WATER QUALITY AND MINING
PART C: REMEDIATION (OF ACID MINE DRAINAGE)

The material presented here has been prepared by George Wilson in April 2021, with input from Dr. Laura Richards and Prof. David Polya of the Department of Earth & Environmental Sciences, The University of Manchester, and other sources as acknowledged. The associated video recordings have been made by George Wilson.

The Transformation by Innovation in Distance Education (TIDE) project is enhancing distance learning in Myanmar by building the capacity of Higher Education staff and students, enhancing programmes of study, and strengthening systems that support Higher Educational Institutions in Myanmar. TIDE is part of the UK-Aid-funded Strategic Partnerships for Higher Education Innovation and Reform (SPHEIR) programme (www.spheir.org.uk). SPHEIR is managed on behalf of FCDO by a consortium led by the British Council that includes PwC and Universities UK International. The TIDE project will close in May 2021.

Monitoring and remediation

- Outline
  - Introduction
  - Objectives
  - Environmental mining regulatory context in Myanmar
  - Remediation of acid mine drainage
  - Selection of an appropriate remediation strategy
  - Learning exercise
  - References & Further Information
- Summary

Introduction

- Mines in Myanmar must adhere to recent legislative changes to mining
- Remediation of mining pollution important to preserving environmental quality
- Example cost-benefit analysis will be covered (as covered in the remediation selection lecture)

Objectives

- Become familiar with regulatory environment framework for mining in Myanmar
- Become familiar with remediation approaches to addressing acid mine drainage
- Learn to undertake a simple cost-benefit analysis, for the selection of an appropriate remediation strategy

ENVIRONMENTAL MINING REGULATORY CONTEXT IN MYANMAR

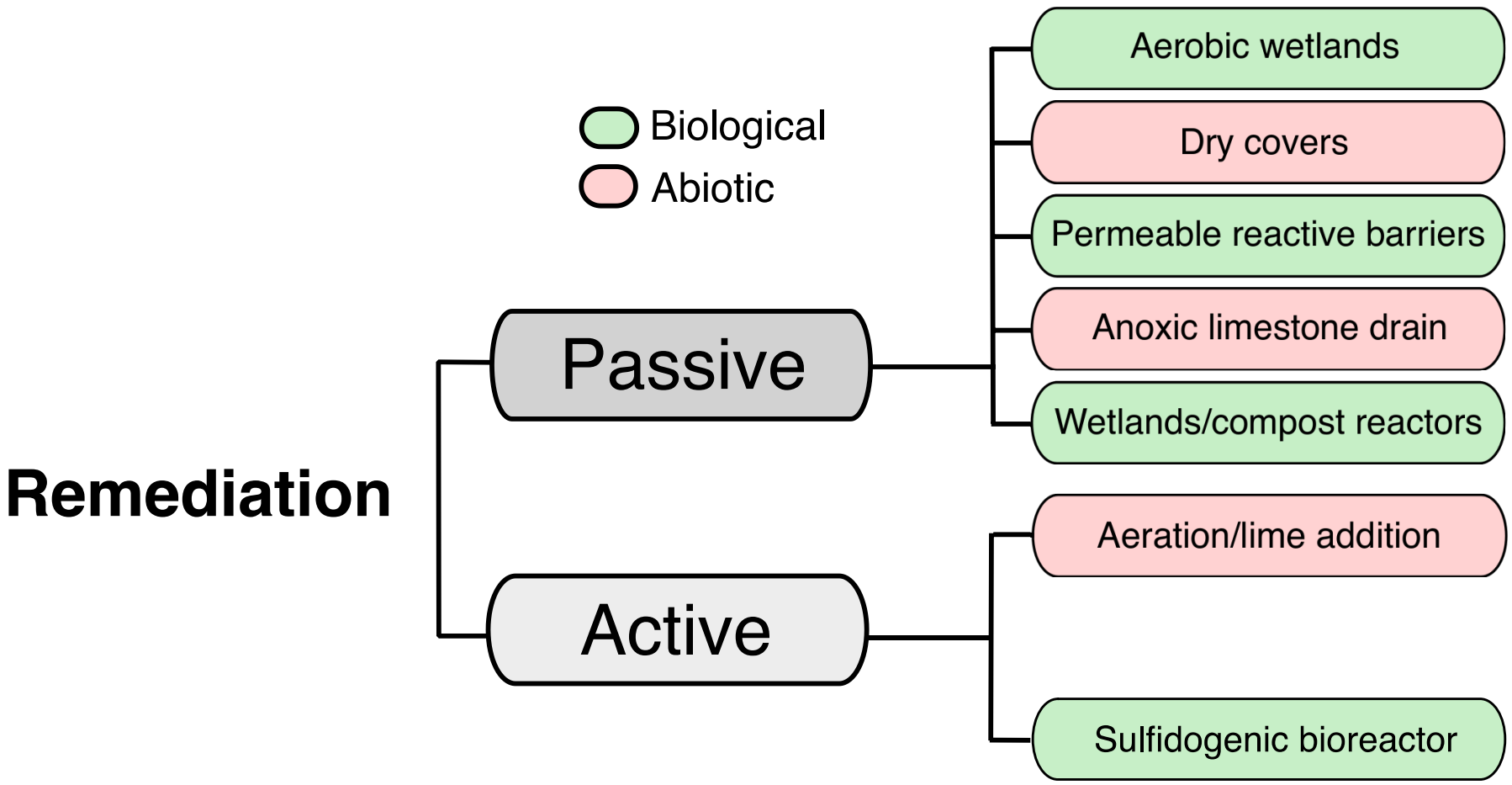
Myanmar mining environmental policy

- Mines must establish conservation and decommissioning practices - Mining Rules 2018
- Establishment of the Environmental Impact Assessment (EIA) in 2015

(OBG, 2019; Ministry of Environmental Conservation and Forestry, 2015) (OA)

REMEDIATION AND MONITORING WITH CONTEXT TO ACID MINE DRAINAGE

AMD remediation options



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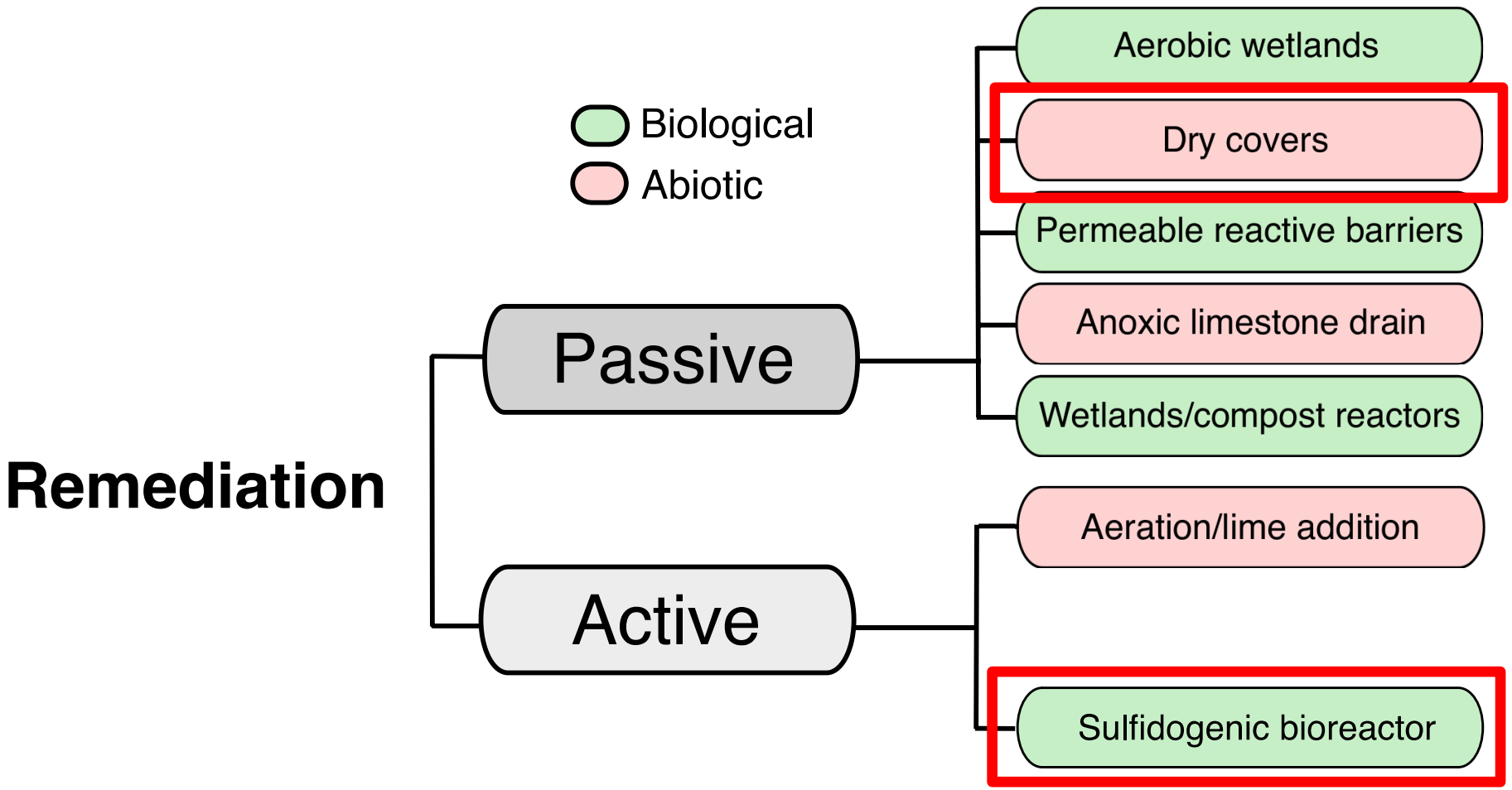
AMD remediation options



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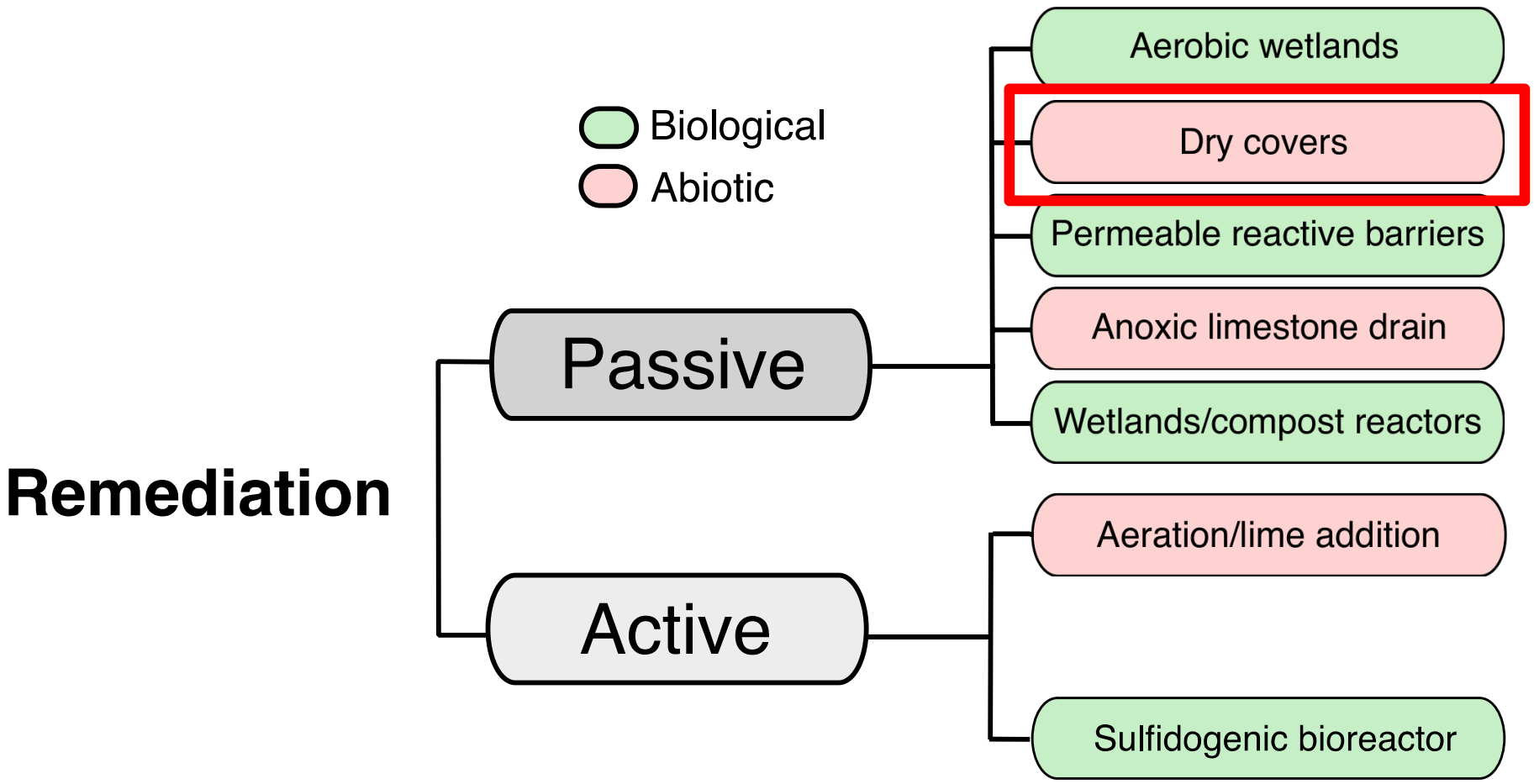
AMD remediation options



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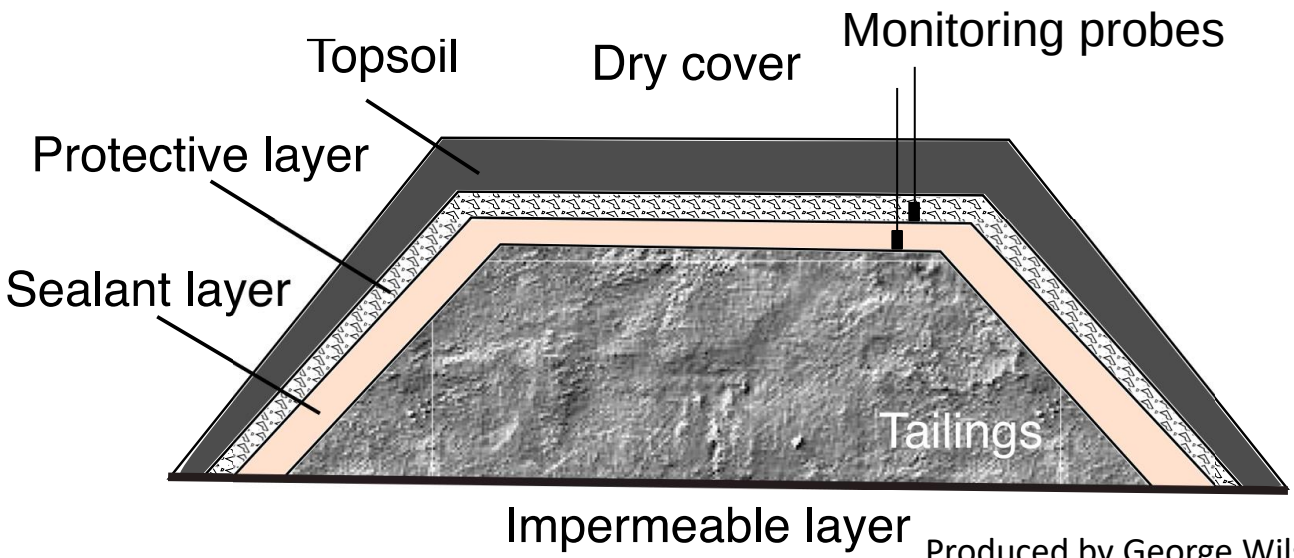
Dry cover

- Layers – Reduce oxygen and water flux. Clay sealant layer (low conductivity) protected by upper layers
- Monitoring – Moisture and soil suction probes used



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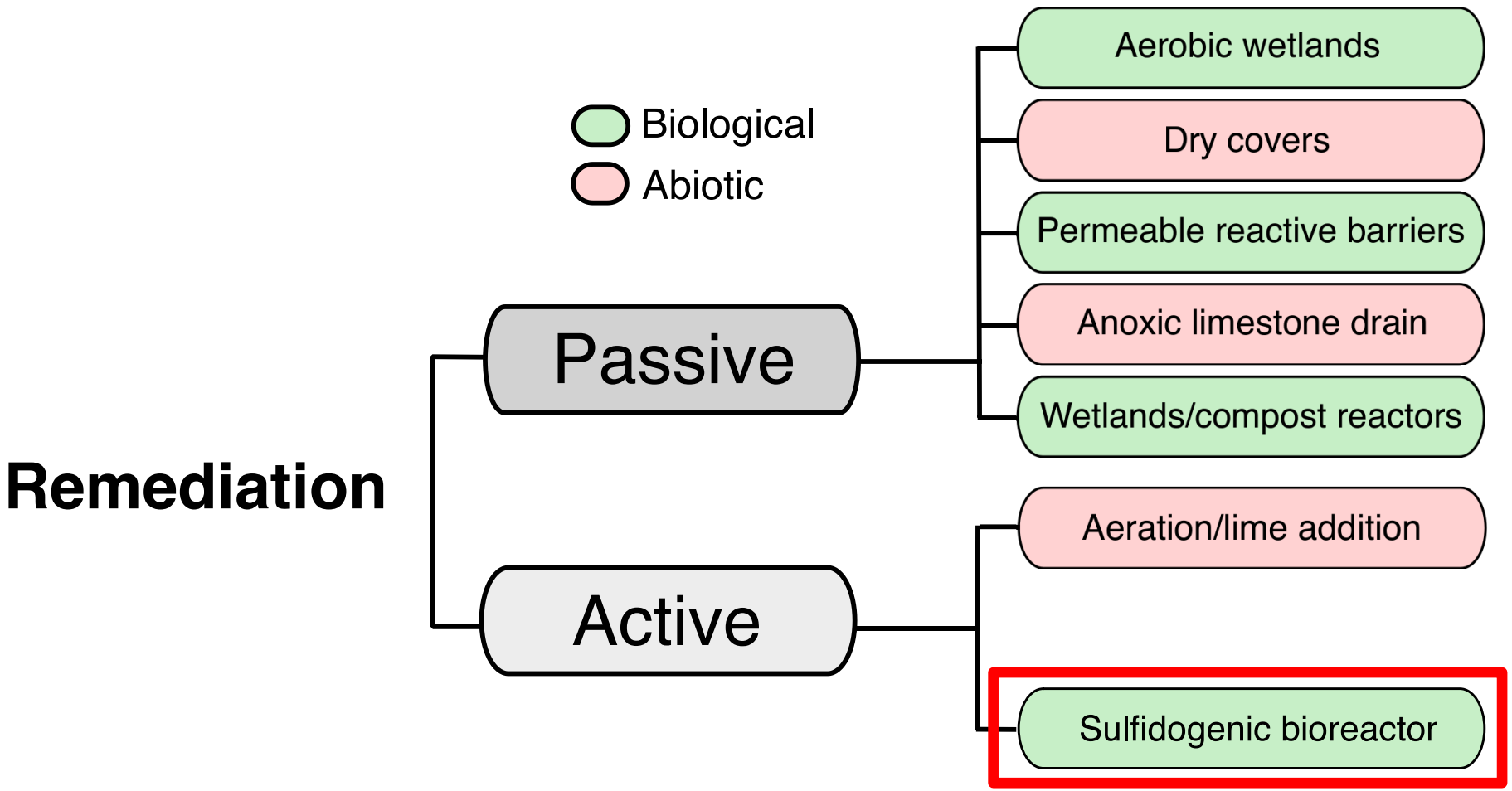
AMD remediation options



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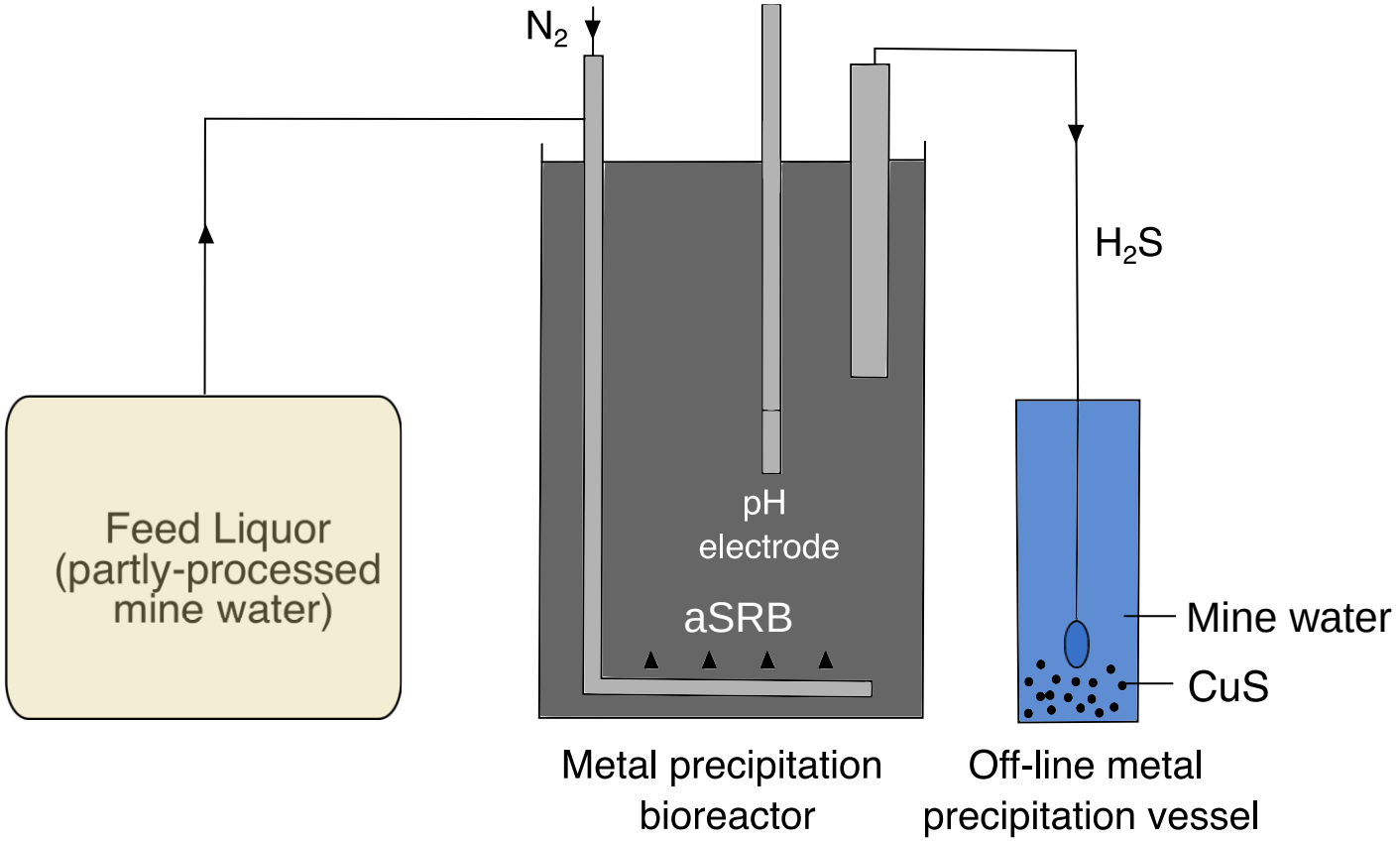
Sulfidogenic reactor



Produced by George Wilson from an adaptation of Santos & Johnson (2017) (OA)

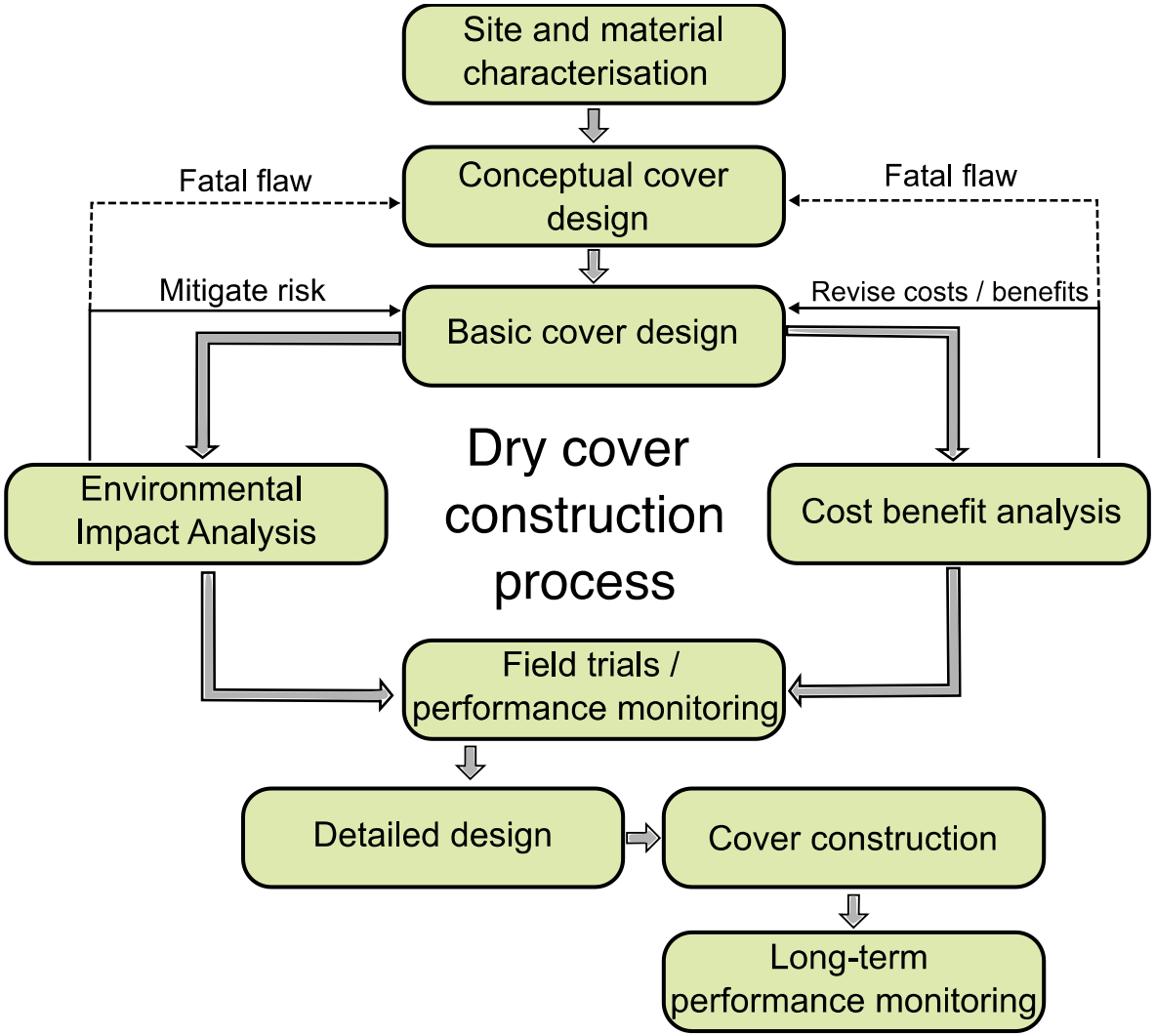
SELECTION OF AN APPROPRIATE REMEDIATION STRATEGY

Remediation selection

- Regulatory framework
- Environmental impact assessment (by law) – what are the risks

- Cost-benefit analysis (CBA)
  - Construction costs e.g. land acquisition, materials
  - Operational costs e.g. salaries, servicing, repairs
  - Decommissioning costs e.g. removal of equipment
  - Benefits e.g. increase in visitors, production of goods

AMD Dry Cover



Produced by George Wilson from an adaptation of O'Kane & Wels (2003) (OA)

AMD Dry Cover

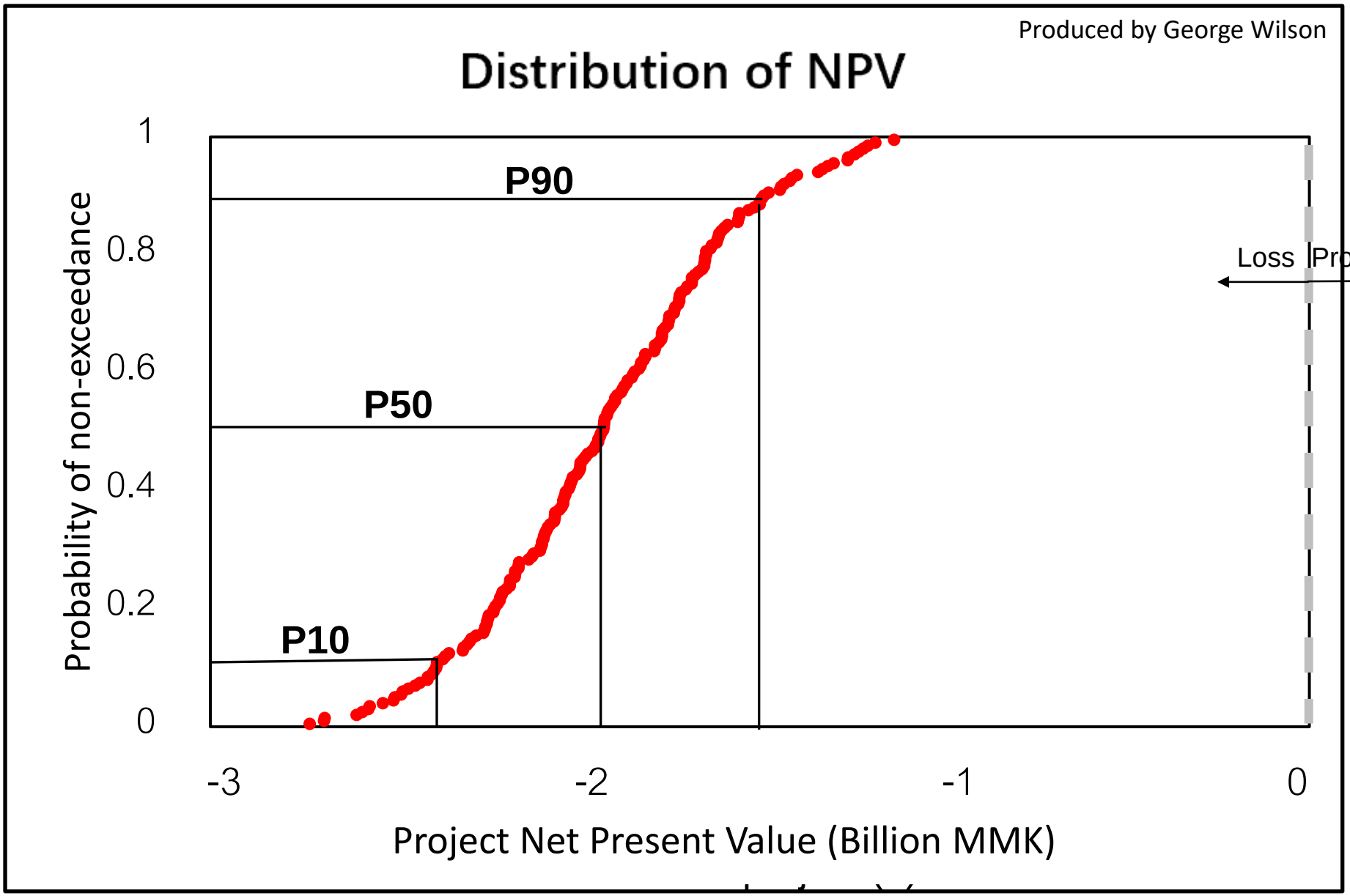
- Area covered by bentonite and soil layers in order to prevent oxygen flux and infiltration

Image taken by George Wilson

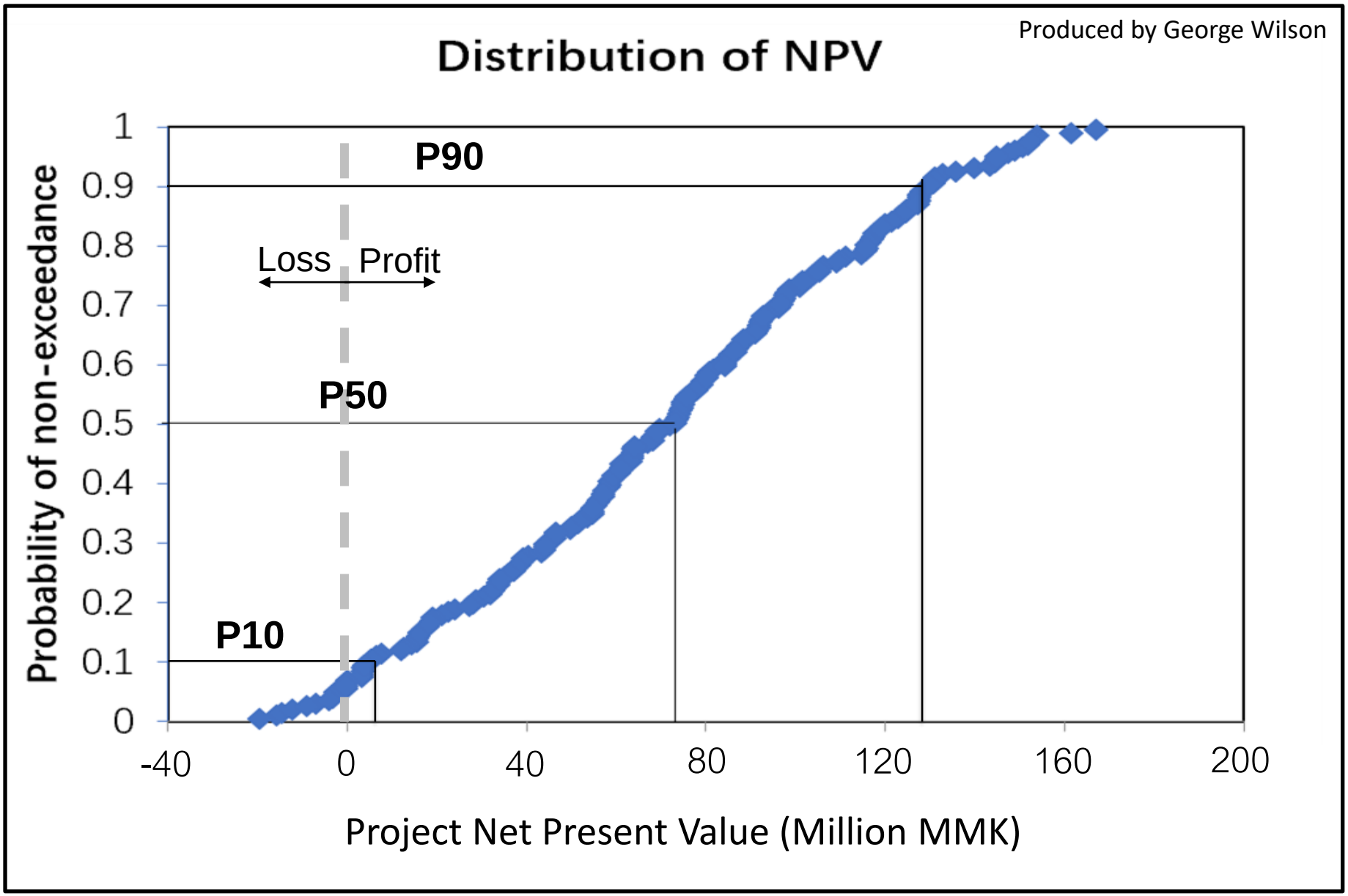
Map data ©2019 Google

- Costs (fixed/operational)? Benefits? Interest rates?...

Dry Cover CBA



Sulfidogenic Reactor CBA



Sulfidogenic Reactor CBA

Item	Type	Indicative cost and description*
Bioreactor	Fixed cost	83 million MMK for reactors operating at 100 L/min (Adam & Kontopoulos, 1996)
Glycerol + yeast	Operational cost	135 million MMK , given 46 kg of glycerol and 10 kg of yeast extract are needed to treat 100m^3 of AMD (Santos & Johnson, 2018)
Labour rate	Operational cost	100,000 MMK/hr (Nordwick *et al.,* 2005)
Observation and Maintenance	Operational cost	1.5 million MMK/yr (Nordwick *et al.,* 2005)
Cu recovery	Benefit	4,200 MMK/m^3 of AMD water treated (Hedrich & Johnson, 2014)
Purified water	Benefit	2.7 million MMK/yr/hectare of water purified (Brink *et al.,* 2011)

*Conversion estimate of GBP/USD to MMK as of 10/04/21

SUMMARY

Summary

- Recent regulatory changes in Myanmar stipulate that owners must adhere to environmental rulings
- A range of remediation and monitoring solutions may be used, grouped as passive/active and biological/abiotic.
- The selection of such remediation is a multi-step process and a CBA should be be considered as a tool for cost analysis

LEARNING EXERCISE

Learning exercise

Produce a cost-benefit flow sheet for a potential mine remediation project in Myanmar. This could be for any operational/relic mine. Please find the spreadsheet which sets this up for you. Will the project likely make a profit? If not, how could you increase the chances of making profit?

REFERENCES & FURTHER RESOURCES

References

Johnson & Hallberg, 2005. Acid mine drainage remediation options: a review. [Online] Available at: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=A224218E8F0C5E6A5AC1D248A90DF060?doi=10.1.1.595.4733&rep=rep1&type=pdf [Accessed 10/04/21]. (OA)

O'Kane, M. and Wels, C., 2003, July. Mine waste cover system design–linking predicted performance to groundwater and surface water impacts. In *6th International Conference on Acid Rock Drainage (ICARD), Cairns.*

Ministry of Environmental Conservation and Forestry, 2015. *Environmental Impact Assessment Procedure*. Notification No. 616. Nay Pyi Taw. (OA)

OBG, 2018. *New Mining Rules revive investor interest in Myanmar mining.* [Online] Available at: https://oxfordbusinessgroup.com/analysis/clear-cut-recently-enacted-mining-rules-have-reinforced-industry-and-revived-investor-appeal#:~:text=Under%20the%20new%202018%20Mining,remain%20unchanged%20at%20nine%20years [Accessed 21/03/21]. (OA)

Santos, A.L. and Johnson, D.B., 2017. The effects of temperature and pH on the kinetics of an acidophilic sulfidogenic bioreactor and indigenous microbial communities. *Hydrometallurgy*, *168*, pp.116-120. https://doi.org/10.1016/j.hydromet.2016.07.018

Further Resources

Detection and monitoring of acid mine drainage:

MEND, 1994. *Application Of Geophysical Methods To The Detection And Monitoring Of Acid Mine Drainage.* MEND Project 4.6.3. [Online] Available at: http://mend-nedem.org/wp-content/uploads/2013/01/4.6.3.pdf (OA)

Review of passive AMD remediation systems:

Skousen, J., Zipper, C.E., Rose, A., Ziemkiewicz, P.F., Nairn, R., McDonald, L.M. and Kleinmann, R.L., 2017. Review of passive systems for acid mine drainage treatment. *Mine Water and the Environment*, *36*(1), pp.133-153. (OA)

Basic cost-benefit analysis flow sheet in Excel:

Grow Your Career, 2013. https://www.youtube.com/watch?v=TIEWxjJ6Rzg [Accessed 29/04/21]. (OA)

Monte Carlo simulation for cost-benefit analysis:

Platon, V. and Constantinescu, A., 2014. Monte Carlo Method in risk analysis for investment projects. *Procedia Economics and Finance*, *15*, pp.393-400. DOI: https://doi.org/10.1016/S2212-5671(14)00463-8 (OA)

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