Remediation of Soil and Ground Water Using Native Desert Phreatophytes

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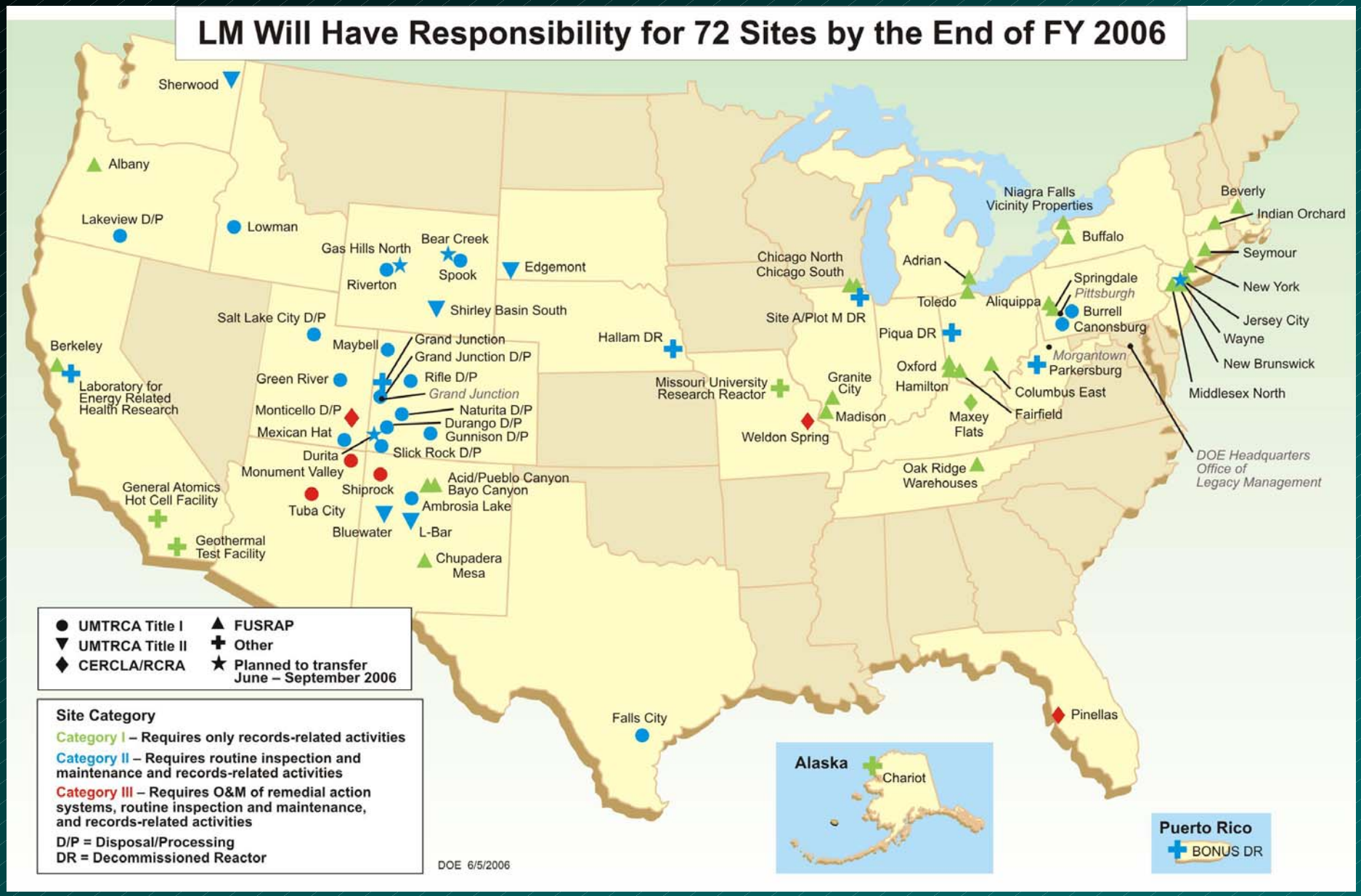
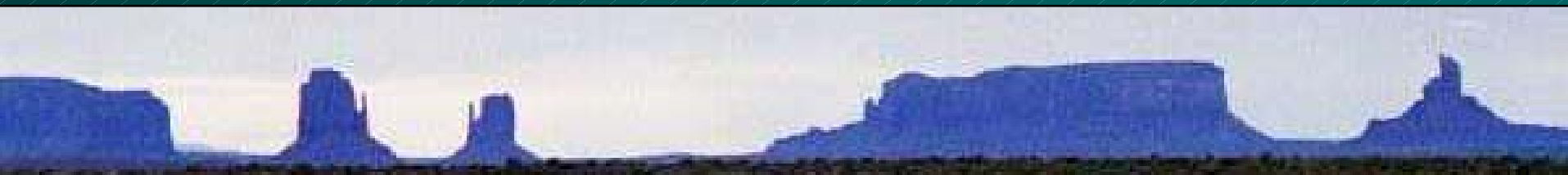
DOE Office of Legacy Management



Topics

- Site History
- Remediation Objectives
- Natural and Enhanced Attenuation
- Land Use Enhancements
- Summary
- Current Work



Site History
Monument Valley, AZ

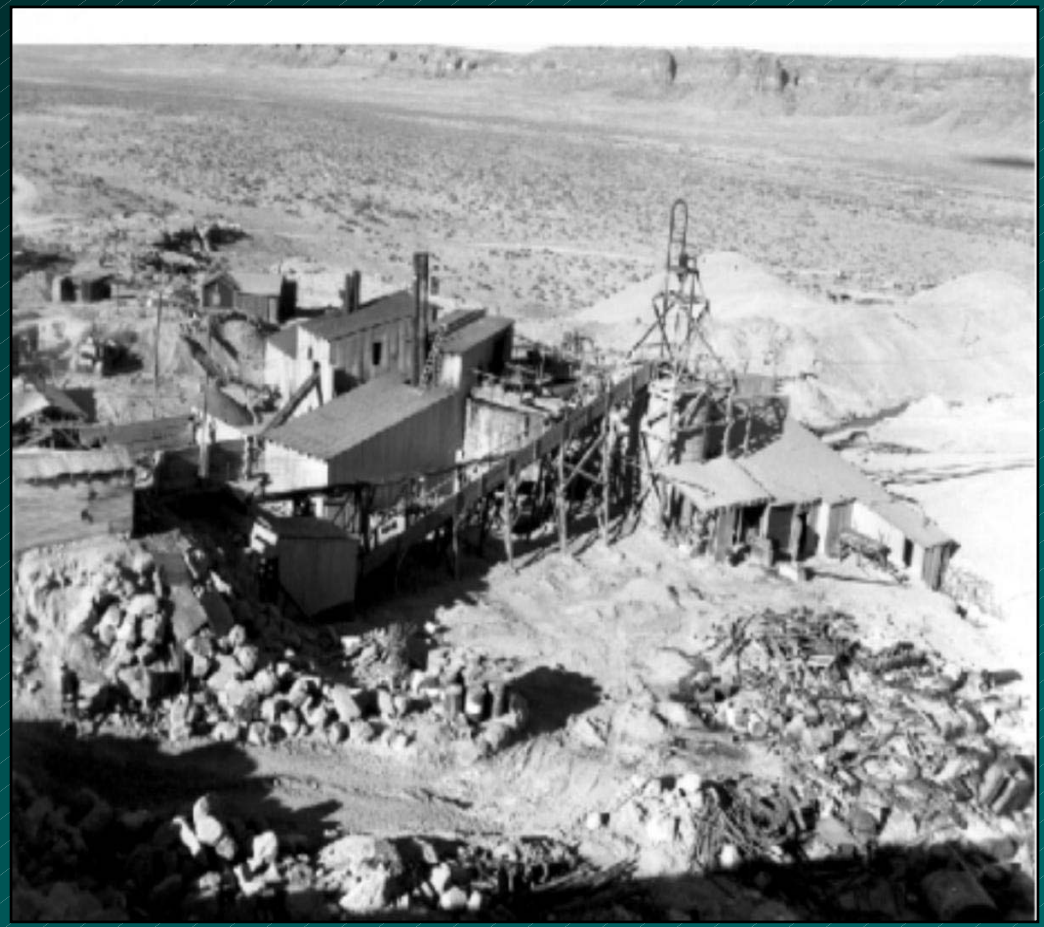
1942: Uranium discovered

1955 – 1964:

- Mechanical milling

1964 – 1968:

- Batch and heap leaching using H_2SO_4
- NH_3 and NH_4NO_3 used to extract U_3O_8



Monument Valley Mill – circa 1960a

Site History
Monument Valley, AZ

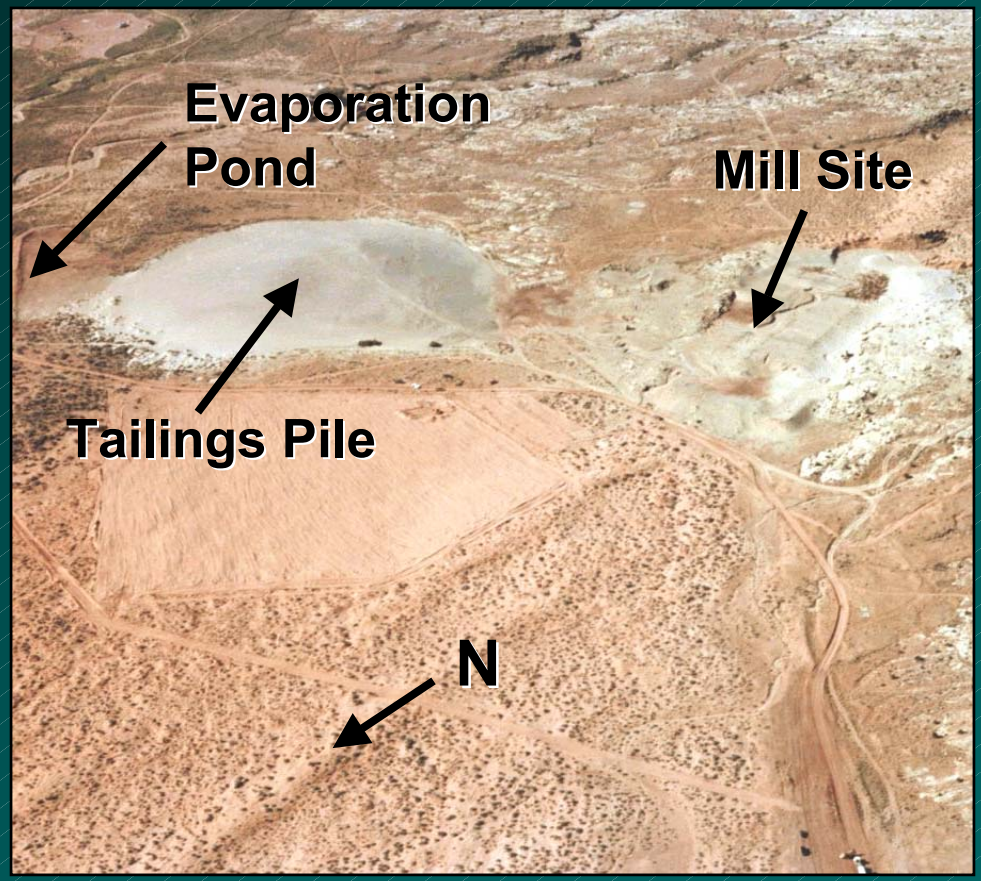
1964 – 1968 (cont.):

- Waste sent to tailings pile and evaporation pond

1968: Mill closed

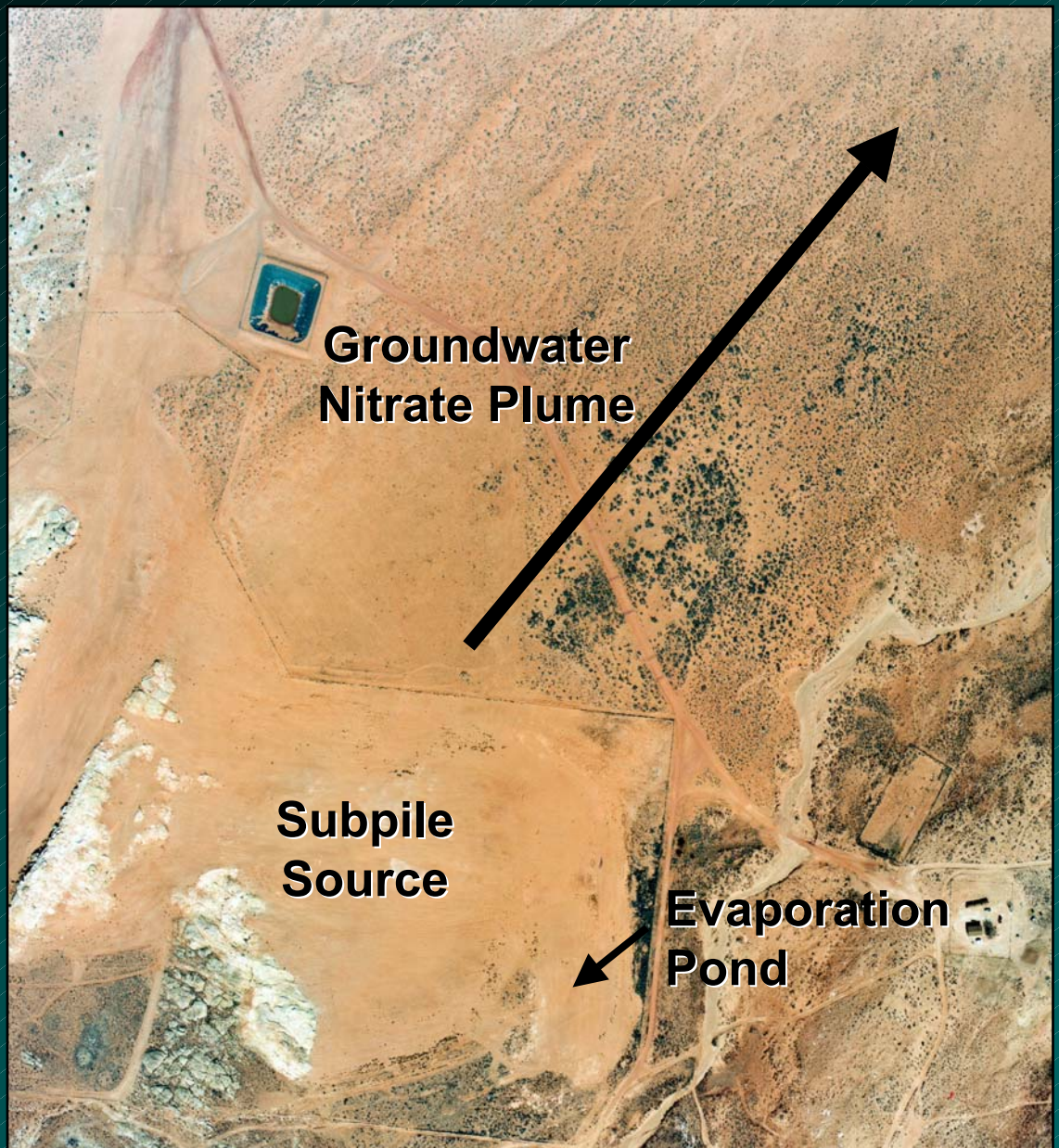
1992: Tailings Remediation

- Tailings pile removed
- *Subpile* NO_3^- and NH_4^+ continuing source for a shallow alluvial plume

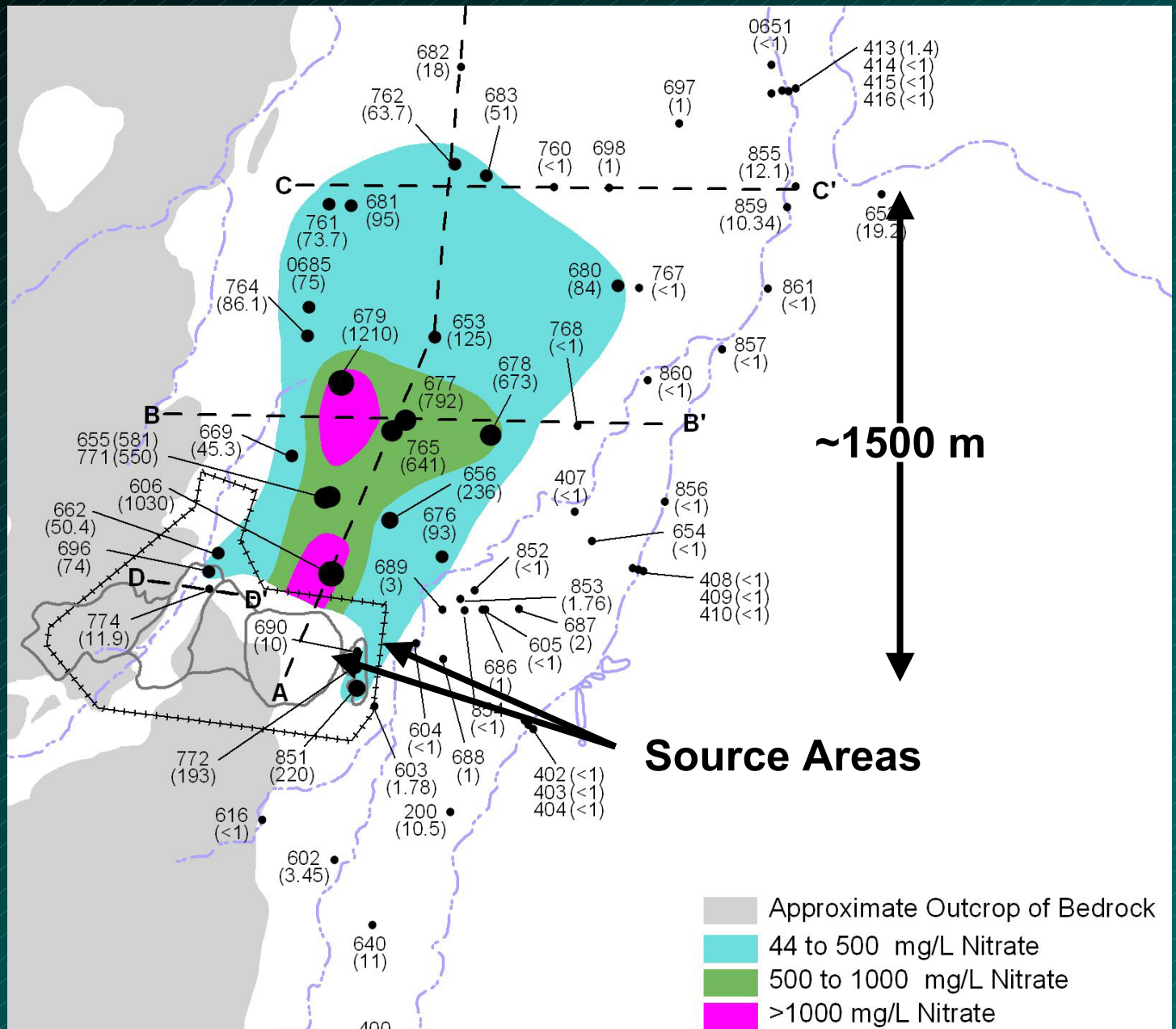


Monument Valley Mill Site and Tailings Pile – 1992

Monument Valley, AZ, Aerial Photo (1996)



Monument Valley Nitrate Plume (1997)



Remediation Objectives

1. Manage soil water balance to limit leaching of NO_3^- and NH_4^+ from source areas into the alluvial aquifer
2. Remove NO_3^- and NH_4^+ from source areas
3. Reduce NO_3^- in the alluvial aquifer to acceptable levels (< 44 mg/L)
4. Create a *beneficial use* of NO_3^- recovered from the plume
5. Return disturbed land to a higher level of productivity

Natural Attenuation: Desert Shrubs used for Phytoremediation at Monument Valley

Black greasewood

Díwózhiishzhiin

(Sarcobatus vermiculatus)

- **Goosefoot family (Chenopodiaceae)**
- **Native perennial shrub**
- **Obligate phreatophyte: roots almost always grow into groundwater**

Desert Shrubs used for Phytoremediation at Monument Valley

Fourwing saltbush

Díwózhii_beii

(Atriplex canescens)

- **Goosefoot family (Chenopodiaceae)**
- **Native perennial shrub**
- **Facultative phreatophyte: roots sometimes grow into groundwater**

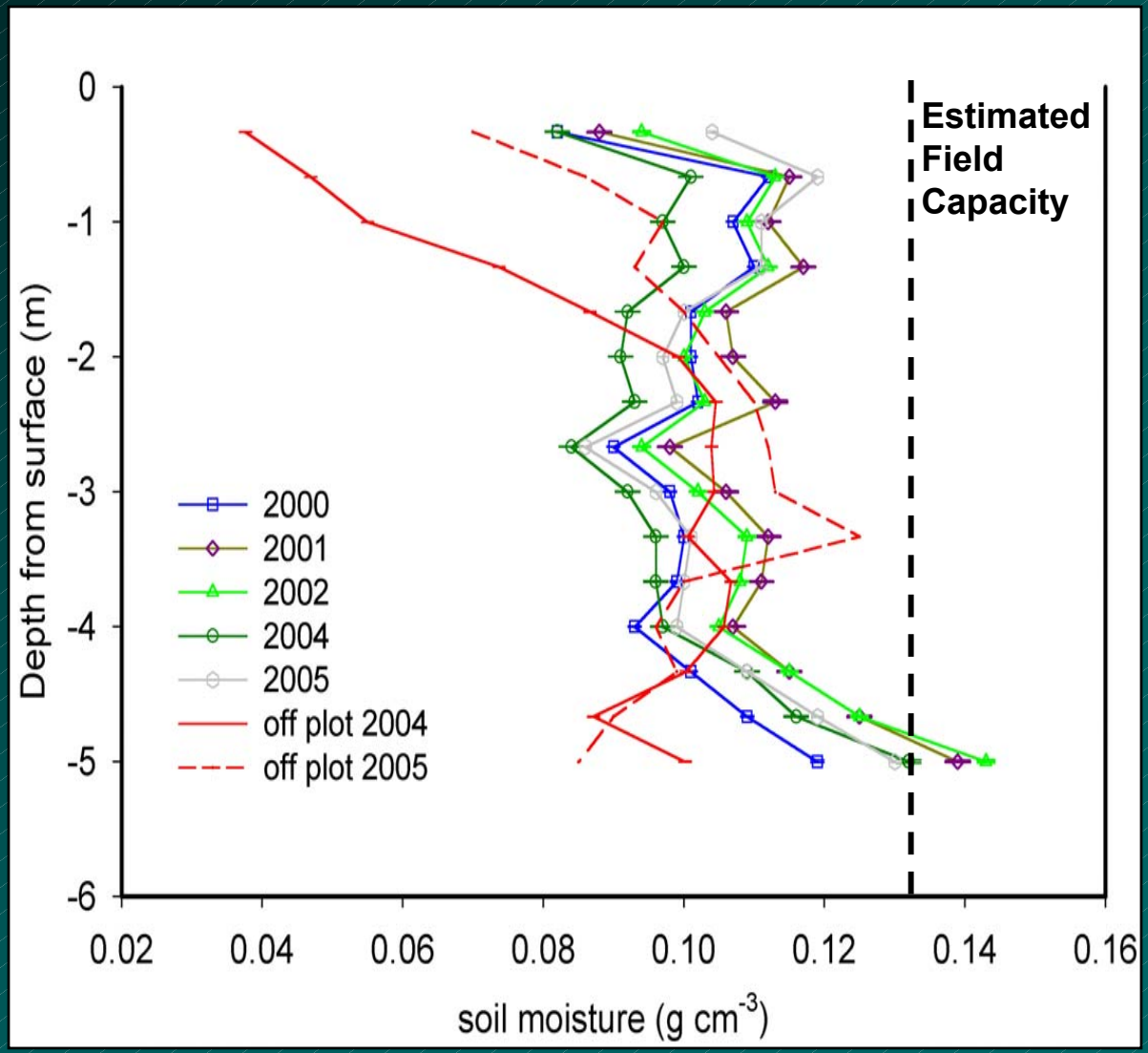
Enhanced Attenuation: Source Area Phytoremediation

Phase I (1999):

- 1.6 ha of source-area planted
- Fine eolian sand
- Saltbush and greasewood
- 4000 plants on 2-meter spacing
- Deficit irrigation (~0.3 m yr^{-1})

Control Soil Water Balance: Soil Moisture Monitoring

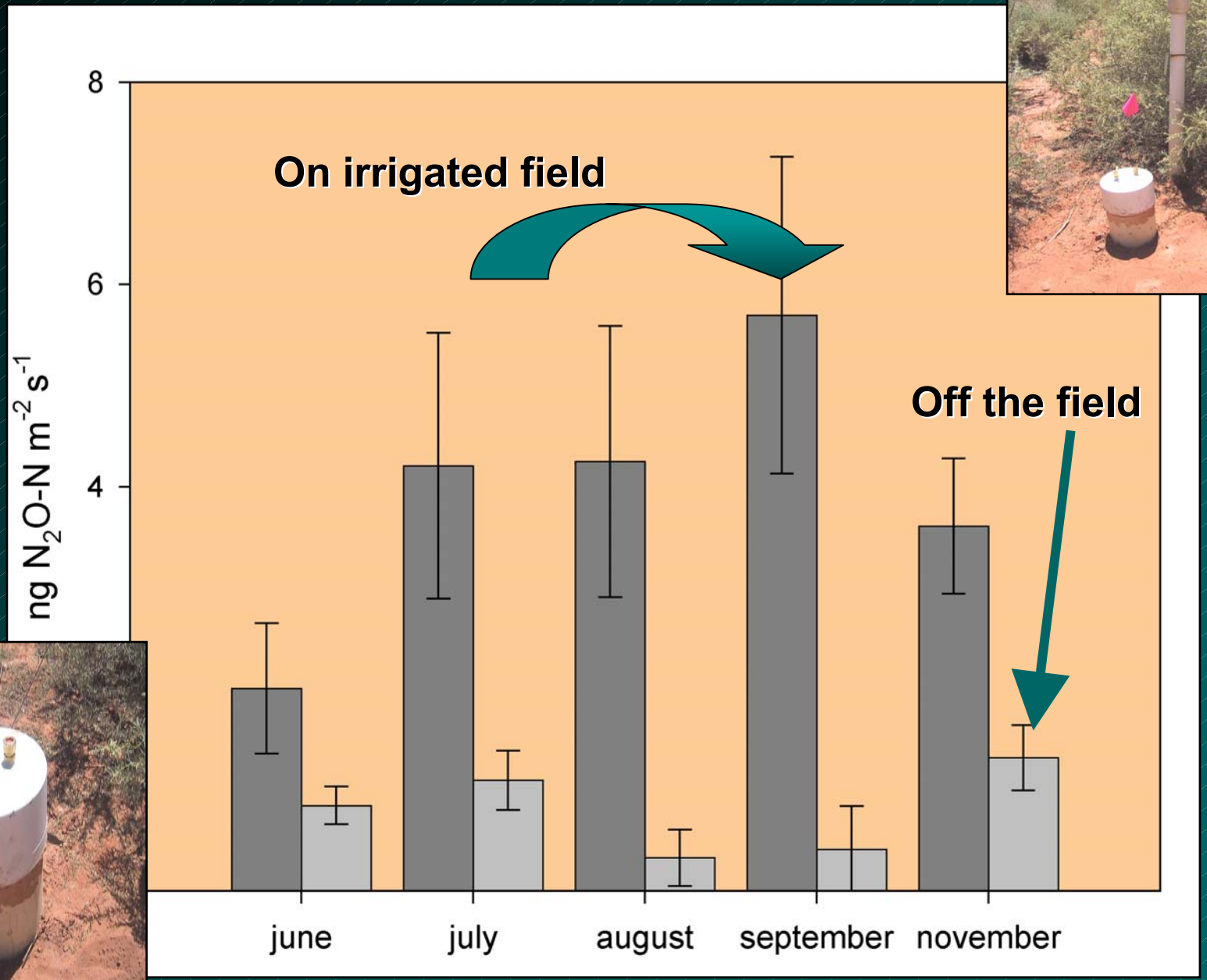
- Neutron hydroprobe
- 20 ports



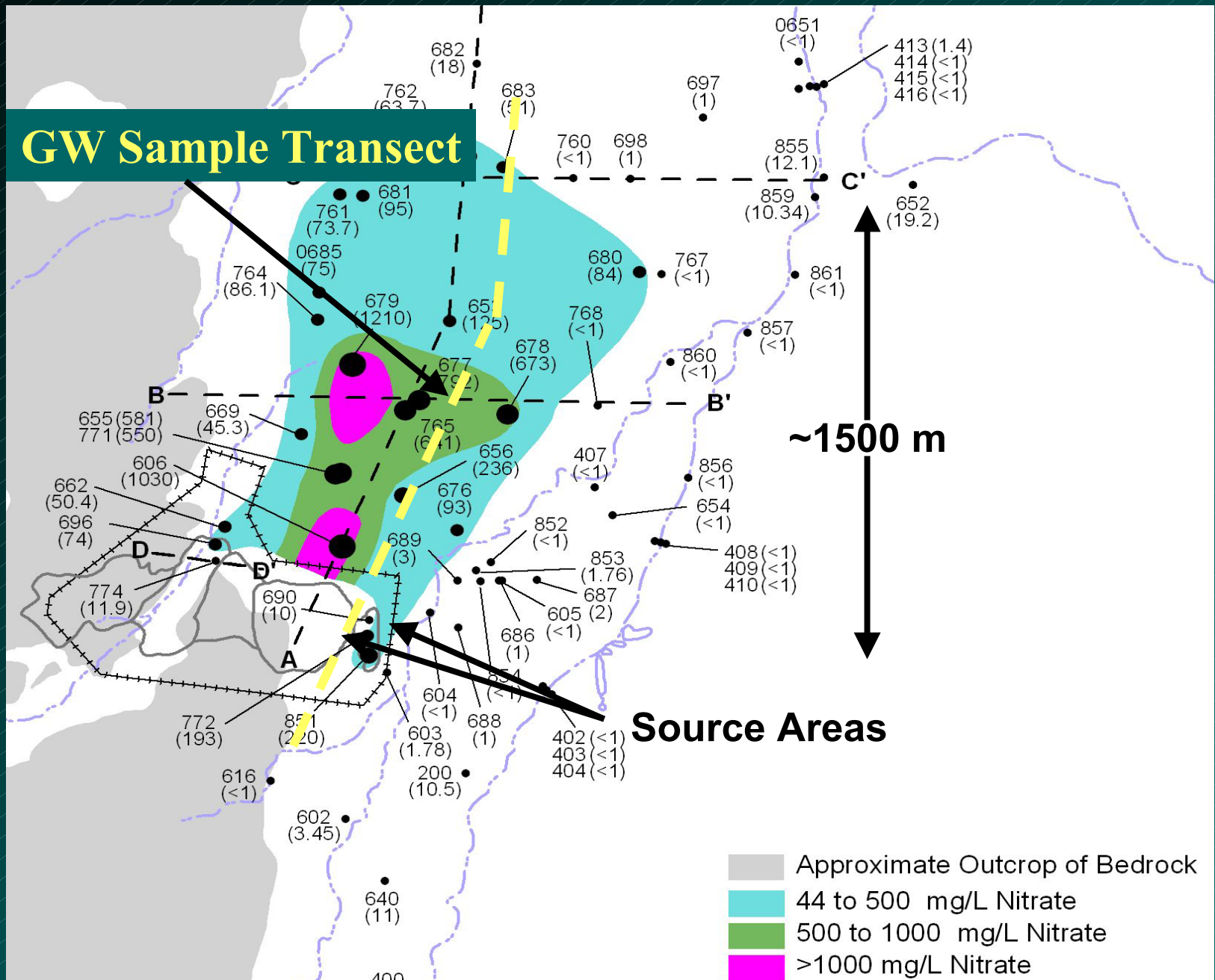
Phytoextraction of Nitrogen

Growing season	Plant Cover (m^2)	Plant N-content (%)	N-uptake (Kg)
2000	0.238 (± 0.003)	1.24 (± 0.10)	
2001	0.732 (± 0.017)	1.99 (± 0.62)	
2002	1.14 (± 0.018)	n. d.	
2004	2.08 (± 0.022)	2.17 (±0.22)	190
2005	2.24 (± 0.009)	2.05 (±0.39)	206

In-situ N_2O Flux Rate



Natural Denitrification



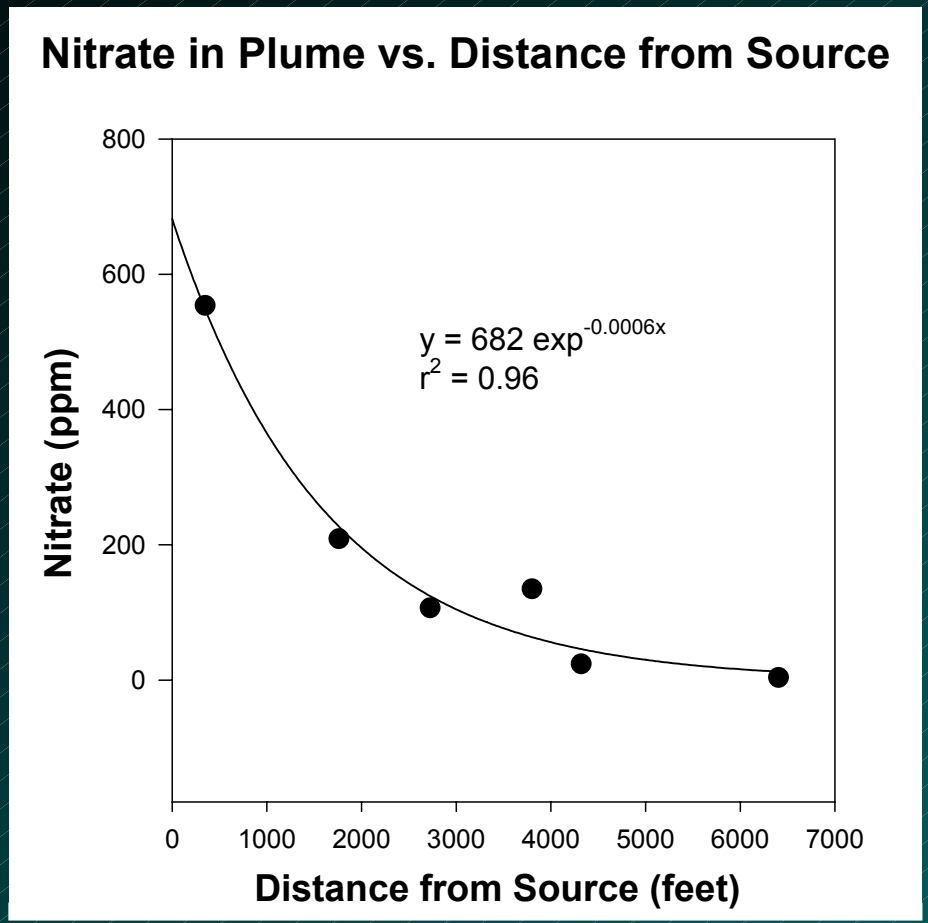
N-Uptake and Evapotranspiration Estimates

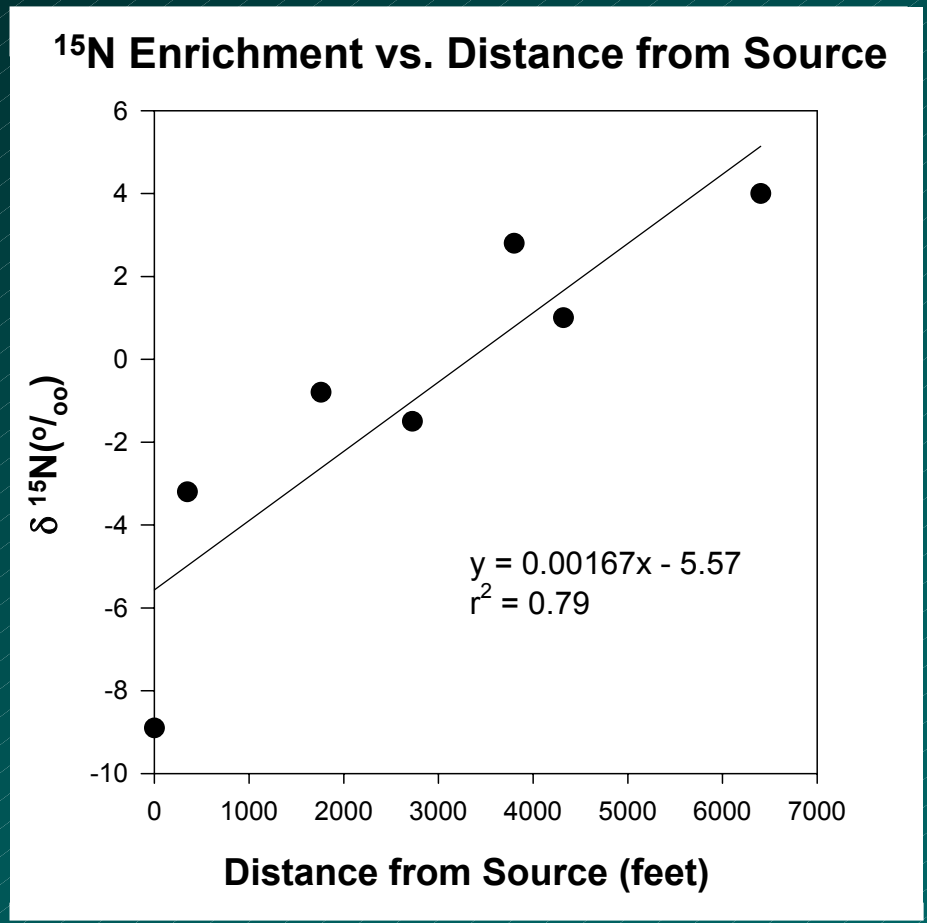
Basis of Estimates:

- Grazed vs protected
- Annual biomass
- Water-use efficiency
- N in annual tissues

	N-Uptake ($kg\ ha^{-1}yr^{-1}$)	ET ($mm\ yr^{-1}$)
Grazed	25	50-270
Protected	181	250-720
	~7X	0-14X

Natural Denitrification: N-15 Enrichment





Preliminary Estimate: 46% nitrate lost as denitrification at leading edge of the plume (~1500 m from source)

Beneficial Use: Native Plant Seed Crop

Fourwing Saltbush

- Seed Production (2002): 950 lbs / acre
- Market Value: $10.00 / lb
- 2002 Seed Crop Value: $9,500 / acre

Summary

Natural Attenuation

- About half of plume NO_3^- removed by natural denitrification

Enhanced Attenuation

- Desert shrubs planted at the source enhance ET, limit recharge and leaching, and remove some NO_3^-
- Irrigation-enhanced denitrification may remove source in <10 yrs
- Desert shrubs protected from grazing slow migration (hydraulic control) and may remove plume NO_3^- in ~30 yrs
- Final remedy: *Combination* of enhanced phytoremediation and denitrification of the source and the plume

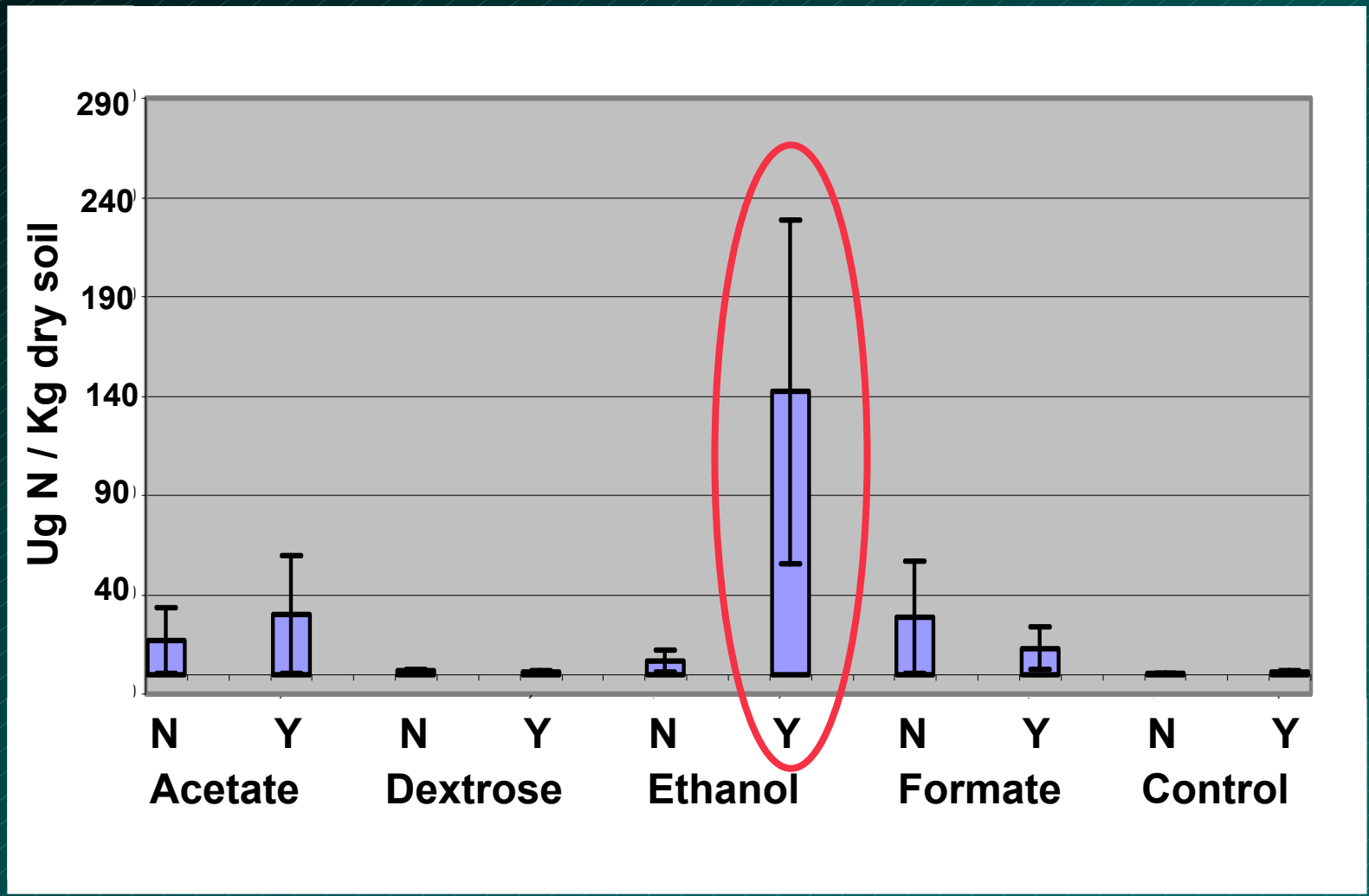
Summary (con't)

Land Use Enhancements—Beneficial Use of NO_3^-

- Plantings improve rangeland ecology, carrying capacity, and create an opportunity for a local enterprise (native seed production for mine land reclamation)

Enhanced Denitrification: Carbon Injection

N_2O production in batch column studies (w & w/o acetylene)



Ground Water Nitrate Shiprock, New Mexico Phytoremediation Study Areas