Heap Leaching 101

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NRC Authority

- Uranium recovery by heap leaching methods is a licensed activity regulated by the NRC.
- Heap leaching covered under 10CFR Part 40
  - Appendix A is directly applicable to licensing, operating and closure of heaps – NRC will consider alternatives to certain criteria
    - Operating and closure of heaps has same requirements as ISR facilities and conventional mills
      - Key point-operating heap will become your long term waste management facility

NRC Application Process

- NRC application process straight forward
- 10CFR Part 40 applies to licensing, operating and closure
  - NRC Regulatory guide DG-3024, May, 2008 provides the necessary guidance information to license a facility
- Applicant must prepare an environmental assessment with license application to assess the impact of facility on the environment
  - NUREG-1748 “Environmental Review Guidance for Licensing Actions Associated with NMSS programs, 2001”

Federal/State Application Process

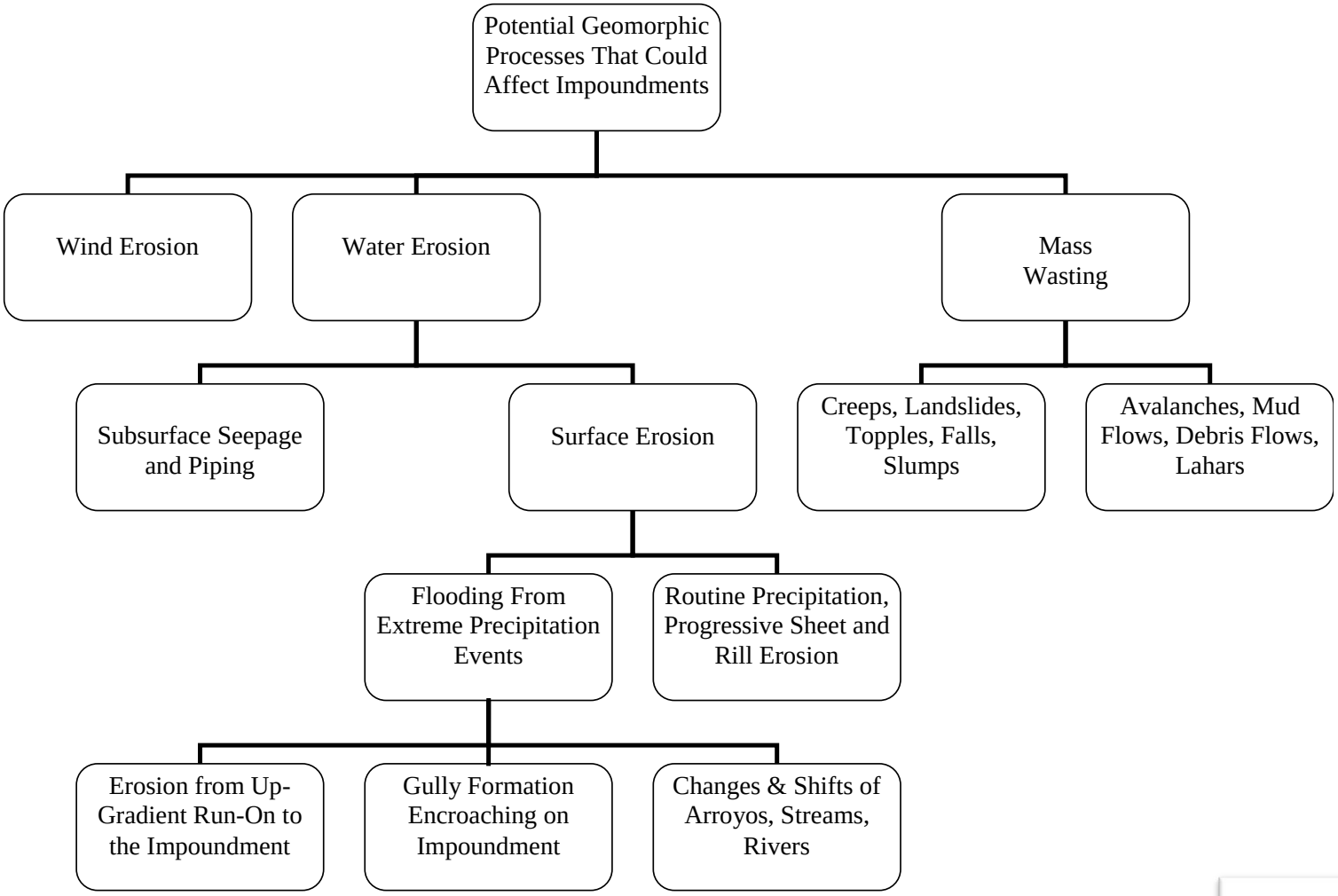
- Non NRC permits may be required
- Permit application requirements vary with agencies
  - Information from NRC submittal fulfills majority of technical requirements
    - Expect State and Local agencies to encroach on NRC authority
    - Expect State and Local agencies to add additional and redundant permit requirements
    - State and Local permit applications can be political

Heap Planning and Design

- Site Selection
  - Most critical aspect in the life cycle of a heap
  - Location, Location, Location
  - Siting a facility is governed by long term closure requirements

- Proper Siting Advantages
  - Reduces operating and monitoring costs
  - Minimizes engineering controls
  - Minimizes long term maintenance
  - Reduces long term custody and surveillance costs
  - Reduces long term care fund provided by owner
  - Avoids relocation of by-product material (heap) at conclusion of operations

Geomorphic Processes



Evaluation of Geomorphic Processes , Seismic Events– The Key to Properly Locating a Site

- Regulatory Guide CR-4260 - “Methodologies for Evaluating Long Term Stabilization Designs of Uranium Mill Tailings Impoundments”
- Precipitation events affecting heap facilities
  - PMP and cumulative routine precipitation events
    - Flooding of impoundment
    - Gullies, arroyos, head cutting causing intrusion
    - Stream shifts

- Long term wind erosive forces
  - Degradation of heap covers
- Landside/creep areas
  - Long term movements affecting cover integrity
  - Operational difficulties

- Seismic Events
- Avoidance at Capable Faults
  - Design for maximum credible earthquake
  - Site rupture/liquifacton

Protection of Water Resources

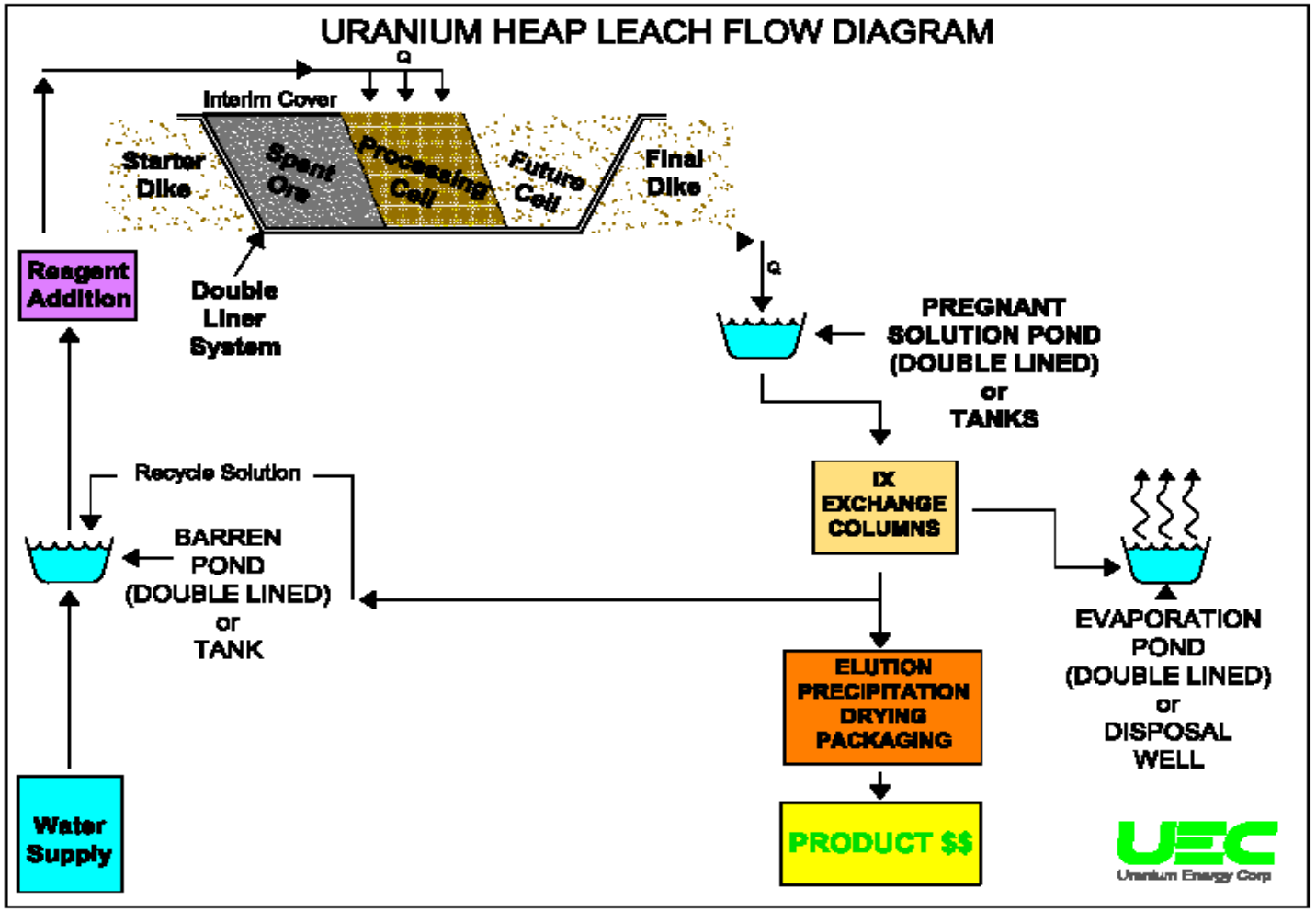
- Groundwater
  - Complete characterization of all potentially affected groundwater aquifers
  - Interaction and communication between surface and groundwaters
  - Knowledge of geochemistry of aquifer matrix
- Groundwater Quality
  - Background
  - Proximity to groundwater users
  - Potential for health risks caused by human exposure from facility

Heap Design and Construction

- Design for full containment
  - Static and dynamic stability and impoundment
  - Settlement considerations
  - Protection of water resources
    - Double liner systems
    - Groundwater monitoring program
  - Construction
    - Rigid QC/QA Program
    - Documentation
      - Regulatory Guide 3.11 “Design, Construction and Inspection of Embankment Retention Systems for Uranium Mills, Revision 2, 1977”

Typical Heap Leach IX Facility

- Fully contained heap
- Water supply
- Heap solutions – leaching
- Pregnant solution ponds or tanks
- Ion Exchange
- Elution, precipitation, drying, packaging
- Waste disposal (bleed) ponds or deep disposal well
  - NUREG-1569 standard review plan for in-situ uranium extraction license application
  - Consider pertinent portions of Sections 3, 4 and 5 relevant to IX processing


URANIUM HEAP LEACH FLOW DIAGRAM
Q
Interim Cover
Starter Dike
Spent Ore
Processing Cell
Future Cell
Final Dike
Reagent Addition
Double Liner System
Q
PREGNANT SOLUTION POND (DOUBLE LINED) or TANKS
Recycle Solution
IX EXCHANGE COLUMNS
BARREN POND (DOUBLE LINED) or TANK
EVAPORATION POND (DOUBLE LINED) or DISPOSAL WELL
ELUTION PRECIPITATION DRYING PACKAGING
Water Supply
PRODUCT $$
Uranium Energy Corp

Operations

- Pre-operational and operating monitoring
  - 10CFR Part 20 Standards for protection against radiation
    - Regulatory Guide 4.14 – “Radiological Effluental Environmental Monitoring at Uranium Mills”

- Effluent and Emissions Controls
  - Develop an ALARA Program
    - Management commitment to ALARA
    - Procedures, engineering controls, process controls
    - Surveys and effluent monitoring
    - ALARA reviews and audits
    - Worker training

      - Regulatory Guide 8.10-“Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable”
      - Regulatory Guide 8.31-“Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Mills Will Be As Low As Is Reasonably Achievable

Drip emitter system for controlled leaching

After: Allen J. Breitenbech

Drainage Layer Placement over heap liner

After: Allen J. Breitenbech

Closure

- Close with long term objectives
  - Impoundment stable for 1000 years, and at least 200 years
  - Limit long term emissions from closed facilities to have no more than 20 picocuries/m^2/see
  - Radiation from facility no greater than twice background
  - Monitoring system to verify protection of water resources for the long term
  - Surety

    - NUREG-1620 – “Draft Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act (Draft Revision 1)
    - NUREG-1623 – “Design of Erosion Protection For The

Heap Leaching Basics

- Ore Heaps
  - Fully contained double liner/leak detection system
  - Typically 20 to 25 feet high
- Uniform Leaching – Optimum Recovery
  - Avoidance of preferential flow paths
  - Uniform ore size – 1-1/4 inch
  - Uniform placement
    - Stackers, conveyors, dozers
    - Avoid Dumping
    - Placement of fine material in separate cells
      - 15% fines (10 mesh) 60 fold decrease in permeability

- Application of Leach Solutions
  - Drip system – uniform application rate
  - Application rate ~0.15 to .3 gal/min/Ft^2
  - Spraying – Non-uniform application, loss of surface permeability, worker protection issues, maintenance issues, micro-droplet loss of reagents to wind

Improvement of Leach Kinetics

- Pretreatment of ore with leach solution during placement (curing of ore)
- Bioleaching
- Agglomeration

Environment/Closure

- Consider heap flushing/neutralization at closure
- Drain sealing
  - Pile drains to specific retention
  - Use sulfate resistant grouts (Type V cement to seal drains)

Looking Forward

- Innovative leaching – hybrid heap-In-Situ
  - Leaching of partially saturated ore zones
    - Applicable to shallow zones/open pits
  - Injection Wells
    - Conventional spacing
    - Oxygen-Bicarbonate leach
    - Can inject as partially saturated flow
      - Vertical Flows
    - Horizontal collection drain below ore zone

- Aquifer restoration
  - Partially saturated flow
  - Reduced Time and effort for restoration

CONCLUSIONS

Heap Leach Basics

- Simple process – short construction period
- Low capital expenditures
- Low operating costs
- Radiation exposures less than at conventional mill sites
  - Major exposures
    - Dusting of ore piles
    - Dusting for ore heap
      - Moisture addition
      - Consider geotextiles on heap

- Ore Heaps
  - Fully Contained Engineered double liner/leak detection system
  - Typically 20 to 25 feet high
  - Construct Heap for Optimum Recovery
    - Avoidance of preferential flow paths and horizontal impervious layers
    - Uniform ore size – 1-1/4 inch
    - Uniform placement-avoid Compaction
      - Stackers, conveyors, dozers
      - Avoid Dumping
      - Placement of fine material in separate cells or agglomerate
        - 15% fines (10 mesh) 60 fold decrease in permeabilit

- Application of Leach Solutions
  - Application rate ~0.15 to 0.3 gal/min/Ft^2
  - Drip system
    - Uniform application rate
    - Avoids loss of fluids to Environment
    - Low maintenance
  - Avoid Spraying
    - Non-uniform application,
    - Loss of surface permeability,
    - Worker protection issues,
    - Maintenance issues,
    - Loss of reagents to wind

Improvement of Leach Kinetics

- Pretreatment of ore with leach solution
  - Reduces Leach time
- Bioleaching
  - Improves permeability
  - Shortens Leach Time
  - Reduces Acid consumption
  - Increases Recovery
  - Decreases cost
- Agglomeration
  - Reduces fine Content
- Separation of Fines

Environment/Closure

- Consider heap Neutralization/Flushing at closure
  - Enhances groundwater protection
  - Reduces Radon Emissions
    - Reduces Cover Thickness
    - Reduces costs
- Drain sealing
  - Drains remain open until Heap drains to specific retention
  - Use sulfate resistant grouts (Type V cement to seal drains)

Looking Forward

- Innovative leaching – hybrid heap/In-Situ Leach
  - Leaching of Un-Saturated ore zones
    - Applicable to shallow ore zones above water table/open pits
  - Modified Injection Wells
    - Well spacing based on Ore Configuration
    - Oxygen-Bicarbonate leach
    - Inject under a Unit Gradient- partially saturated flow
      - Unit Gradient -Vertical Flow
    - Horizontal collection drains below ore zone

- Aquifer restoration

- Reclaim as In-Place Heap
  - Partially saturated flow- No Flooding
  - Reduced time and effort for restoration