ADVANCEMENTS IN GEOMORPHIC RECLAMATION DESIGN APPROACH

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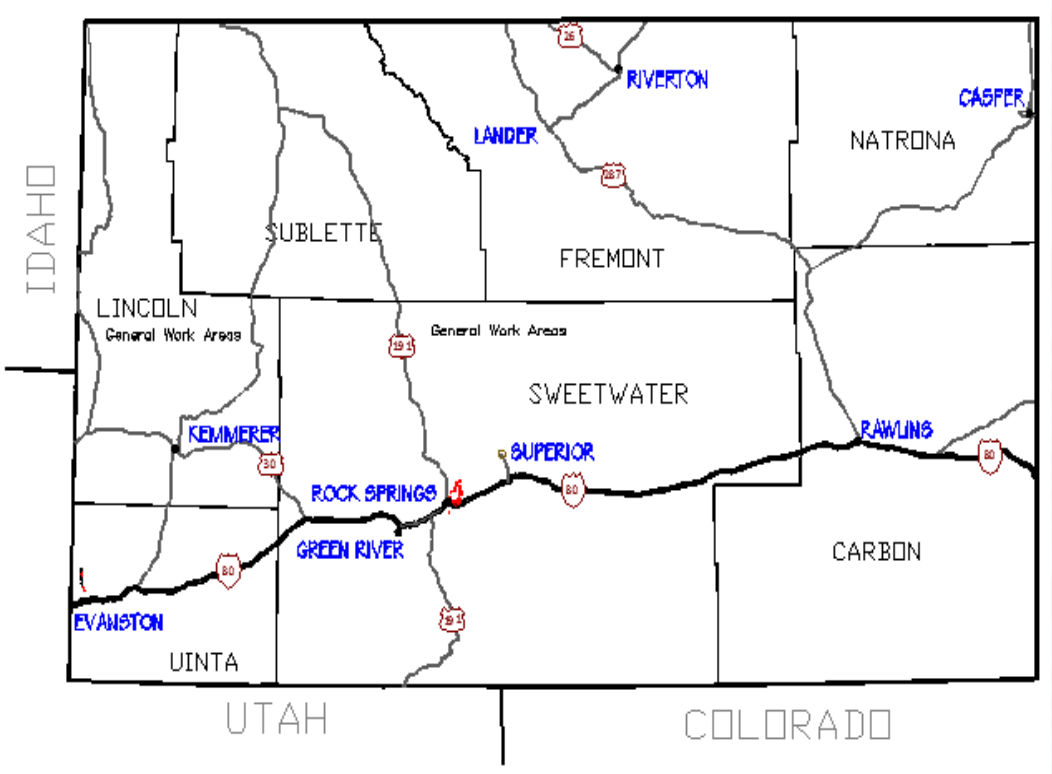
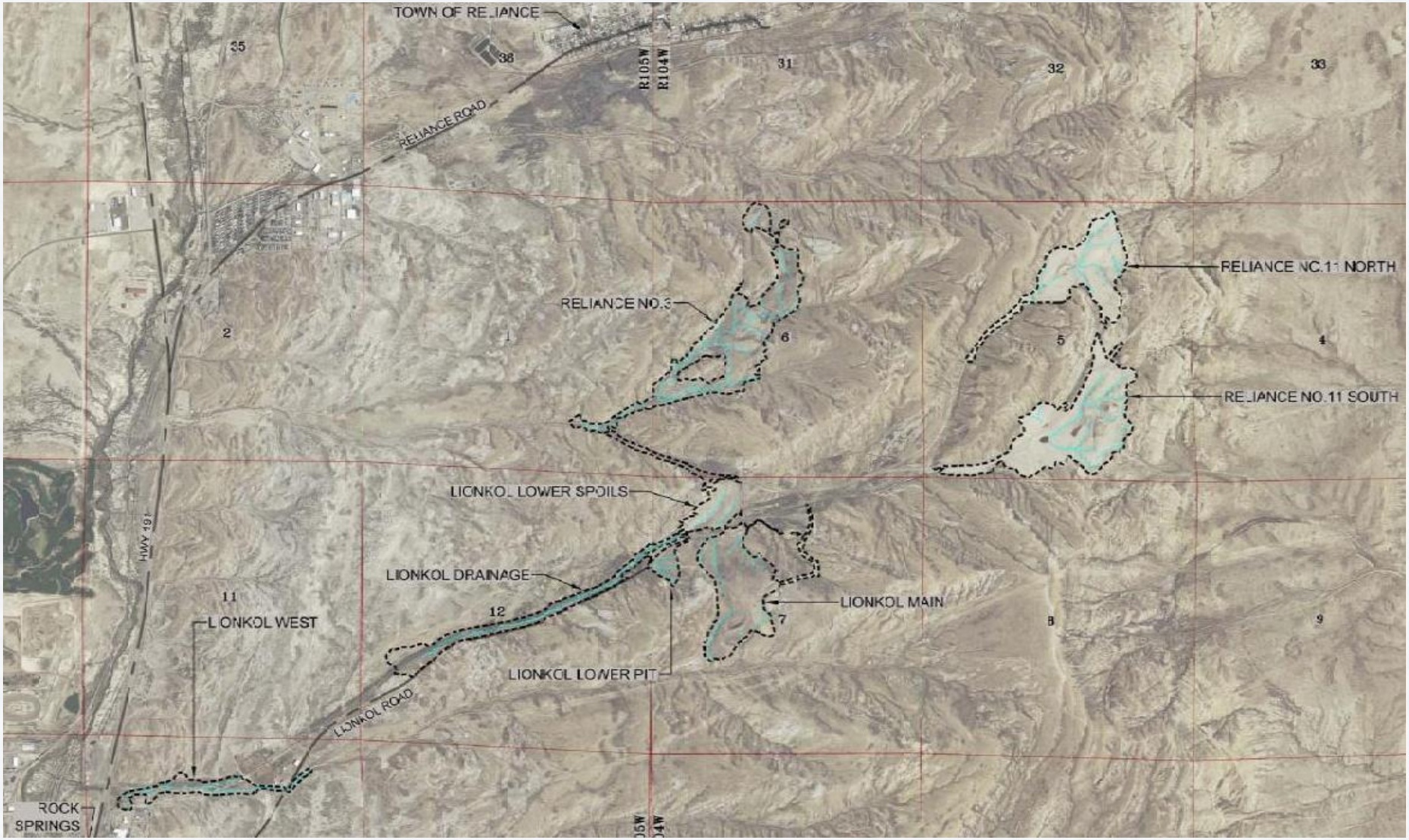
Wyoming Abandoned Mine Land
Project 17 H-2 Lionkol Mining District
Sweetwater County, Wyoming



Department of Environmental Quality
WYOMING

BRS ENGINEERING

Lionkol Coal Mining District



Description of Project Area

- ***Underground Mine Portals, Shafts, and Subsidence***
- ***Four Open Pit Mine Complexes***
- ***320 Acre Disturbance Total***
- ***5 Miles of Degraded Channels***
- ***NRHP Eligible Cultural Sites and Historic Artifacts***
- ***High Public Use Area***

Reclamation Challenges

- ***Arid High Desert Environment***
- ***8.6" Average Annual Precip Incl. Snow***
- ***Elevation Ranging from 6330' to 7000'***
- ***Sparse Vegetation, Poor Soils***
- ***Steep Bedrock Controlled Topography***
- ***Natural Erosive Environment***
- ***Flashy High Intensity Storm Events***

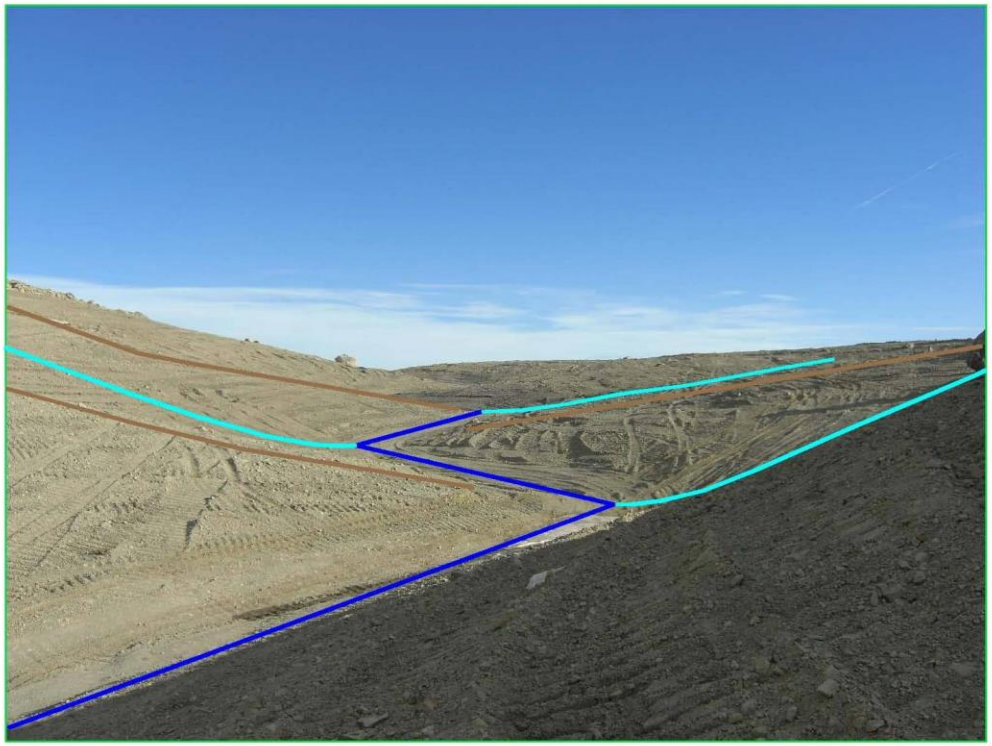
Geomorphic Reclamation Utilizing Natural Regrade Software

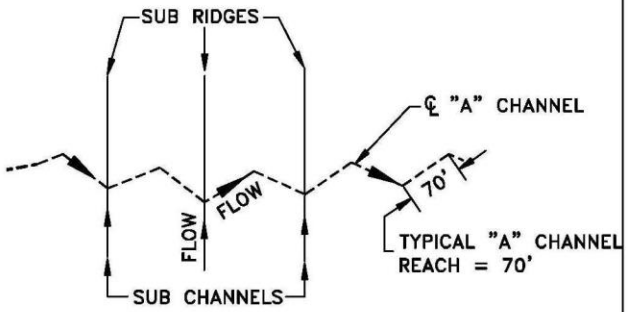
- ***Mimics natural soft sediment topography***
- ***Diverse sustainable landform***
- ***Variable slopes with convex to concave profiles***
- ***Meandering channels to reduce gradient and improve stability***
- ***Small basins and dissection to minimize Q and vary time of concentration***

Advantages of Geomorphic Reclamation

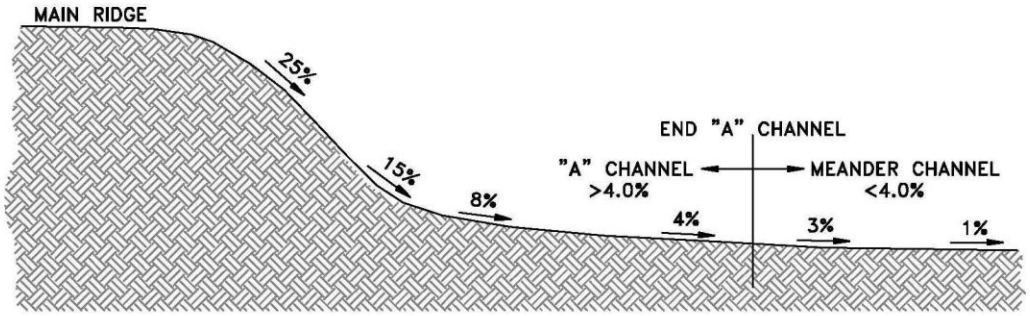
- ***Aesthetically pleasing, sustainable landform***
- ***Increased snow capture***
- ***Anticipated vegetative diversity***
- ***Increased habitat value***

"A" CHANNEL DETAILS

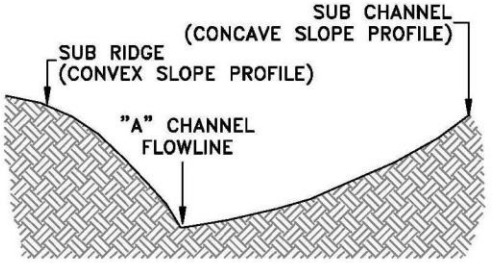




"A" CHANNEL PLAN VIEW
NOT TO SCALE

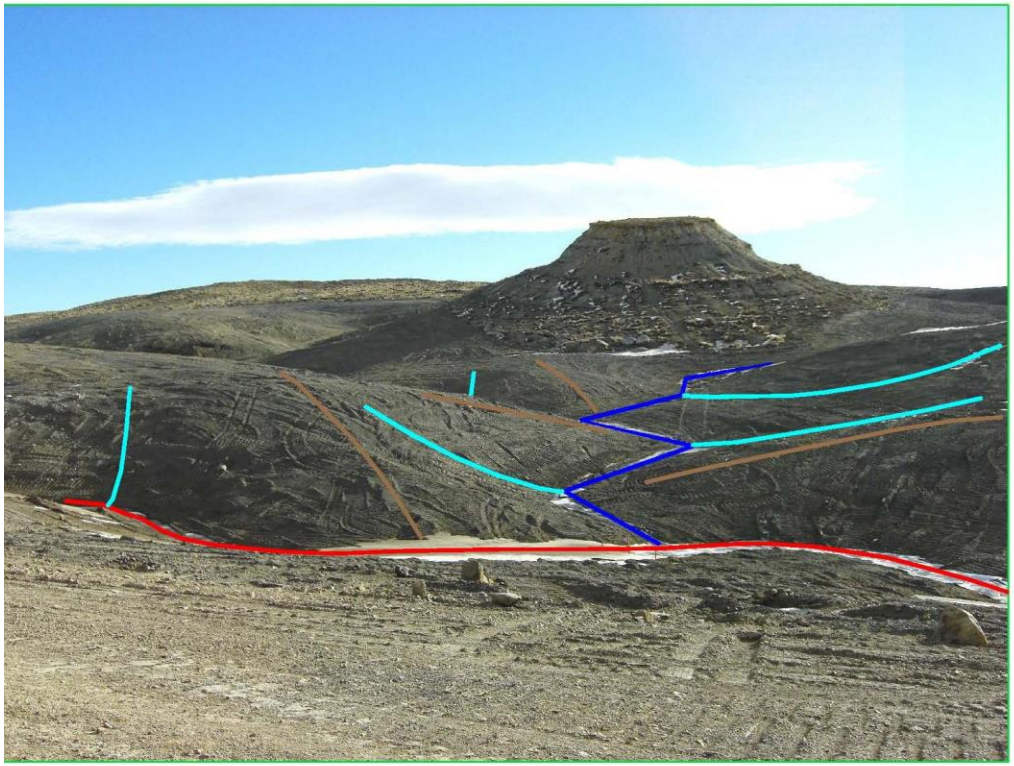


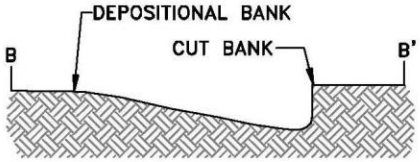
CHANNEL PROFILE
NOT TO SCALE



"A" CHANNEL CROSS SECTION
NOT TO SCALE

MEANDER CHANNEL DETAILS





B–B' CROSS SECTION DETAIL
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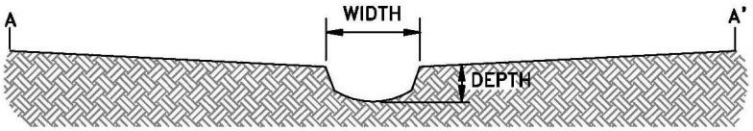
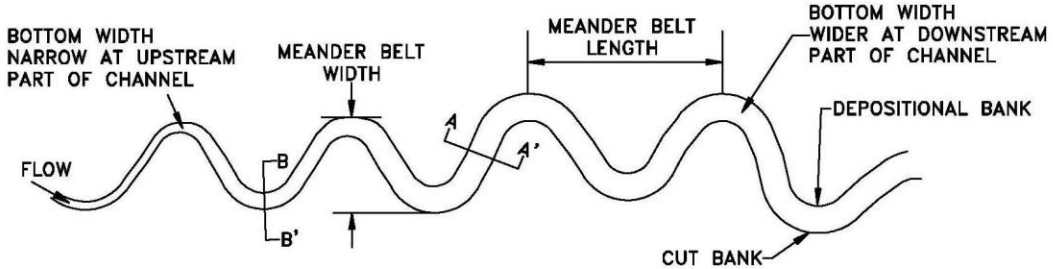


A–A' CROSS SECTION DETAIL
NOT TO SCALE

NOTE:
MEANDER BELT WIDTH, BOTTOM WIDTH, DEPTH, AND BELT LENGTH INCREASE AS CHANNEL PROGRESSES DOWNSTREAM.



MEANDER CHANNEL PLAN VIEW
NOT TO SCALE

Definitions

- ***Bankfull – channel flow condition approximating 2 year frequency or 0.4" in 1 hour for this project.***

Channel bottom based upon conveyance of this event.

- ***Flood Prone - flow condition approximating 50 year frequency or 1.5" in 1 hour for this project.***
- ***Shields Shear Stress – A measure of erosive force based on tractive shear to initiate particle motion.***

Construction Phases

- **17H-2B, Reliance No. 11 North and South Pits**

– Geomorphic Mixed with Traditional Rec.

- **17H-2B-II, Reliance No. 3 and Lionkol Pits**

- Re-constructed Pre-Mine Configuration

- **17H-2B-III, Lionkol Drainage**

- Large Channel Reconstruction with Empirical Runoff Estimation

- **17H-2B-IV, Lionkol West**

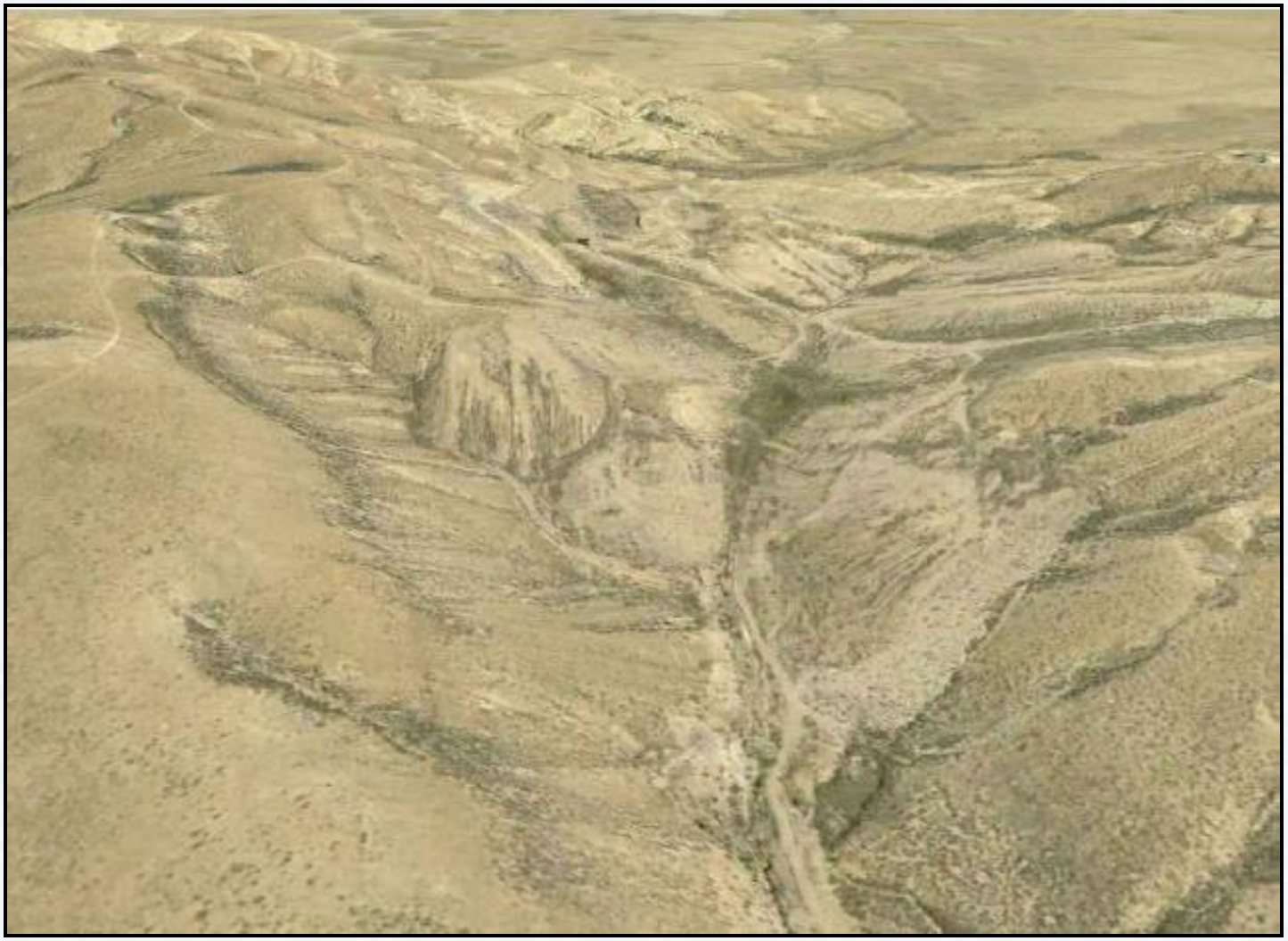
- Channel Reconstruction and Performance Evaluation

AML 17H-2B Project Details

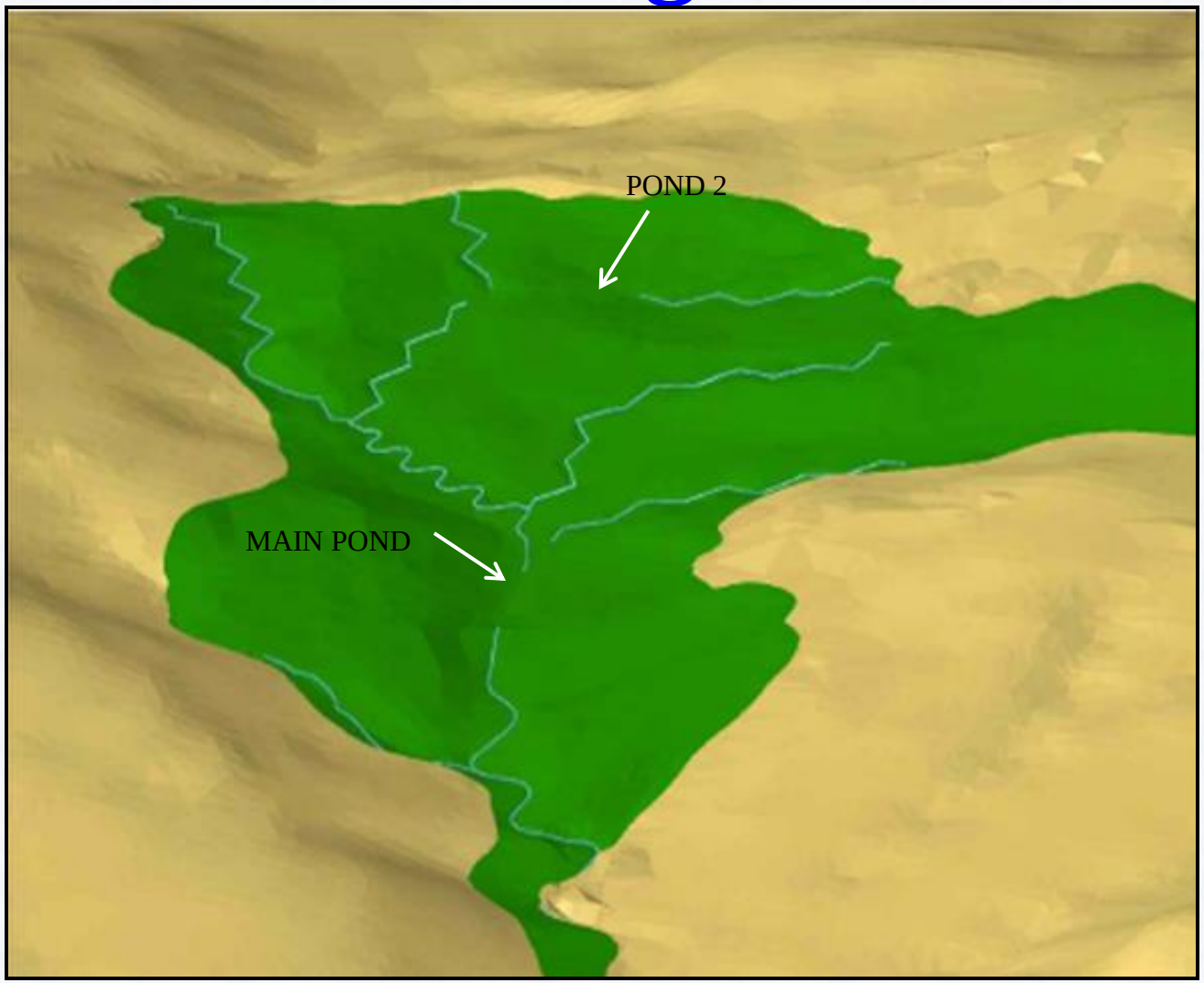
Reliance No. 11 North and South Pits Project

- *1 million cubic yards*
- *$1.9 million bid cost*
- *127 acres of Natural Regrade TM design surface*

Reliance No. 11 North
Pre-Construction

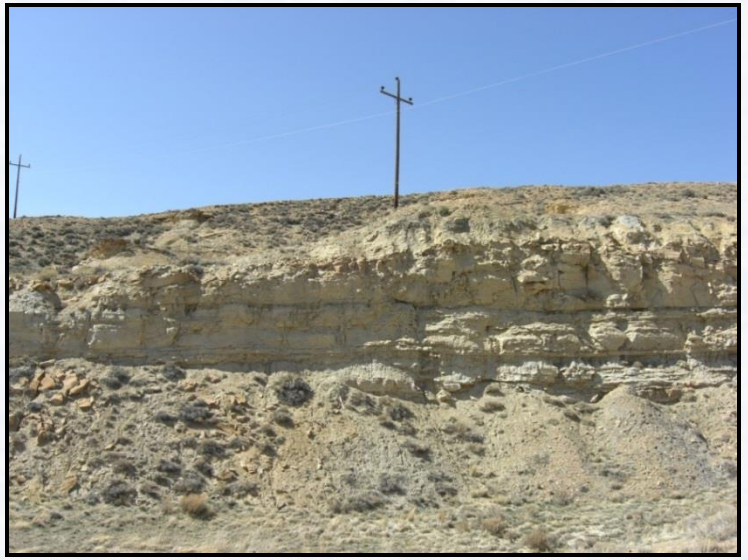


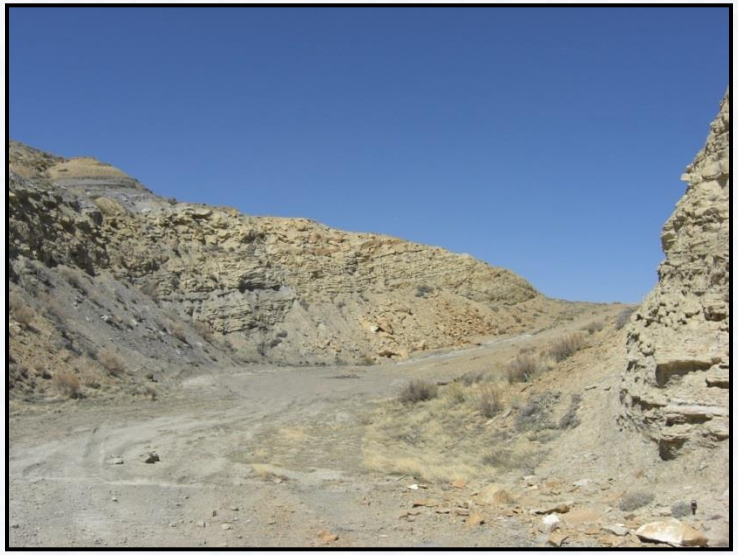
Reliance No. 11 North Design



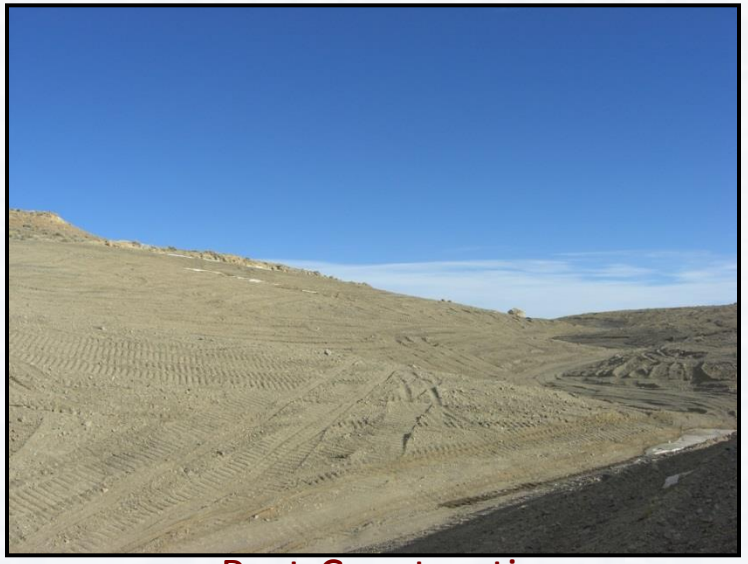
Reliance No. 11 North
Post Construction

Reliance No. 11 North Highwall and Power Line



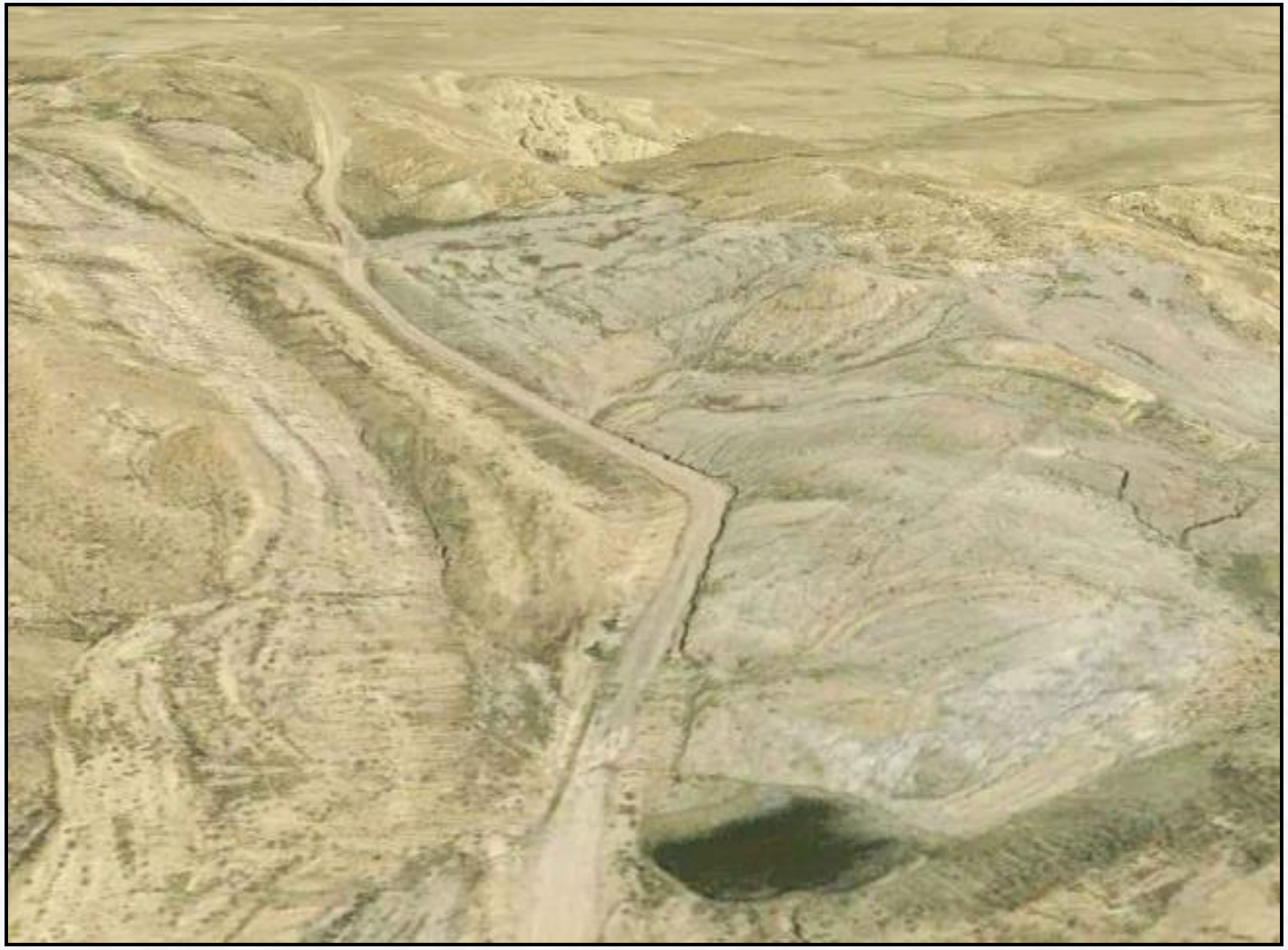


Pre-Construction

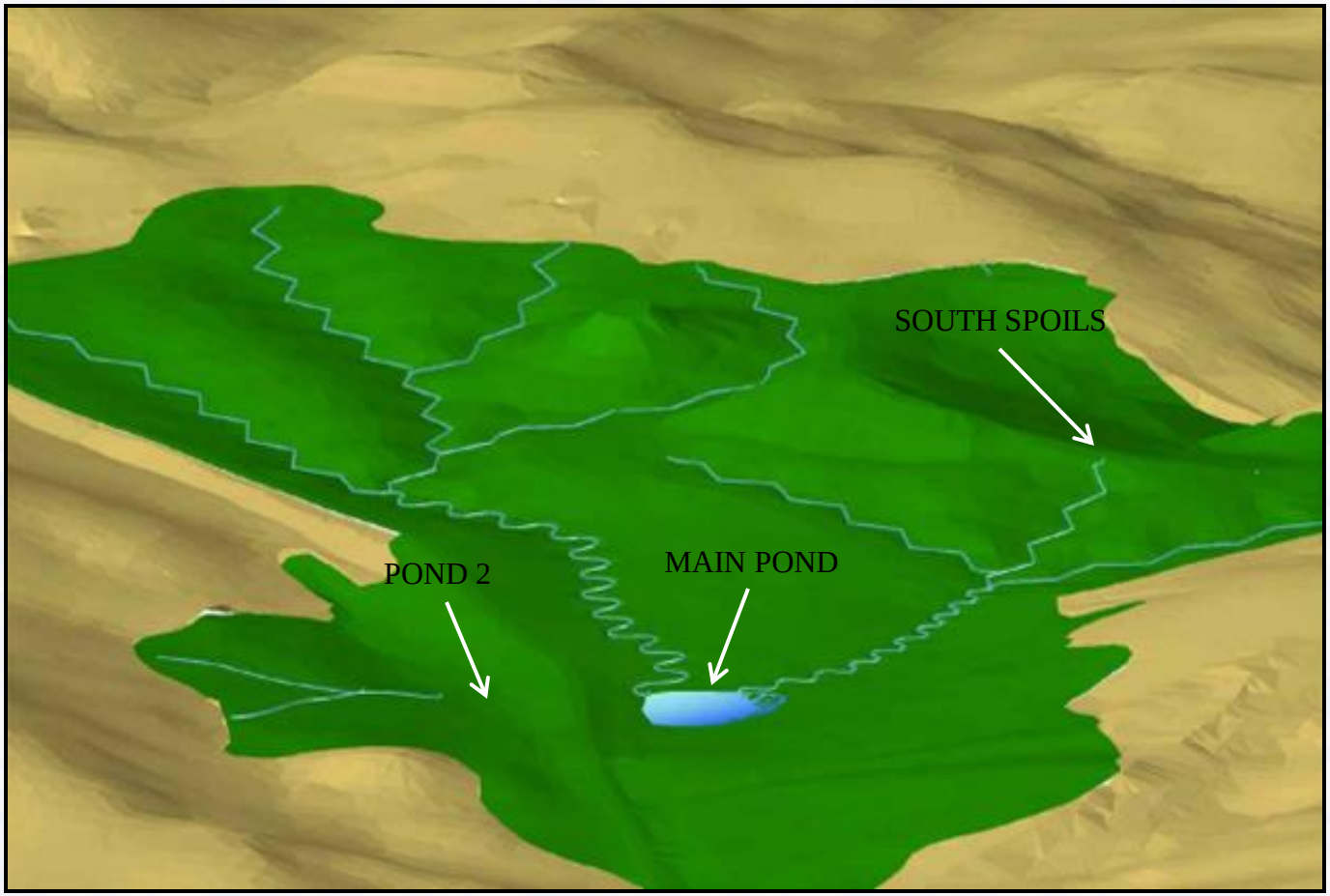


Post-Construction

Reliance No. 11 South
Pre-Construction

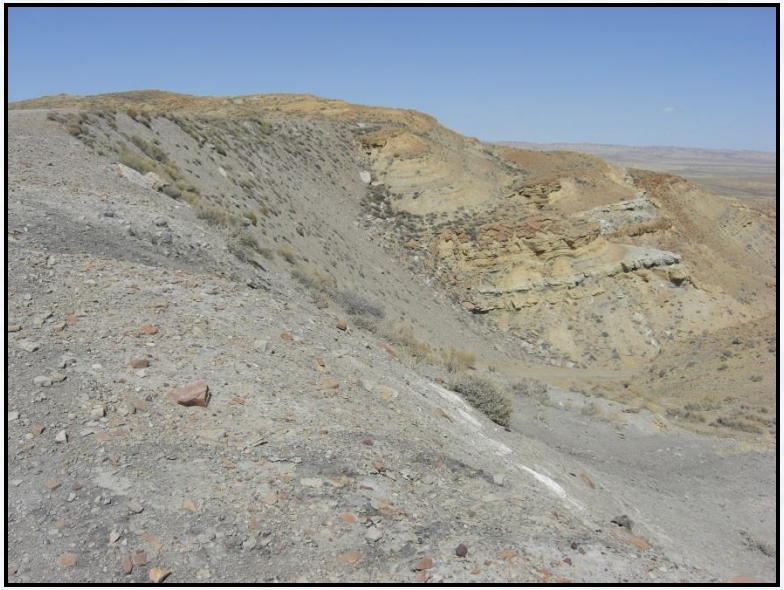


Reliance No. 11 South Design Rendering



Reliance No. 11 South
Post Construction

Dangerous Spoil Pile



Reliance No. 11 South
Eroded Pit Floor and Spoils

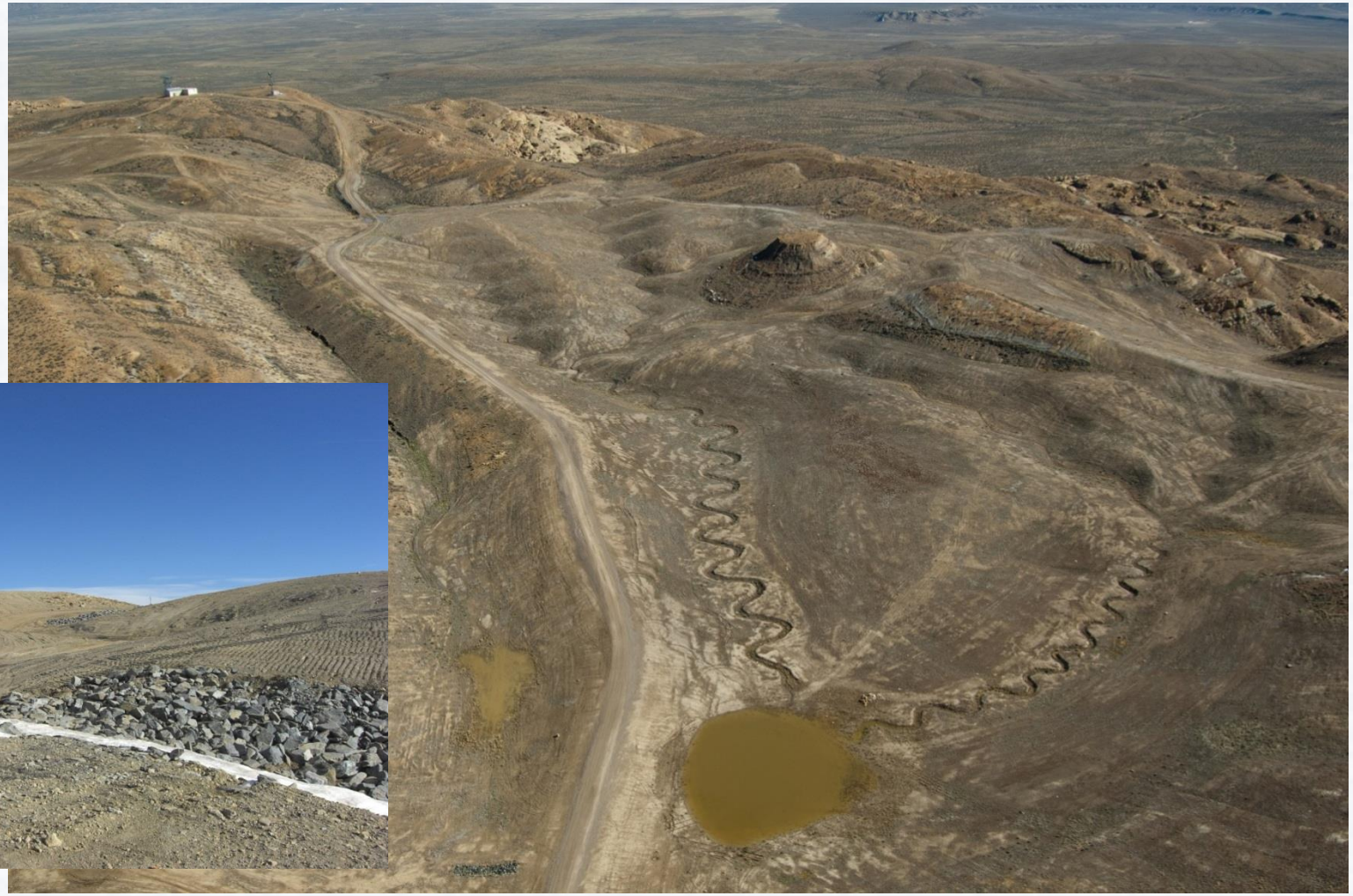
Reliance No. 11 North and South Design Approach

- ***Combination of NR and traditional reclamation techniques***
- ***Blend with native and outcrops***
- ***Used Carlson's stability criteria***
  - ***< 1.0 psf for bankfull flows***
  - ***< 1.5 psf for flood-prone flows***
- ***Traditional structures***
  - ***Runoff attenuation impoundments***
  - ***Traditional flat-bottom channels***
  - ***Riprap erosion control structures***

Reliance No. 11 South Design Representative Runoff Parameters

Basin Name	Bank-full Conditions*				Flood-prone Conditions**			
	width range (ft.)	depth range (ft.)	Shields shear stress, (psf)	Qpk (cfs)	width range (ft.)	depth range (ft.)	Shields shear stress, (psf)	Qpk (cfs)
Main	0.07 to 6.69	0.01 to 0.42	0.06 to 1.33	19.58	0.16 to 12.66	0.02 to 1.22	0.09 to 1.90	65.27
L-1	0.40 to 3.91	0.04 to 0.39	0.19 to 1.19	6.89	0.94 to 9.07	0.11 to 1.04	0.28 to 1.71	22.97
L-2	0.06 to 4.34	0.01 to 0.35	0.05 to 0.77	6.84	0.15 to 9.09	0.02 to 0.94	0.08 to 1.11	22.80
L-1 R1	0.30 to 3.07	0.03 to 0.31	0.24 to 1.07	4.24	0.69 to 7.12	0.08 to 0.81	0.34 to 1.54	14.14
L-1 R1 L1	0.44 to 1.77	0.04 to 0.18	0.39 to 1.07	1.42	1.03 to 4.11	0.12 to 0.47	0.57 to 1.54	4.72
L-2 L1	0.31 to 1.99	0.03 to 0.20	0.13 to 0.71	1.77	0.72 to 4.6	0.08 to 0.53	0.15 to 1.02	5.91
L-2 R1	0.42 to 2.61	0.05 to 0.21	0.16 to 0.67	2.51	0.89 to 5.48	0.09 to 0.63	0.26 to 0.95	8.38

Reliance No. 11
Traditional Reclamation Elements



Reliance No. 11 South Completed Reclamation

Phase 2B

Performance Evaluation

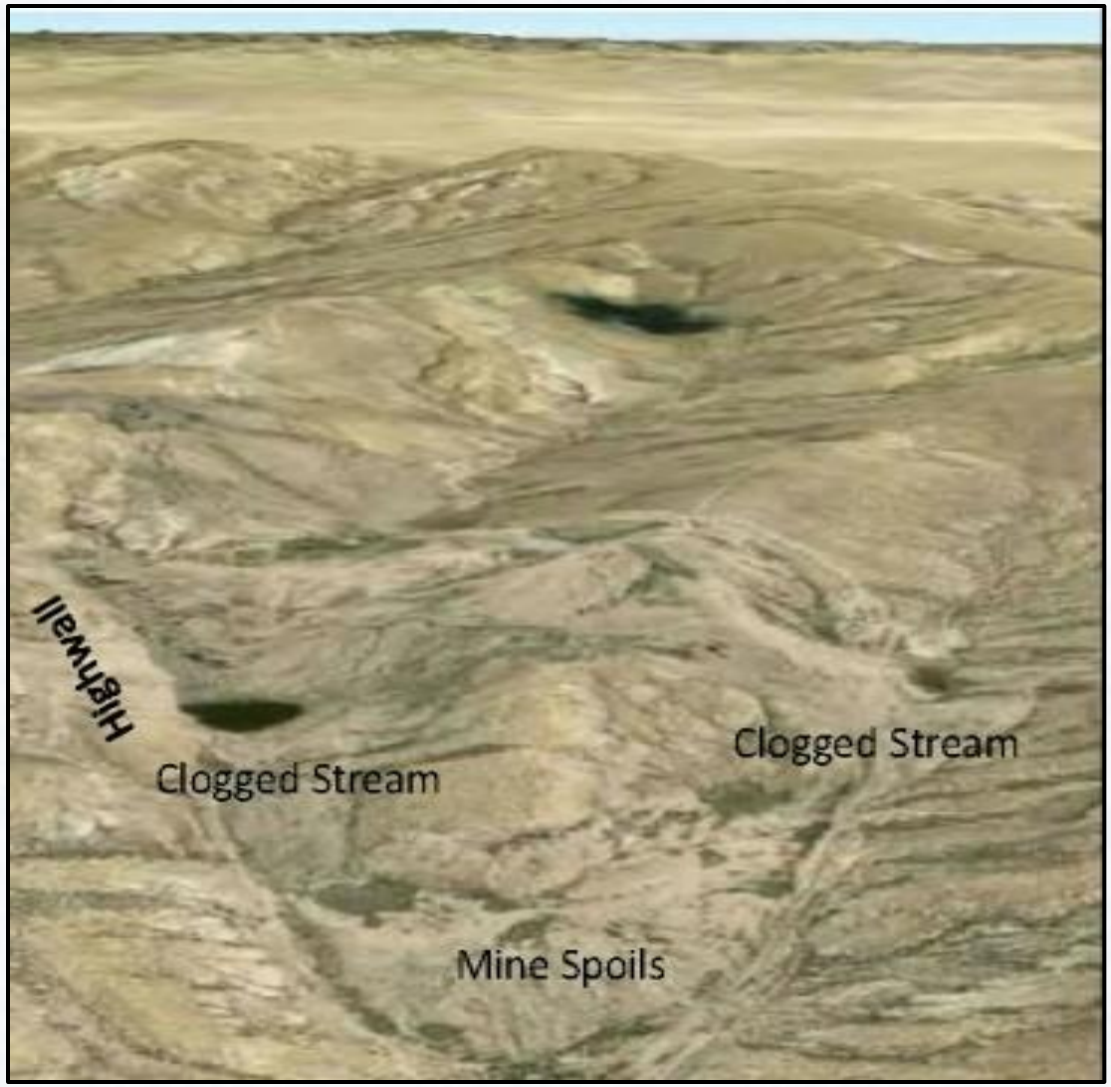
- ***Completed 2013 after four summers, minor vegetation re-establishing***
- ***Despite damage due to off road vehicles, geomorphic channels performing well***
- ***18" pilot channel near a confluence repaired itself after high flows in fall 2013***
- ***Damage to traditional channel areas***

AML 17H-2B-II Project Details

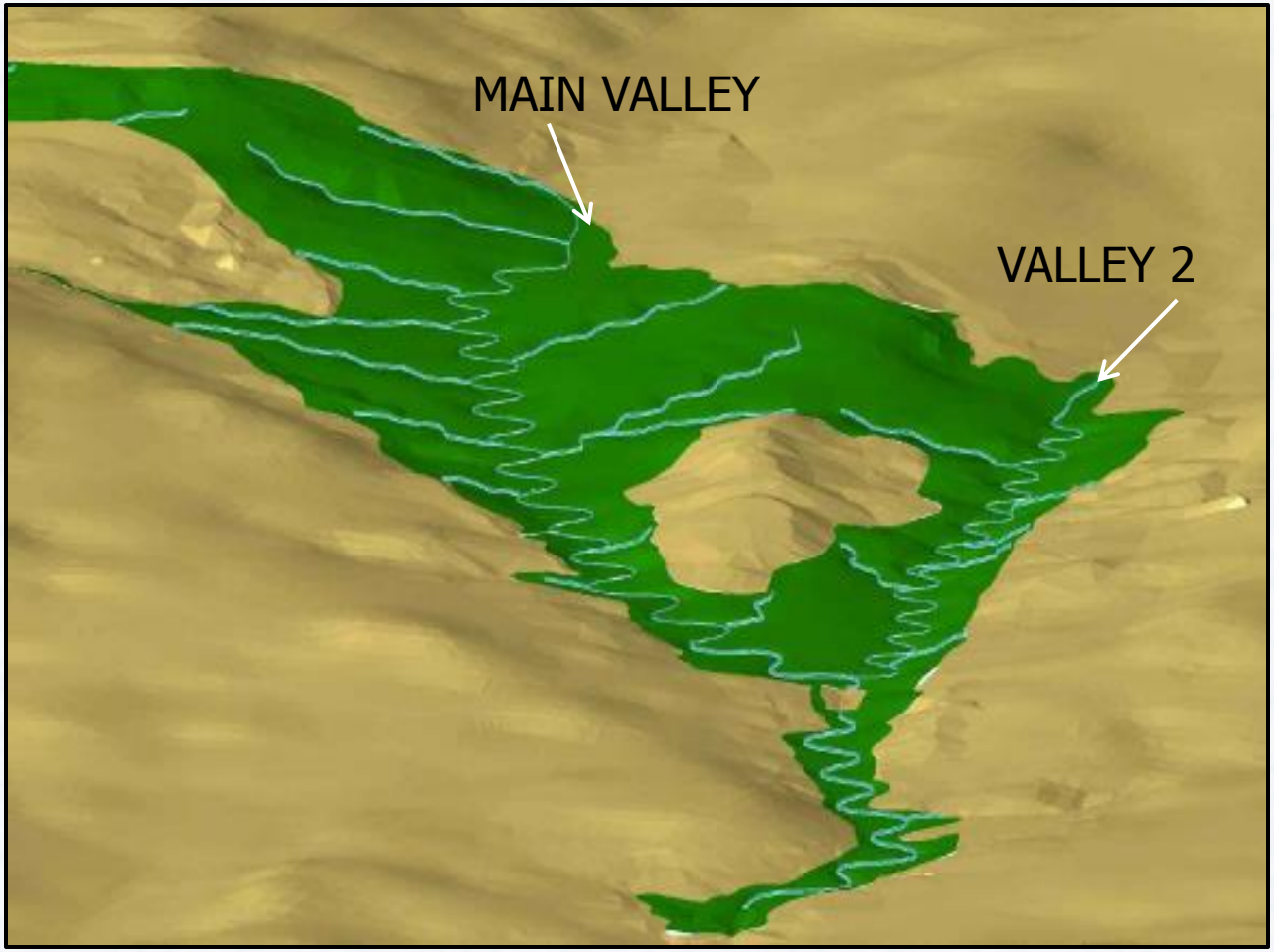
Reliance No. 3 & Lionkol Pits Project

- *1.2 million cubic yards*
- *$1.9 million bid cost*
- *160 acres of Natural Regrade design surface*

Reliance No. 3
Pre-Construction

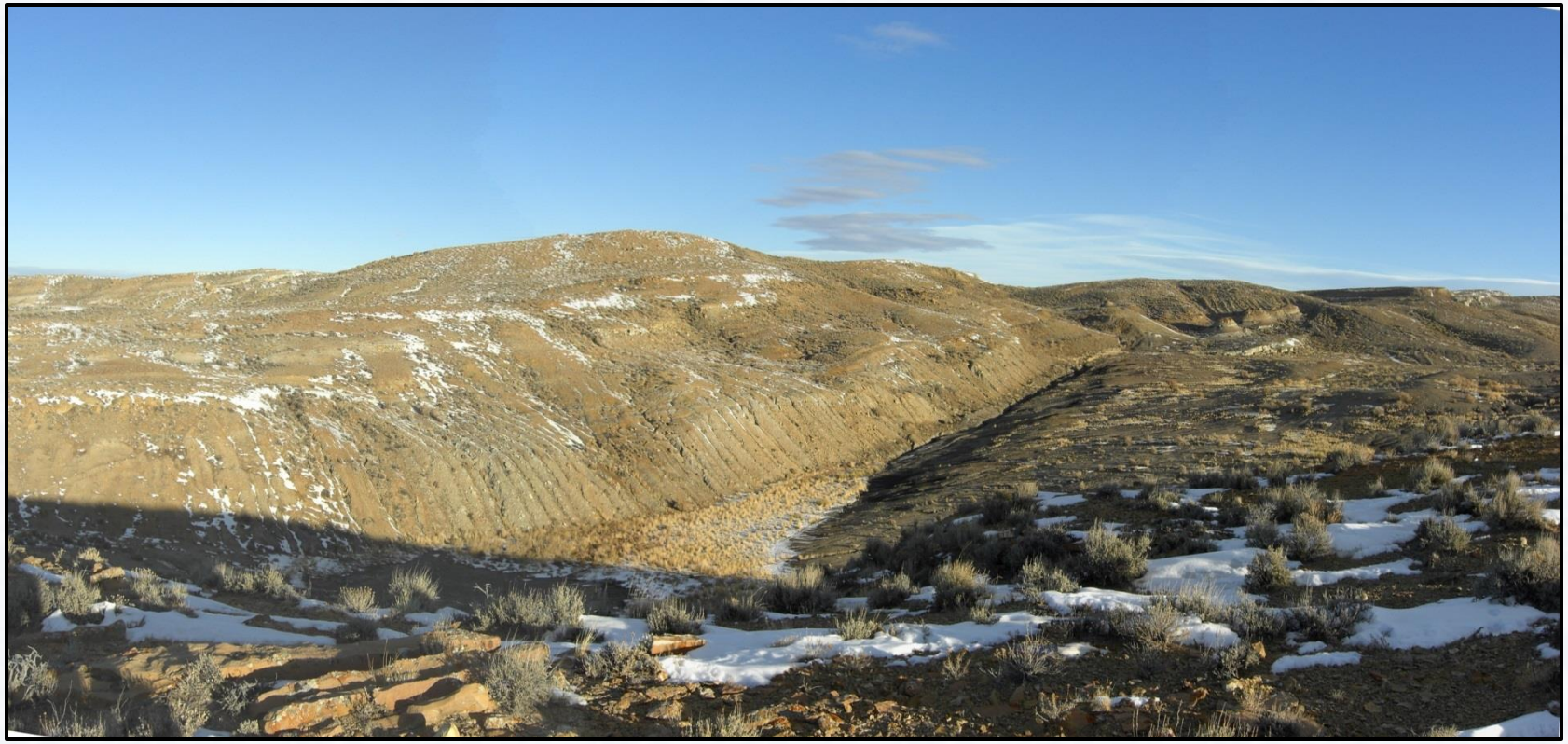


Reliance No. 3
Design Rendering



Reliance No. 3
Post Construction

Reliance No. 3
Highwall



Reliance No.3 Pit with Highwall (center) Prior to Reclamation.

AML 17H-2B-II

Exposed Auger Holes in Reliance No.3 Highwalls.

AML 17H-2B-II

Spoils Blocking a Native Drainage at Reliance No.3 Pit Prior to Reclamation.

Reliance No. 3 and Lionkol Design Approach

- ***Minimal traditional reclamation elements***
- ***Detailed transition surveys to tie in contributing native basins***
- ***High shear stresses allowed as design surface approximated the pre-mine surface with respect to elevations and channel configuration***
- ***Erosion control structures at main channel ends***

Main Runoff Parameters

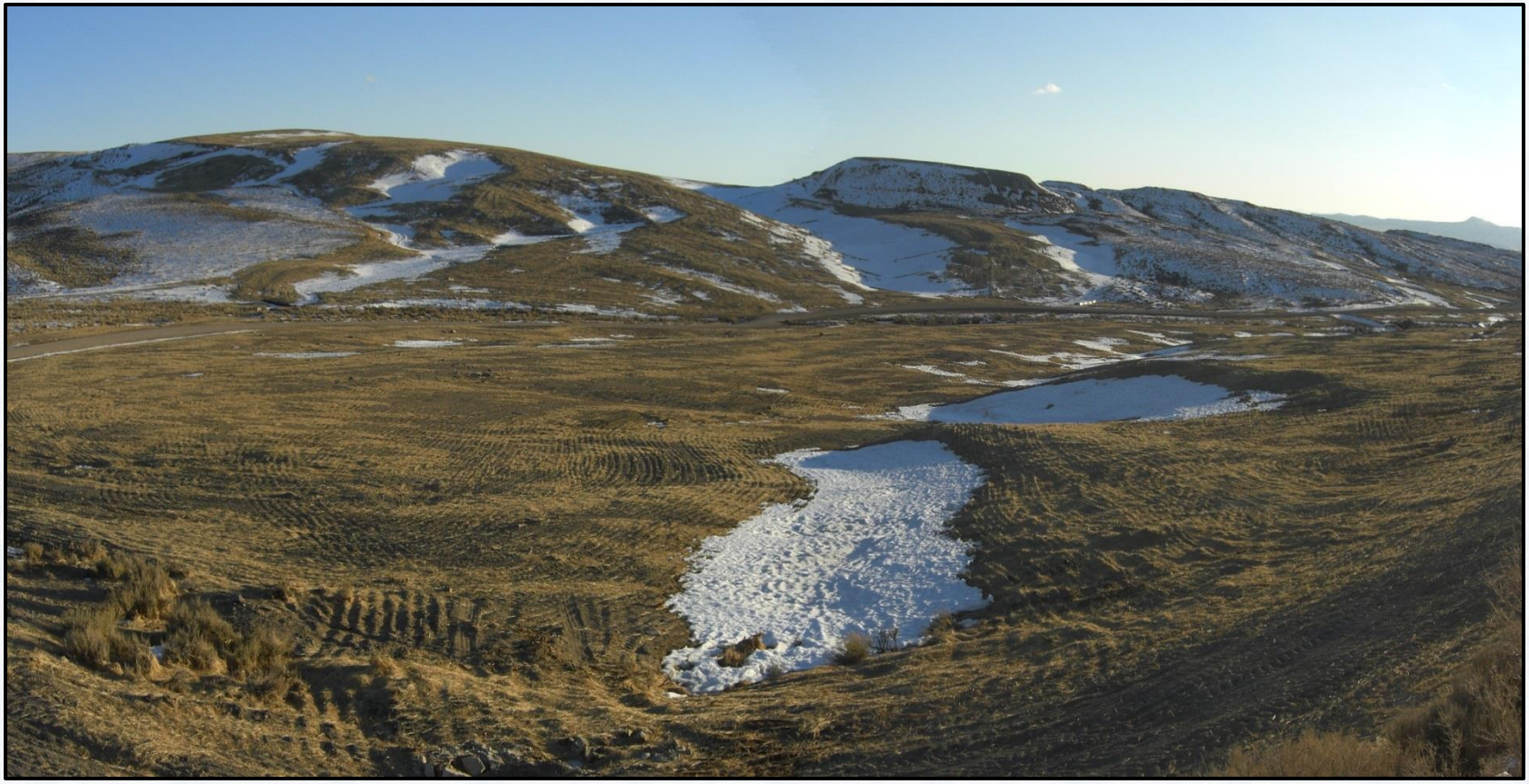
Basin Name	Bank-full Conditions*				Flood-prone Conditions**			
	width range (ft.)	depth range (ft.)	Shields shear stress, (psf)	Qpk (cfs)	width range (ft.)	depth range (ft.)	Shields shear stress, (psf)	Qpk (cfs)
Main	11.40 to 16.19	0.74 to 1.02	1.03 to 1.61	74.08	22.40 to 32.41	2.20 to 3.04	2.58 to 3.00	277.80
L-5	0.40 to 2.46	0.07 to 0.20	0.29 to 0.58	2.24	0.89 to 5.46	0.09 to 0.57	0.49 to 0.88	8.40
L-6	0.22 to 2.65	0.02 to 0.21	0.18 to 0.86	2.55	0.53 to 5.87	0.06 to 0.64	0.27 to 1.31	9.58
L-6 L1	0.38 to 1.05	0.04 to 0.10	0.26 to 0.46	0.49	0.93 to 2.57	0.11 to 0.30	.40 to 0.69	1.85
L7	1.06 to 1.27	0.11 to 0.10	0.22 to 2.08	0.58	2.60 to 2.81	0.27 to 0.32	.36 to 3.17	2.19
L-8	1.06 to 1.49	0.11 to 0.12	0.19 to 0.72	0.81	2.61 to 3.31	0.28 to 0.37	0.32 to 1.09	3.04
R-4	0.24 to 1.98	0.02 to 0.16	0.22 to 1.43	1.46	0.58 to 4.42	0.07 to 0.51	0.37 to 2.17	5.47
R-5	0.20 to 1.96	0.02 to 0.16	0.29 to 0.79	1.40	0.50 to 4.34	0.06 to 0.48	0.48 to 1.20	5.25
R-6	0.89 to 1.62	0.09 to 0.13	0.24 to 0.75	0.96	2.18 to 3.59	0.23 to 0.40	0.40 to 1.13	3.61
R-7	2.07 to 2.66	0.21 to 0.21	0.36 to 0.87	2.58	5.08 to 5.91	0.54 to 0.62	0.61 to 1.33	9.66
R-8	1.36 to 2.11	0.14 to 0.17	-0.54 to 1.18	1.62	3.33 to 4.68	0.35 to 0.53	-0.90 to 1.79	6.06
R-9	1.14 to 2.41	0.11 to 0.19	0.33 to 0.80	2.11	2.81 to 5.36	0.29 to 0.60	0.56 to 1.21	7.91
R-9 R1	1.28 to 1.37	0.13 to 0.14	0.60 to 0.91	0.85	3.15 to 3.37	0.36 to 0.39	0.91 to 1.39	3.18
R-9 R2	0.46 to 0.59	0.05 to 0.06	0.32 to 0.45	0.16	1.13 to 1.46	0.13 to 0.17	0.49 to 0.69	0.60
R-10	1.11 to 1.42	0.11 to 0.11	0.19 to 0.76	0.74	2.74 to 3.16	0.29 to 0.34	0.32 to 1.16	2.76
R-11	1.06 to 1.27	0.11 to 0.10	0.20 to 1.03	0.59	2.60 to 2.83	0.27 to 0.32	0.34 to 1.57	0.59
R-12	3.34 to 3.75	0.33 to 0.30	0.73 to 1.97	5.07	8.22 to 8.32	0.87 to 0.95	1.23 to 2.99	19.00

Lionkol Main Pit

Initiation of Construction at Lionkol Main Pit Showing Oversteepened Slopes with Rilling.

Lionkol Design Rendering

Lionkol Main Pit



Completed Reclamation at Lionkol, Winter 2009. Note "A" Channels Capturing Snow in Upper Left.

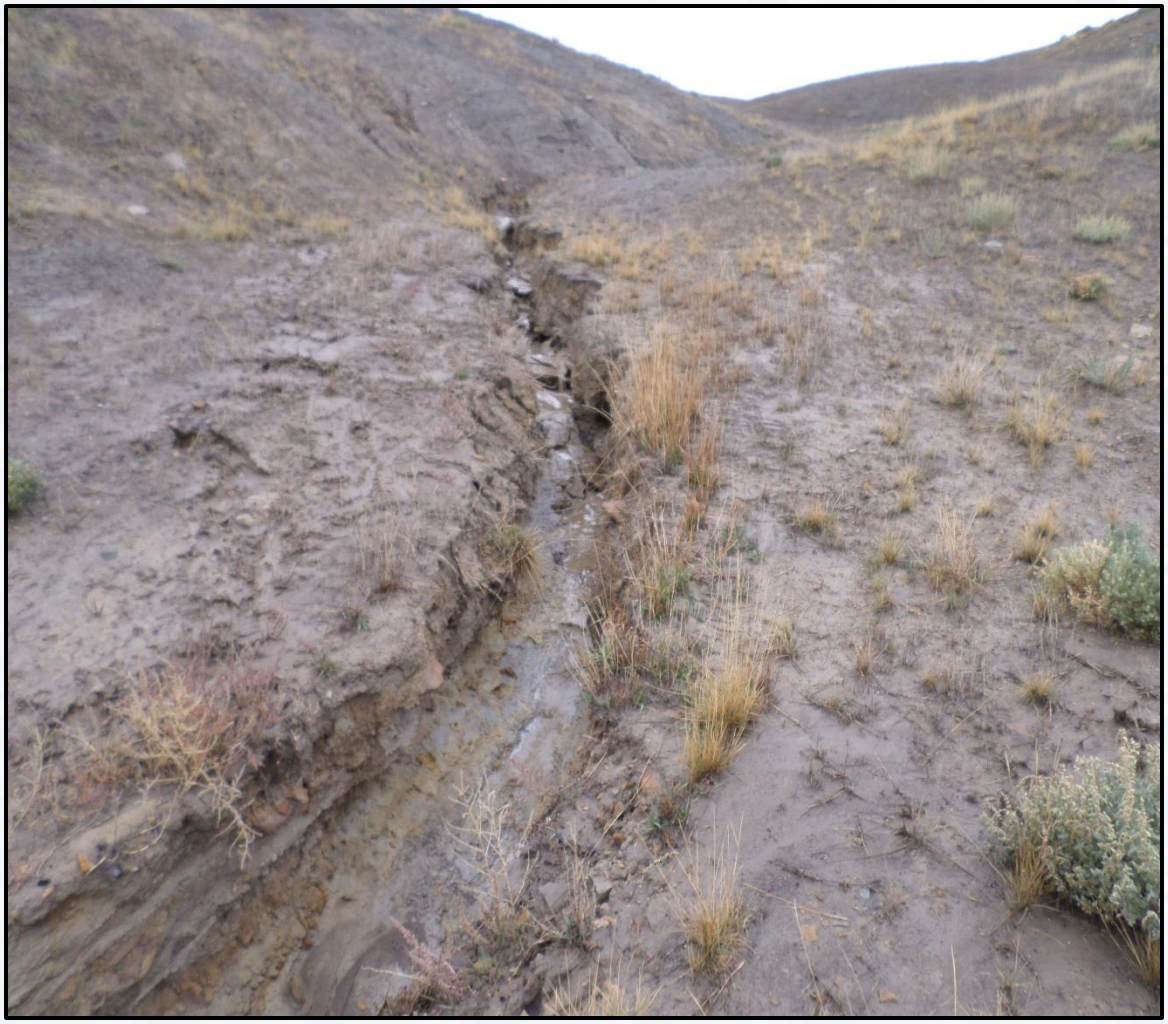
Phase 2B-II

Performance Evaluation

- ***Completed 2013 after four summers, mixed vegetation success***
- ***Despite high design shears, geomorphic channels performing well***
- ***Four pilot channels formed, all on steep gradient "A" channels with contributing basin area.***
- ***Meandering main channels performing well, validating the design approach***

Lionkol

Failing “A” Channel



Reliance No. 3
Native Grass and Shrub Establishment

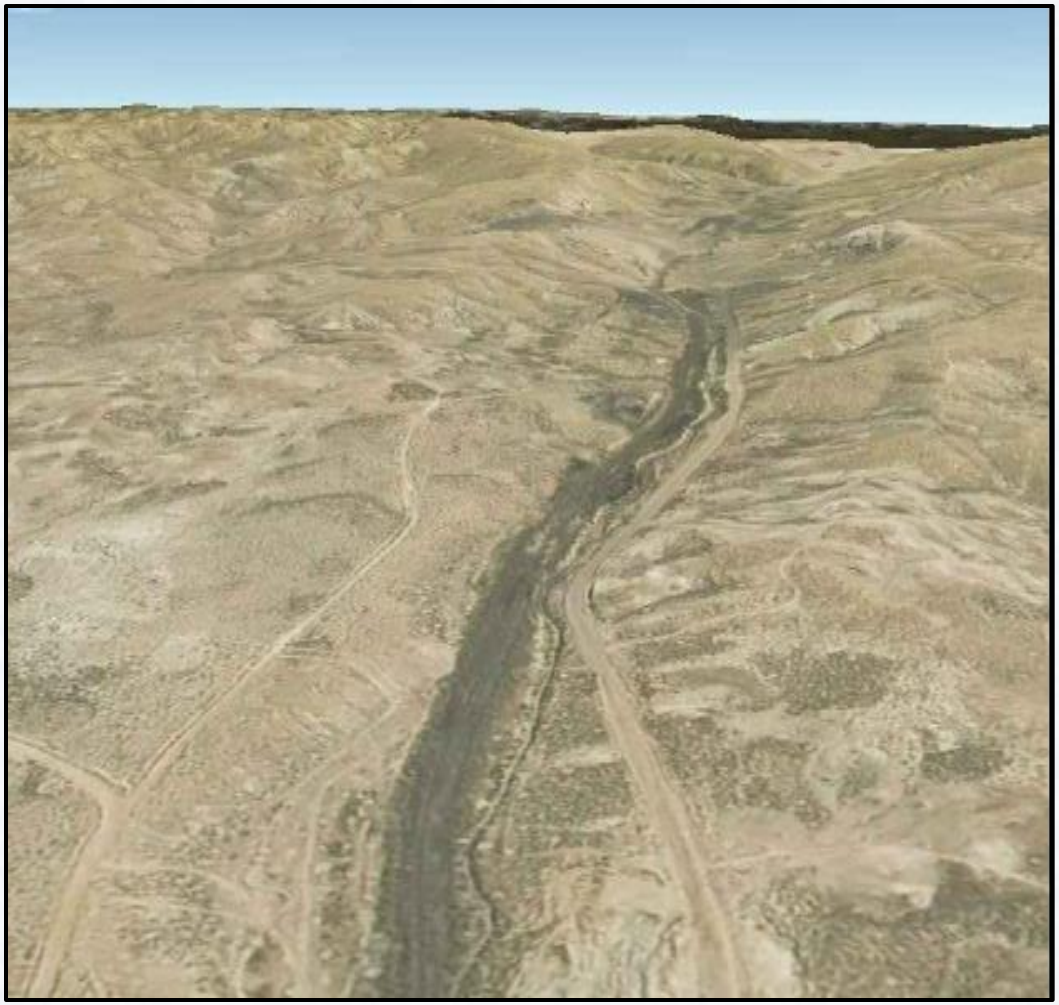
AML 17H-2B-III Project Details

Lionkol Drainage Project

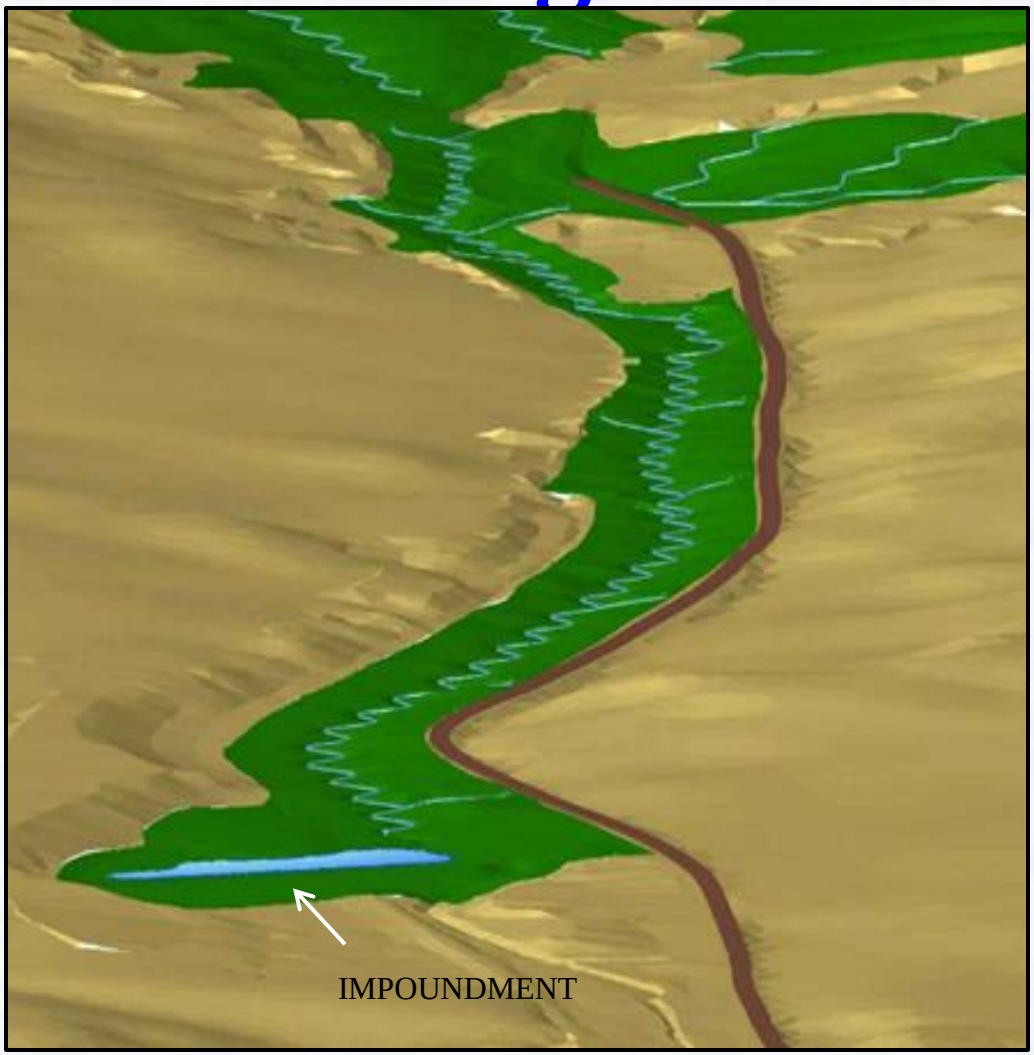
- *135,000 cubic yards*
- *$850,000 bid cost*
- *Zoned embankment, culverts, and road improvement*
- *32 acres of Natural Regrade design surface*

Lionkol Drainage

Pre-Construction



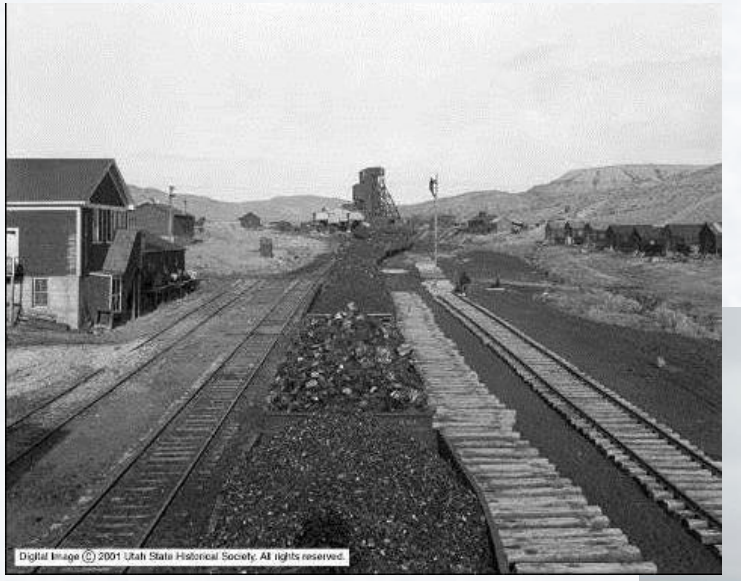
Lionkol Drainage Design



Lionkol Drainage

Post Construction

Lionkol Drainage
Channelization and Erosion



Lionkol Drainage
Channelization and Erosion

Lionkol Drainage Design Approach

- ***Minimal traditional reclamation elements associated with tie in to culverts and final impoundment***
- ***Detailed transition surveys to tie in contributing native basins***
- ***Regional regression equations (Miller 2003) utilized for flow estimates, moving shear stress values closer to criteria***
- ***Provide runoff attenuation and storage***

Lionkol Drainage

Eroded Channel at Historic Tipple

Lionkol Drainage

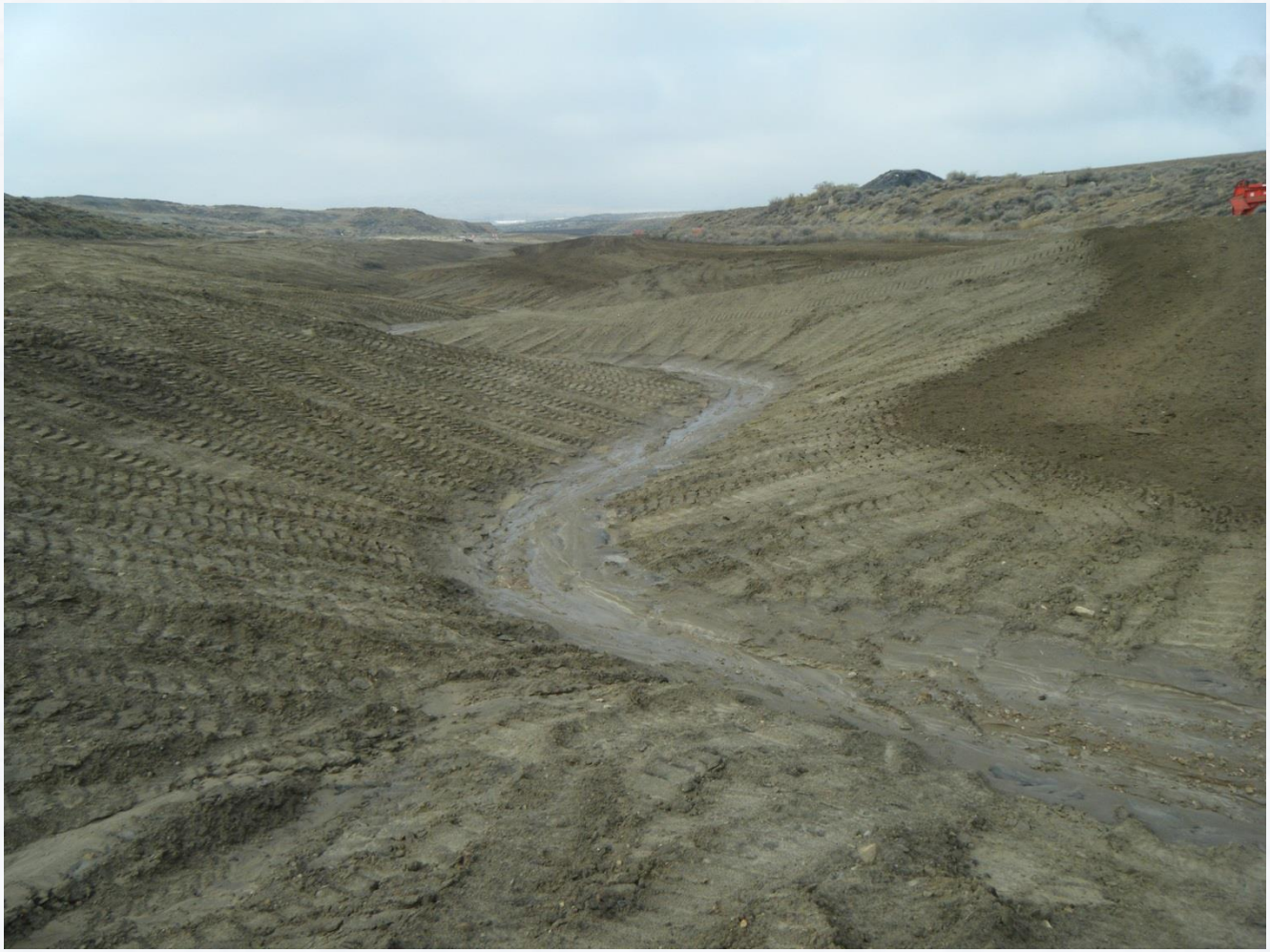
Channel Alignment Around Cultural Site

Phase 2B-III

Performance Evaluation

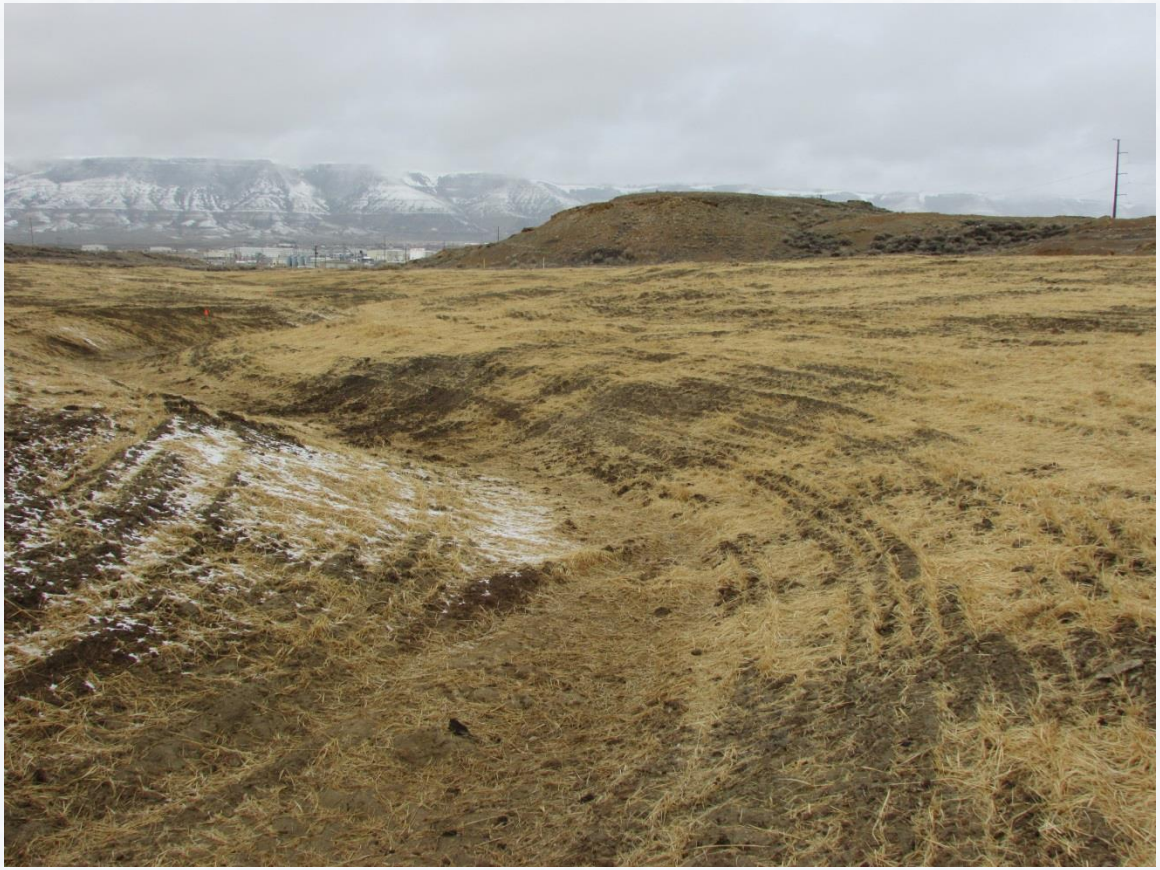
- ***Completed 2013 after one dry summer, limited vegetation***
- ***Despite large basin and high flow events, meandering geomorphic channels performing well***
- ***Failures occurred associated with culverts and rock outlets, not geomorphic reclamation***
- ***Minor rilling of subchannel areas***

Lionkol Drainage
Constructed Channel after Storm



AML 17H-2B-IV Project Details

Lionkol West Drainage Project

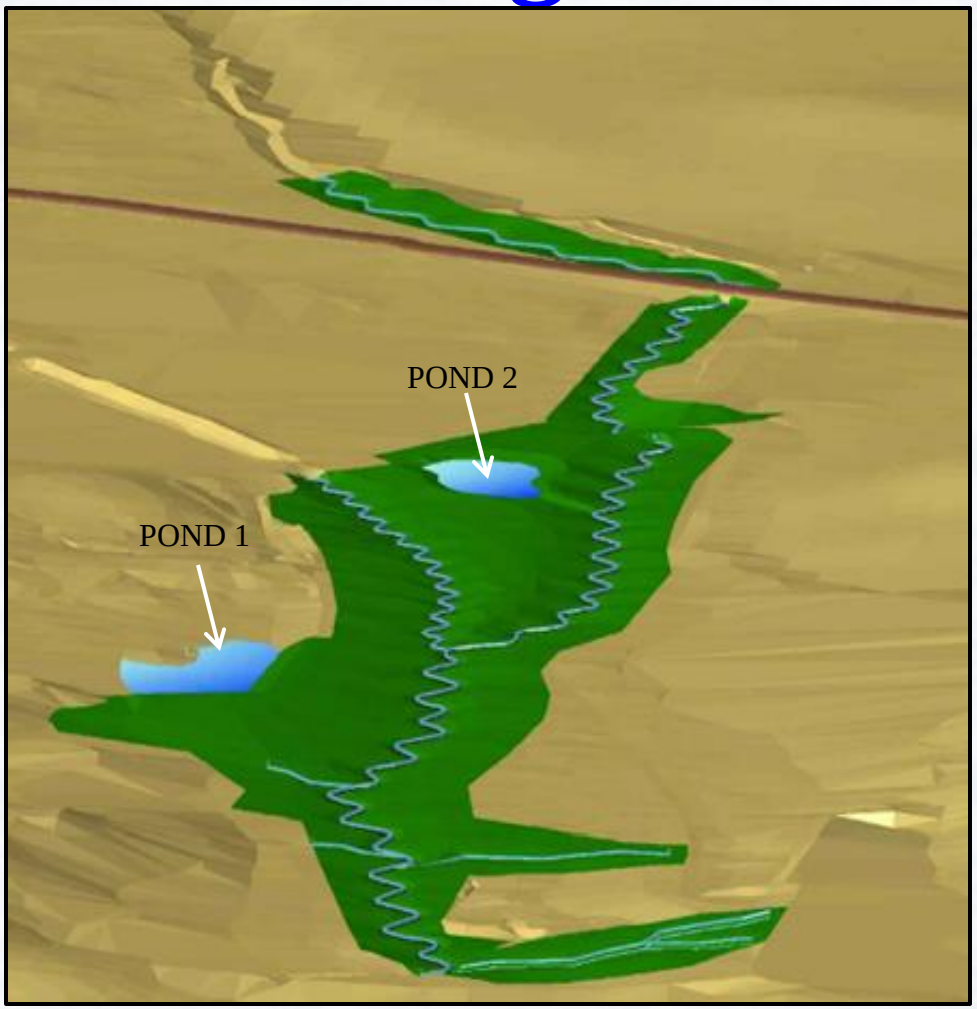


- *50,000 cubic yards*
- *$465,000 bid cost*
- *22 acres of Natural Regrade design surface*
- *Coordination with BLM*

Lionkol West

Pre-Construction

Lionkol West Design



Lionkol West

Post Construction

Lionkol West
Design Approach

- ***Similar to Phase 2B-III***
- ***Coordinated project with BLM to provide off site discharge of storm water from their Wild Horse Holding Facility in accordance with WYPDES requirements***
- ***Site completely constrained by upper and lower culverts***
- ***Additional site constraints due to utilities and cultural site***

Phase 2B-IV

Performance Evaluation

- ***Under construction fall 2013 during approximate 20 year storm flows (.23 to .5" in 24 hours)***
- ***Recent channel constructed of fill experienced erosion, others conveyed flow without significant damage***

Lionkol West
Channels after Storm

Channel Constructed in Fill

Channel Constructed in Cut

Lionkol West
Fourwing Saltbush Planting

AML 17H-2B Lionkol Project

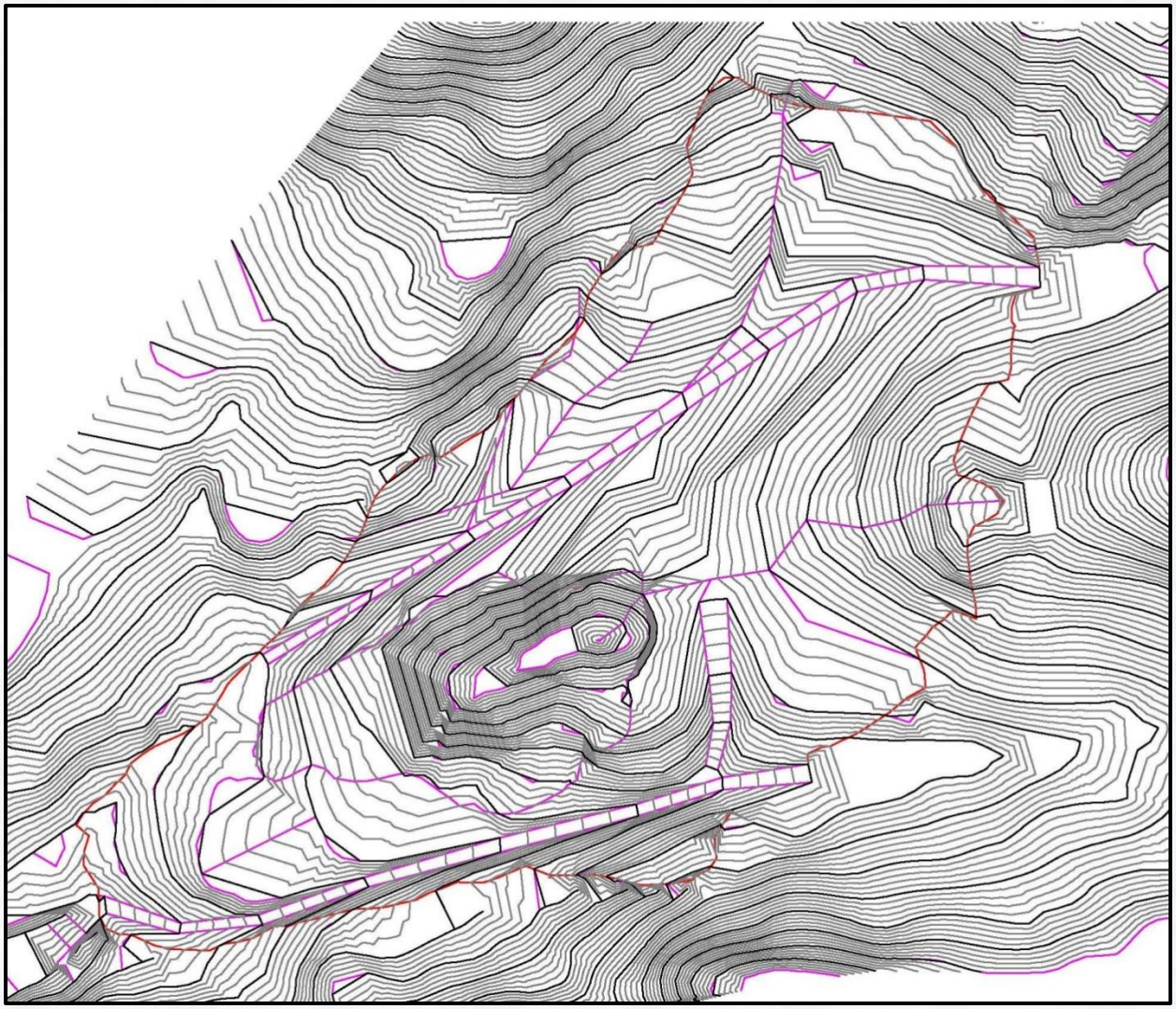
Summary

- ***Implementation of geomorphic reclamation on a variety of site features***
- ***Additional benefits realized by the City of Rock Springs and the BLM***
- ***Advancing design approach provides opportunity for performance evaluations and improvements for future projects***
- ***Overall performance of geomorphic reclamation is superior to traditional***

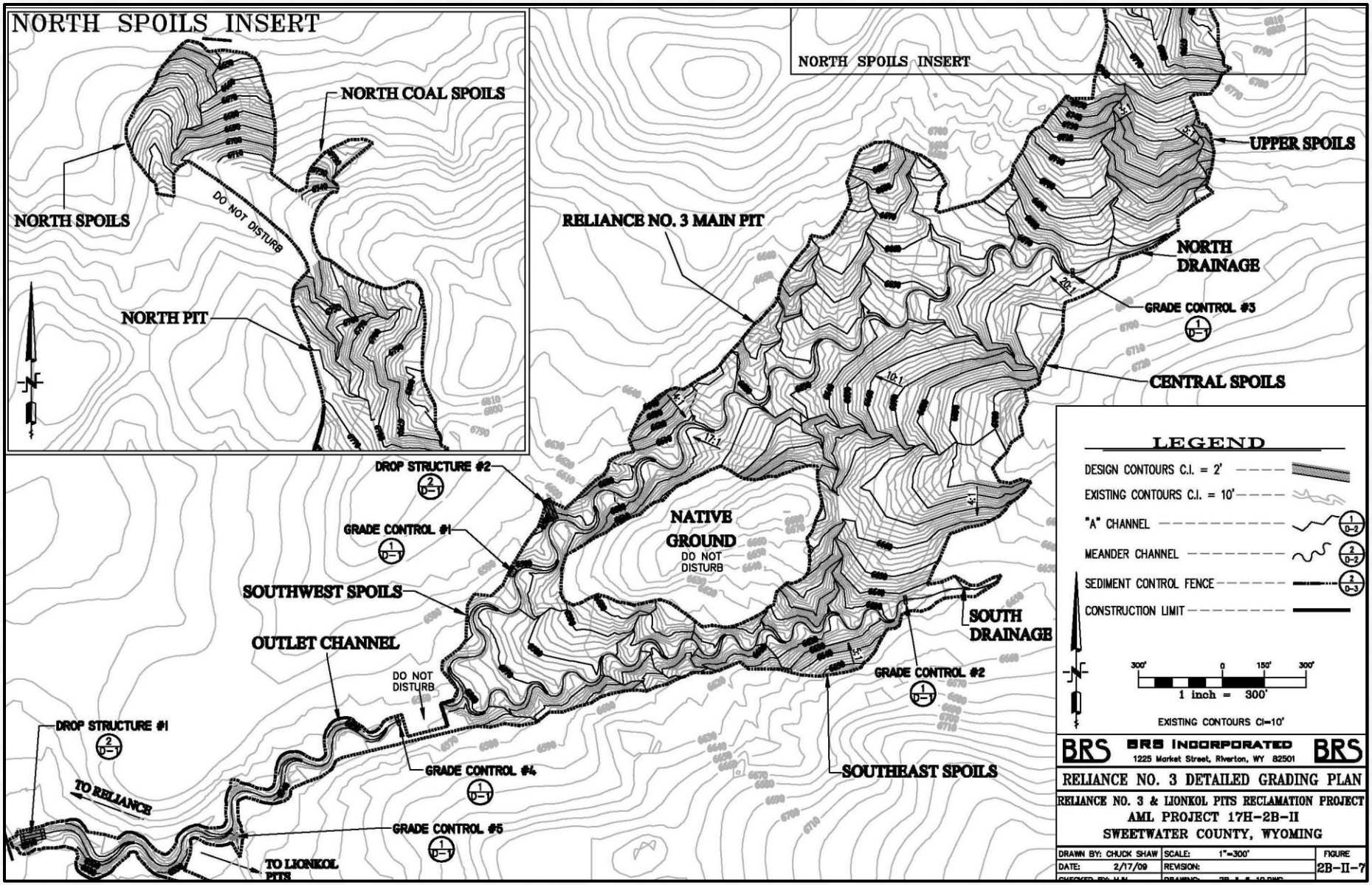
Design Recommendations

- ***Careful characterization of site conditions including contributing basins, drainage characteristics, site materials, constraints***
- ***Site specific estimation of runoff***
- ***Mimic pre-mine configuration as closely as site conditions and budget allow***
- ***Create Conceptual Design for NR Base TIN, to work toward earthworks balance and reasonable slope aspects***
- ***Extensive Digital Terrain Model (DTM) cleanup may be required to obtain earthworks balance and provide safe working slopes without impacting design hydrology negatively.***

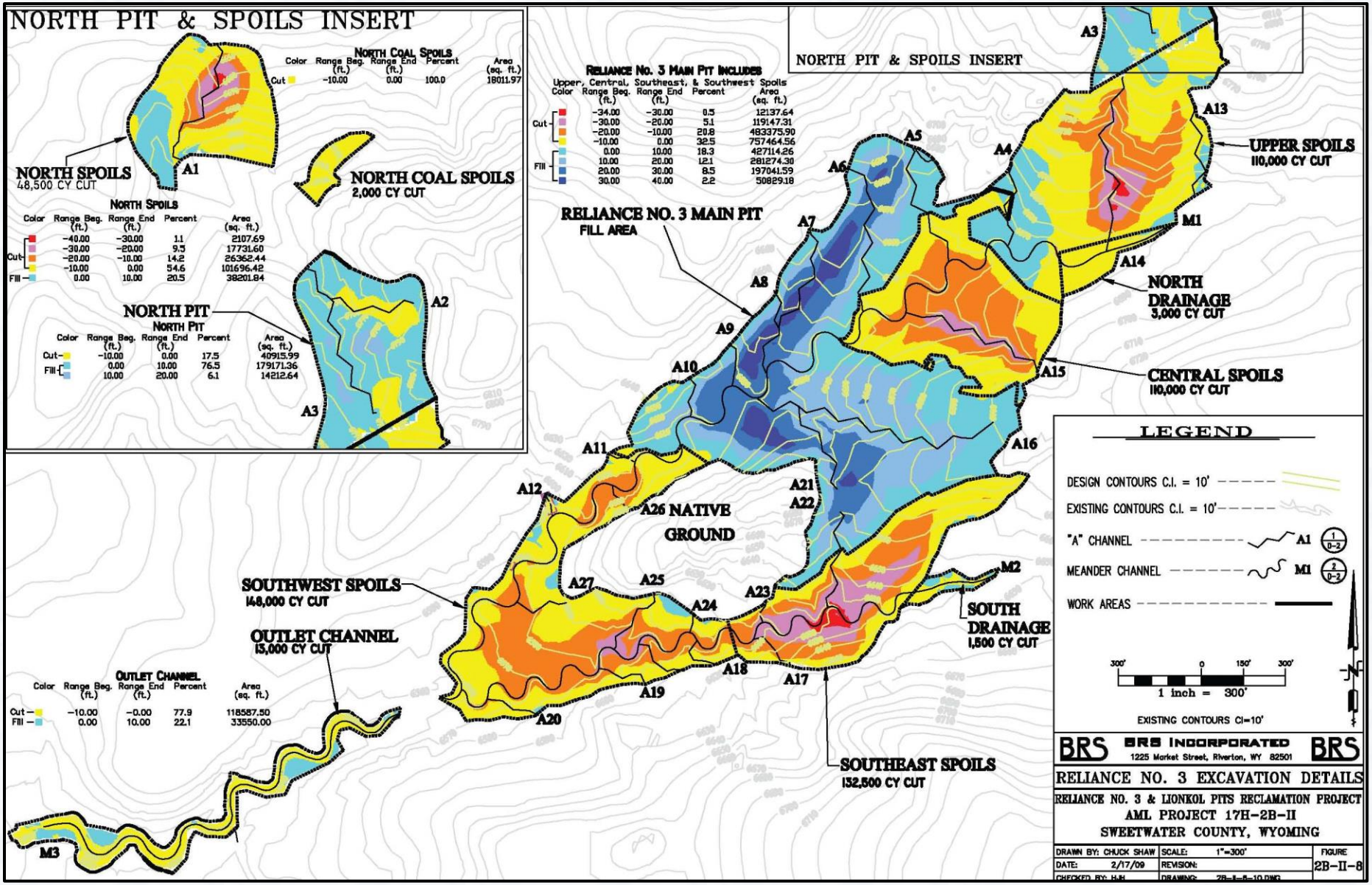
RELIANCE NO. 3 CONCEPTUAL DESIGN



RELIANCE NO. 3 GRADING PLAN



RELIANCE NO. 3 EXCAVATION DETAILS



AML PROJECT 17H-2B
CONSTRUCTION

ADVANCEMENTS IN GEOMORPHIC RECLAMATION DESIGN APPROACH

Paper Available Upon Request

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