Quality of reclaimed water for turfgrass irrigation

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Cost for Increasing Water Supply

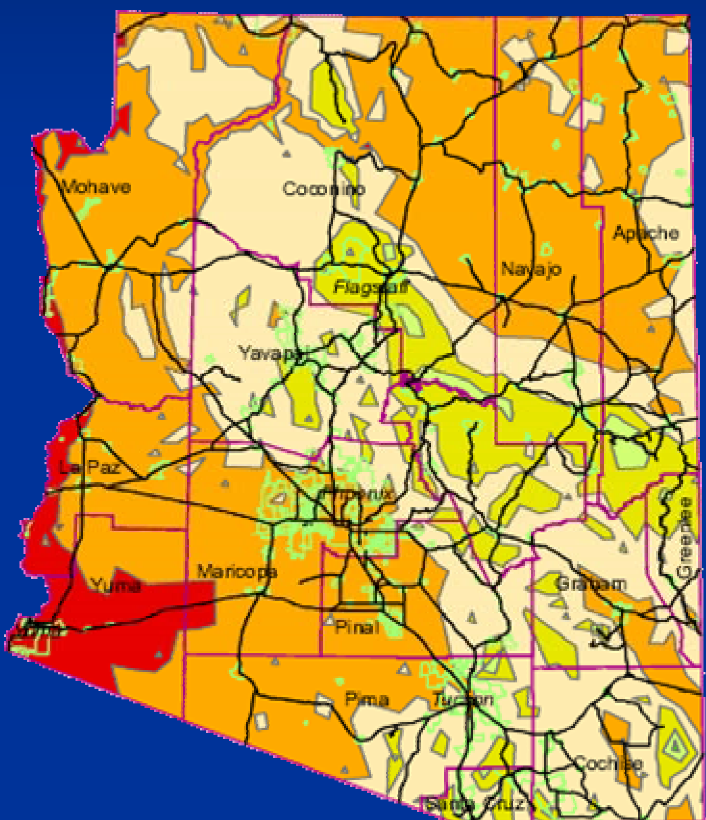
Option	Cost (acre-ft)
Desalination	$1,400
Recycling for Drinking Water	$1,230
Imperial Valley Imports	$800
Current Costs	$500
Landscape Reuse	$70

Water Quality Problems

- **Salinity**
  - Salts reduce water availability through osmotic effects
- **Water Infiltration Rate**
  - Relatively high sodium or low calcium content of soil or water reduces the infiltration rate
- **Specific Ion Toxicity**
  - Certain ions (sodium, chloride, or boron) from soil or water accumulate and cause damage
- **Miscellaneous**
  - Excessive corrosion of equipment

Salinity

Precipitation



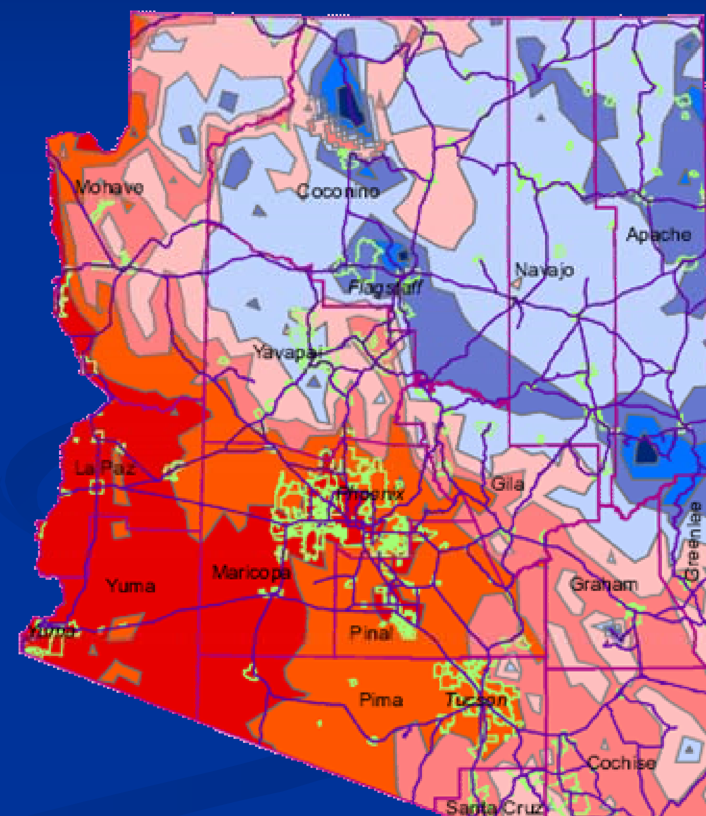
Precipitation (cm)

- < 12.70
- 12.71 – 30.50
- 30.51 – 50.80
- 50.81 – 76.20
- 76.21 – 101.60
- 101.61 – 127.00

Temperature

Temperature (C)

- 0 – 4.40
- 4.41 – 7.20
- 7.21 – 10.00
- 10.01 – 12.80
- 12.81 – 15.60
- 15.61 – 18.30
- 18.31 – 21.10
- > 22.11



Evaporative Demand > Precipitation

Salt River

- 0.8 maf/yr @ 500 mg L^{-1}

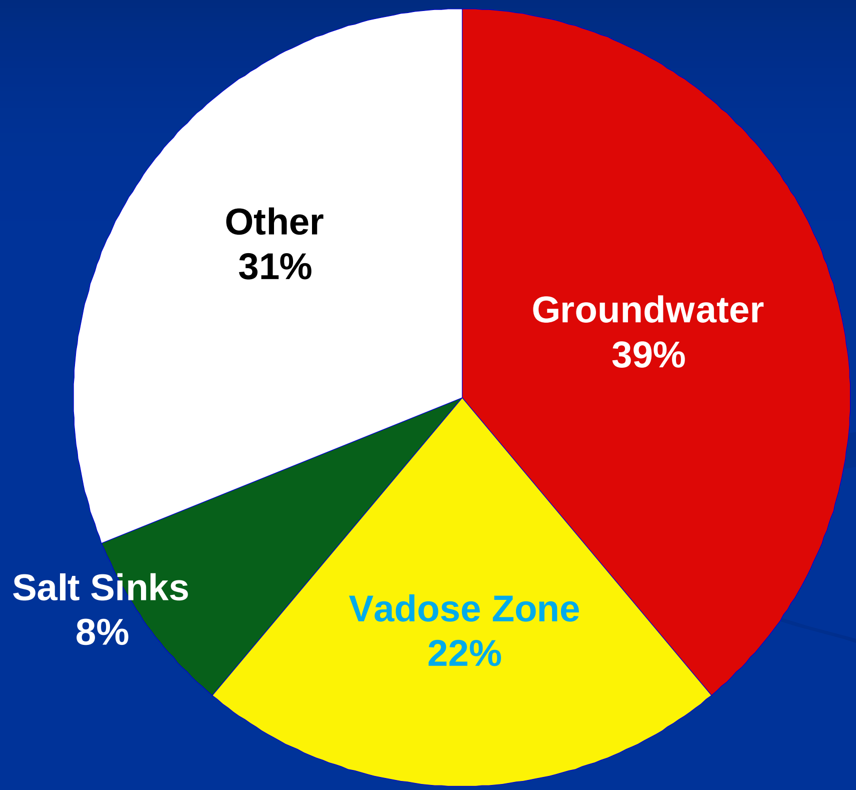
  imports 620,000 metric tons annually

Central Arizona Project

- 1.2 maf/yr @ 650 mg L^{-1}

  imports 960,000 metric tons annually

Salt Accumulation



Units for Salinity

- TDS – Total dissolved solids (mg L^{-1})
  - Measured by filtering then evaporating a sample and weighing the residue
  - Common measurement at sewer treatment plants
- EC – Electrical conductivity
  - Measured by passing a current through a water sample
  - Most management criteria based on EC

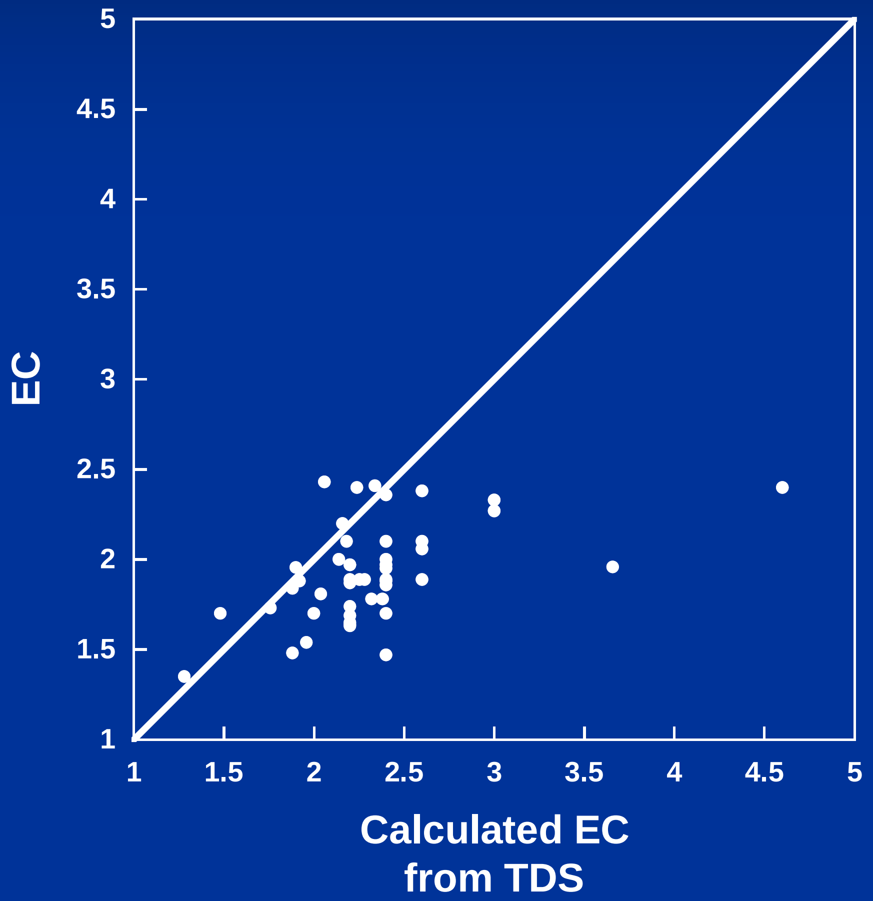
Converting between TDS and EC

$$\mathrm{EC}\left(\frac{\mathrm{dS}}{\mathrm{m}}\right) = \frac{\mathrm{TDS}\left(\frac{\mathrm{mg}}{\mathrm{L}}\right)}{\mathrm{Conversion\ Factor}}$$

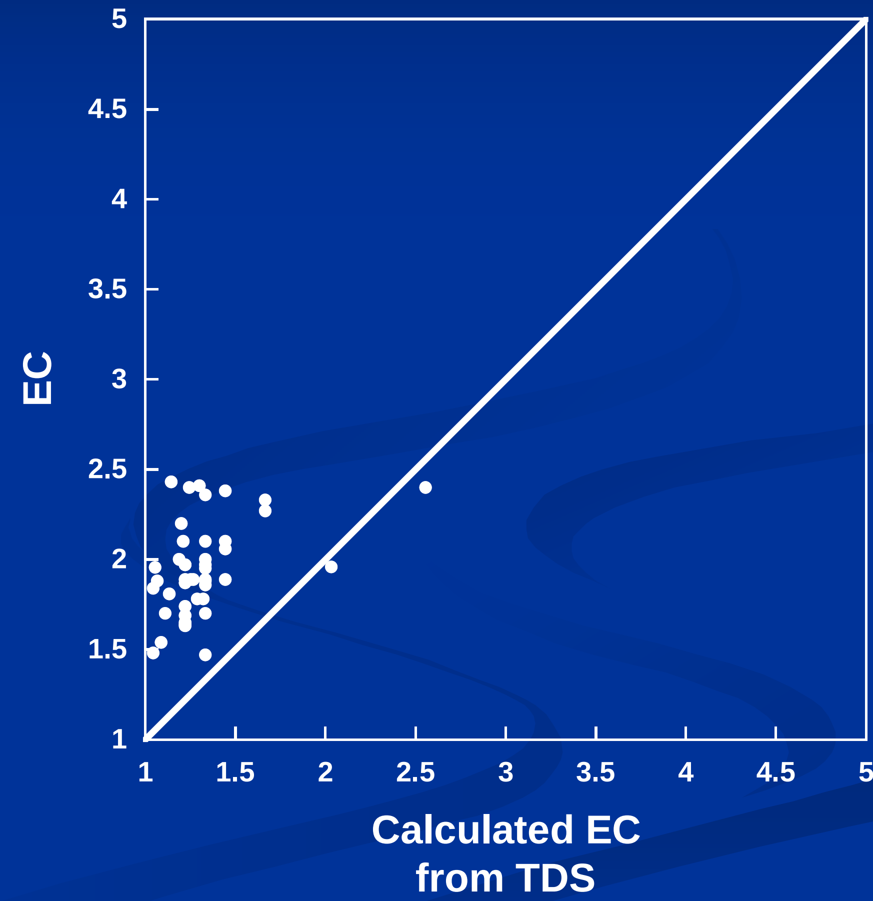
$$\mathrm{TDS}\left(\frac{\mathrm{mg}}{\mathrm{L}}\right) = \mathrm{EC}\left(\frac{\mathrm{dS}}{\mathrm{m}}\right)(\mathrm{Conversion\ Factor})$$

Conversion factor usually 500 – 1000 depending on solution

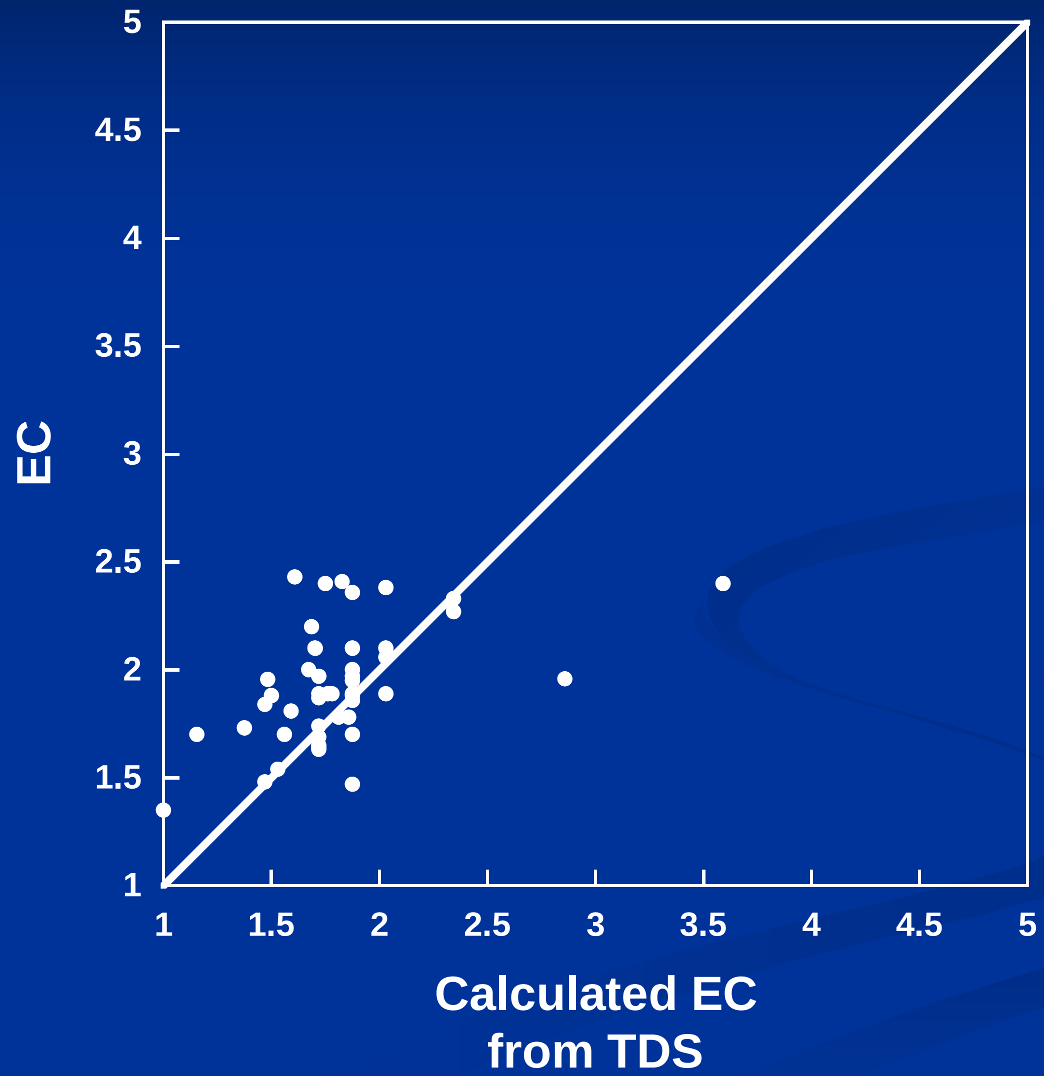
Conversion factor = 900



Conversion factor = 500



For most irrigation waters conversion factor ≈ 640



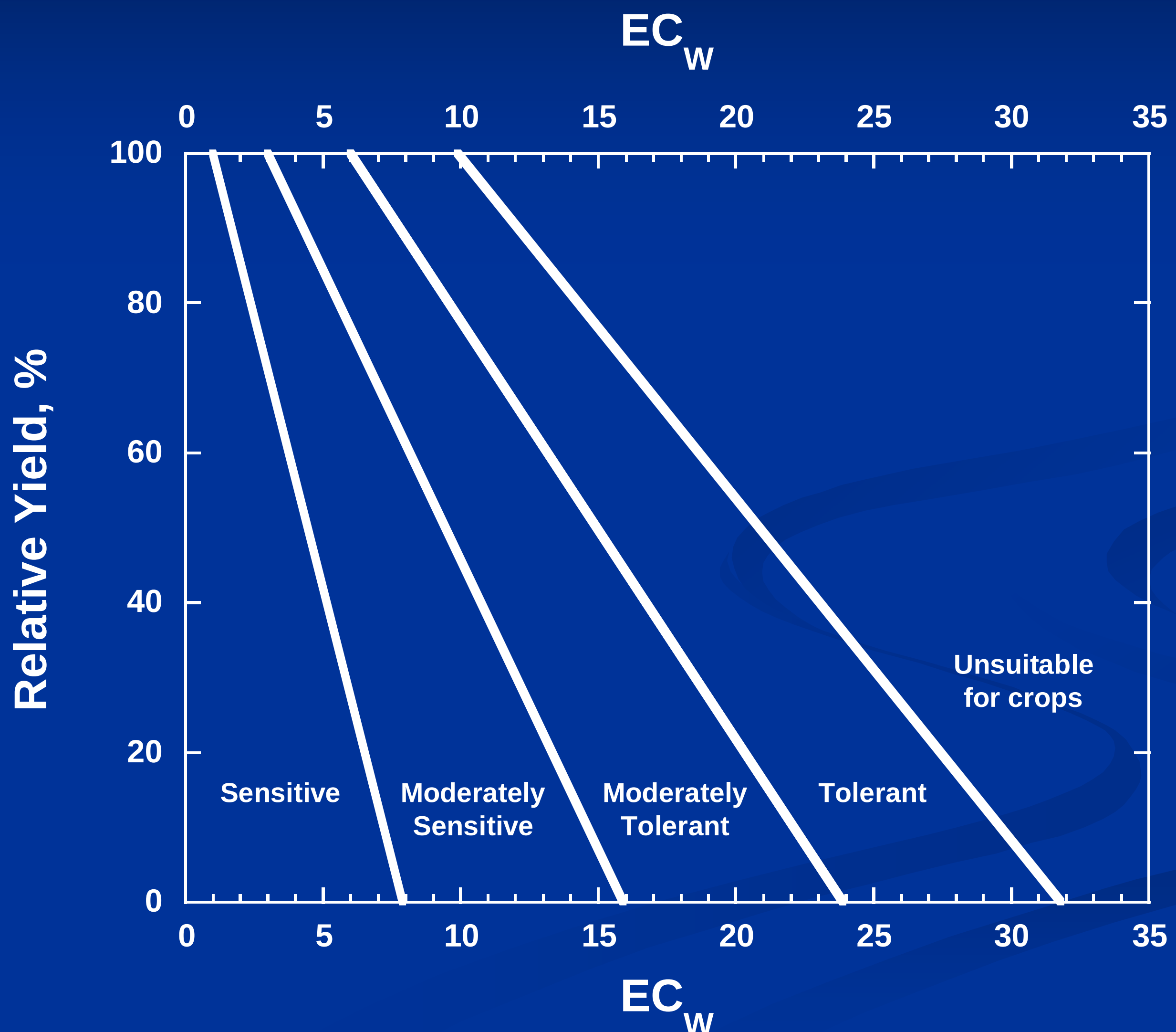
Units for EC

$$\frac{dS}{m} \qquad \frac{\mu S}{cm} \qquad \frac{mmho}{cm} \qquad \frac{\mu mho}{cm}$$

Conversion for EC units

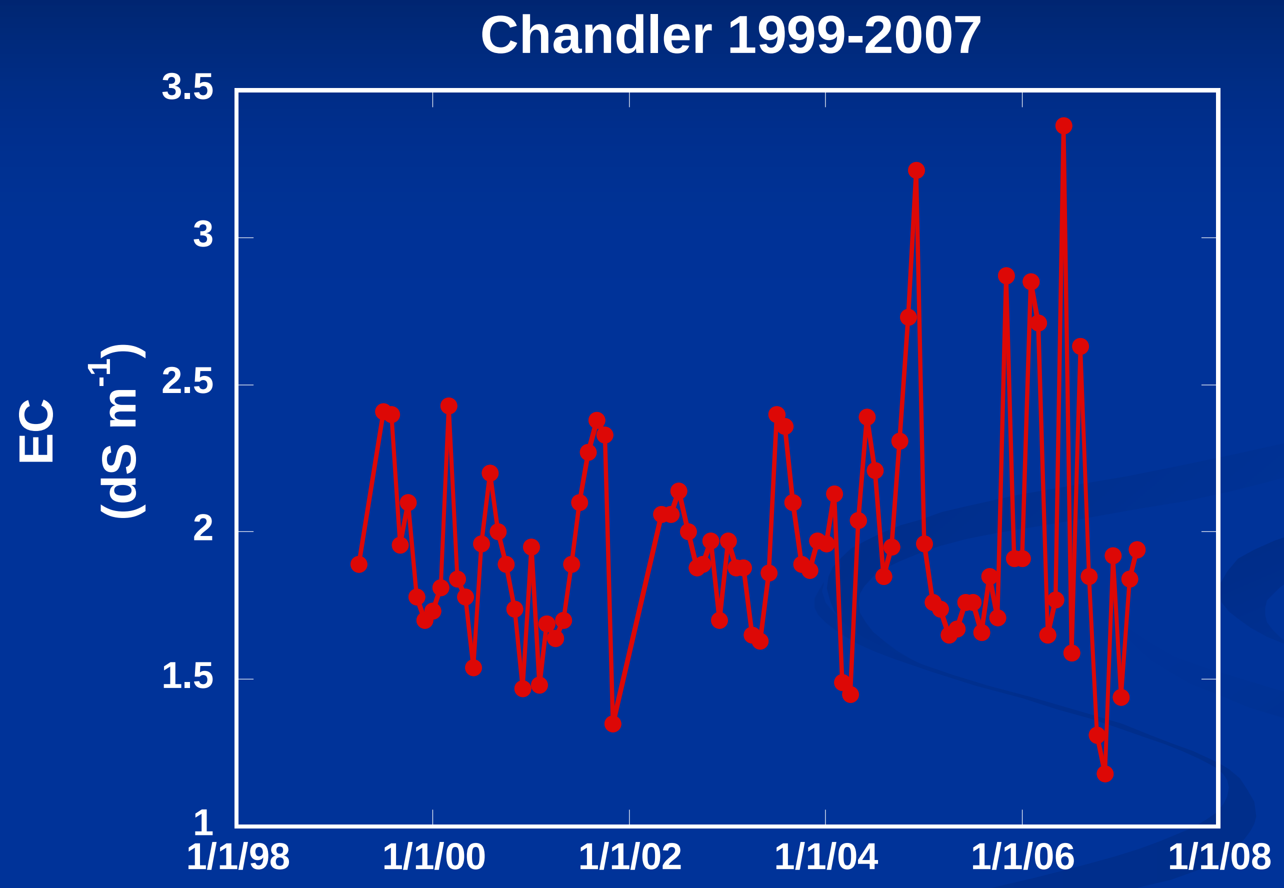
$$\frac{dS}{m} = \frac{\mu S}{cm} = \frac{mmho}{cm} = \frac{\mu mho}{cm} \times 1000$$

Irrigation with Saline Water

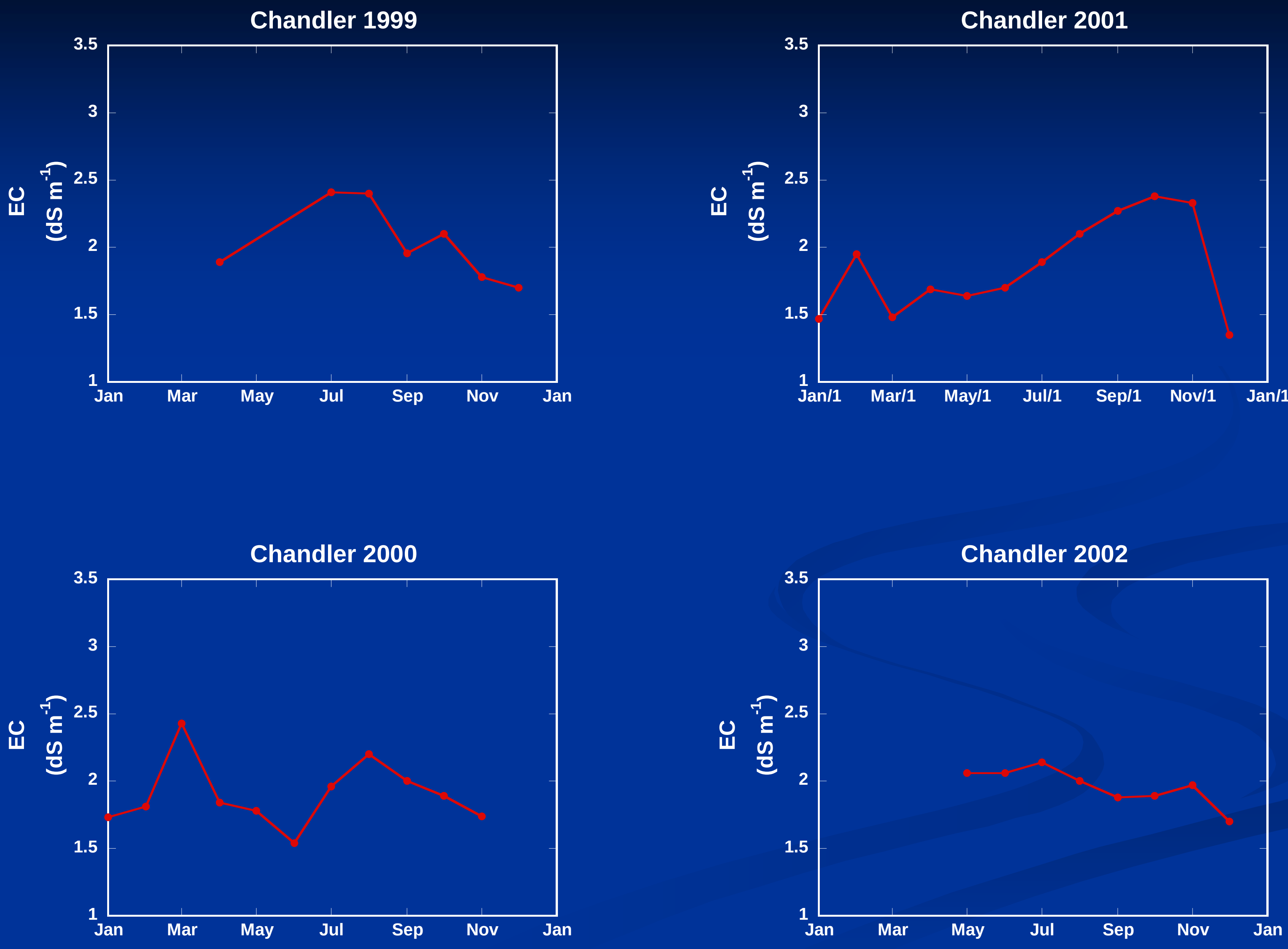


Irrigation Water Quality – Salinity

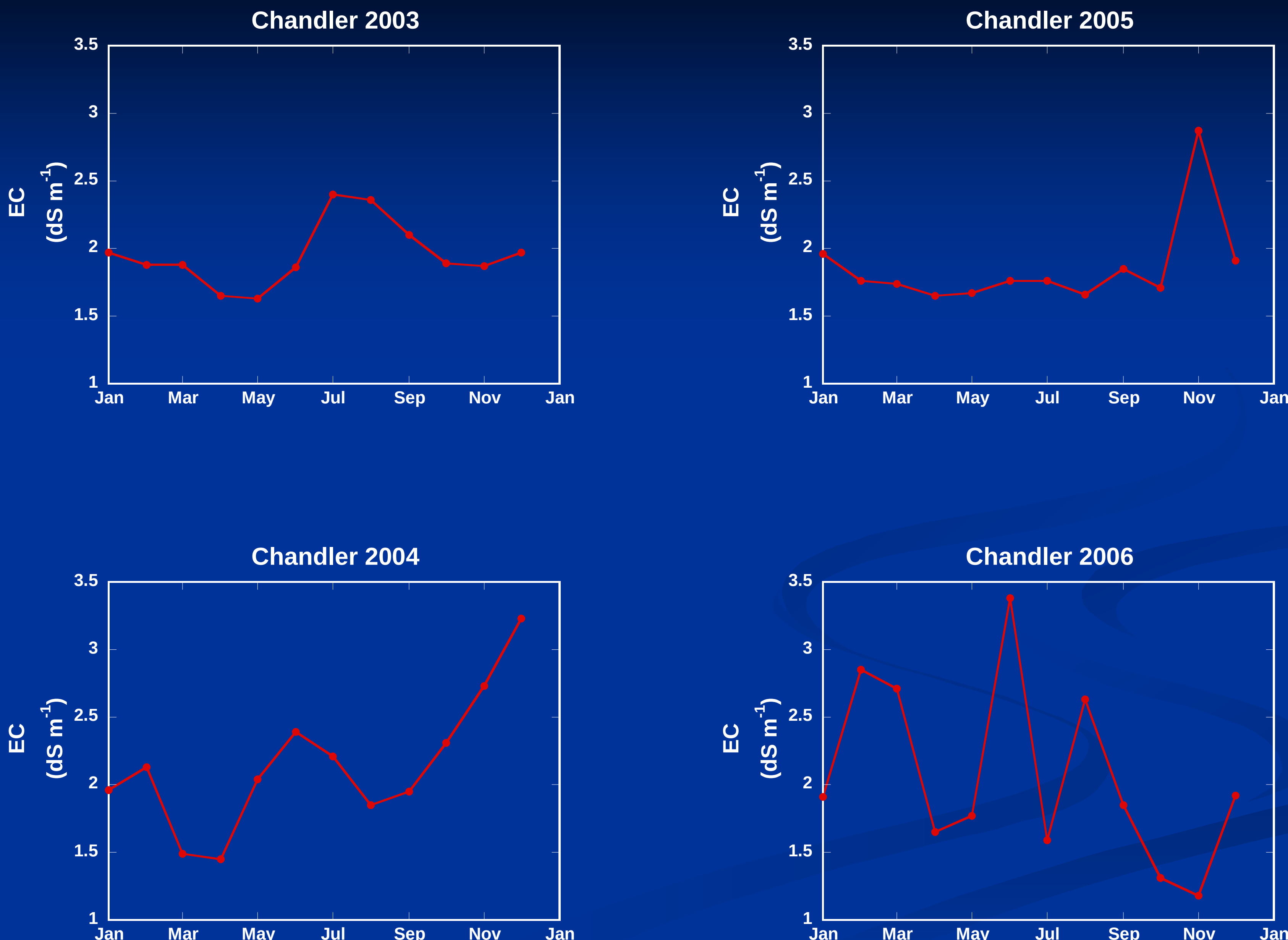
		Degree of Restriction on Use		
	Units	None	Slight to Moderate	Severe
EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
(or)				
TDS	mg/l	< 450	450 – 2000	> 2000



Chandler 1999-2007
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
1/1/98
1/1/00
1/1/02
1/1/04
1/1/06
1/1/08

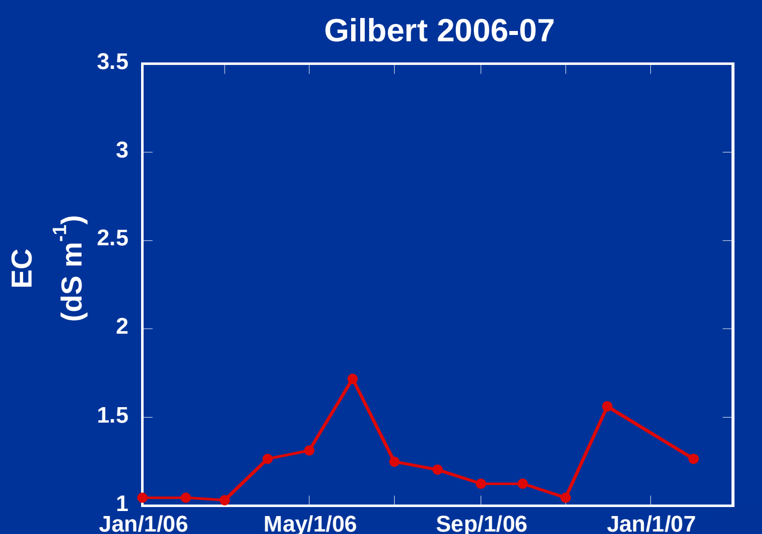


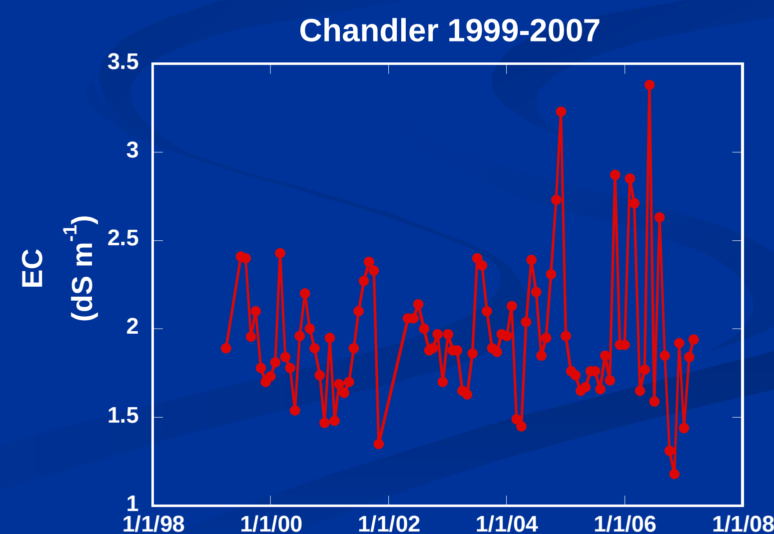
Chandler 1999
Chandler 2001
Chandler 2000
Chandler 2002
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
Jan
Mar
May
Jul
Sep
Nov
Jan
Jan/1
Mar/1
May/1
Jul/1
Sep/1
Nov/1
Jan/1


Chandler 2003
Chandler 2005
Chandler 2004
Chandler 2006
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
Jan
Mar
May
Jul
Sep
Nov
Jan

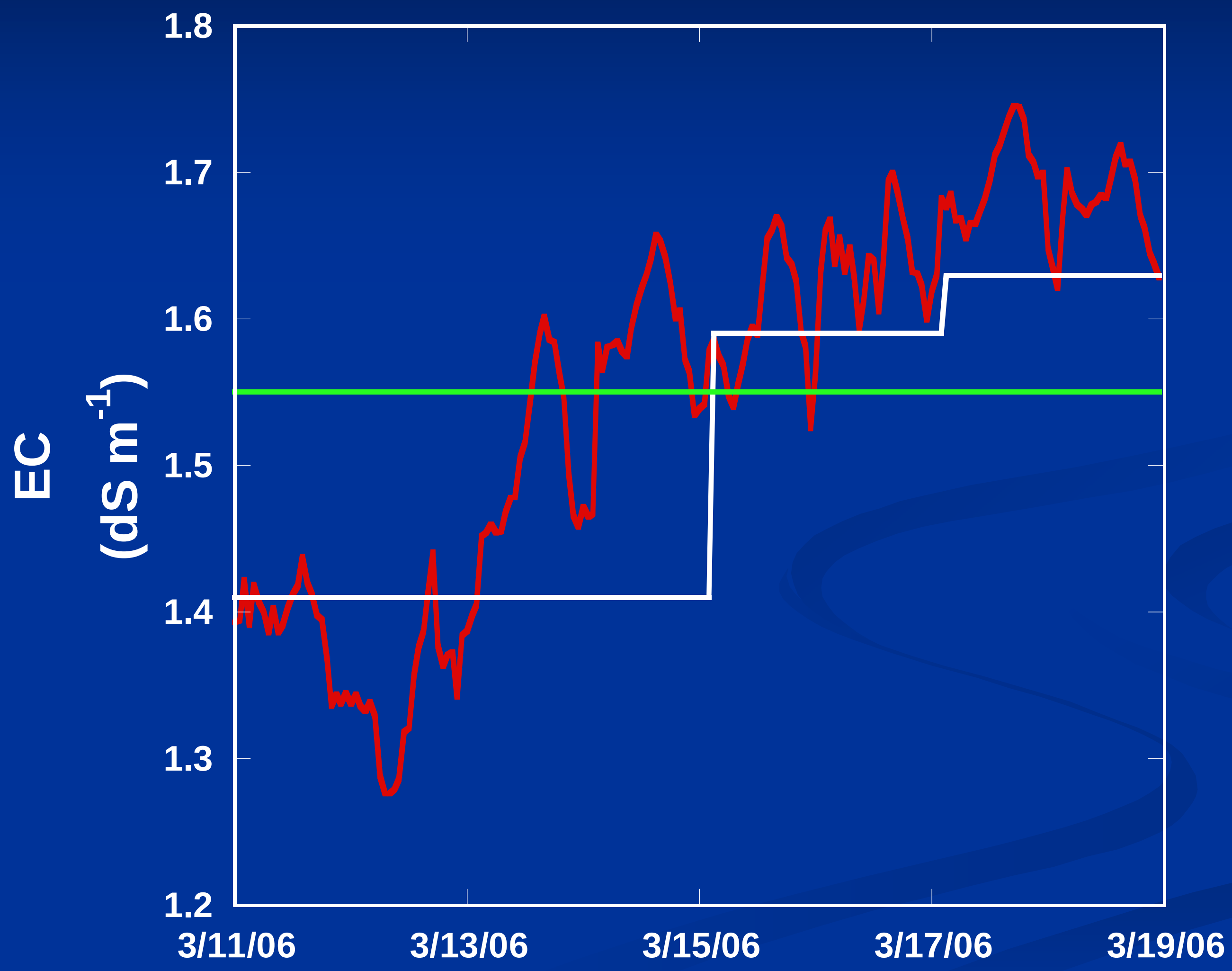

91st Avenue
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
Mar
May
Jul
Sep
Nov
Jan
Mar
May


23rd Avenue
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
Mar
May
Jul
Sep
Nov
Jan
Mar
May


Gilbert 2006-07
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
Jan/1/06
May/1/06
Sep/1/06
Jan/1/07


Chandler 1999-2007
EC
(dS m-1)
3.5
3
2.5
2
1.5
1
1/1/98
1/1/00
1/1/02
1/1/04
1/1/06
1/1/08

Data Collection Rate



Measure salinity often

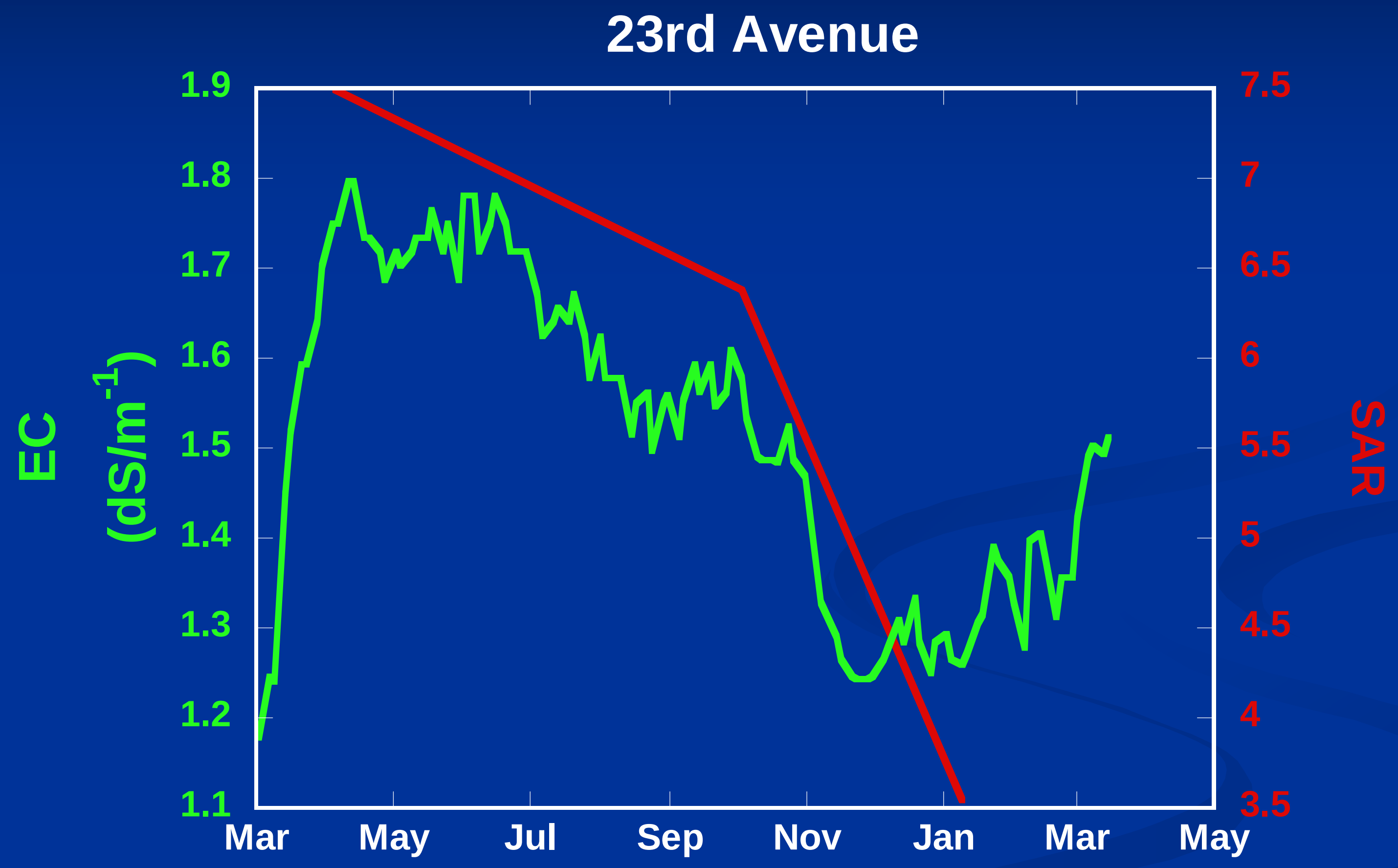
- EC meters range in price from $50 - $1000
- Results are instant
- Track results

Irrigation Water Quality – Sodicity

Potential Infiltration Problems

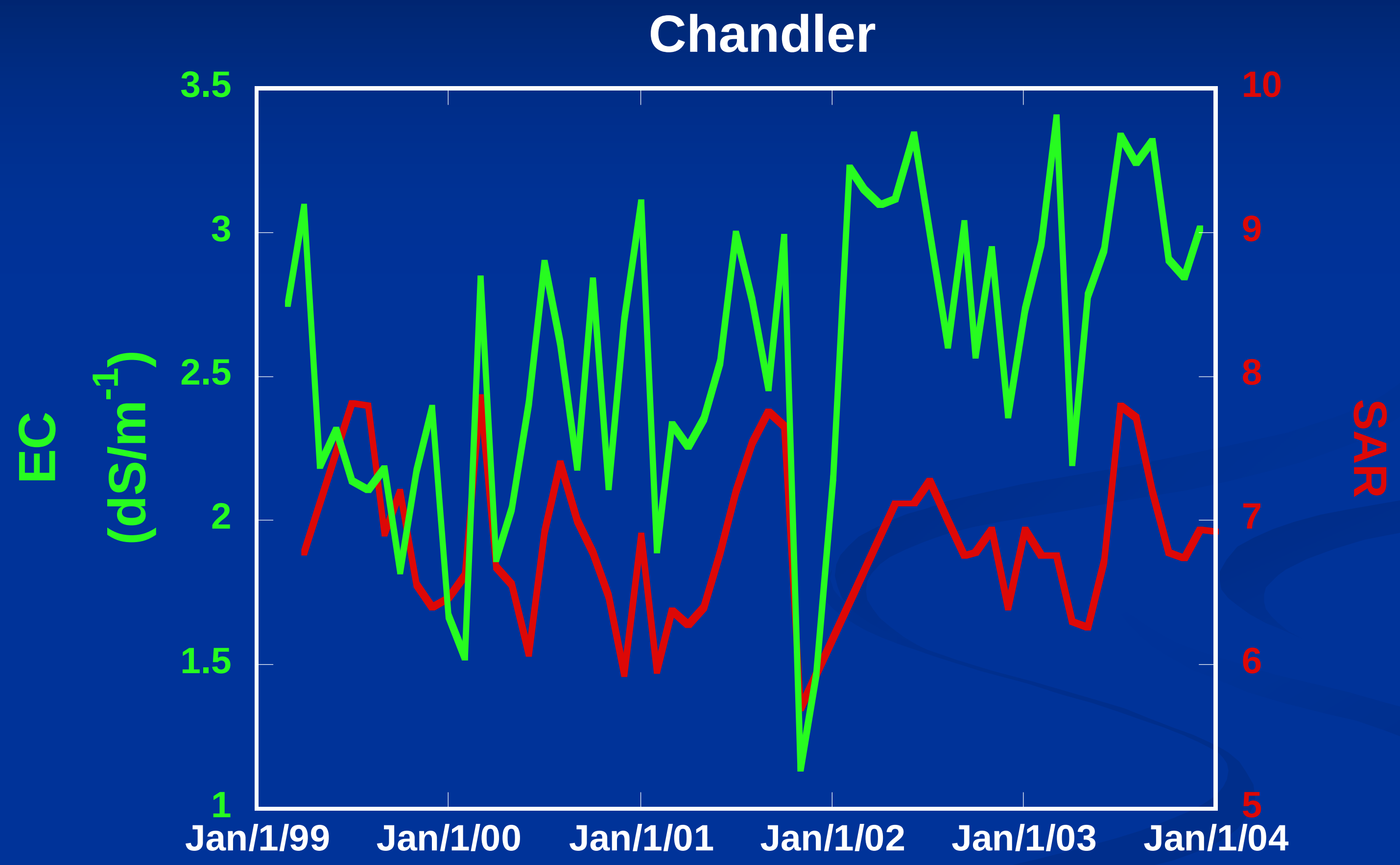
			Degree of Restriction on Use	
		None	Slight to Moderate	Severe
SAR	= 0-3 and EC_W =	> 0.7	0.7 – 0.2	<0.2
	= 3-6 and EC_W =	> 1.2	1.2 – 0.3	<0.3
	= 6-12 and EC_W =	> 1.9	1.9 – 0.5	<0.5
	= 12-20 and EC_W =	> 2.9	2.9 – 1.3	<1.3
	= 20-40 and EC_W =	> 5.0	5.0 – 2.9	<2.9

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+} + Mg^{2+}]}{2}}}\ ; \mathrm{Conc} \Rightarrow \left[\frac{\mathrm{meq}}{\mathrm{l}}\right]$$



23rd Avenue
EC
(dS/m^{-1})
SAR
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
7.5
7
6.5
6
5.5
5
4.5
4
3.5
Mar
May
Jul
Sep
Nov
Jan
Mar
May

91st Avenue
EC
(dS/m^{-1})
SAR
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
7.5
7
6.5
6
5.5
5
4.5
4
3.5
Mar
May
Jul
Sep
Nov
Jan
Mar
May


Chandler
EC
(dS/m-1)
SAR
3.5
3
2.5
2
1.5
1
10
9
8
7
6
5
Jan/1/99
Jan/1/00
Jan/1/01
Jan/1/02
Jan/1/03
Jan/1/04

Irrigation Water Quality – Toxicity

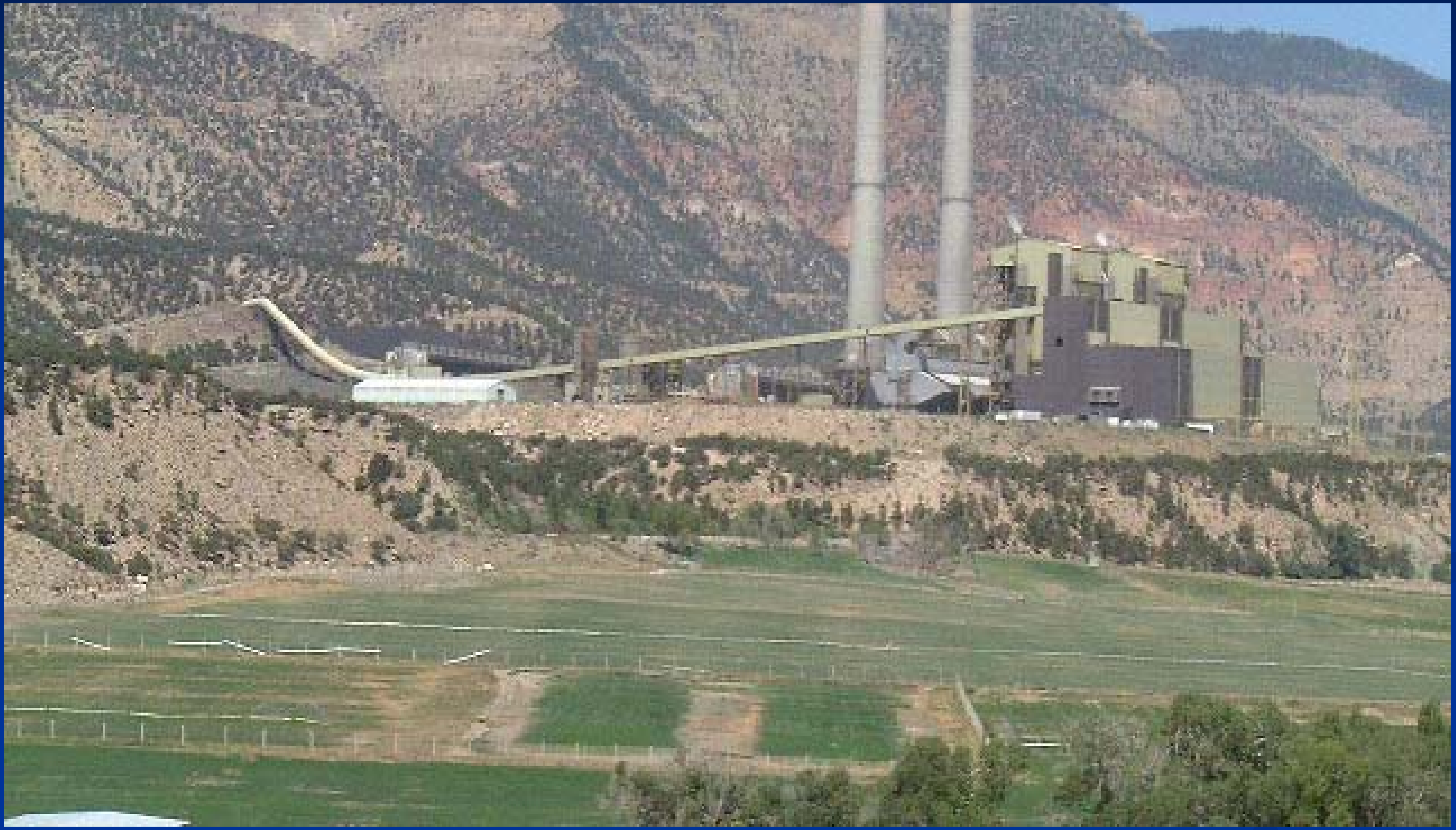
Boron (ppm)

	Tolerance		
Class of Water	Sensitive	Semi-tolerant	Tolerant
Excellent	< 0.33	< 0.67	< 1.00
Good	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
Permissible	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
Unsuitable	> 1.25	> 2.50	> 3.75

Boron accumulates in leaf tips – removal in clippings

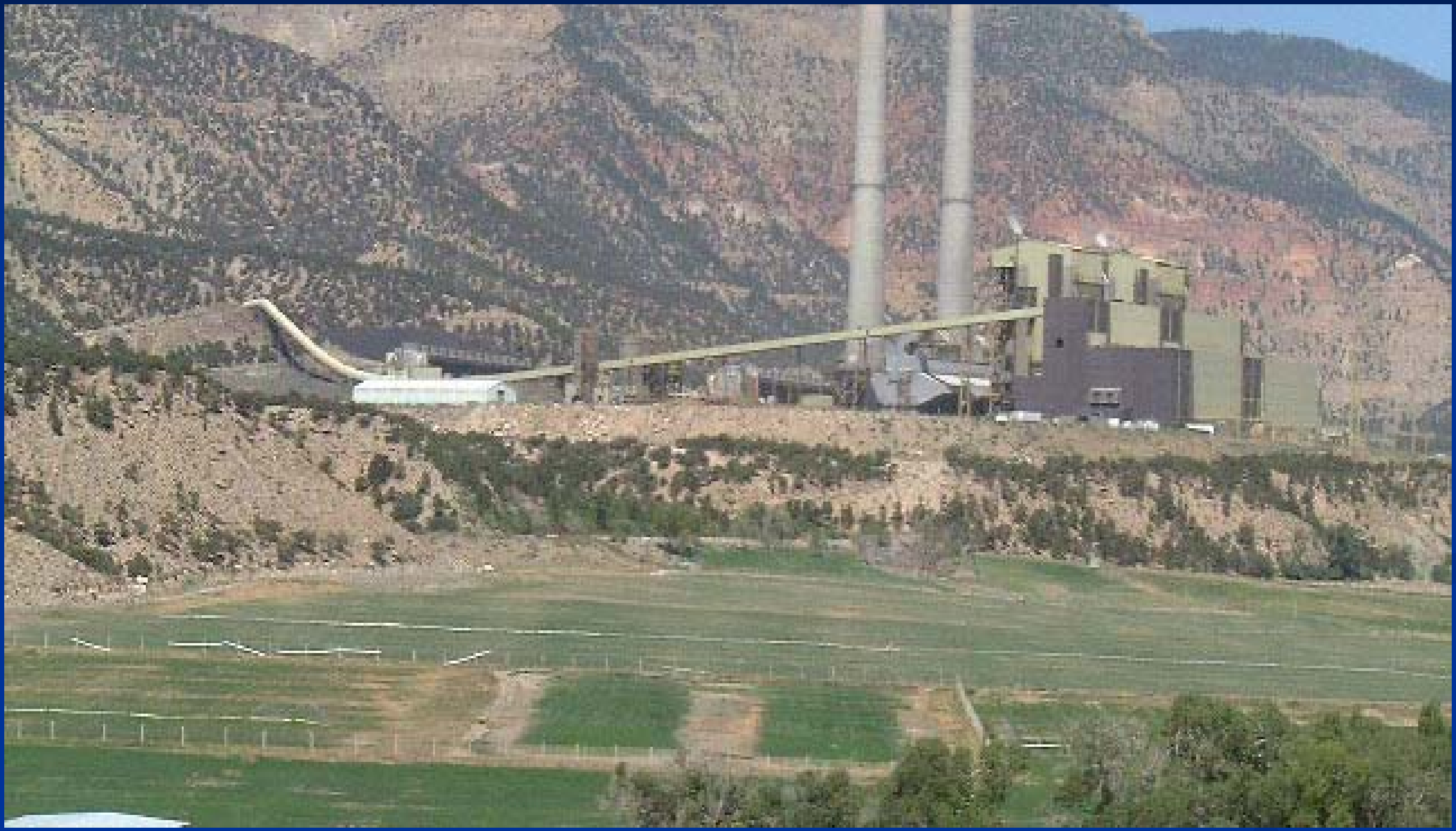
Problem for trees and shrubs

Salinity and wastewater reuse



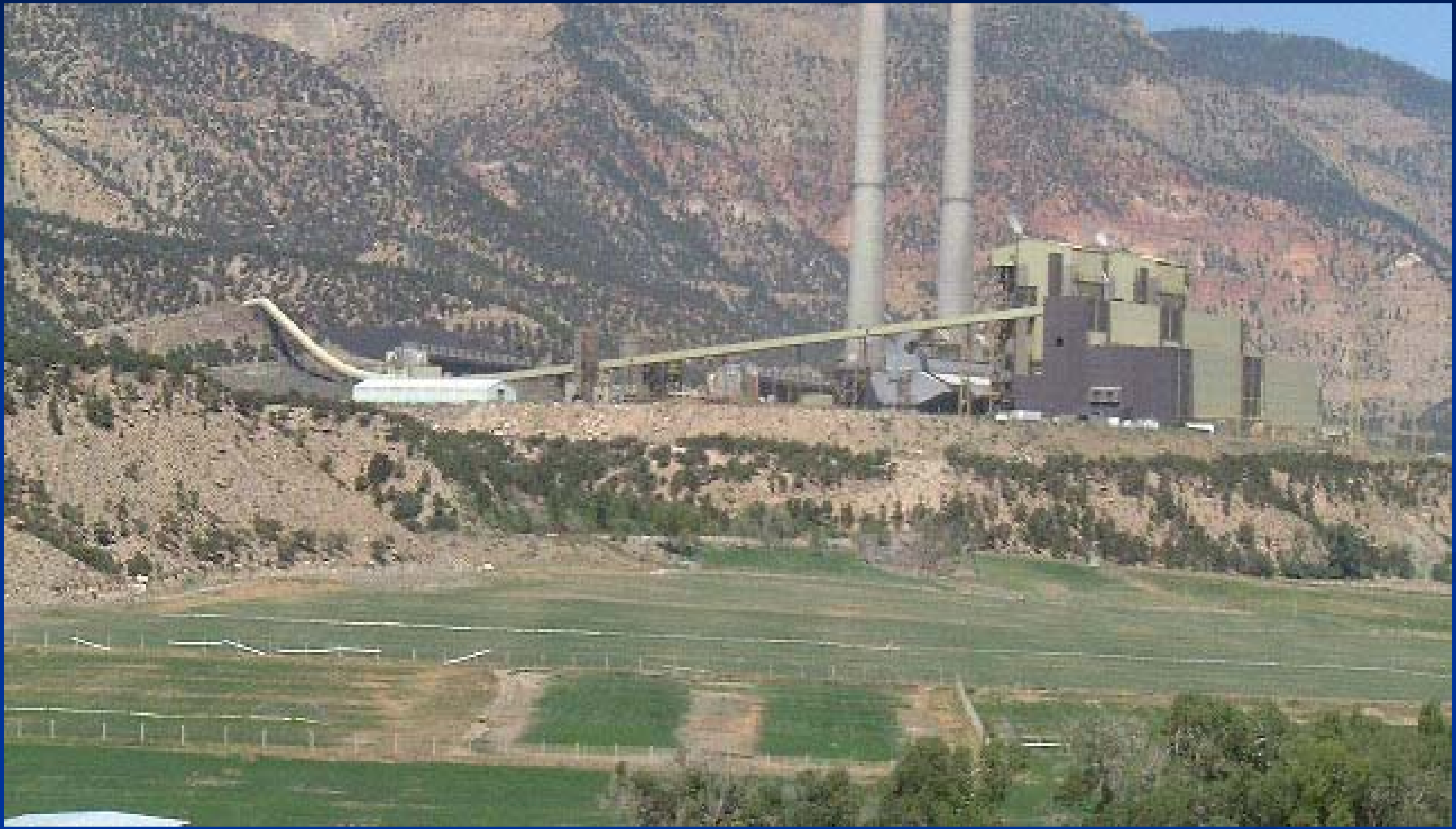
- Power plant has zero discharge permit for spent cooling water.

Salinity and wastewater reuse



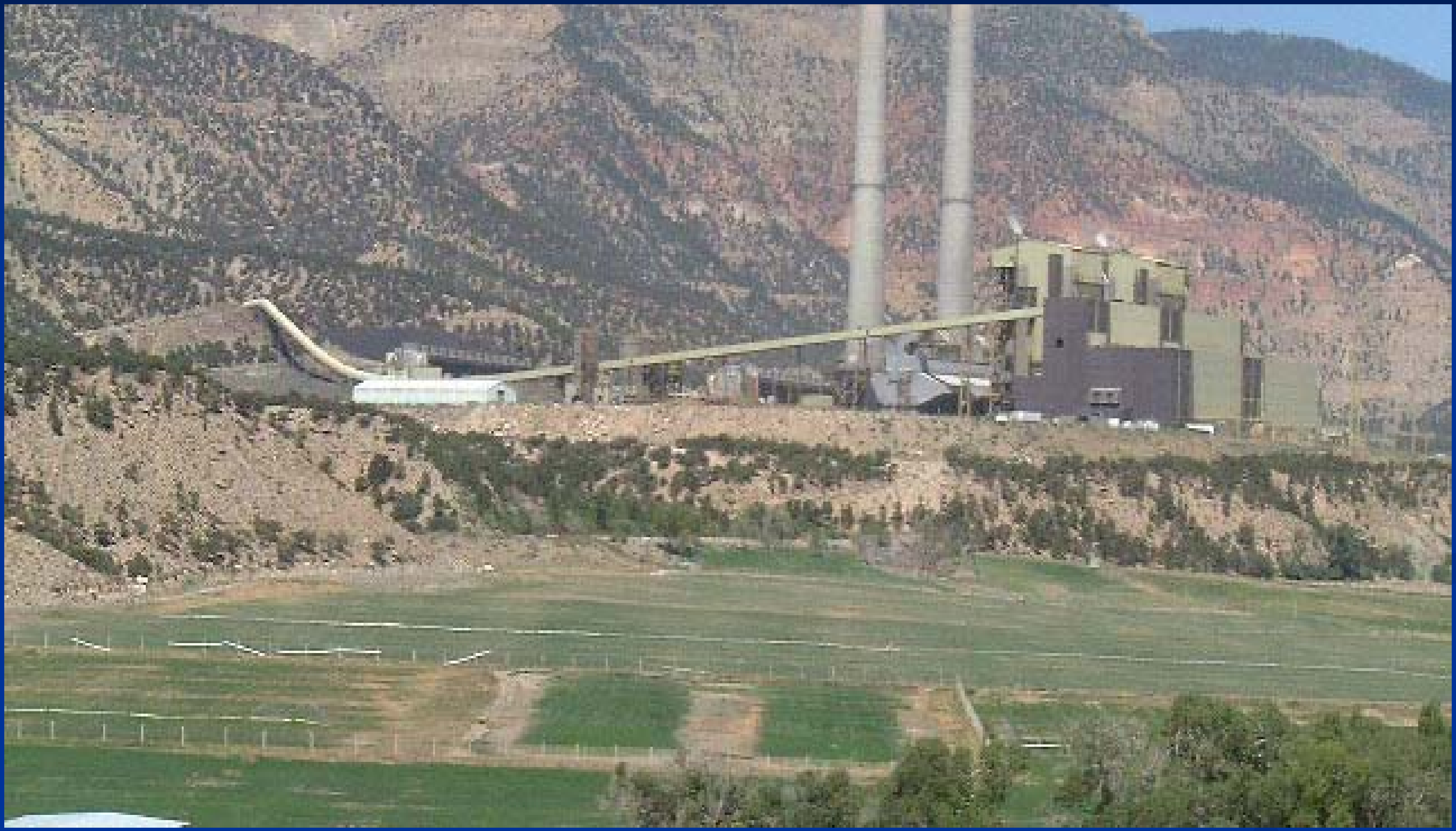
- Waste water is used to irrigate 250 acre farm.

Salinity and wastewater reuse



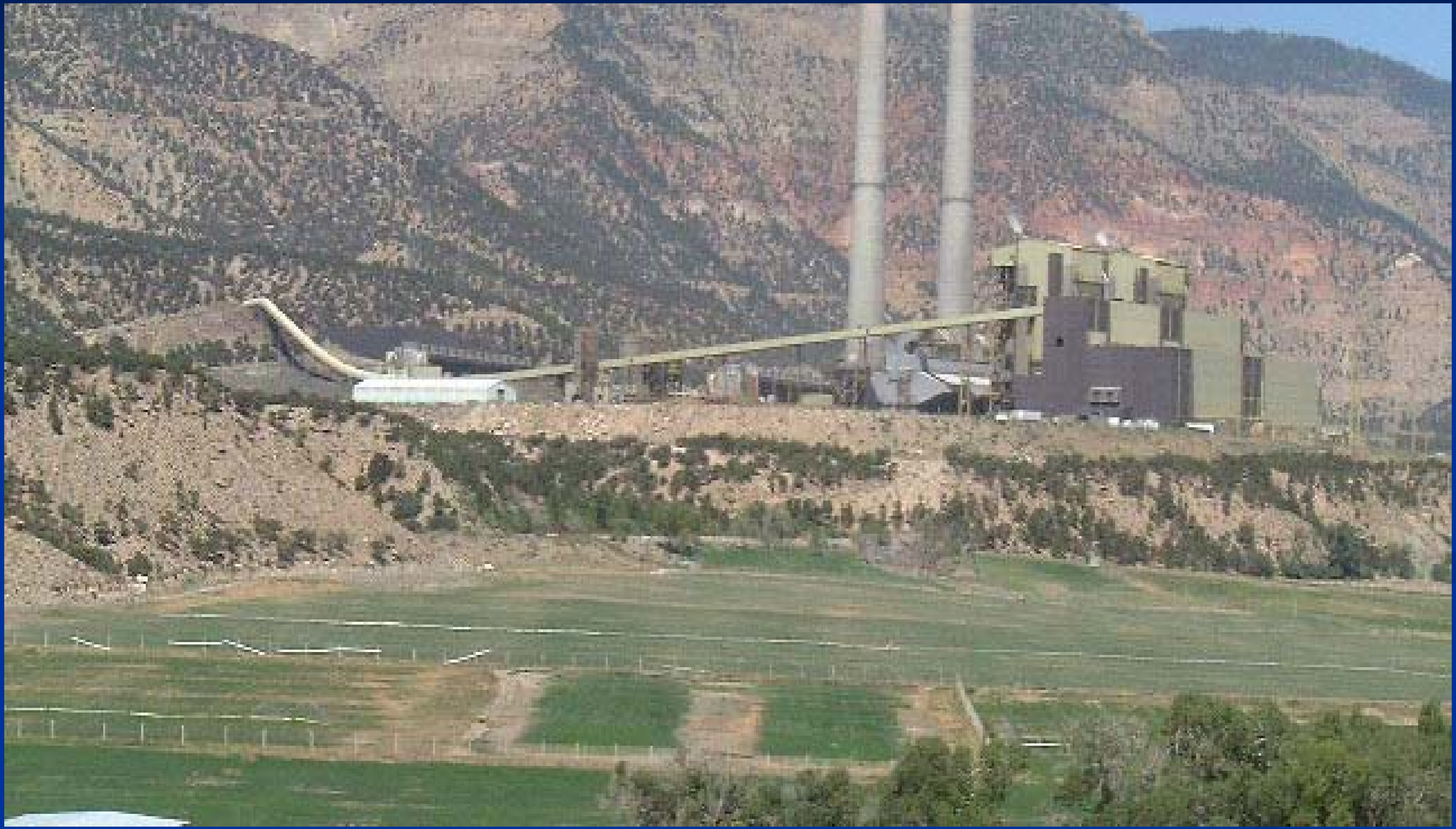
- Ongoing monitoring to determine if salt is leaching out of root zone and the effective life of the farm for waste water disposal.

Experimental Design



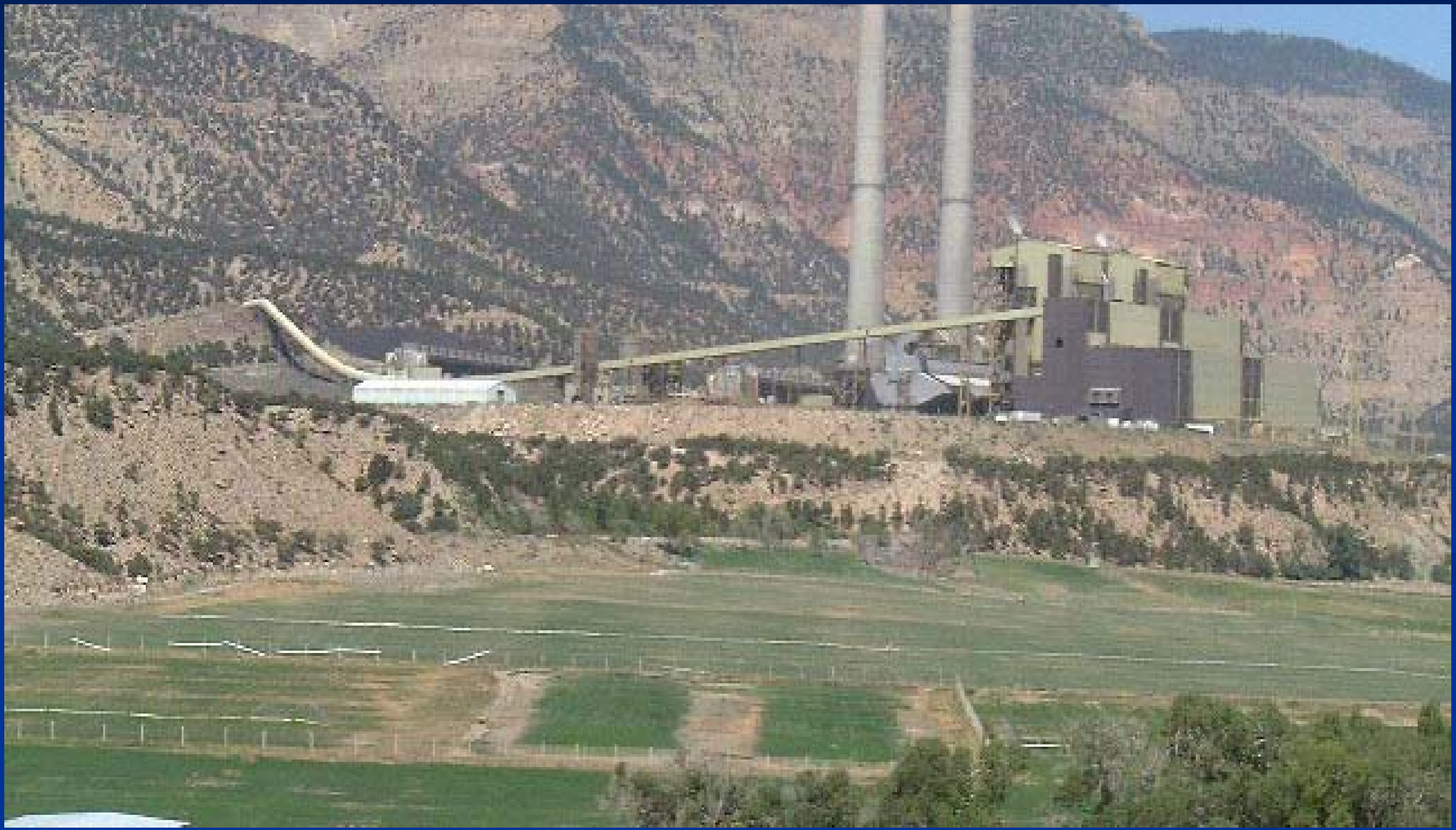
- Two line source sprinkler systems.
  - One waste water
  - One fresh water

Experimental Design



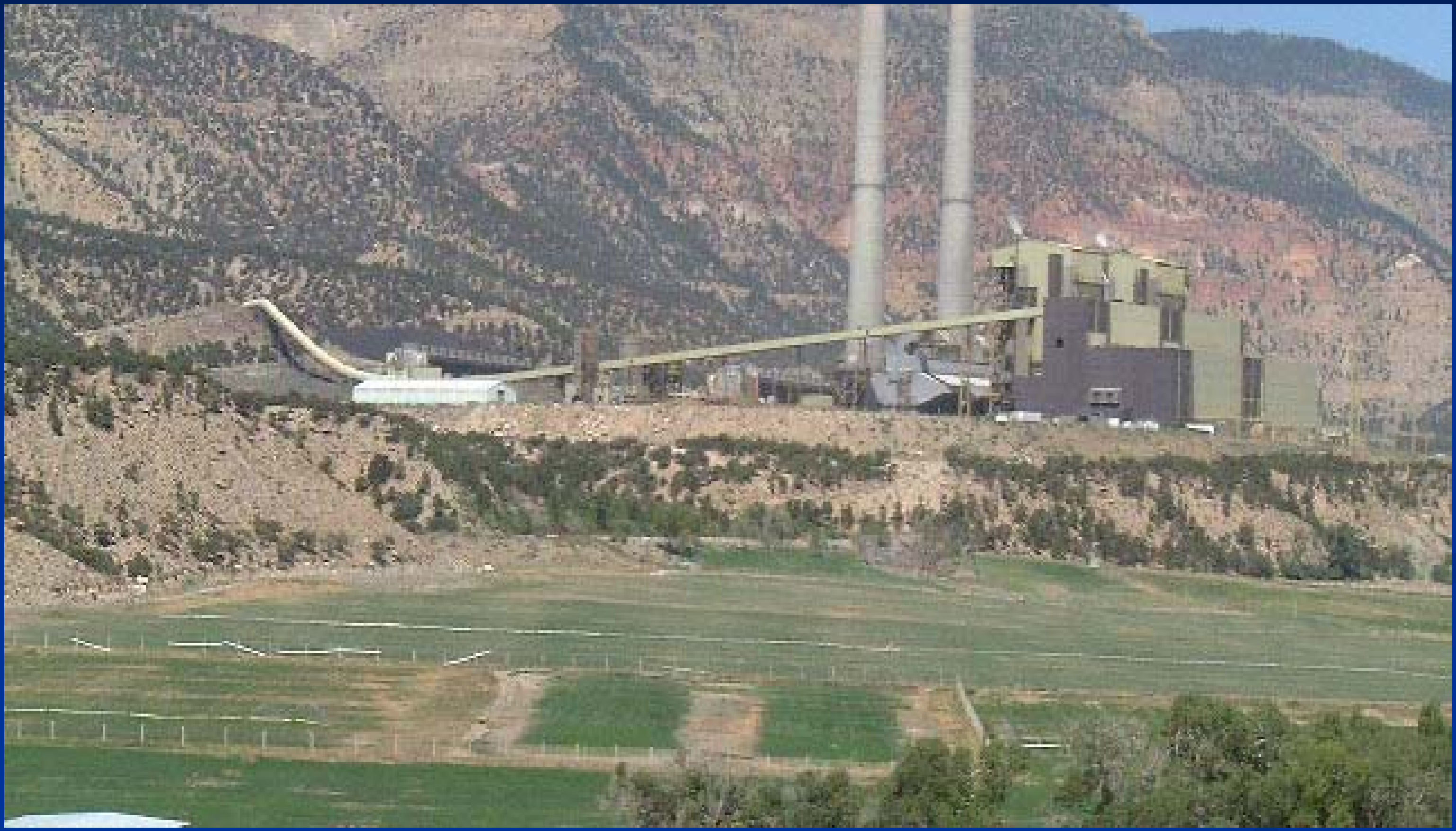
- Six irrigation levels on either side of line source.

Experimental Design



- **Water level 4 is approximately equal to no leaching beyond the root zone.**

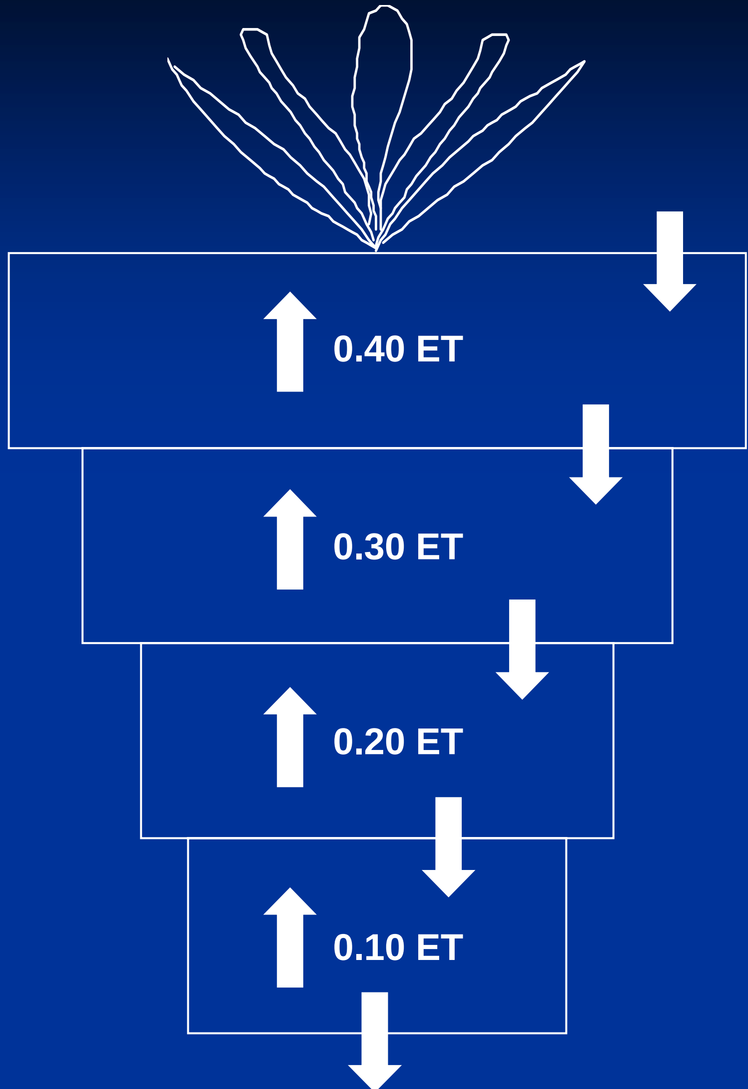
Experimental Design



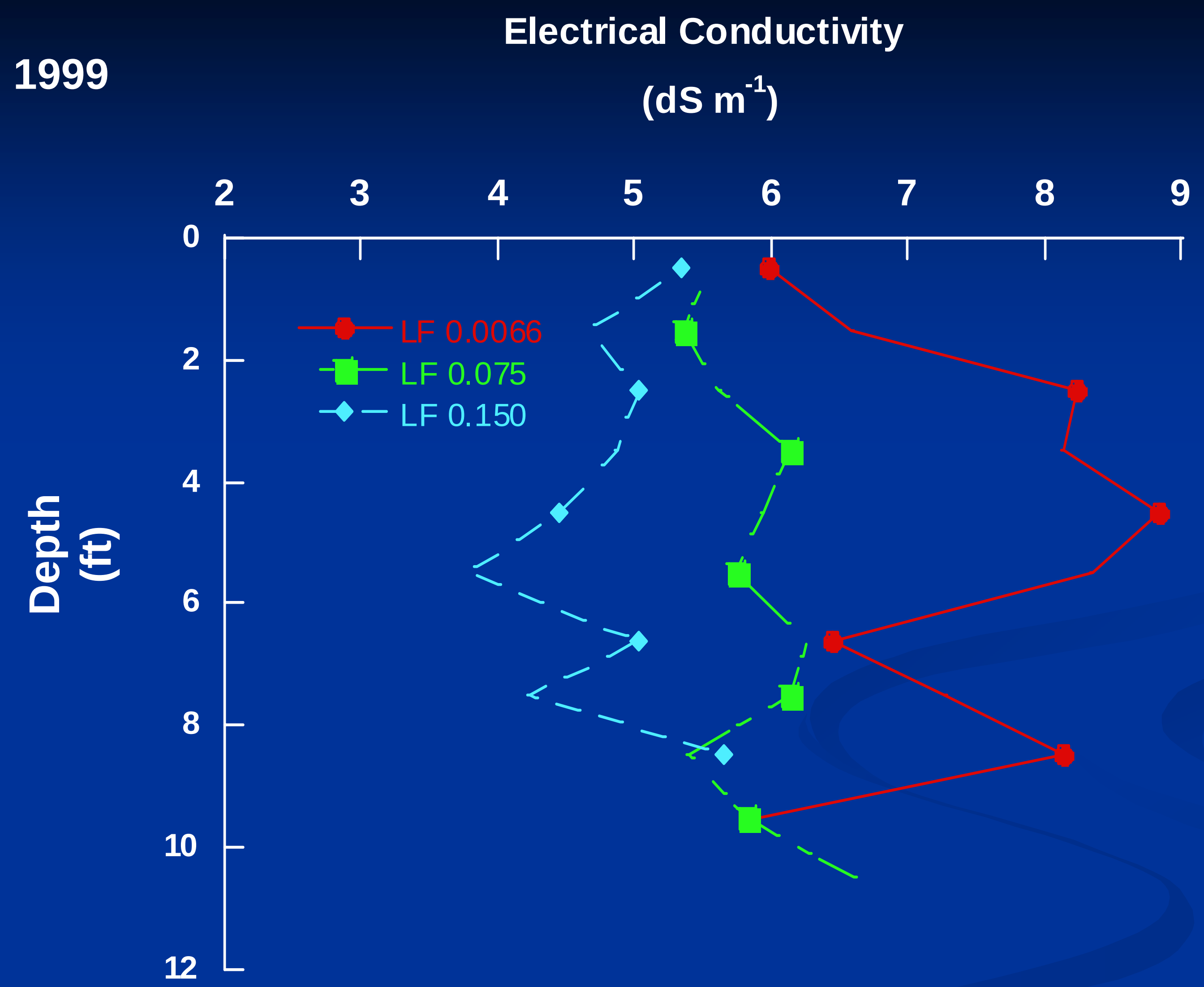
- Water level 5 = LF 0.075
- Water level 6 = LF 0.15

Properties of Waste Water

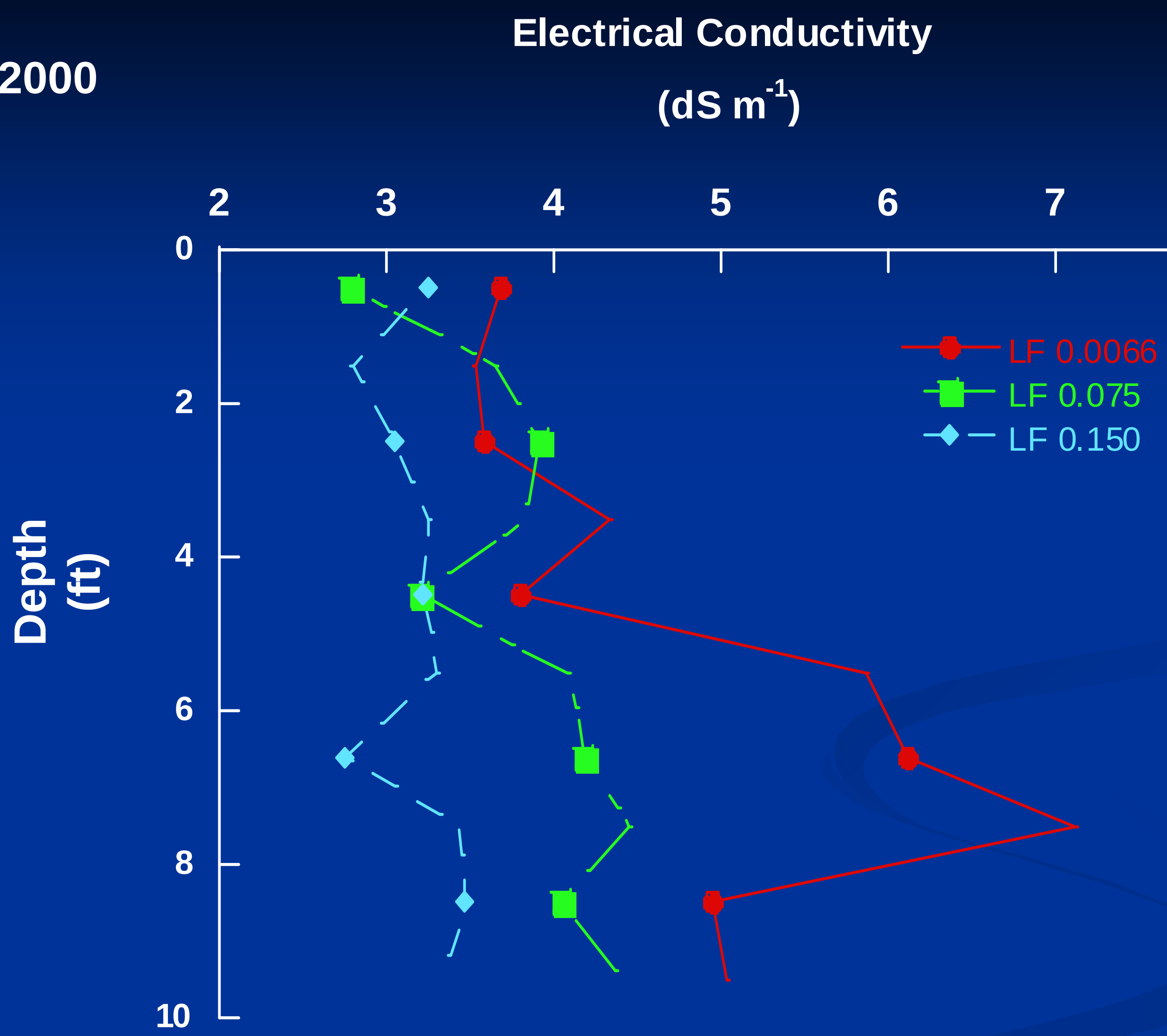
	Concentration ($mg\ L^{-1}$)
Ca	410
Mg	158
Na	268
K	13.2
SO_4	1629
Cl	276
B	317
EC	4.3 $dS\ m^{-1}$



	LF= 0.0066	LF= 0.075	LF= 0.150
	EC_0 = 4.3 dS m^{-1}	EC_0 = 4.3 dS m^{-1}	EC_0 = 4.3 dS m^{-1}
	LF_0 = 1.00	LF_0 = 1.00	LF_0 = 1.00
	EC_1 = 7.1 dS m^{-1}	EC_1 =6.83 dS m^{-1}	EC_1 = 6.5 dS m^{-1}
	LF_1 = 0.602	LF_1 = 0.63	LF_1 = 0.66
	EC_2 = 23.2 dS m^{-1}	EC_2 = 19.4 dS m^{-1}	EC_2 = 16.3 dS m^{-1}
	LF_2 = 0.300	LF_2 = 0.353	LF_2 = 0.40
	EC_3 = 221 dS m^{-1}	EC_3 = 116 dS m^{-1}	EC_3 = 71.0 dS m^{-1}
	LF_3 = 0.110	LF_3 = 0.170	LF_3 = 0.23
	EC_4 = 33,000 dS m^{-1}	EC_4 = 1,541 dS m^{-1}	EC_4 = 472 dS m^{-1}
	LF_4 = 0.0066	LF_4 = 0.075	LF_4 = 0.15
ARZS	6650 dS m^{-1}	338 dS m^{-1}	114 dS m^{-1}


1999
Electrical Conductivity
(dS m-1)
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
Depth
(ft)
LF 0.0066
LF 0.075
LF 0.150

2000



Electrical Conductivity
(dS m-1)
2
3
4
5
6
7
8
0
2
4
6
8
10
Depth
(ft)
LF 0.0066
LF 0.075
LF 0.150

Results

- Salts in solution are not accumulating as fast as predicted.
- $CaSO_4$ precipitation.
- Potential B, Cl, and Na toxicity.

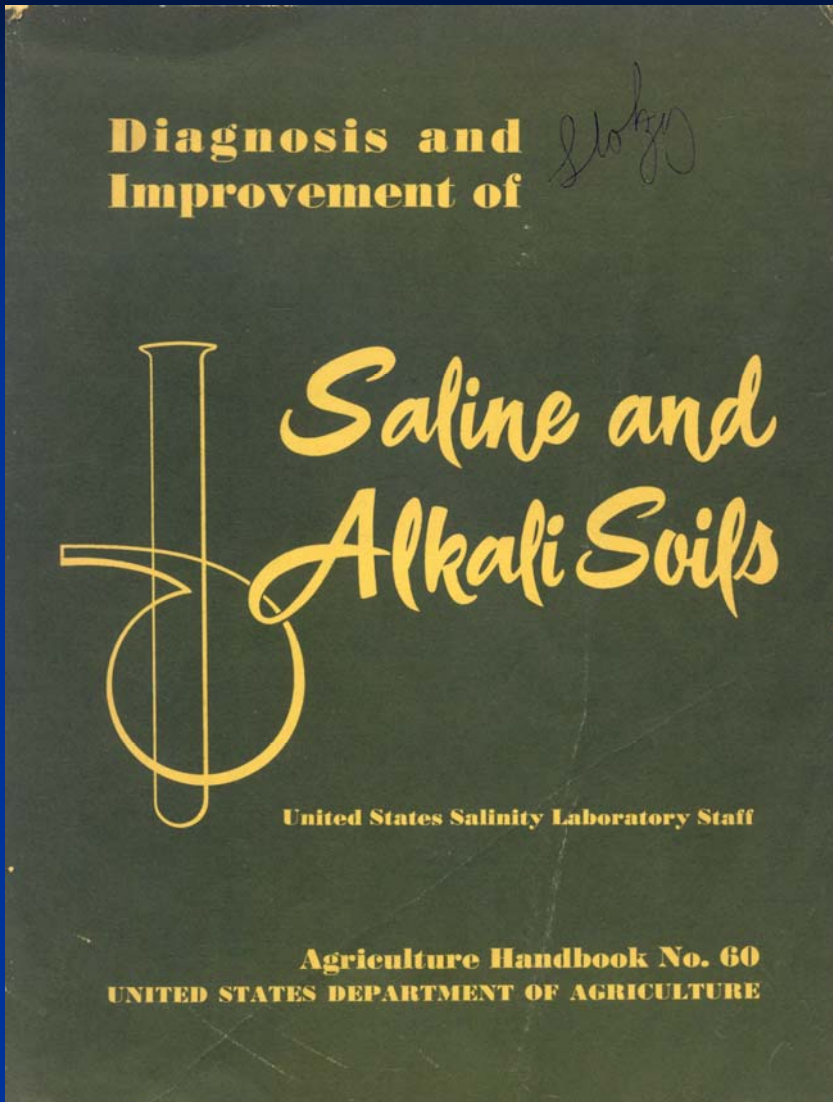
Managing Salinity and SAR

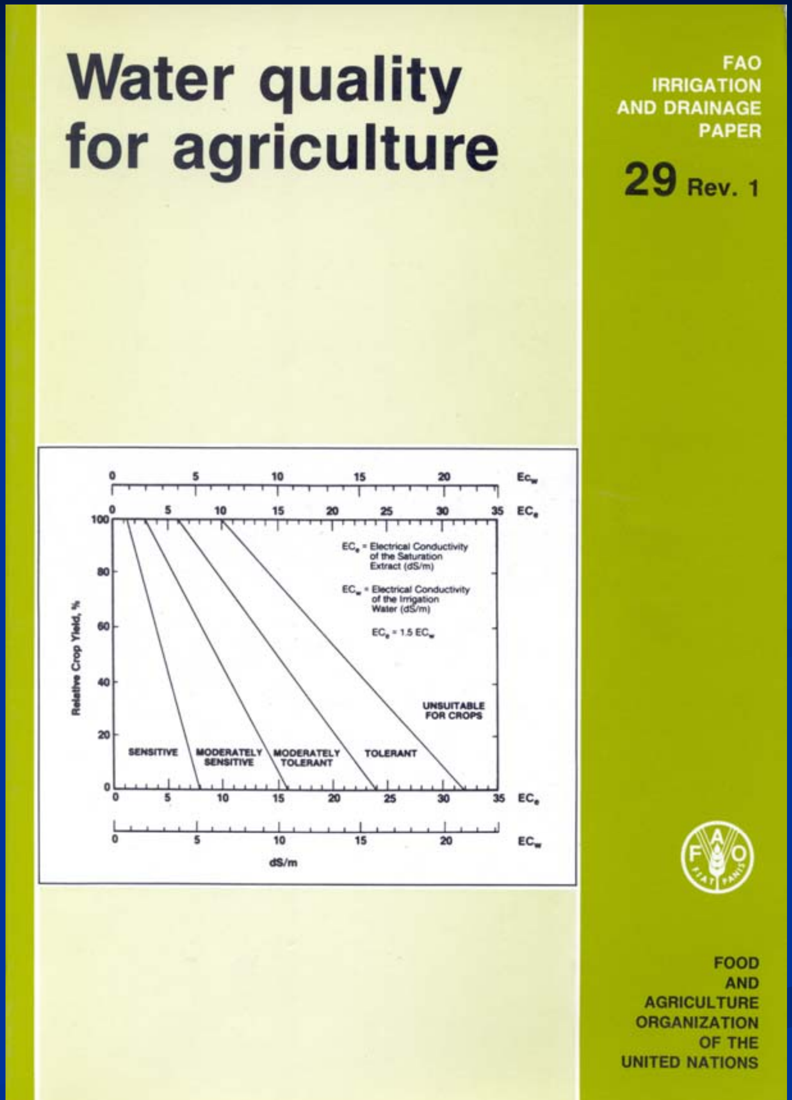
- Measure salinity often
- Monthly samples for SAR
  - Sodium, Calcium, Magnesium
- Quarterly sampling for toxicity
  - Boron, Sodium and Chloride
- Proper leaching fraction
- Replace sodium with polyvalent ions (Ca^{2+})

Managing Salinity and SAR

- Record Keeping

http://www.fao.org/docrep/003/T0234E/T0234E00.HTM





http://www.ars.usda.gov/SP2UserFiles/Place/53102000/hb60_pdf/hb60complete.pdf