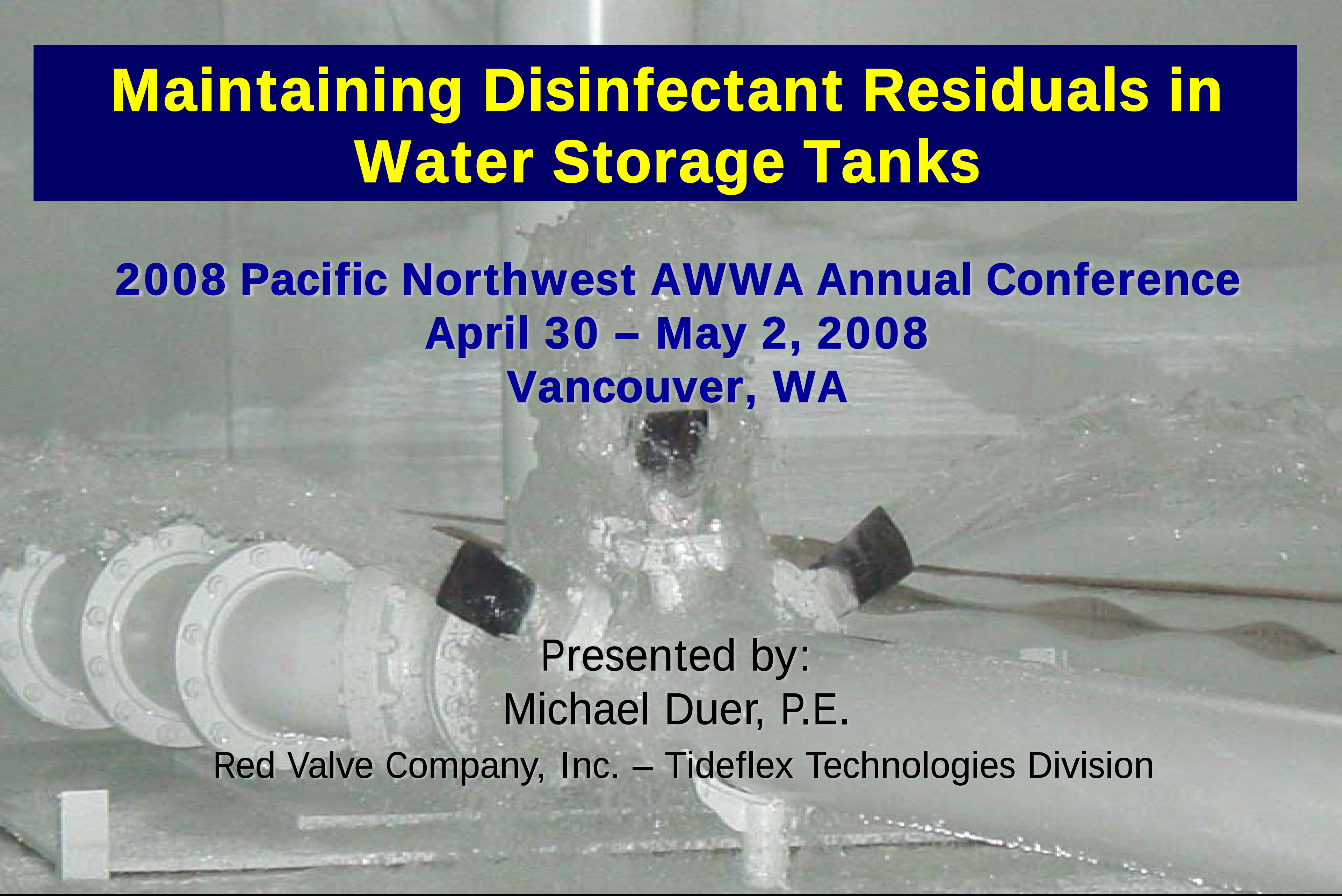
Maintaining Disinfectant Residuals in Water Storage Tanks



2008 Pacific Northwest AWWA Annual Conference
April 30 – May 2, 2008
Vancouver, WA

Presented by:
Michael Duer, P.E.
Red Valve Company, Inc. – Tideflex Technologies Division

Tideflex Technologies

Types of Water Storage Tanks

- Ground Level Tanks (Rectangular)
- Ground Level Tanks (Circular)
- Elevated Tanks
- Standpipes

How to Maintain Water Quality in Reservoirs

1) Minimize Short-Circuiting and Stagnant Areas
(SEPARATE INLET AND OUTLET PIPE)

2) Achieve Complete Mixing During Fill Cycle
(MIXING TIME LESS THAN FILL TIME)

DESIGN (items 1–2)

3) Achieve Adequate Turnover
(FLUCTUATE LEVELS)

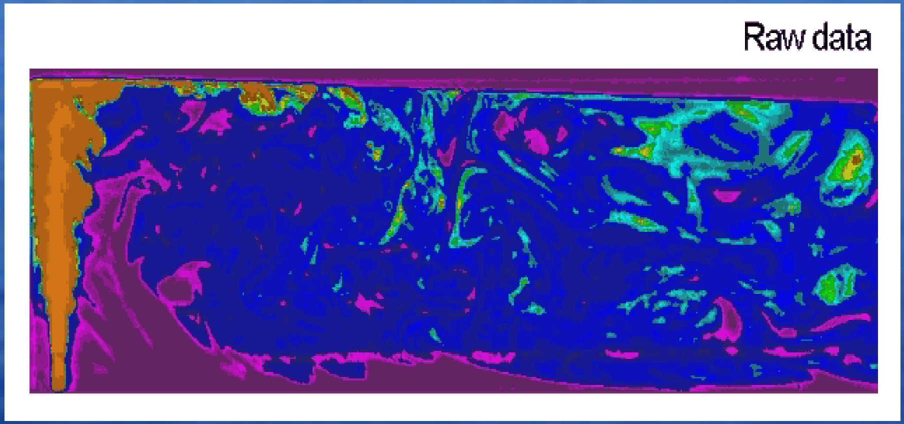
OPERATIONS (item 3)

**** MAINTAIN ADEQUATE DISINFECTANT RESIDUAL ****

COMBINATION OF MIXING SYSTEM DESIGN AND OPERATION/FLUCTUATION OF THE TANK

AwwaRF Project-Tideflex Technologies & Georgia Tech

“Physical Modeling Of Mixing in Water Storage Tanks”

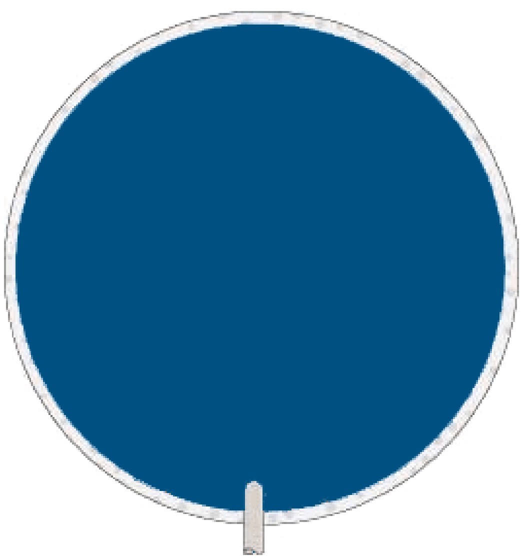


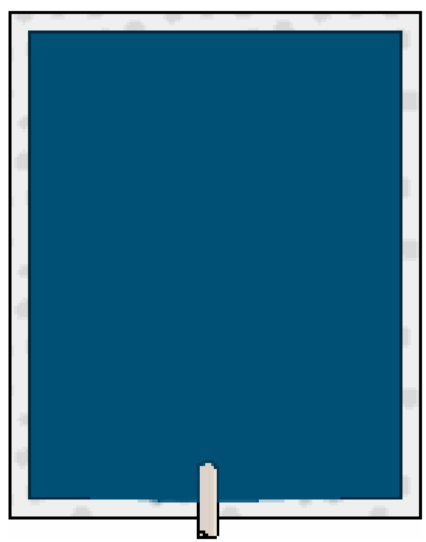
Instantaneous Tracer Animation

Short Circuiting

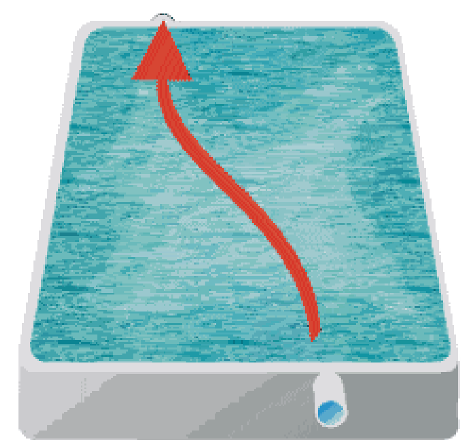
- First In, Last Out (Last in, First Out)
- Water in Close Proximity to Inlet/Outlet is Continually Turned Over. Water away from Inlet/Outlet stagnates.
- Some States Now Mandate Separate Inlet/Outlet Pipes

Common Inlet / Outlet



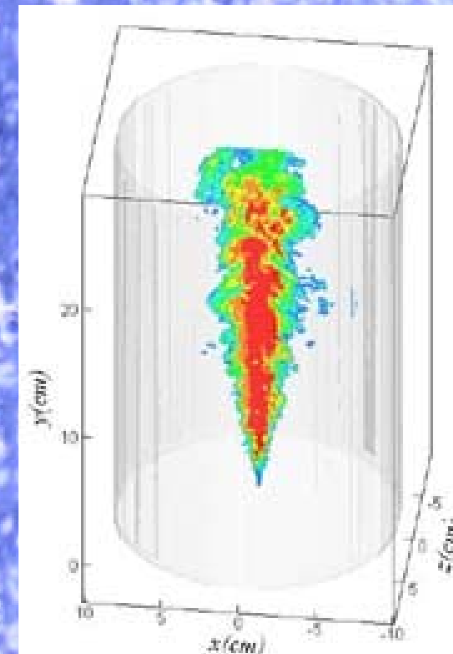


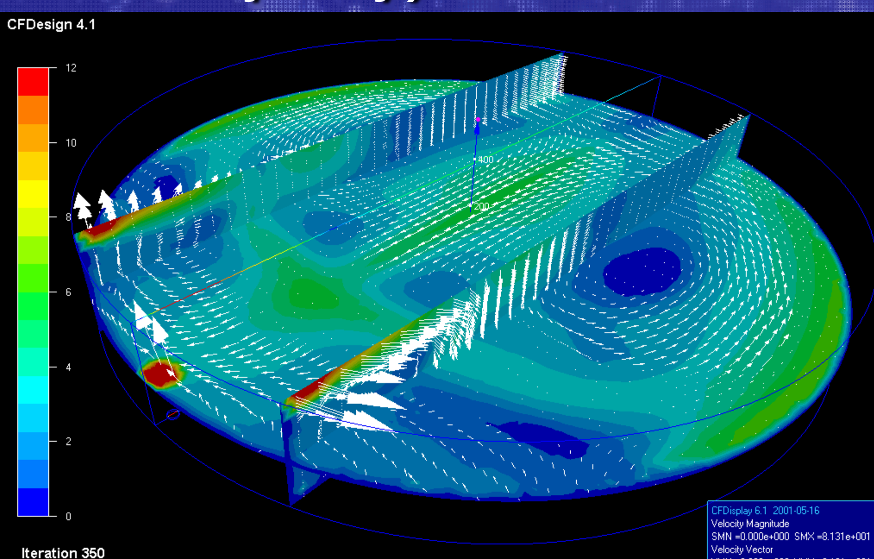
Separate Inlet / Outlet

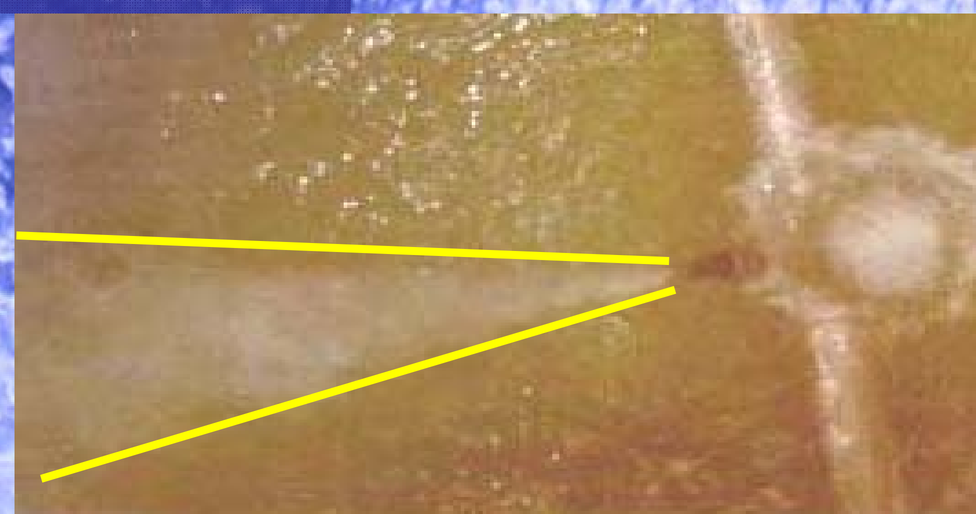


Hydrodynamic Mixing

- Turbulent Inlet Jet (Only source of Energy) into Large Waterbody
- Velocity Discontinuity between Inlet and Ambient yields Entrainment
- Circulation Patterns form due to Conservation of Momentum
- Can be Strongly Dampened by Temperature Differentials (+ and - Buoyancy)







Empirical Mixing Time Equation

How Long doYou Need to Fill Tank to Mix it?

Mixing time (hours) = $4.9\ H^{1/2} * D^{2/3} / M^{1/2}$

or $10.2\ V^{2/3} / M^{1/2}$

M = momentum = flow rate x velocity (Q * U)

V = volume of water in tank at start of fill, feet^3

Q = inflow rate, cfs

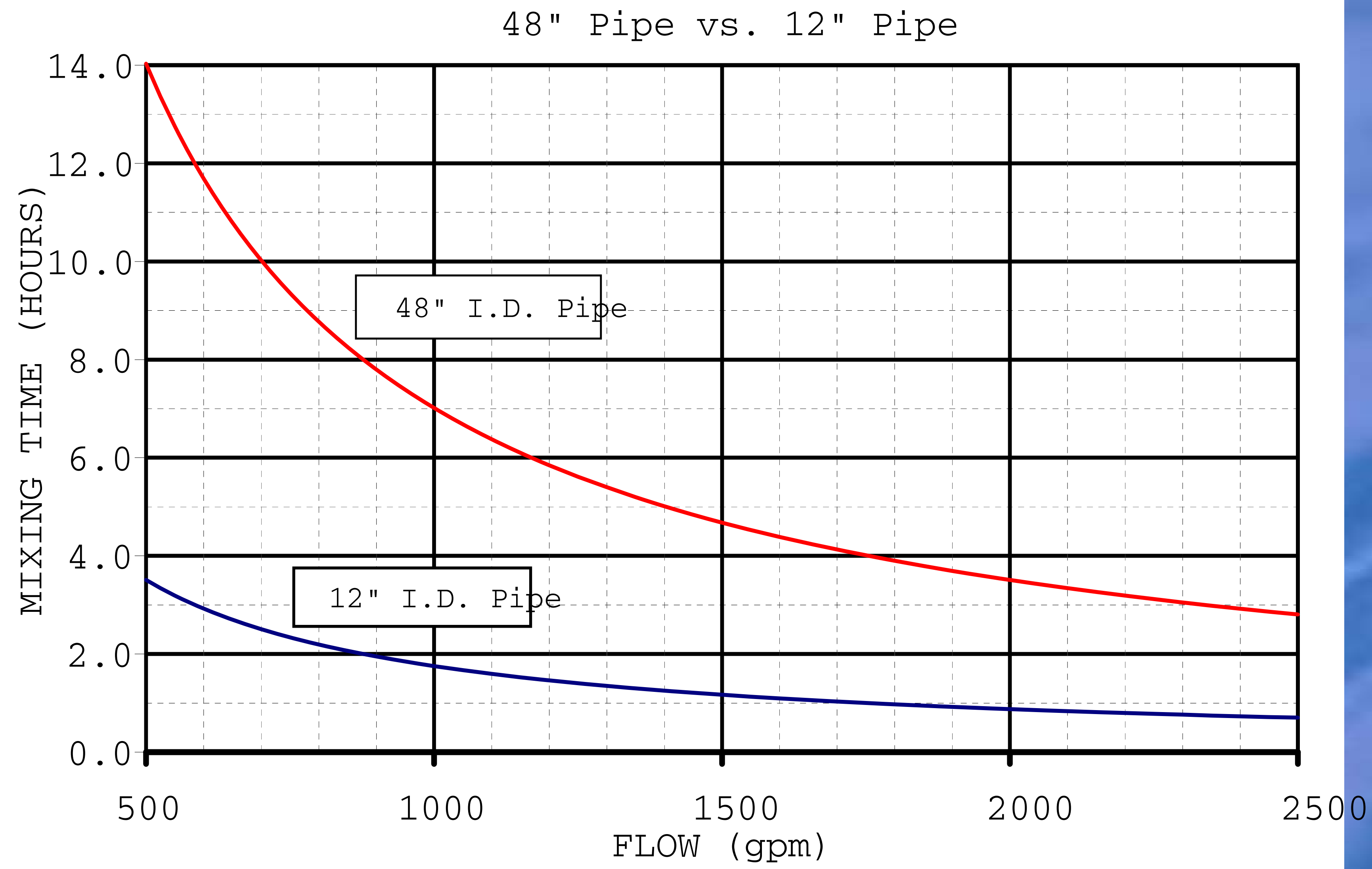
U = inflow velocity, feet per second

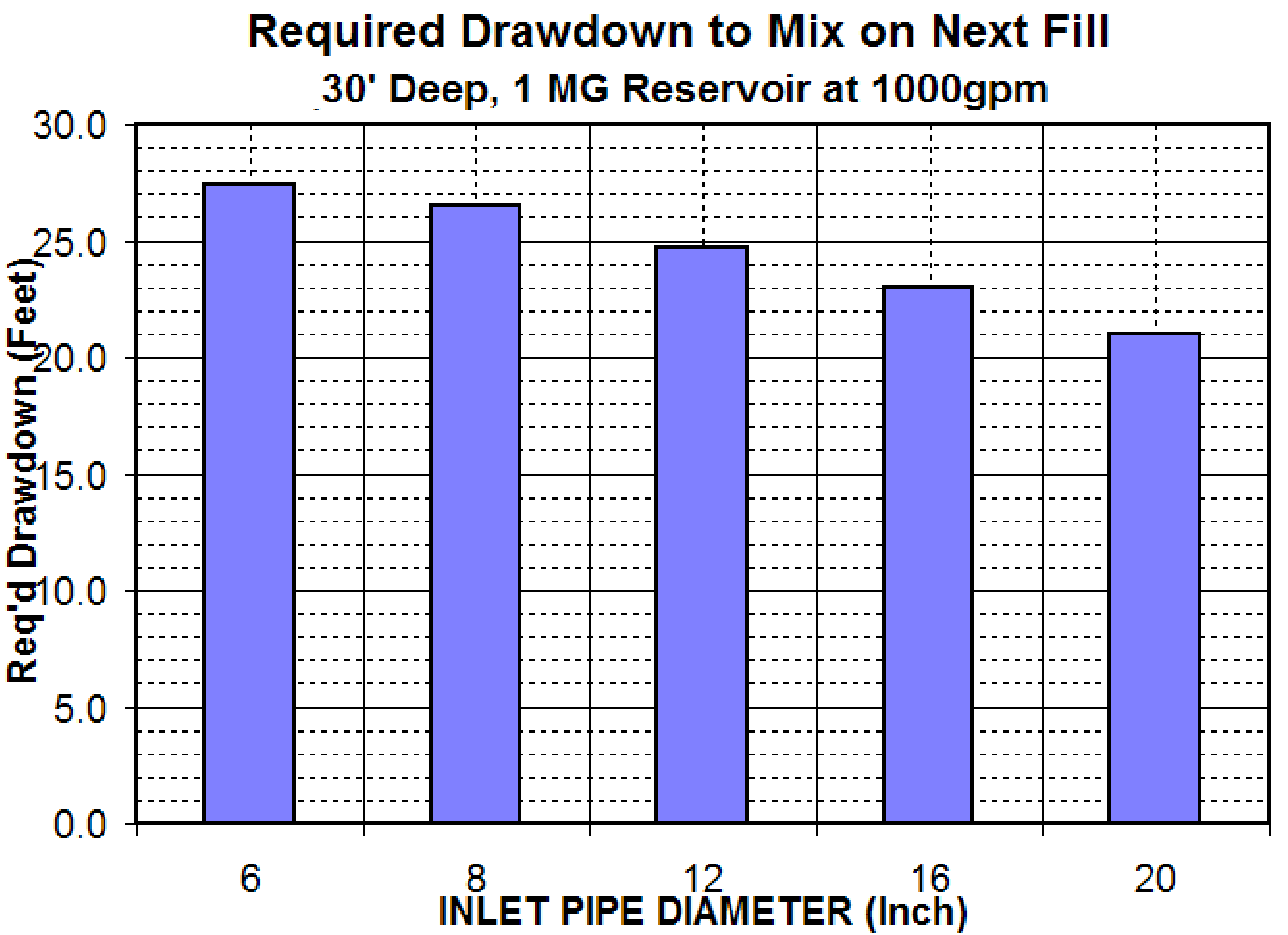
H = Water depth, feet

D = Tank Diameter, feet

Caution: No Variables in Equations or Limitations of Equation for Considering Temperature Differences Between Inlet Water and Tank Water

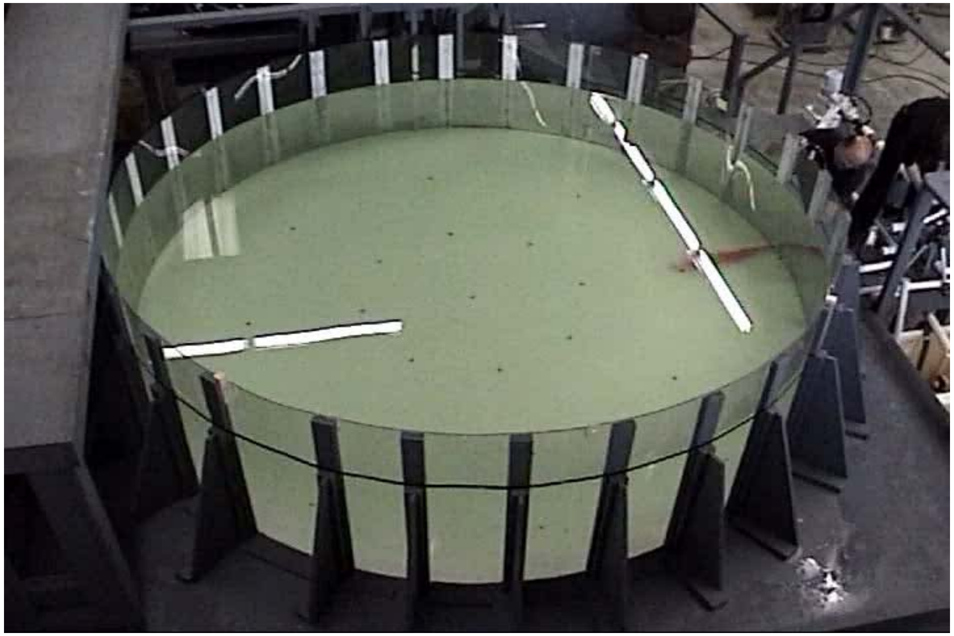
Mixing Time Comparison (1 MG Reservoir)





Tideflex Technologies' Tideflex® Mixing System

Multiple Inlet Ports Result in Significantly Faster Mixing



Single Shell Penetration | **5-Port TMS**

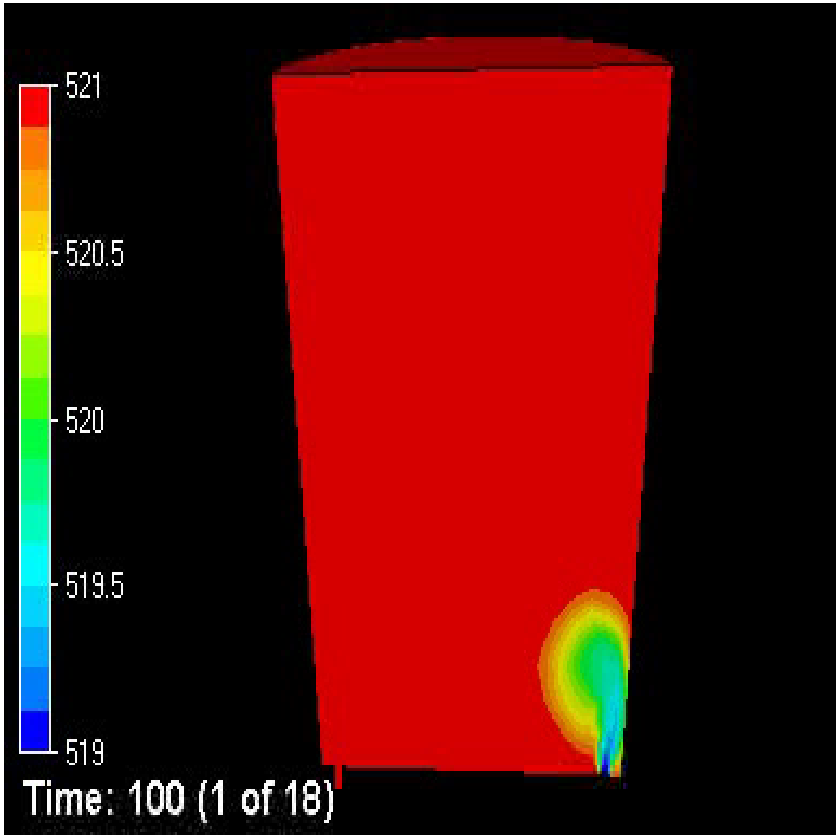
SCALE MODELING OF 1MG RESERVOIR

Animations courtesy of :

Los Angeles Department of Water & Power
Northwest Hydraulic Consultants

Mixing Time Equation is Limited to Same Inlet and Tank Water Temperature

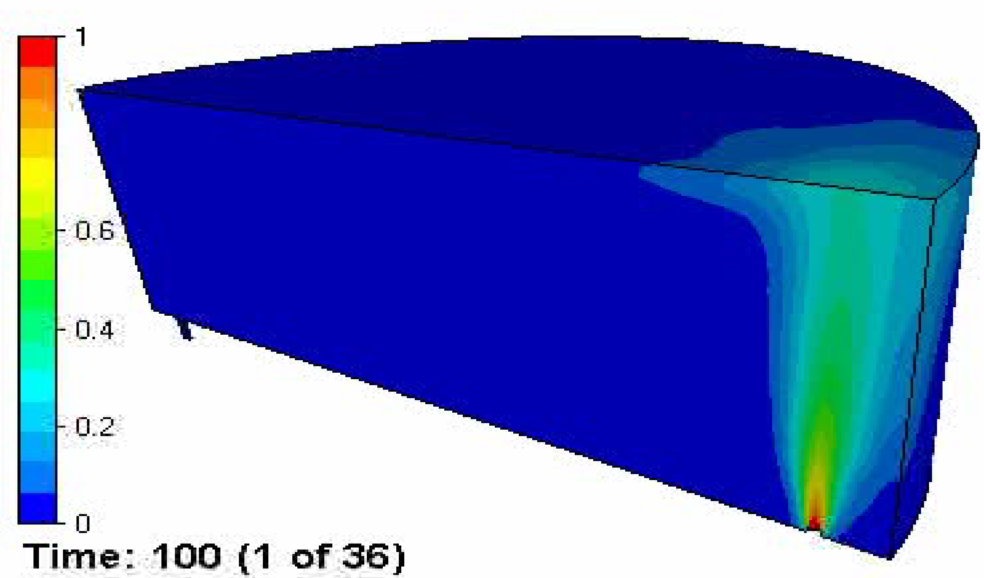
- Mixing Time Equation May Grossly Underestimate Fill Time Required to Mix
- Jet Must Reach Water Surface to Mix Tank
- Mixing Will Only Occur to Terminal Rise Height (TRH) of Jet
- Below TRH - Adequate Mixing, Temperature, and Residual
- Above TRH – No Mixing, Water Age Continually Increases With Each Fill & Draw Cycle, Lose Residual
- Have No Idea of Potential Problem Even if Sampling Outside of Tank



2ºF Colder Inlet Water

Effect Of Colder Inlet Water on Mixing in *Reservoir*

CFD Model – 2.5MG Reservoir (120' Dia. X 30' SWD)

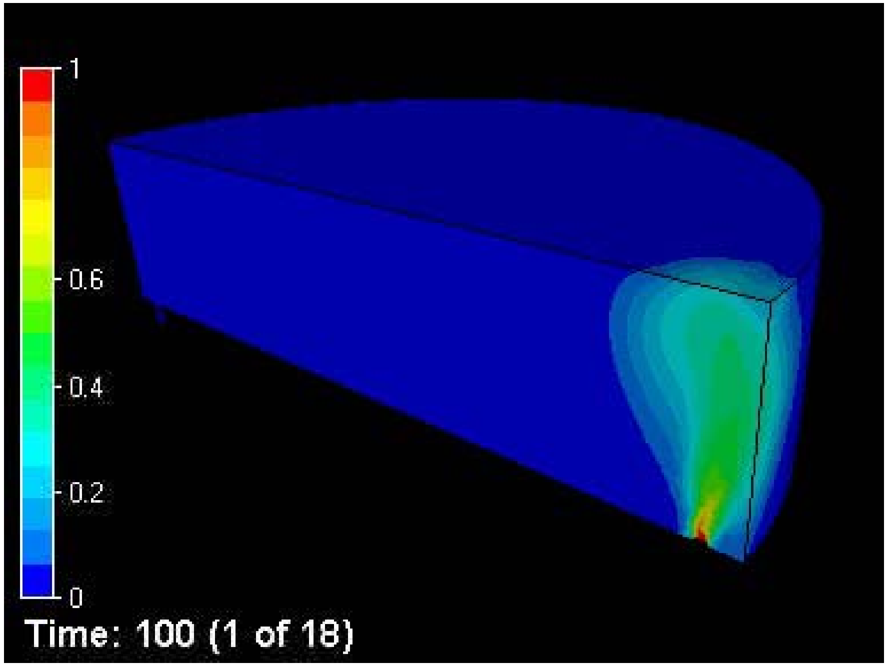


INLET 4° F COLDER

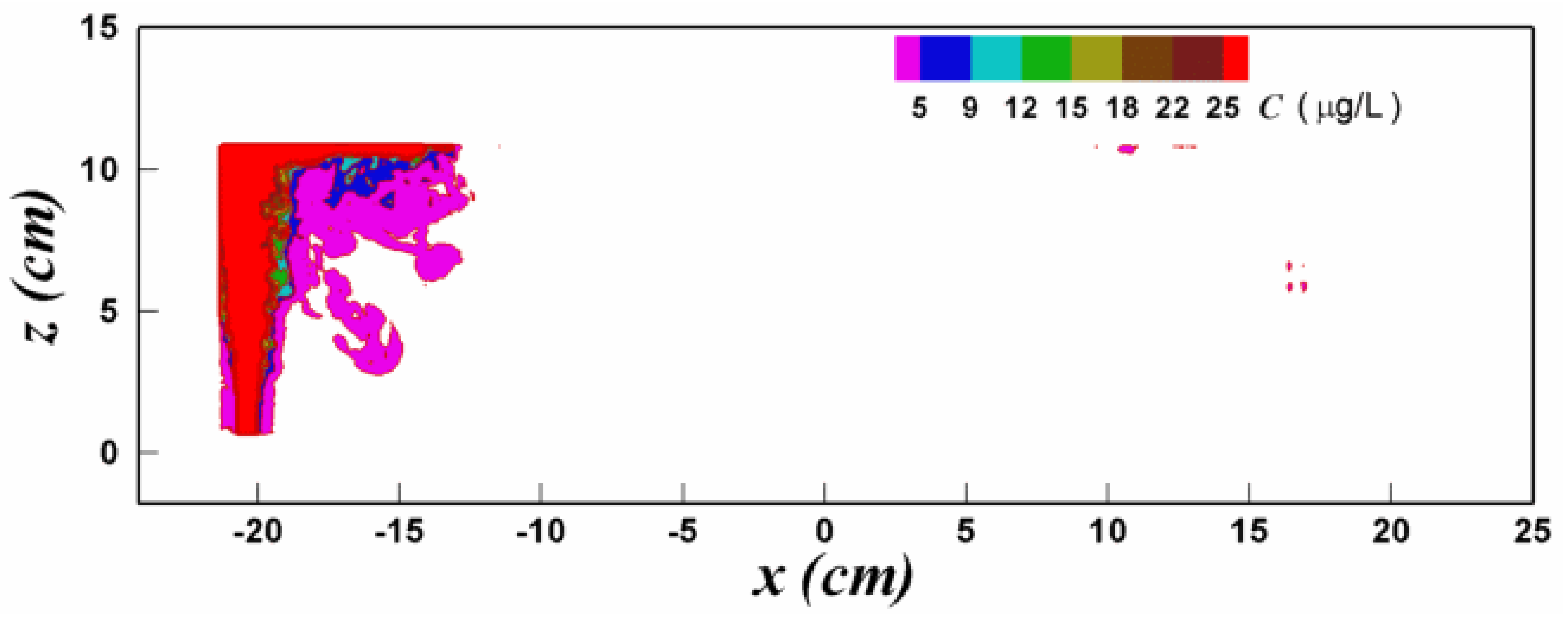
- **Will Short-Circuit Even with Separate Outlet Pipe**
- **Will Not Mix Tank Regardless How Long it is Filled**

ISOTHERMAL

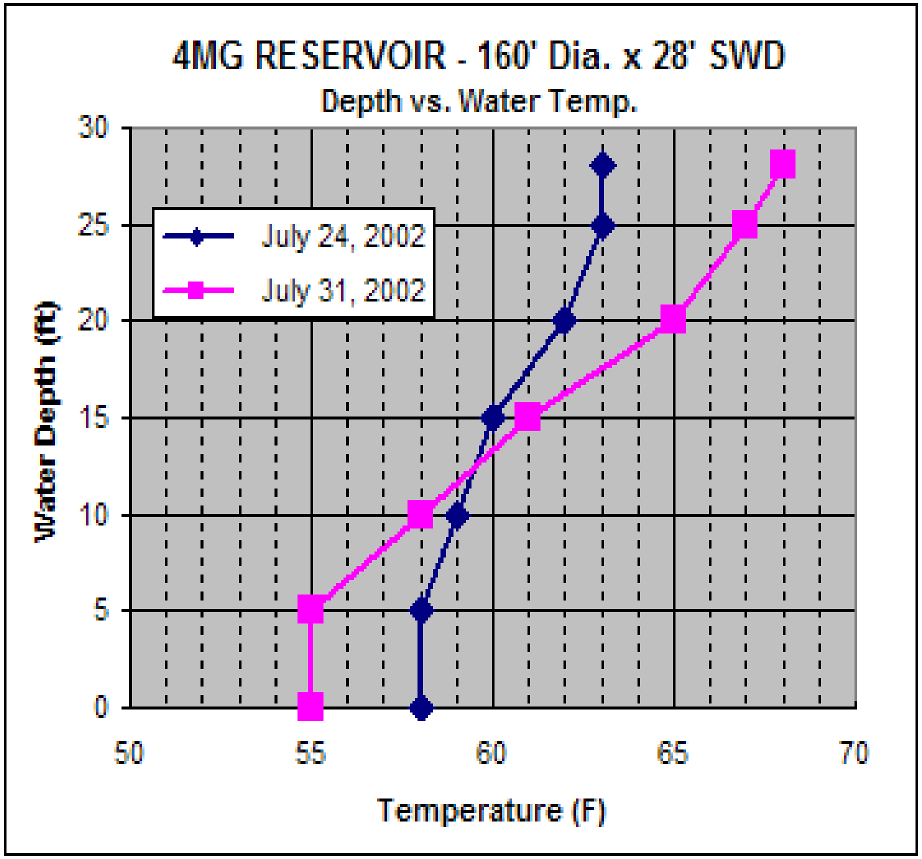
- **Will Not Short-Circuit with Separate Outlet Pipe**
- **Will Mix Tank IF Fill Long Enough**

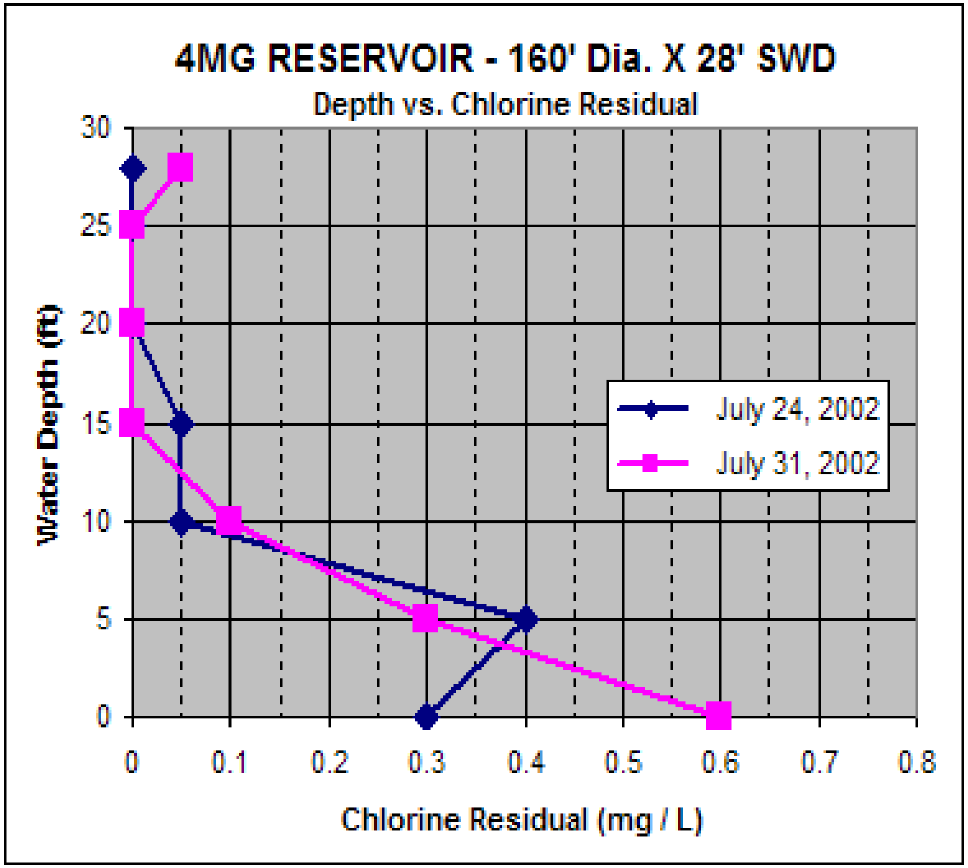


In Reservoirs (Dia. > Depth), a Single Inlet ***<u>May Not Mix</u>*** the Tank with Colder Inlet Water



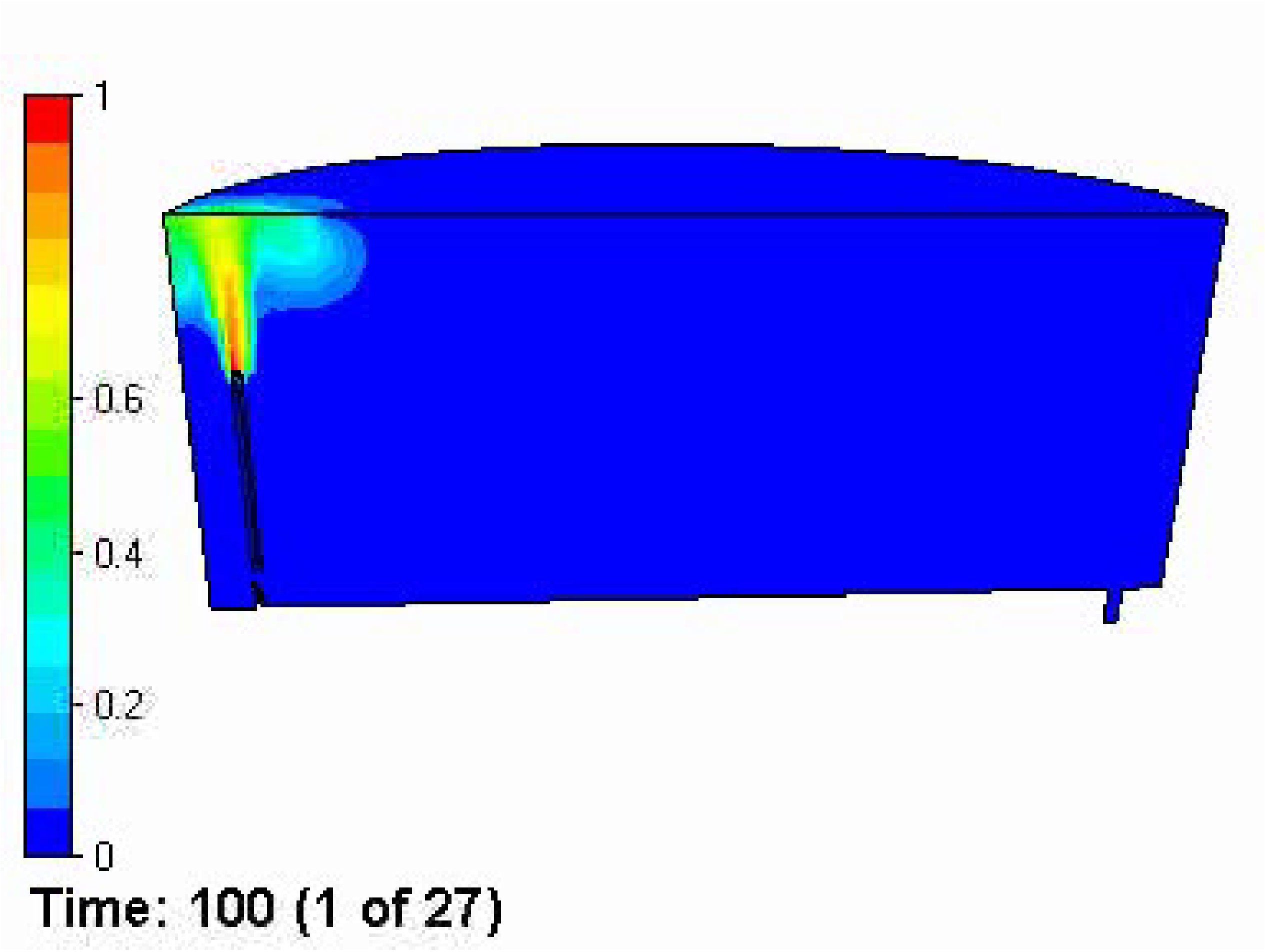
Temperature and Cl_2 Residual Data
4MG Steel Reservoir – Northern California



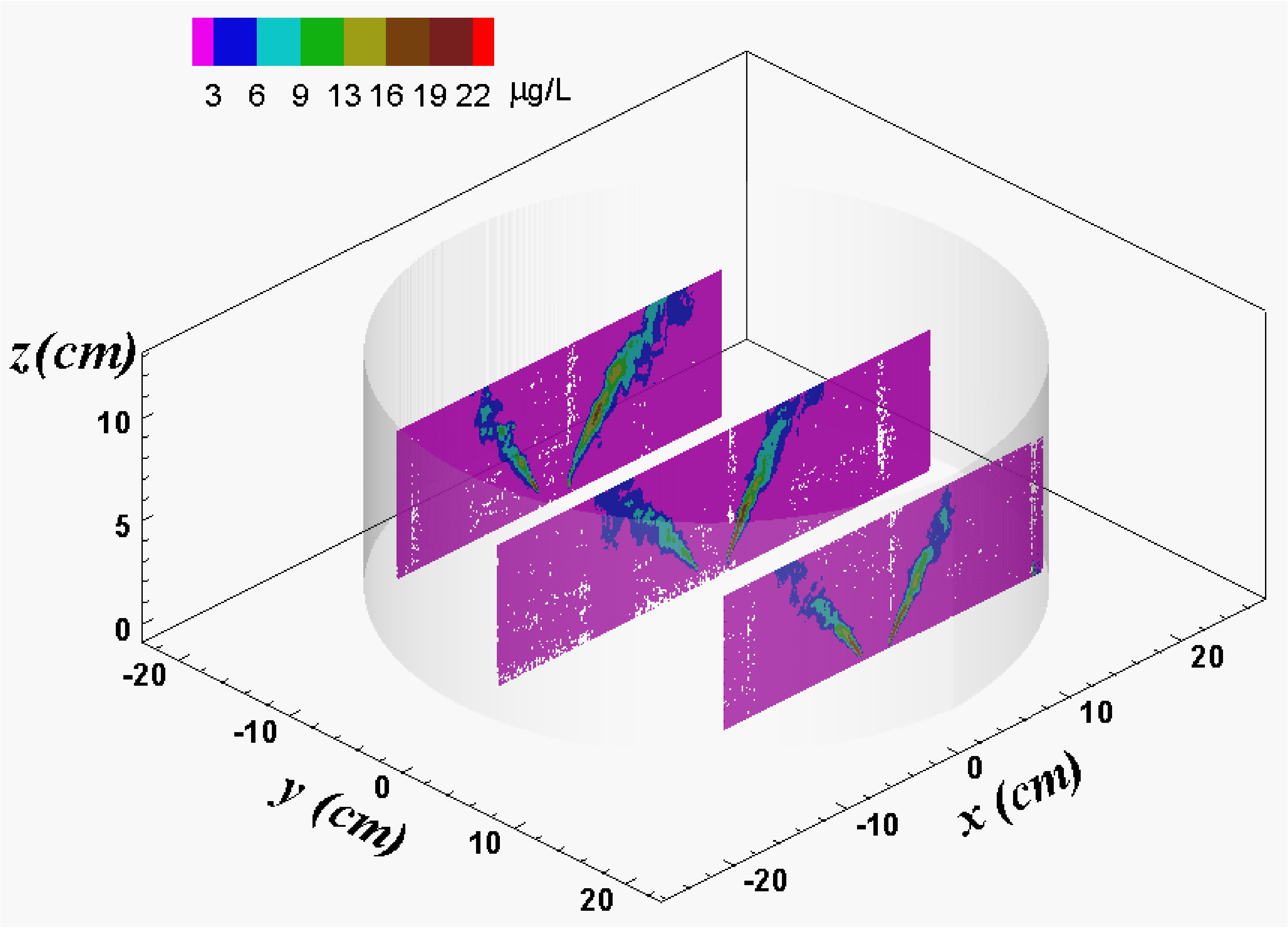


Effect Of Colder Inlet Water on Mixing in *Reservoir*

Inlet Riser Still Result in Incomplete Mixing and Stratification

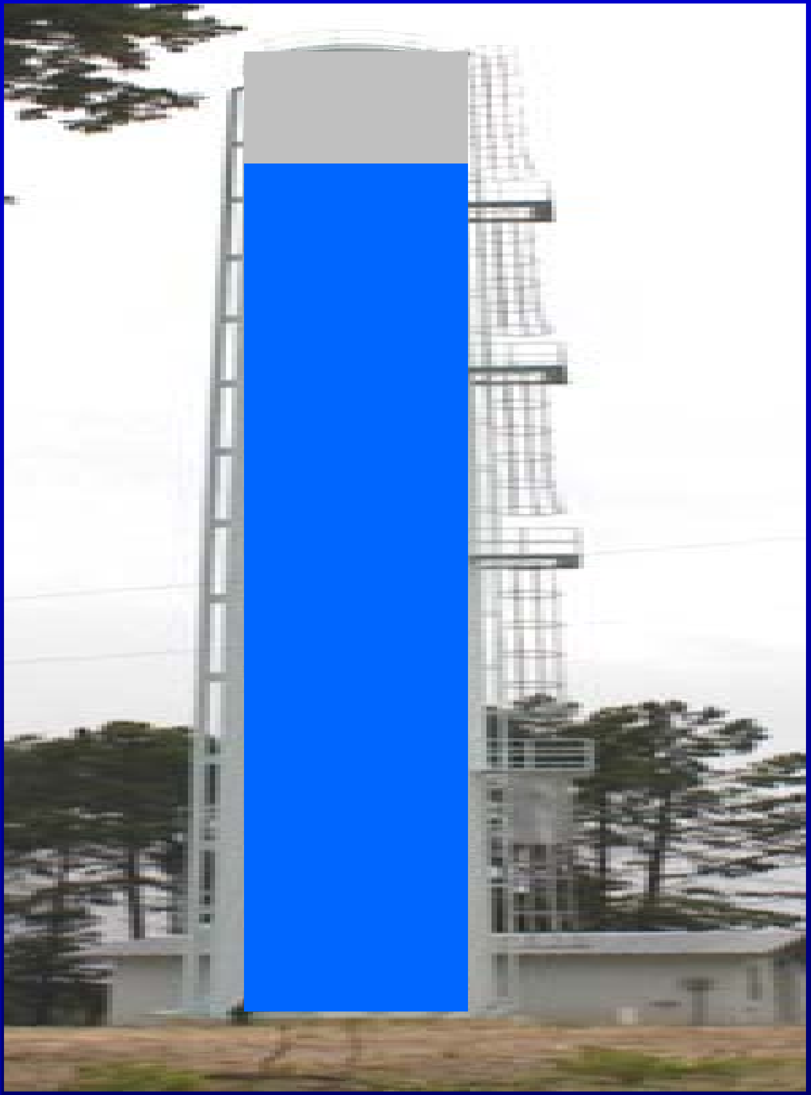


Multiple Inlets Can Mix a Tank With Colder Inlet Water When Single Inlets Result in Stratification



Achieve Adequate Turnover

- Fluctuate Tank Levels
- Must Know Mixing Time to Know How Far to Draw Tank
- Must Account for Temperature Differences - so be Conservative
- Spatial Sampling (Residual and Temperature) Recommended



Tideflex Technologies' Tideflex® Mixing System

Water Utility Department Bout

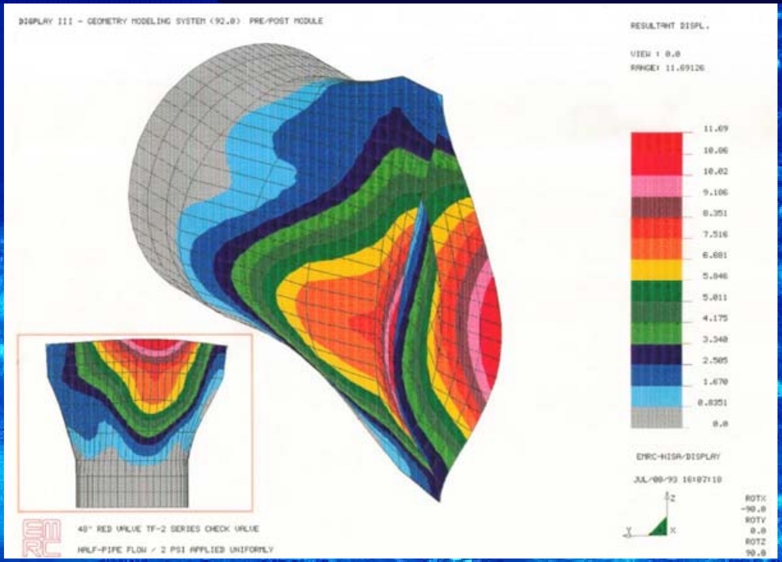
Operations vs. Water Quality

"I need to keep the tanks full for pressure and fire protection"

"You need to turn them over to reduce water age"

Extensive modeling and field-validation has proven that a properly designed mixing system can maintain water quality without requiring excessive turnover

TIDEFLEX Research & Development

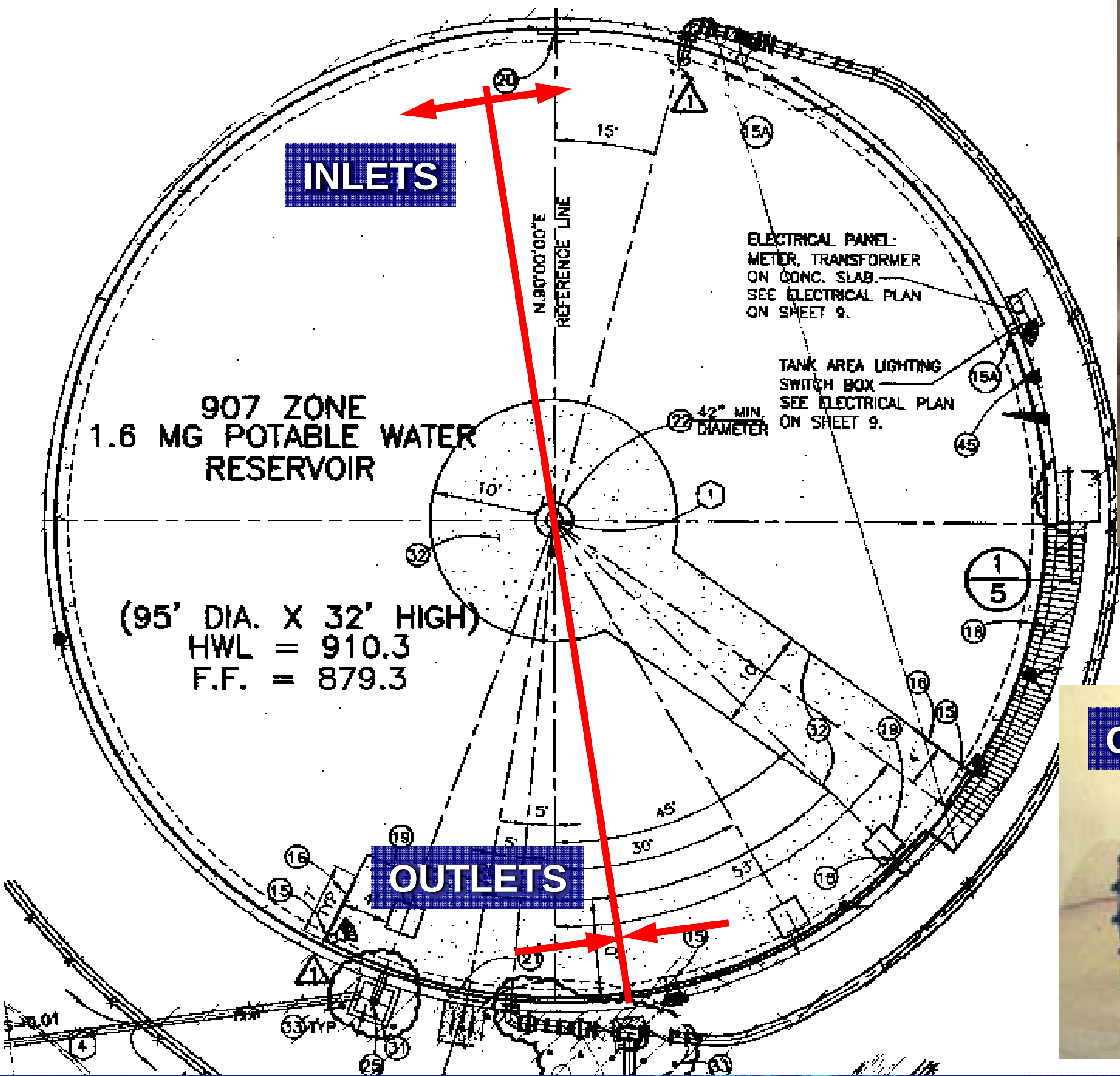


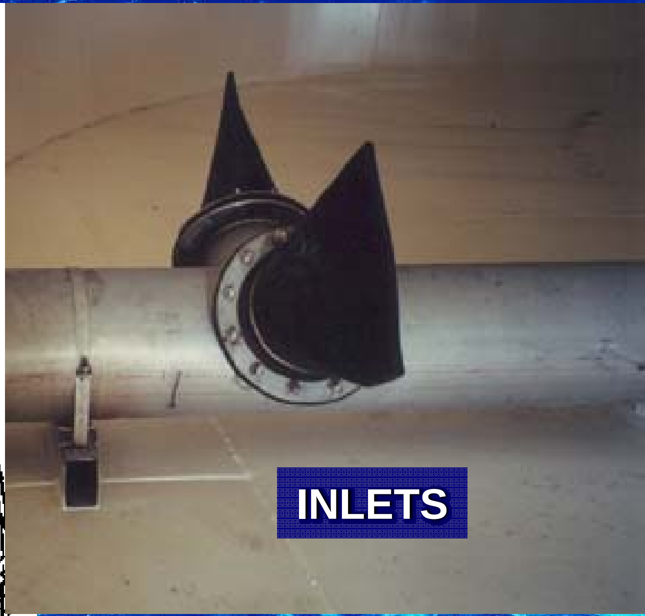
FINITE ELEMENT ANALYSIS (FEA)

OVER 50 VARIATIONS IN GEOMETRY AND STIFFNESS PER SIZE FOR HYDRAULIC OPTIMIZATION OF TMS

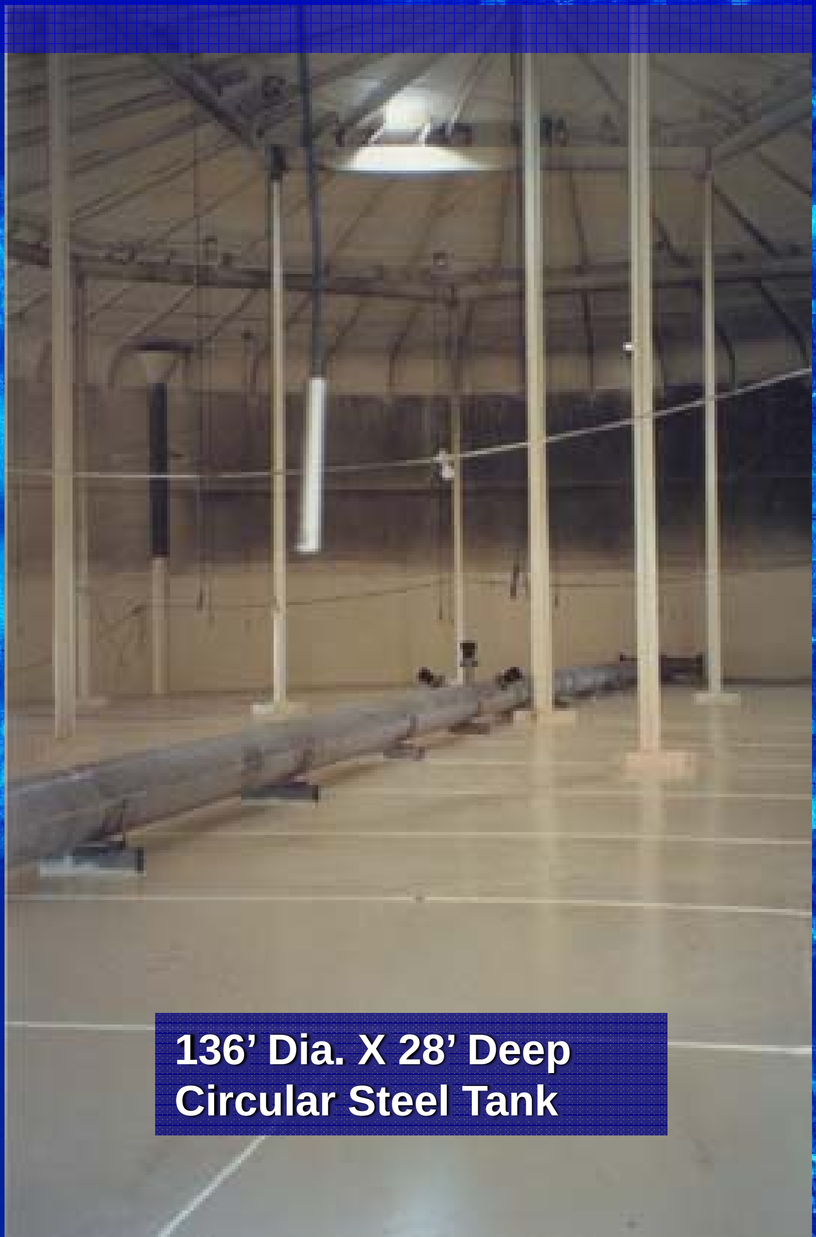
INDEPENDENT HYDRAULIC TESTING

Use of Tideflex for Inlet/Outlet Separation



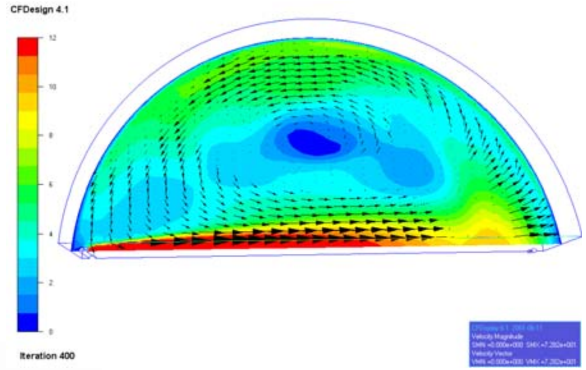


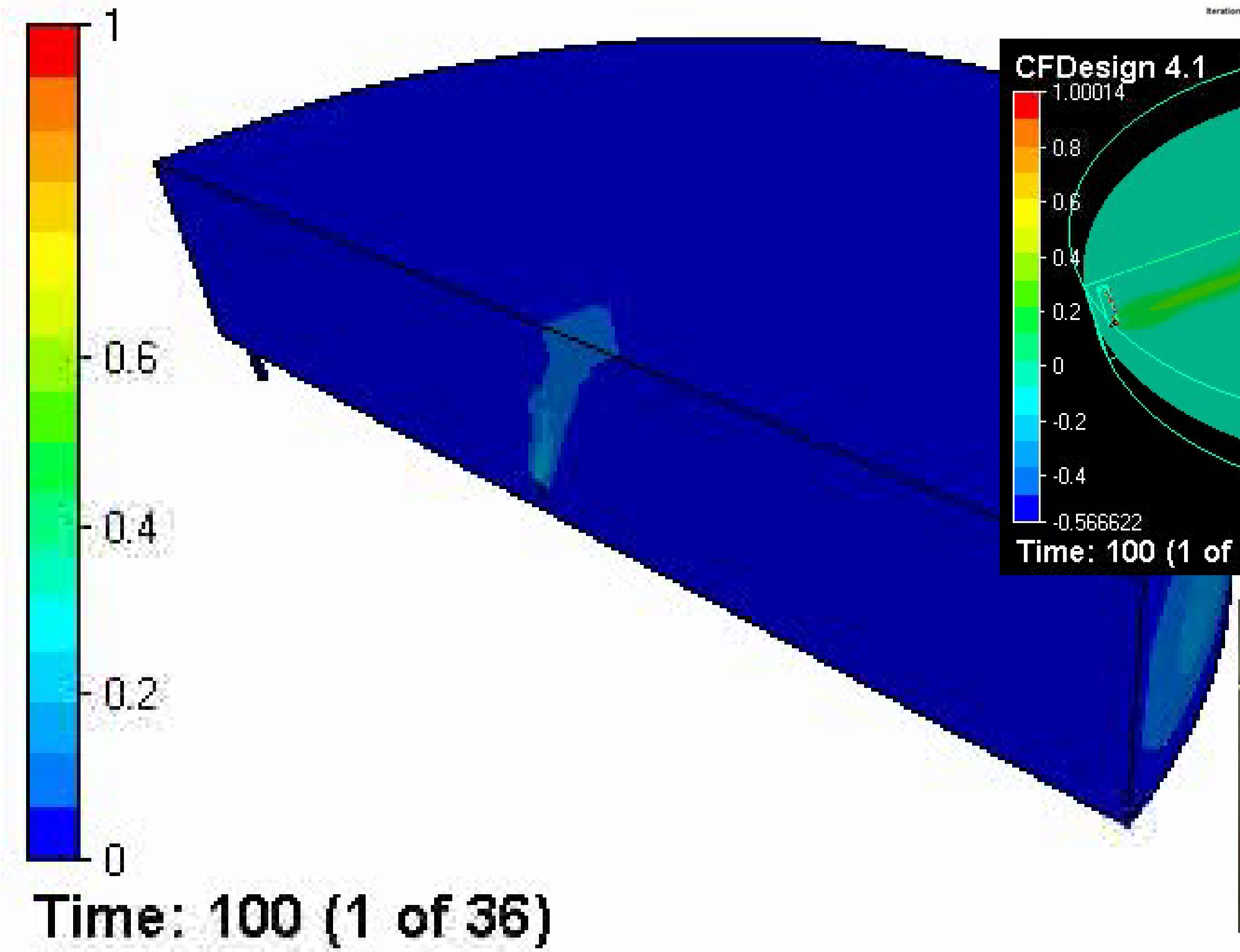
Typical TMS for Circular Reservoir

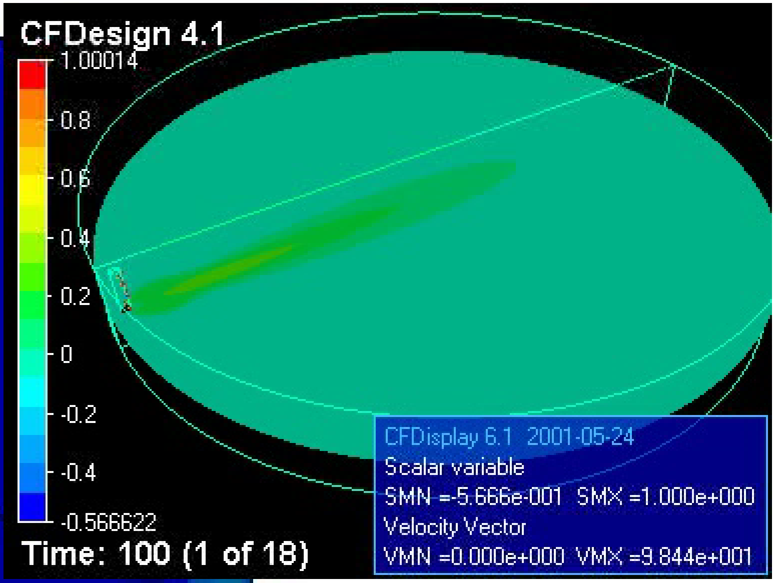


136’ Dia. X 28’ Deep
Circular Steel Tank

CFD Model of 1MG Reservoir (Simulated Tracer Distribution)

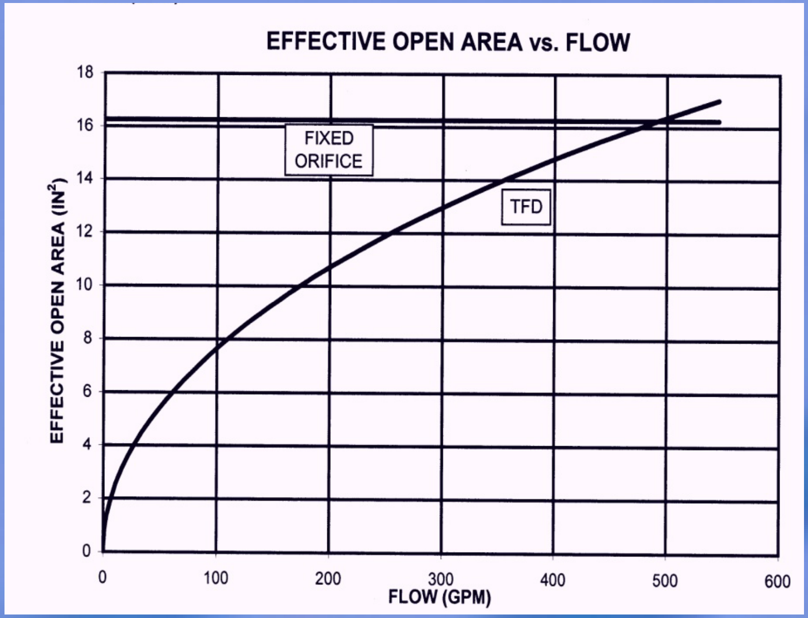


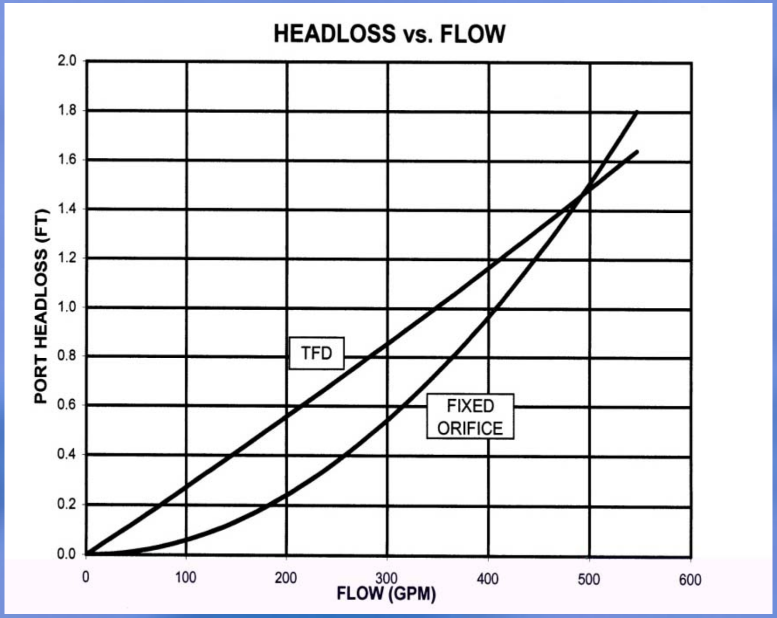


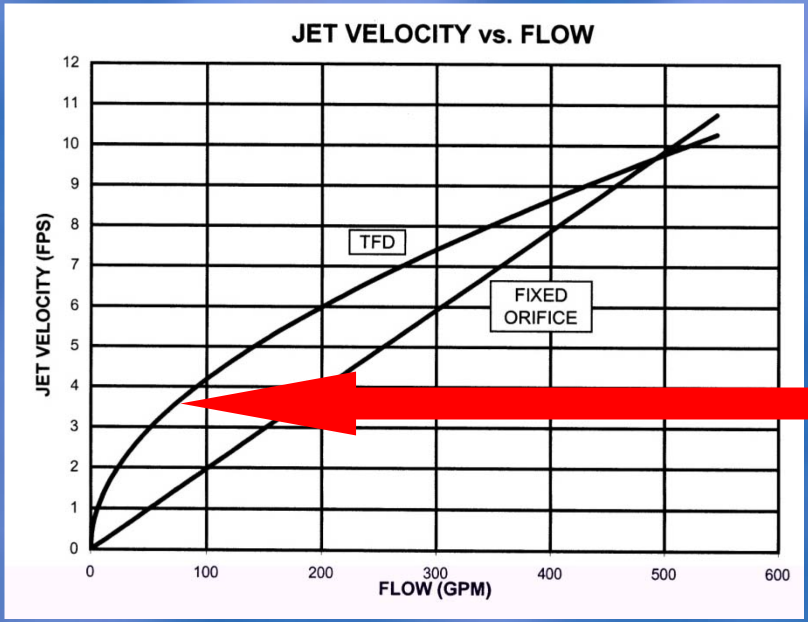


TMS in Operation During Initial Fill

Optimized Hydraulics of Tideflex







Tideflex Inlet Nozzles Maximize Jet Velocity at ALL Flow Rates Compared to Fixed-Diameter Pipe

Tideflex Technologies

RESERVOIR MIXING ANALYSIS (TMS)

08-Jan-2009

RESERVOIR / TANK NAME: WEST STREET

CONSULTANT:
Contact:
Address:
phone
fax
email

END USER:
Contact:
Address:
phone
fax
email

GUIDE TO TANK FLUCTUATION AND TURNOVER

Theoretical Mixing Time (Fill Time Req'd for Complete Mixing) MT = K * V^(2/3) / M^(1/2) (Minutes)	(Hours)	Req'd Drawdown on Previous Draw to Mix on Next Fill (feet) (SEE NOTE 2)	% Turnover Required (%) (SEE NOTE 2)	Volume Exchange Required (gallons) (SEE NOTE 2)
305.3	5.1	8.0	7.6	76,000
182.8	3.0	9.6	9.1	91,000
107.2	1.8	11.3	10.7	107,000
89.8	1.5	11.9	11.3	113,000

SEE NOTE 2

MINIMUM TANK FLUCTUATION TARGET

** If "Effective

GUIDE TO TANK FLUCTUATION AND TURNOVER

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107.2	1.8	11.3	10.7	107,000
89.8	1.5	11.9	11.3	113,000

SEE NOTE 2

MINIMUM TANK FLUCTUATION TARGET

FILL

INLET FLOW RATES (gpm)		Jet Velocity (fps)	JV^2 / 2g (feet)	Reynold's Number	Inlet Momentum (ft^4 / min^2)	Velocity Gradient, G (1/sec)
min	250	3.80	0.22	203,186	7,620	1.57
ave	500	5.30	0.44	339,352	21,255	3.10
peak	1000	7.70	0.92	578,470	61,763	6.37
future	1261	8.70	1.18	690,486	87,998	8.09

DRAW

OUTLET FLOW RATES (gpm)		TIME TO DRAW TANK FROM FULL TO EMPTY (Hours)	(Days)	Time to Draw Down 1' Depth (Minutes)	(Hours)	Pipe Velocity (fps)
min	250	66.67	2.78	38.10	0.63	0.71
ave	500	33.33	1.39	19.05	0.32	1.42
fire	1000	16.67	0.69	9.52	0.16	2.83
future	1261	13.22	0.55	7.55	0.13	3.57

Volume Exchange Required (gallons)	Draw Time Required (Hours)		
113,000 →	7.5	@	250 gpm Draw Rate
113,000 →	3.8	@	500 gpm Draw Rate
113,000 →	1.9	@	1000 gpm Draw Rate
113,000 →	1.5	@	1261 gpm Draw Rate

*** NOTE:** 1. TIDEFLEX VALVES ARE INHERENTLY A VARIABLE ORIFICE SO THE TMS EFFECTIVE DIAMETER VARIES WITH FLOW RATE
2. MIXING TIME EQUATIONS DO NOT ACCOUNT FOR DIFFERENCES IN TEMPERATURE BETWEEN INLET WATER AND TANK (BUOYANT JETS) THESE CALCULATIONS MAY UNDERESTIMATE THE FILL TIME REQUIRED FOR MIXING.

Preventing Water Stagnation in Storage Tanks

Reservoir Case Study

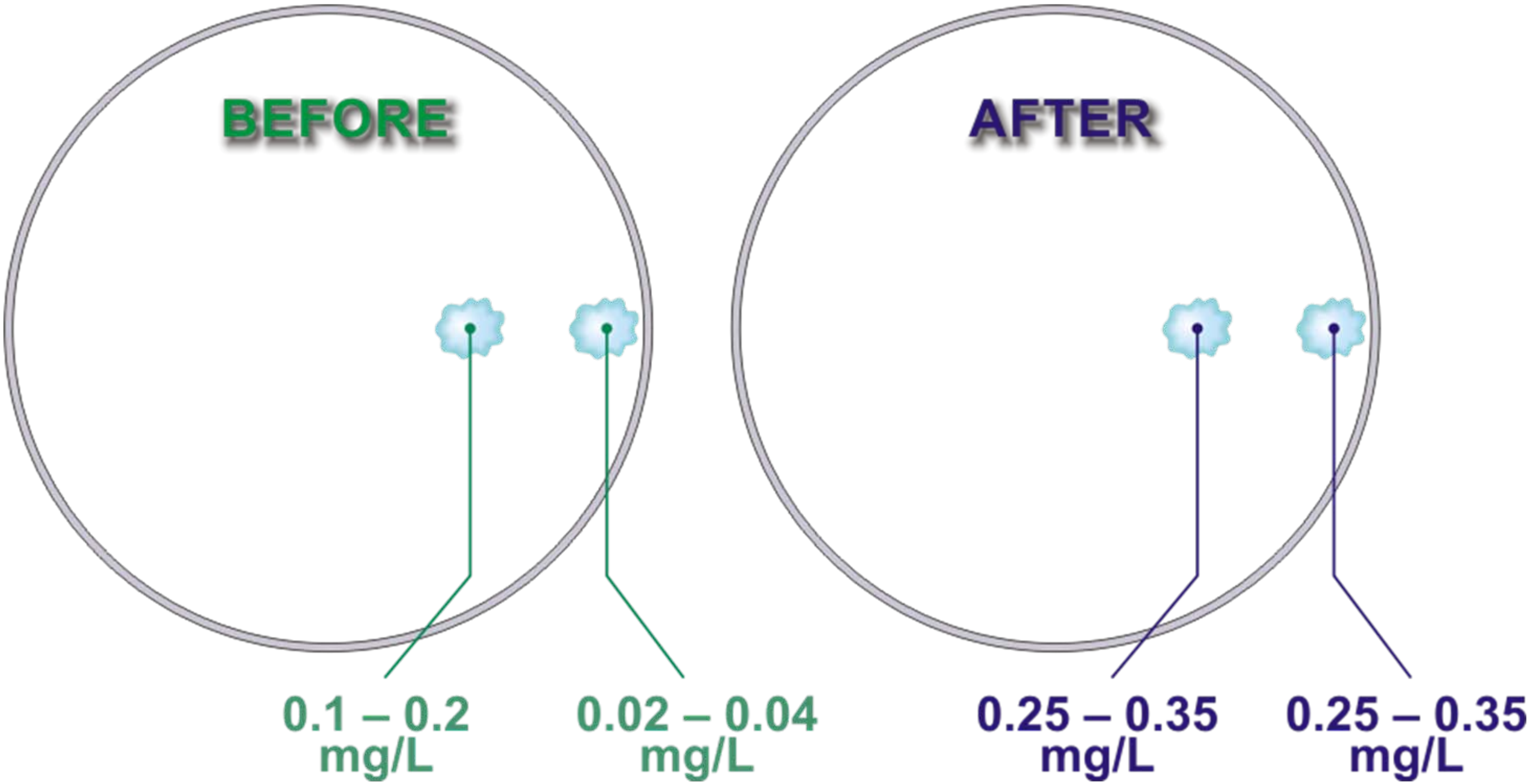
EWEB

Eugene Water & Electric Board

Eugene Water & Electric Board
Brown & Caldwell Engineering

Chlorine Residuals are Consistent Throughout Tank

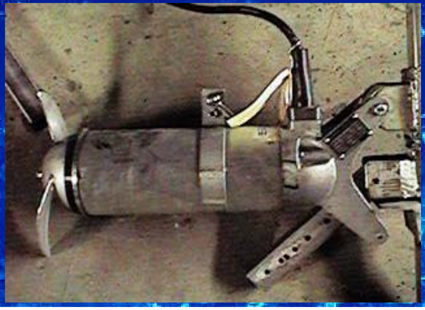
Slide Courtesy of Brown & Caldwell and EWEB

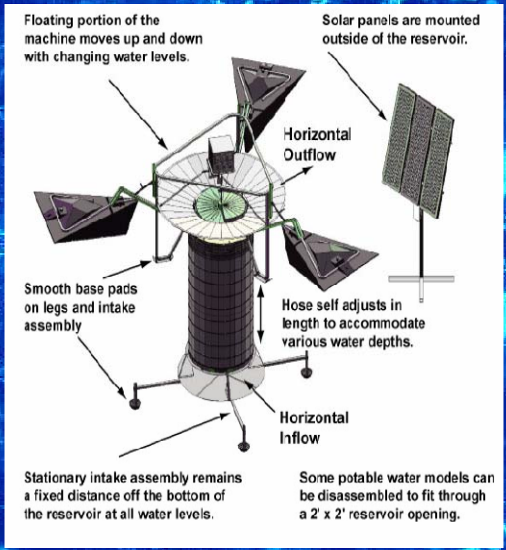


Mechanical Mixers (Electric and Solar Powered)

Consider:

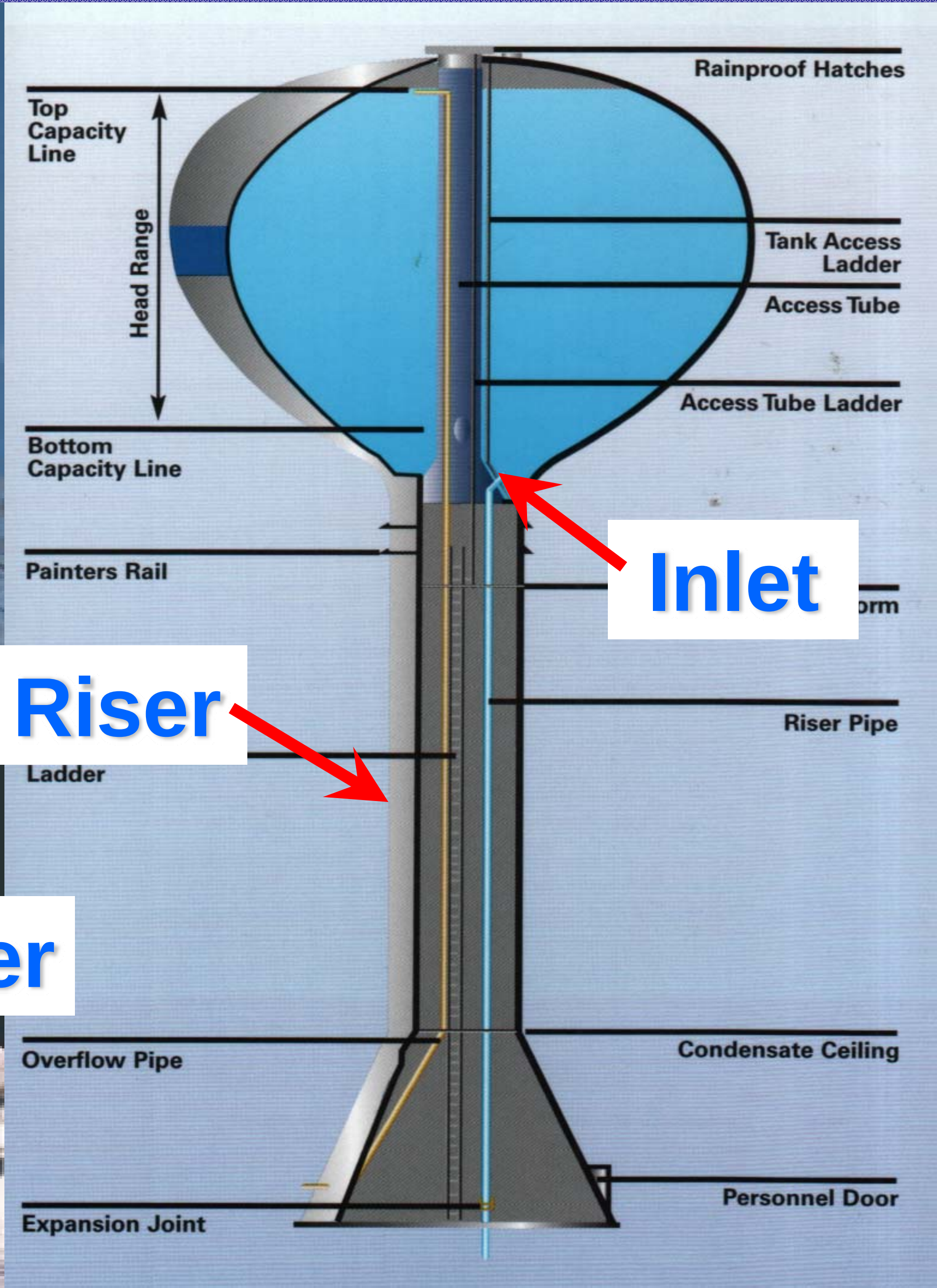
- External Energy Source
- Capital Cost
- Operational Cost
- No Impact on Water Age
- No Separation of Inlet/Outlet
- Safety? Electric & Water
- Maintenance
- Roof Reinforcement Req'd
- Another Penetration for Wires
- Interfere with Cathodic Protection
- Contamination?
- Vandalism
- NSF Certified?
- Limited Installations
- Limited Testing and Field Validation



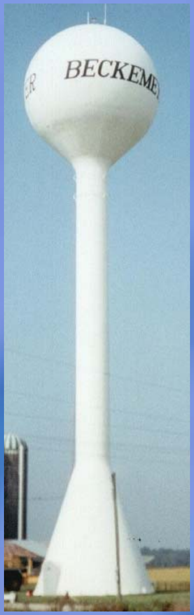


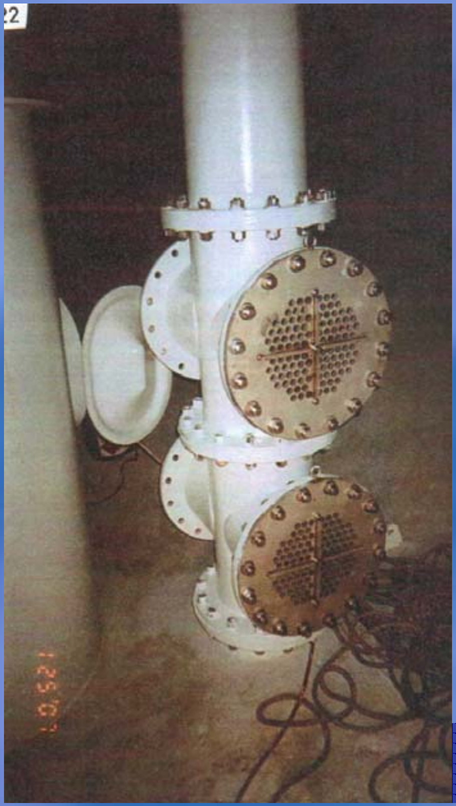
Simply put, mechanical mixers add another source of energy to the tank to mix. However, there is already a built-in source of energy – differential pressure. Tanks need to fill and draw to minimize water age. The differential pressure present during the fill can mix the tank with properly designed mixing system.

Elevated Storage Tanks



TMS for Pedesphere, Hydropillar and Composite Elevated Tanks

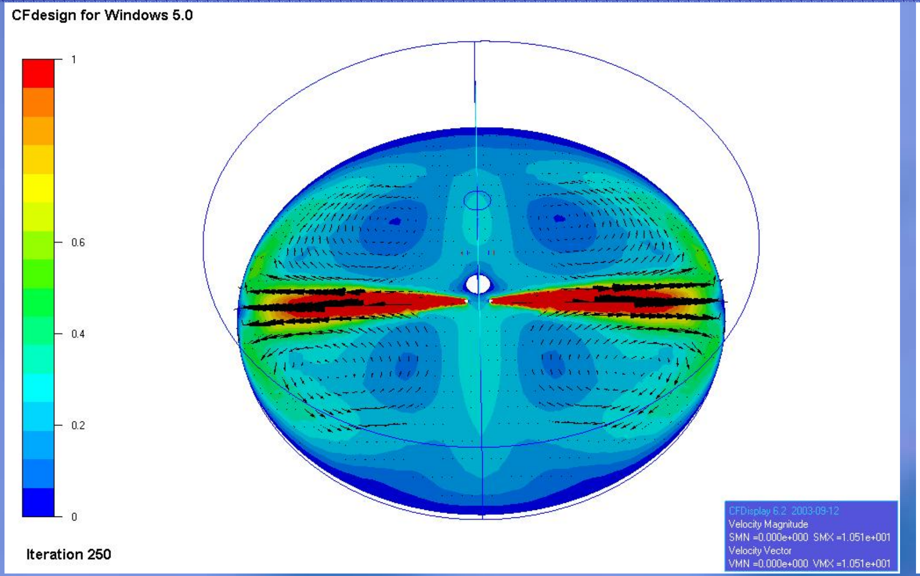


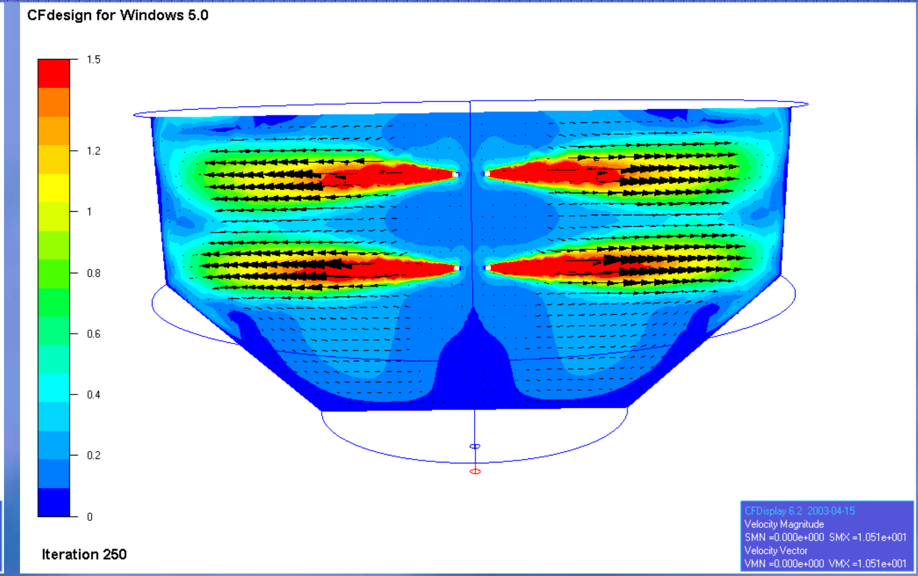


Tideflex Inlet Nozzles

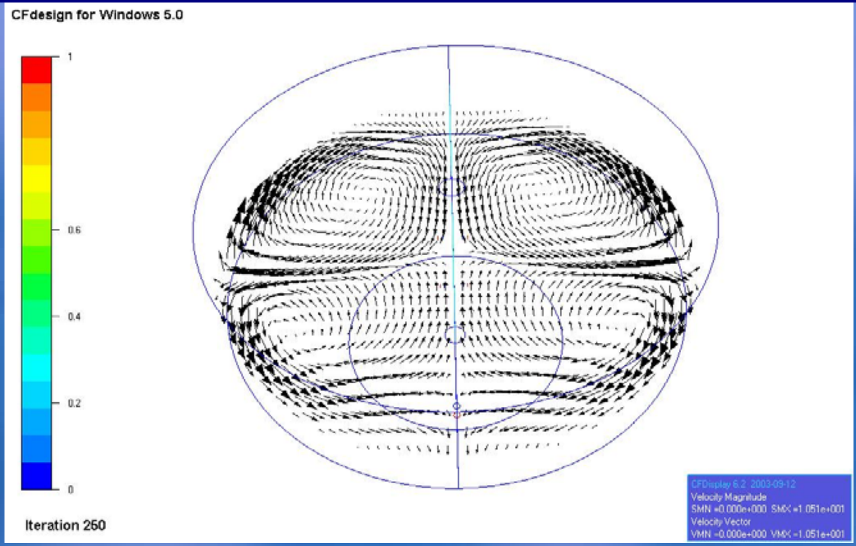
Waterflex Outlet Valves

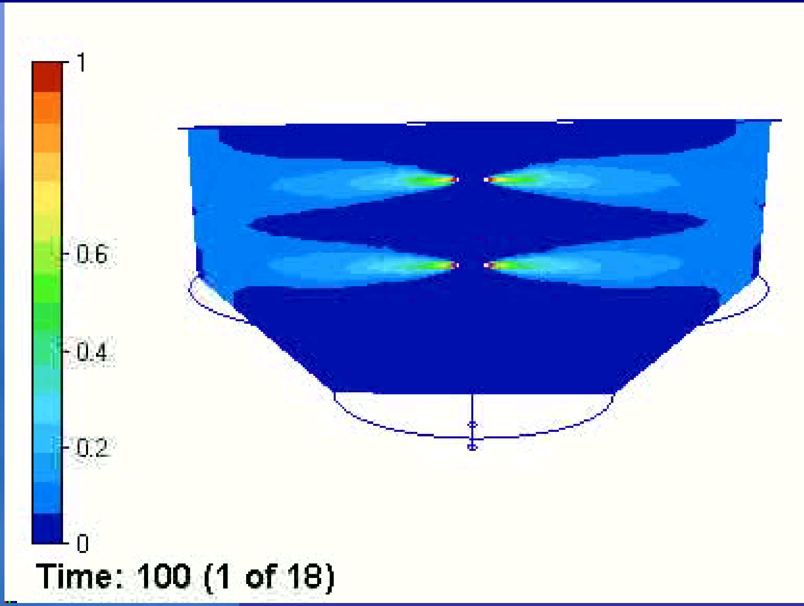
CFD Model – Elevated Hydropillar



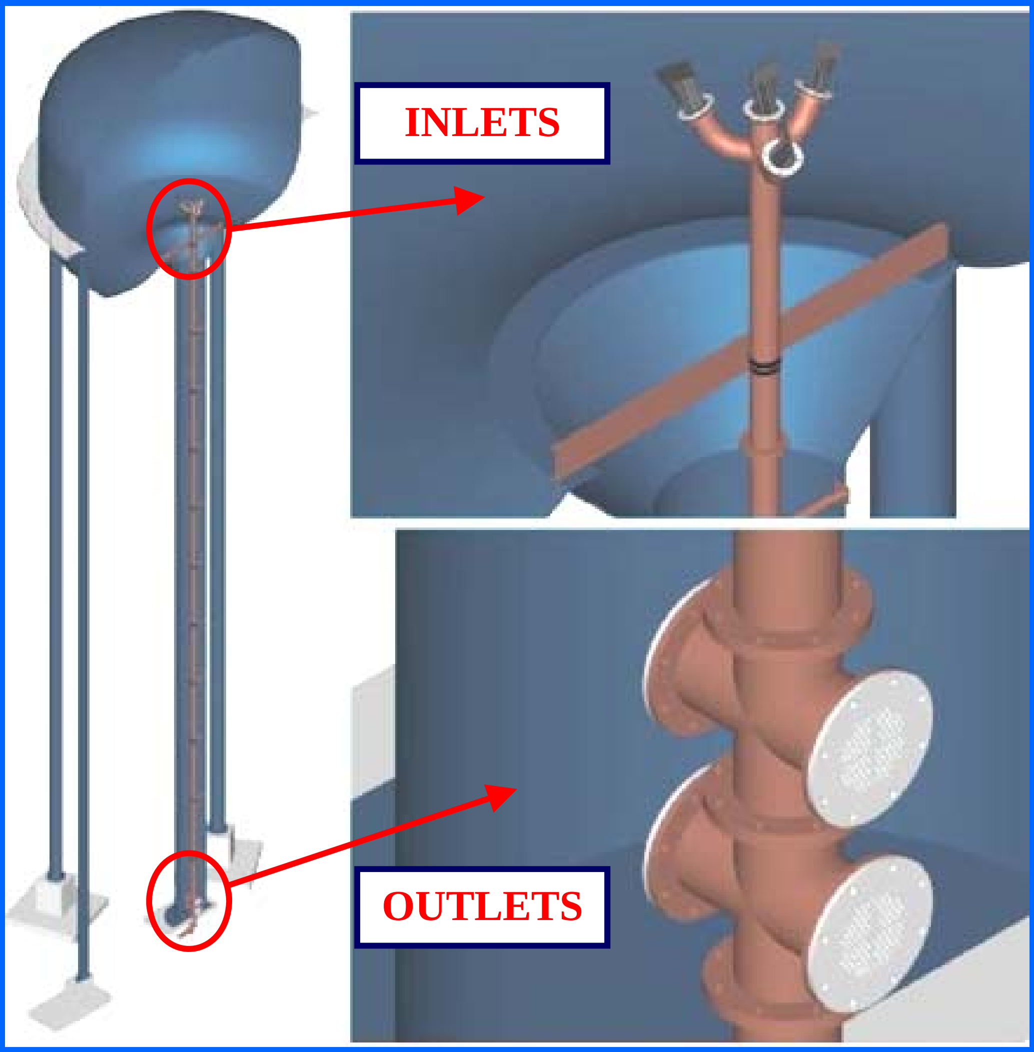


Two Inlet Valves at Two Elevations (Four Total)

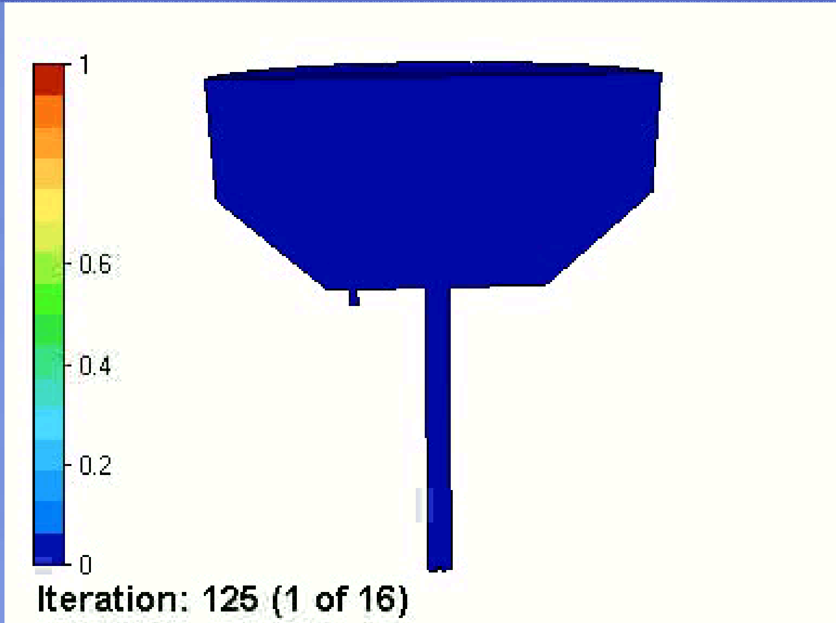




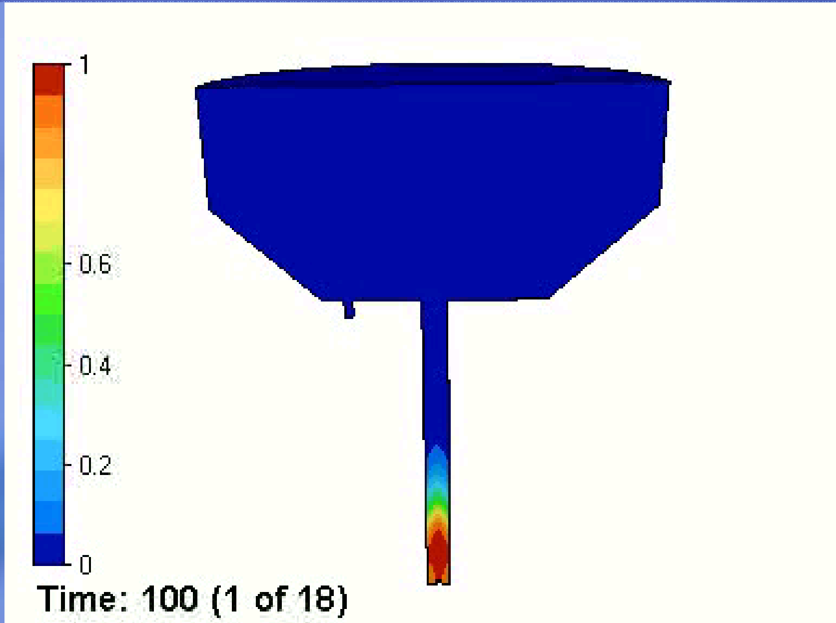
TMS for Elevated Tank with Wet Riser



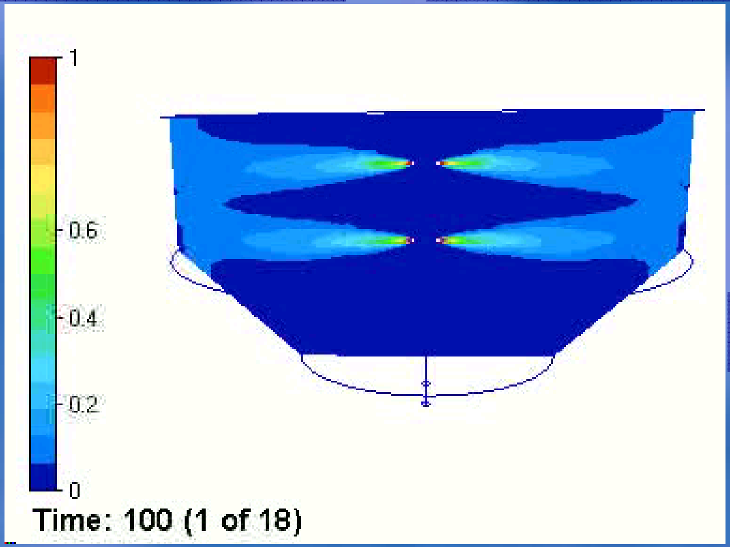
CFD Model - Elevated Tank with Wet Riser



Isothermal



10° F Colder Inlet Water



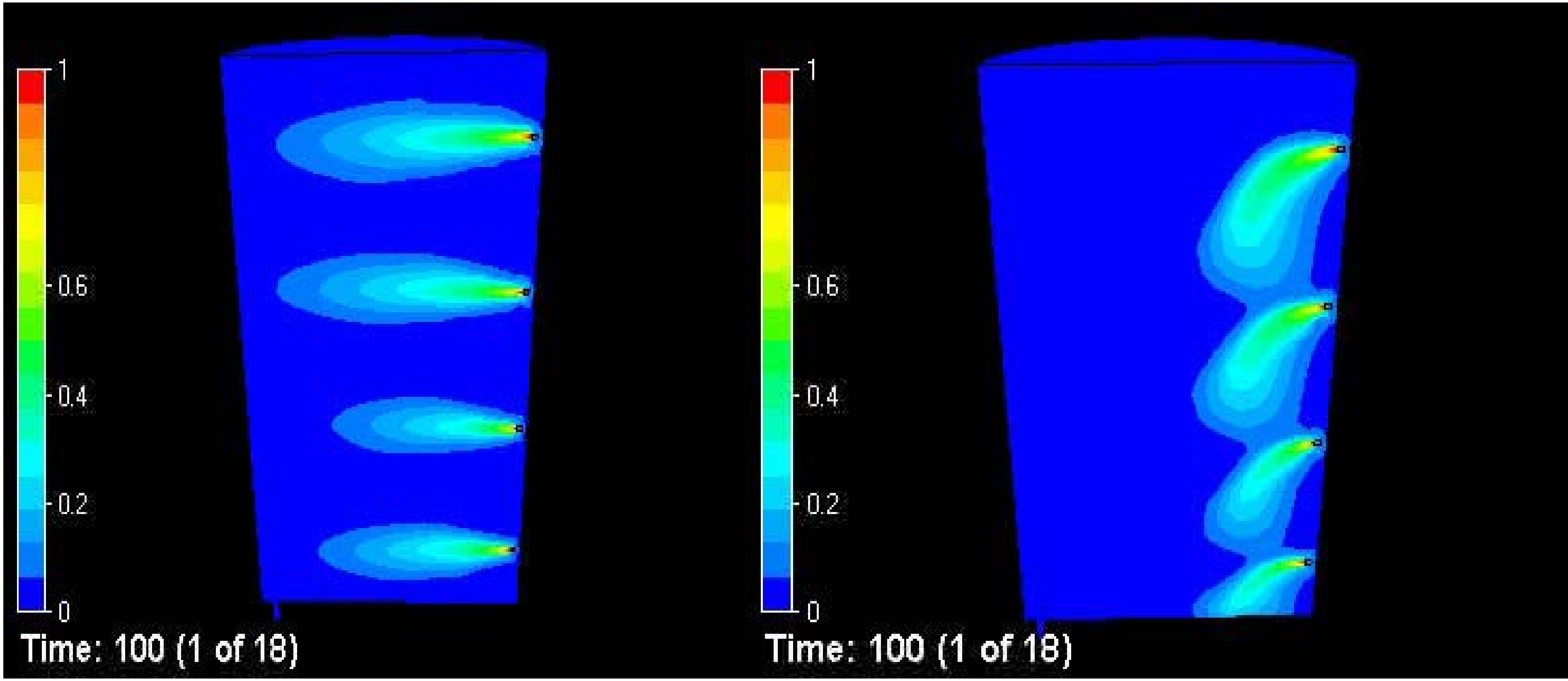
Multi-Port Isothermal

TMS for Standpipes

TIDEFLEX INLET NOZZLES

WATERFLEX OUTLET VALVES

Standpipe CFD Model – Multiple Inlets



Isothermal

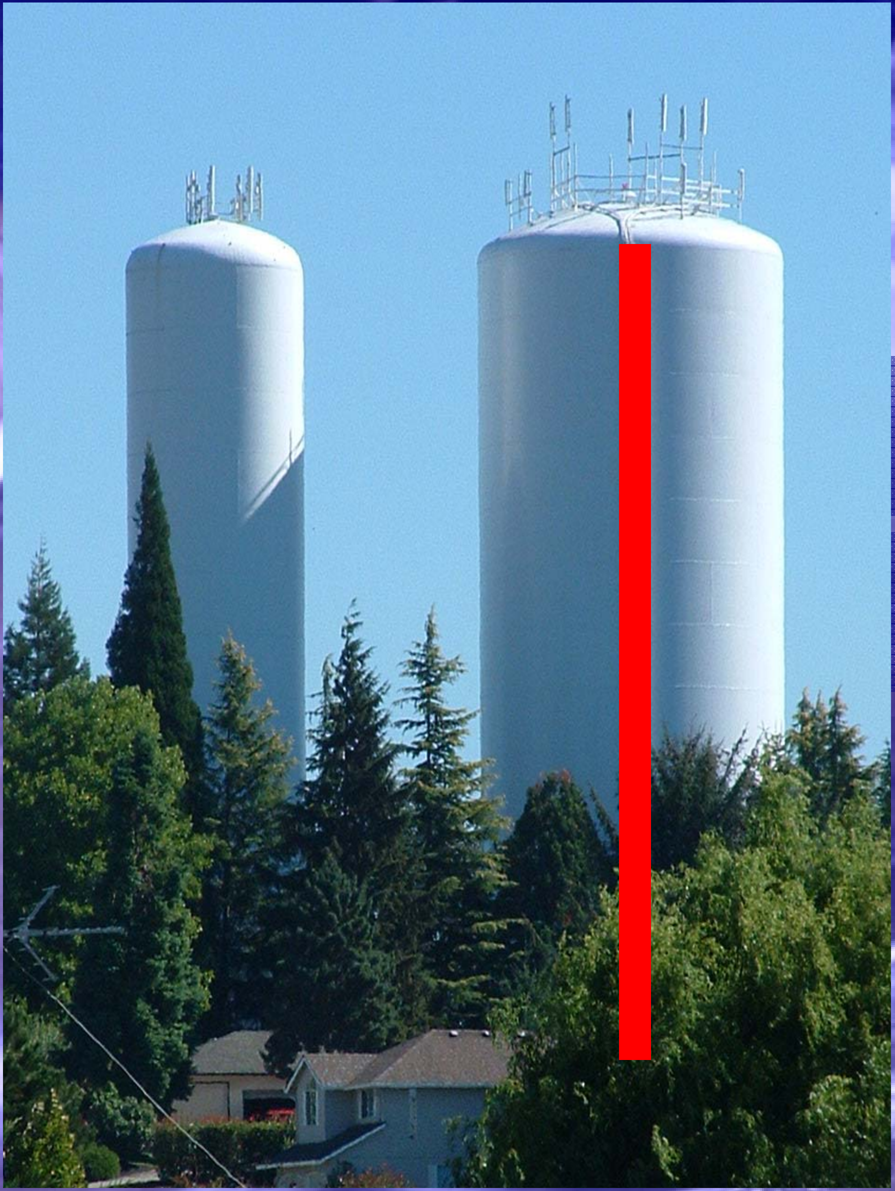
Negatively Buoyant

Temperature Profiling - Adjacent Standpipes

Courtesy of:

Clark Public Utilities

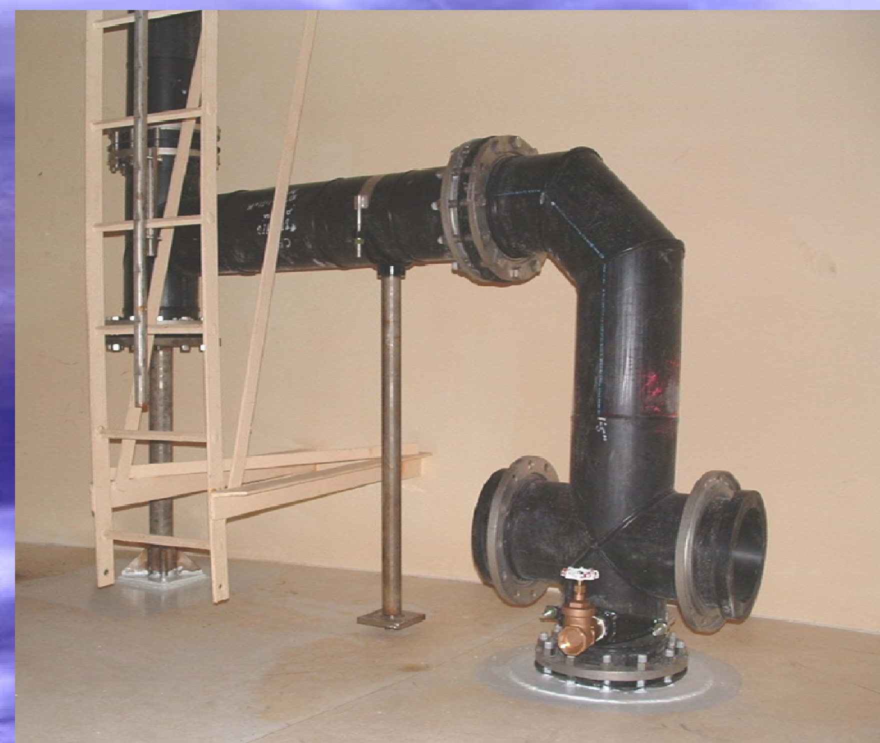
Customer-owned, customer-focused



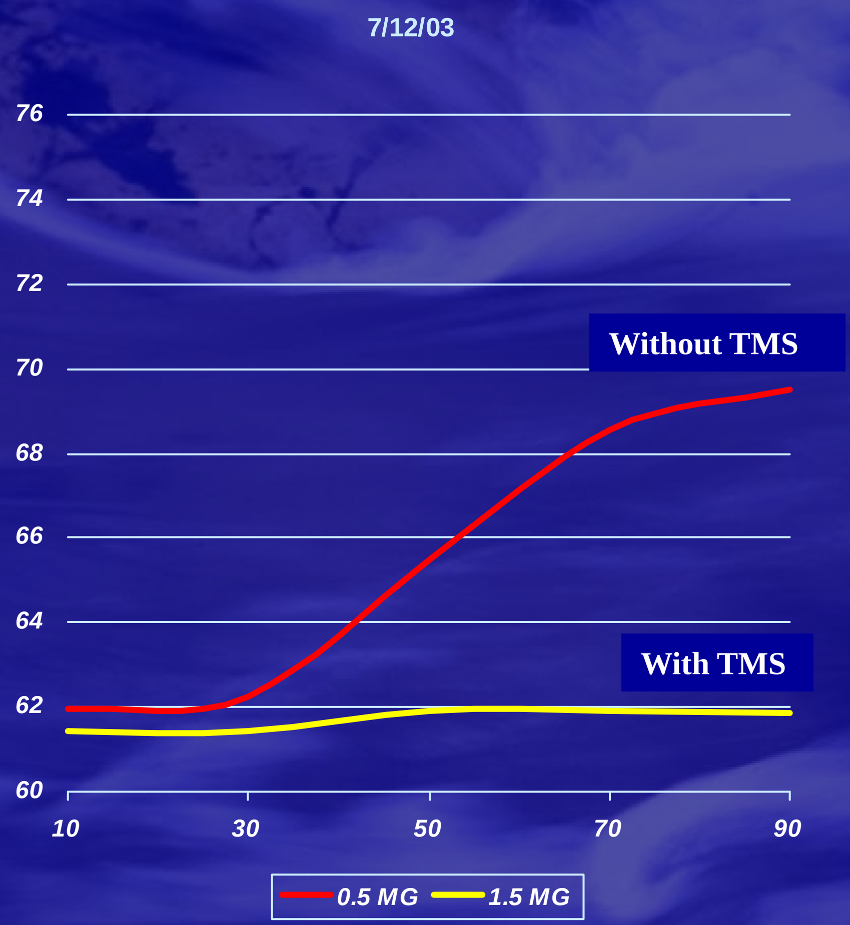
Tideflex Mixing System

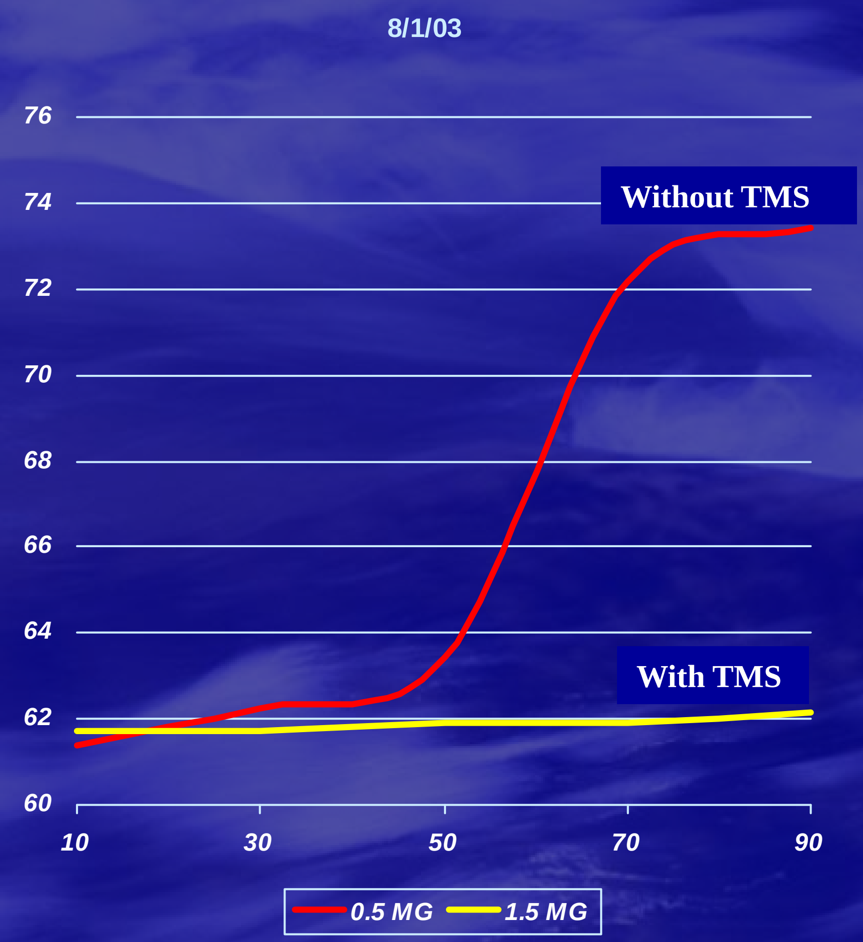
(installed in larger tank)

Waterflex Outlet

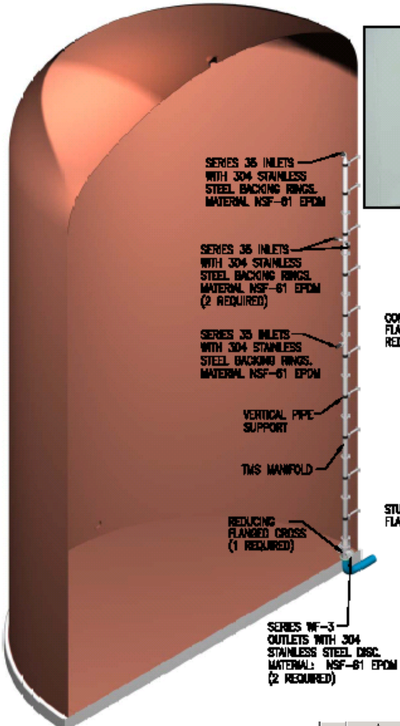


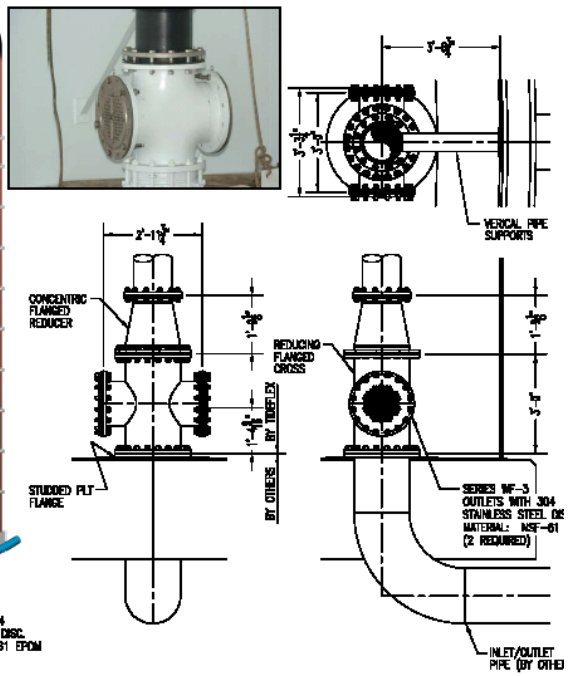
Temperature vs. Depth

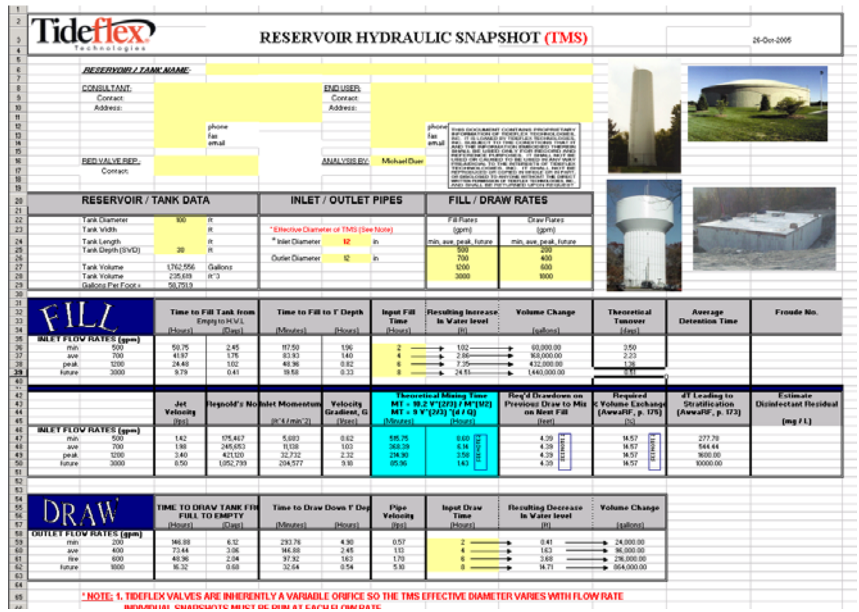




Complete System Design and Hydraulic Analysis







TIDEFLEX MIXING SYSTEM (TMS) Manifold Hydraulics

26-Oct-2005

RESERVOIR FILLING MANIFOLD
5,300 GPM _ PEAK FLOW

Reservoir Name: Stay Reservoir — Ambient Density = 62.4 lbm/ft^3
Reservoir Size (WxL): 150 FT X 150 FT — Effluent Density = 62.4 lbm/ft^3
Reservoir Capacity: 2 MG — dS/S = 0
End User: City of Yute — C = 100 Hazen Williams Roughness Coefficient
Consultant: Independent Consultants — Cd = 0.95

Port Number	Tideflex Nominal Diameter (in) dp	Catalog Number	Pipe Diameter (in) D	Pipe Area (in^2) AD	Total Head (ft) E	Cd Sharp Edged Cd	Port Discharge Sharp Edged (cfs)	(gpm)	CUMULATIVE FLOW (gpm)	Jet Velocity (fps)	Port Froude #	Inc. in Pipe Vel. (fps)	Header Pipe Vel. (fps)	Velocity Head (ft)	Dist. Next Port (ft)	Friction Loss (ft)	% Slope	Decrease in Depth (ft)	Density Head (ft)	Hazen-Williams Total Head (ft)
1	10	519	24	452.4	1.12	0.95	1.14	513.2	513.2	8.2		0.36	0.36	0.002	0.0	0.000	0.0	0.000	0.000	1.1
2	10	519	24	452.4	1.12	0.95	1.14	513.2	1026.4	8.2		0.36	0.73	0.008	30.0	0.004	0.0	0.000	0.000	1.1
3	10	519	24	452.4	1.12	0.95	1.15	515.1	1541.6	8.3		0.37	1.09	0.019	0.0	0.000	0.0	0.000	0.000	1.1
4	10	519	24	452.4	1.12	0.95	1.15	515.1	2056.7	8.3		0.37	1.46	0.033	30.0	0.016	0.0	0.000	0.000	1.1
5	10	519	24	452.4	1.14	0.95	1.16	522.1	2578.8	8.3		0.37	1.83	0.052	0.0	0.000	0.0	0.000	0.000	1.1
6	10	519	24	452.4	1.14	0.95	1.16	522.1	3100.9	8.3		0.37	2.20	0.075	30.0	0.035	0.0	0.000	0.000	1.2
7	10	519	24	452.4	1.17	0.95	1.20	537.0	3637.9	8.4		0.38	2.58	0.104	0.0	0.000	0.0	0.000	0.000	1.2
8	10	519	24	452.4	1.17	0.95	1.20	537.0	4174.8	8.4		0.38	2.96	0.137	30.0	0.060	0.0	0.000	0.000	1.2
9	10	519	24	452.4	1.23	0.95	1.25	562.6	4737.4	8.7		0.40	3.36	0.176	0.0	0.000	0.0	0.000	0.000	1.2
10	10	519	24	452.4	1.23	0.95	1.25	562.6	5300.0	8.7		0.40	3.76	0.220	15.0	0.047	0.0	0.000	0.000	1.3

TOTAL FLOW = 5300.00 GPM
7.63 MGD

MANIFOLD LENGTH : 135.00 FT
TOTAL FRICTION HEADLOSS = 0.05 FT
HEAD REQUIRED TO DRIVE 1.28 FT

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QUESTIONS ?

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