GEOTECHNICAL CONSIDERATIONS FOR PIPING SUPPORT OVER BULKHEADS

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GEOTECHNICAL CONSIDERATIONS FOR PIPING SUPPORT OVER BULKHEADS

BULKHEADS

- LARGE AND STIFF STRUCTURAL ELEMENTS
- SOFT AND WEAK RETAINED FILLS
- MARINE ENVIRONMENT
- SEISMIC LOADING

PIPING SUPPORT CONDITIONS

- HIGHLY VARIABLE
- LARGE GROUND DEFORMATIONS
- UNSTABLE AND EXTREME GROUND CONDITIONS

GEOTECHNICAL CONSIDERATIONS FOR PIPING SUPPORT

VARYING CONDITIONS ALONG PIPING ALIGNMENT

- VARYING SUBSURFACE CONDITIONS
- SOFT AND/OR LIQUEFIABLE SOILS (e.g. HYDRAULIC FILLS)
- UNSTABLE SLOPES
- LATERAL SPREAD AND FAILURE ZONES
- MULTIDIRECTIONAL BENDS IN PIPING
- CONNECTIONS TO OR PENETRATIONS THROUGH STRUCTURES OR TANKS ON DIFFERENT FOUNDATION TYPES

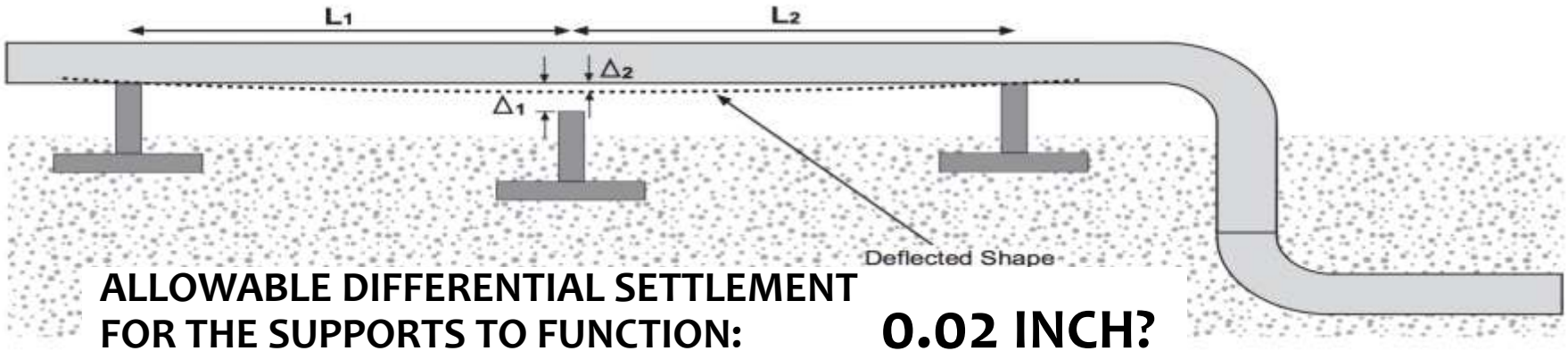
SETTLEMENT AND GROUND DEFORMATIONS

DIFFERENTIAL SETTLEMENT OR SUPPORT CONDITIONS

EXAMPLE - ABOVE GROUND PIPE SUPPORT “FAILURE”

DIFFERENTIAL PIPE SETTLEMENT
ABOVE-GROUND PIPE

FOR THE 42-INCH DIAMETER PIPE WITH 32 FEET SPAN (L1+L2): **DEFLECTION (Δ2) = 0.08 INCH**



ALLOWABLE DIFFERENTIAL SETTLEMENT FOR THE SUPPORTS TO FUNCTION: **0.02 INCH?**

ESTIMATED DIFFERENTTIAL SETTLEMENT: PER DESIGN DOCUMENTS **3/4 INCH**

PIPE SUPPORT "FAILURE"

Observations

- Strap changed support to load
- Other supports affected?
- Solution? Additional Maintenance?
- Wrong foundation type?

Lessons

- Differential settlement critical for piping/support performance
- Allowable differential settlement depends on soil-structure interaction
- Geotechnical estimates of differential settlement are typically for "ground settlement"

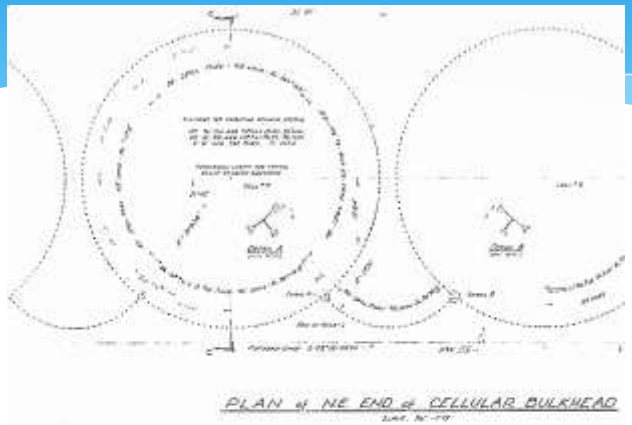
TYPICAL GROUND SETTLEMENT AT A PORT SITE

TABLE 3-3 SUMMARY OF LIQUEFACTION ANALYSIS USING SITE-SPECIFIC SOIL INVESTIGATION

	Approximate Elevations of Liquefiable Zone (ft, MLLW)		Approximate Seismically induced Settlement (inches)	
Boring / CPT	Under Level 1 EQ	Under Level 2 EQ	Under Level 1 EQ	Under Level 2 EQ
09-B1	None	-4.8 to -9.8, -33.5 to -38.5	0.4	2.8
09-B2	None	+5.0 to -24.8	0.7	8.1
09-B3	None	+5.0 to -28.5	2.3	9.9
09-C1	None	+5.0 to -25.2, -32.6 to -39.8, -44.8 to -46.2	0.2	10.4
09-C1A	None	+5.0 to -24.6, -30.8 to -39.5	0.1	10.0
09-C2	None	+5.0 to -0.4, -14.1 to -15.0, -31.1 to -33.1, -39.0 to -41.0, -50.1 to -51.1	0.1	4.9
09-C3	None	+5.0 to -24.6, -33.2 to -40.3, -48.5 to -50.3	0.1	10.3
09-C4	None	-6.2 to -9.5, -32.6 to -35.7, -38.3 to -40.8, -48.0 to -50.0	0.1	3.7
09-C5	None	+2.2 to -1.3, -6.8 to -9.6, -33.1 to -35.4, -36.2 to -39.0, -48.8 to -50.6	0.3	4.8
09-C6	None	+5.0 to +3.8, -2.9 to -16.5, -22.1 to -25.2, -34.7 to -36.4	0.1	6.4
09-C7	None	+4.6 to +4.0, +2.5 to +1.4, -1.9 to -9.5, -30.5 to -33.2, -38.2 to -40.8	0.1	4.9
09-C8	None	+5.0 to -25.3, -32.3 to -35.4, -36.5 to -39.0, -45.9 to -47.5, -60.0 to -61.3	0.0	8.9

Reference: Chemoil MOTEMS Initial Audit report, 2009, by Earth Mechanics, Inc.

BURIED PIPING SUPPORT AT PORT FACILITIES WITH SHEET PILE BULKHEAD



CELL DIAMETER:
62 FEET

EMBEDMENT TO:
-60 FEET MLLW

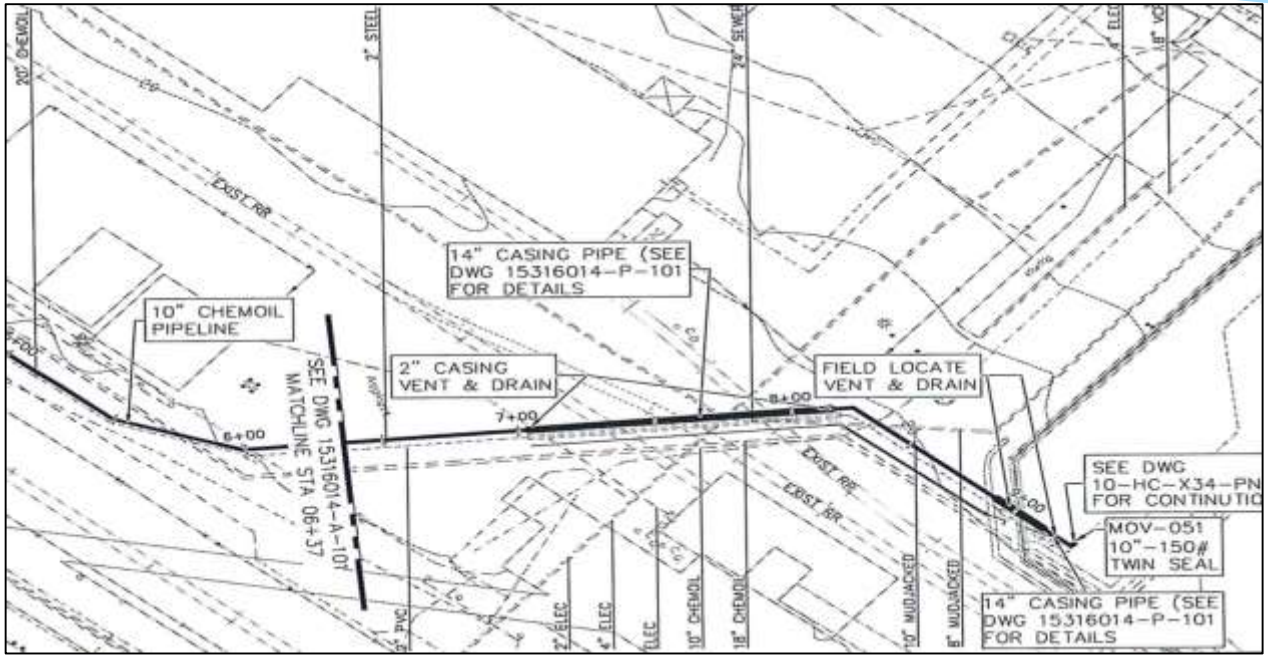
VARIABLE SUPPORT CONDITIONS OVER SHORT DISTANCES:

- VERTICAL SETTLEMENT OF SHEET PILES LESS THAN **1 INCH**
- LATERAL SHEAR DEFORMATION OF SHEET PILES – **UP TO 3 FEET**
- SETTLEMENT OF FILL INSIDE OR OUTSIDE CELL: **3 TO 11 INCHES**

VALVE WITHIN THE CELL NEEDS TO BE FUNCTIONAL AT ALL TIMES

BURIED PIPING SUPPORT AT PORT FACILITIES WITH SHEET PILE BULKHEAD

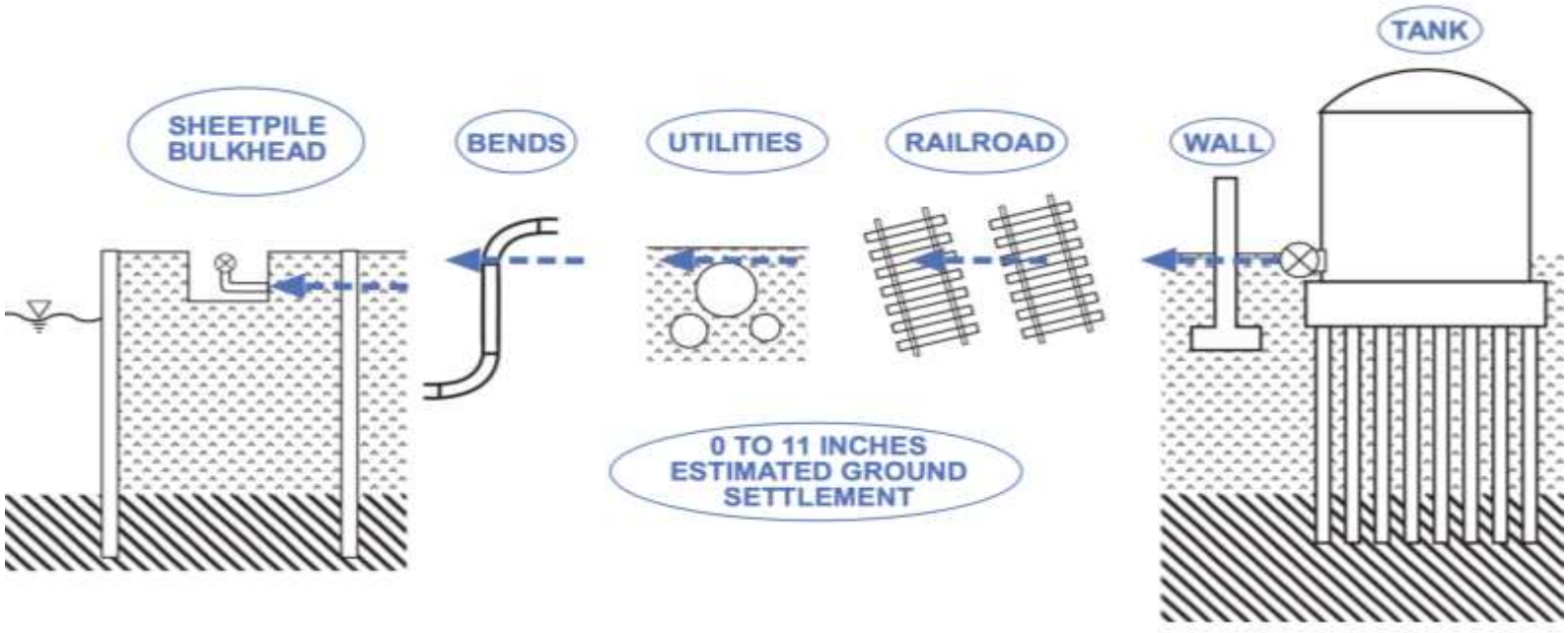
PARTIAL SITE PLAN



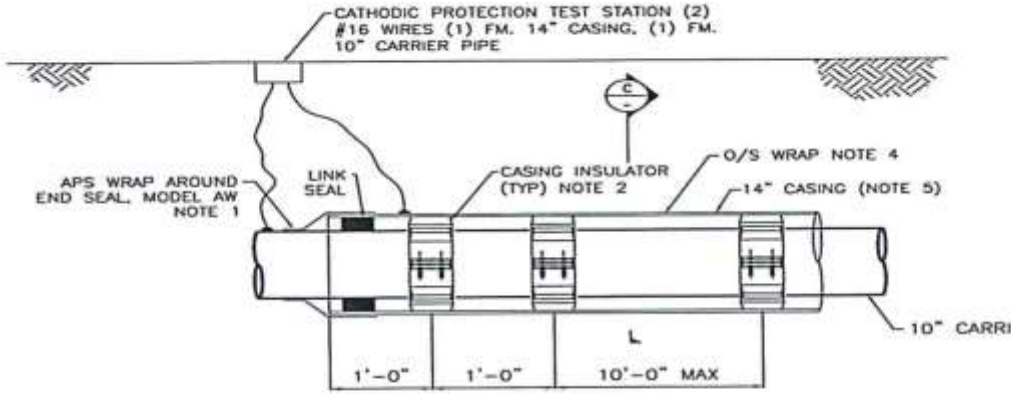
- 10-INCH DIA. TRANSMIX LINE
- ~900 FEET LENGTH
- ORIGINATE FROM TANK FARM
- ENDS AT VALVEPIT WITHIN BULKHEAD CELL
- VARIOUS UTILITIES AND RAILROADS

BURIED PIPING OVER BULKHEAD

VARIABLE SUBSURFACE CONDITIONS



CASING DETAIL
AT RAILROAD CROSSING

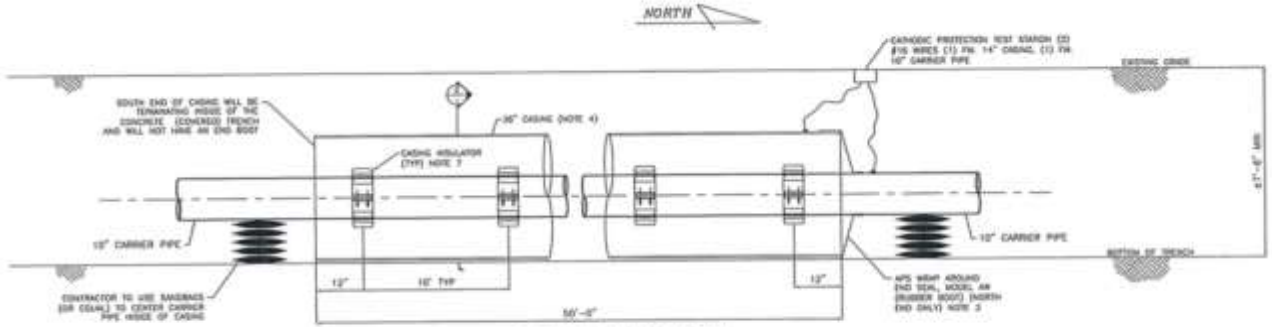


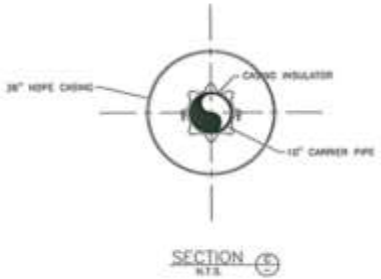
TYPICAL CASING AND INSULATOR DETAIL
(TYPICAL BOTH ENDS)

SECTION
N.T.S.

Reference: Chemoil Transmix Line Drawings, 2017, by IQA Solutions, Inc.

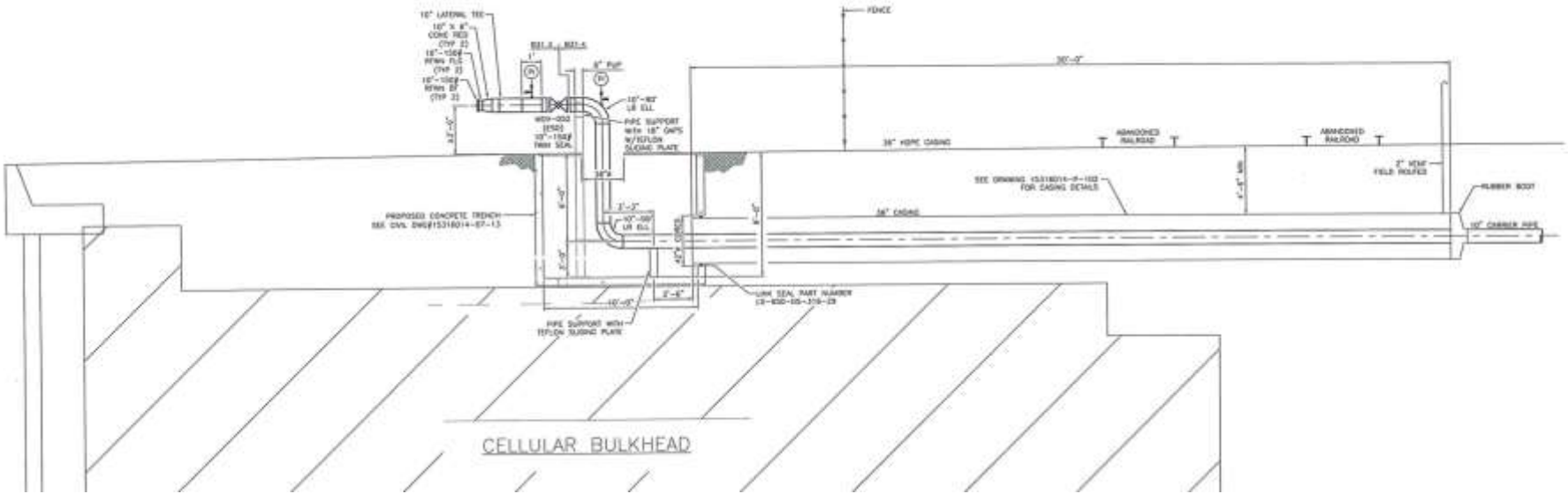
CASING DETAIL
AT BULKHEAD AND VALVEPIT





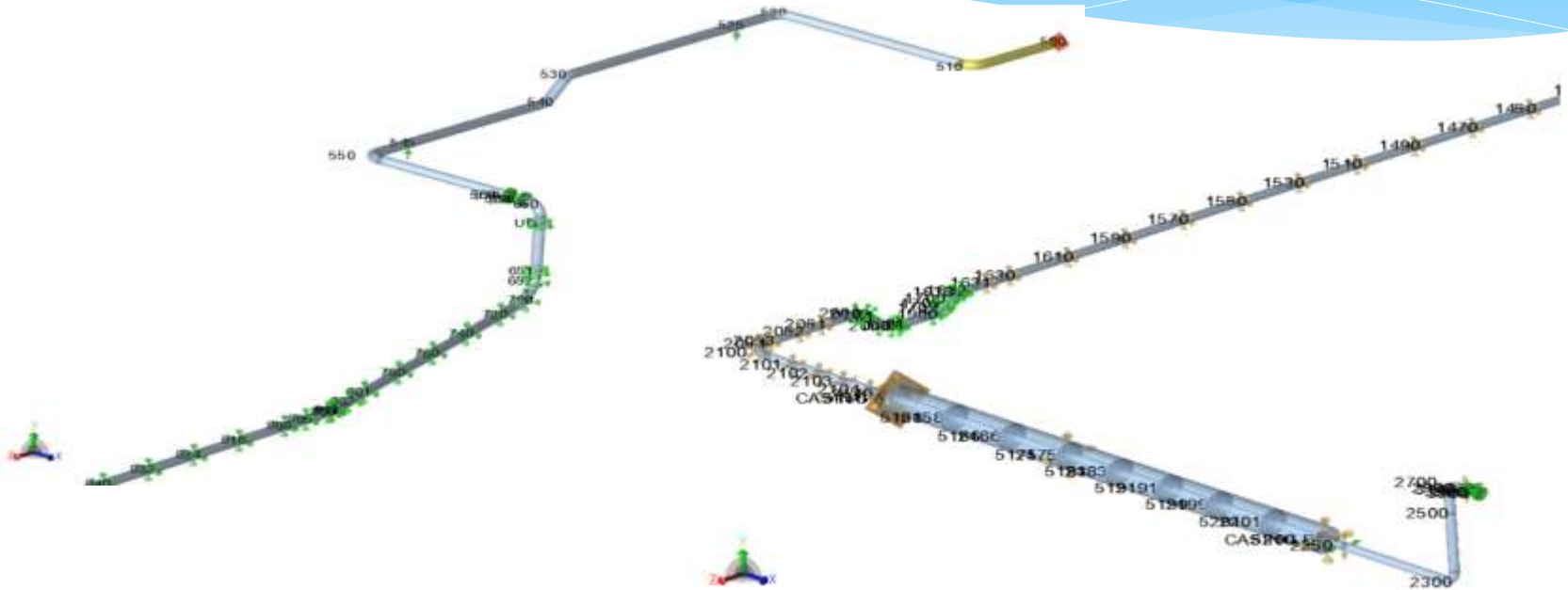
Reference: Chemoil Transmix Line Drawings, 2017, by IQA Solutions, Inc.

CASING ARRANGEMENT
AT BULKHEAD AND VALVEPIT

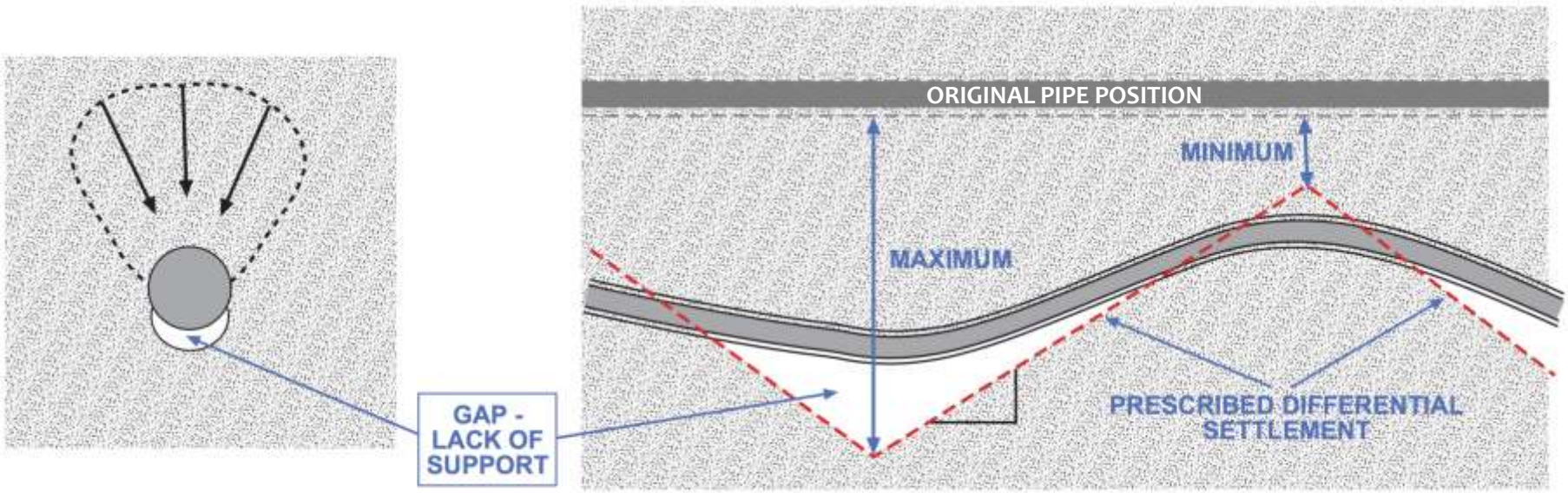


Reference: Chemoil Transmix Line Drawings, 2017, by IQA Solutions, Inc.

PIPE STRESS ANALYSIS MODELS



MODELING OF GROUND DEFORMATION



ABOVE AND BELOW GROUND PIPING PROS AND CONS

ABOVE-GROUND GROUND PIPING

INSPECTION AND MAINTENANCE

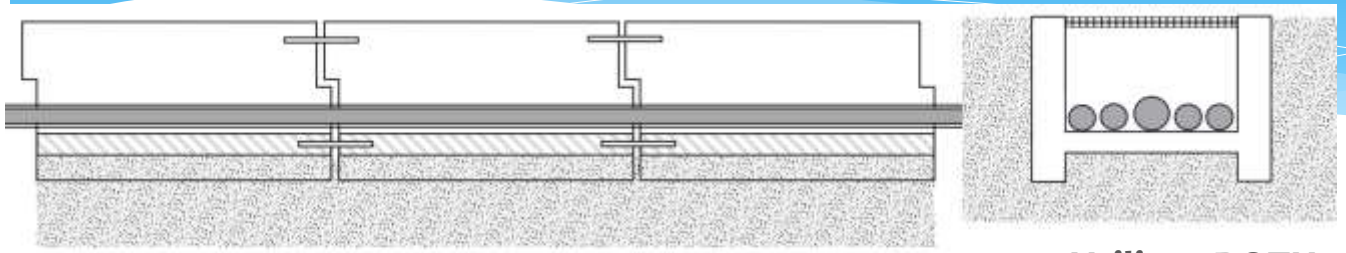
LOSS OF USABLE SPACE

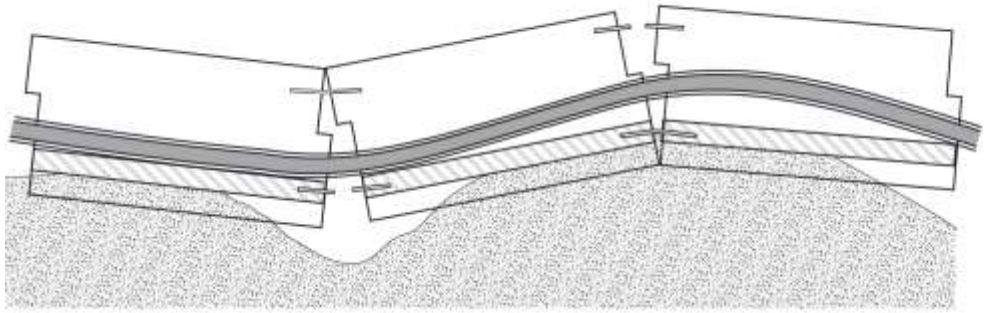
CONSTRUCTION COST

EXTREME SITE VARIABILITY

BELOW-PIPING

DESIGN FOR EXTREME SITE VARIABILITY
Ground movement in feet; Failure/Flow zones
REINFORCED CONCRETE PIPE TRENCH WITH JOINTS





- **Utilizes BOTH concrete strength/ stiffness and pipe ductility**
- **May be re-leveled after earthquake**
- **Combines advantages of both above and below grade piping**
- **Additional protection layers possible**
- **Possible alternate to ground improvement in some cases**

DESIGN STRATEGY FOR PIPING SUPPORT

- ISOLATE PIPE FROM SUDDEN VARIATIONS IN SUPPORT CONDITIONS
- MAINTAIN AND UTILIZE PIPE DUCTILITY
- RELATIVE STIFFNESS OF SUPPORTS SHOULD BE GREATER THAN THE STIFFNESS OF PIPING
- NONLINEAR SOIL-STRUCTURE INTERACTION ANALYSES NEEDED FOR EXTREME CONDITIONS
- COMBINE FOUNDATIONS IF POSSIBLE
- AVOID BENDS AND OTHER FEATURES IF POSSIBLE
- PROVIDE LAYERS OF PROTECTION IN EXTREME SUBSURFACE CONDITIONS
- CONSIDER ALTERNATIVES TO GROUND IMPROVEMENT

Acknowledgements

* **CSLC**
* **Chemoil Terminals Corporation**
* **Earth Mechanics Inc.**
* **IQA Solutions Inc.**