Bench-Scale Testing for Controlling Desalinated Seawater Quality

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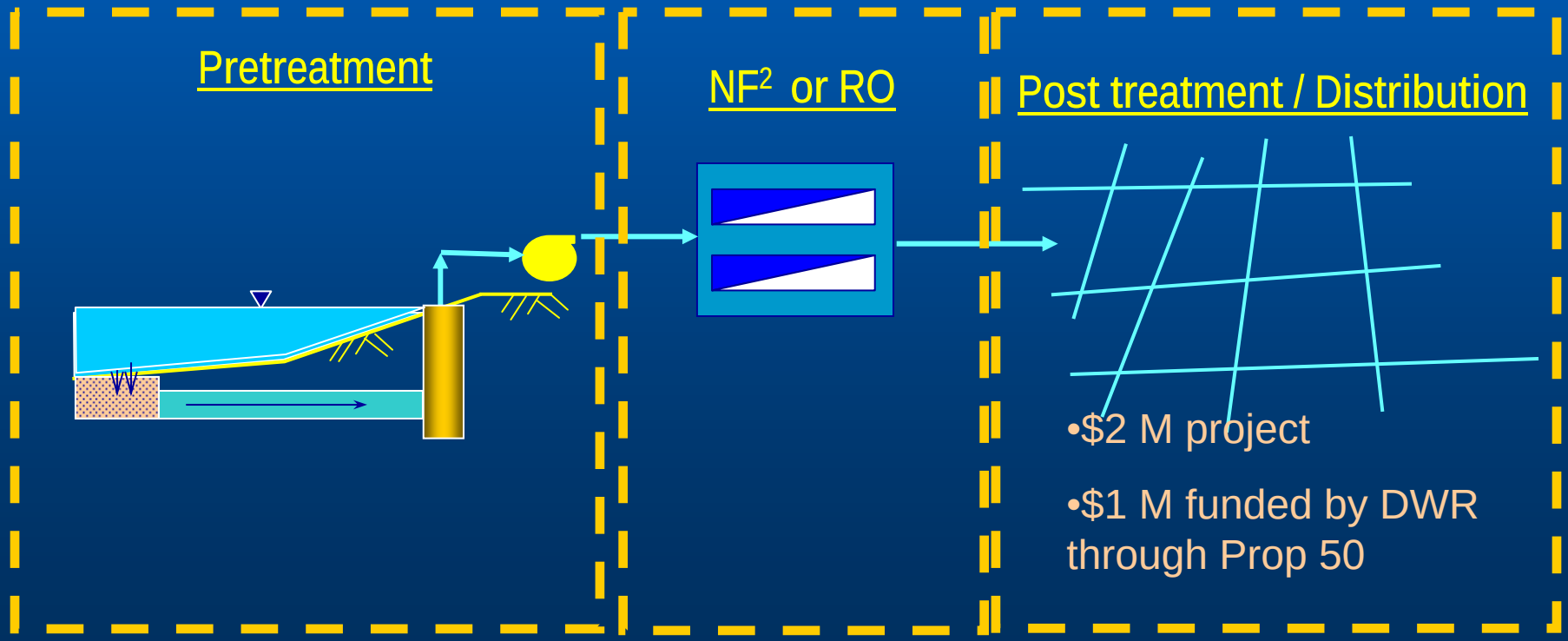
LBWD's Seawater Desalination Program

- A $20 M, 10-year investment
- Leverage various partnerships for technical input and other support
- Federal / State / Local Funding



Elements of Interest in Seawater

H																He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Nb	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Select Water Quality Parameters

		Raw seawater	DI	DW	DSW
Br	mg/L	72	ND	0.6	0.07
TOC	mg/L	0.35	0.11	0.12	2.0
pH	units	7.6	7.4	7.3	8.3
TDS	mg/L	34130	7.0	60	260
Alk-T	mg/L-$CaCO_3$	100	3.6	15	117
Ca	mg/L	424	ND	0.3	28
Mg	mg/L	1110	ND	<0.5	7.2
SO_4	mg/L	2393	ND	<10	50

Concerns with Seawater Quality

- Higher-than-normal levels of bromide
  - Disinfection byproducts (DBP) formation skewed towards brominated compounds?
  - Residual stability issues associated with brominated acids?
  - Perform bench-scale DBP tests
- Corrosion – low minerals content
  - Leaching of minerals?
  - Perform corrosion tests
  - Evaluate corrosion indices

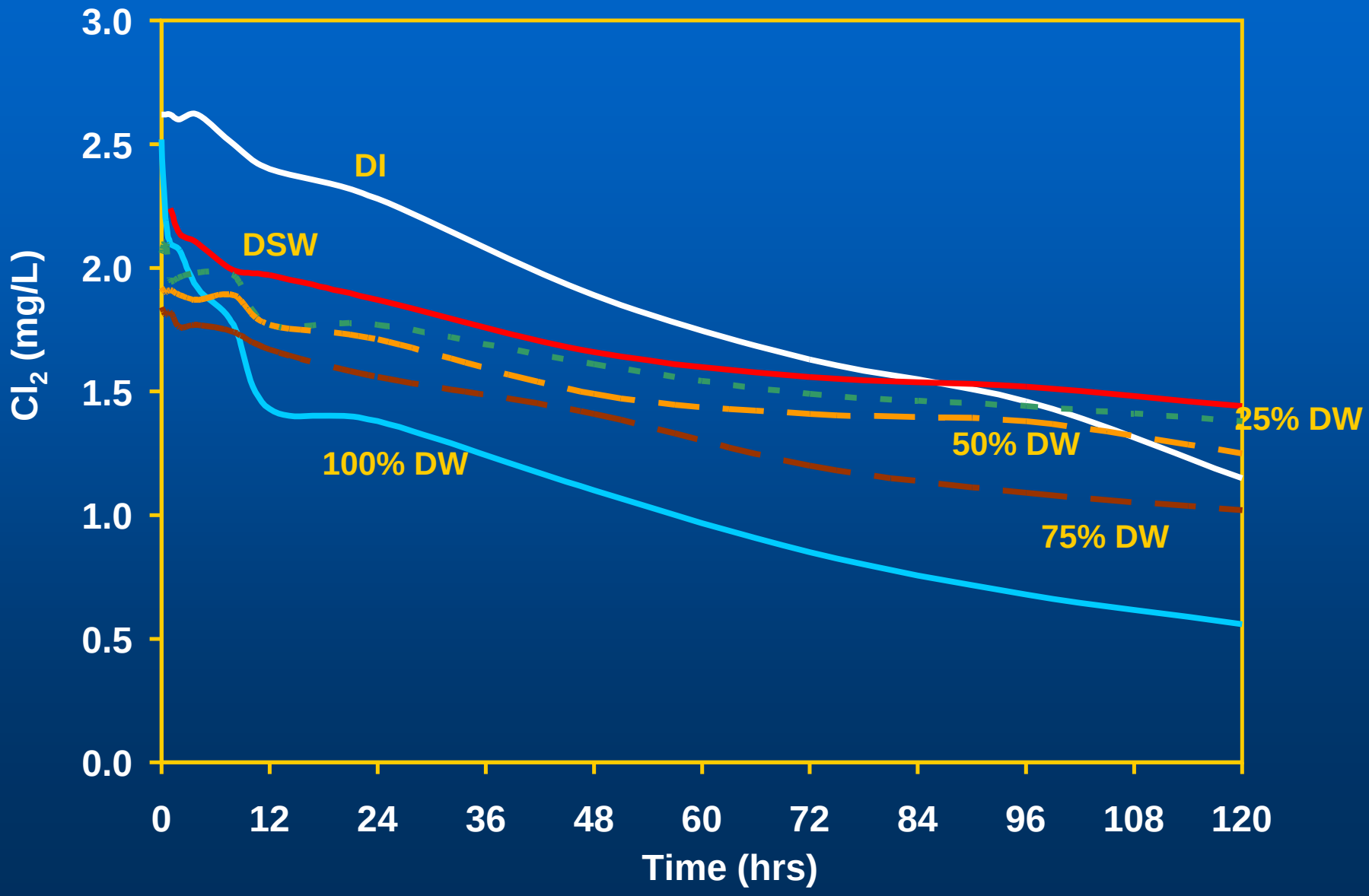
Bench-Scale DBP Testing

- Will desalinated waters, by itself or in a blend, cause
  - residual instability?
  - DBP compliance issues?
- Evaluated 6 different waters
  - deionized water (DI) - control
  - existing distribution system water (DSW)
  - 100% desalinated seawater (DW) by NF2 process
  - 25% DW – 75% DSW
  - 50% DW – 50% DSW
  - 75% DW – 25% DSW

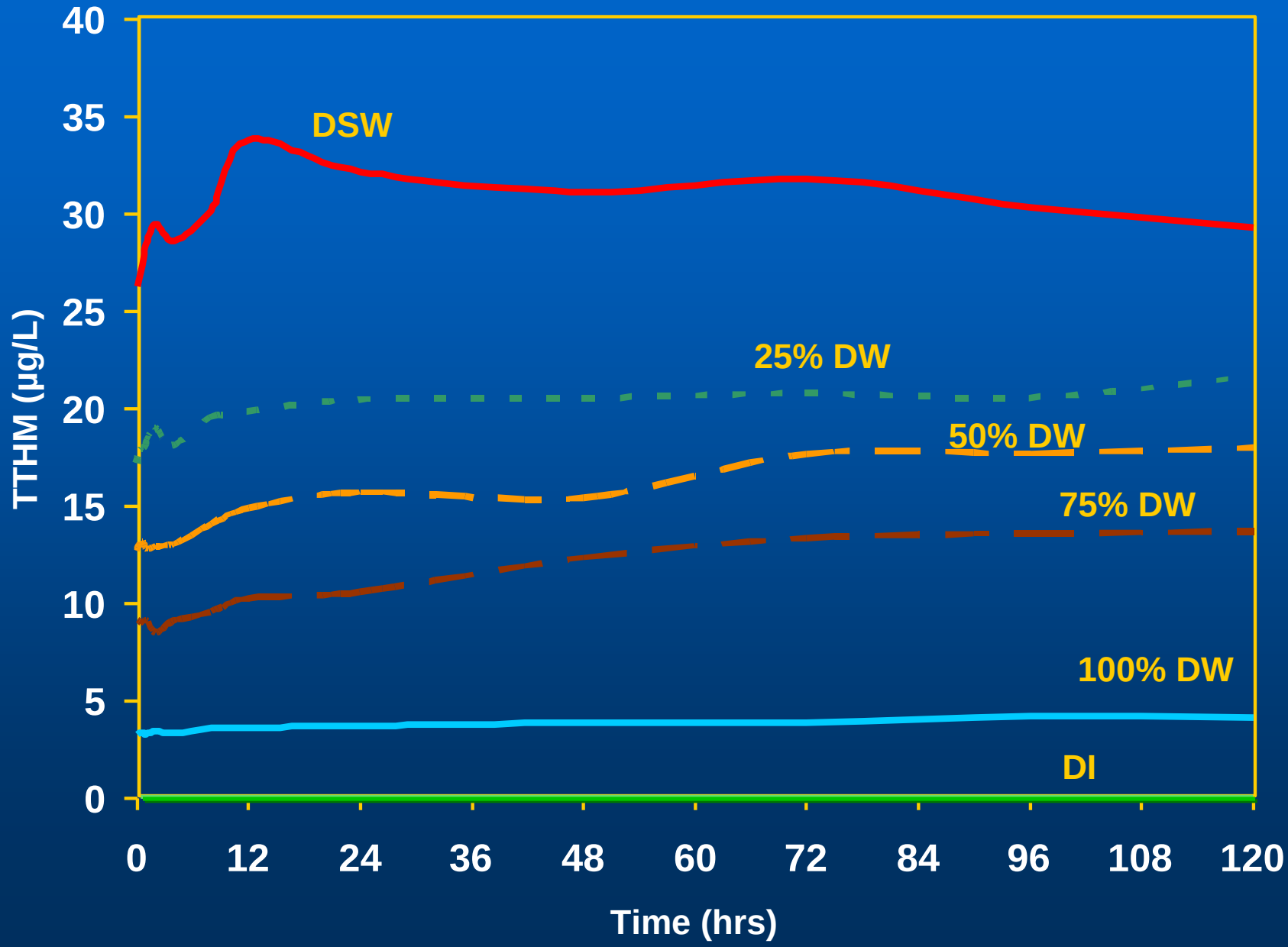
Bench-Scale DBP Testing

- Test sequence
  - Free chlorine residual at 2.5 mg/L at end of 45 min.
  - Blends adjusted to ~ pH = 8 using phosphoric acid
  - NH_3 added for a 5:1 Cl_2:NH_3 ratio (t = 0)
  - Each time and blend sampled from individual headspace-free bottle, held in the dark
- Analyzed for
  - pH, Cl_2, NH_3, THM, HAA9
- Analyzed at
  - t = 0.5, 1, 2, 4, 8, 12, 24, 48, 72, 96, 120 hrs

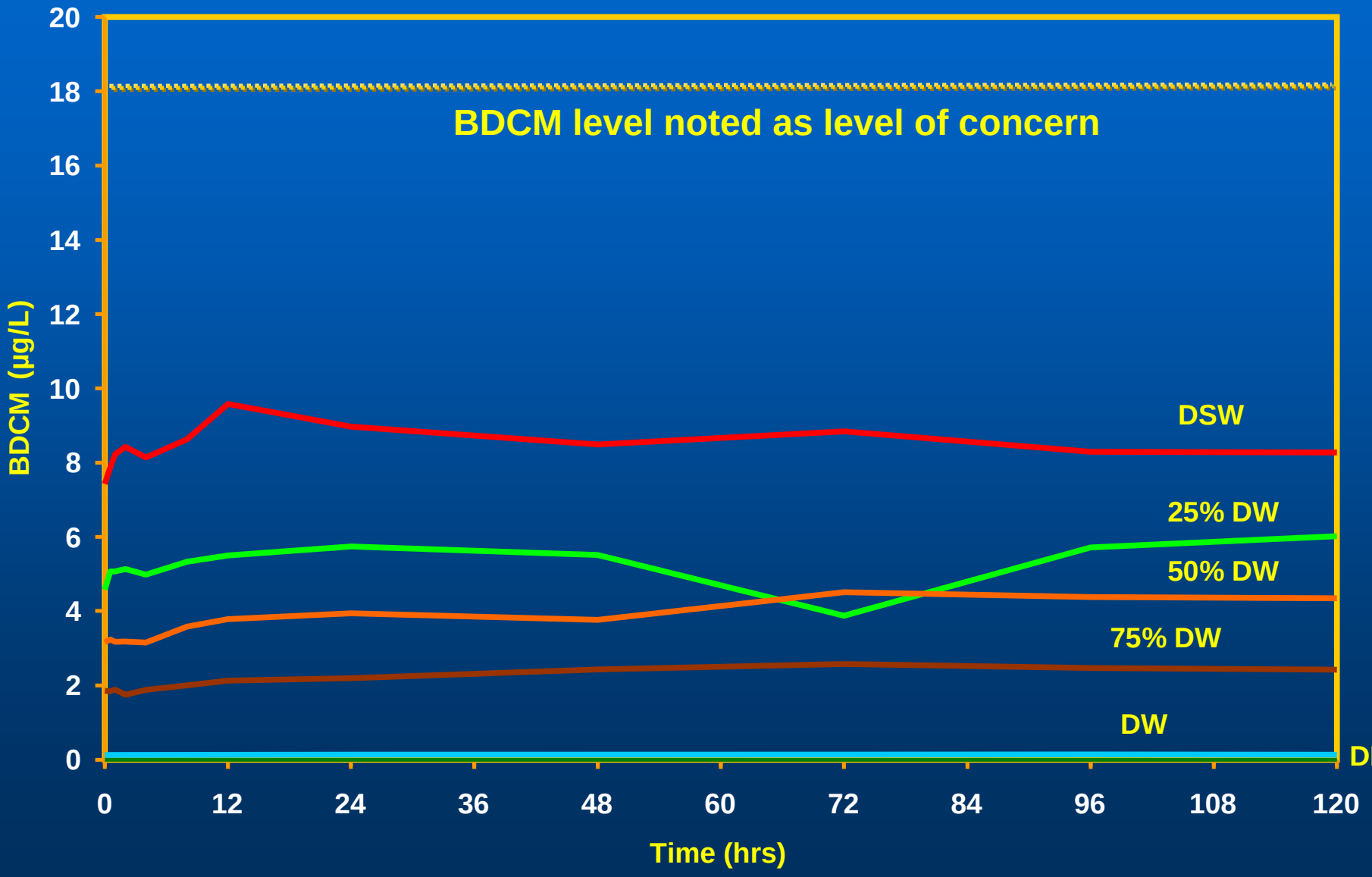
Chlorine Residual Results



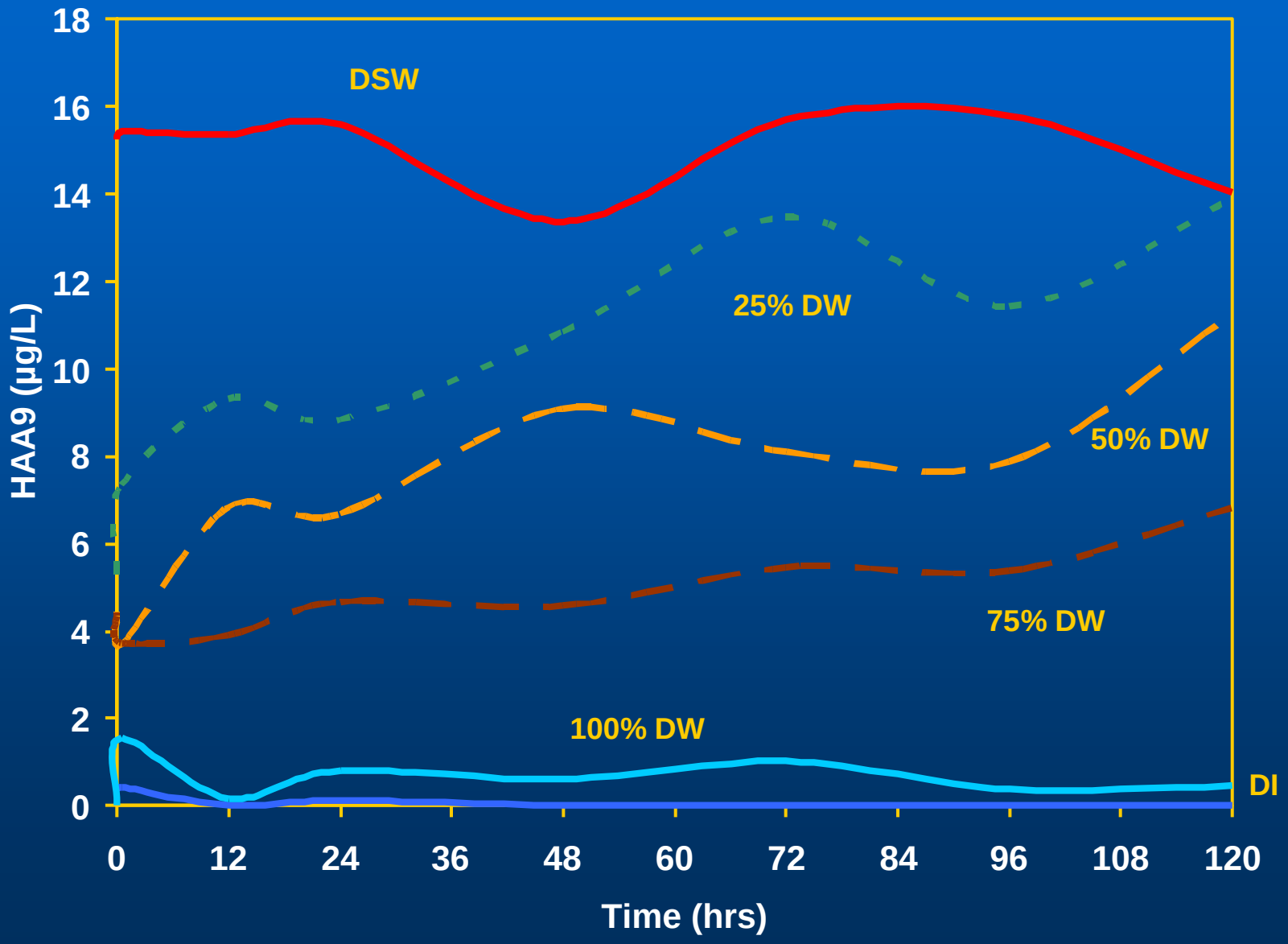
TTHM Results



BDCM Results



HAA9 Results



DBP Testing Results

- Chlorine degradation
  - 60% less Cl_2 in DW as compared to DSW over 120 hours
  - Blending stabilized the effect (13% decrease in 50% DS)
- TTHM production
  - No increase observed with desalinated seawater
  - BDCM levels all less than 18 µg/L
- HAA9 production
  - No increase observed with desalinated seawater

Corrosion Testing

- Corrosion indices
  - general prediction based on source water quality
  - advantage – simple to use
  - disadvantage – not completely accurate
- Bench-scale tests
  - marble test – gauge of $CaCO_3$ saturation
  - pipe section test – expose water to actual pipes
  - better predictor than indices, but still batch tests
- Pipe-loop test
  - allows for flow-through testing of waters on different pipe materials
  - provides most accurate results of all tools

LBWD Pipe Materials

- Cast iron (CI, oldest)
  - used until 1950s
  - 225 miles
- Asbestos cement (AC, no longer used)
  - available from 1940 until 1990s
  - 400 miles
- Ductile iron (DI, currently used)
  - available from 1970s on
  - 203 miles

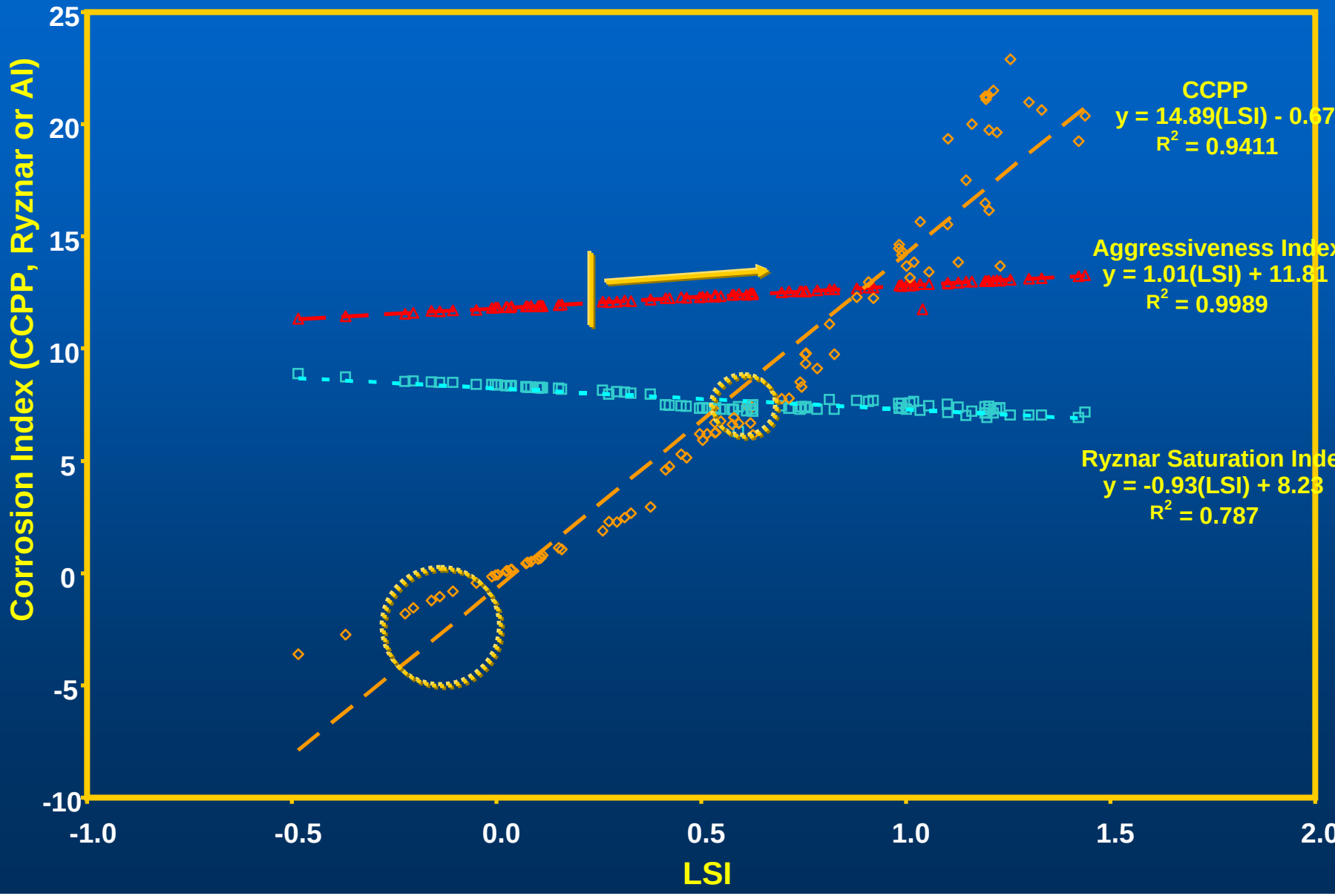
Corrosion Indices

- Langelier Saturation Index (LSI)
  - Indicator of whether conditions favorable for $CaCO_3$ precipitation
  - f(Ca, pH, TDS, T, Alk-T)
- Most other common corrosion indices based on calcium carbonate
  - Calcium Carbonate Precipitation Potential (CCPP)
  - Ryznar Saturation Index (RSI)
  - Aggressiveness Index (AI) – for AC pipes only
- Calculated with Rothberg Tamburi Windsor (RTW) model

Comparison of Indices

Condition	LSI	RSI	CCPP	AI
Corrosive	< - 0.5	> 6.0	< -5	<12.0
Passive	-0.5 - +0.5	6.0	-5 - 0	≥ 12.0
Scaling	> 0.5	< 6.0	> 0	

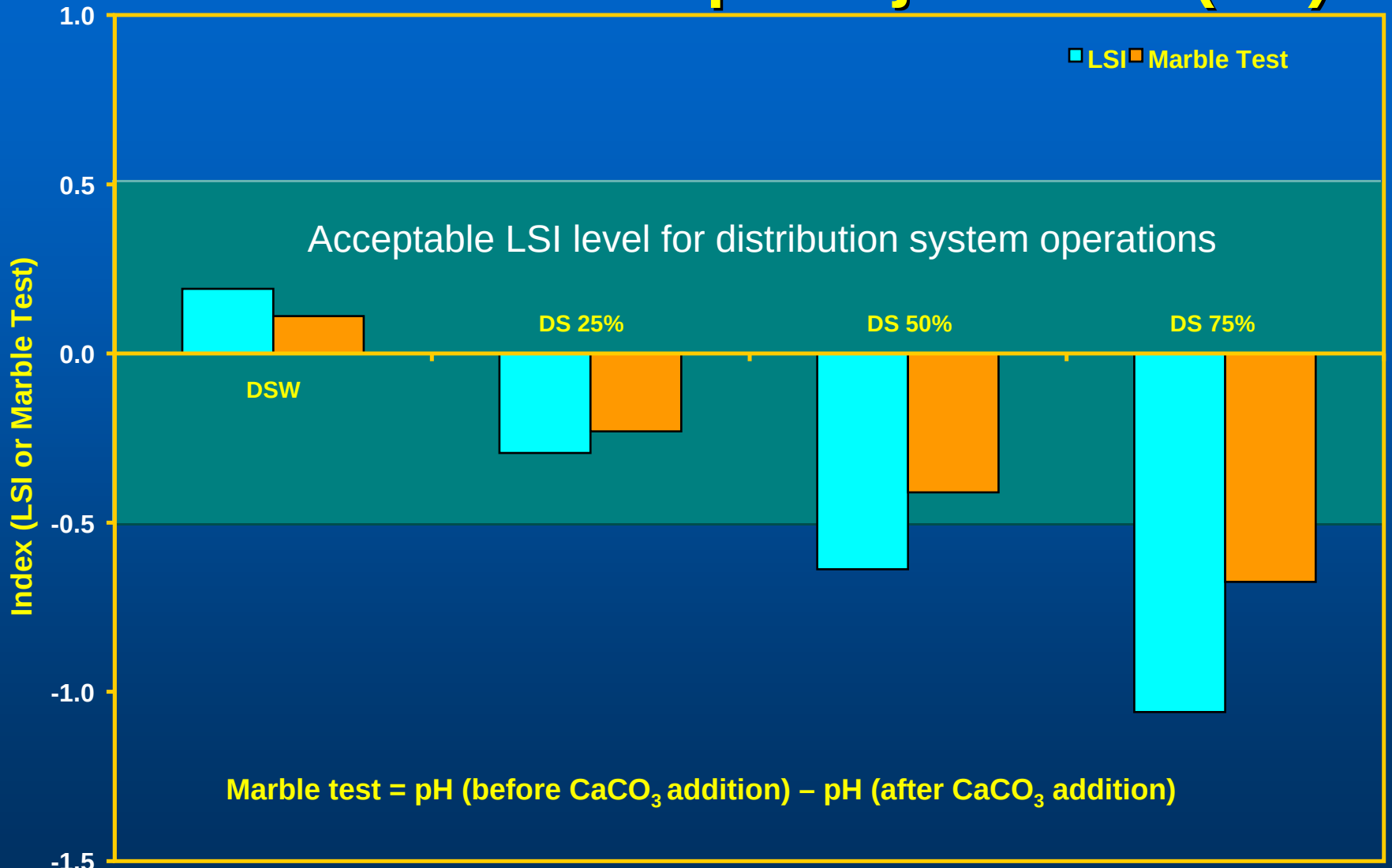
LSI is representative of other indices



Marble Test

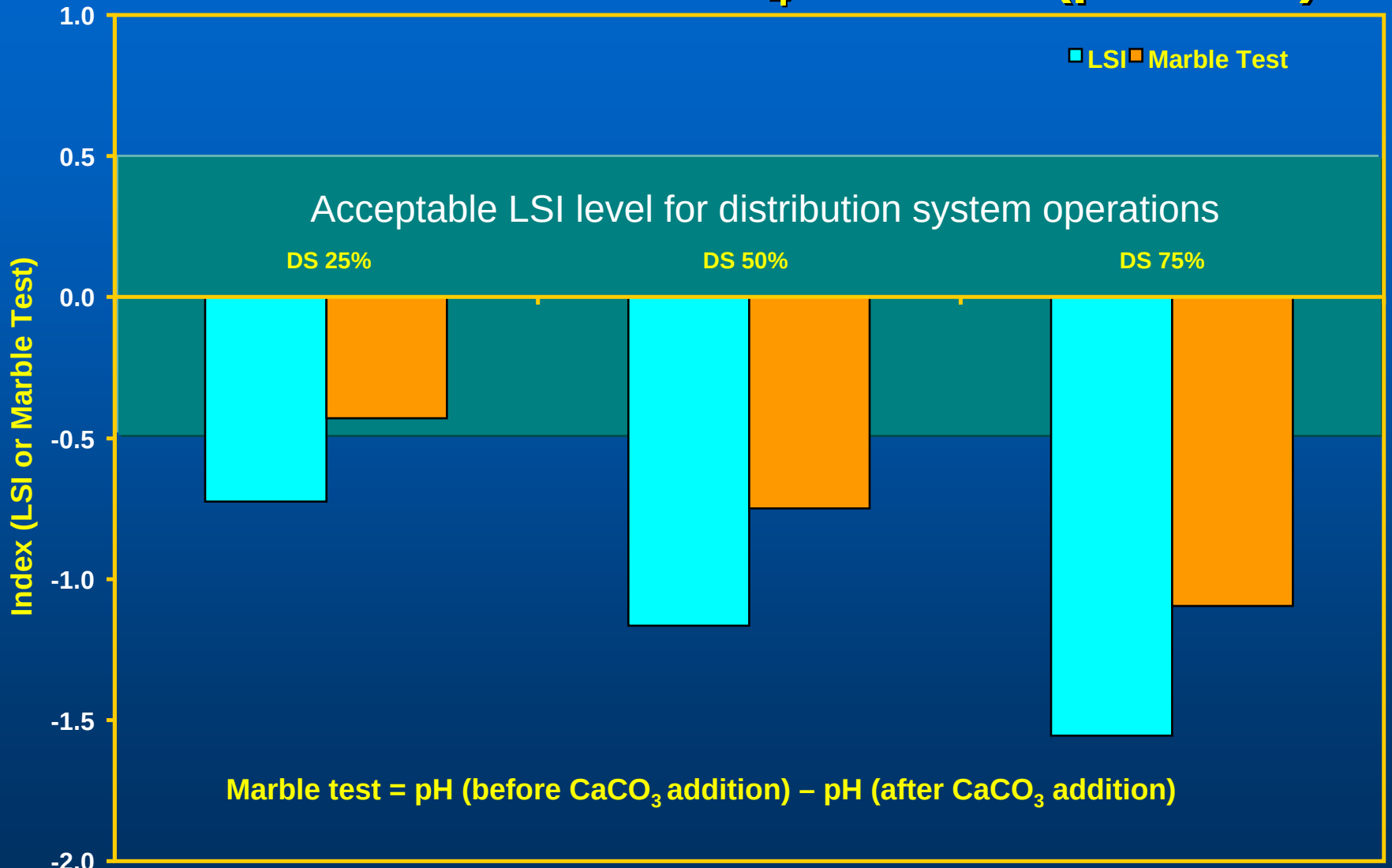
- SM2330c
- Over- or undersaturation with $CaCO_3$
- Measures pH of sample before and after $CaCO_3$ addition
- 300 mg $CaCO_3$:300 mL sample
- Would expect results to correlate well with LSI

LSI vs. Marble Test
Corrosion Control = pH adjustment (8.0)



LSI vs. Marble Test

Corrosion Control = OPO_4 addition (pH = 7.5)



Pipe Section Test

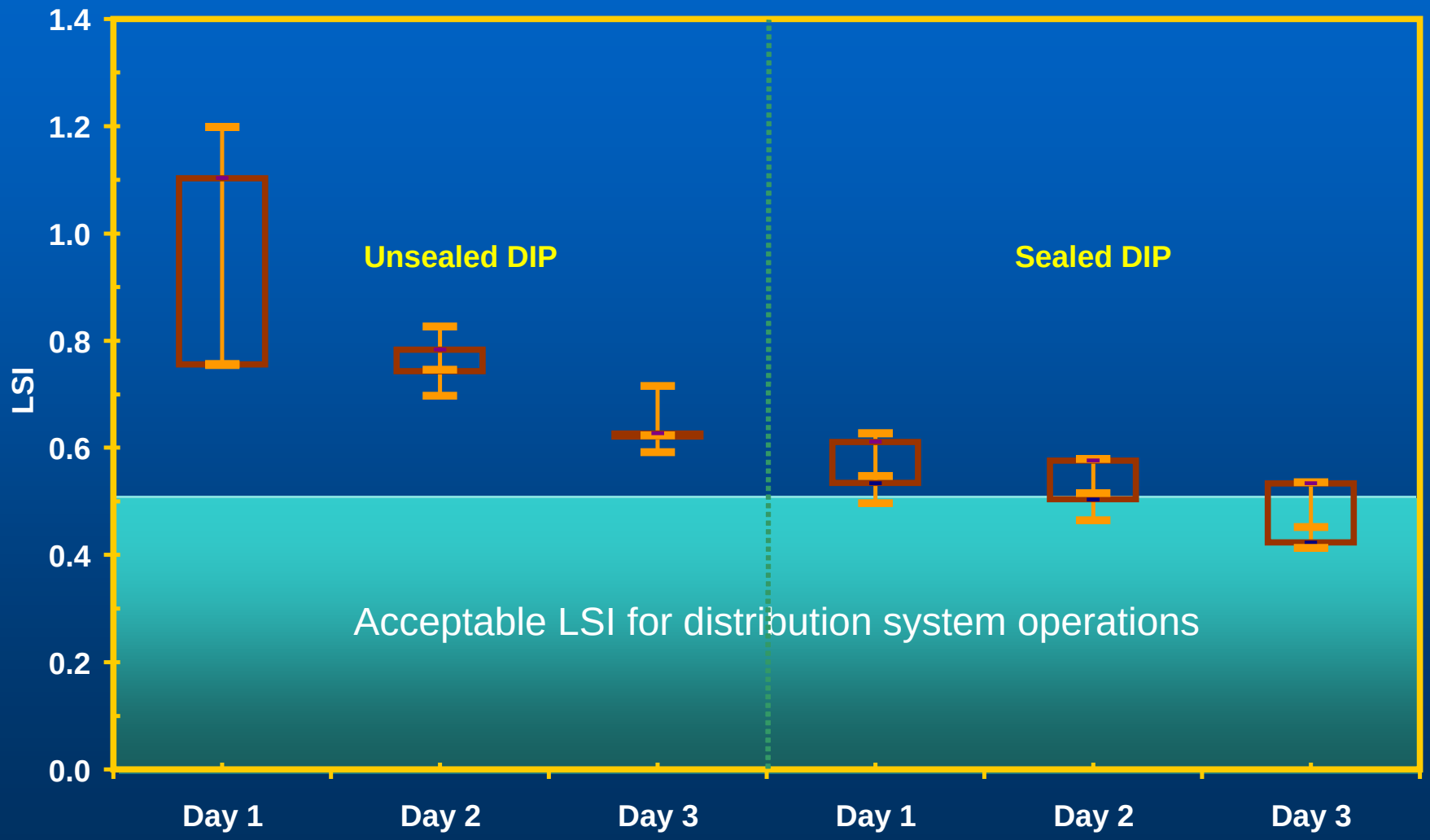
- AWWA C104 (Ductile iron pipe)
- Section 5.2 – Testing of Seal Coat protocol
- Tested sections of ductile-iron pipe
  - seal-coated and unsealed
  - up to 15, 12” x 4” pipes
  - determined that minimum 5 sections required for statistically significant results
- Tested for 72 hrs
  - changed water every 24 hrs
  - analyzed for pH, T, alkalinity, TDS, Ca, Mg, Cl, SO_4
- Provides indication of the stability of water as related to pipe material

Pipe Section Test Setup

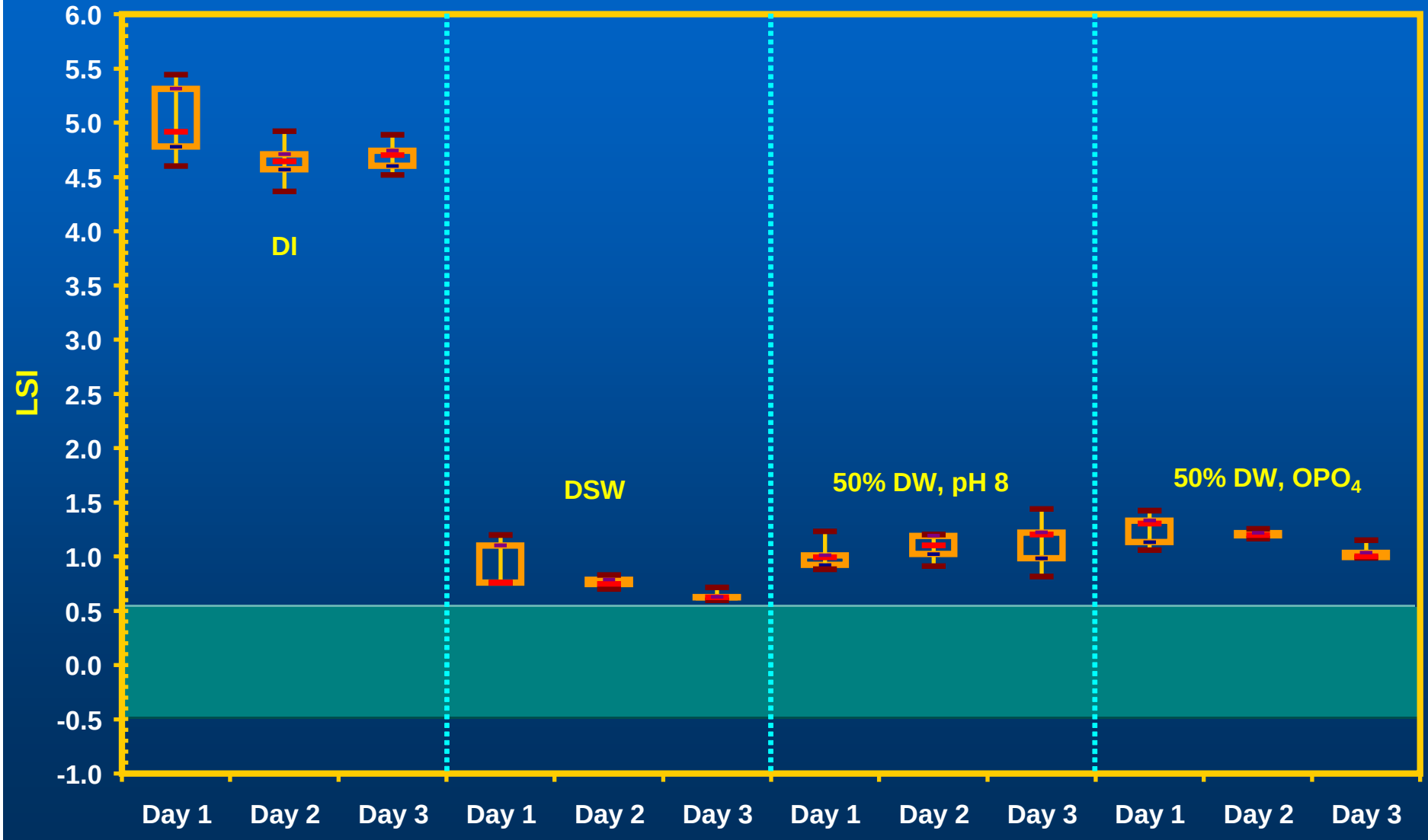
Water Conditioning

- Aerate desalinated water (DW)
  - Allows for CO_2 absorption, lower pH from > 9 to pH 7
- Add 40 mg/L of baking soda to provide 25 mg/L alkalinity as $CaCO_3$
- Blend DW with DSW at following ratios
  - 75:25, 50:50 or 25:75
- Final pH adjustment as needed

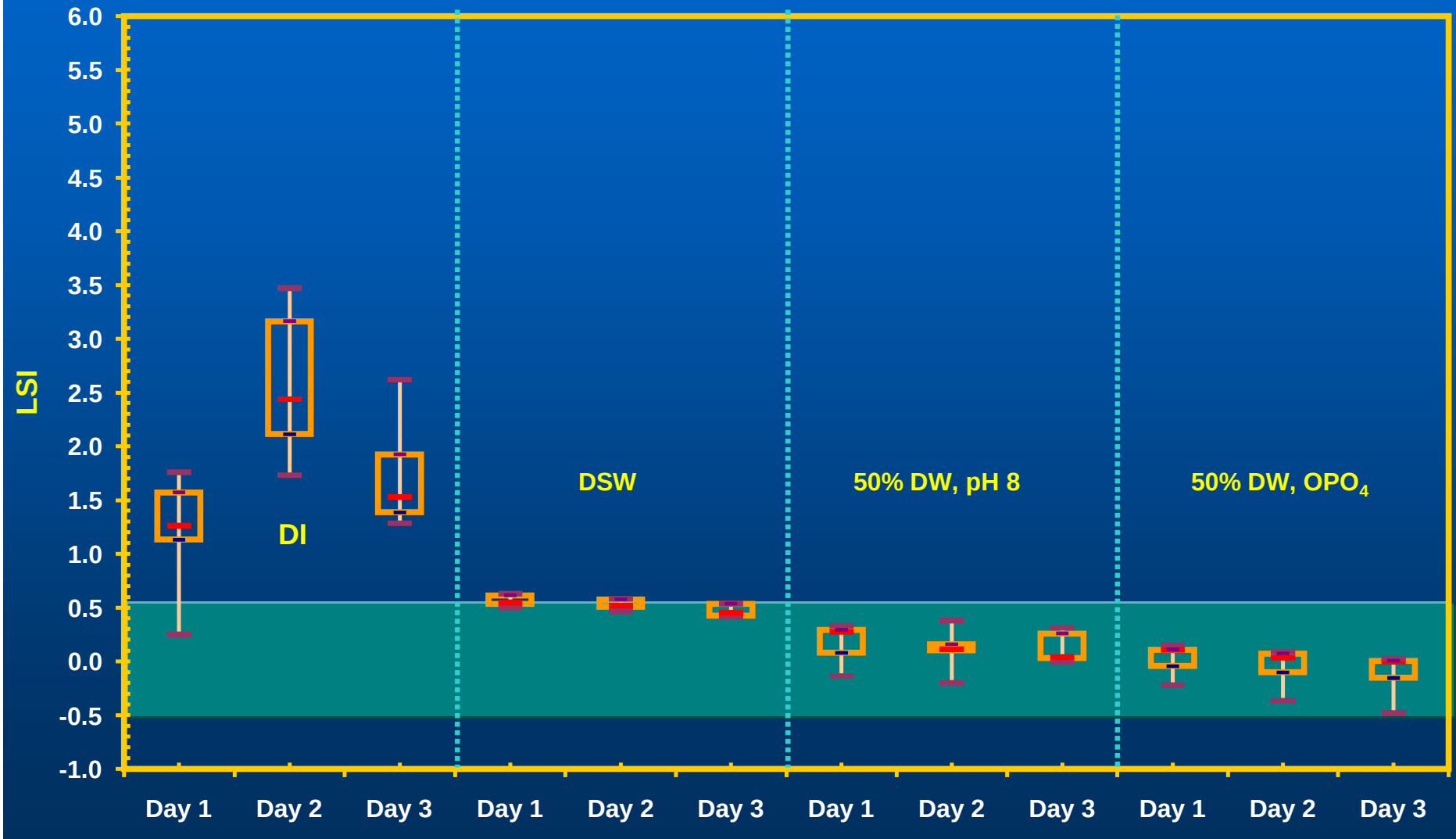
Comparison of LSI for DSW Sealed and Unsealed DIP



Comparison of LSI for Various Waters Unsealed DIP



Comparison of LSI for Various Waters Sealed DIP



Corrosion Testing Results

- Indices
  - Aggressiveness index, RSI, and CCPP correlated well with LSI
  - Indicated that up to 50% DS blend should be acceptable
- Bench-scale tests
  - marble tests correlated well with LSI
  - pipe section tests provides better indication of behavior of water with specific pipes
- Pipe material
  - Seal-coating provides better protection against corrosion than no seal coat

Unresolved Issues/Future Work

- Microbial growth issues
- Exposure of existing pipe to new water blends
- Reaction of various residential plumbing materials (copper, galvanized) to new water blends
- Pipe loop testing for 12 months

Acknowledgement

www.lbwater.org