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Multiuse 'Triple Play' Hot Sedimentary Aquifer (HSA) Potential of Victoria, Australia

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ABSTRACT

Greenearth Energy Ltd holds geothermal exploration permits to the east and west of Melbourne, Victoria Australia. These permits are located on the Otway and Gippsland basins that straddle the southern part of the State. The basin fills range up to 6 km thick and forms an insulating blanket over Palaeozoic basement rocks.

Geothermal gradients are somewhat elevated, with heat flows up to 100 mW/m^2 in places, and projected temperatures of 150 ^{o}C at around 3 kilometres (km) depth.

Sandy units at the base of the basin sequences offer potential for geothermal development of Hot Sedimentary Aquifers (HSA) while longer term Hot Dry Rocks (HDR) prospectivity exists in Palaeozoic granites buried beneath the sedimentary insulating cover. The HSA's are a triple play with potential for electricity generation, direct heat applications and potential sequestration sites.

A geothermal resource has been estimated for the area south of Geelong, encompassing both HWA and EGS geothermal plays. A proposal has been modeled for a 10.7 MW and 48 MW geothermal development accessing part of the HWA geothermal resource.

1. INTRODUCTION

Greenearth Energy Ltd (Greenearth) is a small listed Australian Geothermal explorer. It has geothermal exploration permits near Melbourne Australia (Fig 1) that underlie the industrial hub of southeastern Australia. These areas have a significant greenhouse gas footprint. To the east of Melbourne, in Gippsland, the permits include the Latrobe Valley area, the State of Victoria's power generation hub with over 6000 MW of brown coal fired electricity generation. To the west of Melbourne a permit covers the Geelong region, the most carbon constrained community in Australia. Major industry includes an aluminum smelter, cement works and a brown coal fired power station. Greenearth has established inferred resources in both its Geelong and Gippsland permits. To the southwest of Geelong an inferred resource of 260,000 PJ is calculated (Beardsmore, 2008), encompassing both a hot wet aquifer resource (HWA) and a deeper engineered geothermal system (EGS), while in the Gippsland area a small inferred geothermal resource of 39,000 PJ is estimated (Beardesmore, 2009).

The Australian Government has set a target that 20 % of all energy generation by 2020 will be from renewable sources (Department of Climate Change, 2008). Therefore potentially approximately 45,000 gigawatt-hours from renewable energy sources will be required by 2020. The thick sedimentary basins running east and west of Melbourne, the higher than normal heat flows in the basin margin areas and the potential for thick sandy sequences in the temperature depth widow of 3-4 km make the Greenearth permits prospective for geothermal development of hot sedimentary aquifers.

2. GEOLOGY AND GEOTHERMAL DESCRIPTION

A Mesozoic rift basin established along the southeastern

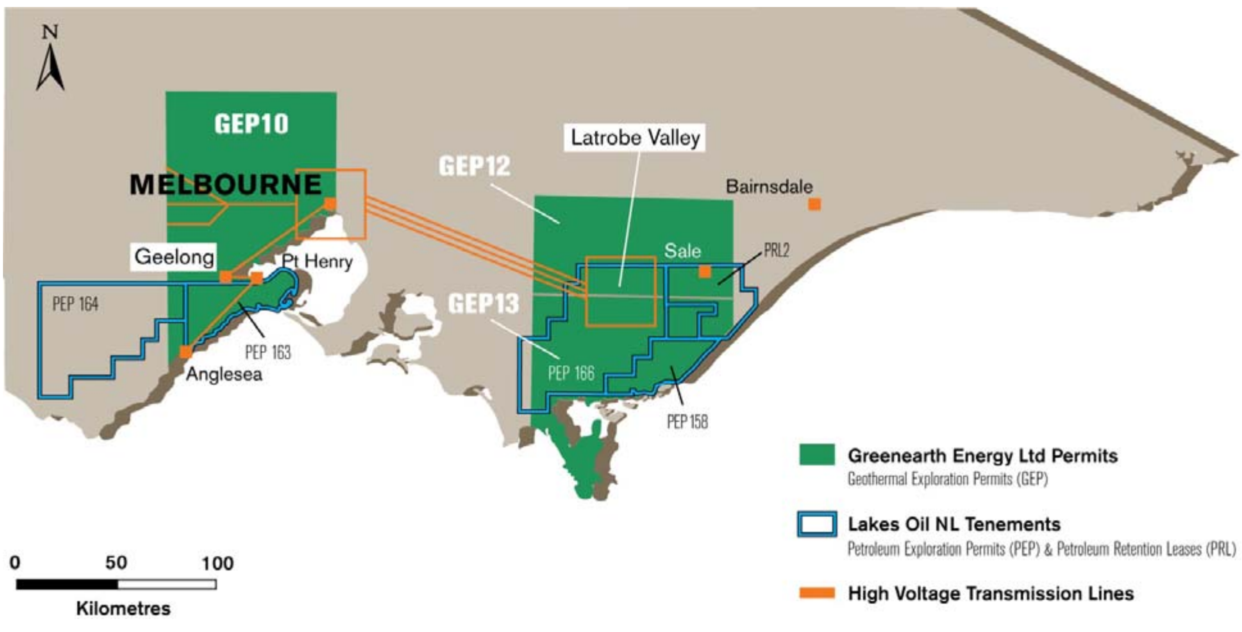

Figure 1: Greenearth Energy Ltd permits.

margin of Australia during Gondwana separation. To the west of Melbourne is the Otway Basin, stretching 500 km, while the Gippsland Basin is located to the southeast of Melbourne.

Both basins have undergone significant petroleum exploration with the offshore part of the Gippsland Basin being a major hydrocarbon province.

While the detailed stratigraphic nomenclature varies between the two basins, the overall sedimentary history is similar. Sedimentation commenced in the early Cretaceous with fluvial sediments (Pretty Hill/Rintouls Creek) deposited onto the rifting basement. This is overlain by thick non-marine volcanogenic sandstones and siltstones. These sediments are in turn unconformable overlain by a series of marine sediments spanning the late Cretaceous to mid Tertiary (Duddy, 2003; Holdgate and Gallagher, 2003).

The geothermal potential is associated with the initial sedimentary basin fill which offer permeability potential. Faulting is extensive in the basins with major faults bounding half grabens, originally normal and then subsequently reactivated as reverse faults. Faulting in or adjacent to any sandy basal units, in particular fracture zones, should provide access to broader reservoir areas (fig 2).

2.1 Latrobe Valley and Gippsland

In the Gippsland area the base of the sedimentary basin is in the range 3000-4000 m or deeper. The basal units (Rintouls Creek Sandstone and Tyers Conglomerate) have known porosity and offer a geothermal target where they are most deeply buried.

Heat flow investigations show that there is a trend of elevated heat flow through the Latrobe Valley area. Measurements on 10 wells returned estimates up to 101 +/- 26 mW/m^2 (Fig 3) (Walsh, 2009a). One of the most significant temperature projections is that at the Loy Yang-2 well, drilled in 2005 to 1443 m and re-entered in 2008 for precision temperature logging to 713m. From the original well composite log, measured and fair estimates of conductivity were applied to different layers. The resulting thermal conductivity profile yielded a heat flow of 90 mW/m^2

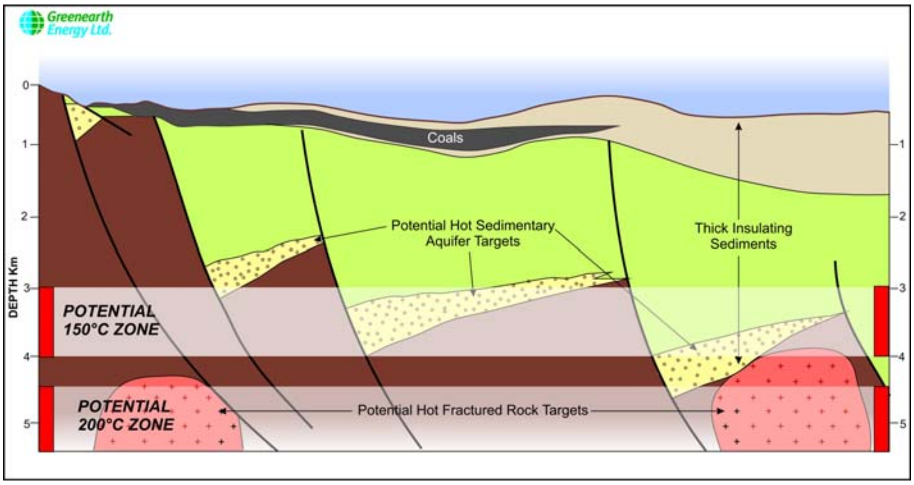

Figure 2: Schematic geological model for Hot Sedimentary Aquifers, Otway and Gippsland basins.

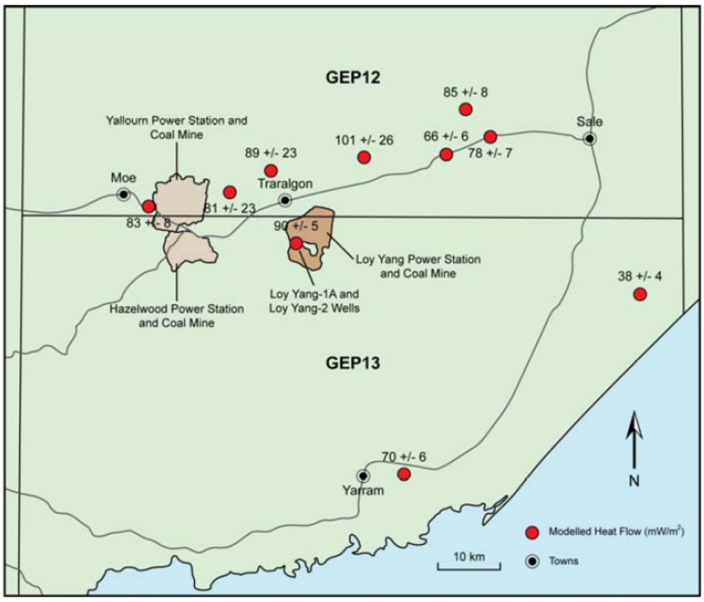

Figure 3: Summary of heat flow investigations. The Latrobe Valley area shows heat flows well above the global average.

Based on this information a heat flow model was used to predict the temperature beneath the well. Well log data from the adjacent Loy Yang-1 well was able to give the stratigraphy to a depth of 1735 m. and a scenario was modeled down to 3500 m. An estimated temperature of 150 ^{0} C was achieved at a projected depth of 2900m +/- 400m (Fig 4) (Walsh, 2009b, Greenearth Energy Ltd, 2009).

Any porous sandy sediment at that depth in the Latrobe Valley area provides an exploration target for hot sedimentary aquifer style geothermal resources. In the Latrobe Valley brown coal generation hub opportunities exist for both electricity generation as well as direct heat application for drying brown coal or pre-heating boiler feed water.

These same units also offer potential targets for investigation as sequestration reservoirs. The brown coal electricity generation in the Latrobe Valley area produces around 60 mtpa of CO_2. Any sandy units located at depths of 2.5 km, or deeper under the power generation area, provides the opportunity for their further investigation in terms of their ability to act as onshore CO_2 storage sites.

2.2 Geelong area

In the Geelong area the basal parts of the insulating sedimentary cover (Crayfish Group/ Pretty Hill Sandstone) reaches depths of 4000-5000 m (St John, 2007). Just to the west of the permit boundary the Pretty Hill Sandstone is 615 m thick.

This area has potential for both Hot Sedimentary Rock (HSA) geothermal plays in the shallower sand-prone beds of the early Cretaceous Crayfish Group as well as Hot Dry Rock (EGS/HDR) geothermal plays in the Palaeozoic basement.

Seismic mapping has identified the distribution of two possible sand-prone units in the early Cretaceous CrayFish Group. These two sequences are described as units F and E1 (Fig 5) and may constitute viable sedimentary aquifers Both units show characteristic syn-dypositional growth towards the major bounding faults with Unit F reaching a maximum thickness of about 600 m and Unit E1 reaching a maximum thickness of about 700 m (Cooper and Waining, 2008; Cooper, Waining and Pollington, 2008) (Fig 6).

Inferred Resource estimates have been made on three reservoir targets. The targets fall into two categories of geothermal reservoir-;

- buried sedimentary aquifers (Hot Sedimentary Aquifers –HSA) type plays, targeting sandstones units in the Crayfish Group (E1 and F reservoirs); and
- Engineered Geothermal System (EGS/HDR), targeting Palaeozoic basement.

The HSA targets were defined via sequence stratigraphic methods incorporating 2D seismic with local and regional well data from the Otway Basin. The EGS target has been defined by the seismic data and constitutes the basement beneath the insulative Otway Basin sediments.

A stored heat method was used to estimate a HSA inferred geothermal resource of 40,000 PJ and the EGS inferred resource of 220,000 PJ. The resource covers an area of 462 km^2 and is contained in 656 km^3 volume of rock. The resource estimate complies with the *Australian code for reporting exploration results geothermal resources and geothermal reserves (2008 edition).*

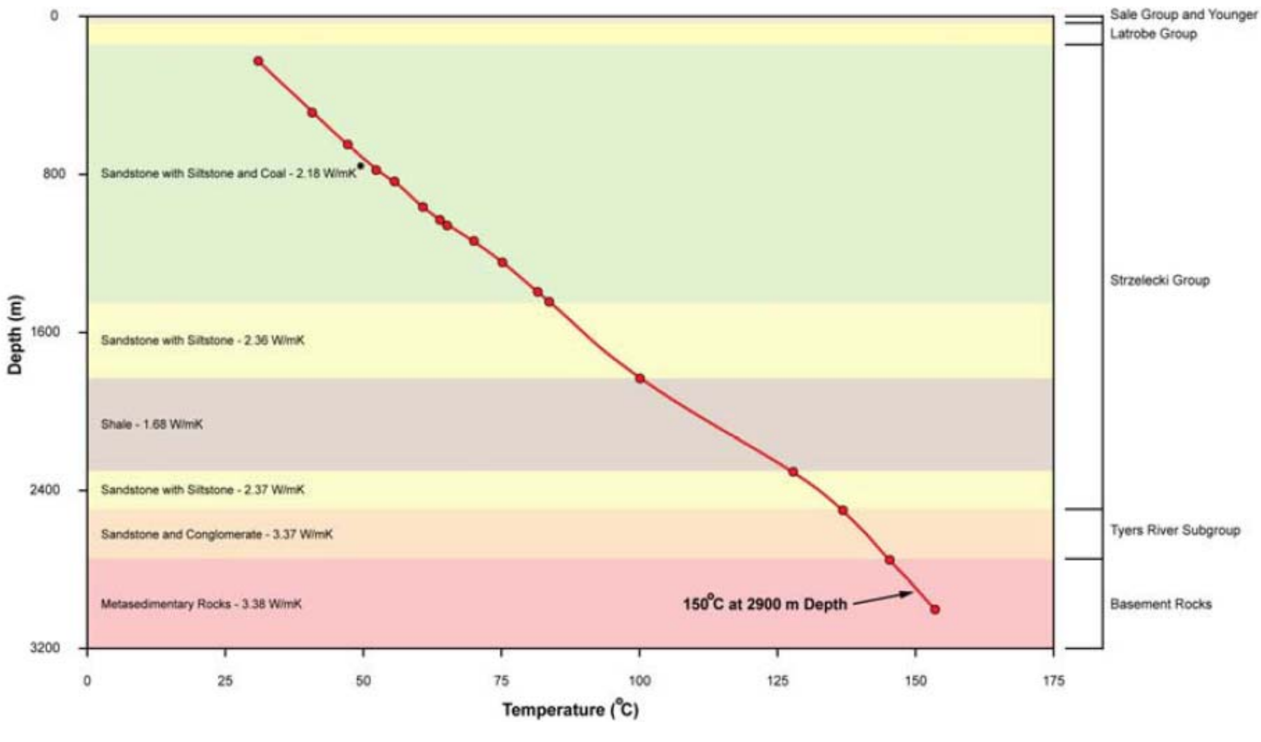

Figure 4: Modeled temperature of Loy Yang-2 Well

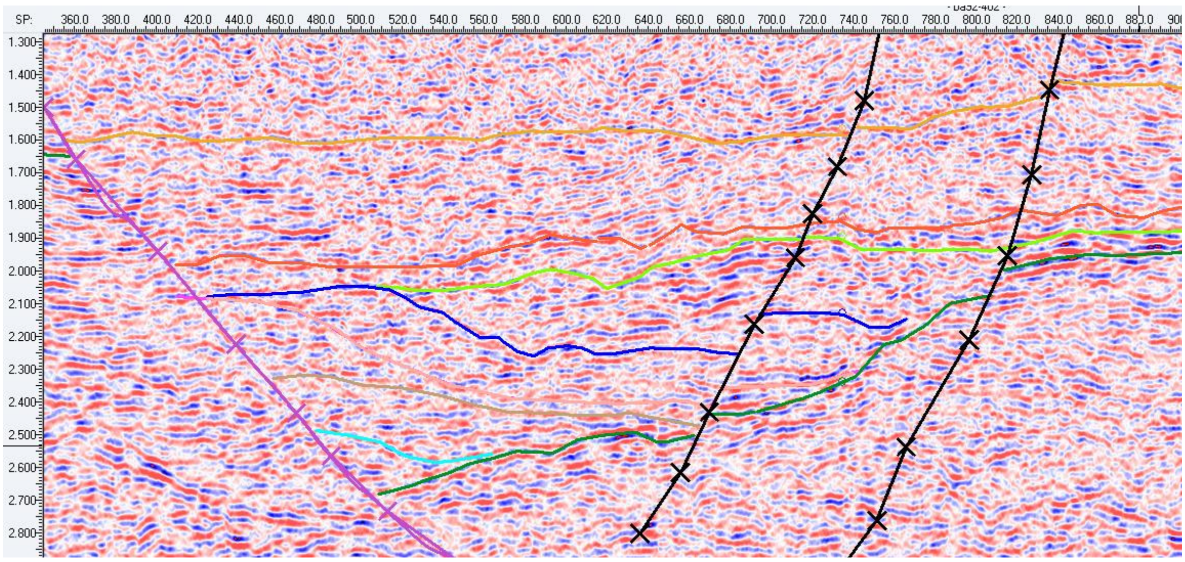

Figure 5: Seismic line OGF 92-402 showing distribution of possible sand prone units. Yellow – top E1, blue – top F, brown – base F, light blue – top Casterton A.

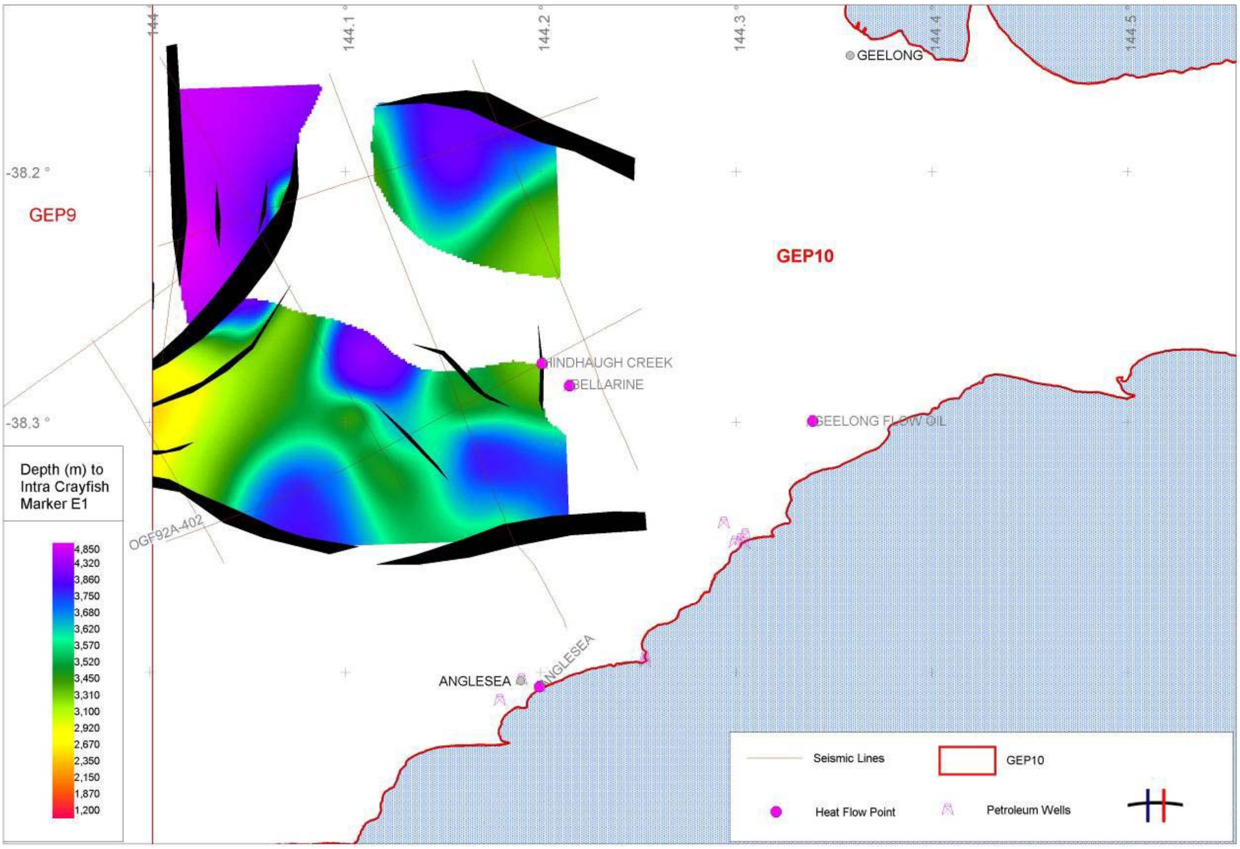

Figure 6: Depth map of the E1 marker, the top of the potential reservoir unit in the Crayfish Group. Distribution is controlled by early Cretaceous growth faults.

This work has led to the development of a HSA commercial model for geothermal based electricity generation southwest of Geelong.

This model assumes that a portion of the inferred HSA geothermal resource of 40,000PJ present in Geothermal Exploration Permit (GEP) 10 is available to utilize for power generation.

Well intersecting the Pretty Hill Sandstone in the wider Otway Basin show variable porosity and permeability. Based on the limited data available, it is feasible that the Pretty Hill Sandstone may have porosity in the range 10-15 % and average permeabilities of 50-150 mD at the target depth of 3450 m (Fig 7). It would be expected that the reservoir unit would need to have a thickness of > 100 m of permeable rock to achieve a permeability-thickness function (Darcy-metre) required for commercial flows.

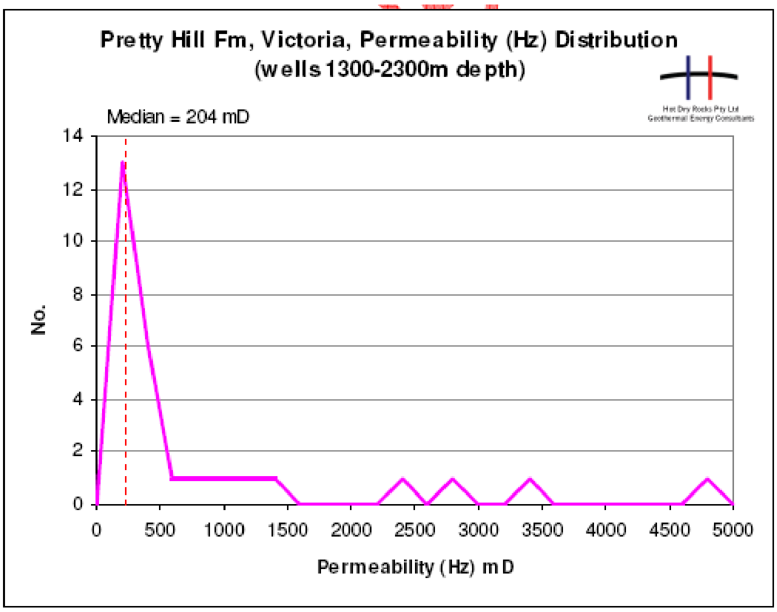

Figure 7: Frequency distribution of horizontal permeability from core samples for the Pretty Hill at Waracburunah-2, Hawkesdale-1, Garvoc-1, Pretty Hill-1, and Woolsthorpe-1. The distribution is strongly log-normal with a median value of 204 mD.

A 1D conductive heat flow model on data from the Bellarine-1 well and extrapolated to basement from seismic data illustrate that the geothermal working fluid (150 ^{o}C) is intersected at about 3040m with a heat flow of 90 +/- mW/m^2 (Fig 8).

A target geothermal resource temperature of 170 degrees centigrade at the modest target depth of 3,450 metres with an assumed flow rate of 100 litres per second, should yield sufficient heat flow to build an operating geothermal power plant.

There are several possible sites for a geothermal power plant in GEP 10 and a potential site was selected approximately 3 kilometres north-northeast of the old Wensleydale Coal Mine, 9.5 kilometres from the Anglesea–Point Henry electricity transmission line.

A commercial study modeled the costs and outcomes that may reasonably be expected for developing a 10.7 megawatt (MW) geothermal power plant. Similarly the study modeled an expansion to establish a 48 MW geothermal plant (Cooper, Waining and Pollington, 2008). Borrowing costs were amortized over the life of the projects (20 years). Costs were discounted as has the generation (MWhr) to calculate the levelised cost (LEC) of both scenarios.

The commercial model shows that over a 20 year life for the proposed geothermal power plant:

- The levelised cost of electricity (LOCE) would be in the range of $96-114 per MW hour.
- Generation of attractive pre-tax revenue and discounted cash flows for the project.

Result in a displacement of at least 1.2 million tonnes and up to 7.3 million tonnes of Carbon Dioxide “greenhouse gases” emitted by conventional power stations.

3. CONCLUSION

Greenarth Energy Ltd has geothermal exploration permits that underlie the industrial hub of southeastern Australia. The permits contain in excess of 6000 MW of brown coal fired electricity power generation with the Latrobe Valley power stations alone having a greenhouse gas footprint in excess of 60 mtpa.

The southern Victorian Cretaceous-Tertiary sedimentary basins that straddle the permits have substantial seismic and well data from previous petroleum exploration. Heat flows vary, however, in places values of up to 100 mW/m^2 were recorded. In the Geelong and Latrobe Valley area temperatures are estimated to reach 150 ^{o}C at around 3 km depth. The basal units of the sedimentary pile, where they occur in the 3-4 km depth range have potential to contain hot wet aquifer that may be suitable for power development using organic rankin cycle technology. The high moisture content of the brown coals used for electricity generation may present opportunities for direct heat application using geothermal fluids to dry coal. Given the high level of greenhouse gas emission in the permit areas, these same units are a target for further research as to their capacity to also act as reservoirs for Greenhouse gases.

In the Geelong area good seismic coverage has enable the calculation of n inferred geothermal resource. A site was selected for a conceptual geothermal development approximately 3 kilometres north-northeast of the old Wensleydale Coal Mine, 9.5 kilometres from the Anglesea–Point Henry electricity transmission line.

The costs and outcomes for conceptual 10.7 megawatt (MW) and a 48 MW.geothermal power plant were modeled.

The levelised cost of electricity (LOCE) would be in the range of AUS$96-114 per MW hour.

The plants would produce 1.65 and 7.41 GWh of renewable electricity.

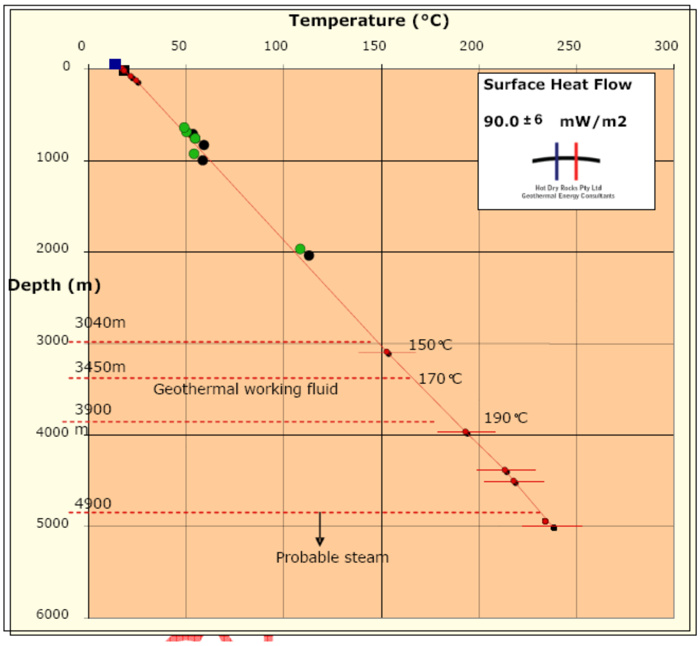

Figure 8: Sample conductive 1D heat flow model based on temperature data from Bellarine-1 and measured thermal conductivity data for all major lithologies in GEP 10. The model has been extrapolated on based on seismic depth grids.

ACKNOWLEDGEMENTS

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