BHP

Western Ridge: Nankunya (Afghan Springs) Monitoring Program

January 2023

Document Amendment Record

Version	Description of Version	Key changes	Issue date
Draft v1	Proposed monitoring program provided to KNAC for information and review	New document	13/9/2021
Draft v1.1	Revised document provided to KNAC for information and review	Updated to include latest monitoring information and hydrological conceptualisation	14/10/2022
Version 2	Version submitted to the EPA	Update to wording in Table 2 regarding potential installation of signage.	13/01/2023

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1 Monitoring program purpose

BHP proposes to implement a water monitoring program for Nankunya (Afghan Springs) (Figure 1). The purpose of the monitoring program is to refine the understanding of the natural variability of the Afghan Springs system, to support the management of cultural heritage and biodiversity values of Afghan Springs.

BHP has identified Nankunya as a heritage and environmental value relevant to the Newman Hub (Western Ridge) Derived Proposal (the Proposal) (BHP 2021a). While BHP's validation of the Inland Waters environmental factor for the Proposal confirms that it is unlikely that there will be any impacts on values at Nankunya from approved dewatering at BHP's operating OB29/30/35 mine or proposed dewatering at Western Ridge, given the high cultural heritage and biodiversity values associated with this location, BHP has begun the implementation of this monitoring program. This program also includes dust monitoring, in response to a request from Nyiyaparli representatives. BHP consulted with the Nyiyaparli Traditional Owners regarding the implementation of the monitoring program (EWS 2021).

2 Survey and study findings

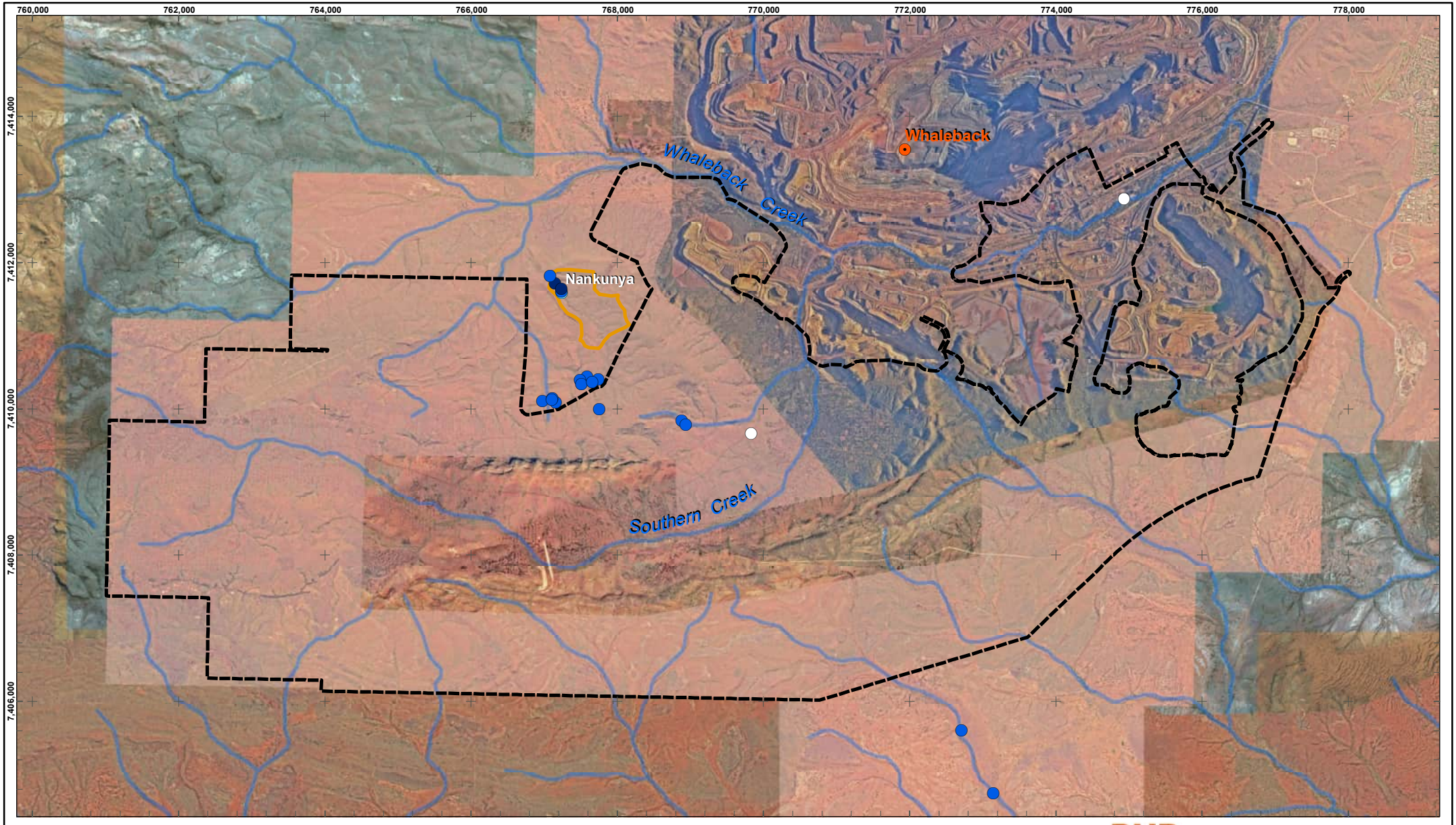
Table 1 summarises the relevant surveys and studies undertaken in relation to Nankunya to date, including findings and key assumptions and uncertainties.

Table 1: Survey and study findings

Surveys and studies	Survey and study findings	Key assumptions and uncertainties
The surveys and studies used to develop this monitoring plan are listed below:[1] • *Nankunya – Surface Water Monitoring 2022* (BHP 2022a, in prep) • *Triennial Aquifer Review 2022* (BHP 2022b) • *Afghan Springs Desktop and Hydrogeological Conceptualisation* (BHP 2021b). • *Western Ridge and OB29/30/35 Detailed Hydrogeological Assessment* (BHP 2021c) • *FY21 Afghan Springs ENV Phase 1 Hydrogeological Drilling Report* (BHP 2021d) • *Stable hydrogen, oxygen, and sulphur isotope and hydrochemical compositions of water – Afghan Spring, sampling on 12/10/2020* (Skrzypek 2020) • *Bills Hill and Xanadu Field Mapping Report FY14* (BHP 2014) • *Bills Hill and Xanadu Drilling and Modelling Report 2015* (BHP 2015) • *Mt Helen and Bill's Hill Geological Modelling Report 2018* (BHP 2018) • *Western Ridge: Afghan Spring Baseline Aquatic Ecosystem Survey* (Biologic 2021a) • *Western Ridge Single Season Detailed Flora and Vegetation Survey* (Biologic 2021b).	Key findings from the surveys and studies are summarised below: • Nankunya (Afghan Springs) comprises a collection of pools and seeps located in a gorge north of the Western Ridge Development Envelope, mapped by BHP during surveys in 2019 (Figure 1 and Figure 4). BHP commenced investigations to understand the hydrology and hydrogeology of the Afghan Spring system in March 2020. • Nankunya is understood to be the traditional Nyiyaparli name for the gorge and pools. Afghan Springs is the informal non-Indigenous name for the gorge and pools. **Hydrogeological setting** • Nankunya comprises a number of pools located within a northwest/southeast oriented, narrow gorge, deeply incised into elevated Hamersley Group metasediments. The individual water feature commonly referred to as Afghan Spring (Pool 1) is located at the base of the cliff that defines the head of the gorge (i.e. the extent of deep erosional incision). The gorge extends for approximately 280 m from the head of the gorge to the northern extent of the gorge (Figure 4). • The pools range in elevation from approximately 619 mRL (WB94 datum) to 648 m within the gorge. The elevation of Pool 6 (above the cliff) is approximately 659 mRL. • The drilling program confirmed that the pools are located in a fractured rock aquifer setting within unmineralised Brockman Iron Formation (Joffre Member and the Mount Whaleback Shale Member). The Mount Whaleback Shale Member is a known aquitard elsewhere. The lower groundwater level in the Dales Gorge Member compared to the groundwater levels in the Joffre Member indicates that the Mt Whaleback Shale Member acts as an aquitard (flow barrier) to downward groundwater flow in the area (Figure 2). • The hydraulic connection along bedding, between the proposed Western Ridge pits within the highly permeable orebody aquifer on the southern limb and hinge zone of the Western Ridge syncline, and the unmineralised Joffre Member sequence on the northern limb where the pools are located, is likely to be poor due to the change from mineralised (high permeability) to unmineralised (low permeability) material. • The rate of rainfall infiltration over the local catchment exceeds the rate of leakage through the Mount Whaleback Shale Member and other flow barriers, allowing groundwater levels in the fractured rock aquifer to mound. The level of mounding is constrained locally by the presence of the discharge location at the base of a large topographic change (i.e. the gorge). The groundwater mounding is understood to result in a perched aquifer. • The groundwater elevation of the perched aquifer of Nankunya (in the Joffre Member) is much higher than the groundwater level in the regional (Dales Gorge Member) aquifer in the vicinity of Nankunya. Afghan Spring (Pool 1) is located at the base of a major change in topographic level (base of cliff) where the local, perched groundwater can discharge. The elevation of Afghan Spring (Pool 1) is approximately 640 mRL, approximately 70 m above the regional aquifer system groundwater level (570 mRL) (Figure 2). • Dewatering has occurred at the Orebody (OB) 29/30/35 mine (currently at OB35 located approximately 4 km southwest of Nankunya) since 2016 and the groundwater level in the OB35 pit has declined by approximately 40 m. However, the groundwater level in the regional aquifer system (between OB35 and Nankunya) which is hydraulically isolated from the orebody aquifer, has remained stable at approximately 573 m (BHP 2022b), similar to the regional aquifer system groundwater level in the vicinity of Nankunya (570 m). **Pool hydrology and water quality** The following information is based on the analysis of climate, creek flow and pool data from January 2022 to September 2022 (BHP 2022a): • Creek flow at the Creek Sampling Point ((Figure 4) correlates with rainfall events, with flow generated following rainfall of approximately 10 mm. • The pools are shallow and generally fluctuate between dry or near dry conditions and a depth of approximately 0.2 m, with the lowest levels recorded in Pool 5 (less than 0.12 m). The pool water levels increased after the largest recorded rainfall event (23 mm) within the monitoring period to up to 0.36 m depth but receded within days. • While large rainfall events appear to have a short-lived influence on pool water levels, the main influence on pool water levels appears to be temperature (and evaporation) with generally lower water levels observed during the hotter, wetter months and higher water levels in the cooler, drier months. • The climate, creek flow and pool data indicate that the pools are supported by a permanent groundwater source as higher pool water levels are observed during the cooler, drier months. However, due to the effects of temperature and evaporation, dry or near dry pool conditions have been observed during warmer months, suggesting that the pools are semi-permanent. BHP will continue monitoring to confirm the permanence and seasonal variation of the pools. The following information was obtained from site visits and investigations conducted in 2020/2021: • The ephemeral creek line within the gorge is poorly defined due to the presence of boulders, talus, colluvium and vegetation, except where it flows over outcrop. Numerous damp patches were observed in patches of humus/soil visible between the talus and colluvium on the gorge floor. • The largest pool (Pool 1) measured approximately 2.5 m in diameter in March 2020, following high rainfall in February 2020. At the time of the March site visit the pool appeared to be fed by water dripping down through the sedges on the headwall cliff behind the pool, with minor contributions from a cave located approximately 10 m east of the pool. Mineral coatings observed on the cave walls indicate a substantial duration of seepage discharge. • The extent of the pools is likely to change seasonally. The water levels in the pools will be dependent on antecedent climatic conditions and groundwater levels in the fractured rock aquifer, which governs the amount of discharge from the local aquifer. • The pool features in the colluvium/alluvium along the base of the gorge reflect saturated conditions in those materials and will be present as long as storage is replenished by groundwater discharge into the gorge and occasional surface water flow events.	**Assumptions** • The pools and seeps associated with Nankunya are supported by a combination of surface water runoff, infiltration of surface water to a local, perched, fractured rock aquifer (Figure 3), and subsequent discharge of water from that aquifer at topographic low points along the creek line. • Nankunya is unlikely to be affected by drawdown from the current dewatering at OB29/30/35 or the proposed dewatering at Western Ridge as the local aquifer system, which is understood to support the pools, is hydraulically disconnected from the regional and orebody aquifer system. • Water quality data collected to date is representative of both the surface water pools and the groundwater system (monitoring bore data). **Uncertainties** • Understanding of the natural variability of the hydrologic regime of Nankunya - persistence of pools and seeps, particularly during dry extended periods (drought conditions). • Seasonal changes in surface water (pools) and groundwater chemistry (both wet and dry seasons). • Surface water flow characteristics (volumes and duration) of the creek at Nankunya.

[1] Note that these studies were undertaken prior to identification of the traditional Nyiyaparli name for the gorge and pools referred to as Afghan Springs. Where possible, the Nyiyaparli name, Nankunya is now used.

Surveys and studies	Survey and study findings	Key assumptions and uncertainties
	• The pools are potentially semi-permanent to permanent water features, although there is currently insufficient time series data and site specific hydrological and hydrogeological data to establish the permanence of the pools. • Four rounds of water quality sampling were undertaken at Nankunya between March 2020 and May 2021 (March 2020, October 2020, February 2021 and April/May 2021), for measured field parameters, comprehensive analytical suite and isotype composition. • Salinity concentrations and pH are generally higher in the groundwater samples (average pH of 7.9 and salinity of 459 mg/L) compared to the pools (average pH of 7.4 and salinity of 278 mg/L). • The isotope sampling indicates that Pools 1 to 5 likely contain groundwater, while Pool 6 primarily contained rainwater or shallow alluvial water and is disconnected from groundwater input. • The distinctly different chemical signatures of the water chemistry in the pools and bores in the regional aquifer system further supports the conclusion that the local perched aquifer system that supports Nankunya is disconnected from the regional aquifer system. **Pool vegetation** • No phreatophytic tree species were observed during the vegetation survey. Phreatophytic species are dependent on groundwater and are therefore an indicator of permanent groundwater. However, the shallow/skeletal soils most likely hinder the growth of phreatophytic tree species. • Numerous mesophytic (terrestrial plants that need water) and hydrophytic (plants adapted to aquatic environments) shrubs and macrophytes (aquatic plants) were observed during the surveys. **Air quality** • At the time off preparation of this monitoring program, no dust deposition data is available for Nankunya. Implementation of dust deposition monitoring at Nankunya is intended to establish a baseline of ambient dust levels prior to implementation of the Proposal and to monitor during construction and at least the first two years of operation.	



Water feature
- Artificial
- Permanent Seep
- Temporary Seep
- Temporary Surface Pool
- BHP operations
- Nankunya catchment

Development Envelope
Waterways

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0 0.8 1.6 2.4 3.2 4
KILOMETRES

GDA 1994 MGA ZONE 50

BHP

PUBLIC

WESTERN RIDGE

Nankunya location

PLANNING & STANDARDS - IRON ORE

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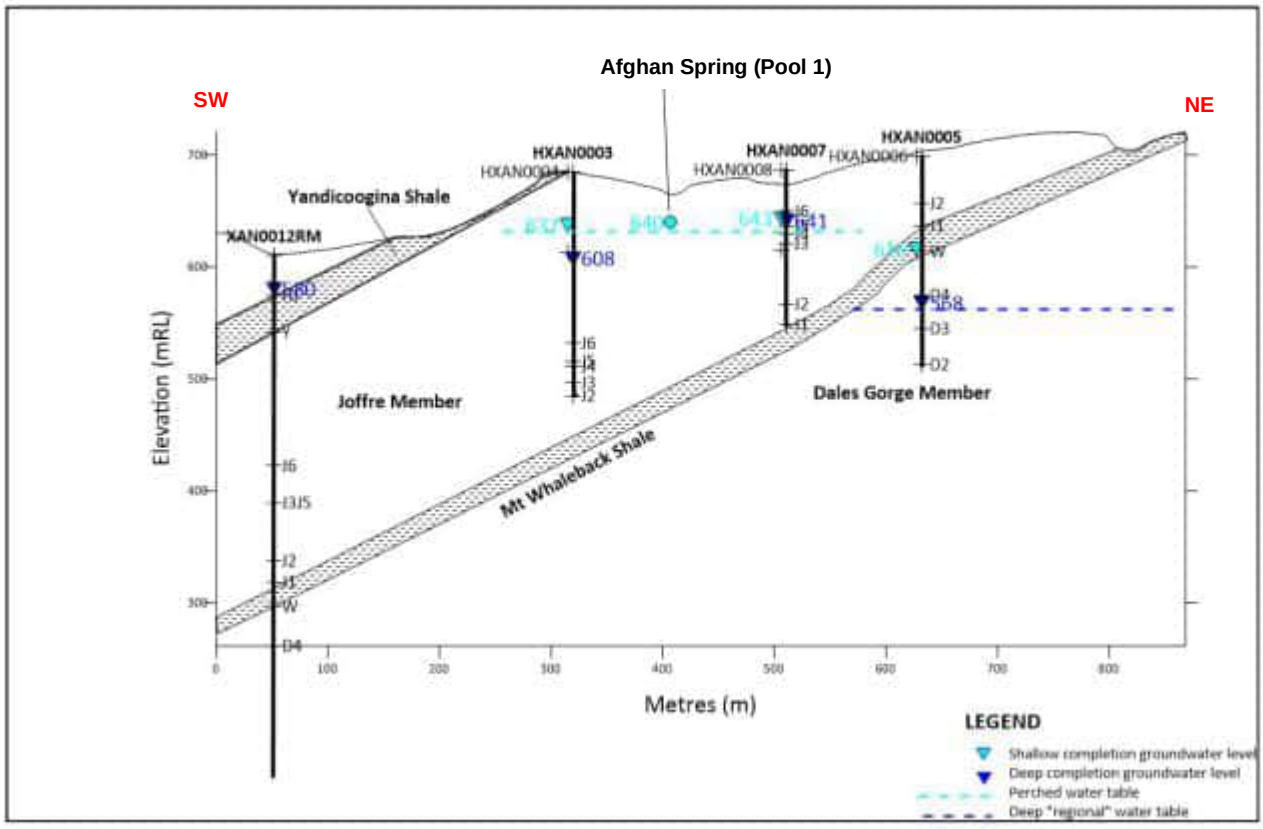


Note: groundwater levels from 15/4/2021.

Figure 2: Nankunya (Afghan Springs) cross-section

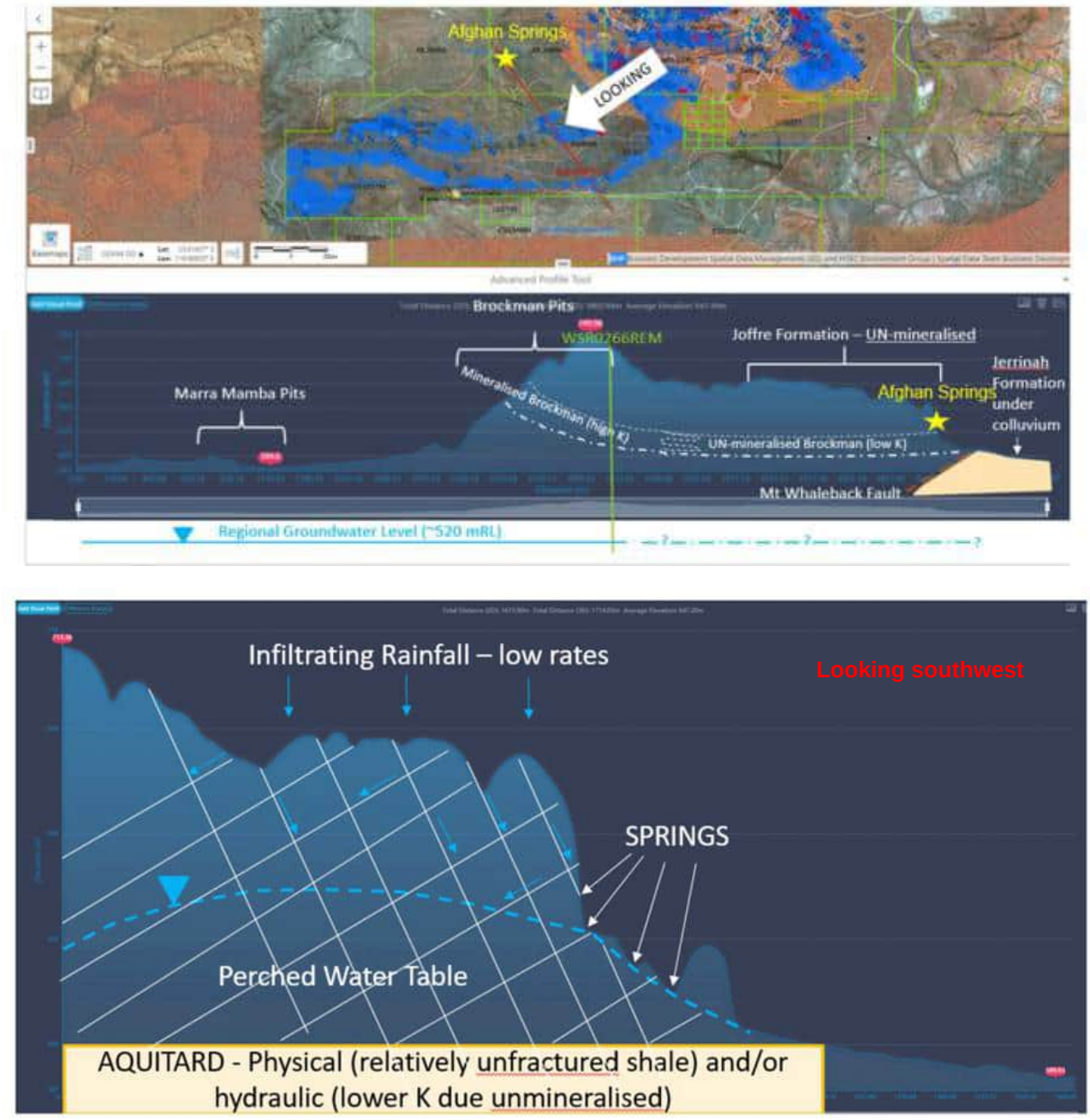


Figure 3: Nankunya (Afghan Springs) aquifer conceptualisation

3 Monitoring program detail

3.1 Monitoring approach

Monitoring will include the local Nankunya area (Figure 4) and the regional area between Nankunya and existing mining operations (Orebody 35) and proposed mining operations (Western Ridge) (Figure 5).

Monitoring initially be undertaken at a higher frequency (nominally for 2-3 years) prior to implementation of the Proposal, to better understand the natural variability of the hydrologic regime of the system. After this period, BHP will review the monitoring approach and frequency, and reduce the frequency of monitoring, if appropriate and update the monitoring program if required.

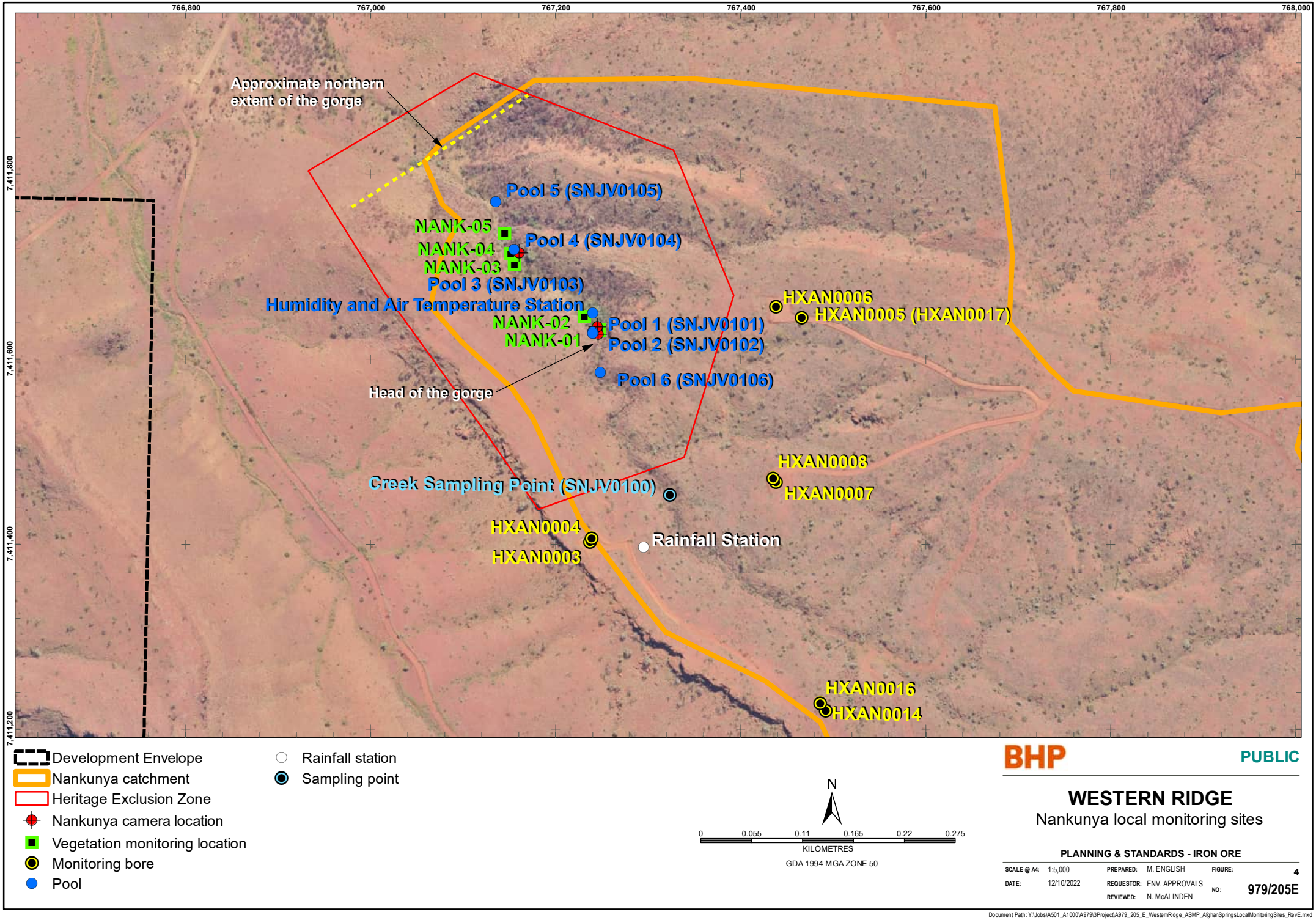
In addition to the three site visits to Nankunya completed since March 2020 to manually obtain pool data, BHP has also started monitoring groundwater levels in Nankunya monitoring bores (Figure 4).

BHP will also continue to monitor the wider Newman hub area including Western Ridge and Whaleback (using existing and/or new bores) to refine the conceptual model, validate the understanding of groundwater flow, storage and permeability values assigned to stratigraphic units and the degree of connection between orebodies and with the regional aquifer.

Table 2: Nankunya monitoring details

Parameter to be measured	Limitations	Site Name / Site Reference	Frequency	Monitoring rationale/detail
Climate: • Rainfall • Humidity and air temperature	• Telemetry system relies on cellular or satellite connection to transmit data • Solar exposure not optimal due to surrounding area (rock faces, gorge etc)	Rainfall: Afghan Springs Rainfall (Figure 4) Humidity and air temperature: Additional Climate Station at Pool 3 (SNJV0103) (Figure 4)	Continuous data: • Telemetered automatic data logger - remote access to data through remote data portal	Pools are partly supported by rainfall, either direct infiltration and/or from seepage into the local perched aquifer that supports Afghan Springs. Climate data (rainfall, humidity, temperature) is required to correlate any changes in the hydrologic regime of the system (e.g. changes in surface water flow, pool water levels and water quality, vegetation condition). The rainfall station (Afghan Springs Rainfall), including tipping bucket rain gauge, was installed in December 2021 above the gorge in high open ground near the surface water gauging station for optimum correlation (particularly for interpolating flow records if there are gaps in the flow record). The humidity and air temperature station (Additional Climate Station) was installed in the gorge (at Afghan Springs Pool 3) in December 2021, for optimum correlation with pool water levels.
Surface water flow	Telemetry system relies on cellular or satellite connection to transmit data	Creek Sampling Point (SNJV0100) (Figure 4)	Continuous data: • Telemetered automatic data logger - remote access to data through remote data portal	Pools are understood to be partly supported by surface water flow. Monitoring of surface water flow volumes and duration in the creek line upstream of the gorge will help BHP understand the variability in flows and the relative contribution of surface water to the pools. The surface water gauging station (Creek Sampling Point) was installed in November 2021, in the creek line upstream of the gorge, outside the boundary of heritage site, near the rainfall station. A pressure transducer was installed in the creek and a solar panel and logger/telemetry unit mounted on a tree out of the flood (and shade) zone. The level data is available continuously from the remote data portal. A 2D hydraulic model is used to produce a rating curve to convert the measured depth (m) to flow (m^3/s).
Pools • Presence/absence • Water levels • Water temperature • Water quality • Pool condition	Access: • Difficult access. Pools are located in a narrow gorge and the terrain is steep and rocky	Pools (Figure 4): • Pool 1 (SNJV0101) • Pool 2 (SNJV0102) • Pool 3 (SNJV0103) • Pool 4 (SNJV0104) • Pool 5 (SNJV0105) • Pool 6 (SNJV0106) Photo points - TBC Reference site – TBC, if required	Continuous data - pool levels and water temperature: • Telemetered automatic data logger - remote access to data through remote data portal Quarterly: • Pool characteristics (width, length, depth) • Pool water quality • Visual monitoring of pool condition	Initial frequent monitoring (quarterly) of pool characteristics and pool water chemistry (comprehensive analytical suite) is required for a period long enough (2-3 years) to understand the natural variability of pools in the gorge, e.g. presence/absence of mapped pools, identification of new pools and persistence of pools - whether they are temporary after rainfall, semi-permanent (change in extent seasonally) or permanent. The focus of the monitoring is on the mapped Pools 1 to 6 as these have been identified during previous site visits. If BHP identifies any additional pools or changes to the identified pools during site visits, BHP review whether there needs to be any changes to the pools selected for monitoring. Monitoring units were installed at all pools except Pool 6 in December 2021 (due to access limitations). Pool 6 was installed in January 2022. The pool data will be analysed to understand correlations with climate, including antecedent climatic conditions, to help explain any changes in the pools (i.e due to rainfall, temperature/evaporation and/or groundwater levels). Sampling of water quality (chemistry) will initially include the comprehensive analytical suite (excluding isotypes) i(approximately1-2 years) to understand seasonal variation, then will focus on key field parameters (pH, salinity, temperature, turbidity etc.). Quarterly visual monitoring and development of a photographic record (using high resolution camera) of the condition of the pools (e.g. turbidity, presence of algae etc.) will support the data obtained on pool characteristics and water quality. Subject to Traditional Owner consent and input, photo points will be located at key locations including Pool 1 (largest pool) and an overhang situated approximately 10 m east of Pool 1 where a seep and dripping water is evident. If a reference site is required, BHP will nominate a reference site following input from biodiversity consultants on an appropriate reference site (see also Pool vegetation).
Pool vegetation (emergent vegetation): • Species richness • Percent cover	Access - limitations as for pools. Emergent vegetation - is dynamic.	Vegetation quadrats and photo points (Figure 4): • Nankunya-01 • Nankunya-02 • Nankunya-03 • Nankunya-04 • Nankunya-05 Remote camera locations (Figure 4) Reference site - TBC if required	Biannual quadrat monitoring for 2 years Photos from high resolution camera - frequency TBC Photos from remote camera - hourly	Vegetation monitoring (quadrat and photographic) combined with data from the pool monitoring and the groundwater monitoring should enable pool / groundwater levels and vegetation condition to be correlated to help understand the cause or contributing factors (natural or otherwise) of any changes in the Nankunya system. Five 10 x 10m riparian vegetation monitoring quadrats were established in May 2022. Photo points were established at each corner of each quadrat. The quadrats have been set up to monitor emergent macrophyte vegetation (species richness and percent cover). The photo points have been set up to develop a photographic record (botanist to collect photos using high resolution camera at same time as quadrat monitoring). The percentage of cover alive and dead can provide a metric of vegetation health and together with the photographic record will provide context for any changes. BHP has also installed 4 remote cameras at 3 locations, 2 of which will be 'live' monitoring sites. The cameras are battery powered and are programmed to take images every hour from the time they were installed. The advantage of remote cameras is that they provide a more frequent record, whilst minimising the need for physical access to a monitoring location and can also provide an early indication of changes to vegetation and pools. The limitation with emergent vegetation is that it is dynamic (isn't static like trees), e.g. a flood could wash all the emergent vegetation away. The record from the photo points together with the surface water flow record from the gauging station should be able to contextualize this.

Parameter to be measured	Limitations	Site Name / Site Reference	Frequency	Monitoring rationale/detail
				The advantage of emergent vegetation is that it will be the first to decline if pool levels decline, so although there will be a lag if there is a decline in pool levels, it is a sensitive indicator.
Groundwater • Groundwater levels • Groundwater quality	Relies on hydrogeological conceptualisation as to where best (location/depth) to drill representative bores	Local aquifer (Figure 4): • Shallow monitoring bores: HXAN0004M, HXAN0006M HXAN005M (shallow VWP installations) and HXAN0008M • Deep monitoring bores: HXAN003M, HXAN005M (two deep VWP installations), HXAN007M, HXAN0017M (the monitoring bore replacing HXAN0005M) Regional aquifer - between Nankunya, Orebody 35 and Western Ridge (Figure 5): • Five monitoring bores have recently been completed at very shallow (10-15 m to understand any surface flow / recharge), shallow and deep levels.	Quarterly - groundwater levels (quarterly download): • Automatic groundwater level loggers installed in HXAN0004M, HXAN0005M (VWP), HXAN0007M, HXAN0008M • Quarterly manual water level monitoring at HXAN0003M, HXAN0004M, HXAN0006M, HXAN0007M, HXAN0008M and HXAN0017M • Quarterly – water quality sampling of groundwater from HXAN0004M, HXAN0007M, HXAN0008M and HXAN0017M • Biannual groundwater level monitoring of the five regional monitoring bores	**Local aquifer monitoring** Quarterly monitoring of groundwater levels at existing monitoring bores: HXAN0003M, HXAN0004M, HXAN0006M, HXAN0007M and HXAN0008M. A multi-level Vibrating Wire Piezometer (VWP) has been installed at HXAN0005M installation, which provides pore pressures from a number of depths, which can be converted to water levels. A new monitoring bore (HXAN0017M) has been constructed to replace HXAN0005M and allow access to the Dales Gorge Member (regional) aquifer for groundwater level and quality sampling. The replacement bore was constructed in accordance with Australian water bore construction guidelines (NUDLC 2020), to ensure the local (perched) and regional aquifers are not hydraulically connected by the bore. Monitoring at HXAN0017M is planned to start in mid CY2023. Groundwater quality (chemistry) will be monitored quarterly for a period long enough to understand natural variability (2 to 3 years). As for pool water quality, groundwater will be sampled for the comprehensive analytical suite initially (1-2 years) to understand seasonal variation, then focus on key field parameters (pH, salinity etc.) and silica. **Regional aquifer monitoring** Regional monitoring bores have been installed at selected locations within the Joffre Member and Dales Gorge Member, to the east and south of Nankunya, and between Nankunya and the existing below water table mine pits (Orebody 35) and proposed mine pits (Western Ridge). Manual water level monitoring will be undertaken biannually at the new regional bores and is planned to start in CY2023. The data obtained will enable BHP to understand and compare changes, if any, in the Nankunya local aquifer, regional aquifer and orebody aquifer groundwater levels in response to current mine dewatering at the OB29/30/35 mine and the proposed Western Ridge mine. Additional monitoring and/or increased monitoring frequency will be undertaken if analysis indicates differences compared to the current hydrogeological conceptualisation (local Nankunya aquifer and/or regional/orebody aquifers).
Air quality • Dust deposition	Given steep, rocky terrain within the Nankunya gorge, it is not possible to install dust deposition gauges within the gorge. Gauges will therefore be located outside of, but in proximity to the mouth of the gorge and head of the gorge.	Mouth of gorge (MOG) (two potential locations, of which one will be selected): • LOC 1 – MOG (Easting 766964.533, Northing 7411846.602) or • LOC 2 – MOG (Easting 766818.358, Northing 7411861.098); and Head of gorge (HOG): • LOC 4 HOG (Easting 767238.866, Northing 7411405.124) • (note LOC 3 HOG was a previously identified site no longer considered suitable due to distance from head of gorge) (Figure 6)s	Monthly monitoring of dust deposition	Monthly monitoring of dust deposition will commence prior to implementation of the Proposal to enable establishment of baseline. Monthly monitoring will continue throughout construction and for a minimum of two years during operation. The continuation of dust monitoring beyond the first two years of operation will be considered and will be informed by the outcomes of monitoring.



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WESTERN RIDGE

Nankunya local monitoring sites

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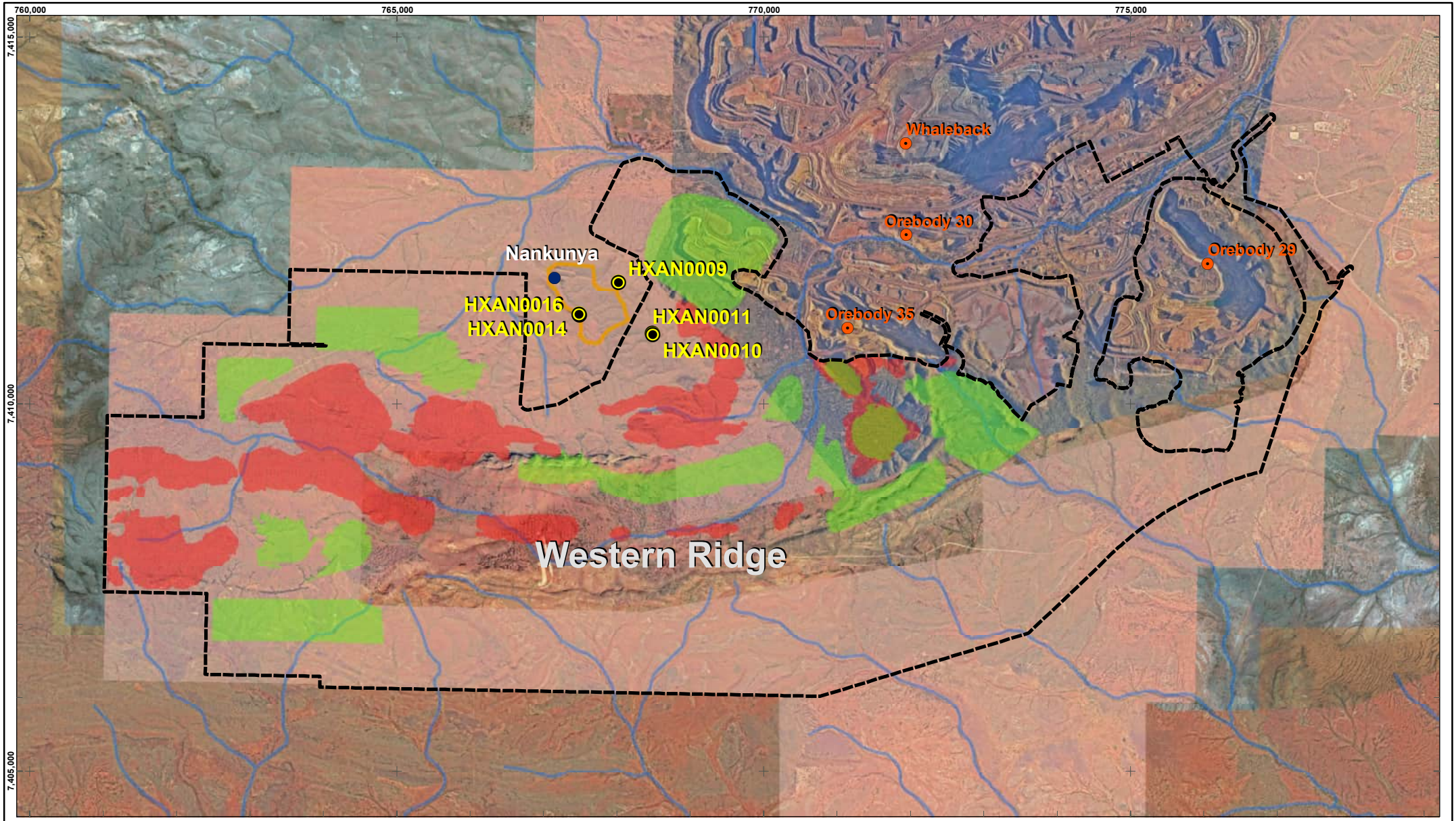

- Monitoring bore
- Water feature
  - Artificial
  - Permanent Seep
  - Temporary Seep
  - Temporary Surface Pool
- BHP operations
- Nankunya catchment
- Development Envelope
- Waterways
- Western Ridge indicative OSAs
- Western Ridge indicative pits

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0 0.8 1.6 2.4 3.2 4

KILOMETRES

GDA 1994 MGA ZONE 50

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PUBLIC

WESTERN RIDGE

Nankunya regional monitoring sites

PLANNING & STANDARDS - IRON ORE

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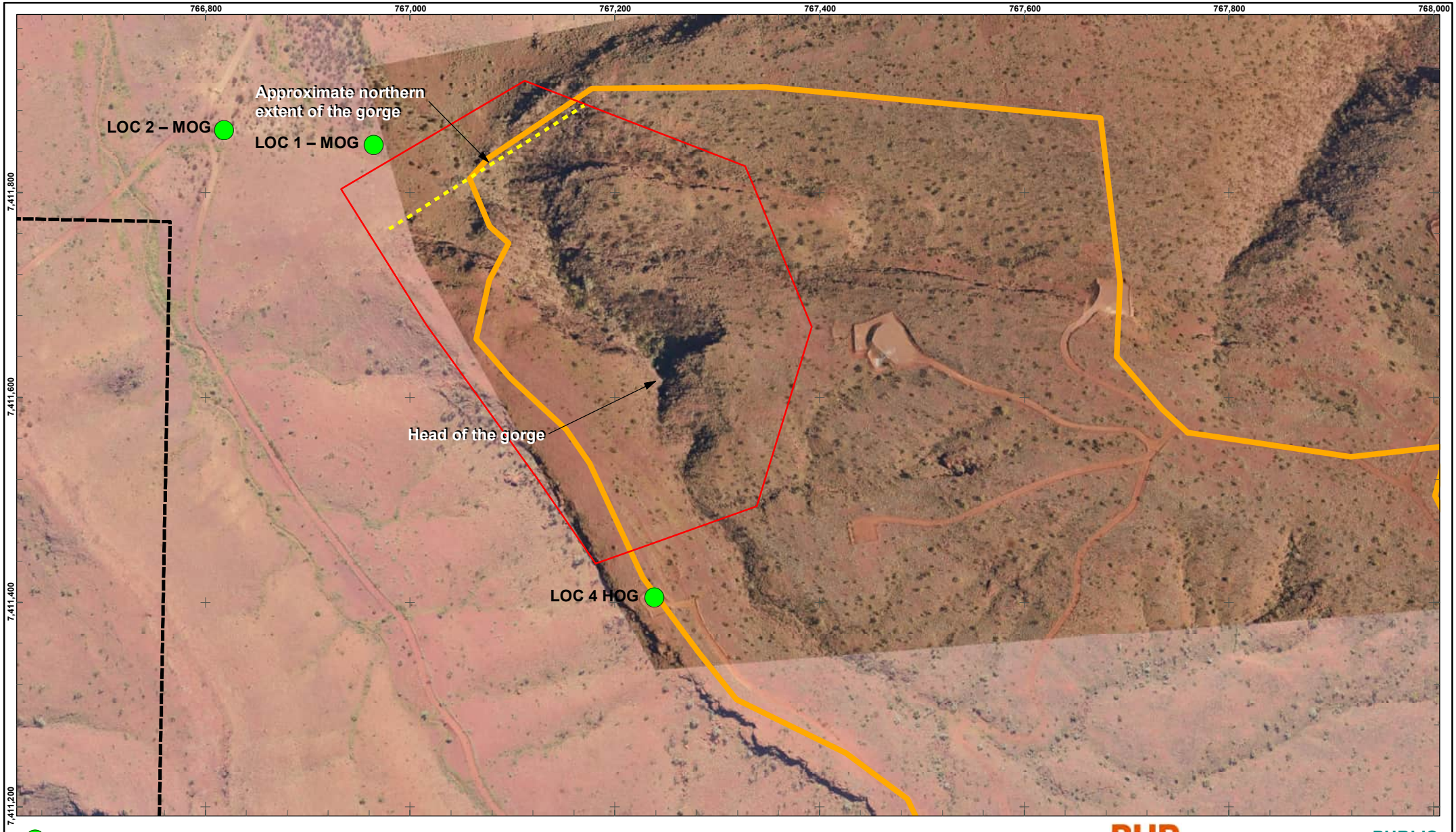

Proposed dust monitoring locations
Development Envelope
Nankunya catchment
Heritage Exclusion Zone

N

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KILOMETRES

GDA 1994 MGA ZONE 50

BHP

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WESTERN RIDGE

Proposed dust monitoring locations

PLANNING & STANDARDS - IRON ORE

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