A waste fines cell with a multitude of concurrent activities

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Outline of presentation

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- Mining and dewatering
- Characteristics of foundation, waste fines and embankment materials
- Embankment design considerations
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- Blast assessment
- Closure
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- Questions?
Introduction

- Project located in Western Australia
- In the Pilbara region of WA
- In-pit waste fines (tailings)
- Boring in-pit? Let’s see…
Project located in Western Australia

- Ore derived from Channel Iron Deposit (CID)
- Waste fines cells (WFCs) located at bottom of pit excavations
- Pit floor typically exposes upper surface of Limonite-Goethite Channel (LGC) succession
- Pit sidewall characterised by alluvium successions
- Dewatering to elevations compatible with upper surface of LGC (pit floor)
- Original WFCA embankments end-tipped to RL 480 m (30 m high)
- Potential contractive nature of embankment fill necessitated remedial measures and alternative construction method
- Look at WFCA and WFCB
WFCA comprises northern and southern embankments

Northern embankment - future use an Autonomous Haul System (AHS) haul road
WFCA comprises northern and southern embankments

Northern embankment future use - an Autonomous Haul System (AHS) haul road

WFCA embankments developed in different stages:
- Stage 1 – geotechnical investigation, buttress construction as mitigation measure and embankment raise (to RL 490)
- Stage 2 – Increase size and modify geometry of northern buttress
- Stage 3 – Raise northern embankment beyond Stage 2 to form future haul road
WFCA embankment staging - summary

- 61 m
- 55 m
- 330 m

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Background (cont.)

- WFCB located to the north of WFCA
- Comprises interim and final cell
Background (cont.)

- WFCB located to the north of WFCA
- Comprises interim and final cell
- Embankment locations dictated by rate of mining
- Interim cell eventually submerged by final cell
- Waste fines being discharged via multiple spigots of WFCA northern embankment
Site characteristics

- Pit part of Paleo channel system - (CID)
- CID approximately 500 to 750 m wide and bounded by lower permeability Weeli Wolli Formation.
Site characteristics

- Pit part of Paleo channel system - (CID)
- CID approximately 300 to 500 m wide and bounded by lower permeability Weeli Wolli Formation.
- More than 80 % of CID below water table and forms an aquifer.
- Basal Clayey Conglomerate (BCC) layer lies beneath CID, which is overlain by overburden comprised of alluvial gravels (ALL).
- Groundwater moves principally within two aquifer systems at the Mine site, namely through the CID (historical drainage) and alluvial (current drainage) aquifers.
- CID and alluvial aquifers inter-connected and are recharged from infiltration generated by water flowing along the creeks.
Mining and dewatering

- Mining area and WFC within autonomous zone
- Rate of mining dictates available storage and rate of embankment advancement
- Mining location dictates waste source and type
- Personnel and equipment immediately downstream of facility
- Ongoing RAs and updating of TARPs
Mining and dewatering
Mining and dewatering

- Mining area and WFC within autonomous zone
- Rate of mining dictates available storage
- Mining location dictates waste source and type
- Personnel and equipment immediately downstream of facility
- Ongoing RA’s and updating of TARPs
- Pit actively dewatered
- Dewatering undertaken using “sacrificial” in-pit bores, in-pit sumps and ex-pit bores
- Bores decommissioned as mining progresses
- Impact of rate of ground water rebound on WFC embankment stability and seepage regime
Material characteristics – Foundation

- Conducted investigation to characterise historic waste material and underlying foundation (LGC) – part of BCC
- Drilled through waste, cased holes, probed underlying LGC and retrieved samples
- Laboratory testing campaign to estimate properties.
- Installed VWPs in foundation to check performance under embankment loading
- The LGC material highly variable, with relatively isolated lenses of clayey material encountered, typically surrounded by rock or more gravelly clays.
Material characteristics – waste fines

- Waste fines classified as a clayey Silt
- Particle SG of 3.8 and a $P_{80}$ of 75 μm.
- Waste fines deposited at RoR of 24 m/yr in WFCA
Material characteristics - embankments

- Investigation indicated fines content of embankment materials high (~25% passing 75 micron)
- End-tipped embankment materials below RL 480:
  - susceptible to static liquefaction should it become saturated
  - in a loose state
  - contractive behaviour likely in saturated portions of embankment.
- Piping assessment (Wan and Fell) indicated loosely end-tipped embankment materials likely internally unstable.
- Waste variability – some influence on waste source
Embankment design considerations

- Construction method
  - End-tipped construction method not preferred.
  - End-tipping used as first access layer onto pit floor – coarse waste
  - Changed from end-tipping to paddock dumping – massive shift in mindset!
  - Conducted field trial to simulate paddock dumping, assess node spacing, lift thickness and expected field density
  - Trial provided opportunity for mine to adapt AHS requirements.
  - Embankment zoning not possible.
  - Specify offset distances to account for longitudinal cracking.
Buttressing

To improve short term stability of historical end-tipped embankments

While end-tipped material generally unsuitable for tailings retaining earth structures, in specific context of buttressing of the embankments, end-tipping was still likely to produce improved stability conditions for existing WFC embankments.
Embankment design considerations - Buttressing

- End-tipping and progression of buttress
Embankment design considerations

- Buttressing
  - To improve short term stability of end-tipped embankments
  - While end-tipped material generally unsuitable for tailings retaining earth structures, in specific context of buttressing of the embankments, end-tipping was still likely to produce improved stability conditions for existing WFC embankments.

- Embankment staging
  - WFCA embankments raised to RL 490 – paddock dumping
  - WFCA northern buttress raise to RL 475
Embankment design consideration - staging
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- Embankment staging
  - WFCA embankments raised to RL 90 – paddock dumping
  - WFCA northern buttress raise to RL 475
  - Construction of WFCB interim embankment dependant on available storage on WFCA and rate of mining
  - WFCB interim embankment temporary – end-tipped and overfilled
  - WFCB final embankment location not finalised. Likely location to coincide with *insitu* waste block.
WFCB embankments
Embankment design considerations

- Sump levels
  - Seepage from waste fines flux through base of embankments and blasted/fractured pit floor - accumulates in sumps downstream of WFC embankments.
  - Stability analyses revealed sump water levels to be maintained below estimated target levels.
Embankment design considerations

- Equipment constraints
  - Minimum running width of 55 m
  - Fill tipped and dozed at angle of repose (1V:1.33H)
  - Trucks do not contribute much to compaction
  - Restricted access
  - Design adopted to suit
Blast assessment

- Blasting occurred immediately downstream of WFC embankments as part of mining activities.
- Appropriate limits for blast-induced vibrations were defined.
- PPV limit of 25 mm/s was recommended for WFC embankments. This PPV limit yielded offset distances between the WFC embankments and mining activities.
- Offset distances sterilise ore!
- WFCB interim embankment during construction and prior to waste fines deposition was dry and not prone to liquefaction – PPV limit of 100 mm/s applied.
- Ongoing blast monitoring conducted to refine the blast model.
Stability

- Stability analyses conducted to:
  - Estimate buttress geometry during construction and long term
  - Estimate sump trigger levels
  - Estimate VWP trigger levels
  - Estimate offset distances for steep fill angles
Seepage Analyses

- Seepage assessment conducted to:
  - Estimate seepage from WFCs
  - Estimate the location and shape of the phreatic surface for different scenarios
  - Check impact of groundwater rebound

- Assessment indicated that phreatic surface within embankment controlled by downstream sump levels

- Localised seepage expressions expected along lift interfaces and in downstream zones
Closure

- Pit to be backfilled with waste fines (WFCA and WFCB), such that no in-pit lake will form following closure.
- Close as you go!
Conclusions

- During this project, a multitude of simultaneous technical studies and analyses were carried out to support embankment raises and ongoing development of the WFCs.
- The designs had to take cognisance of equipment constraints, ongoing blasting and mining, de-watering and forward planning to create ongoing fines storage while at the same time maintaining a safe and stable structure.
- WFCA has since been successfully decommissioned while WFCB is currently in operation.
- Raising of the WFCB interim embankment and mining to the north of the interim embankment are currently ongoing while planning for the construction of the WFCB final embankment has been completed.
Questions??