Modernized Approach for Salt Impacted Soils: Final Results and Conclusions

Anthony Knafla (Equilibrium Environmental Inc.)

Introduction

- **OUTLINE OF APPROACH**
  - Site Characterization
  - Use of Subsoil Salinity Tool (SST)
    - Assessment of Excavation and Influence on Objectives
  - Examine Use of Groundwater for Salt Leaching
  - Examine Growth Potential of Various Species
  - Examine Phytoremediation Potential
- **ACKNOWLEDGEMENTS**
  - Equilibrium team
    - Mike Callaghan, Greg Huber, Jillian Carey, Sunita Ranganathan, Dr. Konstantinon Vasilakos
  - AENV & PTAC – SST
  - Talisman Energy
    - NAL Oil and Gas Trust (Cost Sharing Partner)
  - Matrix Solutions Inc. (Groundwater, SCADA)
  - Strata Environmental (Soil Investigations, Remediation Activities Coordination)

SST - Site Characterization

- **Proposed general requirements**
  - Geophysical survey
  - Rigorous background characterization (n=4 to 8 boreholes)
  - Textural analysis
  - Deep drilling
  - Groundwater (elevations, conductivity, gradient)

- **Not currently proposed as a requirement, but useful**
  - Nested piezometers

- **Certain issues remaining to be resolved**
  - Background chloride concentrations
    - Current value is 100 mg/kg
    - Certain environmental conditions can lead to greater values
    - Intermittent slough soils (300 mg/kg?) – may be associated with high sulfate
    - Poses a challenge for defining area of impact
  - Risk-based co-contaminant (boron) guideline
  - Literature based approach to a possible SAR guideline

SST & Excavation Scenario Module

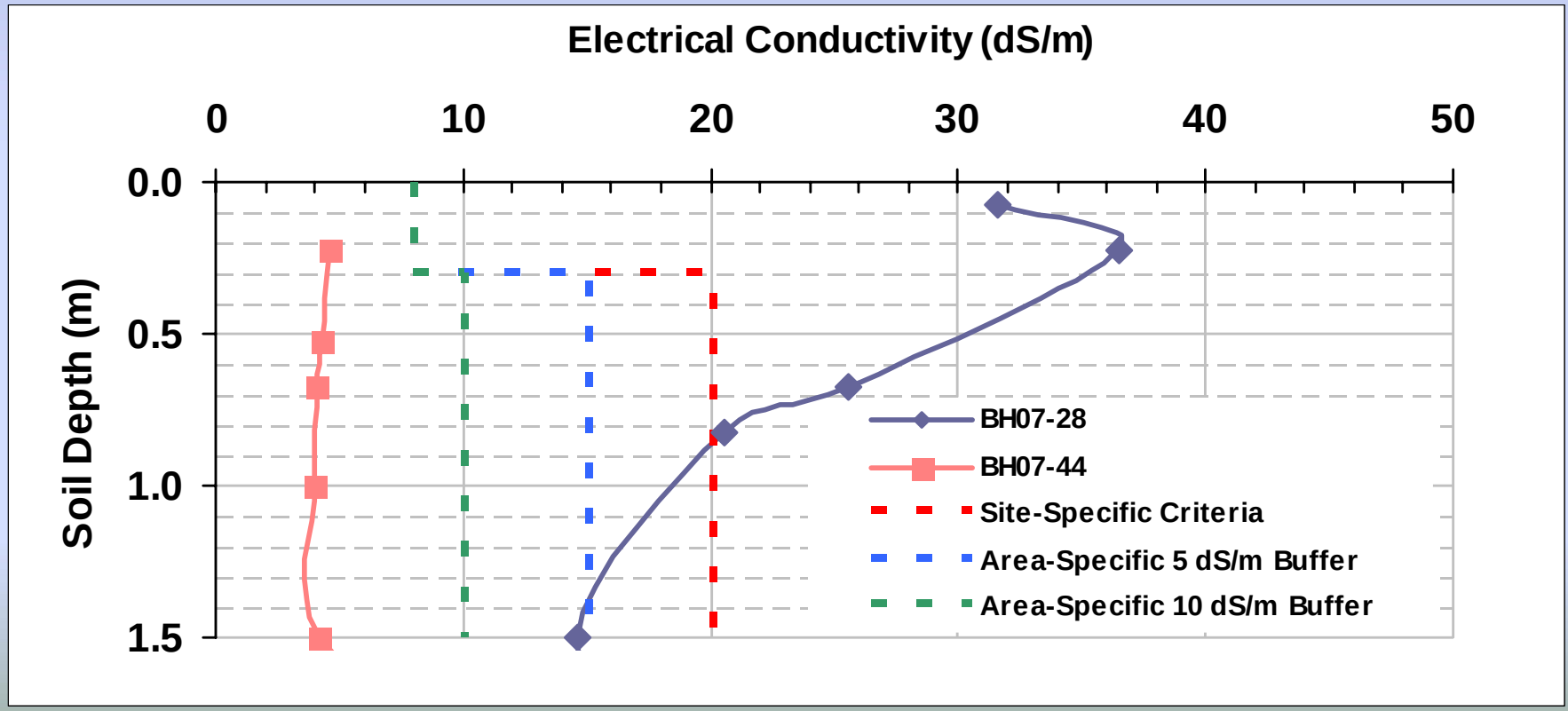
- **Current developing and beta testing SST**
  - **guideline development**
  - **site-specific application by proponents**

- **New version release with an excavation scenario module**
  - **Anticipated release - end of November, 2007**
  - **Allows user to assess volumes of soil requiring excavation to meet site-specific guideline values**
  - **Certain software glitches fixed**
  - **Natural region tool**
  - **Individuals interested in beta-testing can download the software at www.ptac.org**
  - **Guarantee improvement in ease of use when help file is read**
    - **Can save scenarios!**

SST Excavation Module

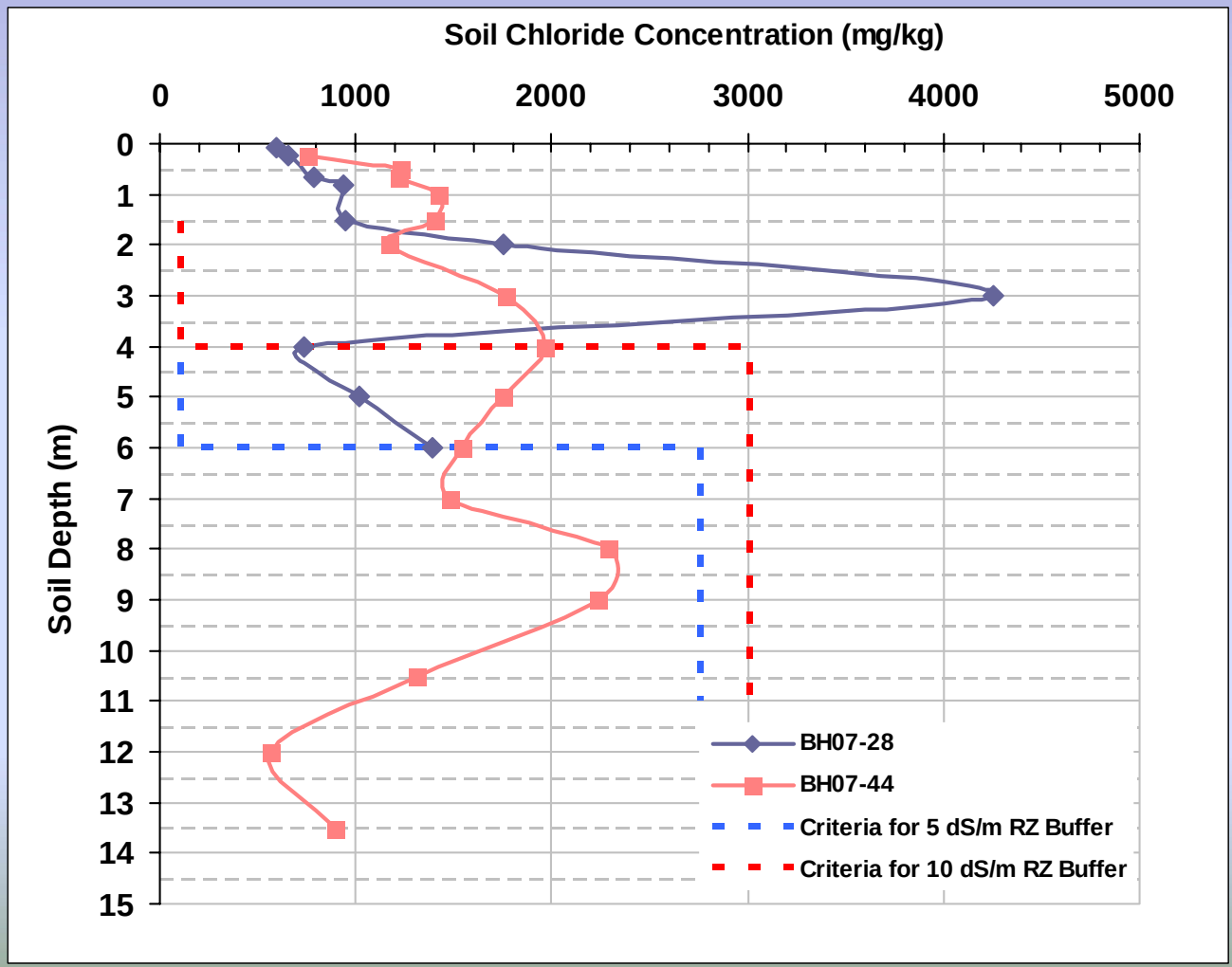
- Important to characterize backfill material
- Determines buffer
  - Greater reduction in excavation volumes in areas with naturally high salinity

Root Zone Salinity Profile



SST Excavation Module

- **Varying excavation depths depending on buffer size**
  - **Equivalent risk**
  - **Assess borehole by borehole**



Salt Leaching for Remediation

- **Talisman Energy**
  - Salt impacted site – excavation not feasible

- **Alternate approach**
  - Goal
    - Remediate root zone - equivalent use (plants, livestock pasturing)
    - Acknowledged that longer term control measures will be required
  - Groundwater collected in tile system as an irrigation source
  - Improve surface soil permeability for infiltration
    - Evaluation of manure versus compost incorporation
    - Establish plant growth in high EC soils – macropore formation
  - Assess relative contribution to plant toxicity (salts, boron)
  - Evaluate phytoremediation potential
  - Evaluate growth of a variety of agricultural plant species

General Site Improvement

– BEFORE (2004)

(AFTER – 2007)

Grassy Knoll

Mostly Weeds

Agricultural Species Plots

Treatments

- Manure or Compost
- Tilled
- Seeded
  - -Barley, alfalfa, wheatgrasses, brome

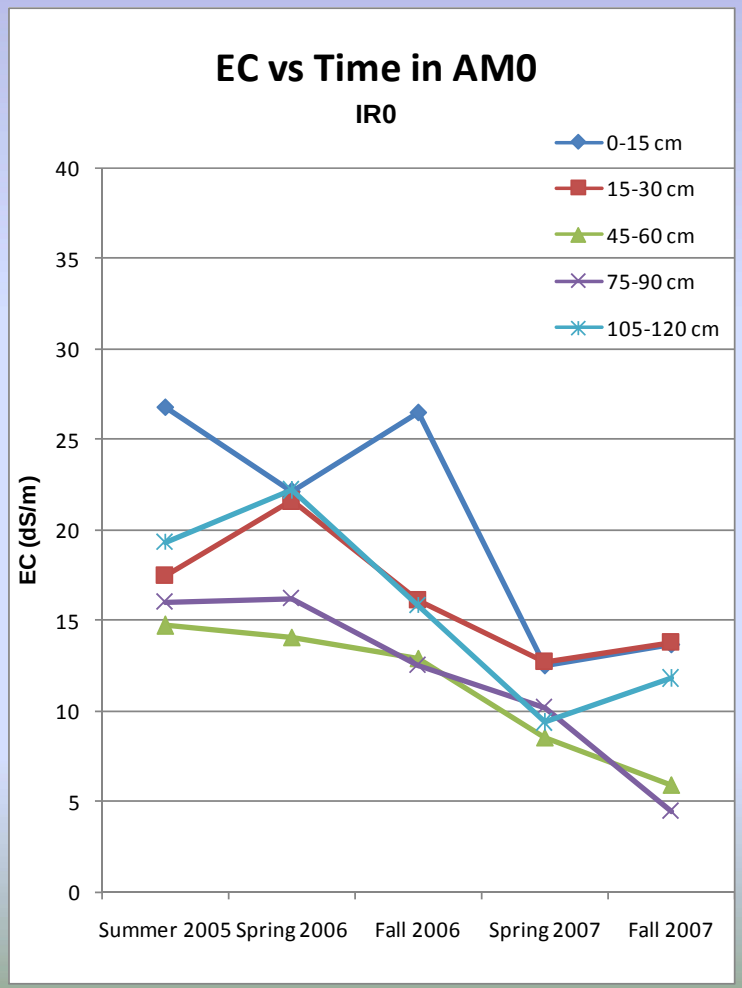
2006 Assessment - Irrigation Rates

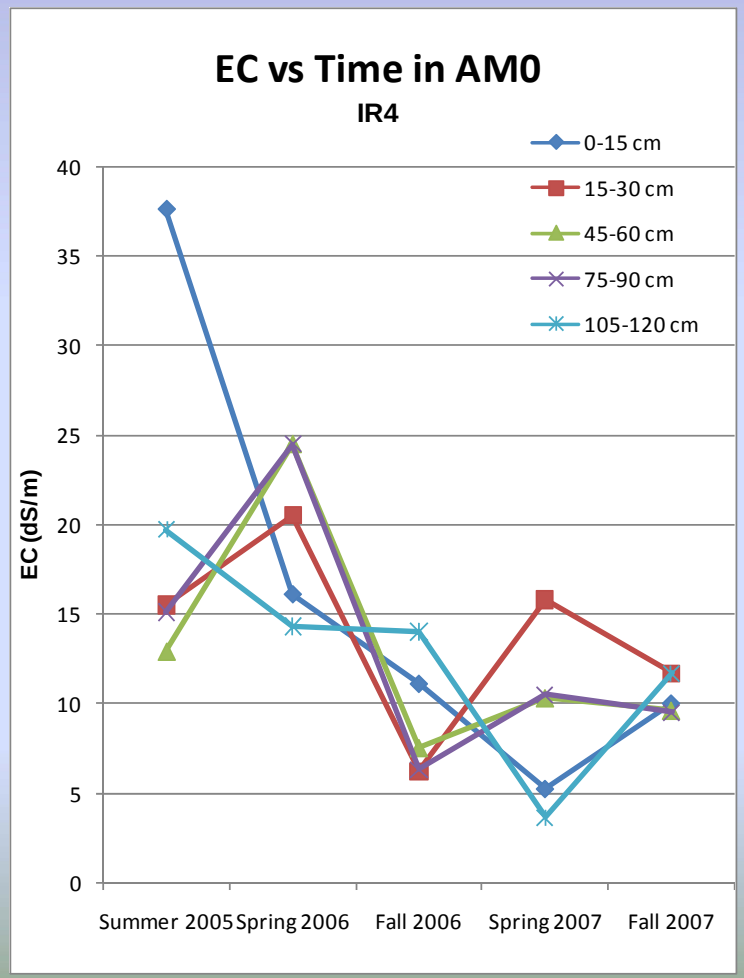
- **Irrigation water ~ 3,500 mg/L TDS**
  - **note – not groundwater – trucked from nearby ('05 to 07' experiment)**
  - **Similar salinity, applied at same Talisman site**
  - **IR0 (none), IR1 to IR4 – increasing irrigation rates**
  - **Significant decrease in shallow soil EC and boron (0 to 30 cm)**
  - **Boron may be leachable**
  - **Arguable difference between non-irrigated and irrigated plots**
  - **Although improved growth was observed with irrigation**

Ammendment and Irrigation		Summer 2005 Average EC 0-30 cm (dS/m)	Summer 2005 Average Boron 0-30 cm (mg/kg)	Fall 2007 Average EC 0-30 cm (dS/m)	Fall 2007 Average Boron 0-30 cm (mg/kg)	% change EC (%)	% change Boron (%)
AM0	IR0	22.2	3.3	13.8	1.6	**-38%**	**-51%**
	IR1	18.9	2.8	8.9	1.0	**-53%**	**-64%**
	IR3	42.7	2.9	13.2	1.4	**-69%**	**-51%**
	IR4	26.6	3.7	10.9	1.2	**-59%**	**-68%**
AM1	IR0	30.6	4.3	10.6	2.4	**-66%**	**-45%**
	IR1	20.1	4.6	8.1	4.9	**-60%**	**8%**
	IR3	18.2	3.8	9.3	5.7	**-49%**	**52%**
	IR4	25.6	5.3	13.3	3.2	**-48%**	**-39%**

Irrigation with Slightly Saline Water

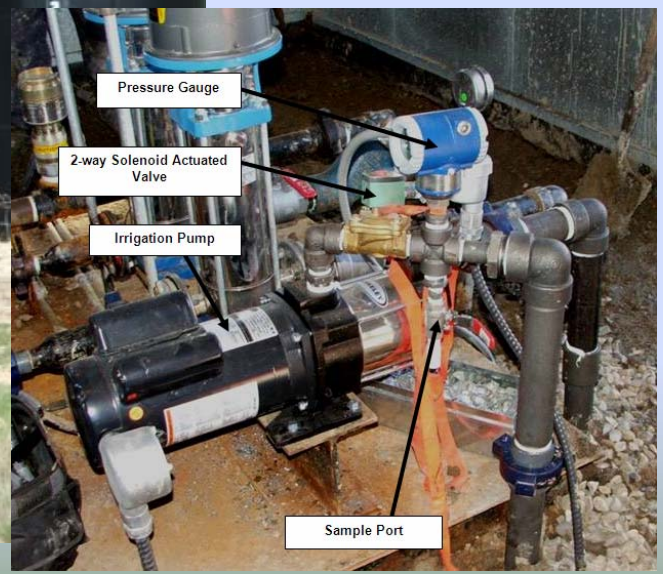
- Greater trends of decreasing salts at deeper depths with irrigation
- By fall of '07, EC values generally < 15 dS/m – close to background
- Slight rebound post irrigation (2007) – groundwater control
- Minimal decreases seen in untreated plots lacking growth





Use of Groundwater for Irrigation

- Collection and pumping system designed by Equilibrium & Talisman
- Groundwater collection and storage for irrigation
- Matrix incorporated into the infiltration gallery and SCADA system

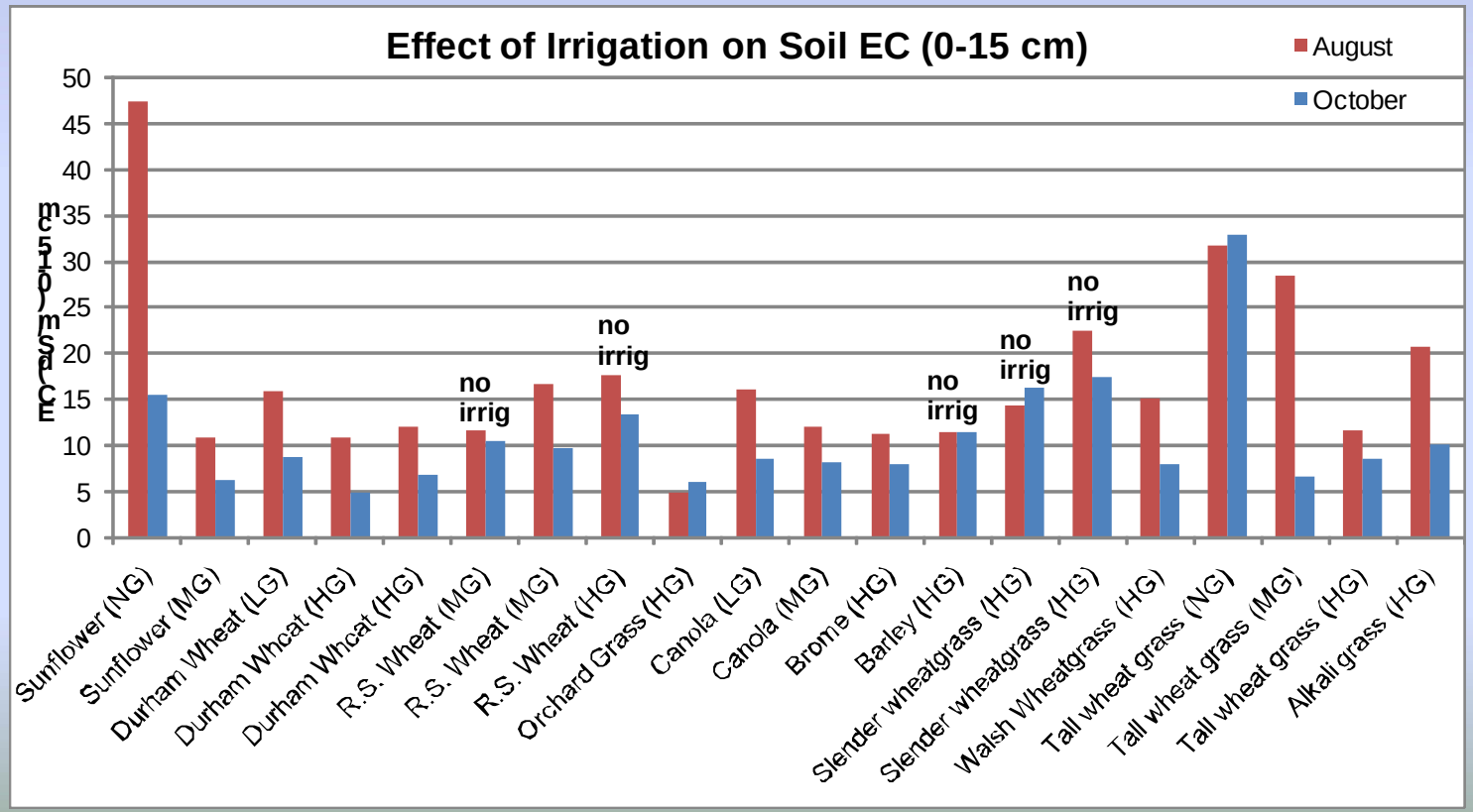


Use of Groundwater for Irrigation

- Groundwater collected when TDS < 3,800 mg/L
- Groundwater TDS ranged seasonally - 2,800 to 6,500 mg/L
- Water collected Mid June to End of June (15 days)
- Rapid pumping – up to 100 cu.m/day
- System could refill during the spring, summer, early fall
  - takes advantage of intermittent decreases in groundwater TDS
  - Provides a greater volume of irrigation water
- Irrigation application rate
  - 4x per day (beginning of program)
  - 8x per day (fall) to drain tanks
  - Averaged program irrigation rate of 16 mm/day

Irrigation with Saline GroundWater

- Second irrigation plot area developed – use tank stored water
- Average TDS of irrigation water was 4,000 to 4,500 mg/L
- (boron of 1 mg/L ~ 2x guideline)
- Greatest reductions were in plots with higher EC values
- Some increase in SAR when baseline soil had SAR < 6
- General trends of decreasing salts with irrigation



Irrigation with Saline GroundWater

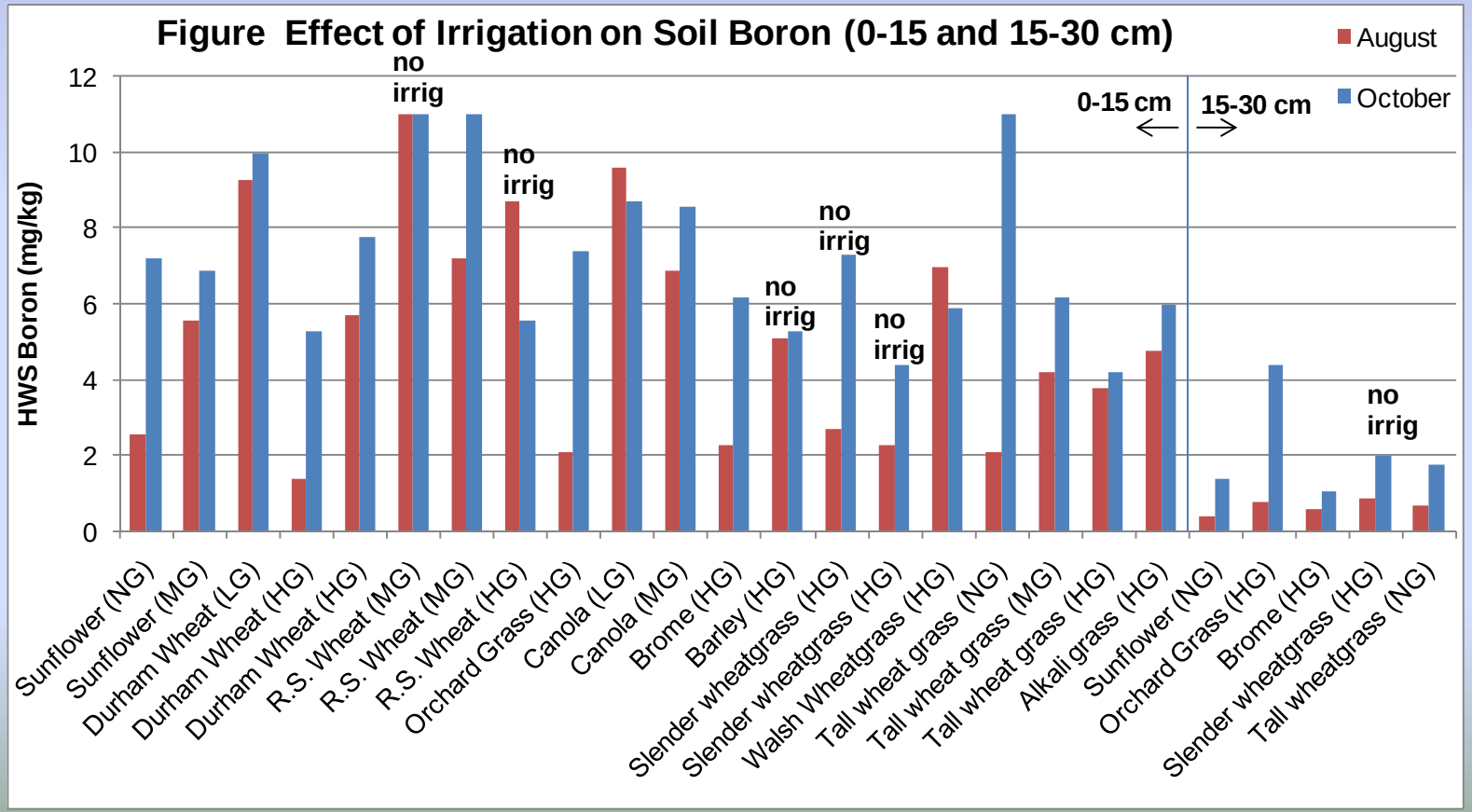
- Good growth obtained prior to irrigation
- Irrigation did not lead to significant plant dieback
- Growth of sunflower, alfalfa, Orchard grass, wheatgrasses (3 sp.), wheat (2 sp.), alkali grass, barley – due to amendments
- Weeds were outcompeted

Red Spring Wheat

Barley

Irrigation with Saline GroundWater

- Significantly elevated boron concentrations also present
- General observed increase in boron
  - From 2 to 6 - 8 mg/kg HWS) - at low baseline concentrations
  - variable results
- Careful monitoring required to use groundwater as irrigation water with boron concentrations > 0.5 mg/L (guideline)

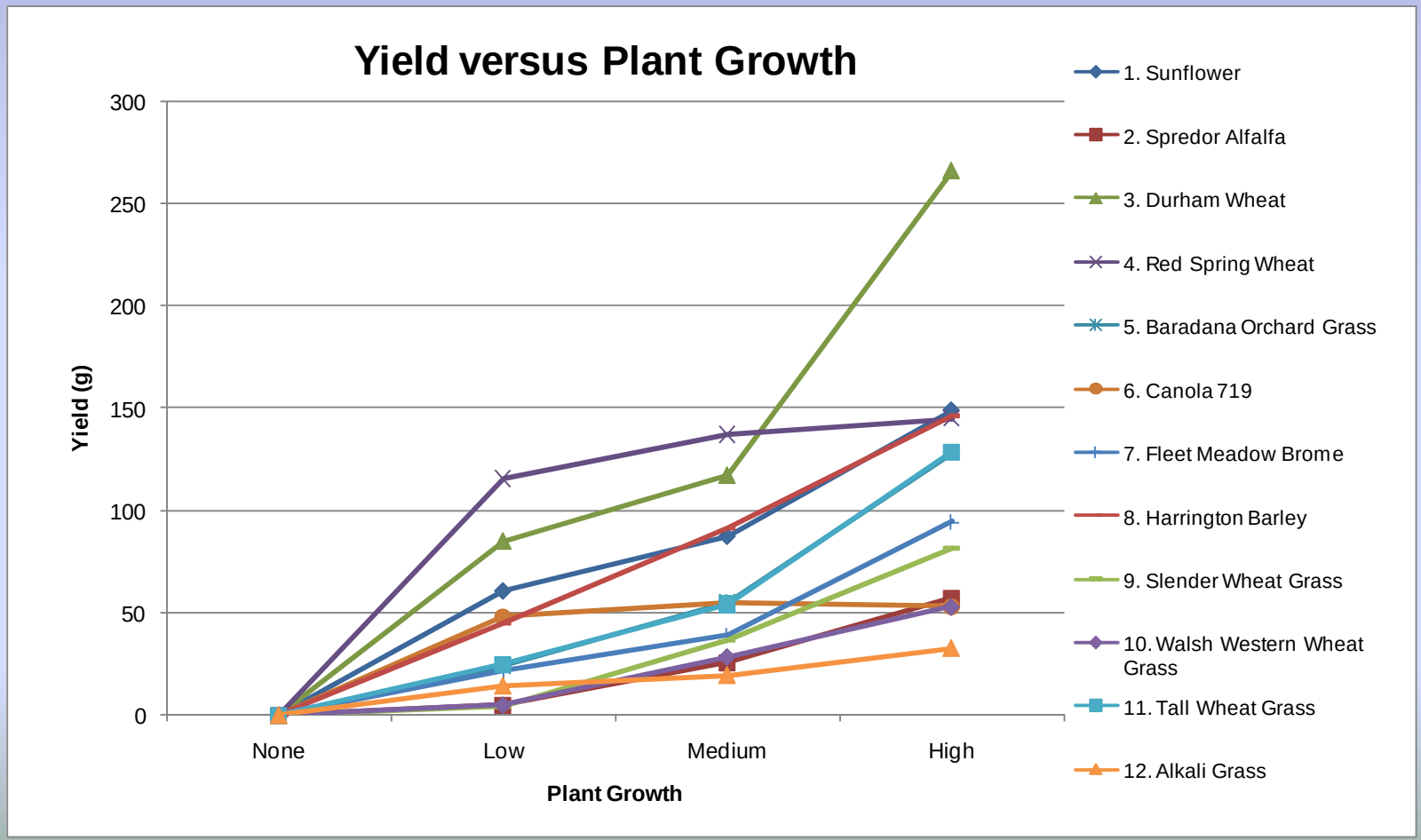


Boron

- Boron issue – concentrations ranging from 2 to 11 mg/kg HWS
- How can we address this issue?
- Change the guideline - of course!
- Examine plant growth (height and dry yield) of various species in soils with elevated EC values and boron concentrations
- Attempt to identify whether boron is inhibiting plant growth
- Attempt to identify any interactive effects between boron and salts
- Sampling from various species plots in areas of No, Low, Medium, and High Growth

Boron

- Plant height generally correlated with yield
- We focused on quantitative yield measurements



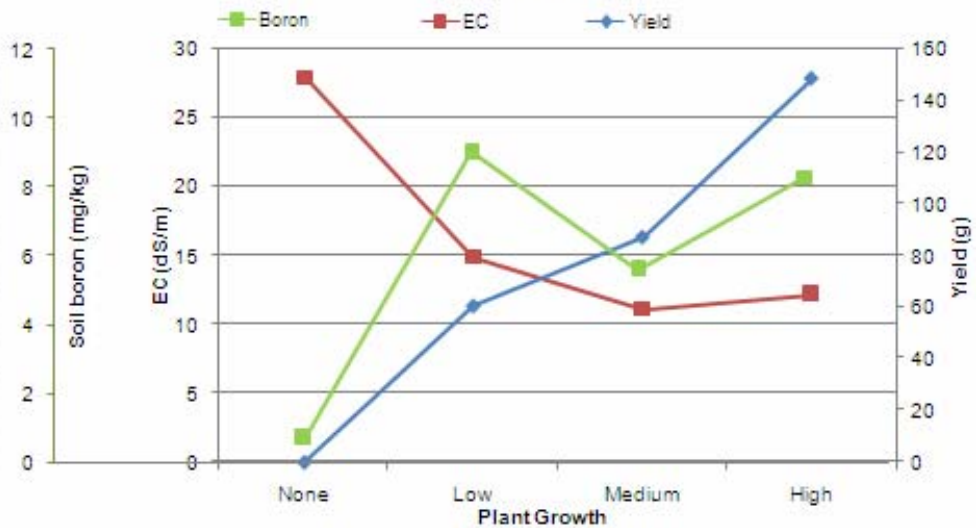
Sunflower Yield

- Good growth and seed head production for sunflower
- Increased growth with decreasing salinity
- Increased growth with increasing boron

Medium Growth

High Growth

Low growth



Sunflower Growth

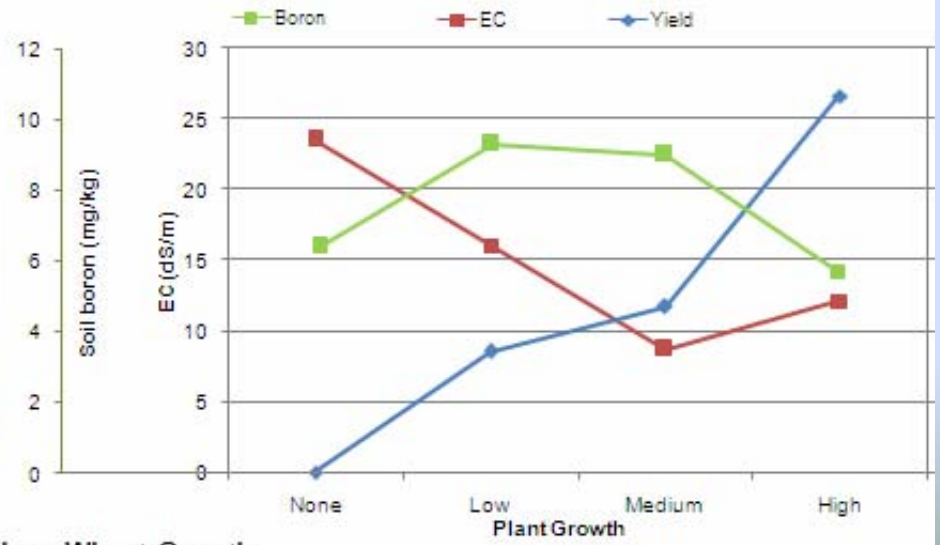
Durham Wheat Yield

- Good growth and seed heads for wheat – sensitive boron species
- Increased growth with decreasing salinity
- Possible increase in yield with boron decrease from 9 to 5.8 HWS

Medium Growth

High Growth

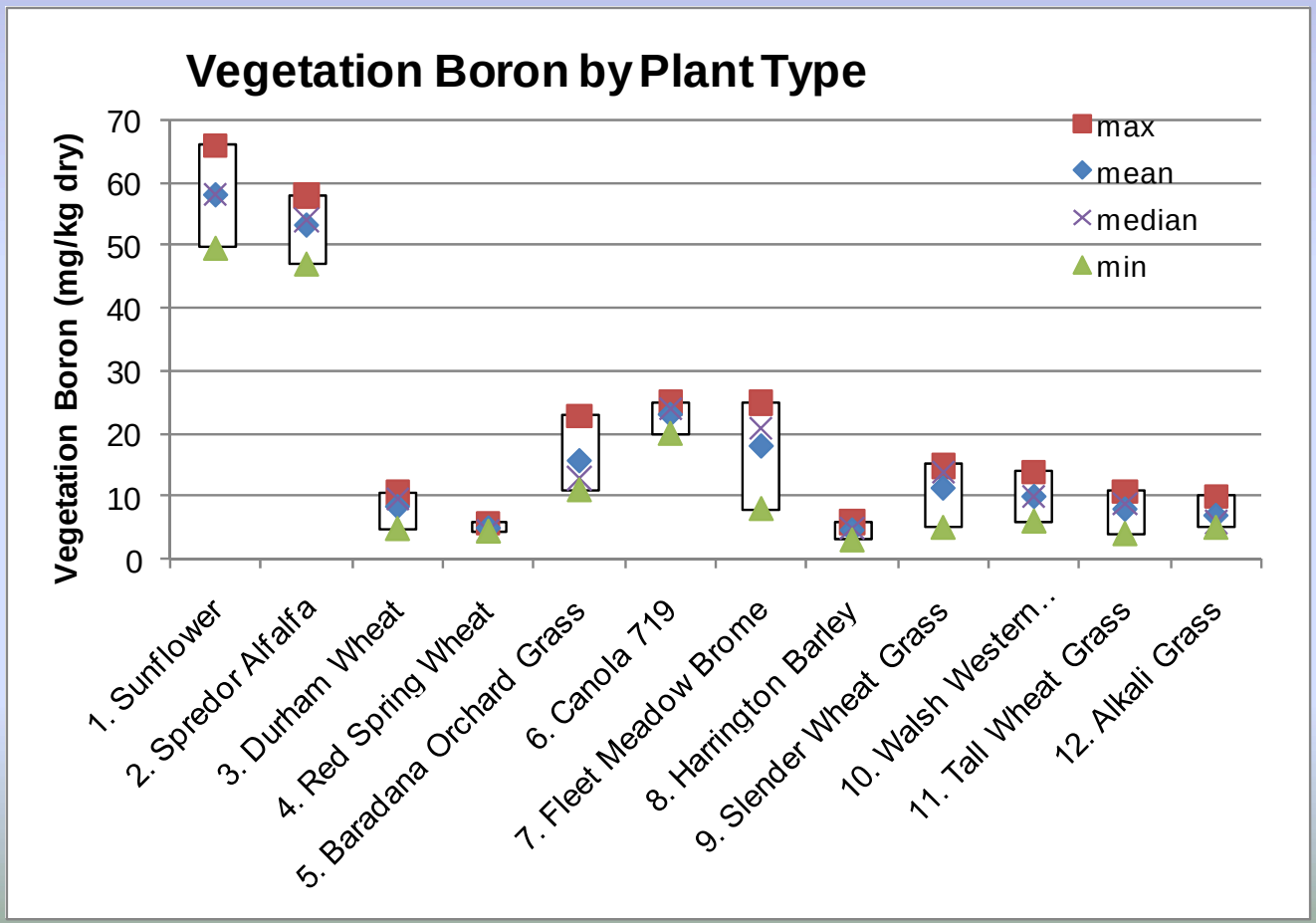
Low growth



Durham Wheat Growth

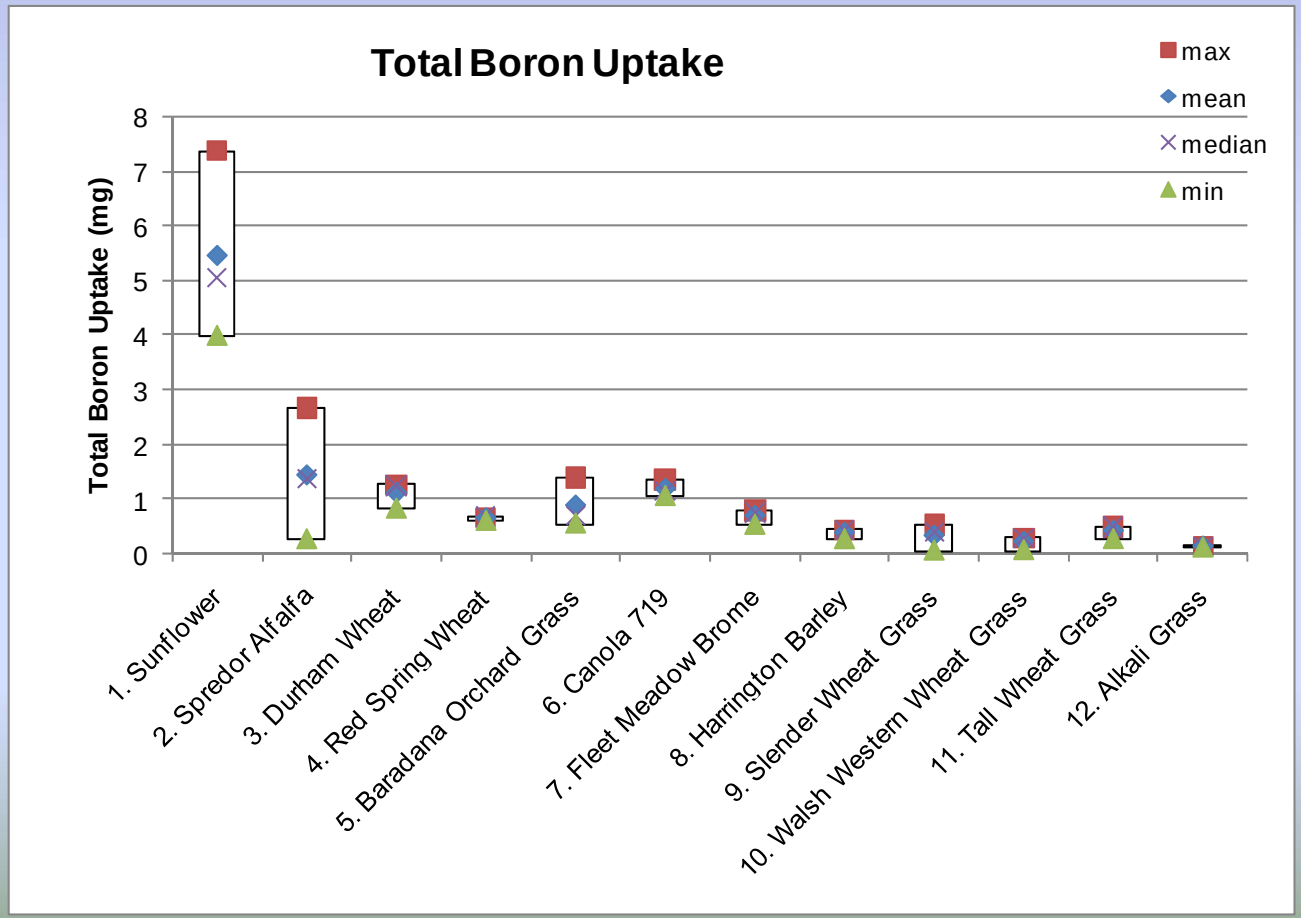
Boron Concentrations in Plants

- Greatest accumulators of boron – sunflower and alfalfa
- Boron in soil up to 10 mg/kg HWS - based on these plant species,
  - No unacceptable risks predicted for grazing livestock
  - important for equivalent land use
- Salts may be inhibiting boron uptake – 2x greater alfalfa boron concentrations (100 mg/kg dry) measured in soils up to 9 mg/kg boron



Boron Phytoremediation

- Based on concentration in soil, plant tissue, and plant yield
- Sunflower had 3x greater potential for boron phytoremediation
- > 10 years to remediate from 6 to 2 mg/kg HWS (3% decr./year)
- In absence of salts, accumulation may be greater (~10% decr./year)
  - Phytoremediation could be applied if salts leached to acceptable guidelines but boron concentrations remain above the guideline



Conclusions

- Get familiar with the SST
- Establishing plant growth by improving surface soil structure & nutrients may improve downward leaching
- Saline groundwater can be used to irrigate soils with high salinity and boron concentrations
- May allow natural precipitation to be more effective once plants have been established
- Careful baseline study required prior to irrigation to avoid increases in salinity
- Boron in saline irrigation water can be problematic at a concentration of > 0.5 mg/L (guideline)
- No clear signs of plant toxicity were observed with boron increasing from 2 to 10 mg/kg HWS
- HWS boron may not be the most appropriate measure of soil concentrations that may be toxic to plants
- Boron phytoremediation appears limited in the presence of salts – may be a feasible approach at low soil salinity