GOLDER

REPORT

Geological and Soils Desktop Study

Western Outer Ring Main Project

Submitted to:

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Distribution List

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Executive Summary

Golder Associates Pty Ltd (Golder) has prepared a Geological and Geotechnical Assessment Report on behalf of APA[1] to support a desk top review for a proposed pipeline between Plumpton and Wollert known as the Western Outer Ring Main (WORM). This information will inform both the Environment Protection & Biodiversity Conservation (EPBC) referral and the Environmental Effects Statement (EES) referral. APA is proposing to construct a 500mm diameter, buried steel, high pressure gas pipeline approximately 50 kilometres in length. The project also includes an upgrade to the existing compressor station at Wollert.

The topographical and the geological conditions were assessed in the study area along the Preliminary Pipeline Alignment (PPA) and the geological and geotechnical riskss identified and potential mitigation measures discussed.

The topography of the WORM study area is typically flat to gently undulating, with some significant valleys dissecting the terrain. Significant low elevation points occur at valley crossings at Jacksons Creek and Deep Creek. The sides of the valleys of Jacksons Creek and Deep Creek are relatively steep compared to the surrounding plains and the proposed pipeline route generally descends and climbs the valley slopes at close to the maximum slope angle.

The geology underlying the study area is predominantly Quaternary aged Newer Volcanics. The volcanic materials were typically formed as a series of lava flows, typically originating from eruption centres to the north. The lava flows covered the previous terrain and created relatively flat plains. Recent deposition of alluvial and colluvial materials has also occurred in the watercourse valleys that cross the PPA.

Geological and geotechnical risks that are potentially present during construction and operation of the WORM pipeline include slope instability on the sides of the more significant creek valleys, potential erosion of soils on the sideslopes of the valleys and other areas disturbed by construction activities, poor trafficability of the soils along the PPA, including the residual soils associated with the Newer Volcanics, and the potential for acid sulfate soils to be present along the PPA. Geotechnical construction considerations include excavatability of the soil and rock during trenching, ground surface settlement due to ground loss from horizontal boring at road and rail crossings and trench sidewall instability during construction of the pipeline.

To reduce the risks from the hazards, further assessment of the ground conditions will be required as design of the pipeline progresses, including field mapping, intrusive site investigations such as boreholes, test pits and possibly geophysics and associated sampling and laboratory testing.

[1] Note: APA VTS Australia (Operations) Pty Ltd is a wholly owned subsidiary of the APA group (together referred to as APA)

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1.0 ENGAGEMENT

Golder Associates Pty Ltd (Golder) has prepared this Geological and Geotechnical Assessment Report on behalf of APA[2] to support a desk top review for a proposed pipeline between Plumpton and Wollert known as the Western Outer Ring Main (WORM) (alignment shown in Figures 1 and 3). This information will inform both the Environment Protection & Biodiversity Conservation (EPBC) referral and the Environment Effects Statement (EES) referral. APA is proposing to construct a 500mm diameter, buried steel, high pressure gas pipeline approximately 50 kilometres in length. The project also includes an upgrade to the existing compressor station at Wollert.

The scope of work for this assessment was to undertake a desktop review the geological conditions in the study area along the WORM Preliminary Pipeline Alignment (PPA) and provide preliminary commentary on potential geological and geotechnical risks to the pipeline, including geohazards and geotechnical construction risks.

2.0 PROJECT DESCRIPTION

A description of the project is provided in the Biosis Pty Ltd (Biosis) document 'Western Outer Ring Main (WORM), Project Description', Biosis reference: *29563.WORM.Project.Description.DFT01.20190710*, dated July 2019.

The overall WORM PPA is shown on Figures 1 and 3, overprinted on published geological mapping and aerial imagery respectively. Figures 2A to 2E and Figures 4A to 4E shows locations where the PPA crosses areas with changing geological conditions, such as creek crossings (discussed in Section 4 below), overprinted on published geological mapping and aerial imagery respectively.

2.1 Key Construction Activities

The key construction activities include the following activities:

1. **Survey and fencing** - The pipeline is surveyed and fencing modified to facilitate access during construction;
2. **Clear and grade** - Graders, bulldozers and excavators are generally used to clear and prepare the easement ready for construction to commence. Topsoil and vegetation are stockpiled separately to assist in restoration works after the pipeline is completed;
3. **Stringing** - Pipe is transported into the easement and laid end to end next to where the trench will be dug;
4. **Bending** – Where required, specialised machinery is used to bend the pipe to conform with the contours of the land and the pipeline route;
5. **Welding and non-destructive testing** – Pipe sections are welded together;
6. **Joint coating** – The areas of weld are cleaned and pipe joints are coated to reduce the possibility of corrosion;
7. **Trenching** – Specialised trenching machines and excavators are used to dig the trench up to about 2 m deep.
8. **Lowering in and padding** – Specialist equipment (Side booms) is used to lower the pipe into the trench. The pipe is then covered by fine grained material (padding) to protect the pipeline coating from stones and other sharp objects;
9. **Backfilling** – The trench is backfilled with the previously excavated subsoil material;

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10. **Hydrostatic testing** – Using water, the pipe is pressure tested to ensure it is fit for operational service; and
11. **Restoration and signage** – Disturbed areas are reinstated to match existing landforms, including re-contouring and installation of permanent erosion control structures. Topsoil is respread. Rehabilitation is undertaken. Signs will be placed at regular intervals.

2.2 Operational Activities

The pipeline will be underground with intermittent indicators of its presence, including valve enclosures, marker posts, cathodic protection test points and signage. The pipeline will be owned and maintained by APA, including routine maintenance and testing.

3.0 STUDY AREA TOPOGRAPHY

The topography of the WORM study area is typically flat to gently undulating. The elevation generally gently rises from Plumpton (KP 0) to the northernmost point of the pipeline at Kalkallo at an approximate elevation of RL 270 m AHD at KP 41.5, then gently descends to approximately RL 210 m AHD at the pipeline connection location at Wollert (KP 50.7). Significant low elevation points occur at valley crossings at Jacksons Creek (KP 13.8) and Deep Creek (KP 17.1) with approximate elevations at the creek crossing points of RL 120 m AHD and RL 100 m AHD respectively. The sides of the valleys of Jacksons Creek and Deep Creek are relatively steep compared to the surrounding plains. The proposed pipeline route generally descends and climbs the valley slopes at close to the maximum slope angle.

4.0 STUDY AREA GEOLOGY

According to the 1:50,000 Seamless Geological Map of Victoria, published by the Geological Survey of Victoria in electronic GIS format, the geology underlying the study area is predominantly Quaternary aged Newer Volcanics ('Neo' or 'Neo1' and 'Neo2' as shown on Figures 1 and 2A to 2E). The volcanic materials were typically formed as a series of lava flows, typically originating from eruption centres to the north. The lava flows covered the previous terrain and created relatively flat plains.

The volcanic plains have been dissected by watercourses since their formation, with the regional drainage pattern generally running from north to south. Some of the watercourses have incised through the Newer Volcanics and into the underlying geology. Recent deposition of alluvial and colluvial materials has also occurred in the watercourse valleys.

A summary of the mapped geological units along the proposed pipeline route, from the 1:50,000 Seamless Geological Map, is provided in Table 1 below. Figure 1 shows an overview map of the geological units along the pipeline route, and Figures 2A to 2E show smaller scale, more detailed areas where geological conditions change along the pipeline, such as at creek valley crossings. Geological abbreviations in the figures are provided in the table below.

Table 1: Geological units in the study area

Approximate KP from (km)	Approximate KP to (km)	Geological unit	Description
0	13.7	Newer Volcanics (Neo)	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff
13.7	13.8	Quaternary alluvium (Qa1)	Gravel, sand, silt – variably sorted and rounded. Likely to be a thin layer in the base of the Jackson Creek valley, overlying Newer Volcanics basalt.
13.8	16.6	Newer Volcanics (Neo)	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff
16.6	16.7	Silurian Deep Creek Siltstone (Sxd)	Interbedded siltstone and sandstone
16.7	16.8	Quaternary alluvial terrace deposit (Qa2)	Gravel, sand, silt – variably sorted and rounded. Occurs in an elevated terrace adjacent to the watercourse.
16.8	17.0	Silurian Deep Creek Siltstone (Sxd)	Interbedded siltstone and sandstone
17.0	17.4	Quaternary alluvium (Qa1)	Gravel, sand, silt – variably sorted and rounded. Likely to be a thin layer in the base of the valley, overlying Deep Creek Siltstone.
17.4	17.5	Silurian Deep Creek Siltstone (Sxd)	Interbedded siltstone and sandstone
17.6	17.65	Tertiary Brighton Group (Nb)	Gravel, sand, silt, variably calcareous to ferruginous sandstones
17.65	29.1	Newer Volcanics (Neo)	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff
29.1	29.4	Humevale Siltstone (Dxh)	Siltstone, laminated, with minor interbedded fine sandstone
29.4	29.8	Newer Volcanics (Neo)	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff
29.8	30.2	Humevale Siltstone (Dxh)	Siltstone, laminated, with minor interbedded fine sandstone

Approximate KP from (km)	Approximate KP to (km)	Geological unit	Description
30.2	30.3	Incised Colluvium (Nc1)	Silt, sand, gravel, poorly sorted and poorly rounded, infilling a gully in the Humevale Siltstone
30.3	31.0	Humevale Siltstone (Dxh)	Siltstone, laminated, with minor interbedded fine sandstone
31.0	31.1	Incised Colluvium (Nc1)	Silt, sand, gravel, poorly sorted and poorly rounded, infilling a gully between the Humevale Siltstone and Newer Volcanics boundary
31.1	31.4	Newer Volcanics (Neo)	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff
31.4	32.9	Incised Colluvium (Nc1)	Silt, sand, gravel, poorly sorted and poorly rounded, infilling a gully between the Humevale Siltstone and Newer Volcanics boundary
32.9	34.9	Quaternary alluvial terrace deposit (Qa2)	Gravel, sand, silt – variably sorted and rounded. Generally floodplain deposits.
34.9	36.2	Newer Volcanics (Neo2), stony rises basalt	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff, stony rise terrain
36.2	40.3	Newer Volcanics (Neo)	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff
40.3	50.7	Newer Volcanics (Neo2), stony rises basalt	Olivine basalt, minor limburgite, trachy-andesite, scoria, thin interbedded sand, silt and tuff, stony rise terrain

4.1 Newer Volcanics (Neo, Neo1, Neo2)

On the volcanic plains, the different characteristics of the lava flows have created different surface geological features. Where the study area traverses Newer Volcanics, generally flat volcanic plain topography occurs prior to pipeline KP 34.9, while after KP 34.9 intermittent surface undulations occur which comprise basalt cobbles and boulder mounds, due to volcanic 'stony rise' terrain being present.

The subsurface profile of the Newer Volcanics plains is typically a layer of topsoil up to 0.5 m thick overlying high plasticity residual clay and extremely weathered basalt with a layer thickness of about 1 m to 3 m, which overlies highly weathered or better basalt. The depths and thicknesses of the weathering profile can vary significantly due to the complex flow nature of the basalt. The change in weathering profile in the basalt is typically abrupt, with a change from residual soil to high strength, slightly weathered rock occurring over a relatively small depth interval. Corestone weathering may also be present, with high strength basalt boulders present within a residual soil or extremely weathered, very low strength rock matrix. In stony rise terrain numerous surface basalt cobbles and boulders are typically present in mounds, with the above described typical weathering profile being present between the mounds. The thickness of the Newer Volcanics basalt is typically greater than 30 m but thins towards the exposed flow contacts with the underlying geology.

Within the study area, depressions may occur in the volcanic plain, and between the stony rises, that may have swampy conditions, including wetter soil conditions and accumulations of soil and organic materials. The swampy areas are not shown on published geological mapping but are expected to comprise a relatively minor proportion of the PPA. Delineation of swampy areas along the PPA would be undertaken by field mapping during site investigations.

4.2 Sub volcanics geology

The study area crosses geology underlying the Newer Volcanics in the Deep Creek Valley, which comprise Silurian aged Deep Creek Formation and Tertiary age Brighton Group.

The Deep Creek Formation generally comprises interbedded, folded and faulted siltstone and sandstone. Based on assessment of available aerial imagery, the weathering profile of the Deep Creek Formation in the base of the valley is not apparent.

A relatively thin layer of Brighton Group materials has been mapped in the eastern slopes of the Deep Creek valley, between the overlying Newer Volcanics and underlying Deep Creek Formation. The Brighton Group comprises variably cemented silts, sands and gravels and is typically described as extremely to highly weathered where described as a rock.

Between KP 29.1 and KP 31.0, the study area traverses the Devonian aged Humevale Formation, which also stratigraphically underlies the Newer Volcanics. The Humevale Formation comprises interbedded siltstone and fine grained sandstone. At this location the older topography comprising Humevale Formation was not covered by the lava flows of the Newer Volcanics and remained exposed. Based on small cutting exposures along Donnybrook Road in the vicinity of the study area, it appears that relatively shallow weathered rock is present where Humevale Formation is the surface geology.

4.3 Transported soil units

Transported soil geological units, such as alluvium and colluvium, occurs in the lower elevation points of the pipeline route, such as in creek valleys.

Alluvium and colluvium typically comprises variable proportions of clay, silt, sand and gravel, with occasional cobbles and boulders, depending on the geological and depositional setting. Due to the proximity to watercourses and low lying areas, the alluvium and colluvium is likely to have a relatively high moisture content.

Recent alluvium will likely occur in varying amounts in most watercourse drainage lines, even where not present on the geological map. The pipeline route is also proposed to traverse a terrace of older alluvium on the western slope of the Deep Creek valley.

Colluvium may occur on side slopes of valleys as a product of slope wash erosion or from landslides. In the study area, colluvium has been mapped on the eastern slope of the Deep Creek valley and from KP 30.2 to KP 32.8, adjacent to the edge of the basalt flows. The origin of the colluvium in the Deep Creek valley is unclear and may originate from slope wash or landslide processes. Although the geological mapping indicates that colluvium is not present on the PPA, the scale of the mapping is such that relatively minor colluvium deposits may still be present. It is likely that the origin of the colluvium from KP 30.2 to KP 32.8 is from slope wash processes, with eroded material from the adjacent hills being deposited onto the gentle gradients of the valley floor.

4.4 Fill

The geological map does not show the distribution of fill materials. As the proposed pipeline alignment is typically within open paddocks, fill materials are typically not expected to be encountered. However, a topsoil layer (potentially disturbed by agricultural uses) is likely to be present at the ground surface and there may be local areas where fill is present associated with existing roads and other infrastructure and backfilled farm dams.

4.5 Groundwater

Groundwater is typically expected to be several metres below the trench. However, perched groundwater could be present in local areas, and the depth to groundwater is likely to be shallow near the proposed creek crossings.

5.0 POTENTIAL GEOLOGICAL AND GEOTECHNICAL RISKS AND MITIGATION MEASURES

5.1 Slope stability

The PPA traverses creek valleys with potentially steep slopes at Jacksons Creek (KP 13.8) and Deep Creek (KP 17.1). Geomorphological evidence of natural slope instability along the creek valleys in the area has been observed. Instability may occur where the toe of a slope is undercut by erosion, making the slope oversteep, or when extreme rainfall events occur, which elevates groundwater levels and soil moisture and may also cause high levels of erosion. Human activities such as the creation of cuts and fills on slopes may also cause instability.

At the location of the proposed pipeline crossing, the northern slopes of the Jackson Creek valley show potential geomorphological evidence of previous slope instability (shown in Plate 1), indicating that the current slopes may be marginally stable. Similarly, the western slope of the Deep Creek valley at the pipeline crossing location shows potential evidence of previous slope instability and steep slopes (shown in Plate 2). On the western slope of the valley, colluvium has been mapped, which may be marginally stable due to the nature of colluvium deposition.

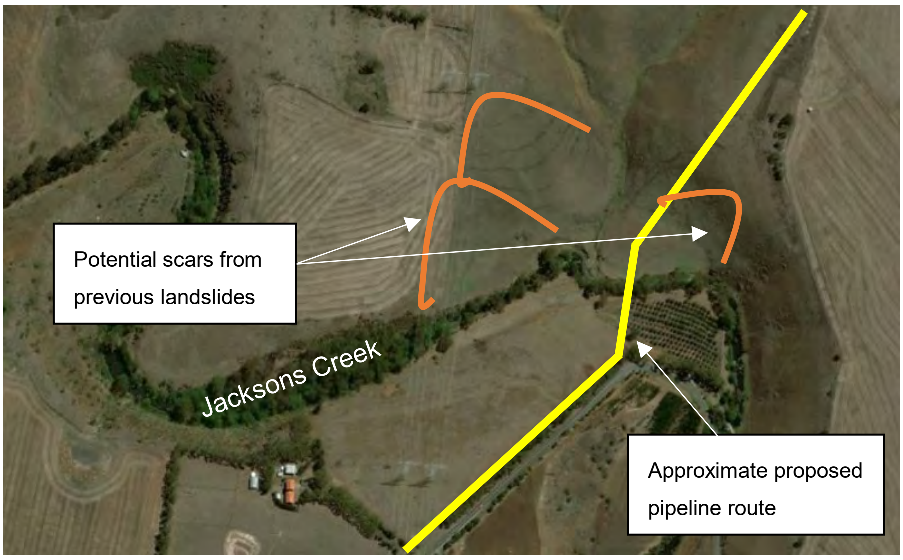


Plate 1: Proposed Jacksons Creek pipeline crossing location, with potential indicators of previous slope instability

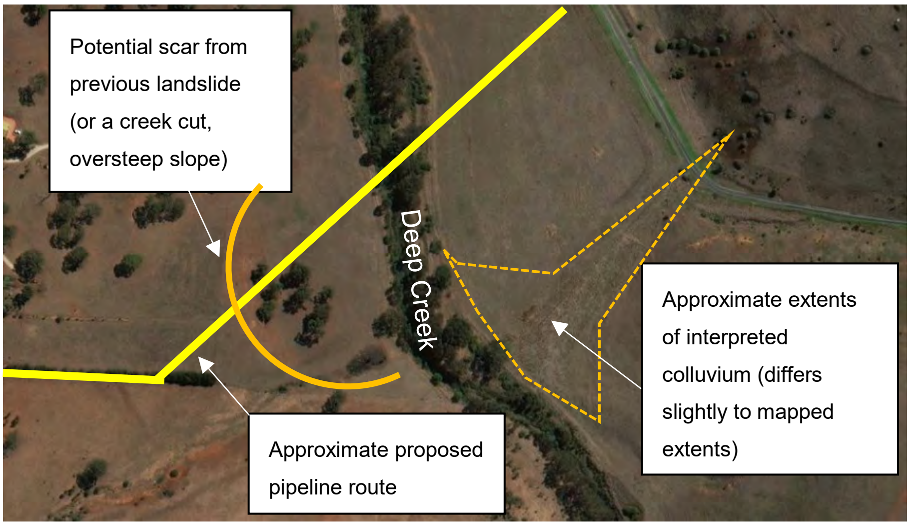


Plate 2: Proposed Deep Creek pipeline crossing location, with mapped colluvium and potential indicators of previous slope instability

We recommend that more detailed site specific studies be undertaken to assess the creek crossing valleys for potential slope instability. Where potential slope instability is identified, slope stabilisation measures, pipeline rerouting, and pipeline design against slope movements could be used as mitigation measures. Construction methodology specifically addressing potential slope instability could be used to mitigate against risks during construction.

5.2 Erosion Potential

Residual soils derived from the Newer Volcanics and the Deep Creek Formation and Humevale Formation siltstone and sandstone geological units are usually considered to have a low erosion potential in natural, vegetated conditions. On the volcanic plains, the low slope angles means surface water runoff energy is typically low, reducing scour potential.

During construction, high traffic volumes and heavy traffic loads on unsealed roads, particularly during wet weather, may cause rutting which can create a long term erosion concentration point. Construction roads and site traffic procedures should be designed to minimize the potential for rutting to occur.

The erosion potential of the materials in the creek valleys is uncertain. The higher slope angles will increase the scour potential of surface water runoff on the valley slopes, compared to the volcanic plains. Based on previous experience, the Brighton Group materials exposed in the eastern slopes of the Deep Creek valley have relatively high erosion potential. Evidence for erosion of the Brighton Group materials on the valley slopes to the north of the PPA crossing was observed on aerial imagery.

At creek crossings, where trenching will occur through the creek bed, the trench should be designed to include measures to reduce long term creek bed erosion in the vicinity of the trench. Erosion mitigation measures should also be included on the valley side slopes, which could include the establishment of vegetation and construction of hillside berms or check drains to reduce the velocity and scour potential of surface water running down the slopes.

We recommend that a targeted site investigation including laboratory testing for dispersivity potential be undertaken for soil units traversed by the pipeline, including alluvium, colluvium and Brighton Group materials.

5.3 Acid Sulfate Soils

Acid sulfate soils are subsurface materials that contain minerals such as sulfides that form acid when exposed to air, usually by excavation. The acid generated can harm the environment if allowed to form and if not contained.

Acid sulfate soils are typically present in reducing chemical environments such as below the permanent water table. Although areas at highest risk of having acid sulfate soils present are usually considered to be below RL 5 m AHD, close to the coast, some inland soil environments may have relatively high potential for the presence of acid sulfate soils, including saturated soils with a high organic content.

Based on the geological conditions and the elevation of the PPA, there is likely to be a low risk of encountering acid sulfate soil. The Australian Soil Resource Information System (ASRIS) online maps (http://www.asris.csiro.au/mapping/viewer.htm) indicate that there is an extremely low or low probability of acid sulfate soil occurrence along the PPA. However, we recommend that the low potential is confirmed by a limited ASS field assessment for all soil units traversed by the pipeline, with soil units with higher potential such as alluvium and colluvium have a higher frequency of testing. Swampy areas on the volcanic plains should also be targeted. The extent of swampy areas along the alignment is expected to be minor, and would be assessed by field mapping as part of site investigation fieldwork.

Should ASS be assessed to be an unacceptable risk we recommend that an Acid Sulfate Soil Management Plan is developed in accordance with state guidelines for the project and earthwork procedures developed to adhere to the Plan, to manage exposure of acid sulfate soils through excavation activities.

5.4 Potential construction risks

5.4.1 Pipeline trench excavation

Soils along the PPA should be able to be excavated by traditional excavator bucket methods or by specialist trenching machinery.

Newer Volcanics basalt may be high strength or stronger. Excavation by toothed bucket methods are not likely to be effective in such materials. Excavation methods for high strength materials, such as using rock breaking attachments on excavators, or blasting may need to be adopted to achieve acceptable excavation rates.

It is likely that extremely and highly weathered siltstone and sandstone of the Deep Creek Formation and Humevale Formation could be excavated by traditional excavator methods or trenching machinery. Rock breaking attachments or tynes may be required to assist excavation of moderately weathered or better siltstone or sandstone.

Future geotechnical investigation along the PPA should include an assessment of the depth to rock and the likely excavation characteristics.

There is a risk of ground loss induced surface settlement where horizontal boring is used to excavate beneath road and rail crossings. To reduce the risk of unacceptable ground surface settlement, site investigation should be undertaken at crossing locations to assess the ground conditions and the horizontal boring methodology should be selected in collaboration with specialist contractors. Survey monitoring of the ground surface during the horizontal boring may need to be undertaken to check unacceptable settlement limits are not exceeded.

Whilst trenching is typically not expected to encounter groundwater, provision for the management of groundwater inflow should be made for the creek crossings. There may also be local areas of perched groundwater in low lying areas or backfilled farm dams, if present.

5.4.2 Trench stability during construction

A nominal minimum depth of 1.2m cover is required over the pipeline. This depth will vary across the alignment depending on other requirements (avoiding other services, boring, grades etc.). The pipeline trench will be wide enough to allow placement of the 500 mm diameter pipe. Generally, trenches of such dimensions with vertical walls excavated in Newer Volcanics basalt rock and siltstone and sandstone bedrock will have a low, but not zero, incidence of sidewall instability. There will also be a risk that isolated unstable rock blocks or wedges could detach from the trench walls and fall into the trench.

Trenches excavated in residual soil, alluvium or colluvium will have a higher incidence of sidewall instability. It is unlikely that trenches with stable vertical sidewalls will be able to be formed. The risk of trench sidewall instability will increase where the sidewall materials have a high moisture content. Trench sidewalls in soils should be battered back to stable slope angles or engineered trench stabilisation measures such as shoring should be used. Shoring may be required in saturated soils where batters cannot be practically formed, particularly alluvial soils in the base of the creek valleys.

Trenches formed in ‘stony rise’ basalt terrain may have a higher potential for loose basalt boulders and other variable soil and rock conditions in the sidewalls and at the crest of the trench. Loose boulders should be assessed for stability prior to pipe laying works occurring.

To reduce the risk of trench wall collapse impacting workers and construction operations, we recommend that stable batter angles be adopted based on the trench material or suitable temporary support such as shoring designed to resist the imposed earth pressures is installed. We also recommend that trench excavation is undertaken to Worksafe approved practices, including exclusion buffers for plant, stockpiles and personnel back from the crest of the trench walls and personnel exclusion from trench excavations.

5.4.3 Trench backfill materials

The materials generated by the trench excavation are expected to include high plasticity residual basaltic clay soils that are susceptible to significant volume change with changes in moisture content. Excavation in weathered rock may also generate poorly graded granular materials including cobbles and boulders. If the excavated spoil is used to backfill the trench following installation of the pipe and padding materials, consideration will need to be given to the methods for moisture conditioning, placing and compacting the backfill materials. A topsoil layer is also expected to be encountered. The use of high plasticity clays as earthworks materials can be problematic because of their sensitivity to change in moisture content. The use of poorly graded granular material or cobbles and boulders can also result in voids being formed in the backfill. If backfill materials are not well compacted there is the risk of subsidence of the surface above the trench which could exacerbate erosion issues or increase the risk of pipe damage. Backfilled trenches can also provide a conduit for surface water infiltration which can lead to the swelling of high plasticity clays. Hence, it is important that the uppermost layers of backfill in the trench is of low hydraulic conductivity to provide a barrier to infiltration.

6.0 CONCLUSIONS AND RECOMMENDATIONS

We consider the following geological and geotechnical risks to potentially be present during construction and operation of the WORM pipeline:

- Slope instability may be induced at the Jacksons Creek and Deep Creek valleys by changing the slope conditions by construction of the pipeline. We recommend site specific slope stability assessments be undertaken at the valley crossing locations, which may include site works such as drilling investigations and should include an assessment of the groundwater level. Design mitigation against slope instability may include rerouting the pipeline, pipeline design against slope movements and slope stabilisation works.
- The erosion potential of soil geological units, such as alluvium and colluvium, and Brighton Group materials exposed in the side slopes of the Deep Creek valley is uncertain. We recommend a targeted investigation of the dispersion potential of these materials. Design of the PPA for construction activities as well as long term operation should consider erosion, particularly on the side slopes of the creek valleys.
- Trafficability of the surface soils is likely to be poor during periods of wet weather, which may cause rutting in construction roads along the PPA. Rutting has the potential to become a concentration point for erosion. Construction roads should be designed and site traffic practices implemented to minimize the potential for rutting of construction roads.
- A targeted, preliminary site investigation should be undertaken to assess the potential for acid sulfate soils to be present along the PPA. Geological units that should be targeted are soil units under permanent water, such as swamp areas in the volcanic plains and alluvium and colluvium in the base of the creek valleys.
- Trench excavation in the Newer Volcanics, Deep Creek Formation and Humevale Formation geological units may not be possible using excavator bucket techniques and may require higher excavation energy such as rock breaking attachments for excavators, or blasting.
- Ground surface settlement due to ground loss should be considered during the design and the selection of the construction methodology of the horizontal bores planned at road and rail crossings.

- Trench sidewall stability must be considered in the construction methodology of the pipeline, including stable batter angles, exclusion zones back from the crest of the trench walls for plant, stockpiles and personnel and exclusion of personnel from trench excavations. Trench walls comprising soils, particularly with high moisture content, are more susceptible to instability.

The characteristics of the material generated by the trench excavation (likely to include high plasticity clay, cobbles and boulders of rock and topsoil materials) should be considered when developing methodology for the placement and compaction of trench backfill materials.

More detailed discussion on the above risks and mitigation measures is provided in Sections 5.1 to 5.4. Geotechnical investigations targeted at the PPA will be required to address these risks as the design progresses.

7.0 IMPORTANT INFORMATION

Your attention is drawn to the document – 'Important Information Relating to This Report' (LEG04, RL2), which is included in Appendix A of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing. We would be pleased to answer any questions the reader may have regarding the 'Important Information'.

We would be pleased to answer any questions about this important information from the reader of this report.

Signature Page

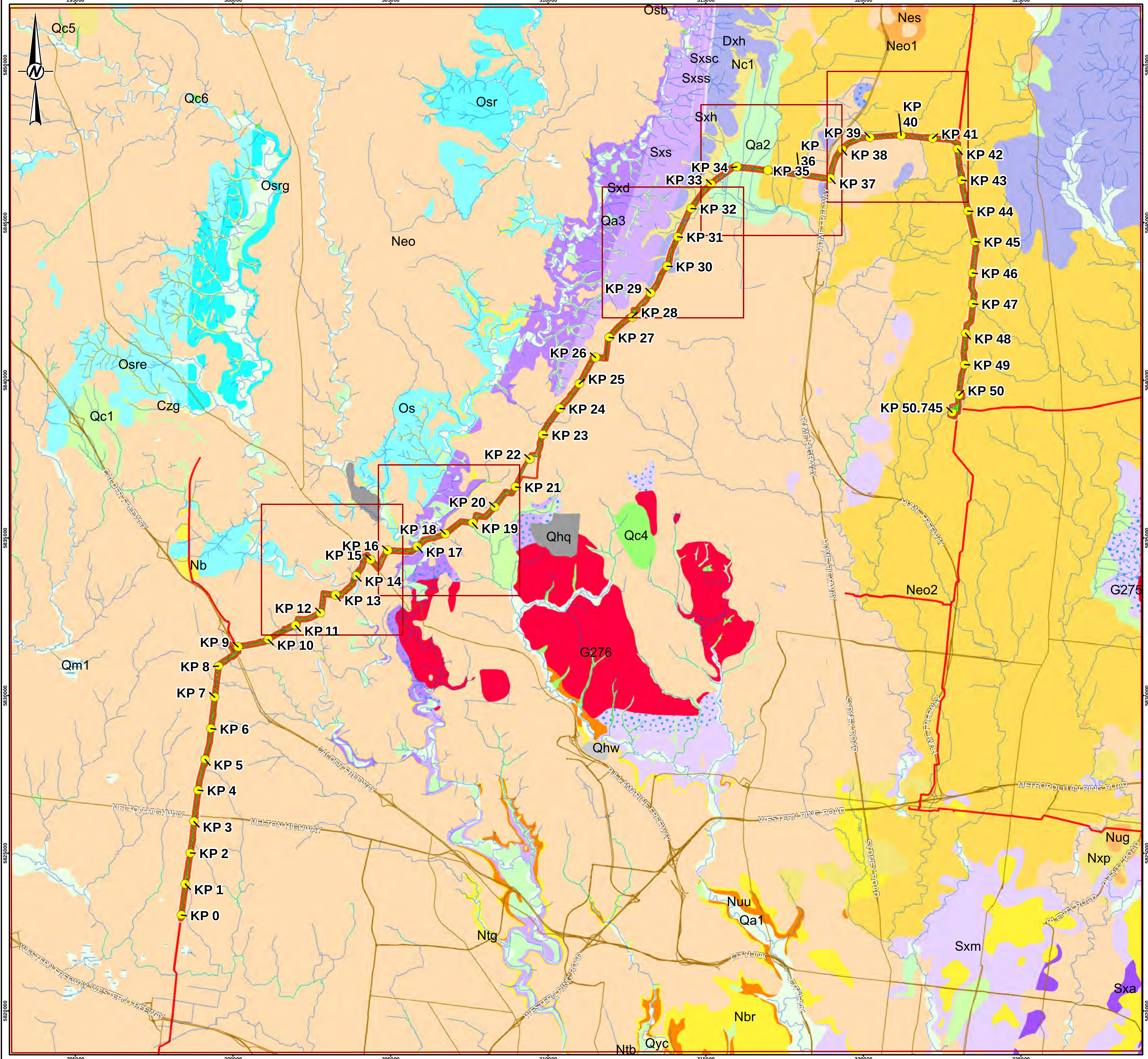
Golder Associates Pty Ltd

Glenn Meyer
Senior Engineering Geologist

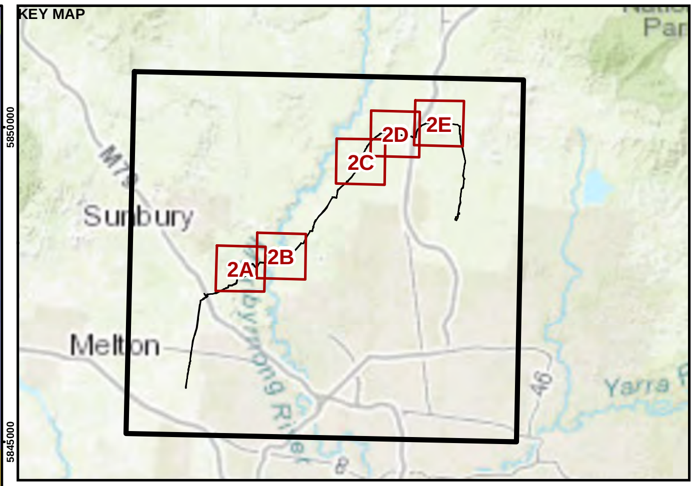
GEM/SC:GH/gem

A.B.N. 64 006 107 857

https://golderassociates.sharepoint.com/sites/105326/project files/6 deliverables/003/19118704-003-r-rev1 geological assessment.docx



KEY MAP



LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Major Roads
- Watercourse
- Study Area

GEOLOGICAL UNITS 50K
(REFER TO REPORT TEXT)

- Dxh
- Dxh
- Nc1
- Neo
- Neo1
- Neo2
- Qa1
- Qa2
- Qc1
- Sxd
- Sxd

0 2,000 4,000 6,000 8,000 10,000

1:120,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.
4. GEOLOGY INFORMATION SOURCED FROM SEAMLESS GEOLOGY VICTORIA - 2014

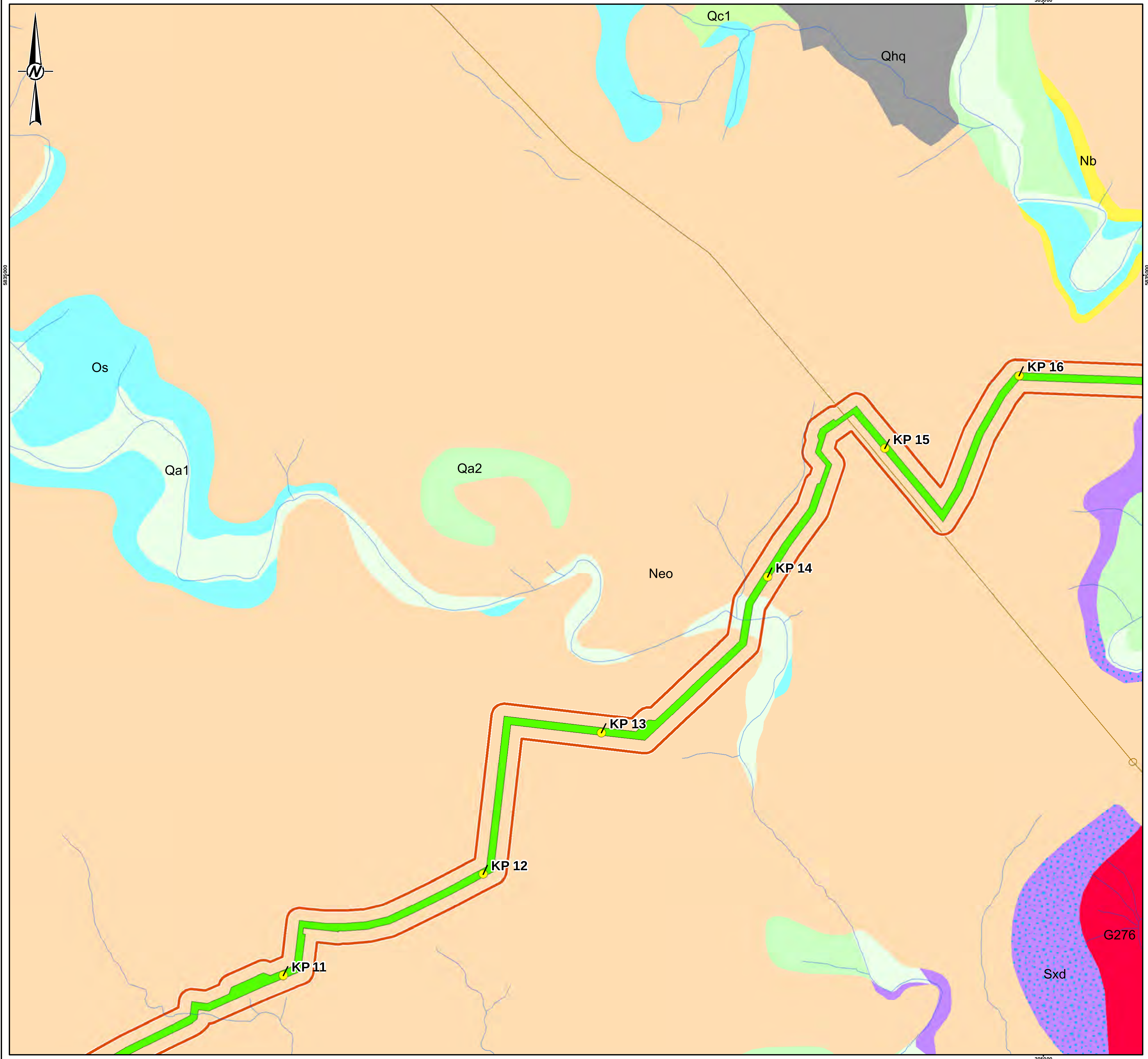
CLIENT	APA
PROJECT	APA WORM PROJECT
TITLE	GEOLOGICAL PLAN WITH PRELIMINARY ALIGNMENT

CONSULTANT: GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3



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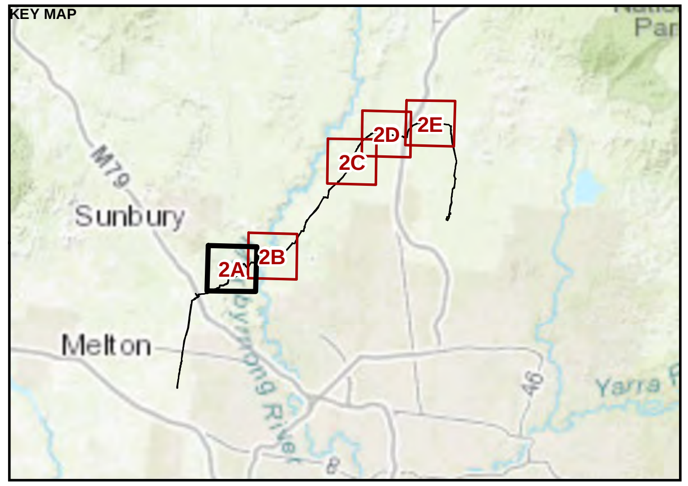


LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Major Roads
- Watercourse
- Study Area

GEOLOGICAL UNITS 50K
(REFER TO REPORT TEXT)

- Dxh
- Dxh
- Nc1
- Neo
- Neo1
- Neo2
- Qa1
- Qa2
- Qc1
- Sxd
- Sxd

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.
4. GEOLOGY INFORMATION SOURCED FROM SEAMLESS GEOLOGY VICTORIA - 2014

CLIENT
APA

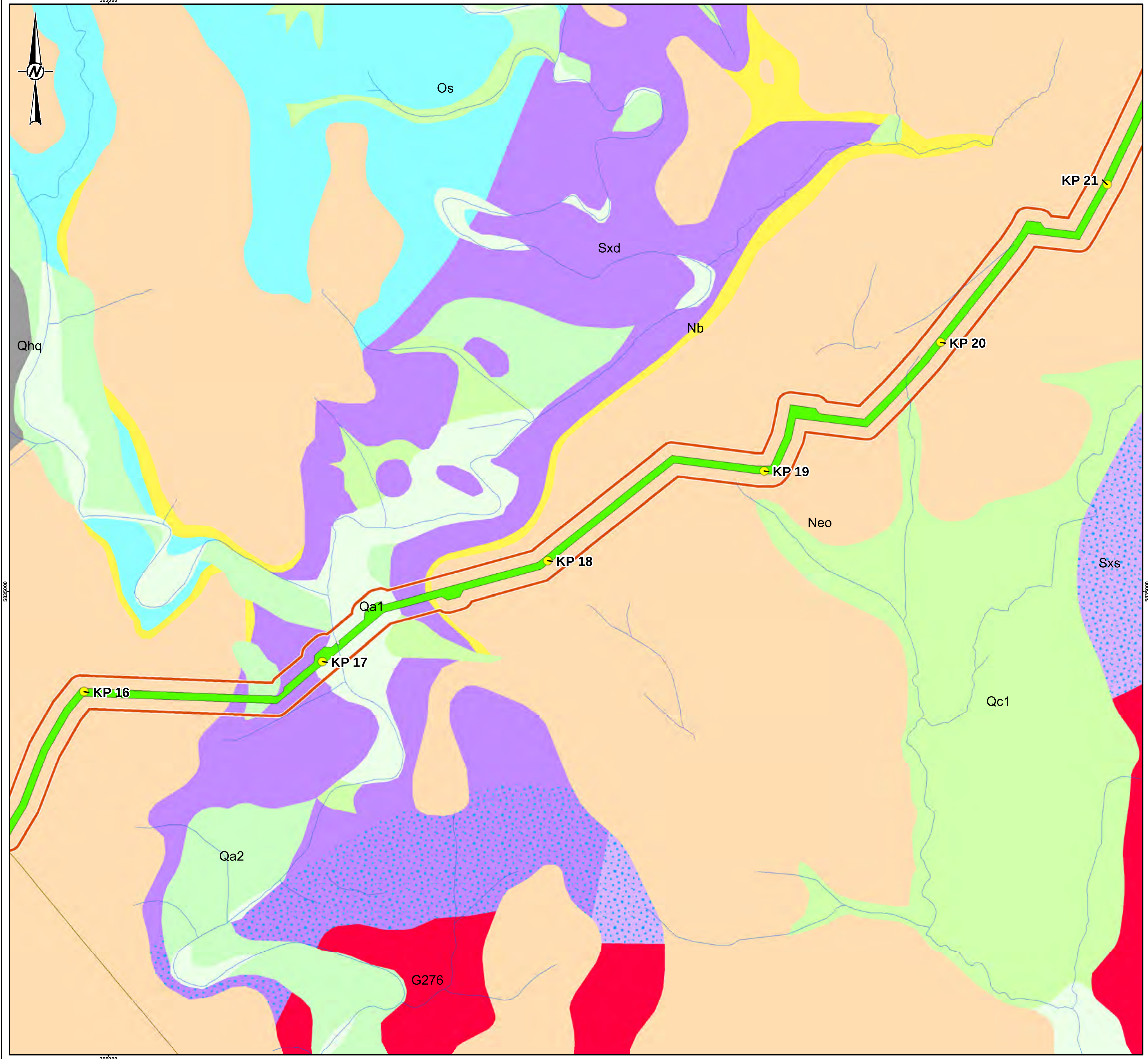
PROJECT
APA WORM PROJECT

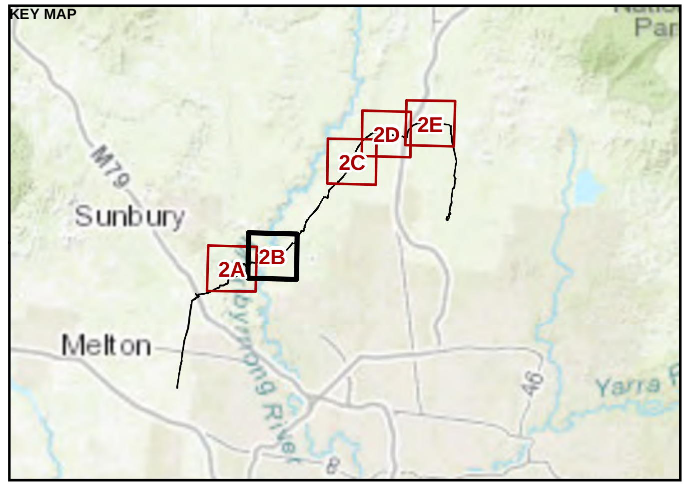
TITLE
GEOLOGICAL PLAN WITH PRELIMINARY ALIGNMENT

CONSULTANT: GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	2A





LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Major Roads
- Watercourse
- Study Area

GEOLOGICAL UNITS 50K (REFER TO REPORT TEXT)

- Dxh
- Dxh
- Nc1
- Neo
- Neo1
- Neo2
- Qa1
- Qa2
- Qc1
- Sxd
- Sxd

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
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3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.
4. GEOLOGY INFORMATION SOURCED FROM SEAMLESS GEOLOGY VICTORIA - 2014

CLIENT
APA

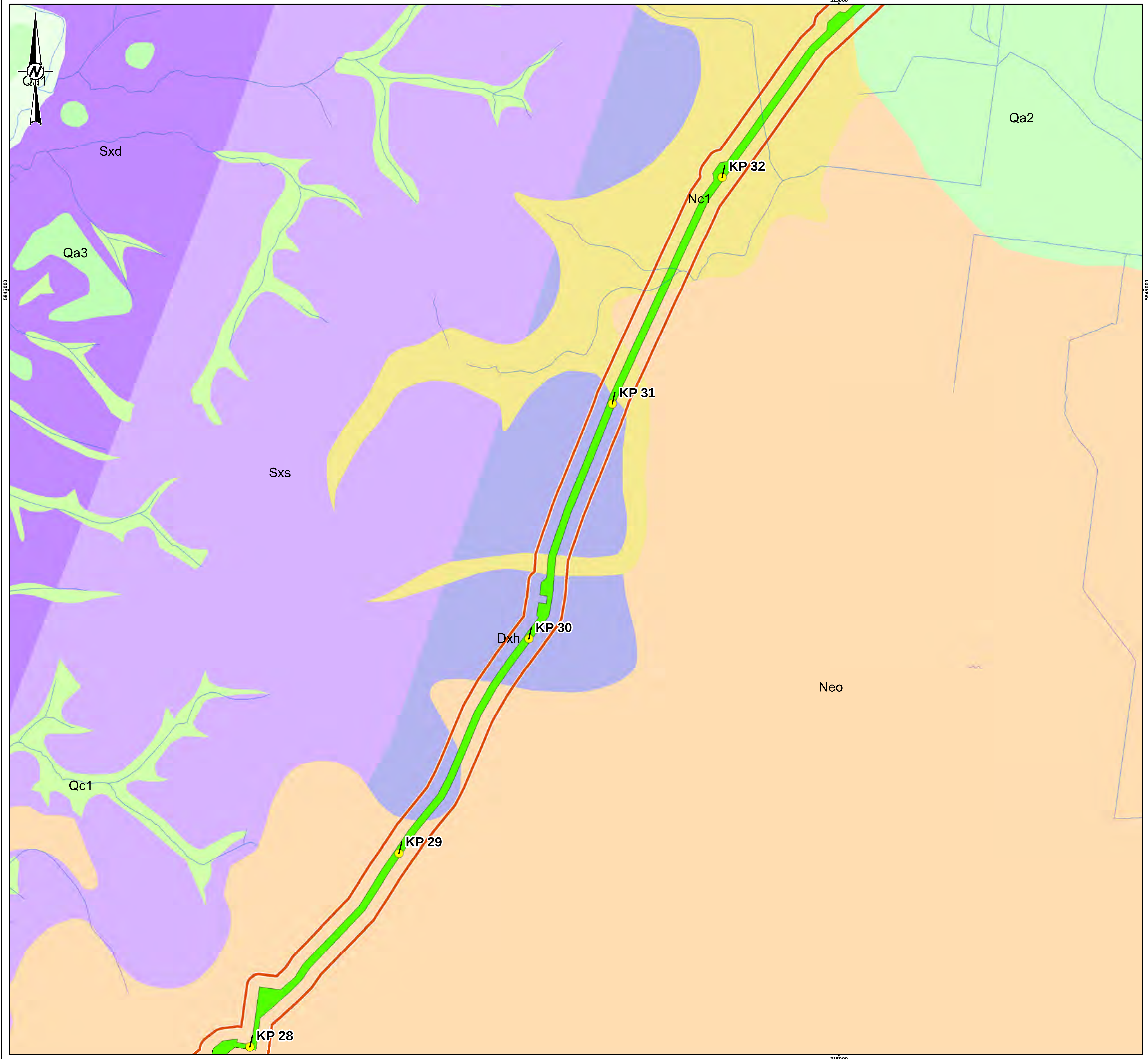
PROJECT
APA WORM PROJECT

TITLE
GEOLOGICAL PLAN WITH PRELIMINARY ALIGNMENT

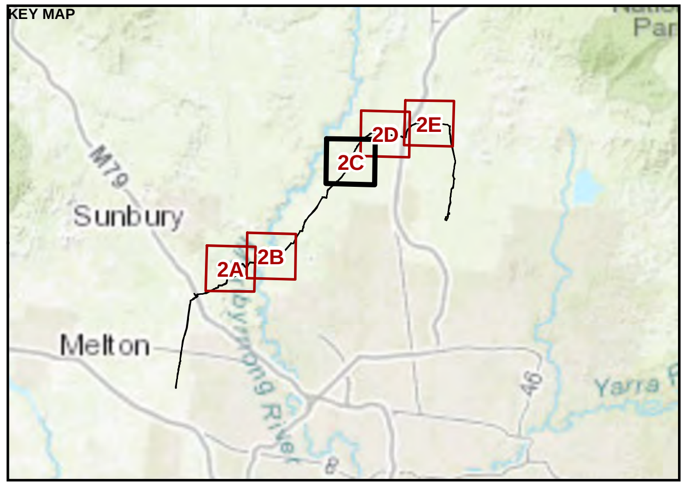
CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	2B



KEY MAP



LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Watercourse
- Study Area

GEOLOGICAL UNITS 50K
(REFER TO REPORT TEXT)

- Dxh
- Dxh
- Nc1
- Neo
- Neo1
- Neo2
- Qa1
- Qa2
- Qc1
- Sxd
- Sxd

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.
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CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
GEOLOGICAL PLAN WITH PRELIMINARY ALIGNMENT

CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	2C

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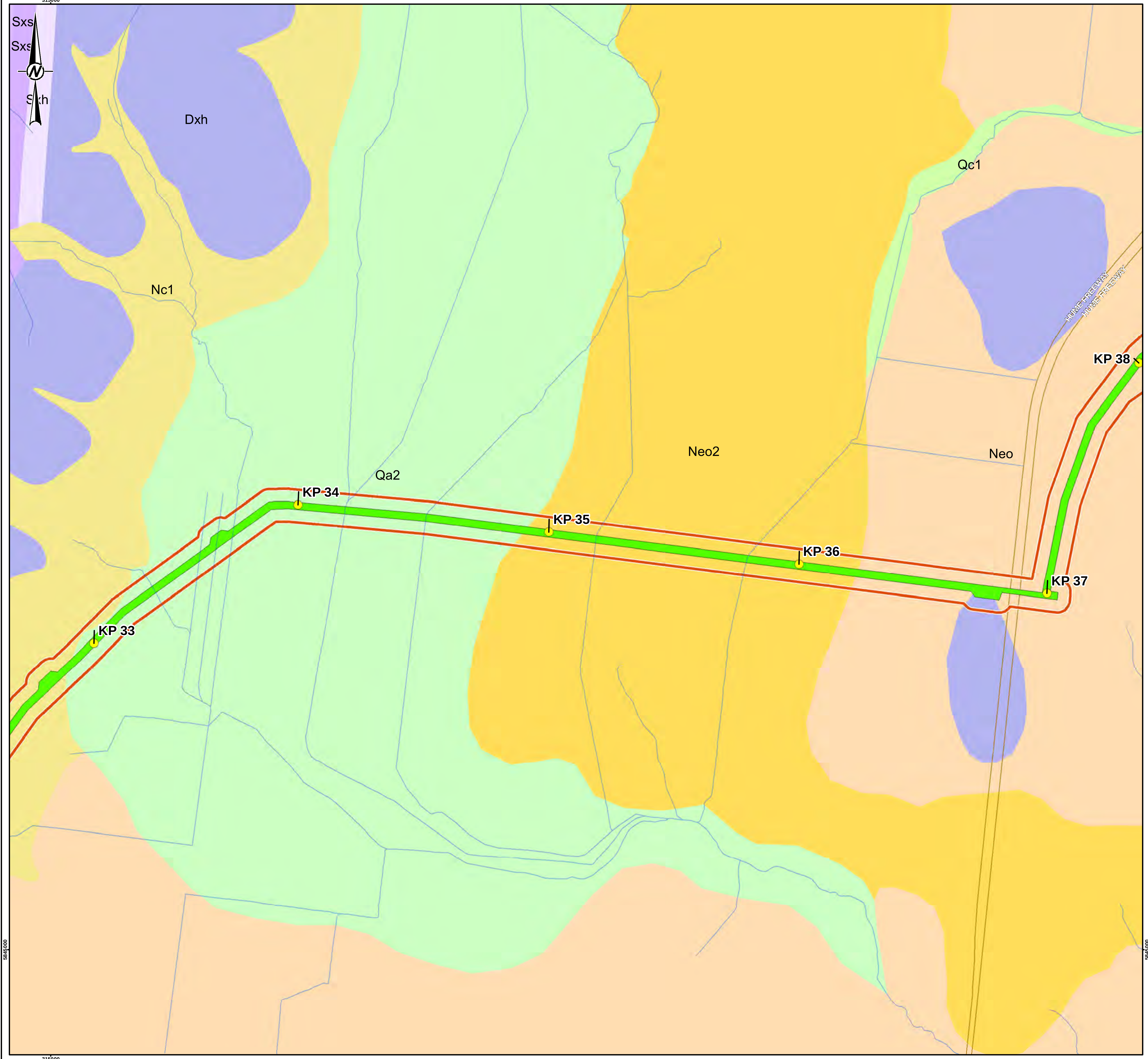

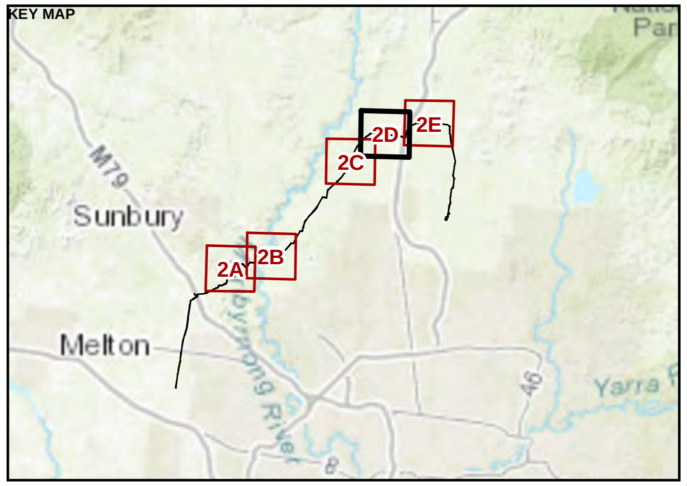

LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Major Roads
- Watercourse
- Study Area

GEOLOGICAL UNITS 50K (REFER TO REPORT TEXT)

- Dxh
- Dxh
- Nc1
- Neo
- Neo1
- Neo2
- Qa1
- Qa2
- Qc1
- Sxd
- Sxd

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
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CLIENT
APA

PROJECT
APA WORM PROJECT

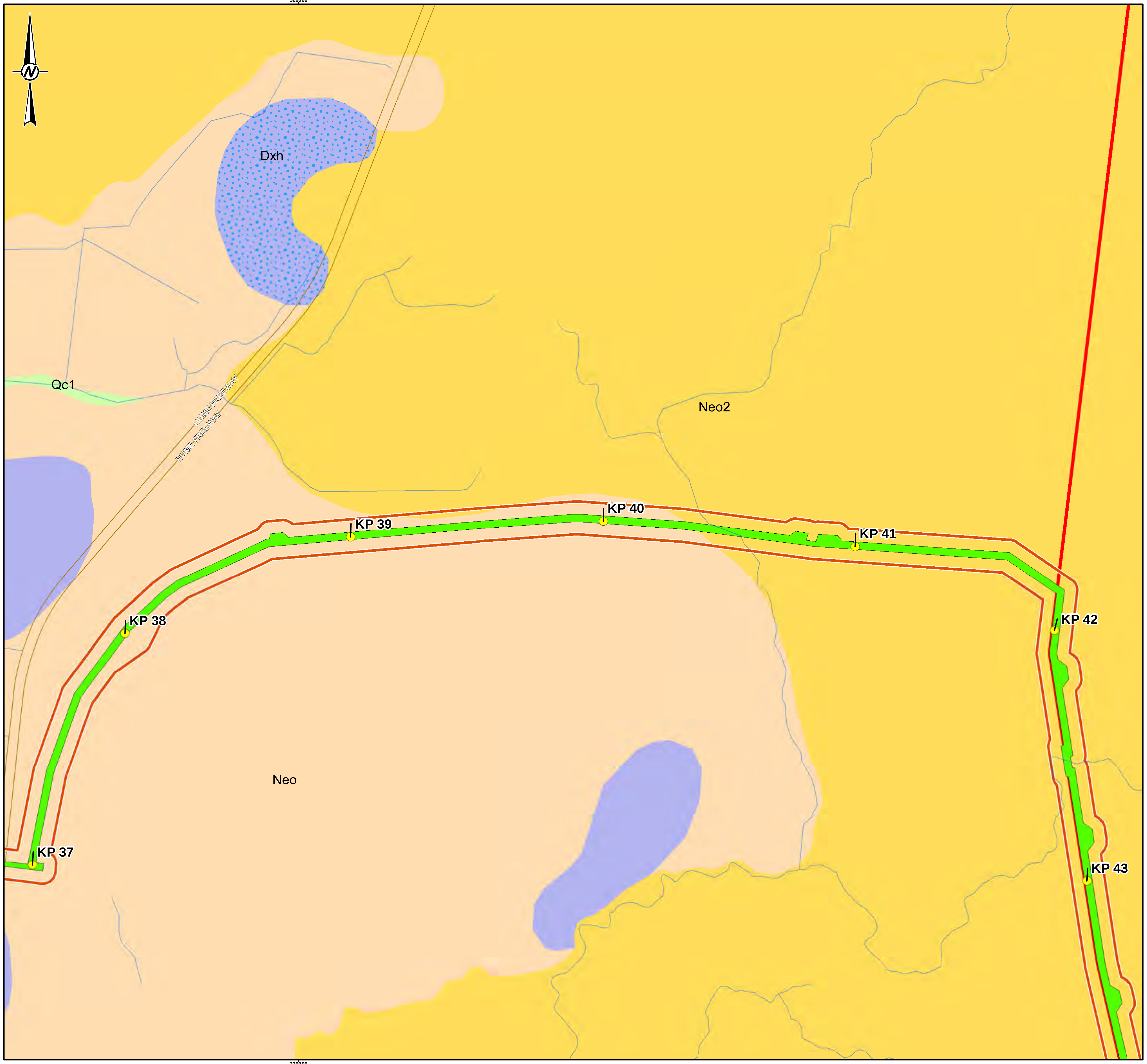
TITLE
GEOLOGICAL PLAN WITH PRELIMINARY ALIGNMENT

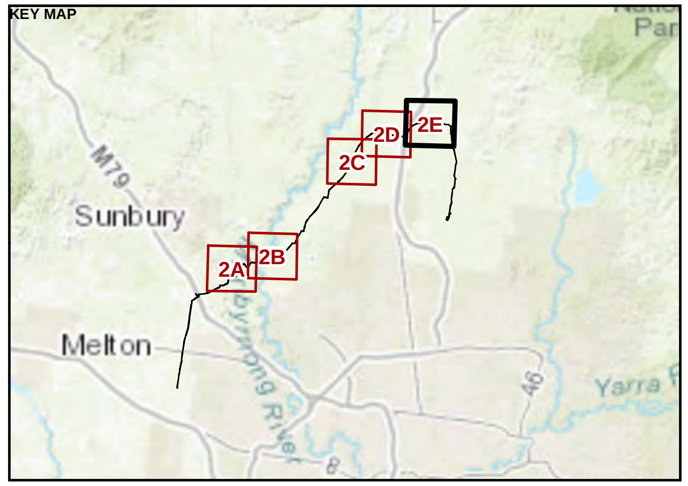
CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	2D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3





LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Major Roads
- Watercourse
- Study Area

GEOLOGICAL UNITS 50K (REFER TO REPORT TEXT)

- Dxh
- Dxh
- Nc1
- Neo
- Neo1
- Neo2
- Qa1
- Qa2
- Qc1
- Sxd
- Sxd

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.
4. GEOLOGY INFORMATION SOURCED FROM SEAMLESS GEOLOGY VICTORIA - 2014

CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
GEOLOGICAL PLAN WITH PRELIMINARY ALIGNMENT

CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	2E

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

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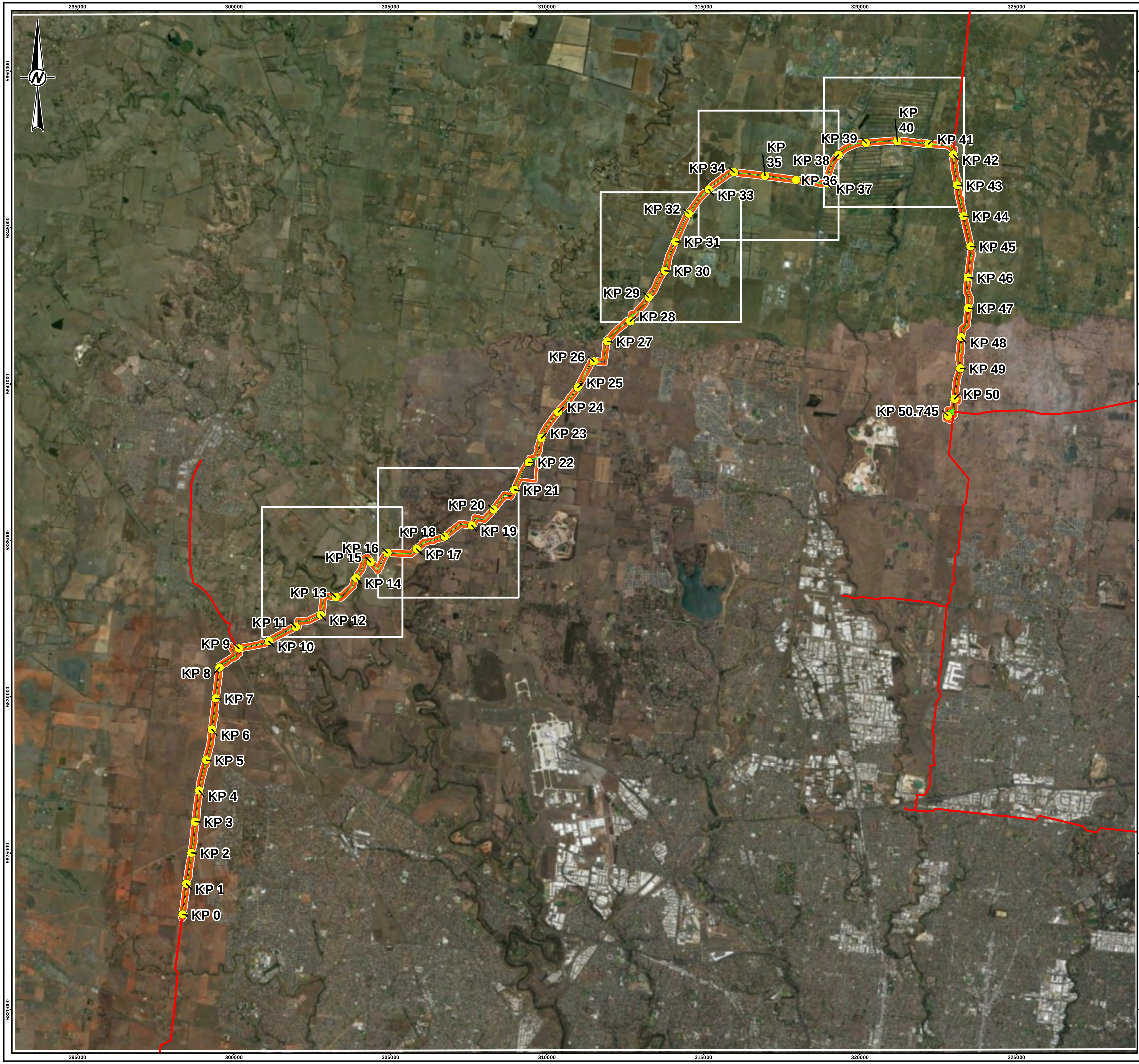
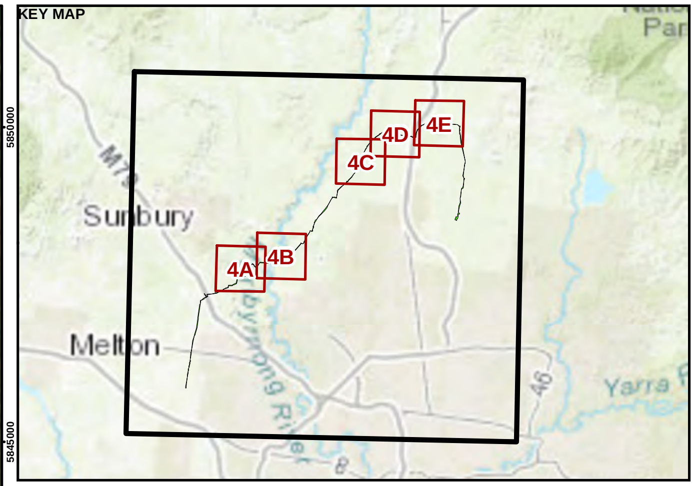


KEY MAP



LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Study Area

0 2,000 4,000 6,000 8,000 10,000

1:120,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
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2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.

CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
DETAILED AERIAL VIEW WITH PRELIMINARY ALIGNMENT

CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	3

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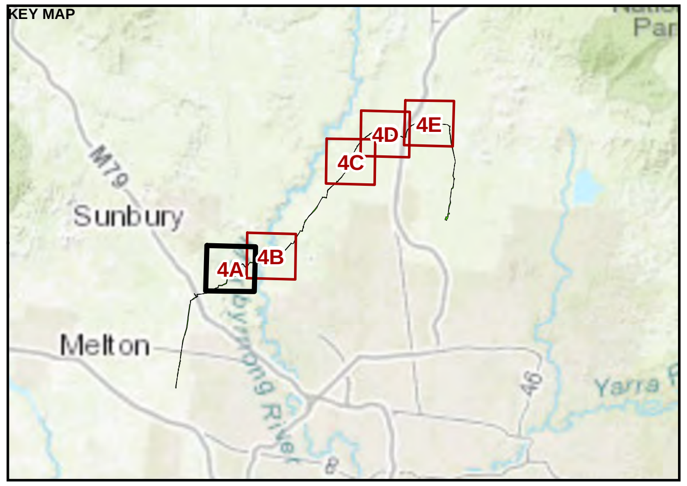
KEY MAP



LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Study Area

0 | 260 | 520 | 780 | 1,040 | 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.

CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
DETAILED AERIAL VIEW WITH PRELIMINARY ALIGNMENT

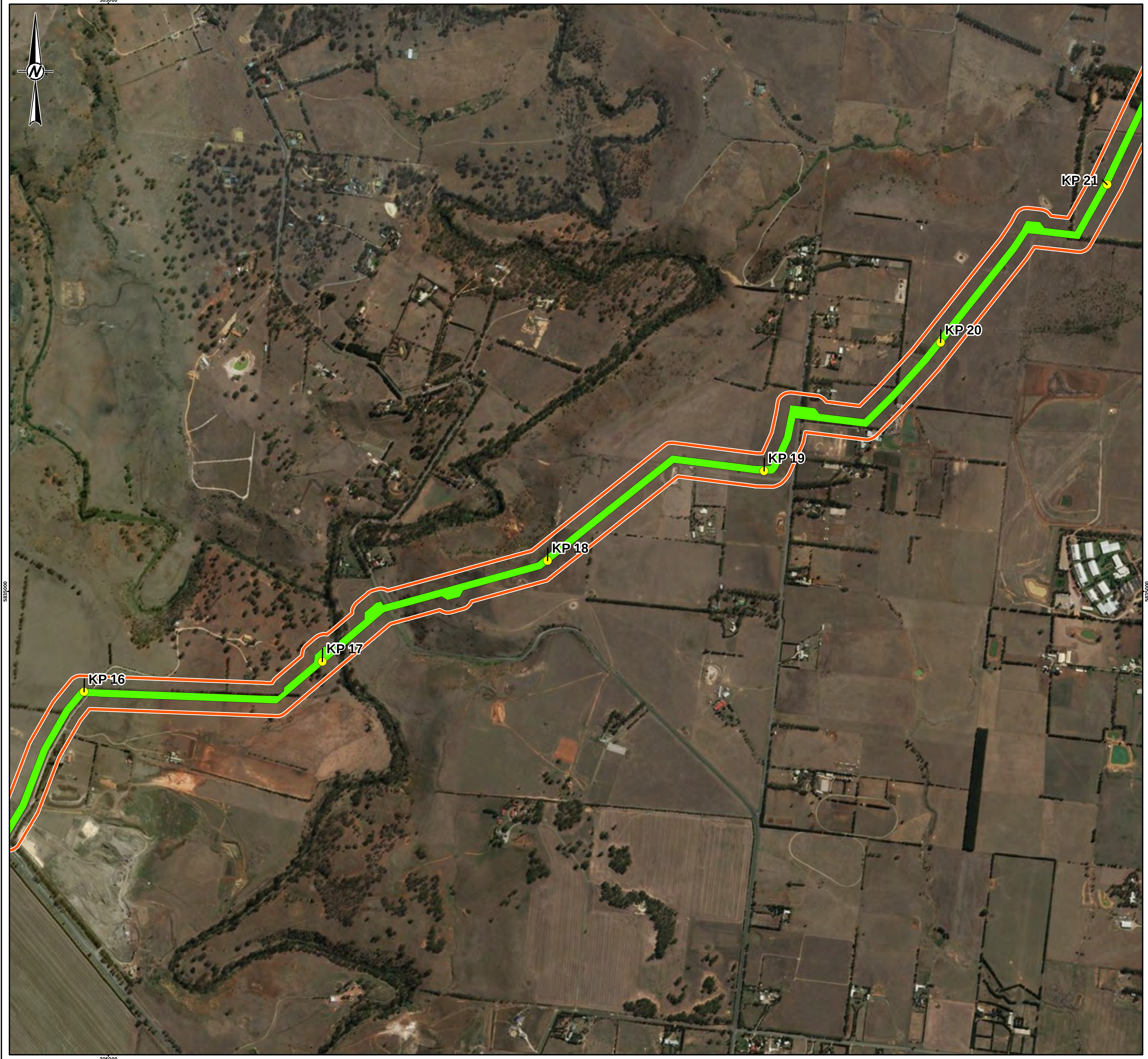
CONSULTANT

GOLDER

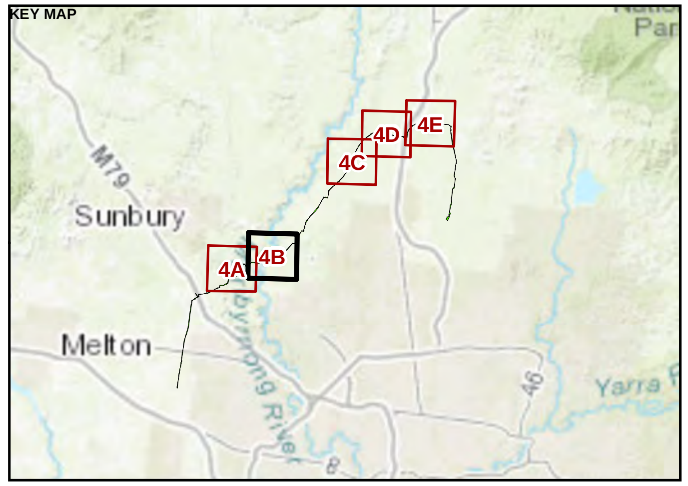
YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	4A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3



KEY MAP



LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Study Area

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
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3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.

CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
DETAILED AERIAL VIEW WITH PRELIMINARY ALIGNMENT

CONSULTANT

GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	4B

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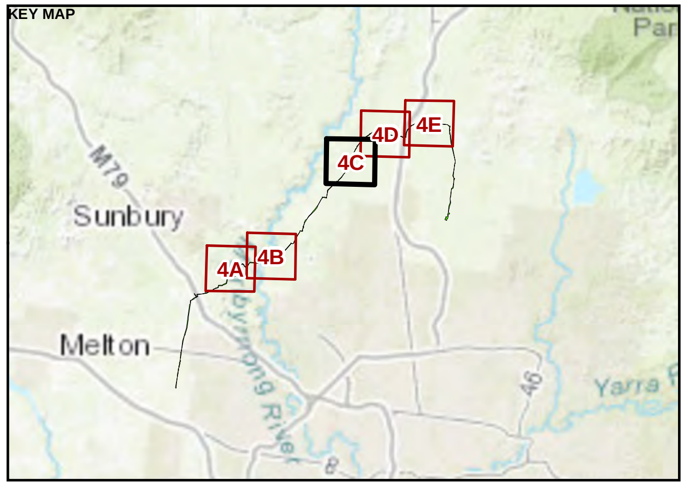

LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Study Area

0 | 260 | 520 | 780 | 1,040 | 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
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2. AERIAL IMAGERY SOURCED FROM ESRI ONLINE BASEMAPS
3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.

CLIENT
APA

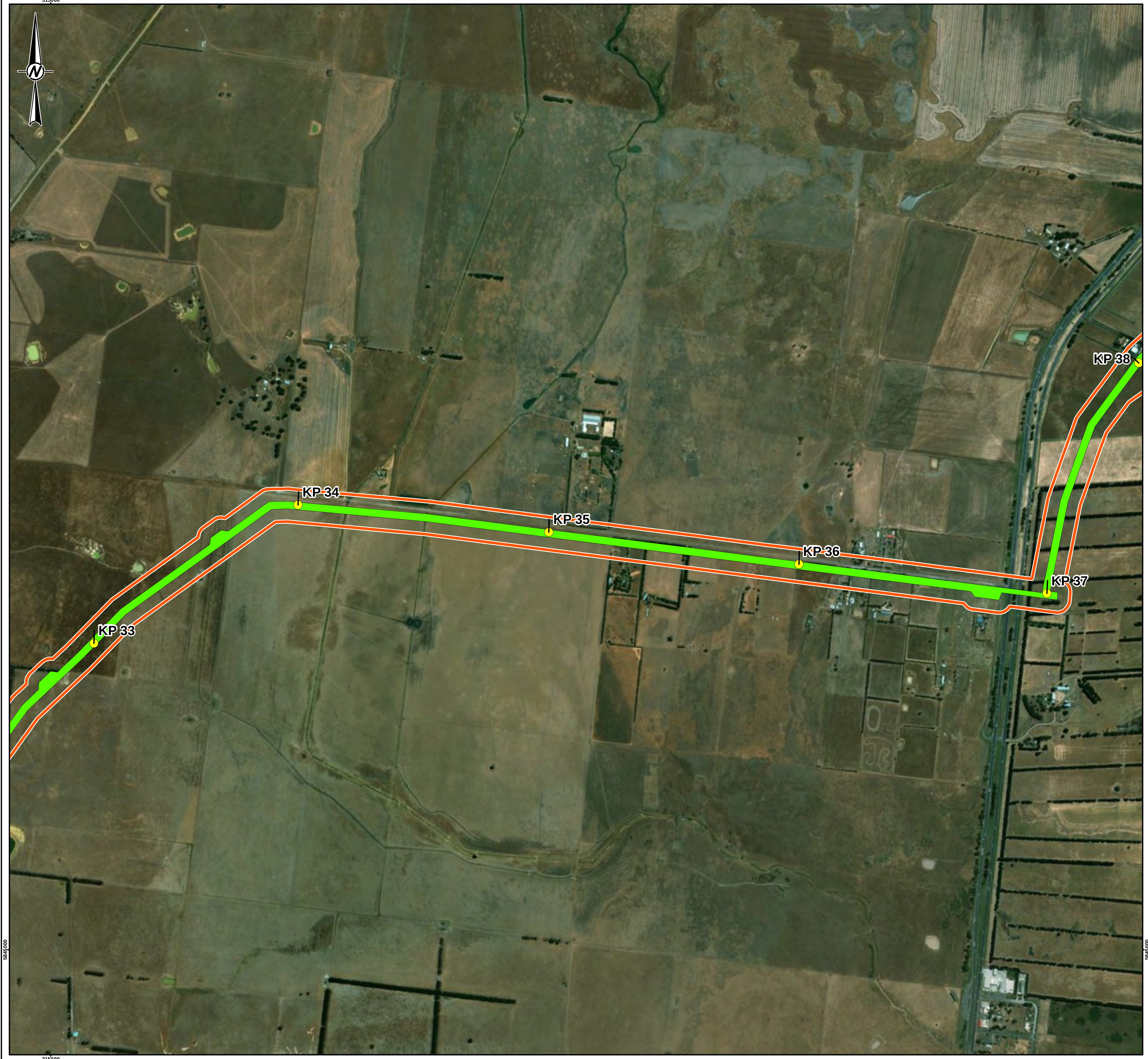
PROJECT
APA WORM PROJECT

TITLE
DETAILED AERIAL VIEW WITH PRELIMINARY ALIGNMENT

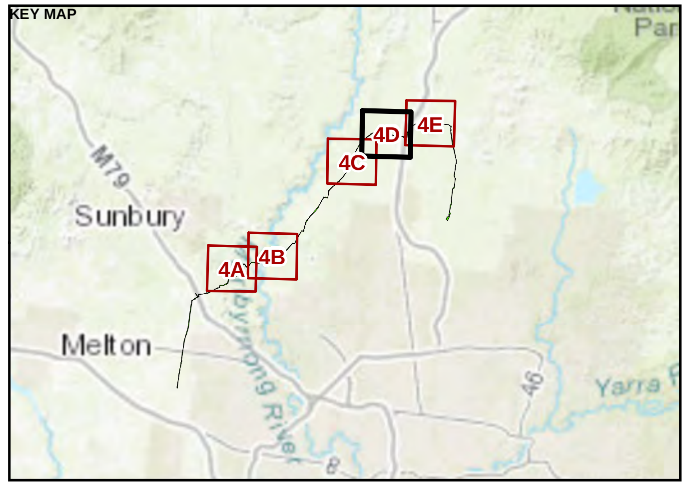
CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	4C



KEY MAP



LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Study Area

0 260 520 780 1,040 1,300

1:15,000

METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
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CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
DETAILED AERIAL VIEW WITH PRELIMINARY ALIGNMENT

CONSULTANT
GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	4D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
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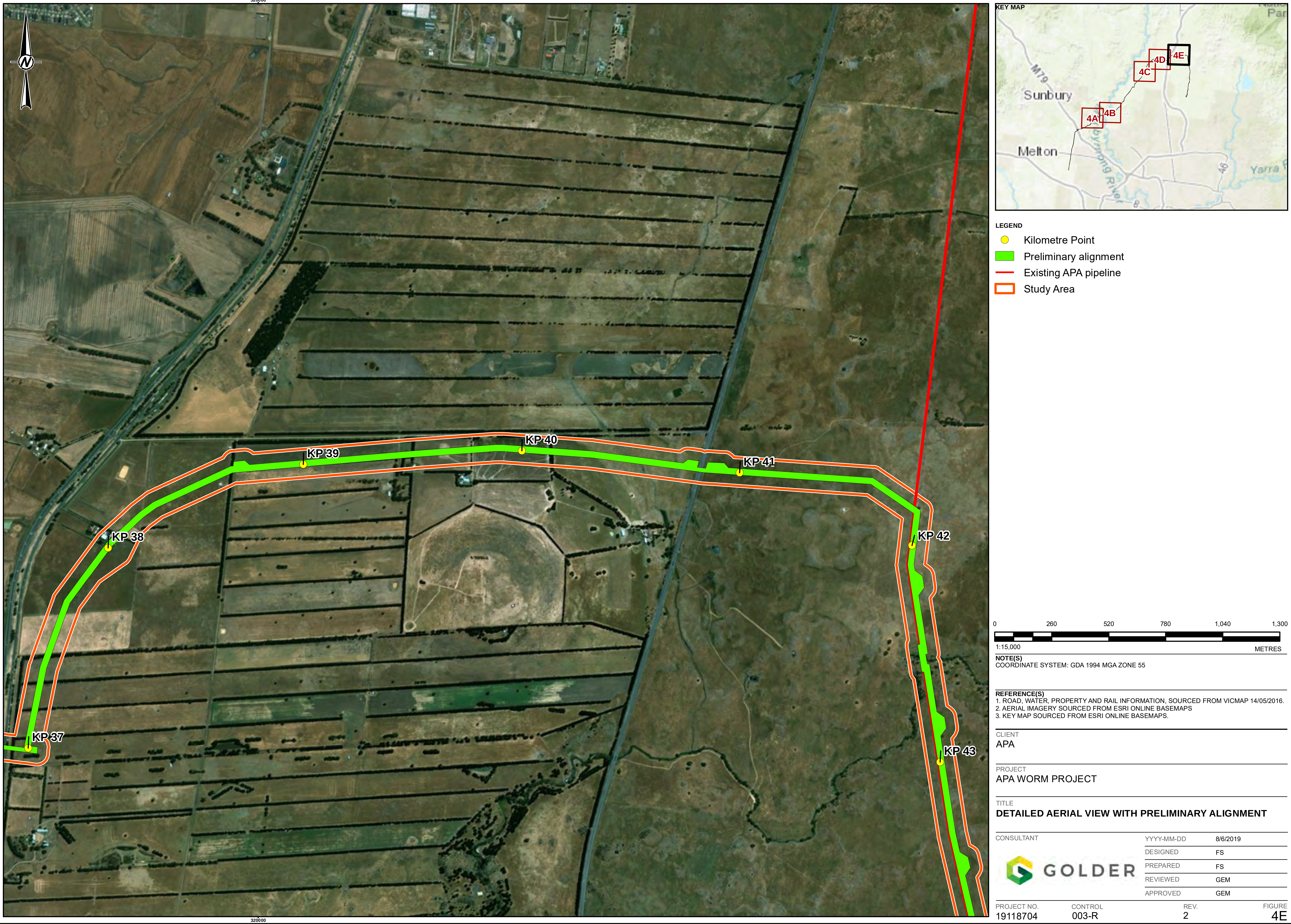

LEGEND

- Kilometre Point
- Preliminary alignment
- Existing APA pipeline
- Study Area

0 260 520 780 1,040 1,300

1:15,000 METRES

NOTE(S)
COORDINATE SYSTEM: GDA 1994 MGA ZONE 55

REFERENCE(S)
1. ROAD, WATER, PROPERTY AND RAIL INFORMATION, SOURCED FROM VICMAP 14/05/2016.
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3. KEY MAP SOURCED FROM ESRI ONLINE BASEMAPS.

CLIENT
APA

PROJECT
APA WORM PROJECT

TITLE
DETAILED AERIAL VIEW WITH PRELIMINARY ALIGNMENT

CONSULTANT

GOLDER

YYYY-MM-DD	8/6/2019
DESIGNED	FS
PREPARED	FS
REVIEWED	GEM
APPROVED	GEM

PROJECT NO.	CONTROL	REV.	FIGURE
19118704	003-R	2	4E

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

APPENDIX A

Important Information Regarding This Report

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

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