Integration of MBR Technology and Desalting Membranes for Water Reuse

James DeCarolis, Samer Adham, Joan Oppenheimer
William H. Pearce, Larry Wasserman,

Membrane Technology Conference & Exposition
March 6-9 2005
Phoenix, Arizona

Acknowledgments

- USEPA, Bruce Macler, Ph.D., Vance Fong, P.E.
- Metropolitan Water District of Southern, CA (DRIP), Sun Liang, Ph.D., P.E.
- San Diego County Water Authority, Cesar Lopez
- Bureau of Reclamation (USBR), Water Treatment Engineering and Research Group

Acknowledgments (cont.)

- City of San Diego MWWD, Steve Lagos, Neil Tran, Dwight Smith
- Membrane Suppliers, Saehan, Hydranautics, Osmonics, Kubota, Zenon and Mitsubishi
- EDC/PPCP Sample Analysis, Greg Loraine (SDSU) and Shane Snyder (SNWA)

Outline of Discussion

- Project Background
- Materials and Methods
- MBR & NF/RO Performance Data
- EDC/PCPPs Analysis
- Cost Estimate Analysis
- Conclusions

Project Background

- Funding provided by the USEPA under DRIP to evaluate MBR as pretreatment to RO
- Project was partially conducted in parallel with USBR funded project aimed at optimizing various MBR Systems for water reuse
- Conducted at the PLWTP located in San Diego
  - ➙ PLWTP uses 1 MGD Potable Water for Industrial use
  - ➙ Wastewater at PLWTP is inherently high in salt (TDS=1,600 mg/L)
  - ➙ City considering MBR ➨ RO System to meet Reclaimed Water Needs

Project Objectives

- Evaluate MBR Systems recently introduced to US Market
- Assess the Impact of adding Coagulant and Polymer to the MBR Feed Water on MBR Performance
- Evaluate MBR performance under extreme operating conditions (Increased Flux, Low HRT)

Project Objectives

- Evaluate several different desalting membranes (NF/RO) following pretreatment by MBR

- Evaluate the ability of commercially available MBR/RO Process units to Remove EDC/PPCPs from advanced primary effluent

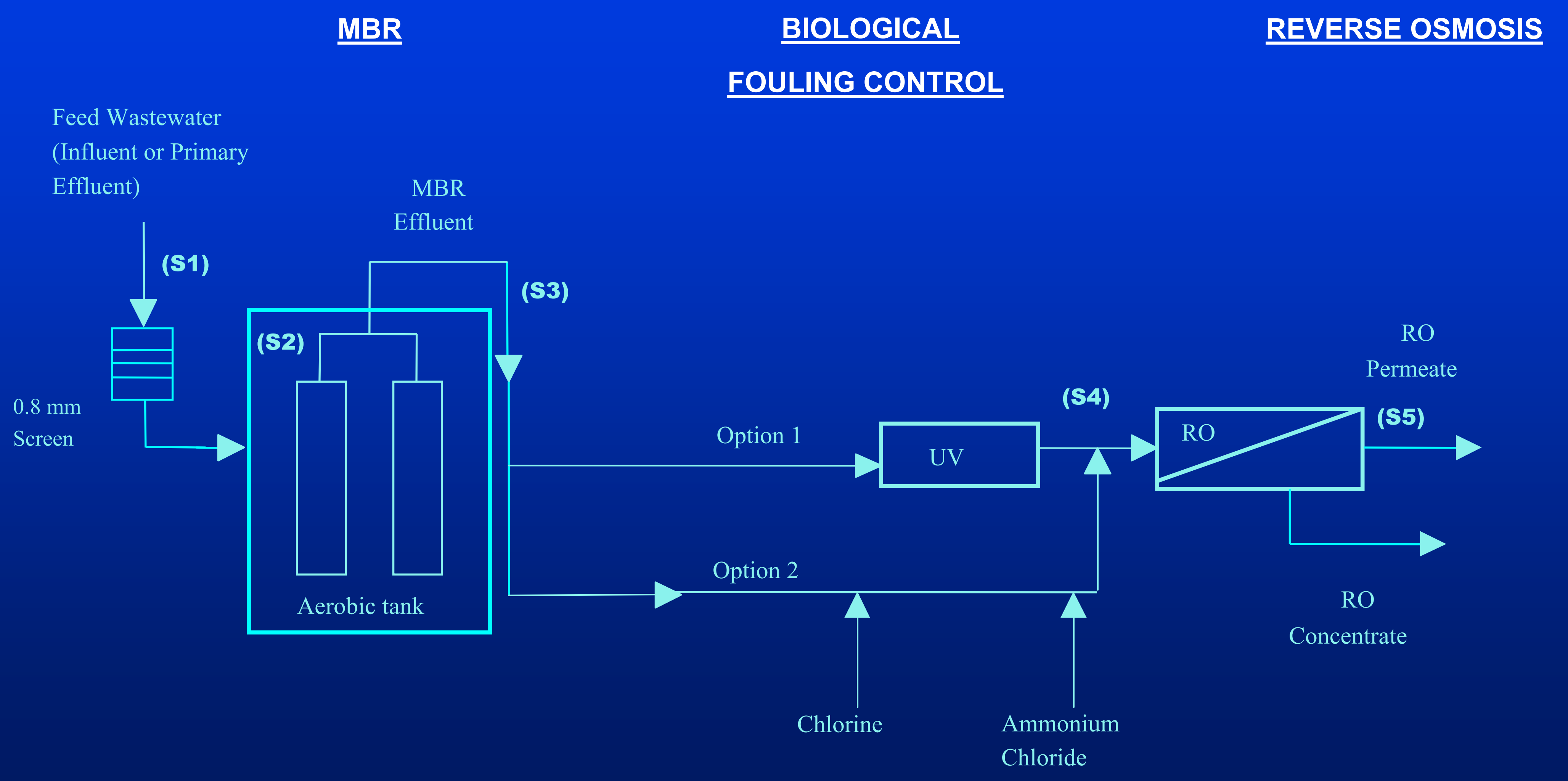
- Perform cost analysis: 1.) compare cost of conventional and MBR as pretreatment to RO 2.) determine the cost associated with RO during wastewater reclamation

Material and Methods

Pilot Testing

- Performed pilot testing: train consisted of MBR ➨ UV/chloramine ➨ NF/RO
- Phase I - Operated New MBR Systems on Raw Wastewater and Advanced Primary Effluent
- Phase II - Operated Established Suppliers on advanced primary effluent (tested extreme operating conditions)
- Throughout MBR testing operated RO/NF downstream of MBR - in all tested 4 different desalting membranes flux 10-12 gfd FWR 50 -75%

Pilot Treatment Train



MBR Pilot Systems (New Suppliers)

KUBOTA

US Filter

MBR Pilot Systems (Established)

MITSUBISHI

ZENON

MBR Membranes Specifications

	Units	Kubota	Zenon	Mitsubishi
Commercial Designation	----	Type 510	ZW 500 D	Sterapore HF
Membrane Classification	----	MF	UF	MF
Membrane Configuration		Vertical	Vertical	Horizontal
Approx. Size of Element (LxWxH)	mm	490X6X1000	1930X711X229	886X606X1483
Number of Sheets per membrane cassette	---	100	------	------
Number of Fibers per membrane cassette	-----	-----	~2700	~1820
Inside Diameter of Fiber	mm	-----	0.75	0.35
Outside Diameter of Fiber	mm	-----	1.9	0.54
Length of Fiber	m	-----	1.7	3.24
Active Membrane Area (MBR Pilot)	ft^2 (m^2)	1721 (160)	720 (67)	1076 (100)
[1] Flow Capacity (MBR Pilot)	gpm	17.6	7.5	9.2
Flow Direction	---	outside - in	outside - in	outside - in
Nominal Membrane Pore Size	micron	0.4	0.04	0.4
Absolute Membrane Pore Size	micron	-----	0.1	0.5
Membrane Material/Construction	---	chlorinated polyethylene; flat sheet	proprietary/ hollow fiber	polyethylene/ hollow fiber
Recommended Design Flux	gfd (L/h-m^2)	14.7 (24.9)	15 (25.4)	12.3 (20.8)
Standard Testing pH range	---	5.8 - 8.6	5-9.5	2-12
Vacuum Pressure for System	psi (bar)	<3 (<0.2)	<11.9 (<0.8)	<5.8(<0.4)

[1] **Flow capacity based on MFG recommended design flux and active membrane supplied with pilot unit.**

Desalting Membranes Specifications

	Units	Saehan	Saehan	Hydranautics	Osmonics
Commercial Designation	---	RE 4040-BL	RE 4040-FL	LFC3-4040	HL-4040FF
Membrane Type		[1]RO	[2]RO	[2]RO	NF
Active Membrane Area	ft^2 (m^2)	85 (7.9)	85 (7.9)	85 (7.9)	88.5 (8.2)
Membrane Material	---	Polyamide (TFC)	Polyamide (TFC)	Polyamide (TFC)	Polyamide (TFC)
Operating pH Range	---	3-10	3-10	3-10	3-10
Max. Feedwater Turbidity	NTU	<1	<1	1.0	<1
Max.Feedwater SDI_{15}	---	<5	<5	<5	<5
Max. Operating Temperature	^{o}F (^{o}C)	113 (45)	113 (45)	113 (45)	113 (45)
Free Chlorine Resistance	mg/L	<0.1	<0.1	<0.1	<0.1
Specific Flux @ 25 deg C	gfd/psi	0.20	0.15	0.10	0.27
Max. Operating Pressure	psi (bar)	600 (40)	600 (40)	600 (40)	600 (40)

[1] Low Pressure RO; [2] Fouling Resistant RO

MBR Pilot Operating Conditions

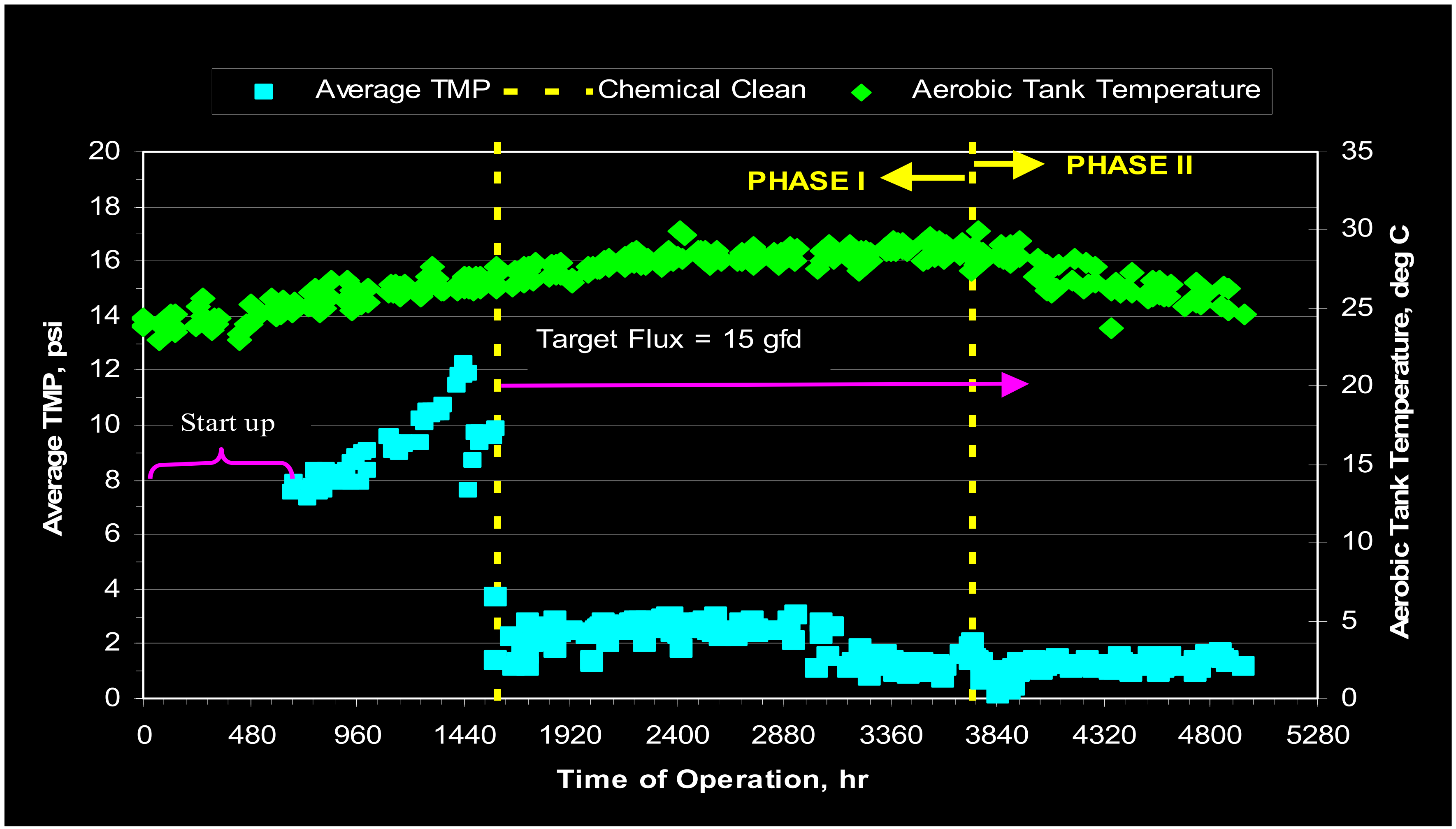
	US Filter	Kubota	Zenon	Mitsubishi
Raw Wastewater	✓	✓	-------	-------
Advanced Primary	✓	✓	✓	✓
Flux, gfd	14.5	15	22	15
HRT, hrs	5.7	5.0	2.0	2.8
SRT, days	20-60	11- 24	18-20	25-30
MLSS, g/L	9-12	9-16	10-12	10-12

RO Operating Conditions

Testing Phase	Membrane	Feed Source	Biofouling Control	Flux (gfd)	Recovery (%)
I	Hydranautics LFC3-4040	Kubota MBR	UV/Chloramine	10-12	50
	Saehan RE4040-BL	Kubota MBR	UV/Chloramine	10-12	50
	Osmonics HL-4040	Zenon and Mitsubishi MBR	Chloramine	10-12	50
	Saehan RE4040-FL	Zenon and Mitsubishi MBR	Chloramine	10-12	50
II	Saehan RE4040-FL	Zenon and Mitsubishi MBR	Chloramine	12	75

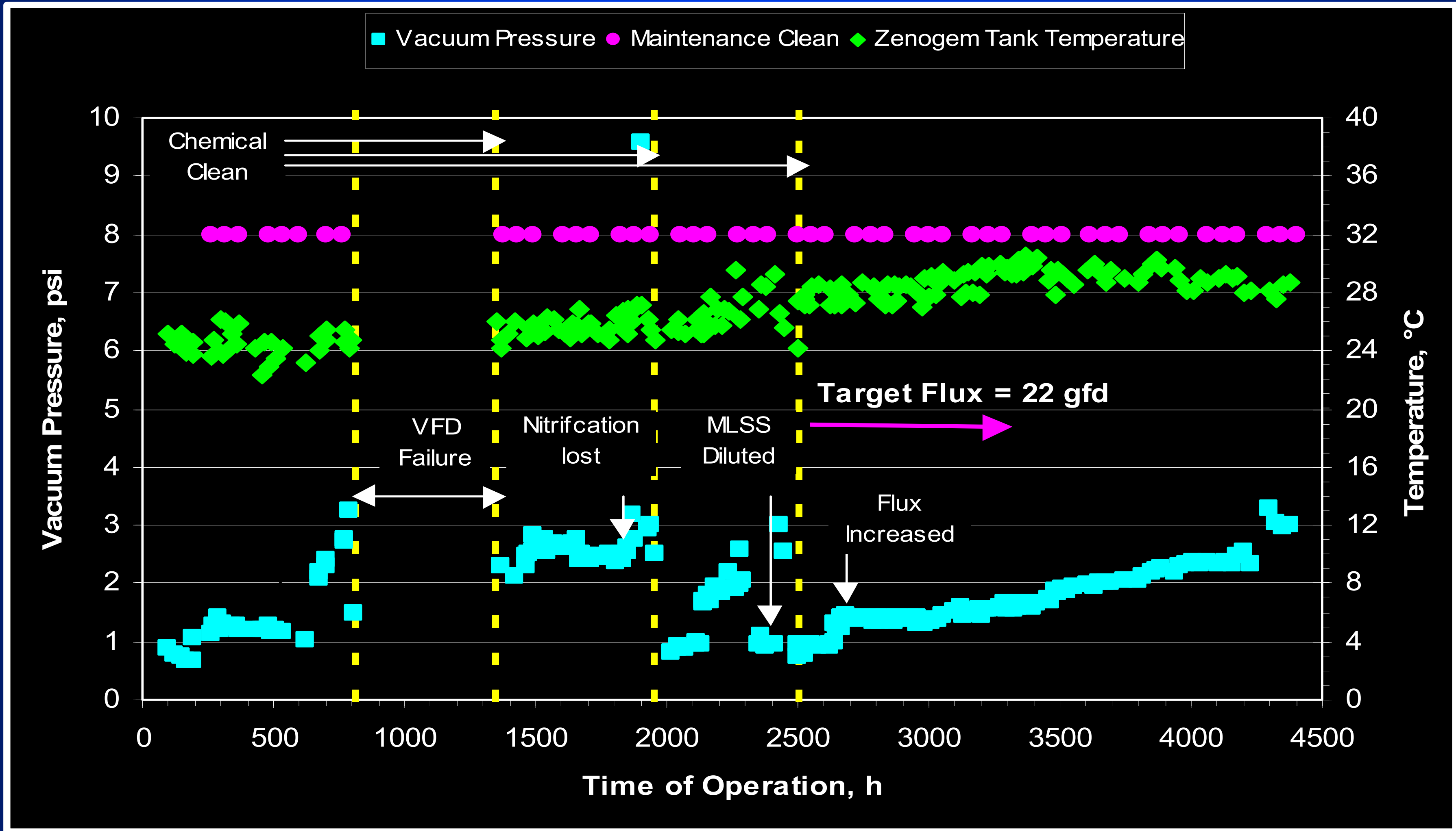
MBR PERFORMANCE DATA

MBR Operational Data



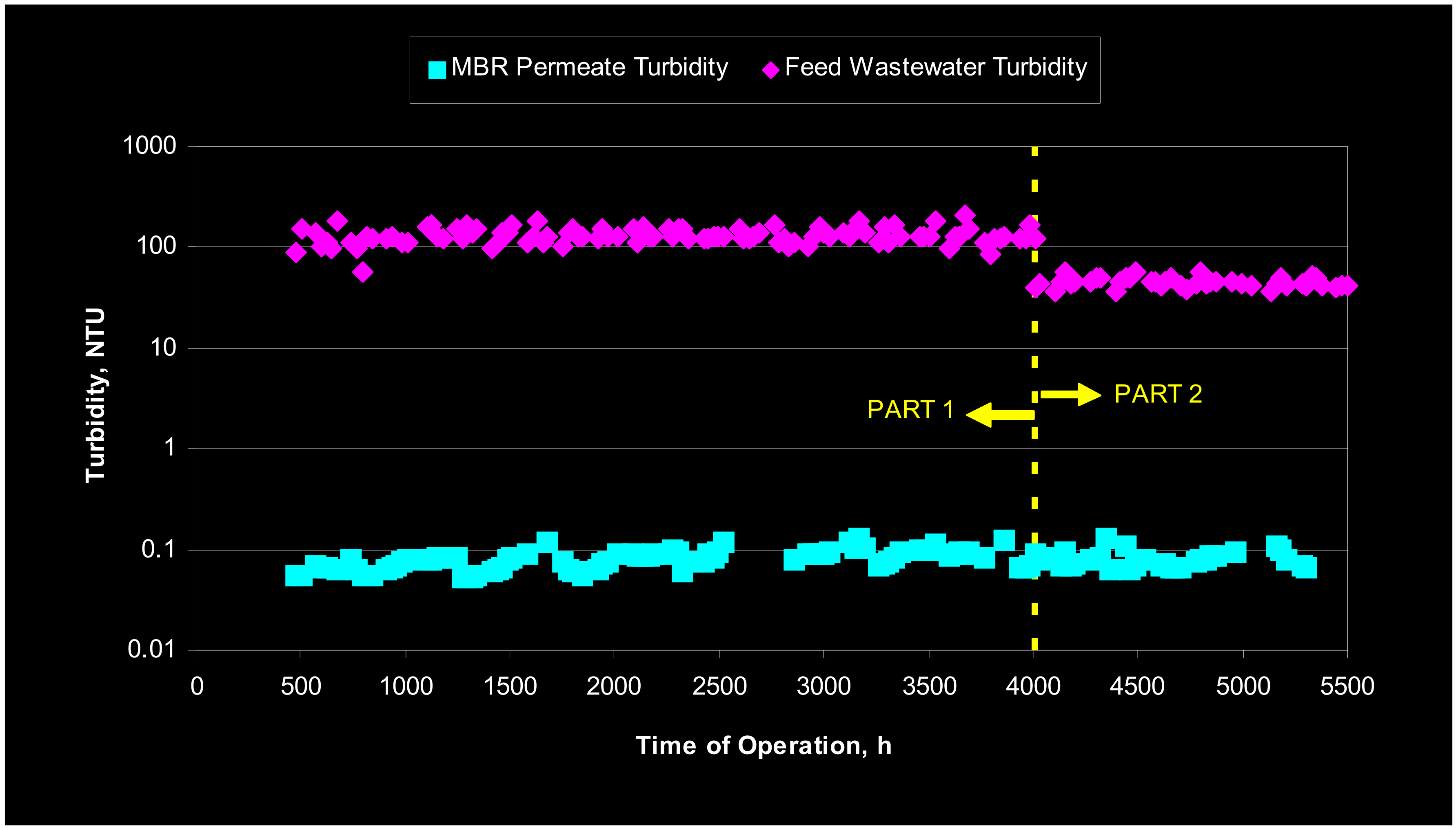
Kubota MBR System, 2002 - Point Loma

MBR Operational Data



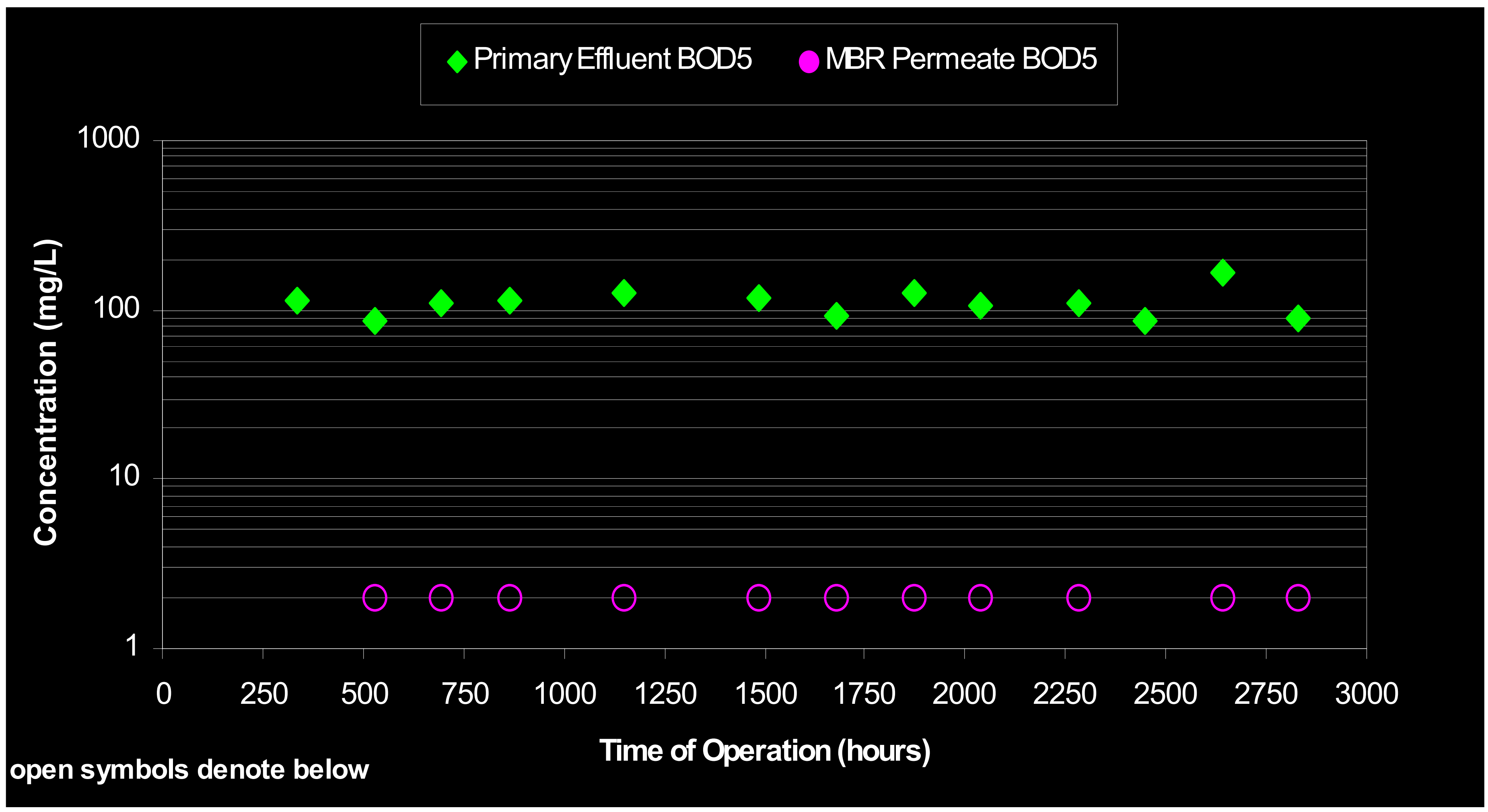
Zenon MBR System, Point Loma

MBR Particulate Removal



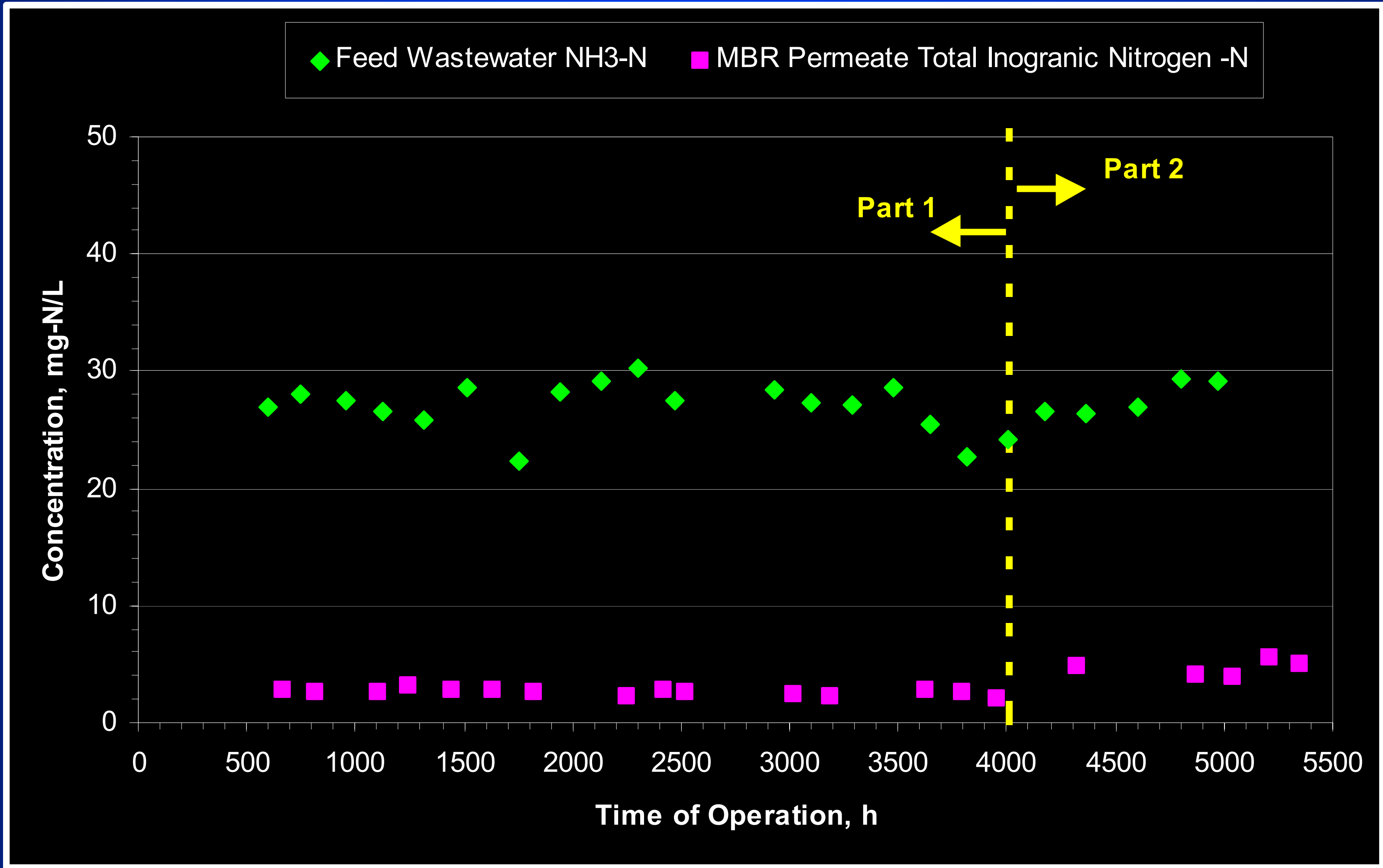
Kubota MBR System, 2002 - Point Loma

MBR Organic Removal



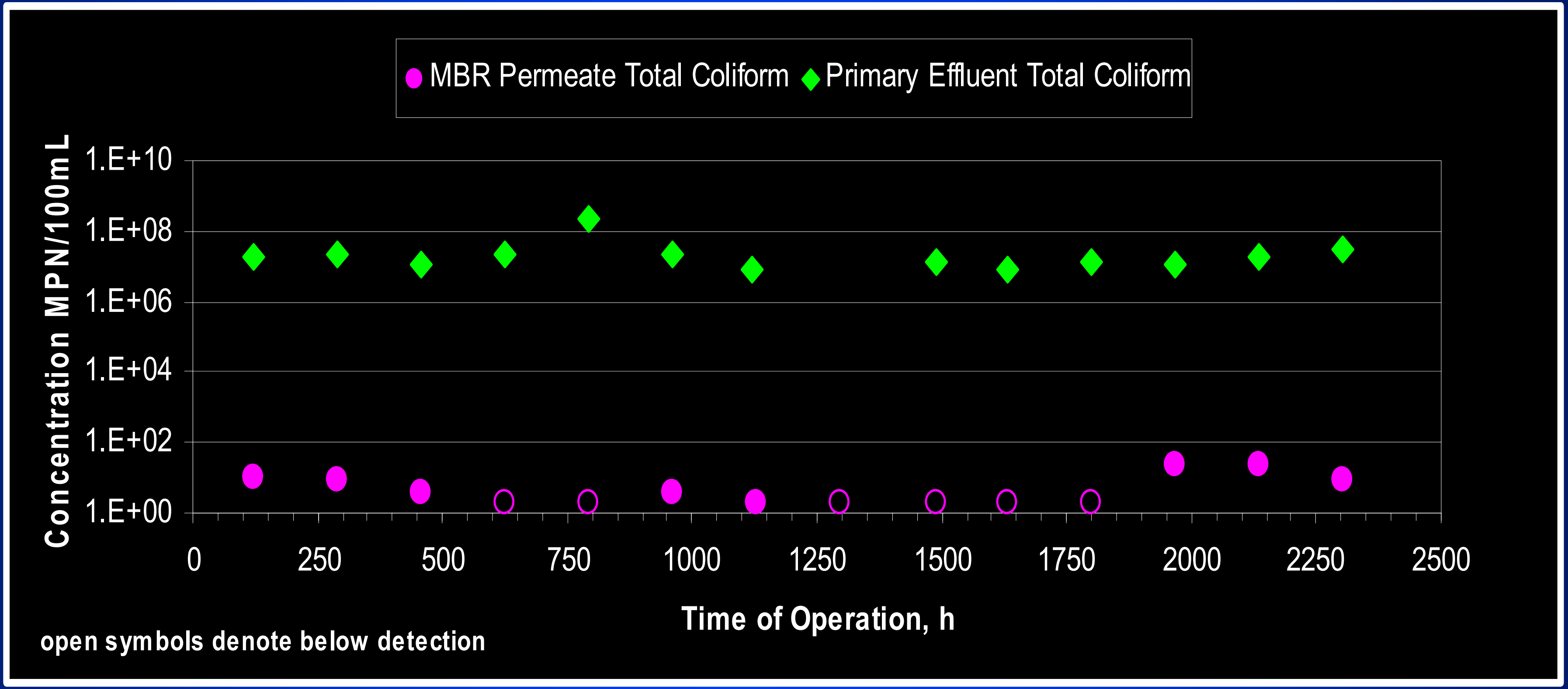
Zenon MBR System, 2003 - Point Loma

MBR Inorganic Nitrogen Removal



Kubota MBR System, 2002 - Point Loma

MBR Microbial Rejection

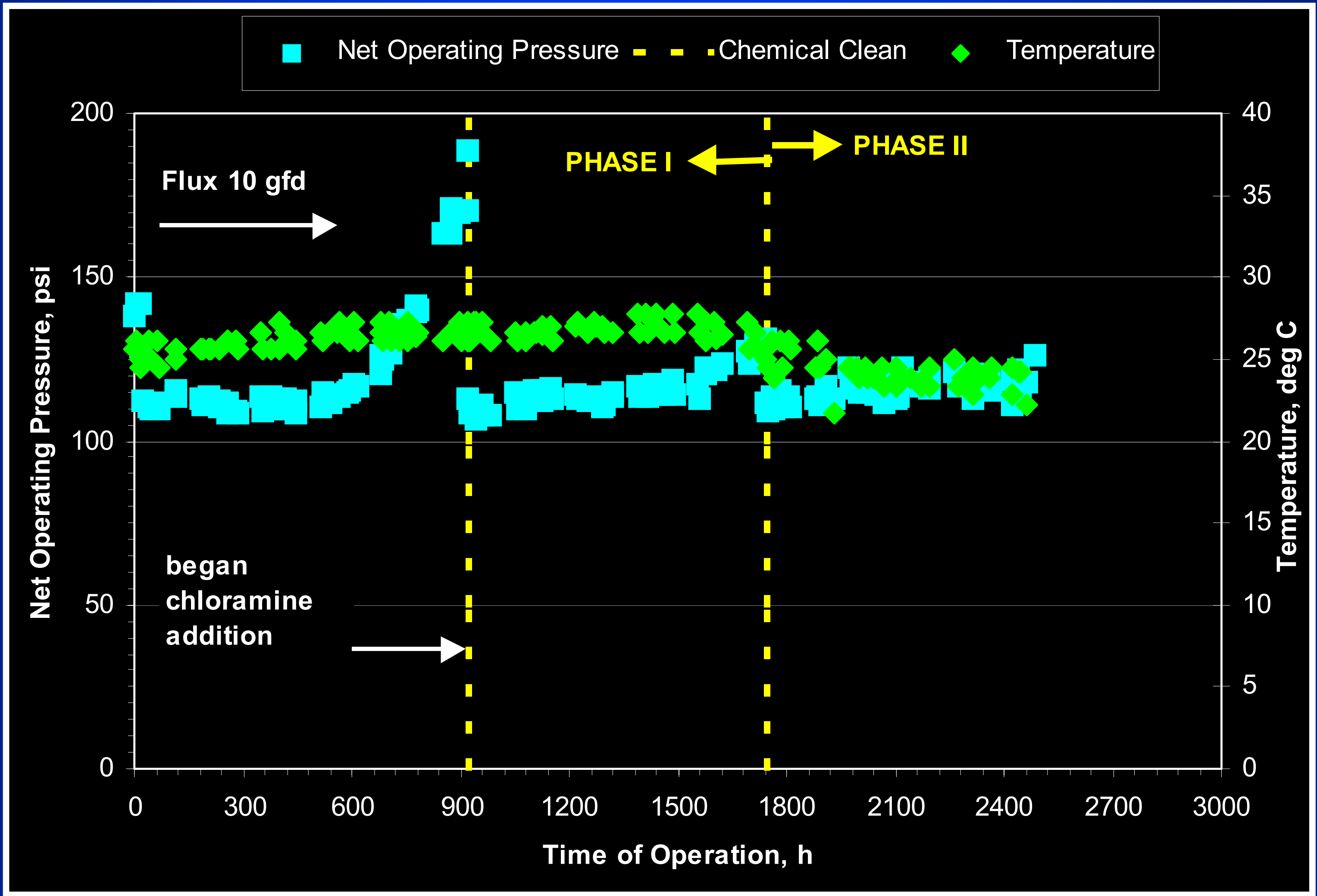


Mitsubishi MBR System, 2003 - Point Loma

RO PERFORMANCE DATA

RO Operational Data

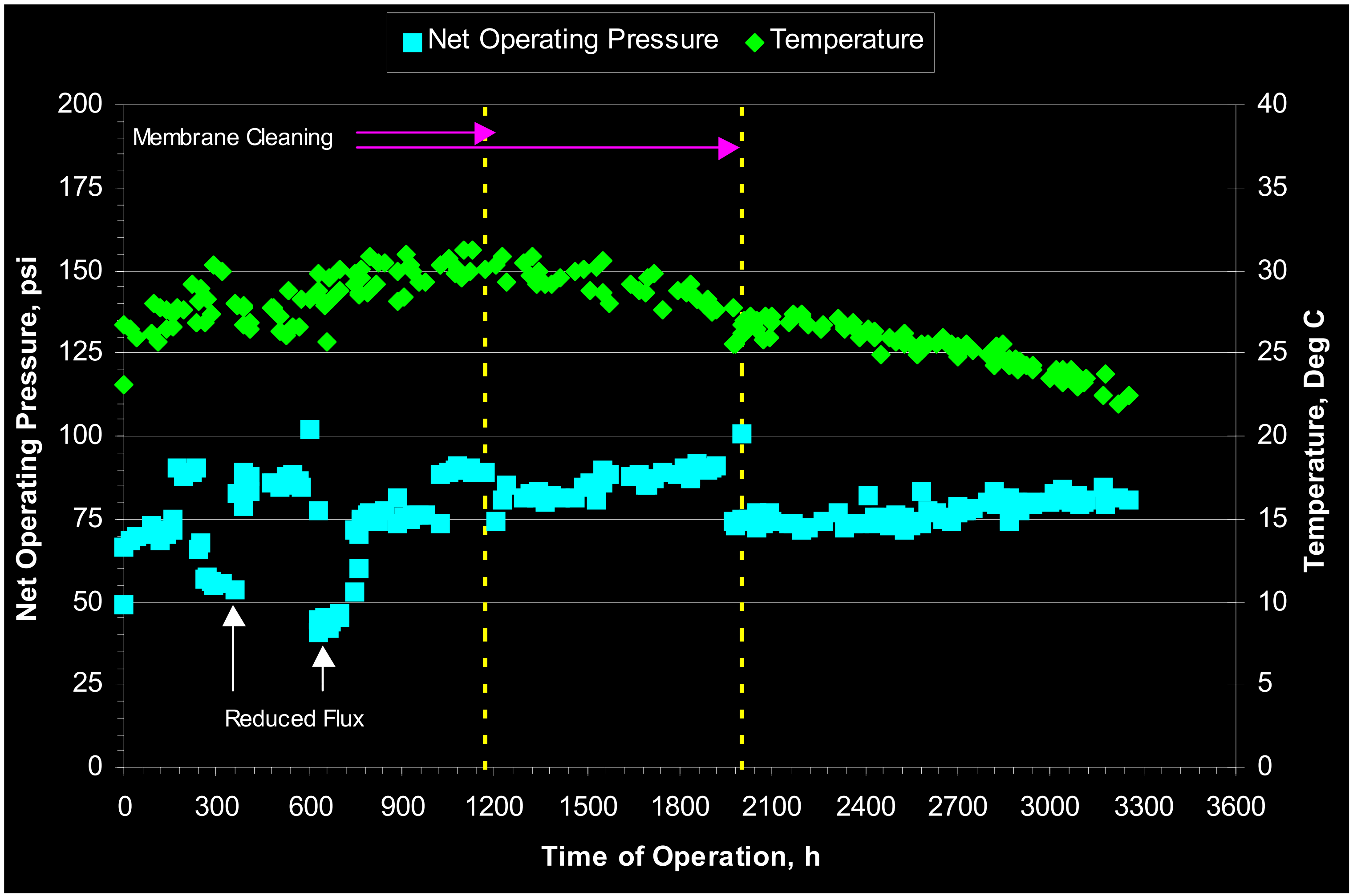
FWR = 50%



Hydranautics LFC3 Membrane, 2002 - Point Loma

RO Operational Data

FWR = 75%



Saehan RE4040 FL Membrane, 2003 - Point Loma

RO Water Quality Data

Paramater	Units	RO Feed	RO Permeate
Conductivity	micromho	2,620	117
Ammonia-N	mg/L	0.8	0.3
Nitrate/Nitirite -N	mg/L	18.9	4.80
Nitirite -N	mg/L	0.034	0.01
TKN	mg/L	0.99	ND
Ortho-Phosphate-P	mg/L	0.53	ND
UV 254	cm^{-1}	0.139	0.007
TOC	mg/L	6.6	ND
Total Hardness	mg/L	424	3.38
Alkalinity	mg/L	75	5.63

***Values shown are median of measured values throughout testing.**

EDC/PCPPs Analysis

- Sampling was done Phase II Testing (Zenon and Mitsubishi MBRs)
- RO membrane was Saehan 4040 FRM membrane flux of 12 gfd feed water recovery = 75%
- Samples taken in summer and late autumn; analyzed by two different laboratories

Cost Analysis

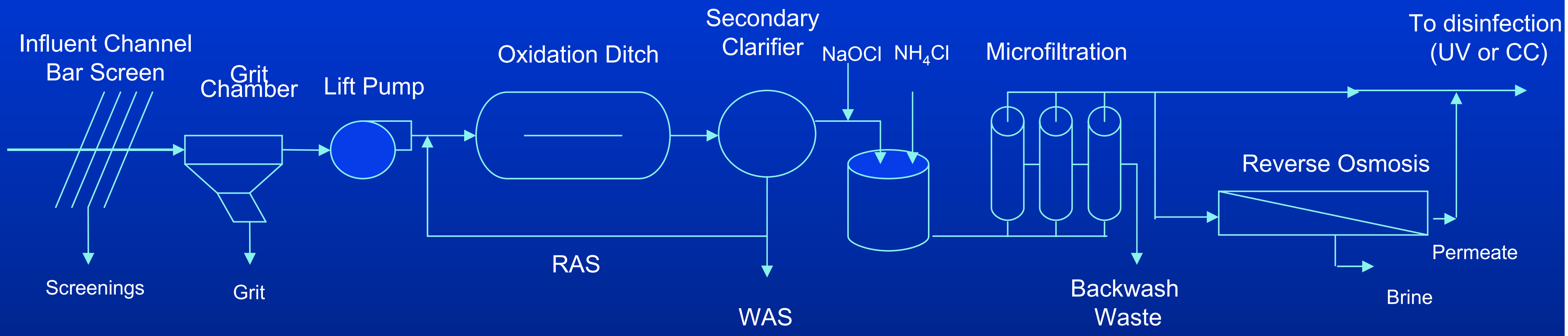
- Costs were developed for two reclaimed water treatment trains: conventional and MBR

- The analysis also compared disinfection costs of chlorine vs. UV to meet Class I unrestricted reuse CDHS Title 22 Standards

- RO costs were estimated to achieve target TDS of 1,000 mg/L. Sizing of RO system based on required blend ratio

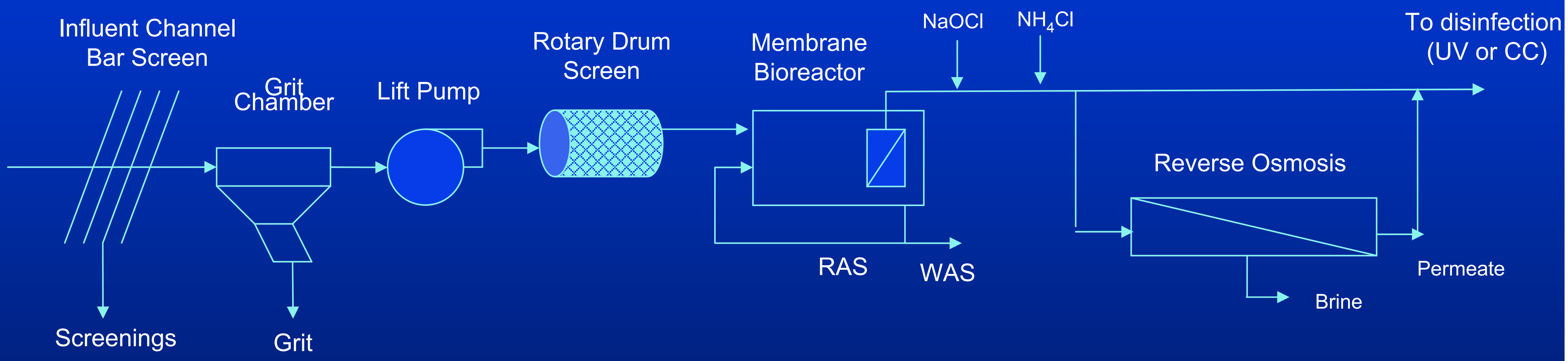
Conventional Train

Oxidation Ditch/MF w/RO Blending and Disinfection



MBR Train

MBR w/RO Blending and Disinfection



Cost Items: Ditch + MF and MBR

Capital Costs	Ditch + MF	MBR
Headworks	X	X
Screening Facility (0.8 mm)		X
Secondary Treatment (Oxidation Ditch)	X	
Chlorine handling, storage and metering	X	X
Operations-laboratory building	X	X
Maintenance Building	X	X
Microfiltration Unit	X	
MBR Process Costs (e.g. Basins, Blower and Pump Building, Mech.)		X
MBR Membrane System		X
O&M Costs	**Ditch + MF**	**MBR**
Personnel	X	X
Power	X	X
Spare Parts	X	X
Chemicals	X	
Sludge handling and disposal	X	X
MBR Membrane Replacement		X
MBR Chemical Cleaning		X
MF O& M Costs	X	

Cost Items: Chlorine Contact and UV

Capital Costs	**Chlorine Contact**	**UV**
Chlorine Contact Tank	X	
Chlorine handling, storage and metering	X	
UV System		X
O&M Costs	**Chlorine Contact**	**UV**
Personnel	X	X
Power	X	X
Replacement Lamp Costs for UV		X
Chemicals	X	

Cost Items: Reverse Osmosis

Capital Costs	RO
RO System	X
Chloramine handling, storage and metering	X
O&M Costs	**RO**
Personnel	X
Power	X
Chemicals for RO	X
RO Membrane Replacement	X
RO Cartridge Filter Replacement	X
RO Maintenance	X

Conclusions

- All MBR systems produced effluent suitable for RO by achieving high removal of particulate, organic, nitrogen and microbial contaminates

- MBR systems operated successfully on advanced primary effluent containing polymer / coagulant residual and under extreme operating conditions

- Different types of desalting membranes from various suppliers successfully operated on municipal wastewater pretreated with MBR

Conclusions

- MBR/RO effective barrier for most of the EDC/PCPPS analyzed

- Cost estimates showed 1 MGD MBR/Cl_2 reclaimed water train to be $3.13/Kgal compared to $4.31/Kgal for conventional train consisting of Ditch + MF/Cl_2

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MWH

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