STILLWATER
MINING COMPANY

Knight Piésold
CONSULTING

Adding Value. Delivering Results.

Embankment Underdrain for Nitrogen Source Reduction

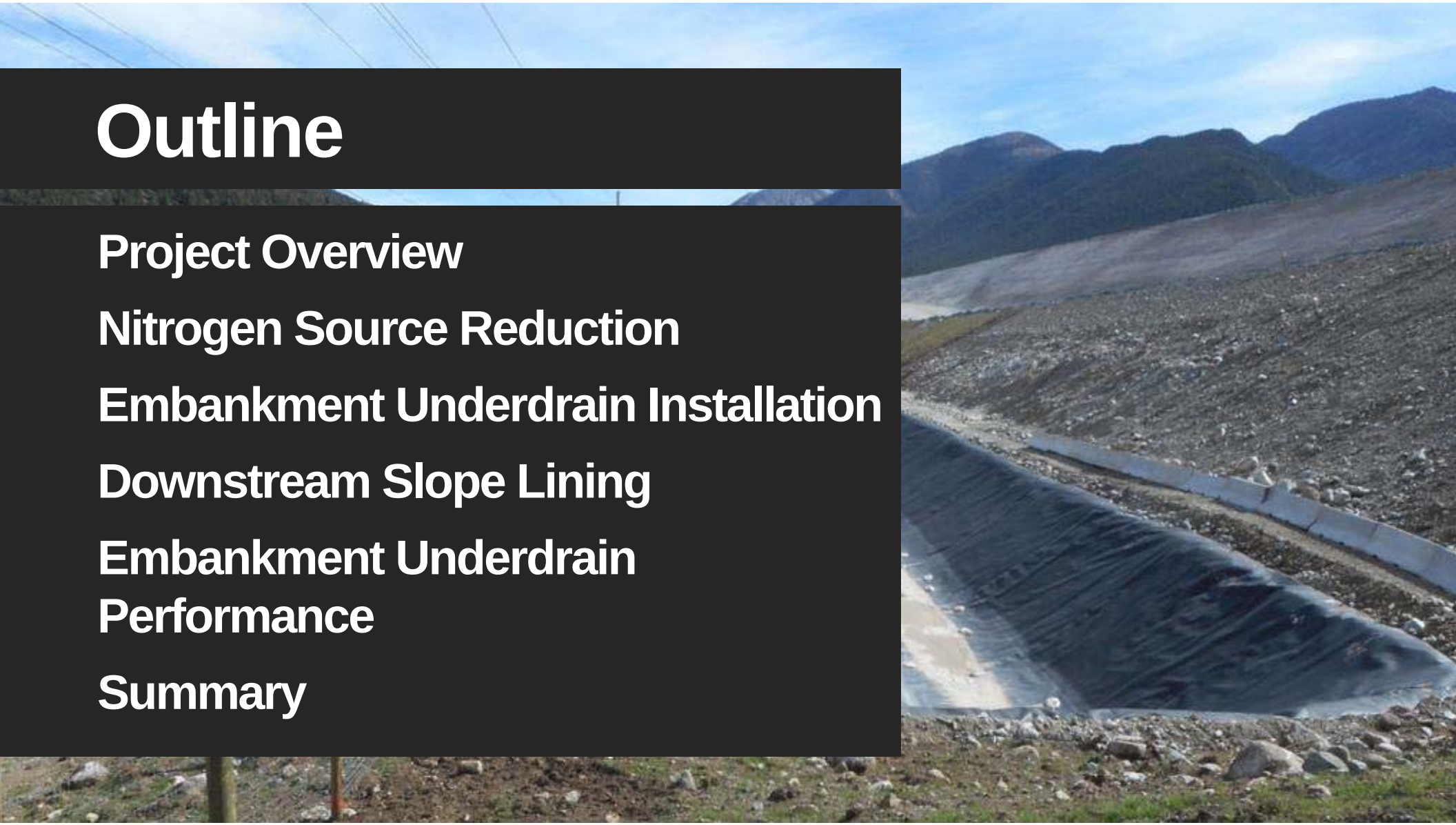
Matt Wolfe, Craig Hall

Key Points

- Run of Mine (ROM) rockfill used to construct Tailing Storage Facility Embankments was identified as a nitrogen source contributing to the elevated concentrations of aqueous nitrate
- An Embankment Underdrain was installed to collect and reduce the amount of meteoric water that percolates through the ROM rockfill
- The Embankment Underdrain has provided effective collection of nitrogen which has reduced operating costs

Outline

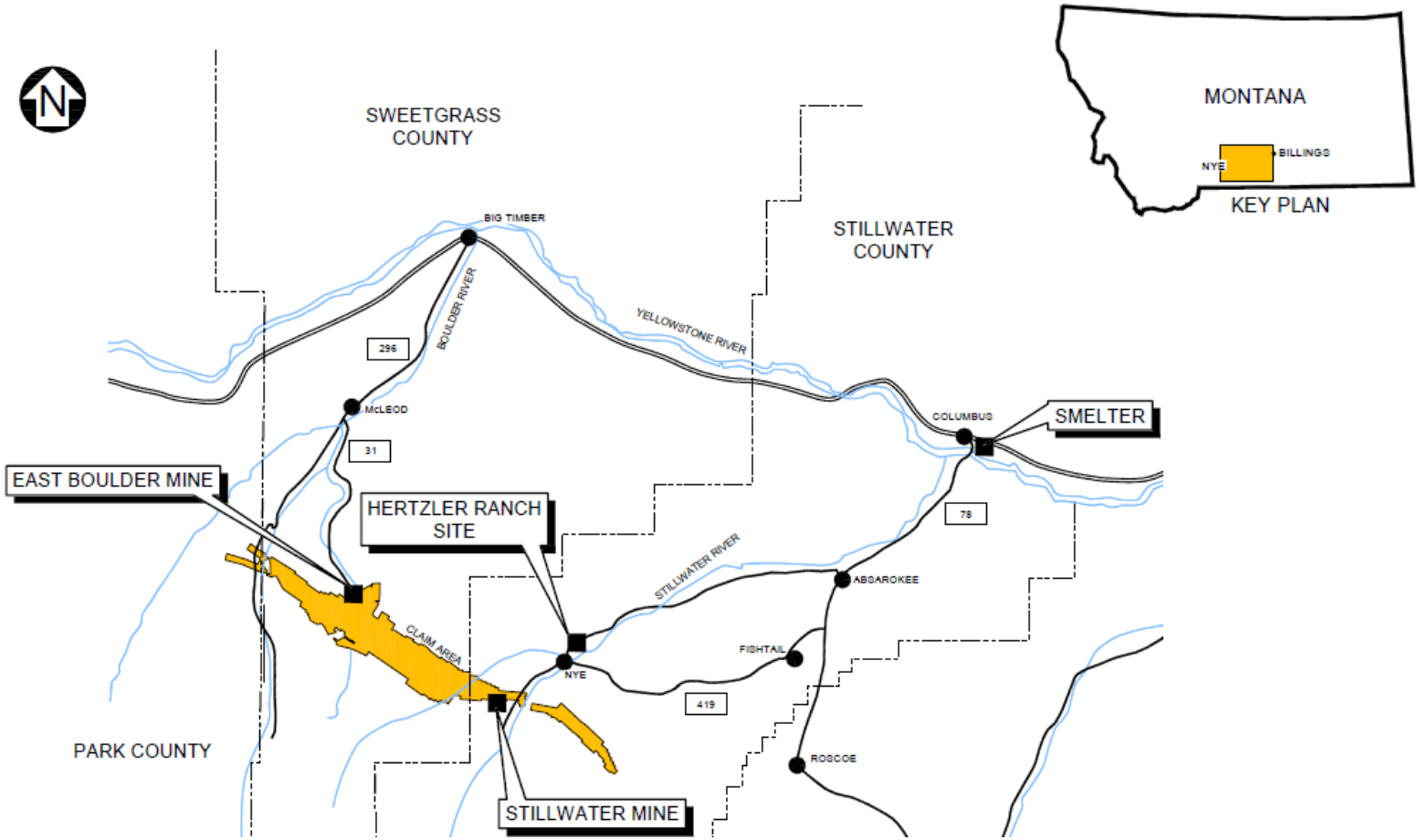
- Project Overview
- Nitrogen Source Reduction
- Embankment Underdrain Installation
- Downstream Slope Lining
- Embankment Underdrain Performance
- Summary



Project Overview

Project Overview

East Boulder Mine Location



Project Overview

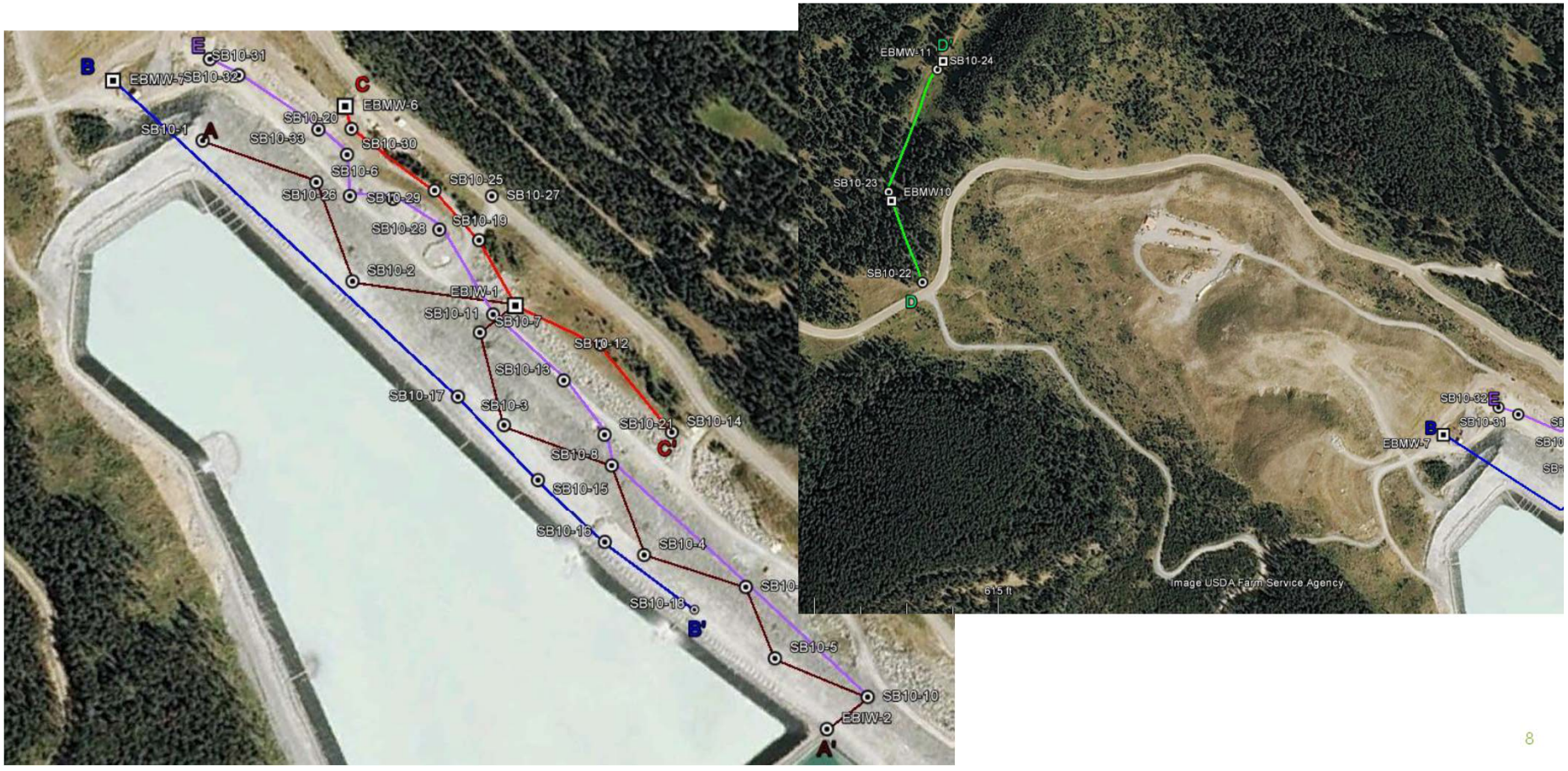
East Boulder Mine

Project Overview

East Boulder TSF

Project Overview

Nitrogen Source Identification



Nitrogen Source Reduction

AA4

Nitrogen Source Reduction

Voluntary Reduction Measures

- SMC installed methanol injection wells to provide in situ treatment of aqueous nitrate
- Two groundwater pump back wells were installed
- SMC switched blasting agents from ANFO to stick powder to reduce residual nitrate concentrations

Knight Piésold

Slide 10

AA4 Same comment as before - switching between text and photo might make a stick slip presentation.
Amy Adams, 4/25/2017

AA5

Nitrogen Source Reduction

Mitigation Alternatives Considered

- Rinsing waste rock underground prior to being brought to surface to remove nitrates
- Application of a carbon source to ROM rockfill at surface to provide in place treatment
- Covering the existing embankment ROM rockfill with a low permeable soil or geomembrane to reduce infiltration of meteoric water
- Constructing an embankment underdrain below the Stage 4 and 5 embankments to collect meteoric water that would percolate through future embankment ROM rockfill

Knight Piésold

Slide 11

AA5 Any photos of this?
Amy Adams, 4/25/2017

Nitrogen Source Reduction

Selected Mitigation

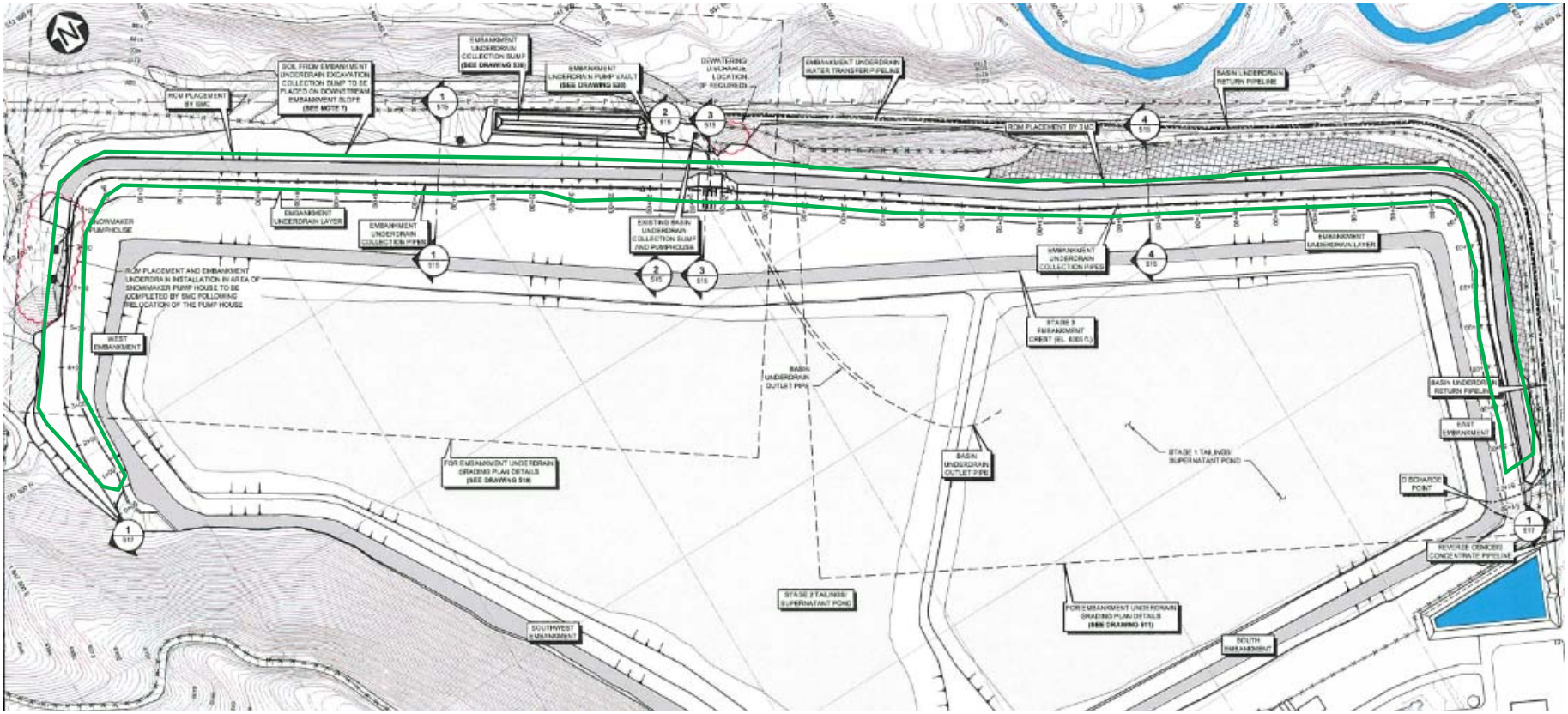
- Embankment Underdrain below the Stage 4 and 5 north, east and west embankments
- Install a geomembrane cover over the Stage 3 north, east and west embankments

Embankment Underdrain Installation

AA7

Embankment Underdrain Design

Underdrain Layer – Overall Layout



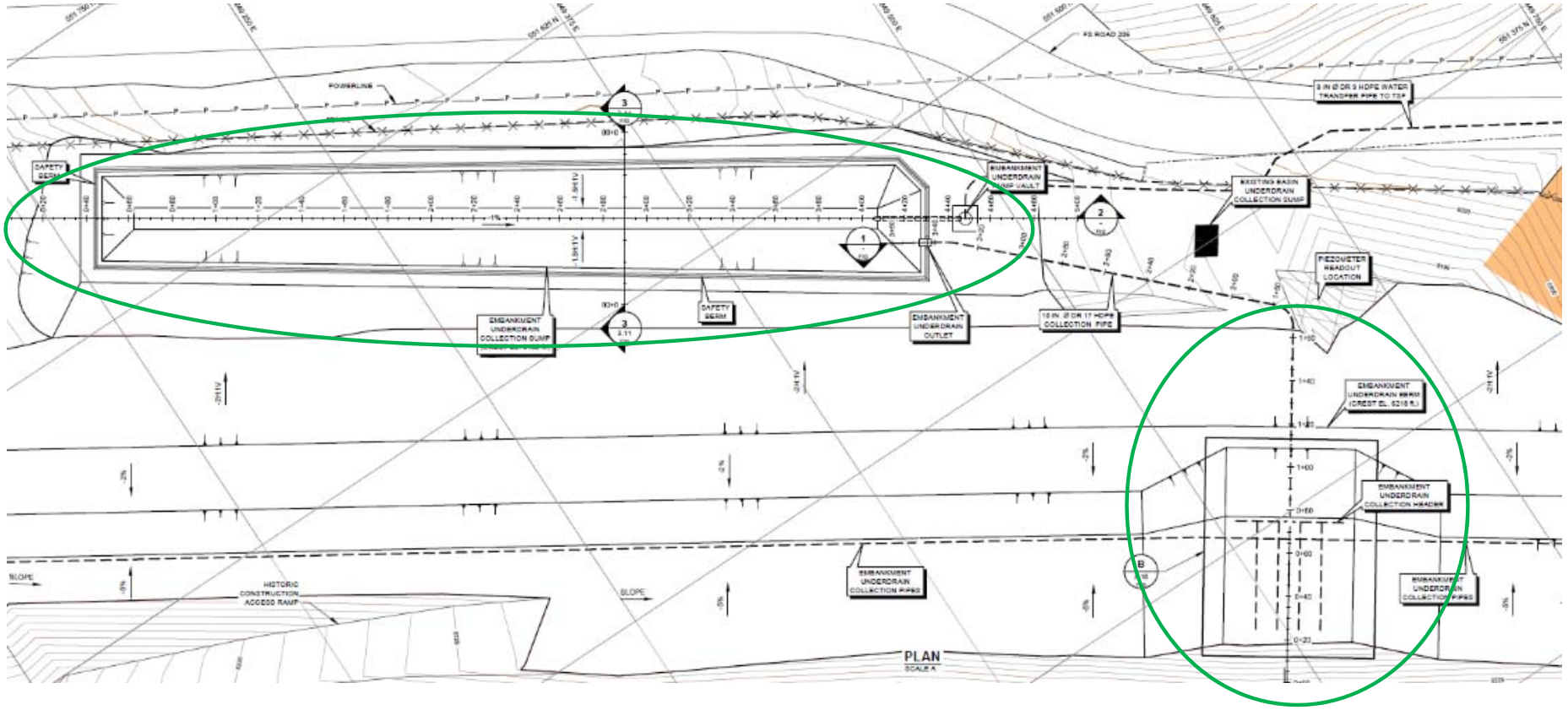
Slide 14

AA7 Will you add any shapes to highlight specific areas to draw the audiences attention? Labels?
Amy Adams, 4/25/2017

AA8

Embankment Underdrain Design

Underdrain Layer – Collection System



Knight Piésold

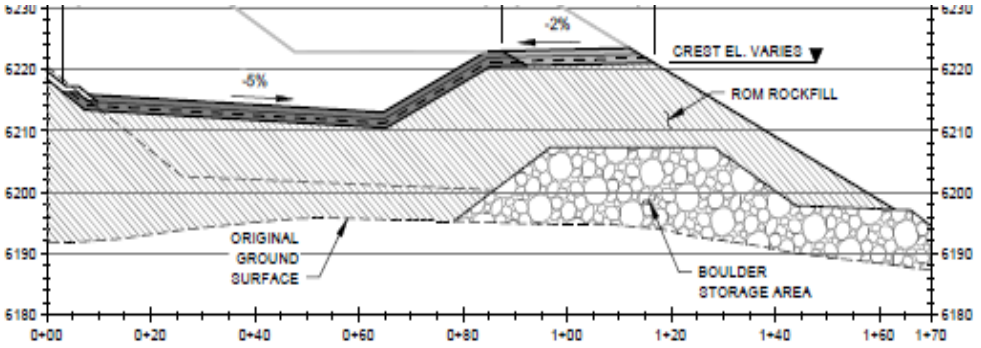
Slide 15

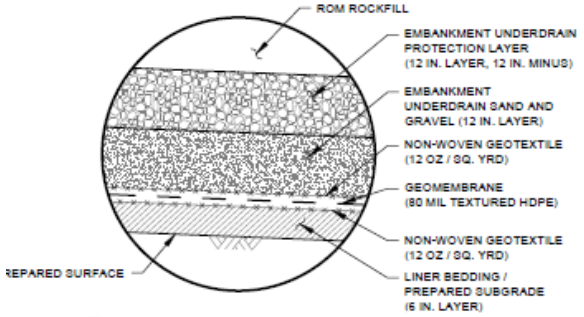
AA8 shapes / labels?

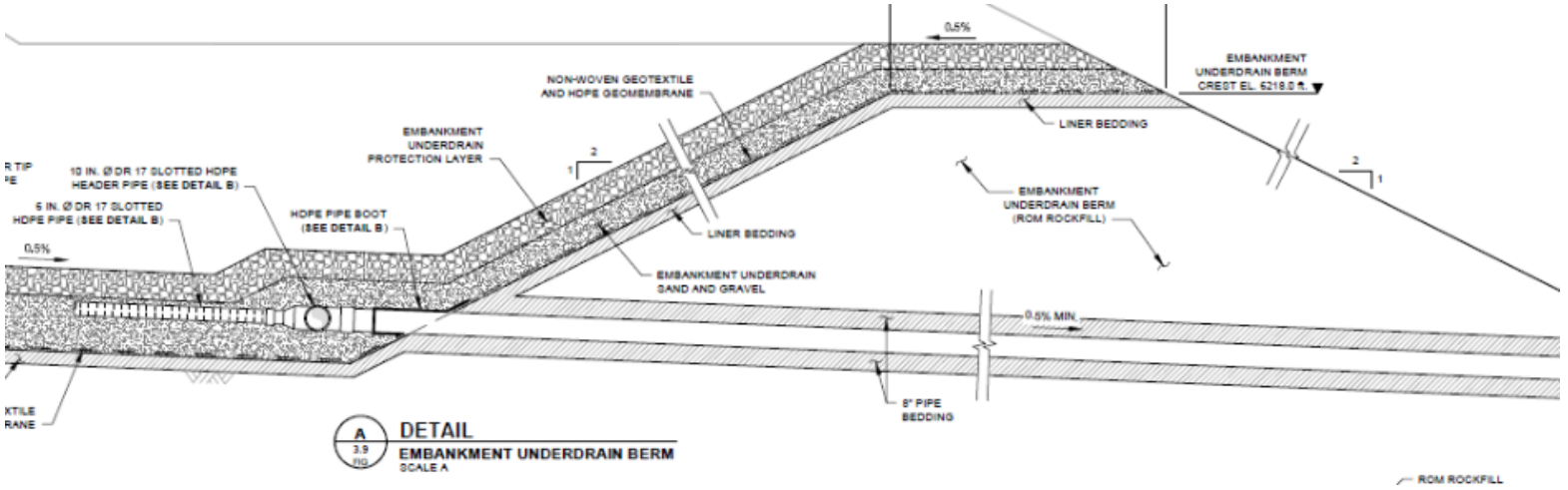
Amy Adams, 4/25/2017

Embankment Underdrain Design

Underdrain Layer – Typical Sections







Embankment Underdrain Installation

Underdrain Shaping, Subgrade Preparation, and Geosynthetics Installation

Embankment Underdrain Installation

Drainage Layer Installation

Embankment Underdrain Installation

Collection Sump

Downstream Slope Lining

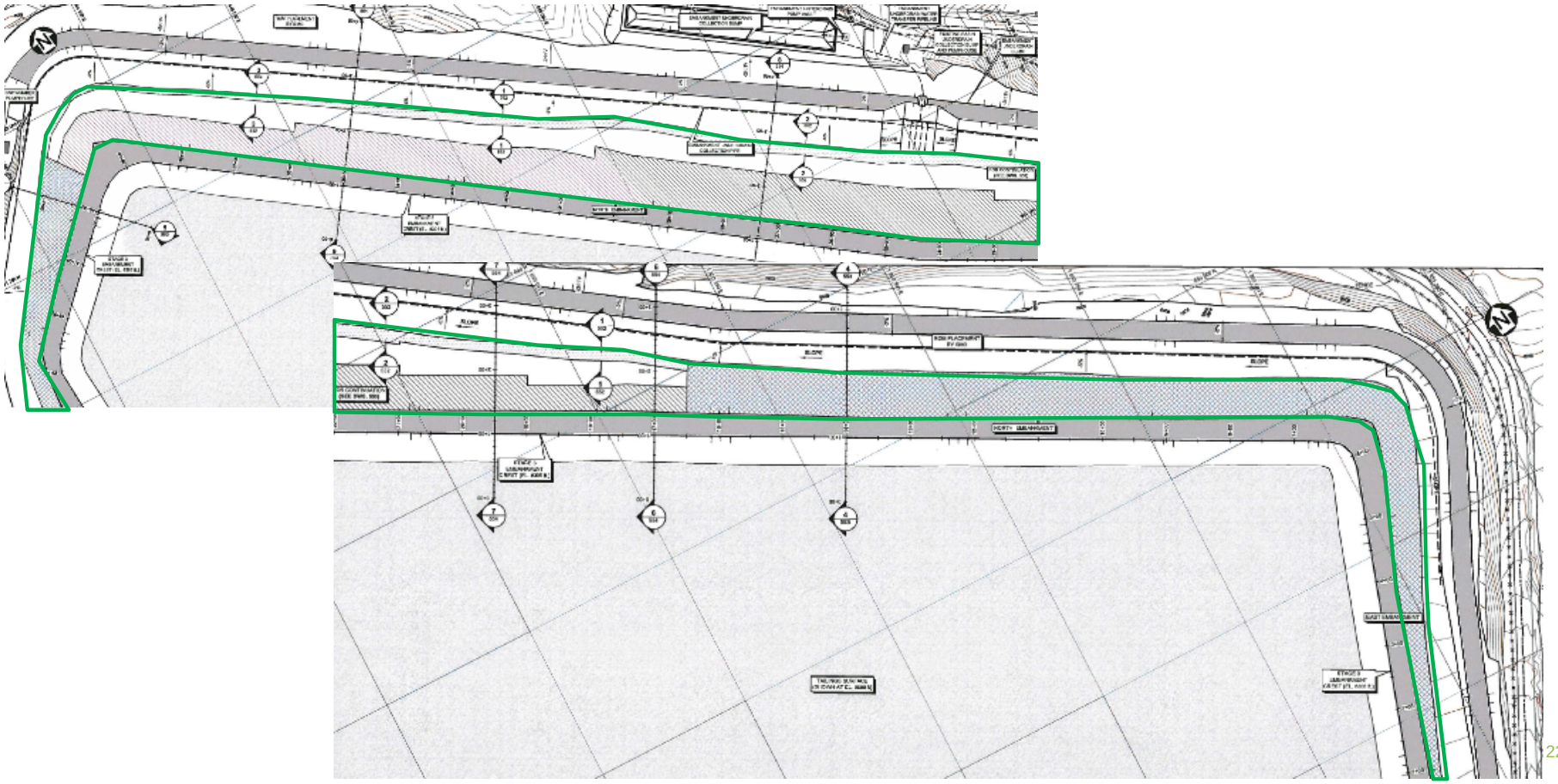
Downstream Slope Lining

Embankment Trimming and Posi-Shell® Application

- Interim measures to reduce infiltration into the embankment ROM rockfill
- Downstream slope of the Stage 3 embankment trimmed and compacted

Downstream Slope Lining

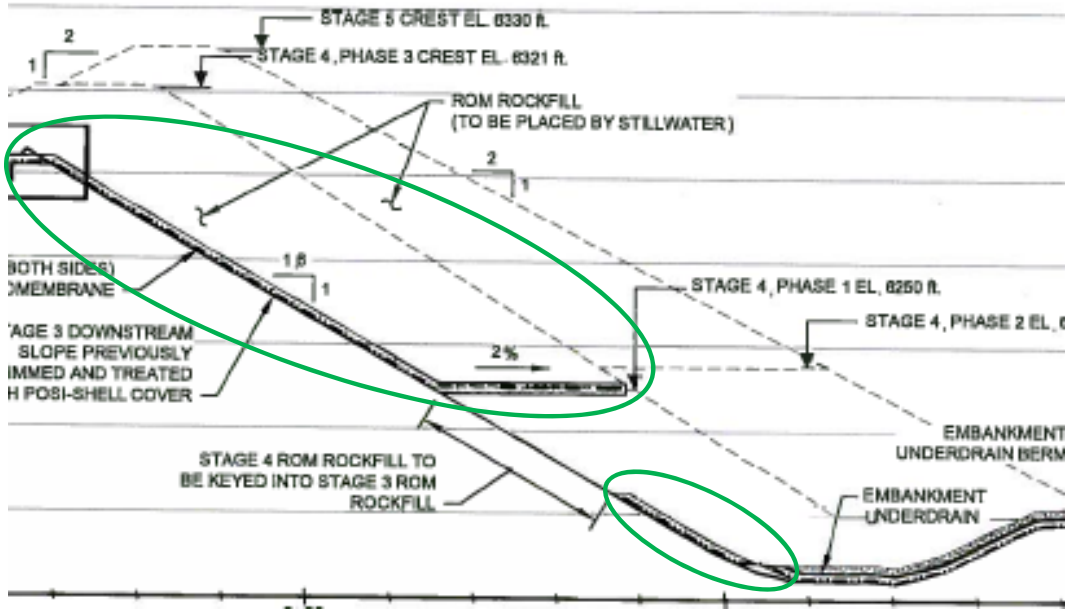
Layout



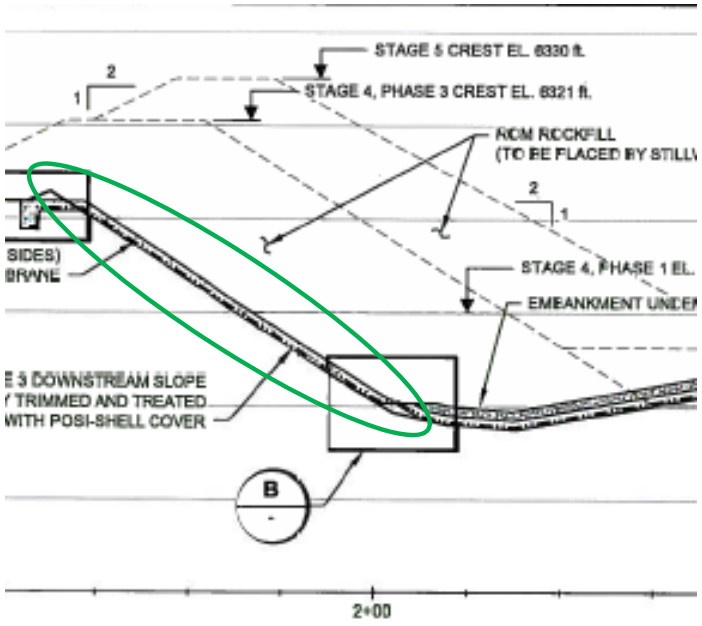
Downstream Slope Lining

Typical Sections for geomembrane Installation

PHASE 1 & 3

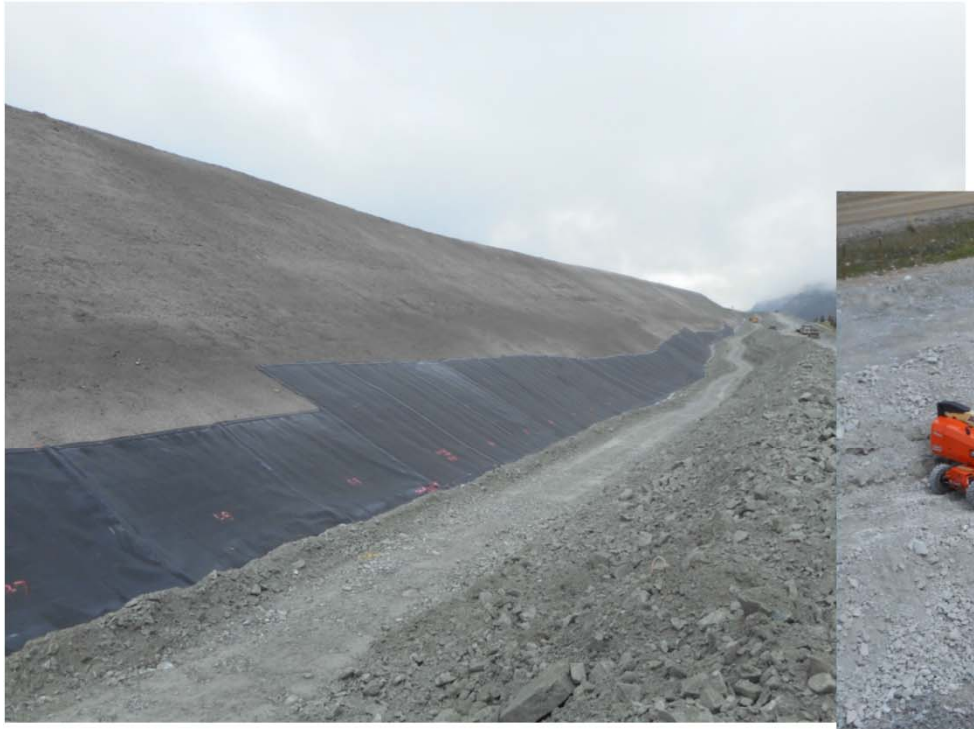


PHASE 2



Embankment Underdrain Installation

Phase 1 Downstream Slope Geomembrane Installation



Downstream Slope Lining

Phase 2 Downstream Slope Geomembrane Installation

Downstream Slope Lining

Phase 3 Downstream Slope Geomembrane Installation

Embankment Underdrain Performance

Embankment Underdrain Performance

2015 Embankment Underdrain Monitoring

- Approximately 4.0 M gal was recovered through the Embankment Underdrain System
- Total nitrogen concentrations ranged from approximately 110 to 730 mg/L
- Approximately 11,500 lbs of nitrogen was recovered

2016 Embankment Underdrain Monitoring

- Approximately 4.8 M gal was recovered through the Embankment Underdrain System
- Total nitrogen concentrations ranged from approximately 150 to 600 mg/L
- Approximately 16,200 lbs of nitrogen was recovered

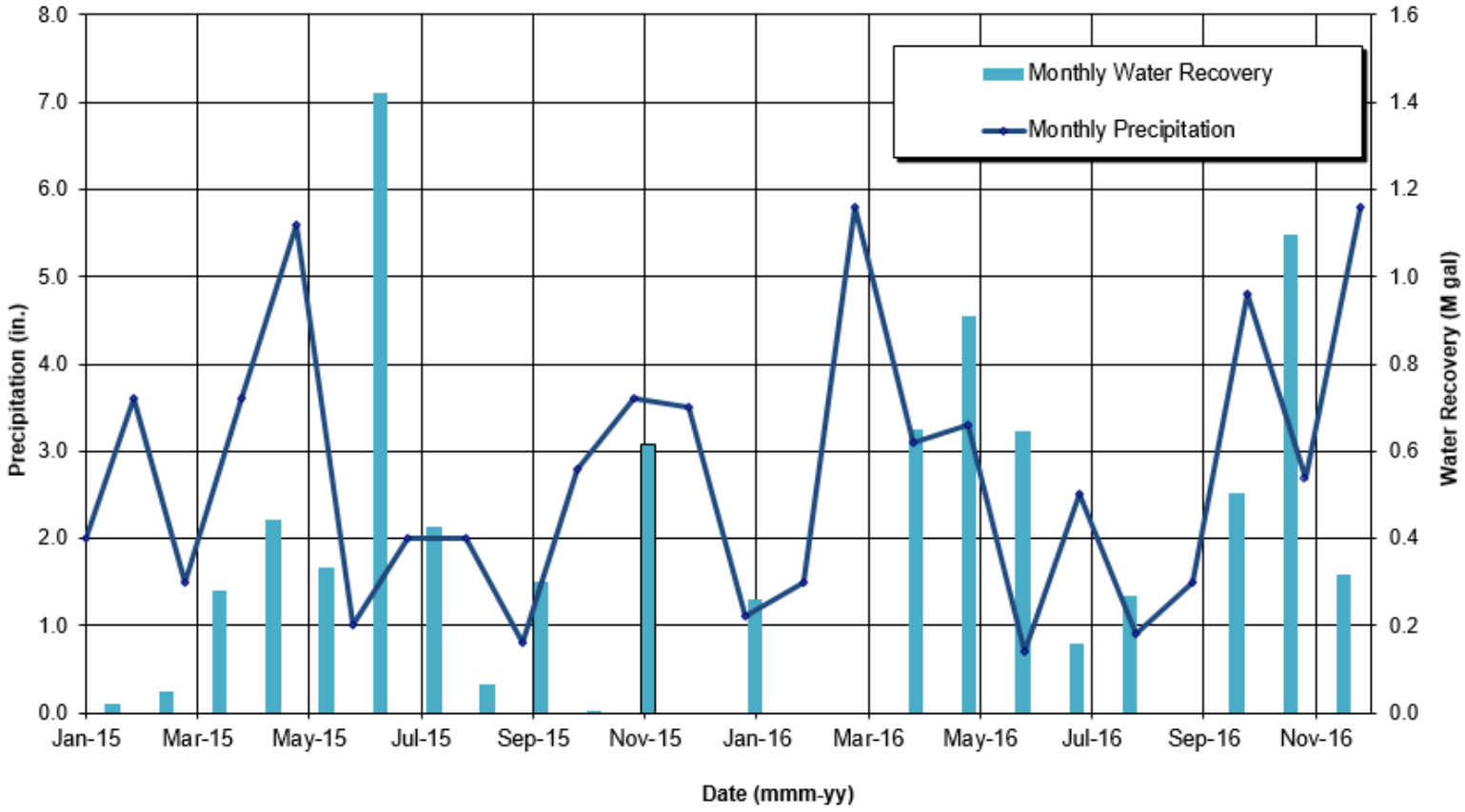
AA9

Slide 28

AA9 Did concentrations stay the same, increase or decrease? Any comment?
Amy Adams, 4/25/2017

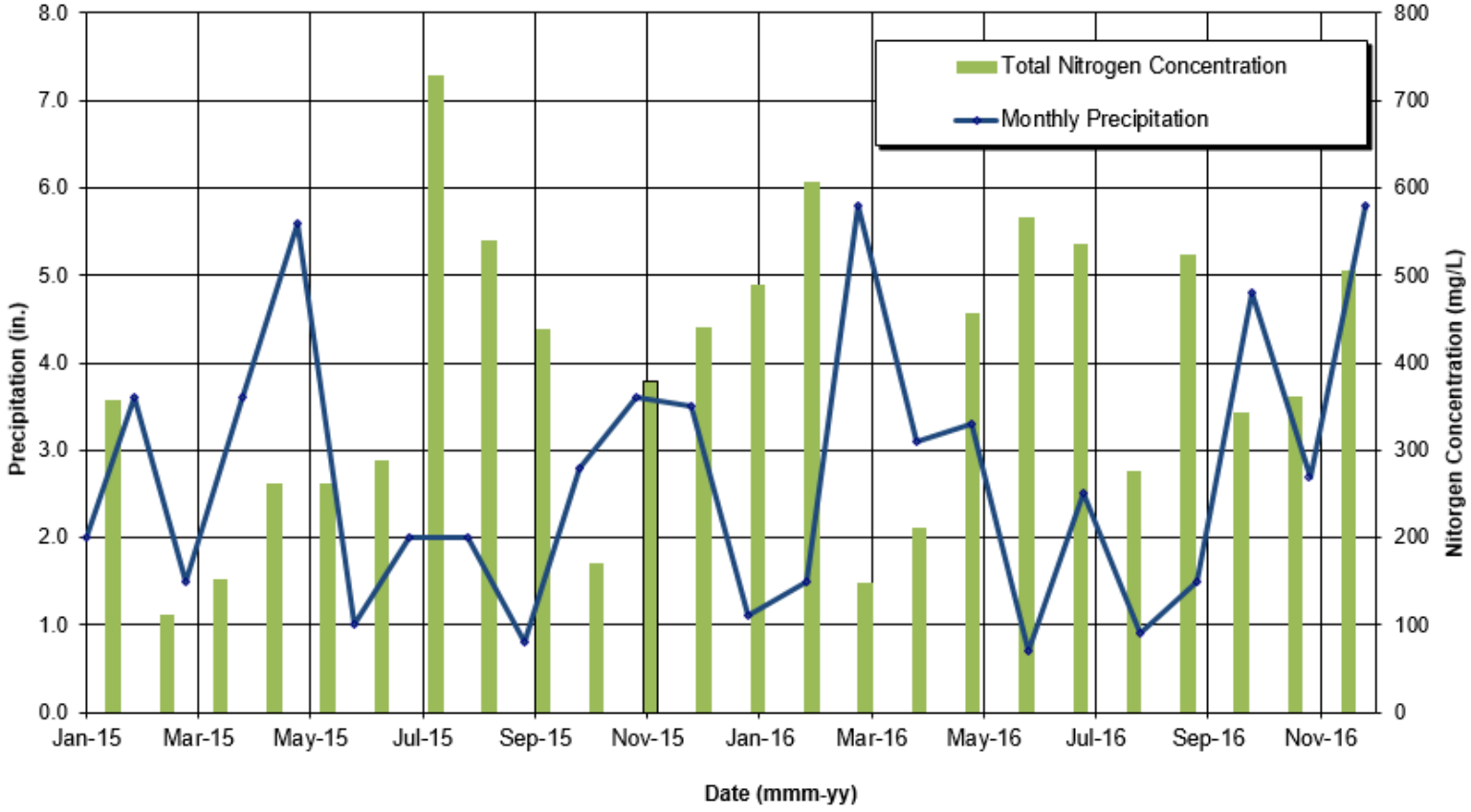
Embankment Underdrain Performance

Precipitation vs. Monthly Water Recovery



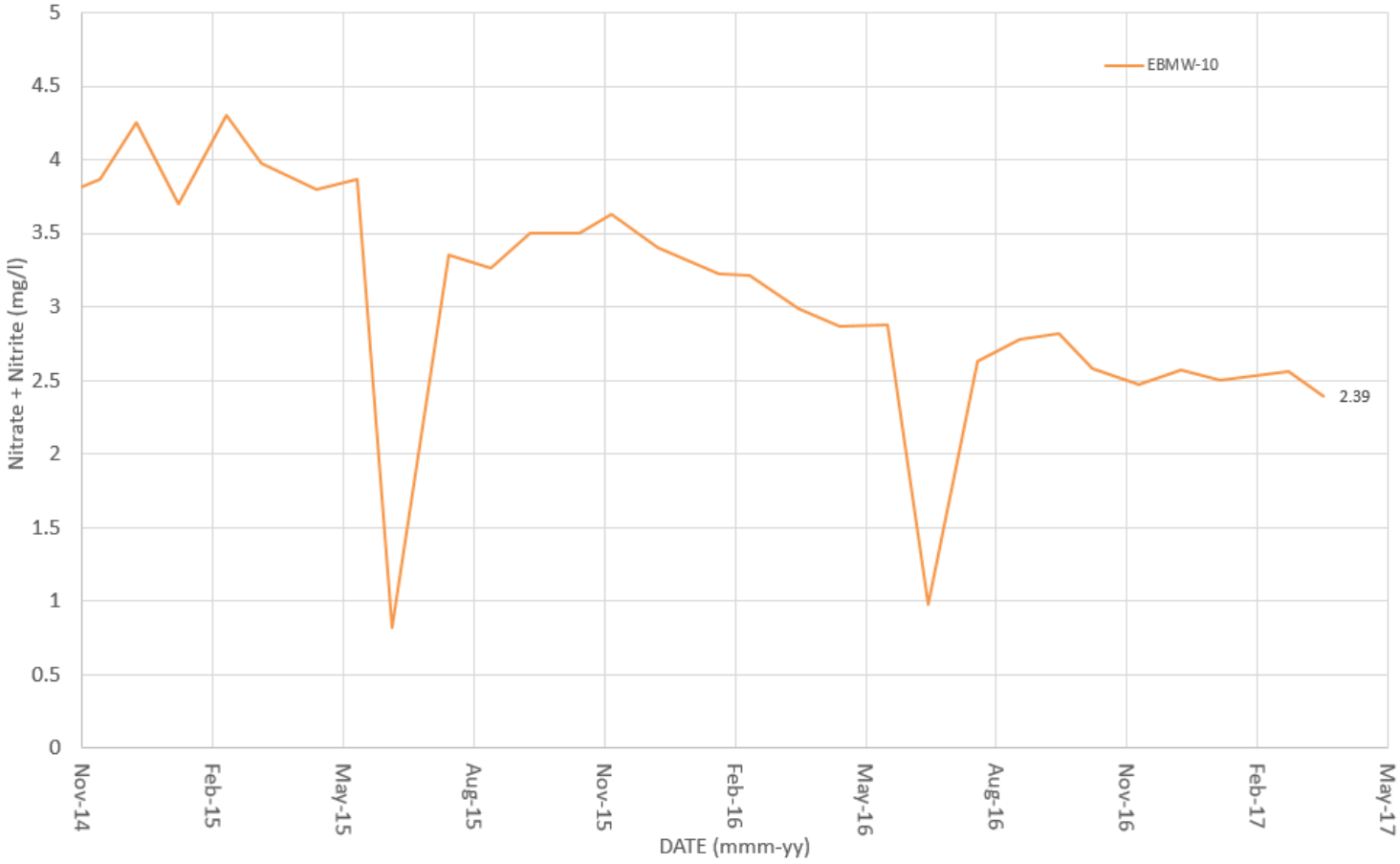
Embankment Underdrain Performance

Precipitation vs. Total Nitrogen Concentration



Embankment Underdrain Performance

Ground Water Monitoring Well Monitoring



Summary

Summary and Conclusions

Embankment Underdrain

- Embankment ROM rock fill was identified as a nitrogen source contributing to the elevated concentrations of aqueous nitrate
- An Embankment Underdrain was installed to collect and reduce the amount of meteoric water that percolates the through the ROM rockfill
- The Embankment Underdrain has provided effective collection of nitrogen
- Mitigation measures have allowed SMC to resume use of ANFO underground and reduce methanol injection for in situ treatment which has reduced operating costs

THANK YOU

Matt Wolfe
Environmental Manager, Stillwater Mining Company
mwolfe@stillwatermining.com

Craig Hall, P.Eng.
Specialist Geotechnical Engineer | Associate, Knight Piésold Ltd.
chall@knightpiesold.com