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Groundwater Supply Investigation for the Uis Tin Project, Namibia

Geophysical Survey Report

Prepared for:
AfriTin Mining (Namibia) (Pty) Ltd

Project Number:
AFT7220

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This document has been prepared by Digby Wells Environmental.

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Name	Responsibility	Signature	Date
Megan Edwards	Report Writer		30 June 2022
Andre van Coller	Report Review		30 June 2022

EXECUTIVE SUMMARY

Digby Wells Environmental (hereinafter Digby Wells) was appointed by AfriTin Mining (Namibia) (Pty) Ltd (hereinafter AfriTin) to undertake a water supply assessment for the planned expansion of production at the Uis Tin Mine, in Namibia. A parallel investigation is confirming if the ten (10) boreholes AfriTin currently have near to the mine, could potentially cover the Phase 1 (Stage I and II) water requirements. The focus of this report, therefore, is on locating potential drilling targets within the regional aquifers surrounding the mine to provide an additional source of groundwater for the Phase 2 expansion and/or supplement the Phase 1 (Stage II) expansion requirements should the current boreholes be insufficient for this requirement.

The study area is in the Damara Orogen, which is an east-north-east trending belt formed during the convergence between the Kaapvaal and Congo cratons, resulting in a complex geological and structural environment. The study area is also classified as a hot dessert climate which receives minimal rainfall during the year (average of 88 mm/a). As a result of the low rainfall, there is a low recharge potential to the groundwater aquifers (between 0 – 1%). The two main river systems (Ugab and Omaruru Rivers) that flow through the study area have catchments in the mountainous regions to the east which receive higher rainfall.

Six (6) target areas were identified at desktop level with potential marble and/or alluvial aquifer systems. Within these target areas eight locations were identified as potential geophysical survey areas. These eight locations were prioritised to the three locations which could be surveyed with electromagnetic (EM) and electrical resistivity tomography (resistivity) geophysical survey methods. Three (3) EM and two (2) resistivity lines were surveyed for each of the target areas.

Target 2 is located approximately 27 km northwest of the Uis Tin Mine and represents an alluvial aquifer with the potential to have high yielding boreholes (an existing borehole with an estimate yield of 27 m^3/hr is potentially located near to this target area). The profiles show a 10 – 20 m alluvial (or weathered) layer overlying a more resistive rock (likely to be granite). There are two vertical low resistivity features within the more resistive rock which could represent deeper weathered and/or fracture zones. Two (2) drilling targets were identified targeting the two vertical low resistivity features (one on each profile).

Target 3 is located approximately 37 km northwest of the Uis Tin Mine and is characterised by a potential regional fault which intersects marble unit. There is an alluvial aquifer flowing across this location as well which could assist with recharging the fault and/or marble aquifer. The profiles show an approximately 15 m thick alluvial (or weathered) layer, which is more conductive where the marbles outcrop. The marble has a lower resistivity to the surrounding granitic and felsic pyroclastic rocks and appears to dip towards the north. One (1) drill target was identified targeting the marble unit to the north of the outcrop area and aligning with the regional fault location.

Target 5 is located approximately 55 km northwest of the Uis Tin Mine and is characterised by a potential marble unit with an alluvial aquifer (with a large catchment area) potentially supplying a source of recharge to the marble aquifer. The profiles show a weathered layer with clusters of high resistivity near surface. There is a high resistivity anomaly on both profiles which corresponds to a rock exposure on aerial imagery. Two streams meet and flow around this feature. The profiles show a low resistivity feature to the south and underlying the high resistivity anomaly which could represent the marble unit. Two drilling targets were identified targeting the two low resistivity features (one on each profile).

The details of the eight (8) proposed drill targets are provided in the table below.

The boreholes should be drilled using air-percussion drilling methods. Boreholes should be drilled to a final end-of-hole diameter of 8 inches. Should a borehole intersect yields of greater than 20 m^3/hr, the borehole will need to be reamed to a larger diameter. Screened PVC casing should be installed in all boreholes which intersect a water strike to prevent collapse of the borehole. The annulus of the borehole must be filled with 3 – 5 mm silica sand/gravel until approximately 1 m below surface. A 1 m bentonite seal should be installed at surface to prevent surface contamination from entering the borehole.

After the boreholes have been drilled and constructed, they will need to be aquifer tested to verify the sustainable yield of the borehole. A four (4) hour step test followed by a forty-eight (48) constant discharge test should be performed on all successful boreholes. During the aquifer test, samples should be collected for analysis to determine the groundwater quality.

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Geophysical Target	Drill Target	Longitude	Latitude	Proposed Depth (m)	Priority	Comment
Target 2	ATBH1	498914	7678037	80	High	
Target 2	ATBH2	498616	7677743	80	Low	
Target 2	ATBH3	498907	7677846	80	High	
Target 3	ATBH4	505650	7686133	100	High	This target is projected off the original survey profiles and may need to be resurveyed to confirm the fault location
Target 3	ATBH5	505852	7685532	80	High	
Target 5	ATBH6	518114	7698470	100	High	There were community issues when surveying Target 5. Water supply may be requested if boreholes are drilled here.
Target 5	ATBH7	518258	7698584	100	High	
Target 5	ATBH8	518262	7698716	80	Low	

The following additional recommendations are proposed:

- It is recommended to locate the existing boreholes within the six (6) target areas and if located determine if they can be used by the mine. The boreholes which can be used will need to be aquifer tested to confirm their sustainable yields. Should the existing boreholes all be located, and the estimate yield confirmed the existing boreholes could potentially provide 279 m^3/hr.

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1. Introduction

Digby Wells Environmental (hereinafter Digby Wells) was appointed by AfriTin Mining (Namibia) (Pty) Ltd (hereinafter AfriTin) to undertake a water supply assessment for the planned expansion of production at the Uis Tin Mine, in Namibia.

Currently the pilot processing plant in operation for the Phase 1 Stage I project produces ~65 tonnes of tin concentrate per month. Water demand for the Phase 1 Stage I plant requires ~0.288 Ml/day (12 m^3/hr), which is sourced from the UIS wellfield boreholes, located in the alluvial aquifer of the Uis River. AfriTin has completed a Definitive Feasibility Study (DFS) for the expansion of its Phase 1 Stage I Pilot Processing Facility, which will occur in two phases. The Phase 1 Stage II expansion is a precursor to the long-term Phase 2 expansion, which aims to increase the mining area and develop a full-scale processing plant for the mine.

The expansion of the pilot processing plant for Phase 1 Stage II will increase production to ~100 tonnes of tin concentrate per month, which will increase the water demand of the plant to ~0.432 Ml/day (18 m^3/hr). The Phase 2 expansion plans to increase production to ~1 250 tonnes of tin concentrate per month. The water demand for the Phase 2 expansion still needs to be confirmed.

The aim of the water supply assessment is to:

- Verify the potential supply constraints of the Uis wellfield for the planned Phase 1 Stage II expansion; and
- Investigate the regional aquifer systems as an additional source of groundwater for the Phase 2 expansion.

A parallel investigation is confirming if the ten (10) boreholes AfriTin currently have near to the mine, could potentially cover the Phase 1 (Stage I and II) water requirements. The focus of this report, therefore, is on locating potential drilling targets within the regional aquifers surrounding the mine to provide an additional source of groundwater for the Phase 2 expansion and/or supplement the Phase 1 (Stage II) expansion requirements should the current boreholes be insufficient for this requirement.

2. Baseline Conditions

2.1. Climate

The study area is classified as a hot desert climate (BWh) based on the Köppen-Geiger classification system. The BWh classification characterises areas where evaporation and transpiration exceed precipitation with hot to exceptionally hot (over 40°C) periods of the year.

Annual rainfall data was collected from four weather stations around the project area, which were measured daily between 1979 and 2014. The rainfall data is relatively consistent between the weather stations. Rainfall typically occurs between October and April, with the months of February and March receiving the highest rainfall (Figure 2-1). The annual rainfall for the project area ranges between ~2 - 592 mm, with an average of 88 mm per year (National Centers for Environmental Prediction, 2022) (Environmental Compliance Consultancy, 2021).

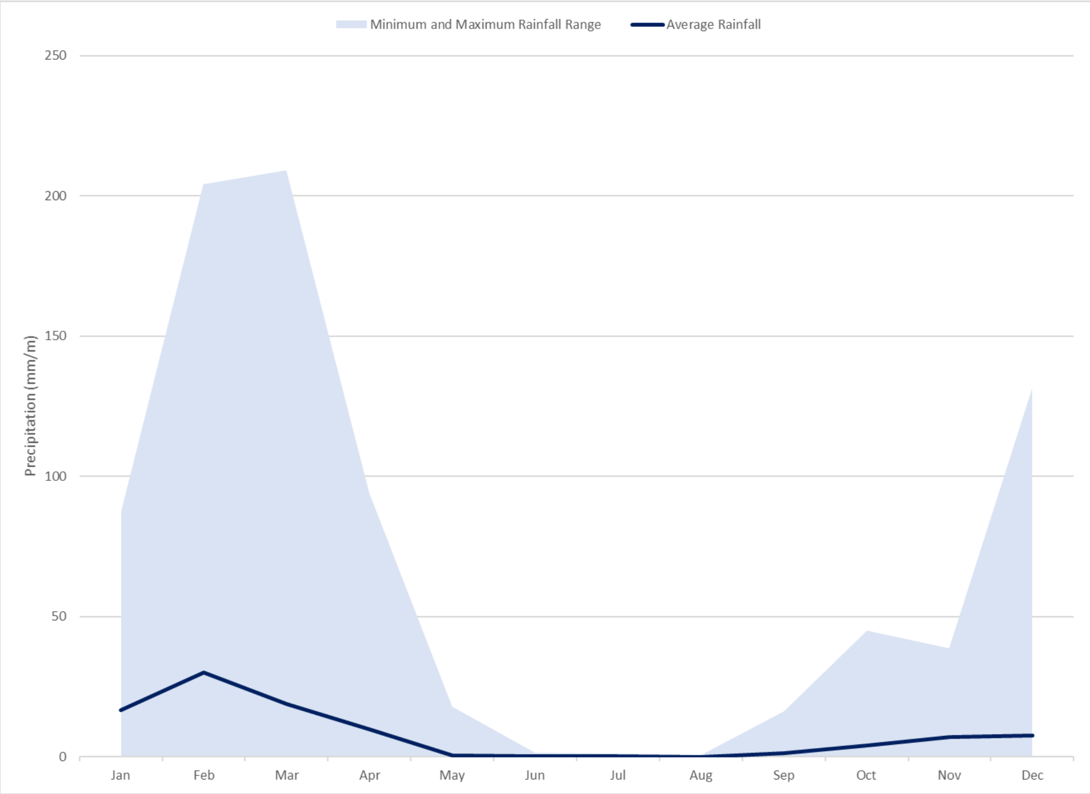

Figure 2-1: Monthly Rainfall

2.2. Recharge

The NA-MIS (Namibian Monitoring Information System) and hydrogeological map of Namibia indicates that the area has an effective groundwater recharge percentage of between 0 – 1% (Figure 2-2) of the average annual recharge (Groundwater Management Institute, 2022). The highest recharge potential occurs in Target Area D.

Although Target Area C, E and F are located in the area which indicates 0% recharge, a chloride mass balance calculation using a rainwater sample collected on 19 January 2022 indicates that the boreholes near Uis do receive approximately 0.7% recharge. This would indicate a maximum contribution percentage as the equation does not account for surface water runoff or the presence of chloride in the environment (i.e., gypsum) which may influence the chloride concentration recharging to or occurring within the aquifer. The following equation was used to calculate the recharge to the aquifer using chloride as a tracer:

$$R = P.\frac{Clp}{Clgw}$$

Where R is the groundwater recharge flux, P is the average annual precipitation, Cl_p is the average chloride concentration for precipitation and Cl_{gw} is the average chloride concentration for groundwater.

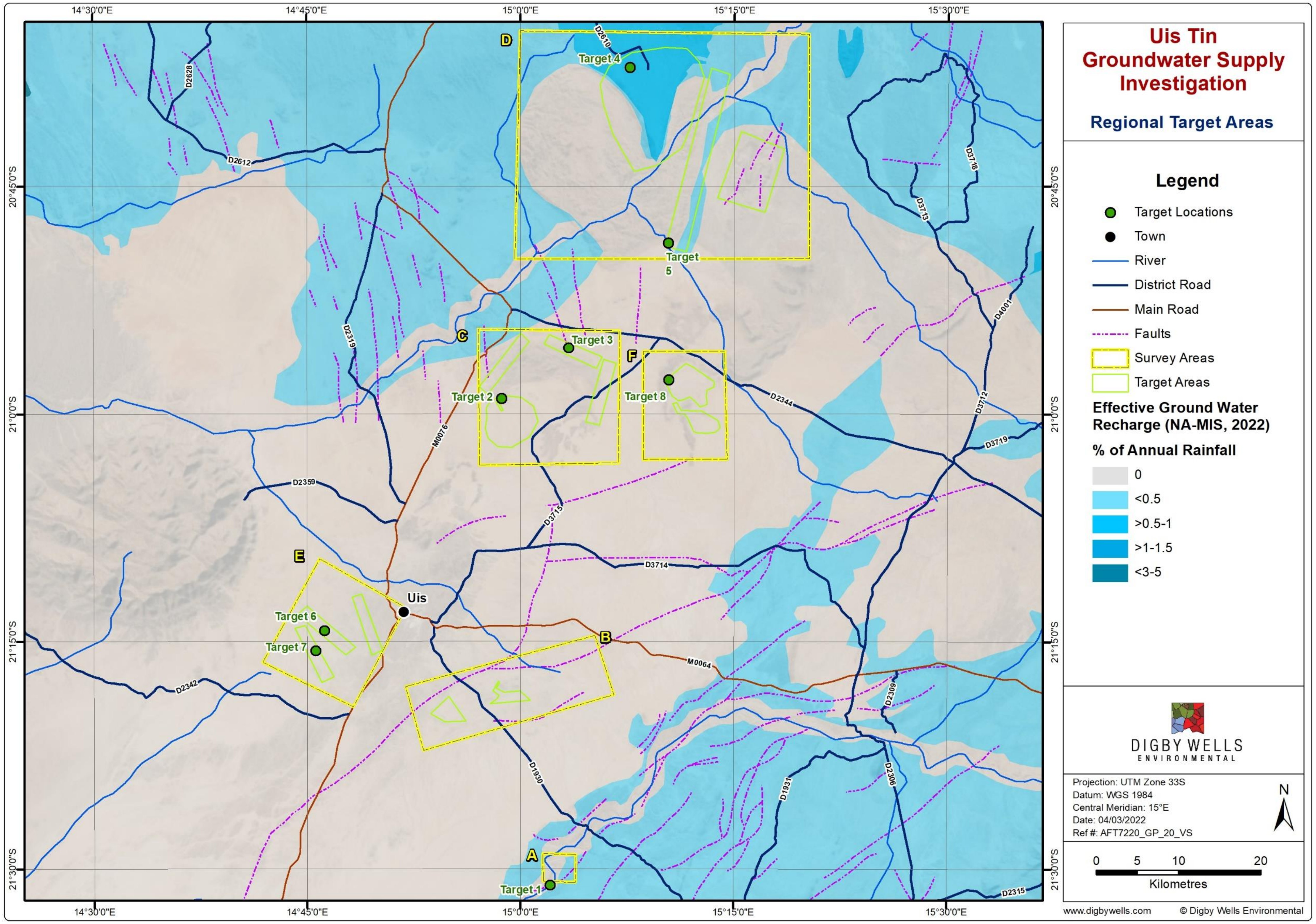

Figure 2-2: Recharge

2.3. Topography and Drainage

The town of Uis is located within the Uis River which is a tributary within the Ugab Catchment Area. The Uis River drains the project area in a north-westerly direction until it joins the Ugab River. The Ugab River is the main river that drains the Ugab Catchment which has an area of ~29 000 m^2. The Ugab Catchment starts in a mountainous region which receives a higher annual rainfall of between ~500 - 550 mm.

Although the town of Uis is located in the Ugab Catchment Area, the town receives water from the Omaruru River. The Omaruru River drains the Omaruru Catchment which has an area of ~11 500 m^2 and receives an annual rainfall of between ~300 - 350 mm from the mountainous region upstream.

3. Regional Survey Targets

A desktop level assessment (AfriTin Mining, 2021) identified six (6) regional target areas that could potentially supply groundwater for the Uis Tin Mine. The six (6) target areas were identified based on the available geological and catchment information (Figure 3-1).

The 1:250 000 geological map of the region indicates that the regional targets are distributed between the Zerrissene and Swakop Groups of the Damara Sequence (Ministry of Mines and Energy. Geological Survey of Namibia, 2006) (Ministry of Mines and Energy. Geological Survey of Namibia and Finland, 1997). The Damara Orogen is an East-North-East trending belt formed during the convergence between the Congo and Kalahari Cratons. The belt comprises of multiple fault and shear bounded zones with varying structural styles and lithologies (Gray, et al., 2008). A summary of the main stratigraphy for each of the Target Areas is provided in Table 3-1. A brief description of the geology is provided for each of the Target Areas under the respective subsections.

Table 3-1: Regional Stratigraphy

Supergroup	Group	Formation	Lithology	Map Code	Target
Quaternary			Undifferentiated sediments	Qs	B, C, E, F
			Gravel	Qg	D
Damara Granites			Granite (fine-medium grained, monzogranite)	OgSsp	C
			Granite (fine-medium grained)	єggp	E
			Granite (coarse grained, porphyritic)	NgSAs	C, D, F
			Granite (medium-coarse grained, porphyritic)	NgSAp	C
Damara Sequence	Swakop	Kuiseb	Mica schist and shale	NKs	A, B, D
	Swakop	Karibib	Marbles	NKb	A, B, D
	Zerrissene[1]	Amis	Meta-greywacke and meta-pelites	NAm	E
	Swakop	Okatjise	Dolomite	NOz	C, D
	Nosib	Naauwpoort (Summas Member)	Felsic pyroclastic rocks	NNpSm	C, D

[1] Zerrissene Group is mapped as part of the Southern Kaoko Zone whilst the Swakop Group is mapped as part of the Swakop (Central) Zone. The Amis Formation metamorphic events occurred at a similar time to the Karibib Formation metamorphism.

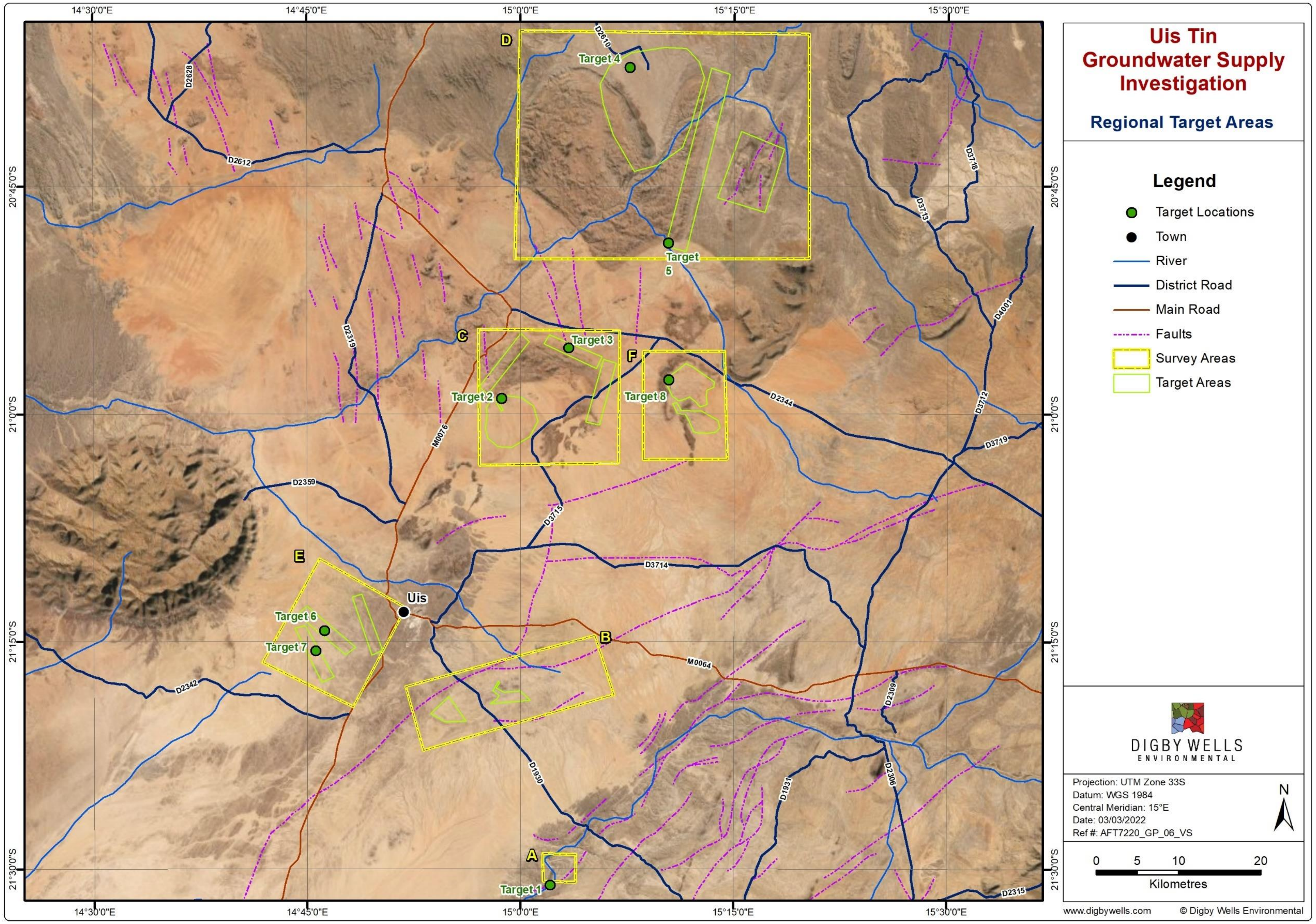

Figure 3-1: Regional Targets

3.1. Target Areas

3.1.1. Target Area A

Target Area A is located on the Omaruru River system, which has a large catchment area upstream of the target area (Figure 3-2). Borehole targets could be positioned within the water course area, without a geophysical survey, to assess the potential of this alluvial aquifer.

Target Area A also has an outcrop of marble which has been significantly folded, occurring as a synclinal fold on the limb of a larger anticlinal fold structure. This marble may be recharged by the Omaruru River which intersects the marble on the western side. The continuity of the marble underneath the younger mica schist (east of this area) is unknown but based on the geological cross-section (provided with the 1:250 000 map) indicates that there may not be a connection to the marbles east of Target A, as the marbles to the east are associated with a synclinal feature.

There is some faulting in this area which is predominantly northeast-southwest orientated, parallel to the Omaruru River. This marble lithology is likely to be isolated with limited recharge potential, and therefore the alluvial aquifer of the Omaruru River system may be the best water source option within this Target Area.

No boreholes have been previously identified in this Target Area, so potential borehole yields are unknown. However, there is a water scheme within this Target Area that provides fresh water to Uis.

Target 1 has been positioned just south of the Target Area A and is considered an intermediate priority target (for a geophysical survey). The borehole could be positioned in the Omaruru River without a geophysical survey however a geophysical survey could assist with identifying the fault at the marble schist contact.

3.1.2. Target Area B

Target Area B is located on a water divide between the Omaruru and Ugab River systems, in an area which likely receives little recharge from rainfall (~50-150 mm per year). The alluvial aquifers in this Target Area have a relatively small catchment area from which recharge can be collected, which will reduce the sustainability of water supply from this Target Area (Figure 3-3). This target area would need to focus on intersecting fractures.

Target Area B is also associated with an outcrop of a marble lithological unit as part of an anticlinal fold surrounded by mica schist. There may be continuity between the marble unit in Target Area B and the marble unit to the southeast may be possible via a synclinal feature underlying the mica schist, however both these areas are on the water divide with limited recharge potential. Secondary porosity features would need to be connected at depth between these two marble units, as the mapped faulting in the mica schist occurs in a northeast southwest orientation (parallel to the marble outcrop areas).

No boreholes have been previously identified in this Target Area, so an estimated yield is unknown. No priority areas have been identified in this Target Area.

3.1.3. Target Area C

Target Area C is located around an anticlinal feature with a thin marble unit surrounding a core of pyroclastic rocks (Figure 3-4). The target areas proposed for this area focus on the marble unit and an alluvial aquifer. The alluvial aquifer has one drainage point which could potentially allow for the storage of groundwater as flow may potentially be obstructed by the pyroclastic rocks. Boreholes were identified in the alluvial aquifer which indicated yields of between 0.4 l/s and 7.7l/s. Two geophysical survey priority areas have been identified in this Target Area.

Target 2 is located in the alluvial aquifer to try and characterise the deeper flow channel. The catchment area for this alluvial aquifer may be relatively small, but there are potentially high yielding boreholes from this system. It is also recommended to locate, and aquifer test the highest yielding borehole in this area. Target 2 has been identified as a high priority area for the geophysical survey.

Target 3 is located on a fault structure which intersects the marble unit. There is a drainage system which flows through this feature which would provide an additional source of water from the alluvial catchment area. Target 3 has been identified as a high priority area for the geophysical survey.

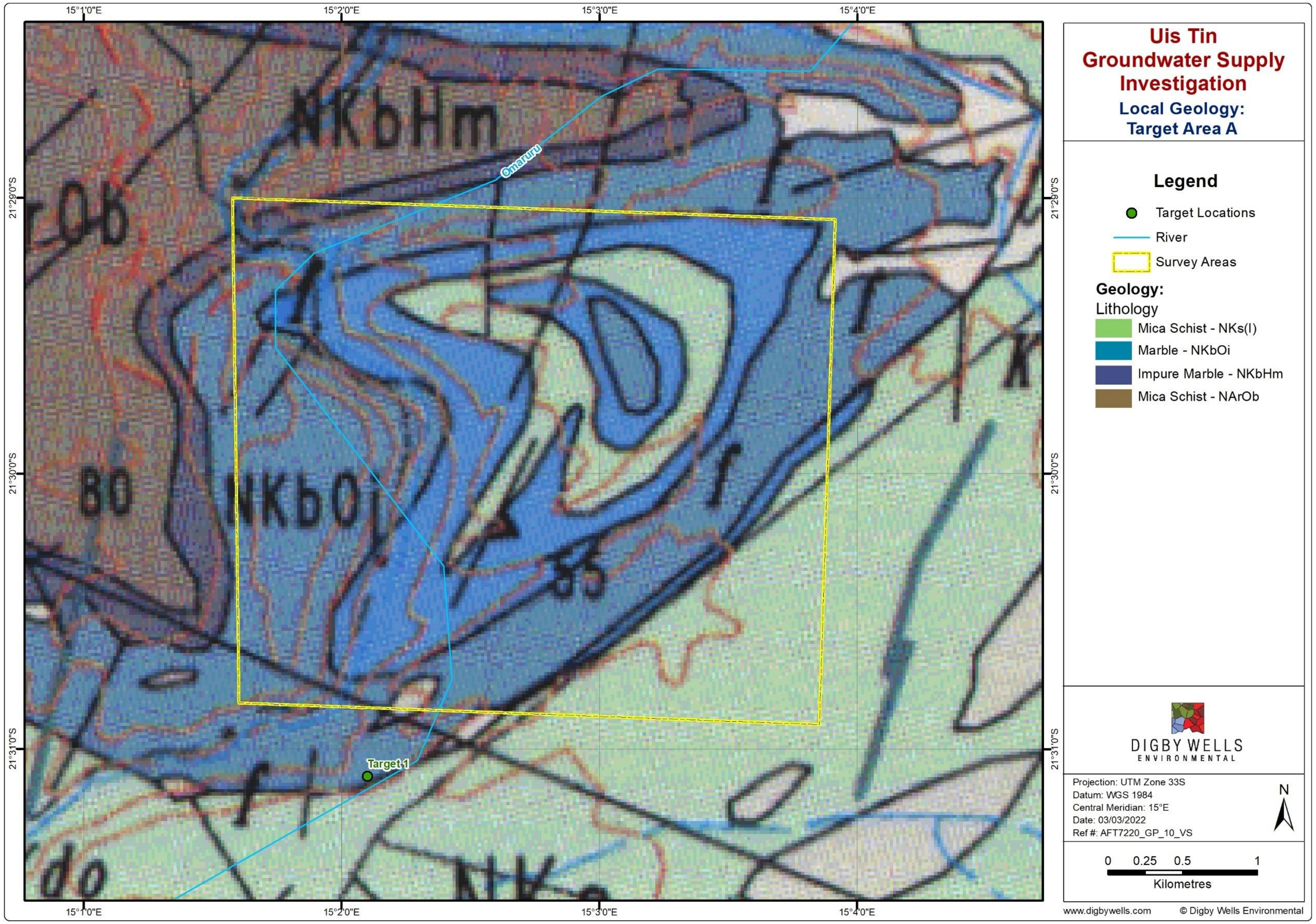

Figure 3-2: Target Area A

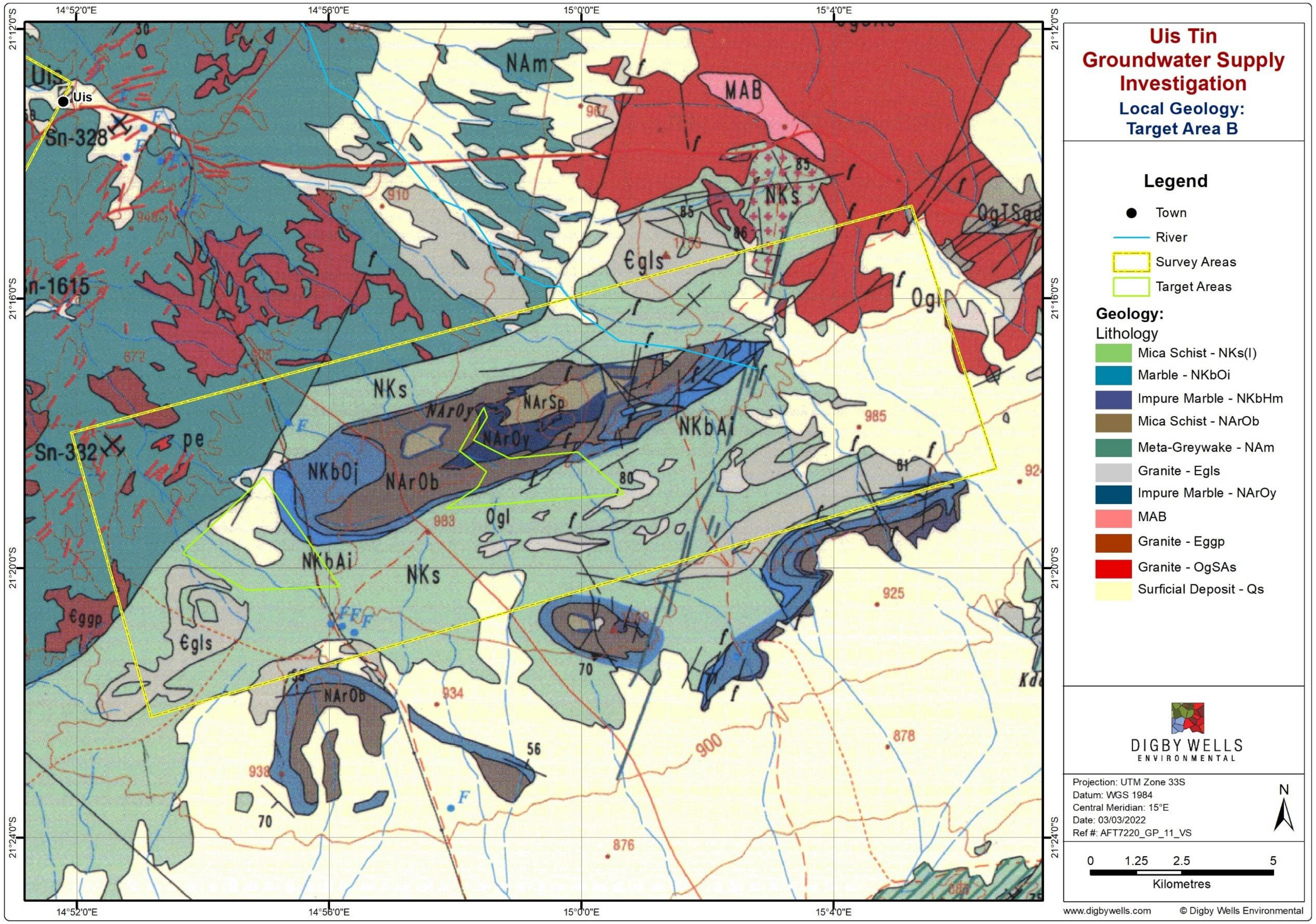

Figure 3-3: Target Area B

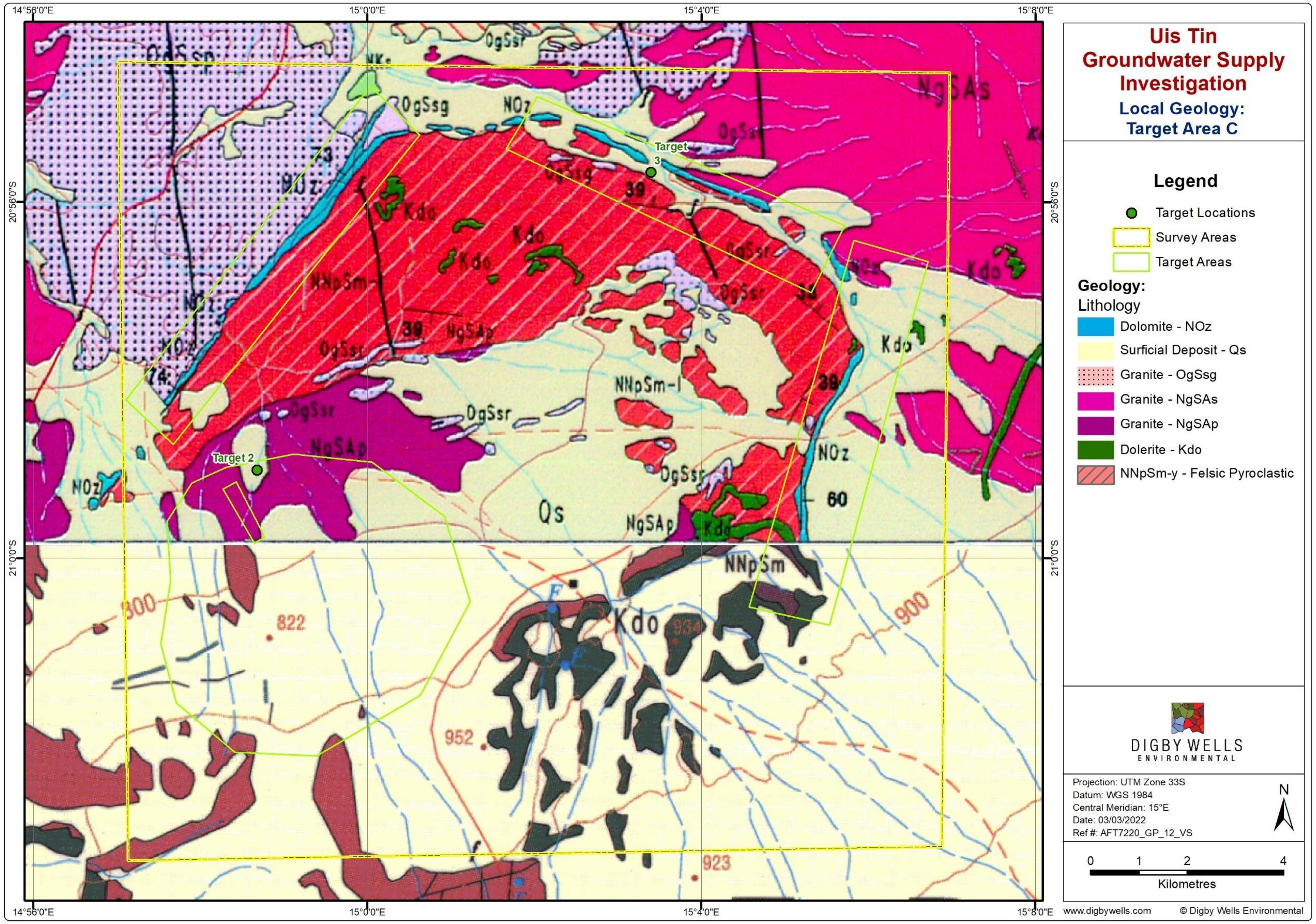

Figure 3-4: Target Area C

3.1.4. Target Area D

Target Area D is a large area located on and in close proximity to the Ugab River system (Figure 3-5). Boreholes have been identified in this Target Area with yields that range between 1.1 l/s and 23.9 l/s. The highest yielding boreholes are in an alluvial sedimentary layer which terminates in a fold structure comprising of marble and pyroclastic rocks. It is recommended to locate the two existing, high yielding boreholes and aquifer test them to confirm their sustainable yields.

Should these boreholes not be located, then this area could be investigated further using the ground geophysical survey methods. The alluvial area is identified as Target 4. However, it is considered an intermediate priority target for the geophysical survey based on the presence of existing boreholes which can be tested, and the significant distance between this area and the mine.

Another potential priority area (Target 5) within Target Area D is located on the southern end of subsection a. This section has a linear marble unit which intersects the Ugab River as a potential recharge source for any underlying secondary porosity features. The marble unit potentially extends underneath an alluvial aquifer which has a large catchment area for potential recharge to the southeast of this location in addition to the above-mentioned marble unit. Target 5 is therefore considered a high priority target.

3.1.5. Target Area E

Target Area E is located on tributaries of the Ugab River system (Figure 3-6). A dyke feature may cross these tributaries downstream of the proposed target areas which may assist with storage of groundwater in the alluvial aquifers upgradient of the dyke. There are no mapped faults in this area.

The mine has drilled boreholes upstream of the eastern-most tributary (tributary closest to the mine) which are scheduled to be aquifer tested as part of Phase 1 of the water supply investigation to determine their sustainable yields. Utilising these boreholes will likely reduce water flow to the downstream target area, indicating that the eastern-most target in Target Area E may be unsustainable as a long-term source.

The two other targets in Target Area E are associated with different tributaries. Boreholes with an estimated yield of between 1.4 l/s and 3.4 l/s have been identified in these tributaries. It is recommended that these boreholes be located, as alternative water supply boreholes, which can be aquifer tested to confirm the sustainable yield. Should the boreholes not be located, new boreholes could be installed within the tributary alluvials without a geophysical survey.

Target 6 and 7 have been identified in this Target Area but are considered low priority targets for a geophysical survey, as boreholes can be positioned in the tributary footprint without a geophysical survey and there are existing boreholes which could be tested.

3.1.6. Target Area F

Target Area F is located within a half ring dyke structure where the alluvial aquifer only has one exit point for a tributary of the Ugab River system (Figure 3-7). The alluvial catchment area within this ring structure is relatively small indicating the sustainability of this source may be limited. One low yielding borehole (0.3 l/s) has been identified in this Target Area. Two other boreholes have been identified in this Target Area, but the yields for these boreholes are unknown. It is recommended to locate these boreholes and aquifer test them if possible.

A geophysical survey target (Target 8) has been identified in this area. However, it is considered a low priority target for the geophysical survey based on the presence of existing boreholes that could be tested. It should be noted that if this target would be developed as a water supply, it could potentially reduce the yield from the alluvial aquifer at the downgradient Target 3.

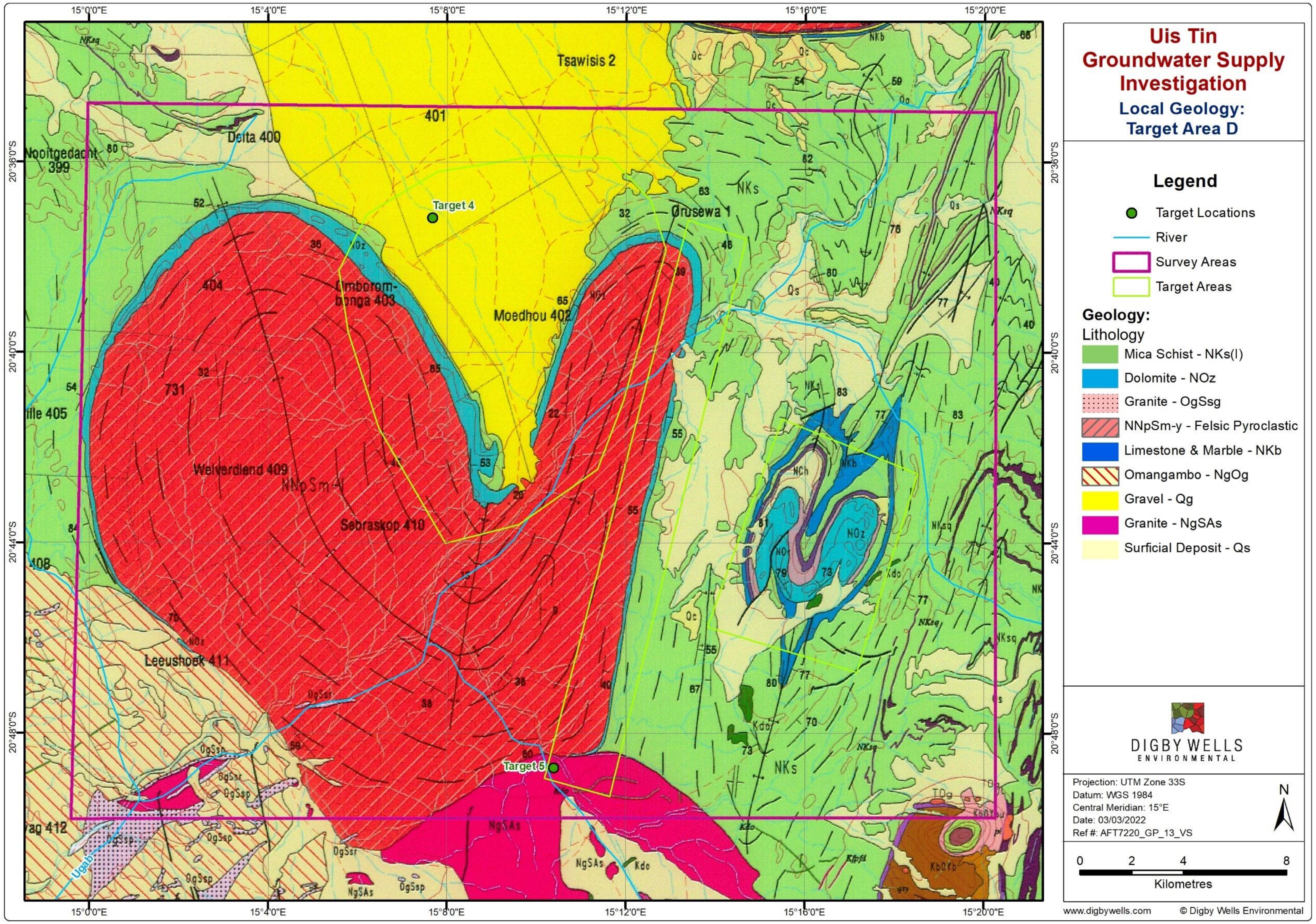

Figure 3-5: Target Area D

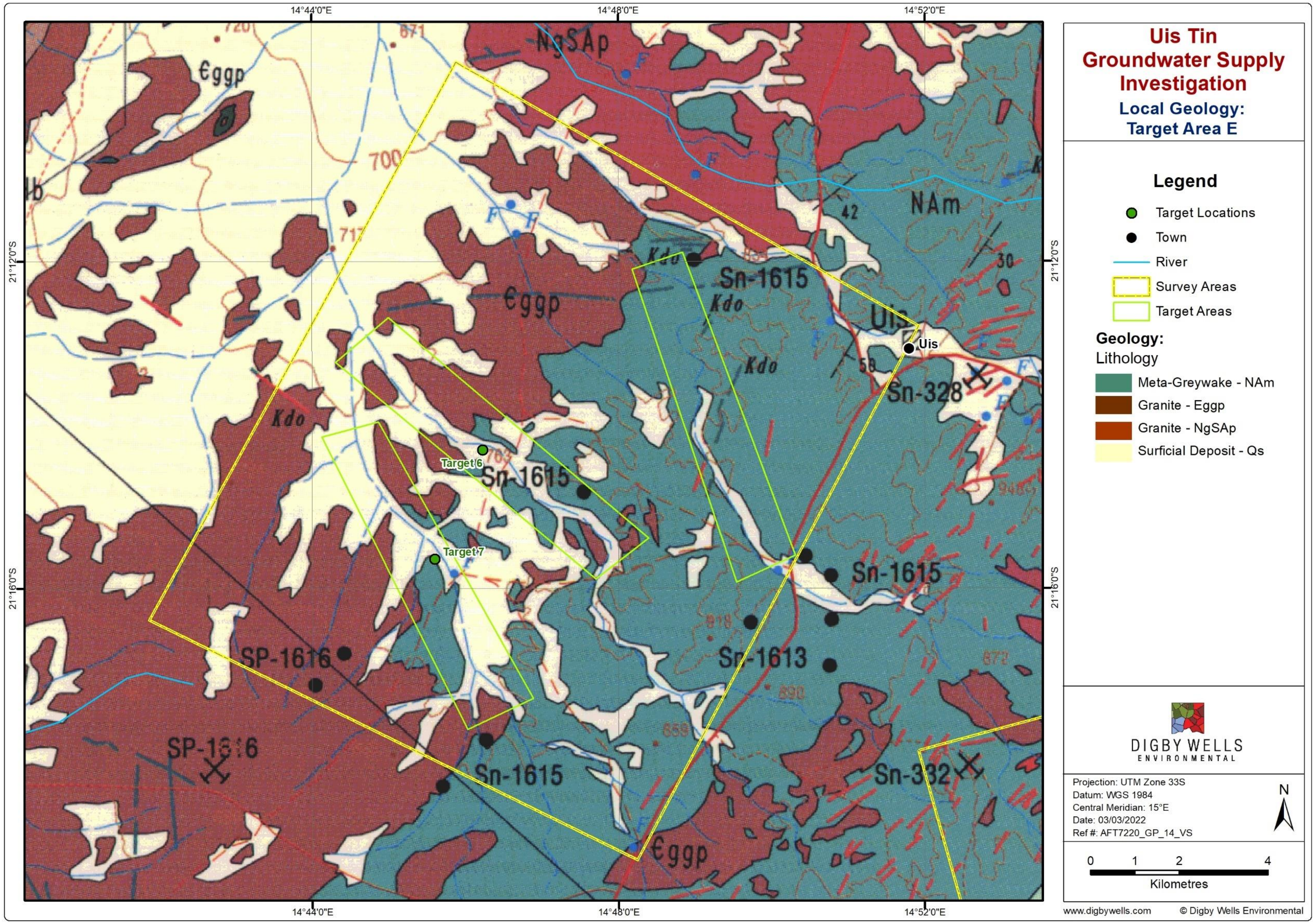

Figure 3-6: Target Area E

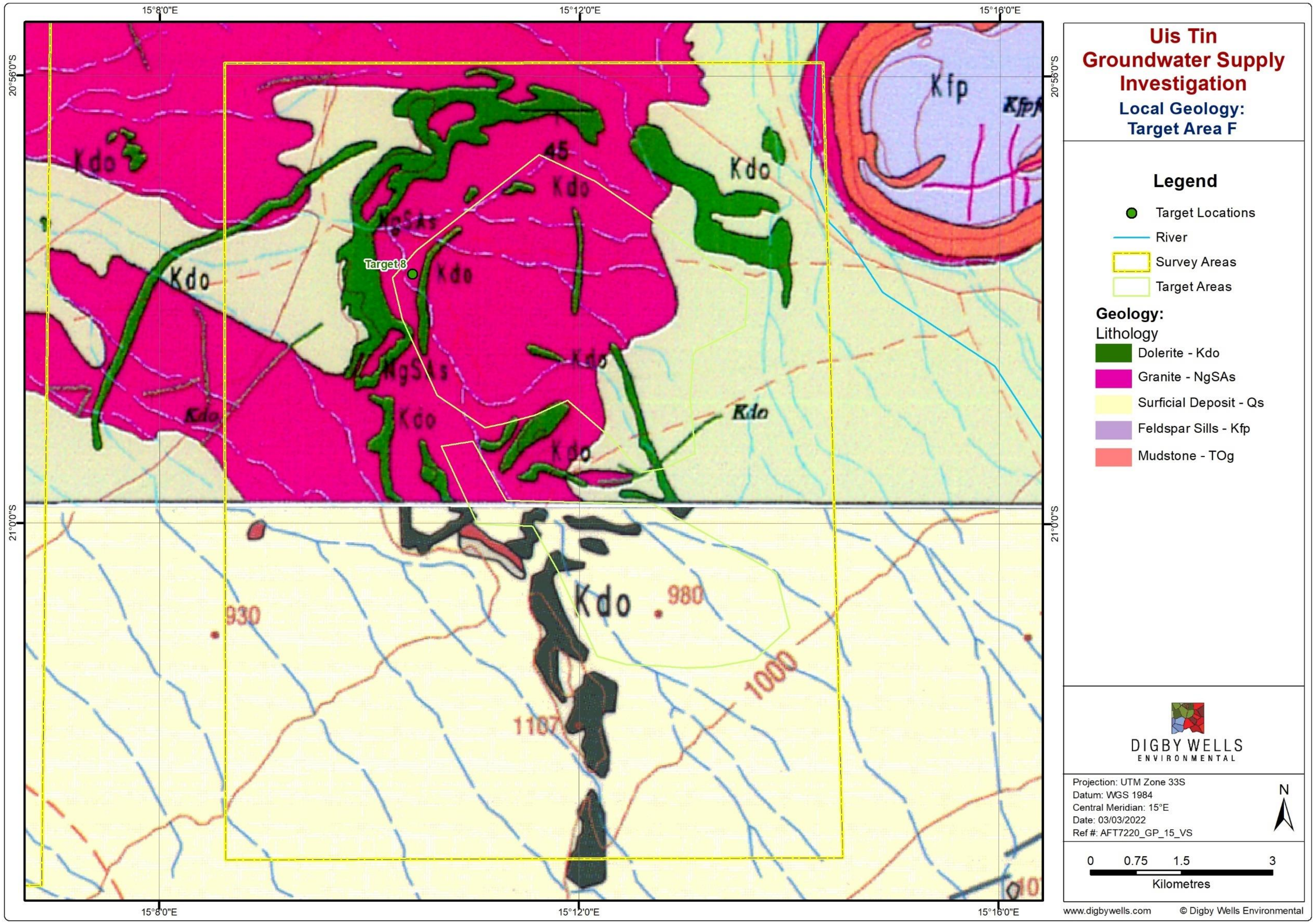

Figure 3-7: Target Area F

3.2. Priority Target Locations for Geophysical Surveys

Based on the review of the available information, a total of eight priority areas have been identified for the geophysical survey within the six proposed Target Areas. These are summarized in Table 3-2 below and prioritized to the three (3) highest priority areas.

It is recommended to try and locate the identified boreholes in Target Areas C, D, E and F and if possible, test these boreholes to confirm a sustainable yield from an already existing borehole. If these boreholes no longer exist, a geophysical survey could be undertaken to intersect the same feature and potentially try duplicate the estimated yields from these areas.

Table 3-2: Summary of Priority Targets for the Geophysical Survey

Target ID	Priority	Reason
3	High	Marble unit, intersected by a fault with a drainage line associated with an alluvial catchment area.
5	High	Marble unit potentially recharged by the Ugab River, and a drainage line associated with an alluvial catchment area.
2	High	In a potentially high yielding alluvial aquifer, recommend locating and test existing high yielding borehole. Located closer to the mine so given a higher priority.
4	Intermediate	In a potentially high yielding alluvial aquifer, recommend locating and test existing high yielding boreholes first.
1	Intermediate	In a the Omaruru River which has a large catchment area, geophysics could be used to target the fault at the marble schist contact
8	Low	In a ring structure with a relatively small catchment area for the alluvial aquifer.
6	Low	In a tributary channel for the Ugab River, catchment area limited by water divide, could potentially site boreholes without geophysics.
7	Low	In a tributary channel for the Ugab River, catchment area limited by water divide, could potentially site boreholes without geophysics.

4. Study Limitations

The following limitations are applicable to this assessment:

- The 2D resistivity survey can only be conducted in areas where there is sedimentary cover into which the stainless-steel pegs can be inserted. This survey method is therefore limited to the alluvial aquifer systems as well as aquifer systems which may underly the alluvial aquifers; and
- Target areas have identified marble lithological units as potential targets. Marbles are a metamorphosed carbonate rocks which have the potential to be water bearing but only via secondary porosity features (fractures and cavities). For a sustainable water supply from marbles, the secondary porosity features would need to be interconnected and linked to a recharge area and have a sufficient aquifer extent to be able to sustainably yield sufficient volumes of groundwater.

5. Survey Results

The three high priority targets (Table 3-2) were assessed using electromagnetic (EM) and electrical resistivity tomography (resistivity) geophysical survey methods. The EM method was surveyed first to identify any high conductive targets which could be assessed better with the resistivity method afterwards. The methodology is provided in Appendix A and the individual profiles are provided in Appendix B.

5.1. Target 2

Target 2 is located approximately 27 km northwest of the Uis Tin Mine. This target area is characterised by a sedimentary cover which is drained in a north-westerly direction by a tributary to the Ugab River. The catchment area converges against an outcrop of granite. Although the catchment area of the stream is relatively small and located within a low recharge zone of the study area, there is an existing borehole located in this catchment that has an estimated yield of 27 m^3/hr (AfriTin Mining, 2021).

The survey area was selected to assess the alluvial sediments within the river channel upstream of the granite outcrop. This existing borehole is located approximately 1 km east of the surveyed area.

Three (3) EM survey lines and two (2) resistivity lines were walked for this target (Table 5-1 and Figure 5-1).

Table 5-1: Target 2 Survey Lines

Method	Label	Start		End		Length (m)	Direction
		Longitude	Latitude	Longitude	Latitude		
EM	Line 1	499051	7678216	498340	7677802	800	NE-SW
	Line 2	499129	7678121	498371	7677798	820	NE-SW
	Line 3	499169	7677995	498451	7677670	800	NE-SW
Res	Line 3	499156	7677923	498181	7677598	1 000	NE-SW
	Line 5	498993	7678064	498410	7677864	600	NE-SW

The contoured EM results indicate a range of conductivities between -13 – 16 mS/m, with the higher values representing rocks which are more conductive. The EM results (Figure 5-2) identified a high conductive feature on the western area of the contoured area. This area is characterised by sediments with more of an orange colour. The resistivity lines were planned to survey across this feature.

The resistivity profiles are shown with a range of resistivity of between 0.6 – 14 786 ohm.m (Figure 5-3). Values in the range of 0.6 – 47 ohm.m are represented in shades of blue and indicate rocks with more conductive properties. Values in the range of 829 – 14 786 ohm.m are represented by shades of orange, red and purple and indicate rocks with more resistive properties.

The profiles show that there is a 10 – 20 m layer at the top of both profiles with a lower resistivity range of between 11 – 196 ohm.m. This layer is likely to be representative of the alluvial cover. Underlying this alluvial cover is a more resistive rocks with a range of between 829 – 14 786 ohm.m which is likely to be granite based on the 1:250 000 geological map. Fresh unweathered igneous and metamorphic rocks typically have a range in resistivity of between 1 000 – 100 000 ohm.m (GeoSci Developers, 2022). Within the higher resistivity rock there are two vertical zones which have a lower resistivity in the range of 47 – 829 ohm.m on Line 3.

The low resistive feature between stations 160 – 320 aligns with a defined stream channel on the aerial imagery. This feature could be associated with deeper weathering along the stream and/or a fractured zone within the higher resistivity “granite” rock. This feature is identified on Line 5, between stations 50 – 110. A drilling target (Table 6-1) is proposed on this feature on the Line 5 profile as the resistivity values on Line 5 are slight lower than Line 3 (although they fall in the same 47 – 829 ohm.m range).

The low resistive feature between stations 540 – 650 corresponds to the high conductivity feature identified in the EM results. This feature has a slightly higher resistive base (of 829 ohm.m) at a depth of approximately 30 m indicating that this feature could be associated with deeper weathering. The profile for Line 5 indicates that the 829 ohm.m resistivities are slightly shallower at between 10 – 20 m depth with the Line 3 feature possibly extending to Line 5 between stations 240 – 290 or after station 510. This feature has a higher resistivity at depth and is therefore less likely to have water compared to the first feature. A secondary drill target (Table 6-1) is proposed here but is assigned a lower priority.

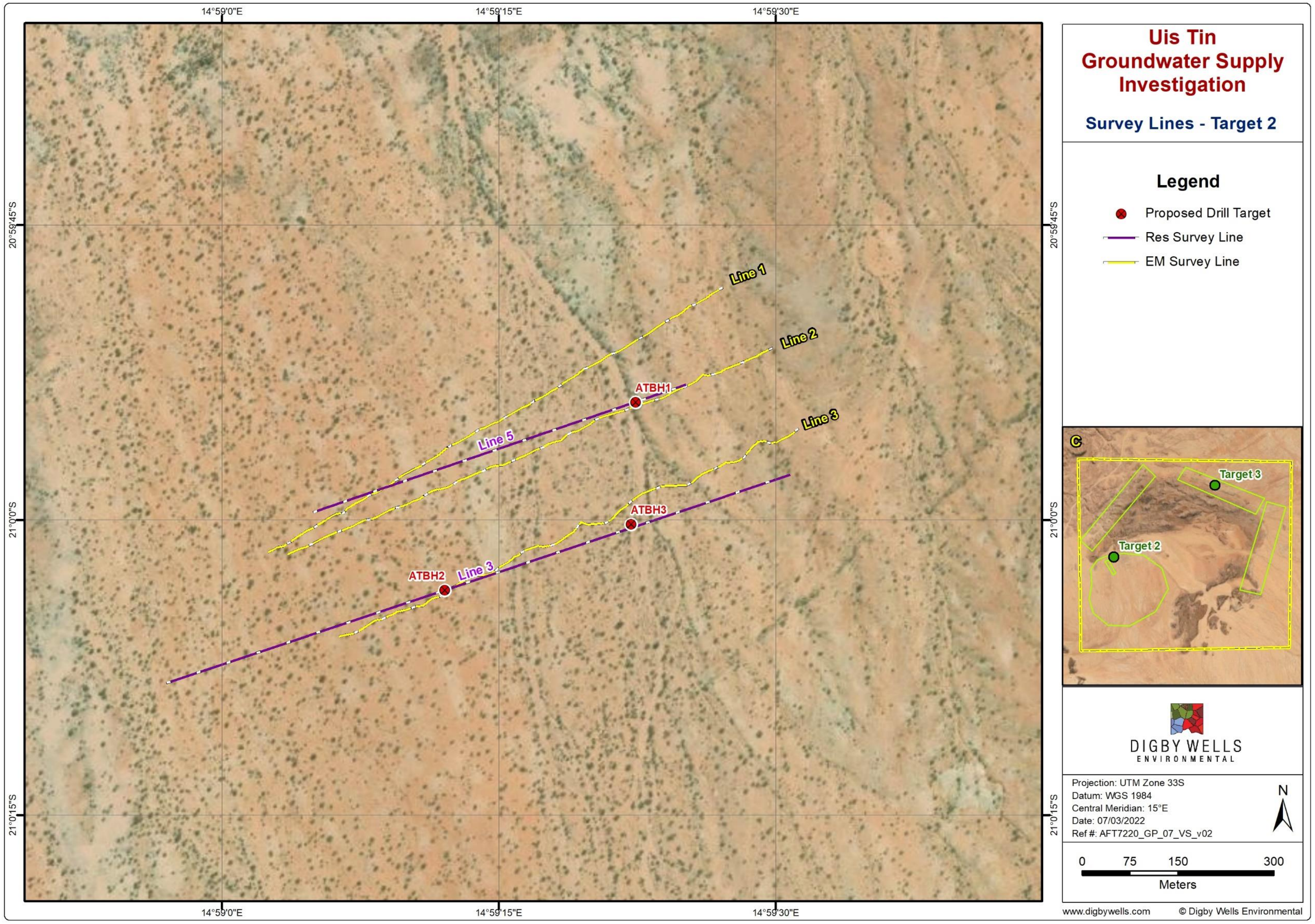

Figure 5-1: Target 2 Survey Lines

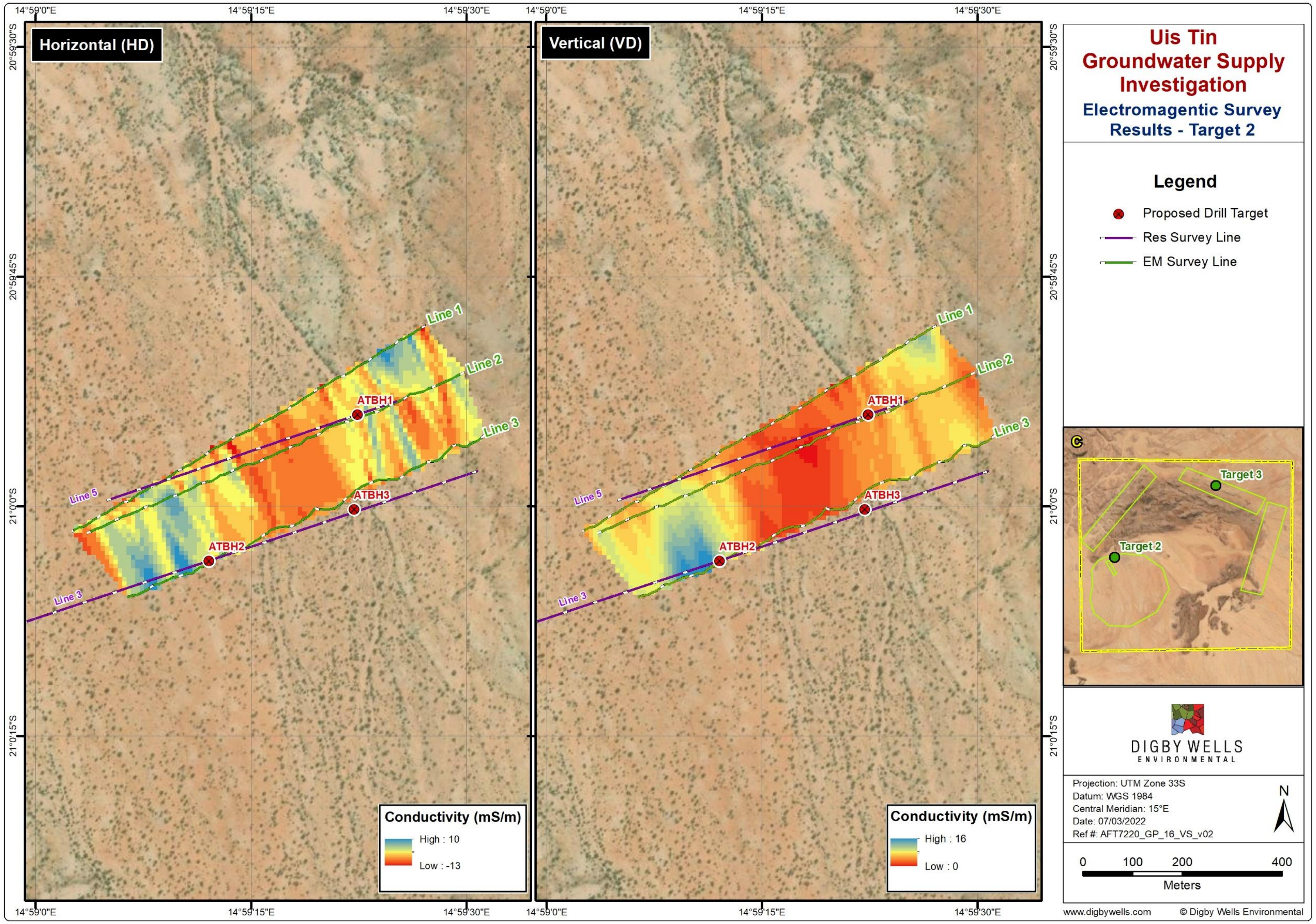

Figure 5-2: Target 2 Contoured EM Results

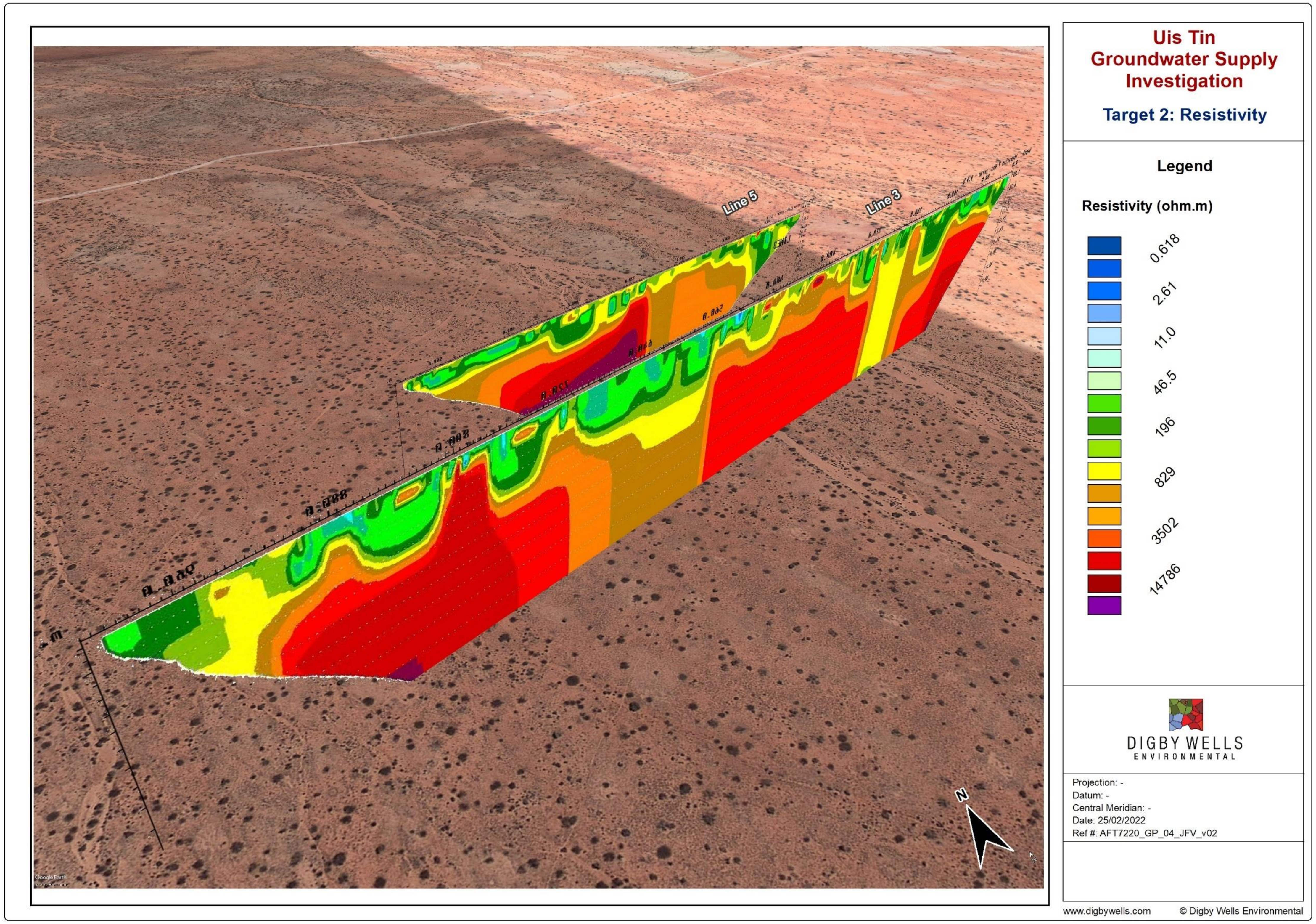

Figure 5-3: Target 2 Resistivity Profiles

5.2. Target 3

Target 3 is located approximately 37 km northwest of the Uis Tin Mine. This target is characterised by a marble unit which is potentially intersected by a regional northwest-southeast trending fault (which could potentially extend to the Ugab River). An alluvial aquifer is also present in this area which drains the catchment area in a north-westerly direction along the marble unit and across the fault structure which could assist with recharging the fractured aquifer. The catchment area is larger than that of Target 2, but it is still located within the low recharge zone. Should the regional fault be connected to the Ugab River system however this target could receive a more sustainable source of recharge.

Three (3) EM survey lines and two (2) resistivity lines were walked for this target (Table 5-2 and Figure 5-4).

Table 5-2: Target 3 Survey Lines

Method	Label	Start		End		Length (m)	Direction
		Longitude	Latitude	Longitude	Latitude		
EM	Line 1	505380	7685624	506123	7685907	800	SW-NE
	Line 2	505457	7685509	506191	7685818	800	SW-NE
	Line 3	505559	7685406	506298	7685700	800	SW-NE
Res	Line 1	505557	7685410	506291	7685741	800	SW-NE
	Line 2	505498	7685948	506203	7685218	1 100	NW-SE

The contoured EM results indicate a range of conductivities between 1 – 74 mS/m, with the higher values representing rocks which are more conductive. The EM results (Figure 5-5) identified a high conductive feature in the regional fault across the marble unit of the contoured area. The resistivity lines were planned to survey across this feature.

The resistivity profiles are shown with the same resistivity range as Target 2 (0.6 – 14 786 ohm.m) (Figure 5-6).

The profiles show that there is a layer approximately 15 m thick at the top of both profiles with a lower resistivity range of between 0.6 – 47 ohm.m. The lower resistivity values in this layer correspond to the location of the marble unit. Underlying this layer are more resistive rocks with a resistivity in the range of 3 502 ohm.m.

Profile 1 was surveyed perpendicularly across the fault and marble and shows a lower resistive feature between stations 290 – 560 which corresponds to where the marble unit is on the profile and the likely position of the fault. The high resistive rocks on either side of this feature corresponds to granite and felsic pyroclastic lithologies on the 1:250 000 geological map.

Profile 2 was surveyed across the fault and along the marble. This profile shows a low resistive feature between station 0 – 210 which would correspond to the northern contact of the marble with the granite rock. Dip direction in the felsic pyroclastic rocks near Target 5 indicate that there is a dip towards the north in this area. If the marble follows the same dip this would indicate that the marbles would be dipping towards the low resistive feature in Profile 2 and that the high resistive feature between station 210 – 1 100 would be influenced by the felsic pyroclastic rocks beneath the surface exposure of the marble. A drill target (Table 6-1) is proposed to intersect the fault within the marble unit (north of the surface exposure of the marble).

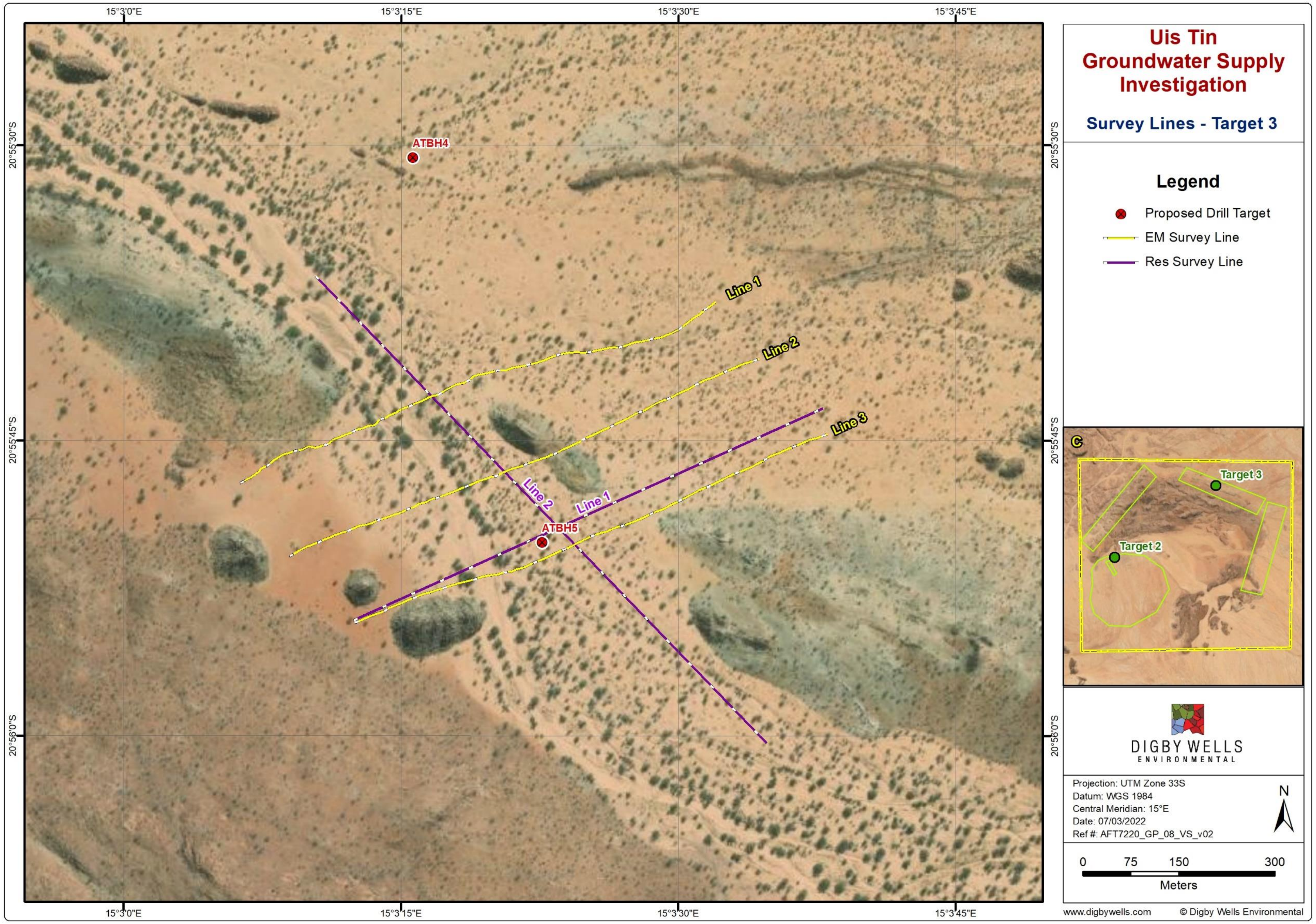

Figure 5-4: Target 3 Survey Lines

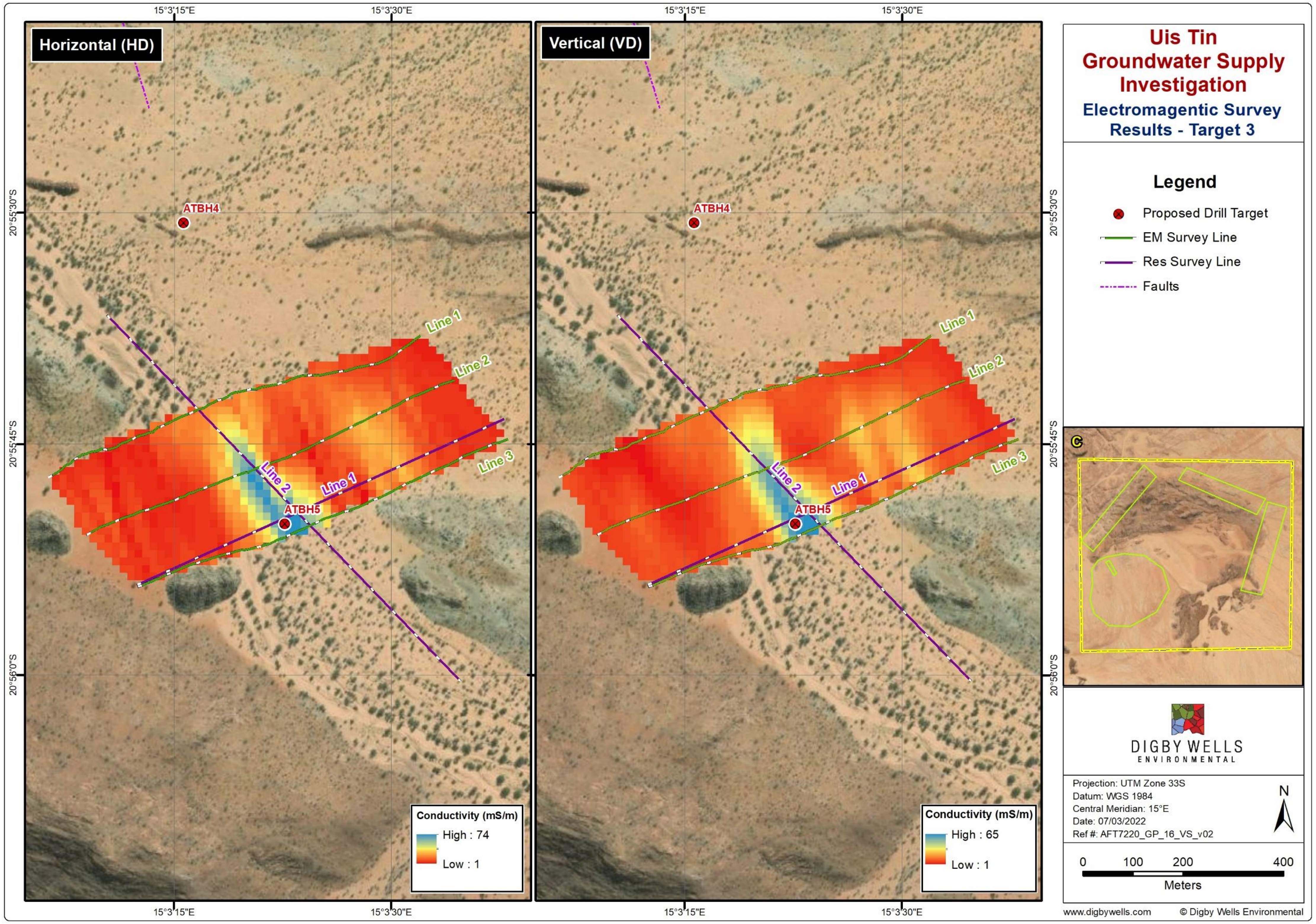

Figure 5-5: Target 3 Contoured EM Results

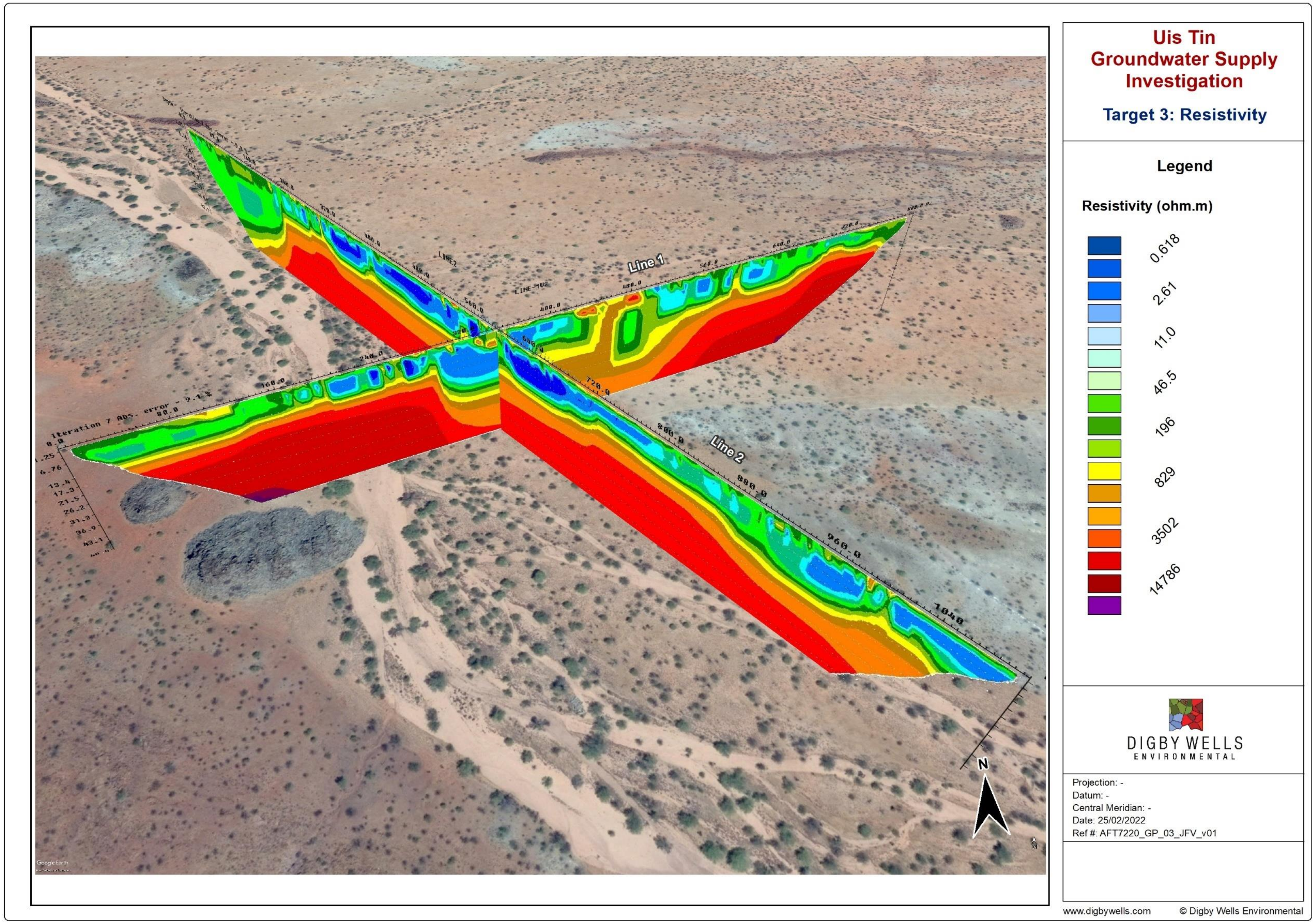

Figure 5-6: Target 3 Resistivity Profiles

5.3. Target 5

Target 5 is located approximately 55 km northwest of the Uis Tin Mine. This target is characterised by a marble unit. The marble unit is crossed by the Ugab River upgradient of the target which could provide a potentially sustainable source of recharge via fractures (if present). An alluvial aquifer is also present in this area which drains the catchment area in a north-westerly direction. The catchment area is large with tributaries starting approximately 33 km southeast of the target area. The tributaries of the alluvial aquifer are located in the low recharge zone however the marble has a potentially higher recharge potential in this area.

Three (3) EM survey lines and two (2) resistivity lines were walked for this target (Table 5-3 and Figure 5-7).

Table 5-3: Target 5 Survey Lines

Method	Label	Start		End		Length (m)	Direction
		Longitude	Latitude	Longitude	Latitude		
EM	Line 1	518249	7698764	517948	7697995	800	NNE-SSW
	Line 2	518150	7698768	517948	7698017	800	NNE-SSW
	Line 3	518072	7698772	517940	7698048	800	NNE-SSW
Res	Line 4	518424	7698975	517909	7698138	1 000	NE-SW
	Line 6	518386	7698801	518094	7698303	600	NE-SW

The contoured EM results indicate a range of conductivities between -10 – 14 mS/m, with the higher values representing rocks which are more conductive. The EM results (Figure 5-8) identified a high conductive feature aligning with the stream channel as well as on the north-eastern area of the contoured results. A kraal fence may have influenced the results on the north-eastern area. The resistivity lines were planned to survey both these features.

The resistivity profiles are shown with the same resistivity range as Target 2 (0.6 – 14 786 ohm.m) (Figure 5-9).

The profiles show that the surface (top) zone is more resistive than the previous targets, with high resistivity clusters near surface of greater than 829 ohm.m. There is however still a weathered zone of approximately 6 - 15 m thick with a range in resistivity of between 47 – 196 ohm.m.

Both profiles show a high resistive feature of approximately 3 502 ohm.m. This feature occurs between stations 440 – 560 in Profile 4 and between stations 290 – 510 in Profile 6 and corresponds to a grey rock exposure in the aerial imagery. Field notes made during the EM survey indicate this rock is fractured granite. The stream from the northeast and the southeast diverts around the southern edge of this rock exposure which competent based on the high resistivity feature. The rocks with a resistivity of between 829 – 3 502 ohm.m in these profiles would correspond to granite and felsic pyroclastic rocks as mapped on the

1:250 000 geological map. The dip direction measurements in the felsic pyroclastic rocks indicates that there is a dip towards the south in the Target 5 area.

There is a low resistivity feature (11 – 196 ohm.m) at the northern contact with the felsic pyroclastic rocks. The feature occurs to a depth of approximately 30 m indicating this may represent a weathered feature or if fractured that the fractures are limited to shallow depths. Another low resistivity feature is present between station 570 – 680 on Profile 4 with a range in resistivity between 196 – 829 ohm.m. This feature may be connected to the deeper low resistive feature on Profile 6 with the same range in resistivity. This feature may be representative of preferential weathering underneath the more competent feature or the presence of marble (if dipping in the same direction as the felsic pyroclastic rocks). Two drill targets (Table 6-1) are proposed to intersect this low resistive feature one on each profile.

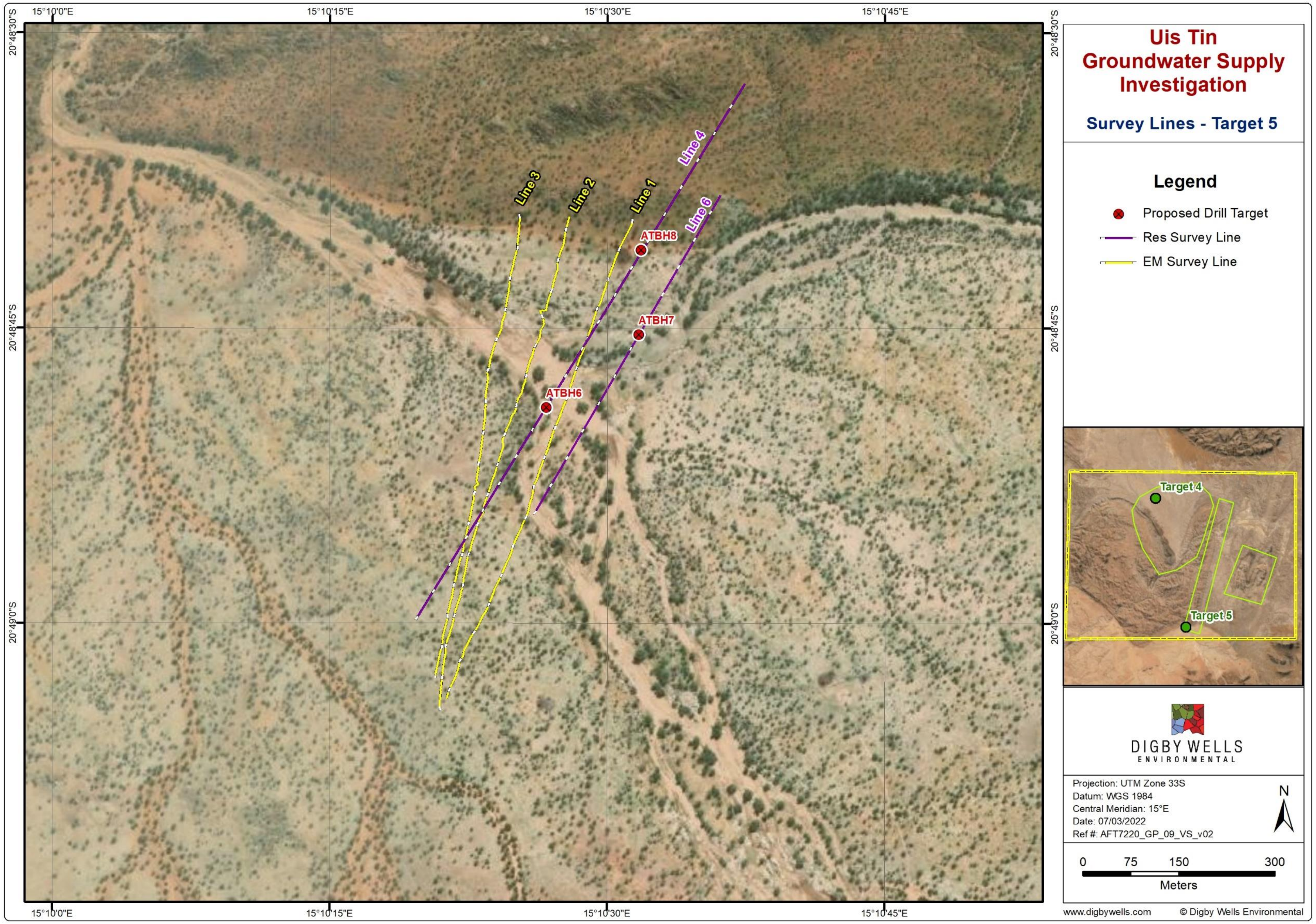

Figure 5-7: Target 5 Survey Lines

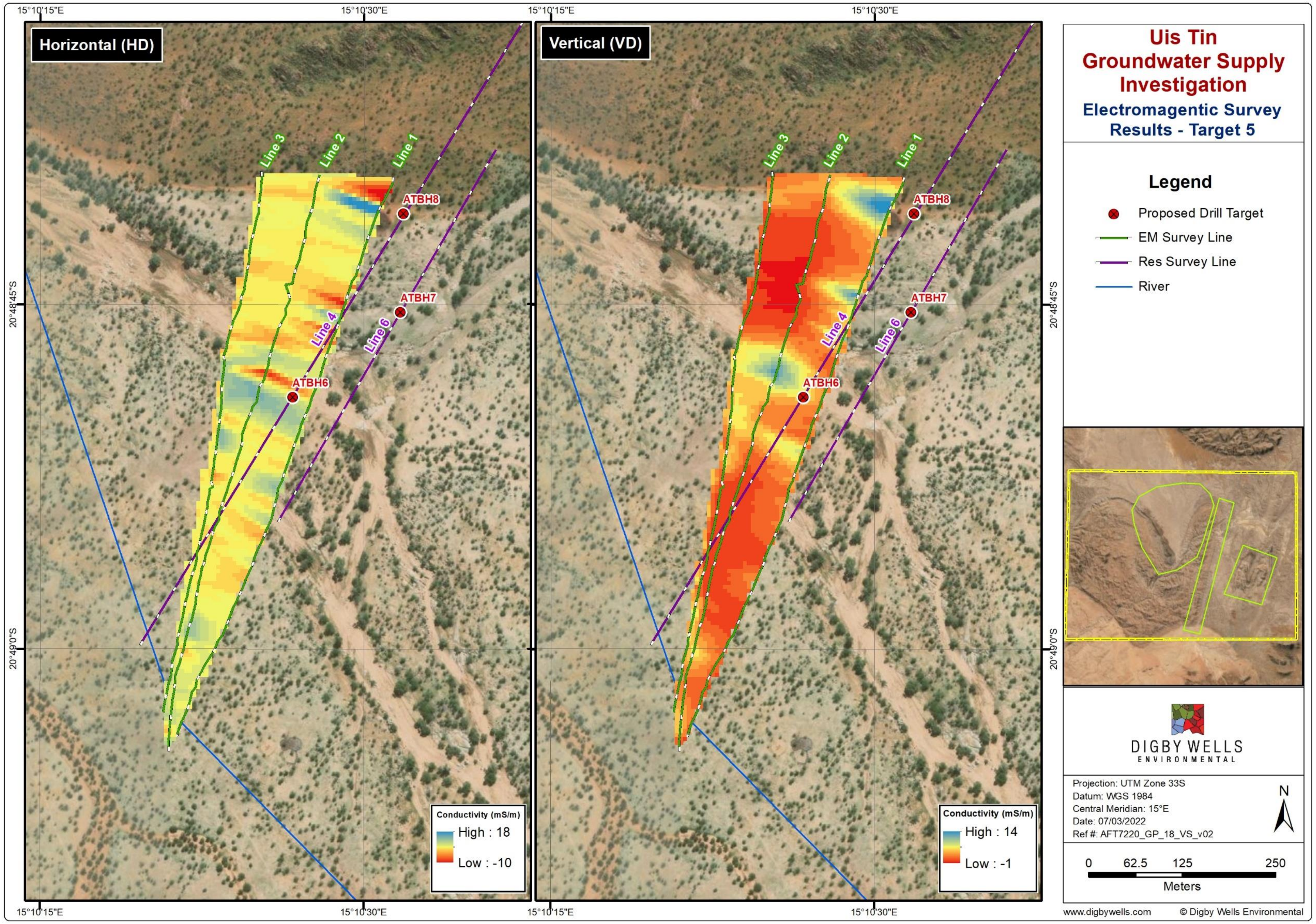

Figure 5-8: Target 5 Contoured EM Results

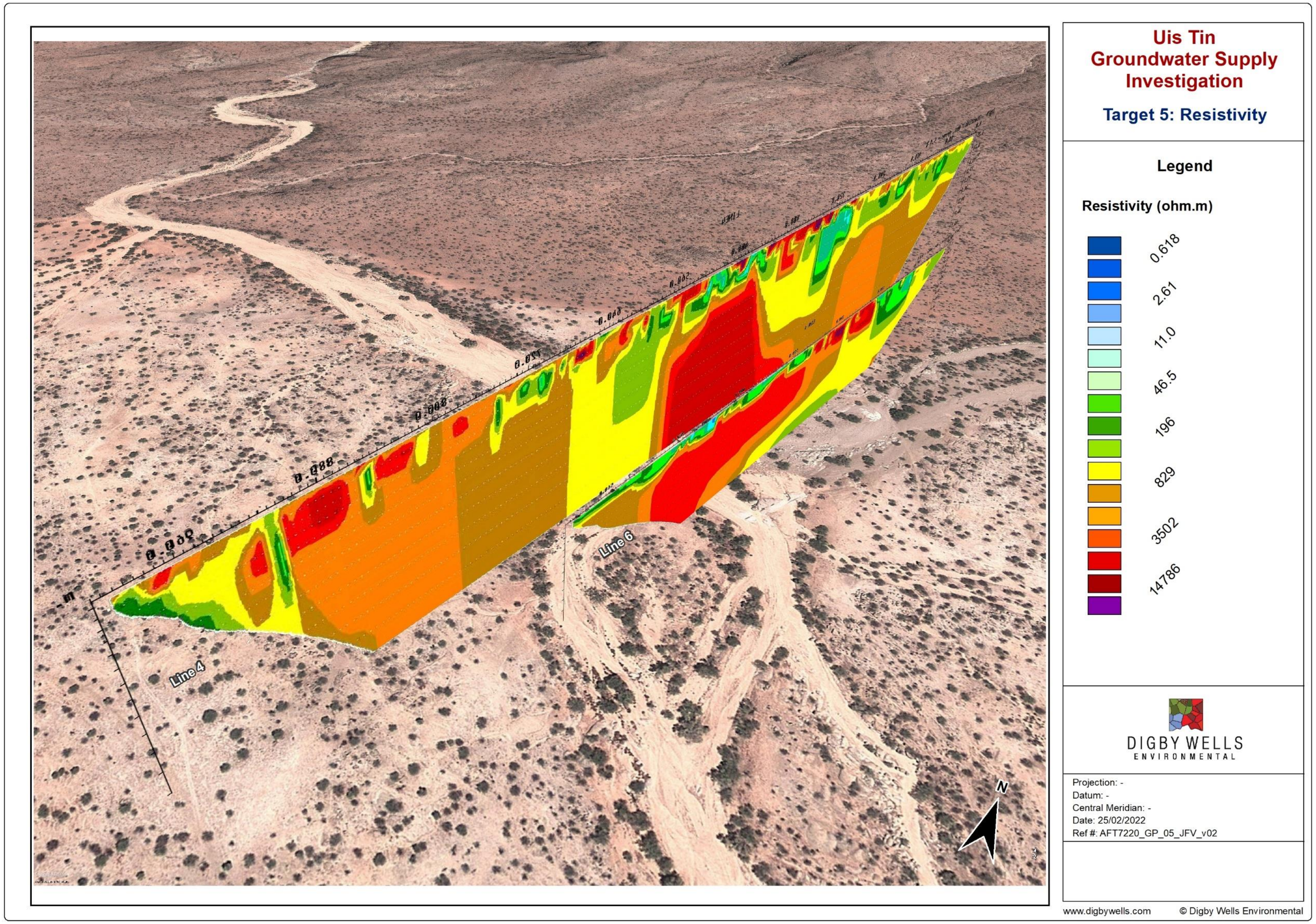

Figure 5-9: Target 5 Resistivity Profiles

6. Conclusion

Six (6) target areas were identified at desktop level with potential marble and/or alluvial aquifer systems. Within these target areas eight locations were identified as potential geophysical survey areas. These eight locations were prioritised to the three locations which could be surveyed with EM and resistivity geophysical survey methods.

Target 2 surveyed an alluvial aquifer with the potential to have high yielding boreholes (an existing borehole with an estimate yield of 27 m^3/hr is potentially located near to this target area). Two drilling targets were identified from the geophysical survey data for this target.

Target 3 surveyed a potential regional fault which intersects marble unit. There is an alluvial aquifer flowing across this location as well which could assist with recharging the fault and/or marble aquifer. One drill target was identified from the geophysical data for this target.

Target 5 surveyed a potential marble unit with an alluvial aquifer (with a large catchment area) potentially supplying a source of recharge to the marble aquifer. Two drilling targets were identified from the geophysical survey data for this target.

A total of eight (8) drilling targets have been proposed which are summarised in Table 6-1.

The boreholes should be drilled using air-percussion drilling methods. Boreholes should be drilled to a final end-of-hole diameter of 8 inches. Should a borehole intersect yields of greater than 20 m^3/hr, the borehole will need to be reamed to a larger diameter. Screened PVC casing should be installed in all boreholes which intersect a water strike to prevent collapse of the borehole. The annulus of the borehole must be filled with 3 – 5 mm silica sand/gravel until approximately 1 m below surface. A 1 m bentonite seal should be installed at surface to prevent surface contamination from entering the borehole.

After the boreholes have been drilled and constructed, they will need to be aquifer tested to verify the sustainable yield of the borehole. A four (4) hour step test followed by a forty-eight (48) constant discharge test should be performed on all successful boreholes. During the aquifer test, samples should be collected for analysis to determine the groundwater quality.

Table 6-1: Proposed Drill Targets

Geophysical Target	Drill Target	Longitude	Latitude	Proposed Depth (m)	Priority	Resistivity Station	Comment
Target 2	ATBH1	498914	7678037	80	High	Line 5 - 70	
Target 2	ATBH2	498616	7677743	80	Low	Line 3 - 570	
Target 2	ATBH3	498907	7677846	80	High	Line 3 - 270	
Target 3	ATBH4	505650	7686133	100	High	-	This target is projected off the original survey profiles and may need to be resurveyed to confirm the fault location
Target 3	ATBH5	505852	7685532	80	High	Line 1 - 310	
Target 5	ATBH6	518114	7698470	100	High	Line 4 - 600	There were community issues when surveying Target 5. Water supply may be requested if boreholes are drilled here.
Target 5	ATBH7	518258	7698584	100	High	Line 6 - 250	
Target 5	ATBH8	518262	7698716	80	Low	Line 4 - 320	

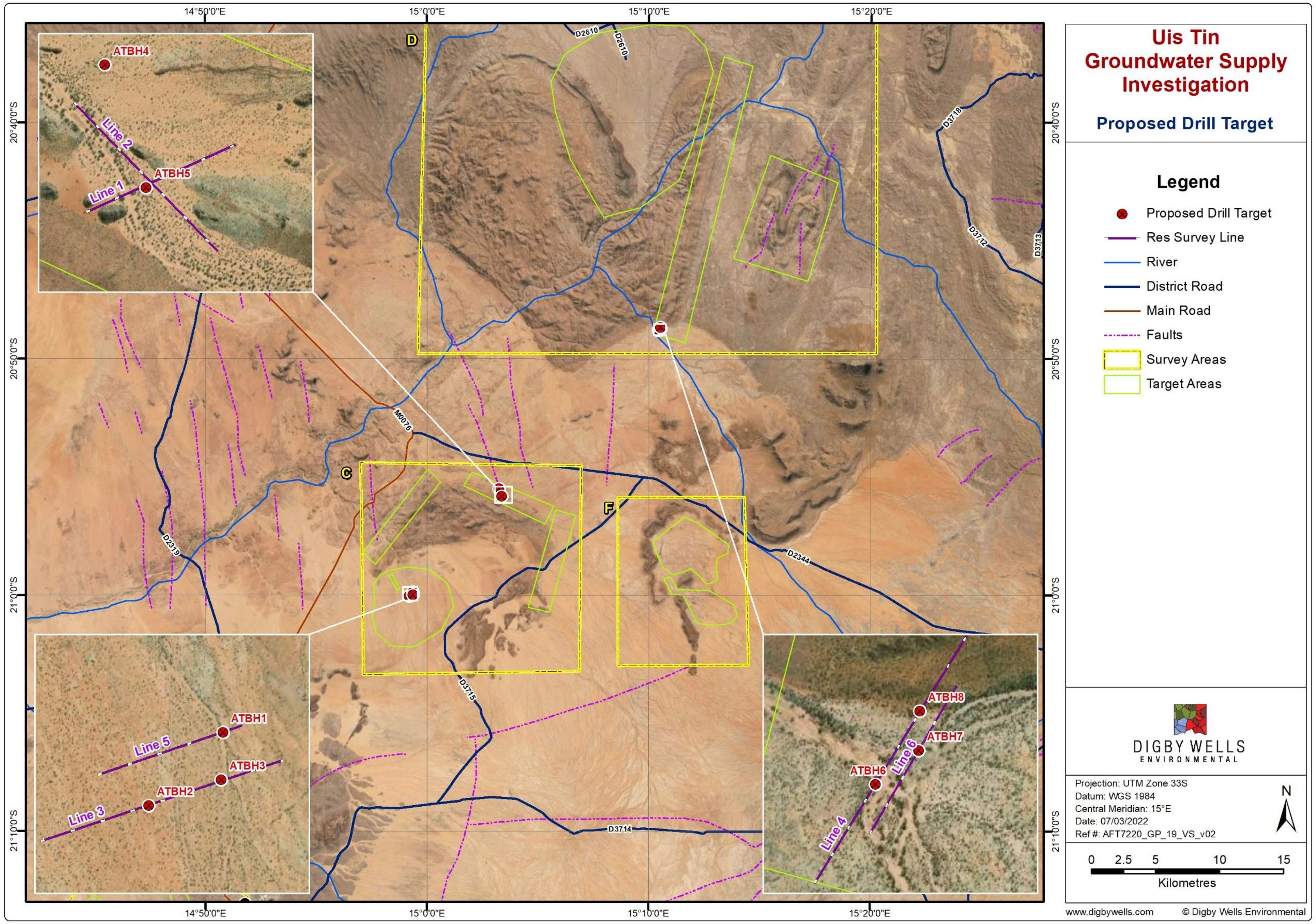

Figure 6-1: Proposed Drill Targets

7. Recommendations

The following additional recommendations are proposed:

- It is recommended to locate the existing boreholes within the six (6) target areas and if located determine if they can be used by the mine. The boreholes which can be used will need to be aquifer tested to confirm their sustainable yields. Should the existing boreholes all be located, and the estimate yield confirmed the existing boreholes could potentially provide 279 m^3/hr.

8. References

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Appendix A: Methodology

Electromagnetic Method

Nine (9) survey lines were investigated using the electromagnetic geophysical survey method using an a two-man portable EM 34 instrument with 20 m coil separation. Both the horizontal (HD) and vertical (VD) dipole modes where applied. These modes measure the out-of-phase component of the induced electromagnetic field, which gives an indication of the subsurface conductivity.

Electrical Resistivity Tomography Method

Six (6) survey lines were investigated using the electrical resistivity tomography geophysical survey method using the ABEM Terrameter LS 2. Electrical Resistivity Tomography (ERT / Resistivity / Res) is a geophysical survey method measuring resistivity, which is a physical property of materials that describes how difficult it is for an electrical current to pass through the material.

The LS2 instrument was setup using four (4) 100 m cables with 5 m electrode spacing. The 5 m electrode spacing allows for a mean survey depth of approximately 60 m. The resistivity survey was conducted using the wenner-α array, which is a four (4) electrode setup that is less sensitive to noise and has a high signal to noise ratio reducing the potential for errors.

Data Processing

The 2D resistivity data was processed using a de-spiking and predictive error analysis method to remove readings which are known to be incorrect. The data was corrected for the following issues:

- Noisy data (e.g., negative values or large single data point anomalies) was removed;
- Linear interpolation was undertaken to removed singular noisy data points;
- A preliminary inversion was run using RES2DINV software. Data points with large RMS errors were excluded using the RMS error statistics bar chart algorithm available within the RES2DINV software;
- The final inversion is presented in this report as 2D tomographs (or profiles) and as a google earth .kml file to assist with spatially viewing the profiles; and
- The resistivity profiles were georeferenced to the survey line locations (Figure 2 and Figure 3) to spatially view the profile results.

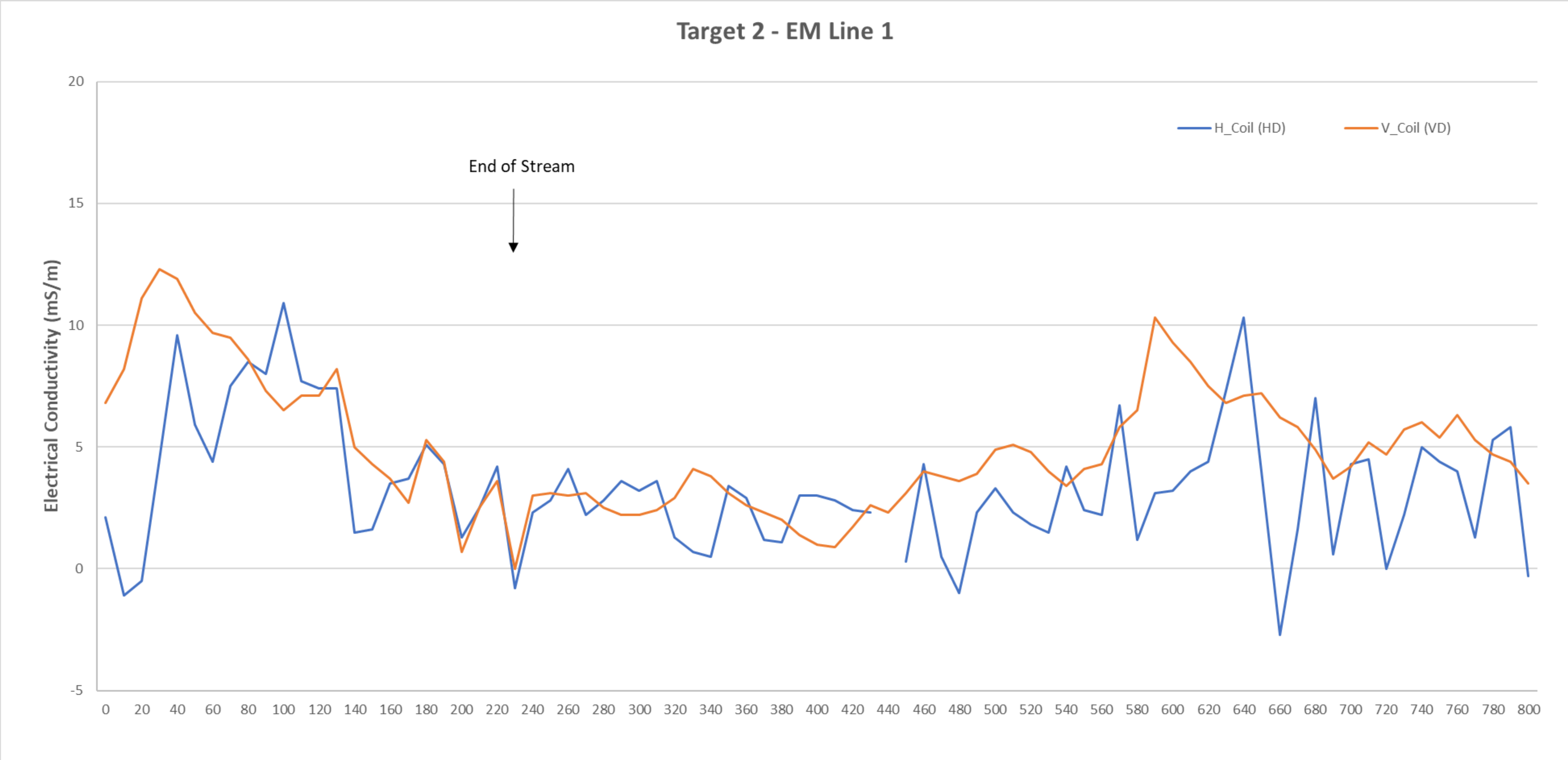
Interpretation

The following factors influence the interpretation of the resistivity and IP survey results:

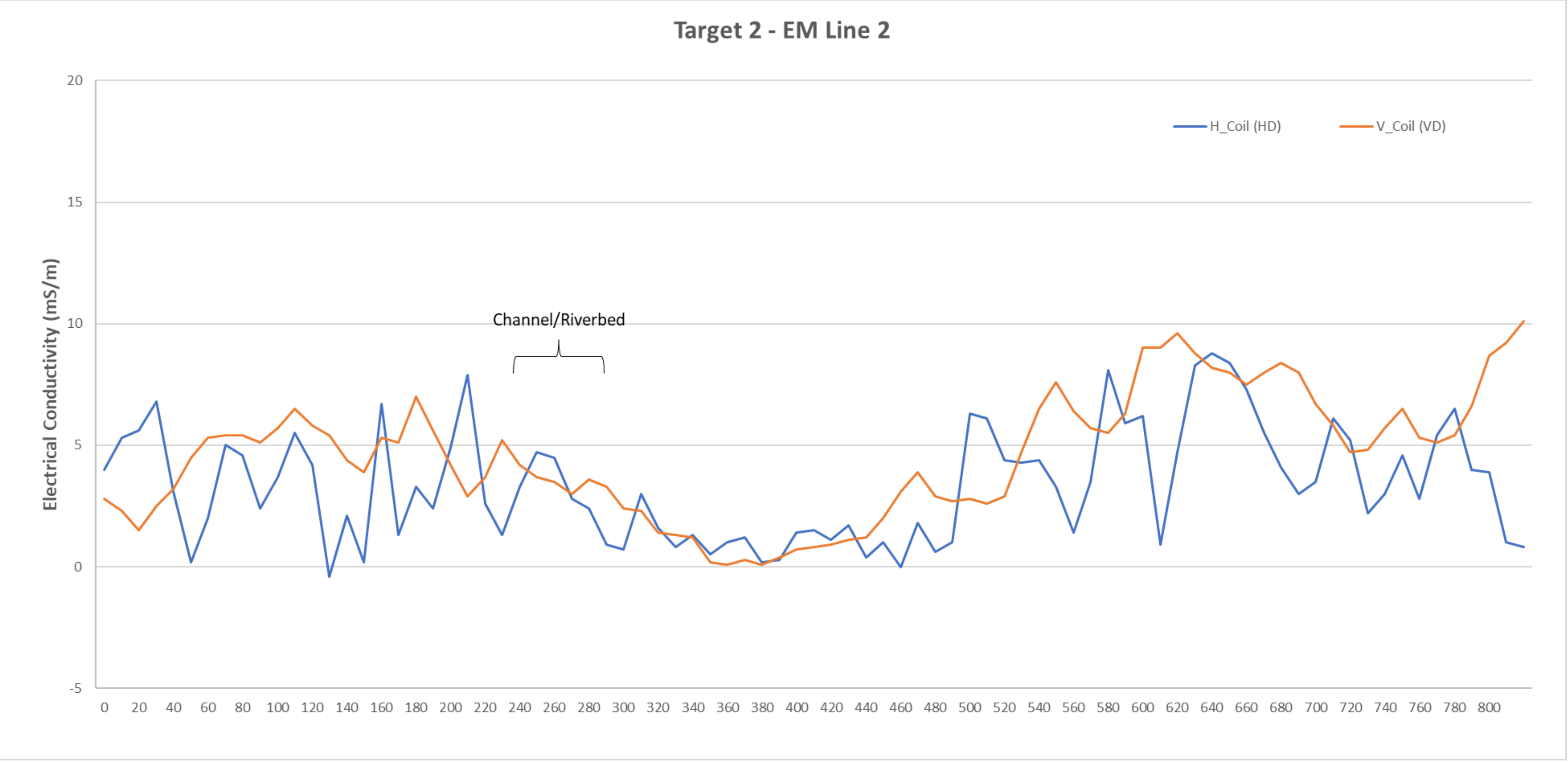
- Porosity, pore saturation and pore fluid can affect the resistivity of rocks. Pore spaces can be filled with air (unsaturated pores) and/or fluids (saturated pores). The properties of air make it very resistive to transmitting a current, thereby forcing the current to flow through the minerals comprising the rock resulting in high resistivity responses. Pore-fluids (which comprise of fresh, brackish, or saline water) however have a higher conductivity compared with most rock forming minerals and as a result a current is more likely to flow through saturated pore spaces (discussed further under tortuosity);

- The complexity and connectivity (tortuosity) of pore spaces can affect the resistivity characteristics of rocks. Tortuosity determines how effectively a current is transmitted through the rock. Rocks with low tortuosity have simple flow paths resulting in more conductive (less resistive) characteristics. As the tortuosity increases so does the resistivity of the rock; and
- Presence of mineralisation within the rocks can affect the resistivity of rocks. Electrical currents preferentially flow through minerals which are more conductive than the pore fluids. Native metals, metal-oxides and metal-sulphides frequently present in ore-bearing rocks as well as graphite have properties which make them more conductive than pore fluids, which lower the resistive properties of the rocks.

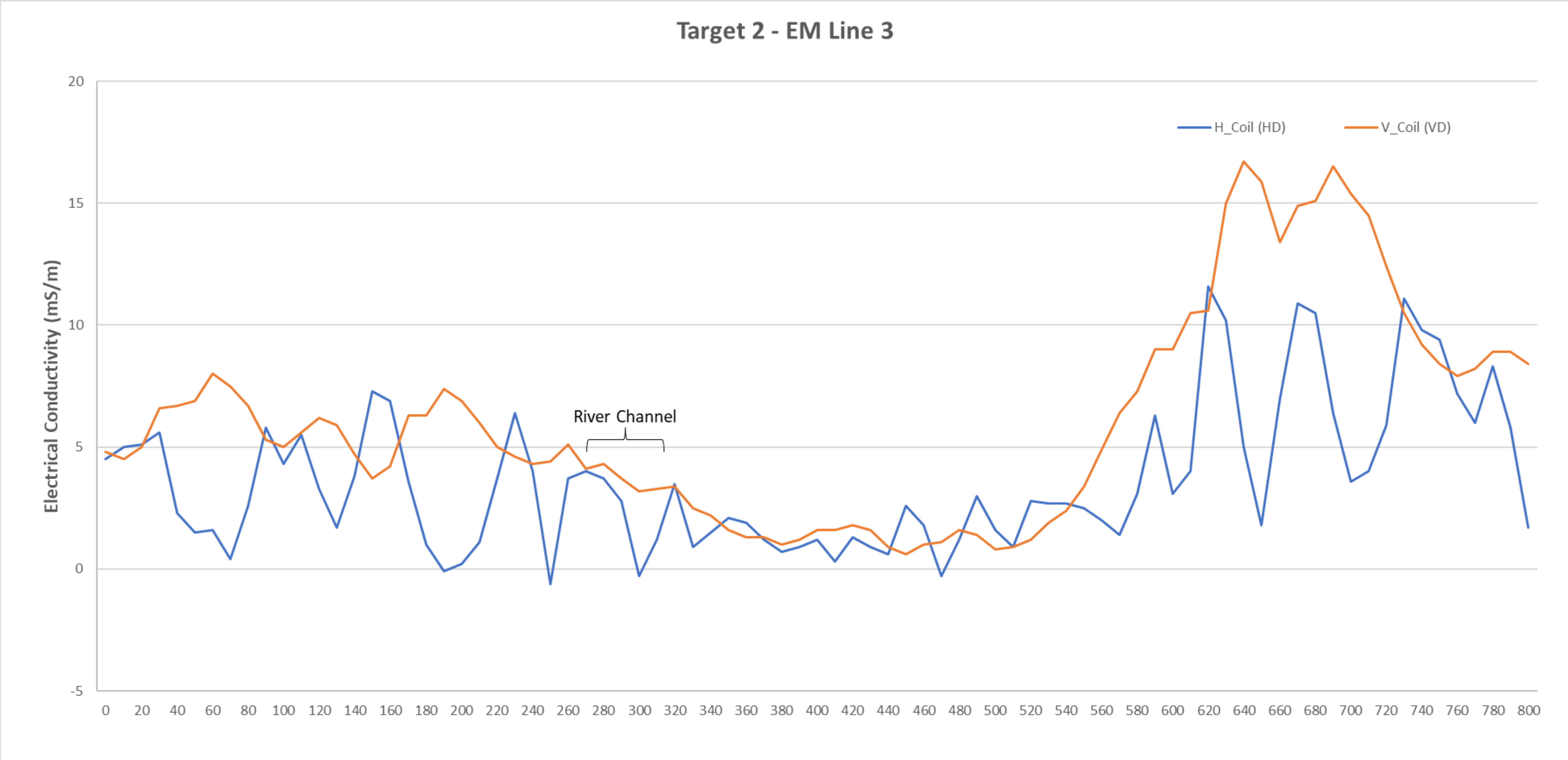
Appendix B: Electromagnetic and Resistivity Profiles



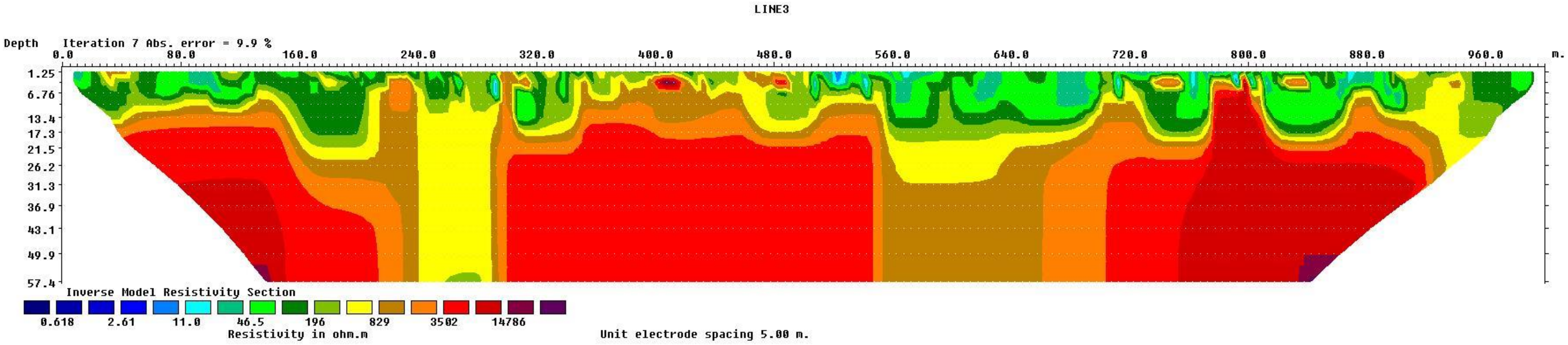
Target 2 EM Profile 1



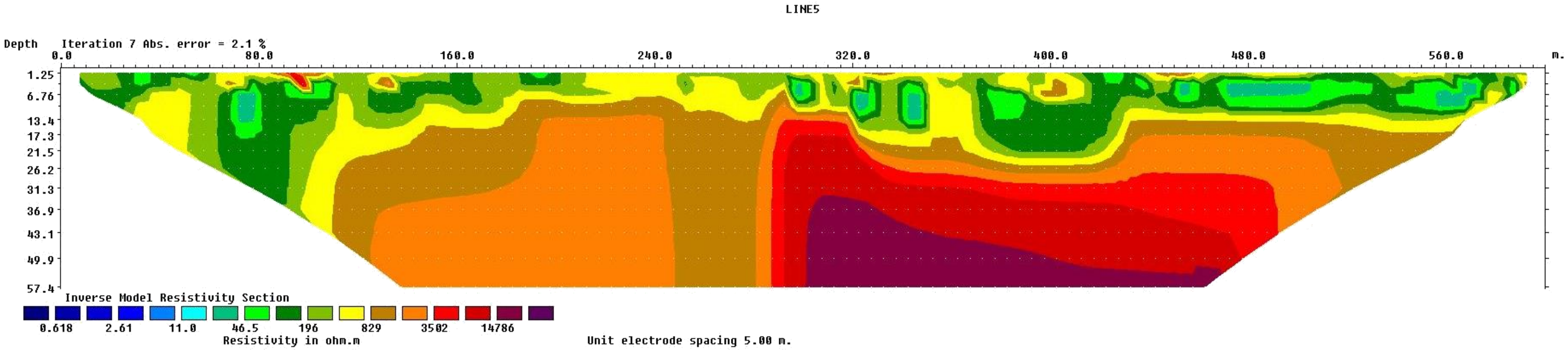
Target 2 EM Profile 2



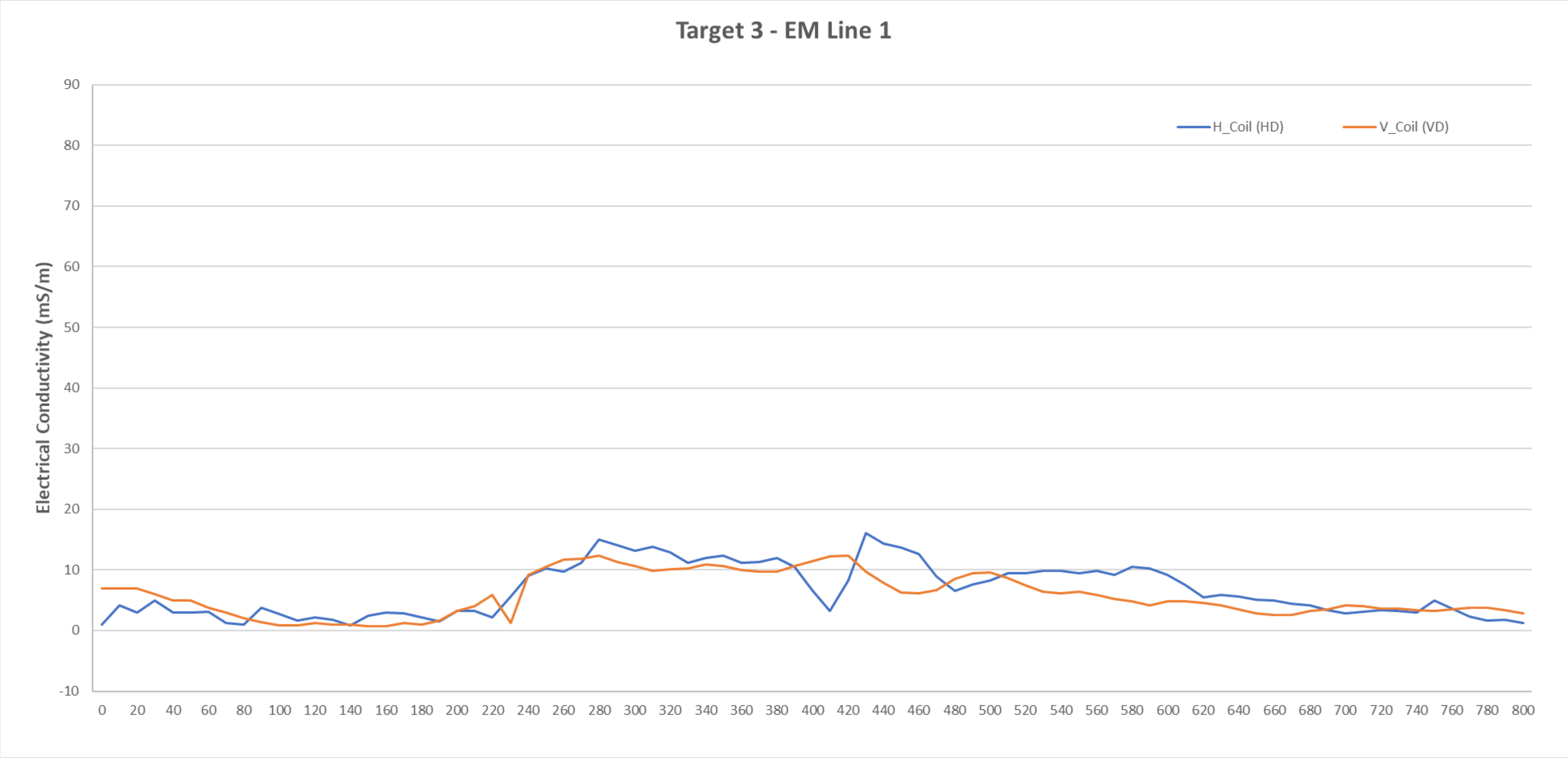
Target 2 EM Profile 3



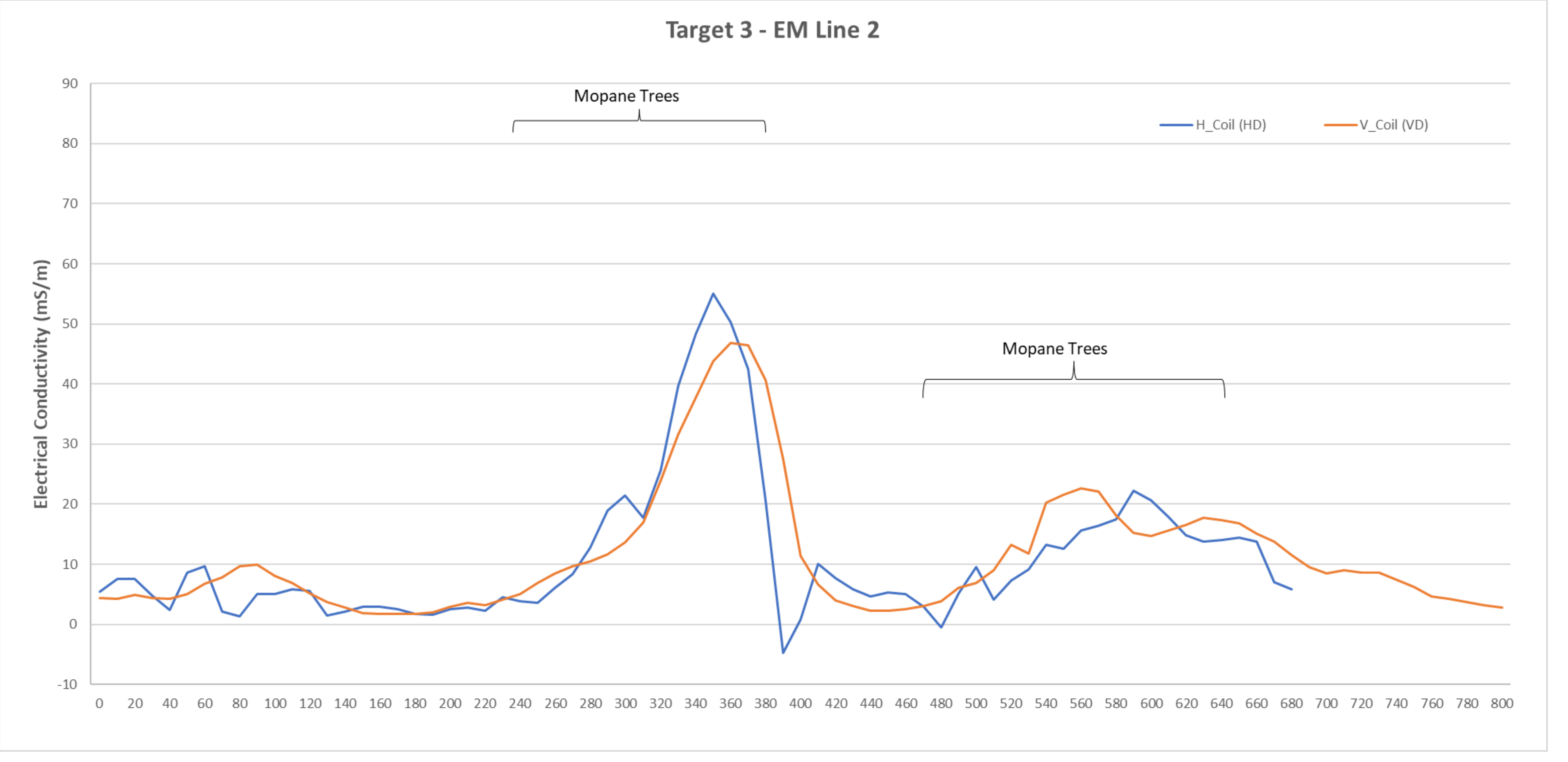
Target 2 Resistivity Profile 3



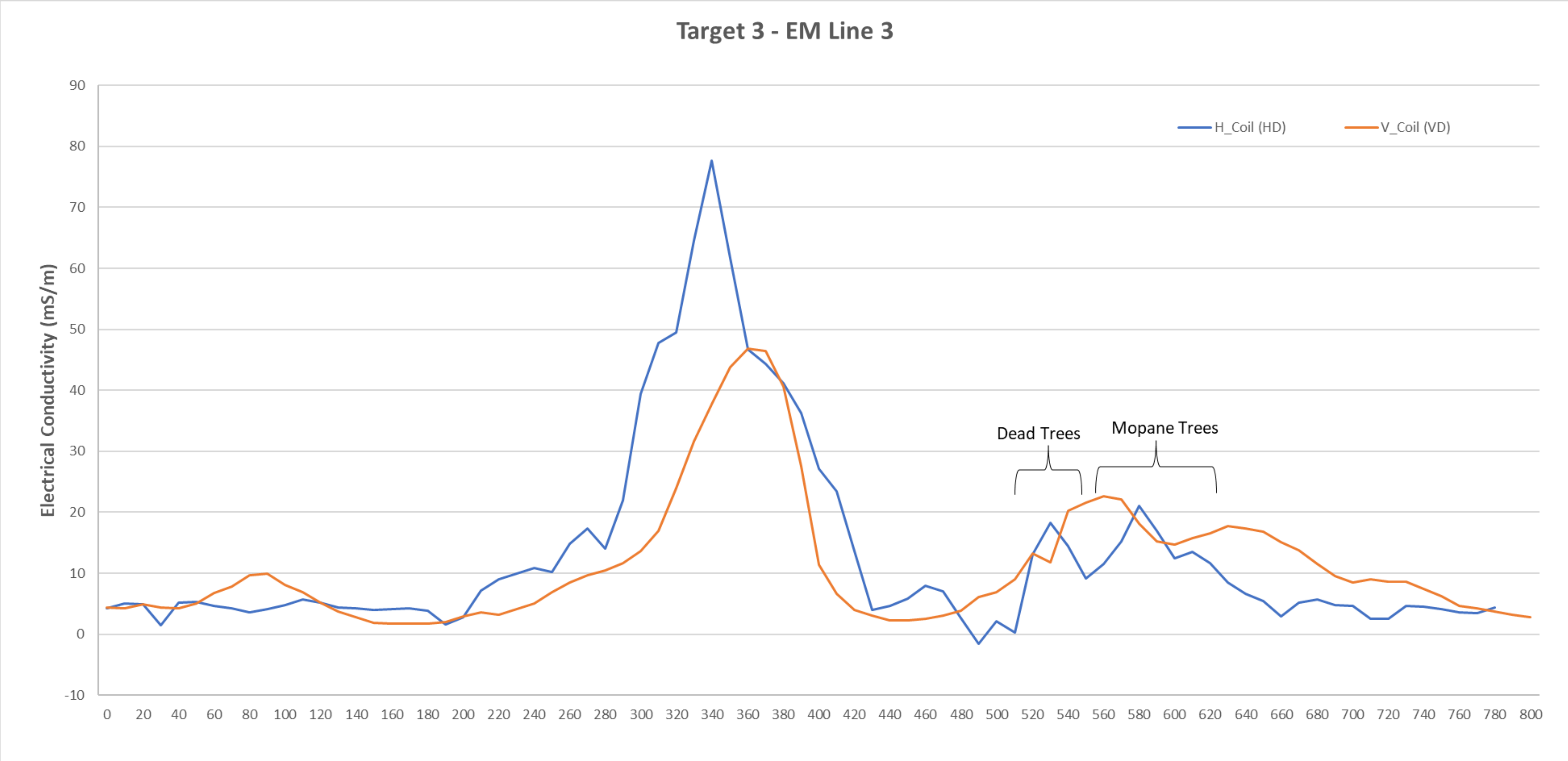
Target 2 Resistivity Profile 5



Target 3 EM Profile 1



Target 3 EM Profile 2



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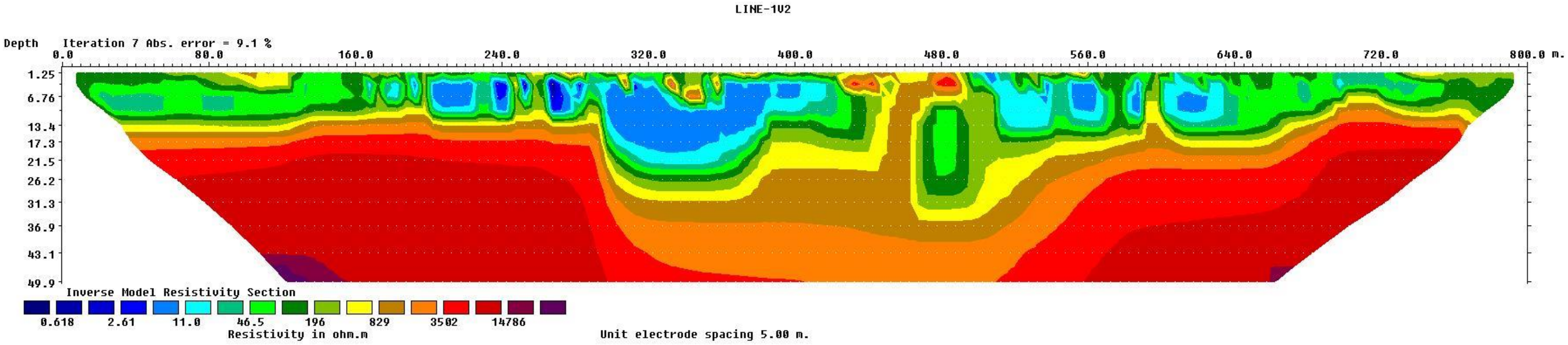
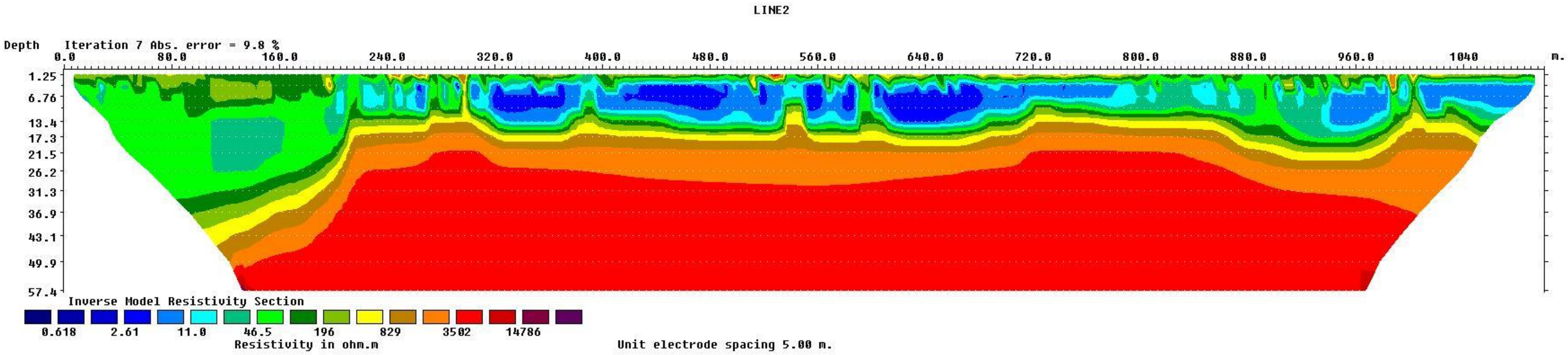
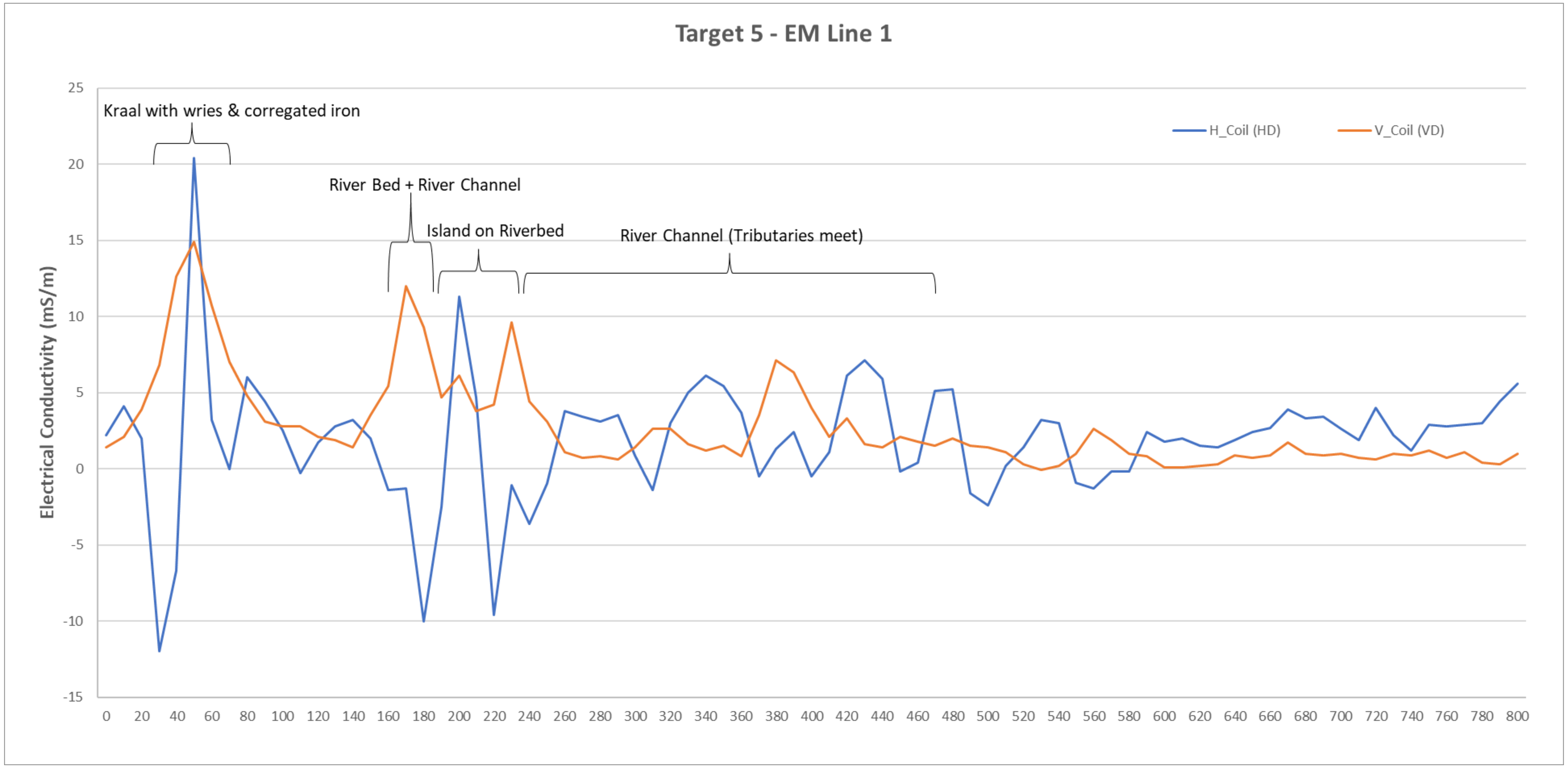


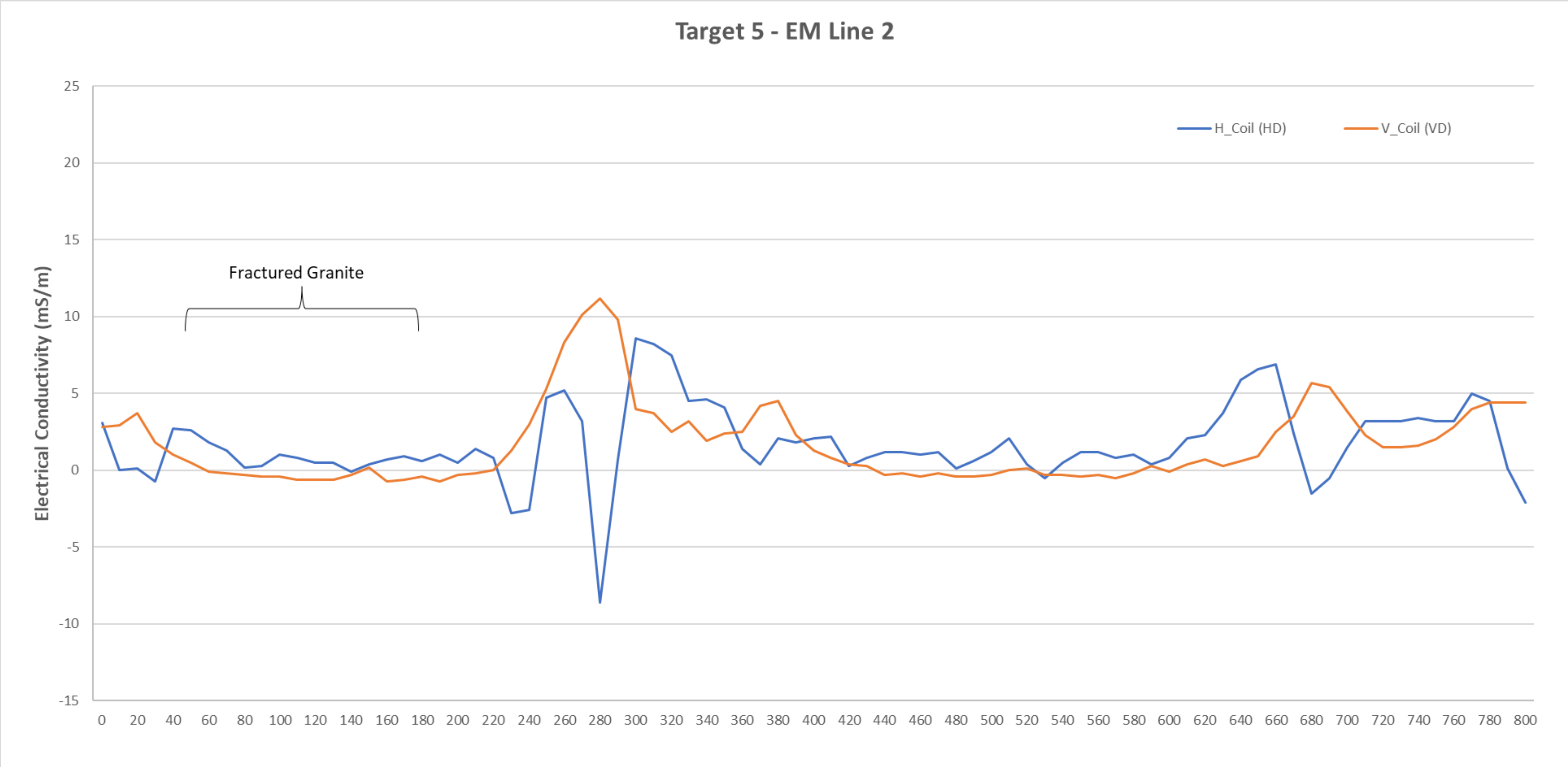
Target 3 Resistivity Profile 1



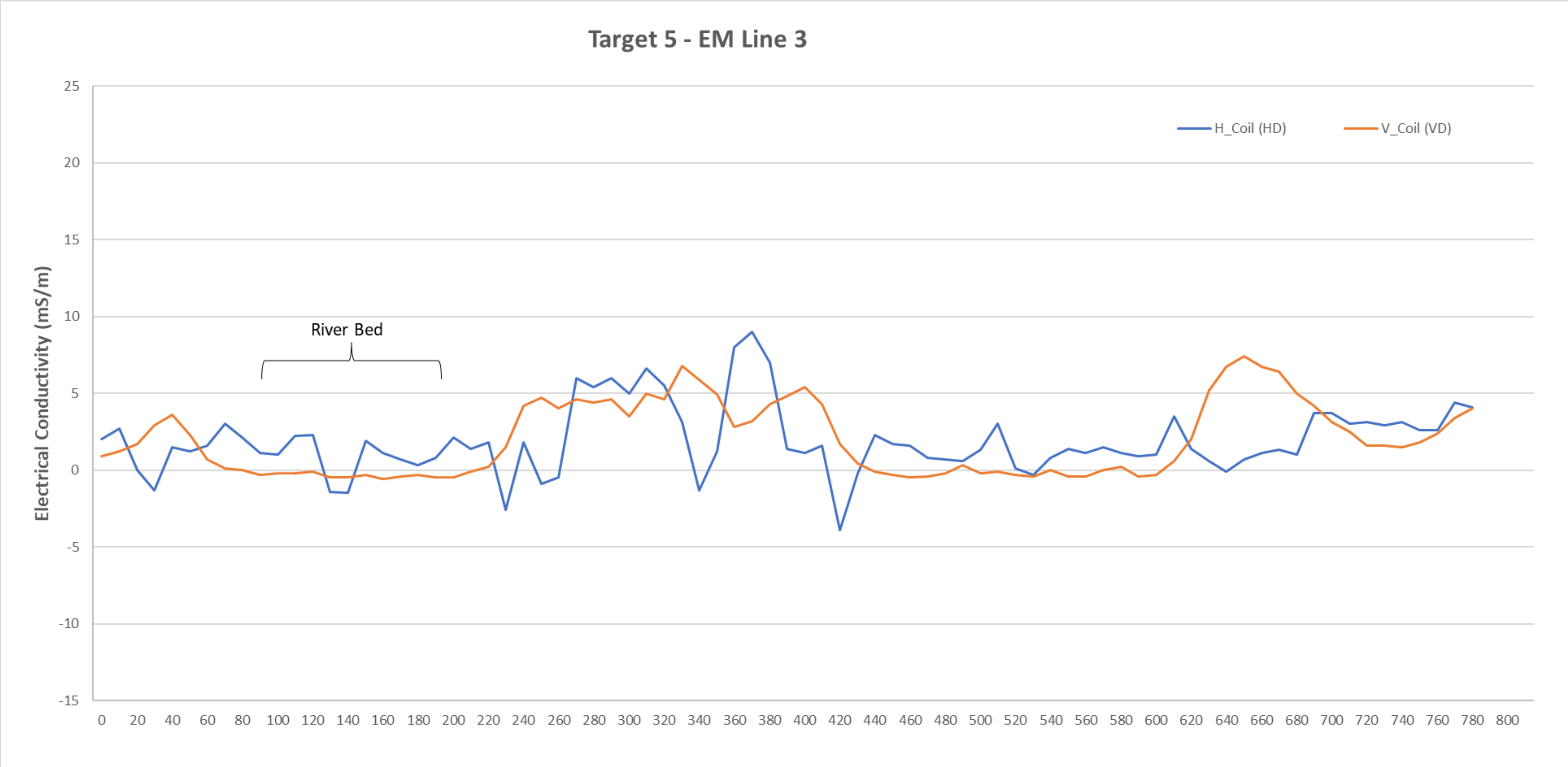
Target 3 Resistivity Profile 2



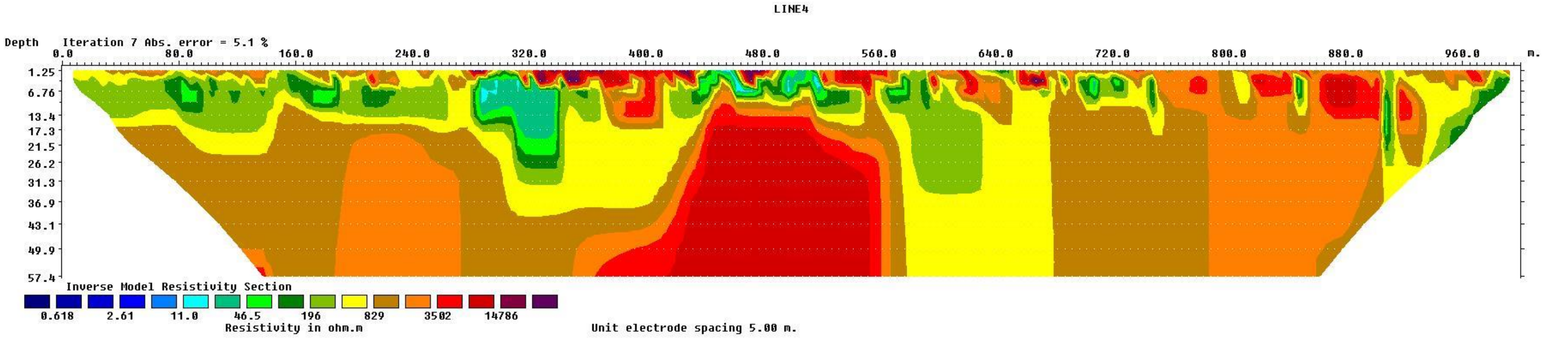
Target 5 EM Profile 1



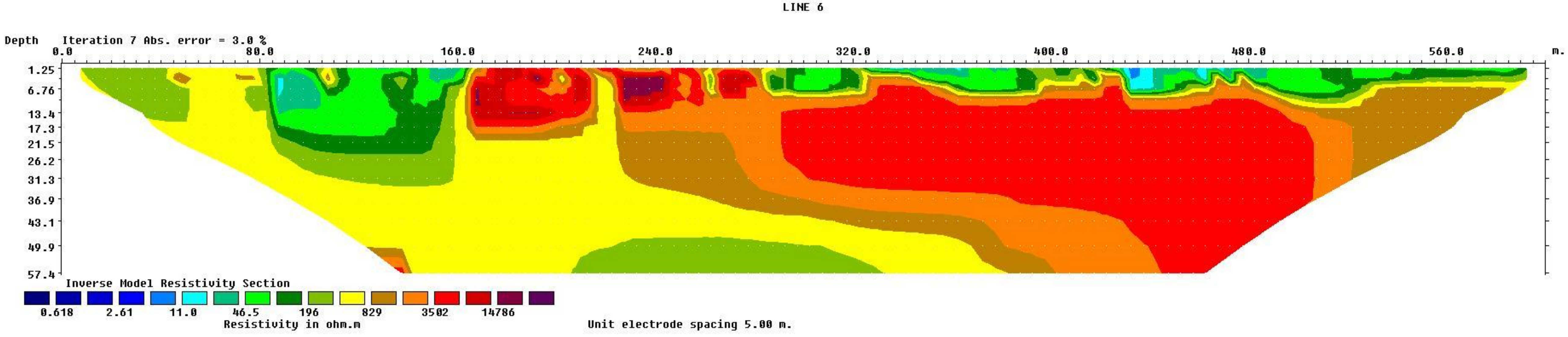
Target 5 EM Profile 2



Target 5 EM Profile 3



Target 5 Resistivity Profile 4



Target 5 Resistivity Profile 6