Los Angeles Department of Water & Power

Water System Overview

Taiwan Delegation
October 8, 2019

Simon Hsu
Water Resources Division

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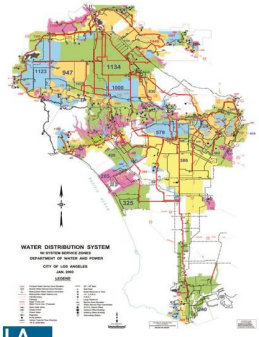
LADWP TODAY



- Service area (472 sq.mi. or 1,222 Sq. Km.)
- Provide Water and Power to over 4 million people every day
- Over 467 million gallons of water delivered per day – 523,100 acre-feet per year (1.77 billion liters per day, 645 MCM per year)

* 1 AF = 1233.5 M^3

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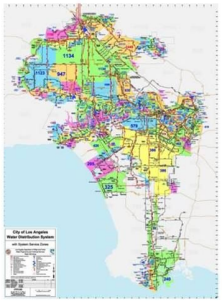
Infrastructure

- 111 Pressure zones
- 7,336 miles of pipeline (11,800 Km)
- 209,800 gate valves
- 60,900 fire hydrants
- 740,000 service connections



6,773 miles from LA to Taipei
(10,900 Km)

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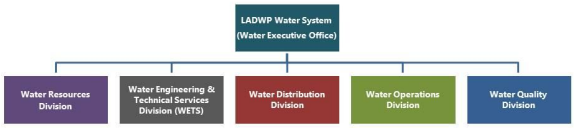

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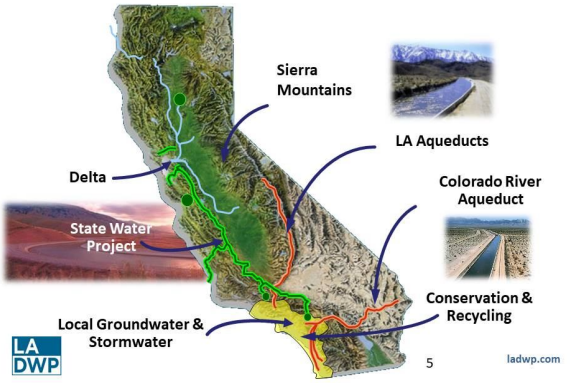
LOS ANGELES' WATER SUPPLIES



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WATER SUPPLY & RELIABILITY CHALLENGES

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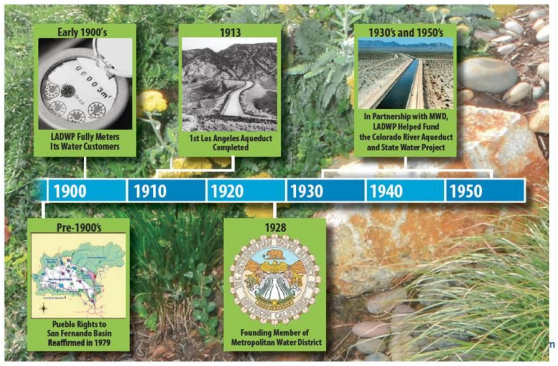
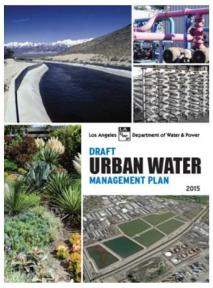
WATER RESOURCES PLANNING AND DEVELOPMENT HAS TRANSFORMED LA



WATER RESOURCES PLANNING AND DEVELOPMENT HAS TRANSFORMED LA

PURPOSE OF UWMP

- **Water Supply Reliability to Year 2040**
  - 2015 UWMP available for download at: www.ladwp.com/2015UWMP
- **Urban Water Management Planning Act (1984)**
  - Required for agencies serving more than 3,000 customers or 3,000 AFY (3.7 MCM per year)
- **State Grant/Loan Eligibility**



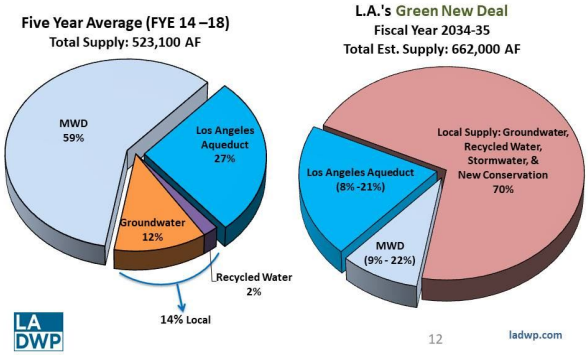
URBAN WATER MANAGEMENT PLAN

Recycle **100%** of Waste Water by 2035

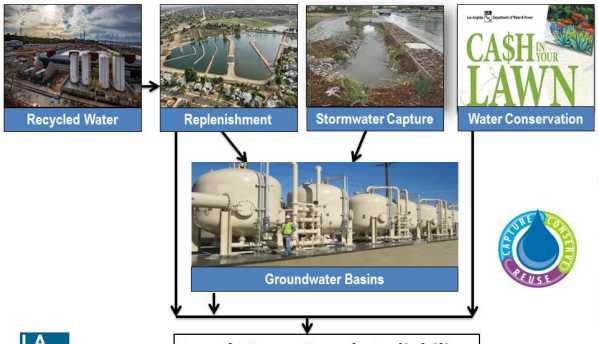
Source **70%** of all water locally by 2035

Reduce Potable Water Use **22.5%** By 2025 **25%** By 2035

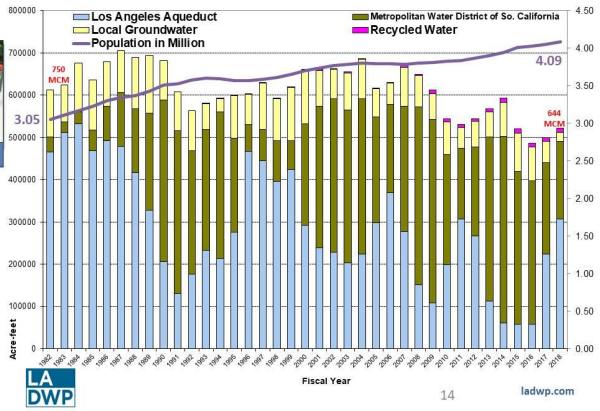
WATER SUPPLY RELIABILITY



LOCAL WATER SUPPLY PROGRAM



HISTORICAL WATER SUPPLY FOR THE DEPARTMENT



LOCAL SUPPLY DEVELOPMENT CONSERVATION

* 1 AF = 1233.5 M^3

RESIDENTIAL AND COMMERCIAL CONSERVATION REBATES

LOCAL SUPPLY DEVELOPMENT STORMWATER CAPTURE

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TUJUNGA SPREADING GROUNDS ENHANCEMENT PROJECT

As of September 2019
- Basin Improvements Completed
  - New Intakes in Late 2019
- Open Space Starting Early 2020
- Project Completion in Early 2021

- Doubling stormwater capture capacity to 16,000 acre-feet to recharge the groundwater basin annually
- Increase stormwater diversion from the flood control channel for peak flow attenuation and downstream flood mitigation
- Provide community open space, neighborhood greening, and passive recreational space
- Improve water quality in the downstream water receiving bodies.
- Project Cost- $50.4M
- Cost-benefit - $85/AF

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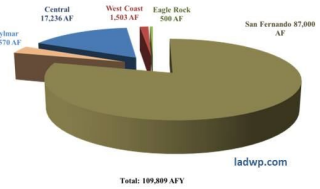
SF GROUNDWATER BASIN REMEDIATION

Planned groundwater basin remediation will be crucial to restoring the health and beneficial uses of the San Fernando Basin



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NORTH HOLLYWOOD WEST WELLHEAD TREATMENT FACILITY

- **Type of Proposed Treatment:**
  - 1,4-Dioxane Treatment using AOP w/LPGAC
- **Construction: STARTED – 55% Complete**
  - September 2017 – September 2020
  - LADWP Construction Forces
- **Submitted Steps 1-4 of DDW's 97-005 Policy Permitting Process**

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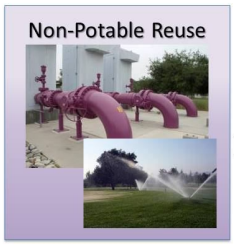
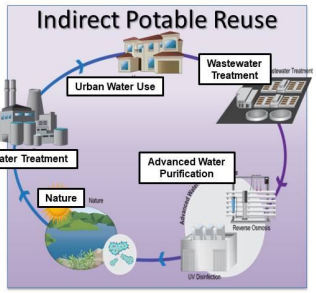
LOCAL SUPPLY DEVELOPMENT RECYCLED WATER





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NEW RECYCLED WATER INITIATIVE AT HYPERION

Program Objective:
Recycle 100% of available treated wastewater for beneficial reuse from the Hyperion Water Reclamation Plant by 2035.

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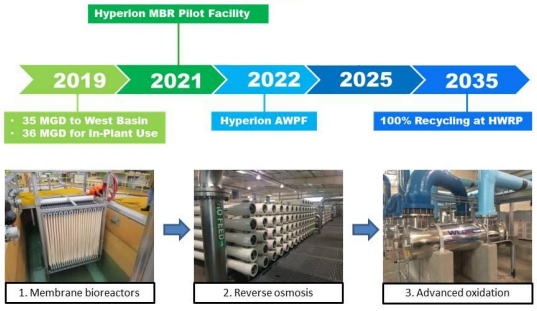
RECYCLED WATER PROGRAM AT HWRP



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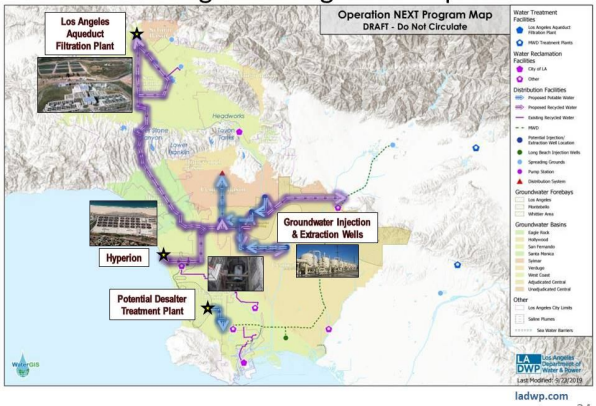
Potential Regional Program Components



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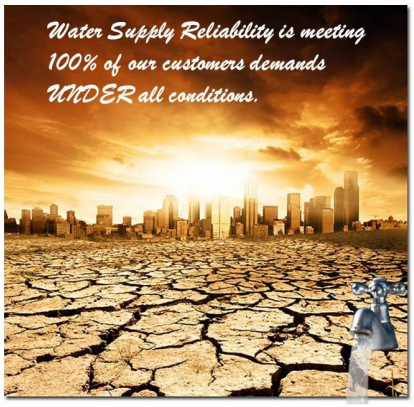
SEISMIC RISK TO IMPORTED SUPPLIES

SEISMIC RESPONSE (MWD)

- MWD's Diamond Valley Lake, SWP terminal reservoir storage, and member-agency emergency storage can adequately provide for a 6-month supply of water with a temporary 25% reduction in demand.
- Emergency storage in Castaic and Pyramid Lakes can deliver water into LA's west San Fernando Valley, Calleguas, and Las Virgenes if SWP and LAA are severed. If these emergency sources are cut off, 50 cfs (1.4 cms)of CRA water could be moved through MWD's system to serve these areas until repairs could be made.
- On-call contractors working around the clock could be deployed to repair seismic damage in as short as a two-week time period.

SEISMIC RESPONSE (LADWP)

- If the LAA is severed, LADWP will use Bouquet Reservoir to provide water to the City while repairs are made.
- In addition, if the California Aqueduct is intact south of the Neenach Pump Station (1st LAA – SWP Connection), arrangements may be made to transfer LAA water into the California Aqueduct for delivery to MWD. Arrangements can then be made to deliver water to the City through MWD's connections.



THANK YOU

LA DWP Los Angeles Department of Water & Power

CUSTOMERS FIRST

Los Angeles Department of Water & Power

Strengthening the Distribution System *with* Earthquake Resistant Pipes

LADWP Water Distribution Division
Genevieve Han P.E. & Martin Lam P.E.
Tuesday, October 8, 2019

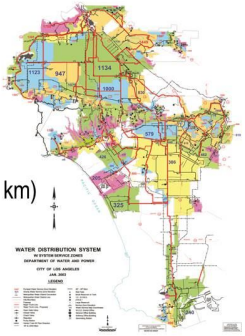
Presentation Outline

- LADWP Water Distribution System
- Water System Vulnerability
- Seismic Resilient Pipe Network
- EQ Pipe Evaluation Process
  - Planning
  - Design
  - Procurement
  - Construction
- Challenges
- Lessons Learned
- Future Goals

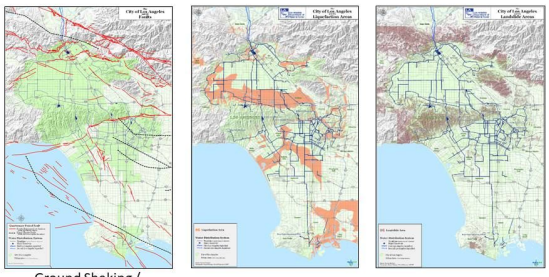
LADWP Water Distribution System

- 5 Water Operating Districts
- 465 square miles (1,204 km²)
- 2,806 large valves
- 60,902 fire hydrants
- 732,350 service connections
- 7,337 miles of pipeline (11,808 km)

7,490 miles from LA to Sydney

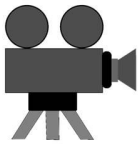


Water System Vulnerability

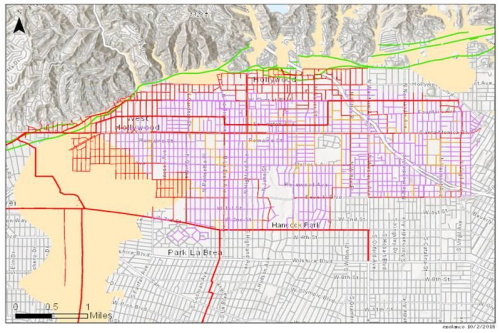


Ground Shaking / Fault Ruptures | Liquefaction | Landslides

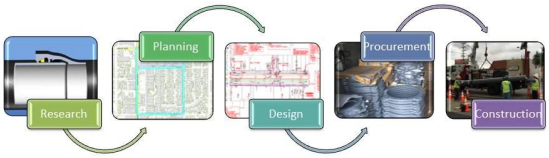
Seismic Resilient Pipe Network (SRPN)



Seismic Resilient Pipe Network



Earthquake Pipe Evaluation



Research

Available Products

Research

Standard – ISO 16134

INTERNATIONAL STANDARD ISO 16134
Earthquake and subsidence-resistance design of ductile iron pipelines.

	CLASS	COMPONENT PERFORMANCE
Expansion/Contraction Performance (Elongation)	S1	± 1% L or more
	S2	± 0.5% L to ± 1% of L
	S3	Less than ± 0.5% of L
Pull Apart Resistance	A	17,000 d lbs +
	B	8,500 d lbs–17,000 d lbs
	C	4,250 d lbs–8,500 d lbs
	D	Less than 4,250 d lbs
Joint Deflection Angle	M1	15° or more
	M2	7.5° < 15°
	M3	Less than 7.5°

"L" is the component length in inches
"d" is the nominal pipe diameter in inches

ISO: International Organization for Standardization

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Research

- Different vendors
- Review performance results
- Compatibility with existing system
- Material lead time
- Costs
- Special tools for construction

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Planning

Selection Criteria

- Pipe network serves critical facilities
- Historic leaks and pipe age
- Pipe network is within or adjacent to a fault or liquefaction zone
- Direct trunk line connections

Brainard Ave ERDIP Project (US Pipe)

Reseda Blvd ERDIP Project (Kubota)

Mission Hills ERDIP Project (American Pipe)

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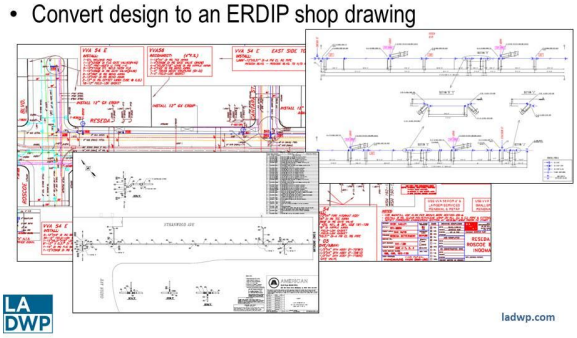
Design

- Start with traditional DI design
- Convert design to an ERDIP shop drawing



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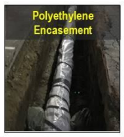
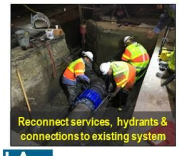
Construction





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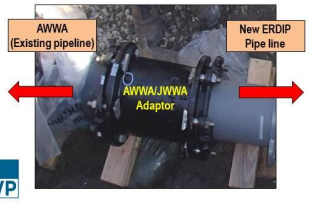
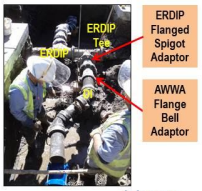
Construction

Connections to Existing System





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Construction

- Easy Installation
- S1, A, M2 (8-inch pipe)
- Compatible with existing materials
- Established material supply chain
- Requires welders

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American Earthquake Joint System

PERFORMANCE SPECS

SIZE (IN.)	PIPE JOINT DEFLECTION (DEGREES)	CASTING JOINT DEFLECTION (DEGREES)	COMBINED ASSEMBLY DEFLECTION (DEGREES)	EXPANSION OR CONTRACTION FROM MID-POINT	DEAD-END THRUST RESISTANCE (LBS.)	EQ CASTING ISO PERFORMANCE
6	5	3	8	± 2.4"	102,000	A, S1, M2
8	5	3	8	± 2.4"	136,000	A, S1, M2
12	5	3	8	± 2.4"	204,000	A, S1, M2
16	5	2	7	± 2.4"	272,000	A, S1, M3
20	4	2	6	± 2.4"	340,000	A, S1, M3
24	4	2	6	± 2.4"	408,000	A, S1, M3

American Flex-Ring Restrained Joint Ductile Iron Pipe and Fittings

PERFORMANCE SPECS - AMERICAN FLEX-RING® JOINT EARTHQUAKE CAPACITY

SIZE (IN.)	NOMINAL LAY LENGTH (IN.)	RADIUS OF CURVATURE (LINEAR FT.)	MINIMUM PULL APART RESISTANCE (LBS.)	JOINT DEFLECTION (DEGREES)	ELONGATION AT FULL INSERTION ASSEMBLY	ISO 16134 DESIGNATION
4	239 (19'-11")	230	68,000	5.00	+0.31% (0.75")	A, M3, S3
6	239 (19'-11")	230	102,000	5.00	+0.31% (0.75")	A, M3, S3
8	239 (19'-11")	230	136,000	5.00	+0.31% (0.75")	A, M3, S3
10	238 (19'-10")	230	170,000	5.00	+0.32% (0.75")	A, M3, S3
12	238 (19'-10")	230	204,000	5.00	+0.32% (0.75")	A, M3, S3
14	238 (19'-10")	285	238,000	4.00	+0.53% (1.25")	A, M3, S2
16	237.5 (19'-9.5")	305	272,000	3.75	+0.53% (1.25")	A, M3, S2
18	237 (19'-9")	305	306,000	3.75	+0.53% (1.25")	A, M3, S2
20	237 (19'-9")	327	340,000	3.50	+0.53% (1.25")	A, M3, S2
24	237 (19'-9")	380	408,000	3.00	+0.53% (1.25")	A, M3, S2
30	236.75 (19'-8.75")	458	510,000	2.50	+0.53% (1.25")	A, M3, S2
36	236.75 (19'-8.75")	570	612,000	2.00	+0.53% (1.25")	A, M3, S2
42	236.75 (19'-8.75")	570	714,000	2.00	+0.53% (1.25")	A, M3, S2
48	235.75 (19'-7.75")	570	816,000	2.00	+0.53% (1.25")	A, M3, S2
54	235.75 (19'-7.75")	570	918,000	1.50	+0.53% (1.25")	A, M3, S2

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American Flex-Lok Ball Joint

PERFORMANCE SPECS - AMERICAN FLEX-LOK® JOINT EARTHQUAKE CAPACITY

SIZE (IN.)	NOMINAL LAY LENGTH (IN.)	RADIUS OF CURVATURE (LINEAR FT.)	MINIMUM PULL APART RESISTANCE (LBS.)	JOINT DEFLECTION (DEGREES)	ELONGATION AT FULL INSERTION ASSEMBLY	ISO 16134 DESIGNATION
4	258 (21'-6")	48	68,000	25.00	+0.68% (1.75")	A, M1, S2
6	259 (21'-7")	49	102,000	25.00	+0.68% (1.75")	A, M1, S2
8	260 (21'-8")	49	136,000	25.00	+0.68% (1.75")	A, M1, S2
10	259.63 (21'-7.63")	49	170,000	25.00	+0.68% (1.75")	A, M1, S2
12	260.63 (21'-8.63")	49	204,000	25.00	+0.68% (1.75")	A, M1, S2
14	246 (20'-6")	78	238,000	15.00	+0.10% (0.25")	A, M1, S3
16	247.25 (20'-7.25")	52	272,000	22.50	+1.10% (2.75")	A, M1, S1
18	246 (20'-6")	78	306,000	15.00	+0.10% (0.25")	A, M1, S3
20	247.25 (20'-7.25")	53	340,000	22.00	+1.10% (2.75")	A, M1, S1
24	246 (20'-6")	55	408,000	21.00	+1.80% (4.50")	A, M1, S1
30	259 (21'-7")	82	255,000	15.00	+0.77% (2.00")	A, M1, S2
36	265 (22'-1")	84	612,000	15.00	+0.75% (2.00")	A, M1, S2

FLEX-LOK ADVANTAGES

- Ideal for joints adjacent to structures and areas subject to significant displacement
- Bottless joint designed for 15-degree or greater universal deflection

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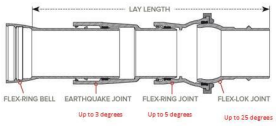
American Flex-Lok Ball Joint

PERFORMANCE SPECS - COMBINED ALLOWABLE DEFLECTION

DIAMETER (IN.)	WORKING PRESSURE (PSI)	COMBINED ALLOWABLE DEFLECTION (DEGREES)	NORMAL MIDPOINT LAY LENGTH	MINIMUM MIDPOINT LAY LENGTH	COMBINED CONTRACTION OR ELONGATION AT MIDPOINT ASSEMBLY (IN.)	MINIMUM PULL APART RESISTANCE (LBS.)	ISO 16134 DESIGNATION
6	250	33.0	23'-1.81"	6'-9"	±3.65	102,000	A, M1, S1
8	250	33.0	23'-3.16"	6'-10"	±3.65	136,000	A, M1, S1
12	250	33.0	23'-5.48"	7'-2"	±3.65	204,000	A, M1, S1
16	250	28.5	24'-2.23"	8'-5"	±4.4	272,000	A, M1, S1
20	250	28.0	24'-3.60"	8'-7"	±4.4	340,000	A, M1, S1
24	250	27.0	24'-11.50"	9'-3"	±5.28	408,000	A, M1, S1



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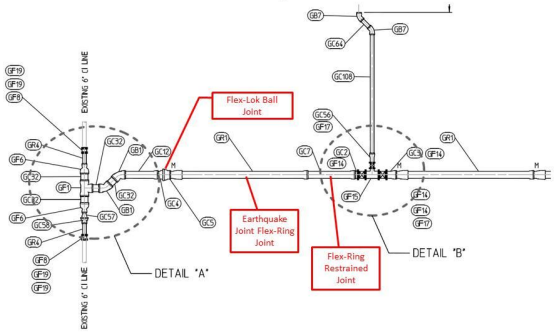
American ERDIP Design



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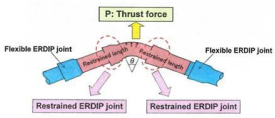
Design Challenges

- High learning curve (limited/no experience with ERDIP designs)
- Restrained length calculations
  - Location identification for restraint (such as use of liners)
- Joint types and locations
- Expansion/contraction presets
- Deflection presets
- Compatibility with existing system



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Construction Challenges

- High learning curve (slower lay rate)
- Different joints and fittings compared to traditional ductile iron pipe
- Re-establishing pipe projection
  - Cut pipes: spigot ring method (slow process) vs. use of P-links (additional measurements)
- Substructures – vertical and horizontal offsets (material availability)
- Changes in field conditions – how do they affect the restrained lengths
- Quality control documents (tedious)
- Tools - extras

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Lessons Learned

- Design/Construction
  - Substructure research (use of Ground Penetrating Radar)
  - Restrained length calculations
  - Options for the crew if there are changes during construction due to unforeseen substructures
- Material procurement
  - Account for extras for unforeseen field conditions
  - Order additional materials for leak repairs
  - Order service saddles that are compatible with ERDIP pipe diameter
  - Order extra tools
- Construction
  - Unforeseen utilities required improvised changes in design during construction
  - Measureable evaluation metrics for construction

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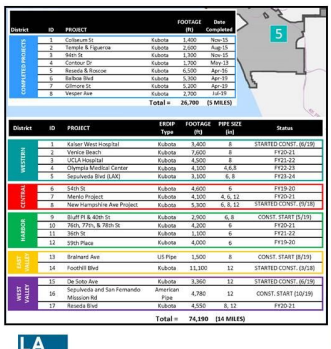
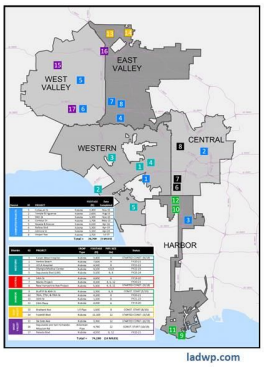
ERDIP Mainline Projects



District	ID	PROJECT	ERDIP Type	FOOTAGE (ft)	PIPE SIZE (in)	Status
COMPLETED PROJECTS	1	Colleum St	Kubota	1,400	Now-15	
	2	Temple & Figueroa	Kubota	2,000	Aug-15	
	3	84th St	Kubota	1,300	Nov-15	
	4	Contour Dr	Kubota	1,700	May-13	
	5	Reseda & Roscoe	Kubota	6,500	Apr-16	
	6	Balboa Blvd	Kubota	5,300	Apr-17	
	7	Gilmore St	Kubota	5,200	Apr-19	
	8	Vesper Ave	Kubota	2,700	Jun-18	
			Total =	26,700	(5 MILES)	
WESTERN	1	Kaiser West Hospital	Kubota	3,400	8	STARTED CONST. (6/19)
	2	Venice Beach	Kubota	7,600	8	FY20-21
	3	UCLA Hospital	Kubota	4,500	8	FY21-22
	4	Olympia Medical Center	Kubota	4,100	4,6,8	FY22-23
	5	Sepulveda Blvd (LAX)	Kubota	3,100	6, 8	FY23-24
CENTRAL	6	54th St	Kubota	4,600	6	FY19-20
	7	Manto Project	Kubota	4,100	4, 6, 12	FY20-21
	8	New Hampshire Ave Project	Kubota	5,300	6, 8, 12	STARTED CONST. (5/19)
HARBOR	9	Bluff Pl & 40th St	Kubota	2,900	6, 8	CONST. START (5/19)
	10	76th, 77th, & 78th St	Kubota	4,200	6	FY20-21
	11	36th St	Kubota	1,100	6	FY21-22
	12	39th Place	Kubota	4,000	6	FY19-20
EAST VALLEY	13	Brainard Ave	US Pipe	1,500	8	CONST. START (8/19)
	14	Foothill Blvd	Kubota	11,100	12	STARTED CONST. (3/18)
WEST VALLEY	15	De Soto Ave	Kubota	3,360	12	STARTED CONST. (6/19)
	16	Sepulveda and San Fernando Mission Rd	American Pipe	4,780	12	CONST. START (10/19)
	17	Reseda Blvd	Kubota	4,550	8, 12	FY20-21
			Total =	74,190	(14 MILES)	



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Future Plans & Goals

- Improve quality control process
- Develop Design Criteria and Construction standards for earthquake resistant pipe
- Continue working with manufacturers to improve their products
- Continue promoting technologies and innovation
- Develop a Seismic Resilient Pipe Network (SRPN)

LA DWP Los Angeles Department of Water & Power

CUSTOMERS FIRST

LA DWP

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Metropolitan's System Reliability Strategy

Member Agency Manager's Meeting August 23, 2019

Who Are We?

The Metropolitan Water District of Southern California, is a regional water wholesaler that provides water for 26 member public agencies living in six counties across a 5,200 square-mile service area. The district imports water from the Colorado River and Northern California to supplement local supplies and helps its members develop increased water conservation, recycling, storage and other resource management programs.

Member Agency Manager's Meeting August 23, 2019

Metropolitan Water District

Member Agency Manager's Meeting August 23, 2019

Southern California Imported Water Supply

Member Agency Manager's Meeting August 23, 2019

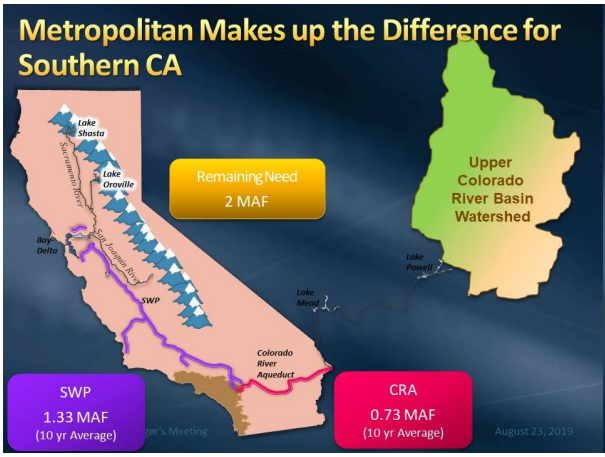
Metropolitan's Imported Water Supply

Member Agency Manager's Meeting August 23, 2019

Southern California Water Supplies

Member Agency Manager's Meeting August 23, 2019

Metropolitan Makes up the Difference for Southern CA



Member Agency Manager's Meeting August 23, 2019

Southern California's Water Portfolio

- 25% Colorado River
- 30% State Water Project
  - supplies from Bay/Delta
- 45% Local
  - Los Angeles Aqueduct
  - Groundwater recovery
  - Recycling
  - Desalination
- + Conservation

$$

Member Agency Manager's Meeting August 23, 2019

Purpose of Meeting

- Present Metropolitan's strategy to maintain overall system reliability specifically seismic reliability
  - Components of reliability
  - Activities and studies

System Reliability Strategy

- Developed as part of 2007 Integrated Area Study
- Collaborative effort between Metropolitan and member agencies

1. Water Supply Reliability

Develop and maintain an adequate water supply portfolio to meet full-service retail demands under all foreseeable hydrologic conditions

- Integrated Water Resources Plan (IRP)
  - Board Adopted
    - 1996, 2004, 2010, 2015
- 2015 IRP Findings
  - Diversify water portfolio
  - Invest in imported and local water supplies and conservation
  - Stabilize imported supplies
  - Local water supply target of 2.4 million acre-feet by 2040

Example: Regional Recycled Water Program

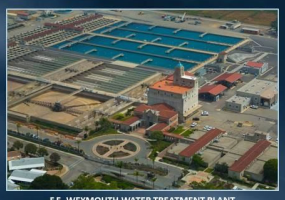
- Development of new regional water source
- Up to 150 MGD (168,000 AFY)
- Augment regional supplies during normal, drought, and emergency conditions
- Reduced frequency and magnitude of supply allocations

DEMONSTRATION PLANT AT JWPCP

2. System Capacity

Develop facilities to convey, treat, and distribute supplies to meet firm demands under peak condition

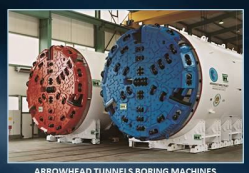
- System Overview Study
  - 2004 Report
- Integrated Area Study
  - 2007 Report
- Hydraulic Modeling
- Capital Investment Plan



F.E. WEYMOUTH WATER TREATMENT PLANT

Example: Inland Feeder & Diamond Valley Lake

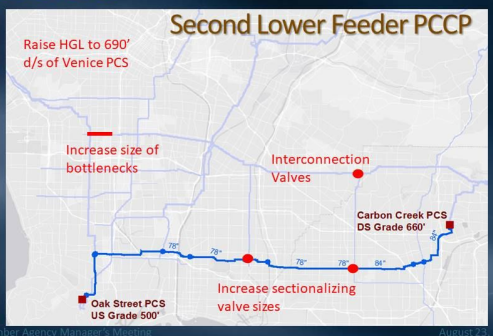
- Inland Feeder
  - More than doubled water delivery capacity from SWP East Branch
  - Improved SWP/CRA blends
- Diamond Valley Lake
  - Nearly doubled in-region surface storage
  - Increased emergency storage capacity



ARROWHEAD TUNNELS BORING MACHINES

DIAMOND VALLEY LAKE WEST DAM & FOREBAY

Example: Support for PCCP Design Decisions



3. Infrastructure Reliability

Maintain facilities in state of readiness to ensure system deliveries

- Joint task between Engineering and Operations

4. System Flexibility

Respond to short-term changes in water supply, water demands, and water quality; and meet member agency needs during planned or unplanned outages

- Operational Flexibility
  - Operational adjustments
    - Hydraulic modeling
- Delivery Flexibility
  - Demand-driven projects
    - System Reliability Study

Example: System Reliability Study

- Presented as part of the IAS
- Purpose
  - Identify areas in our system that are vulnerable to a loss of service from a 7-day outage
- Approach
  - Postulate a single component failure
  - Evaluate options to restore service
    - MWD capability to re-route water to impacted area
    - Member agency alternative connections to MWD
    - Member agency wells & surface storage
    - Member agency interconnections
  - Quantify effect

5. Emergency Response

The ability to respond to unplanned outages and restore service as quickly as practical.

- Addressed through:
  - Emergency Response Plan
    - System Security Planning
  - Business Continuity Plan
  - Information Technology Disaster Recovery Plan
  - Mutual aid agreements
  - Seismic Resilience Task Force

Examples: Emergency Response

- Metropolitan maintains its own manufacturing shop facilities to fabricate and repair equipment and roll steel pipe


Structural Supplies

- The capability of these facilities has recently been upgraded substantially in order to expedite urgent repairs
  - Has the ability to repair at least two large diameter pipe breaks simultaneously


Fabrication Equipment

- Workshops and exercises are conducted regularly, including simulations of major seismic events

California Aqueducts

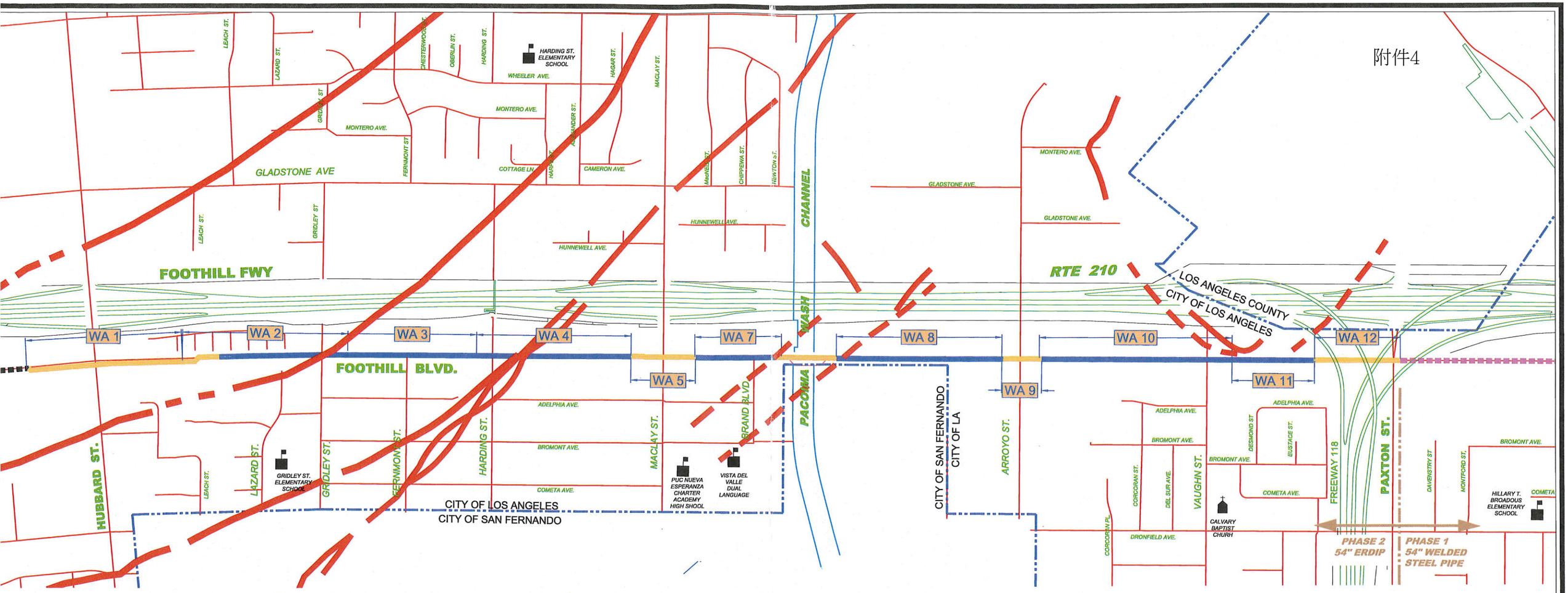
California Dams and Reservoirs

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Videos

- https://www.youtube.com/watch?v=Ozle7tS1SgQ
- https://www.youtube.com/watch?v=8A1v1Rr2neU

附件4



N

NOT TO SCALE

LEGEND:

- EXISTING 60" PCCR (PLR 96468, 1982)
- PROPOSED 54" EARTHQUAKE RESISTANT DUCTILE IRON PIPE (ERDIP) PHASE 2 (BY LADWP) APPROXIMATELY - 6,800 ft
- PROPOSED , 54" WELDED STEEL PIPE - PHASE 2 (BY OTHERS)
- INSTALLED 54" WELDED STEEL PIPE - PHASE 1
- CITY OF LOS ANGELES - BOUNDARY LINE
- EDUCATIONAL INSTITUTION
- RELIGIOUS INSTITUTION
- WA — WORK AREA
- FAULTS

TLC SUPPORT GROUP

FOOTHILL TRUNK LINE

UNIT 3 - Phase 2

Construction Map

LA DWP

The Research of Repairing Method of Water Tank Leakage

Jiunn-Shyong Shiu
Director of Public Works Department
Taiwan Water Corporation

台灣自來水公司 TAIWAN WATER CORPORATION

October 9, 2019

《OUTLINE》

- ✓ Overview of TWC
- ✓ Purpose of the study
- ✓ Causes and types of leakage
- ✓ Water tank leakage repair method
- ✓ Three typical repair cases
- ✓ Conclusion

TAIWAN WATER CORPORATION 2

Overview of TWC

TAIWAN WATER CORPORATION

Water Supply Area	10,800 (km²)
Branches	12
User Number	6.87 millions
Water Supply Amount	8.63 millions (CMD)
Main Length	60,000 (km)
Number of Water Supply System	144
Number of Water Purification Plant	449
Number of Monitoring Station	3,200

3

Overview of TWC

- The risk of water resources development in Taiwan


Drought


Typhoon


Earthquake

4

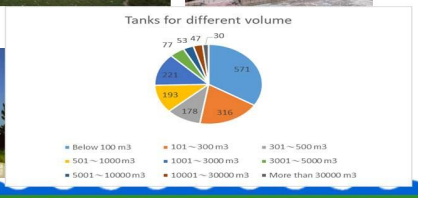
Purpose of the study

- Strengthening water resources management and reducing the water leakage rate
- Water leakage from water supply systems generally occurs in pipeline facilities and distribution water tanks.

2019/12/27 5

Purpose of the study

- TWC has 1,686 distribution water tanks, with a total capacity 3.6M m³.



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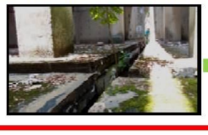
Purpose of the study

- Earthquake damage to the water tanks
- Large damage→ Remolition and reconstruction

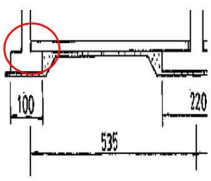


- Leakage→ Repair

7

Causes and types of leakage

- **Seam**
- Joints : Construction joint, Expansion joint, Turning joint



8

Causes and types of leakage

- **Seam**
  - Temperature change crack
  - Earthquake or uneven subsidence
  - Rusting and displacement of reinforcing steel
  - Honeycomb phenomenon

9

Causes and types of leakage

- **Perforation**

- **Concrete quality**
  - The water tightness of concrete is not enough
  - Bleeding phenomenon

10

Water tank leakage repair method

- **Summary of leakage type**

Plate	Wall	Crack
• Construction joints • Expansion joints • Transition joints • Temperature change cracks • Earthquake or uneven subsidence • Steel rust, displacement • Honeycomb phenomenon • Perforation • Waterproof layer damage, deficiencies • Insufficient water tightness of concrete • Bleeding.	• Construction joints • Expansion joints • Transition joints • Temperature change cracks • Earthquake or uneven subsidence • Steel rust, displacement • Honeycomb phenomenon • Perforation • Waterproof layer damage, deficiencies • Insufficient water tightness of concrete • Bleeding.	• Construction joints • Expansion joints • Transition joints • Temperature change cracks • Earthquakes or uneven subsidence • Steel bars rust, displacement • Honeycomb phenomenon

11

Water tank leakage repair method

- **Covering the waterproof layer**

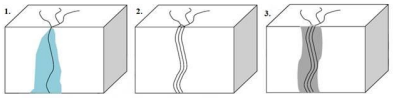
Cover with Fiber-Reinforced Plastic(FRP)

Use steel plate to cover

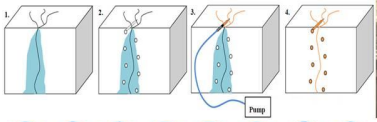
12

Water tank leakage repair method

- **Set the V-shaped groove to apply the waterproofing agent cement mortar.**



- **Cracks are stopped by high-pressure grouting.**



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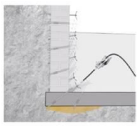
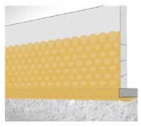
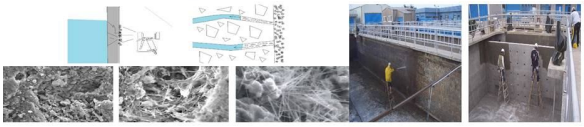
Water tank leakage repair method

- **Through the outer wall to fill the grout**





- **Concrete deep osmosis coating agent**



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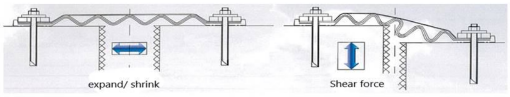
Water tank leakage repair method

- **Rubber bead with stainless steel plate**



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Water tank leakage repair method

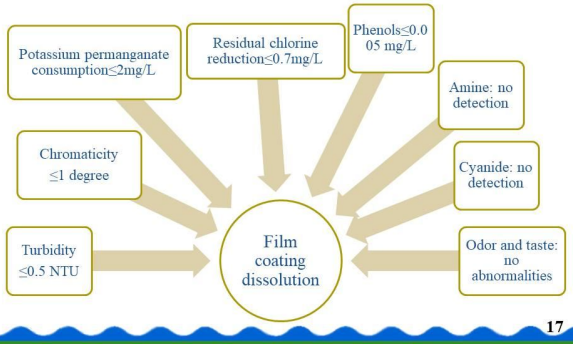
- **Repair of cracks or expansion joints.**

Processing site	Material type
Filler	PE rod, waterproof foam, expanded rubber strip
Caulk	Epoxy resin, polyurethane (PU) sealant
Surface strengthening	FRP, non-woven fabric, elastic rubber water stop, stainless steel plate
External processing	Elastic rubber water stop, elastic cement, stainless steel

16

Water tank leakage repair method

- Repair materials must not affect water quality.



17

Water tank leakage repair method

- Summary of repair method

Plate	Wall	Crack
• Covering waterproof layer • Internal coating waterproof coating • Through the wall outside the curtain grouting • Concrete deep osmosis coating agent	• Covering waterproof layer • Internal coating waterproof coating • Through the wall outside the curtain grouting • Concrete deep osmosis coating agen	• Use V-shaped groove to apply waterproofing agent cement mortar • High-pressure grouting to stop leakage • Concrete deep-layer osmosis coating agent • Rubber bead with stainless steel plate

18

Three typical repair cases

- Yuchi 3,000 m³ distribution water tank repair
- Leakage at the bottom of the water tank.

1.FRP material

2. FRP laying and coating on water tank bottom

3. FRP laying and coating on water tank wall

19

Three typical repair cases

- Salu 40,000 m³ distribution water tank repair
- The expansion joints were displaced

1. Removed the old joint filler material

2. Expansion joint cleaning

3. Epoxy resin filling and repair

4. Elastic sealant filling

5. Laying FRP as a protective layer.

6. Soft rubber plus stainless steel plate construction

20

Three typical repair cases

- Liyutan 50,000 m³ distribution water tank repair
- The expansion joints were displaced and leaked

1. Disinfection before diving

2. sludge removal

3. Remove the old expansion joint filler

4. Expansion joint cleaning

5. New rubber stop strip installation

6. Bottom floor drilling

7. Grouting through the bottom plate

21

Conclusion

- The basis for the applicability of the repair method should be determined by the size of the crack, the degree of damage, the water supply conditions of the water tank.
- The expansion joint is often the main cause of leakage of the water tank. Designed into multiple tanks and reducing the setting of the expansion joints can reduce the probability of water leakage.
- For expansion joints setting, it should consider the common shear steel bars, water stops, and caulking materials.
- Repair materials should pay attention to the safety of water quality. The materials should be inspected and confirmed to not affect the drinking water quality before use.

22

Thank you

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TAIWAN WATER CORPORATION

23

The 11th CTWWA/JWWA/WRF Water System Seismic Conference

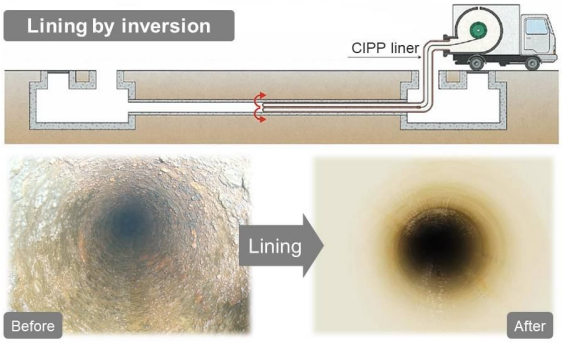
A study on the behavior of a multiple-layered, fully-structural cured-in-place pipe in ultimate limit state in earthquakes

Hiromasa ISHIZEKI
Manager, Potable Water Products
PALTEM, Ashimori Industry Co., Ltd.

Agenda

1. **Introduction**
2. Characteristics of "Base Hose"
3. Verification of adhesive-backed hose's performance to accommodate joint displacement
4. Bending test on a fully-structural CIPP

Introduction – CIPP (Cured-in-place pipe)



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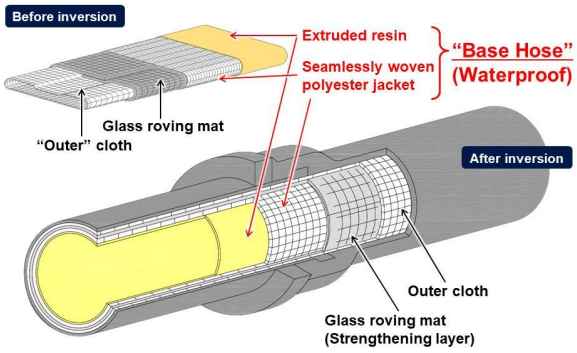
Introduction – CIPP (Cured-in-place pipe)

4

Introduction – CIPP, example of PALTEM



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Introduction – Industrial background

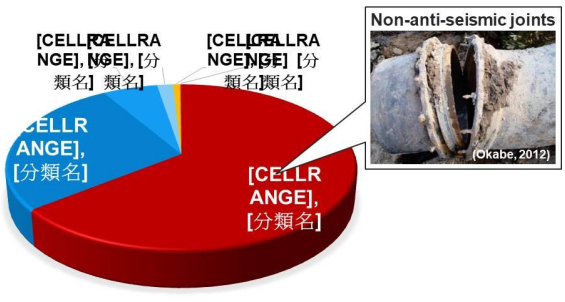
Seismic standards for trenchless pipe rehab

- **Sewer**
  Level 1 & 2 classification and performance criteria for CIPP
- **Gas**
  CIPP standardized for sealing purpose in earthquakes
- **Potable water**
  CIPP installation records not enough for standardization

6

Introduction – past experiences

400 km of our liners were used in...



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Introduction – continuous studies

Last workshop...

- Survey proved past performance
- Pipe with CIPP behaved like continuous pipe
- Calculation method selected for CIPP

Study continues:

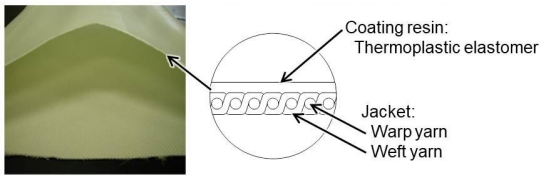
- CIPP's behavior in bending displacement?

8

Agenda

1. Why we do this
2. **Characteristics of "Base Hose"**
3. Verification of adhesive-backed hose's performance to accommodate joint displacement
4. Bending test on a fully structural CIPP

"Base Hose" - Characteristics



Thickness		mm	1.5～2.0
Axial tensile strength		N/mm	210～270
Burst pressure		MPa	0.30～0.75
Elongation at break	Jacket	%	15
	Coating resin	%	400

10

"Base Hose" - functions

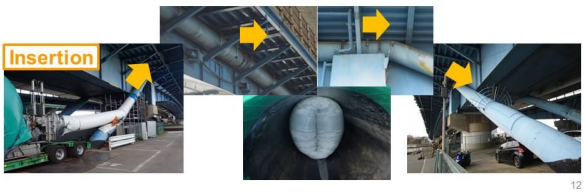
Base Hose : "Adhesive-backed hose" or "cured-in-place liner"

- JWWA
  "Sealing material in-pipe installation method"
- ISO11295
  "Class-C and Class-D of "Lining with adhesive-backed hose"

Manufacturing stage	✓ Holding resin ✓ Protection for strengthening layer
Installation stage	✓ Air inversion ✓ Steam cure
In-service	✓ Conformance to drinking water quality ✓ Leak/corrosion prevention

11

"Base Hose" - functions

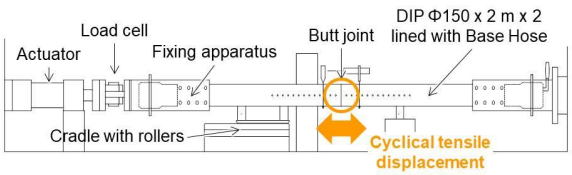


12

Agenda

1. Why we do this
2. Characteristics of "Base Hose"
3. **Verification of adhesive-backed hose's performance to accommodate joint displacement**
   - **Dynamic axial tensile test**
   - **Bending displacement test**
4. Bending test on a fully structural CIPP

Dynamic tensile test – Base Hose by itself



Sample	Internal pressure (MPa)	Joint separation (mm)	Amplitude (mm)	Frequency (Hz)	Number of displacement cycles	Results
1	0.50	100	±50	1.0	30	No leakage
2		100	±10	3.0	90	
3		100	±20	3.0	90	

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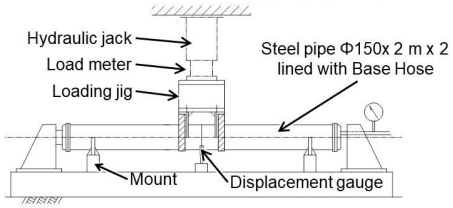
Dynamic tensile test – Base Hose by itself

15

Bending test – Base Hose by itself



Sample	Internal air pressure (MPa)	Host pipe joint break		Max displacement		Result
		Displacement (mm)	Bending angle	Displacement (mm)	Bending angle	
1	0.33	32	2.2	150	15.1	No Leakage
2		13	0.9			
3		18	1.2			

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Capability of Base Hose – observations

- **Base Hose used as ABH (CIPL) debonds in displacement**
- **Debonded section accommodates further displacement and maintain water-tightness**
- **This phenomenon improves host pipe joints**

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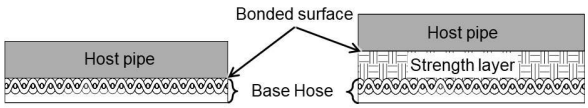
Agenda

1. Why we do this
2. Characteristics of “Base Hose”
3. Verification of adhesive-backed hose’s performance to accommodate joint displacement
4. **Bending test on a fully-structural CIPP**

Bending test - fully structural CIPP with BH

Adhesive-backed hose
- Corrosion prevention
- No strength layer
- Accommodation to displacement

Fully-structural CIPP
- Structural rehabilitation
- Strength layer for structural performance & long-term performance
- Pullout prevention & accommodation displacement



19

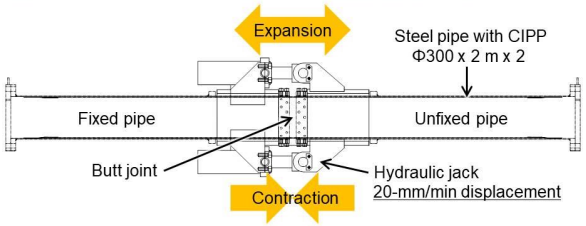
Bending test - fully structural CIPP with BH

Specification of the tested CIPP

Nominal Diameter		mm	300
Strength layer	Thickness	mm	4.0
	Flexural strength (hoop)	MPa	230
	Flexural modulus (hoop)	MPa	13,000
	Tensile strength (hoop)	MPa	210
	Tensile modulus (axial)	MPa	9,500
	Burst pressure	MPa	5.6
	Elongation at break	%	2.0
Waterproof layer	Thickness	mm	1.3
	Elongation at break	%	15.0

20

Bending test - fully structural CIPP with BH

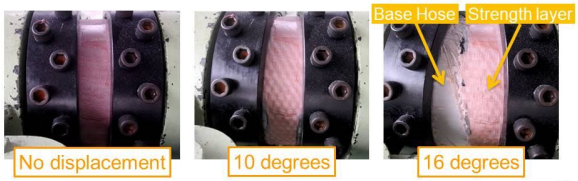


21

Bending test - fully structural CIPP with BH

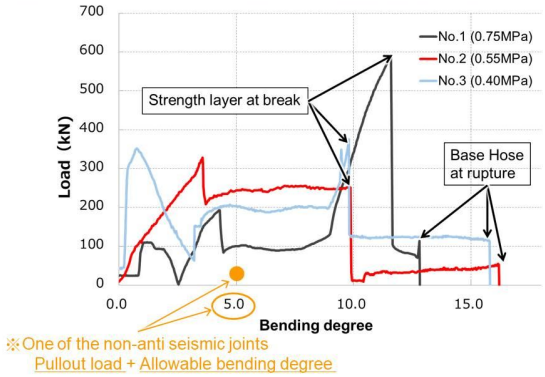
Sample	Internal pressure (MPa)	Strengthening layer at break		Base Hose at rupture		Leakage
		Load (kN)	Bending angle	Load (kN)	Bending angle	
1	0.75	591	11.5	100	12.5	Yes
2	0.55	251	10.0	53	16.0	Yes
3	0.40	362	10.0	-	16.0	No*

*Test aborted at max bending of apparatus



22

Bending test - fully structural CIPP with BH

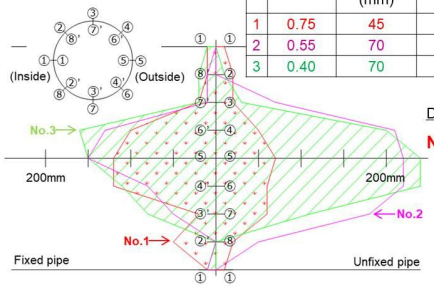


※One of the non-anti seismic joints
Pullout load + Allowable bending degree

23

Bending test - fully structural CIPP with BH

	Internal pressure (MPa)	Dipsplace-ment in outside of bending (mm)	Waterproof layer		
			Max debonded length (mm)	Elongation (%)	
				Actual	Spec
1	0.75	45	190	23.7	15.0
2	0.55	70	385	18.2	
3	0.40	70	370	18.9	



Debonded length
No.1 < No.2 ≒ No.3

24

Conclusions

- Base Hose in CIPP behaved equivalently to adhesive-backed-hose (or CIPL)
- CIPP maintained strength up to 10° bending
- Strength layer suppressed bending displacement in non-anti seismic joints
- Multi-layered CIPP maintained water-tightness up to certain displacement after strength layer ruptured

25

Q&A

Further challenges still remain

Contact: Hiromasa Ishizeki

hiomasa_ishizeki@ashimori.co.jp

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Review of TWC Emergency Response System for Hualien Earthquake Disaster

Presenter：Wu-Lung Lin
2019.10
Head of Engineering Department
The Ninth Branch of Taiwan Water Corporation

Contents

- Introduction of water supply
- Overview of Hualien earthquake disaster
- Emergency response
- Review and recommendations
- Conclusion

1

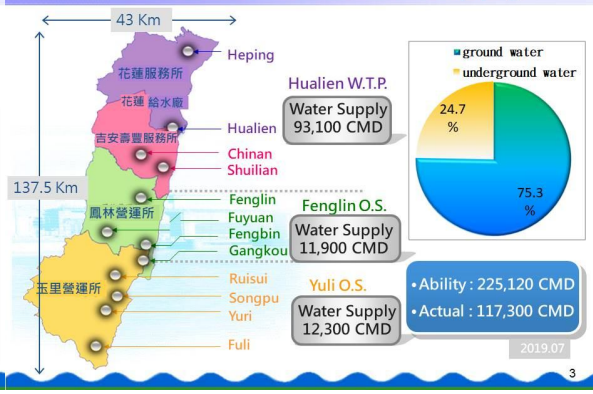
Introduction of water supply

Hualien County,
The Ninth Branch

Item	9th branch (a)	TWC (b)	Ratio (a/b)
Geographical area (Km*Km)	4,629	36,193	12.79%
Number of workers (people)	162	5,686	2.85%
Population served (people)	286,000	18,162,000	1.57%
Water supply (CMD)	117,300	8,810,000	1.33%
Pipeline length (Km)	1,892	62,369	3.03%

2

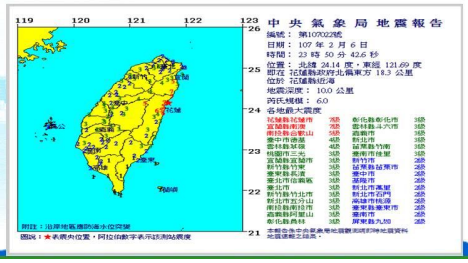
Introduction of water supply



3

Overview of Hualien earthquake disaster

- The Hualien 0206 earthquake, occurred at 23:50 on February 6, 2018.The earthquake scale was ML 6.2, MW 6.4, and had a focal depth of 6.3 km.
- About 400 aftershocks were recorded till February 11, averaging about 80 times a day.

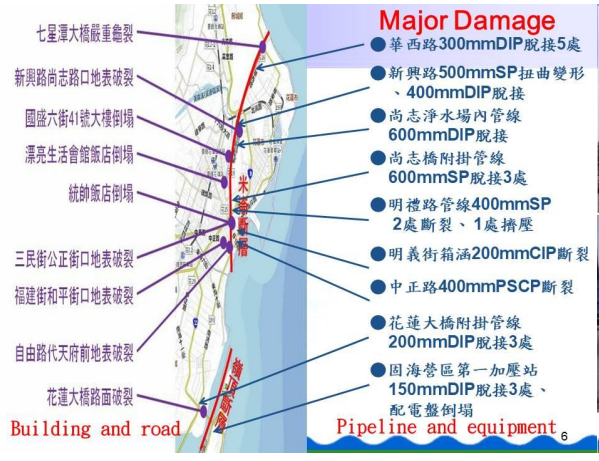


4

Overview of Hualien earthquake disaster

- 4 buildings partially collapsed or were severely damaged, 3 piers in Hualien Port were cracked, 39 roads were damaged, 17 people died, 295 people were injured.
- Domestic water supply for 40,000 households was affected from February 7, and fully restored on February 14.
- The pipelines, equipments near the Milun fault and the Lingding fault were seriously damaged.
- The most serious damage of the tap water is the 600mm steel pipe, for the supply of Hualien city, attached to both sides of the Shangzhi Bridge, were disconnected, and the 500mm steel pipe on Xinxing Road severely distorted.
- As of February 14, 731 repairs were completed, and up to 1,950 repairs till April.

5

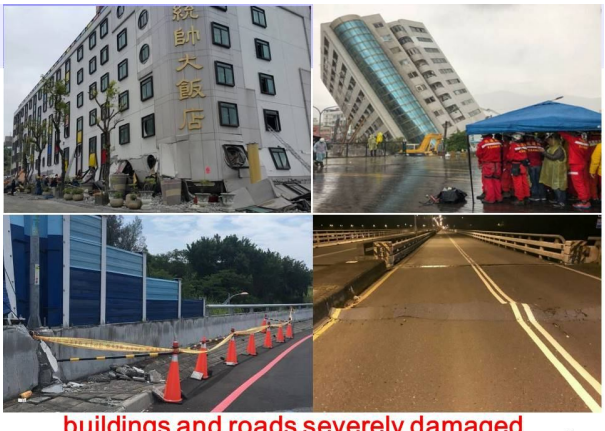


Major Damage

- 華西路300mmDIP脫接5處
- 新興路500mmSP扭曲變形、400mmDIP脫接
- 尚志淨水場內管線600mmDIP脫接
- 尚志橋附掛管線600mmSP脫接3處
- 明禮路管線400mmSP 2處斷裂、1處擠壓
- 明義街箱涵200mmCIP斷裂
- 中正路400mmPSCP斷裂
- 花蓮大橋附掛管線200mmDIP脫接3處
- 固海營區第一加壓站150mmDIP脫接3處、配電盤倒塌

Pipeline and equipment

6



buildings and roads severely damaged

7

600mm steel pipe, attached to Shangzhi Bridge. 8

400mm steel pipe on Mingli Road,2 breaks,1 extrusion. 9

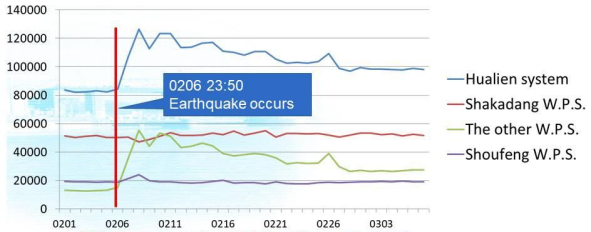
200mm steel, attached to Hualien Bridge, 2 disconnections, 1 break. 10

500mm steel pipe on Xinxing Road severely distorted. 11

The communication pipe break is the most common case. 12

Overview of Hualien earthquake disaster

- The average water supply of Hualien system was 87,388 CMD in 2017, and up to 125,000 CMD during the earthquake, and about 88,000 CMD for recently.



Water supply of Hualien system 13

Emergency response

According to the "Guidelines for Emergency Response Team", "Standard Operating Procedures for Disaster Event", etc., the following emergency response procedures were carried out, and TWC staff went all out for restoration to mitigate public inconvenience as soon as possible.

- Establish the Emergency response team
- Strengthen emergency procurement
- Efficient release of news and information
- Zone the leak area
- Repair with heart and soul
- Enhancement of communication channels
- Optimize customer service
- Flexible setting of water supply stations
- Enhance water tankers dispatch
- Confirmation of restoration

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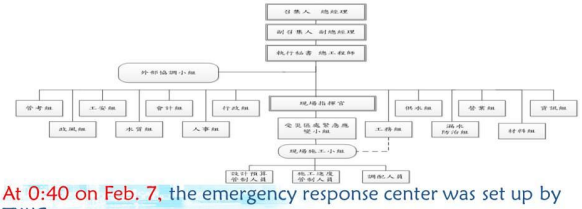
Emergency response

- Establish the Emergency response team



At 0:40 on Feb. 7, the emergency response center was set up by TWC.
All resources were led and dispatched by experienced personnel, including the former Chairman of TWC and now Chairman of CTWWA, Chun-Ming Kuo, the President of TWC, Nan-Tzer Hu, and the former Chief Engineer and now the vice-president, Jia-Rung Lee.

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Emergency response

- Strengthen emergency procurement
  - Using properly with support terms of contract.
  - Drew up and signed negotiation procedure with non-contract manufacturers according to government procurement laws and examples on February 7 .

主旨：有關本公司第六區管理處1家修漏廠商支援本處「0206花蓮之天然災害-地震」管線破裂修復乙案，復如說明，請鑒核。
說明：
一、依據六區處「台南給水廠107年東、南區配水管線修工程（契約編號：W6-107-0601-14）」，管線修漏工程投標施工補充說明第8條第6、7項辦理。
二、花蓮地區屬偏遠地區，請以合約單價計價後，總金額加成15%，議約金額概估200萬元整。
擬辦：奉核後，移請發包中心辦理議約程序。

主旨：為本處107年2月6日花蓮地區發生規模6.0地震，肇致管線嚴重受損，擬邀請雄聖水電工程行、正文水電工程行、樹亞工程有限公司、慈利工程有限公司、大鵬水電工程行及國鑫水電工程行、永浩工程行等辦理緊急搶修作業，簽請核示。
說明：
一、依據「政府採購法第 105 條第 1 項第 2 款」及「特別採購招標決標處理辦法第 2 條、第 5 條、第 6 條及第 7 條」規定辦理。
二、緣起：107年2月6日23:50花蓮強震造成本處轄區管線破裂。
三、辦理緊急採購之必要：本處轄區管線、設備多處損壞，經通報漏水地點已逾一百處(詳附件1)，恐因漏水造成地基及道路掏空，導致人民之生命、身體、健康及財產遭遇緊急危難，故為盡速完成搶修作業，擬依「特別採購招標決標處理辦法」第5條第2項規定，採彈性措施，得不適用政府採購法第二章招標及第三章決標之條文（詳如附件2）；其得採行之措施未敘明者，仍適用採購法之規定。
四、邀請指定廠商之理由：本處管線設備維修廠商王董水電公司及本公司災害緊急搶修廠商遴選名單列冊之通佑營造工程有限公司因人力、機具有限，恐無法完成本次突發之眾

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Emergency response

- Efficient release of news and information

Release date	News, information contents
9:00, February 7	Location of water supply station.
14:00, February 10	Hualien 0206 earthquake, TWC water supply route map (7 routes).
16:00, February 10	Hualien 0206 earthquake, The list of water and electricity operators for the damage of the private facilities and leaks.
22:00, February 11	Check the inside of the house for leaks to avoid sudden increase in bills.(Check the red triangle of the meter rotate or not)
09:00, February 14	Hualien 0206 earthquake, Water supply fully restored.
09:00, February 17	The President is concerned about post-disaster recovery, and the Vice President personally encourages TWC.
17：00, March 9	Hualien earthquake disaster review, TWC thanks all walks of life for their support.

In order to let the people feel at ease, understand the restore progress, etc., press release is issued in appropriate time.

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Emergency response

- Zone the leak area
  - From Feb. 7 to Feb. 23, the leak detection members came from all the branch of TWC (80 people), were sent to Hualien City as a key area to divide the area of responsibility and perform pipeline inspections and surveys at night.
  - 315 leaks on the ground and 350 leaks under the ground, a total of 665 leaks were detected. And all of these were transferred to nearby leak-repairing manufacturers.

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Emergency response

- Repair with heart and soul

During the repair process, 22 manufacturers covering leak repair, leak detection, water supply monitoring, formed 29 groups of manpower. In addition, 5 self-employed manpower of TWC for leak repair, did their best for 24 hours. As of Feb. 14, 731 pipe repairs were completed, and water was restored to almost all customers.

一區	湧薪工程有限公司	九區	王董水電工程行
	桔原企業有限公司		永浩工程行
二區	祥智工程有限公司		雄聖工程有限公司
三區	仲賓工程有限公司		國鑫水電有限公司
	甫東工程有限公司		樹亞工程有限公司
五區	翊安水電工程行		慈利工程有限公司
六區	豪通工程行		正文水電工程有限公司
	弓銓企業有限公司		大鵬水電工程行
七區	啟忠水管工程有限公司		禾鄢有限公司
八區	利合伯水電工程有限公司	十二區	易原工程有限公司
	萬基工程有限公司		昊潤工程有限公司

19

Emergency response

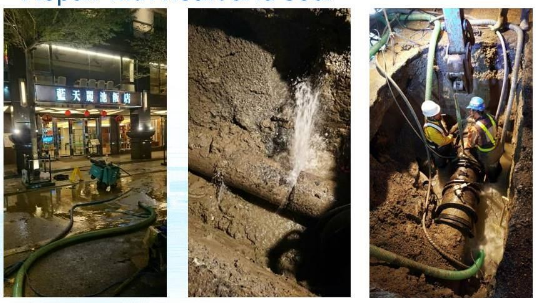
- Repair with heart and soul

600mm steel pipe, under Shangzhi Bridge

20

Emergency response

- Repair with heart and soul



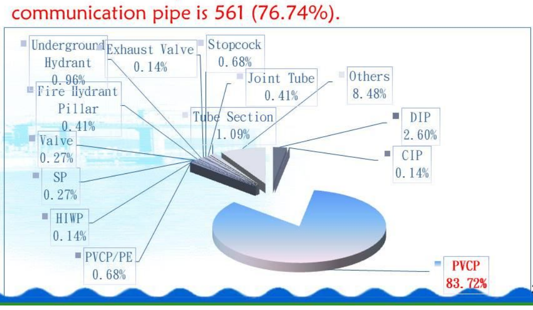
400mm pre-stressed concrete pipe, Zhongzheng Road

21

Emergency response

- Repair with heart and soul

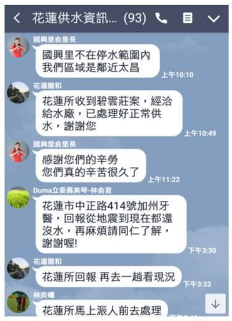
From Feb. 6 to 14, the number of leak items was 731. The leaks of PVCP reached up to 83.72%, of which the number of communication pipe is 561 (76.74%).



22

Emergency response

- Enhancement of communication channels
  - Setup the JUIKER group "0206 Hualien Earthquake" for internal communication.
  - Setup the LINE group“0206 Pipeline Inspection and Repair ”, ”Water Truck Group”, etc., for each team staff.
  - Setup the LINE group “HuaLien Water Supply Information”, for public communication, and the county councilor, village mayors, public opinion representatives of all levels, each can receive instant information.



23

Emergency response

- Optimize customer service

Date	February 7	February 8	February 9	February 10	February 11	February 12	February 13	February 14
Number of entry	1039	1519	1442	731	716	622	452	358

- The Customer Service Center collected and analyzed all water shortage incoming calls and the respective location every 2 hours, and announced the analytics in the "0206 Hualien earthquake" JUIKER group.
- The emergency response team could grasp the disaster situation and determined the priority for processing water supply stations, leak repair, etc.

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Emergency response

- Optimize customer service
  - Issues with the water meter box components would be handled immediately by the service staff.
  - User's internal issues (eg. internal leaks, pumping motor failure, etc.) would be explained in detail.
  - As for leaks from the outside which locations could not be confirmed, the leak prevention department would be notified to assist in leak detection.
  - As the leak location was confirmed, the Hualien Water Treatment Plant would record and dispatch for the repairs.
  - End-to-end control by the customer service system.

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Emergency response

- Flexible setting of water supply stations
  - The water supply station reached max of 45 stations, and the locations could be changed according to the water supply situation.
  - Priority was given to sending water to the medical institutions, and injecting water into the basement reservoir of the building, which could immediately improve the water demand and eliminate the hardship for people to transport water.
  - At 14:30 on February 10, 7 water delivery routes (refer to the garbage truck route) were started to meet the water demand.


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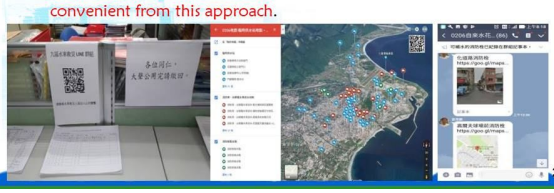
Emergency response

- Enhance water tankers dispatch
  - When a worker reported for duty, he was required to scan the QR CODE to join the LINE group.
  - Locations of all Water Purification Station and water supply station were jotted down on Google Maps.
  - These Google maps were then posted and shared in the LINE group notes, so everyone could automatically navigate after clicking.
  - After the work was allocated, the driver could automatically navigate according to the assigned locations. Handover of work was also more convenient from this approach.



27

Emergency response

- Enhance water tankers dispatch

Water tankers dispatch was up to 49 a day, the traffic volume of water supply was up to 219 times a day, and 980 times for all. With the assistance of technology, we could handle water tanker dispatching in an orderly manner.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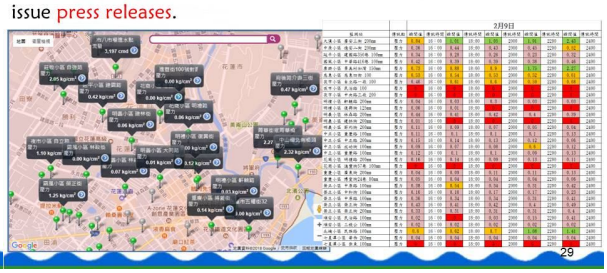
Emergency response

- Confirmation of restoration

By using the water supply monitoring system, the 9th branch of TWC could instantly understand the water pressure of the pipe network, prioritize maintenance and repair, respond to users, and issue press releases.



29

Emergency response

- Confirmation of restoration
  - The water supply status reporting system on the website of TWC, which was developed after the earthquake, allowed all users to report the water supply situation at their location, such as normal, low water pressure, and water shortage. Such reports could be instantly displayed on the map in different colors.
  - With this system, we can quickly understand the water supply situation from the users feedback in the event of a water supply disaster in the future.

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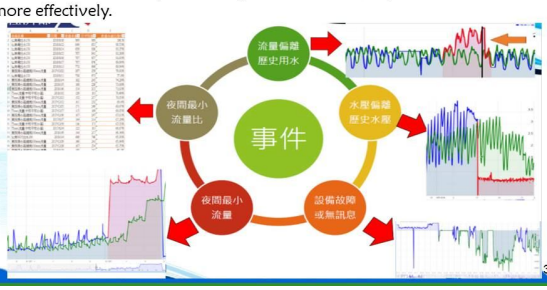
Emergency response

- Confirmation of restoration

The WADA (Water Advanced Data Analysis) system developed by the big data project team of TWC has achieved great results. In the future, it can be applied to the automated analysis of a large number of DMAs, and can detect leaks more effectively.



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Review and recommendations

After the restoration, TWC held 2 meetings ,on March 9 and April 20. The following suggestions were made:

- Record of emergency response: special personnel or professionals should be hired to handle the recording of the catastrophic recovery process. The record will be used for news release and subsequent employee training.
- Emergency Rehearsal: In order to ensure a smooth operation of water supply, and to enhance each employee's awareness of disaster prevention and their ability of emergency response, the compound disaster situation should be simulated.


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Review and recommendations

- Increase manpower and complete GIS map inquiry APP: When manufacturers come to support the repairs, not only maintenance personnel, but also supervisors and operators should provide the support together. This is required to complete the repair data in detail with photos. After the repair, manpower should confirm whether the water valve has been restored or not, and strengthen the drainage and exhaust operation. After the impact, operation manpower of the 9th branch has added 8 people in 2018. In addition, a GIS inquiry APP has been completed to facilitate instant query of the pipeline network map.
- Distinguish the responsibility of leak detection and repair personnel according to the DMAs of the network.

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Review and recommendations

- Construction of leak detection and repair system APP: case explosion, should be managed by a system together with leak detection and repair for effectiveness. Furthermore, such system can promote the efficiency of our customer service center with value-adding applications, such as combined water outage areas, instant pressure return, etc.
- Continue to build pressure observation stations and strengthen monitoring system maintenance.
- Avoid important valve be undergrounded: Due to the road leveling project, the road management department asked the pipeline company to bury the valve and the hole cover under the ground. It increases the digging time and the leak detection operation cannot be tested by sections, which will seriously affect the repair efficiency.

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Review and recommendations

- Provide accurate water repair estimation to avoid public grievances.
- Introduce local resources to assist: For example, the water truck can be assisted by local residents; small repairs to the water meter box components can be assisted by local technicians; and customer service calls can be answered by volunteers.
- Introduce the ductile cast iron pipe with seismic joint (NS-type DIP):The NS-type DIP developed in Japan have performed well in many earthquakes. However, the current low demand in Taiwan leads to high costs, and it can only be piloted in high-potential areas with frequent earthquakes and liquefaction to improve the seismic resistance. And it will be piloted in both Tainan and Hualien from 2019.

35

Conclusion

- During the repair period, experienced commanders of TWC such like Chun-Ming Kuo (former chairman), Nan-Tzer Hu (president), Jia-Rung Lee (vice-president), led the team and dispatched all the resources to the recovery work.
- 49 water tankers, 29 manufacturers assisted the repair, over 500 people were mobilized, 45 water supply stations were set up, 7 routes were launched in the water shortage areas, and water trucks were dispatched to provide water injection service to basement reservoir of buildings.
- Without taking any break during the Chinese New Year, all the team did their best to minimize public inconvenience.

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Conclusion

- Through various countermeasures and good use of technology tools, the water supply restored quickly. TWC reduced complaints and won applause.
- This is all credited to the people and companies for their concern and assistance during the restoration.
- We believe, with continuous review and response improvement after each disaster, TWC will become stronger.

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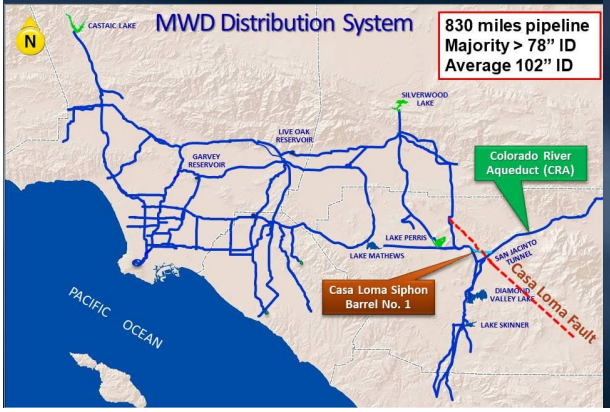
Mitigation of Fault Displacement and Ground Subsidence for Large Diameter Pipeline

Tao Peng, P.E., S.E.
Cathy Chau, P.E.
Metropolitan Water District of Southern California

Presentation Outline

- Introduction
- Background
- Geologic Hazard Evaluation
- Seismic Design Criteria
- Mitigation Strategy
- Numerical Modeling
- Conclusions

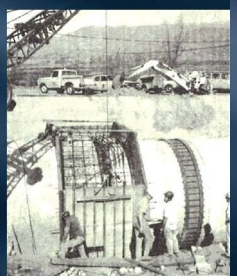
Introduction



Casa Loma Siphon No. 1 Location Map

Background

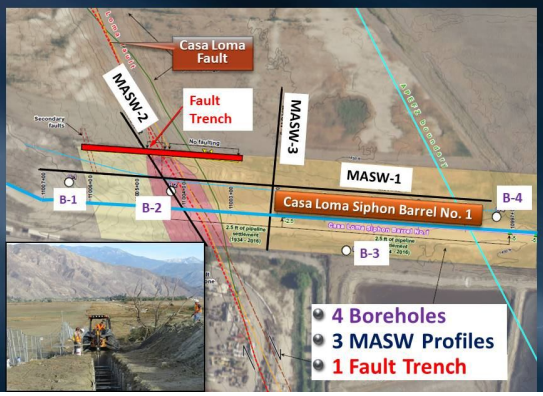
- 148-in concrete pipe constructed in 1935
- Ground subsidence due to ground water withdrawal
- Leaks have recurred for over 50 years
- Multiple repairs to address leaks
  - 300 ft of concrete pipe replaced with steel pipe in 1968
  - Internal seals installed in 1996 and 2017



Background

- Ground Subsidence
  - 5 feet of settlement in 800 feet
  - 0.8-in/year settlement adjacent to the Casa Loma Fault
- Casa Loma Fault (San Jacinto Fault System)
  - Capable of producing 7+ magnitude EQ
  - Potential displacement
    - 1 foot if fault ruptures on its own
    - 13 feet if multiple reaches rupture

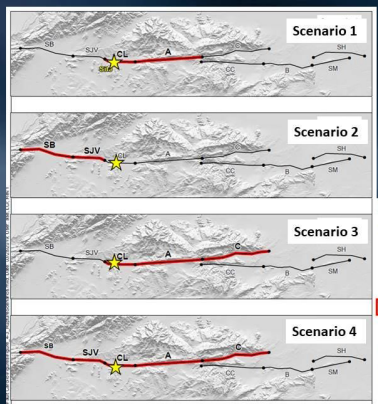
Geo-Hazard Field Investigations



Geo-Hazard Characterization Study

- Logic Tree Approach
  - Capture uncertainties in primary parameters
  - Tree branches represent values of parameters
  - Weights define distribution of values
- Fault Displacement Parameters
  - Rupture sources
  - Slip rate
  - Rupture length
  - Earthquake magnitude & recurrence
  - Fault displacement prediction model

Logic Tree Example – Rupture Sources

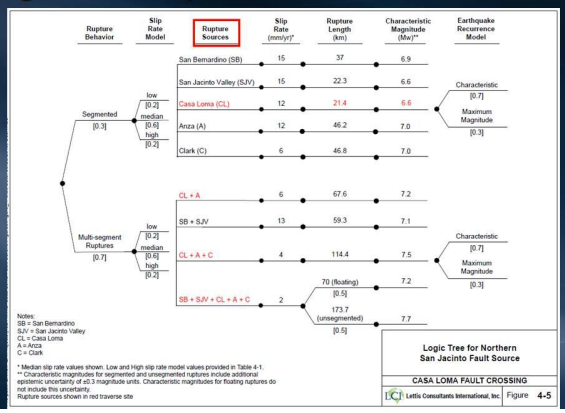


EXPLANATION

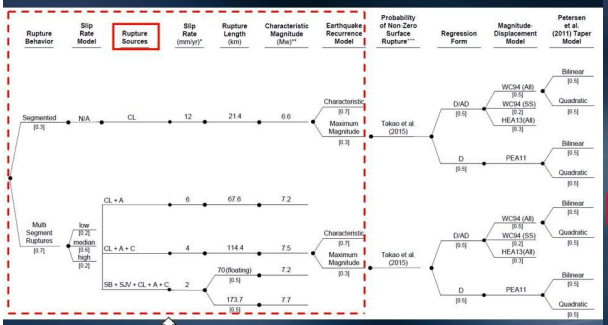
- ☆ Casa Loma fault crossing
- • Fault section end point

SB	San Bernardino
SJV	San Jacinto Valley
CL	Casa Loma
A	Anza
C	Clark
CC	Coyote Creek
B	Borrego
SH	Superstition Hills
SM	Superstition Mountain

Logic Tree Example – Fault Source



Logic Tree Example – Prob. Fault Displacement



Seismic Design Criteria

- Estimated Fault Displacement

Deterministic (DFDHA)	Horizontal	Vertical
50th percentile	4.8 feet (1.46 meters)	1.0 foot (0.3 meter)
84th percentile	14.2 feet (4.33 meters)	2.9 feet (0.9 meter)
Probabilistic (PFDHA)	**Horizontal**	**Vertical**
975 years (5% in 50 years)	5.9 feet (1.8 meters)	1.2 feet (0.4 meter)
2475 years (2% in 50 years)	**12.8 feet (3.9 meters)**	**2.6 feet (0.8 meter)**

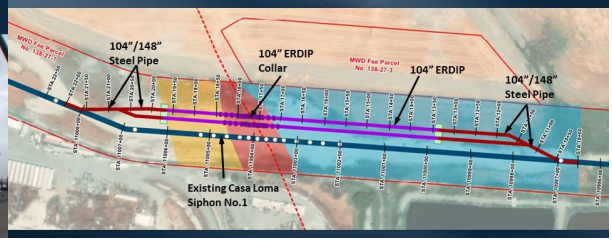
- Estimated Non-Tectonic Settlement
  - Settlement rate 0.8-in/year
  - Total 5 feet for 75 years
- Total displacement = Fault displacement + Settlement

Mitigation Strategy

- Earthquake Resistant Ductile Iron Pipe (ERDIP)
  - Absorbs large displacements & allows pipeline to remain intact
  - Over 50 years of experience in Japan
  - Used in US and Canada since 2013

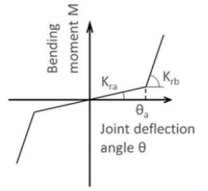
Project Scope

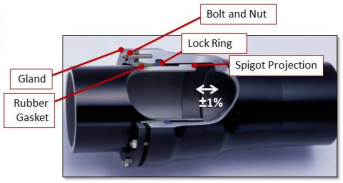
- Replace approx. 1000 feet of 148-in diameter steel and concrete pipe at fault crossing
  - Dual barrels of 104-in diameter ERDIP
  - Designed to withstand 13 feet horizontal and 3 feet vertical fault displacement plus 5 feet ground subsidence



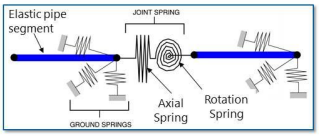
ERDIP Joint Modeling

Rotation (Bending) Spring

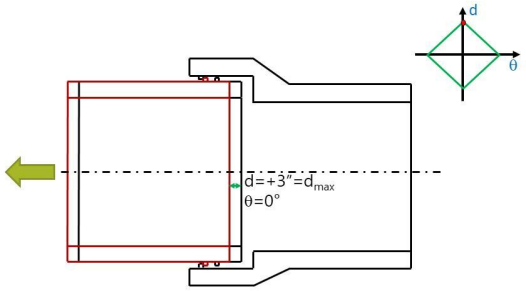




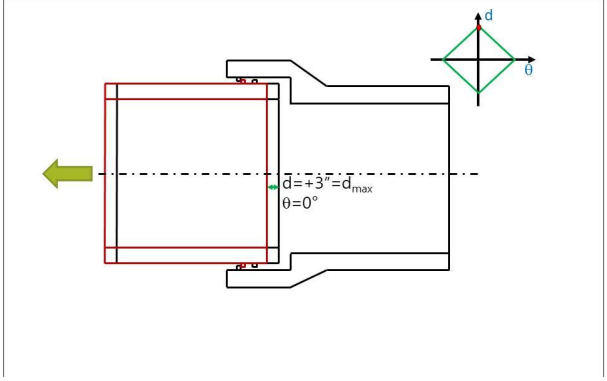
Rotation (Bending) Spring	
K_{ra}	7.10×10^1 (kN-m/deg)
K_{rb}	2.02×10^3 (kN-m/deg)
θ_a	1.3(deg)



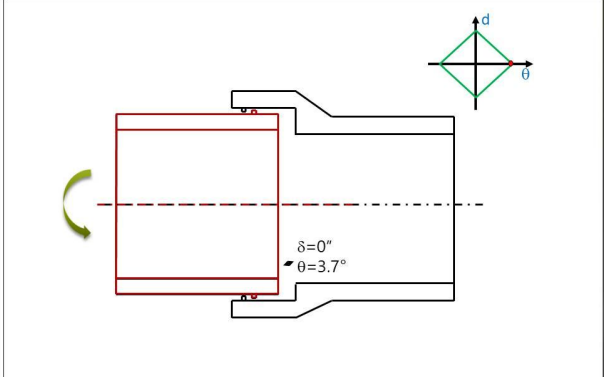
Joint behavior: Moving in tension



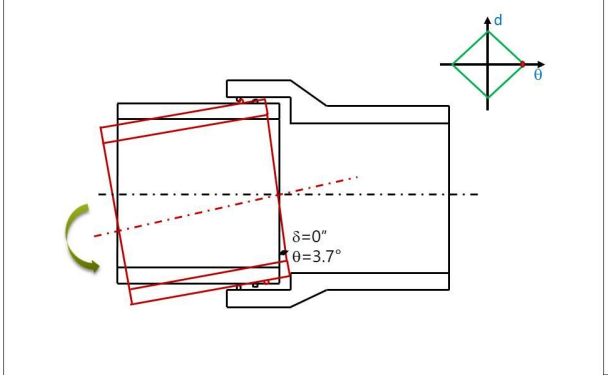
Joint behavior: Locking in tension



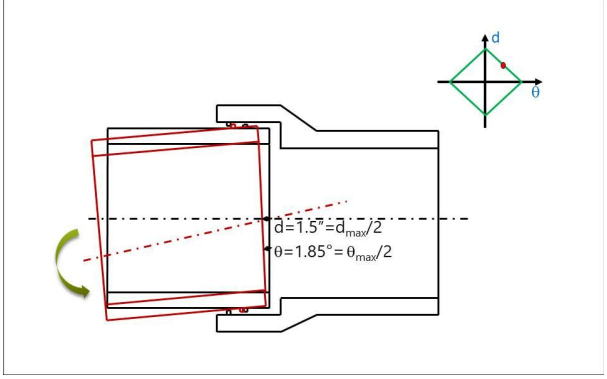
Joint behavior: Rotation



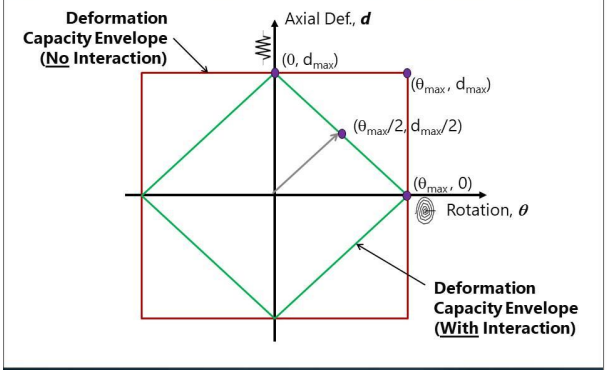
Joint behavior: Locking in rotation



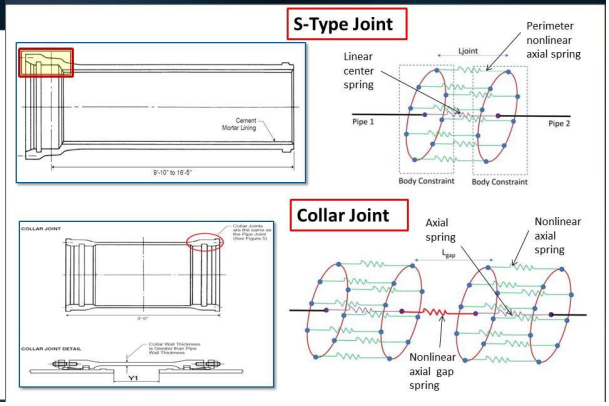
Joint behavior: Locking in rotation and tension



Axial/rotation joint capacity with and without interaction

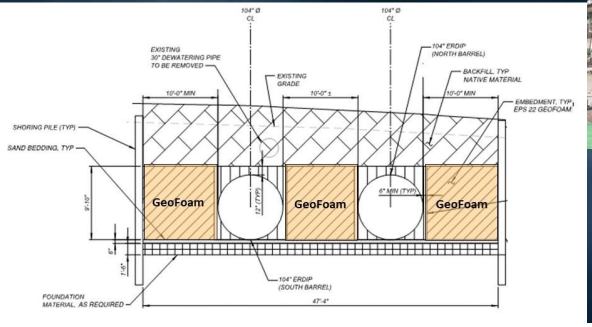


ERDIP Joint Modeling



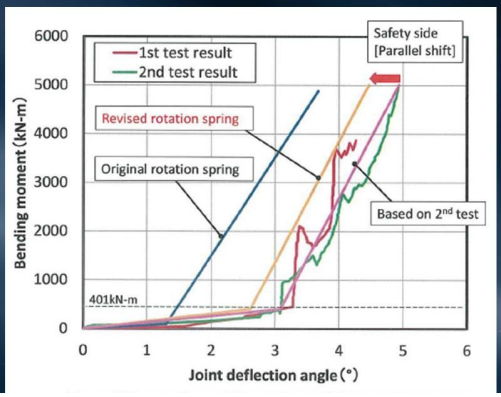
Pipeline and Fault Interaction Modeling

- Optimization of the modeling using EPS GeoFoam as backfill material



ERDIP Performance Testing

Revised Rotation Spring

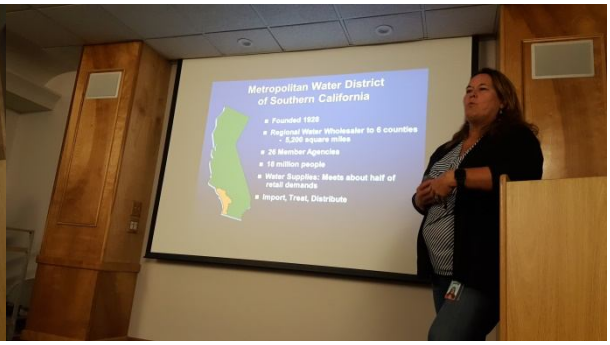


Conclusions

- The displacement hazard would cause large stresses in a conventional continuous pipeline.
- ERDIP absorbs the displacement through axial movement and rotation within the joints.
- The pipeline system could be designed for large displacement with a combination of S-type joints, collar joints, and engineered backfill.

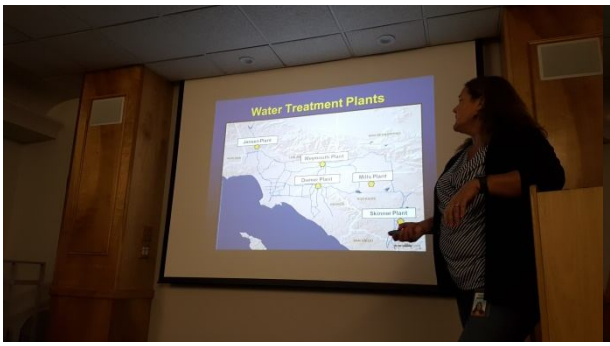
Questions?


Diemer
Water Treatment Plant


Metropolitan Water District
of Southern California
Founded 1928
Regional Water Wholesaler to 6 counties
- 5,200 square miles
26 Member Agencies
18 million people
Water Supplies: Meets about half of
retail demands
Import, Treat, Distribute

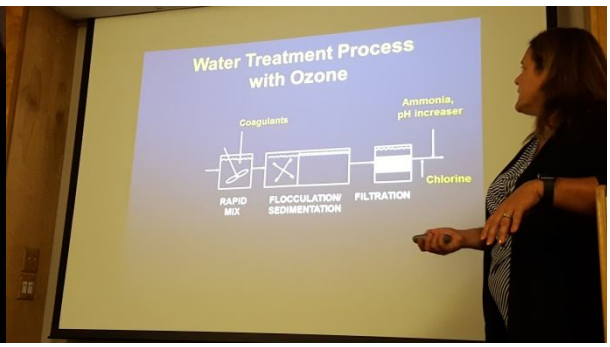

Where Southern California
Gets its Water
LA Aqueduct
Colorado River
Aqueduct
State
Water
Project
Local Supplies
Groundwater, Recycling,
Conservation

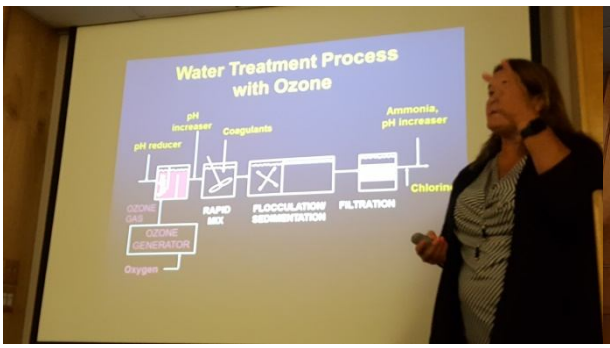

The Metropolitan Water District of Southern California

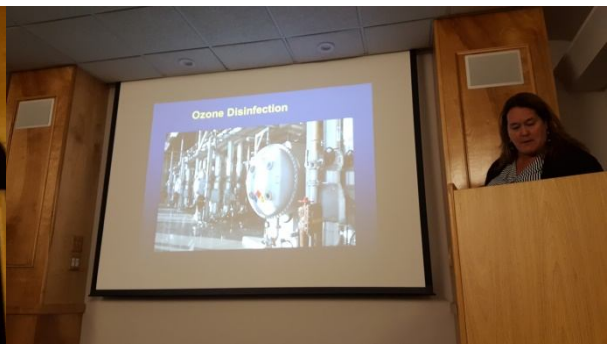

Water Treatment Plants


Diemer Water Treatment Plant

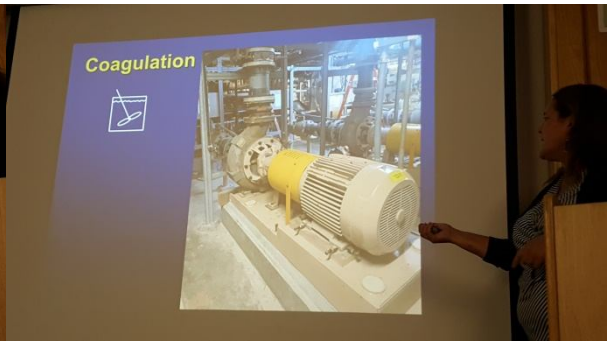

Diemer Water Treatment Plant
2009

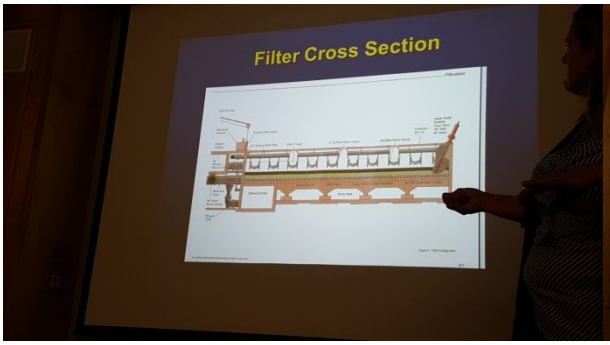

Water Treatment Process
with Ozone
Coagulants
Ammonia,
pH increaser
Chlorine
RAPID
MIX
FLOCCULATION/
SEDIMENTATION
FILTRATION


Water Treatment Process
with Ozone
pH
increaser
pH reducer
Coagulants
Ammonia,
pH increaser
Chlorine
OZONE
GAS
OZONE
GENERATOR
Oxygen
RAPID
MIX
FLOCCULATION/
SEDIMENTATION
FILTRATION


Ozone Disinfection


Ozone Disinfection

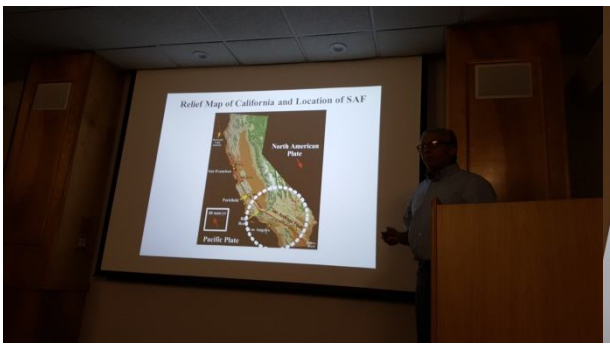

Coagulation


Filter Cross Section

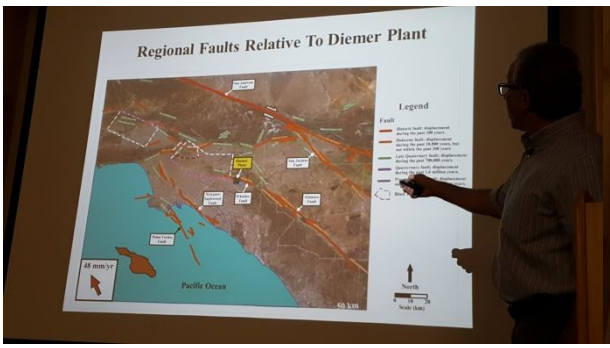

Finished Water Storage

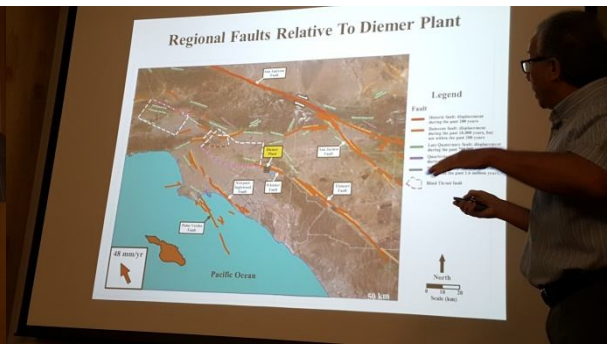

Regulatory Oversight
Enforced by EPA and the California Department of Public Health
Safe Drinking Water Act
– Enhanced Surface Water Treatment Rule
– Disinfection By-Product Rule
– Total Coliform Rule
– Lead and Copper Rule
Chemical and biological components
Over 120 regulated components

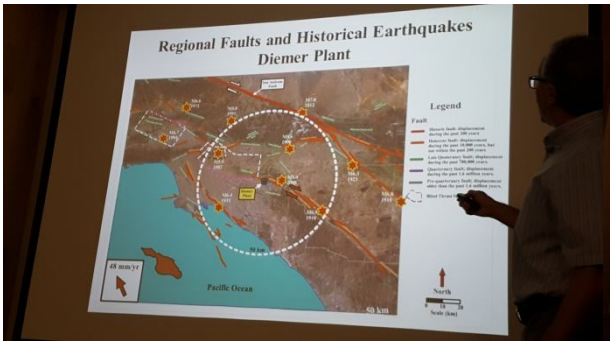

Thank you

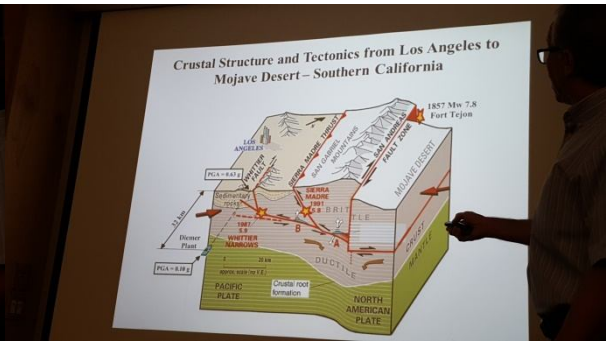

Relief Map of California and Location of SAF
North American Plate
Pacific Plate


Relief Map of California and Location of SAF
North American Plate
San Francisco
Parkfield
48 mm/yr
Pacific Plate

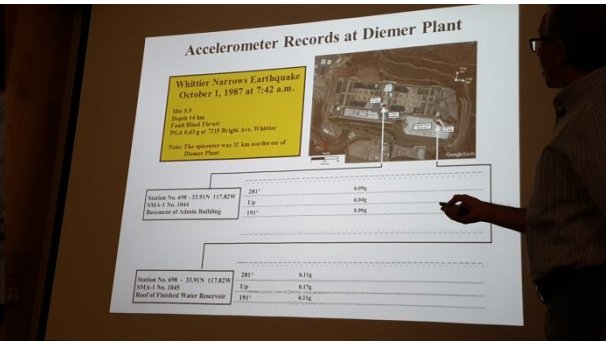

Regional Faults Relative To Diemer Plant
Legend
Fault
48 mm/yr
Pacific Ocean
North


Regional Faults Relative To Diemer Plant
Legend
Fault
48 mm/yr
Pacific Ocean
North

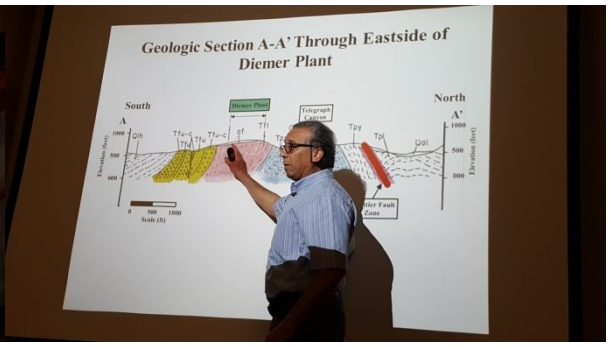

Regional Faults and Historical Earthquakes
Diemer Plant
Legend
Pacific Ocean
48 mm/YR
50 km
North

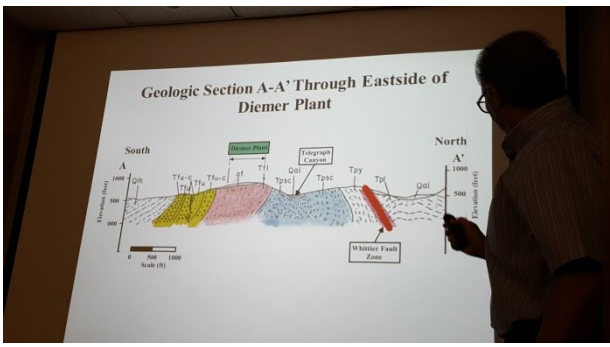

Crustal Structure and Tectonics from Los Angeles to Mojave Desert – Southern California
1857 Mw 7.8 Fort Tejon
LOS ANGELES
WHITTIER
SIERRA MADRE
SAN GABRIEL MOUNTAINS
SAN ANDREAS FAULT ZONE
MOJAVE DESERT
SIERRA MADRE 1991
WHITTIER NARROWS 1987
Diemer Plant
BRITTLE
DUCTILE
CRUST
MANTLE
PACIFIC PLATE
Crustal root formation
NORTH AMERICAN PLATE

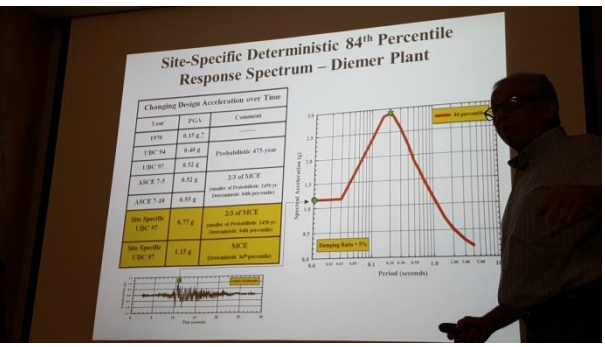

Aerial View of Diemer Plant and Locations of Two Accelerometers
Admin Building
Finished Water Reservoir
Google Earth


Accelerometer Records at Diemer Plant
Whittier Narrows Earthquake
October 1, 1987 at 7:42 a.m.

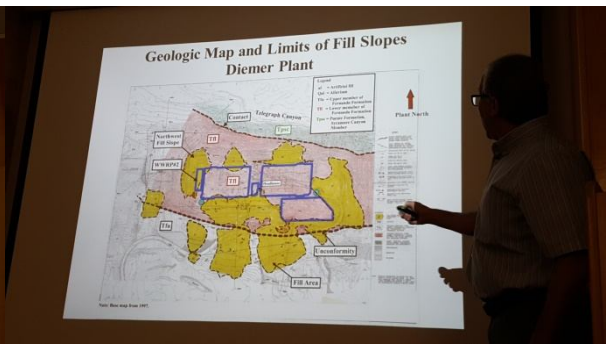

Area Geologic Map – Diemer Plant
Whittier Fault
Telegraph Canyon
Diemer Plant
North

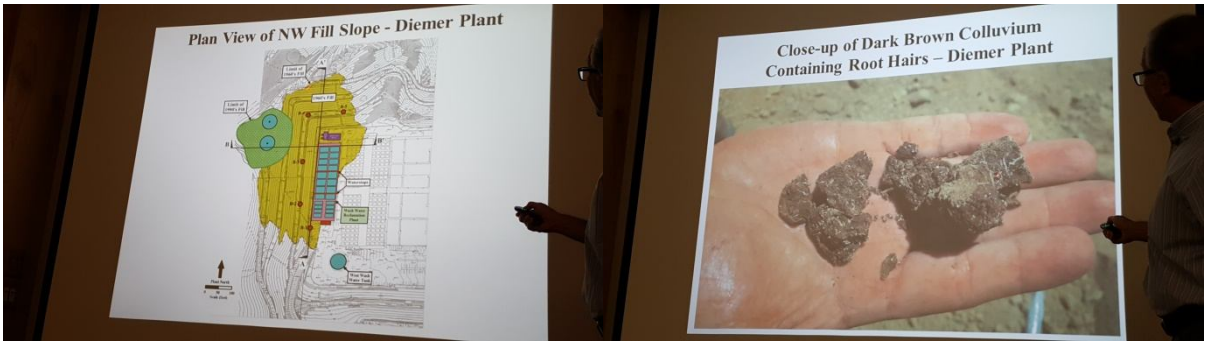

Geologic Section A-A' Through Eastside of Diemer Plant
South
North
Diemer Plant
Telegraph Canyon
Whittier Fault Zone


Geologic Section A-A' Through Eastside of Diemer Plant
South
North
Diemer Plant
Telegraph Canyon
Whittier Fault Zone

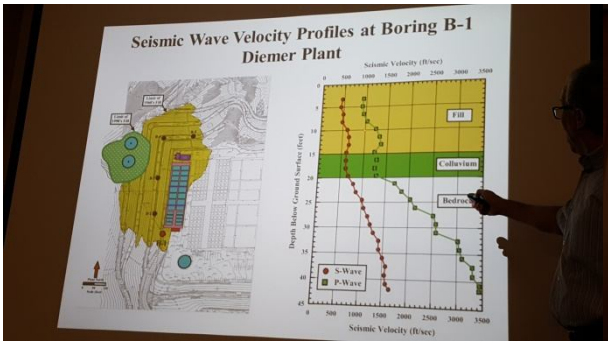

Site-Specific Deterministic 84th Percentile Response Spectrum – Diemer Plant
Changing Design Acceleration over Time
Period (seconds)

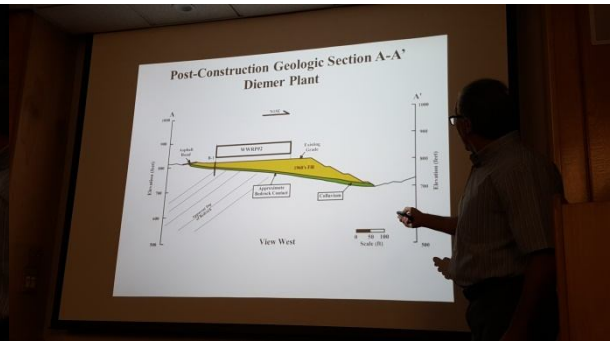

Diemer Plant During Construction in 1963
Northwest Fill Slope
East North

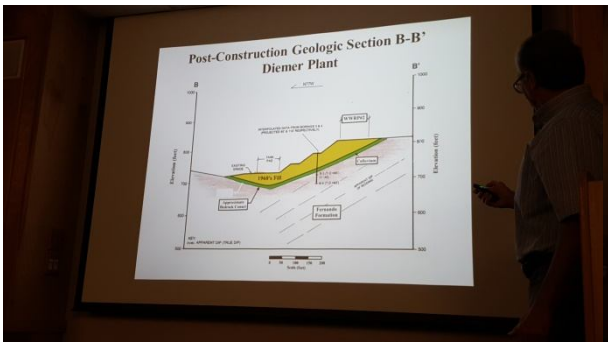

Geologic Map and Limits of Fill Slopes
Diemer Plant
Telegraph Canyon
Northwest Fill Slope
Unconformity
Fill Area
Plant North

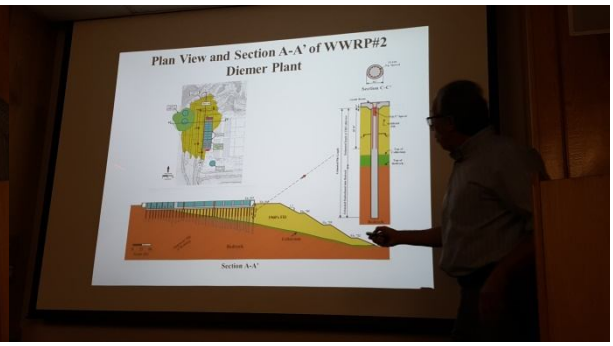

Plan View of NW Fill Slope - Diemer Plant

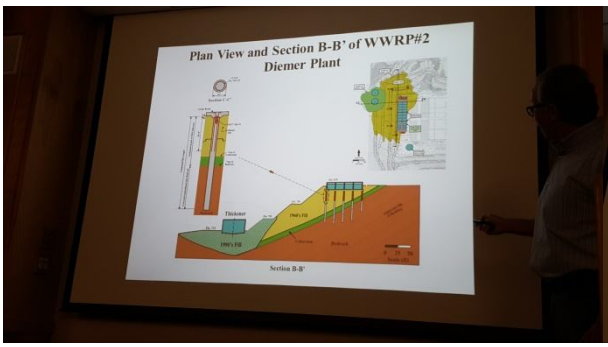
Close-up of Dark Brown Colluvium
Containing Root Hairs – Diemer Plant

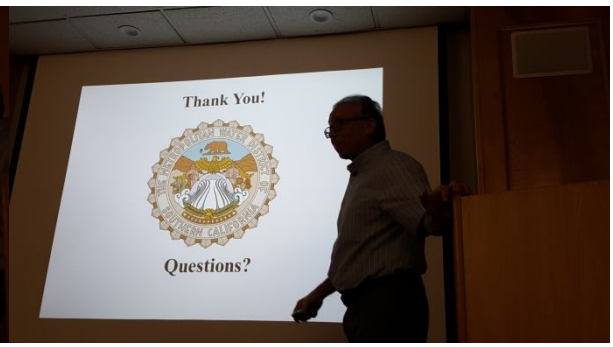

Seismic Wave Velocity Profiles at Boring B-1
Diemer Plant
Fill
Colluvium
Bedrock
S-Wave
P-Wave
Seismic Velocity (ft/sec)


Post-Construction Geologic Section A-A'
Diemer Plant
View West

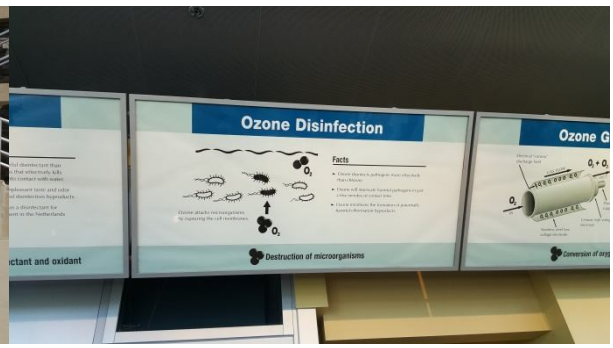

Post-Construction Geologic Section B-B'
Diemer Plant


Plan View and Section A-A' of WWRP#2
Diemer Plant
Section A-A'

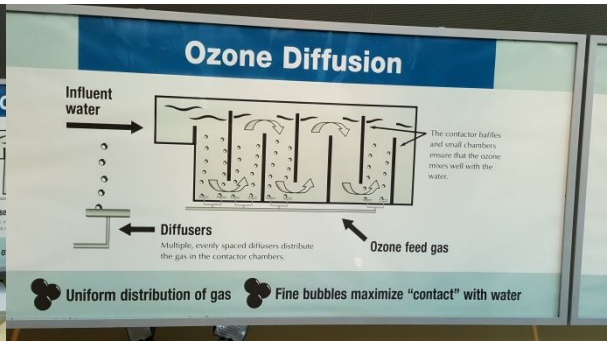

Plan View and Section B-B' of WWRP#2
Diemer Plant
Section B-B'

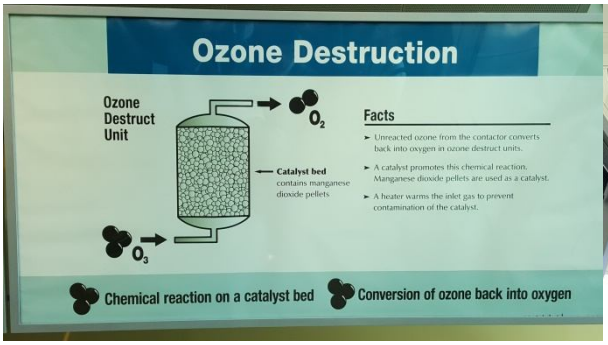

Thank You!
Questions?

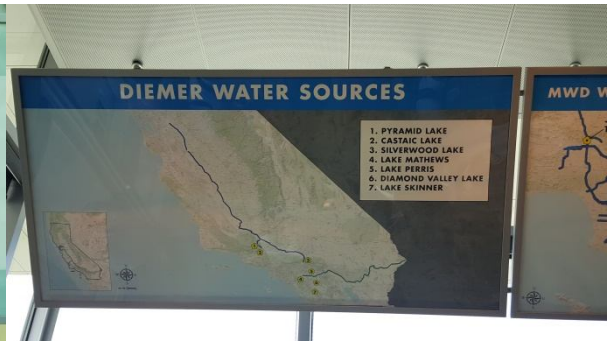

Challenges

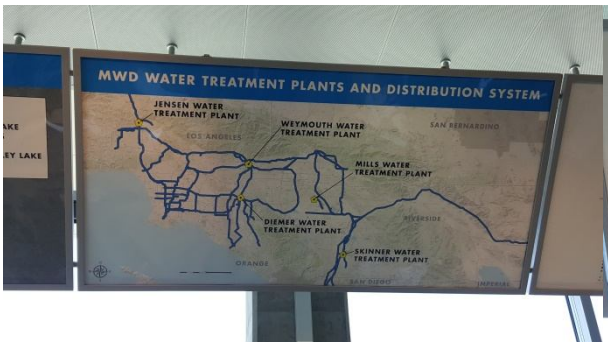

Ozone Disinfection
Facts
Destruction of microorganisms

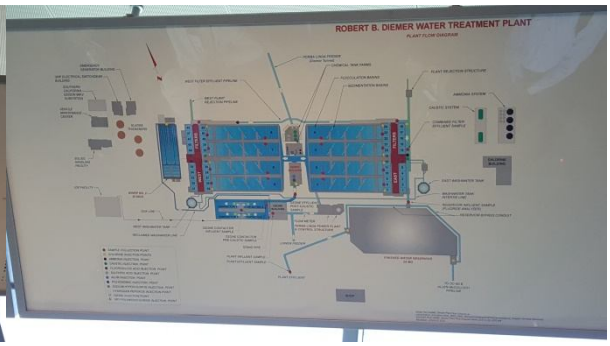

Ozone Generation
Facts
Conversion of oxygen to ozone


Ozone Diffusion
Influent water
Diffusers
Ozone feed gas
Uniform distribution of gas
Fine bubbles maximize "contact" with water

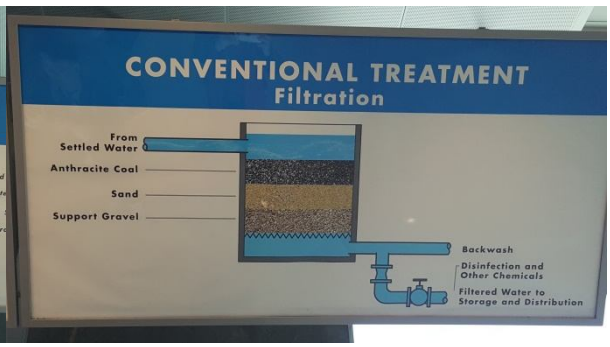

Ozone Destruction
Ozone Destruct Unit
Facts
Catalyst bed
Chemical reaction on a catalyst bed
Conversion of ozone back into oxygen

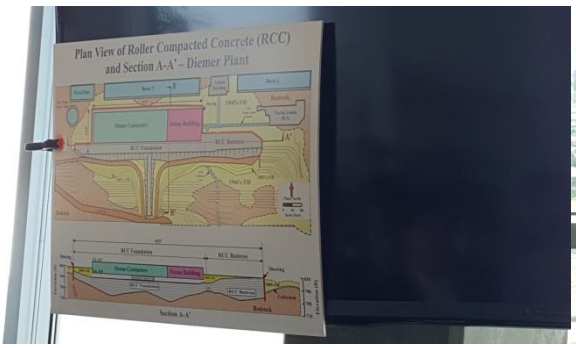

DIEMER WATER SOURCES
1. PYRAMID LAKE
2. CASTAIC LAKE
3. SILVERWOOD LAKE
4. LAKE MATHEWS
5. LAKE PERRIS
6. DIAMOND VALLEY LAKE
7. LAKE SKINNER

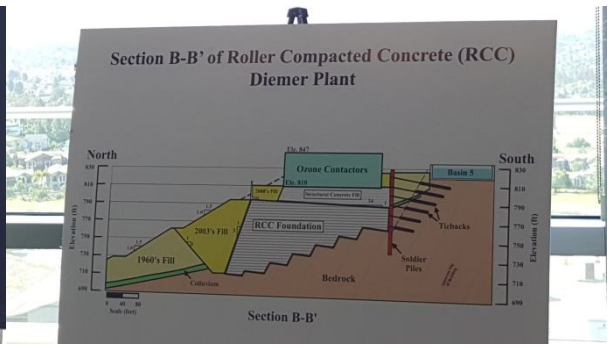

MWD WATER TREATMENT PLANTS AND DISTRIBUTION SYSTEM
JENSEN WATER TREATMENT PLANT
WEYMOUTH WATER TREATMENT PLANT
MILLS WATER TREATMENT PLANT
DIEMER WATER TREATMENT PLANT
SKINNER WATER TREATMENT PLANT

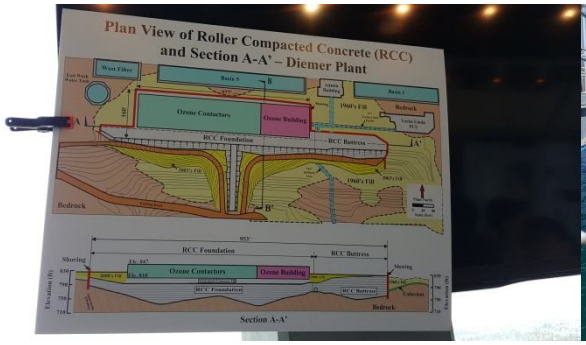

ROBERT B. DIEMER WATER TREATMENT PLANT


CONVENTIONAL TREATMENT
From Ozone Process
Coagulants
Settled Water to Filtration
Rapid Mix
Flocculation
Sedimentation


CONVENTIONAL TREATMENT
Filtration
From Settled Water
Anthracite Coal
Sand
Support Gravel
Backwash
Disinfection and Other Chemicals
Filtered Water to Storage and Distribution


Plan View of Roller Compacted Concrete (RCC) and Section A-A' – Diemer Plant


Section B-B' of Roller Compacted Concrete (RCC)
Diemer Plant
North
South
Ozone Contactors
Basin 5
RCC Foundation
1960's Fill
2003's Fill
Tiebacks
Soldier Piles
Bedrock
Section B-B'

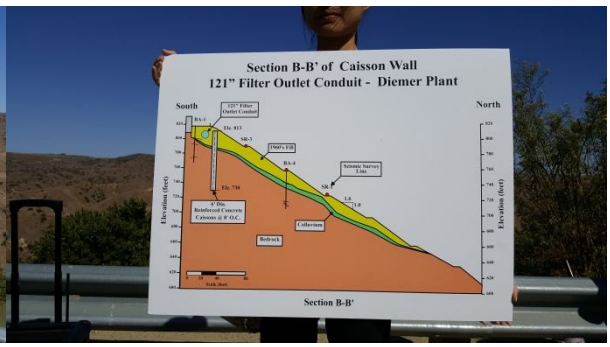

Plan View of Roller Compacted Concrete (RCC)
and Section A-A' – Diemer Plant
Ozone Contactors
Ozone Building
RCC Foundation
RCC Buttress
Bedrock
Section A-A'


Diemer Filter Buildings
Filter Control Building
Top Level
Typical Filter Unit
Middle Level
Sump Area
Lowest Level
Filter Basin

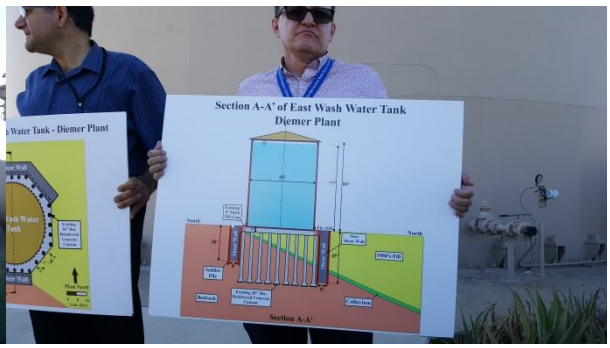

Clarifier Column
Bridge
Sedimentation Basin
New Clarifier Rake
Improved Bridge Anchorage
New Steel Columns
Stiffened Launders
Slotted Launder support to floor force transfer
Steel decked with 24 new anchors
Paddle Wheel
Baffle Wall
DIEMER BASIN IMPROVEMENTS
Upgrade Launders and supports
Upgrade bridge connections
Evaluate baffle walls and basin walls

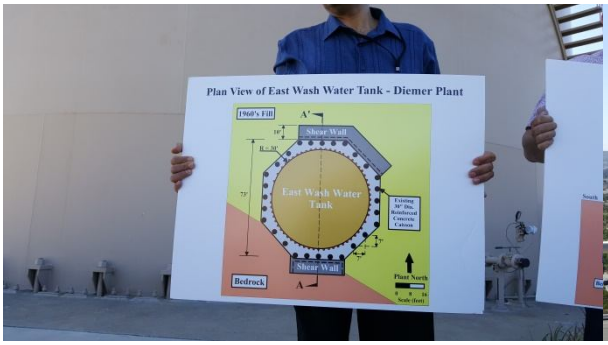

Filter Building Strengthening
Filter Control Bldg. – Top Level
Sump Area – Lowest Level
Reinforce Roof
Reinforce Concrete Frames
New Concrete Piers
Relocate equipment


Filter Ctrl Bldg.
Filter Unit
Filter Gallery

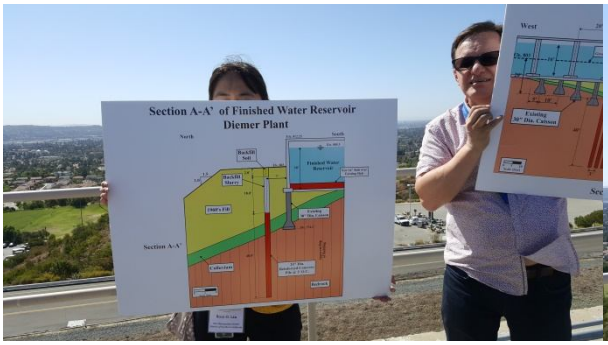

Section B-B' of Caisson Wall
121" Filter Outlet Conduit - Diemer Plant
South
North
Elevation (feet)
Bedrock
Cohesion
Section B-B'

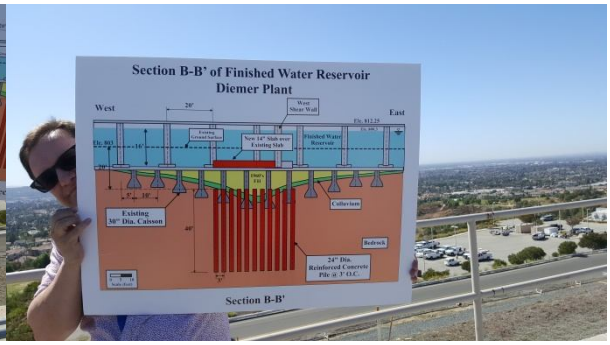

Plan View of Diemer Plant at East Wash Water Tank
1960's Fill
Basin No. 4
Basin No. 3
Basin No. 2
Basin No. 1
Filter
East Wash Water Tank
Bedrock
Limit of 1960's Fill
Finished Water Reservoir

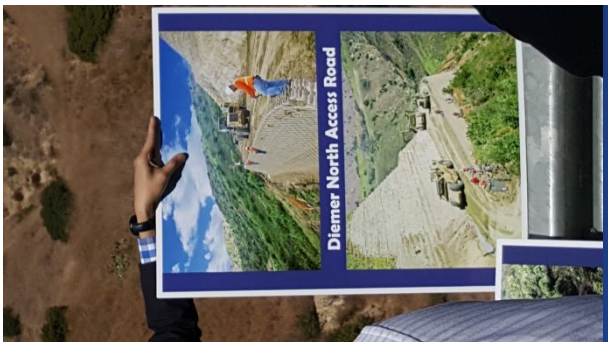

Section A-A' of East Wash Water Tank
Diemer Plant
Section A-A'

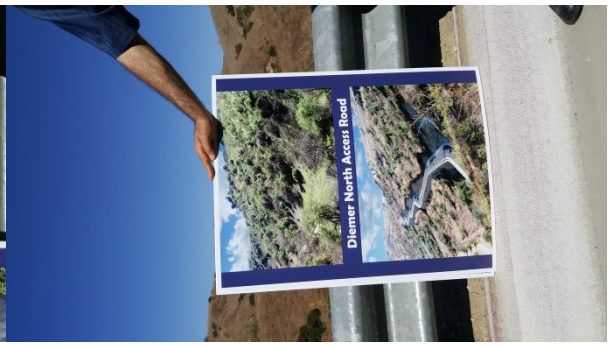

Plan View of East Wash Water Tank - Diemer Plant
East Wash Water Tank
Shear Wall
Bedrock

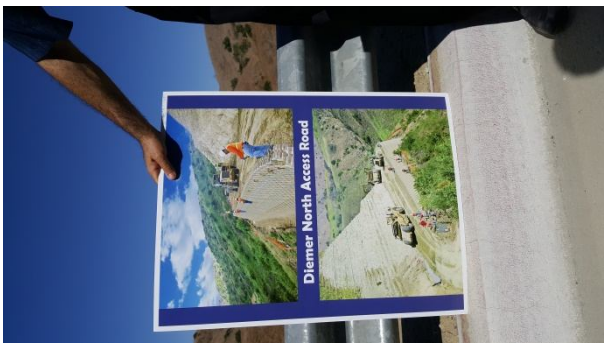

Plan View of Finished Water Reservoir
Diemer Plant
Bedrock


Section A-A' of Finished Water Reservoir
Diemer Plant


Section B-B' of Finished Water Reservoir
Diemer Plant
West
East
Existing 30" Dia. Caisson
Bedrock
Section B-B'


Diemer North Access Road


Diemer North Access Road


Diemer North Access Road