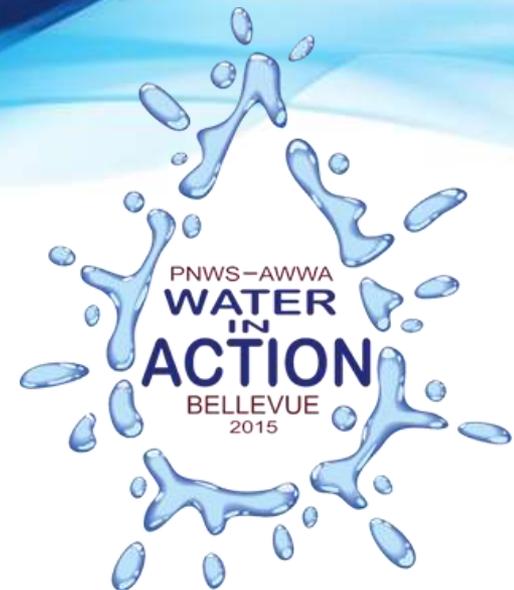


Corrosion Conditions and Mitigation in Reclaimed Water & Groundwater Treatment Facilities

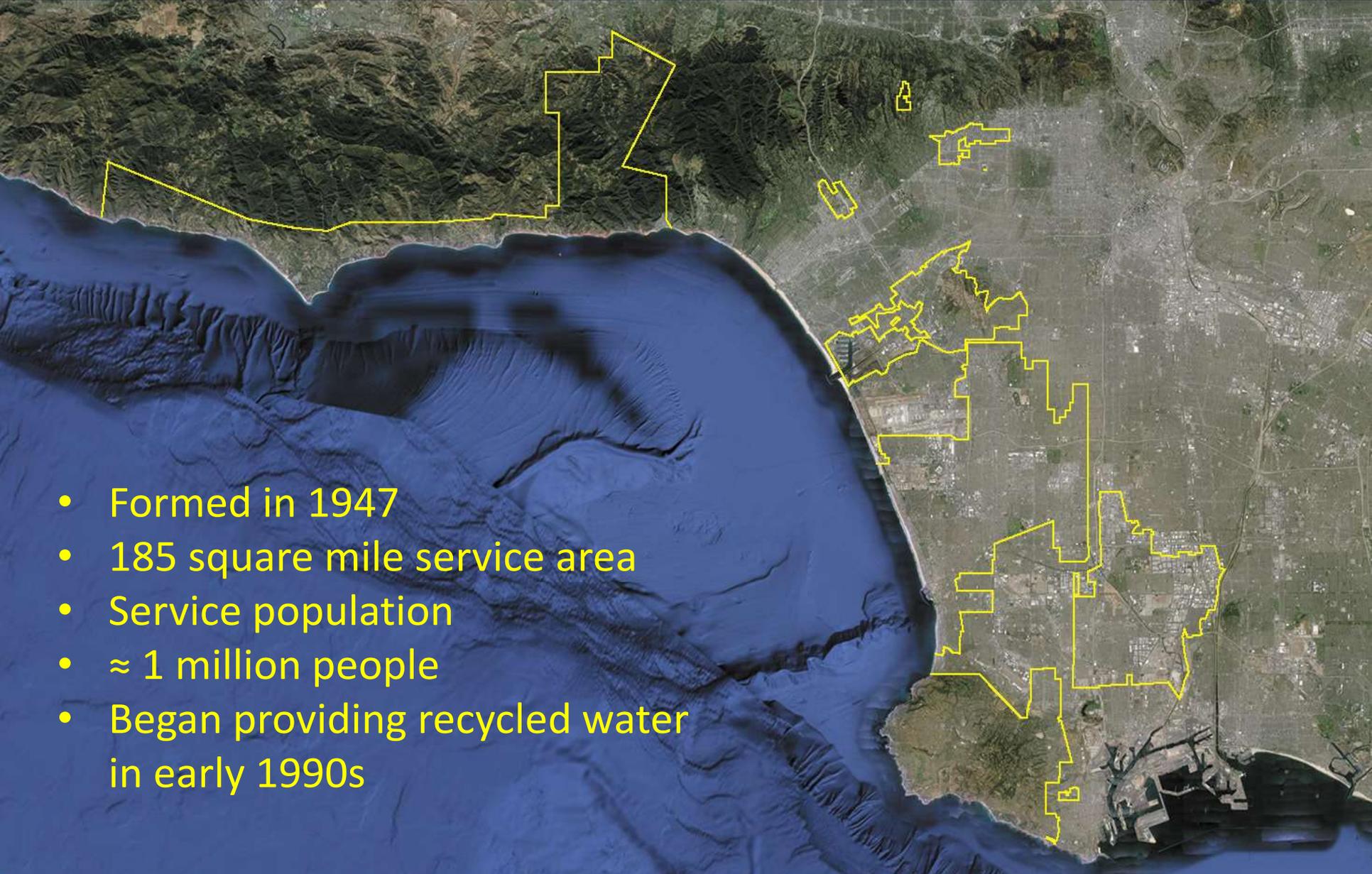
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West Basin Municipal Water District

- Formed in 1947
- 185 square mile service area
- Service population
- \approx 1 million people
- Began providing recycled water in early 1990s



Recycled Water Facilities

▶ Edward C Little Water Recycling Facility

- Supplied with secondary effluent from the Hyperion Treatment Plant
- Designed 1992
- ≈ 40 MGD
- 5 types of designer recycled water
- Industrial & irrigation use

▶ Satellite Facilities

- Chevron Nitrification Facility
 - 5 MGD
 - Nitrified water
- Exxon Mobile Nitrification Facility
 - 6 MGD
 - Blends nitrified and demineralized water
- Carson Regional Recycling Facility (BP)
 - 3.5 MGD
 - Blend nitrified and demineralized water
- Refinery cooling tower & boiler makeup water



Satellite Facility Reclaimed Water Quality

▶ Chevron

- pH: 6.8
- NH₃-N: 0.23 mg/l
- Fe: 1.22 mg/l
- Cl₂: 10 mg/l

▶ Exxon Mobile

- pH: 6.8
- NH₃-N: 0.19 mg/l
- Fe: 0.84 mg/l
- Cl₂: 8 mg/l

▶ Slightly acidic pH

- Deleterious to cement linings

▶ NH₃-N > 0.1 mg/l

- Pitting corrosion of Cu :& Cu alloys

▶ Fe

- Likely due to corrosion of carbon steel piping

▶ Free Cl₂

- Corrosive to carbon steel & copper



Carson Nitrified Product Water Tank

▶ Water Quality

- Cl₂ Residual 5–10 mg/l
- DO 1–8 mg/l
- Conductivity 700-1200 μS/cm
- NH₃-N 0.15-2.5 mg/l
- TOC 9-13 mg/l
- Fe 0.5-2.5 mg/l

▶ 225,000 gal steel tank

▶ 10 years of service

- ROV robotic inspection
- Coating extensively blistered
- Extensive pitting
 - > 60 mils on walls
 - 1/8" to 1/4" pits on floor
 - 25 mils/yr pitting rate



Carson Nitrified Product Water Tank



Carson Nitrified Product Tank Repairs

- ▶ Demolished and replaced roof plates & access hatch
- ▶ Replaced all 24 - W8"X10" purlins
- ▶ Replaced vent
- ▶ Replaced center column
- ▶ Installed new anchors
- ▶ 105 4"-24" patch plates
- ▶ Plural-component polyurethane coating
- ▶ Cathodic protection system
- ▶ 42 days to preform repairs during BP's maintenance period



Edward C Little Filter Piping Corrosion

- ▶ Pitting failures: tees downstream of backwash supply control valve
- ▶ Initial leaks \approx 10 years after filter startup
- ▶ \approx 5 leaks per year



Filter Piping Corrosion

- ▶ Downstream of main backwash flow control valve
- ▶ Initial leaks \approx 2 years after filter startup
- ▶ Initial repairs: pipe clamps & rubber seals



Filter Piping Corrosion

- ▶ 6" X 3/8" steel plate patches



Filter Piping Corrosion

- ▶ 2.5" Φ coupon
- ▶ Remaining epoxy coating
 - \approx 10% coverage
 - Brittle & chalking
- ▶ Pits
 - 15 to 40 mils deep
 - Black ferrous oxide in the bottom of the pits
 - Pitting rate estimated 6.7 mils/yr assuming epoxy lining did not fail for 10 years
 - Remaining pipe life 25 to 40 years



Piping

► Carbon Steel Piping

- 10" to 24"
 - ASTM A 53 Grade B Schedule 20
 - AWWA C210 Liquid Epoxy Lining
- ≥ 30 "
 - AWWA C200
 - AWWA C210 Liquid Epoxy Lining



Erosion Potential

▶ Carbon Steel Pipe

- >20 fps Severe
- 12-20 fps High
- 7 – 12 fps Moderate
- < 7 fps Low

(Nayyar, 1992)

▶ Epoxy Lining

- Erosion at velocities over 12 to 15 fps

▶ Stainless Steel

- Higher erosion-corrosion & cavitation resistance than carbon steel
- $1/5^{\text{th}}$ to $1/10^{\text{th}}$ the erosion rate of carbon steel

▶ Ceramic Lining

- Higher erosion-corrosion & cavitation resistance than carbon steel



Pipe Velocity

Pipe Φ	Velocity (fps)	Velocity at Butterfly Valve (fps)	Carbon Steel Erosion Potential
14"	16.6	27.7	Severe
16"	12.6	15.7	High
24"	5.5	6.9	Low
30"	4.9	5.7	Low
36"	4.2	5.3	Low
42"	3.4	4.3	Low
60"	1.7	2.1	Low



Steel Coupon Corrosion Measurements

Location	Corrosion Rate (mils/year)	Pitting	Degree of Corrosion
Edward C Little Filter Backwash Pipe (low velocity area)	9.4	None	Moderate
Edward C Little Effluent Pump Station	9.4	None	Moderate
Chevron Nitrified Product Water Storage Tank	33.1	Extensive	Severe
Exxon Mobile Nitrified Product Water Storage Tank	24.3	Extensive	High
Carson Nitrified Product Water Storage Tank	24.5	Extensive	High



Piping Rehabilitation Options

Repair Option	Estimated Service Life (years)	Bid
Fiberglass wrap	5	
Stainless steel sections	40	\$228,000
Lining carbon steel pipe with ceramic mortar	20	



Pipeline Repairs

- ▶ Rapid repair required
- ▶ Replaced ten 16-inch X 24-inch carbon steel tees with 316L stainless steel tees
- ▶ Isolation kits at carbon steel/stainless steel interface
- ▶ Replaced two tees at a time.
- ▶ Shutdown limited to an 8 hour window
- ▶ Replaced 25 LF 14 & 16-inch carbon steel backwash piping at flow meter/flow control valve with 316L stainless steel



Future Repairs (2013-2022)

- ▶ Developed schedule for future facility rehabilitation
 - Chevron WRF nitrification water storage tank \$250K-\$300K
 - Exxon Mobil WRF nitrification water storage tank \$250K-\$300K
 - Carson RWRf steel piping, valves & pumps \$300K-\$400K
 - Chevron WRF steel piping, valves & pumps \$300K-\$400K
 - Edward Little WRF steel piping, valves & pumps \$300K-\$400K
 - Conduct corrosion assessment every 5 years



Conclusions – Reclaimed Water

- ▶ Recycled water is considerably more corrosive to steel and copper than potable water
- ▶ Typical epoxy or polyurethane coating life is less than 20 years
- ▶ Pipe velocities over 12 fps can cause erosion corrosion of organic coatings and carbon steel
 - Important consideration at modulating flow control valves and bends/tees
 - Stainless steel and ceramic lining are more erosion corrosion and cavitation resistant than carbon steel



Vancouver Ellsworth WTP

- ▶ 9 MGD
- ▶ 3 wells
- ▶ Mn 0.35 to 0.40 mg/l
- ▶ Fe 0.3 to 0.5 mg/l
- ▶ Operating 20 years
- ▶ Gradual loss of media



2015 Media Replacement



Ellsworth Pressure Filter Corrosion

- ▶ Filter lining: 3 coat polyamide epoxy
- ▶ Adhesion test > 1200 psi after 20 years service
- ▶ Pitting adjacent SS laterals
- ▶ Some pits up to $\frac{1}{8}$ " to $\frac{1}{4}$ " deep
- ▶ Dissimilar metals



Filter Rehabilitation

- ▶ Considered spot coating repair
- ▶ Complete interior recoat
- ▶ Near white blast
- ▶ Dehumidification



Filter Rehabilitation

- ▶ Recoated with 30 mil fast cure plural-component polyurethane
- ▶ Base & acid soaked air scour piping to remove deposits

