ECONOMICS AND ENERGY REQUIREMENTS FOR VARIOUS WATER TREATMENT / BRINE MANAGEMENT OPTIONS

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Focus

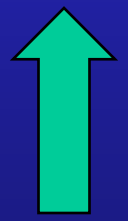
- inland municipal desalination
  - concentrate/brine
    - management options
      - conventional and high recovery
        - cost, energy

DESAL Plant Cost Categories

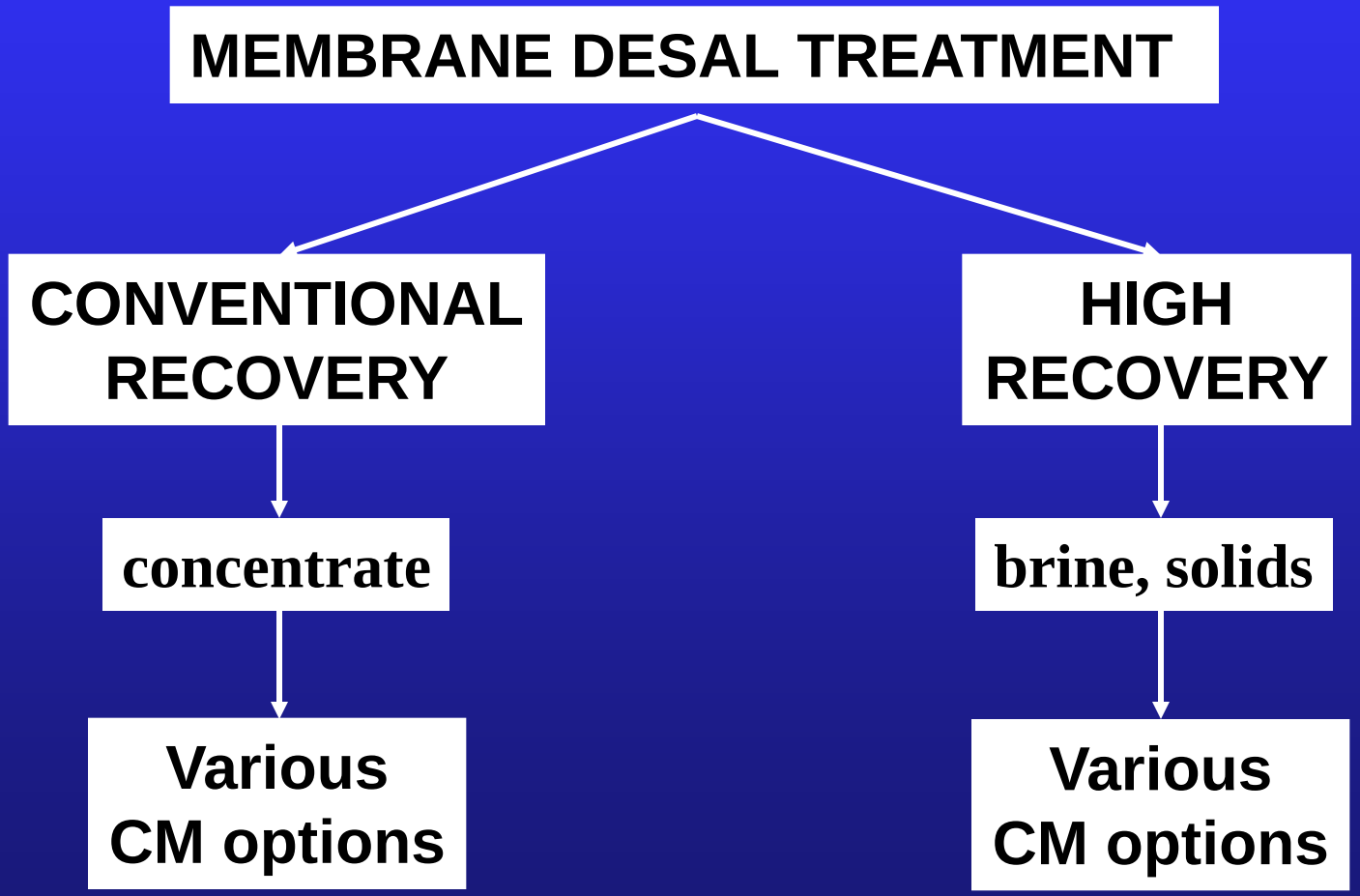
- Source water & transmission
- RO treatment facility (= TREATMENT / PRODUCTION COSTS)
  - Pre-treatment (beyond simple) [seawater, challenging brackish, high recovery]
  - RO (with simple pre-treatment)
- Residuals disposal (= CONCENTRATE MANAGEMENT COSTS)
  - Concentrate/Brine
  - Filter backwash (high suspended solids)
  - Solids [high recovery where significant pretreatment or when take brine to solids]
- Product water transmission
  - Post treatment & disinfection
  - Transmission

Desalination Costs

- = treatment / production cost
  + concentrate management cost
- treatment / production costs
- concentrate management costs



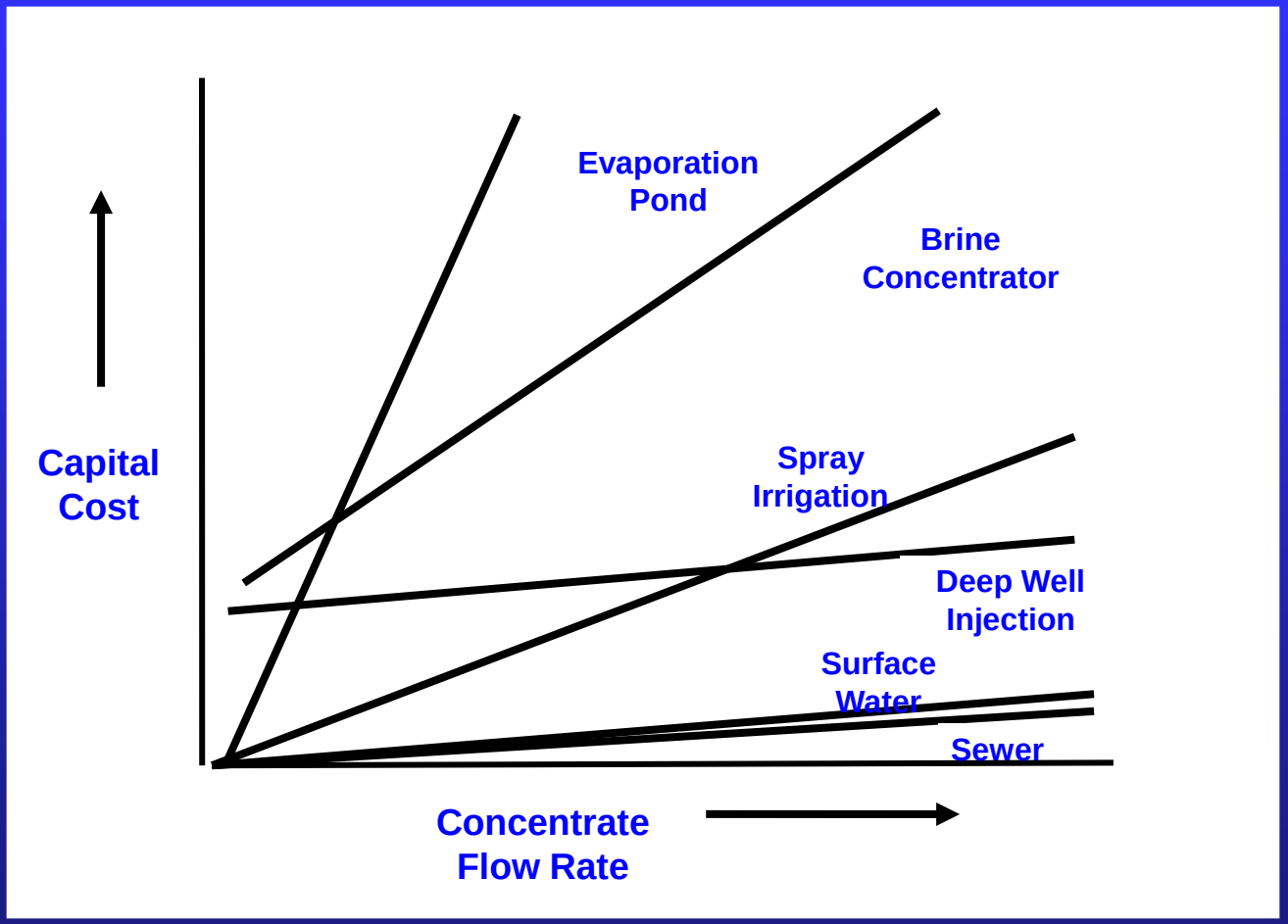
A View of Concentrate Management (CM)



CM options

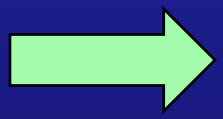
- **CONVENTIONAL RECOVERY (not high recovery)**
  - **Conventional disposal options** → **Estimated to be in use at > 98% of municipal DESAL plants in the U.S.**
    - **Surface water discharge (includes brine lines going direct to ocean)**
    - **Discharge to sewer (includes brine lines going to WWTP)**
    - **Deep well injection**
    - **Land application (mainly irrigation)**
    - **Evaporation pond**
  - **Non-conventional disposal options MINOR POTENTIAL**
  - **Beneficial use of concentrate (other than irrigation) – MINOR POTENTIAL**

RELATIVE COST OF CONCENTRATE DISPOSAL OPTIONS



Summary – Conventional Concentrate Disposal Options

- **Size limitations (& size of plants is increasing)**
- **Location limitations (& plants increasing considered in regions where few options exist)**
- **Increasing other challenges (further affecting feasibility and cost of conventional disposal options)**
- **URGENT CONCERNS in arid southwest (medium and large desalination plants are not being built)**



Need for alternatives

High Recovery (HR) & ZLD

- Recovery greater than that typical of a single membrane step where recovery may be 60-85% (brackish RO)
- As of 2003, no HR or ZLD municipal facilities. Many facilities in other industries.

DEFNs of ZLD used In municipal industry:

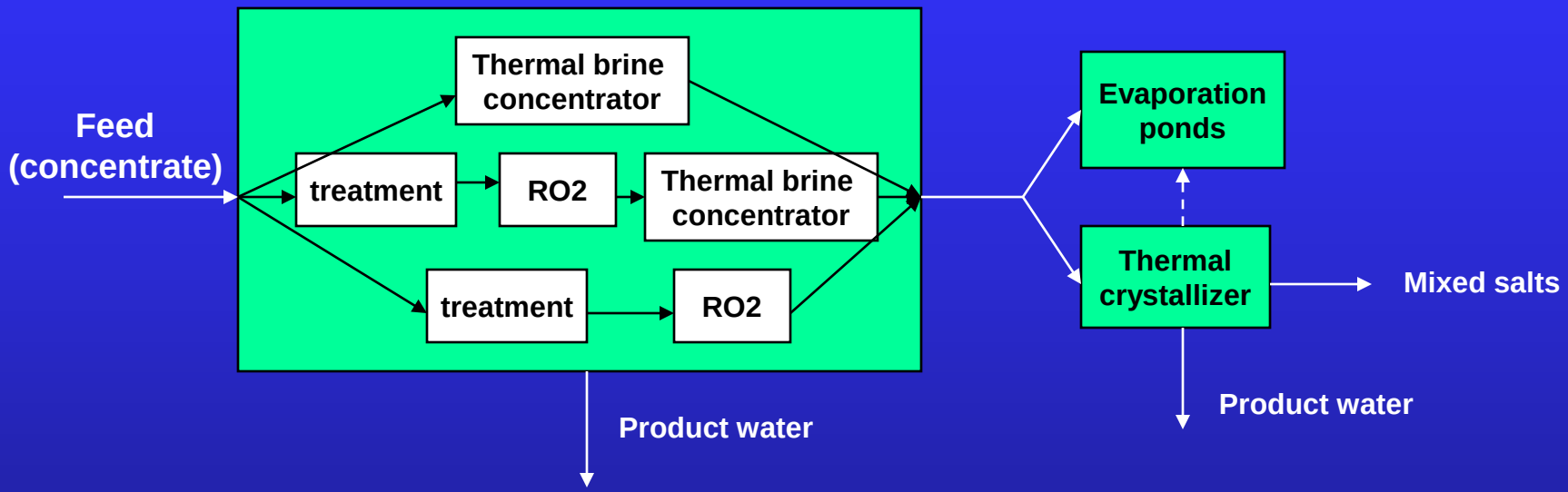
1. **No liquid discharge across plant boundary**
2. **Processing using thermal evaporators**
3. **Processing to solids**

CM options

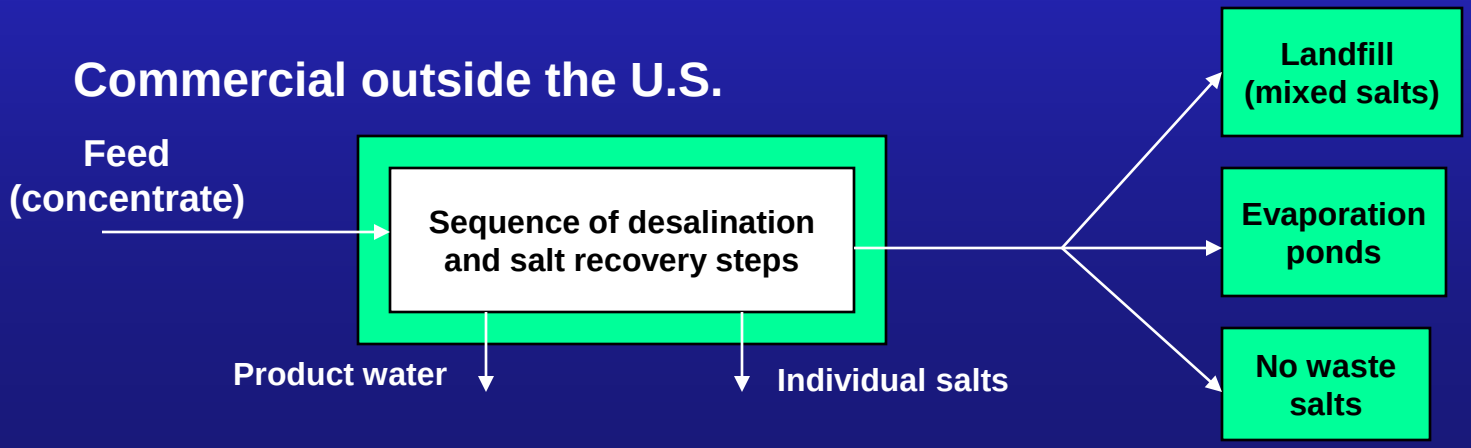
- **HIGH RECOVERY**
  - **Beneficial uses of brine – MINOR POTENTIAL**
  - **Beneficial uses of solids – MINOR POTENTIAL**
    - **Individual commercial grade salts – PROMISING POTENTIAL**
  - **Disposal options**
    - **Deep well injection**
    - **Evaporation pond**
    - **Landfill (for solids)**
    - **[ocean]**

COMMERCIAL ZLD SYSTEMS
(non-municipal industries)

Commercial / Used Approaches in the U.S.



Commercial outside the U.S.



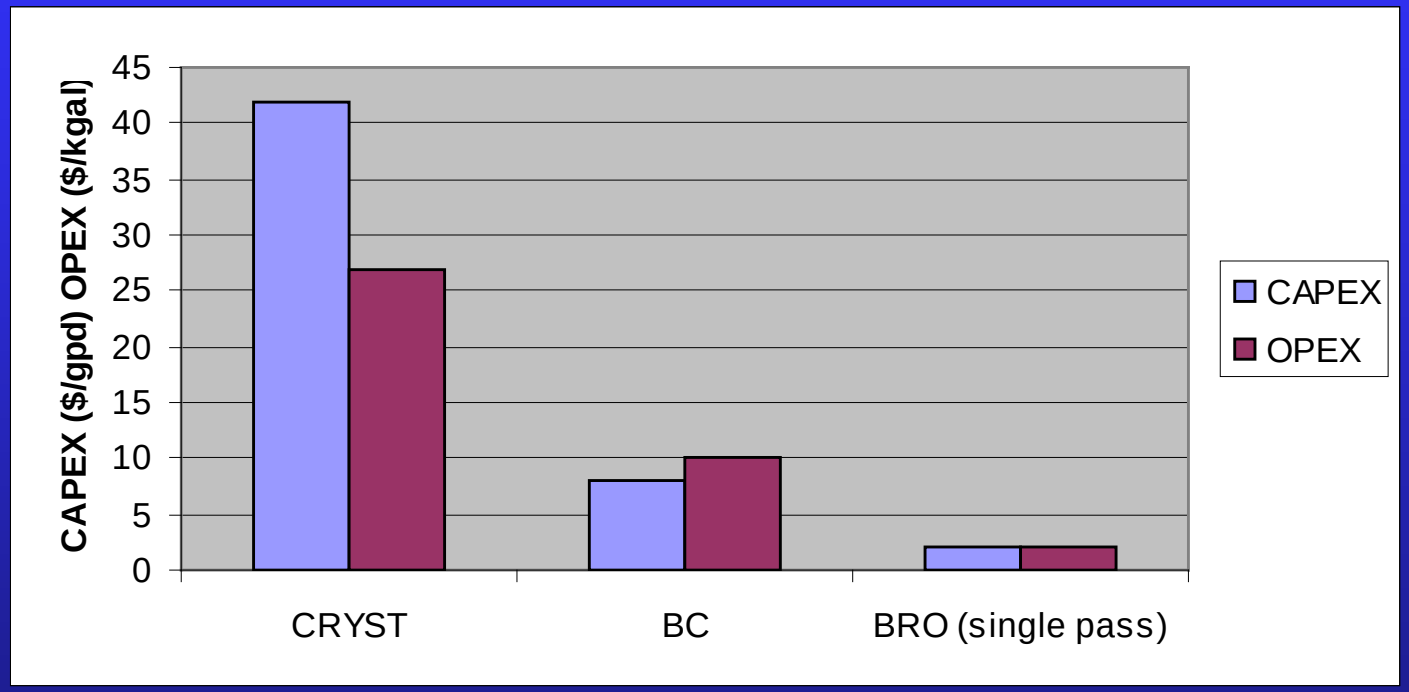
SELECTIVE SALT RECOVERY

One ton product bags ready to leave Geo Processors' SEPCON Plant in Port Augusta, South Australia

Technology is REAL; concerns are marketing and cost; Represents an important step toward sustainability

BALLPARK CAPEX and OPEX

(of individual desalination technologies - 1 MGD systems)



OPEX for CRYST and BC > 95% energy

Commercial ZLD Processing Schemes

1A: CONC → BC → EP
1B: CONC → BC → CRYST → LF
2A: CONC → LS → RO2 → BC → EP
2B: CONC → LS → RO2 → BC → CRYST → LF
3: CONC → LS → RO2 → EP

NOTE: in schemes 2A, 2B, and 3, lime softening solids go to landfill

WateReuse Foundation: ***Survey of High Recovery and Zero Liquid Technologies for Water Utilities,*** **2008.**

VARIABLES

- Processing schemes (5)
- Water quality
  - Salinity (3)
  - Composition (8)
- Size (concentrate flow) (3)

- Used to define 12 cases for each of the 5 processing schemes

Range of Values

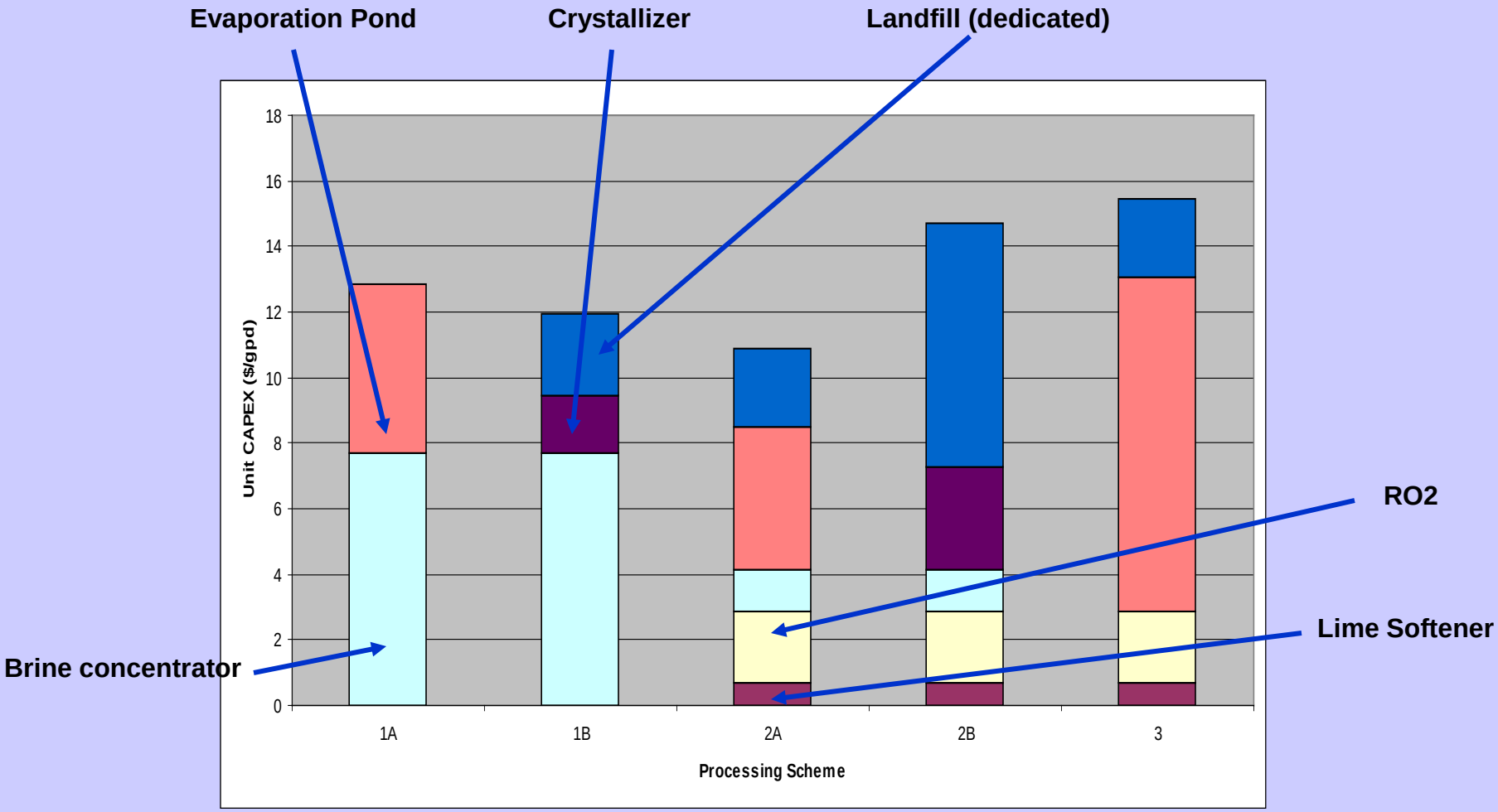
- **Salinity:** 4,000, 8,000 & 12,000 mg/L
- **Concentrate flow:** 1, 10, and 20 mgd
- **Calcium:** 75 – 1,096 mg/L
- **Magnesium:** 36 – 677
- **Sodium:** 456 – 2,043
- **Potassium:** 7 – 114
- **Sulfate:** 6 – 5,346
- **Chloride:** 95 – 4,141
- **Bicarbonate:** 161 – 5,682
- **Silica:** 0 - 194

Performance of BC – Process Schemes 1A and 1B

case	feed TDS (mg/L)	feed flow (MGD)	effluent TDS (mg/L)	effluent flow (gpm)	limiting parameter
1	4,000	1	257,000	210	glauberite
2	4,000	20	257,000	21	glauberite
3	8,000	10	257,000	421	glauberite
4	12,000	1	263,000	30	glauberite
5	12,000	20	263,000	604	glauberite
6	8,000	10	261,000	210	glauberite
7	8,000	10	226,000	231	glauberite
8	8,000	10	358,000	154	NaCl
9	8,000	10	226,000	231	TSS
10	8,000	10	167,000	302	glauberite
11	8,000	10	258,000	210	TSS
12	8,000	10	199,000	278	glauberite

Performance of BC – Process Schemes 2A, 2B & 3

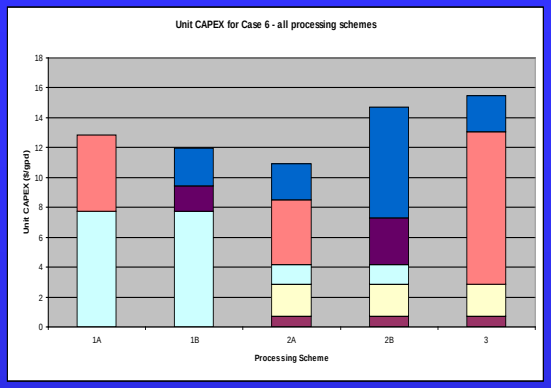
case	feed TDS (mg/L)	feed flow (MGD)	effluent TDS (mg/L)	effluent flow (gpm)	limiting parameter
1	60,803	1.21	145,000	352	glauberite
2	61,010	0.06	145,000	18	glauberite
3	61,010	1.2	145,000	350	glauberite
4	58,506	0.19	145,000	53	glauberite
5	58,506	3.74	145,000	1047	glauberite
6	57,623	1.45	145,000	400	glauberite
7	58,953	0.92	145,000	282	glauberite
8	61,156	1.3	263,000	161	NaCl
9	58,578	0.92	143,000	284	glauberite
10	61,851	1.26	247,000	219	NaCl
11	59,153	1.24	145,000	283	glauberite
12	60,766	1.25	145,000	291	glauberite

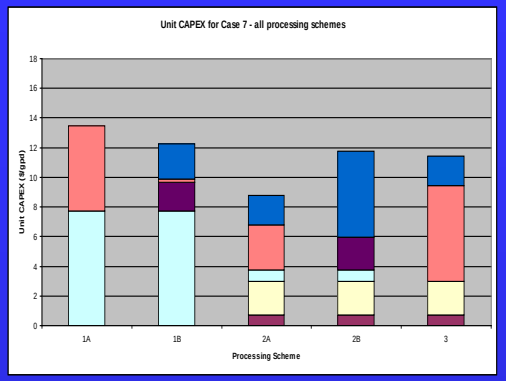


Unit CAPEX ($/gpd)
5 different processing schemes
Las Vegas groundwater

POINTS

--Variability due to process scheme
--Impact of process step
--Final disposal step(s) can be sizeable fraction of total CAPEX

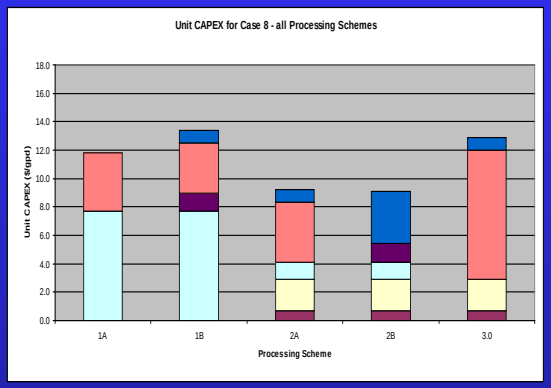


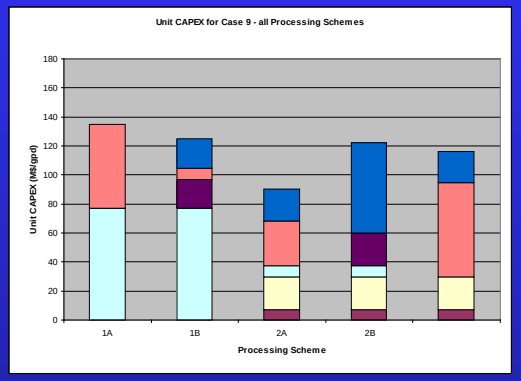


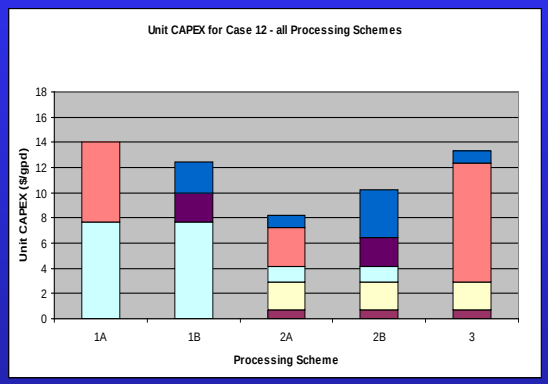
EFFECT OF COMPOSITION On UNIT CAPEX ($/gpd)

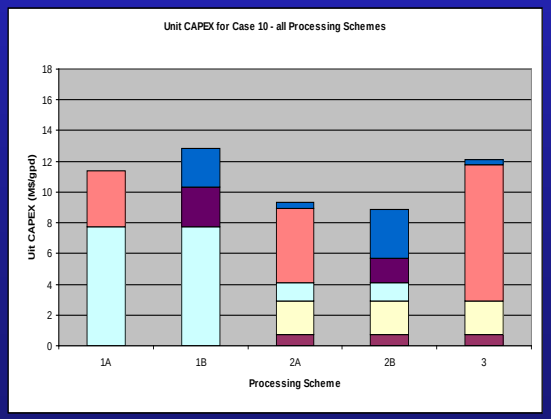
8 different compositions
5 processing schemes

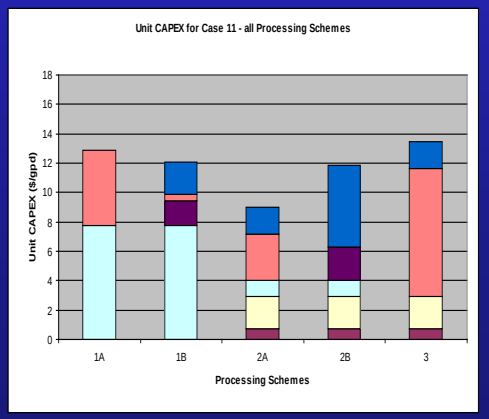
Most variability due to EP & LF

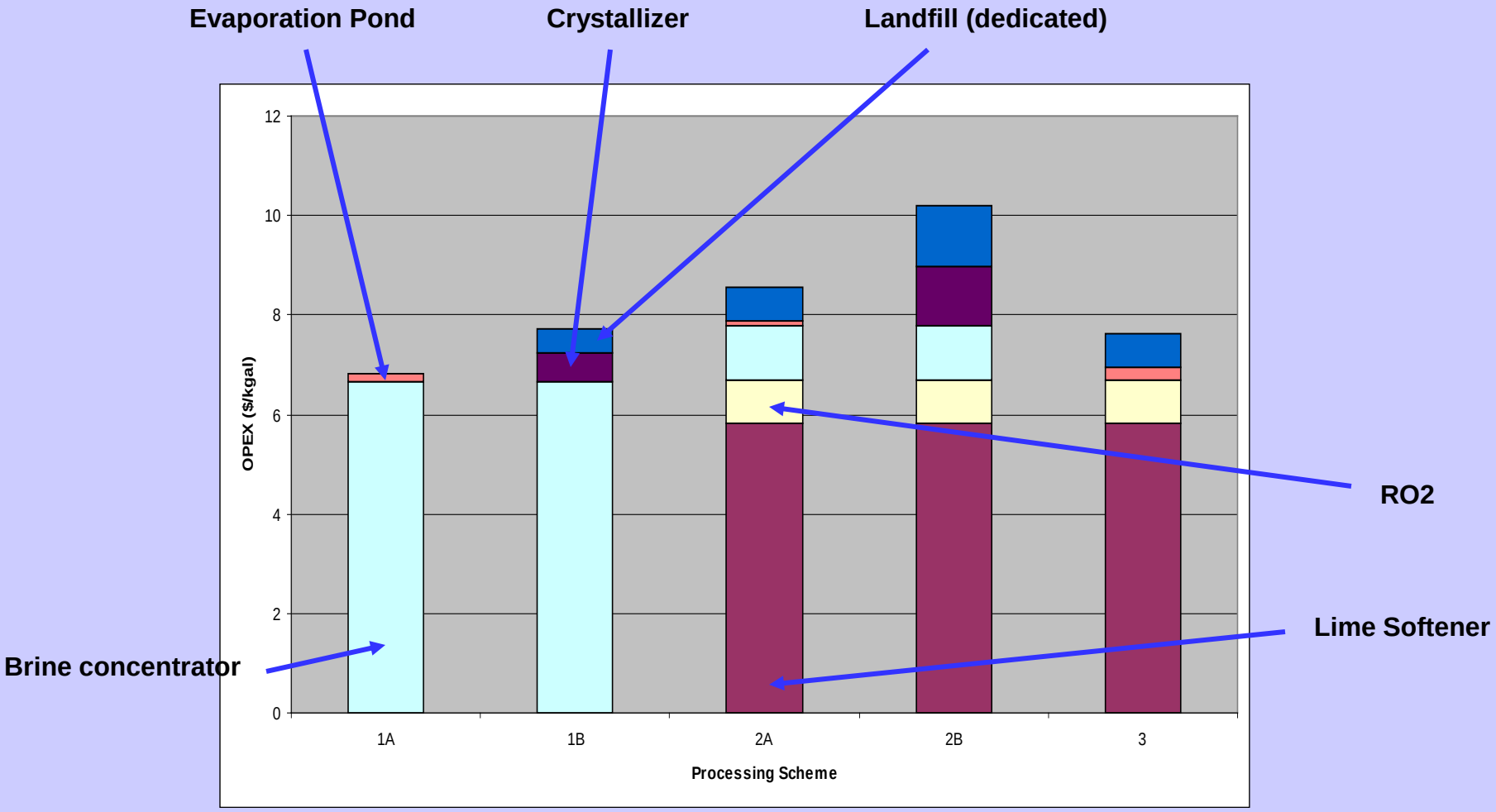








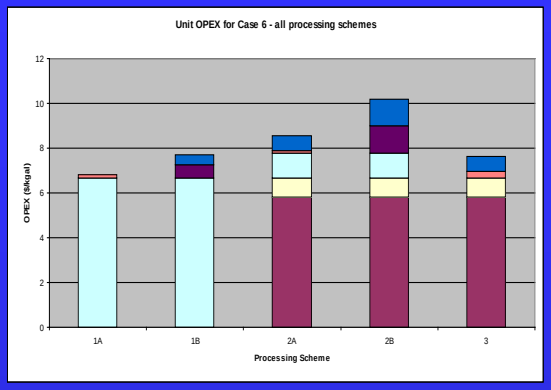


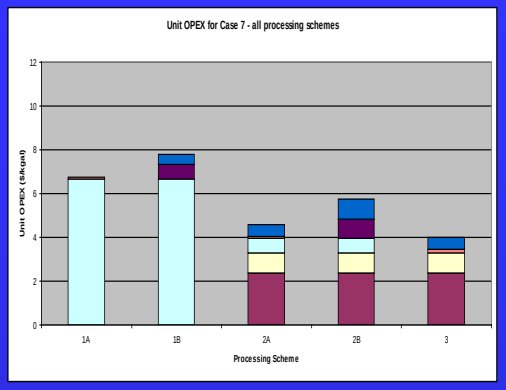


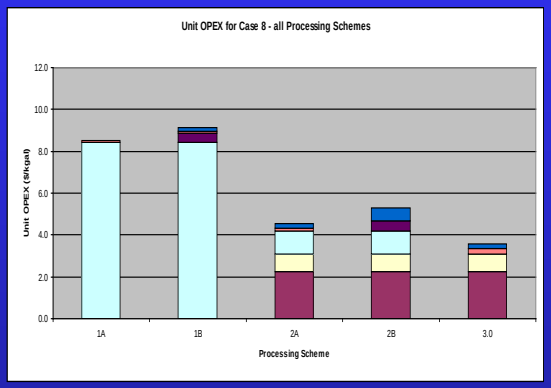
Unit OPEX ($/kgal)
5 different processing schemes
Las Vegas groundwater

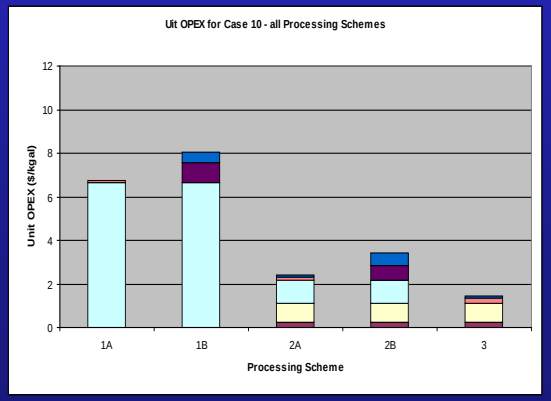
POINTS

--Variability due to process scheme
--Impact of process steps
--Chemical costs of LS largely replace saved energy costs
--Low OPEX of final disposal steps





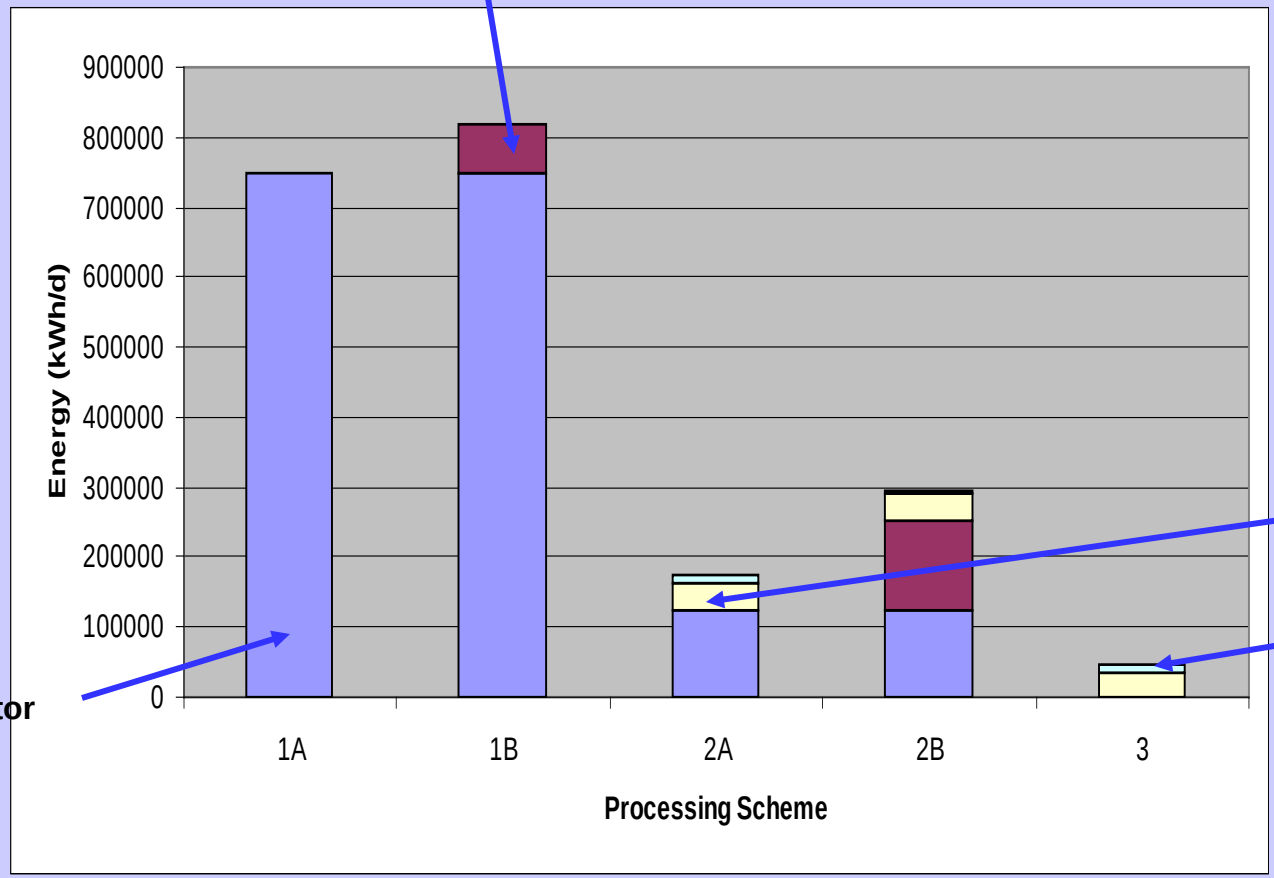




EFFECT OF COMPOSITION On UNIT OPEX ($/kgal)

8 different compositions
5 processing schemes

Most variability due to LS



ENERGY (kWh/d)
5 different processing schemes
Las Vegas groundwater

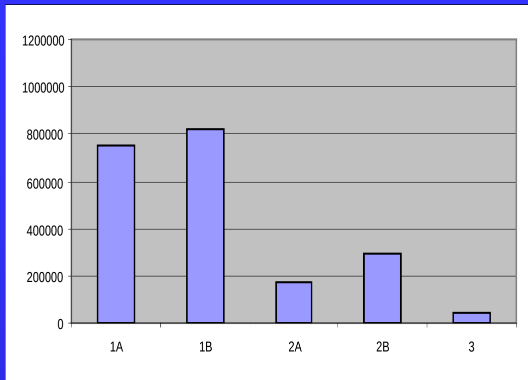
POINTS

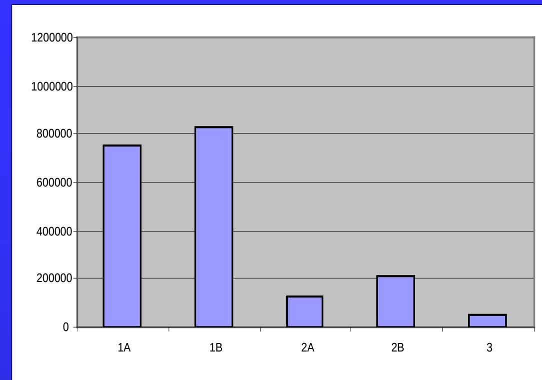
--energy use mostly from thermal processes

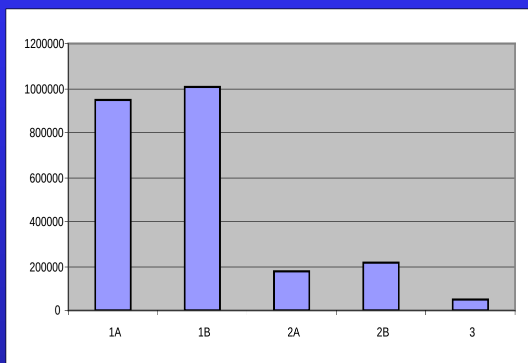
--use of RO2 dramatically reduces energy use

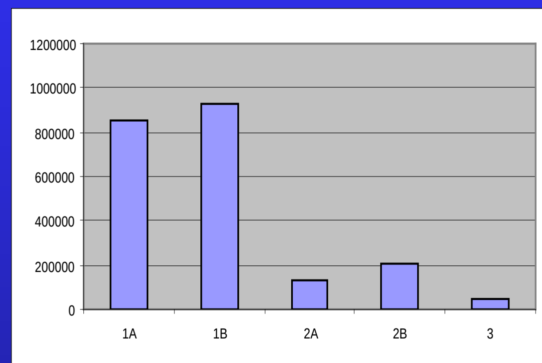
EFFECT OF COMPOSITION On TOTAL ENERGY kWh/d

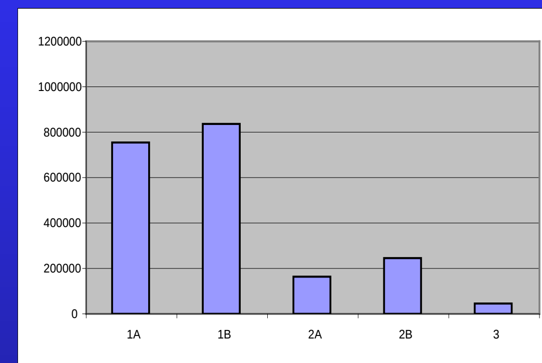
8 different compositions
5 processing schemes

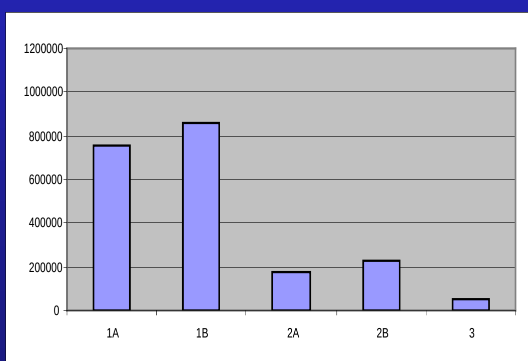


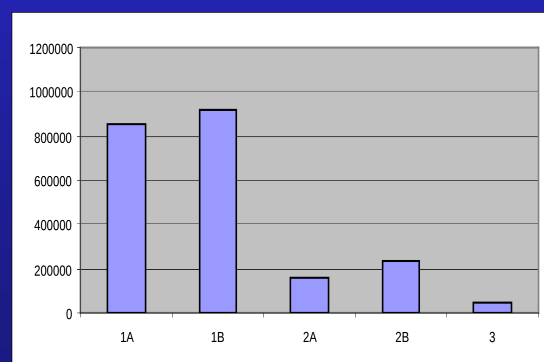


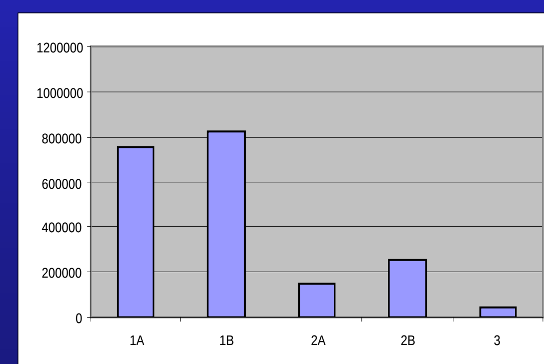










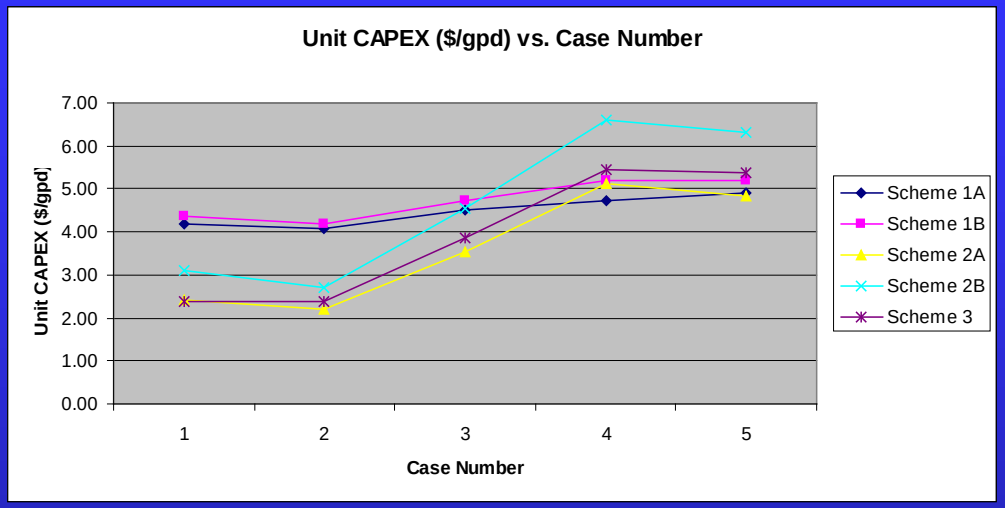


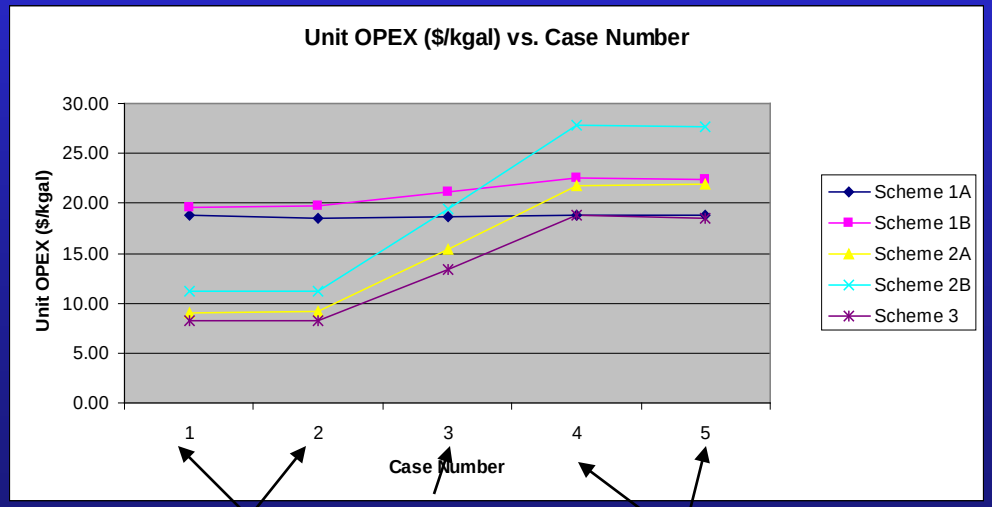
Effect of salinity on UNIT CAPEX And UNIT OPEX

Comparison:
Same relative composition
3 different salinities

5 processing schemes
(5 curves)

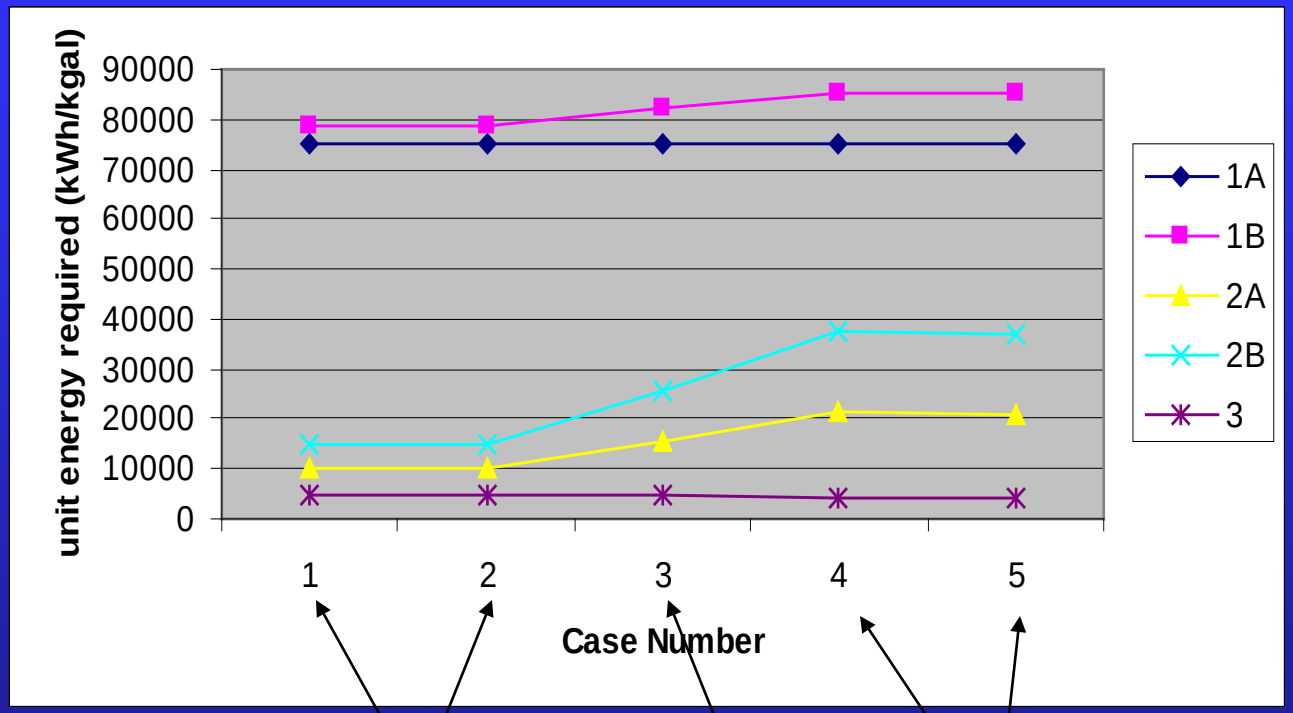
Dramatic effect
on lime softening costs
(schemes 2A,2B, 3)





Salinity: **4,000** **8,000** **12,000**

Effect of salinity on energy

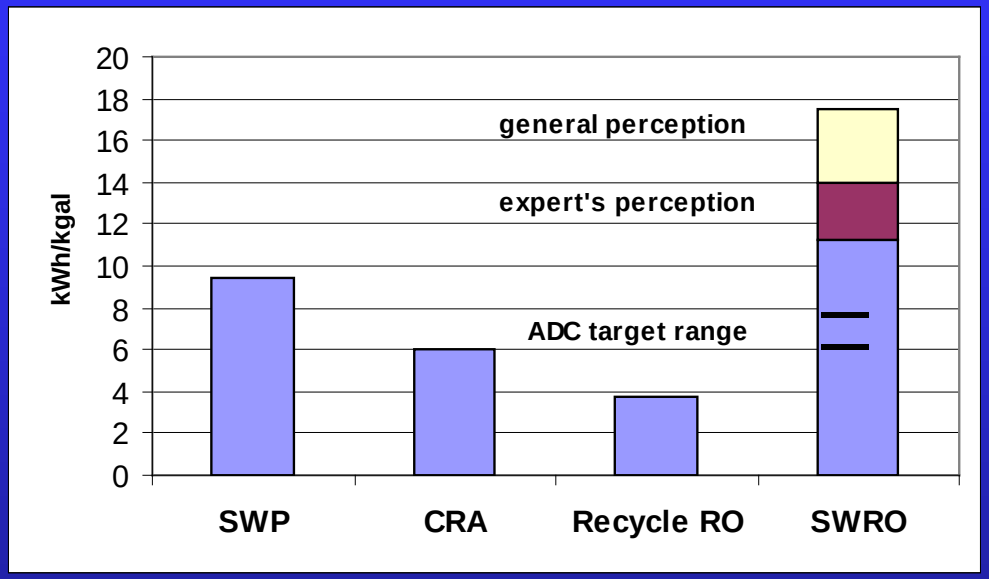


Salinity: **4,000** **8,000** **12,000**

Main effect is where larger volumes go to subsequent Thermal processes (processes 1B, 2A, 2B)

DESAL VS. IMPORT

ENERGY



From: AFFORDABLE DESALINATION COLLABORATION (ADC)

SWP = State Water Project
CRA = Colorado River Aqueduct

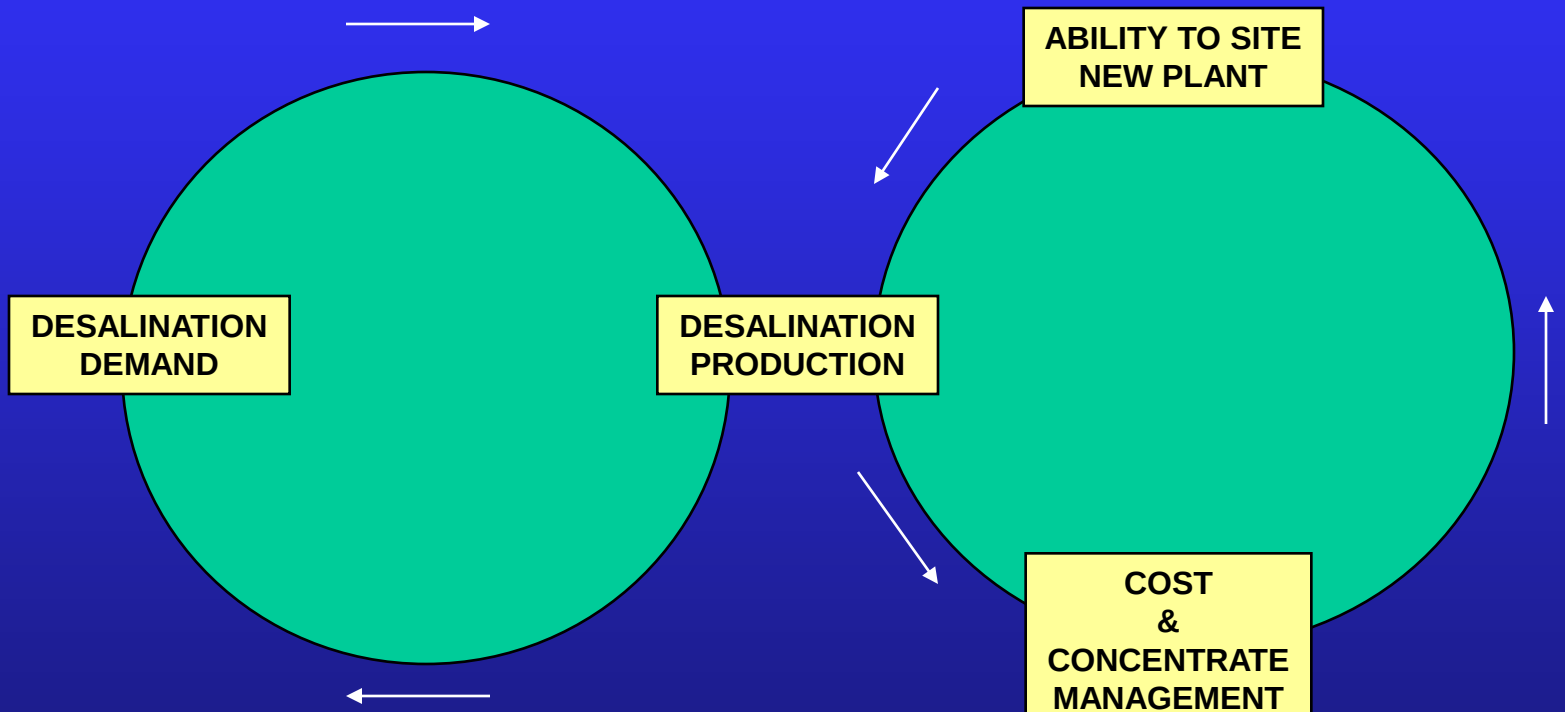
CAPEX & OPEX

Major cost factors

	IMPORT	DESAL
Source water & transmission	X	(x)
Treatment	(x)	X
Residuals disposal		X
Product transmission	X	X

Limits to Growth

(municipal desalination)



SELF-REINFORCING GROWTH PROCESS

LIMITING PROCESS

SUMMARY

- Focus was on inland municipal desalination plants and CM
- CM challenges increasing giving rise to consideration of HR processing
- Looked at CAPEX, OPEX, and energy for DESAL technologies and CM – final disposal of brine/solids is a significant cost for HR processing
- Showed strong dependence of performance, CAPEX, OPEX on water composition and salinity and thus on site-specific conditions.

SUMMARY (2)

- **Showed strong dependence of CAPEX and OPEX on processing scheme**
- **HR (and ZLD) technology exists and is applied in other industries but in general costs are high for application in municipal sector.**
- **Presently, HR may not ‘solve’ CM cost problems but may provide a solution where none otherwise exist**

ACKNOWLEDGEMENTS

Mickley & Associates' Reports:

- **Bureau of Reclamation:** *Membrane Concentrate Disposal: Practices and Regulation*, 1st edition 2001; 2nd edition 2006.

- **Bureau of Reclamation:** *Treatment of Concentrate,* 2008.

- **WateReuse Foundation:** *Survey of High Recovery and Zero Liquid Discharge Technologies for Water Utilities, 2008.*

CH2M HILL Report:

- **WateReuse Foundation***: Beneficial and Non-Traditional Uses of Concentrate, 2006.*