IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of a submission in respect of the **PROPOSED WAIKATO DISTRICT PLAN** by **AMBURY PROPERTIES LIMITED** pursuant to Clause 6 of Schedule 1 of the Act seeking the rezoning of land at Ohinewai

STATEMENT OF EVIDENCE OF CAMERON JOHN LINES

1. INTRODUCTION

1.1 My full name is Cameron John Lines. I am a Principal and Director of Baseline Geotechnical Limited a company I founded in July 2018 which provides mine/quarry development and geotechnical advice to the extractives sector. I spent the previous 15 years working at Tonkin & Taylor Ltd.

Qualifications and experience

1.2 I hold a Bachelor of Science (Geology) from the University of Auckland (1996) and Master of Science (Engineering Geology) from the University of Canterbury (1999). I am a Chartered Member of Engineering New Zealand (Professional Engineering Geologist), a Member of the New Zealand Geotechnical Society (NZGS), the International Association for Engineering Geology and the Environment (IAEG) and the Australian Institute of Mining and Metallurgy (AUSIMM).

1.3 I have 20 years of post-graduate experience in mining/quarrying, land development and large-scale infrastructure development. I specialise in cut slope design, overburden disposal design, geotechnical risk assessment, slope stability and natural hazard assessment. Roles I have undertaken include provision of geotechnical support for mining/quarry operations, slope designer and external peer reviewer.

1.4 Examples of my experience in mining/quarry development and assessment of geotechnical effects include:

(a) Eight years working as a geotechnical consultant for Solid Energy Limited supporting mine cut slope, and overburden disposal design at Rotowaro and Maramarua opencast coal mines. This included involvement in a preliminary geotechnical assessment for a proposed Ohinewai development in the mid to late 2000's;

(b) Peer review and preparation of expert geotechnical evidence to support Waikato Regional Council in their regulatory review of an application by Glencoal Limited for a new open cast coal mine at Mangatawhiri in the North Waikato;

(c) Peer review and preparation of expert geotechnical evidence to support Waikato Regional Council in their regulatory review of an application by Puke Coal Limited for a Municipal Solid Waste facility in a historical mined out void in the North Waikato;

(d) Peer review and preparation of expert geotechnical evidence to support West Coast Regional Council in their regulatory review of an application by Solid Energy New Zealand Limited for the Mt William North mine extension at Stockton;

(e) Geotechnical design for a 1.2 Mm^3 overburden disposal area and preparation of expert evidence to support an application for Resource Consent by Winstone Aggregates Limited for their Dry Creek Replacement Clean Fill project;

(f) Geotechnical design for a 2.4 Mm^3 overburden disposal area and preparation of expert evidence to support an application for Resource Consent by Winstone Aggregates Limited at their Otaika Quarry; and

(g) Over fifteen years working as a geotechnical consultant for Winstone Aggregates supporting quarry cut slope, mine design and overburden design at Hunua Quarry, Belmont Quarry, Flat Top Quarry and Whitehall Quarry.

Involvement in the Ohinewai project

1.5 I was engaged in February 2020 to provide advice to Ambury Properties Limited ("APL") in relation to a further submission in opposition to the rezoning of the site at 52-58 Lumsden Road, 88 Lumsden Road and 231 Tahuna Road, Ohinewai ("the Site") by the Ralph Estates which states[1]:

[1] Further Submission on Proposed Waikato District Plan (Stage 1) under Clause 8 of Schedule 1, Resource Management Act 1991 (RMA), by the Ralph Estates.

> *"The Ralph Estates own the mineral rights beneath a portion of the land that is subject to the rezoning and oppose the proposal on the basis that the development of the site would sterilize those mineral interests."*

Purpose and scope of evidence

1.6 My evidence addresses the nature of the underlying coal resource, methods that could be considered to extract or otherwise exploit the resource, the expected site developments required for each extraction method, and the anticipated environmental effects arising from each development concept.

1.7 Specifically, my evidence will:

(a) Describe the Site (Section 3);

(b) Summarise the methodology I followed in my analysis of the coal resource (Section 4);

(c) Describe the local geology and the coal resource that underlies the Ohinewai area (Section 5);

(d) Provide a broad overview of the methodology that would need to be followed to undertake opencast mining on the site (Section 6), including:

(i) Site infrastructure development needs;

(ii) Extent of opencast and pit slope geometry;

(iii) Overburden extraction and disposal;

(iv) Management of groundwater and surface water inflows;

(v) Winning the coal; and

(vi) Associated environmental effects of open cast development.

(e) Provide a broad overview of the methodology that would need to be followed to undertake underground mining on the site (Section 7), including:

(i) Site infrastructure development needs;

(ii) Accessing the resource, including overburden extraction and disposal;

(iii) Underground extraction methods and extraction efficiency;

(iv) Management of groundwater inflows;

(v) Associated environmental effects of underground development.

(f) Summarise other developing techniques that may be used to exploit the coal resource (Section 8);

(g) Comment on the Council Officer's Report and proposed amendments to plan provisions (Section 9); and

(h) Provide a brief conclusion (Section 10).

1.8 A summary of my evidence is contained in Section 2.

1.9 My evidence should be read alongside the evidence of:

(a) Mr Nick Speight – who addresses the geotechnical characteristics of the near surface soils and geotechnical constraints on development of the site.

(b) Mr David Stafford – who addresses the underlying hydrogeology of the site.

(c) Mr Stuart Penfold, who addresses the likelihood of obtaining the necessary resource consents for a mine on the site.

Expert Witness Code of Conduct

1.10 I have read the Code of Conduct for Expert Witnesses, contained in the Environment Court Consolidated Practice Note (2014) and I agree to comply with it. I can confirm that the issues addressed in this statement are within my area of expertise and that in preparing my evidence I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

2. SUMMARY OF MY EVIDENCE

2.1 The Site is underlain by a thick sequence of poorly consolidated clays, silts and sands of the Tauranga Group, overlying Te Kuiti Group siltstones and sandstones which include a thick sub-bituminous coal seam at depth.

2.2 The coal resource underlying the Site has been known about for many years and was the subject of a State Coal ground investigation programme in the 1980's. However, a mine has never been developed to extract the coal.

2.3 Demand for sub-bituminous coal has fallen over recent years due to the availability of low cost natural gas for local power stations, an increasing focus on renewable energy and concerns around carbon emissions.

2.4 Exploiting the coal resource at Ohinewai by traditional means (opencast or underground mine) is expected to be challenging from a technical point of view.

2.5 The key issues with an opencast pit include:

(a) Very flat slopes will be required to manage pit wall instability risks; this would likely necessitate the removal of Lakes Ohinewai and Rotokawau.

(b) Groundwater inflows into the pit present a risk of hydraulic connection to Lake Waikare and could result in widespread settlement due to dewatering of the Tauranga Group.

(c) A very large area must be set aside for initial overburden placement on foundation soils (Tauranga Group) that are typically unable to accommodate large vertical loads.

2.6 The key issues with an underground mine include:

(a) The high cost of access shafts.

(b) Keeping shafts and drives from converging/collapsing in extremely weak to very weak rock.

(c) Longwall miners are not expected to be well suited to the ground conditions, reducing resource recovery.

(d) Managing the effects of surface settlement, which will influence the volume of coal that may be recovered.

(e) Managing groundwater inflows.

(f) High capital start-up costs and ongoing high operational costs set against anticipated low production rates is expected to result in an uneconomic mine. As an example, despite having already incurred the capital start-up costs, Huntly East mine was unable to overcome high operational costs, and was deemed uneconomic and closed.

2.7 It is my opinion that mining the Ohinewai resource by conventional opencast or underground mining methods is unlikely to be economic due to the technical challenges, potentially significant environmental impacts, low demand and high operational costs.

2.8 Developing techniques to access and utilize deep or difficult to mine coal seams include Underground Coal Gasification (UCG). Injection wells are drilled from surface into an underlying coal seam, and either air or oxygen is injected into the seam along with water, which ignites the coal, and the resultant gas is tapped through production wells.

2.9 Solid Energy New Zealand trialled UCG in 2012 and provided proof of concept. The trial demonstrated that the technique could be used without contaminating groundwater but no data is publicly available that demonstrates the surface settlements that occurred.

2.10 It is my expectation that significant surface settlements could occur if UCG were used within the thick (10-20 m) sections of the resource, unless a substantial volume of coal remains unburnt in the ground.

2.11 Surface settlement associated with UCG would have the potential to impact surface water bodies and drainage systems as well as structures at the ground surface. The separation between injection wells and production wells for some UCG production methodologies may be up 1,500 m. This suggests that UCG may not be incompatible with the proposed development of the Site, providing environmental effects (settlement in particular) can be managed.

3. SITE DESCRIPTION

3.1 I refer to the description of the Site provided in Section 4 of the statement of evidence of Mr Nick Speight. By way of summary, the Site is approximately 178 hectares in size and is located on the eastern side of State Highway 1 at 52-58 Lumsden Road, 88 Lumsden Road and 231 Tahuna Road, Ohinewai. It is predominantly in pasture and used for agricultural purposes.

4. METHODOLOGY

4.1 My evidence is based on a review of documents prepared by RWL Mining Consultants in December 1986[2] as part of a feasibility study for an opencast coal mine at Ohinewai. That proposal included land currently being considered for the APL proposal. It is my understanding that consent was obtained for that opencast coal mine, but the mine was never developed.

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2 RWL Mining Consultants (1986) Ohinewai Opencast Feasibility Study: Geotechnical Investigations Phase II, Volumes 1 & 2RWL

4.2 In addition, I have relied on the Geotechnical Assessment Report prepared by Initia Ltd[3] and the evidence of Mr Nick Speight to support statements I make around the near surface geological units. I also have used published geological information and reports, which are referenced as appropriate.

5. REGIONAL GEOLOGY AND THE COAL RESOURCE

Regional geology

5.1 The near surface geology is entirely made up of the Tauranga Group, a range of marine, estuarine and terrestrial sediments deposited primarily during the Quaternary (the most recent period in the Cenozoic era) in the Bay of Plenty, Waikato and Auckland regions. Section 6 of Mr Speight's statement of evidence addresses the nature of the various geological units within the Tauranga Group.

5.2 Underlying the site below the Tauranga Group sediments (between 80-120m below ground surface) are Te Kuiti Group geological units, being:

(a) The Mangakotuku Formation, comprising:

(i) Rotowaro Siltstone (km)[4] member, which is typically a light grey to dark grey non calcareous, massive siltstone;

(ii) The Pukemiro Sandstone (kp) member, which is typically a green grey, glauconitic muddy sandstone;

(iii) The Glen Afton Claystone (ka) member, which is typically a light grey, non calcareous mudstone with a high proportion of clay minerals.

(b) The Waikato Coal Measures (WCM), which typically comprise brown to grey brown carbonaceous mudstones or siltstones, with occasional sandstone, conglomerate lenses or siderite concretions and several coal seams;

5.3 Below approximately 220-300 m depth, the site is underlain by Greywacke of the Hakarimata Formation. This is the only other geological unit that could be considered for extraction (as a construction aggregate); however,

3 Initia Ltd (2019) Ambury Properties, Proposed Plan Change 231 Tahuna Road, Ohinewai, Geotechnical Assessment Report, P000529 Rev A

4 Note: two letter notation in brackets can be used to identify these units on cross sections in Attachment A.

the thick overburden would make a quarry uneconomic, as greywacke is exposed at ground surface in proximity to the site (at Huntly).

5.4 There have been several changes in terminology for some of these geological units over the years. Some of the material referenced in my evidence spans the dates over which name changes occurred. Therefore, for clarity:

(a) The Mangakotuku Formation prior to 1966 was previously known as the Mangakotuku Siltstone and encompassed all of the three members set out in 5.2 above.

(b) Prior to 1993 the Rotowaro Siltstone Member was referred to as the Mangakotuku Siltstone member (a part of the Mangakotuku Formation).

5.5 All of the Te Kuiti Group units described above have an intact rock strength that may be described as extremely weak to very weak (typical uniaxial compressive strength of <1 MPa to 5 MPa). However, where affected by faulting, the units may behave as a hard soil.

5.6 The contacts between the different units are known to be conformable, i.e., there is no break in deposition between units, and therefore sedimentary structures (bedding, for example) within these units are typically parallel, where present.

5.7 Bedding contacts between the units described above and between coal seams and carbonaceous mudstones are typically sheared, due to a combination of local faulting as well as widespread subsidence of the Te Kuiti Group during formation of coal seams.

5.8 The sheared nature of these bedding contacts mean that they have very low defect strength and are therefore prone to slope instability where exposed in cut slopes. This effect is particularly pronounced at the contact between the Glen Afton Claystone member and the Waikato Coal Measures. This contact is locally known as Buka (base of unit ka, ka being the Glen Afton Claystone).

The coal resource

5.9 The coal within the North Waikato basin is a sub-bituminous coal. This is a thermal coal used primarily for industrial scale heating or power generation.

5.10 Several coal seams are known to exist within the WCM, with those most prominent in the North Waikato being the Ngaro Seam, the Renown Seam, the Kupakupa Seam and the Taupiri Seam.

5.11 The resource at Ohinewai beneath the site is interpreted to be a combined Renown seam in the south which extends to approximately 200 m north of Tahuna Road. North of this point the coal seam splits into an upper Renown seam and a lower Kupakupa seam[5].

5.12 At the southernmost extent of the Site (as shown in Figures A1 & A2 – **Attachment A**), the combined coal seam is interpreted to be approximately 20 m thick and is present at a depth of between 120 m-160 m below ground surface.

5.13 At the northernmost extent of the site the coal seam is split into three thin seams of 2-4 m each, separated by WCM interburden between 4 and 10 m thick. The uppermost coal seam is located approximately 230 m below ground surface in this location.

5.14 Given the gentle dip of the coal seams to the north, I anticipate that if the resource was exploited, regardless of technique, mining activities could be expected to commence in the southern part of the resource area (south of Tahuna Road), where coal is closest to ground surface, thereby reducing the time and development costs between operations commencing and first coal. Mining techniques are discussed in Sections 7-9.

6. DEMAND FOR THERMAL COAL

6.1 Production of sub-bituminous Thermal Coal peaked between 2006 and 2010 and has steadily declined since (Figure 3).

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5 RWL Mining Consultants (1986) Ohinewai Opencast Feasibility Study: Geotechnical Investigations Phase II, Volumes 1 & 2

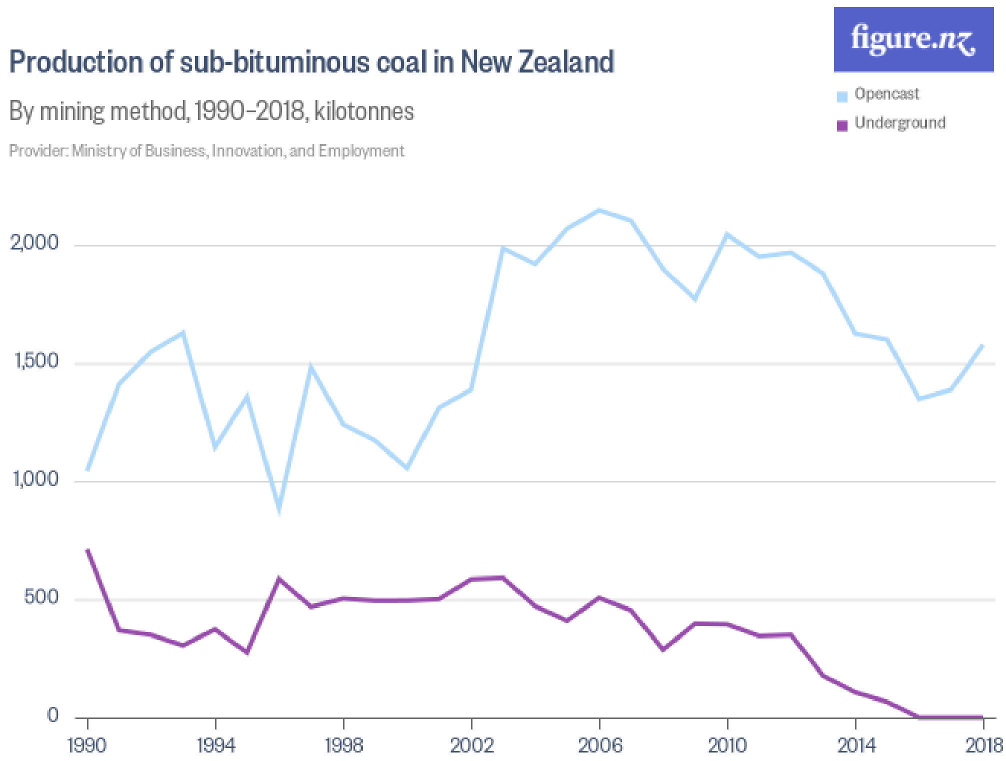

Figure 3 – NZ Sub-Bituminous coal production

6.2 The biggest users of coal from the North Waikato are New Zealand Steel's plant at Glenbrook, the Waikato dairy industry and the Huntly Power station.

6.3 In the North Waikato context, the co-generation capacity (gas and coal) of Genesis Energy's Huntly Power Station means that it is now less reliant on locally won Thermal Coal.

6.4 In addition, the Huntly Power Station is phasing out coal use. Genesis Energy's Chief Executive Marc England was quoted in Early 2019 as saying:[6]

> *"By 2025, Genesis will only use coal in its thermal units in abnormal market conditions, and it is our intent to remove coal completely by 2030."*

6.5 Globally, major investment houses and banks are currently reducing their exposure to Thermal Coal, which is expected to significantly limit the availability of financing for new thermal coal mines[7], which require significant upfront capital to develop.

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[6] Radio New Zealand, 14 February 2018: Genesis Energy to phase out Huntly coal use. https://www.rnz.co.nz/news/national/350390/genesis-energy-to-phase-out-huntly-coal-use

[7] ABC News 28 January 2020: The future of coal has already been decided in boardrooms around the globe https://www.abc.net.au/news/2020-01-28/why-finance-is-fleeing-fossil-fuels/11903928

6.6 An AEMO and CSIRO GenCost report released in late 2018[8] indicates solar and wind generation technologies are the lowest-cost methods to generate electricity in Australia, compared to any other new-build energy technology. This suggests that future increased demand for energy is not likely to have the flow-on effect of an increased demand for thermal coal.

6.7 Overall, global demand is still expected to be underpinned by growth in India and China, but New Zealand's geographic isolation reduces the ability to get thermal coal to market economically for New Zealand mining companies. (This does not include specialty hard coking coals from South Island mines.)

For example, Bathurst Mining, New Zealand's largest coal producer, limits exports to high value specialty coking coal with their thermal coal primarily supplying domestic markets[9].

6.8 Overall, it is my opinion that demand for thermal coal, both domestically and internationally, is expected to continue to reduce for the foreseeable future, making development of new mines progressively less economic.

7. OPENCAST MINING

Overview and site development

7.1 An opencast mine is essentially a deep pit, with side walls excavated at a slope angle that can be safely maintained during operations and later rehabilitation.

7.2 Opencast mines have the advantage of being able to more fully exploit the coal resource (almost all the coal exposed can be extracted), they are typically safer and are (depending on depth) usually more efficient as a variety of excavation plant can be utilised and there is more space to operate within.

7.3 However, opencast mines have a very large footprint of disturbed ground and require a very large footprint for disposal of overburden, all of which require a significant level of rehabilitation on completion of mining.

7.4 At the Site, if the coal resource was exploited, initial development would incorporate development of access roads, haul roads, site offices, truck racks, maintenance facilities, parking areas and coal handling facilities prior to overburden removal operations commencing.

8 IEA (2019), "Coal 2019", IEA, Paris https://www.iea.org/reports/coal-2019.
9 https://bathurst.co.nz/our-operations

7.5 I anticipate that this mine infrastructure would be developed adjacent to initial operations and thus would be likely to be located to the south of Tahuna Road. An example of the infrastructure required for a smaller scale start-up operation is illustrated in Figure 4, which is an annotated aerial image of the nearby Maramarua Opencast (production ~110 kt pa). Depending on eventual production, the final infrastructure area may look more like Rotowaro Opencast (production ~710 kt pa, Figure 5).

Figure 4 – Aerial Image of the Maramarua opencast infrastructure area

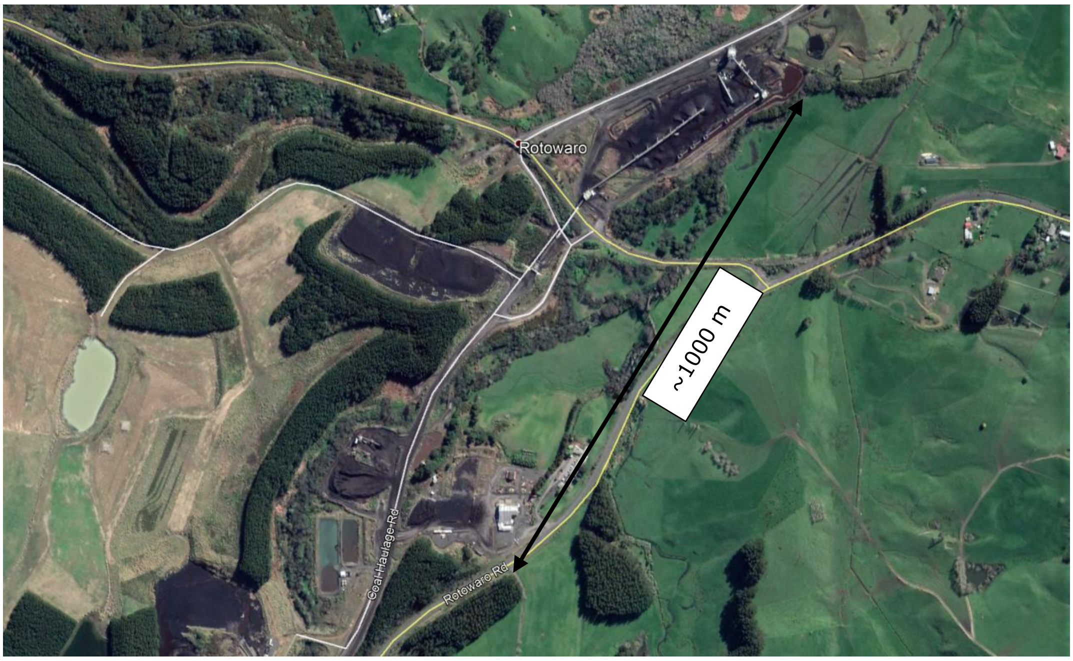

Figure 5 – Aerial Image of the Rotowaro opencast infrastructure area

Conceptual pit slope design and economics

7.6 Pit slope geometry would need to be carefully designed to accommodate the expected ground conditions and potential modes of failure. Historically, assessments completed for State Coal in the early 1980's used a generic 1V:3H overall slope angle when considering several open cast scenarios (refer Figure 2, attachment A).

7.7 It is my view that the overall slope angle proposed at that time may not adequately accommodate thick Tauranga Group Sediments, for example, in the northern part of the site and flatter overall slope angles may result.

7.8 However, adopting a slope angle range between 1V:3H and 1V:3.25H allows for consideration of volumes of overburden that may need to be excavated and placed in off-site disposal areas, prior to sufficient space becoming available in the mined-out pit to allow for in pit overburden disposal. It also allows for a general assessment of strip ratios, which are often considered a proxy (in concept design) for the financial viability of a mine.

7.9 Using the 34 mT design open cast pit being considered in the early 1980's by State Coal (RWL 1986, Figures 1 & 2, Attachment A), I calculate a total overburden volume of approximately 270-290 M m^3. This considers a broadly circular pit (radius 1050 m), a generic slope angle of between 1V:3H and 1V:3.25H and a coal seam located, on average 100 -120 m below surface. I have calculated the volume using these inputs and a conical frustum volume calculation.

7.10 A largely combined coal seam averaging 20 m thick, located at around 120 m below ground surface for this 34 Mt design, would provide a coal volume of 26 M m^3 to 28 M m^3.

7.11 Comparing the volumes of overburden and coal allows for a conceptual strip ratio to be calculated. A commonly adopted strip ratio for the economic limit of surface mining is 1:20, or one unit of coal per twenty units of overburden shifted. In practise this may be adjusted up or down based on a range of factors that may increase or reduce mine operational efficiency.

7.12 A comparison of coal volume against overburden stripping indicates a strip ratio of approximately 1:10 to 1:11. Conceptually, this indicates that the Ohinewai resource may be economic to mine by open cast techniques.

Overburden disposal

7.13 Setting aside mine economics, a very large volume of overburden would need to be excavated before a pit of a sufficient size becomes available to begin in pit disposal (backfilling into the previously mined void). Conservatively estimating this volume at 1/4 of the overall overburden volume, approximately 70 Mm^3 of overburden may require placement in an out of pit Overburden Disposal Area (OBDA).

7.14 A suitable area for overburden disposal would need to be identified during the design phase. Considerations for this site would include:

(a) An area of low ecological value.

(b) Foundation ground and groundwater conditions amenable to the proposed loading.

(c) A site located in proximity to the mine, but not so close to the proposed pit walls to overload the pit slopes when the final design is completed.

(d) Location in an area either not underlain by coal or underlain by non-economic coal.

(e) Either ownership or a long-term lease of the property where the OBDA is to be constructed to allow for the placement of overburden.

7.15 Where possible, overburden is disposed of within previously mined out opencast voids as part of their rehabilitation. None are present in proximity to the proposed mine site, with the possible exception of the Kimihia Opencast which is a small void adjacent to the old Huntly East Mine, to the south. However, a haul distance of approximately 5 km and the fact that this site is in private ownership and is presently being rehabilitated as a lake, makes this an unlikely OBDA location.

7.16 It is our expectation that an OBDA would need to be developed either to the east of the pit or to the north, between Lake Waikare and SH1 (indicatively illustrated on Figure 6).

Figure 6 – Aerial Image of the Ohinewai area. Illustrating the 1986 State Coal 34 Mt pit outline (yellow) and potential overburden disposal areas (orange).

7.17 Both locations are expected to have similar surficial ground conditions to those outlined by Mr Nick Speight in his evidence.

7.18 The soft, wet, compressible Tauranga Group soils would provide a poor foundation for an OBDA and would, in my opinion, present significant technical challenges in the geotechnical slope stability design of the OBDA. A limitation on the height of the OBDA is an expected outcome and therefore a very large surface footprint would be required to accommodate the overburden volume. I consider that a similar footprint to the opencast mine itself may be required to accommodate initial overburden placement, prior to in pit disposal becoming available.

Groundwater-related geotechnical risks to mine development

7.19 Strong groundwater inflows are to be expected into any large opencast in the Ohinewai area, due to the nature of the upper Tauranga Group materials and the proximity to Lakes Ohinewai, Rotokawau and Waikare.

7.20 Management of groundwater inflows may include some combination of dewatering from internal pit floor sumps and/or dewatering from wells positioned around the excavation (known as well pointing).

7.21 Key geotechnical issues related to groundwater flows include:

(a) An elevated slope failure risk due to high groundwater pressures in slopes that back onto the lakes identified above.

(b) The potential for direct hydraulic connection from either the Waikato River or Lake Waikare which could result in high groundwater flow velocities, internal erosion and piping failure of the pit walls.

7.22 While there is significant design assessment that is still required, conceptually the Karapiro Formation is at particular risk of internal erosion/piping failure, due to its sand and gravel composition (high permeability) and channelized nature making its presence hard to predict in ground investigation.

Key considerations in Open Cast development at Ohinewai

7.23 It is apparent from the data that I have reviewed that developing the Ohinewai prospect by way of opencast mining would need to overcome strip ratios that are high, but within commonly accepted thresholds for economic open cast mining.

7.24 The timing of capital is also important: the capital requirements of open cast mines are often substantially weighted at the start of the project. For example, considering just the overburden volume to be removed to access the coal at Ohinewai (estimated at 15-20 M m^3), with a conservative rate of NZD $5/$m^3$ to dig, transport and place overburden, an upfront capital requirement of NZD $100 million plus infrastructure development costs, could be anticipated prior to generating revenue from coal sales.

7.25 In addition to the economic considerations, if an open cast mine were to be developed to win the coal underlying the APL site at Ohinewai, the following environmental effects related to the development could be expected:

(a) The open cast excavation would need to be large, necessitating the removal of Lake Rotokawau and possibly Lake Ohinewai (refer Figure A1, **Attachment A** & Figure 6).

(b) Early stage overburden removal is expected to require a similar footprint to the final footprint of any opencast mine developed at Ohinewai.

(c) Widespread drawdown of groundwater is to be expected in the compressible Tauranga Group soils, resulting in associated widespread ground surface settlement beyond the pit walls. This has the potential to affect SH1 and the North Island Main Trunk rail line.

(d) There is the potential for hydraulic connection into the pit from Lake Waikare or the Waikato River through the higher permeability sand rich Karapairo Formation. Depending on the eventual position of the pit walls, effects could range between the slow dewatering of Lake Waikare, through to the risk of internal erosion (piping) style failure of the pit walls and flooding of the pit from either water source.

(e) Potential instability of the pit walls due to uncertainty in material characteristics and hydrogeology. I note that large scale slope failures have occurred historically in opencasts in the North Waikato coal fields, such as Maramarua and Smiths Pit near Rotowaro.

(f) A shortfall of overburden to backfill the site is expected, due to out of pit placement in early mine development. Over time, depending on rehabilitation requirements and consent conditions, a lake could be expected to form in any residual void, eventually achieving a similar level to the present Lake Rotokawau. Remnant cut slopes retained above this level would present a risk of large-scale lateral spread type failures during seismic events, if not allowed for in rehabilitation design.

7.26 These issues among others are expected to make consenting an opencast mine extremely challenging.

7.27 When considering the strip ratios, the technical difficulties, high up-front capital costs and potential environmental effects I have considerable doubts as to the ability to economically mine the Ohinewai prospect by way of opencast mining.

8. UNDERGROUND MINING

Overview and site development

8.1 An underground mine is a means of accessing coal or other resource present at depth, beyond the economic limit of opencast mining. It is essentially a series of tunnels that allow the resource to be extracted (in part), without the need to directly excavate the large quantities of overlying overburden.

8.2 Development of mine infrastructure is expected to be largely as set out in Sections 7.4 and 7.5 above. A key difference is that the limited space in an underground mine requires specialist mobile plant and limits the size and efficiency of the fleet.

8.3 The initial development of an underground mine at Ohinewai would include an initial access drive or shaft to allow equipment and personnel access to the resource at depth.

8.4 An access drive is generally preferred by mine operators as it is more efficient allowing equipment and mobile plant to be driven into the mine. An access shaft is typically adopted where the resource is deep and/or the overburden is of such poor quality that supporting the roof of an access drive begins to become problematic.

8.5 In my opinion, an access shaft would be the most likely method of accessing the Ohinewai resource for an underground mine, given the soft, unconsolidated nature of the Tauranga Group soils.

8.6 In addition to the main access to the mine, a secondary means of egress from the coal extraction areas would need to be developed to make the underground mine compliant with Section 170 of the Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016.

8.7 For guidance, in 2011 SENZ began construction of an additional ventilation shaft at their Huntly East mine. This was a 4.2 m diameter shaft to a depth of approximately 270 m designed to ventilate the sections of the mine extending at that time beyond the western side of the Waikato River. The cost to develop that shaft was quoted at $NZD 30 million[10], but it was never completed. Solid Energy's eventual administration and a lack of demand for the thermal coal produced resulted in the permanent closure of the mine[11].

8.8 If the Ohinewai Prospect were to be developed by underground methods, I anticipate that at least one of the shafts would need to be of a much larger diameter than the Huntly East example to facilitate the transportation of mining equipment, provision of ventilation and coal transportation to surface. A smaller, separate service shaft would be required for other equipment and personnel or as emergency egress.

8.9 Access and production shafts could be expected to be located in the south of the prospect, south of Tahuna Road, where overburden depths are expected to be shallowest. Long term, additional ventilation shafts would be required as the mine extends away from the initial access points.

8.10 It is expected to be geotechnically challenging and costly to keep shafts and drives in the mine from converging / collapsing due to the combination of very high groundwater pressures (1 to 2 MPa) and an extremely weak to very weak rock mass.

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10 Waikato Times 13 April 2011: Work begins to extend mine life. https://www.pressreader.com/new-zealand/waikato-times/20110413/281556582371210

11 https://www.stuff.co.nz/business/industries/72812848/solid-energy-proposes-the-closure-of-huntly-east-mine

8.11 The early stages of underground mine development would include the development of an OBDA to store the initial spoil removed from the access shafts when creating access to the coal resource. The volumes of overburden that would need to be stored in this initial coal access stage are considerably reduced compared to opencast mining and it is my expectation that these could be disposed of efficiently and safely in proximity to the mine infrastructure area.

8.12 Mining of the coal itself would be undertaken either by continuous miners or by longwall mining. These methodologies are addressed below.

Long wall mining

8.13 Longwall mining uses specialised equipment to mine a face in the order of 100 to 300 m wide, positioned between two initial roadways that form the sides of the longwall block. Once the longwall face equipment has been installed, coal can be extracted along the full length of the face in slices. The longwall extraction unit supports the immediate mining area with the unsupported roof collapsing behind the excavation (in the goaf area[12]).

8.14 Longwall mining allows for very high extraction ratios (upward of 90% in some cases), generates high annual production rates, only requires roof support in the initial roadways and generally has a lower labour cost per tonne of coal mined.

8.15 However, longwall mining has higher capital start-up costs, does not deal with geological structure well (faults & folds), and generates more significant surface settlement effects above areas of collapsed goaf.

8.16 Given that the coal seam is known to be faulted on both a small scale and larger scale at Ohinewai (RWL 1986) and taking account of the higher potential for surface settlement effects it is my opinion that successful longwall mining of the resource is unlikely.

Room and Pillar mining by continuous miners

8.17 Room and pillar mining is a conventional mining system whereby a proportion of the coal is extracted (the rooms) with a proportion of the coal seam retained to support the roof of the mine (the pillars).

12 Goaf may be defined as the area of void remaining after mining has been completed or waste stored in that void

8.18 Room and pillar mining is typically undertaken with continuous miners, which both extract the coal and allow for efficient installation of roof support.

8.19 Initial mining of the resource to develop rooms and pillars typically result in sub-optimal extraction of the coal resource, with as much as 50% of the coal seam remaining unmined.

8.20 Secondary mining of the pillars is often undertaken to increase the proportion of the coal seam that is extracted, but this presents a greater risk of roof collapse in the working area or the previously mined area (goaf). There is therefore both an increasing health and safety risk and surface settlement risk with increasing coal recovery.

Key considerations in underground development at Ohinewai

8.21 The main technical challenge in developing an underground mine at Ohinewai is keeping shafts and drives from converging/collapsing in extremely weak to very weak rock which is subject to hydrostatic groundwater pressures of 1-2 MPa.

8.22 Huntly East underground was able to manage roof support in similar geological conditions. However, it is also an example of a mine where although the upfront capital cost had already been incurred, a lack of demand for coal set against high operating costs (quoted at NZD $500,000/month[13]) meant that the mine became non-economic and in 2015 it was forced to close.

8.23 Longwall techniques are unlikely to be suited to the geological conditions, which will limit coal recovery to conventional room and pillar excavation. Actual coal recovery by room and pillar will be further limited by the nature of any conditions in resource consents for the mine that relate to limits on long-term surface settlement caused by underground mining.

8.24 As a guide, significant surface settlements (up to 0.7-1.0 m) have historically been measured beneath parts of Huntly township as a result of historical underground mining. Ian R Brown Associates Ltd (2015)[14] review of these settlements indicate that the greatest magnitude of settlement was associated with:

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13 https://www.stuff.co.nz/business/industries/72812848/solid-energy-proposes-the-closure-of-huntly-east-mine

14 Ian R Brown Associates Ltd, 2015, Huntly East land subsidence due to coal mining, Investigation and analysis of potential hazard, March 2015, prepared for Waikato District Council.

(a) Areas where mine roof height was extended to 6 m from the 3.5 m design (refer Figure A3 and A4, **Attachment A**);

(b) Roof fall in places which extended the effective pillar height further;

(c) Areas where a reduced thickness of overlying Te Kuiti Group overburden was present;

(d) Areas where the mine was at its shallowest.

8.25 Management of groundwater inflows to an underground mine will require consideration, however, the rock mass permeability of the Te Kuiti Group and previous performance of the Huntly East Underground mine indicate that groundwater inflows should be manageable but may be costly.

8.26 Significant capital will need to be invested into any underground mining operation. Given the cost of a single shaft in 2011 at $NZD 30 million, we anticipate initial development costs would be in the many tens to hundreds of million of dollars, prior to coal revenue becoming available.

8.27 Historically, underground mines in New Zealand have struggled with low production rates (the highest being 500,000 tonnes pa from Spring Creek) due to unfavourable geology and a lack of demand due to a small internal economy and distance to international markets[15].

8.28 The consenting context for new mines within New Zealand also needs to be considered and this is covered by the Evidence of Stuart Penfold.

8.29 I anticipate that high capital costs to develop a mine (in the several tens to hundreds of millions of dollars) challenging geology and technical difficulty, lack of demand and the low proportion of coal able to be mined by the available techniques would make underground mining of the Ohinewai resource uneconomic.

9. DEVELOPING TECHNIQUES TO EXPLOIT THE COAL RESOURCE

9.1 Given the difficulty in developing either opencast or underground mines at Ohinewai and the expected continuing reduction in demand for thermal coal other options to exploit the Ohinewai resource may be considered.

15 Pike River Royal Commission. https://pikeriver.royalcommission.govt.nz/vwluResources/Final-Report-Vol2-Ch19/$file/Vol2-Chapter19-only.pdf

9.2 Underground Coal Seam Gasification (UCG) is one of the options that has historically been trialled by SENZ elsewhere in the North Waikato coalfields.

9.3 UCG is a developing technology that allows for the exploitation of coal seams that are located at a depth that would make traditional mining uneconomic.

9.4 Injection wells are drilled from surface into an underlying coal seam, and either air or oxygen is injected into the seam along with water, which ignites the coal.

9.5 The high temperatures and lack of oxygen result in adjacent coal being oxidized into syngas (hydrogen, carbon monoxide, carbon dioxide , methane and hydrogen sulphide) which is tapped by production wells located away from the injection wells.

9.6 Ignition and production wells move along the coal seam as it is progressively burnt and the resulting syngas is depleted.

9.7 The SENZ UCG pilot plant near Rotongaro, provided proof of concept. However, prior to SENZ going into administration the trial plant in Huntly was shut down[16]. The technology was never put into full production and the economic viability of a commercial scale project is unclear.

9.8 The benefits of UCG are that it requires a substantially reduced surface footprint, reduces use of groundwater, reduces environmental impacts traditionally associated with coal mining and handling and a substantial portion of the sulfur, mercury, arsenic, tar, ash and particulates found in coal remain underground[17].

9.9 The reduced surface footprint is particularly relevant to the Ralph Estate further submission. Mostade (2014)[18] indicates that the economic distance between injection wells and production wells for some UCG production methodologies may be up 1,500 m. Injection wells and production wells on either side of the Site may therefore allow the coal underneath the Sleepyhead Estate to be targeted. This suggests that UCG may not be entirely incompatible with development of the Site, providing environmental effects could be managed.

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16 Solid Energy Quarterly Report to 30 September 2012. https://treasury.govt.nz/sites/default/files/2017-11/soedisc-senz-19oct12.pdf

17 https://www.ergoexergy.com/eUCG_env.htm

18 Mostade, Marc. (2014). Underground Coal Gasification (UCG) – the Path to Commercialization. CPSI Journal. 6. 18-37.

9.10 However, the environmental effects, in this case surface settlement, would need to be managed in such a way that is within the tolerances of the development above the UCG area.

9.11 Environmental effects are considered by Mostade (2014) to typically reduce with increasing depth of coal seams. Those seams located less than 300 m below ground surface, such as Ohinewai, are considered to be inherently more environmentally risky compared with deeper coal seams.

9.12 These environmental risks relate primarily to the potential for contamination of groundwater and surface settlement effects.

9.13 The risk of groundwater contamination is associated with the cavity pressure of the UCG gasifier compared to the surrounding groundwater pressure. This risk is mitigated or exacerbated by the permeability of the surrounding strata and extent and nature of faulting that intersects the coal seam.

9.14 Where the pressure from the gasification process within the coal seam becomes elevated above that of the surrounding groundwater, then there is the potential for migration of gas and associated contaminants into the surrounding strata and groundwater. The depth of the coal seams at Ohinewai (around 120-230 m depth), mean that cavity pressures will be limited to between around 1-2 MPa.

9.15 The Te Kuiti Group mudstones are typically of low permeability. This is beneficial for UCG as it helps mitigate against migration of gas and contaminants into groundwater in the event that cavity pressure exceeds hydrostatic groundwater pressure.

9.16 The extent of faulting of the coal seam and overburden rock mass presents two key technical issues:

(a) Depending on the nature of the faulting, it may provide a preferential pathway for migration of gas and contaminants (finger flow).

(b) Depending on the intensity of faulting (number of faults) and the associated fault offsets, issues around continuity of the coal seam may impact UCG economics, due to a reduction in coal panel length (i.e. injection and production wells would need to be much closer together). Previous interpretation of the coal seams at depth (refer Attachment A, Figure A2) by State Coal indicate significant faulting of the resource, but there is not sufficient information to allow a more detailed assessment of the extent of unknown fault contacts that may exist between those illustrated.

9.17 The SENZ UCG pilot plant was reported to have completed its trial in similar geology without any significant changes in water chemistry outside of the gasifier[19].

9.18 Surface settlements are typically considered to be reduced (but not eliminated) by comparison to underground mines, primarily due to swelling of the surrounding rock from heating, the remaining void space being partially filled with ash and slag by-products of the in-ground coal firing and any coal pillars or panels left in place.

9.19 There is no publicly available data from the SENZ UCG pilot plant with respect to surface settlements. Given that past surface settlement performance related to underground mining (IRBA 2015) has been poor in areas where coal pillar heights were extended to 6 m, there is significant uncertainty in the likely surface settlement performance if UCG were to be undertaken in coal seams that are 10-20 m thick.

9.20 Widespread uncontrolled surface settlement could be expected to result in significant changes to surface water characteristics including Lakes Ohinewai and Rotokawau as well as damage to surface structures. To manage these effects, careful design would be required which is likely to limit full utilisation of the coal resource by UCG.

9.21 In the long term the void space remaining at the completion of the UCG process is expected to become completely flooded with groundwater. However, the process is expected to be very slow due to the very low permeability of the Te Kuiti Group siltstones and mudstones. Conceptually, this groundwater inflow over time is unlikely to result in widespread de-watering of the overlying Tauranga Group sediments or surface water bodies.

9.22 Part of the UCG process produces a significant quantity of Carbon Dioxide (CO^2). The considerations around CO^2 production relate to both consenting and process complexity/cost.

9.23 The evidence of Mr Penfold addresses the consenting context, however I note that while subsequent discharges of greenhouse gases when coal won by mining is later combusted have not to date been a relevant consideration under the RMA, I understand that the production of CO2 generated by UCG,

19 S.M. Pearce , R.M. Dobbs and G.R. Gillard, 2014, Improving Coal Resource Utilisation – A New Zealand UCG Initiative. AUSIMM Branch Conference 2014.

which directly produces CO2, has not previously been considered by the courts.

9.24 Modern UCG technology can allow for improved management of the CO^2 produced, which involves carbon sequestration back into the ground into worked or unworked coal seams. This increases UCG production costs, potentially becoming a commercial viability issue, when comparing the end product syngas against the cost and availability of natural gas.

9.25 Assuming that environmental impacts could be avoided, mitigated or remedied, the feasibility of UCG at the Ohinewai prospect is largely related to economics.

9.26 In a paper prepared in 2014, Pei et al (2014)[20] undertook a cost comparison of syngas produced from UCG and syngas produced from natural gas.

9.27 They found that the cost of producing syngas UCG was broadly comparable to producing syngas from natural gas, with the overall economics driven by the local availability of cheap natural gas.

9.28 The pilot UCG plant constructed by Solid Energy has been quoted at a cost of $22 Million[21]. However, larger scale commercial schemes are considerably more costly. For example, Pei et al (2014) provide estimates around capital start-up costs for a large scale UCG plant that run into the hundreds of millions of dollars.

9.29 A full-scale review of the economics of UCG is beyond the scope of my expertise. However, provided the environmental effects can be limited (particularly settlement effects), it is my opinion that future commercial scale UCG of the Ohinewai coal prospect is not necessarily incompatible with the development of the Site.

10. CONCLUSIONS

10.1 My evidence has overviewed the resource at Ohinewai, the current coal demand, the technical challenges in developing new underground and opencast mines at Ohinewai, and some of the most pronounced sources of environmental effects.

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20 Pei, Peng & Korom, Scott & Ling, Kegang & Nasah, Junior. (2014). Cost comparison of syngas production from natural gas conversion and underground coal gasification. Mitigation and Adaptation Strategies for Global Change. 21. 10.1007/s11027-014-9588-x.

21 https://www.scoop.co.nz/stories/BU1204/S00460/solid-energy-begins-underground-coal-gasification-successful.htm

10.2 Both underground and opencast mines at Ohinewai will be technically difficult and costly but not impossible to develop. The major challenges to mine development relate to domestic and international coal demand, coal price and ability to consent new coal mines under the RMA.

10.3 In my opinion the combination of weakening coal demand, new energy infrastructure transitioning to renewables and high upfront capital costs to develop new coal mines is likely to make development of traditional opencast and underground mines uneconomic for the foreseeable future.

10.4 The significant environmental impacts of opencast mining at Ohinewai related to excavation of a mine pit and development of an OBDA can be expected to make consenting of a new open cast mine under the RMA extremely difficult, costly and time consuming.

10.5 Provided underground mines can manage surface settlement appropriately then environmental impacts are expected to be reduced by comparison to open cast mining. However, managing surface settlements associated with mining is usually achieved by limiting coal extraction, impacting the economics of underground mining the resource.

10.6 Previous experience suggests that UCG could be undertaken at the Ohinewai prospect without adversely affecting local groundwater quality. However, there is significant uncertainty with respect to the extent and magnitude of associated surface settlements. We anticipate that these could be managed by limiting coal extraction (increasing size of pillars) but that this would substantially impacting the economics of UCG.

10.7 Overall, I am of the opinion that traditional methods of mining the Ohinewai Prospect would be technically challenging (and extremely difficult to obtain consent for) and for the foreseeable future are unlikely to be economic.

10.8 Underground coal gasification may not be incompatible with the development of the Site, provided associated surface settlement impacts could be maintained below accepted tolerances for building damage.

Cameron John Lines
9 July 2020

ATTACHMENT A

FIGURES A1, A2, A3 & A4