Surface water solutions for effective mining closures

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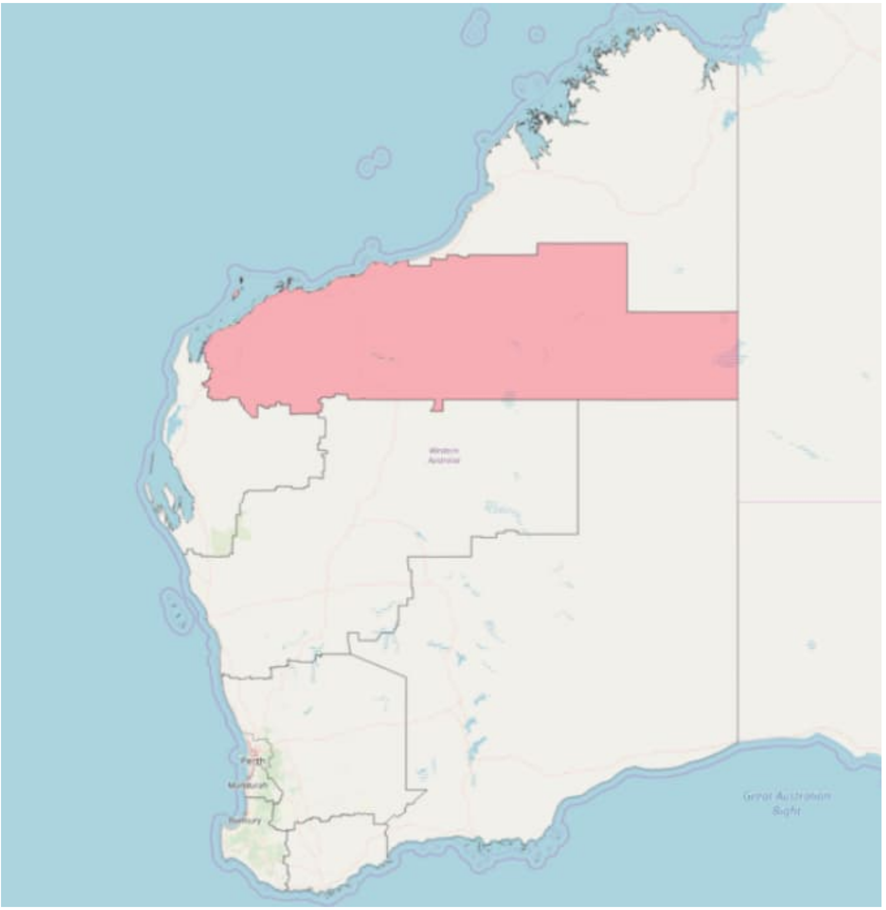
Overview of Talk

1. Why we need to divert creeks and rivers
2. How BHP Iron Ore thinks about diversions which are operational only Vs closure
3. BHP's efforts aims to minimise reduction in catchment areas
4. Concept of creek capture
5. Selection of design event
6. Design Event Vs Design Life
7. Design considerations including longitudinal slopes and revegetation
8. Example of a large diversion and the thinking that goes with it.

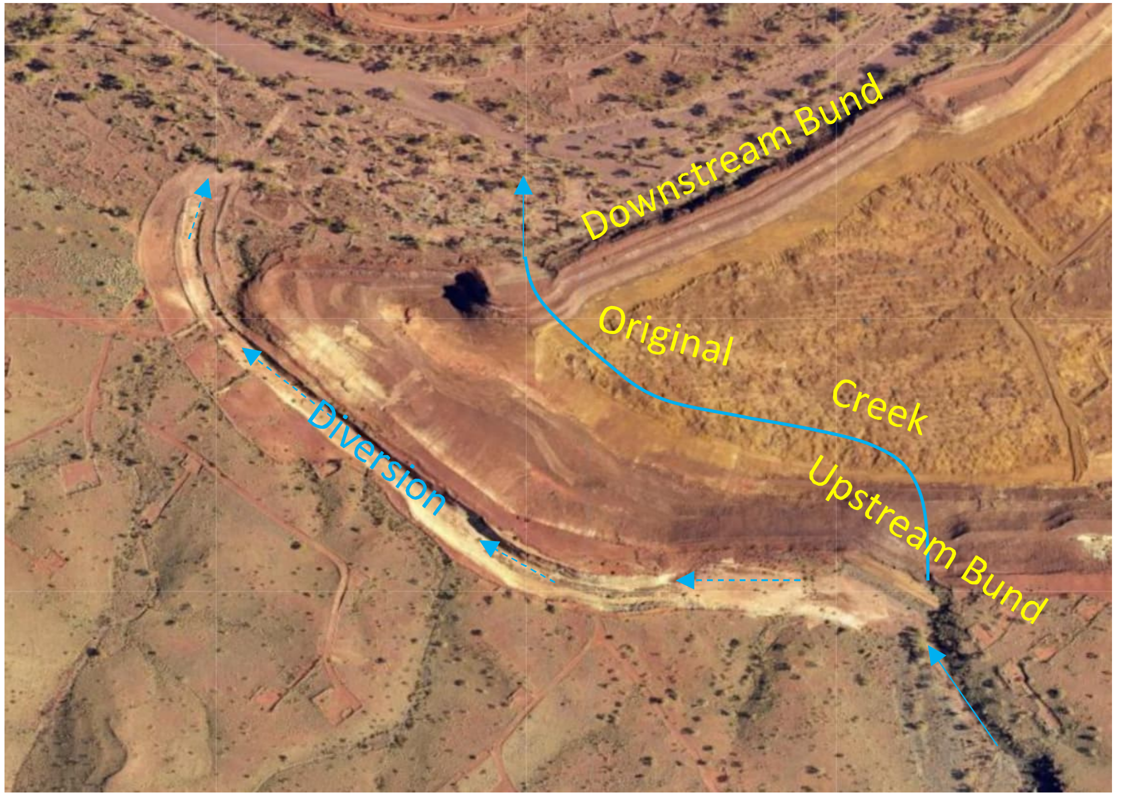
Pilbara Focus

1. World's largest Iron Ore producing region
2. Elevation typically ranges from 500-1000m ASL
3. Rainfall ~350mm year
4. Hard rock environment
5. Typically 2-3 streamflow events per year



1. Why do we need to divert creeks?

Creek Diversions are required to provide access to resources which are otherwise constrained



But sometimes its not worth it

- Innawally Pool
- Approval to mine largely in place
- In 2018 BHP decided not to mine this area due to environmental and heritage values
- NPV reduction of $70M

2. Operational Vs Closure Designs

Operational Designs

Engineering Structures - Aim is simply to avoid flooding of pit and move water downstream

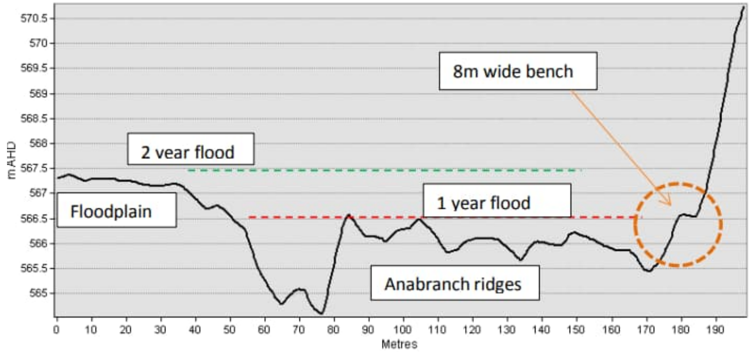
Less consideration of geomorphology, ecology

2. Operational Vs Closure Designs

Closure Designs-Geomorphology input required

- Slope
- Stream power
- Sediment sizing and movement
- Lateral migration
- Creek capture
- Shallow aquifer

Get the physical properties correct and the ecology will come



3. Catchment Loss

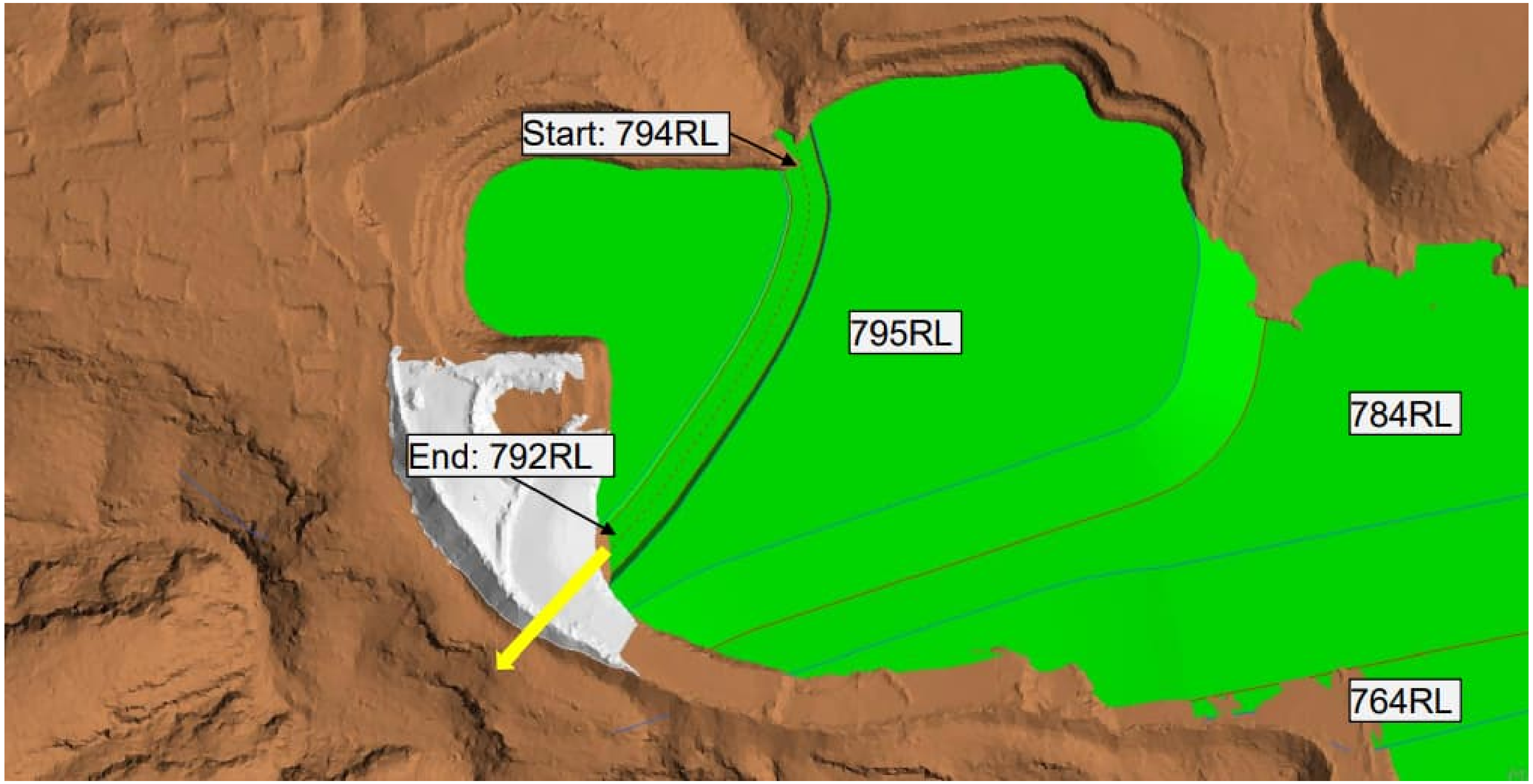
One of the largest post closure impacts through mining is catchment loss

Could be creek capture, but also cumulative impact of small losses

Impact	BHP IO Approach to Reduce Impact
Creek Capture	Backfill at risk pits to above creek invert Use spillways on competent rock to limit extreme flows
Open Pits	Often unavoidable
Ex-pit OSAs	To maximise stability, designed not to shed water. Avoided where possible by maximising in-pit OSAs
Blocking of minor creeks by OSAs	Leave gaps in OSAs to allow drainage to pass through Provide flow path within OSA
Interception of minor creeks by Pits	Divert creek around pit Re-establish creek over backfilled pit

3. Efforts to Reduce Catchment Loss : Landbridge (30km^2)

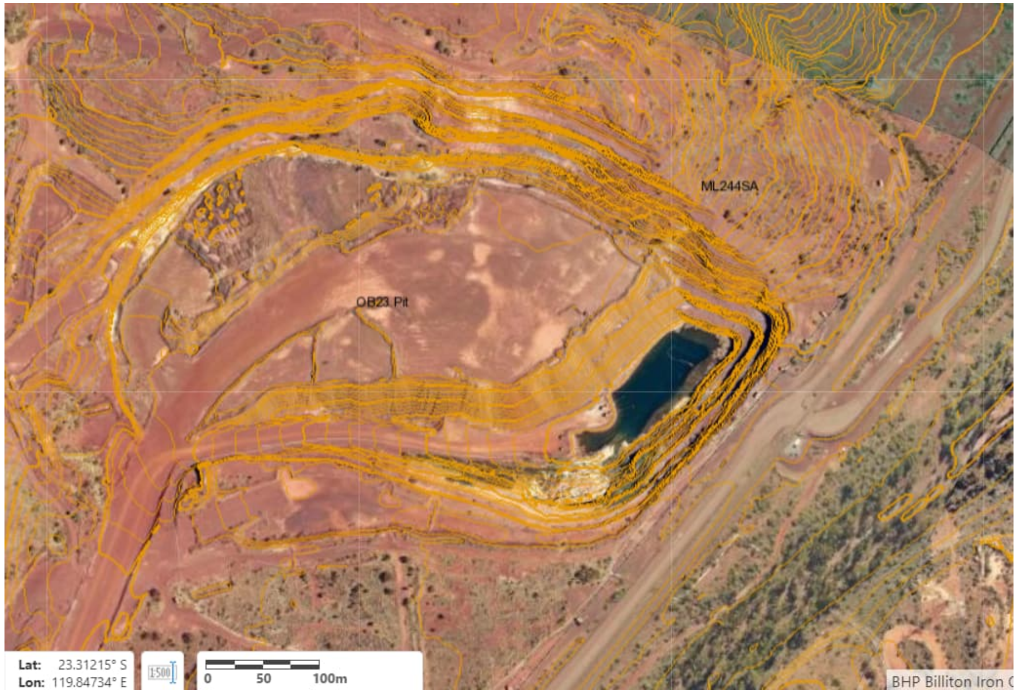
3. Efforts to Reduce Catchment Loss : Creek through OSA (0.5km^2)



4. Creek Capture

- Risk that floods overtop bunds
- Result in very high velocity down the pit face
- Resultant head cut propagates back to the creek thalweg

  - Capturing the creek



- Orebody 23 Pit to be filled above the thalweg level to remove risk (partially complete)

5. Selection of Closure Design Event

- Risk Based Approach
- What is the impact both within the stream and to downstream receptor?
- If an event above the design life occurs, what is the impact? (Creek capture Vs erosion)

Catchment Size	Risk of Creek Capture/Environmental Sensitivity	Selected Level of Flood Immunity
Small (<10km^2)	Low	100 year ARI
Medium (10-100km^2)	Low	500 year ARI
Medium (10-100km^2)	Moderate	1,000 year ARI
Large (~1,000km^2)	High	10,000 year ARI

6. Design Event Vs Design Life. Importance of Quality Control

- There is no point constructing a bund to the elevation of a 10,000 year ARI event if it will be eroded away within 100 years

- 1,000mm high bund. Not constructed to engineering specification
- Piping failure after water ponded 100mm high upstream

6. Design Event Vs Design Life. Importance of Quality Control

Particle size distribution, compaction techniques and verification are critical

Too Fine (6 Years Old).
Will need rebuilding

Localised pockets which were too fine
(Inadequate PSD testing)

6. Design Event Vs Design Life. Importance of Quality Control

Compaction unsuccessful due to low fines content

Embankment in Excellent Condition
(15 years old)

7. Design Consideration – Slope

Slopes need to permit sediment deposition.

No Sediments = No Water Retention/ substrate = No vegetation

Yandi Slims Creek Upstream = 0.2%

Evolving to a healthy ecosystem

7. Design Consideration – Slope

Yandi W4 West Diversion Upstream Section – 0.4%

High Energy, but healthy

7. Design Consideration – Slope

Yandi Slims Creek Downstream 0.6% -

Some sediment and vegetation but too Steep

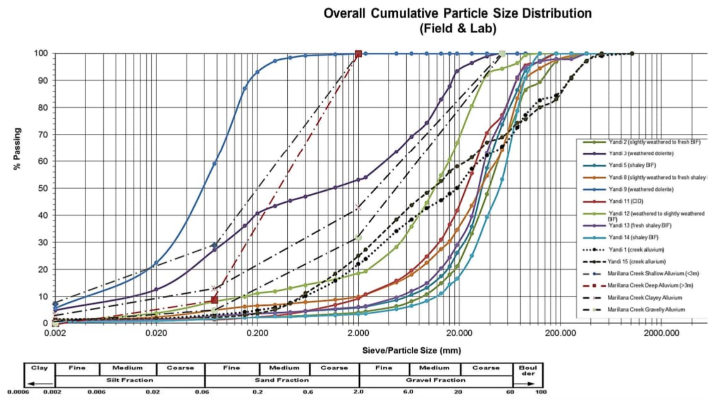
7. Design Consideration – Slope

Yandi W4 West Downstream 0.8%

Too Steep!!

7. Design Consideration – Revegetation

- Vegetation needs soil and water
- Can be achieved via overblasting and importing alluvials
- Need a mix of coarse material (storage) and fine material (matric-pressure)
- Sediment sizing needs to match hydraulic conditions
- Wide range of discipline experts needed



8. Example of Large Diversion Marillana Creek : Catchment 1,500km^2.

Diversion design led by Advisian, Hydrogeology by AQ2

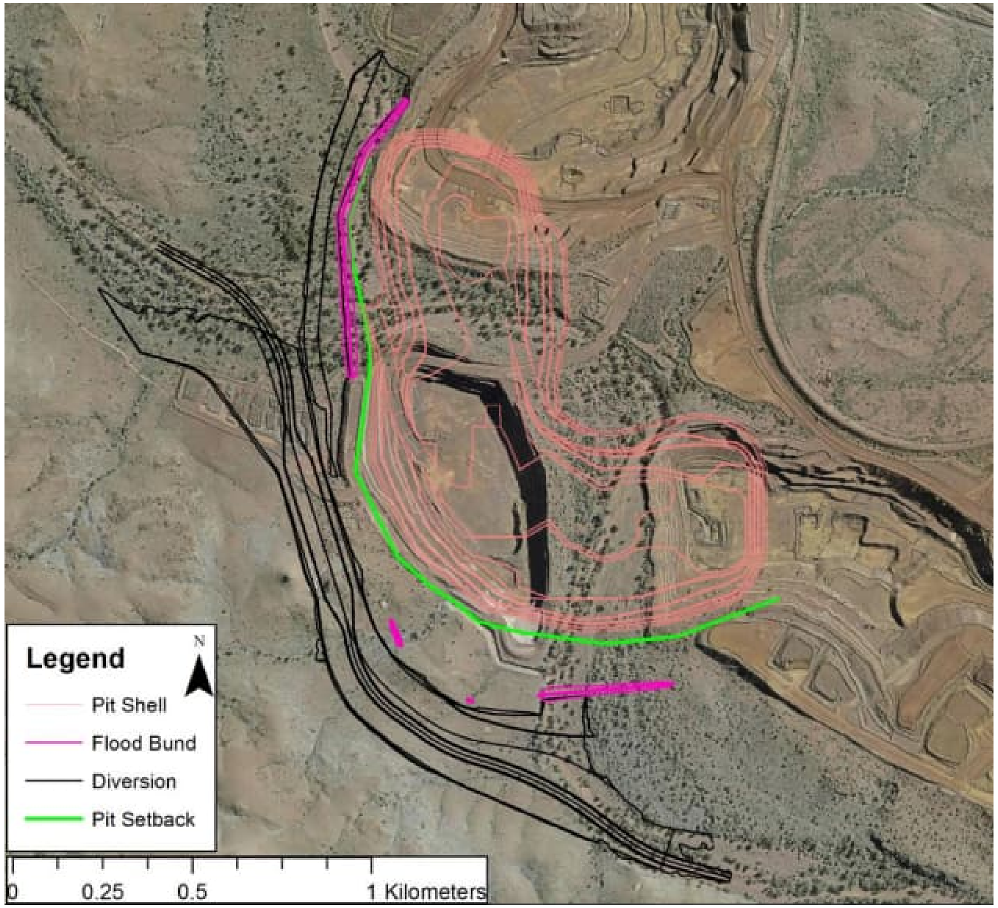
Team of technical experts included:

- Hydrologists
- Hydraulic Modellers
- Geomorphologists
- Civil Engineers
- Geotechnical Engineers
- Hydrogeologists
- Ecologists

Completed 2018. Closure Solution.

Features Include:

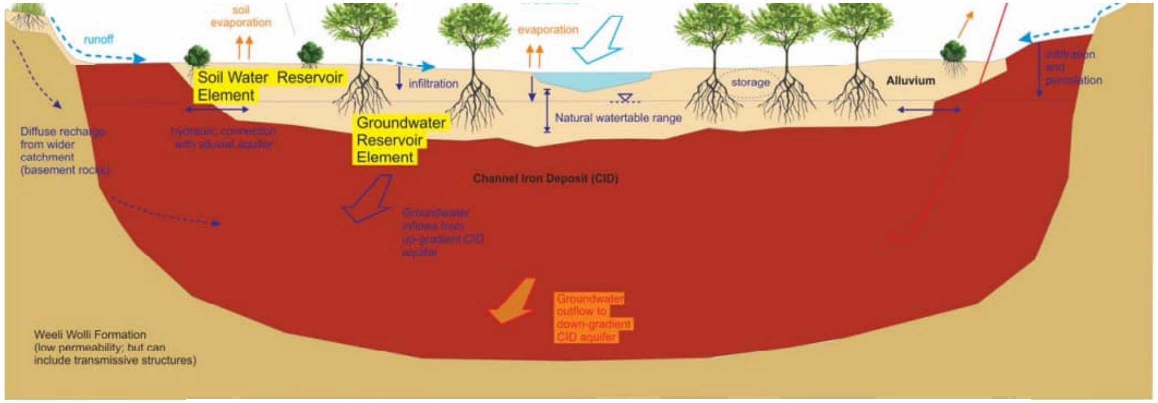
- Roughness Elements
- Overblast
- Imported Alluvium
- Incised and Anabranching Sections

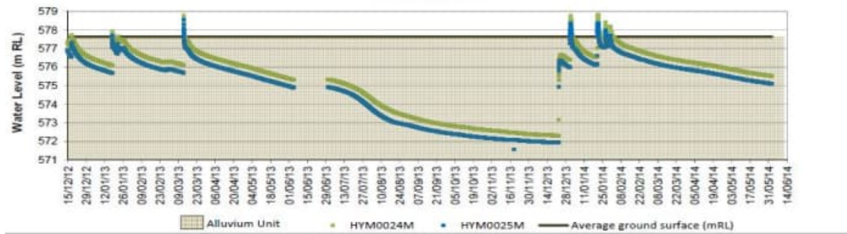


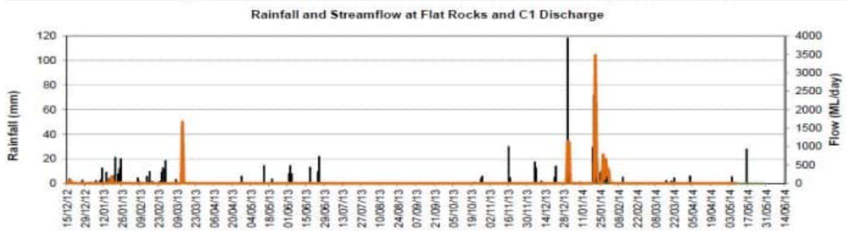
8. Example of Large Diversion: Marillana Creek

Shallow Aquifer

- How does the existing shallow alluvial aquifer work and how does it connect to the regional aquifer?
- What are the Moisture retention curves of existing materials?
- What are the long term hydrographs in the alluvials? Reaction to streamflow
- What is the existing ecohydrology? tree species/density/water requirements
- Stream Flow/ Drought sequences
- How does the soil moisture recharge (Vertical Vs Horizontal)
- Geomorphology – How will the creek move?







8. Example of Large Diversion: Marillana Creek

Shallow Aquifer

- Designed to withstand 6 year drought period
- Depth of 6m
- 3m overblasted materials left in situ
- 3m of alluvial material recovered from bypassed creek

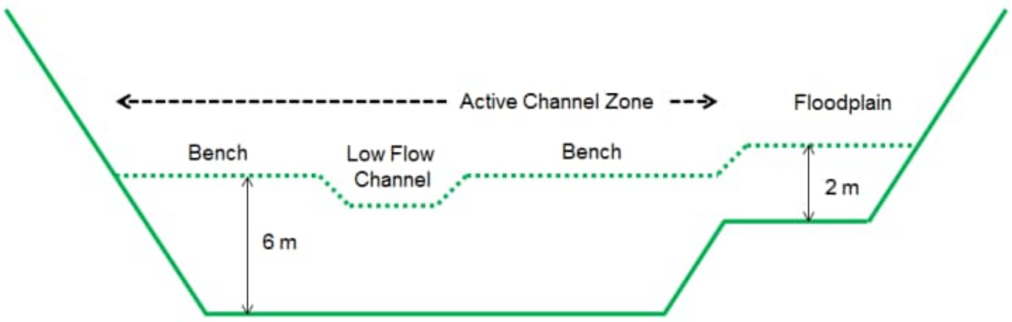


Figure 11: Anabranching reach – aquifer cross-section

8. Example of Large Diversion: Marillana Creek

After Year 1

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8. Example of Large Diversion : Marillana Creek

After Year 3

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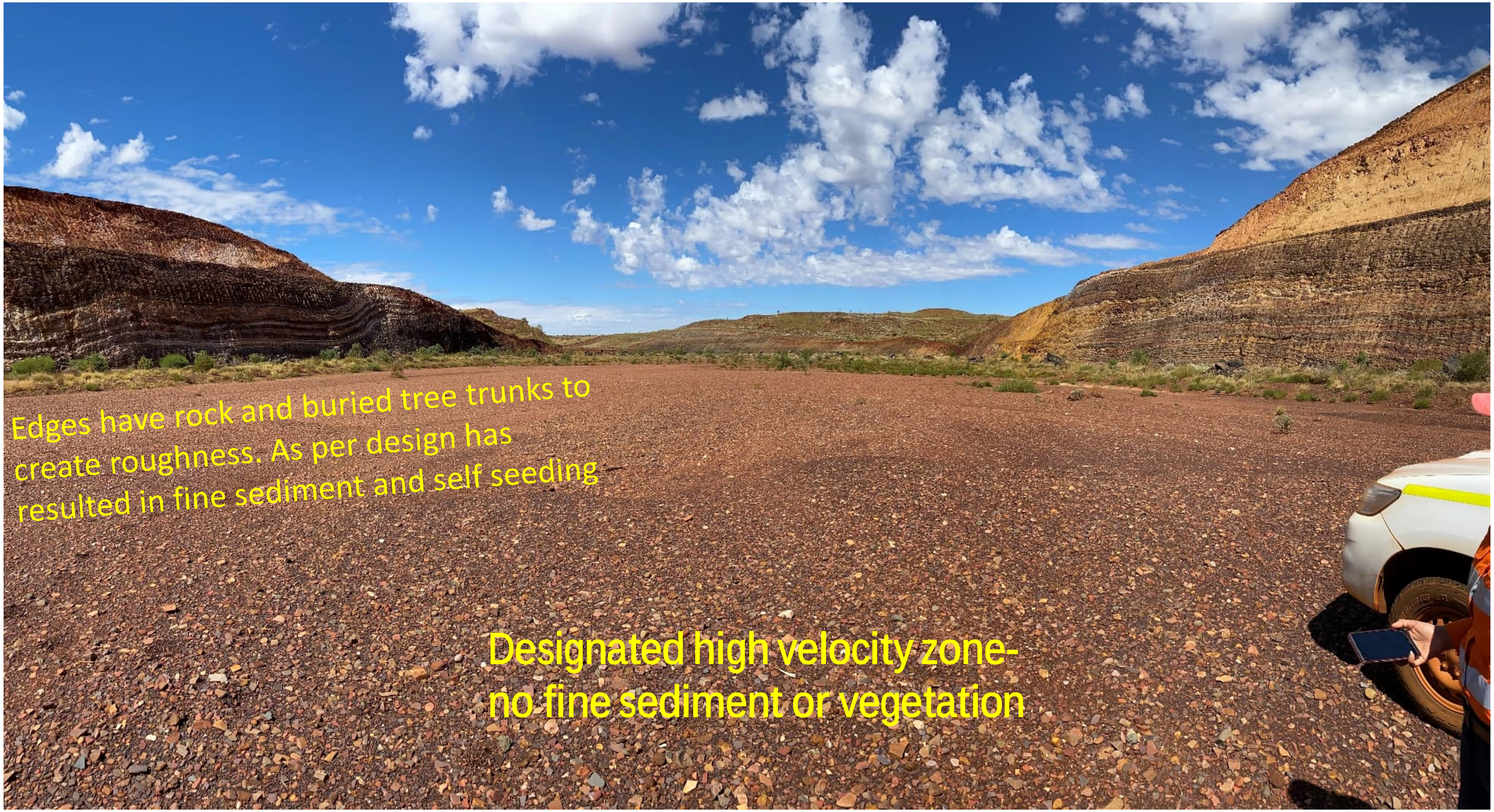


8. Example of Large Diversion : Marillana Creek

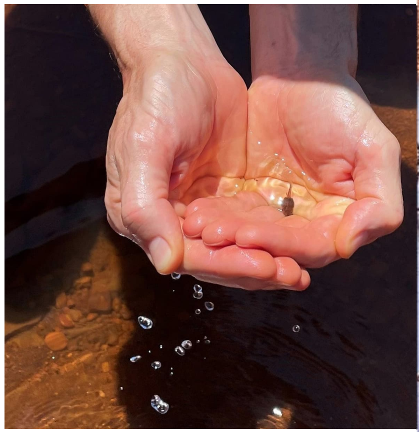
Island of vegetation establishing in lee of placed boulders.

Will further encourage geomorphological diversity

8. Example of Large Diversion : Marillana Creek

Life Returning:

- Variety of invertebrates in water
- Tadpoles in scourholes around trees
- Red Necked Stint (special guest)



8. Example of Large Diversion : Marillana Creek

What does a 4 year old river look like?