Management of Mining and Milling and Other NORM Wastes

Ian Crossland

Crossland Consulting UK

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IAEA
Atoms for Peace: The First Half Century
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Content of the lecture

- Description of NORM wastes
  - how and where they arise
  - physical, chemical and radiological properties
  - associated hazards
- Regulatory standards
- Remediation options
- This talk limited to long-term management of solid wastes

Waste streams Generated during the Different Phases of Mining Projects

- Exploration wastes
- Mining wastes
- Milling wastes/ tailings (most problematic)
- In situ leach wastes (mostly liquid wastes)
- Miscellaneous wastes

Tailings properties: Ore Grade versus tailings volume

Mine	Ore Grade (%)	Uranium Production (t)	Volume of Tailings (t)	Uranium / Tailings Ratio
Beaverlodge	0.21	21,236	10,100,000	475
Key lake	1.95	71,611	4,400,000	61
McArthur	12.75	160,200	4,400,000	27

Other NORM wastes

NORM wastes can arise from any industrial process that handles natural materials. These include

- Oil and gas production
- Geothermal energy production
- Metal (eg U) production
- Coal fired power plants
- Drinking water treatment
- Sewage plants
- Fertilizer plant

Some typical radionuclide concentrations in NORM

Material	Radionuclide Concentrations (Bq/kg)
Scale in pipes and equipment for oil/gas production	0 - 15,000,000 (average one thousand to hundreds of thousand)
Sludges in natural gas supply equipment	up to ~40,000
Sludges from ponds of produced water	10,000 to greater than 40,000
Scales from geothermal energy production	4,000 - 40,000
Uranium mining overburden	100 - 20,000 (only Radium reported) (average ~5,000 total radionuclide concentration)
Coal fired power plants	100 - 25,000
Drinking water treatment waste	Sludges - ~600 (only ^{226}Ra reported) Resins - ~1,300,000 (only ^{226}Ra reported)
Phosphate fertilizer	1,000 - 25,000
Phosphate processing waste	Phosphogypsum - 1,000 - 4,000 Slag - 2,000 - 7,000 Scale - ~40,000 (only ^{226}Ra reported)
Other mineral processing waste	up to 40,000 (generally 100 - 5,000)

These data should only be used as rough indicators of the levels of radioactivity.

Tailings properties: Radiological components

- Typically, 5 - 10% of target metal and other radionuclides remain in the tailings
- Relevant natural radioactive decay series applies: uranium and thorium
- Radium-226 often considered as the most important radiotoxic decay product in the decay series
- Radium-226 produces radon-222, a radioactive inert gas, whose decay products can cause lung cancer

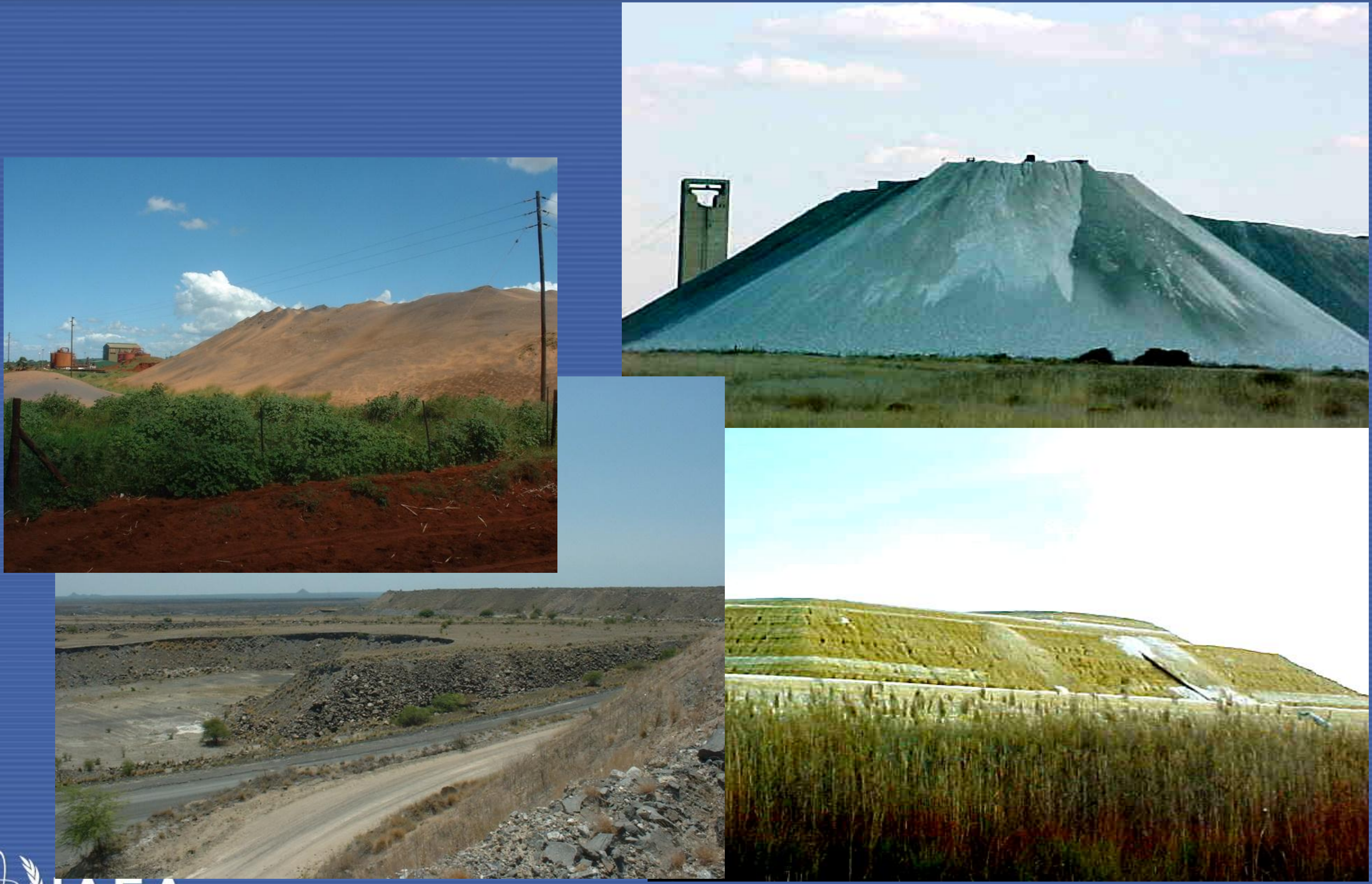
Tailings properties: Acid Mine Drainage

- Caused by the oxidation of sulphide materials such as pyrite and pyrrhotite in the presence of moisture and oxygen
- Common problem around the world (including conventional mines)
- Oxidation process forms sulfuric acid, which results in:
    - Elevated concentrations of toxic heavy metals and radionuclides discharges and seepage from the tailings
    - Reduction in pH of adjacent water systems

Tailings properties: Non-radiological Contaminants

- Large number of non-radiological contaminants most commonly found in the tailings
- Contaminants in tailings depend on the ore and milling process used
- Solid wastes formed as the result of mill effluents and other contaminated waters treatment
    - Sludge from the neutralization of acidic solutions
    - Sludge from the treatment process of mill effluent with barium chloride
    - Usually disposed to the tailings management areas
    - May cause problems due to their poor consolidation properties

Solid waste examples



Regulation

Key issues

- Large volume of waste
- High disposal costs
- Long-lived radionuclides
- Limited containment
- Fairly homogeneous waste

Administrative, Legal and Regulatory Framework

- **National policy and strategy**
  - Policy for managing the waste
  - Strategy to implement the policy
  - Consistent with fundamental safety principles
    - Justification, optimization, protection for individuals, protection of present and future generations
  - Consistent for radiological and non-radiological components
  - Make provision for public consultation

Administrative, Legal and Regulatory Framework

- **Responsibilities**
  - Regulatory body
    - Develop rules, criteria, guidelines
    - Establish licensing system
    - Ensure fulfillment of obligations after mine closure
    - Ensure necessary funding is available
    - Ensure transfer of responsibilities after mine closure
    - Advise prospective purchasers of land
  - Operator
    - Responsible for all safety related issues (e.g. workers, public)
    - Comply with legal requirements

Long Term Impact

- The radiation in uranium waste rock and tailings is extremely long lived
- Impacts cannot only be considered in the short term but must include the potential effects on future generations
- Often larger impacts occur after the closure of a facility

Life Cycle Safety Considerations

- Siting of facility (eg tailings dam)
- Design and construction
- Operation
- Closure
- Removal of regulatory control?

Safety assessment
  Operational phase
  Post-closure phase

Institutional Control for Post-closure Phase

- Actions, mechanisms, arrangements implemented to maintain control or knowledge of the site after closure
- Environmental monitoring, surveillance
- Active controls
- Passive controls
- Should be part of optimization of design for closure
- Reviewed by regulatory body to verify its effectiveness
- Should be based on the safety assessment
- Maintain records in accordance with legal requirements

Options

Solid Mining Wastes – Waste Rock

- Waste rock piles managed to minimize environmental impact
- Environmental impact is site specific: depends on mineralogy of the rock, climatic conditions (esp. rainfall), local topography, pile configuration etc. Mechanical stability is key
- Waste rock management options should be planned early to avoid important site rehabilitation and closure costs
- Possible waste rock management options:
  - Fill material in underground workings or open pits
  - Construction material within the plant
- Radioactivity and geochemistry should be carefully assessed prior to selection of any of the above options

Solid Mining wastes: Scrap material and equipment

- Valuable contaminated drilling, excavating, loading, transport and other mining equipment
  - Should be decontaminated before use elsewhere
  - Clearance criteria should be developed

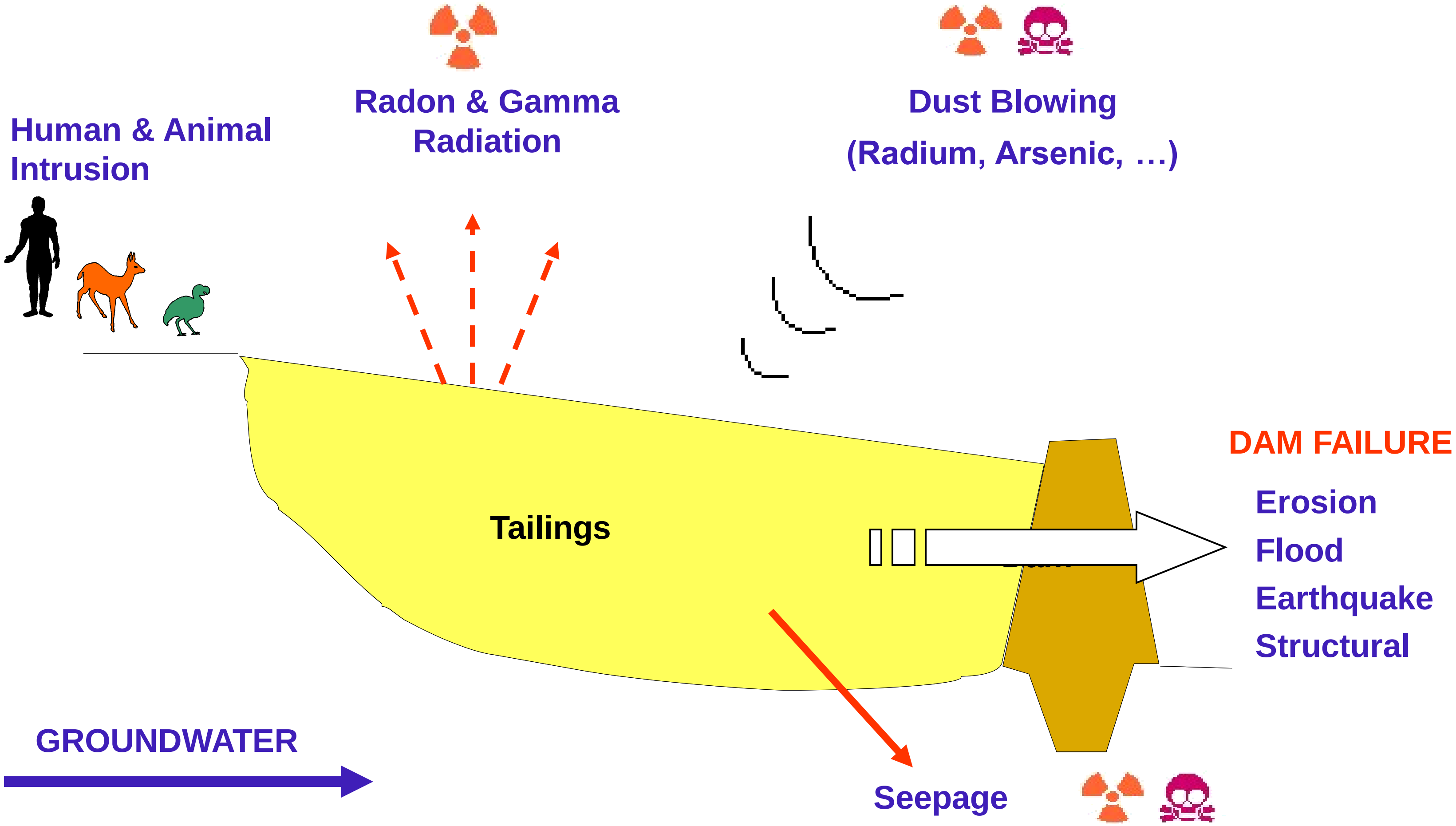
- Scrap contaminated material
  - Disposal option should be selected to prevent public access to the material Disposal options and require approval by the competent authority
  - Possible disposal options include: within the tailings, or waste rock, underground or in open pits etc.
  - Minimize handling time during disposal

Tailings Disposal Methods

- Three main disposal methods
  - Above ground (surface) impoundments
  - Below grade disposal in Mined-out pits
  - Underground disposal in mine voids

- Disposal Objective
  - Control the release of contaminants from the tailings into the environment (air, surface water and groundwater)

URANIUM TAILINGS HAZARDS



Human & Animal Intrusion

Radon & Gamma Radiation

Dust Blowing

(Radium, Arsenic, …)

Tailings

DAM FAILURE

Erosion
Flood
Earthquake
Structural

GROUNDWATER

Seepage

Arsenic, Uranium, Radium…

Surface tailings Impoundments

- Two main layouts using natural features and man-made structures
  - Valley dam impoundments
  - Ring dyke impoundments
- Tailings should be confined using low permeability engineered dams
  - Meet modern static and seismic stability standards
- Minimize seepage

Surface Impoundments: Ring dyke impoundments

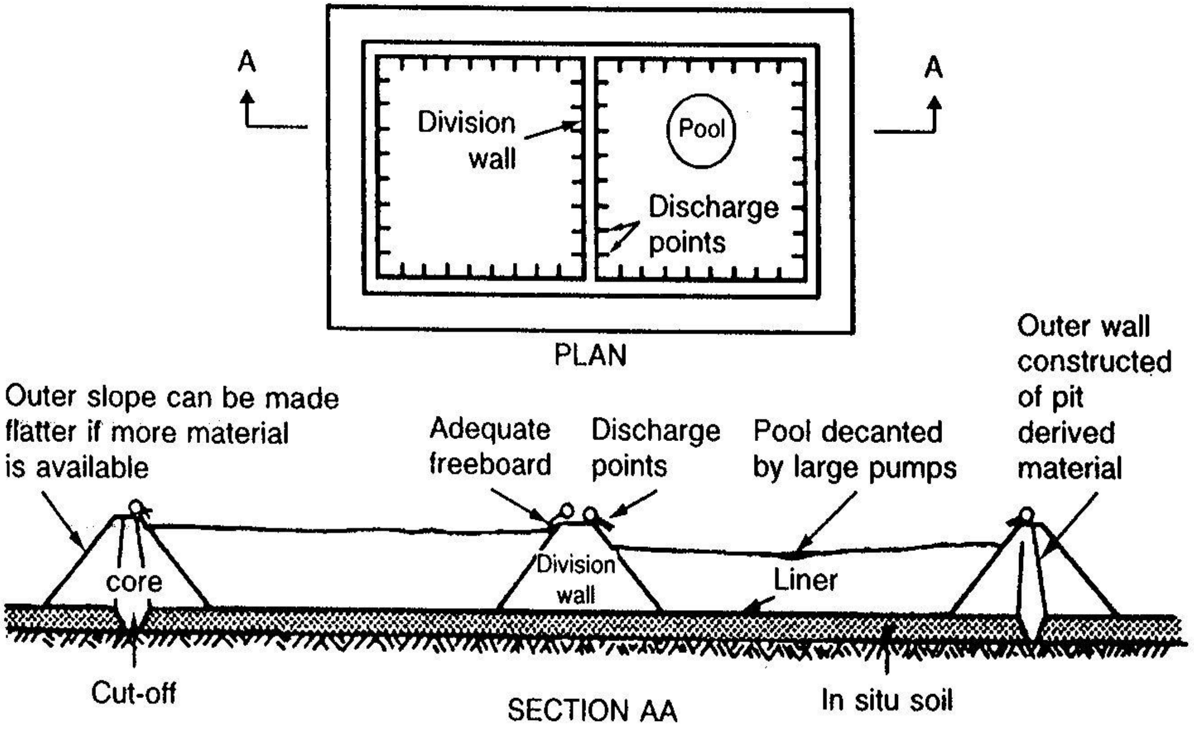


FIG. 9. Typical ring dyke impoundment.

Example of surface ring dyke impoundment– Australia-

Below Grade Disposal: Mine Pit Impoundments

- No tailings release by erosion or failure of man-made structures
- Low risk of intrusion in the long-term
- Could provide a walk-away solution after decommissioning and closure
- Requires little monitoring and maintenance in the long-term
- Design of the pit and tailings disposal system disposal are site specific
- Tailings slurry pre-treated to precipitate out dissolved metals (radium, arsenic etc). Impact on groundwater quality must be carefully analyzed.

Below Grade Disposal: Mine Pit Impoundments

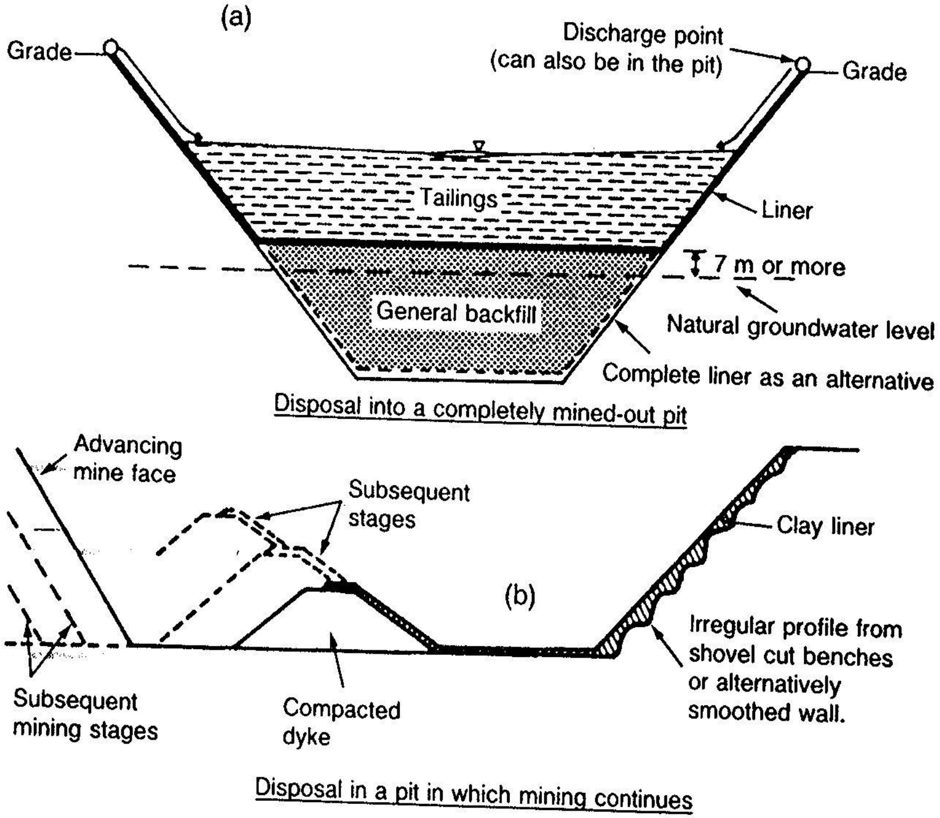
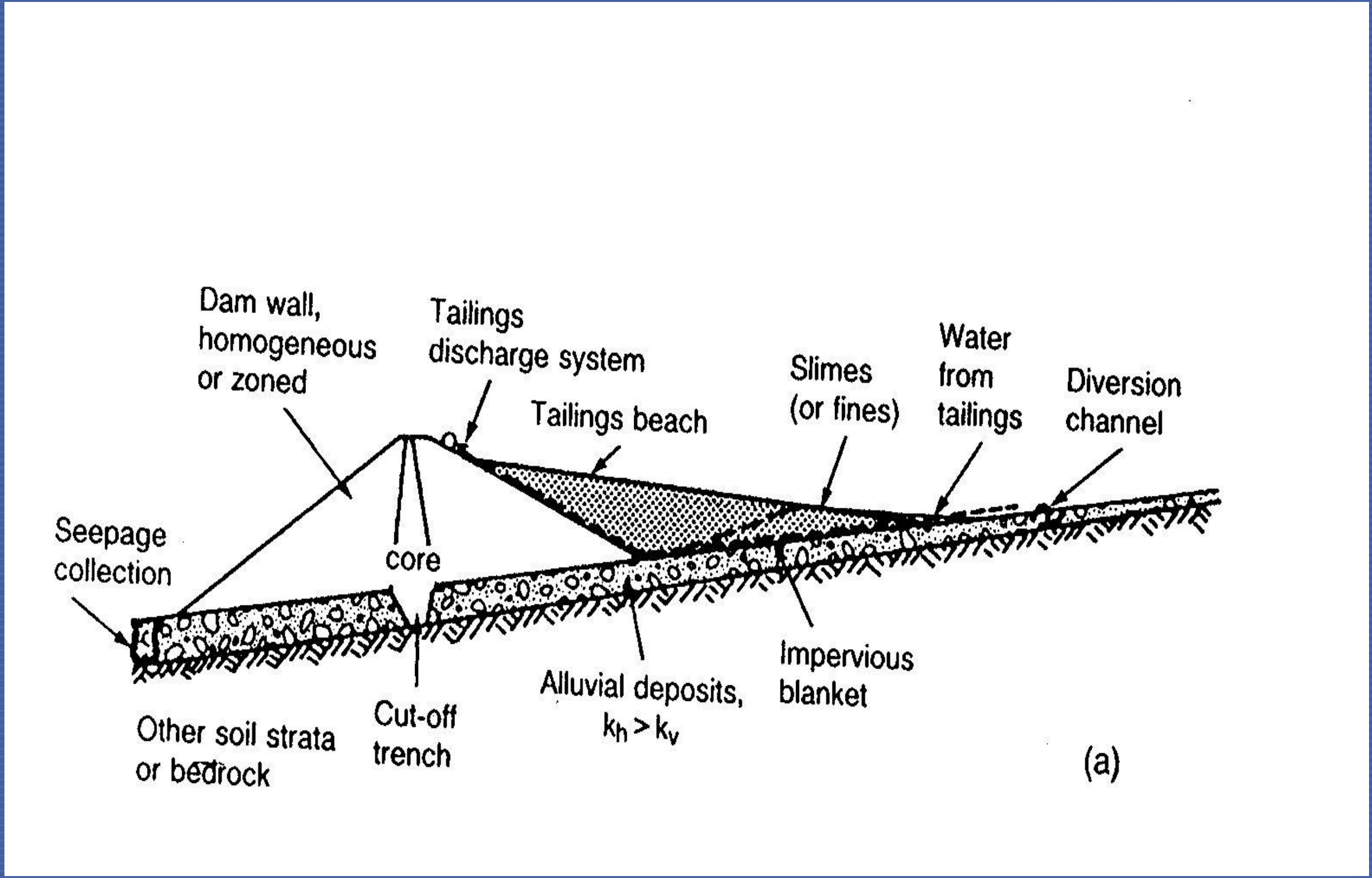


FIG. 10. Section through possible alternative mine pit impoundments [29].

Surface Impoundments: Valley dam impoundments

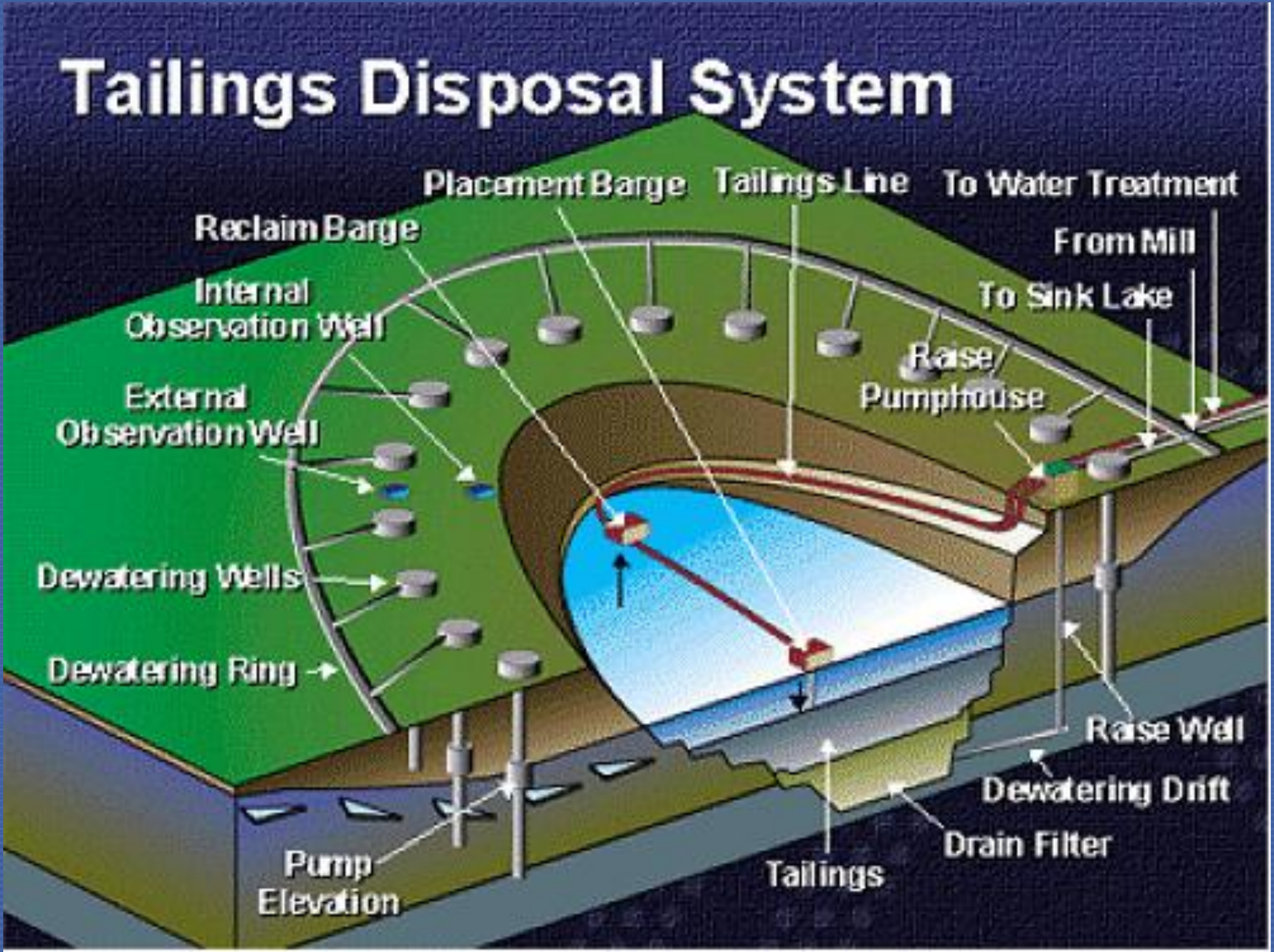


McClean Lake Canada – fully excavated pit

Abstraction borehole array

See McClean Lake Ops on YouTube

McClean Lake Canada: pit impoundment



Disposal in underground mine voids

- Practiced mainly for ground support
- Only 50 to 60% of the tailings can be returned in the mine voids
- Site specific methods
- Impact on groundwater quality must be carefully assessed

Main messages

- Mining and milling wastes mostly consist of naturally occurring radioactive materials
- These are very long-lived and radium is the usual suspect
- Regulatory regime for these wastes is different from nuclear wastes
- Variety of methods have been developed for tailings management and waste rock piles and tailings impoundments will usually become disposal facilities