Global review of pit lake case studies

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November 2018

Case Studies

GLOBAL PIT LAKES

- Documented 180 pit lakes reported in literature
- Examined whether pit lake was successful or not, and reason
- Compiled best practices and lessons learned

‘Successful’ versus ‘Unsuccessful’ Pit Lakes

SINCE THERE ARE NO GLOBALLY ACCEPTED CRITERIA, HERE ARE OURS:

<u>Successful</u>

- Met intended purpose such as fish and wildlife habitat, aquaculture, drinking water, recreation, water treatment, or other uses desired by stakeholders
- Certified for relinquishment by regulators

<u>Unsuccessful</u>

- Have water quality issues, requiring water treatment or artificial containment indefinitely
- Do not meet regulatory requirements
- Are not following a deliberately planned trajectory toward meeting objectives

Pit Lakes: The Challenge

HOW TO GET TO A 'SUCCESSFUL' PIT LAKE?

Active coal mine – future pit lake near Leipzig, Germany

Former coal mine – now a pit lake (Lake Zwenkau) with residences, restaurants, marina and dive shop near Leipzig, Germany

Globally, the Most Common Remediation of Pit Lakes

LIME, LOTS AND LOTS OF LIME

Addition of lime in Lake Koschen, Lusatian District, Germany (photo from Geller et al. 2012)

Addition of lime in Lake Zwenkau, Lusatian District, Germany

Case Studies

SUCCESS FACTORS

- *Understand the regulatory, social and environmental aspects as early in the mine life as possible, then manage appropriately; with monitoring demonstrating objective achievement and feeding back into a* ***pre-developed*** *adaptive management plan*
- *Attain a detailed knowledge of mine pit construction and waste materials, and incorporate that knowledge into a comprehensive mine closure plan that identifies the most appropriate method of treating and storing each waste stream*

Case Studies

HALLMARKS OF FAILED PIT LAKES

- *Mining began before regulatory standards required a full closure plan, and before mine waste characterization and predictive modelling approaches became industry standards*

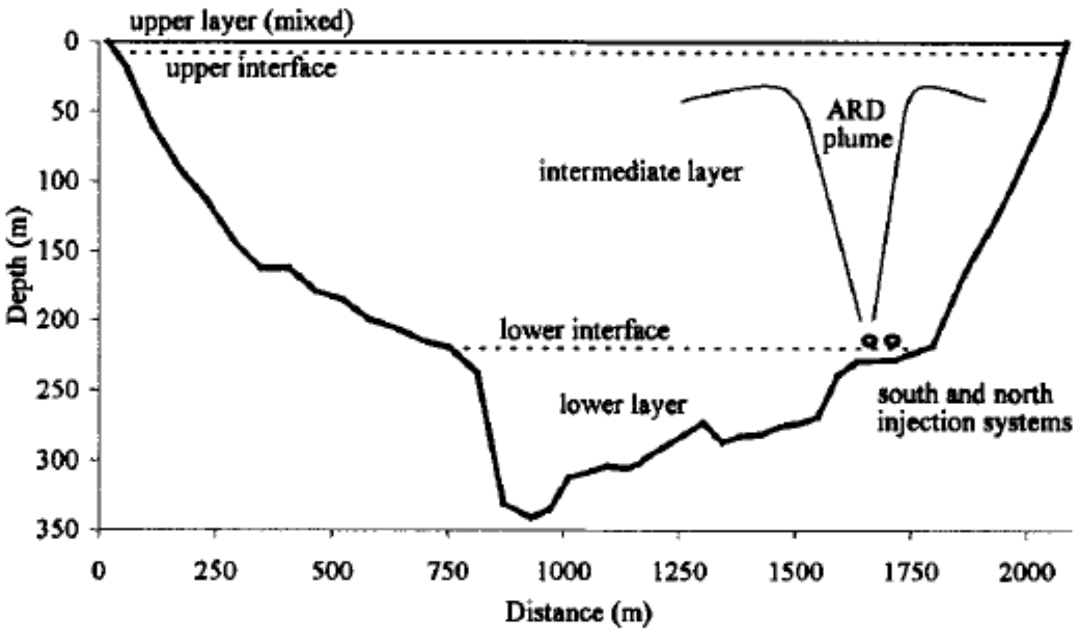
Drone boat sampling Berkeley Pit Lake, which is not safe to access

Case Studies - Unsuccessful

BERKELEY PIT LAKE – 1984 AND 2014

Case Studies – Adaptive Management

ISLAND COPPER MINE PIT LAKE



Fisher and Lawrence (2006)

Case Studies - Successful

ALBERTA COAL MINES

Case Studies - Successful

AUSTRALIAN COAL MINES

Best Practices and Lessons Learned

Greatest Risk: Public Access and Safety

SOMETIMES CALLED “ATTRACTIVE NUISANCES”

Minneapolis boy, 13, drowns in Crosby mine pit lake
Star Tribune • 3 months ago

- Teen drowns in lake near Crosby trying to retrieve a frisbee
  Bring Me The News • 3 months ago

View more

Preliminary autopsy of Lumberton man consistent with drowning, final cause of death in 6 - 8 weeks
12newsnow.com KBMT-KJAC • 21 days ago

Deluge riles creek that pulled 13-year-old into mine pit, where he drowned
St. Paul Pioneer Press • 3 months ago

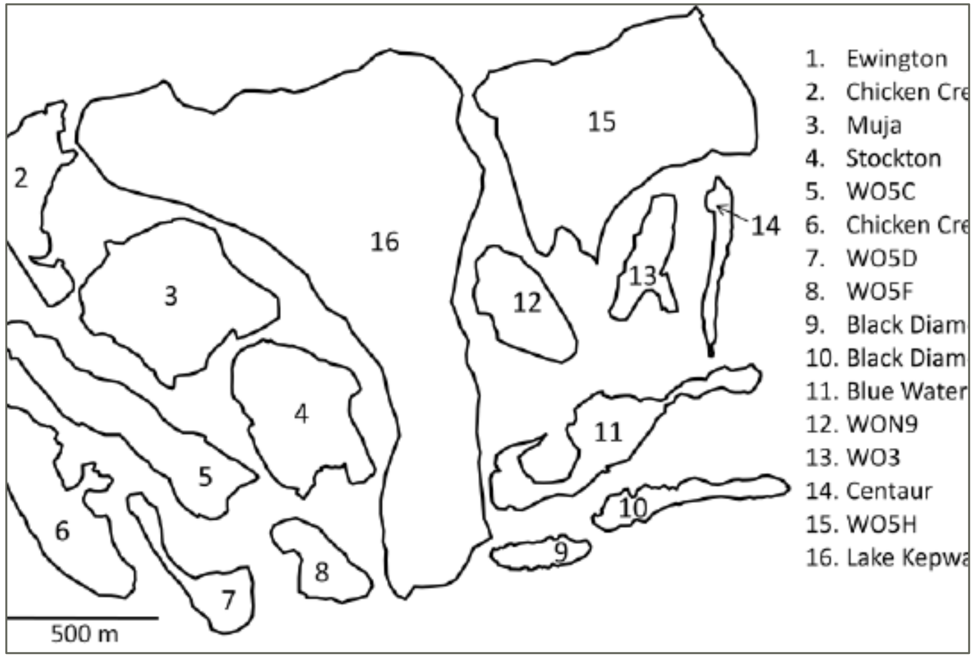
One of the fatalities occurred at the Red Mountain mine near Rossland in 2001 when a youth drowned in an abandoned surface pit which had filled with water.

Cause of Death on Abandoned Mines in USA (2001-2017)	
Drowning	**201**
ATV accident	23
Fall	24
Asphyxiation/suffocation	9
Other	21
Total	**278**

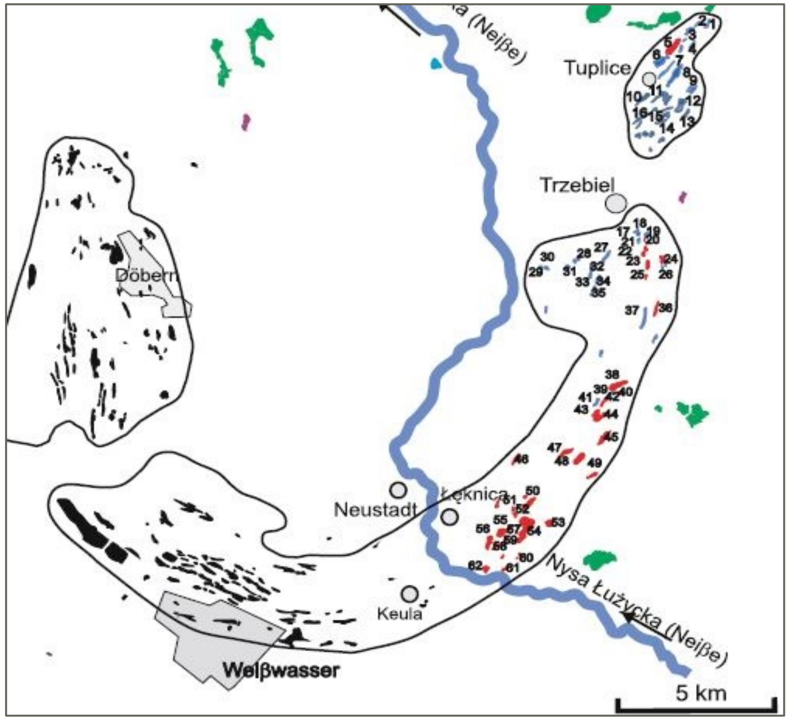
Note – during the same period, there were 63,648 drowning deaths in the USA

Creation of Lake Districts

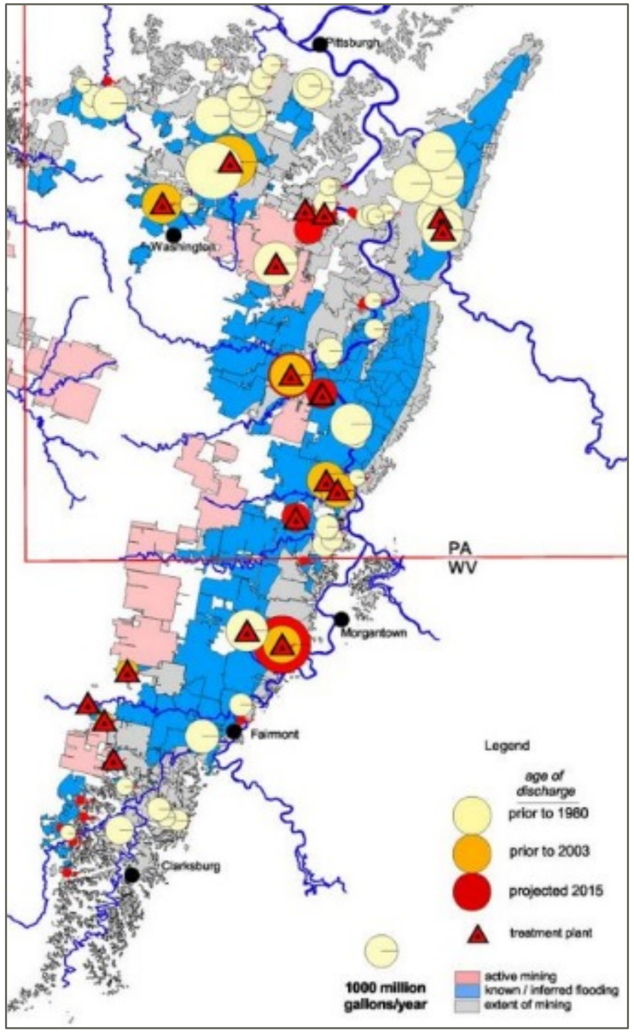
FOUND IN SEVERAL MINING REGIONS



Collie, Western Australia



Pit lake district on Poland – Germany border (Geller et al. 2012)

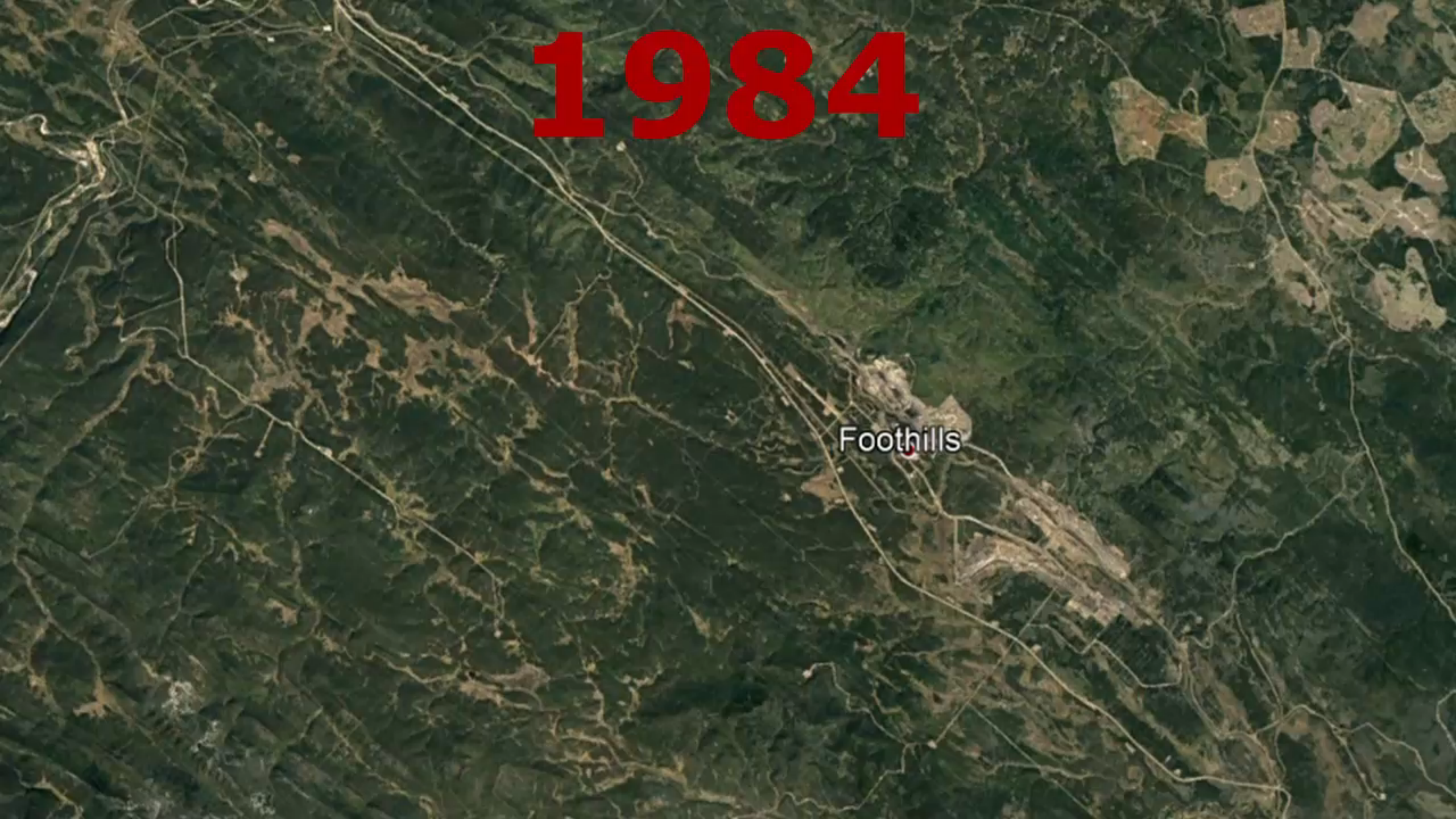


Pennsylvania and West Virginia (Miller 2008)

Creation of Lake Districts

FOUND IN SEVERAL MINING REGIONS

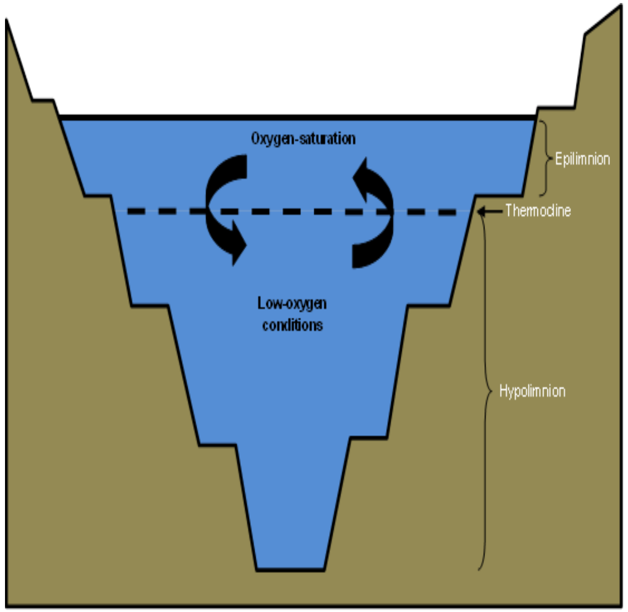
Coal mine pit lakes in West-central Alberta


1984
Foothills

Understanding Pit Lake Limnology is Essential

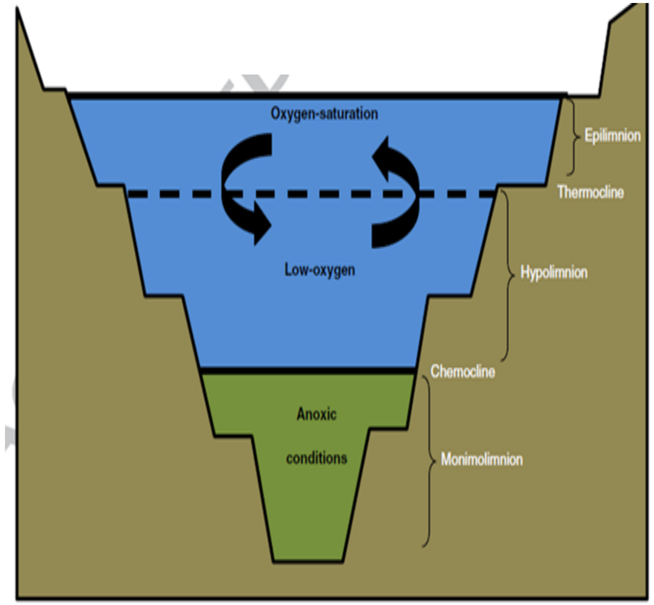
AFFECTS LAKE CHEMISTRY AND BIOLOGY

Holomictic Lakes



- Completely mix annually
- Stratify seasonally

Meromictic Lakes



- Do not completely mix
- Stratify seasonally

Consider Beneficial End Uses

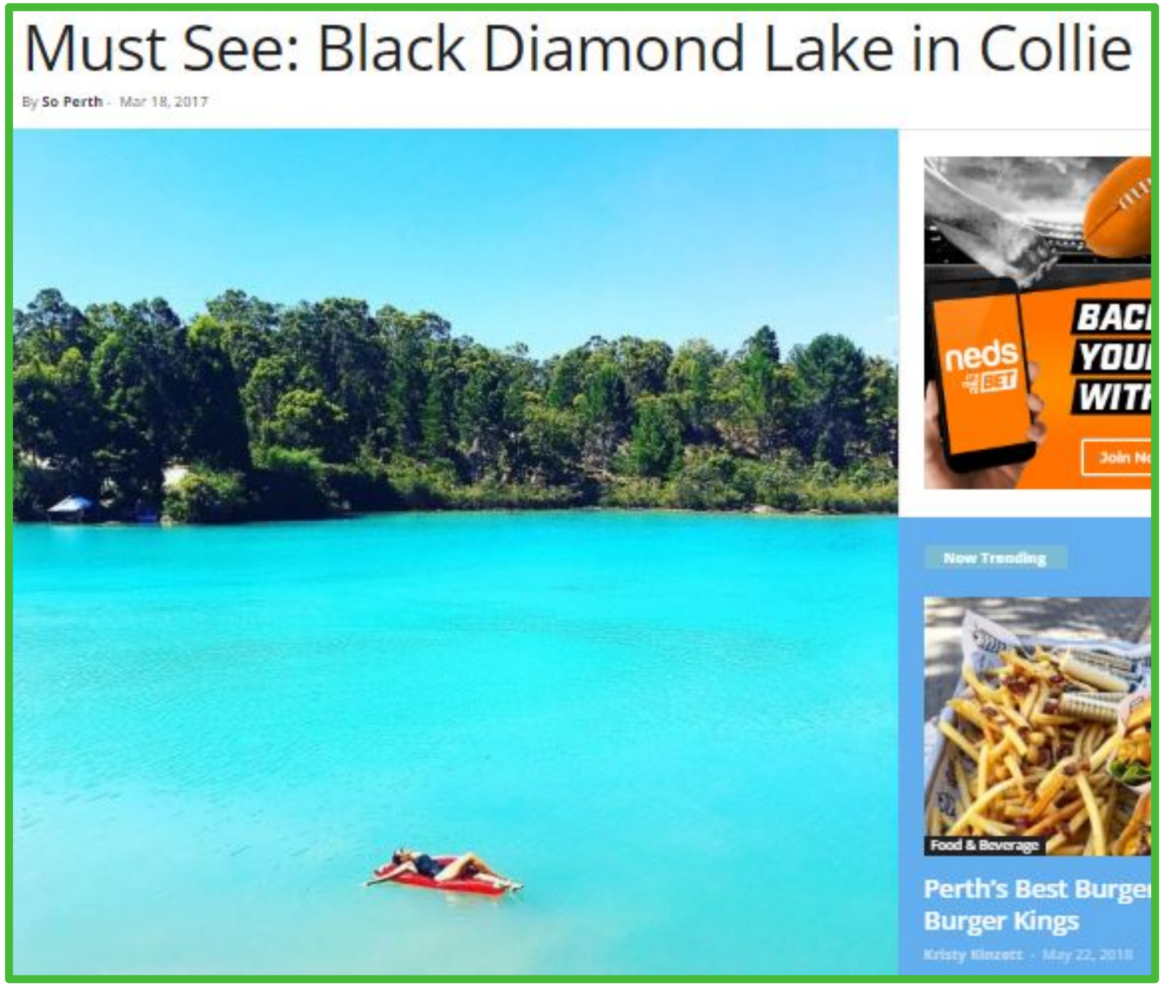
BEST PRACTICES

Potential benefits, *if properly planned*:

- Increase aquatic habitat
- Attenuate peaks in discharge and suspended solids
- Add recreational opportunities
- Treat mine waters or other streams

Consider Beneficial End Uses

BEST PRACTICES



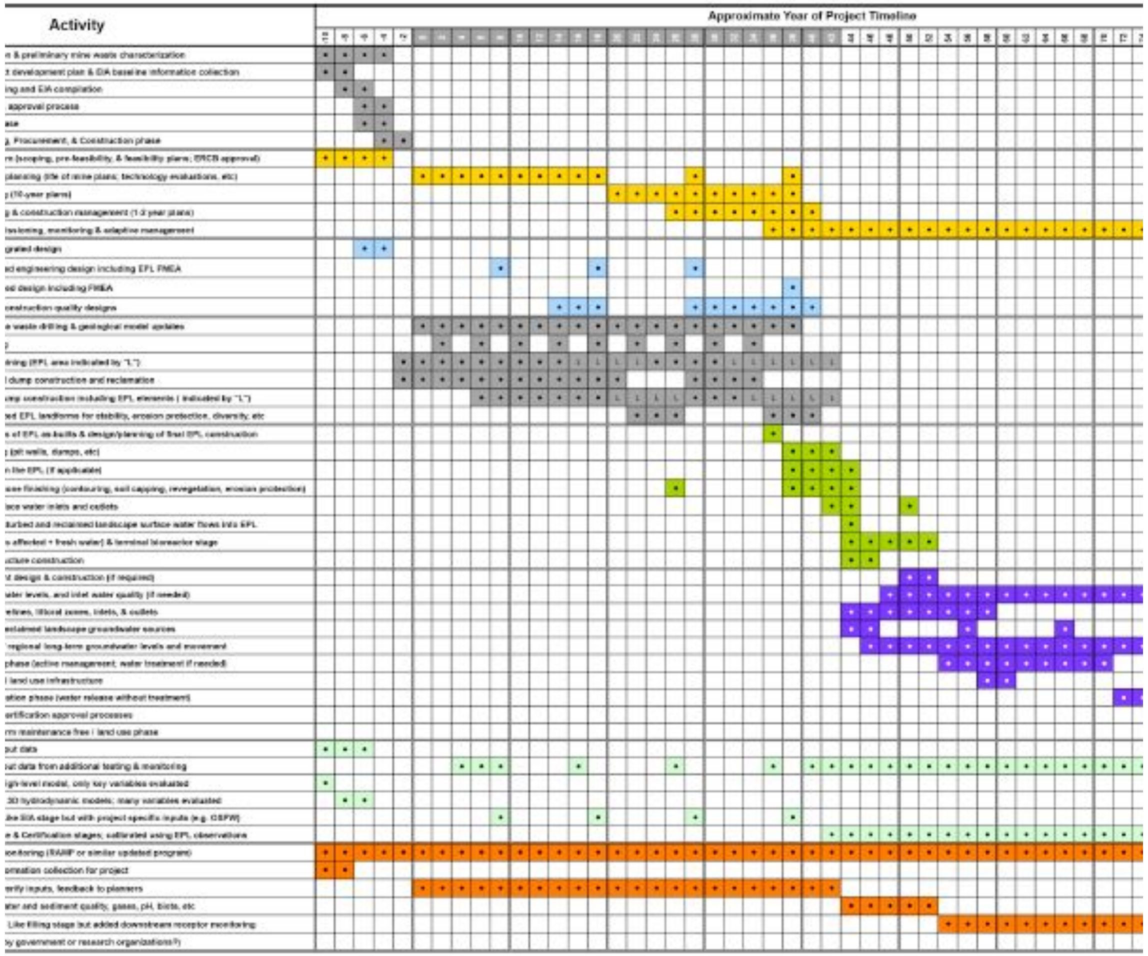
- *What end use is lacking in the region where the mine pit will be dug?*

Engage Stakeholders to Develop End Uses

MINNESOTA PIT LAKES

Early Planning is Key

BEST PRACTICES



- *Few closure management options exist at completion of a mine void, particularly so in the context of a largely completed overall mine site*
- *Development of successful pit lakes typically entailed strategically identifying factors that are critical their success, then incorporating those factors into adaptive closure planning, well in advance of ‘Rubicon’ moments of mine development*

Problematic Geochemistry must be Understood and Managed

BEST PRACTICES

- *Most unsuccessful pit lake closures resulted from misunderstood and mismanaged geochemistry within the pit shell or in-pit waste materials, or by altering the conditions to which mine waste is exposed without understanding the implications of those alterations*
- *A common outcome of this misunderstanding and mismanagement is AMD leading to low pH and elevated metal concentrations and salinity*

Consider Previous Successes and Failures

BEST PRACTICES

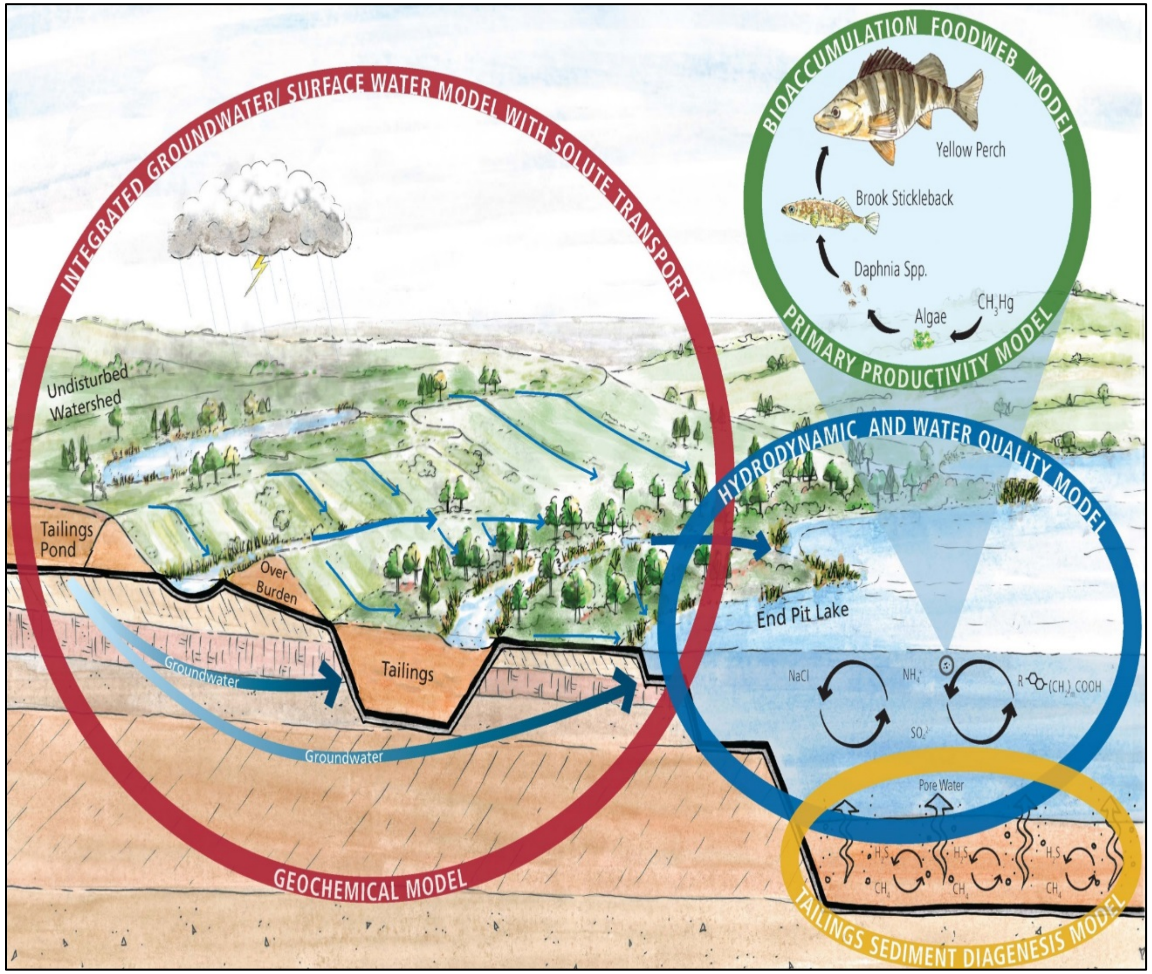
- First pit lake with sub-aqueous tailings disposal
- 1985-1989, pyrite-rich, gold-ore tailings injected into the bottom of a holomictic iron ore pit lake
  - Water cover prevents sulfide oxidation
  - Tailings contained dissolved salts
  - Created meromixis
  - Mixed to 34 m, max depth 58 m
- Nutrients added for treatment 1993-1994
- Good water quality reported in mid-1990’s

Leading mine closure seeks to holistically reduce the total project closure risk and maximize the total project closure benefit by considering landforms inter-dependently of each other

GOLDER

Holistic Planning Views the Pit Lake as One Part of a Larger Closure Landscape

BEST PRACTICES



- Successful pit lake closures were typically well-planned in advance and in consideration of other post-mining landform elements across the closure landscape.
- Holistic planning may improve overall mine closure outcomes (reduced risk and liability) at the expense of reduced pit lake success.

Holistic Mine Closure

BEST PRACTICES

Rather than:

Should the pit lake contain tailings?

Consider:

Given the land disturbance & waste materials generated by a mine, along with the local water balance, climate, economics, desired end land uses and other factors, which closure strategy yields the lowest overall environmental risk?

The Evolution of Mine Pit Lakes

GEN1 PIT LAKES

Mined before 1970's

- No regulations
- No bonding/$$$
- No geochemical testing or predictive models
- No post-closure planning

"First" pit lakes; 1980s and earlier; accidental outcomes:

- *Good*: Minnesota
- *Bad*: Germany
- *Ugly*: Pennsylvania

GEN2 PIT LAKES

Mined 1990's-present

- Regulations/bonding
- Geochem testing and predictive modeling
- Post-closure planning (no harm)
- Monitoring, examples & knowledge

Pit lakes of 1990's

- Nevada
- Michigan
- Active management

GEN3 PIT LAKES

Mined 2000's-present

- Regulations/bonding
- Geochem testing and predictive modeling (geochem and limno)
- Post-closure planning (beneficial end use)
- Monitoring, examples & knowledge
- Industry collaboration
- Mesocosms and microcosms
- Demonstration ponds and lakes

More recently developed

- Alberta
- Australia
- Germany

For More Information

PIT LAKE GUIDANCE DOCUMENTS AND CASE STUDIES

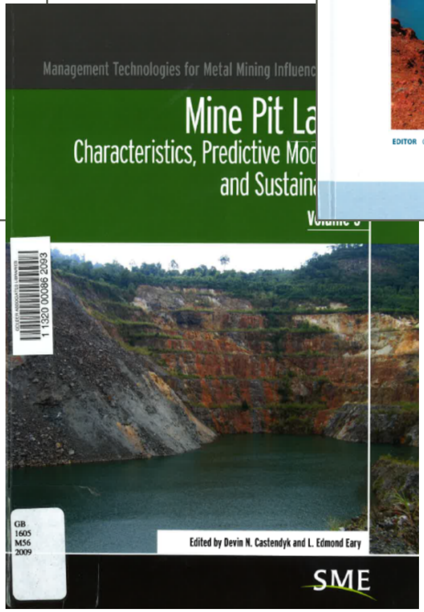
Creating lakes from open pit mines: processes and considerations, with emphasis on northern environments

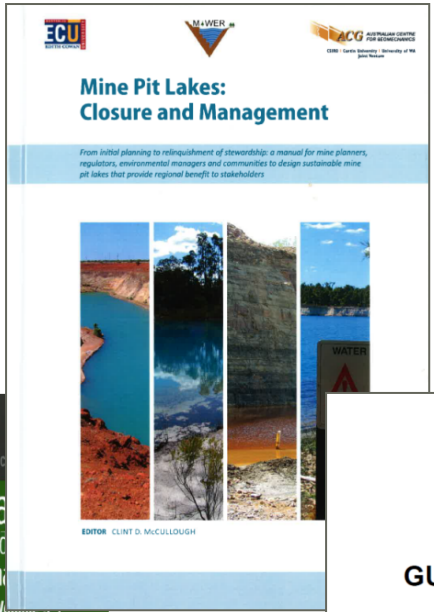
Christopher H. Gammons[1], Les N. Harris[2], James M. Castro[3], Peter A. Cott[4], and Bruce W. Hanna[4]

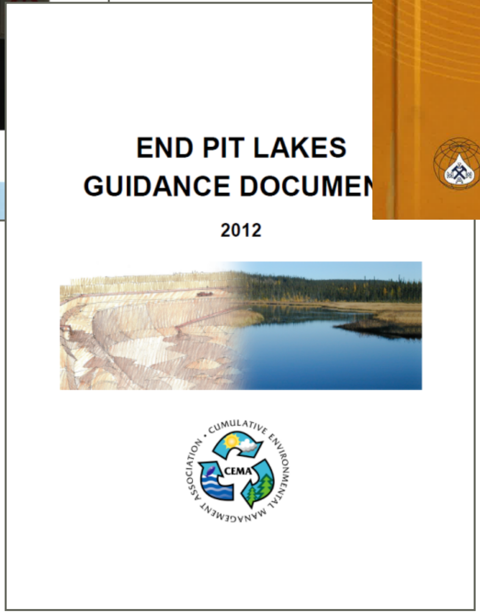
[1]Montana Tech of The University of Montana
Butte, Montana 59701
[2] University of British Columbia
Vancouver, British Columbia V6T 1Z4
[3] Montana Department of Environmental Quality
Helena, Montana 59620
and
[4]Department of Fisheries and Oceans
Yellowknife, Northwest Territories X1A 1E2

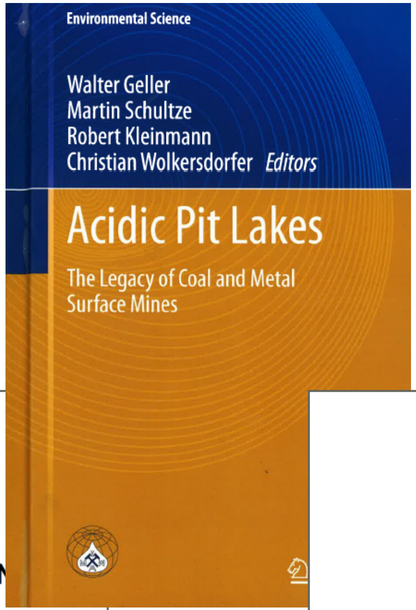
2009

Canadian Technical Report of Fisheries and Aquatic Sciences 2826







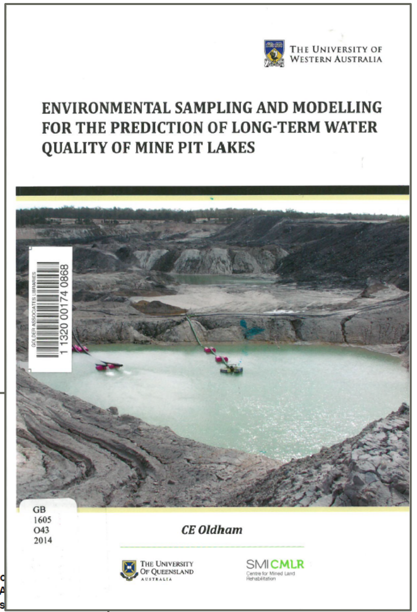


In-Pit Disposal of
Mine Wastes: A
Update and Cas
Results

MEND Report 2.36.1b

This work was done on behalf of the Mine Environment Neutral Drainage (MEND) Program and sponsored by:
The Mining Association of Canada (MAC) and MEND

June 2015



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Thanks for listening

Photo: Quarry Lake, Alberta