Measuring Effectiveness of Phytoremediation for a TCE-Contaminated Groundwater Plume Using Sap Flow Instrumentation

Third International Phytotechnologies Conference Atlanta, GA
April 2005

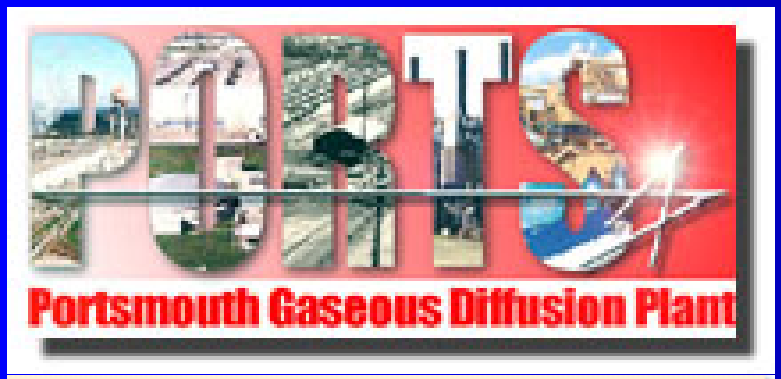
Presentation Plan

- Site Setting and History
- Monitoring Methods
- Sap Monitoring Results
- Conclusions

Site Setting and History

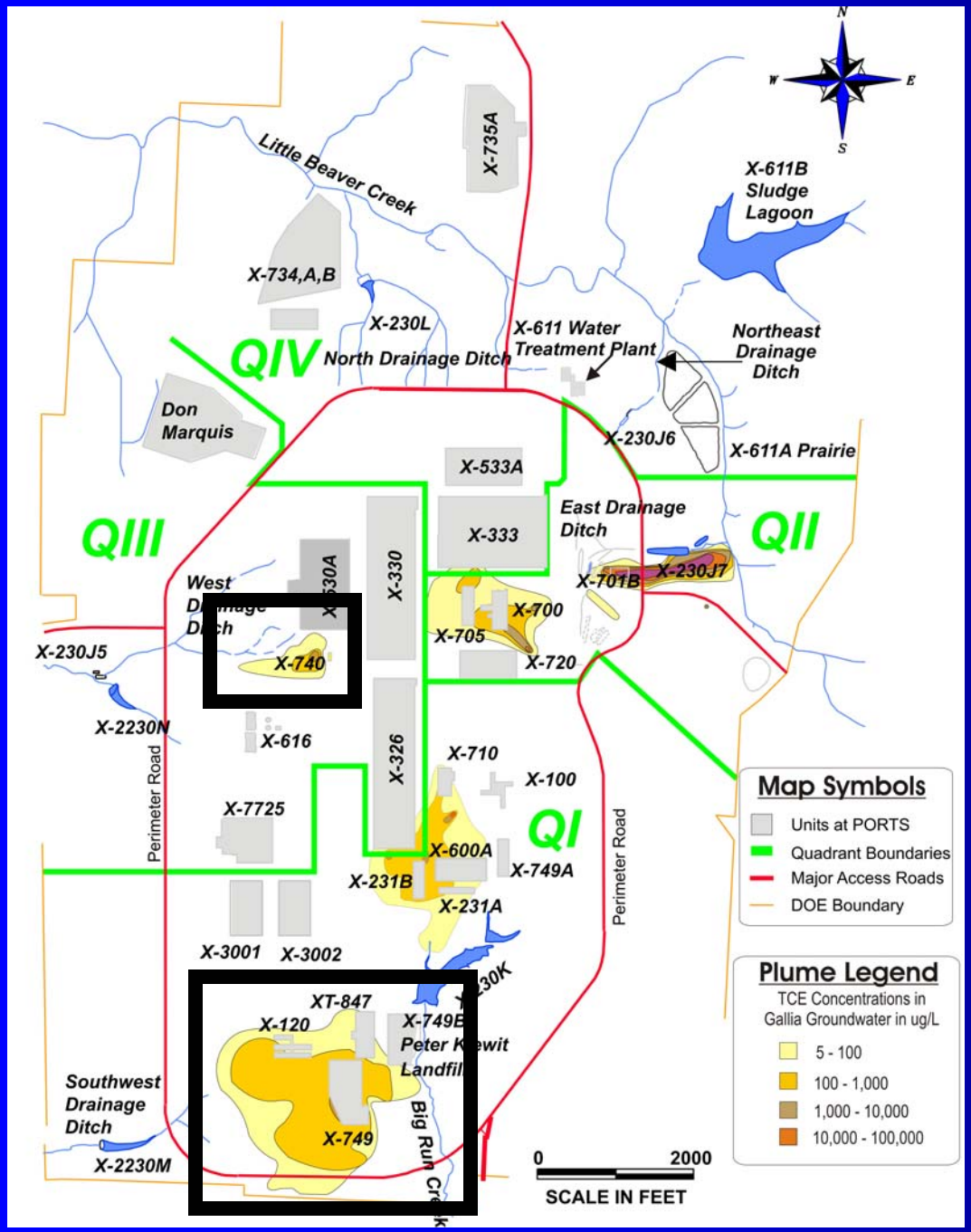
Portsmouth Uranium Enrichment Facility

Site Location



Plant Construction 1952 - 1956

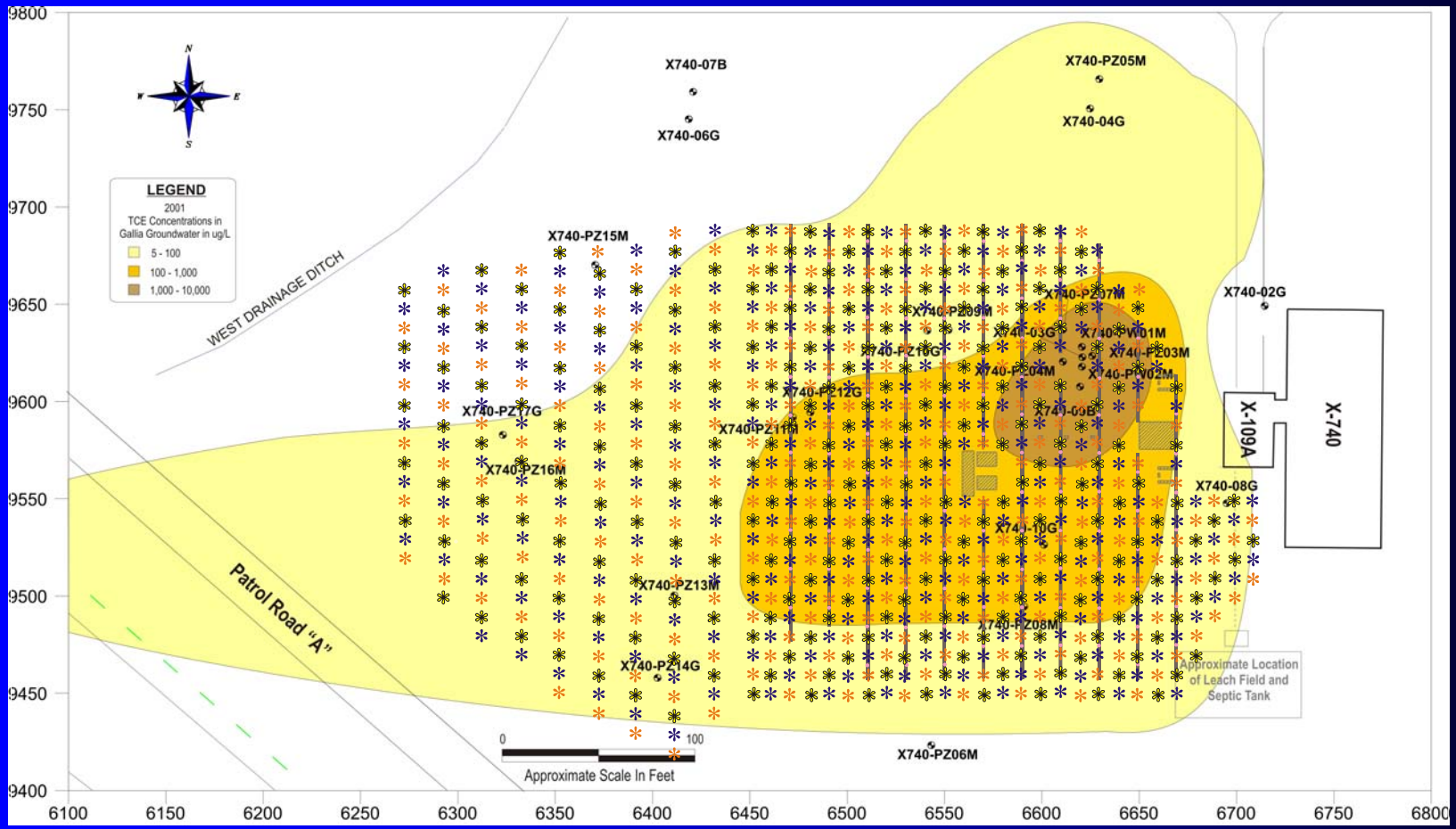
Uranium Enrichment Production Ceased - 2001



- 1990-1993 RCRA Facility Investigation identified five separate groundwater TCE plumes
- 1994-1997 Corrective Measures Study developed alternatives for remediation
  - –Phytoremediation selected for two plumes
    X-740 and
    X-749/X-120

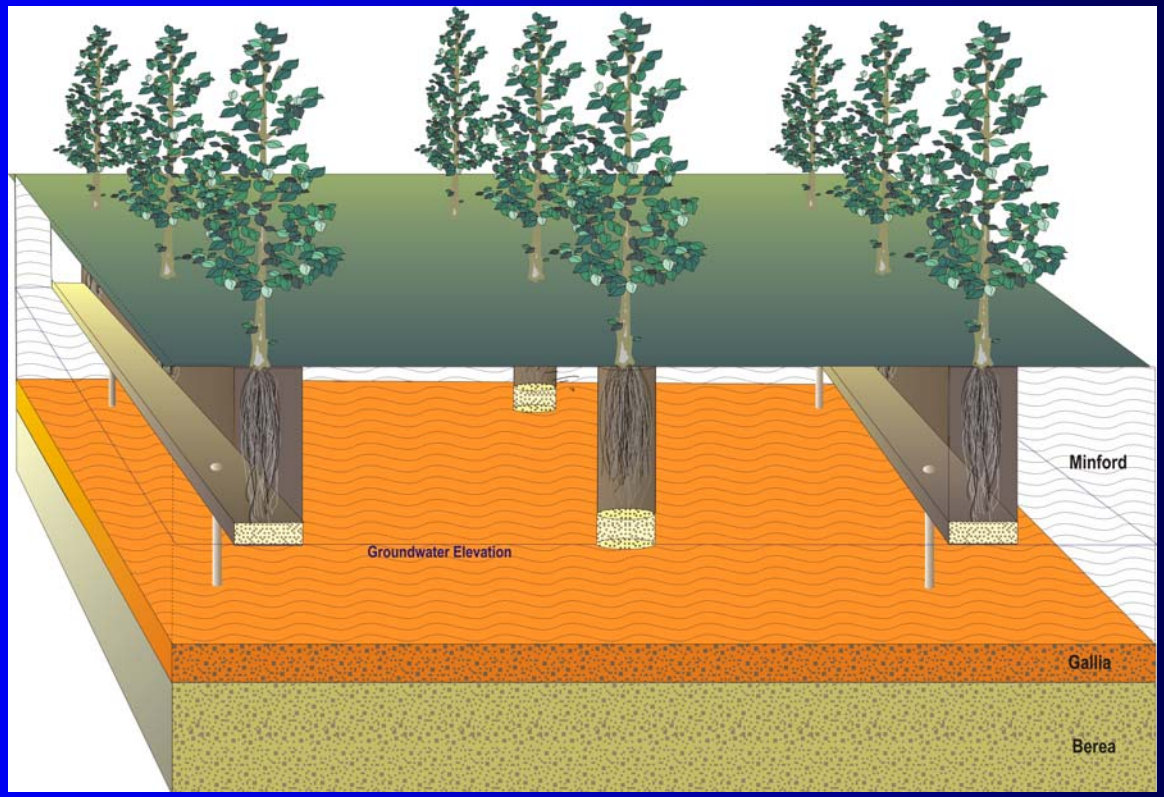
X-740 History

- 1952-1956 – Construction Switchyard (likely source)
- 1982-1992 – X-740 Waste Oil Handling facility operated
- 1999 – Phytoremediation System installed



X-740 Phytoremediation System

- Installed 113 8 in. dia. sand-filled borings 30+ ft to bedrock
- Planted 240 Trees in 2 ft wide trenches excavated 10 ft deep
- Remaining 526 trees planted in 2 ft diameter 10 ft deep borings
- Total Trees Planted 766



Installing Trenches at X-740 Phytoremediation Area

X-740 Tree Growth

First leaves appear by 6/3/99

(one week after planting)

X-740 Tree Growth

Some trees are 6 feet tall by 8/3/99

(9 weeks after planting)

X-740 Tree Growth

Same tree on 10/27/99

(22 weeks after planting)

X-740 Tree Growth

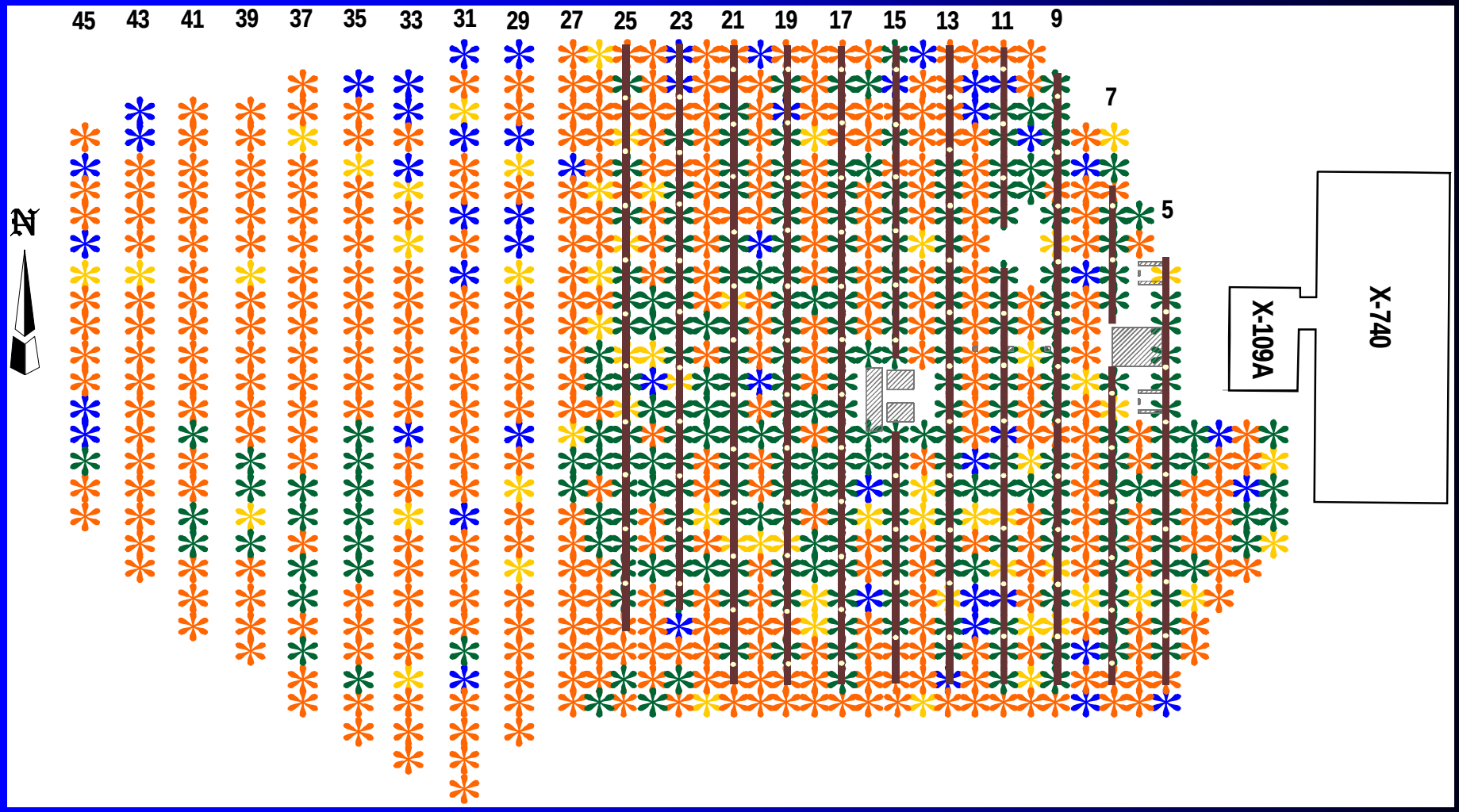
Same tree over 25 ft tall by 6/6/01

(two years after planting)

X-740 Tree Growth

Same tree 7/3/03 (five years after planting)

X-740 Tree Growth

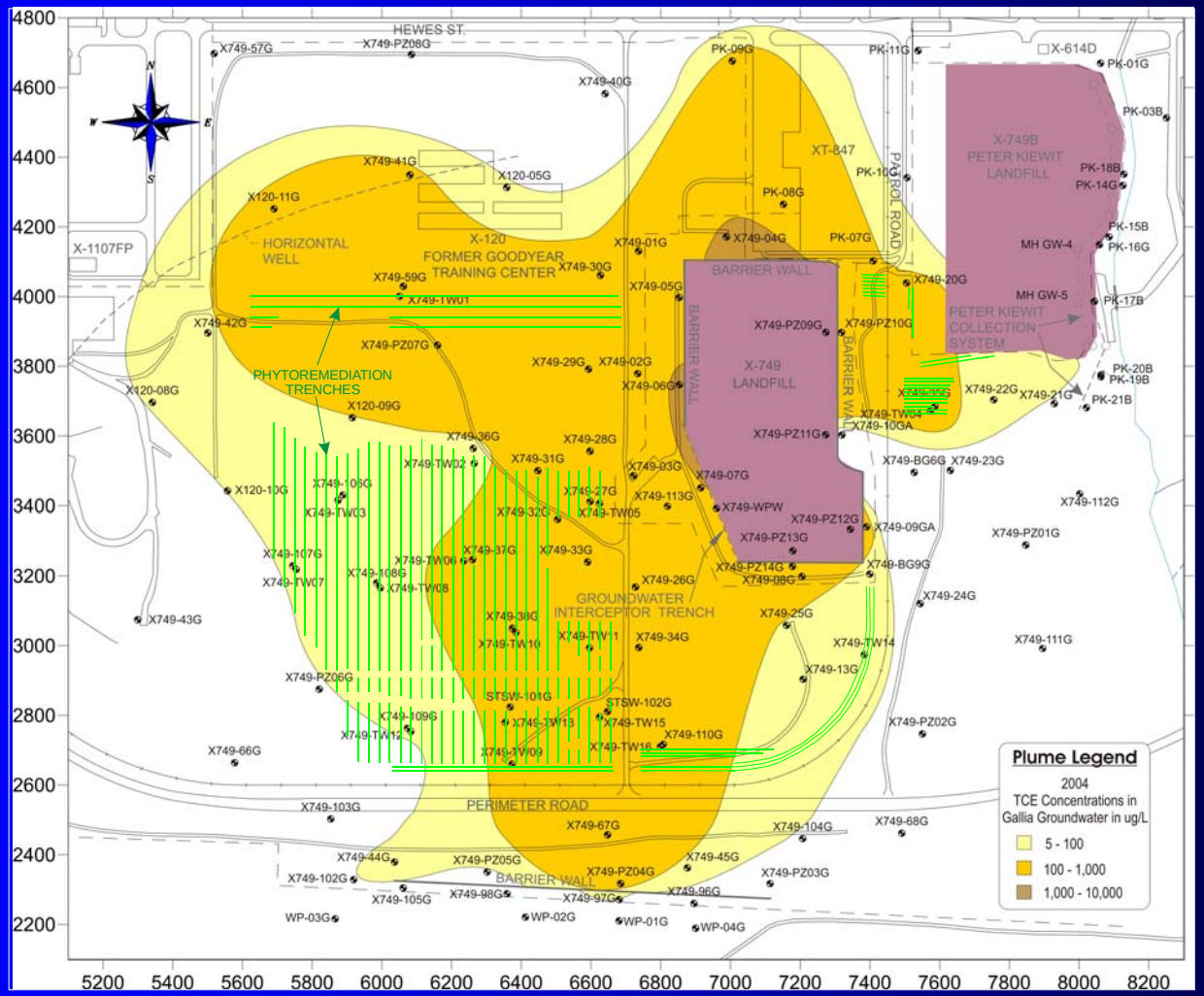


March 2005 Tree Diameter

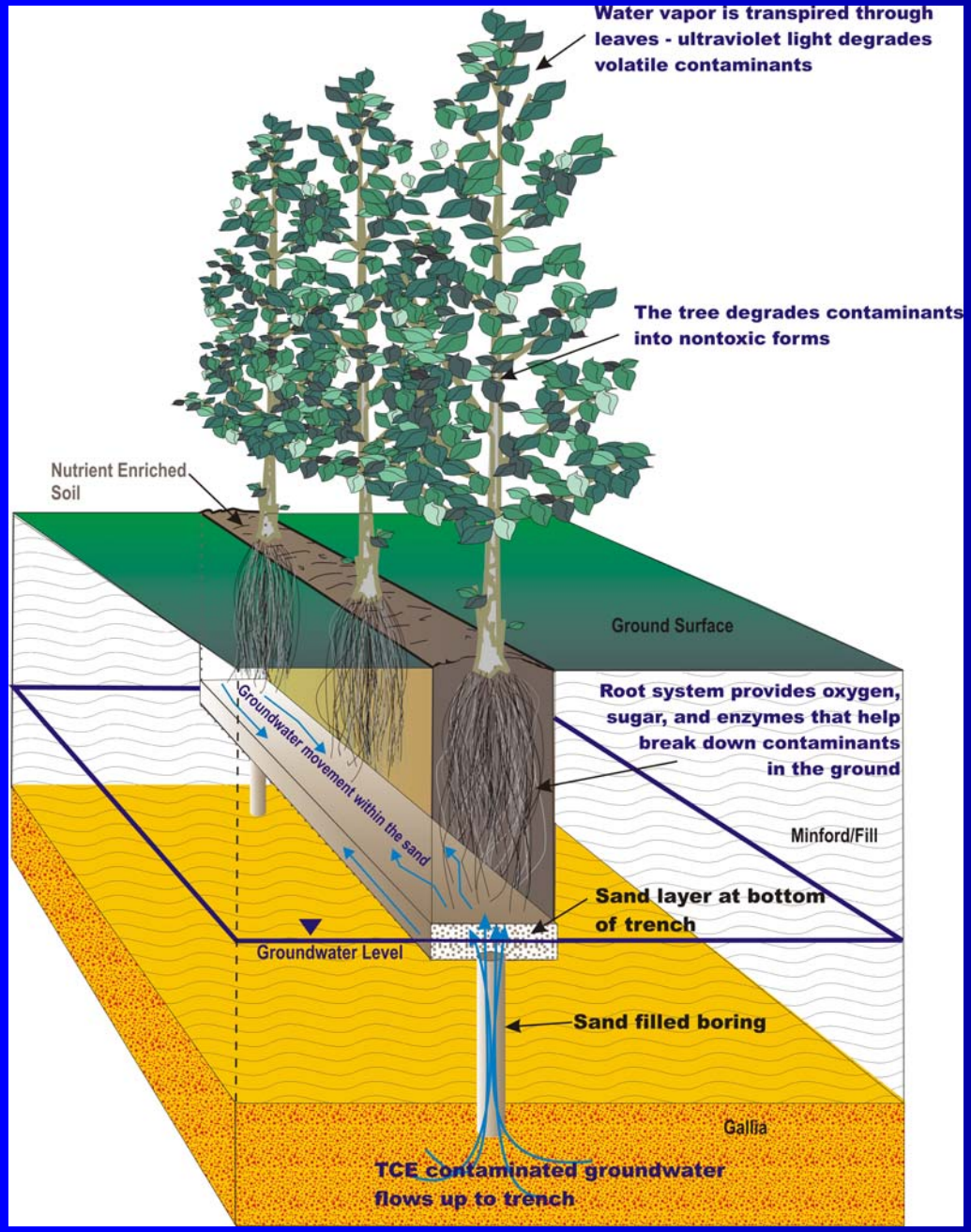
More than 10 cm | Between 3 and 10 cm | Less than 3 cm | Dead

X-749/X-120 Overview

- Three likely source areas: X-749 Landfill, X-120, Old Paint Shop
- 2002-2003 – Phytoremediation System installed



X-749/X-120 Trench Planting Design



- Installed 1500+ 8 in. dia. sand-filled borings 25+ ft to bedrock
- Planted over 3300 trees in 2 ft wide trenches 10 to 15 ft deep


CAT

X-749/X-120 Phytoremediation System

Phytoremediation System covers over 21 acres

Monitoring Methods

Phytoremediation System Monitoring Tools

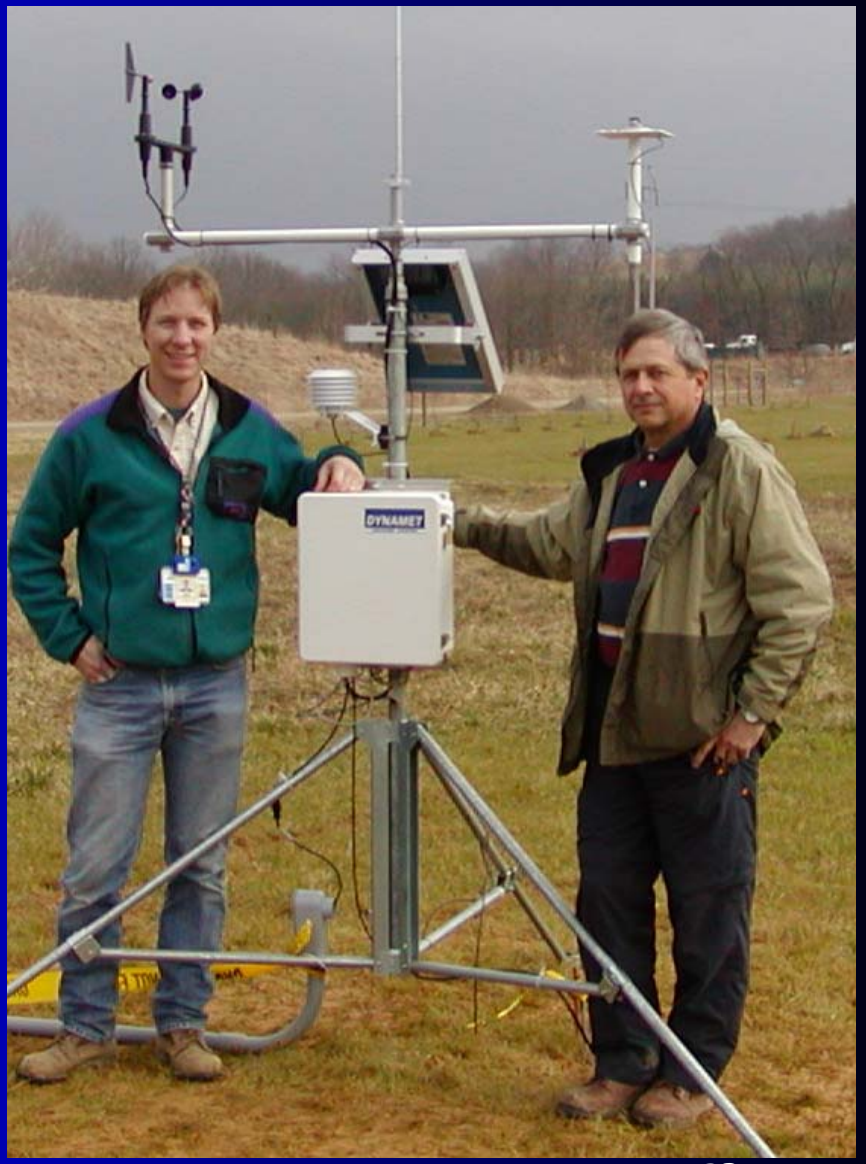
- Collect monitoring well data
  - Water levels
  - Analytical

Phytoremediation System Monitoring Tools

- Collect tree core samples
- Collect transpired stem gas

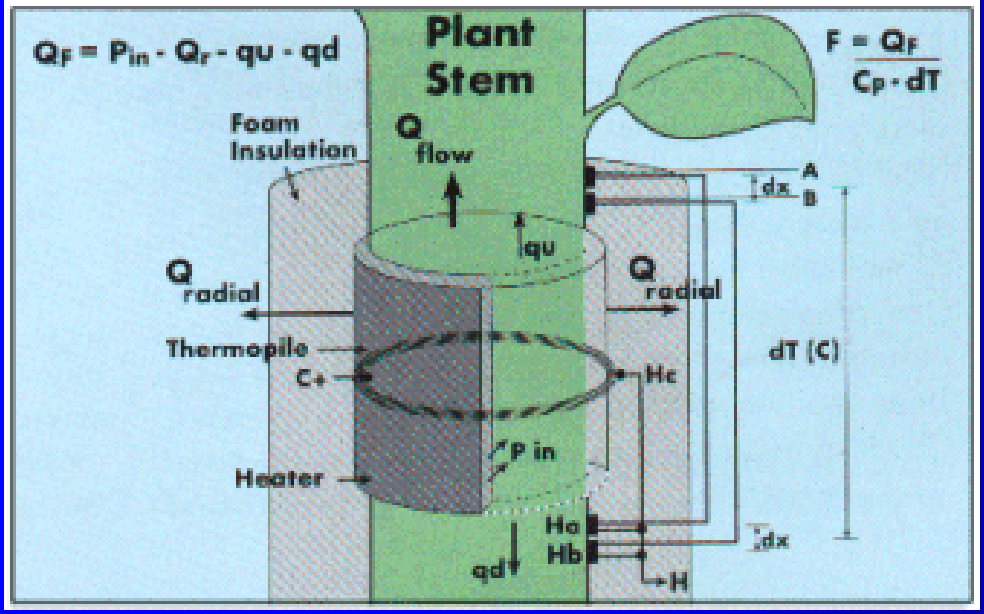
Phytoremediation System Monitoring Tools

- Collect weather data
- Collect soil moisture



Phytoremediation System Monitoring
Dynagage Sap-flow Collars

- Measures change in temperature as sap flows past heated collar



Phytoremediation System Monitoring Thermal Dissipation Probe (TDP)

- Measures temperature dissipation between a heated probe and a reference probe

Objectives of the Sap Flow Monitoring

1. Develop hydrologic budget
   - Determine sap flow relative to tree diameter
   - Determine sap flow relative to weather (ET)
   - Determine groundwater usage for plantation
2. Refine MODFLOW model input to more accurately predict remedial progress
3. Determine monitoring plan for next season at X-740 and adjust for X-749/X-120 area

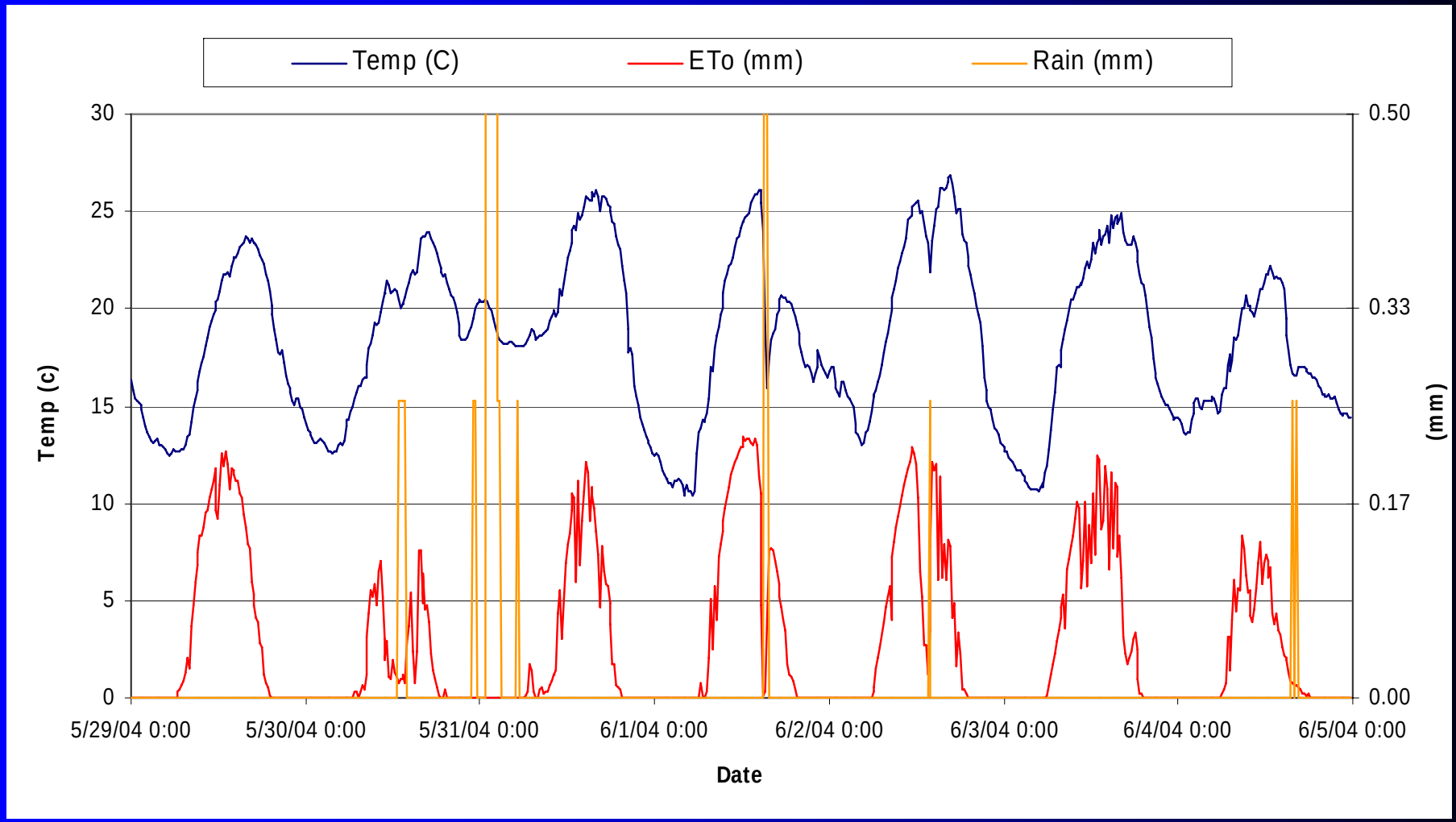
Sap Flow Data Collection

- Using Dynamax Flow32 System

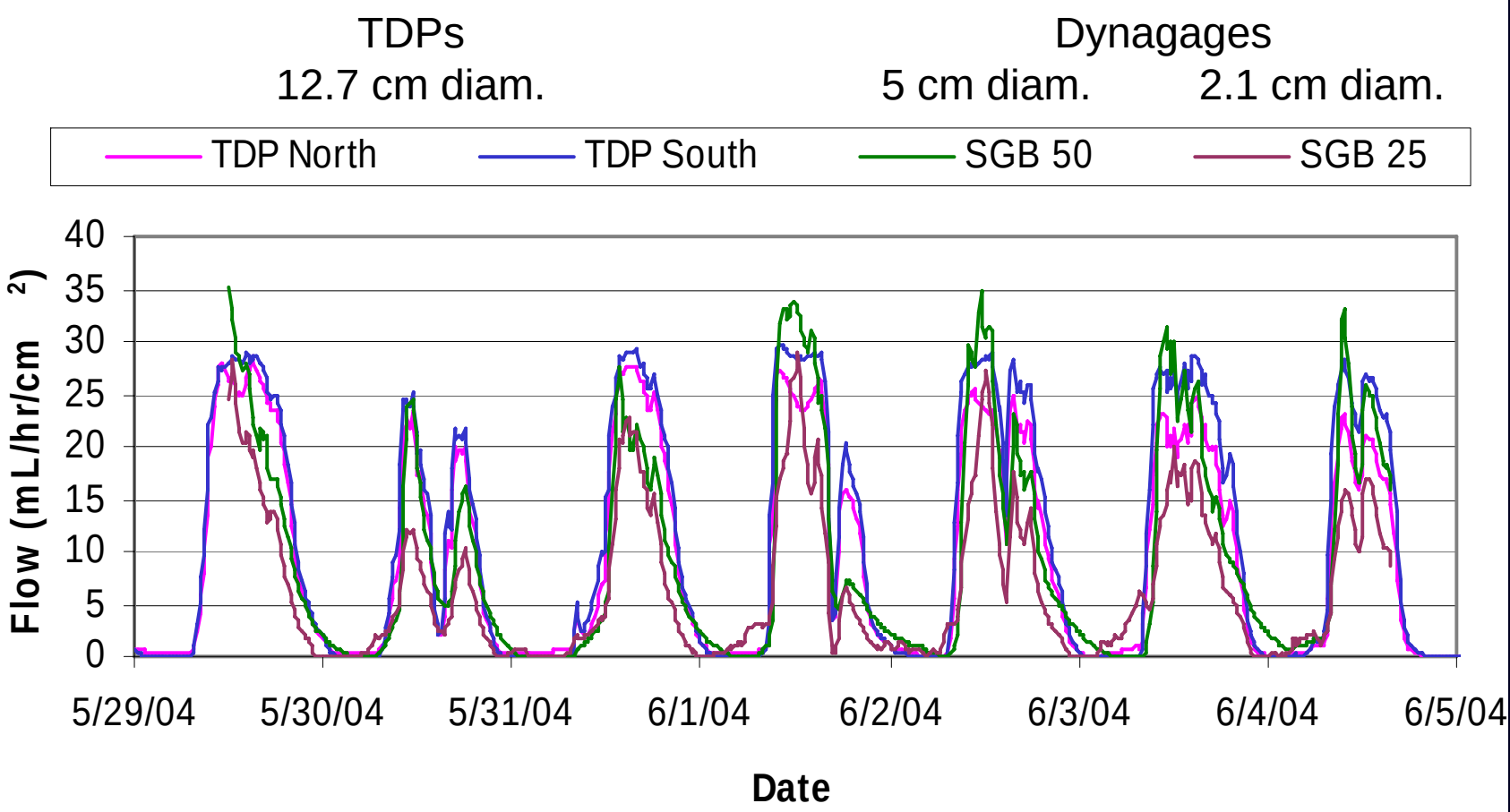
Sap Monitoring Results

Evapotranspiration

May 29, 2004-June 5, 2004



Sap Flow Comparison



Putting It All Together

Measure Test Trees Cross-Sectional Areas

Measure Average Daily Sap Flow for Test Trees

Sap Flow/Stem Area
= 0.203 L/cm²/day

Measure Stand Trees Cross-Sectional Area
705 Trees averaging 61.9 cm²

Indexing to Stand - Trunk Cross-Sectional Area
61.9 cm² x 0.203 L/cm²/day = 12.6 L/day

Putting It All Together (cont.)

Measure Trees/Land Area
3m x 3m and 6m x 3m result in 877 trees/ha

Sap Flow/Land Area
12.6 L/d x 877 trees = 11,000 L/ha/d (1.1 mm/day)

Measure Weather Station ETo
4.4 mm/day

Index Sap Flow / ETo = K_C Crop Coefficient
1.1 mm/d / 4.4 mm/d = 0.25

Apply Crop Coefficient For Seasonal Water Use
Tot. seasonal ET x K_C
858 mm x 0.25 = 215 mm (2,150,000 L/ha)

The values shown above are averaged from July 23 through August 29, 2004 data.

Modified from Dynamax

Conclusions

Conclusions

1. Sap flow monitoring quantifies and adds confidence to remediation predictions
2. Trees in X-740 Phytoremediation Area remove 11,000 liters of water/hectare/day (1176 gal/acre/day)
3. Total water consumption during 2004 growing season is 2,146,000 liters/hector (229,000 gal/acre)
4. Results and experience from X-740 may be used to refine assumptions and approach at X-749/X-120 area

Future Work

1. Continue sap flow monitoring to determine groundwater usage by the trees
2. Conduct soil boring program to determine root extent
3. Collect additional tree core samples
4. Finalize hydrologic budget to determine groundwater extraction rate
5. Update groundwater flow model to better predict remediation

Acknowledgements

- Organizations
  - DOE, Ohio EPA, Bechtel Jacobs Company LLC, Pro2Serve
- Authors
  - Russ Vranicar (DOE)
  - Maria Galanti (OEPA)
  - John Sokol & Sandy Childers (BJC)
  - Dave Rieske, Joe Ritchey, Steven Thompson (P2S)
- Contributors
  - Michael van Bavel (Dynamax)
  - Joel Burken (University of Missouri-Rolla)