

Integrating Water in Mine Planning

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Mine Planning

- Mine planning is a continuous effort:
  - Exploration and discovery leads to a mining project
  - Prior to opening the mine, a Life Of Mine (LOM) plan is made and continually updated in operation
  - During operation, new ore is often discovered leading to expansions
  - Closure planning – in some legislations a plan must exist prior to opening

Mine Water Planning

Potable and sewage – small volumes

- INPUT:
  - Precipitation contact water, mine groundwater, seepage, fresh supply
- Water used in process
- Water storage
- Recycle water
- Discharge

For each of these, need **QUANTITY** and **QUALITY**

Planning is determining the quantity and quality of all these water flows and defining how it is managed to meet treated water quality objectives

Life of Mine Plan - Definition

- Defined as “a detailed mine plan and schedule for ore tonnes and grade, waste movements, treatment schedule, mineral production, capital, operating, and reclamation costs”
- Published information includes:

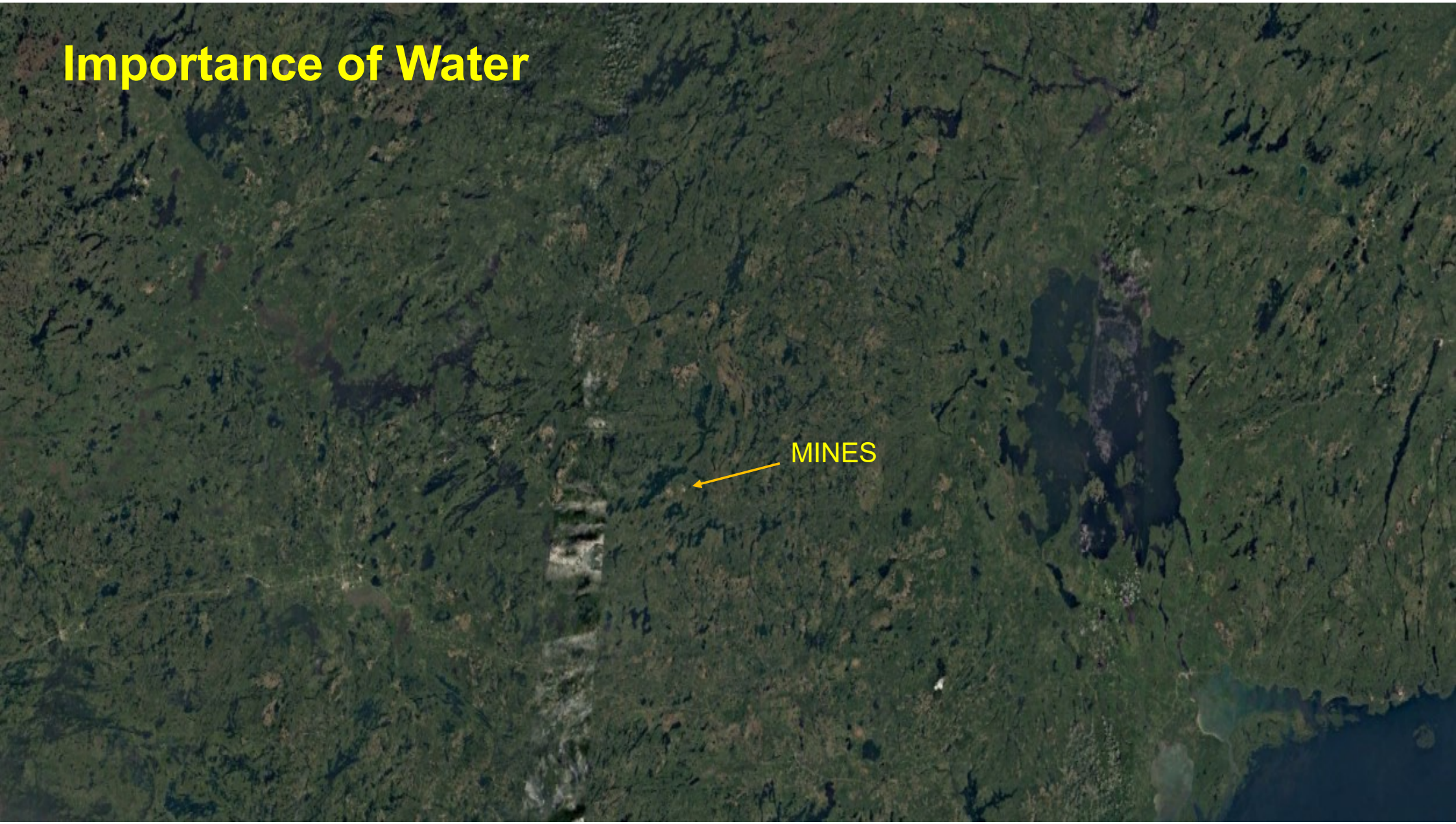
Item	Units
Ore milled	tonnes ‘000
Fixed costs	$ ‘000
Variable costs	$ / tonne
Circuit milling costs	$ ‘000 (calculated)
Head grade	g / tonne
Recovery	%
Ounces of gold recovered	oz (calculated)

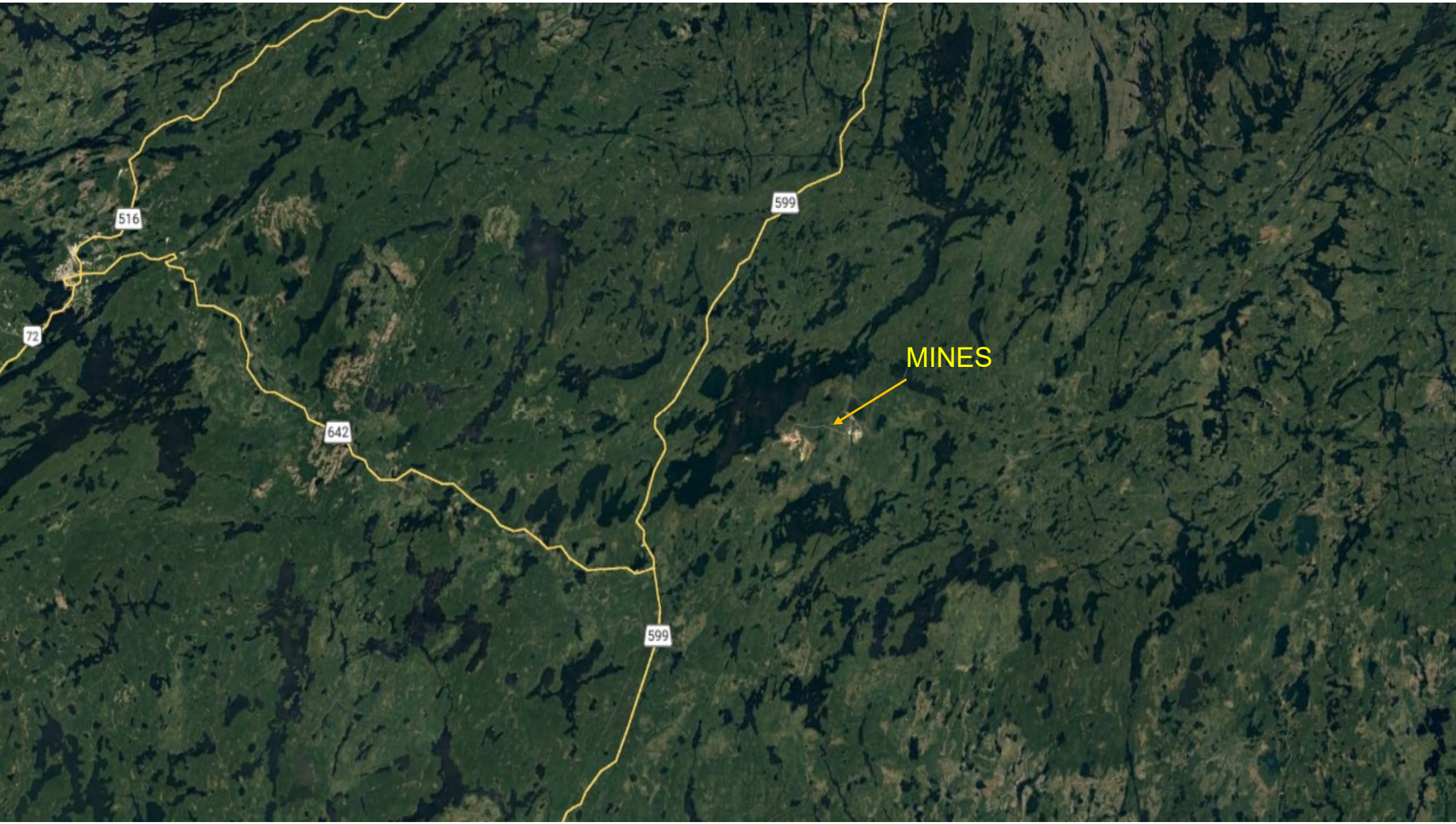
Life of Mine Plan and Water

- The LOM is the formally approved long-term plan for the mine and can be updated every year to every three years
- Also, five-year plans and 2YP and annual budgets, some of this is updated quarterly
- “Reclamation” and/or “environmental” often included as a cost only

- Impact on or of water not a typical line in the LOM
  - Water not updated quarterly
  - Impact of changes in process, tailings, expansions not always included

Importance of Water

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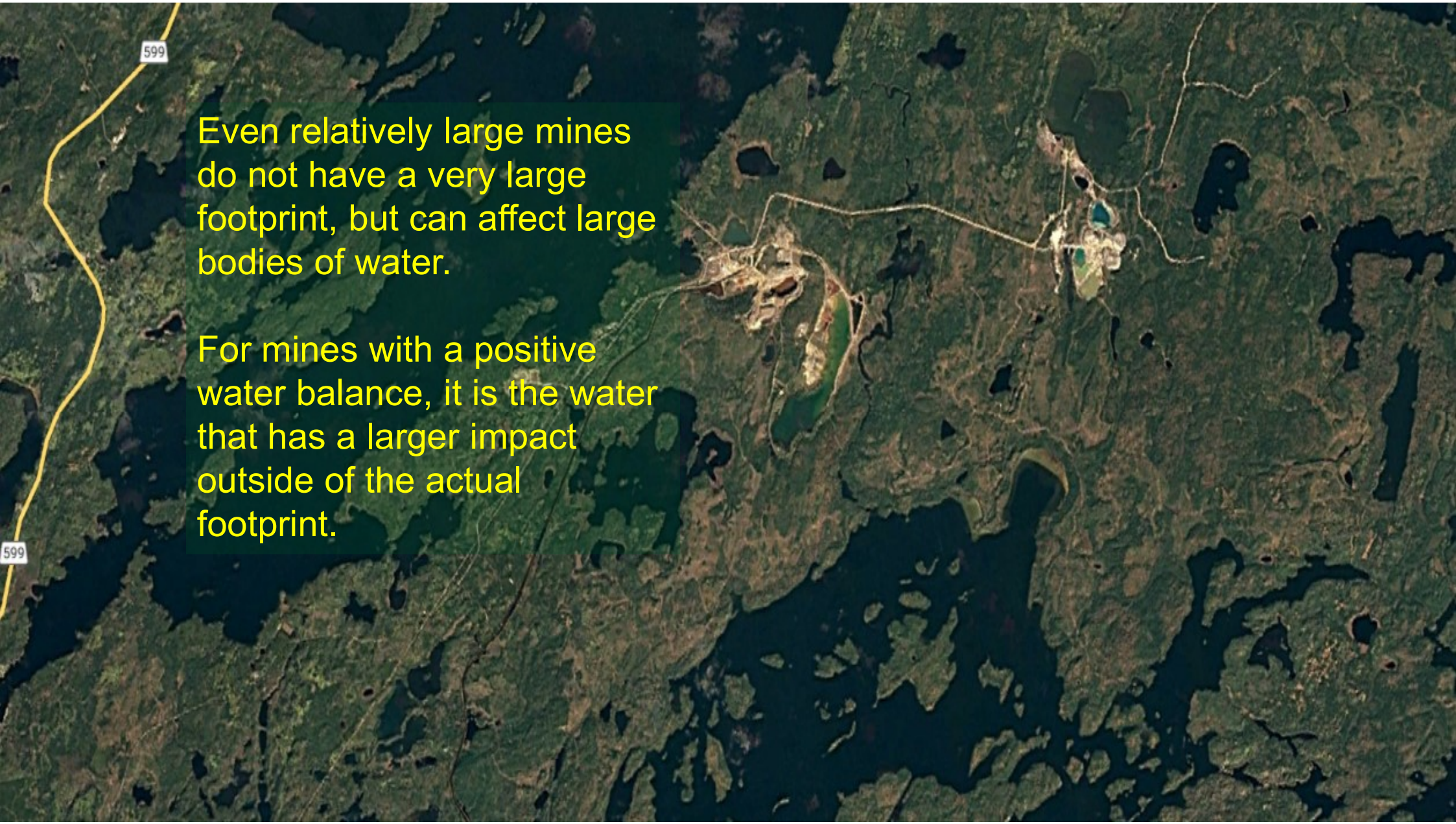
MINES



Even relatively large mines do not have a very large footprint, but can affect large bodies of water.

For mines with a positive water balance, it is the water that has a larger impact outside of the actual footprint.

Water in Mining

- Water is used extensively in mining and recovery all over the world
- Off-site impact in net-positive (wet) areas (like most of Brazil and Canada) is more about water QUALITY than it is about QUANTITY
- In some dry areas, the quantity of water taken is the key issue and water must be recycled

- All this water must be pumped, stored, treated and must meet certain objectives either for re-use or for discharge

Social License to Operate

- A Social License to Operate is an “ongoing acceptance or approval from the local community and other stakeholders”
- Water management in mining operations is one of the key factors
- Any negative impacts at one site will affect this license at other company sites and throughout the world
- Owner must:
  - Not take too much water (affect stakeholders)
  - Not have spills or non-compliance events
  - Not cause any environmental impact or toxicity
  - Not affect public drinking water

Mining Projects

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When an orebody discovered, owner focused on turning this into a mine

For Water? “At this point, we’ll just put $5 million aside for a treatment plant”

- Delineating ore
- Proving metallurgy
- Planning mine workings
- Waste rock and tailings storage
- Access and power infrastructure

Not that simple!

Planning in the Project Stage

- Improper planning in project stage can lead to expensive consequences

EXAMPLE:

- Mining engineers designed the open pit mine and placement of waste rock in most economical and safe fashion
- Late in the final feasibility stage, water experts get involved
- The planned placement of the waste rock spans three watersheds and is too close to a river on one side
  - Water management forced the relocation of waste rock in plans
  - Also forced the design of large ponds in restrained areas
  - Important delays of the project and increased costs of feasibility

Improper Planning and New Mines

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Surprise!
Water Treatment is Needed NOW

- Urgent needs for treatment as the water inventory is high and water quality does not meet objectives
  - No time for proper studies
  - No time to find and engage known water experts
- Result:

PANIC PLANT!

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Panic Plants also occur during operation

- Mine expansion increases footprint, increases runoff water
- As tailings ponds fill up, decreases pond retention time
  - Critical for cyanide and ammonia degradation in gold mines
- Changes in ore can cause changes in water chemistry
- Progressive reclamation can reduce concentrations
  - Sometimes, low concentrations make water harder to treat
- Also mine closure – completely changes water chemistry

Urgent Treatment Solution (Panic Plant)

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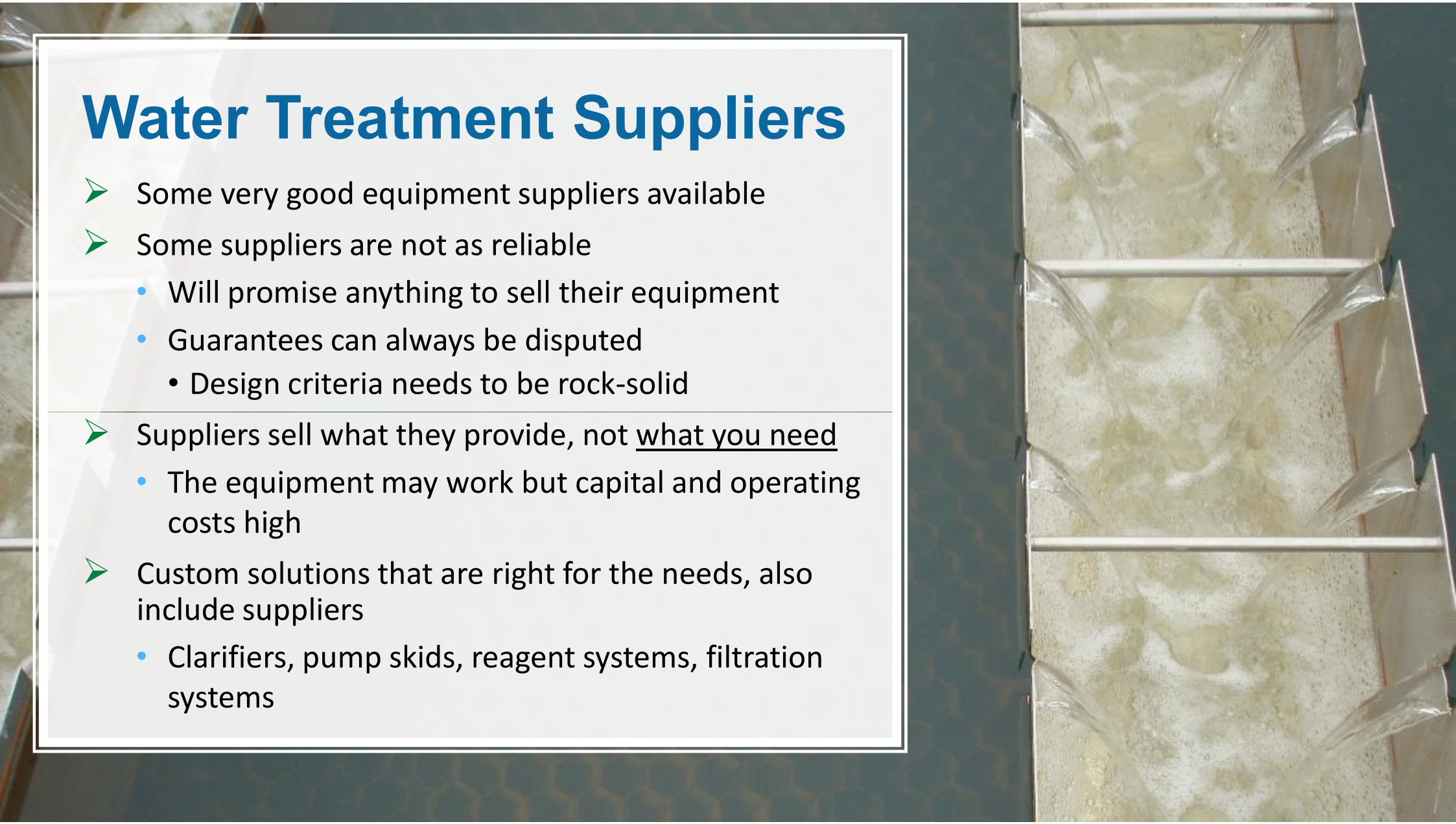
- Owner will react immediately and:
  - Get engineers currently on project to design/build treatment system
    - Based on literature, not experience!
  - Use material or equipment on site for temporary urgent fix
  - No time for Permitting: Promise anything!
  - Buy off-the-shelf supplier solutions

Water Treatment Suppliers

- Some very good equipment suppliers available
- Some suppliers are not as reliable
  - Will promise anything to sell their equipment
  - Guarantees can always be disputed
    - Design criteria needs to be rock-solid
- Suppliers sell what they provide, not what you need
  - The equipment may work but capital and operating costs high
- Custom solutions that are right for the needs, also include suppliers
  - Clarifiers, pump skids, reagent systems, filtration systems



Panic Plant Result

- Very high capital costs, high operating costs
- Uses wrong reagents ($)
- Badly sized – does not meet high flow events
- Wrong type of agitators, inadequate pump choices
- Low waste density, unstable solids, high waste disposal costs
- Does not meet treatment needs – non-compliance!
  - Fish kill, fines, bad press, environmental impacts
  - Owner's social license to operate
- Worst case: hold back water and dam breakage

What Causes the Panic Plant?

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Contact water

- Unexpected Acidic Drainage
- Neutral drainage with contaminant (Ni, Se, Mo, As, sulphate, suspended solids…)

Process water

- Sulphate content, cyanide, ammonia, or reagent accumulation through recycle
- Thiosalts generation

Groundwater

- High salinity, pH, sulphate content, chloride

Avoiding the Panic Plant

NEED TO PROVIDE SUFFICIENT TIME AND DEFINE DESIGN CRITERIA

1. Treated water quality objectives
2. Quantity of water to treat – flowrate
3. Quality of water to treat – raw water chemistry

To avoid a Panic Plant
the mine water planning needs to be integrated
in the entire mine planning process
(part of LOM)

Treated Water Quality Objectives

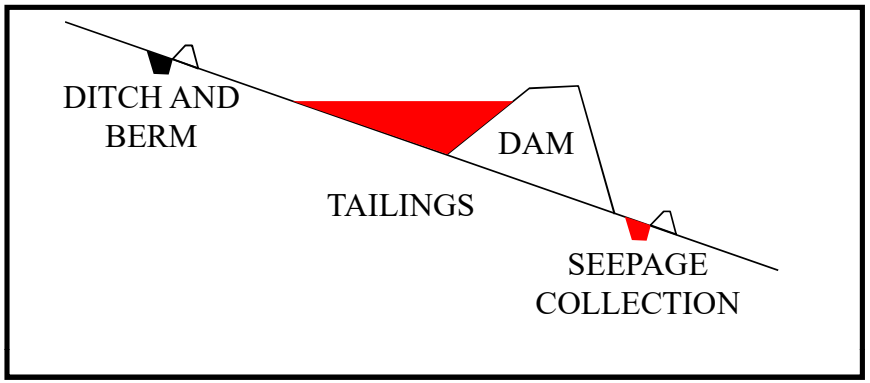
- Recycle water objectives are related to process efficiency (metallurgy), scaling, and toxicity
- Environmental discharge water quality is determined by regulators, community pressure, and internal owner objectives
  - These limits continue to become more stringent
  - Additional parameters are being added every year
  - Often require negotiations – need to understand and have time for this

Quantity – Annual Volumes, Flowrate

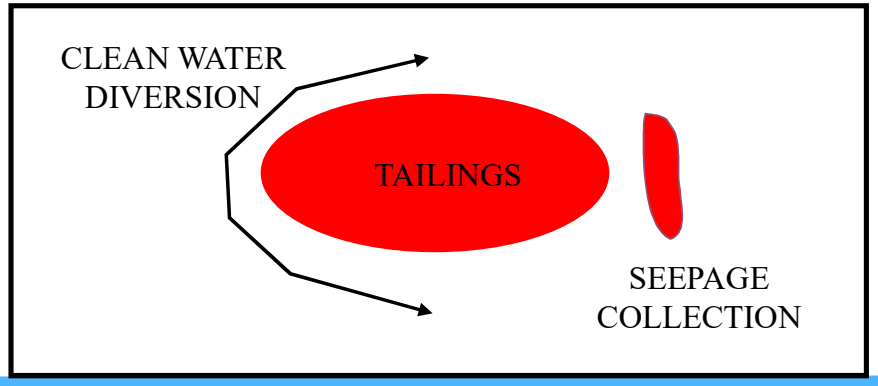
- Detailed hydrology and hydrogeology
  - Design event, e.g. 1:100 year runoff
- Water Management
  - Ensure diversion of all attainable uncontaminated waters to reduce treated volumes
  - Ensure capture of all contaminated waters minimizing mixing with clean waters
  - Minimise footprint and contact
- Ensure capacity to hold back water to manage the surge from design event

Clean Water Diversion - Concept

CONCEPT - CROSS-SECTION



CONCEPT – PLAN VIEW

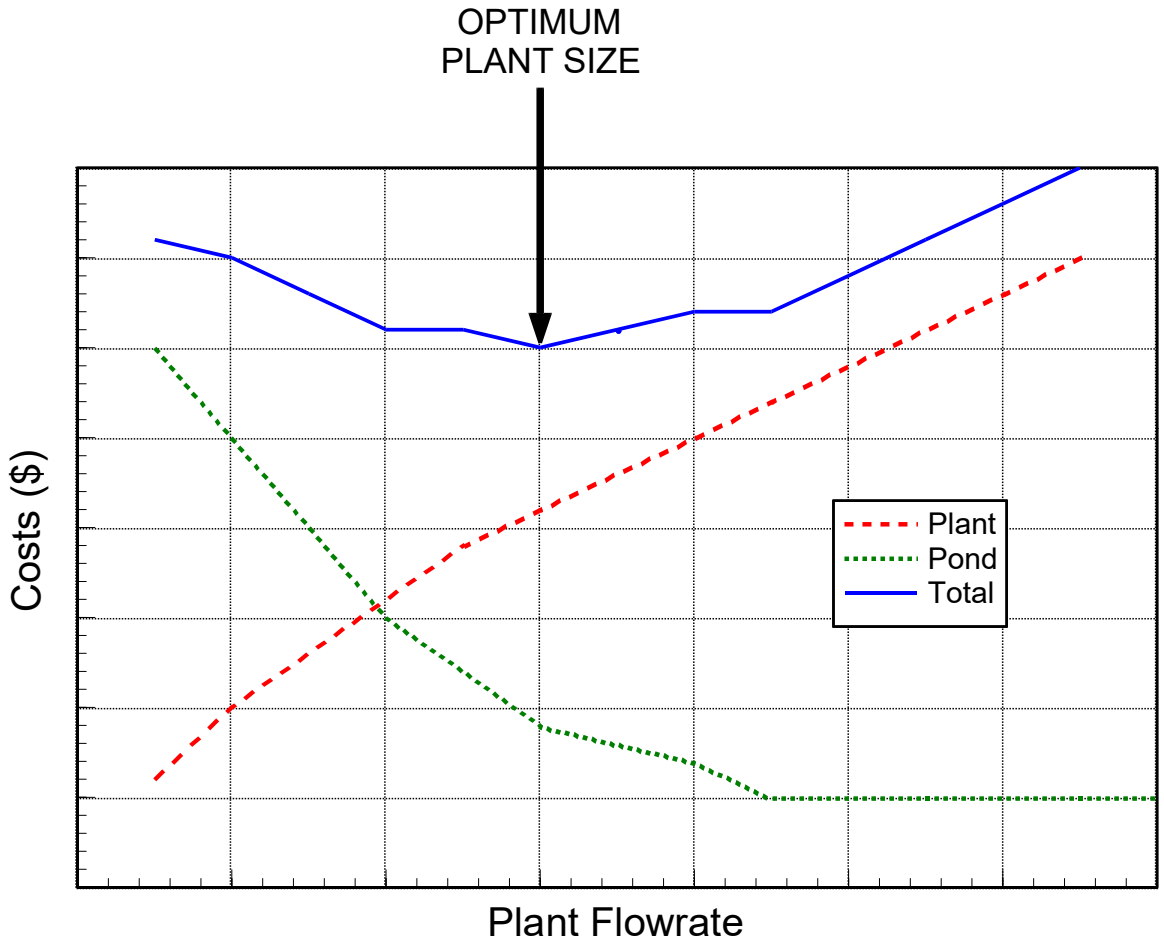


This example uses tailings – could also be waste rock pile, open pit, mill site.

All clean runoff is prevented from contact with potential contaminants

Tailings contact water and seepage are collected and managed

Optimising Treatment Plant and Storage



Little to no storage requires very large treatment plant operating all the time – high capital and operating costs

Very large storage can have plant designed for average yearly flow

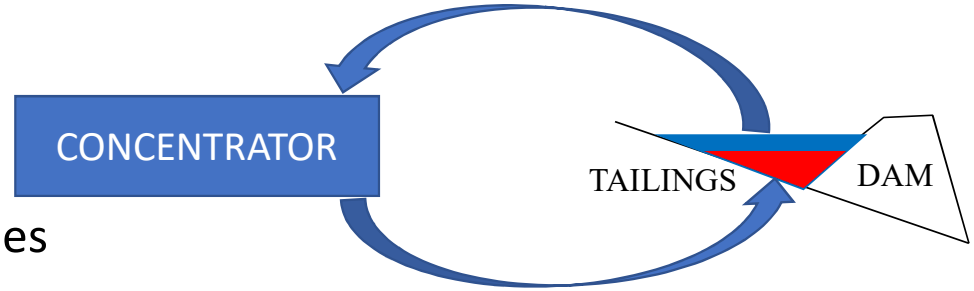
Optimum somewhere in between

Raw Water Quality

- Need to involve a geochemist (mine water quality prediction expert) early
  - Cores used for acid-base accounting
  - Humidity cells, leach tests (lots of samples)
- Boreholes – purge and sample
  - Groundwater can contain contaminants, salinity
- Metallurgical studies – study water too!
  - Simulate tailings pond – recycle water and see effects on thiosalts, salinity, sulphate…

Tailings Water Quality Benchmarking

- Sulphide mines typically accumulate sulphate in tailings water
- Some also have thiosalts
  - Common for Ni, Pb, and some Cu/Zn mines



- Gold mines can have cyanide issues but ammonia, nitrites, and nitrates very common and require retention time for degradation
- Iron mines and diamond mines may only have total suspended solids issues

Putting it Together

- Detailed water and mass balance
  - Better define quality and quantity
  - Have design basis for any treatment needed
- When water exists
  - Step-wise testing: analysis, laboratory, and pilot testing
- Resulting treatment plant
  - Proper choice of reagents and reagent systems
  - Proper sizing and design of reactors and clarifiers
  - Correct choice of equipment for the needs – agitation, pumping, aeration
  - Proven and well-located instrumentation – pH, sludge density, turbidity, sludge inventory

Avoiding the Panic Plant

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- Involve the experts early
  - Hydrologist, geochemist, hydrogeologist, treatment expert
  - All working with geotechnical, mine, and mill process engineers
- Complete a whole mine water and mass balance
  - Must look years ahead and include expansions or other changes
- Ensure capacity to hold back water
  - Initial dam lift on tailings pond higher for start of mine life allows time to understand challenges and build the right plant
  - Future lifts done before being needed for tailings
  - Specific buffer pond

Integrating Mine Water Requires Paradigm Shift

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- When building or expanding a mine, the best equipment (trucks, conveyors, mill, flotation cells…) are purchased for reliability as an understanding of the costs of mineral recovery
- Mine water management is often viewed as an unwanted expense, a necessary evil in mining
  - Water management is often left to last, after consideration of expenses directly related to generating profit
  - The objective is often just to meet the regulations at the lowest possible cost

Paradigm Shift Example

Theoretical example, a mine expands an open pit:

- One (1) 230-tonne haul truck costs approximately $5M
  - No hesitation to buy this truck, costs are considered from the outset in preliminary financial evaluation
- Cost of upgrading water system could be $1M (for example)
  - Not included in initial costs evaluation
  - All efforts are made to reduce or by-pass these costs

Water management must be considered a direct expense in mineral recovery

Not just an unwanted cost but an integrated part of mining as a whole

Who is Responsible?

- Owner/Corporate
  - Particularly in project stage, can't be focused only on potential revenue
  - Final legal liability rests here
- Mine Manager
- Environmental manager
  - Part of the job, must not just put out fires but prevent them
- Regulators
  - Need to ensure that operator has done his job for permitting
  - Should not allow expansion without expanding water system

Conclusion

Integrating water in mine planning is critical to avoid an expensive and unreliable Panic Plant and maintain a social license to operate

- **Planning requires knowledge of three things:**
  - Water quality objectives
  - Water quantity
  - Raw water quality
- **Plus a fourth…**
  - It must be done for the future