Environmental: Upside of Failure

To Channel or Not to Channel: Drainage Density and Flow Concentration

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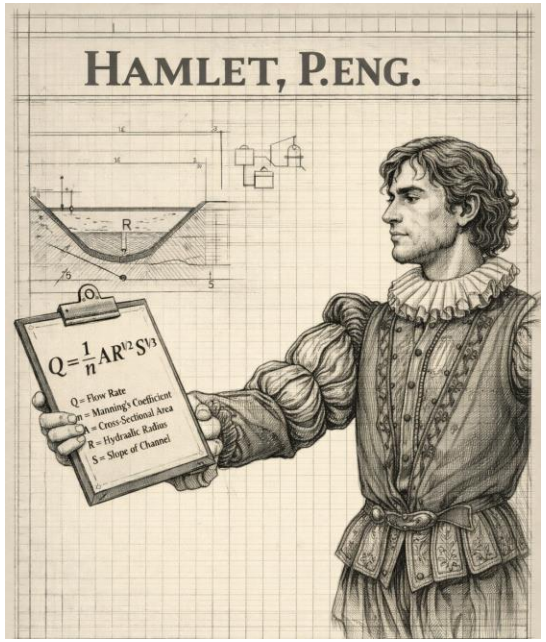
Abstract



To Channel or Not to Channel

Constructed landform designs for post-mining landscapes seek to establish rates of erosion comparable to those of natural landforms in similar watersheds and climate. Design of surface water conveyance systems for a constructed landform considers drainage density, i.e., the number of drainage “lines” per unit area. Drainage density may be minimized in an effort to minimize flow concentration or simulated based on the number of drainage lines in natural analog. This paper examines observed failures with design elements under both approaches. These failure narratives provide insight to design methodology, technical trade-offs and implementation risks. The erosional failure of a minimum drainage density design occurred on reclaimed outslope of a closed copper tailings facility in the arid southwest U.S. The failure consequence was unplanned and extended maintenance of the erosion-resistant soil-rock cover system near the upper reach of the embankment. The erosional failure of a moderate drainage density design involved overland flow into a concrete lined channel. In this case, surface water preferentially bypassed the channel.

Civil Engineering

Serviceability Limit State

The point at which a structure can still withstand demands but no longer functions effectively for its intended purpose (e.g., excessive deflection, cracking, vibration)

Ultimate Limit State

The point at which the structure can no longer tolerate even small incremental demands and experiences total failure/collapse

Failure Mechanisms

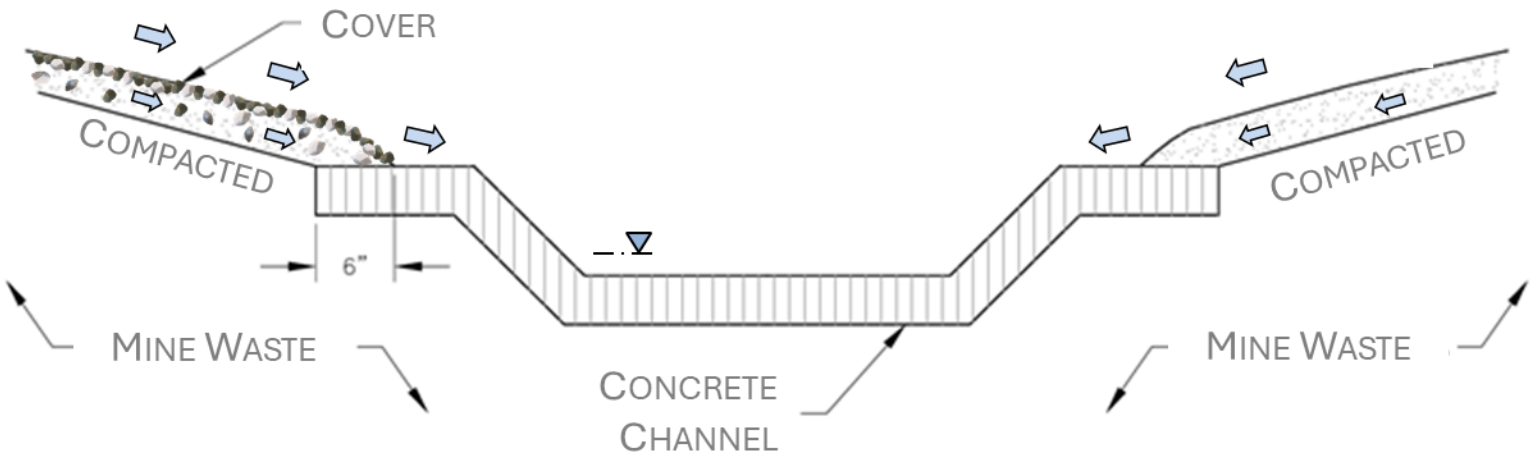
- Seepage-Induced Instability
- Bypass Flow Erosion
- Sediment-induced capacity failure
- Capacity degradation cascade

Example 1

Closed TSF

Desert Southwest U.S.

Design Concept



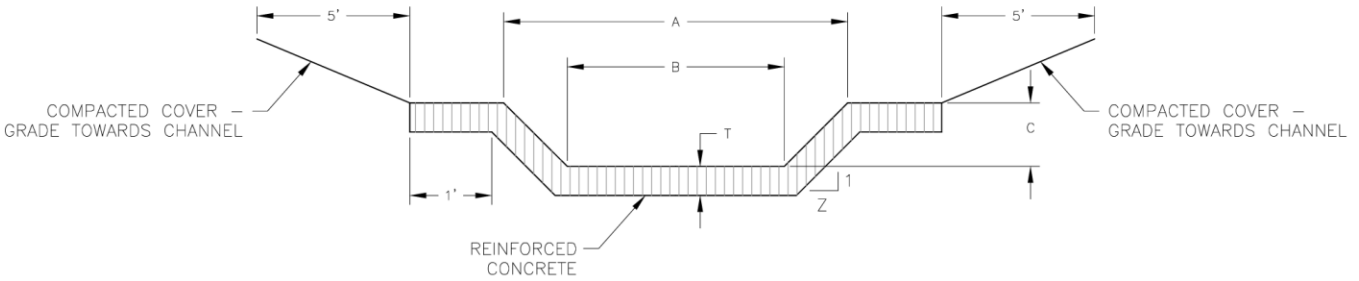
POST COVER TYPICAL CHANNEL SECTION

Not To Scale

Field Performance

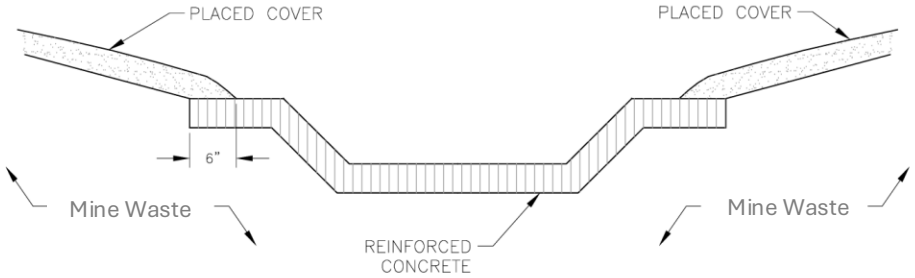
Sub-basin collector channel, 1m base width, 0.75m deep concrete-lined

Field Performance



PRE COVER TYPICAL CHANNEL SECTION

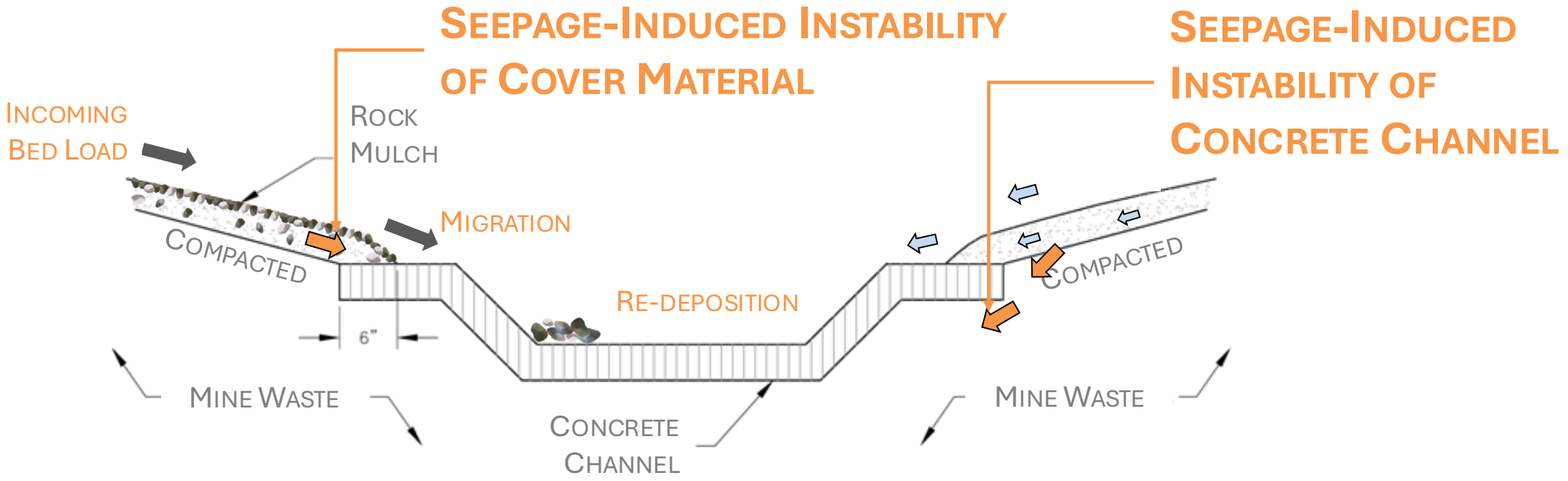
Not To Scale



POST COVER TYPICAL CHANNEL SECTION

Not To Scale

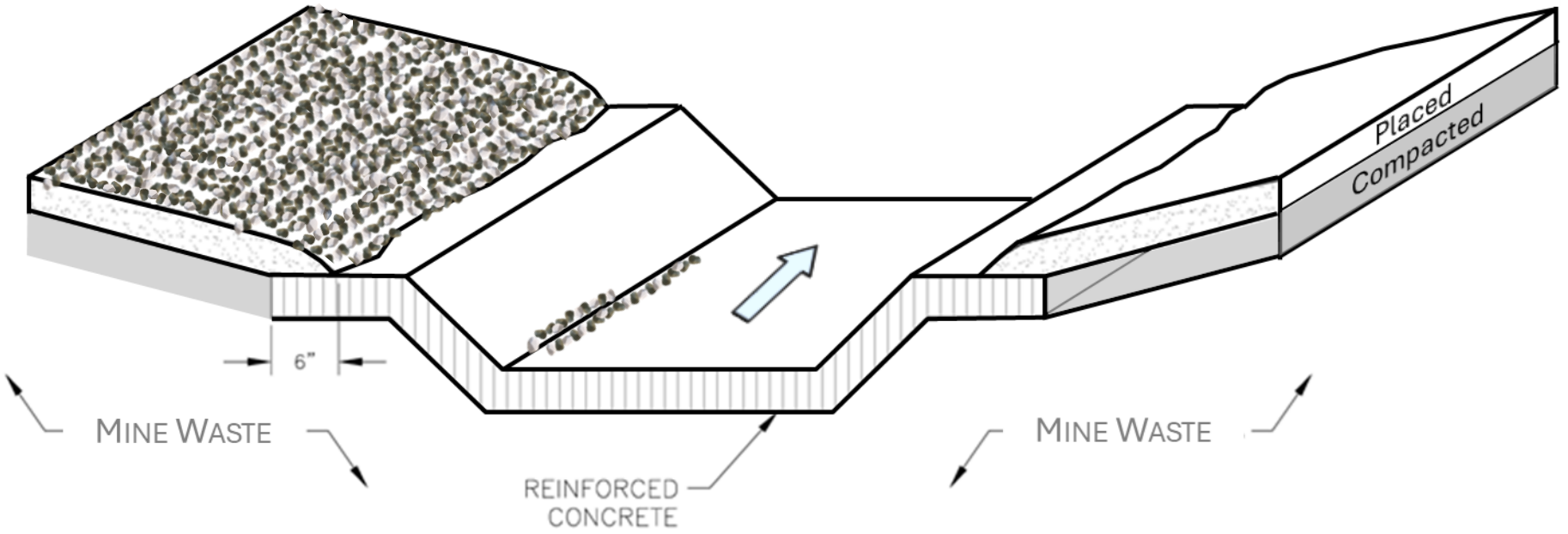
Field Performance



POST COVER TYPICAL CHANNEL SECTION

Not To Scale

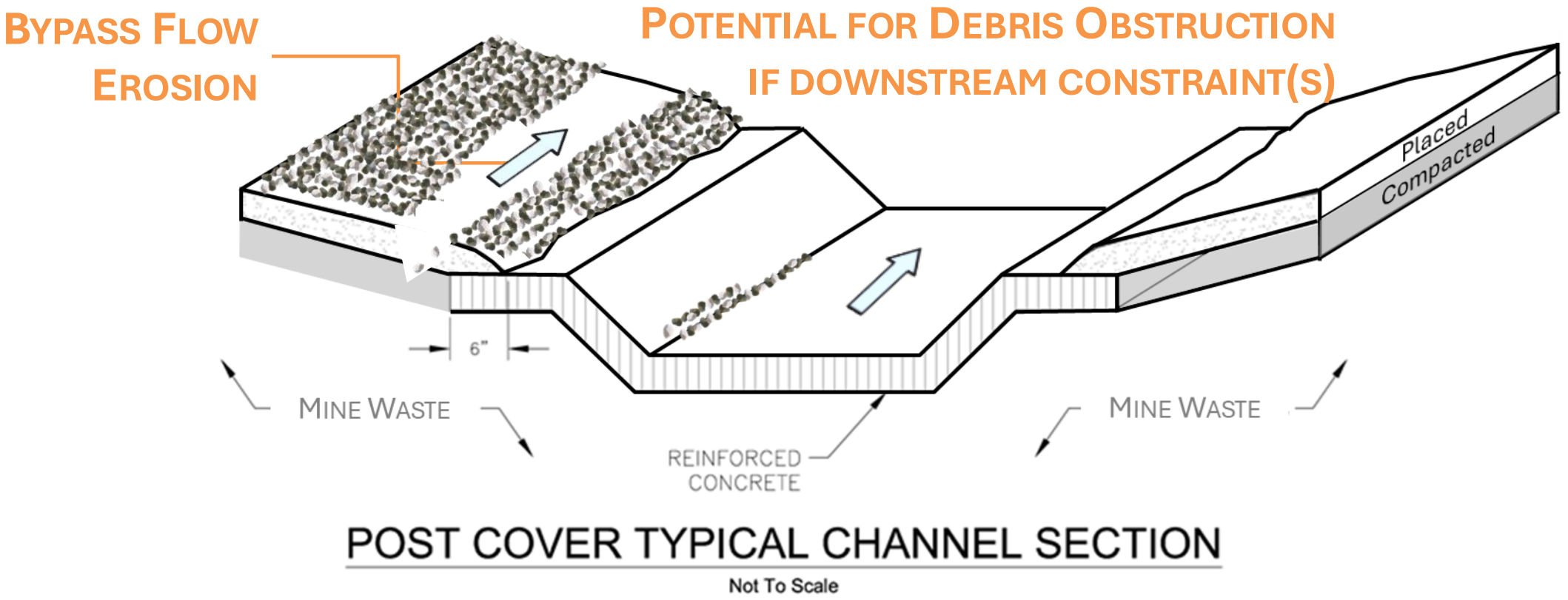
Field Performance



POST COVER TYPICAL CHANNEL SECTION

Not To Scale

Field Performance



POST COVER TYPICAL CHANNEL SECTION

Not To Scale

Failure Classification

Serviceability Limit State – **Early Stage**

“…structure can still withstand demands…”

Re-Design

Example 2

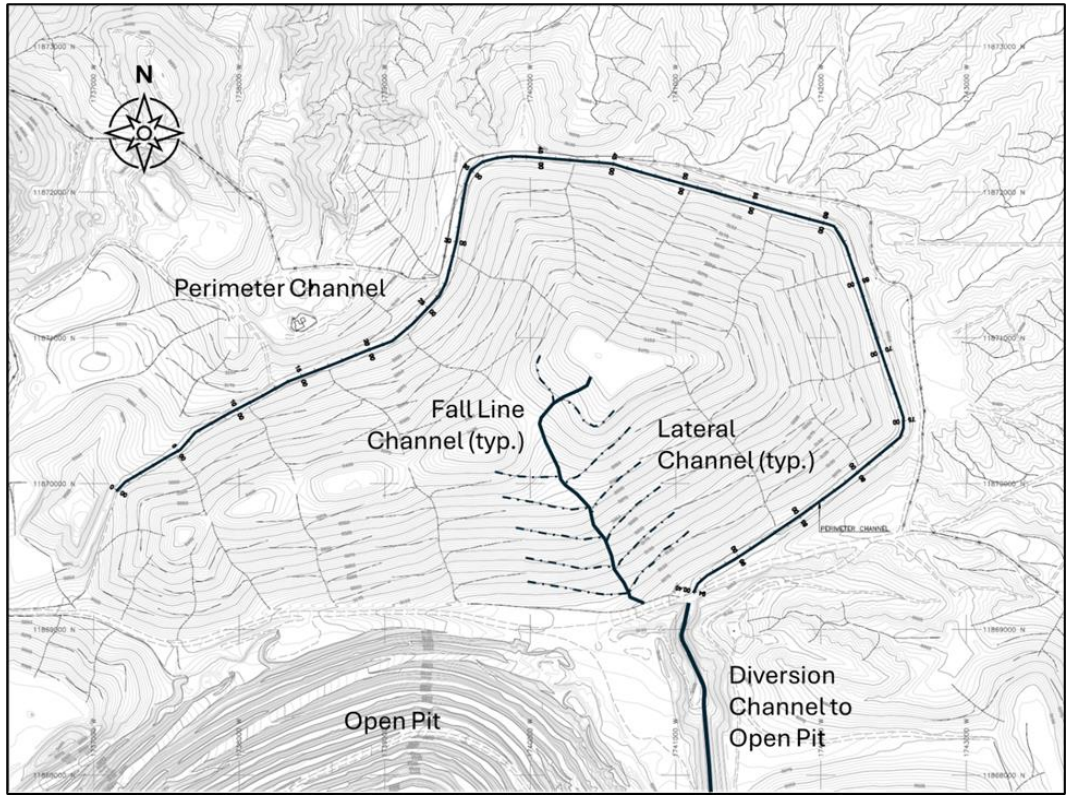
Closed HLF

Desert Southwest U.S.

Heap Leach Facility Closure 1.0 Southwest U.S.

Surface Water Management at Closure

- Regrade to 3H:1V minimum
- Inert overburden cover
- **Lateral and fall line channel** concept



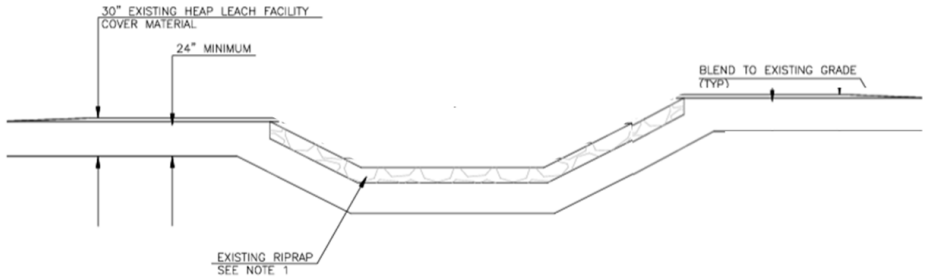
5 consecutive days

- Cumulative total of 10.12 inches of rain, approximately half of average annual precipitation
- Wettest monsoon season on record - a 33-year recurrence event
- **Daily** average precipitation over this period **was less than** the design storm event.

Fall Line Channel

Construction

Design Concept

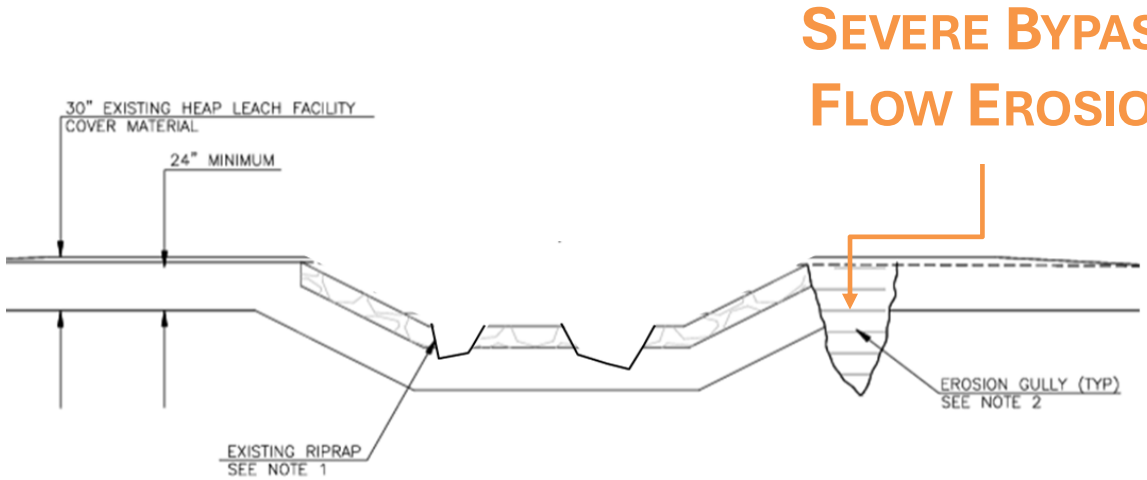


FALL LINE CHANNEL – ORIGINAL DESIGN

Fall Line Channel

Post-Failure

Field Performance



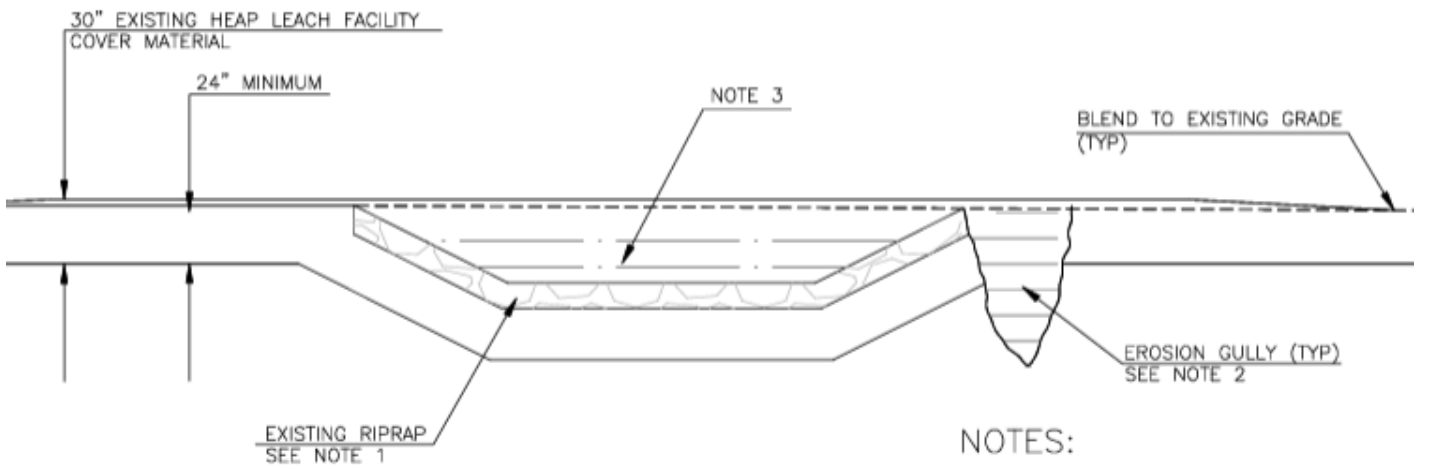
FALL LINE CHANNEL – ORIGINAL DESIGN

Failure Classification

Ultimate Limit State – **Loss of Function**

The point at which the structure can no longer tolerate even small incremental demands and experiences total failure/collapse

Re-Design – Fall Line Channel



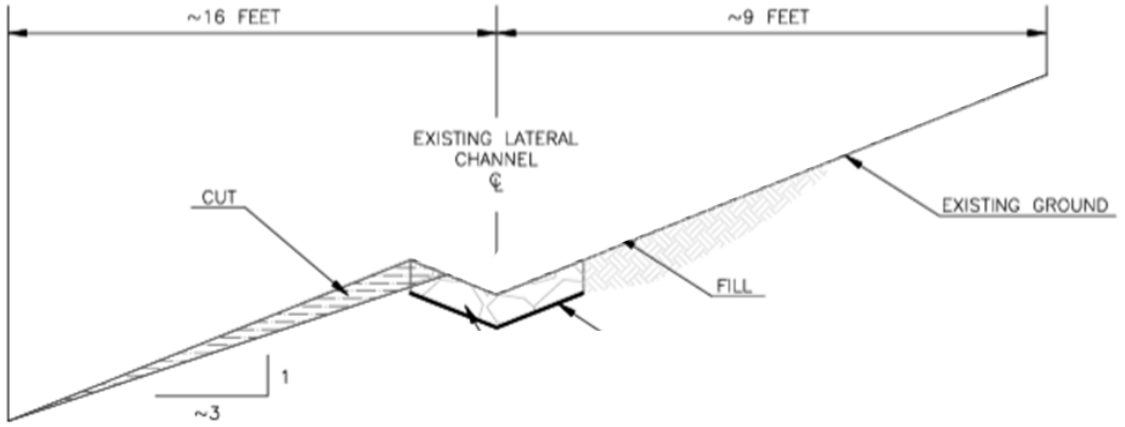
FALL LINE CHANNEL – RE-DESIGN

Rock Armor and Minimizing Potential for Flow Concentration

Lateral Channel

Construction

Design Concept



Lateral Channel

Post-Failure

Field Performance

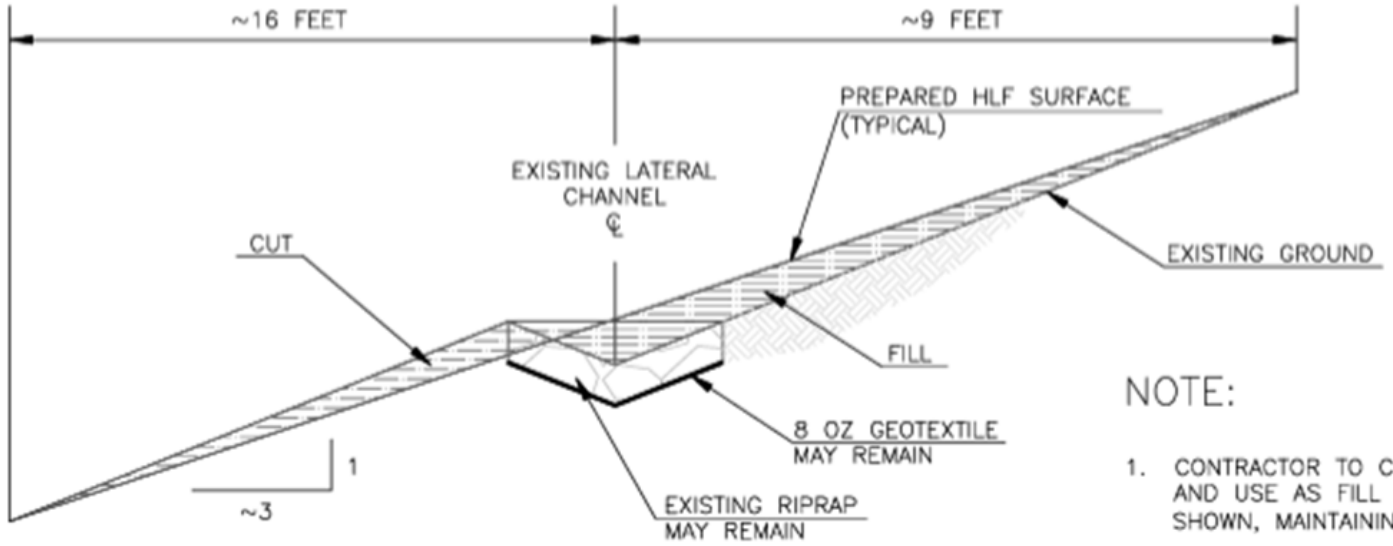
- Sediment-induced capacity failure
- Capacity degradation cascade

Failure Classification

Ultimate Limit State – **Loss of Function**

The point at which the structure can no longer tolerate even small incremental demands and experiences total failure/collapse

Re-Design – Lateral Channel



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LATERAL CHANNEL REGRADE DETAIL
DETAIL
NTS

Rock Armor and Minimizing Potential for Flow Concentration

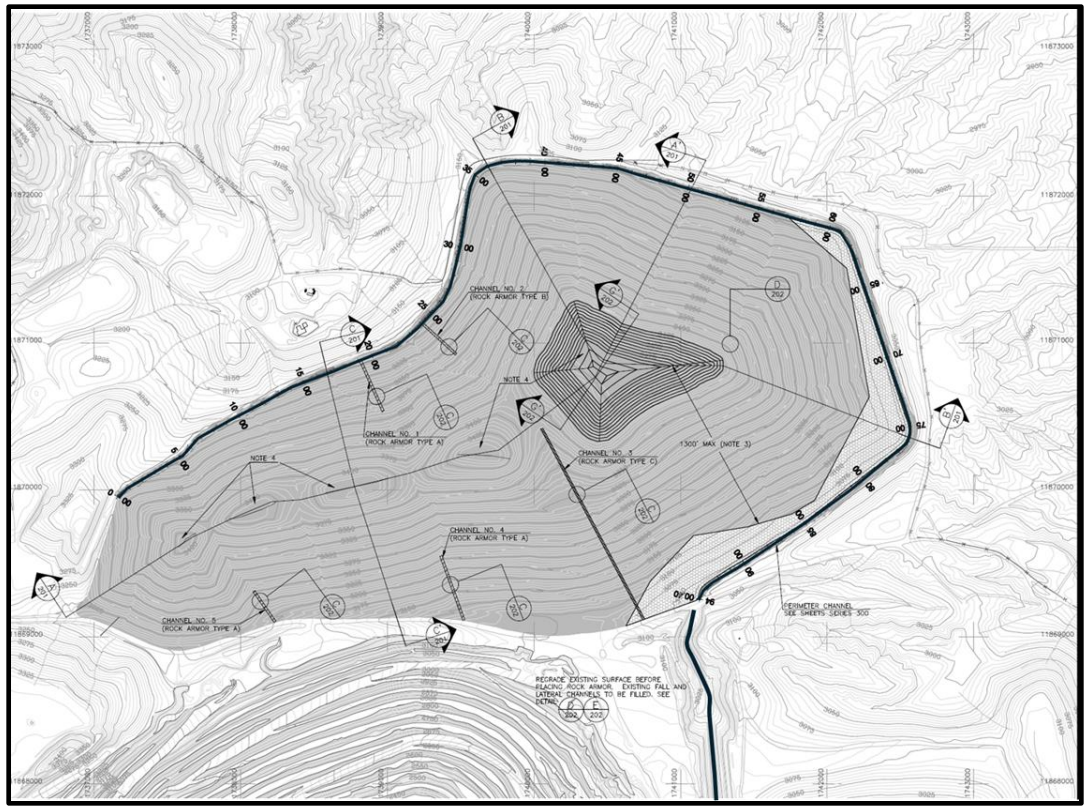
NOTE:

1. CONTRACTOR TO CUT EXISTING HEAP LEACH COVER MATERIAL AND USE AS FILL FOR EXISTING LATERAL CHANNELS AS SHOWN, MAINTAINING A MIN. 24" DEPTH, (TYP)
2. CONTRACTOR SHALL GRADE TO CREATE A FINAL SURFACE THAT DOES NOT IMPEDE DOWNSLOPE SHEETFLOW OR CONCENTRATED CROSS–SLOPE FLOW

Heap Leach Facility Closure 2.0 Southwest U.S.

Surface Water Management at Closure 2.0

- Regrade to 3H:1V minimum
- Minimize flow concentration
- Rock armor on top of inert overburden



Heap Leach Facility Closure 2.0 Southwest U.S.

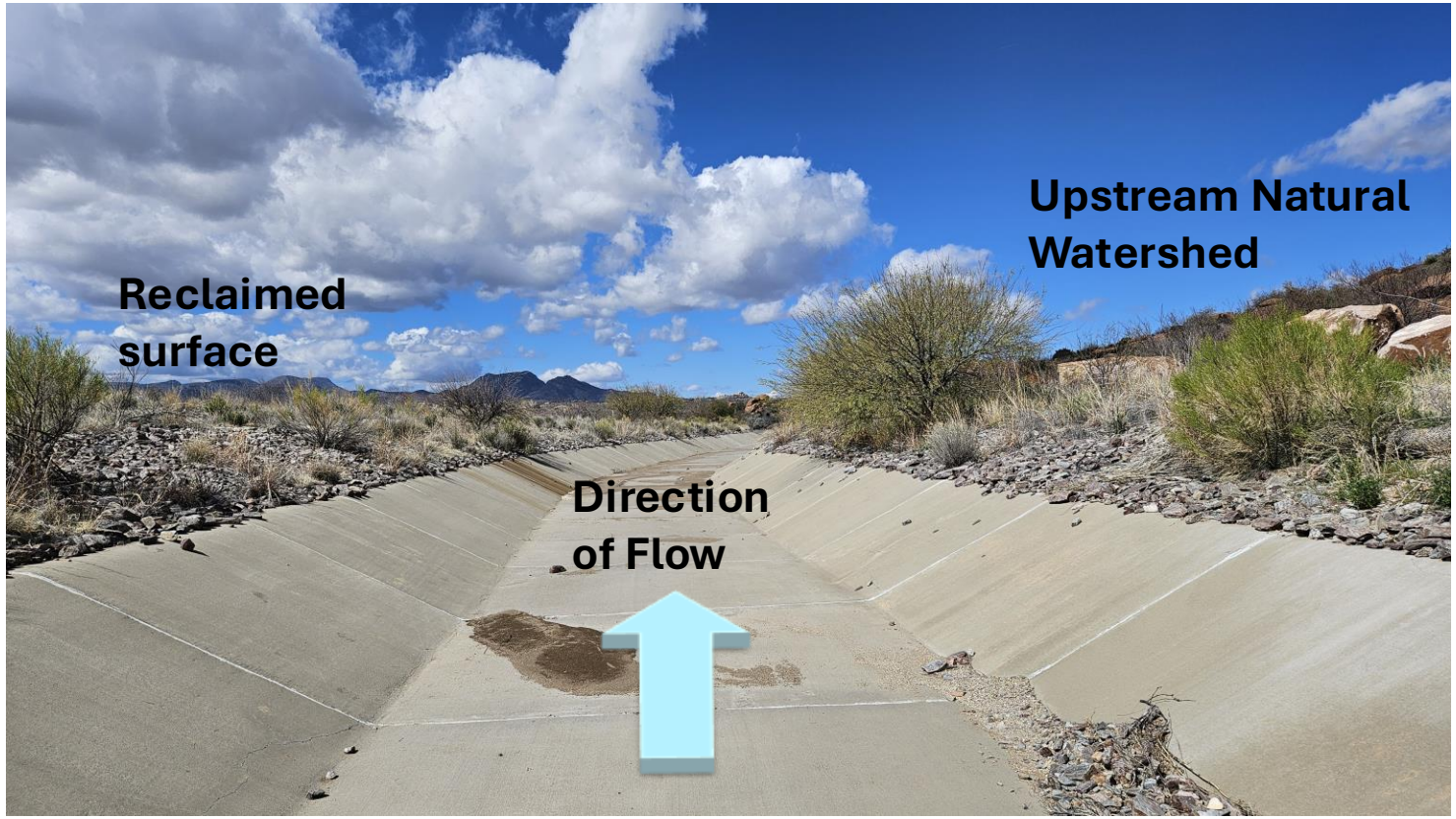
Example 3

Closed TSF

Desert Southwest U.S.

To channel

Upstream diversion channel, 3m+ base width concrete-lined trapezoidal cross section



To channel

Upstream diversion channel, concrete-lined trapezoidal cross section

Takeaways

Conventional Surface Water Design

Defined service life and active maintenance

Mine Closure Surface Water Design

Perpetual liability requiring passive, ultra-long-term performance

Takeaways

Conservative design basis for surface water volume and flow estimates

Evaluate Natural vs. Restrained Systems

Aspirational Goal:

Sediment IN should equal Sediment OUT

Thank you

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