

BUILDING A WORLD OF DIFFERENCE

FAULT CROSSING DESIGN OF 66-INCH PIPELINE SAN FRANCISCO HETCH-HETCHY WATER SYSTEM

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San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission



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AGENDA

SFPUC Water System

Seismic Hazards

Pipeline Response to Faulting

Analysis Methodology

Design

Long Term Monitoring

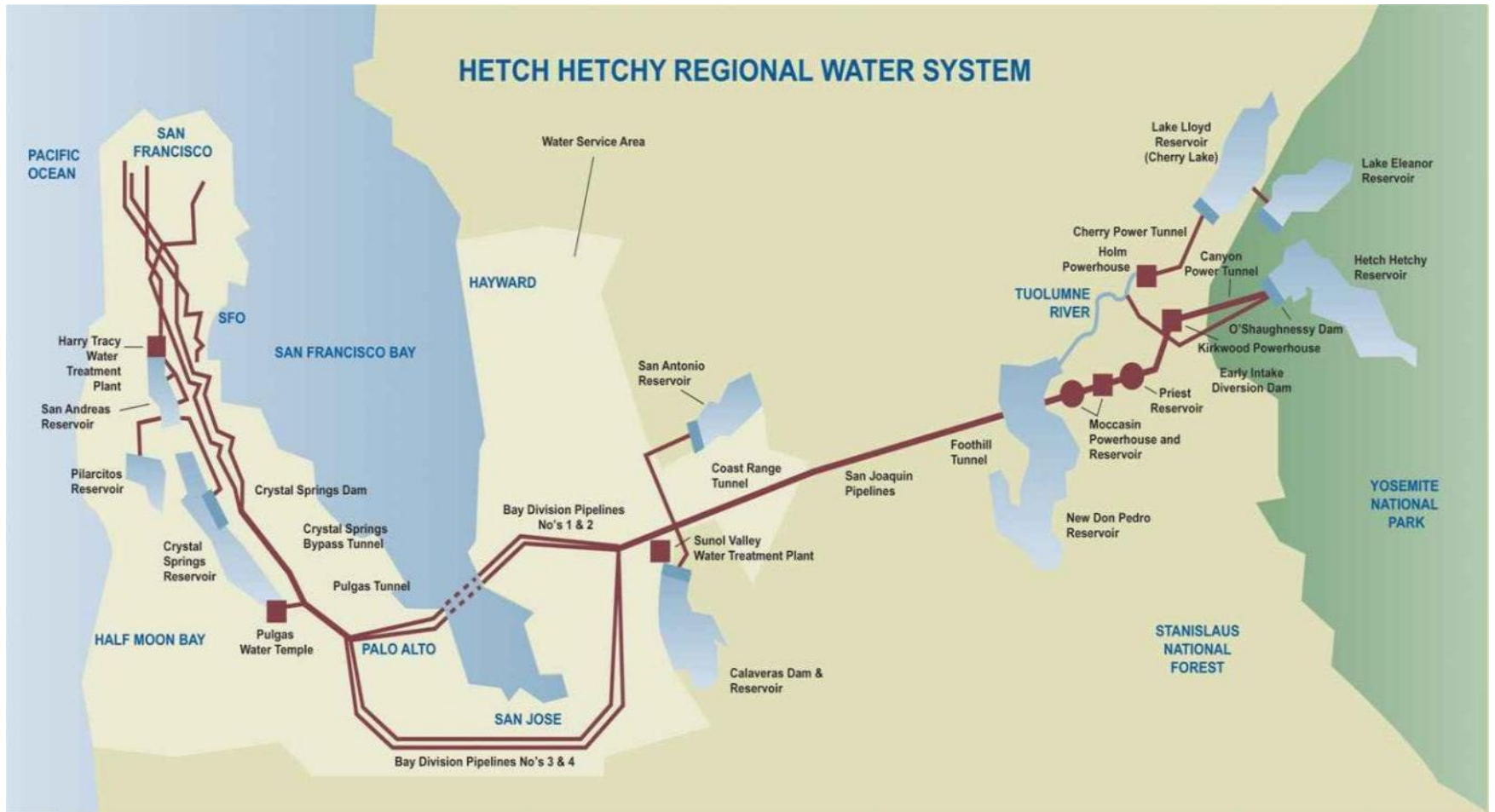


ABOUT SFPUC

- Department of the City and County of San Francisco
- Water
 - Retail water services to San Francisco
 - Wholesale water to four Bay Area counties
 - Serving 2.6 million customers
- Wastewater services to San Francisco
- Hydroelectric and solar power to San Francisco's municipal departments

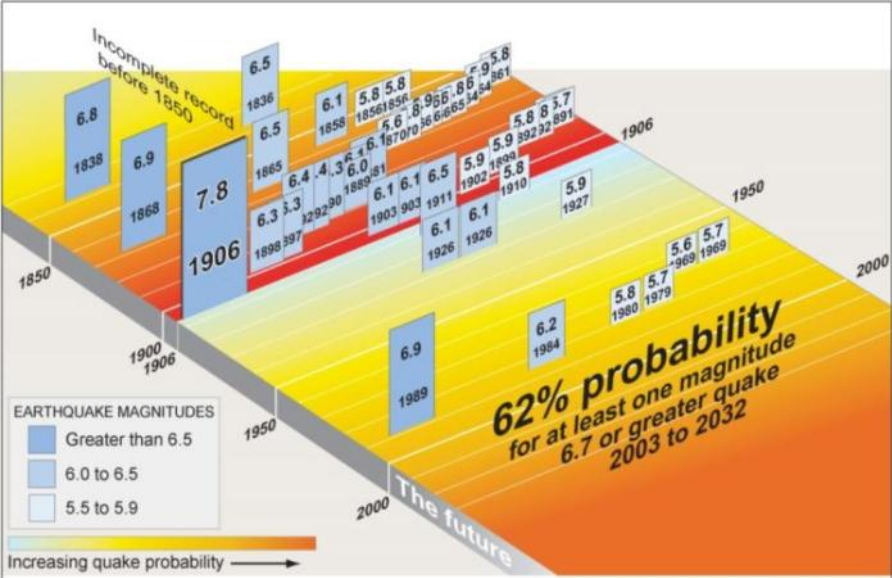


SFPUC WATER SYSTEM



SEISMIC HAZARD

- High probability of a major earthquake in the San Francisco Bay Area

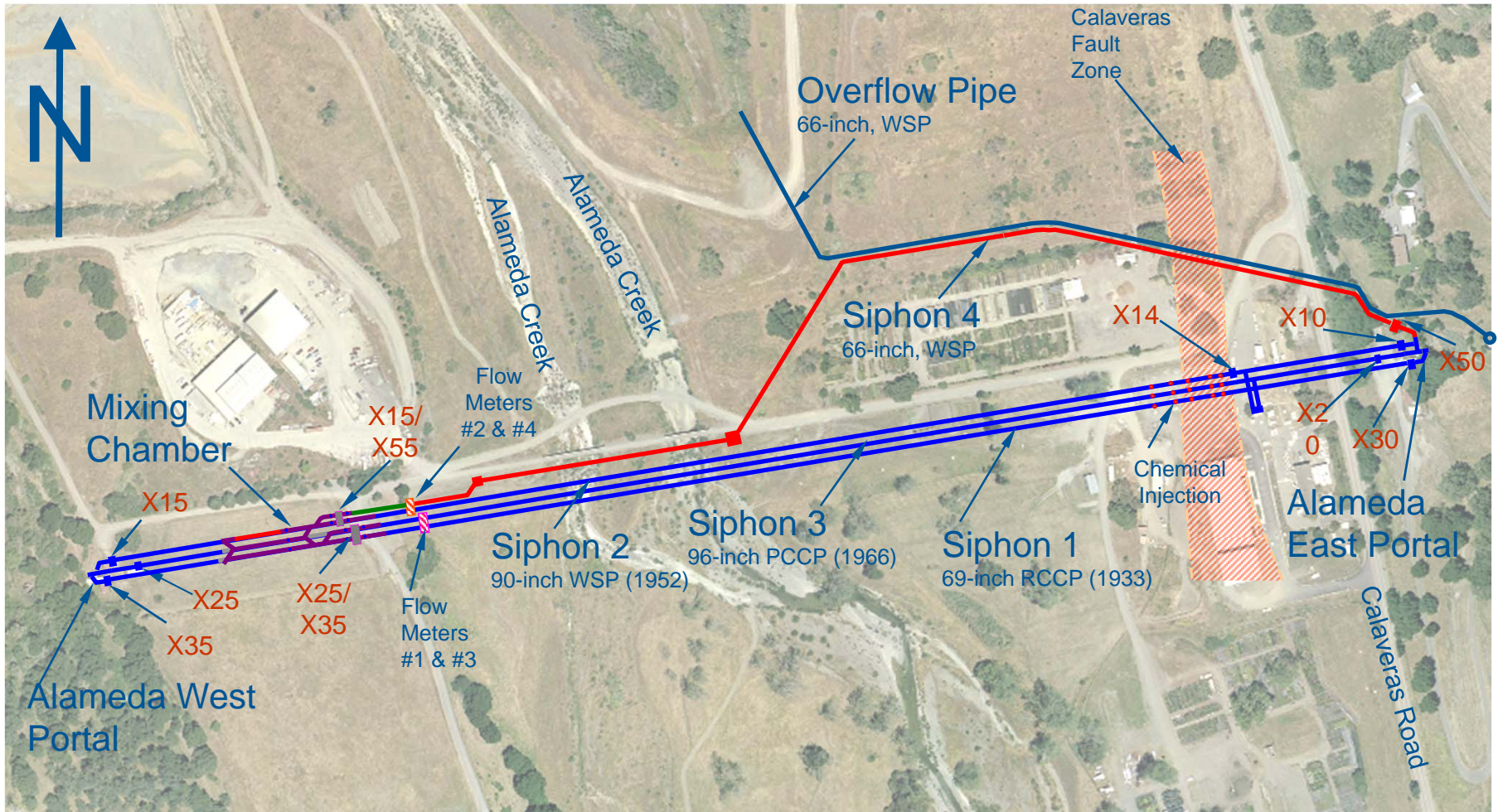


WATER SYSTEM IMPROVEMENT PROGRAM (WSIP)

- **Program Overview**
 - **\$4.6 billion infrastructure improvement program**
 - **Started 2005 Forecast Complete 2016**
- **LOS AS4 Goals**
 - **Minimum 120 mgd required within 24 hours of a major earthquake**
 - **Minimum 160 mgd required within 30 days of a major earthquake**
- **AS4 Project Goals**
 - **Reliable water transmission across Sunol Valley**



CALAVERAS FAULT CROSSING



PROJECT DETAILS

- **Project Components**

- AS4 pipeline
- AEP connection/upgrade
- Other

- **Constraints**

- Connection to 1930s Infrastructure
- Proximity of Calaveras Road
- Uncertainty in fault location

- **Project Cost**

- Approved Total Budget \$65m

- **Status**

- Const. completion: Mar, 2013
- Pipeline Monitoring Survey



DESIGN CONSIDERATIONS



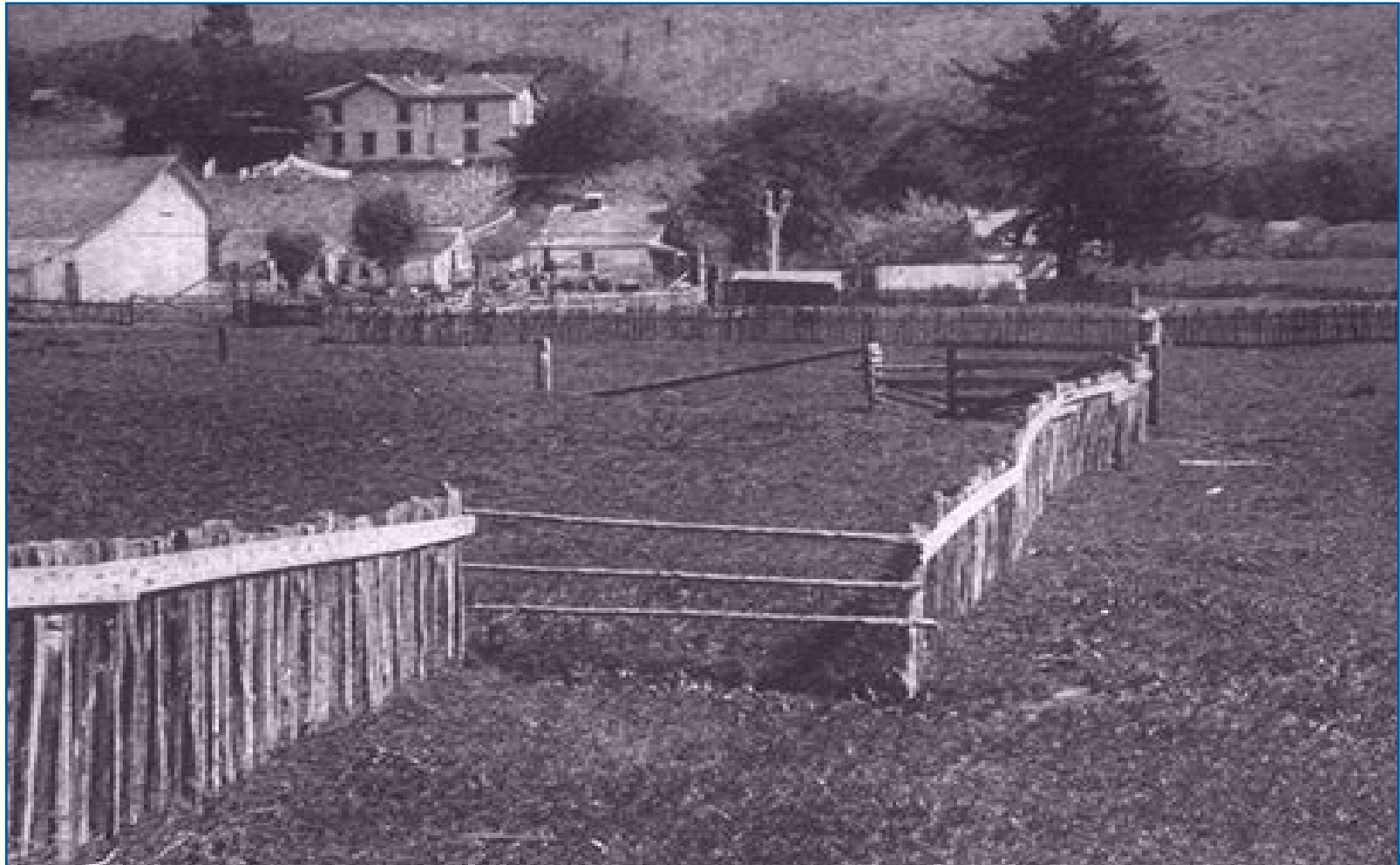
PIPELINE DAMAGE IN PAST EARTHQUAKES



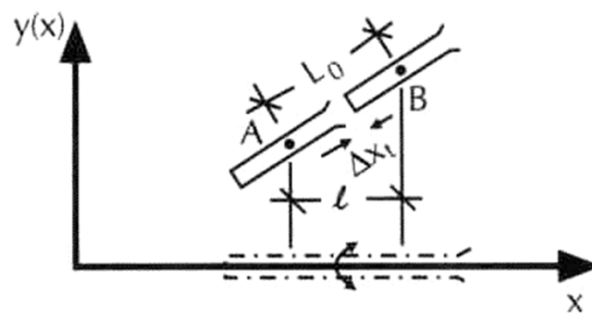
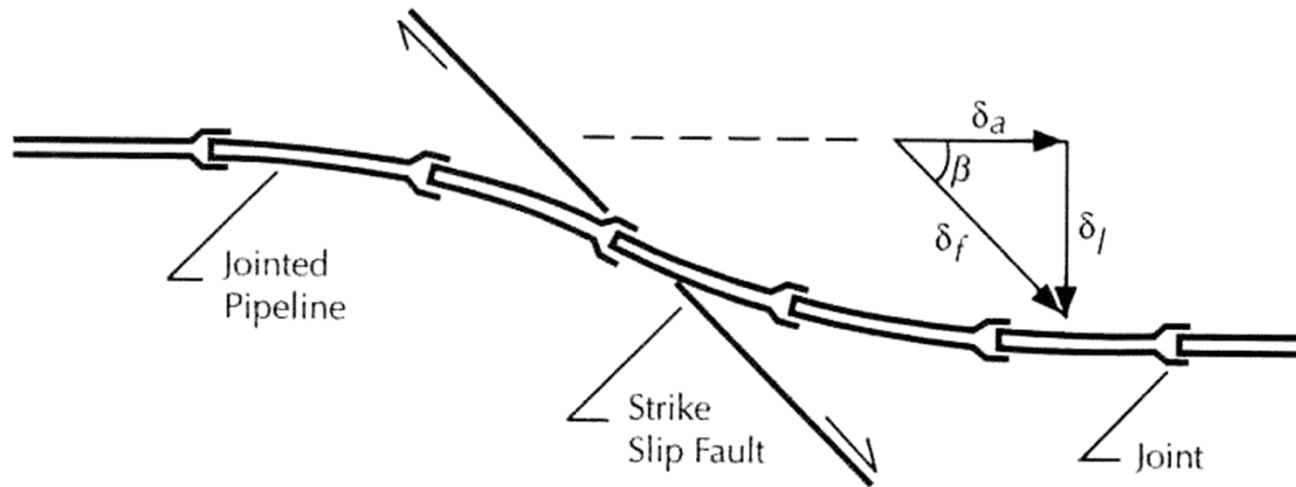
Rupture in 120-inch Soledad Siphon (1994 Northridge Earthquake)



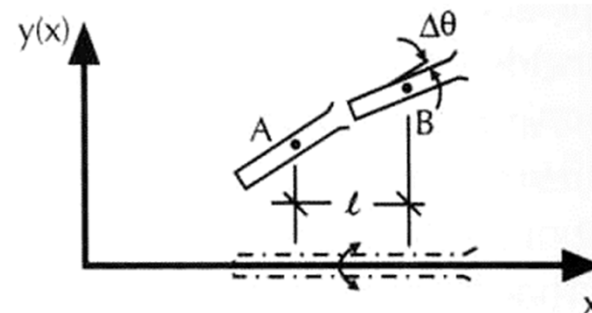
FAULT RUPTURE



PIPELINE RESPONSE TO FAULTING



(a) Joint Extension



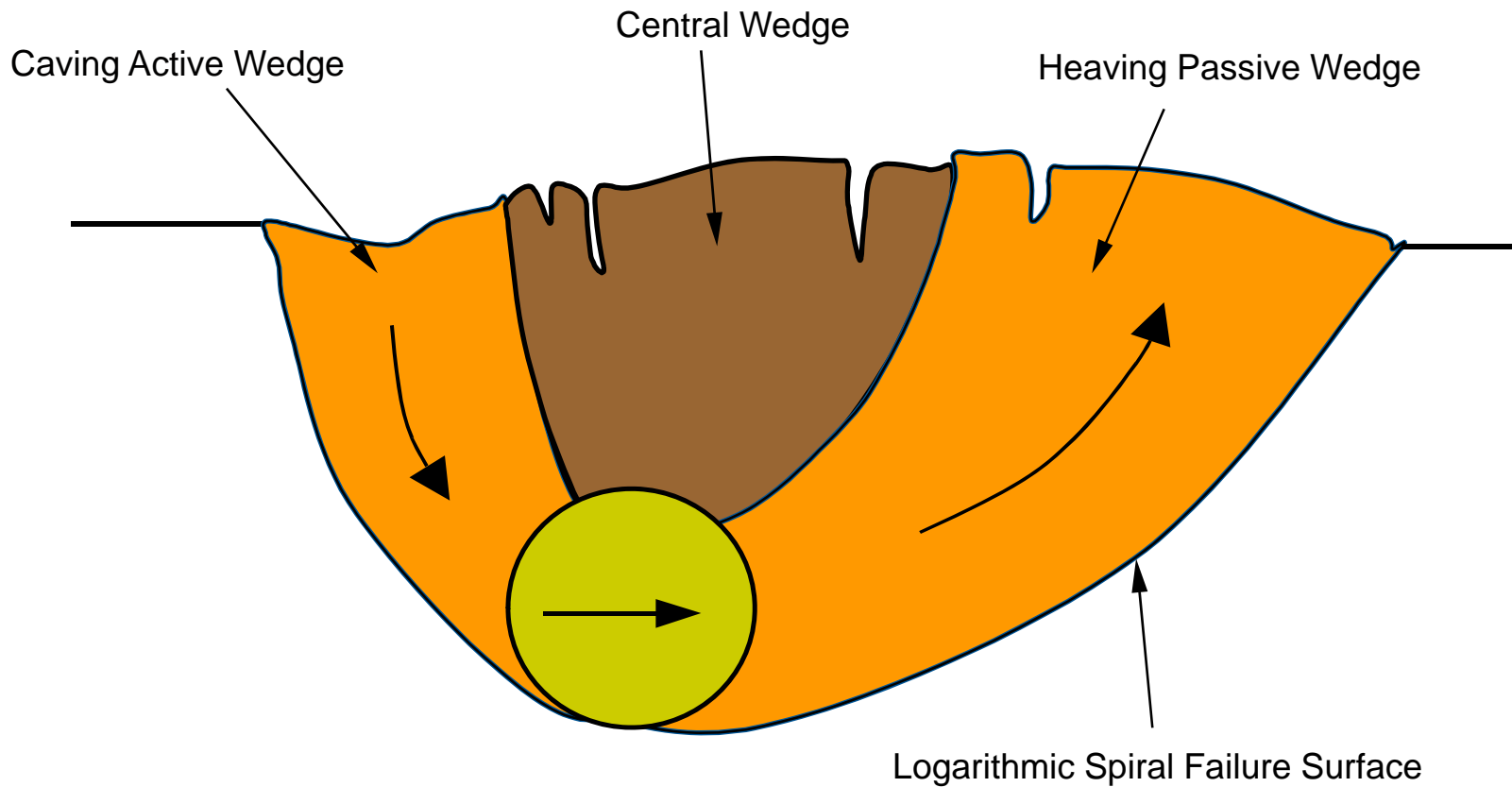
(b) Joint Rotation

Segmented Pipeline

Ref:



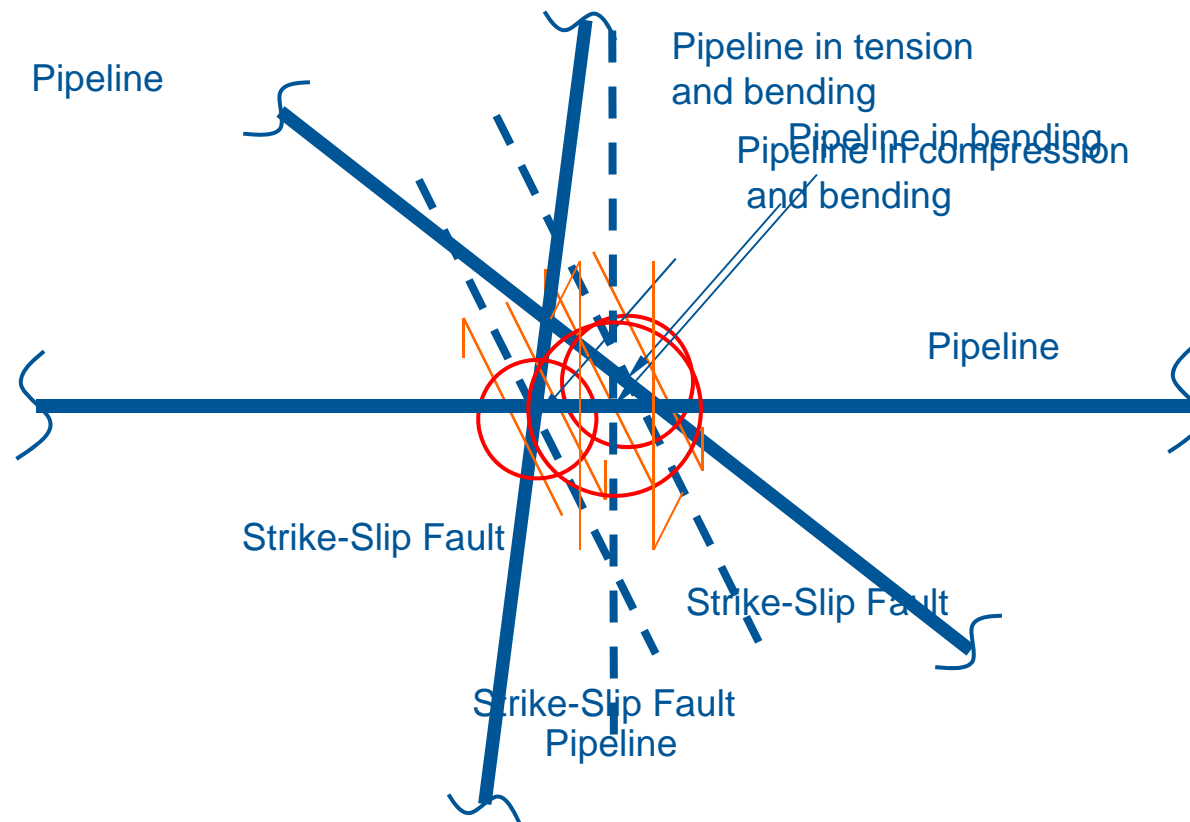
PIPELINE RESPONSE TO FAULTING



Continuous Pipeline



PIPELINE RESPONSE TO FAULTING



Angle of Crossing = 90 Degrees

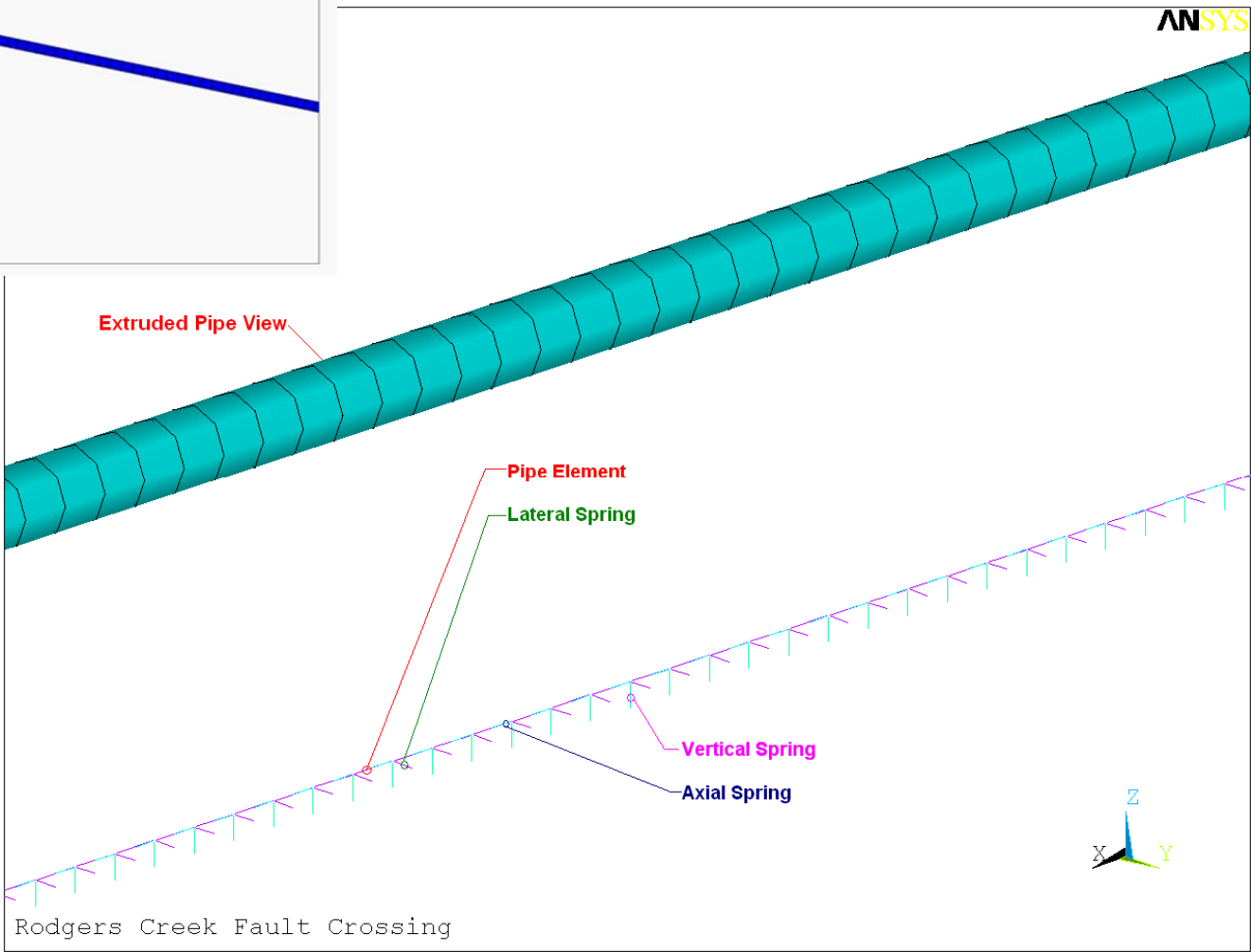


SPECIAL DESIGN REQUIREMENTS

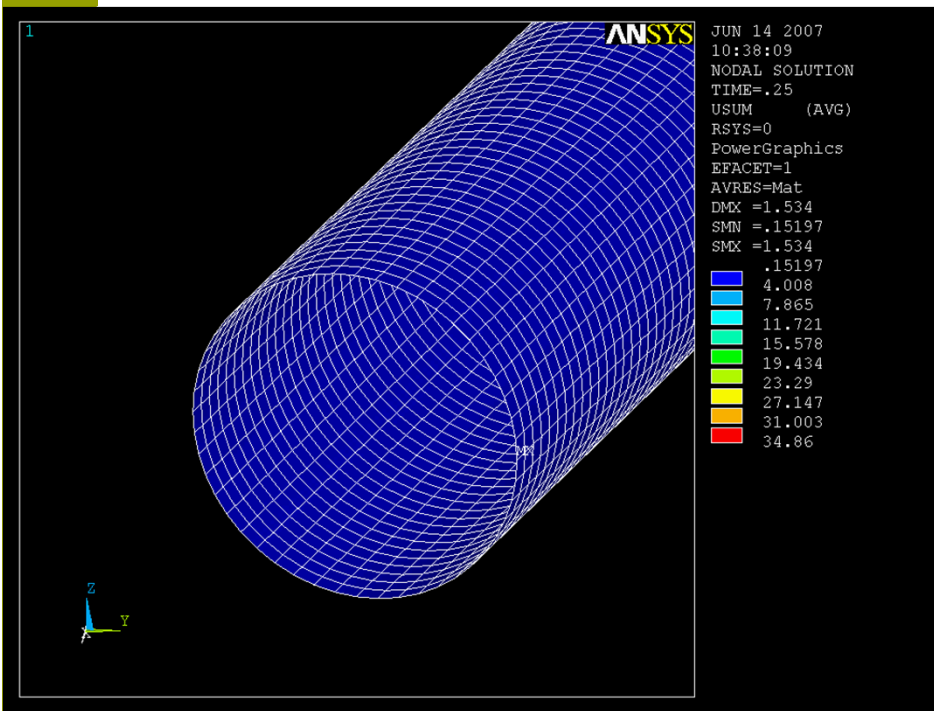
- Acceptance Criteria
 - Average Tensile Strain Limit = 4%
 - Compressive Strain Limit = 3.7% (D/t ratio)
- Material Properties
 - Yield Strength
 - Yield to Ultimate Strength Ratio

Controlled Plasticity

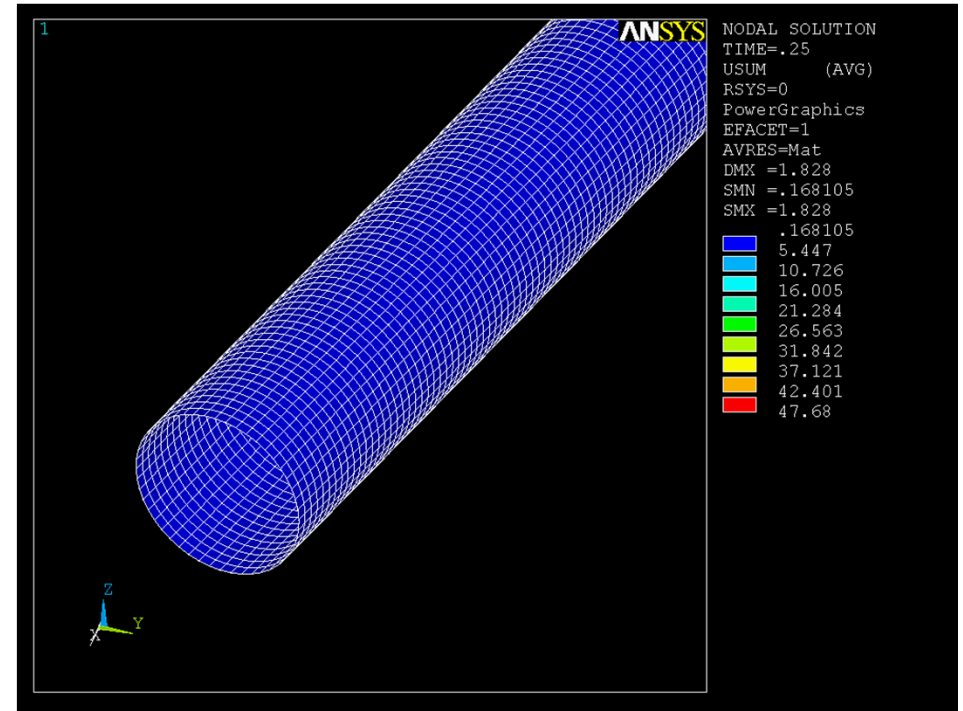




PIPE OVALIZATION STUDY



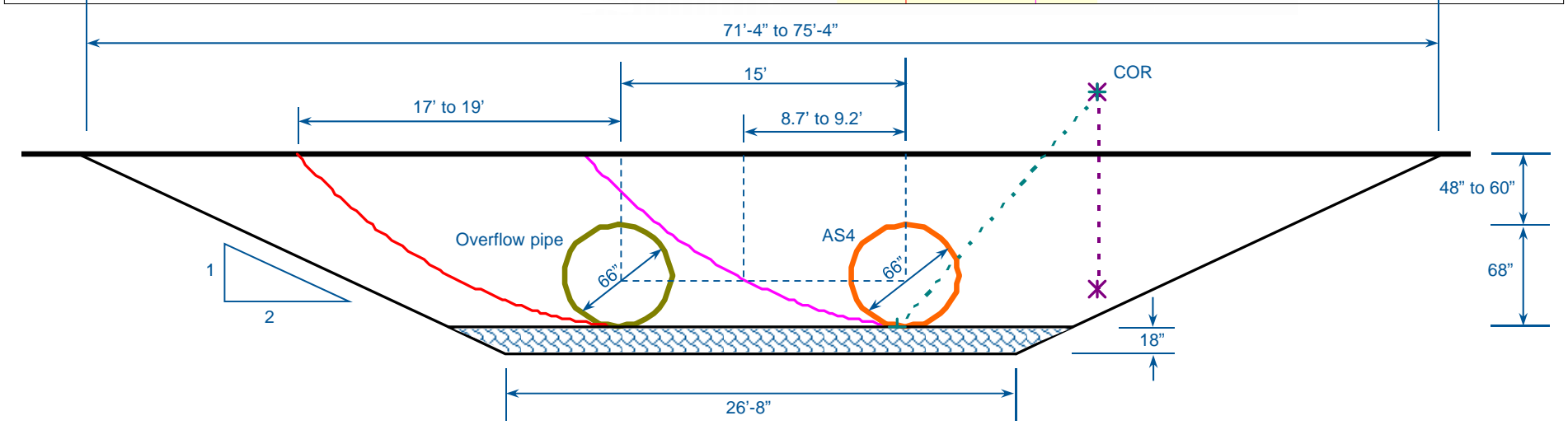
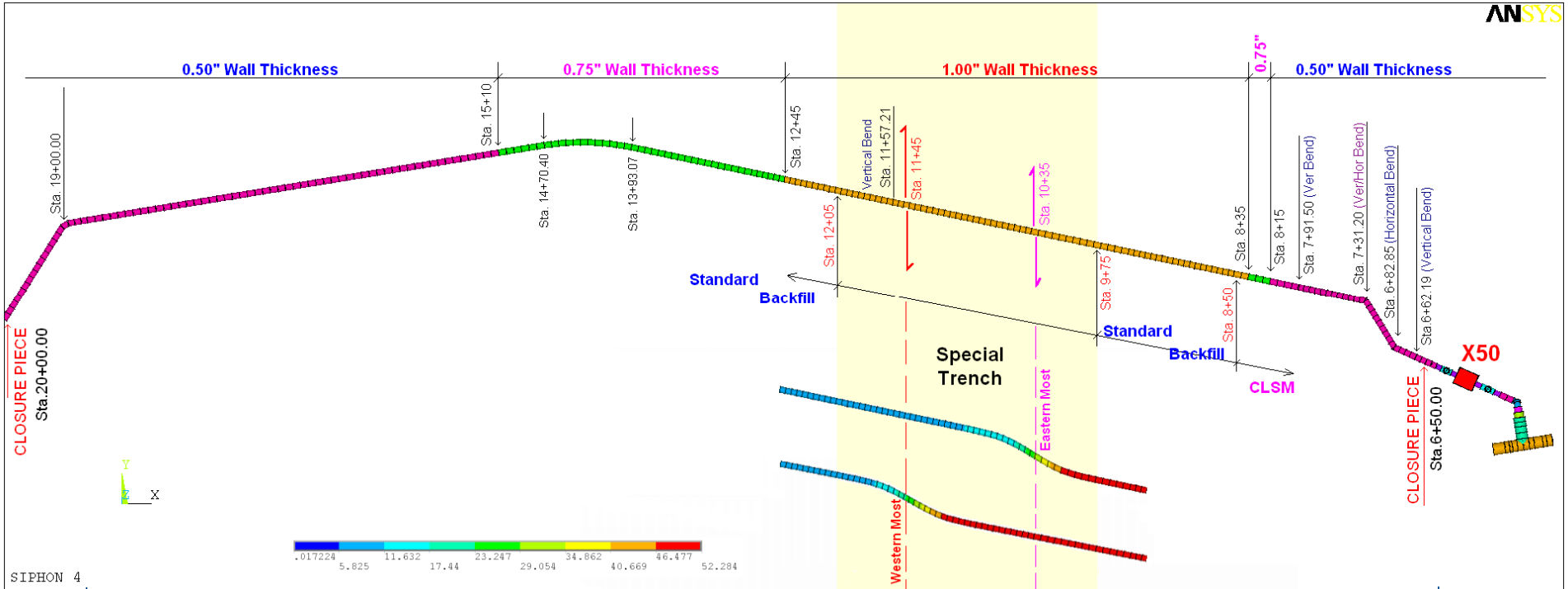
3/4 inch pipe thickness (Grade 36 steel)
Max Displacement = 5 ft



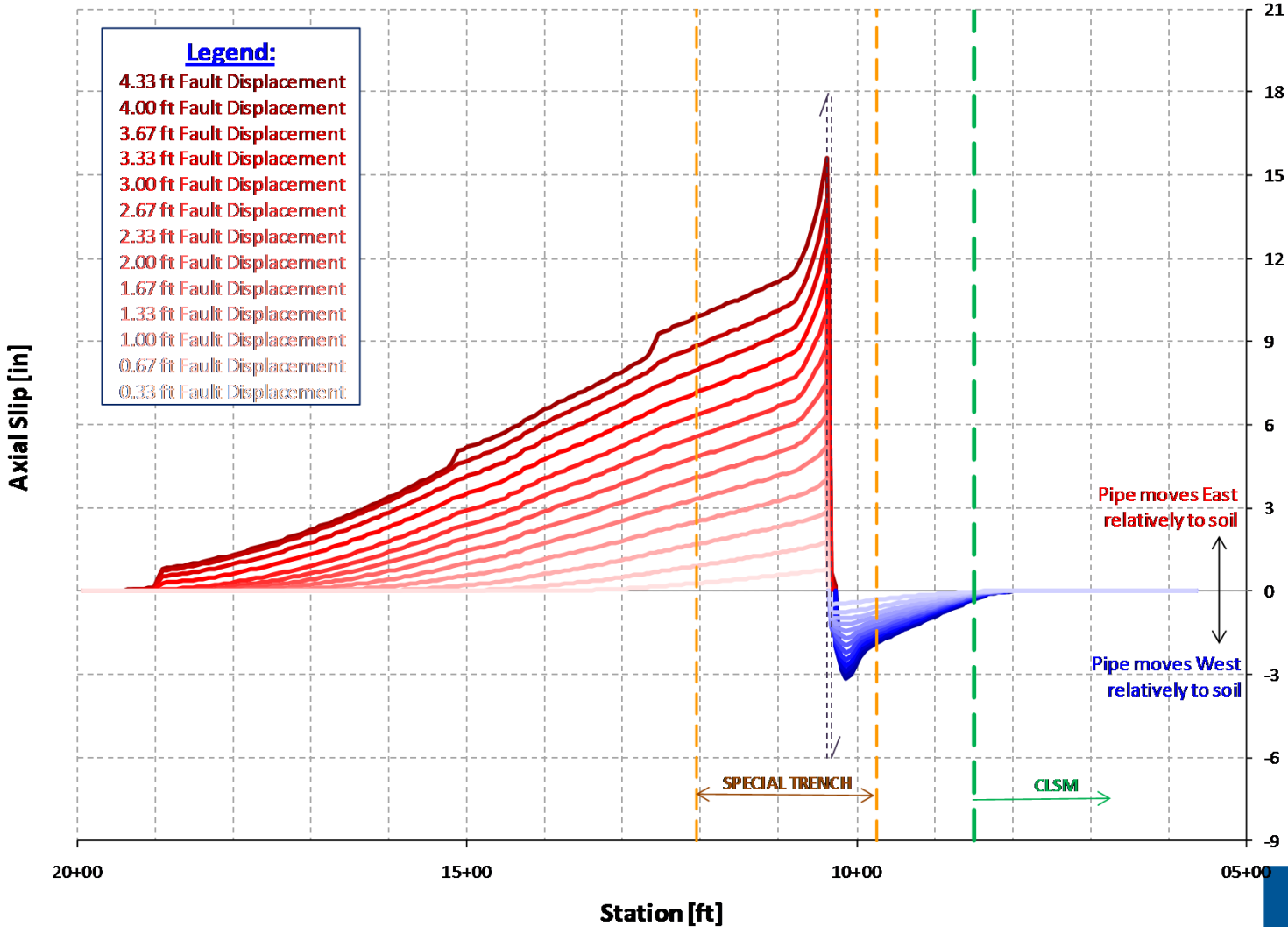
1 inch pipe thickness (Grade 36 steel)
Max Displacement = 6 ft



Final Design



RELATIVE SLIP AT SOIL/PIPE INTERFACE



CONSIDERATIONS

- AWWA silent regarding fault crossings and strain based design
- AWWA C200 is the readily available pipe
- Bulk of project will be standard water pipe
- Owner is a water utility and familiar with AWWA
- Contractor will have water pipeline experience

ADDITIONAL REQUIREMENTS

- Maximum yield strength (42 ksi) for pipe in certain areas.
- Butt Welds
- Shop welding as much as possible
- Material traceability
- Limited heats in certain areas
- Limitations on pass holes and nozzles in certain areas.
- Limitations on where closure pieces can be used.
- 100% NDE in certain areas



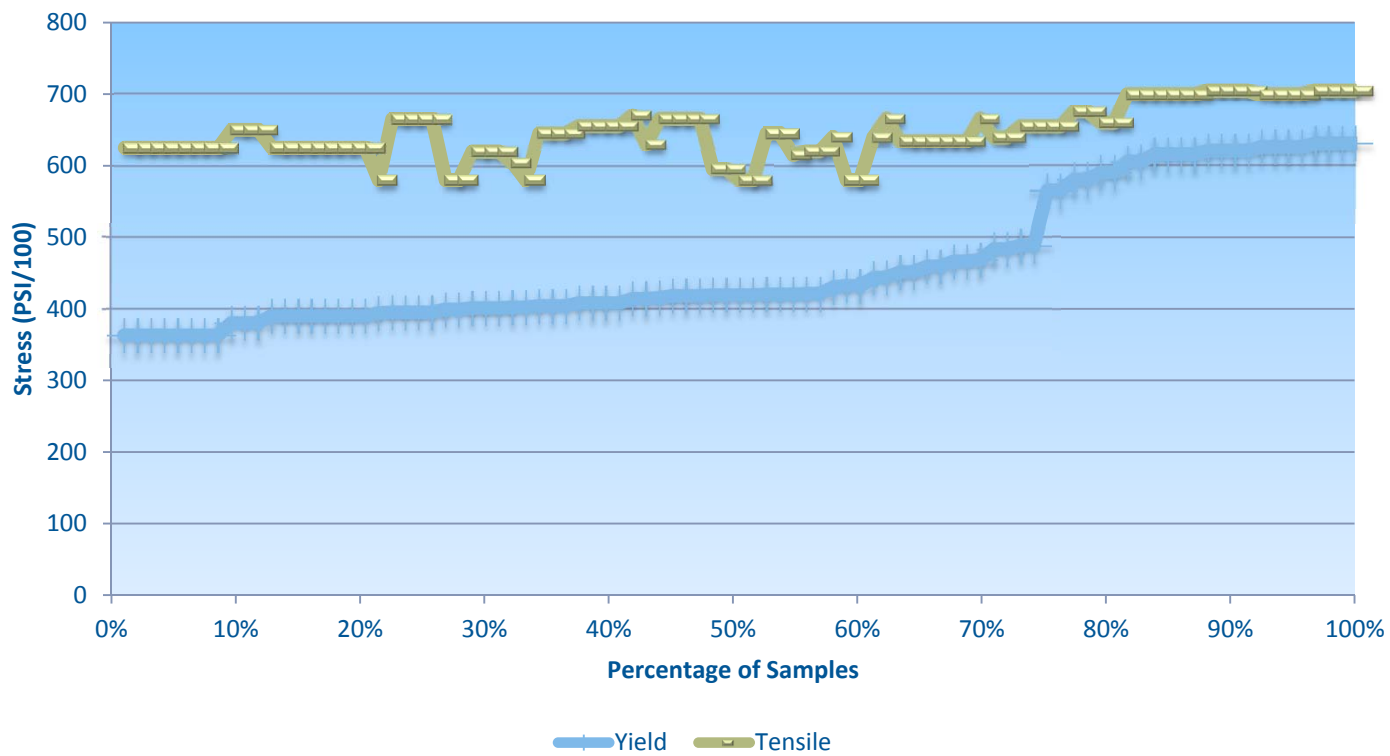
PIPE SCHEDULE

BEGINNING STATION	END STATION	PIPE SPECIFICATION	MINIMUM INSIDE DIAMETER (INCHES)	TRENCH SECTION	ALABAMA SIPHON		PIPE SCHEDULE (P4-P9)						
					MINIMUM PIPE WALL THICKNESS (INCHES)	FIELD JOINTS (NOTE 7)	TESTING OF FIELD JOINTS	LINING (09872)	COATING (NOTE 1) (09872)	POLYETHYLENE BAG (NOTE 2)	NOZZLES / PASS HOLES (NOTE 3)	CLOSURE PIECES (NOTE 4)	NONDESTRUCTIVE TESTING OF PIPE SEAMS (NOTE 5)
5+52	5+68	11211	66	-	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	ALLOWED	REQUIRED
5+68	6+41	11211	66	3/P20	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	ALLOWED	REQUIRED
6+41	7+31	11211	66	4/P20	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
7+31	8+15	11211	66	2/P20	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
8+15	8+35	11211	66	2/P20	0.75	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
8+35	8+50	11211	66	2/P20	1.00	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
8+50	9+73	11211	66	1/P21	1.00	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
9+73	12+05	11211	66	1/P20	1.00	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	EPOXY OR POLYURETHANE	YES	NOT ALLOWED	NOT ALLOWED	REQUIRED
12+05	12+45	11211	66	1/P21	1.00	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
12+45	15+10	11211	66	1/P21	0.75	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
15+10	19+00	11211	66	1/P21	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	REQUIRED
19+00	20+00	11211	66	2/P21	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	NOT ALLOWED	NOT REQUIRED
20+00	23+53	11211	66	2/P21	0.50	BUTT WELDED	NDT (NOTE 6)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	ALLOWED	NOT REQUIRED
23+53	29+32	11211 02380 02430	66	MICROTUNNEL (P19)	0.50	WELDED BELL & SPIGOT JOINT	AIR TEST (NOTE 7)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	ALLOWED	NOT REQUIRED
29+32	29+67	11211	66	2/P21	0.50	WELDED BELL & SPIGOT JOINT	AIR TEST (NOTE 7)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	ALLOWED	NOT REQUIRED
29+67	33+79	11211	66	3/P21	0.50	WELDED BELL & SPIGOT JOINT	AIR TEST (NOTE 7)	EPOXY OR POLYURETHANE	TAPE OVERCOAT WITH CEMENT MORTAR	NO	ALLOWED	ALLOWED	NOT REQUIRED

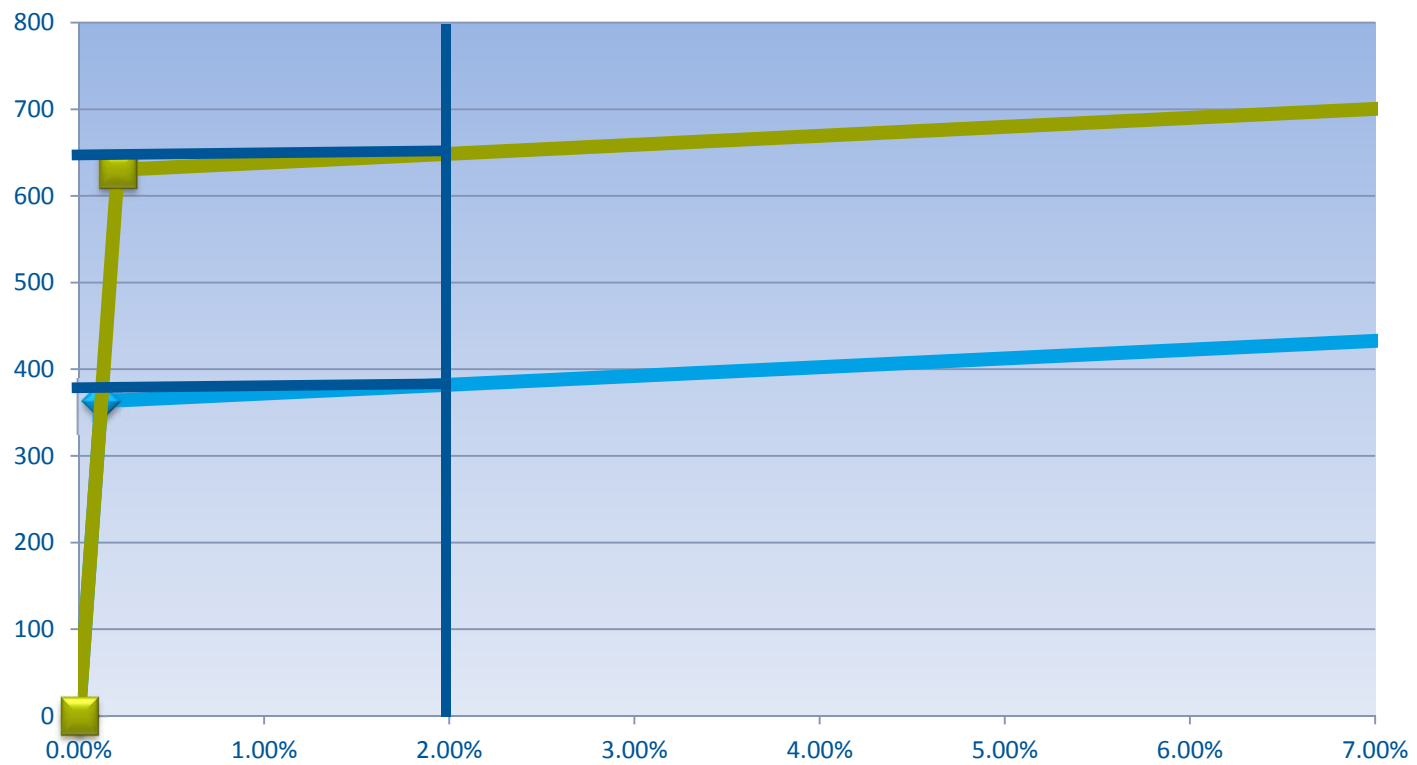
NOTES:

- COATINGS ARE LISTED FOR BURIED SECTIONS OF PIPE. REFER TO SPECIFICATION SECTION 09872 FOR COATINGS OF PIPE IN VAULTS.
- INDICATES LOCATIONS WHERE THE PIPE SHALL BE ENCLOSED IN POLYETHYLENE SLEEVE PER SPECIFICATION 09950.
- INDICATES LOCATIONS WHERE PASS THROUGH HOLES OR OTHER TEMPORARY HOLES TO USE IN CONSTRUCTION ARE ALLOWED. NOZZLE REINFORCEMENT SHALL MAINTAIN PRESSURE RATING OF PIPE.
- INDICATES EQUIPMENT WHERE THE USE OF DOT 394'S AND 3950'S ARE REQUIRED.
- INDICATES PIPE REQUIRING NONDESTRUCTIVE TESTING AS SPECIFIED IN SPECIFICATION 11211-W100A 5.3.
- NDT SHALL MEET THE REQUIREMENTS OF SPECIFICATION SECTION 11211-W100A 5.3.
- AIR TEST SHALL MEET THE REQUIREMENT OF SPECIFICATION SECTION 11211, ARTICLE 3.04.
- HYDROSTATIC TEST PER SPECIFICATION SECTION 02704.

MATERIAL PROPERTIES OF STEEL PLATE



ASTM A 36 STRESS/STRAIN



CONCLUSIONS

- **Fault displacement design requires strain based design, AWWA M11 is not sufficient.**
- **ALA and PRCI provide guidelines for strain based design of pipelines.**
- **AWWA C200 pipe can work for these applications.**
- **Need to control parameters**
 - Material properties
 - Coating
 - Trench
 - Other
- **More rigorous quality control (ASME BPV)**
- **Address variability and specify limits. (minimum and maximum rather than just minimum)**

LONG-TERM MONITORING



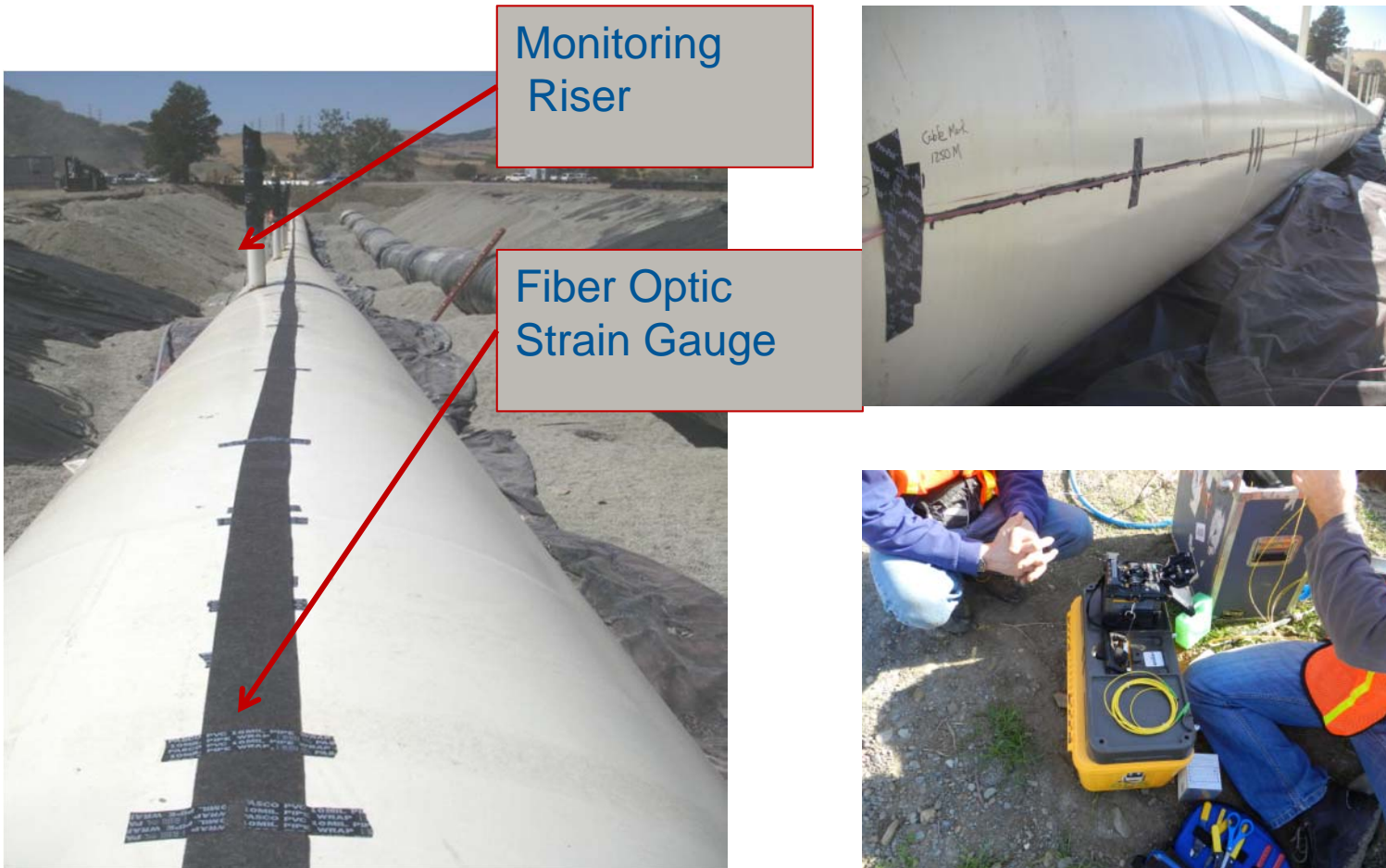




FAULT MONITORING – PIPE POSITION



FAULT MONITORING- PIPE STRAIN



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Together



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