The Art of Successful Mine Land Reclamation

- **The keys principles I have learned for successful mined land Reclamation**
  - Totally understand the environment you mine in
  - Begin mine planning with the end in mind
  - Plan/Design for better than pre-mine state
  - Integrate reclamation into the day to day mine planning
  - Assuring each part of the program is as important as the other
  - Continually look for ways to improve your reclamation to benefit the entire ecosystem

The Art of Reclamation at Navajo Mine

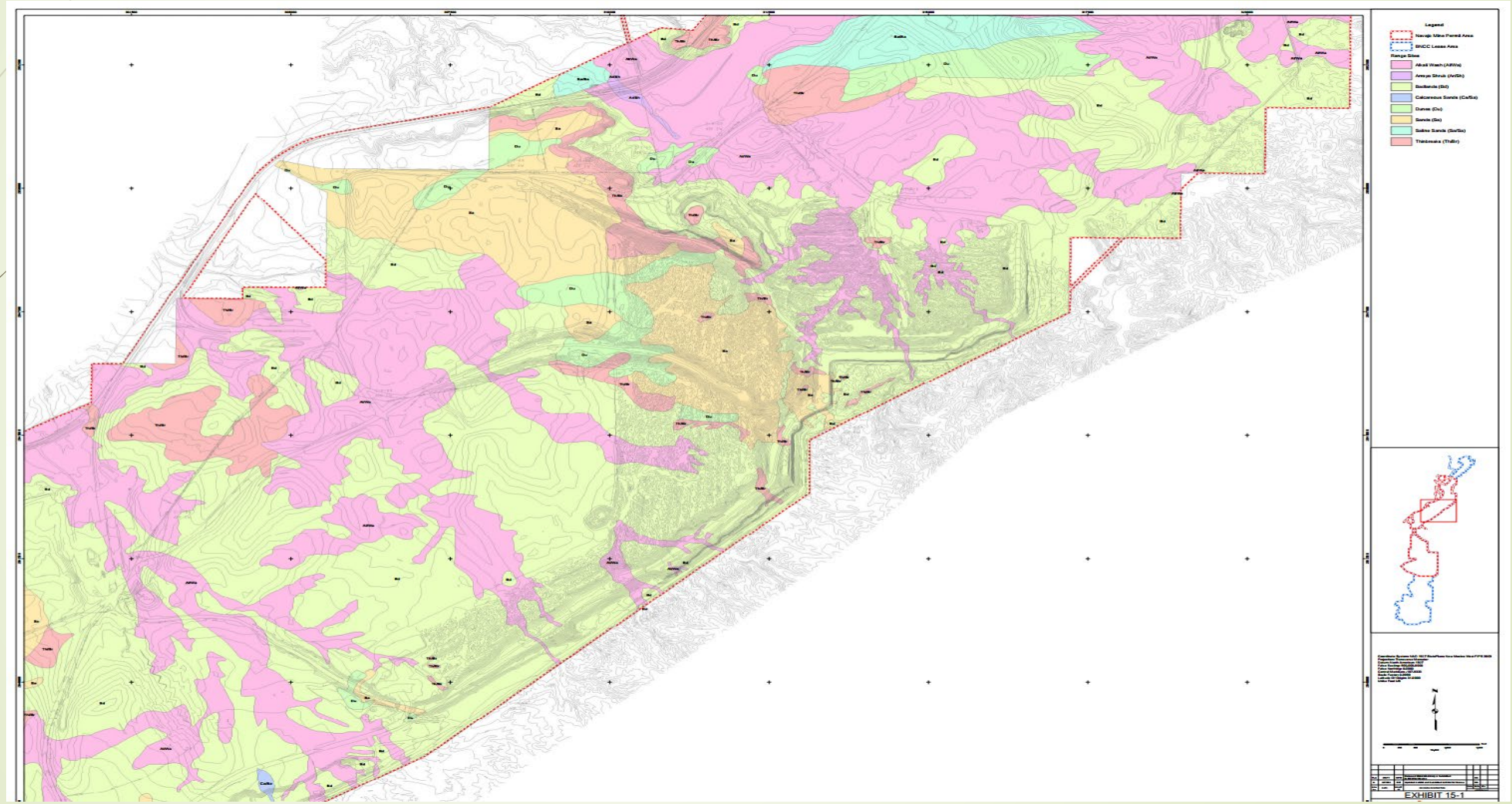
What are we trying to accomplish?

- Maintenance free regrade landforms
- Vegetation composition and diversity
- Stable against erosion
- Promote post-mine land use
- Bond release

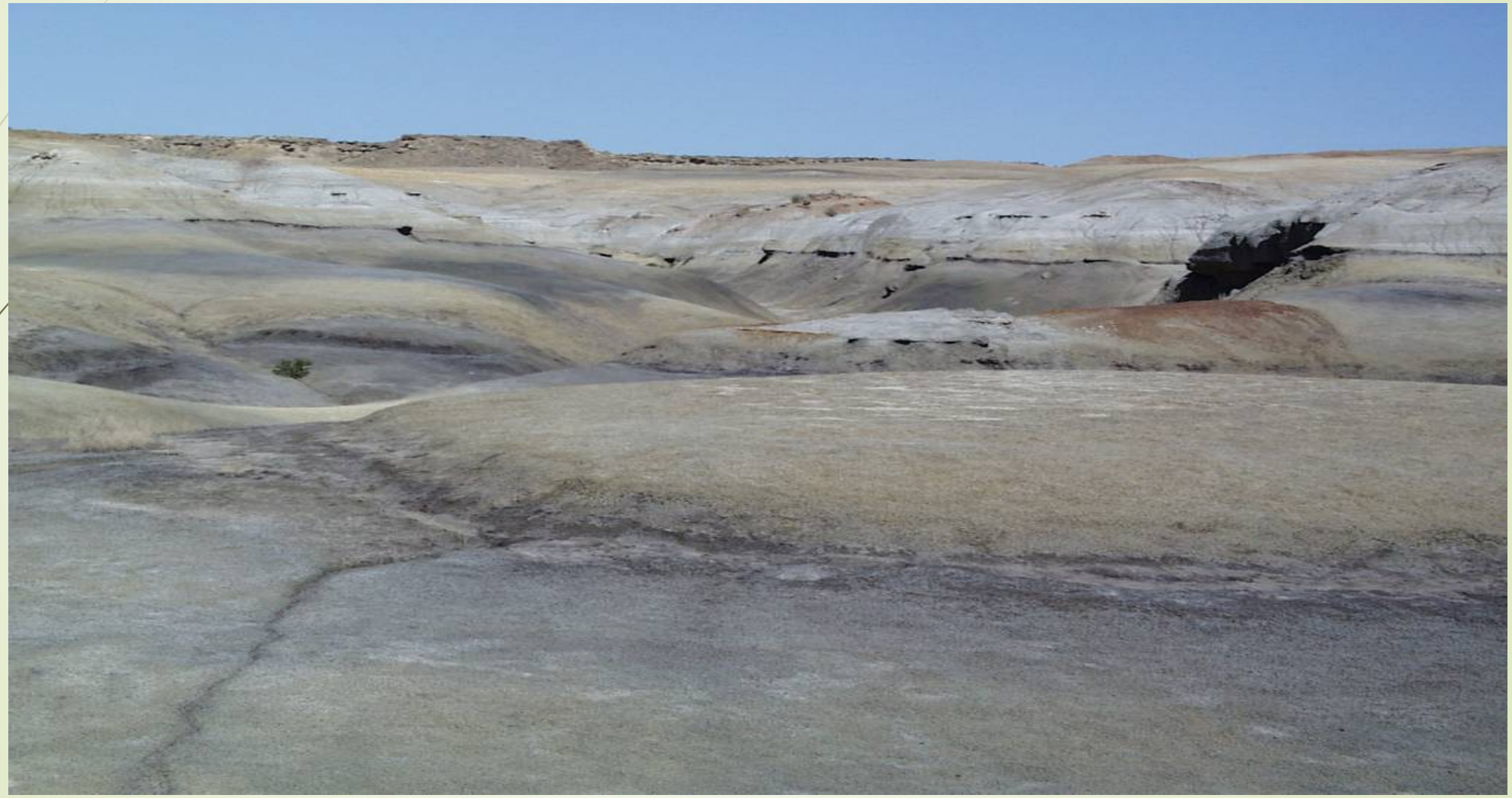
All the Key Components of Reclamation at Navajo Mine and the Importance of Each

Topdressing	Limit supply and poor quality
Spoil Quality	Sodium affected and poor quality
Stable Land Form	Highly erosive environment, sparse vegetation
Compaction	Heavy equipment conducting reclamation
Seed Bed Prep	Proper seed placement & seed to soil contact
Seeding Mix	Meet bond release requirements
Seed Placement	Right seed at the right depth
Mulching	Quality Material for proper application
Crimping	Proper installation and on contour
Irrigation	Adequate application for germination and establishment
Genetically Improved Atriplex	Cross between Atriplex canescens x A. obovata
Wetland Re-establishment	Utilize Navajo Irrigation Projects Tail Waters

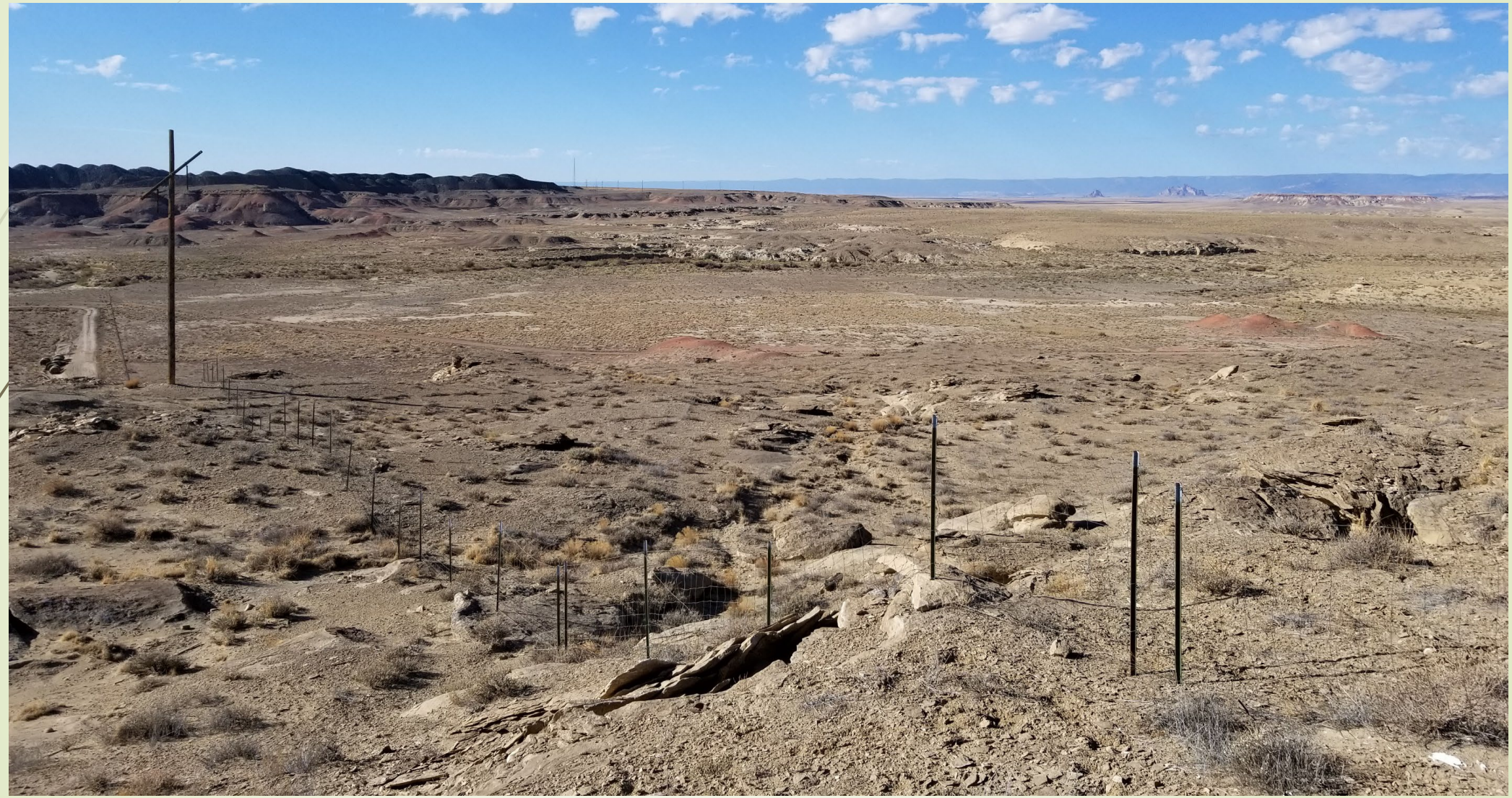
Pre-Mine Vegetation Communities



Bad Lands And Sodium Affected Soils



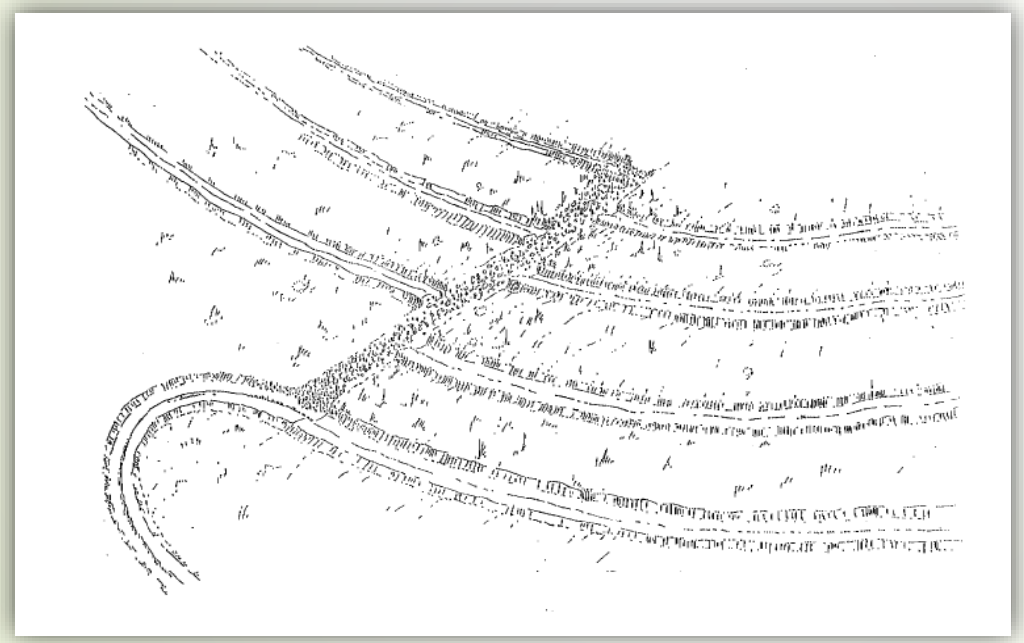
Native Landscape



Topsoil Removal of Deep Deposits of Topdressing

Early Reclamation at Navajo Mine

- Traditional Approach
  - Typified of FSC surfaces dependent on rip-rap, gradient terraces, or other "hard engineered" structures to stabilize drainages and control erosion.



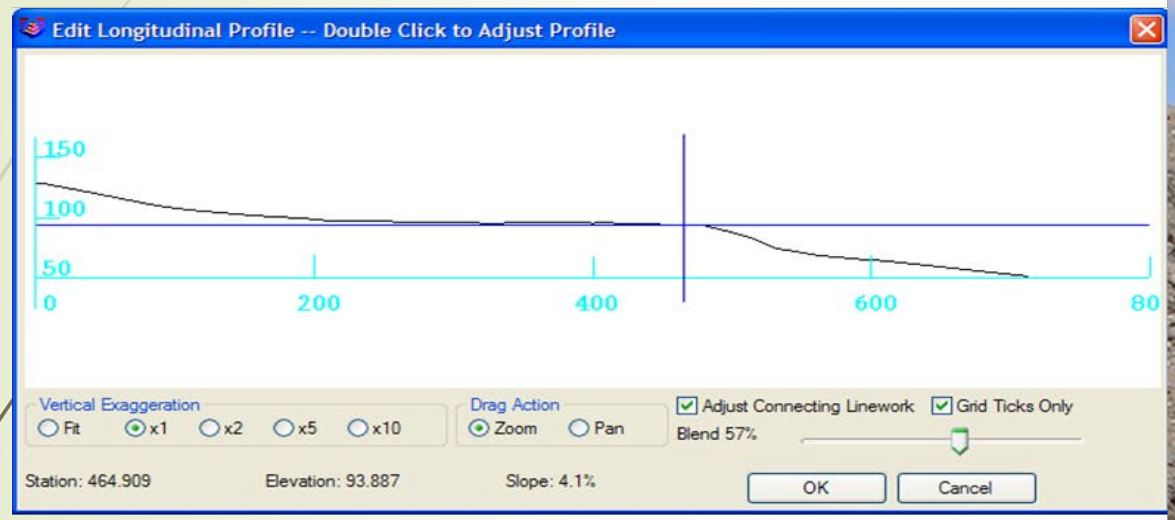
Confluence of a series of typical gradient terraces with a drop structure connecting to a reclaimed channel.

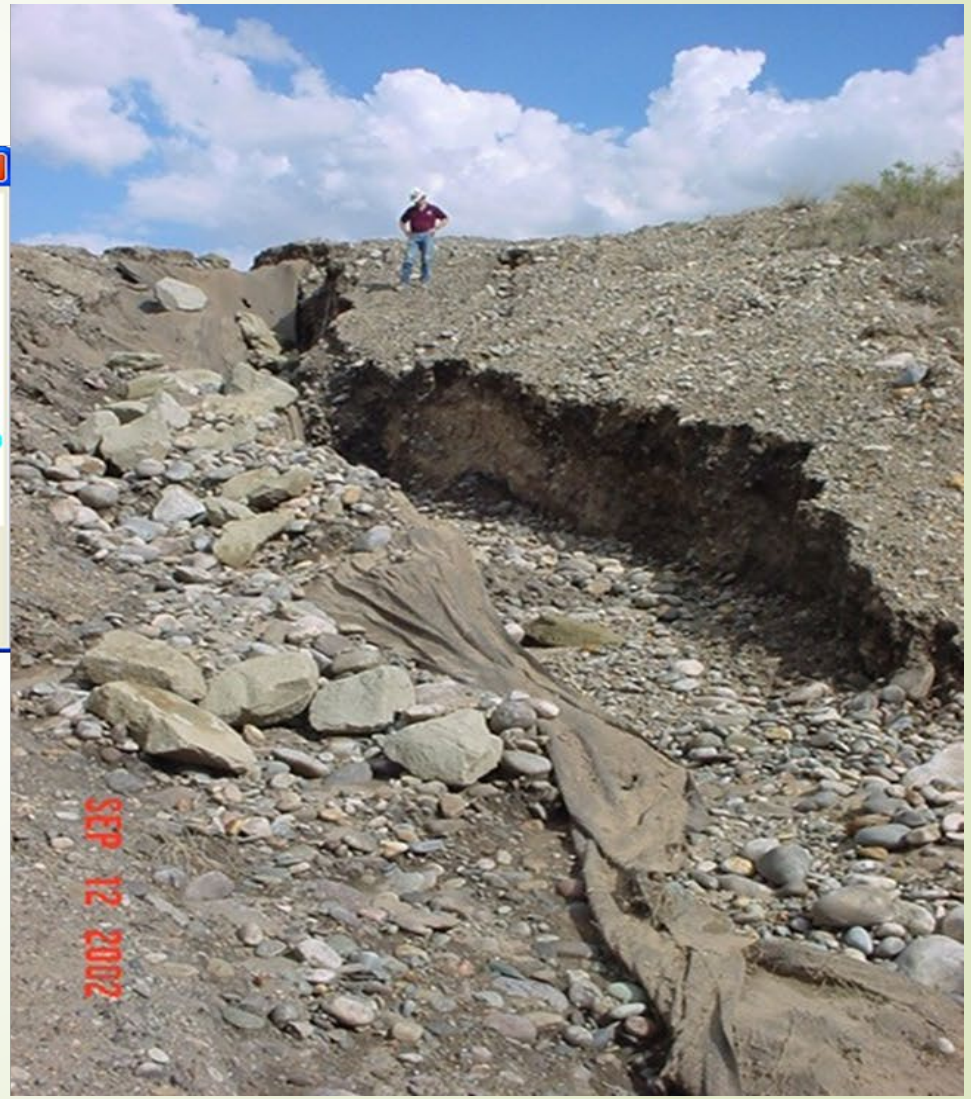
Erosive Landform of Early Reclaim Lands at Navajo Mine

Erosive Landform, Gradient Terraces at Navajo Mine

Erosive Landforms in Early Reclamation

Knickpoints off a Gradient Terrace





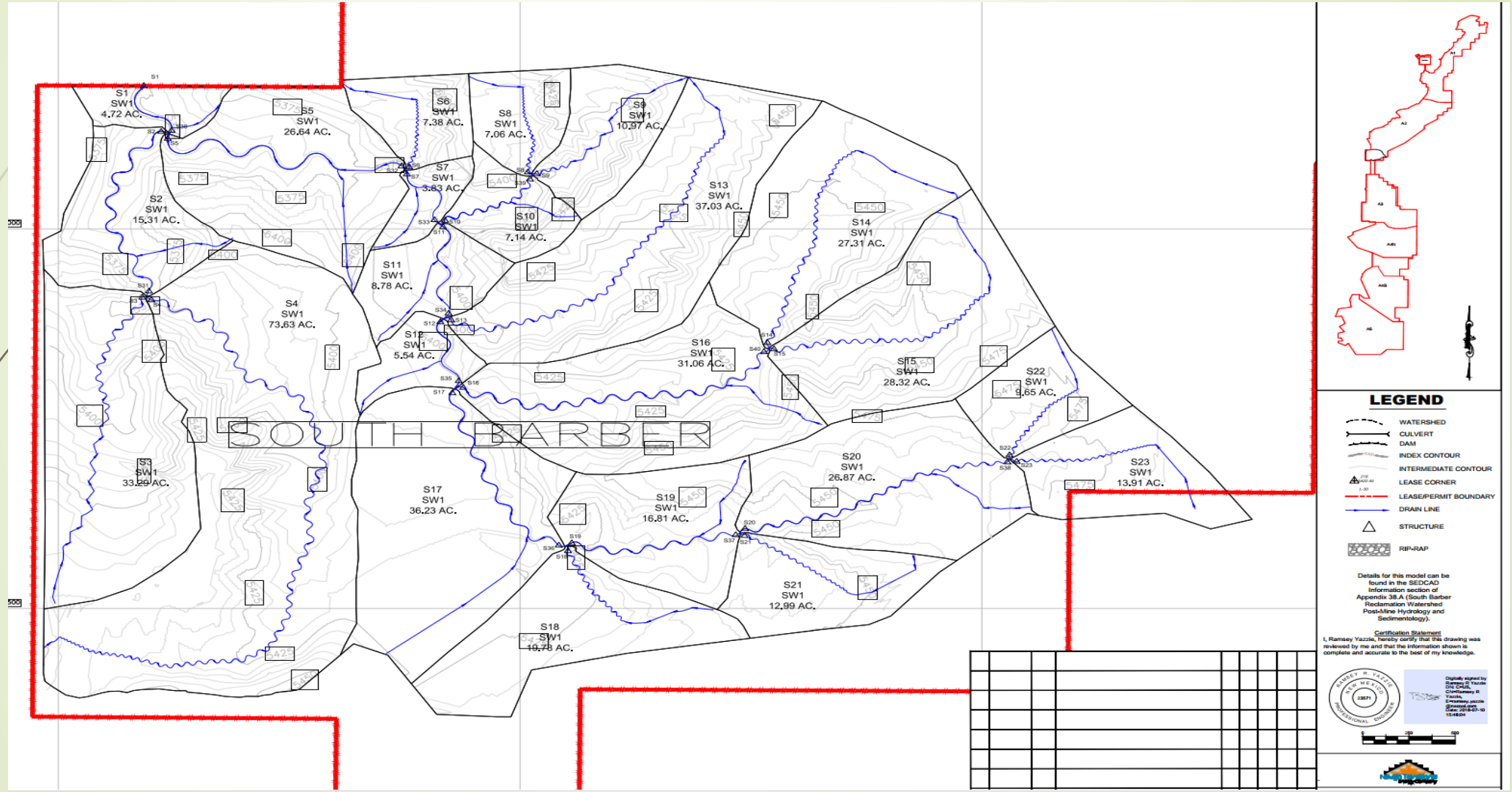
Poor Vegetation Establishment

- Improper Irrigation
- Improper seeding
- Improper mulch
- Compaction
- Poor Seed Bed Prep.

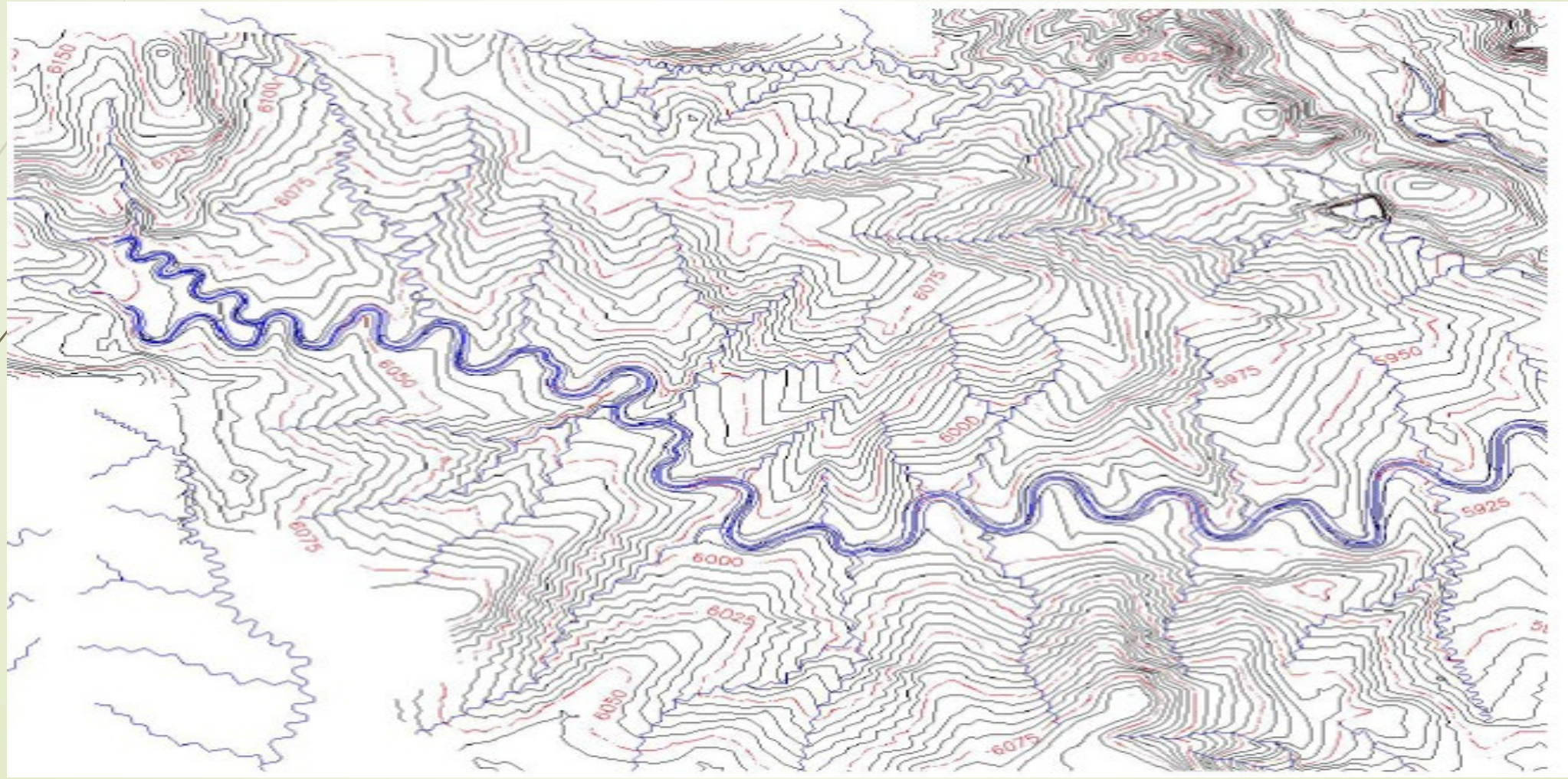
Creation of Stable Landforms

- Geomporhic Practices
  - Surfaces designed utilizing fluvial geomorphic principles such as;
    - Utilizing geomorphically appropriate slopes, drainage densities, and channel profiles;
    - Constructing geomorphically appropriate channel slopes, channel meander lengths, and cross sections; and
    - Configuring reclaimed channel configuration based on bed and bank (substrate) material.

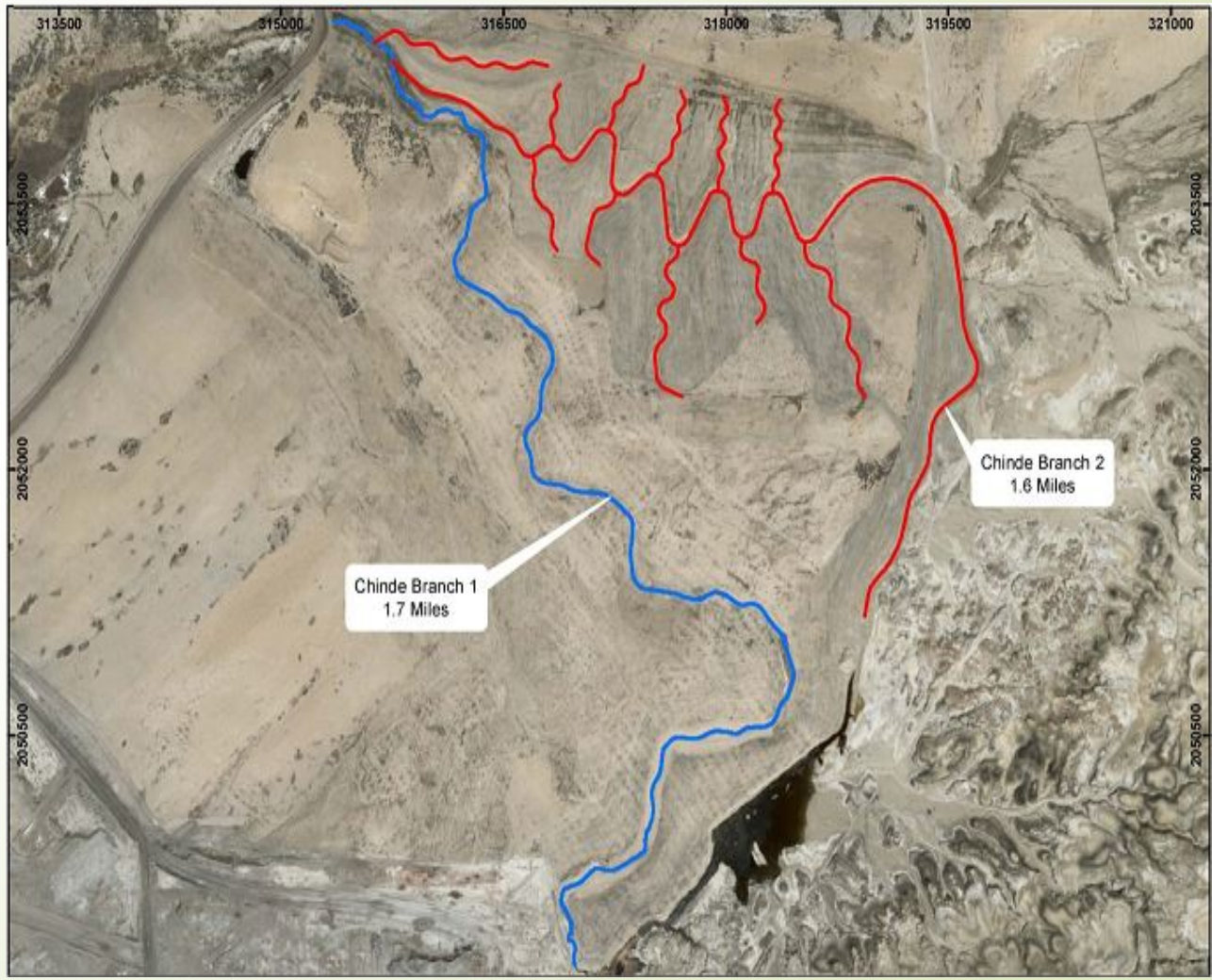
Designing Geomorphic Stable Land Form



The Art of Geomorphic Design



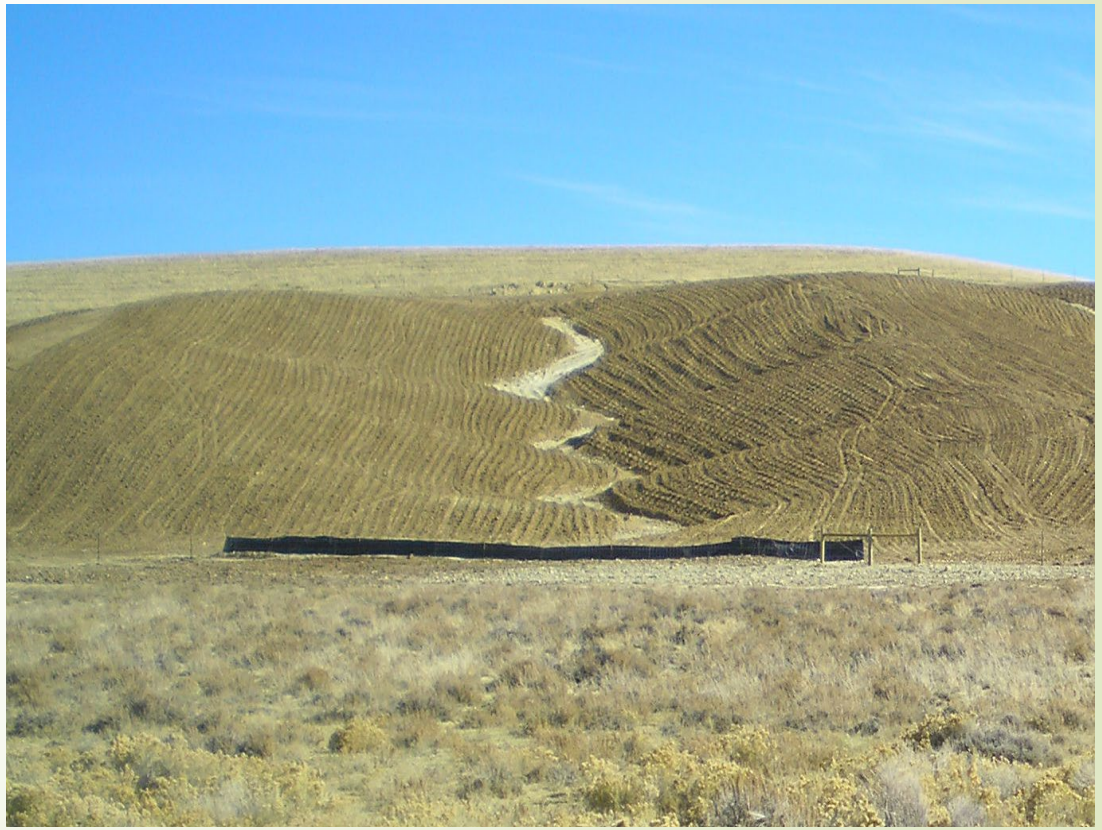
Traditional Engineered Drop Structures to a Geomorphic C Type Channel



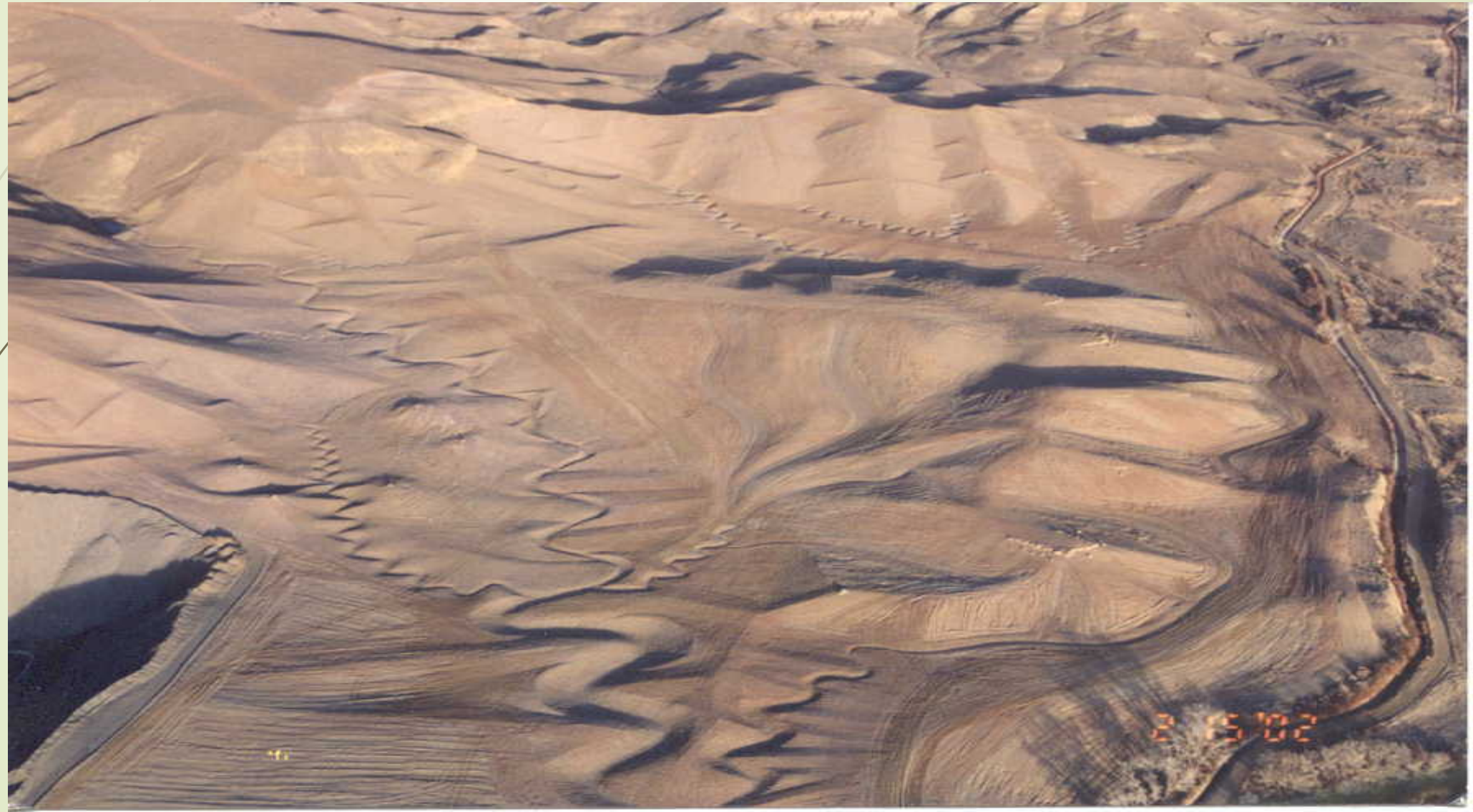
Traditional Approach Reclamation vs Geomorphic

Erosive, Constant 3:1 Slope

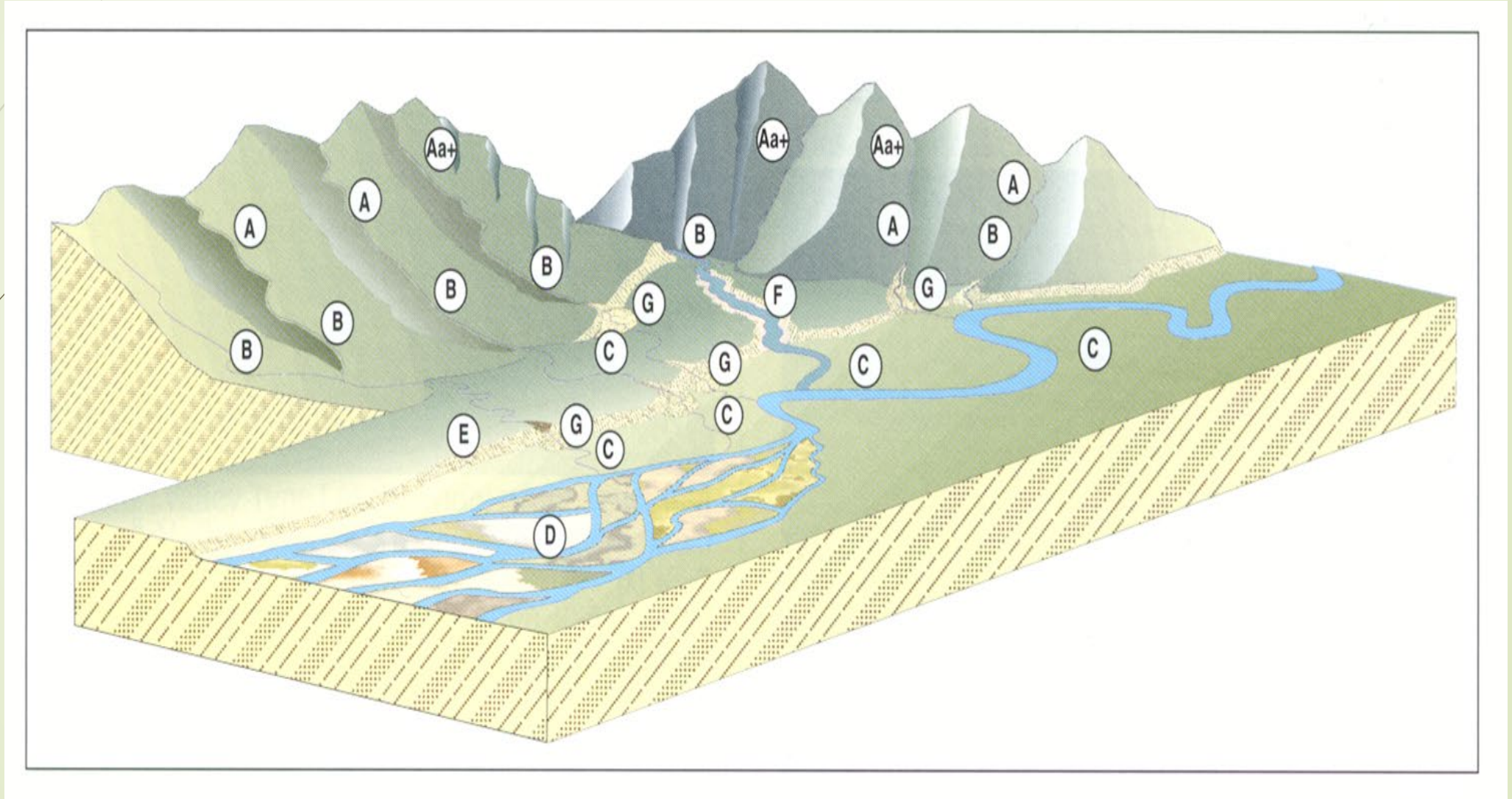
Replaced with A-Type Channels

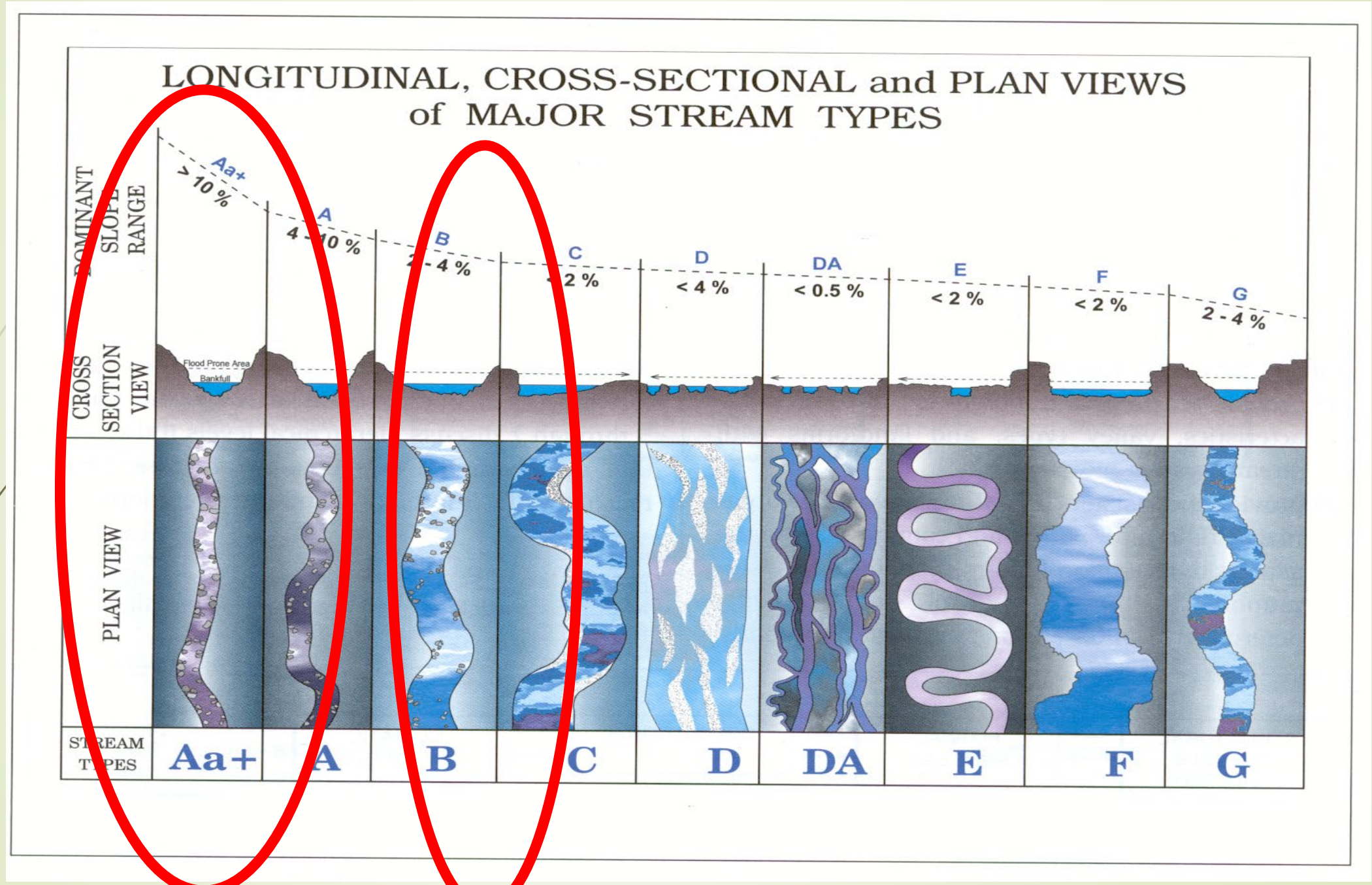


Final Geomorphic Land Form

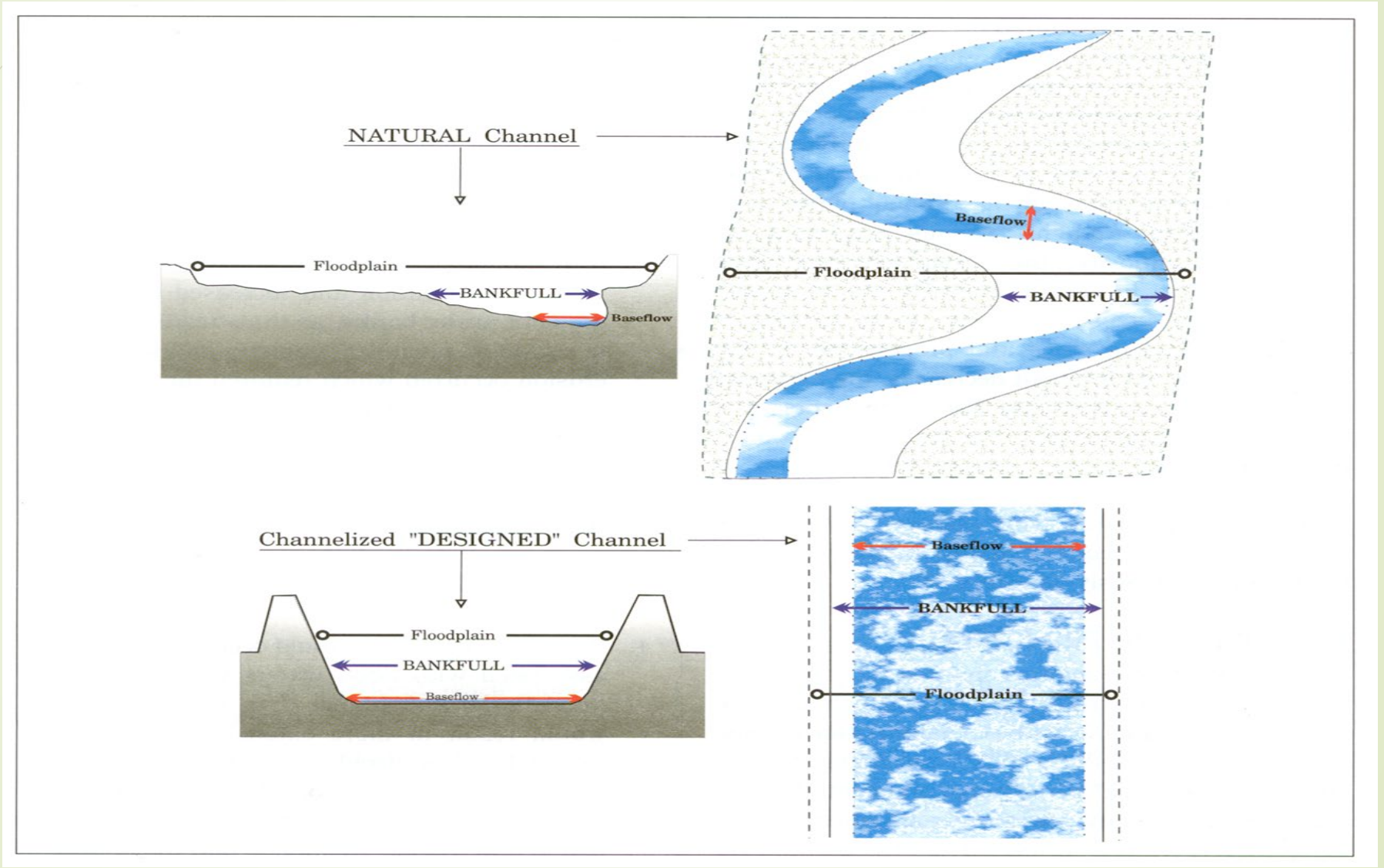


Natural Channel Types

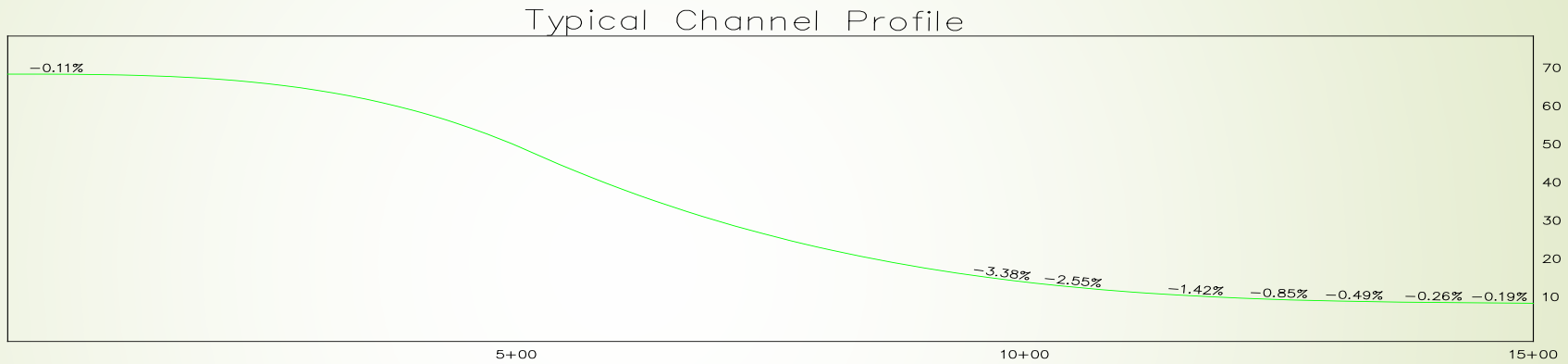


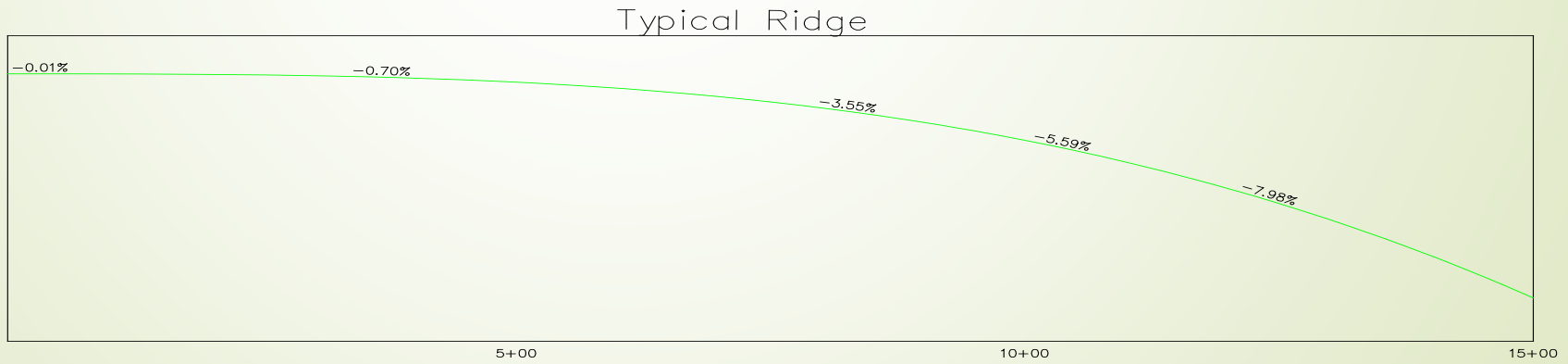

LONGITUDINAL, CROSS-SECTIONAL and PLAN VIEWS
of MAJOR STREAM TYPES
DOMINANT SLOPE RANGE
CROSS SECTION VIEW
PLAN VIEW
STREAM TYPES
Aa+
> 10 %
A
4 - 10 %
B
2 - 4 %
C
< 2 %
D
< 4 %
DA
< 0.5 %
E
< 2 %
F
< 2 %
G
2 - 4 %
Flood Prone Area
Bankfull
Aa+
A
B
C
D
DA
E
F
G

Natural Channels

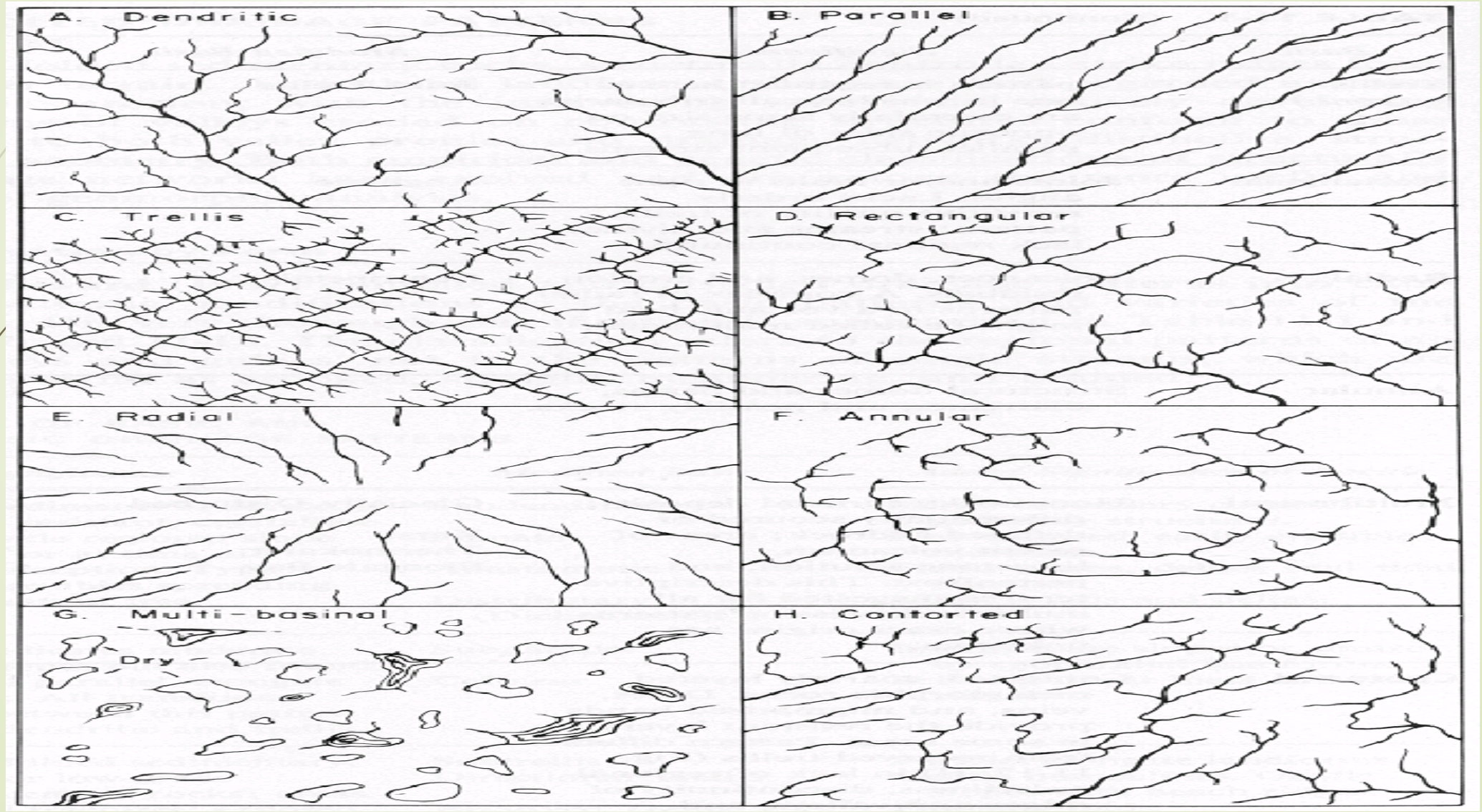


Typical Channel and Slope Profiles

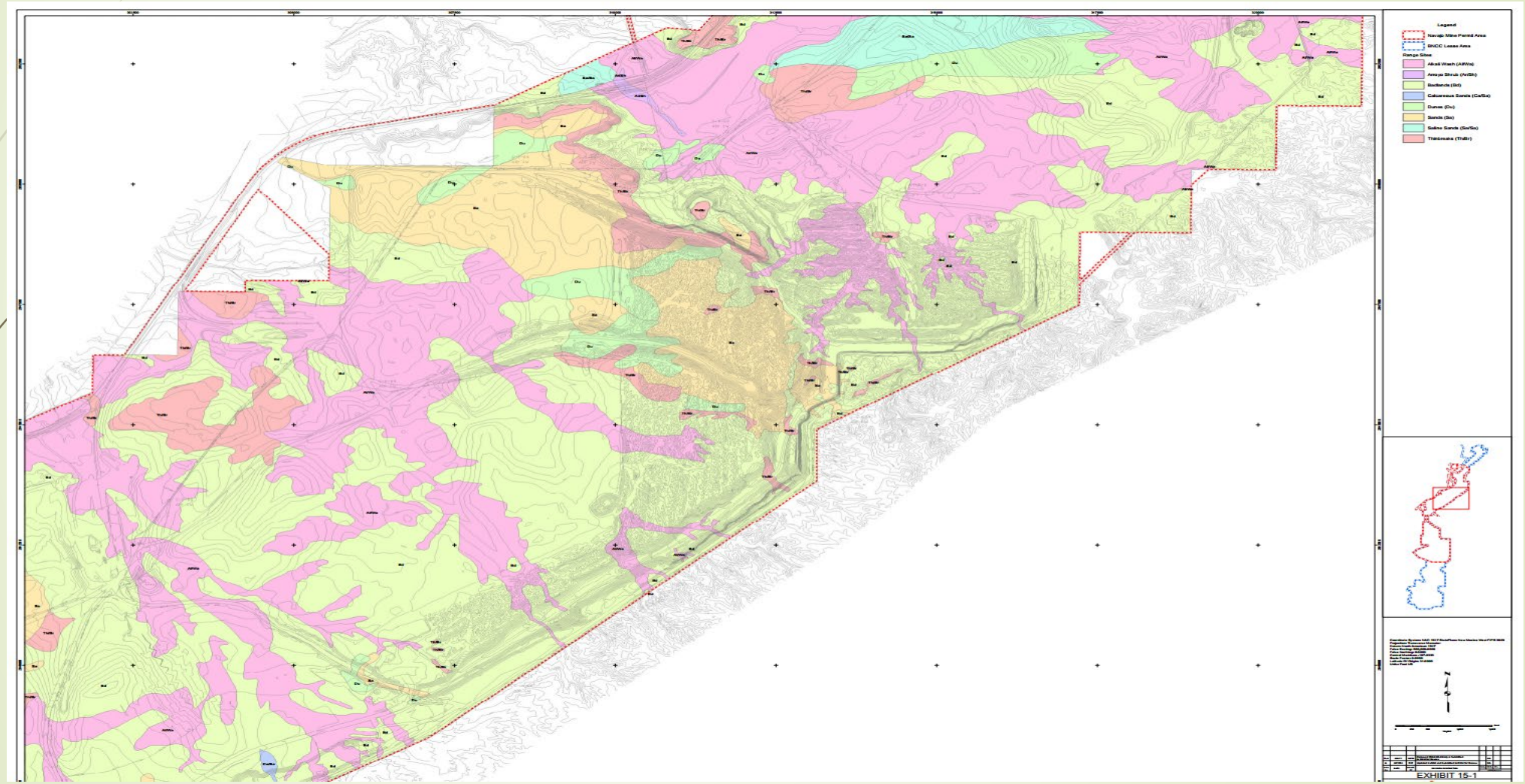




Different Drainage Types

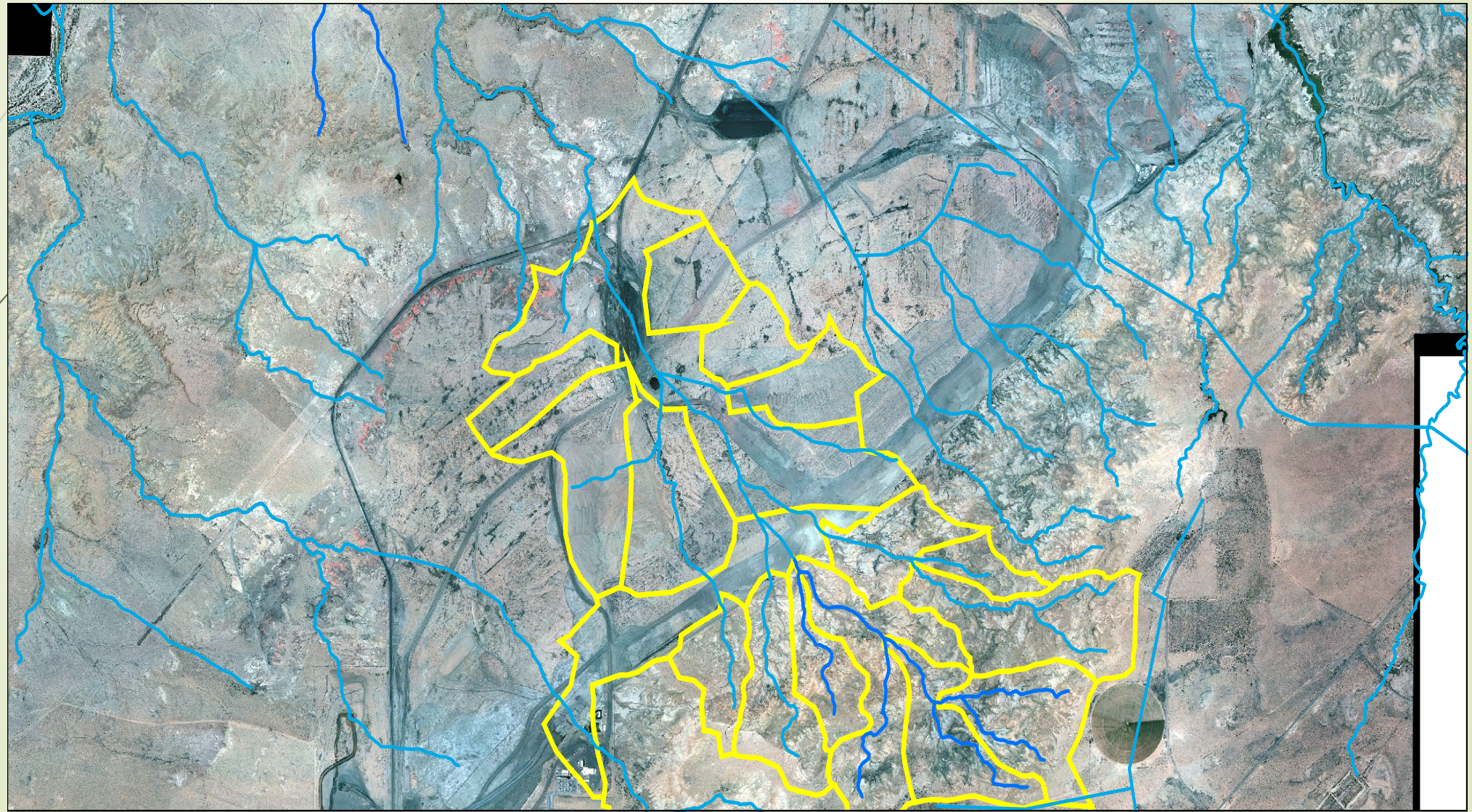


Pre-Mine Vegetation Communities

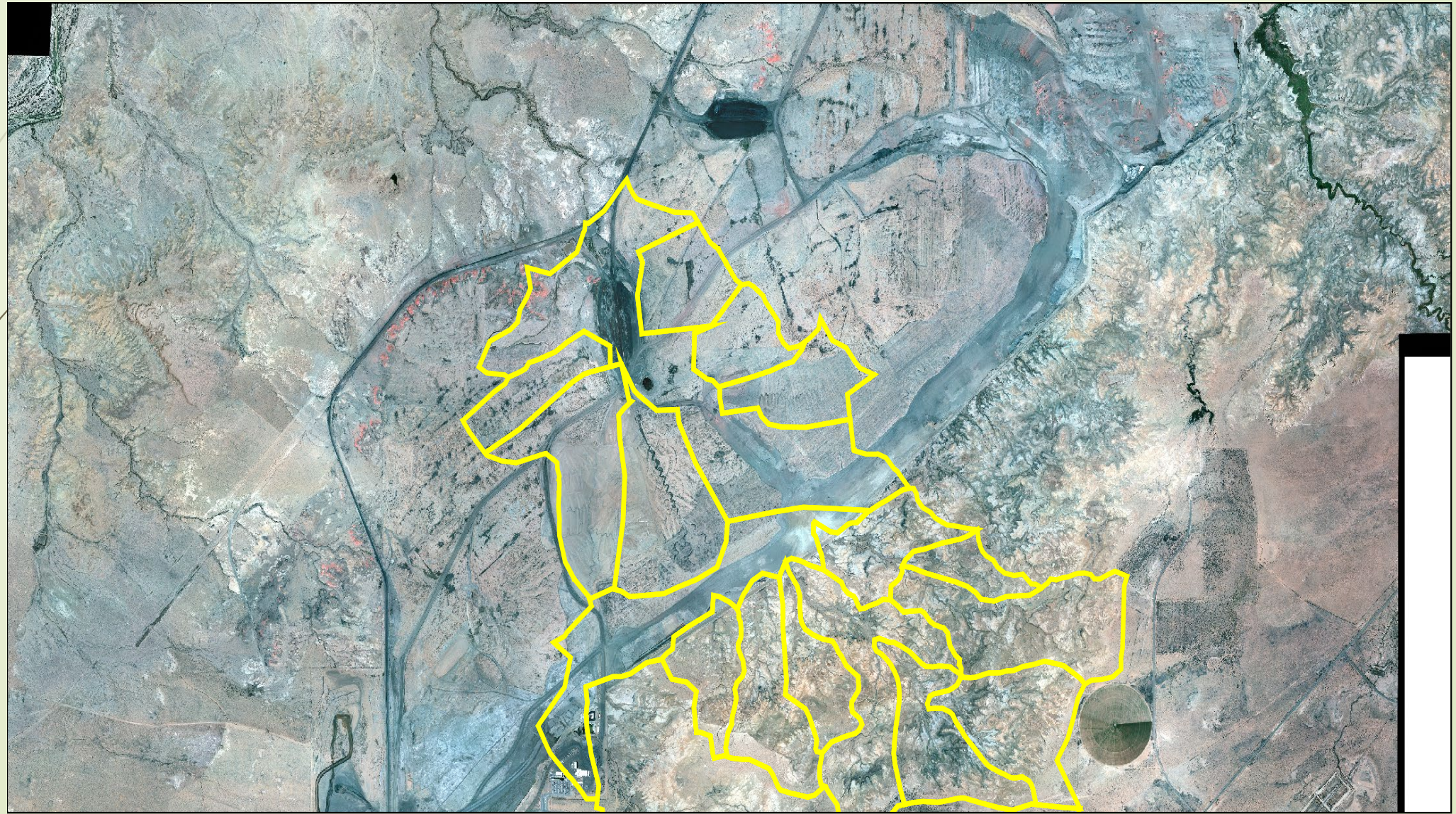


Navajo Mine – North Barber

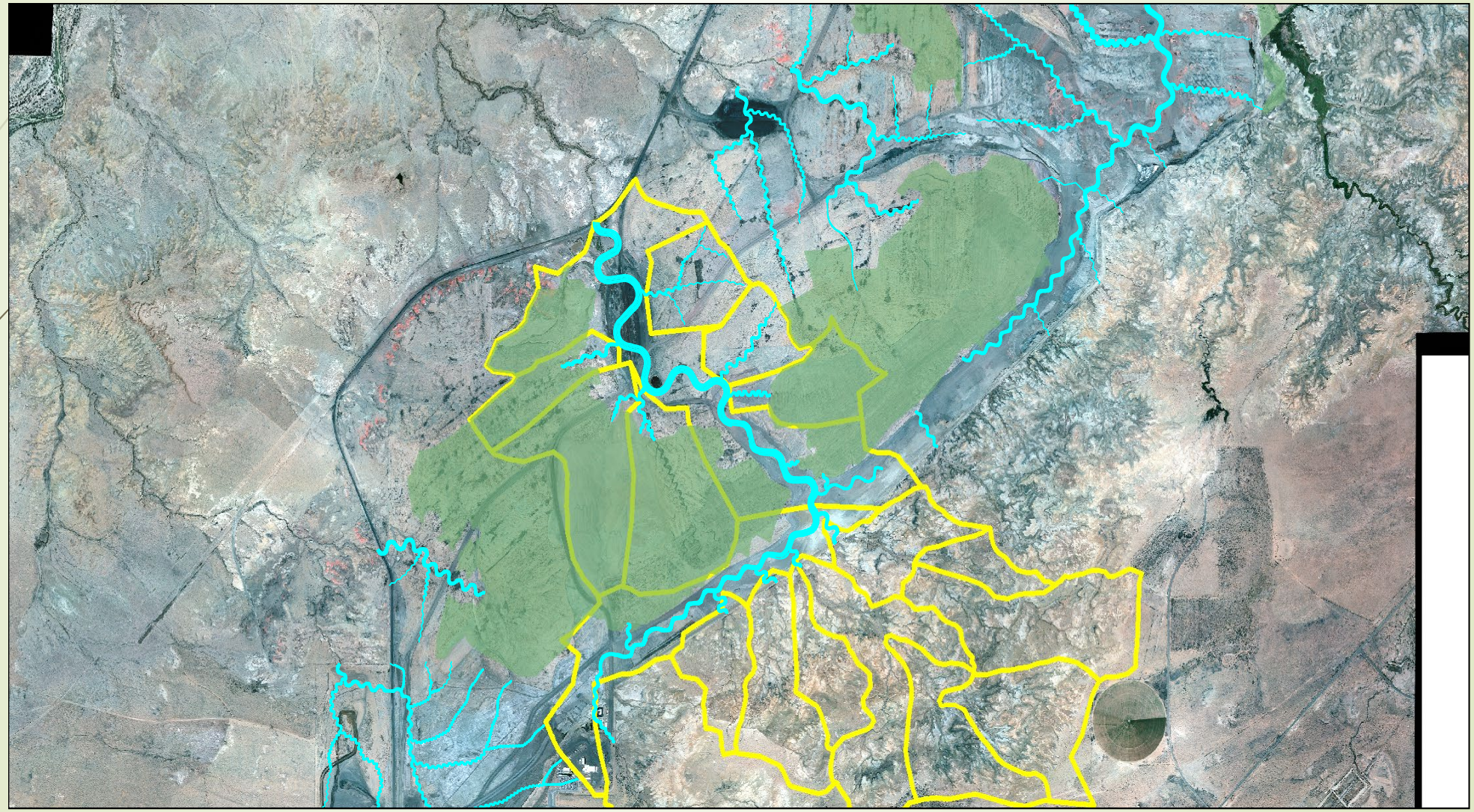
Navajo Mine –North Barber Drainage Density



Navajo Mine –North Barber Watershed



Tie-Ins to Pre-Existing Reclaim



Dozer Cutting Channel

Regrade To Geomorphic Designs

Channel Construction

- A-channels keyed into regrade
- A-channel excavation to build ridges

Final Grade Geomorphic Land Form

Topdressed Geomorphic Final Land Form

Seedbed Prep

Disking and Indian Ricegrass Planting

Seed-Bed Prep. - Eliminate Compaction

Seeding

Seed Mix

Table 37-2 Cool Season Reclamation Seed Mixture[3]

Species common name	Species scientific name	Seeding method/seed group	Seeding depth	Ave. # of seeds/lb	Seeding rate ave. PLS lb/ac	PLS/sq. ft
Thickspike Wheatgrass	Agropyron dasystachyum	D/LS	1/2″- 1″	154,000	0.75	2.65
Blue Grama	Bouteloua gracilis	D/F	¼″-1/2″	825,000	0.15	2.84
Galleta	Hilaria jamesii[1]	D/LS	1/2″- 1″	470,000	0.15	1.62
Prairie Junegrass	Koeleria cristata	B/B	<1/4″	2,315,400	0.05	2.66
Indian Ricegrass	Oryzopsis hymenoides [2]	D/LS	3″- 6″	141,000	1.50	4.86
Bottlebrush Squirreltail	Sitanion hystrix	D/LS	1/2″- 1″	192,000	0.50	2.20
Alkali Sacaton	Sporobolus airoides	B/B	<1/4″	1,758,000	0.04	1.61
Needle and Thread	Stipa comata	D/F	¼″-1/2″	115,000	0.20	0.53
Fourwing Saltbush	Atriplex canescens	D/LS	1/2″- 1″	52,000	1.20	1.43
Shadscale	Atriplex confertfolia	D/LS	1/2″- 1″	64,900	1.00	1.49
Winterfat	Ceratoides lanata	B/B	<1/4″	56,700	1.30	1.69
Evening Primrose	Oenothera pallida	D/LS	1/2″- 1″	512,000	0.30	3.53
Palmer Penstemon	Penstemon palmeri	B/B	<1/4″	210,000	0.40	1.93
Globemallow	Sphaeralcea grossulariaefolia.	D/F	¼″-1/2″	500,000	0.30	3.44
				TOTAL:	7.84	32.48

[1] Caryopsis will be used when available.

[2] Oryzopsis hymenoides is seed separately in sandy topdressing.

[3] Seed mixture established November 1999.

Seeding method: B = Broadcast, D = Drilled; Seed Group: Seeds are separated into groups; B = Broadcast group, F = Fluffy seed, LS = Larg= Fluffy seed, LS = Large smooth seed

Geomorphic Channel Seeded and Mulched

Seeding and Mulching

Mulching

Irrigation

Irrigation

Final Geomorphic Reclamation

Final Geomorphic Reclamation

Final Geomorphic Reclamation

Vegetation Benefits of Geomorphic Landscapes

Recreated Rock Rim and Talus Slope

Re-Created Talus Slopes with Rock and Red Dog Armor

Establishment of Wetland Utilizing Farmland Tail Waters

Chinde Arroyo Utilizing Farmland Tail Waters

Genetically Improved Atriplex

CONTENTS OF EXPERIMENTAL PLOTS

"Breeding and Selection of Superior Plants for Reclamation"

October 1998

by Dr. Howard C. Stutz

Atriplex Cross between Atriplex canescens x A. obovata

"That's all Folks!"