

# Characterization and Monitoring During Different Phases of Mining

Characterizing, Predicting, and Modeling  
Water from Mine Sites

James R. Kuipers, P.E.  
Kuipers & Associates



# Characterization and Monitoring During Different Phases of Mining

- Geochemical characterization and monitoring are complimentary activities
- Phases of Mining
  - Exploration Phase
  - Development Phase
  - Active Mining Phase
  - Reclamation, Closure and Post-Closure Phases

# Characterization During Different Phases of Mining

- Successful mine site characterization is directly related to the phase of mine development.
  - Earliest exploration stages - little site-specific information available.
  - Post-closure phase
    - Potential water quality impacts are better known
    - Mine site can be characterized with a higher degree of certainty.

# Characterization During Different Phases of Mining

- Extent of geochemical characterization
  - Site conditions and the nature of the deposit
    - Complex geology and mineralogy requiring a greater sampling and characterization effort.
    - Complex mixed oxide/sulfide ore body might require a highly rigorous program
    - Deposit with distinct oxide/sulfide zoning might require a less rigorous program.

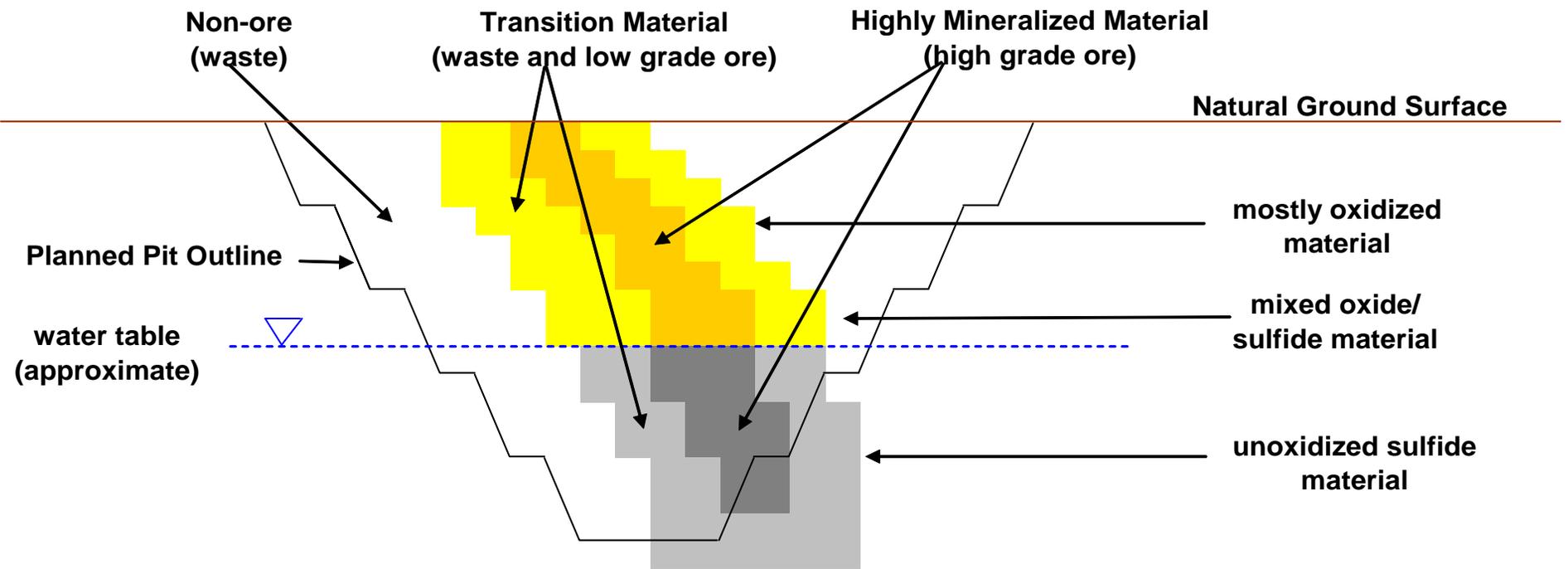
# Characterization During Different Phases of Mining

- Important features of an effective program:
  - Adequate sampling to ensure representation of the source materials
  - Sampling of distinct geology or mineralogy types when they are encountered
  - A level of environmental characterization that is commensurate with the level of ore characterization.

# Characterization During Different Phases of Mining

- In general, the amount and type of data should be commensurate with the phase of development
  - More detailed evaluations taking place with more advanced phases of the regulatory and economic decision-making processes.
- The characterization program should be both reactive and proactive
  - Results are received and evaluated in a timely fashion
  - The mine plan can change in response to any unexpected findings.

# Characterization - Exploration Phase



# Characterization – Exploration Phase

- The prospecting and exploration stages of mining involve long periods of investment with a high risk of failure (SME, 1992).
- The primary objective of exploration is to find an economic mineral deposit (NRC, 1999).
- More money is spent on exploration than is ever made by actual mining, with perhaps a few exceptions (anonymous).

# Characterization – Exploration Phase

- There are three generally recognized stages of exploration:
  - (1) prospecting
  - (2) detailed surface reconnaissance
  - (3) surface drilling and/or underground exploration
- The exploration phase can last for a few years to more than 10 years.

# Characterization – Exploration Phase

- The recommended characterization methods to be employed during the exploration phase are:
  - Whole rock analysis
  - Mineralogy
  - Drill core descriptions
  - Block model or similar model
  - Available literature on the ore deposit
  - Mineral occurrences with an emphasis on sulfides and carbonate
  - Acid-base accounting

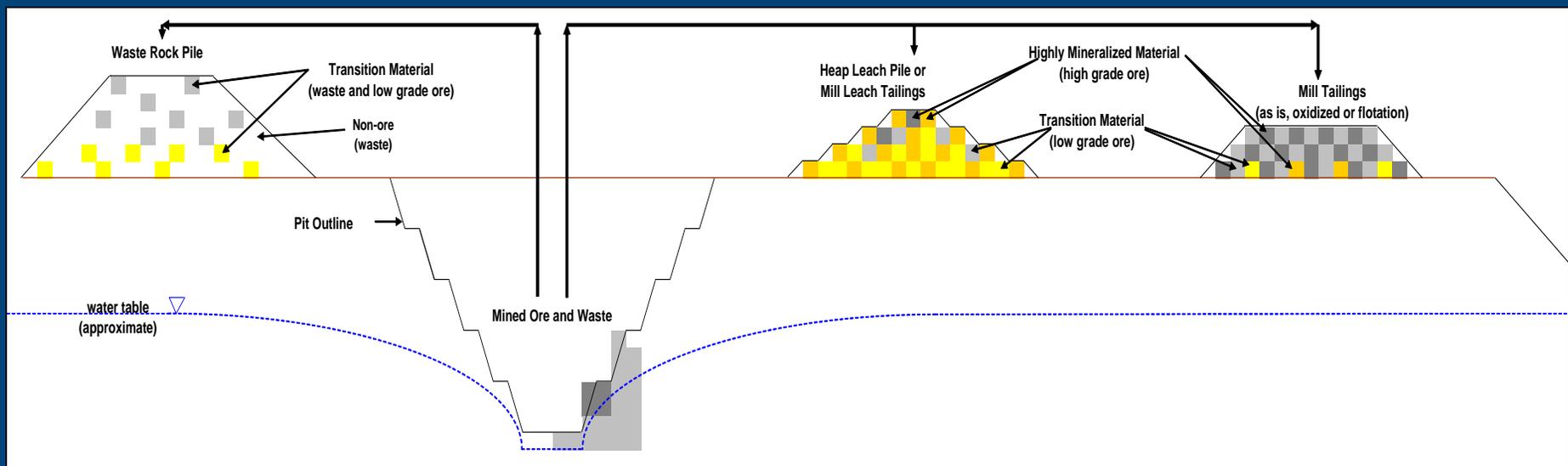
# Characterization – Exploration Phase

- Startup of long-term kinetic testing; possible startup of test pads
- Baseline surface and ground water quality and flows (including springs)
- Potentiometric surface for groundwater
- Hydraulic properties of soil, vadose zone, and groundwater aquifers, especially under proposed locations of mine facilities
- Examination of characteristics of similar mines in region/area
- Hydrogeochemical models for prediction of water quality.

# Characterization – Exploration Phase

- Exploration phase information can allow for a gross characterization of potential environmental conditions
  - Extent of oxide, mixed oxide/sulfide, and sulfide ore
  - Net acid generation potential (net AGP)
  - Contaminants of concern.
- Because long-term characterization has not been conducted, estimates of water quality impact potential made during this stage should be viewed as preliminary and highly uncertain.

# Characterization – Development and Active Mining Phases



# Characterization – Development Phase

- Take the resource identified by exploration efforts and determine by what means (e.g., open pit versus underground mining) and at what revenue stream (return on investment) the ore deposit might actually be mined and processed.
- Ore “deposit,” “resources,” and “reserves”
- Feasibility Study
- Design, permit and construct mine, process and ancillary facilities.

# Ore “deposit,” “resources,” and “reserves”

- A mine is nothing more than a hole in the ground with a liar standing next to it (M. Twain).
  - **Deposits**, are mineral occurrences or prospects which are of geological interest but may not be of economic interest
  - **Mineral resources**, include those which are potentially economically and technically feasible, and those which are not
  - **Ore reserves**, must be economically and technically feasible to extract

# Characterization – Development Phase

- During the development phase, the following types of characterization should be conducted:
  - Continued sampling of geology and mineralogy of ore and waste
  - Continued acid-base accounting and kinetic testing of mined materials; startup of field test plots, if waste will be stored at surface. (Note: the design of the test plots must correspond to the conceptual model for how the waste would ultimately be stored.)

# Characterization – Development Phase

- Continued testing of hydraulic properties of soils, vadose zone, and aquifers
- Tailings bench scale testing
- Creation of a mine waste management plan
- Study of changes in groundwater potentiometric surface from dewatering or other mining-related stresses
- More detailed hydrogeochemical models for prediction of water quality.

# Characterization – Active Mining Phase

- As the mine matures, the amount and degree of useful characterization information increases substantially, allowing for either
  - Confidence in the original source characterizations and water-quality predictions, or
  - The realization that errors in previous characterization and prediction work may require changes in the site conceptual model and potentially the mine plan itself.
- It is almost always more efficient and less expensive to adapt to changes in characterization information by modifying the project than to ignore the information received during the operations phase of mining.

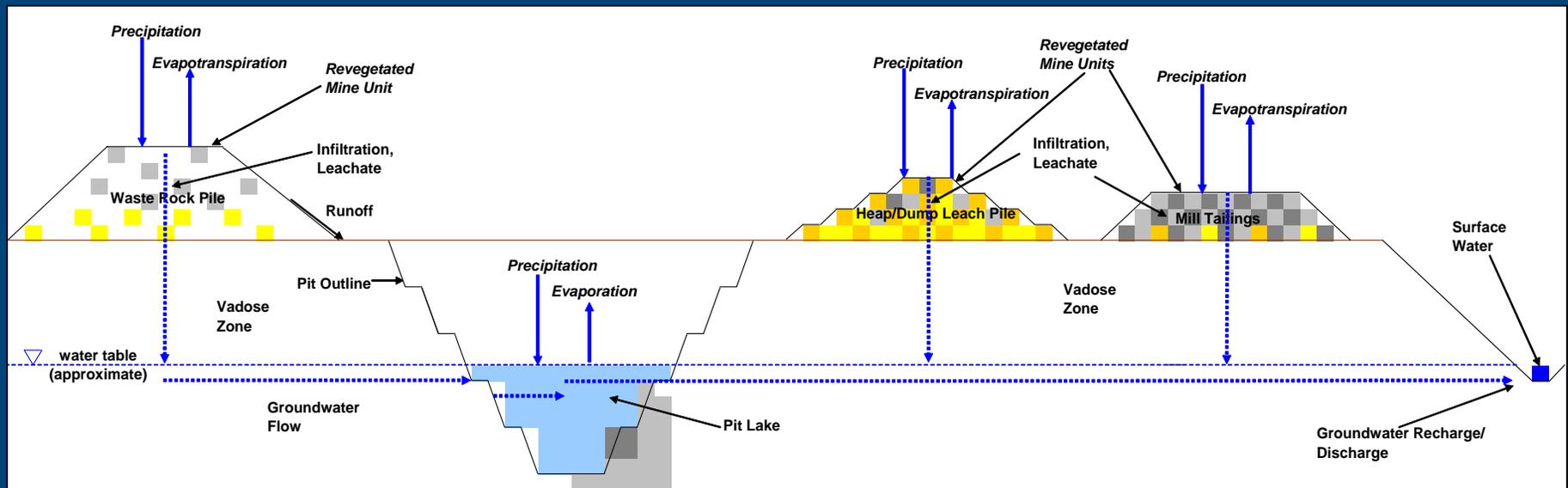
# Characterization – Active Mining Phase

- During the active mining phase, the following types of characterization are recommended:
  - Continued geochemical characterization of mined materials (field and laboratory)
  - Continued predictive and laboratory verification of the mine waste management plan
  - Collection and sampling of leachate from waste rock, tailings, and other facilities
  - Sampling of water quality in streams and groundwater upstream/gradient and downstream/gradient of mine facilities

# Characterization – Active Mining Phase

- Testing of hydraulic properties of mined materials (e.g., waste rock, heap leach material, tailings)
- Continued observation of changes in groundwater potentiometric surface resulting from mining-related stresses
- Comparison of predicted (from characterization and modeling efforts) and actual water quality
- Routine evaluation of the results of ongoing characterization for significance to monitoring programs, operational controls, mine planning, and closure planning.

# Characterization – Reclamation, Closure and Post-Closure Phases



# Characterization – Reclamation, Closure and Post-Closure Phases

- Where reactions are occurring and water quality has already been impacted during or shortly after mining, empirical evidence may serve as a good predictor of future water quality.
- In cases where maturation has not occurred, or similarly where leachate has not yet reached water resources, existing data may not adequately predict future impacts even though mine operations may have ceased.
  - Forward models using existing water quality and mineralogic information can be used to predict potential future water quality

# Characterization – Reclamation, Closure and Post-Closure Phases

- During the closure, reclamation, and post-closure phases of mining, the following characterization methods should be employed:
  - Comparison of predicted and actual water quality
  - Continued sampling of quality and quantity of water resources, including springs, leachate, surface water, and groundwater at points of compliance and other locations
  - Measurement of recharge in groundwater levels over time after groundwater pumping has ceased
  - Monitoring of effectiveness of mitigation measures and comparison to predicted performance.

“You don’t get a second chance to do it right the first time”

VERSUS

