

# **Global review of pit lake** case studies

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# **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:

# Successful

- 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

### **Unsuccessful**

- 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





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



 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

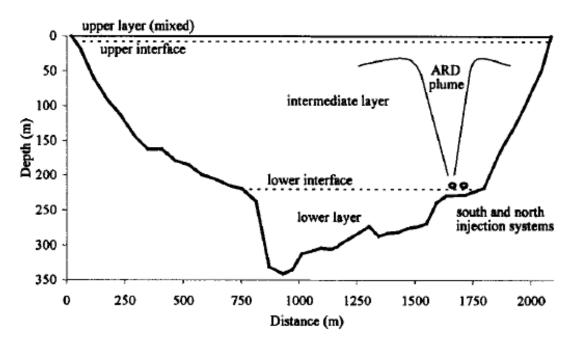




# **Case Studies – Adaptive Management**

#### **ISLAND COPPER MINE PIT LAKE**





Fisher and Lawrence (2006)



# **Case Studies - Successful**

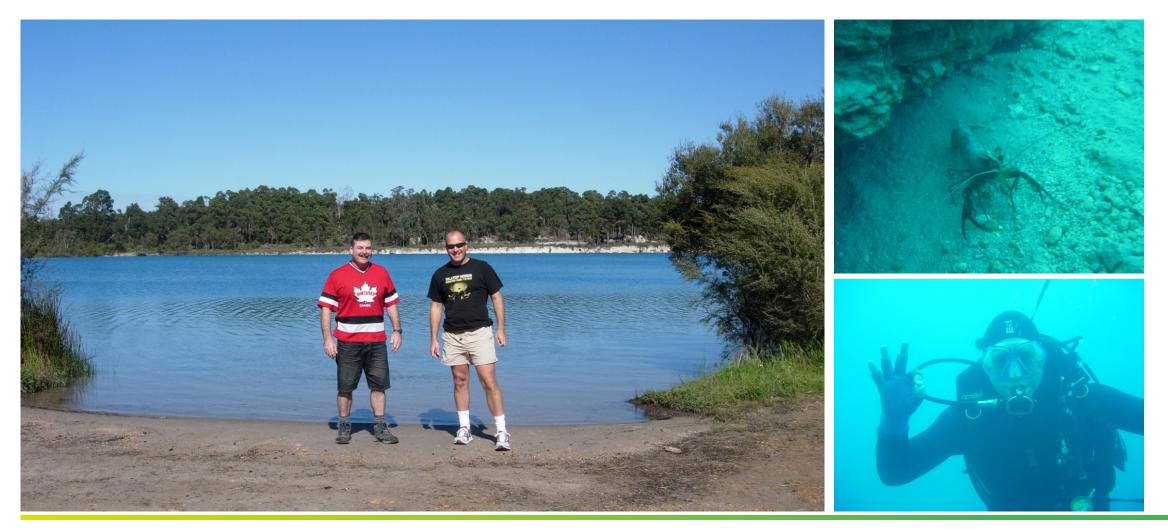
#### ALBERTA COAL MINES





# **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



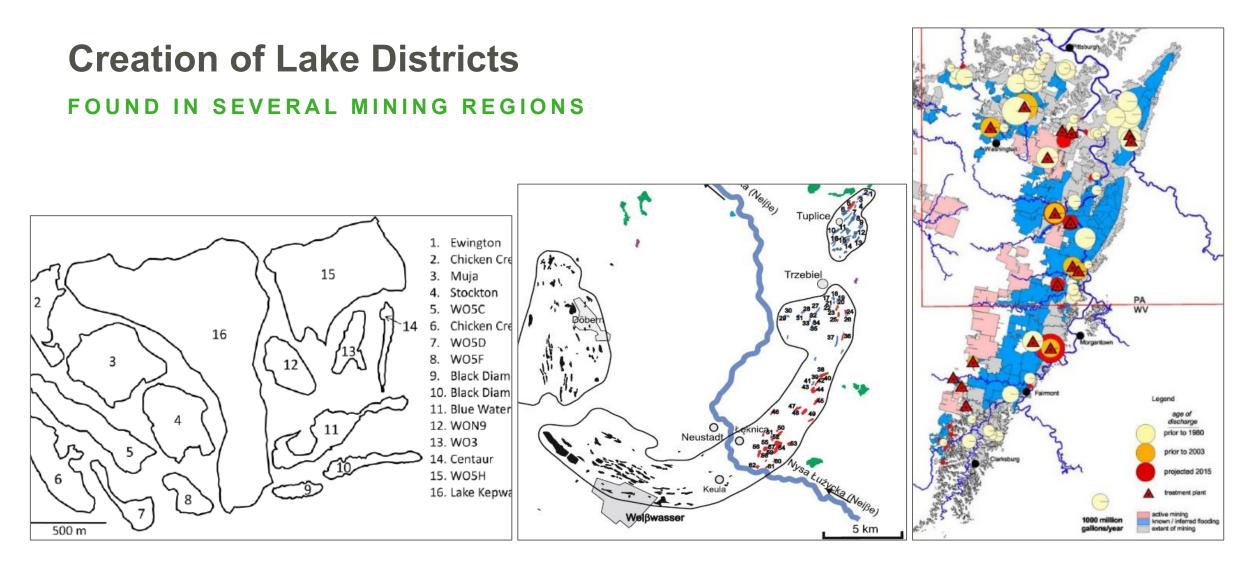
St. Paul Pioneer Press • 3 months ago

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 (2001-2017)	in USA
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





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

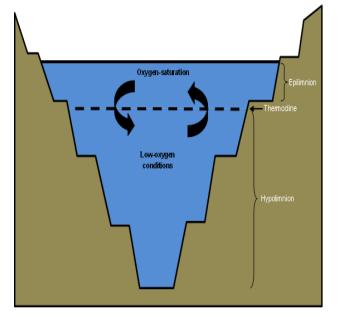




# **Understanding Pit Lake Limnology is Essential**

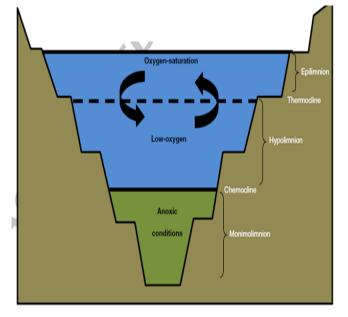
#### AFFECTS LAKE CHEMISTRY AND BIOLOGY

Holomictic Lakes



- Completely mix annually
- Stratify seasonally

## **Meromictic Lakes**



- Do not completely mix
- Stratify seasonally



# **Consider Beneficial End Uses**

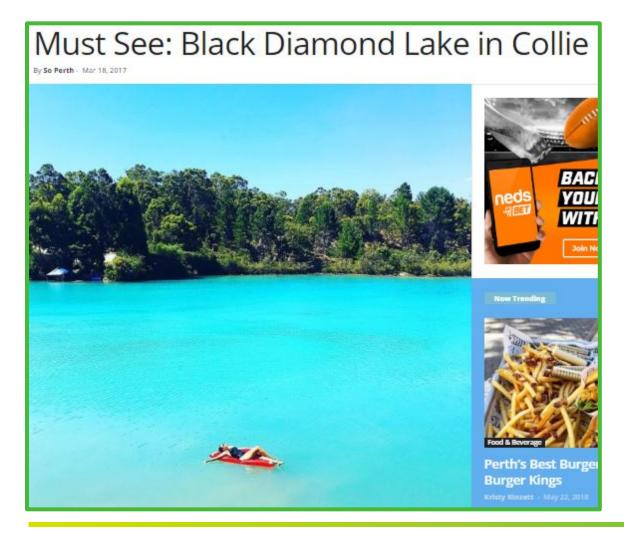
#### **BEST PRACTICES**

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



DEPART NATURA	MENT OF L RESOURCES				Search for
RECREATION	DESTINATIONS	NATURE	EDUCATION & SAFETY	LICENSES, PERMITS & REGULATIONS	EVENTS & SEASONS

Home > Destinations > State parks and recreation areas >

Cuyuna Country StatesRecreation AreaPark HomeAbout the ParkEvents CalendarMapsSeasonal UpdateCamping & LodgingReservationsTrailsRecreation FacilitiesAmenitiesEnergy-Smart at DNR

#### **Cuyuna Country State Recreation Area**





# Early Planning is Key

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- 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

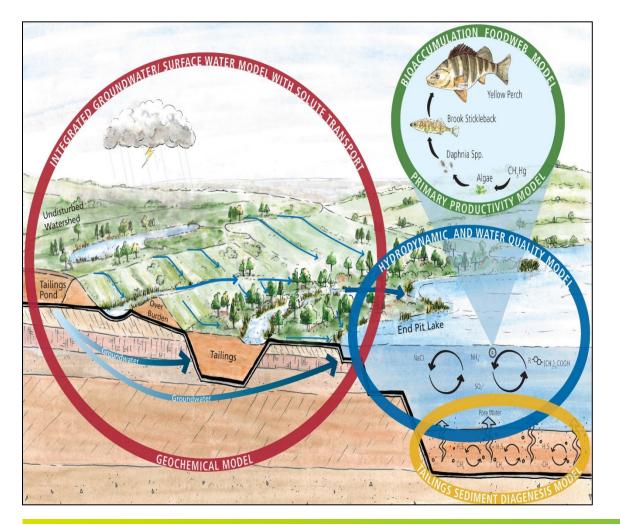




Leading mine closure seeks to holistically reduce the total project closure risk and maximize the total project closure benefit by considering landforms interdependently of each other



# 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 postmining 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

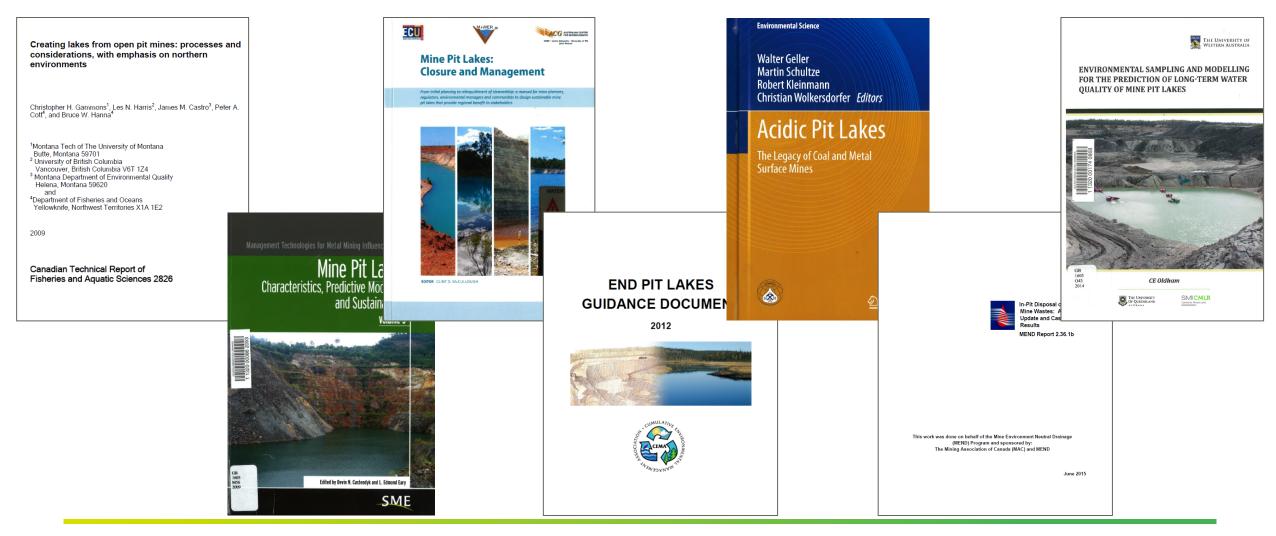
- Regulations/bonding
- Geochem testing and predictive modeling (geochem and limno)
- Post-closure planning (beneficial end use)
- Monitoring, examples & knowledge
- Industry collaboration
- Mesocosms and microcosms
- Demonstration ponds and lakes

#### More recently developed

- Alberta
- Australia
- Germany

# **For More Information**

#### PIT LAKE GUIDANCE DOCUMENTS AND CASE STUDIES







# Thanks for listening



Photo: Quarry Lake, Alberta