Components of Successful Drainage Treatment

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- Treatment includes a diverse group of processes ranging:
  - From one-time to periodic, perpetual treatment of ARD or neutral pH drainage, and
  - From very expensive, active chemical treatment to less expensive, treatment in a wetland
- Collection and treatment is the primary means of environmental protection at many major historic and older mine sites.

For new mines:

- Collection and treatment is often the only feasible mitigation strategy for open pits and underground mines producing poor drainage chemistry.
- Primary contingency measure where there is significant uncertainty regarding future drainage chemistry

Successful treatment of contaminated drainage includes five main components:

- Diversion of clean water
- Collection of contaminated drainage
- Treatment of contaminated drainage
- Discharge of treated drainage
- Disposal of treatment wastes

Diversion of Clean Water

Diversion Objectives: intercept and transport clean water over, around and away contaminant sources

Diversion of clean water has several purposes:

- Maintains flow and increase dilution of treated effluent in small water courses below mine
- Reduces required capacity of collection and treatment structures
- Reduces annual collection and treatment costs

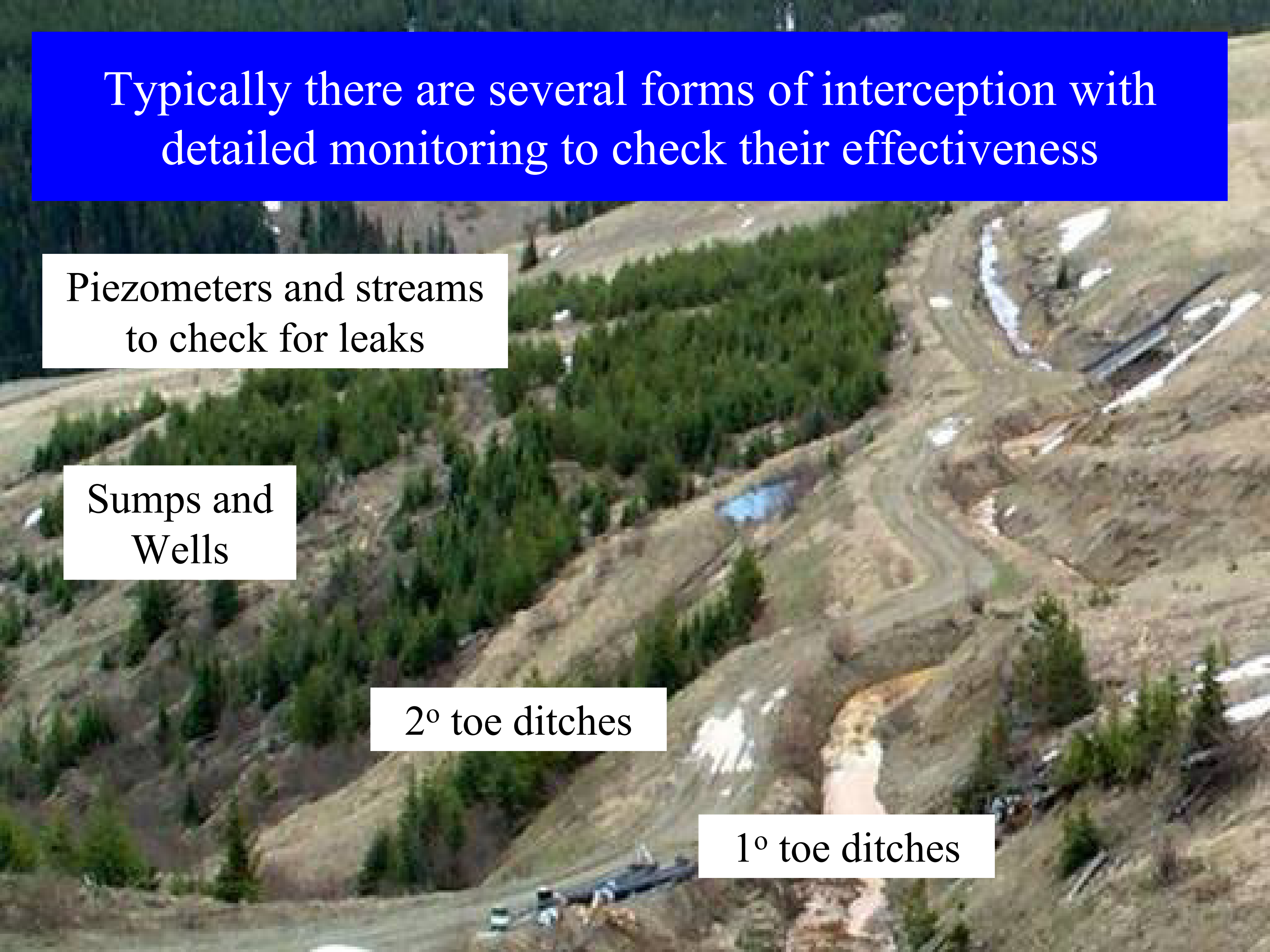
Existing water courses may be diverted over or re-routed around mine wastes

Collection of Contaminated Drainage

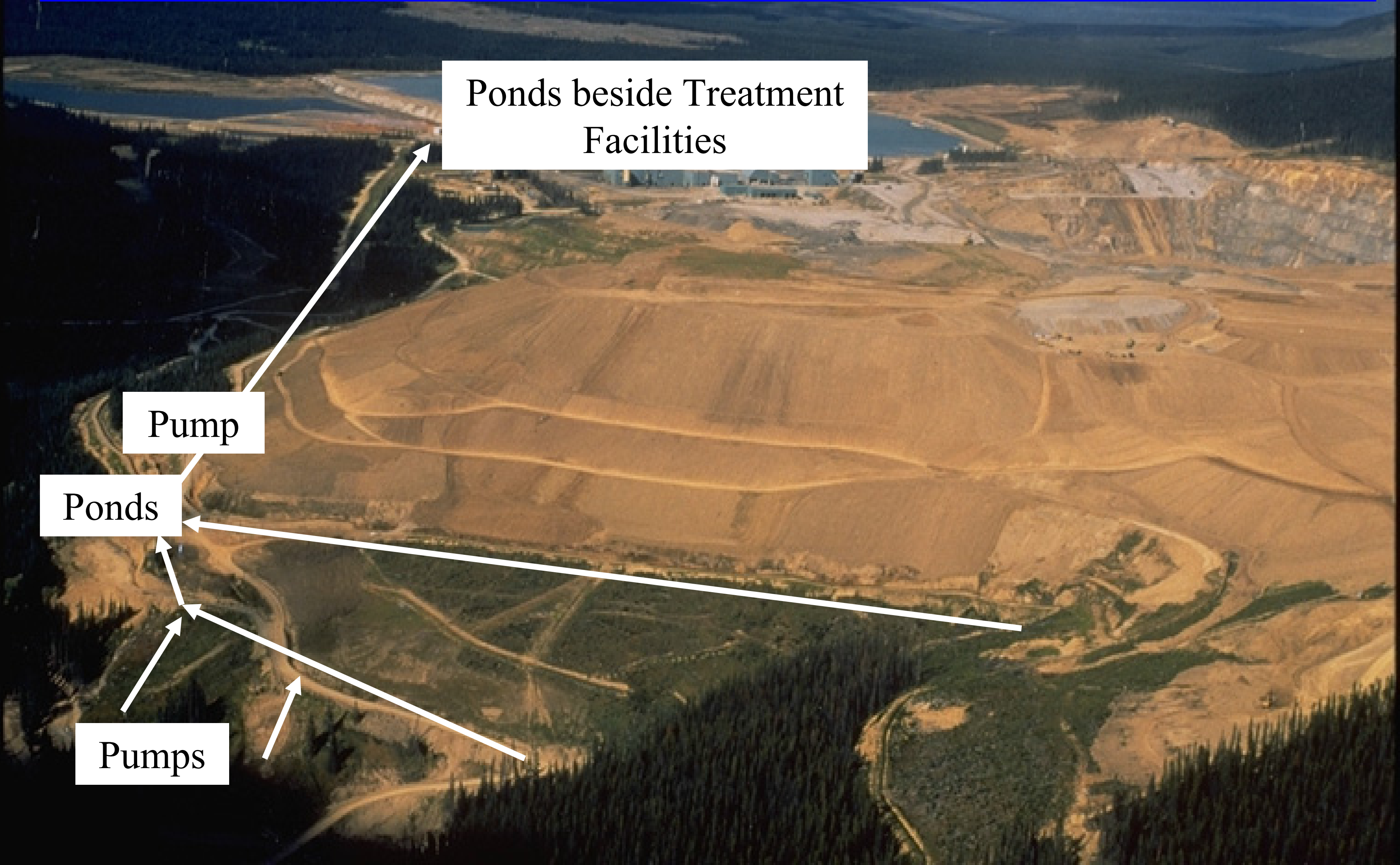
Collection Objectives:

- First intercept and then transport contaminated drainage to treatment facilities

Typically there are several forms of interception with detailed monitoring to check their effectiveness



Methods for transporting contaminated drainage depend on the layout, terrain and surficial materials



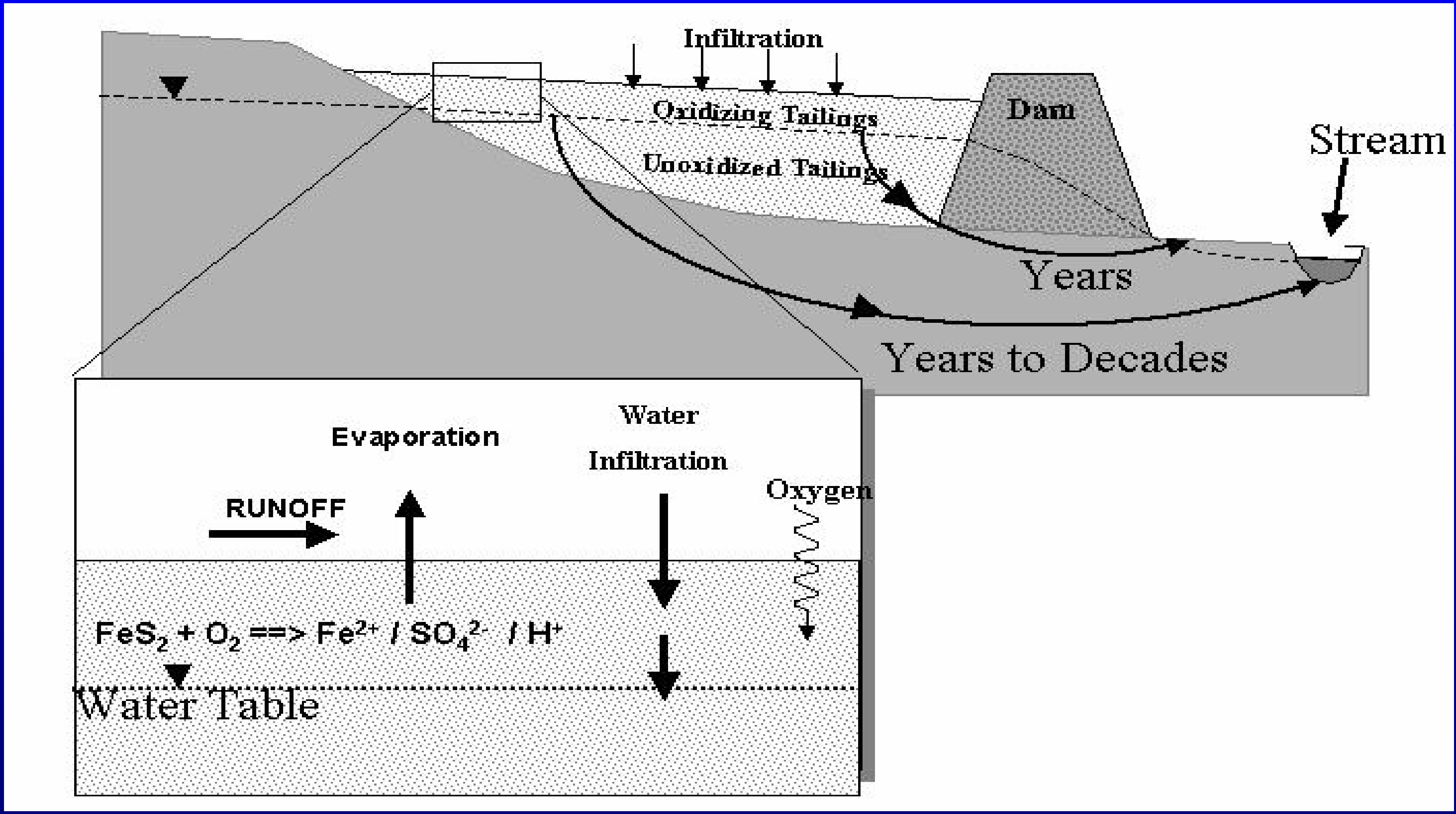
Collection information requirements include:

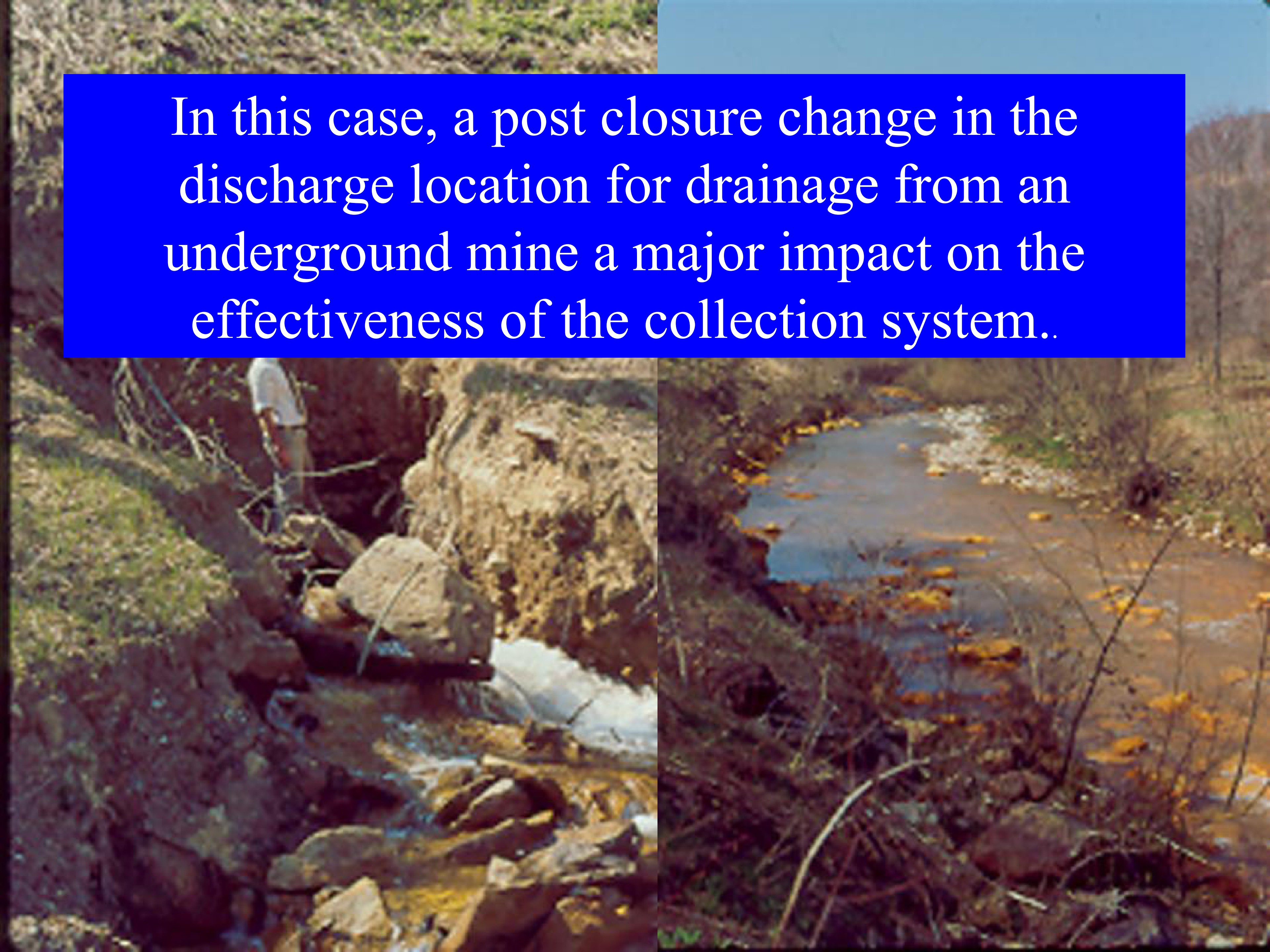
- Potential contaminated drainage sources
- Paths of contaminated drainage
- Discharge locations
- Seasonal, annual and long-term variability in flow volumes
- Required collection efficiency

for all site components that are presently or potentially sources of contaminated drainage

Collection can be a challenge at older sites where materials handling not planned with mitigation in mind

Lack of poor quality drainage to date does not mean it will not occur in the future once the NP or other forms of attenuation are exhausted or slow flow paths are traversed.




In this case, a post closure change in the discharge location for drainage from an underground mine a major impact on the effectiveness of the collection system..

- Hydrology and hydrogeology data needed to design collection system depends on site conditions and required collection efficiency
- Ongoing monitoring of hydrology and hydrogeology is needed for proactive management and to verify effectiveness of system.

Storage ponds are required at pumping locations:

- To avoid running pumps during periods of low flow
- For periods of maintenance, upset or when runoff exceeds capacity of pumps

Storage ponds for contaminated drainage are also required:

- To avoid running treatment plant during periods of low flow
- For periods of maintenance, upset or when runoff exceeds capacity of treatment facilities

Pumping capacity must match maximum drainage inputs when there is a lack of space for large storage ponds prior to sensitive resources

- Ongoing monitoring of downstream drainage is needed to verify effectiveness of collection of contaminated drainage (orange gloves optional).

Treatment of Contaminated Drainage

Treatment Objectives:

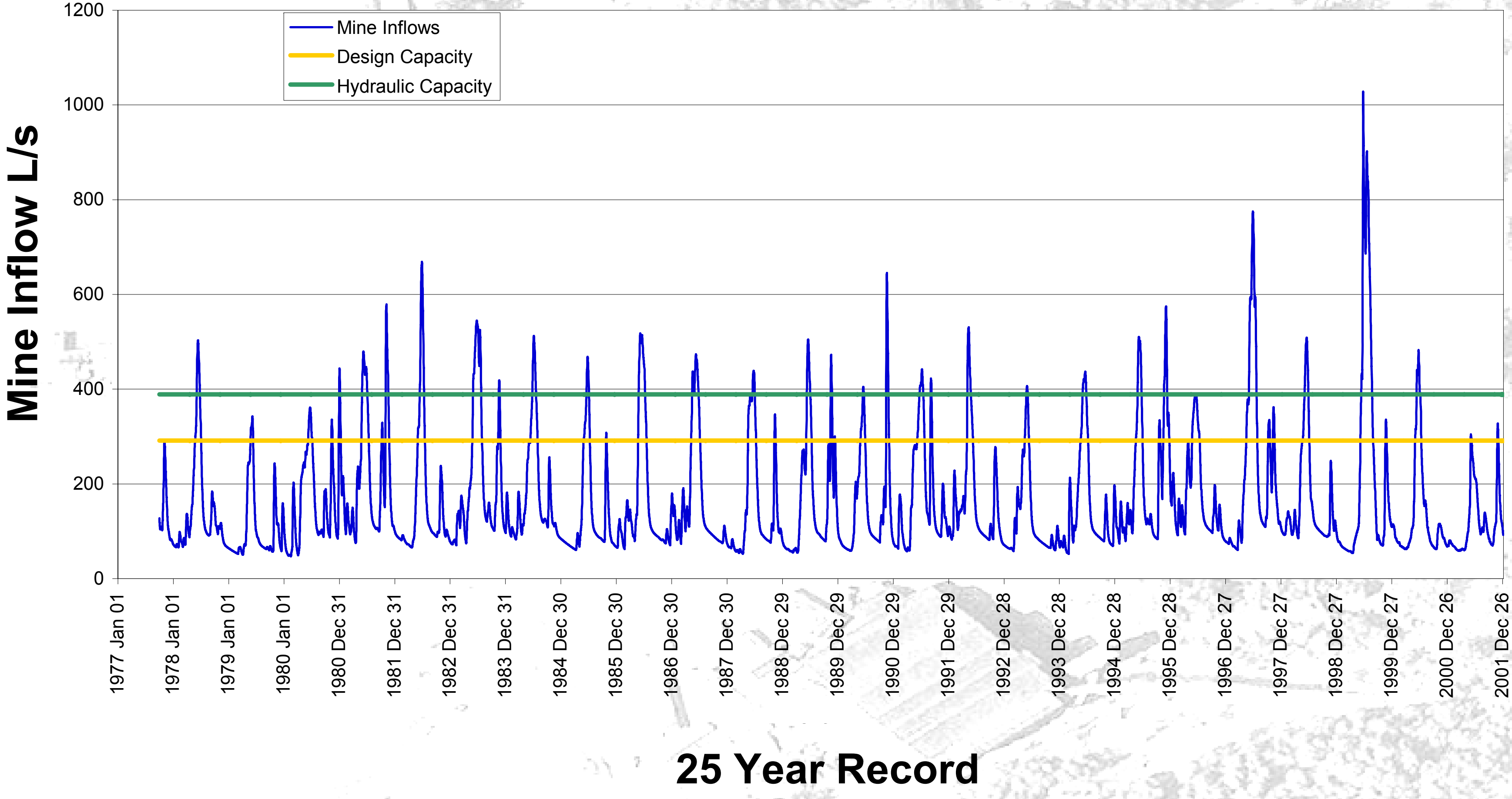
- Convert contaminated drainage into dischargeable drainage
- Cost-effectiveness

Effective Treatment

Requires:

- Prediction of maximum contaminant loads
- Process control of key treatment conditions, such as retention time, pH and redox
- Adequate supply of amendments
- Separation of precipitated contaminants from clean water
- Plumbing (getting drainage in, around and out)

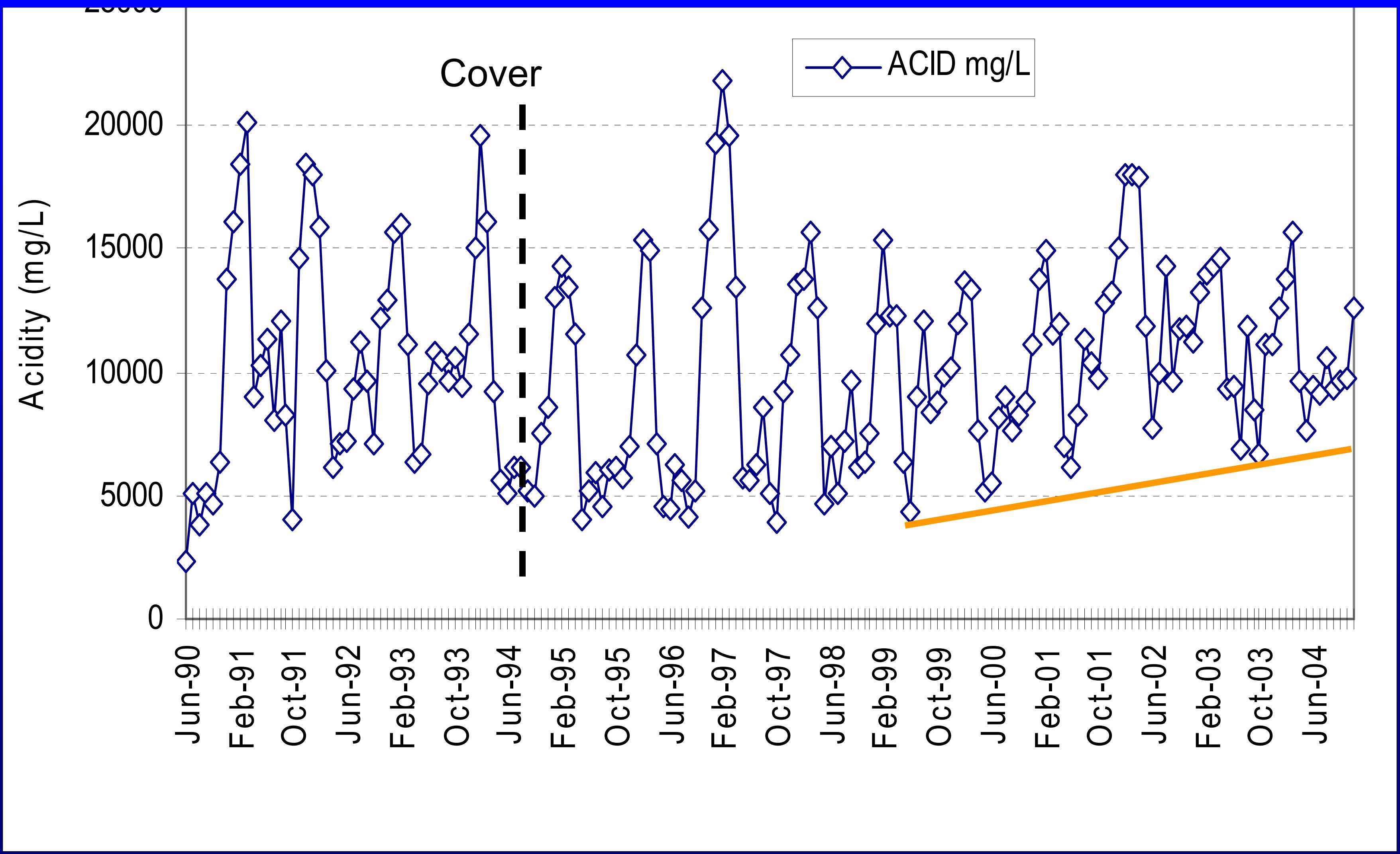
Need to estimate volume of water that needs to be treated



Ministry of Agriculture and Lands

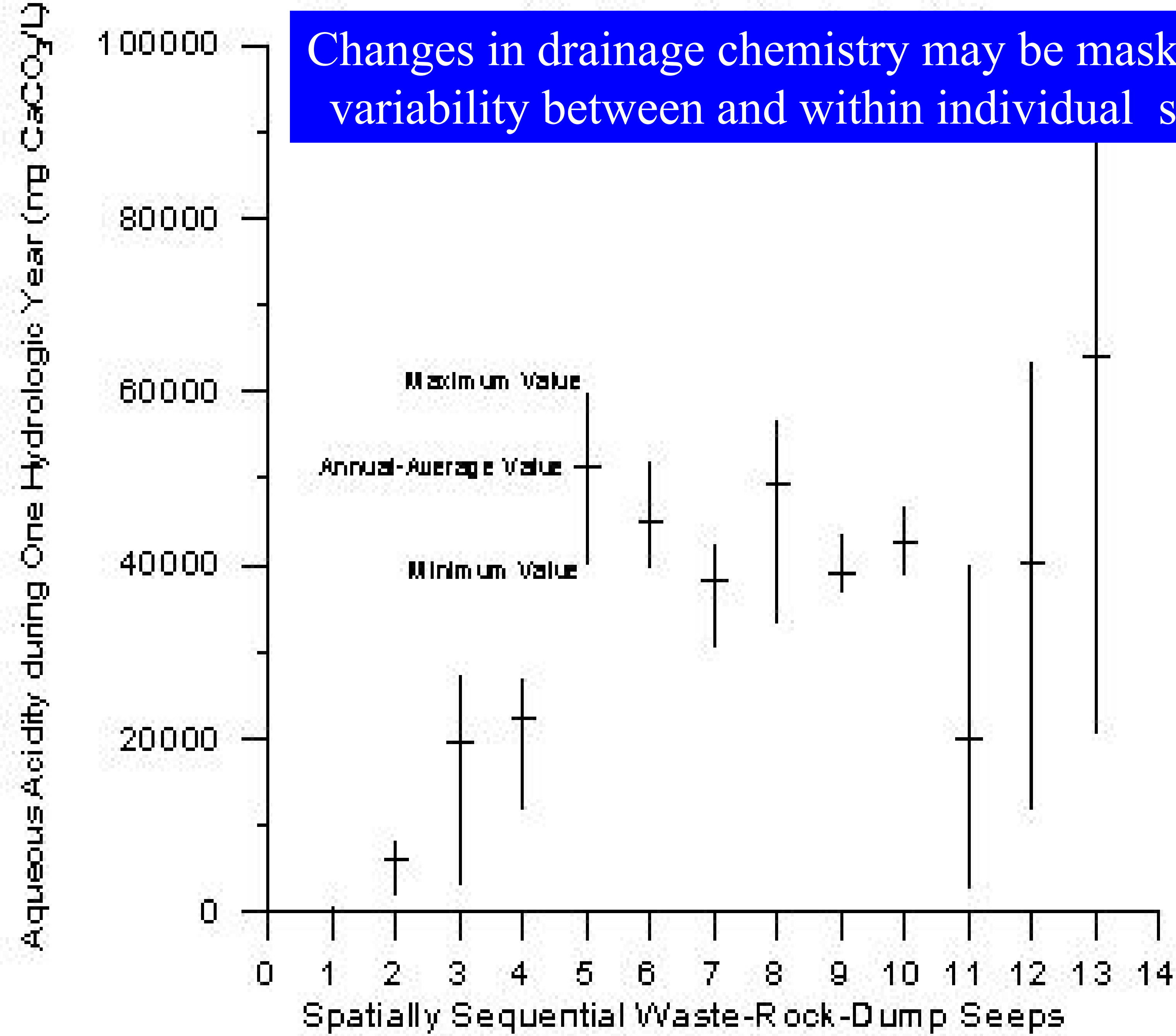
Golder Associates

It is important to predict and monitor future geochemistry. Depletion of neutralizing minerals and accumulation of solutes in dumps may increase acidity and reduce the capacity of treatment facilities to handle major runoff events.

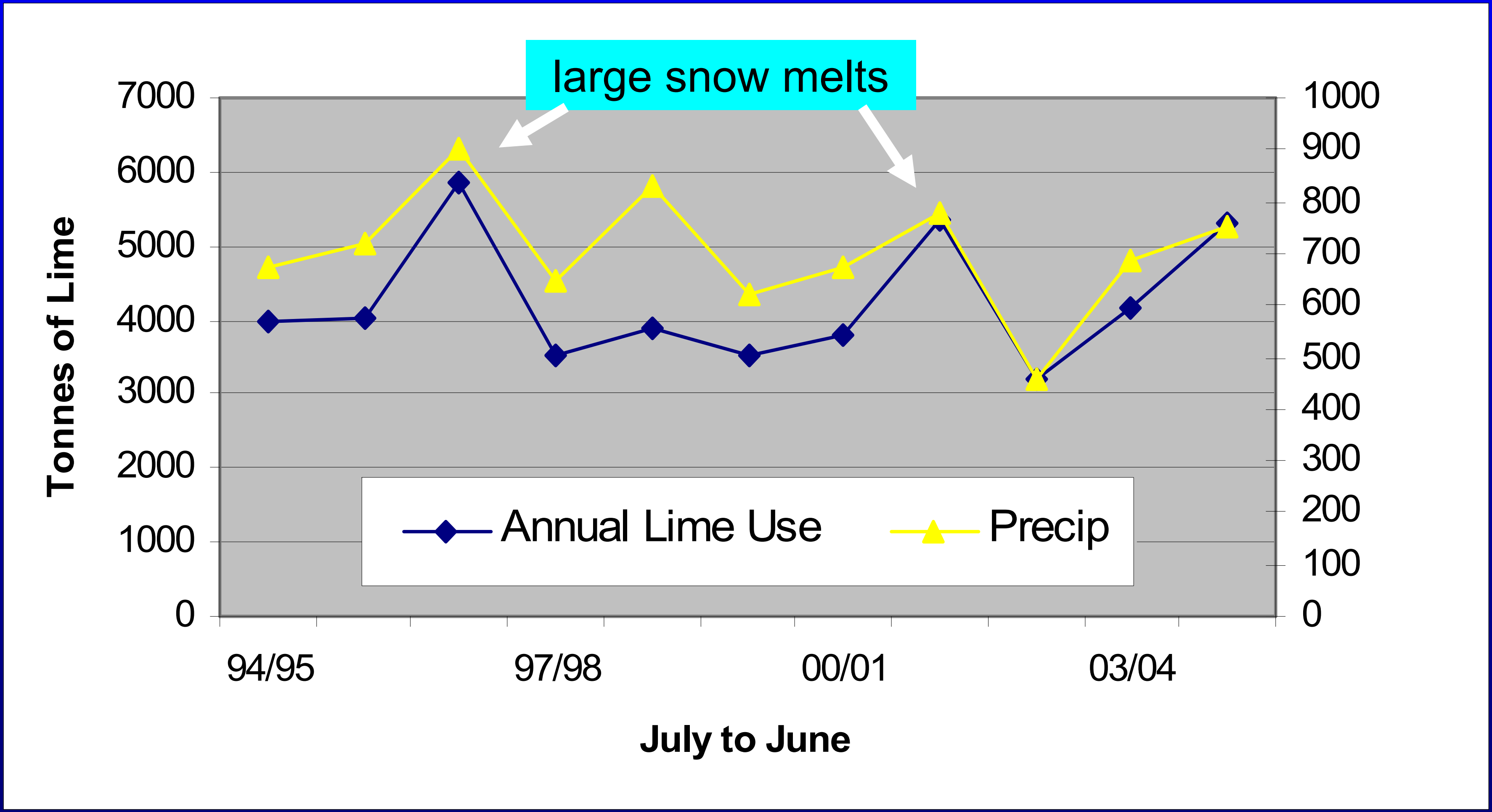


A number of mine sites have underestimated future contaminant loads and as a result have had to increase their treatment capacity and make other improvements to treatment process.

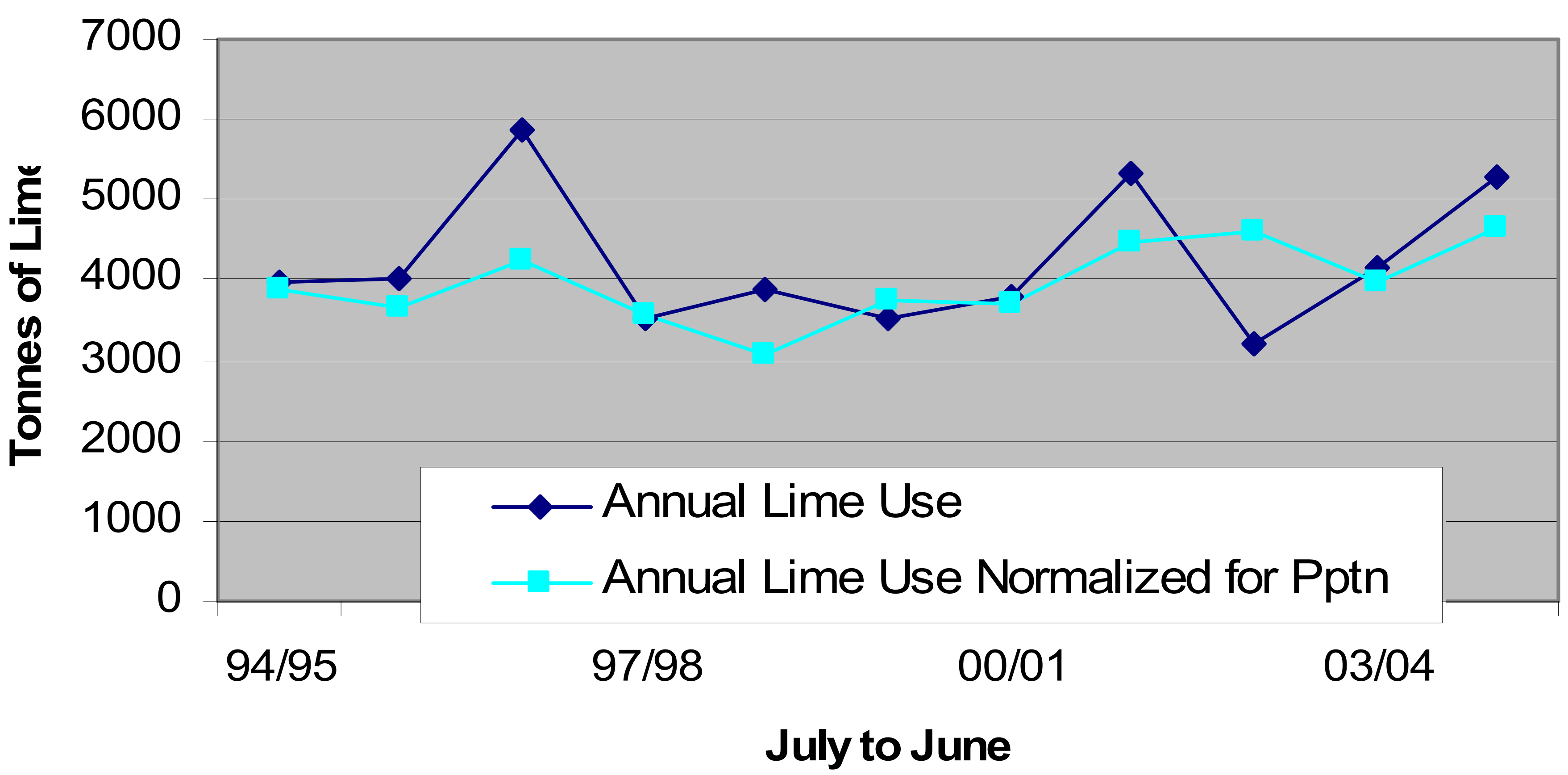
Changes in drainage chemistry may be masked by variability between and within individual seeps



The fluctuation in annual precipitation, especially the magnitude of large flushing events may also mask increases in load and solubility of contaminant within a waste rock dump.

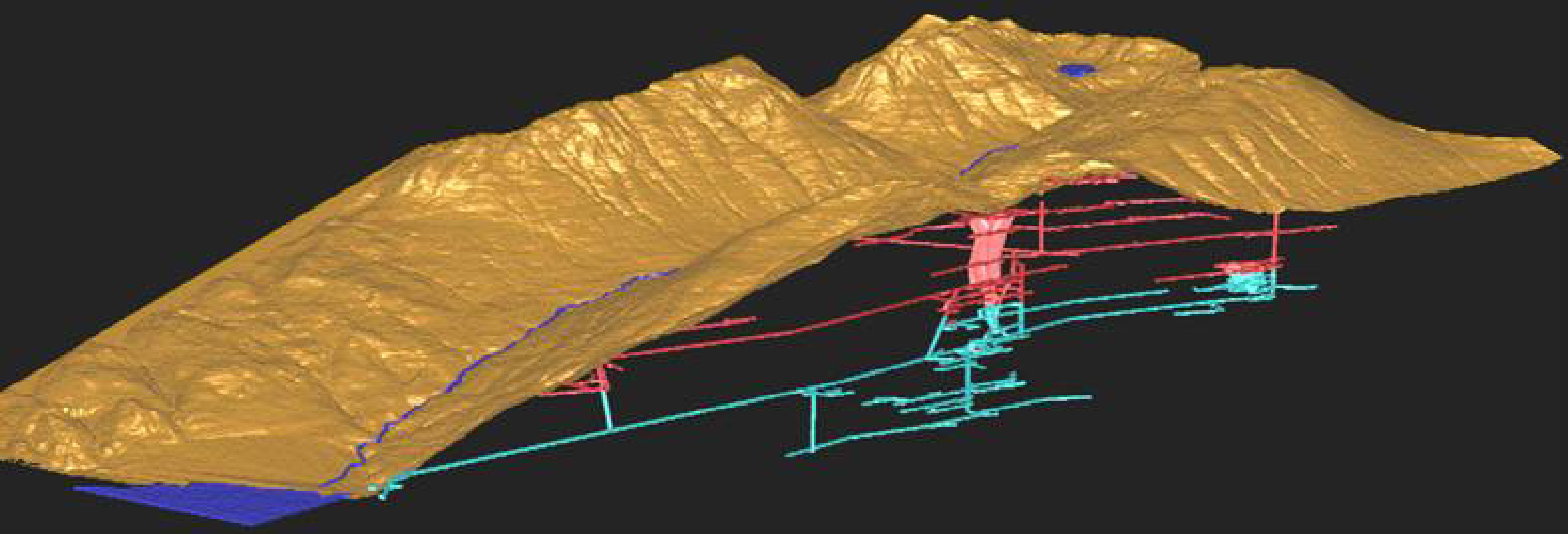


Evidence of changes in geochemistry may be provided by normalizing load data for differences from the average precipitation.



- Treatment plant can be designed to handle average rather than maximum volume of flow and loadings if the site can store contaminated drainage for that periods of time.
- Large storage facilities may also preclude need for extremely accurate prediction of flow and loadings
- Use of pits for storing contaminated drainage may delay need for treatment facilities for decades.

- Underground workings can also be used for storing contaminated drainage prior to treatment
- Do not fill workings above height where there may be significant drainage losses through drill holes, fractures and mine openings



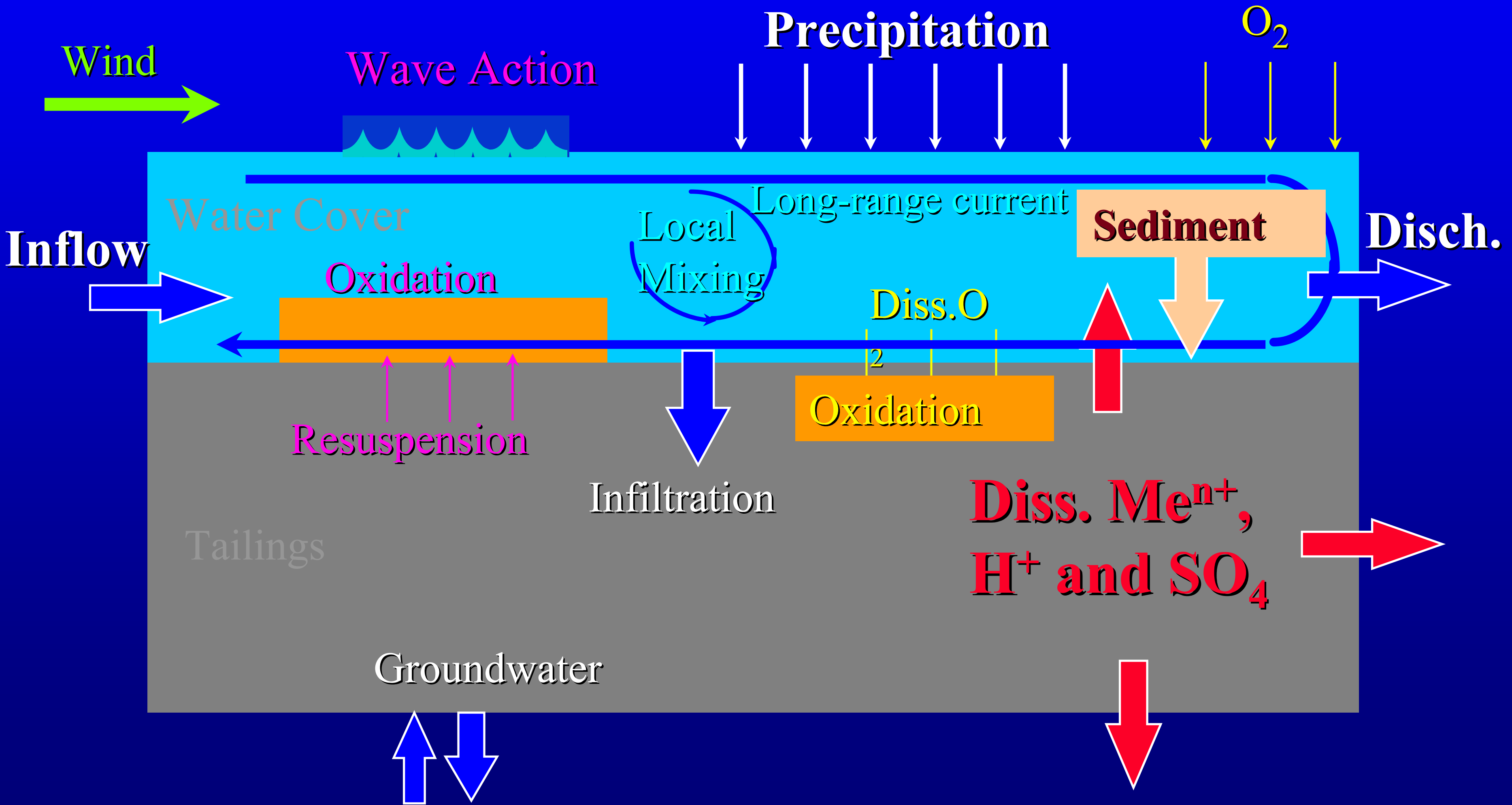
Britannia

- Maintaining adequate reagent supply can be challenging for treatment with lime and ferric sulphate
- Process control (raise pH to 8.5 to 9) may be relatively simple for treatment with lime and ferric sulphate compared to biological systems.

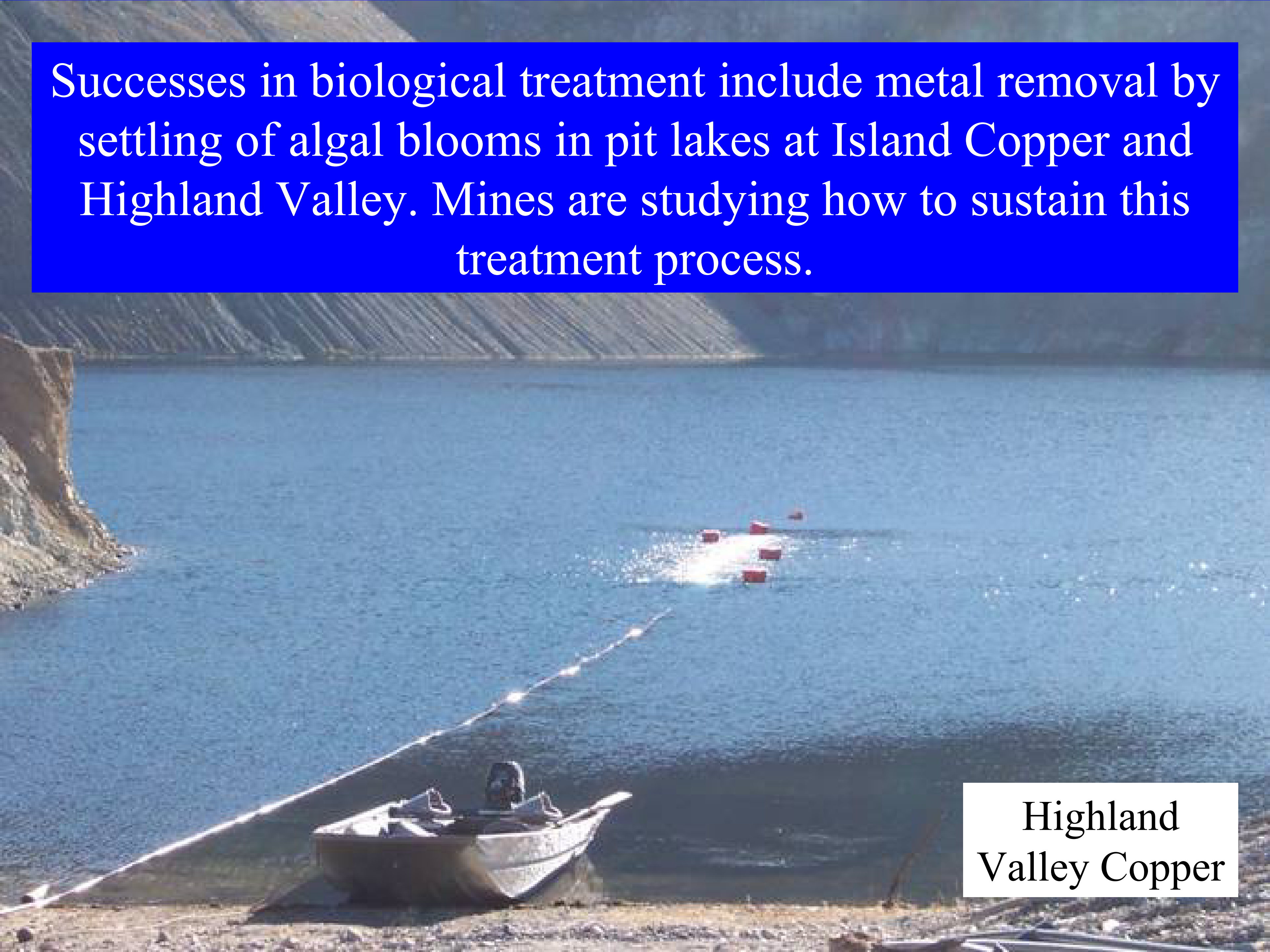
"So-Called" Passive Treatment

- A number of sites are using biological and other less-costly treatment alternatives.
- Better described as 'less active'. At a minimum passive treatment systems require ongoing monitoring, maintenance, and/or regular replacement.

Reliable, sustainable process control is a major challenge in assuring 'open' biological systems meet discharge objectives.



Successes in biological treatment include metal removal by settling of algal blooms in pit lakes at Island Copper and Highland Valley. Mines are studying how to sustain this treatment process.



Challenges of flow-through biological treatment include:

- maintaining properties of substrates
- preventing plugging by Fe and Al
- sustaining rapid bacterial activity
- providing sufficient residence time

Discharge of Treated Drainage

- Discharge requirements will depend on effluent quality and quantity and discharge limits and locations*
- After treatment, dilution may be needed to achieve receiving environment objectives

- * based on sensitivity of downstream environment

Storage of treated effluent is required to:

- handle treatment volumes that exceed permissible dilution
- handle upsets that result in lower effluent quality
- ensure discharged effluent has average rather than maximum contaminant levels
- polishing pond to degrade of products such as thiosalts and allow dilution of and by other site drainages

It can be a challenge finding enough off-site dilution for large volumes of treatment effluent especially if dilution is required for directly dischargeable drainage from other mine components such as the tailings impoundment.

Environmental effects monitoring is needed to verify that treated effluent has no impact on receiving environment

Disposal of Treatment Waste

- Need to predict quality and quantity of treatment wastes, and develop disposal plans that provide long-term physical and geochemical stability
- For the iron hydroxide products of lime and ferric sulphate treatment, this means keeping the treatment sludge permanently oxygenated. Oxygenated conditions can be achieved by placing them sub-aerially on a gravel pad.

Disposal of sludge in a pit lake entrains oxygen and maintains oxygenated conditions as long as there is continuous sludge disposal.

Volume of low density lime treatment sludge and therefore storage facilities are large and storage and handling may be difficult

Re-handling sludge, especially low density sludge, is costly and time consuming

High density sludge treatment system (HDS) greatly reduces sludge volume and logistical problems compared to LDS.

Disposal of Other Waste Products

- Proposals for biological treatment systems also need to provide disposal plans if the ‘treatment matrix’ will be eventually be replaced (e.g., when system plug).

Challenges in Sustaining Successful Treatment

Contingency Plans for Upset Conditions

- Need to identify potential failure mechanisms, evaluate the risks and provide contingency plans for upset conditions such as breakdown of equipment.
- Contingency actions typically include provision of additional treatment cells, structures for spill containment, back-up power and pumps, spare parts, and additional options for transportation and supply of reagents in the event access is cut-off or there is a rail or truckers strike.

Collection and treatment should be capable of withstanding normal periodic events such as power failures, forest fires, road flooding, strikes and inflation.

Redundant and complementary pumps are important safeguards.

Generators should be purchased to provide back-up power.

Pumps and ponds may be monitored remotely.

Maintenance and Regular Testing

Operational maintenance and regular testing is needed to ensure design capacity is sustained. For collection system this includes:

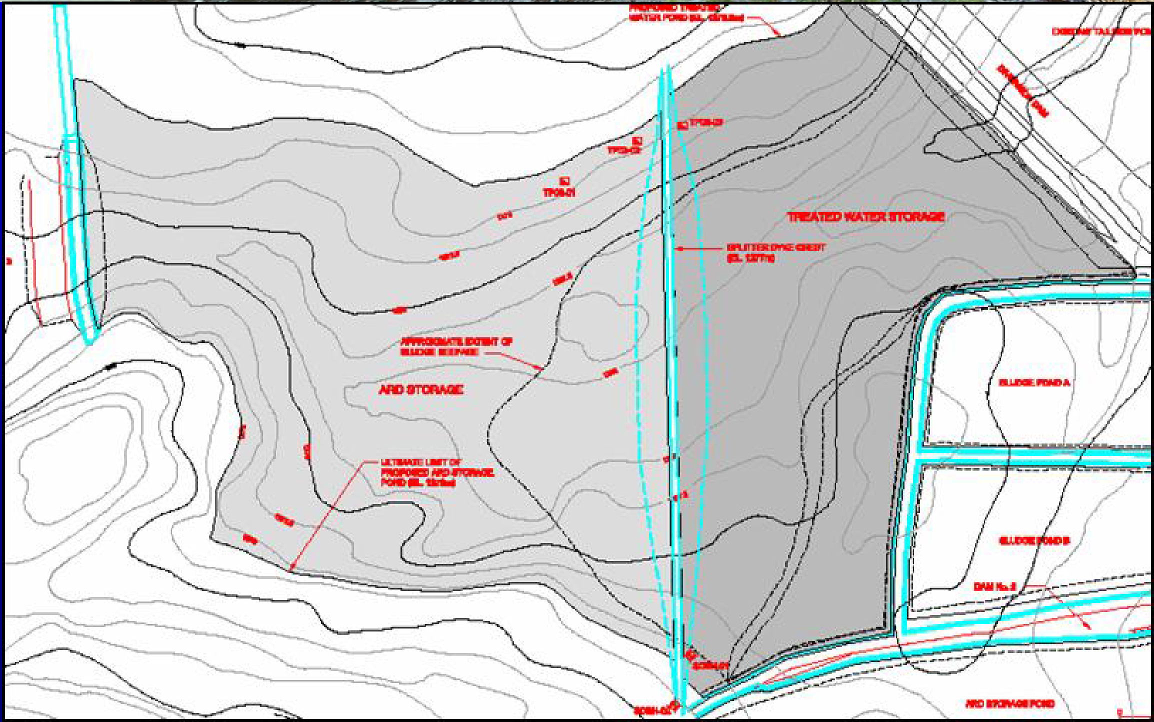
- Regular cleaning of pumps, ditches, sumps and ponds
- Ice, snow and sediment removal prior to runoff
- Adequate training, experience and number of staff

Limited experience and fore thought may be a challenge in the maintenance of structures such as dry covers which are a major part of the clean diversion at many sites that collect and treat.

Extreme Climate Events

Collect and Treat must be able to achieve operational objectives during and after extreme climate events. Predicting extreme meteorological events and impact of climate change has proven to be a major challenge at some sites.

- One way to handle uncertainty regarding maximum flow events is with extra pumping and storage capacity to handle unexpected drainage.



Retention of the Collective Knowledge

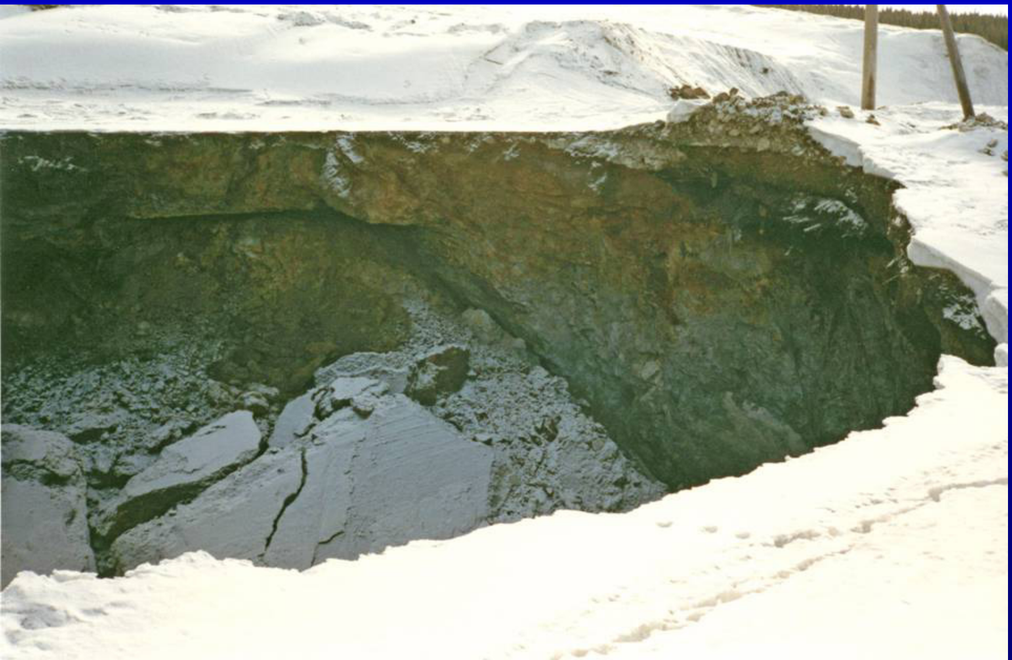
- Critical knowledge and records often disappear when projects are completed, mines are longer generating revenue and staff change .
- Without this information, key activities and data are forgotten or lost and valuable resources are wasted.

Retention of the Collective Knowledge

- Oral history, expert reviews and computer models cannot replace detailed site information.
- Sites need have systems that are regularly updated and kept in a secure place:
  - operating manuals for management, maintenance, sampling and analysis
  - data bases to track changes and guide future management decisions and maintenance requirements.

Financial Security

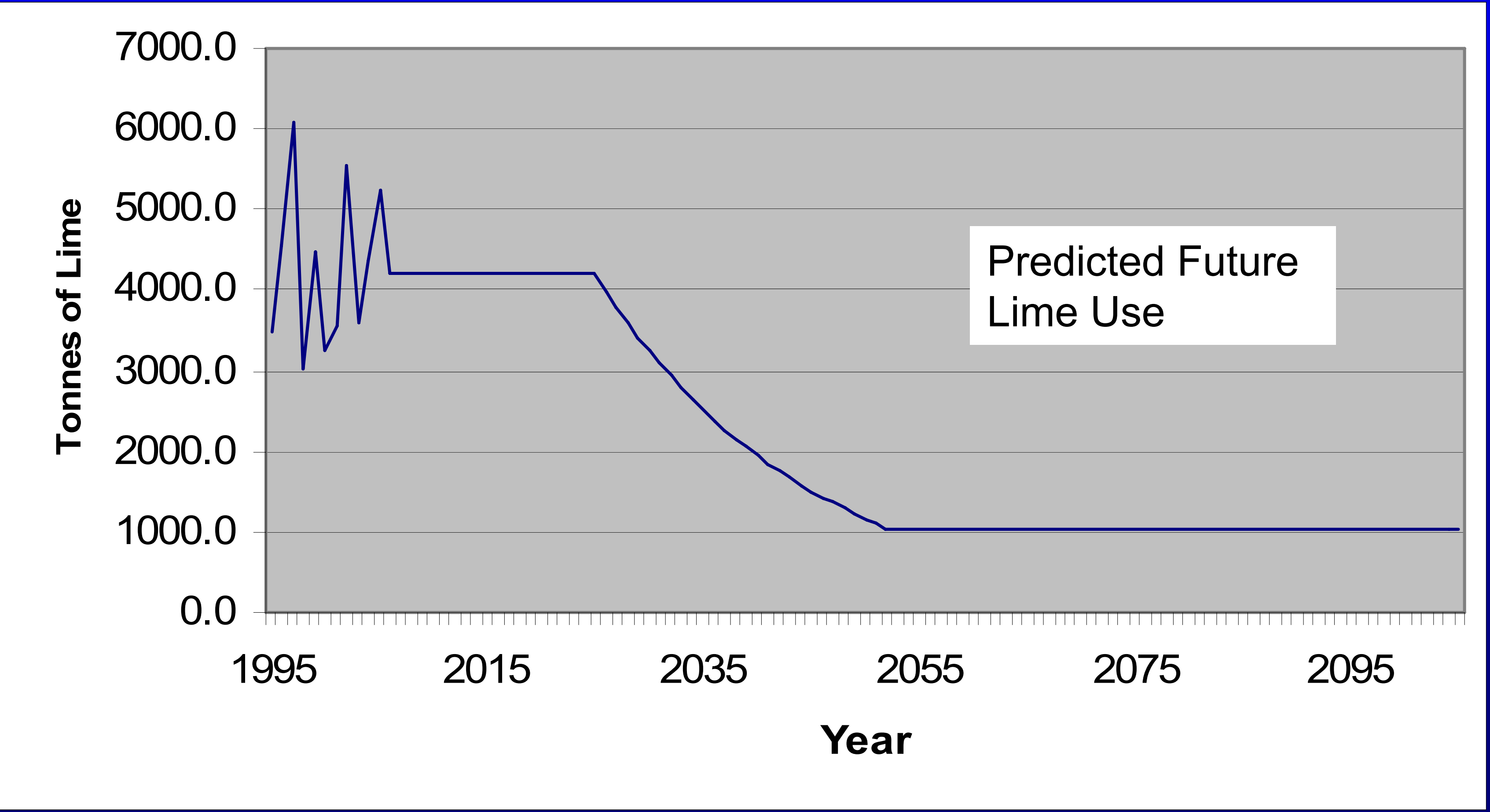
- Total liability may be $100s of millions with operating costs over $1.5 million per year
- As with all forms of mitigation, existing and projected future capital and operating costs must be estimated (reagent, power, labour, maintenance/replacement and contingency costs)
- This information will be used to determine the liability and ensure the required financial resources will be available.



Properties in Flux

- The geological materials and environmental processes on mine sites are complex and continually changing.
- Mine workings filling, changes to the height of the regional water table and solute accumulation in mine wastes may change the magnitude and location of contaminant outputs.
- Many of key properties and processes contributing to drainage volume and chemistry are impossible to predict.

Due to the limited industry experience and future properties that are difficult to predict, prediction of future costs is at best an educated guess work. Future monitoring and analysis will hopefully allow timely adjustments.



Micro-hydro Plant at Britannia Mine

To help sustain performance, some BC mine sites are developing non-mining revenue sources, such as land fills and micro-hydro, to offset treatment costs

Conclusions

Collection and treatment of contaminated drainage can be a highly effective and reliable means of protecting the environment.

In British Columbia approx:

- twelve sites use or will use lime treatment
- three sites use ferric sulphate to treat neutral pH drainage
- several operational examples of biological treatment

The Treatment Conundrum

- Reliability and effectiveness makes it a favoured mitigation strategy for existing mine sites
- High costs, large management requirements, secondary waste production and risk of spills make perpetual treatment the mitigation strategy of last resort for new mines

Critical questions for any treatment system:

1. At how high a load and flow rate can the system reliably produce dischargeable drainage, for how long and at what cost?
2. What systems are needed to ensure C & T are effective and sustainable?
3. What is required in terms of process control, equipment, personnel, monitoring, maintenance and redundancy in design for diversion of clean water, collection and treatment of contaminated drainage, discharge of treated drainage and disposal of treatment wastes?

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