SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

Lesson Learned from the Installation of a Flexible Seismic Product Pipeline Mitigation System

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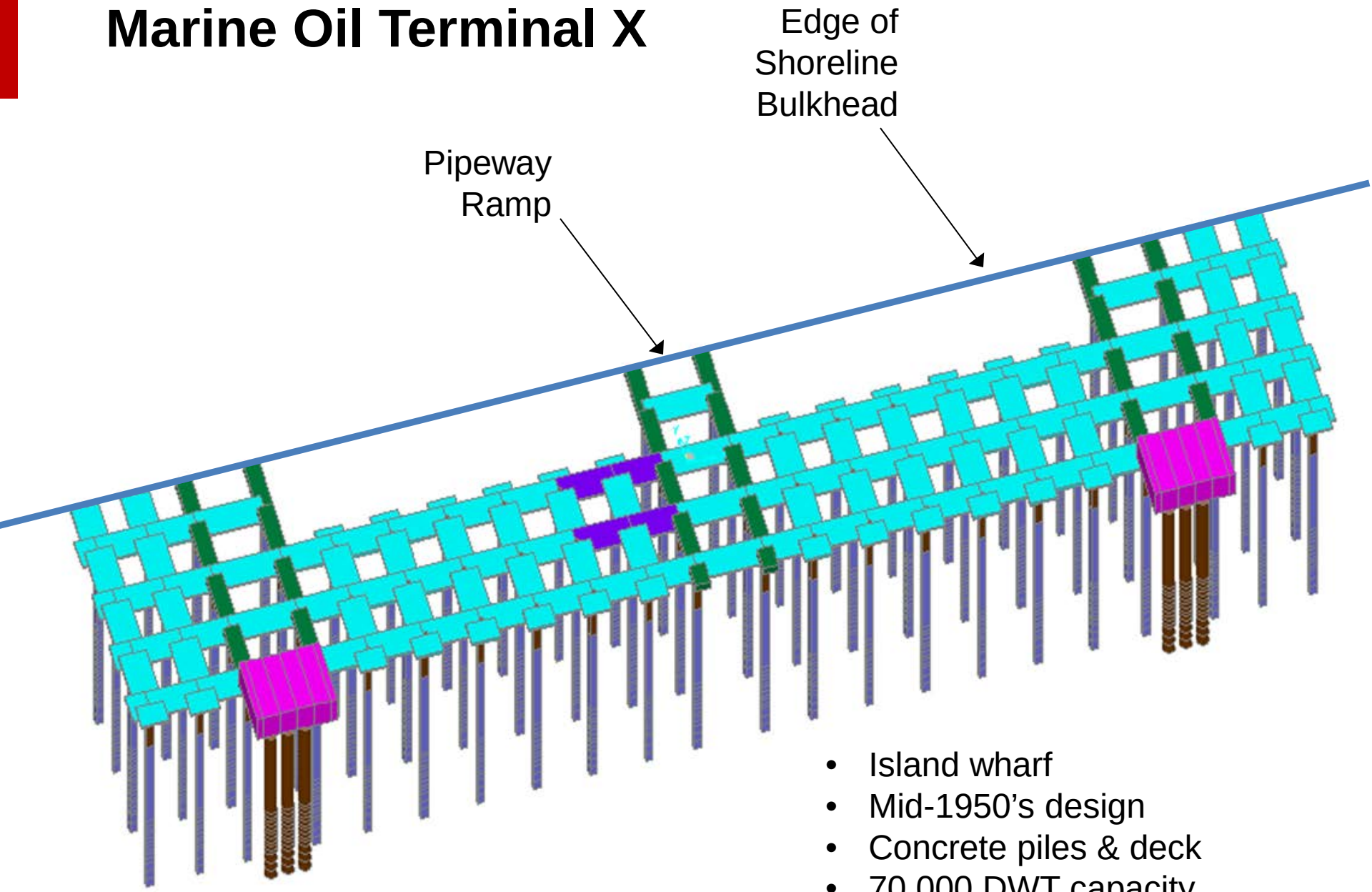
October 7, 2014

Prevention First 2014, Long Beach, California

The story you are about to see is true.

The names have been changed to protect the innocent.

Marine Oil Terminal X

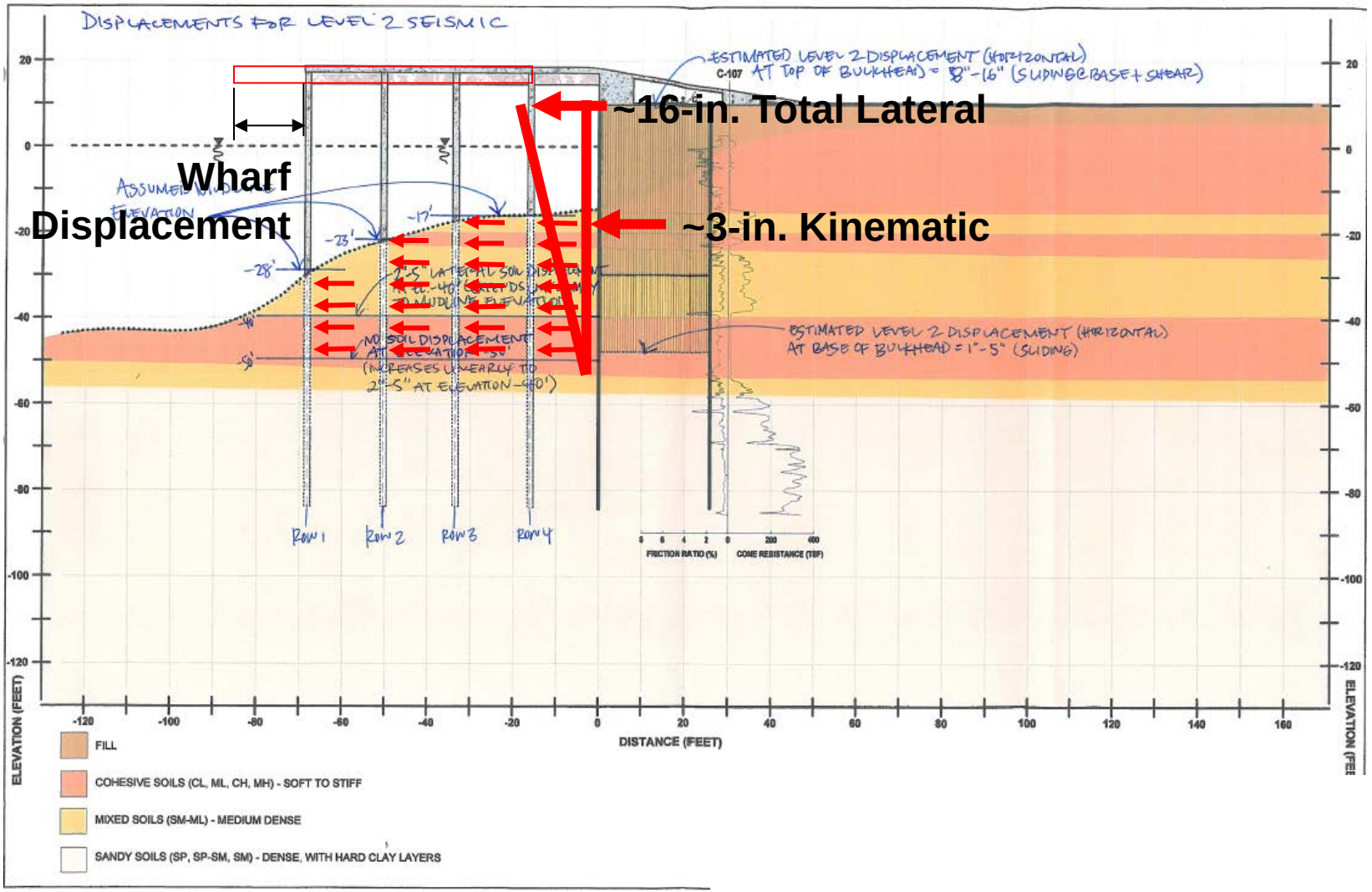


- Island wharf
- Mid-1950's design
- Concrete piles & deck
- 70,000 DWT capacity

Terminal X's MOTEMS History

- Medium Risk MOT
- 2010 Initial Audit Completed
  - Complicated kinematic situation
  - Seismically deficient wharf – but vague on reasons/mitigations
  - Pipelines = spill risk in seismic condition
- 2011-2012 Subsequent Seismic Mitigation Development
  - Goal = Develop mitigation plan
  - Wharf Level 2 compliance verified as-is, except …
    - Ramp Damage = Pipeline spill risk
    - Large Seismic Displacements
      - 44 inches (+/- 22 inches) Perpendicular to Shore
      - 40 inches (+/- 20 inches) Parallel to Shore
      - 12 inches (+/- 6 inches) Vertical Moment
- 2012-2014 Implementation of Mitigation

Level 2 Kinematic Seismic Movements



Terminal X – Impacted Wharf Pipelines

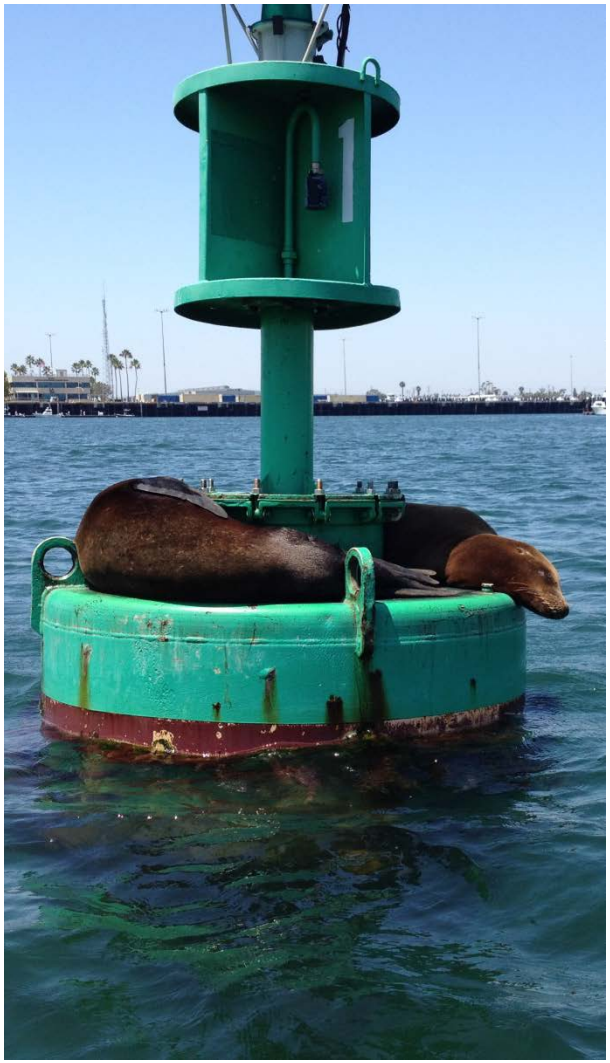
Terminal X – Very Congested

Terminal X's Seismic Compliance Challenges

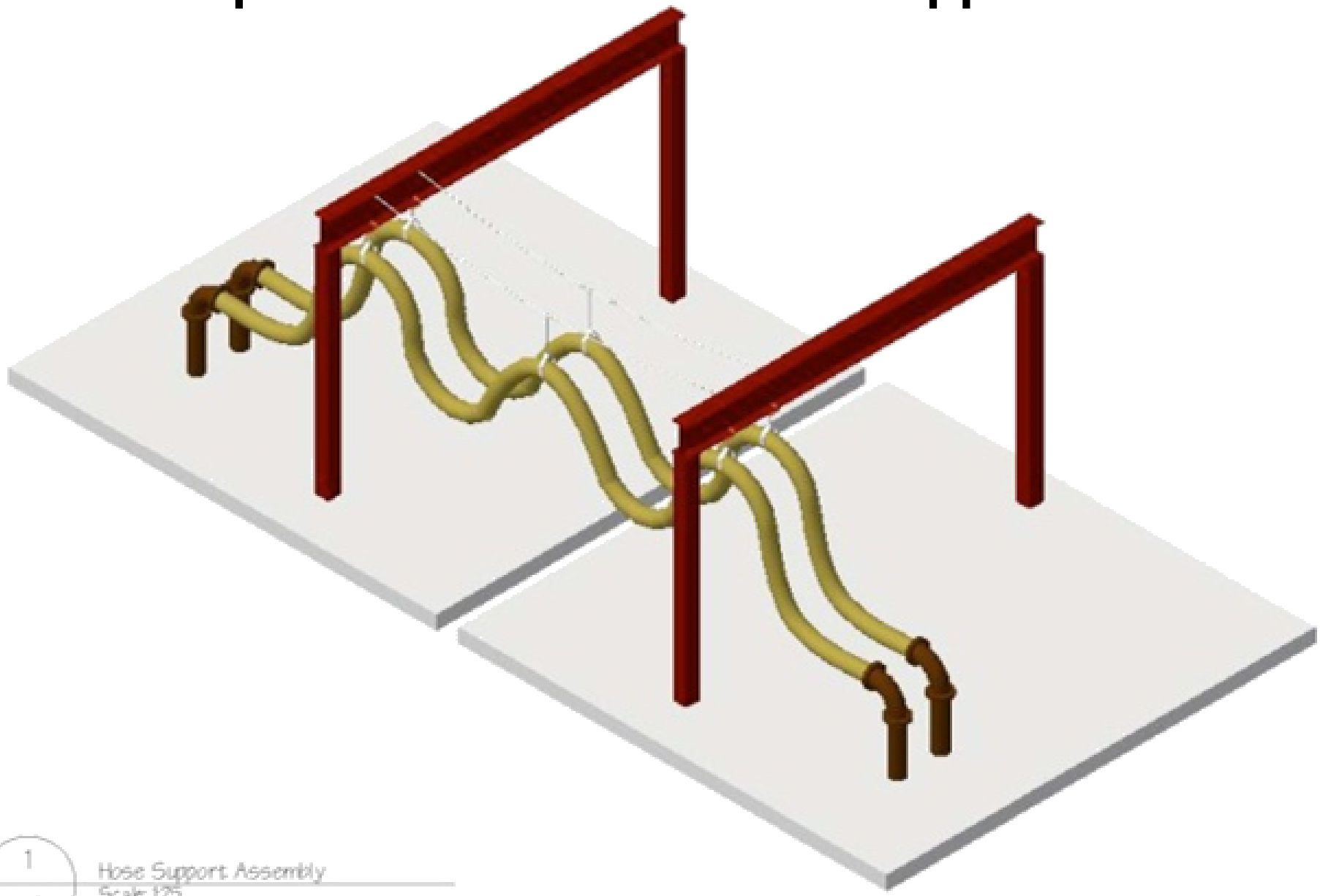
- Large seismic displacements
- Extensive existing infrastructure in project area
- Traditional piping expansion loops would not work !
  - Limited working footprint
  - Convention loops to big
- No clear regulatory path to introduce "new" technologies or non-traditional approaches
- What would State Lands accept?

Terminal X's Mitigation Attack Plan

1) Brainstorm solutions
   - Include all stakeholders
2) Work out the technical issues
   - Avoid the unproven concepts
   - Apply available technologies
   - Minimize regulatory issues
3) Concept ranking
   - Risk reduction & overall safety
   - Present & future cost
   - Regulatory risk
4) Develop regulatory path forward
   - Concept driven
   - Regulator participation
   - Stepped approach



Concept 1 - Conventional Hose Approach



Think Vessel-to-Vessel

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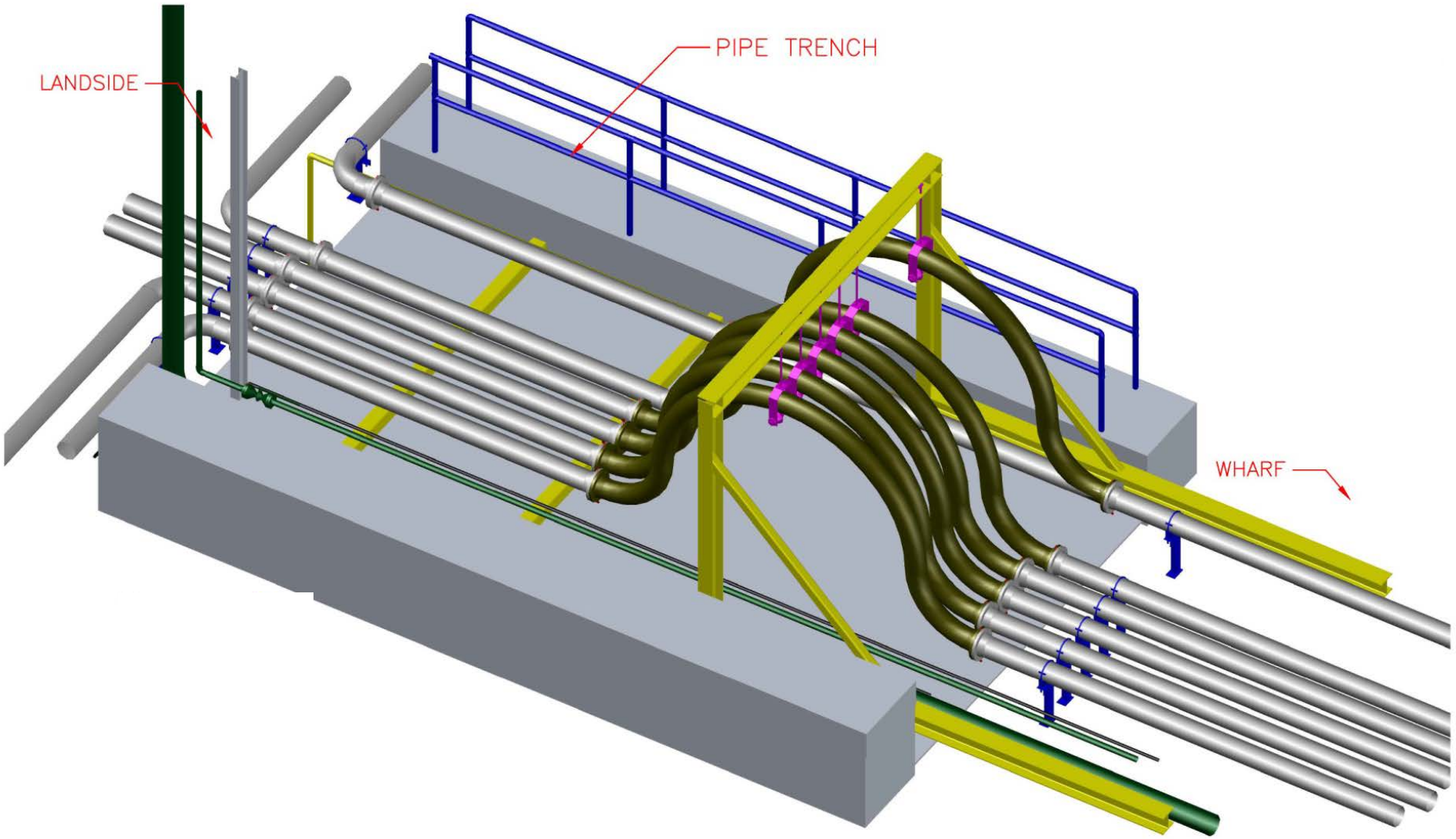
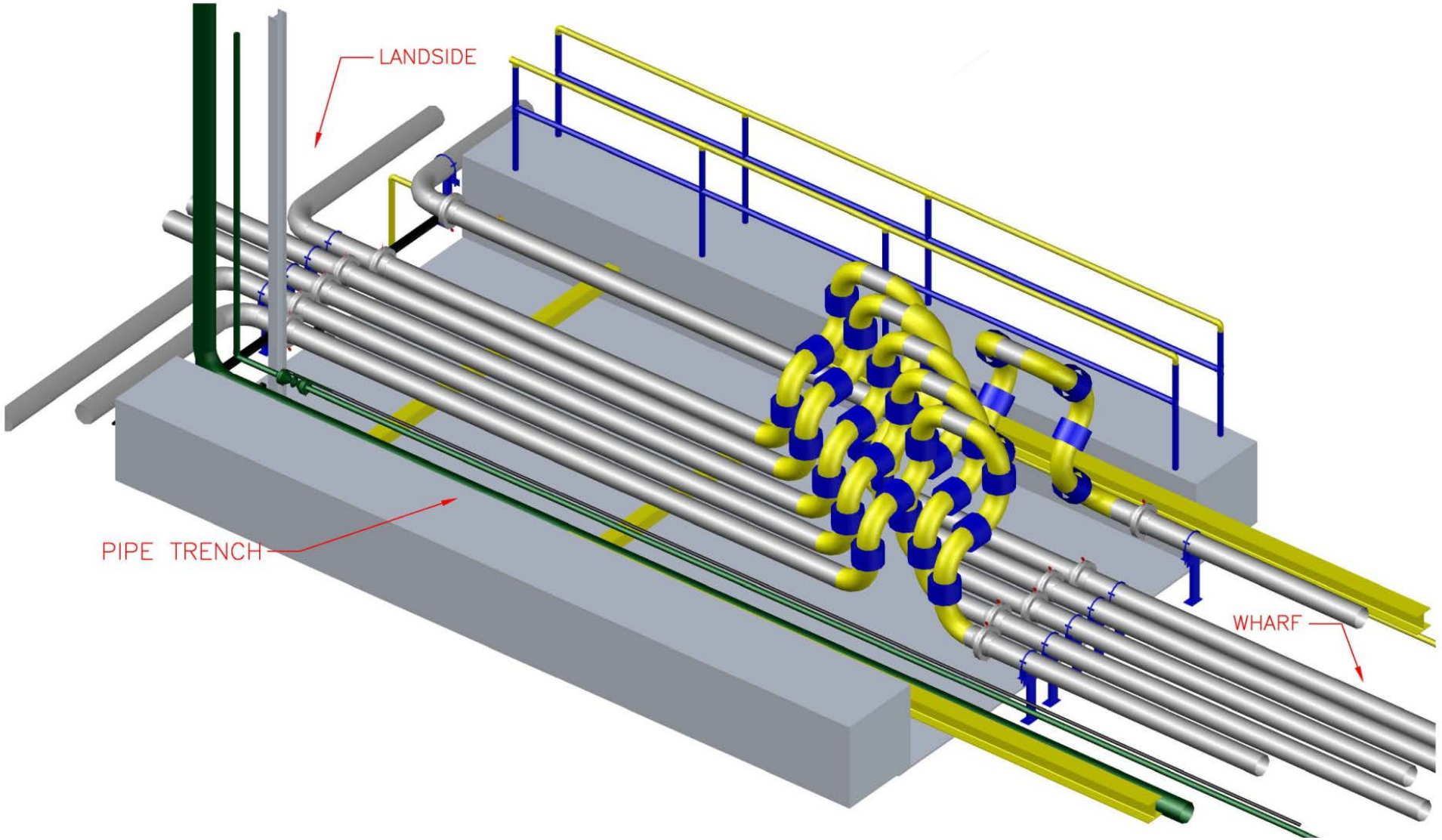
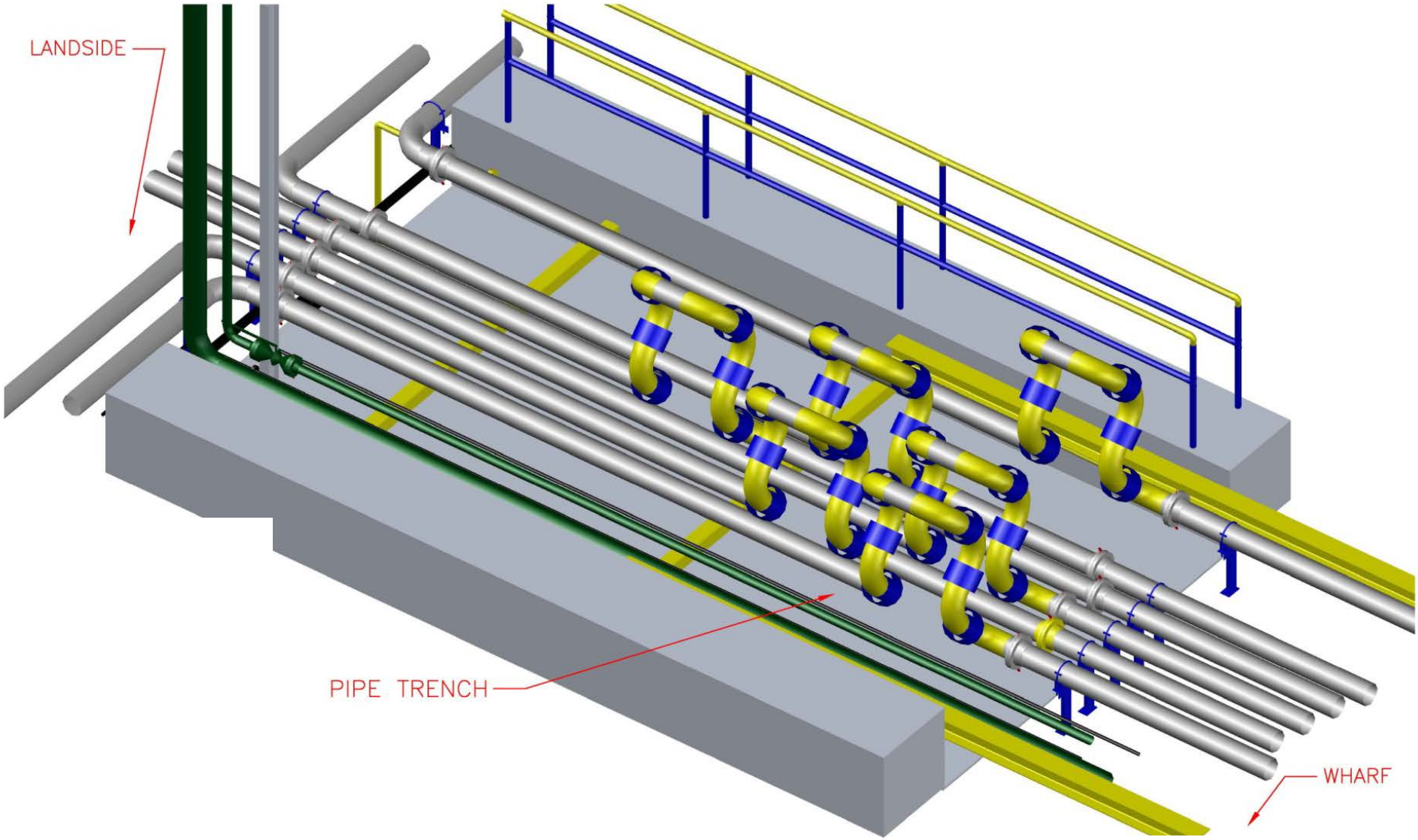
Concept 2 - Flex-Hose Loop Approach



Concept 3a - Swivel Joints – Nested Approach



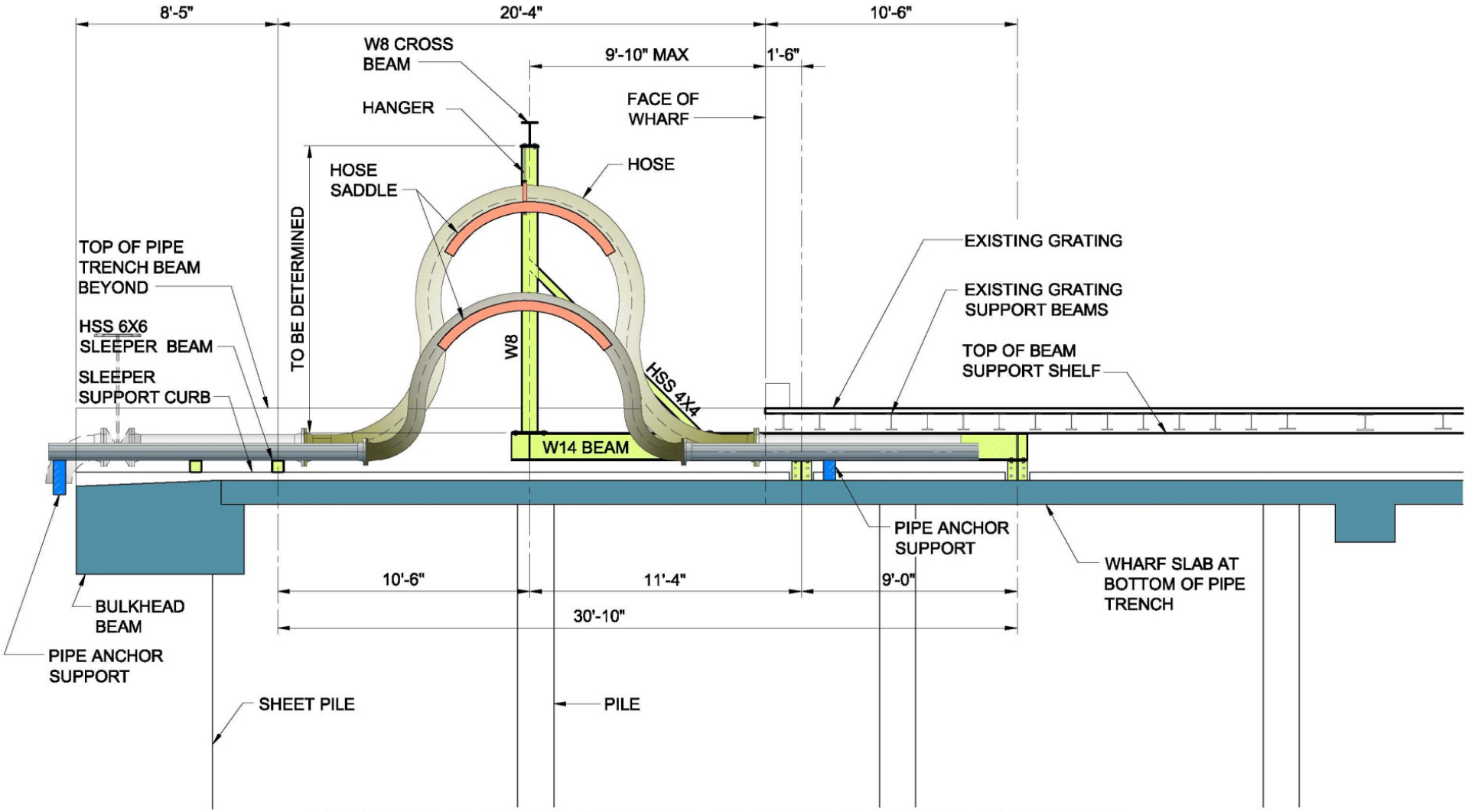
Concept 3b – Swivel Joints – Distributed Approach



Terminal X's Final Decision

- Flex-hose was selected over swivel joint designs
  - Equal safety & spill risk reduction
  - Greater displacement flexibility / More robust
  - Quicker installation
  - Flex-hoses significantly less costly
    - ~½ (even with periodic replacement)
  - No swivel joint maintenance / exercising
- State Lands Concessions
  - Conduct Hazard & Risk Assessment of Concept
  - Flex-hose treated like convention transfer hoses
    - Follow existing hose regulations
    - Annual hydrotesting
    - Maximum replacement interval

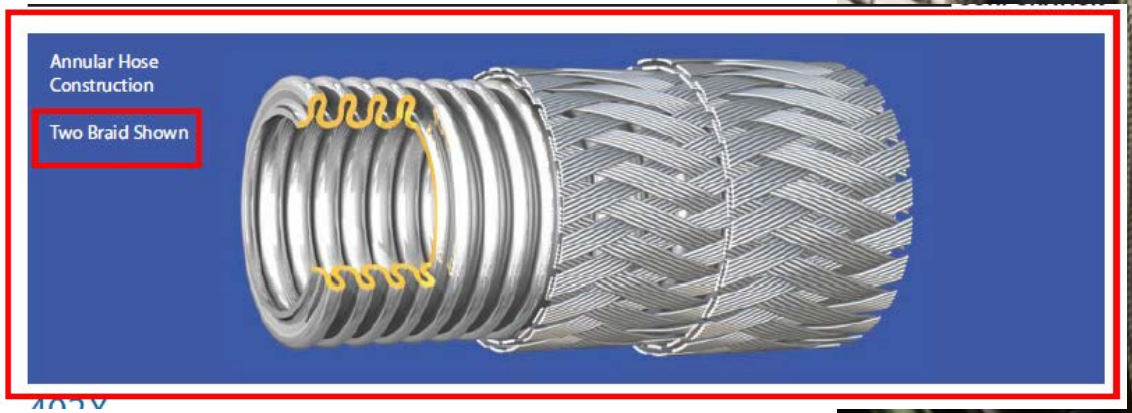
Flex-Hose Loop Design

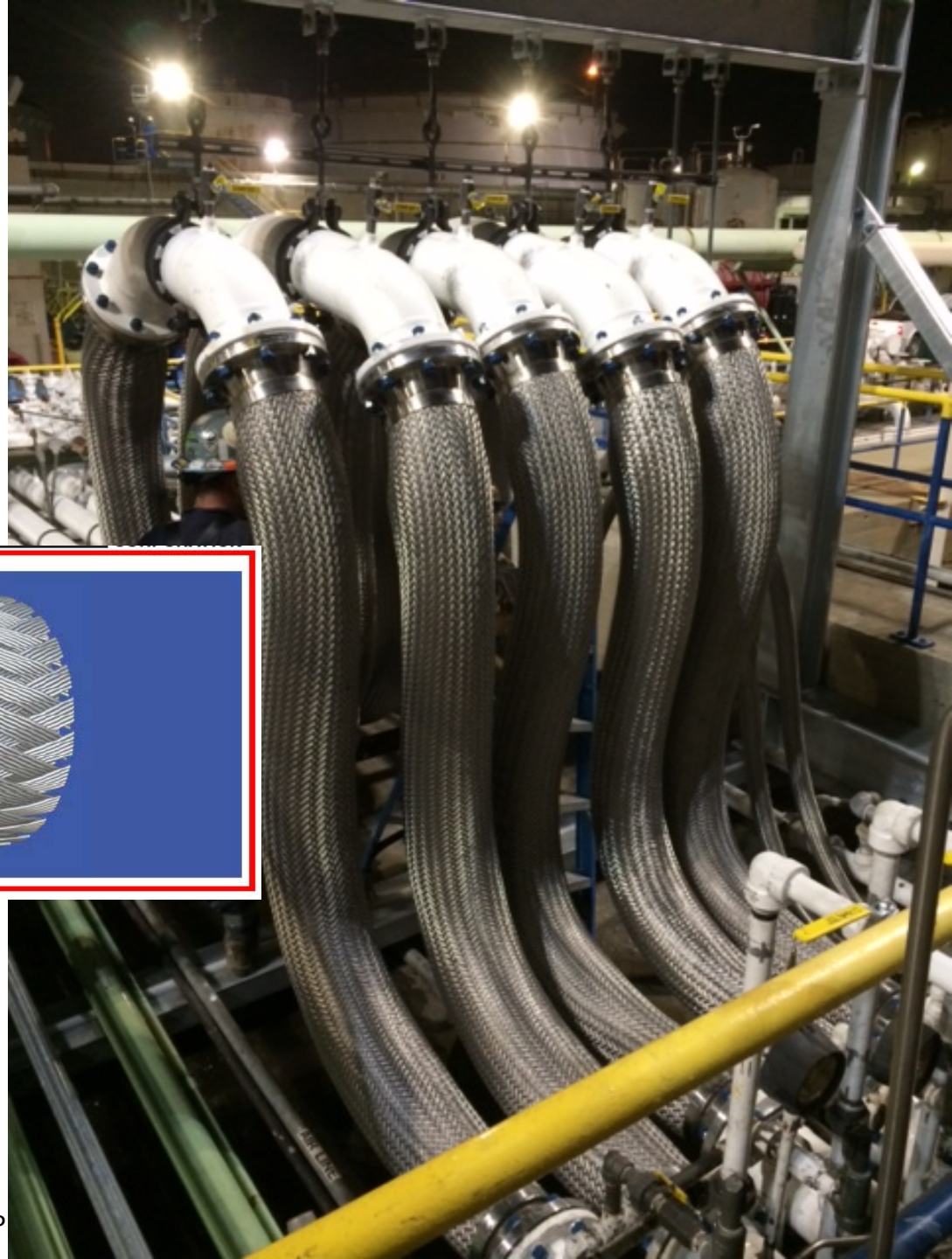


TYPICAL LONGITUDINAL SECTION - HOSE OPTION

Flex-Hose Loop

- Stainless steel double braided hose
- Hard piped hose saddle





Lessons Learned

- Don’t exclude Operators from design! – They know a lot !
- Regulatory approval process takes time – Plan for it !
  - New systems require extra thought
  - Communicate with State Lands often
    - Educate them on goals / problems / constraints
    - Listen to their concerns (often defines path forward)
    - Update them on progress
- Critical systems assessment and hazard & risk assessment are effective tools …
    - to define mitigation scope
      - Pipelines are the only systems requiring post-event operability
      - Not all systems require flexibility
    - to identify design risks
    - to address regulators concerns
    - to document design process

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Questions?

… and special thanks to **Terminal X** for allowing SGH to share their story!