Arsenic Removal Alternatives for Carter/Chouteau County Water and Sewer District

Mark Reinsel

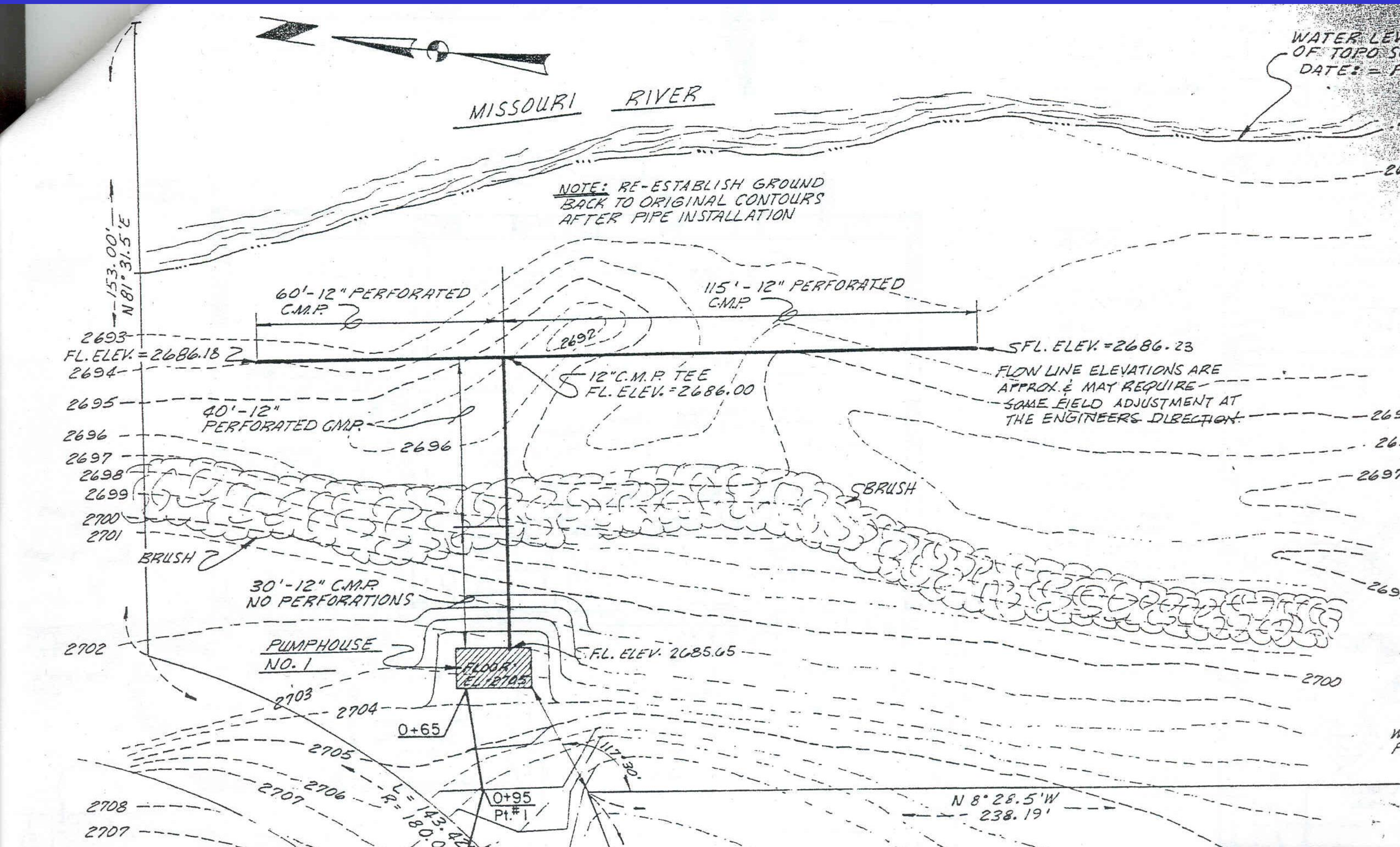
Apex Engineering, PLLC

Joel Pilcher

Great West Engineering, Inc.

Current Water System

- Groundwater under the influence of surface water (Missouri River)
- Chlorine addition
- 48 miles of piping
- System is 28 years old


MISSOURI RIVER
NOTE: RE-ESTABLISH GROUND BACK TO ORIGINAL CONTOURS AFTER PIPE INSTALLATION
153.00'
N 81° 31.5' E
60'-12" PERFORATED C.M.P.
115'-12" PERFORATED C.M.P.
FL. ELEV. = 2686.18
FL. ELEV. = 2686.23
12" C.M.P. TEE FL. ELEV. = 2686.00
FLOW LINE ELEVATIONS ARE APPROX. & MAY REQUIRE SOME FIELD ADJUSTMENT AT THE ENGINEERS DIRECTION
40'-12" PERFORATED CMP
BRUSH
BRUSH
30'-12" C.M.P. NO PERFORATIONS
PUMPHOUSE NO. 1
FLOOR EL. 2705
FL. ELEV. 2685.65
0+65
0+95 Pt.#1
L = 143.42
R = 180.00
N 8° 28.5' W
238.19'
2692
2693
2694
2695
2696
2697
2698
2699
2700
2701
2702
2703
2704
2705
2706
2707
2708

Objectives

- Remove arsenic to below the MCL of 10 ug/L (effective January 2006)
- Provide filtration as part of the treatment process, which may be required under GUISW rule
- Investigate processes and compare costs for arsenic/manganese removal alternatives

Design Basis

- Peak daily demand in 2023: 200,000 gpd
- Eighty households and population of 220 in 2023
- Operating costs are based on average daily demand of 103,000 gpd in 2003

Arsenic Background

- Occurs naturally in rocks, soil, water, air, plants and animals
- Can be product of industrial contamination
- Naturally occurring at high levels in western U.S.
- Arsenic in Missouri R. is from Yellowstone Park
- Most recognized threat to DW quality in world

Arsenic Chemistry

- Exists primarily as As(III) or As(V)
- As(III) is more toxic and more soluble
- Readily changes valence state
  - pH
  - Oxidation-reduction potential
  - Presence of complexing ions
  - Microbial activity

Carter Water Chemistry

- Arsenic (III): 33 ug/L
- Arsenic (V): ND
- Nitrate: 0.05 mg/L
- Sulfate: 109 mg/L
- Iron: <0.03 mg/L
- pH: 7.88
- Alkalinity: 199 mg/L

Initial Screening Process

- Compile sources of information
- Determine potential technologies
- Select general evaluation criteria

Sources of Information

- Authors' experience
- "Proven Alternatives for Aboveground Treatment of Arsenic in Groundwater" (EPA 2002)
- "Technologies and Costs for Removal of Arsenic from Drinking Water" (EPA 2000)
- www.mcguireinc.com
- Vendor discussions and websites
- Chapter 4 in DEQ Circular 1

Initial Screening Matrix

	TECHNOLOGY				
	Adsorption	**Precipitation**	**Biological**	**Membrane Filtration**	**Ion Exchange**
Development Status	Full scale	Full scale	Bench scale	Full scale	Full scale
Typically Requires Pretreatment?	Yes	No	No	Yes	Yes
Residuals Produced	Solid, liquid	Solid, liquid	Solid	Liquid	Solid, liquid
Availability	Good	Good	Unknown	Good	Good
Reliability/ Maintainability	Average	Good	Unknown	Average	Average
Overall Cost	Average	Lower	Unknown	Higher	Average

Secondary Screening

- List specific technologies
- More specific evaluation criteria
- Eliminated from consideration:
  - Activated alumina (adsorption)
  - Reverse osmosis (membrane filtration)
  - Ion exchange

Tertiary Screening

- Select several specific technologies
- More specific evaluation criteria

Treatment Technologies

- Sulfur-modified iron (SMI)
- Granular ferric hydroxide (GFH)
- Granular ferric oxide (AD 33)
- Ferrosand
- Macrolite
- Evox
- ABMet

Evaluation Criteria

- Optimum pH
- Water loss
- Residuals produced
- Proven at what scale?
- Interferences
- Runtime before backwash
- Runtime before media replacement
- NSF approved?

Results to This Point

- All seven technologies met basic criteria
- Some were more advantageous than others
- Now look at costs:
  - Capital cost
  - Dimensions of treatment skid
  - Pilot testing cost
  - Operating cost

Cost Comparison

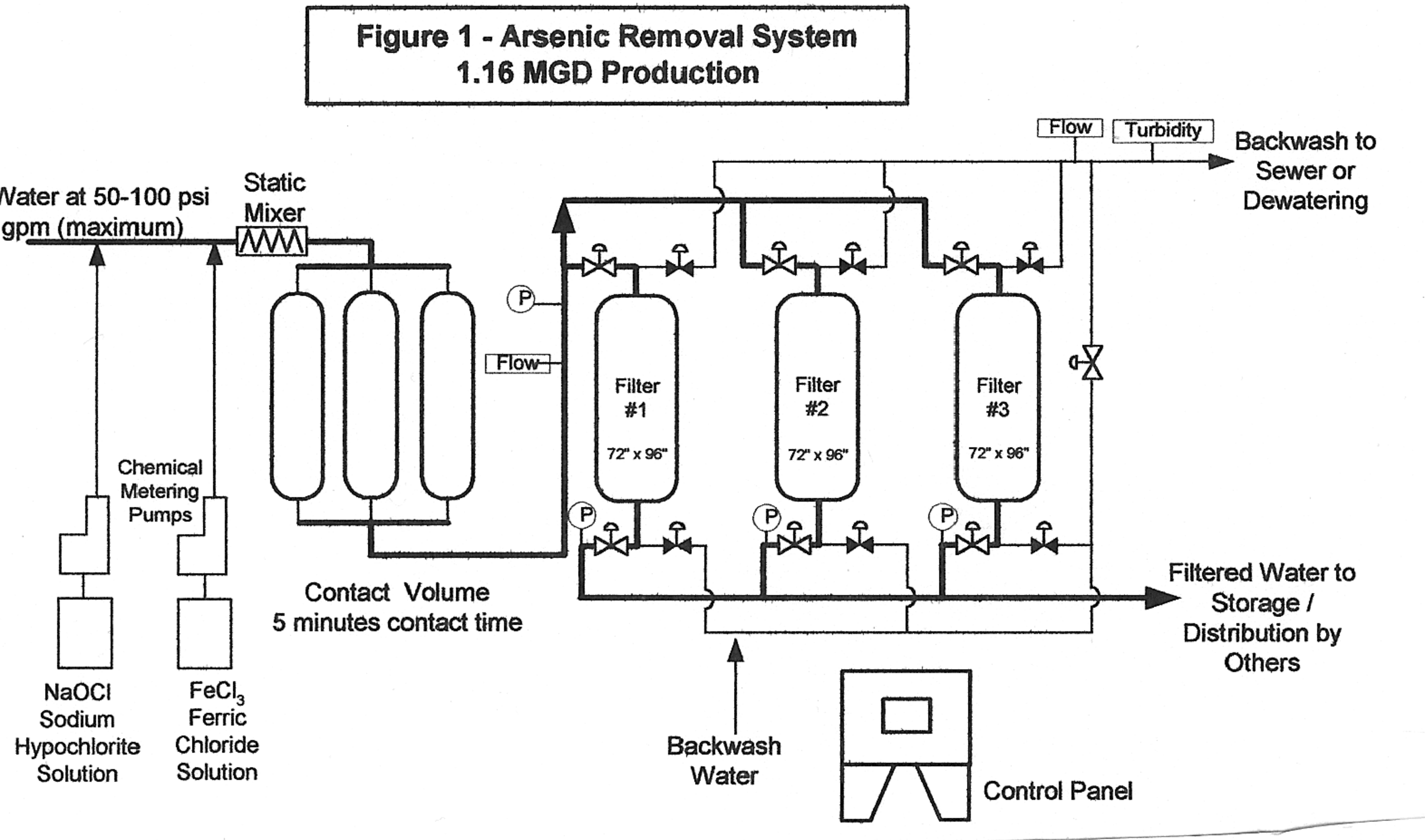
Technology	SMI	GFH	AD 33	Ferrosand	Macrolite	Evox	ABMet
Total Capital Costs	$963,200	$857,900	$857,900	$843,400	$873,000	$750,600	$1,285,500
Annual O&M Costs	$33,000	$40,700	$40,700	$13,000	$13,800	$15,100	$19,300
20-Year Salvage Value	$87,500	$75,500	$75,500	$90,500	$75,500	$81,500	$135,000
Present Worth of Salvage Value	$27,100	$23,400	$23,400	$28,100	$23,400	$25,300	$41,900
Present Worth of Annual O&M Cost	$381,500	$470,500	$470,500	$150,300	$159,500	$174,600	$223,108
Present Worth Cost	$1,320,000	$1,300,000	$1,300,000	$970,000	$1,010,000	$900,000	$1,470,000

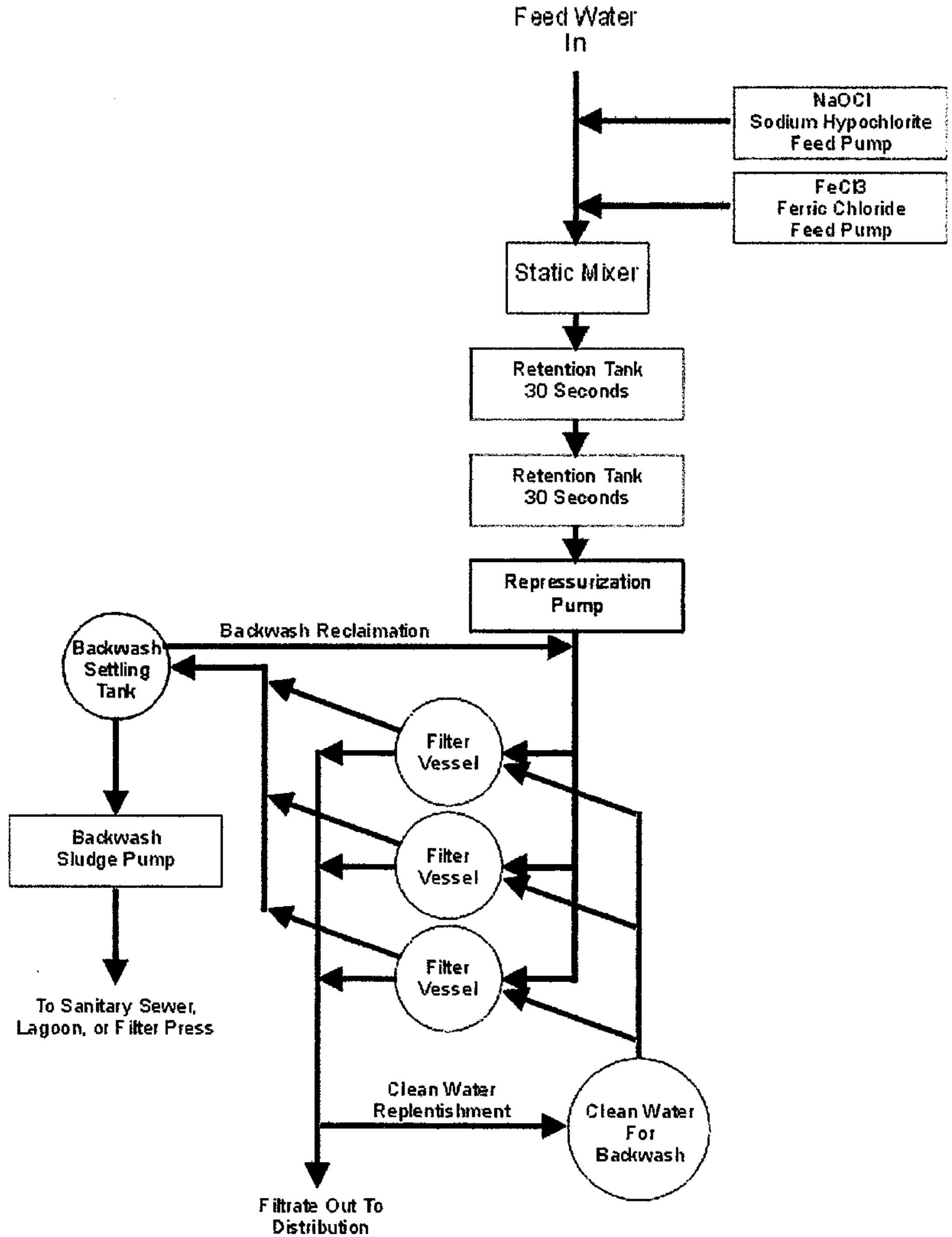
Recommendations

- Pilot-test the three technologies with the lowest present worth costs:
  - Ferrosand
  - Macrolite
  - Evox

Skid-mounted vertically oriented Ferrosand filtration system (photo courtesy of Hungerford & Terry, Inc.)

Macrolite Process





Simple eVox™ Flow Diagram

Subsequent Developments

Due to the high capital cost of a centralized treatment system for a relatively low flow, point-of-use (POU) devices were investigated for the Carter/Chouteau County system.

POU Findings

- Ferrosand is N/A as POU because of its chemical addition requirements.
- Precipitation technologies are N/A as POU because of their size and complexity.
- At least two adsorption technologies are available as POU devices to remove arsenic.

GFH as POU Device

- Offered by Culligan (subsidiary of US Filter)
- Indicator light based on total flow
- Set trigger at 1000 gallons at Carter
- Initial cost: $190/unit + $60 for installation
- Replacement cost: $25/yr
- Not yet NSF approved

AD 33 as POU Device

- Offered by AdEdge Technologies
- Indicator light based on total flow
- Set trigger at 1000 gallons at Carter
- Initial cost: $250/unit + $60 for installation
- Replacement cost: $100/yr
- NSF approved

Conclusions

- Viable treatment systems for arsenic removal were developed and ranked based on present worth analysis
- Point-of-use devices for arsenic removal were recommended
- District will pursue:
  - POU devices for arsenic removal
  - Supply upgrades
  - 12 miles of new water line
  - Water meters