400m, transfers forces, act as water stop







Early Bulkhead Design



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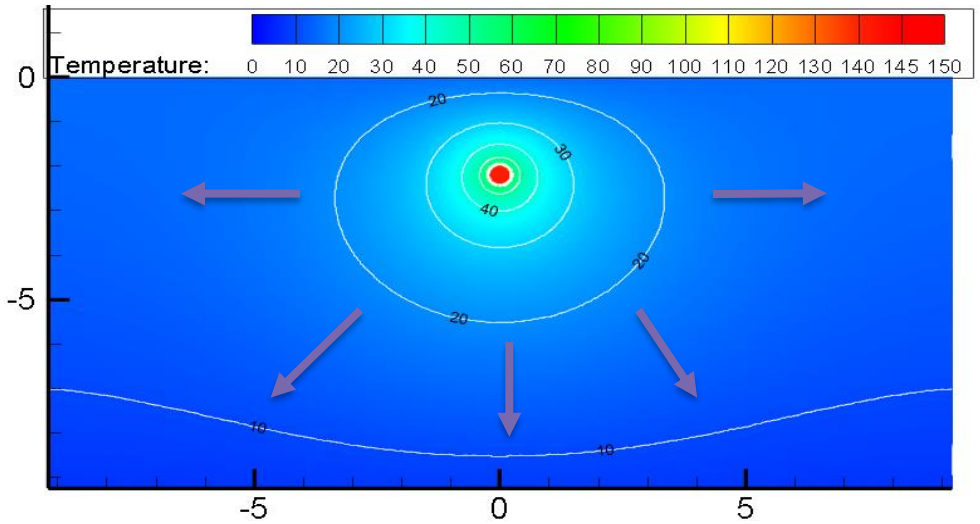
Insulation Material

- Microporous Insulation material selected
- Previously used at this site
- Flexible insulation panel covered with an elastic film, easy for assembling
- Thermal conductivity is low [0.023W/(m.℃)], not sensitive to temperature changes
- Low density, ranges from 200 to 400 kg/m^3

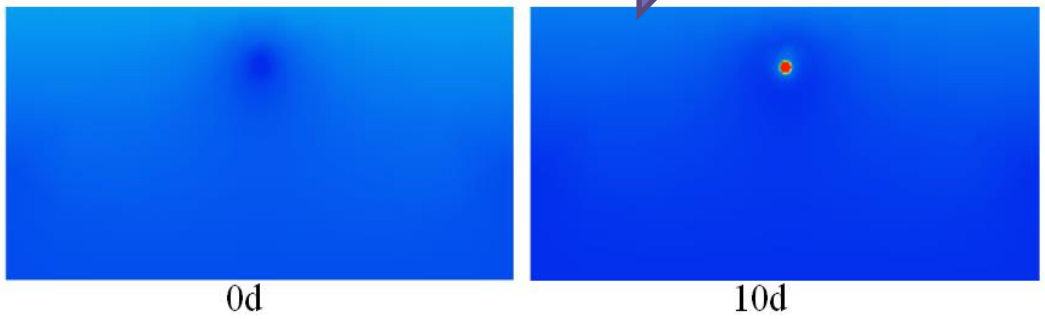
Geothermal Analysis

- Geothermal modelling puts numbers to the heat loss

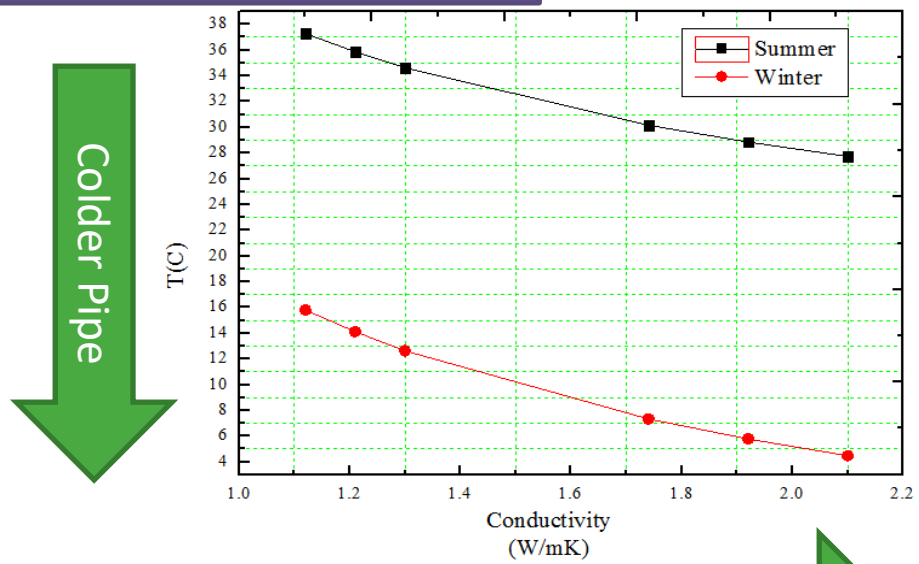
1. Losing heat to soil



2. Heating with Time



3. Soil conductivity and season



Colder Pipe

Wetter Soil

The lower the thermal conductivity of soil is, the higher the temperature of outer pipe will be.

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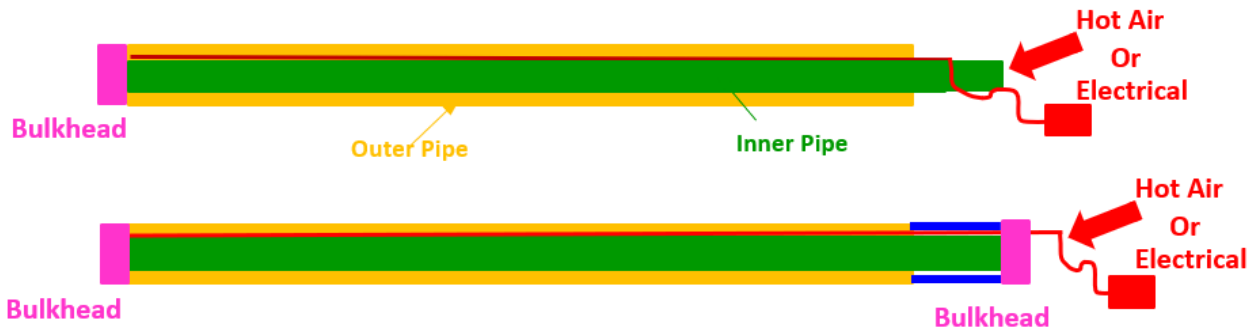
Pre-heat

- Pre-tension selected.
- Inner pipe expanded then ‘locked in’ with outer half shell.

Pre-tension	Pre-stress
Pipes locked together, then expanded	Inner pipe expanded then locked to outer pipe
Soil resists contraction	Outer pipe resists contraction
Must be kept hot until backfill completed	Can cool once weld complete
Inherent stability against buckling	Inherent tendency towards buckling



Single-stage Preheating

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Preheating method 1 – Hot Air

Preheat method comparison: Hot air VS. EHT

Hot Air Preheating

The main equipment for Hot Air Preheating is the compressor packages and the diesel engine generator packages.

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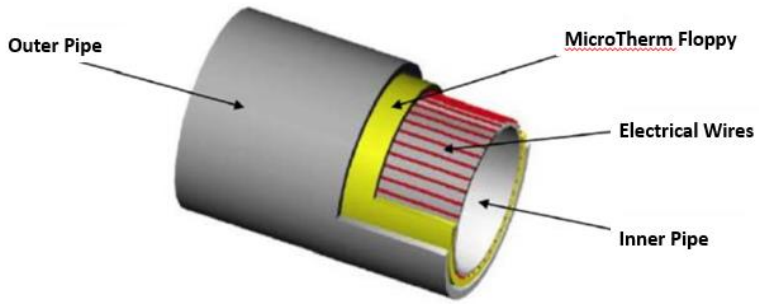
Preheating Method 2 – Electric Cables

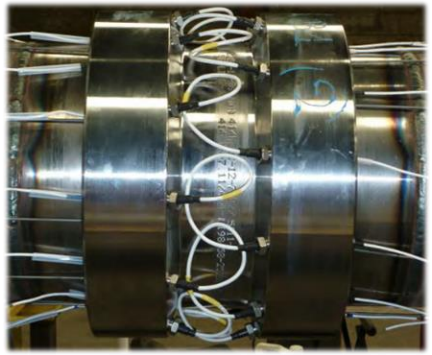
Preheat method comparison: Hot air VS. EHT



Electrical Preheating

Electrical Cable Fabrication

Pipe Joint Connector



Bulkhead Connector

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Not selected.

Preheat Comparison

Preheat method comparation: Hot air VS. EHT

☐ Technical Comparation

Hot Air		EHT	
Pros	**Cons**	**Pros**	**Cons**
1. Less installation time 2. Less preheating time 3. More local contractor 4. More experience in Canada	1. Uneven heating temperature, more difficult to control Long procurement time 2. More equipment 3. Hose vibration and pipeline noise induced by high flow velocity of hot air 4. Human injury risk caused by high flow velocity of hot air at the outlet of pipeline	1. Even heating temperature and easier to control 2. Less equipment 3. Lower human injury risk	1. More cable connectors and easy to damage 2. More fabrication time 3. More preheating time 4. Less local contractor Special design to bulkhead

Preheating in Construction Planning

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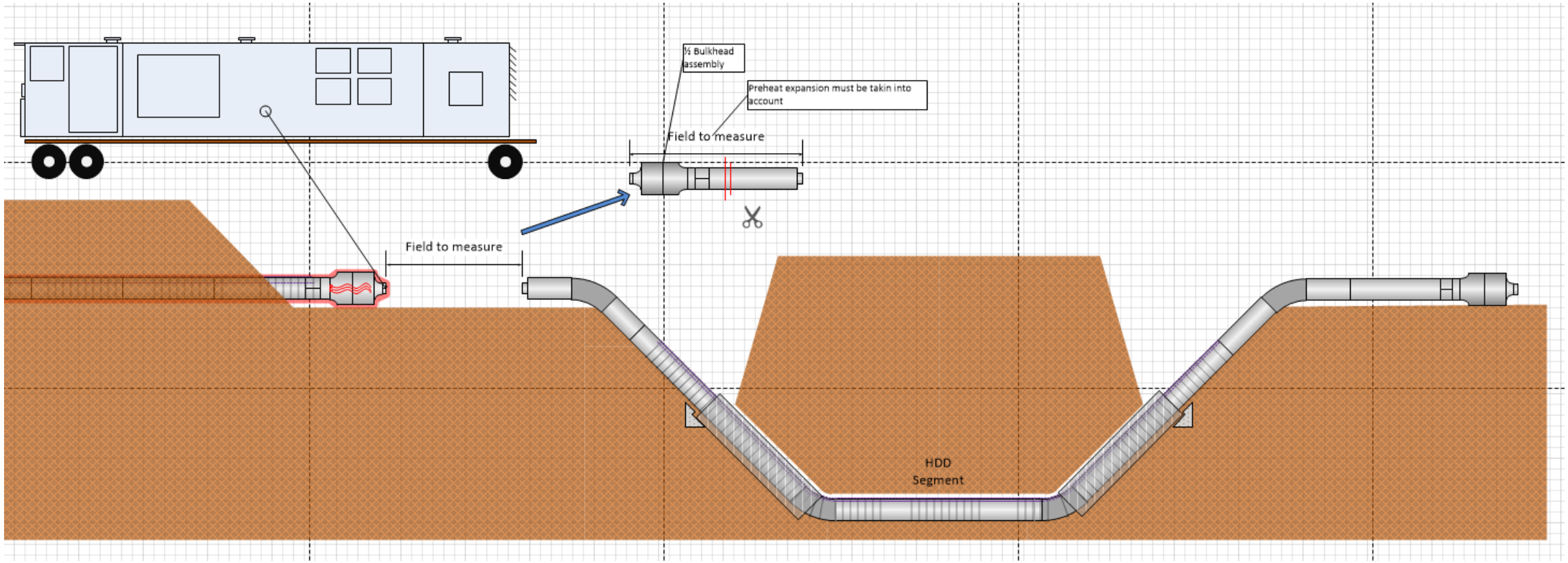
Preheat Step 1 – Field Measure



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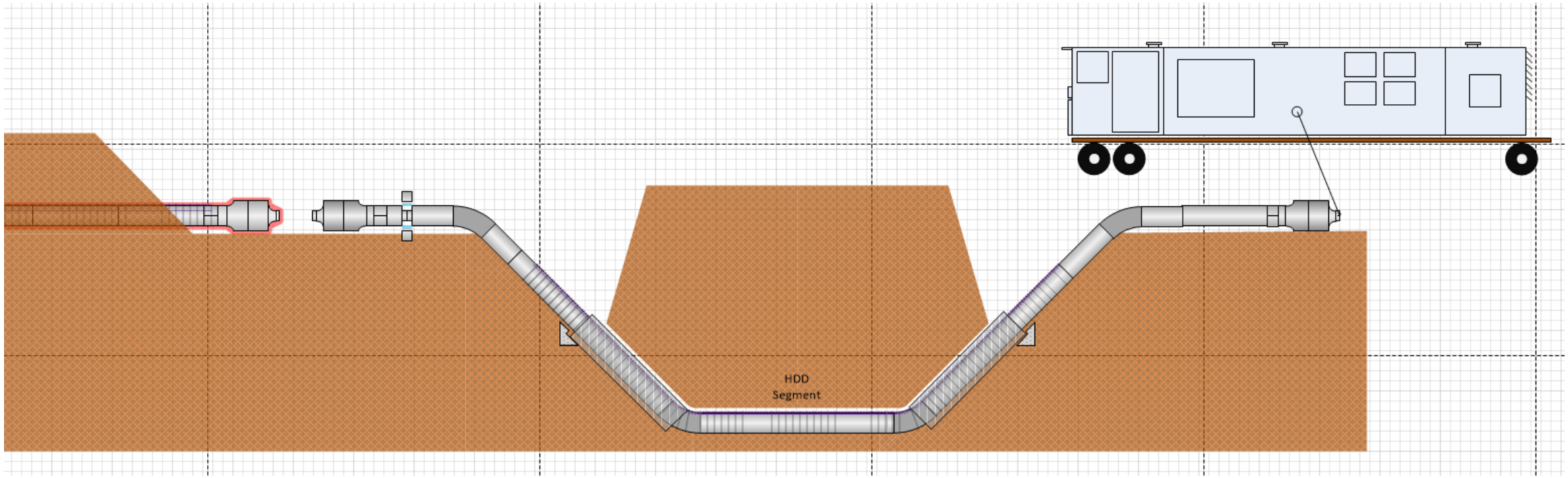
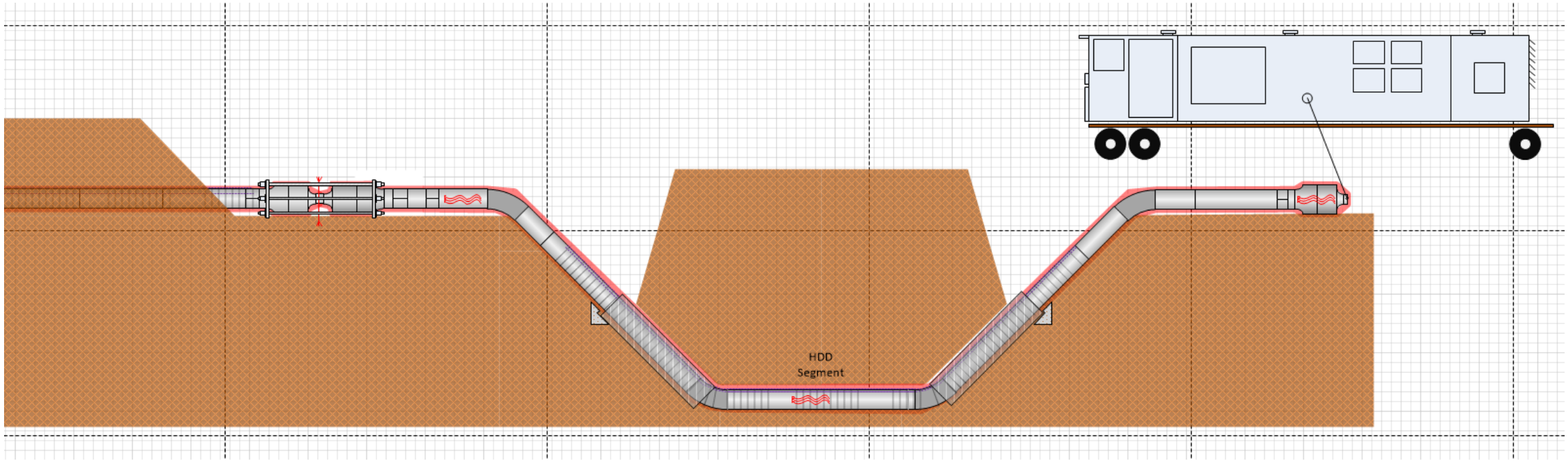
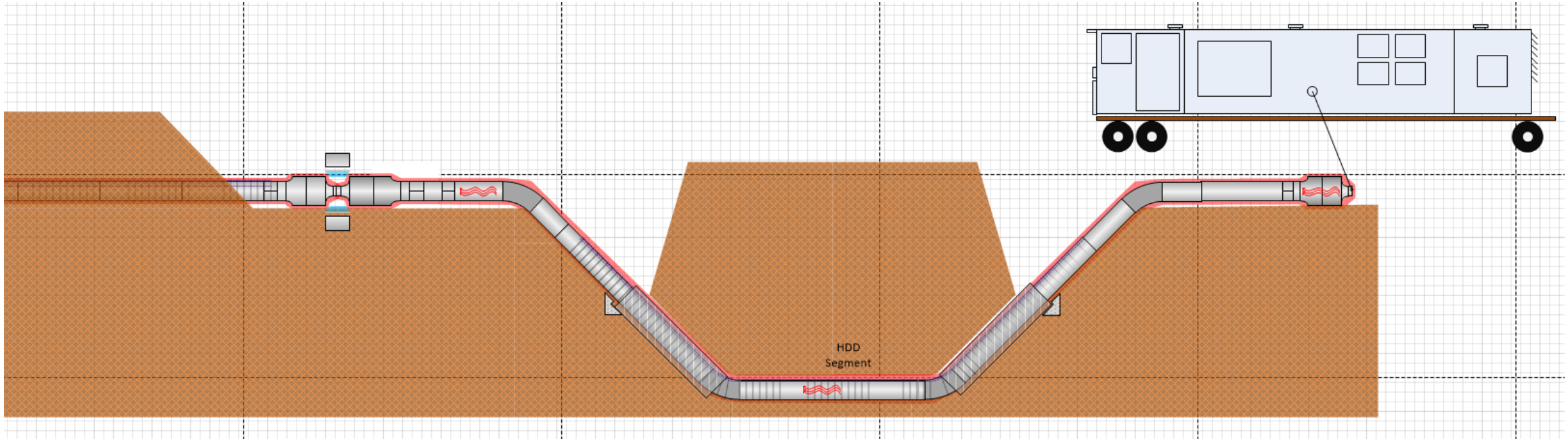
Preheat Step 2 - Preheat



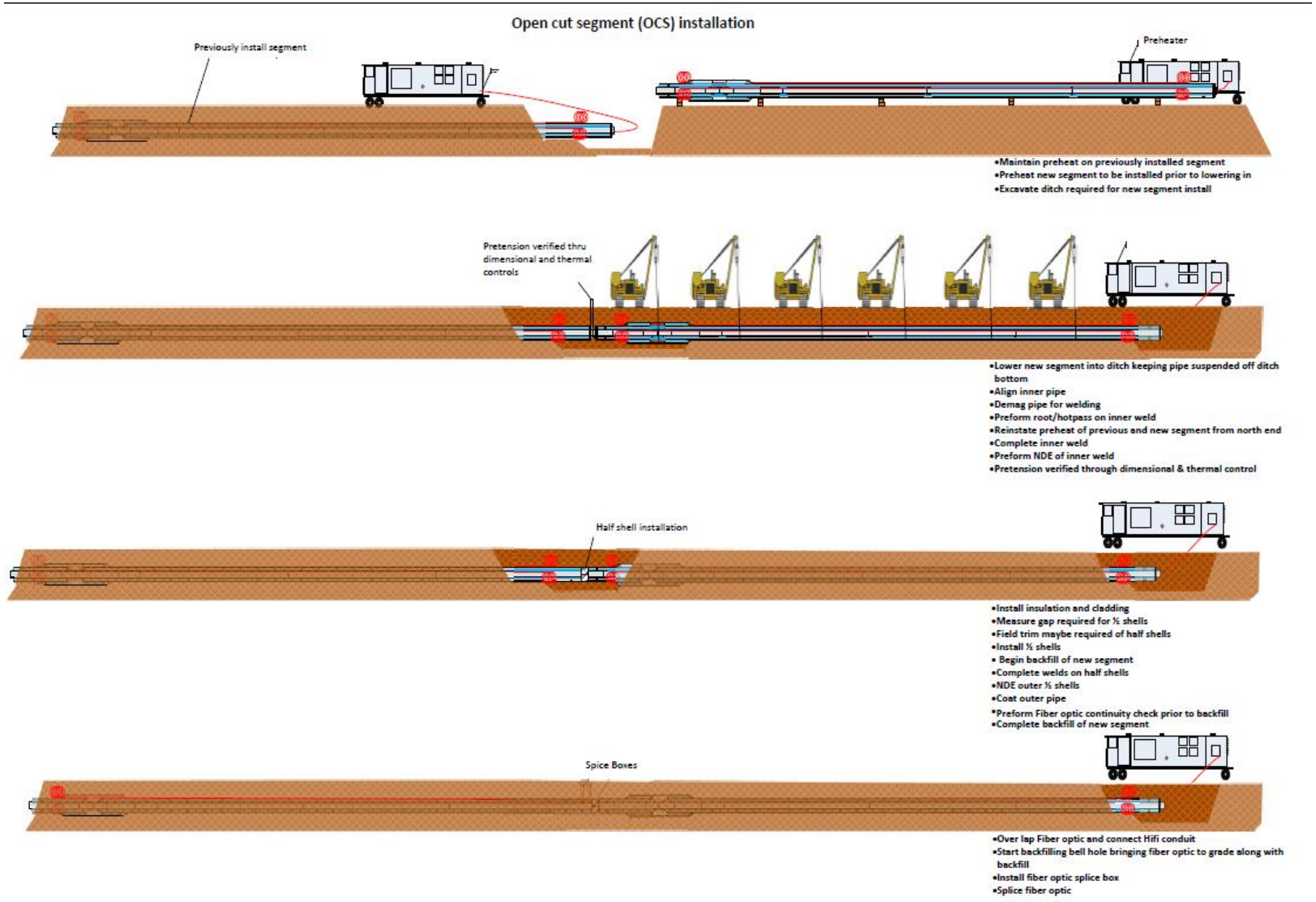
Preheat Step 3 – Tie-in Inner



Preheat Step 4 – Outer Half Shell



Construction planners turned artistic!



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Installation Temperature

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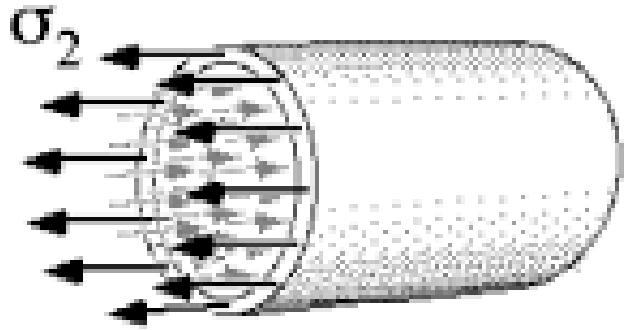
Installation Temperature

- Here is an overview of the theory behind installation temperature.
- Apologies for the equations!
- The summary: installation temperature is as important as the operating temperature, and the Construction Method and Planning has a big effect.

Pipe Stress 1

- Longitudinal Stress is made up of
  1. Poisson's effect σ_v (bulging outwards creates longitudinal contraction)
  2. Pressure σ_P (end cap force)
  3. Bending σ_B
  4. **Thermal Expansion σ_T**
  5. **Pretension σ_X (if applicable)**



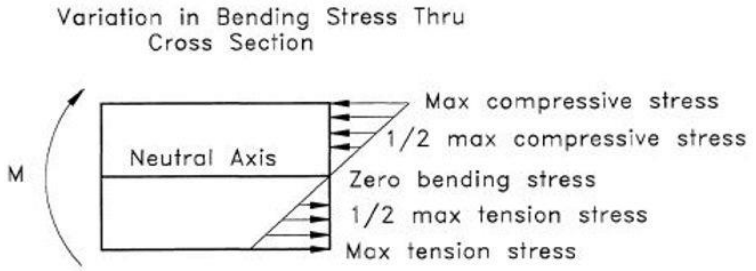


Figure 1-8

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Pipe Stress 2

- Thermal expansion is linearly related to change in temperature.
  - E.g. Force from +20°C is double +10°C
- Change in temperature (ΔT) is between:
  - **Installation Temperature (T_0)**
  - Design Temperature (T_1)
- The following have the same thermal force
  - Installing at +20°C and operating at 110°C
  - Installing at +10°C and operating at 100°C
  - Installing at +0°C and operating at 90°C

$$\delta L = L_0 \cdot \alpha \cdot (T_1 - T_0)$$

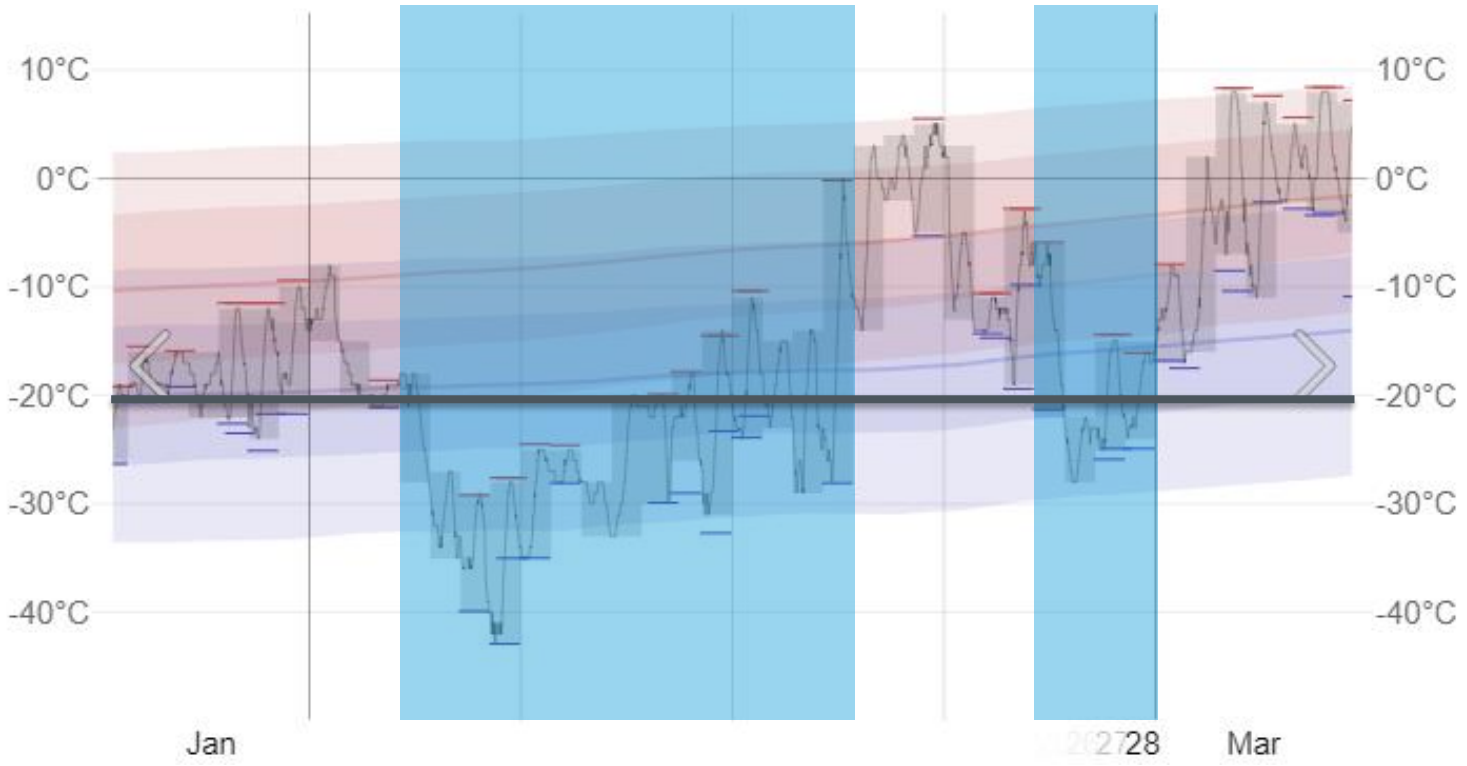
Where,
δL = change in length
L0 = original length
α = coefficient of thermal linear expansion
T1 = final temperature
T0 = initial or reference temperature

Considerations for Pipeline Contractors

- There may be limitations on the installation temperature
  - Dictates the max. & min. temperature at which the pipeline can be lowered and tied-in
- Limited installation temperature will affect construction
  - Limited to allowable weather windows
    - Mid-winter may be too cold
    - Mid-summer may be too hot
  - May drive ‘creative’ approaches
    - Preheating with air / electric cables etc.
    - Cooling by shading, or performing tie-ins early morning / at night.

Illustration of Working Window

-20°C minimum temperature
18 days affected



Fort McMurray Feb 2021 data

Examples from the Analysis

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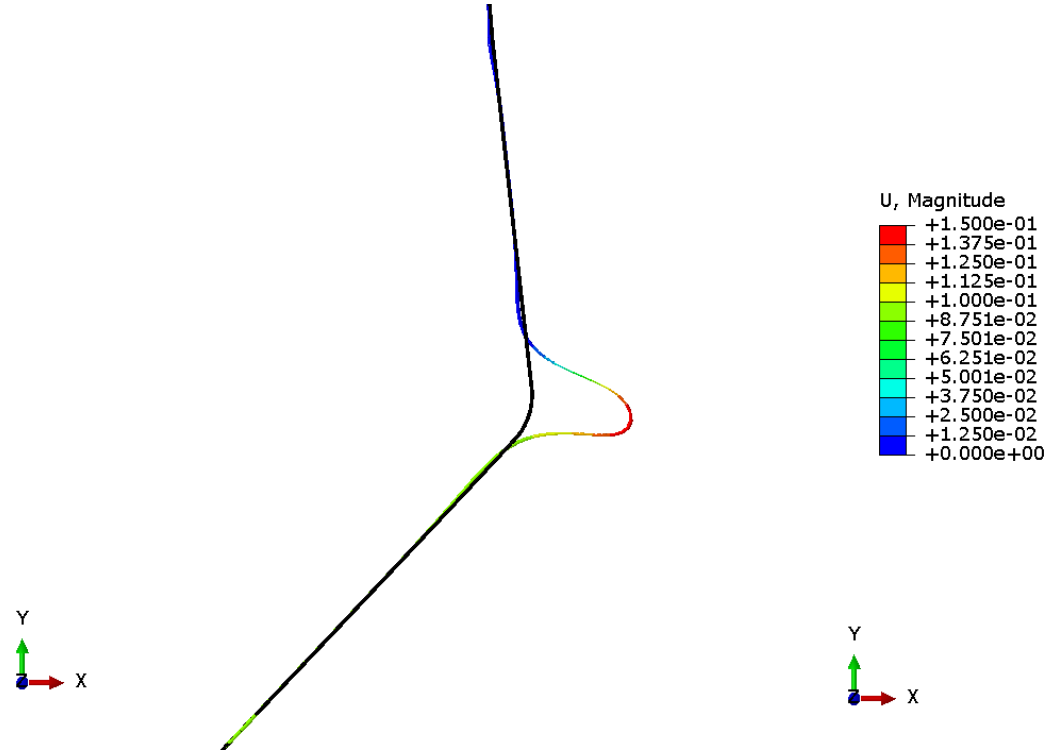
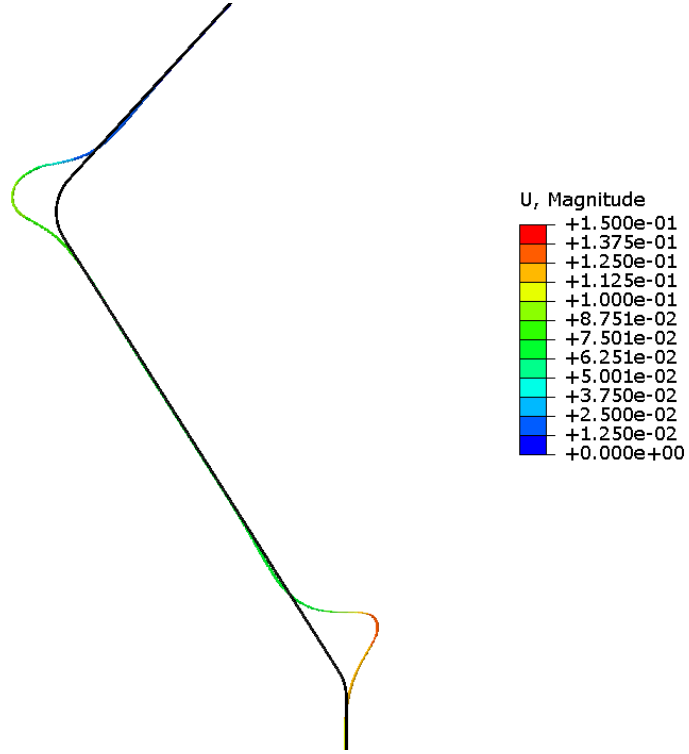
Pipeline Stress Analysis - Example

2. Pipeline In-Place Stress and Upheaval Analysis



Deformation of Bend near Highway 881 HDD(Hydrotest Condition)



Deformation of Bends near Long Lake(Hydrotest Condition)

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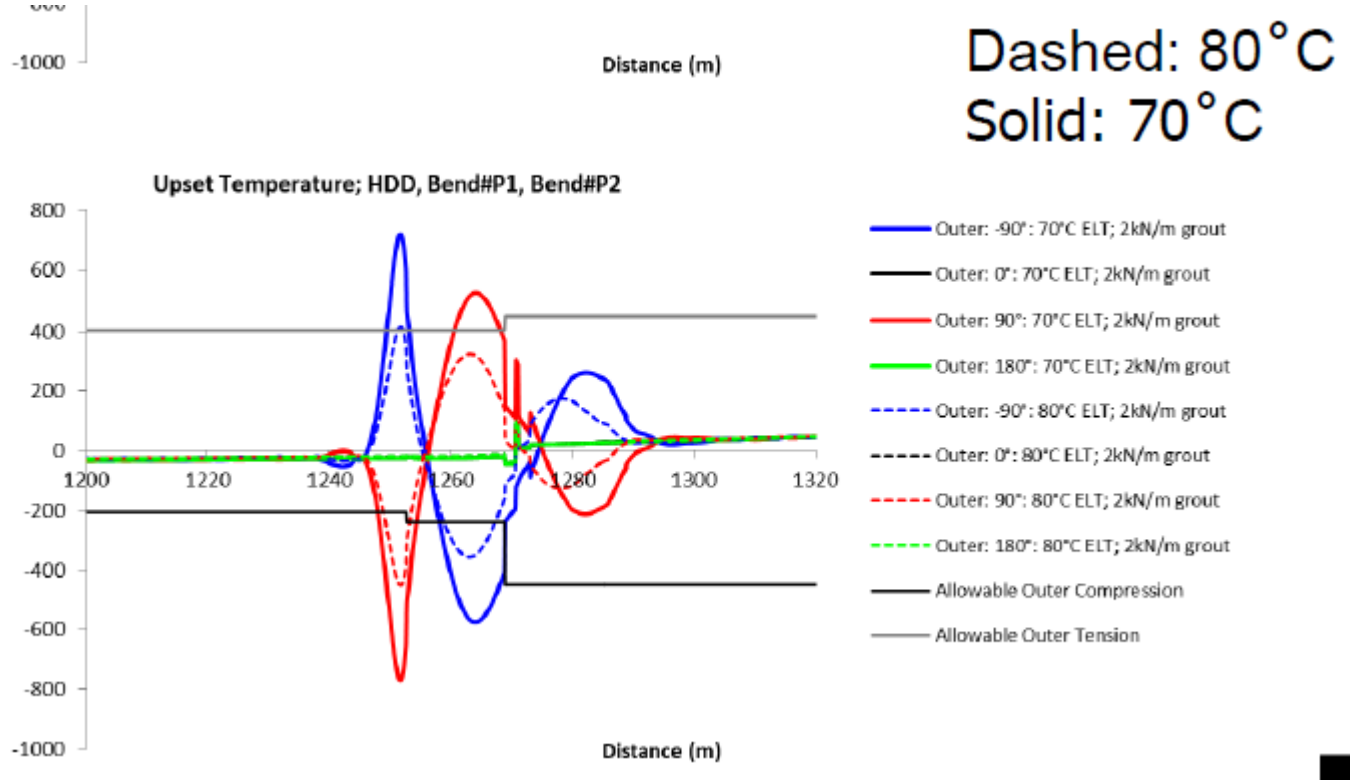
Example of effect of loss of preheat

- Parametric analysis produced many graphs like this to show the change in pretension due to different eventualities



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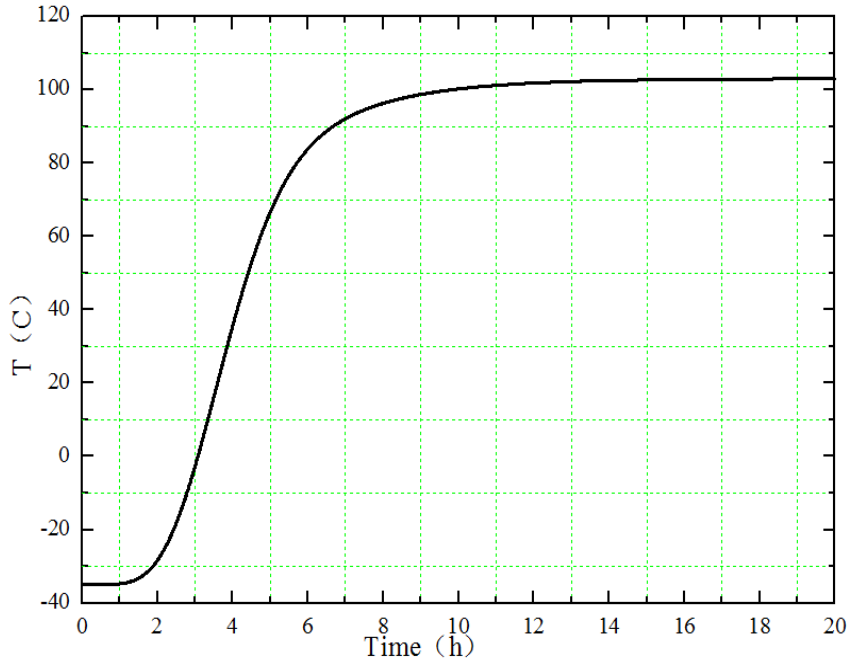
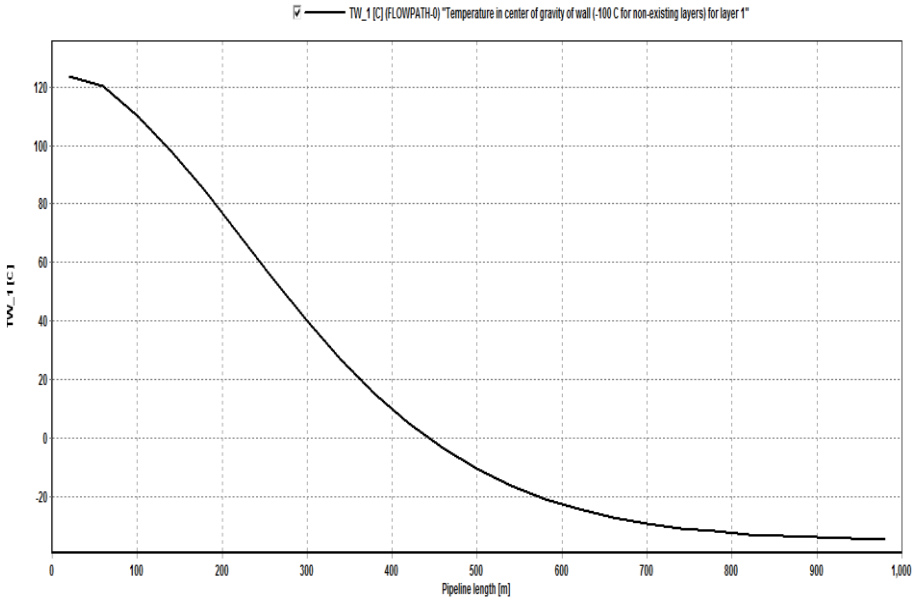
Preheat study - Heat up time

Operating Parameters of Hot-air Preheating

Expected to take 7 hours preheating each pipeline section to reach stable temperature before inner pipe welding.



The temperature change during preheat with hot air at the outlet of exposed pipeline.



The temperature profile along 1km pipeline section during preheat.

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Site Photos

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Photos

Bulkhead forgings

Anchor Flange Forging

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Photos

Typical Right of Way, Winter

Typical Right of Way, Summer

Photos

Typical trench section

Typical HDD Exit

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Photos

Winter Pullback, attaching spacers

Final position, Overbend attached

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Photos

Area with increased soil overburden

HDD Exit with “fillcrete” overburden

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Photos

Inner Pipe Tie-in weld

Sheet piling the anchor block

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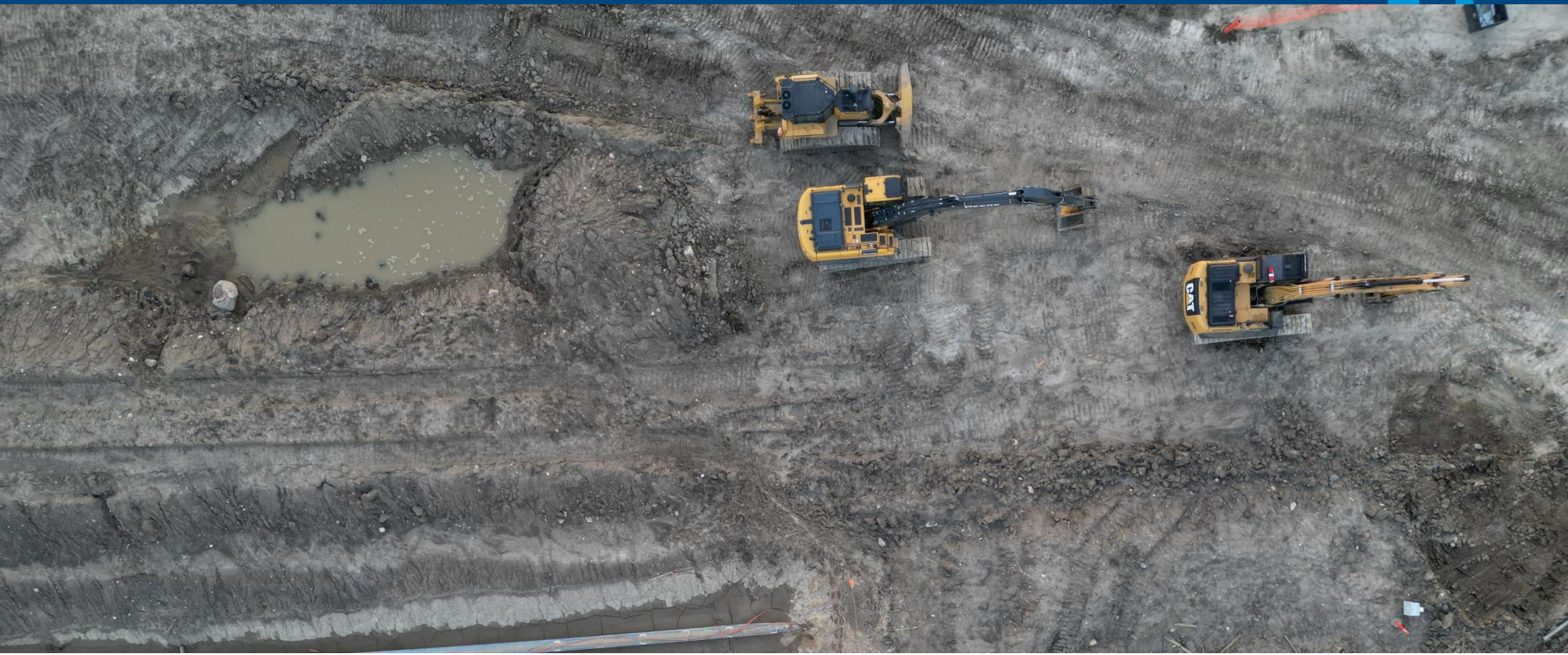
Questions?



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