Characterization of Waste Rock Borrow Material for Use as Rock Armor to Reduce Tailing Impoundment Side-slope Erosion

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Mission Mine Tailing Reclamation

- Approximately 1200 acres of tailings
  - 350 acres of side-slopes
- Rock armor slopes per bankruptcy agreement (Previous reclamation highly eroded)
- Waste rock is cheapest source, but need:
  - Erosion resistant material
  - Non-acid generating, low metal leaching
  - 775,000 tons of material per 12 inches of depth
- Revegetation not a primary criteria

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Historic Reclamation ASARCO Mission Tailing 1&2

Natural Side-Slopes (Sonoran Desert)

Natural Side-Slopes (Sonoran Desert)

Study Objectives

- Identify rock armor sources with > 50% material > 0.5 inches (12.5 mm); geochemically not reactive
- Waste rock borrow material assessment:
  - Identify potential borrow material based on previous geochemical data
  - Characterize particle size distributions (PSDs) and geochemical characteristics of various waste rock sources
  - Evaluate potential phyto-toxicity, revegetation potential
- Erosion analysis of borrow material:
  - Erosion modeling (RUSLE2)
  - Rock armor field erosion test

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WASTE ROCK CHARACTERIZATION

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Acid Base Accounting (ABA)

- ABA provides indication of propensity of material to produce acid mine drainage
  - Acid-neutralization potential (ANP) = assets
  - Acid-generating potential (AGP) = liabilities
  - Net neutralization potential (NNP) = ANP – AGP = equity
- Favorable rock armor ABA criteria: NNP > 0 (ANP/AGP > 1)

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Waste Rock Armor Sources

- Potentially acceptable rock types
  - Volcanics (low Acid Generating Potential (AGP), low Acid Neutralization Potential (ANP))
  - Argillite (moderate AGP and ANP)
  - Arkose (mix of high and low AGP, moderate ANP)
- Six different source areas

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Waste Rock Characterization Approach

- Test pits and trenches
  - Visual logging of material types and oxidation levels
  - Digital images of rock piles and trench walls
- Composite and selected sample testing:
  - Split-Net imaging – Particle Size Distribution (PSD) (n=189)
  - Laboratory PSD (n=28)
  - pH and Acid-Base Accounting (ABA) (n=111)
  - Soil fertility and leachable metals (n=39)

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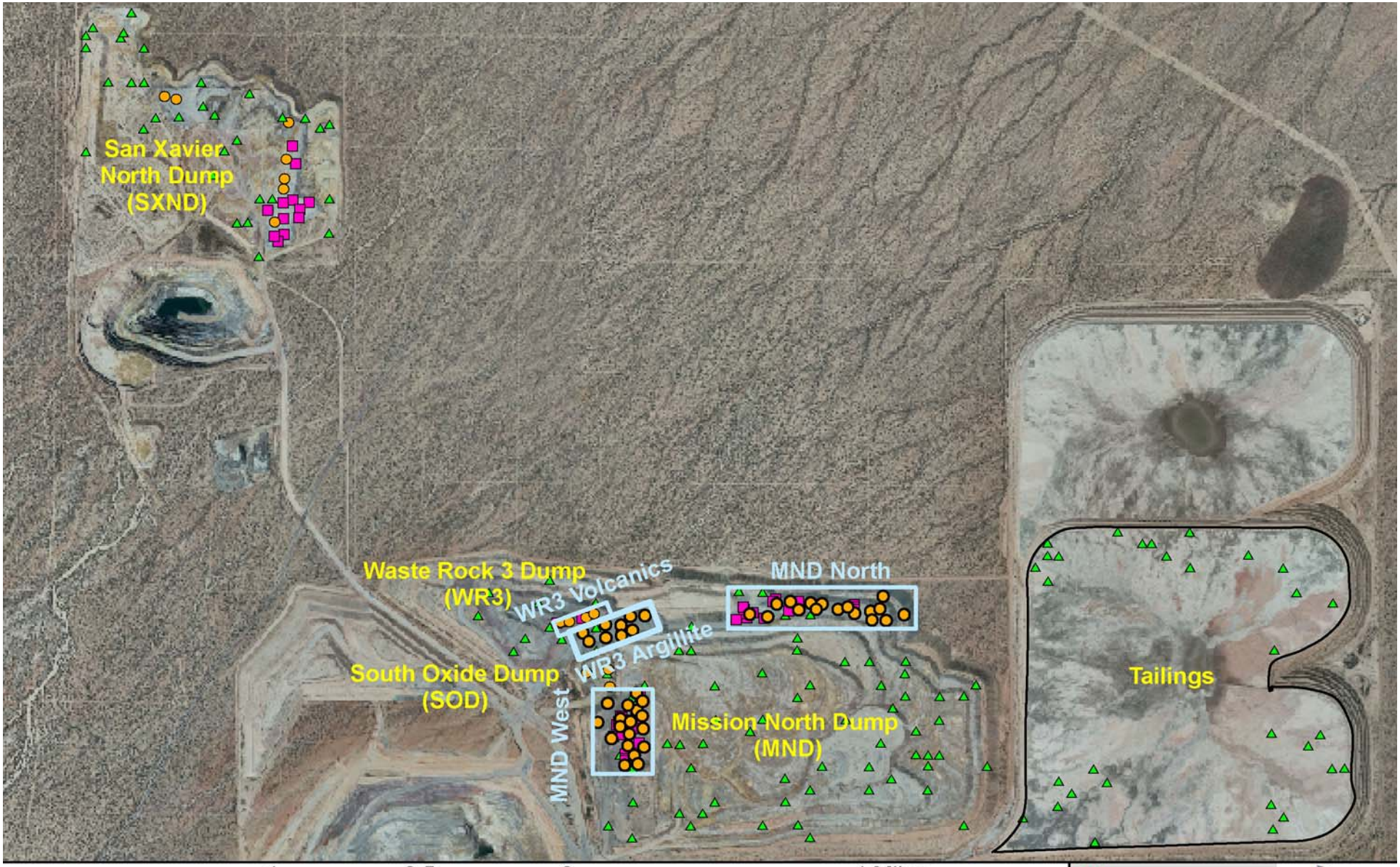

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Drawn: MB 6/23/10 Reviewed: MM
Revised:

Project: 0925 - MWH San Xavier - Side Slope A
Characterization Expansion

Legend

- Asarco Test Pits
- Asarco Trenches

D50

- < 0.7 inches
- > 0.7 inches

Texture

- Coarse
- Fine

N

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Drawn: MB 6/23/10 Reviewed: MM
Revised:

Project: 0925 - MWH San Xavier - Side Slope Armor

Trenching on MND West

Split-Net Image Analysis

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Characterization Results

- Initial Screening
  - ~~WR3 Argillite: Significant oxidation and highly variable NNP~~
  - ~~WR3 Volcanics: 50% material < 0.2 inches~~
  - ~~SOD Area: 50% material < 0.4 inches and Negative NNP~~
  - ~~In-Pit Argillite: Negative NNP~~
  - MND North Argillite, MND West Argillite, SXND Arkose meet screening criteria
- Mean Particle Diameter
  - MND North Argillite: 0.9 inches
  - MND West Argillite: 0.8 inches
  - SXND Arkose: Coarse = 1.5 inches; Fine = 0.3 inches
  - Mean diameter minus one standard deviation still meets criteria
  - More SXND Arkose material > 3.7 inches compared to MND Argillite material

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Geochemical Data

MND North Argillite (n=27)	2.1% pyrite sulfur, 119 tons $CaC0_3$/1000 tons	pH = 7.7 (91% samples pH > 7)	ANP/AGP = 1.73
MND West Argillite (n=35)	2.1% pyrite sulfur 94 tons $CaC0_3$/1000 tons	pH = 7.6 (97% samples pH > 7)	ANP/AGP = 1.37
SXND Arkose (n=24)	1.1% pyrite sulfur 56 tons $CaC0_3$/1000 tons	pH = 7.8 (97% samples pH > 7)	ANP/AGP = 1.83
Alluvium (n=10)	0.15% pyrite sulfur 98 tons $CaC0_3$/1000 tons	pH = 7.6 (100% samples pH > 7)	ANP/AGP = 34

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Soil Fertility and Metals Data

- All samples showed moderate salinity (4 to 5 dS/m)
- High copper values above potential phytotoxicity thresholds
- Zinc and boron above potential phytotoxicity thresholds in some samples
- Native plant species adapted to high-salinity or copper conditions may not be adversely affected

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EROSION ANALYSIS

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Erosion Analyses

- Model potential erosion under various scenarios (using PSD data and RUSLE2)
  - Fine, average and coarse argillite material
  - 150 to 600 foot slope length
  - Furrowing and revegetation
  - Vary percentage of “gravel” cover
- Implement argillite field erosion test pads
  - 12 inches argillite over 12 inches alluvium
  - Unripped, Ripped (6 inches and 24 inches)
- Simulated rainfall with water truck spray:
  - 2 inch rain over 30 minutes (Test #1)
  - 4.5 inch rain over 60 minutes (Test #2)

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Erosion Modeling Results

- Predicted annual Argillite erosion rates increase with slope length (2X from 150 ft to 600 ft)
- Furrowing along the contour on average decreases the predicted erosion by about 10%
- Increasing the gravel cover by 10% reduces predicted erosion rates by approximately 25%
- Coarse Argillite best
- Limit Argillite use to 3:1 slopes < 300 ft

Erosion Test #2

Erosion Test Results

- No significant differences in PSD between pre-and post-test ripping plots
- Argillite ripped to 24 inches was most erosion resistant
- Cascading and rilling observed where ripping not perpendicular to slope, or shallow furrows
- Ripping treatments did not show effective mixing of the alluvium and argillite rock armor material

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Conclusions

- Waste rock armor that is erosion resistant and geochemically inactive is available
- Side-slope reclamation design
  - One foot of alluvium base over tailings (extra ANP, potential for rooting medium)
  - One foot of rock armor material
- Full-length slope design (no benches):
  - MND West and North Argillite areas for use on slopes < 300 feet
  - SXND Arkose areas for use on slopes > 300 feet
  - Need to segregate visibly oxidized waste rock
- Revegetation potential?? – recommend salt tolerant seed mix

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THE REAL EROSION TEST

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Tailing 1-2

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Tailing 3

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Arkose

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