Appendix 4 – Mondilibi Hill Geology, Geomorphology, Eruptive History & Potential for Bat Roost Cavities

MONDILIBI HILL - ERUPTION POINT

(DOWN AMPNEY PROPERTY)

VICTORIA

Geology, Geomorphology, Eruptive History

&

Potential for Bat Roost Cavities

Report prepared for: Hydro Tasmania

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1 INTRODUCTION

This report is in response to a request from Michael Hogan, Project Development Manager, Hydro Tasmania (e-mail 20 Feb 2019) regarding a geological/landform feature (referred to as Mondilibi Volcano by Rosengren 2014 pp. 56 -57) inside the boundary of the proposed Mount Fyans Wind Farm in western Victoria. The site is also referred to as Down Ampney property (Biosis 2017). The request follows submission of documents by other authors who concluded that it was unlikely that suitable roosting sites for Southern Bent-wing Bat occurred at the Mondilibi Volcano.

The request is to review aspects of the:

> *"...geomorphology of the Mondilibi eruption point and assesses whether eruption point landforms of this type are likely to contain cavities / lava tubes that are used as major roost sites by SBWB. This should be complemented by a description on the type of landforms / volcanoes that may contain suitable habitat."*

Prior commitments by this author delayed addressing the request. A bullet point summary was forwarded to Mr Hogan on 12 March 2019. . The present document extends the comments as a formal report. The document was updated in May 2019 to reflect the updated version of the Thomas 2018 report.

1.1 DISCLAIMER

I have not been able to inspect the site for the specific purpose of the present report. I have previous field experience at the site in the course of preparing the geoheritage assessment of areas of the proposed Hydro Tasmania Mount Fyans Wind Farm (Rosengren 2014). For that study, the Mondilibi volcano was visited on March 2 2013 to evaluate geoscience significance and consider potential impacts of the wind farm on those values. Previous visits to Mondilibi were in 1990 on another volcanic project and at least two other occasions between 1995 and 2003 in the course of La Trobe University field teaching.

Approximately 1. 5 hours was spent walking the eruption point and a further 2.5 hours of vehicle traverse of the lava flows surface to the south including the west bank of Salt Creek. The volcano and surrounding terrain was photographed from a light aircraft during a charter flight on March 3 2013.

2 GEOMORPHOLOGY

2.1 Mondilibi Hill

Mondilibi is a distinctive isolated hill 11 km north of Mortlake township on the eastern side of the deeply incised valley of Salt Creek. The summit elevation of ~198 m above sea-level is 40 m to 45 m higher than the surrounding undulating plain (Figure 1, Figure 2).

Figure 1. Mondilibi Hill vertical aerial photograph and form lines at 2 m interval. (Data supplied by Hydro Tasmania).

The hill is broadly conical in form with a broad slightly concave crest surface opening to the north-west with a rim defined by discontinuous low rock ridges and smooth convex higher southern slopes.

Figure 2. Mondilibi hill. 1 concave upper surface, 2 rock ridges, 3 high scoria rim, 4 northern rock ridge, 5 scoria quarry, 6 boulder pile cleared from rocky plain surface. (N. Rosengren March 2013).

The slopes are intact without drainage lines or major slumps or landslides. A prominent irregular rocky outcrop with an apron of fallen and toppled blocks forms the northern slopes (Figure 3).

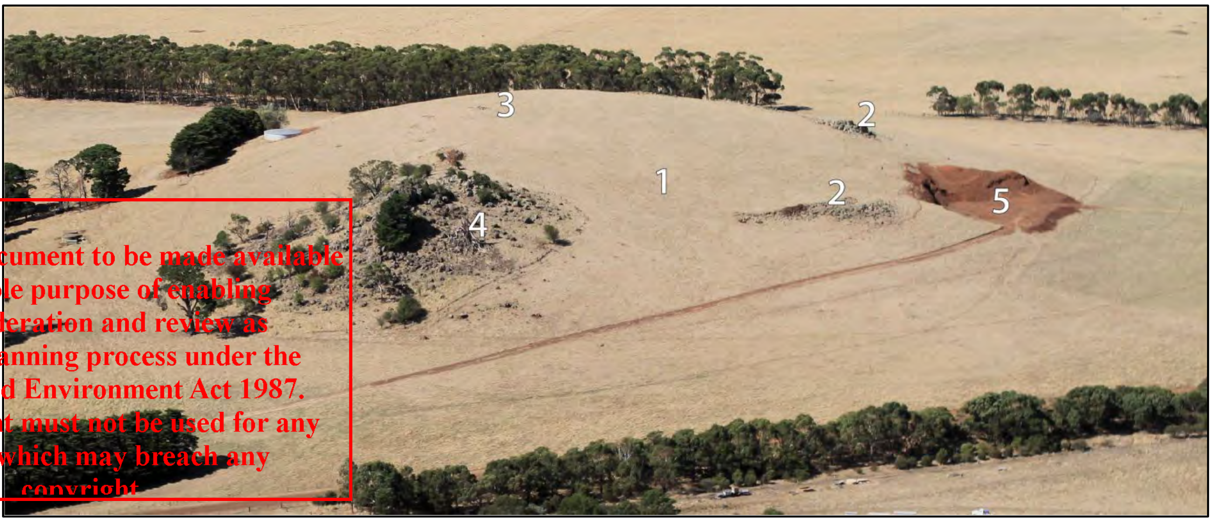

Figure 3. Mondilibi hill. 1: concave upper surface, 2: rock ridges, 3: high scoria rim, 4: northern rock ridge, 5: scoria quarry. (Aerial oblique photograph Neville Rosengren March 2013).

3 GEOLOGY

3.1 Context

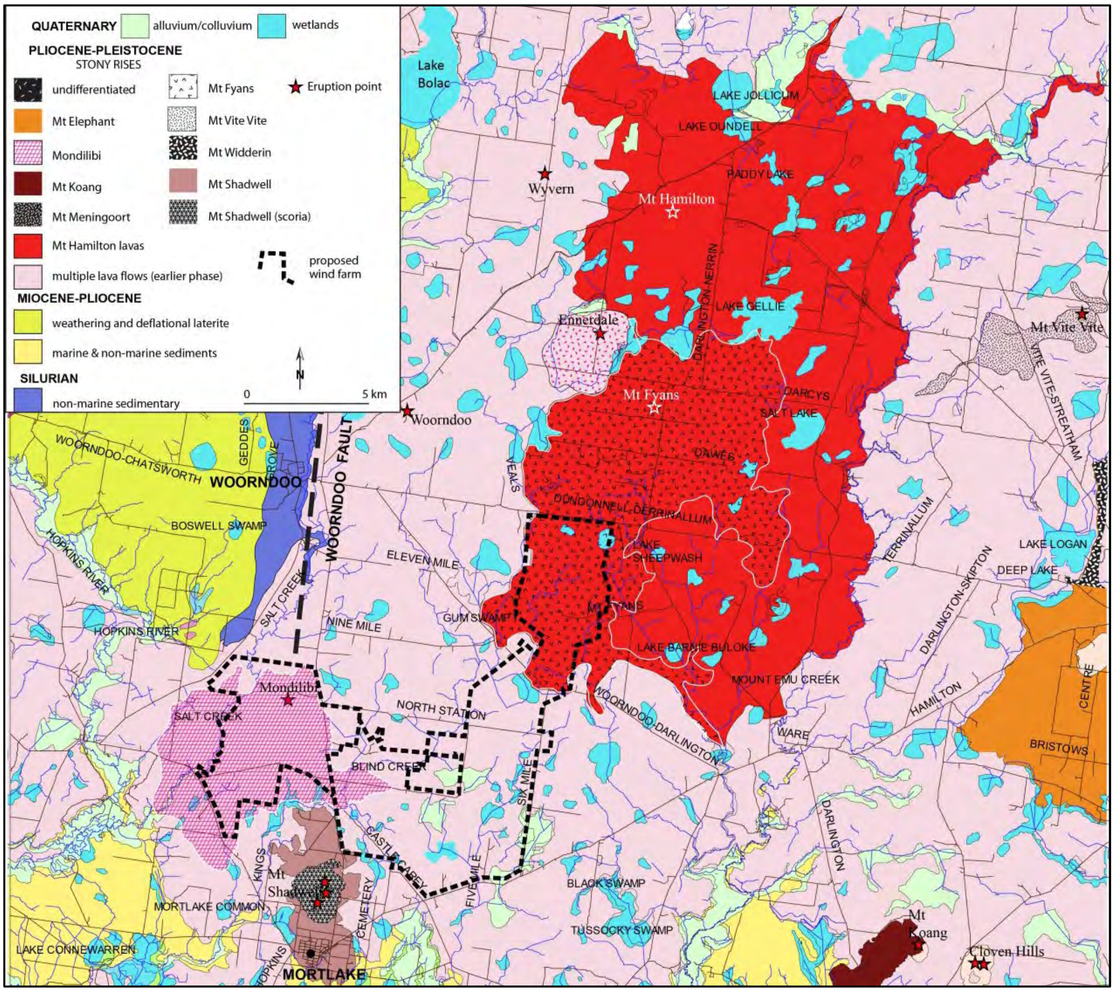

Figure 4. Geology of proposed Mt Fyans Wind Farm including Mondilibi eruption point and lava flows (From Rosengren 2014).

Mondilibi hill is an eruption point in the Newer Volcanic Province (NVP) of Victoria (Rosengren 1993) and one of several volcanoes between Mortlake and Lake Bolac that produced extensive lava flows across a gently undulating surface. The nature and preservation of volcanic features at Mondilibi indicates an eruption around ±1 million years ago. This is much older than the very clearly expressed volcanic features from the youngest eruptions of the NVP around 30,000 years ago at Mount Napier and Budj Bim (Mount Eccles).

3.2 Mondilibi Eruption Point

Mondilibi hill is a composite volcano with at least four stages of eruptive activity evident at the eruption point and in the surrounding plains.

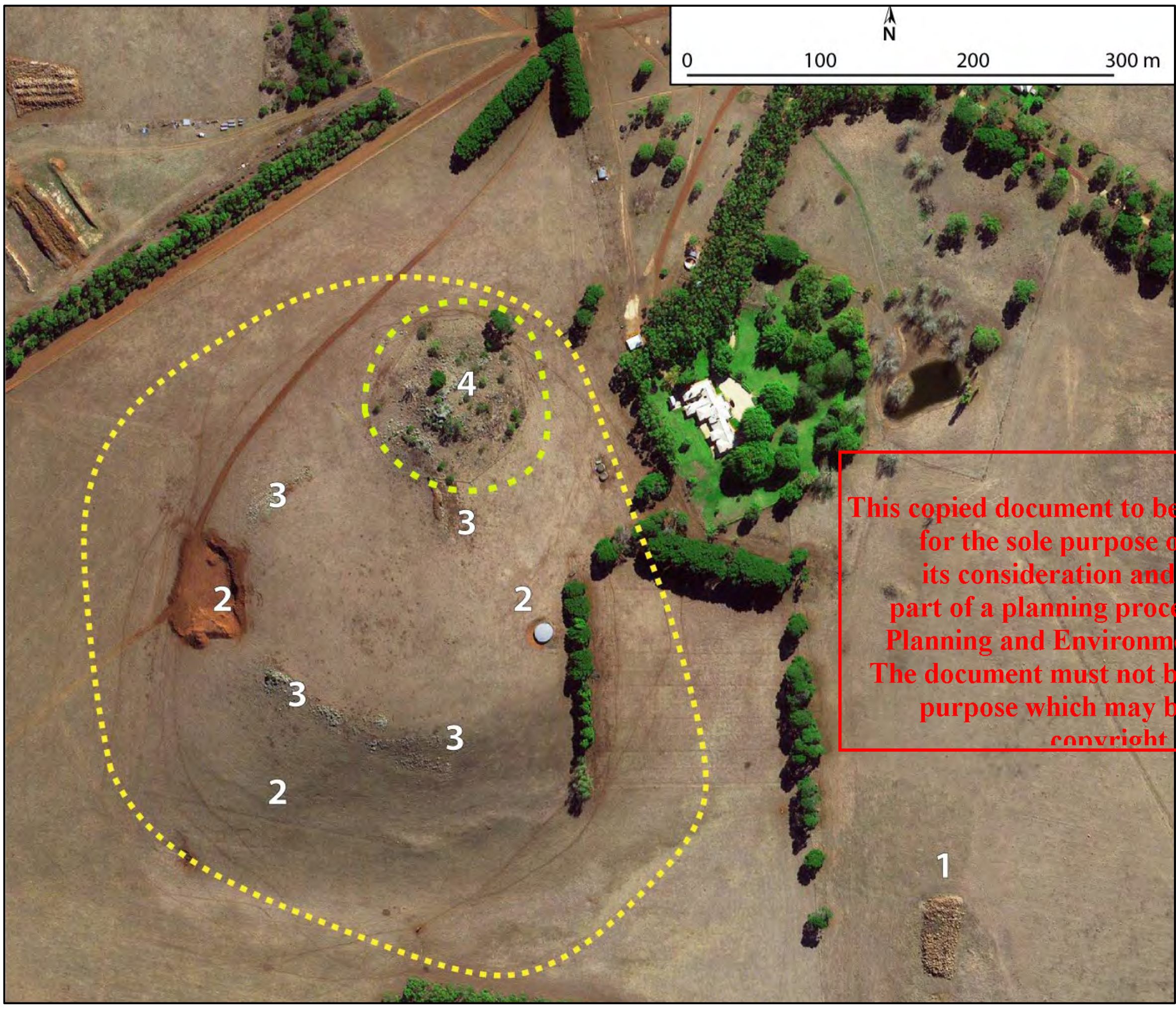

Figure 5. Eruption stages of Mondilibi interpreted from morphology and geology of the volcano. 1: initial lava flows, 2: scoria accumulations, 3: lava disc / dyke, 4: lava squeeze-up / plug

3.2.1 Fluid Lava Phase

The initial eruptions at Mondilibi were relatively gas-poor and low viscosity resulting in coherent lava flows spreading across low-angle slopes and covering the surrounding terrain (1 on Figure 5). Existing drainage lines such as Salt Creek were filled or diverted and a new post-volcanic drainage pattern has developed with deep steep-sided valleys incised into the lava surface. The Mondilibi lavas have a high magnetic signature allowing their distribution to be mapped and distinguished from flows from Mount Hamilton and Mount yans as well as much older and deeply weathered basalts from other sources. The Willaura 1:100,000 geological map shows lava extending 1.1 km north and 5.2 km southwest (limits of mapsheet) from Mondilibi. No detailed mapping of lava flow boundaries at an appropriate scale is available for the areas further south of the volcano and the distribution on Figure 4 has been derived from aerial photo interpretation and magnetic imagery.

No *in situ* lava is exposed around the base or in the immediate vicinity of the hill. Adjacent paddocks have some outcrop but large areas are now cleared of loose stone—evidenced by the numerous accumulated piles (6 on Figure 1).

The later stages of Mondilibi eruption rest on the initial lavas and there is no clear physical surface expression of the connection between them.

3.2.2 Pyroclastic (Scoria) Phase

The main body of Mondilibi is a scoria cone/mound (the common usage in Victoria for pyroclastic-dominant eruption points (2 on Figure 5). This was produced by pyroclastic (fragmental) lava in the form of highly vesicular scoria and some irregular blocky lava bombs produced during a limited "fire-fountaining" eruption of gas-rich lava. The scoria is comprised of blocky to smooth or ropy-surfaced fragments ranging from sand-size to blocks of spatter 10's of cm long showing surface dribbling of fluid lava. The scoria had limited vertical trajectory but cooled sufficiently while air-borne to prevent or limit welding of discrete fragments into a continuous coherent mass. The range of sizes allowed slopes of moderate angle (<15^0) to become stabilised and compacted and resist mass movement sliding or slumping. The continuous nature of the scoria body but the relatively low cohesion is illustrated by the exposures in the quarry showing easy disaggregation of the scoria body (Figure 6).

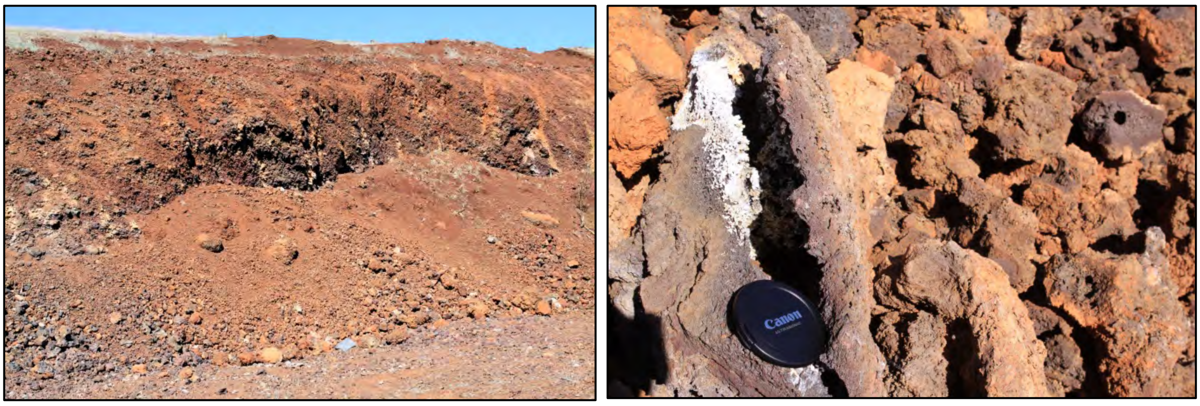

Figure 6. Consolidated/compacted scoria and detail of scoria blocks in quarry at Mondilibi (Neville Rosengren March 2013).

The scoria accumulated in an uneven distribution determined by the angle of the vent and height of trajectory, producing an asymmetrical mound without a central crater which was filled by the last stages of subdued fire-fountaining.

3.2.3 Lava Intrusive Phases

The last eruptive episodes of Mondilibi were intrusions of at least two small bodies of coherent viscous lava into the existing scoria mound (a) a lava disc and (b) a lava plug or squeeze-up. There is no evidence these produced lava flows down the hill slopes.

3.2.3.1 Lava Disc

After the final scoria eruptions a tabular or platy lava body intruded into the scoria piles as a roughly circular disc now outcropping discontinuously around the upper edges of the scoria hill (3 on Figure 5), (Figure 7). The lava is massive with few small (mm - cm) vesicles (gas vents) and irregular fractures resulting in loose and some separated blocks. A small opening into a constricted chamber (too small to be entered) was recorded by Biosis (2017, 2018).

Figure 7. Lava outcrop on western edge of Mondilibi hill.

3.2.3.2 Lava plug

The northern edge of the summit surface is an irregular outcrop of strongly fractured lava blocks in a roughly circular form with some upright irregular columns surrounded by fallen and toppled blocks (4 on Figure 5). This basalt body is interpreted to be a low-gas highly viscous intrusive plug developed during the last stages of eruption and post-dating the circular lava disc described above. It has greater relief (3 m to 5 m) than any other lava surface on Mondilibi. Weathering has enlarged the joints resulting in low overhangs and open narrow vertical to steeply-dipping clefts. These have little internal enclosed or semi-enclosed space and extend only short distances (< 1 m) into the rock mass. The absence of scoria lying across this outcropping basalt indicates the fragmental eruption phase had concluded before the advent of the coherent lava intrusions. There is no evidence of lava extending down the flanks and away from the area of this intrusion.

4 POTENTIAL FOR CAVITIES AT MONDILIBI AND ASSOCIATED LAVAS

4.1 Eruption Point

4.1.1 Scoria Mound

Scoria accumulates from air-fall of fire-fountaining lava as disaggregated blocks of varied size as a result of rapid degassing of magma from a subaerial (open air) vent. Cavities-depressions develop on separated blocks during flight and may be sealed as the surface cools or becomes welded to other blocks or remain open on landing (Figure 6 page 5 above). Fallen blocks are continuously buried by the collapsing lava column and also by slope failure on cooling and consolidation of the scoria pile. Cavities formed in this way may be accessible from the outside but only during the early post-eruption period before settling, compaction and weathering of the scoria mass. The disaggregated nature of scoria reduces the opportunity for post-eruptive cavities to be developed or retained as the mass of the rock is likely to collapse and fill any depression (however formed). In the absence of a crater and after hundreds of thousands of years of weathering and regolith/soil development at Mondilibi, the potential for large (multi-metre) cavities in the scoria body persisting is low and for these to have an open external connection is negligible.

Large i.e. multi metre cavity lengths—either of primary or secondary (post-eruptive) origin to host roosting bats are therefore highly unlikely in the scoria of Mondilibi.

4.1.2 Lava Disc and Plug

Detailed inspection for the specific purpose of identifying potential roosting sites on the coherent lava bodies on the upper slopes of Mondilibi has been conducted by highly experienced professionals in earth and biological science (Thomas 2018). The geologist in the group—the late Ken Grimes—had outstanding credentials in volcanology, geomorphology and speleology to assess the potential for site to contain potential bat roosting sites. In my experience in the field with Mr Grimes and familiarity with his peer-reviewed publications, I have no hesitation in accepting the conclusion of Thomas (2018, page 4):

" ……the structural features of the Mondibili cone:

1. did not provide any fissures or joints in basalt that indicated current or historical use as a major SBWB roost, and;
2. did not provide any cavities or openings considered suitable habitat for a major SBWB roost site."

4.2 Lava Flows

Thomas (2018) was not required to assess the potential for suitable cavities for SBWB roost sites in the lava flows associated with Mondilibi. As an adjunct to the assessment of the Mondilibi hill, this report considers such potential. The assessment is based on: (a) several hours of field work on parts of this lava surface west of Mondilibi on March 2 2013, (b) study of high resolution vertical aerial photograph provided by Tas Hydro, (c) comparison of adjacent lava surfaces from other eruption points in this part of western Victoria.

The Mondilibi lavas are classified as "blocky vesicular basalt flows" by Stuart-Smith and Black (1999). They have similar composition to the nearby flows from Mount Hamilton and Mount Fyans but lack the distinctive stony rise topography of the Mount Fyans flows where hummocks, depressions, ridges and channels with a relief of several metres is well-preserved. The subdued terrain around Mondilibi may be due in part to extensive stone clearing and cultivation but also indicates these are older flows than Mt Fyans and Mt Hamilton.

4.2.1 Cavities on Lava Flows

Caves occurring inside lava flows are a special class of non-solution caves. The development of cavities/caves/tubes of sufficient dimension on lava flows is determined by the initial characteristics of the lava and the flow history. Caves of dimensions ranging from metres to kilometres length and 1 m to >15 m diameter and height are recorded in lavas in Victoria and Queensland. They are an important mechanism in producing lava flows that extend for tens of kilometres and are a feature of long-lived (millennia) eruptions of high-temperature fluid lavas. There are several mechanisms of formation (as observed on active Hawaiian lava flows). The most common are, (a) gradual roofing-over of a lava stream by spatter accumulating along the edges and forming a bridge between the edges of the flow, (b) cooling of the lava surface forming a ridged crust allowing lava to move down-flow leaving an elongate cavity. In both mechanisms, the cave is preserved as lava drains at the end of the flow and the internal lava residue shrinks. The cavities are not accessible (from the outside) until there is collapse of part of the crust creating an entrance.

Over 50 lava caves have been found in the NVP of Victoria in lavas of varied age, location and origin (Webb *et al.* 1993). Lava caves with access and extensive explored passages in Victoria are in lavas from Mount Hamilton, Mount Widderin (Skipton), Mount

Napier, Budj Bim (Mt Eccles) and Mount Porndon. Small lava caves (one usually water-filled) are known on the northern part of the Mount Rouse - Port Fairy flow and at Mount Fyans. In the latter case the cave was revealed by quarrying (Grimes 2006). Not all of these have evidence of modern use by bats. There is more likelihood that caverns with surface opening occur under the stony rise topography of the Mount Fyans lava flows than under the Mondilibi flow. Stream discharge from depressions on part of the Mount Fyans lava flow north of Mount Fyans Lane at Dundonnell indicates a possibly extensive water-filled cavity system.

Unless revealed by excavation or determined by geophysics e.g. ground penetrating radar or drilling, the presence of a cave will not be evident in the landscape until part of the roof collapses. Caves are formed at the time of eruption and they may occur in basalt lava flows of any age. Large caves occur in the youngest lavas of Mt Napier and Budj Bim (~30,000 - 40,000 years) and Mt Porndon (~55,000 years) but cave systems occur in older lavas—300,000 years for Mount Rouse-Port Fairy lava flow (Matchan and Phillips 2011) and ±2.5 million years for lavas containing the cave near Bacchus Marsh. The most extensive caves known in Victoria are in the Mount Hamilton lava with 3 entrances and 1200 metres of branching passages. Although not dated, based on the weathering and regolith development the Mount Hamilton lavas are older than the 300,000 years determined for Mt Rouse lavas.

4.3 Potential for Cavities in Mondilibi Lava Flows

Given the condition for cave development outlined in sections 4.2 above, the possibility that caverns exist in the lavas surrounding Mondilibi cannot be discounted until a subsurface inventory was conducted. However, in the context of this study, the caves are only relevant if there is a surface opening for bats to enter. While this can only be determined by detailed on-ground inspection or high resolution LiDAR sensing, it is reasonable to us proxy indicators such as visible springs and outflow, or seepage and wet ground shown by vegetation. On the Mount Rouse lavas, numerous and such indicators have been inspected and none revealed a cave entrance (Rosengren 2012). Interrogation of property owners /managers is a reasonably reliable source of information regarding presence of caves with entrances but (to my knowledge) has not been conducted for the Mondilibi lava flows.

The lava surfaces surrounding Mondilibi are deeply weathered and the surface is gently undulating to almost flat and slopes very gently south with no protruding lava mounds or tumuli. A narrow ridge extending south west has had stones/blocks harvested and stockpiled. There are broad shallow depressions that are in varying degrees of natural preservation but none has the appearance of the proxy indicators inspected on other lava flows. Most of the lava surface has a history of cultivation that would be expected to reveal any cavern entrances.

The deeply incised gorge of Salt Creek has extensive rock exposure along both sides of the valley for several km. If there are cavern entrances, this would be a target area for close inspection.

5 CONCLUSION

- The scoria accumulation and the thin, contained intrusive late-stage lava bodies that form Mondilibi hill are not conducive to the development of non-solution cavities i,e, lava caves as outlined in section 4.2 (pages 8 - 9 above).
- If cavities occur beneath the Mondilibi lava field, the likelihood that entrances occur is regarded as very low (see next two bullet points).
- There is no evidence on aerial photography or other imagery of cave entrances (see 4.3 page 9 above).
- There is no evidence in the imagery of land use e.g. exclusion fencing that suggests landholders/managers or others—are aware of cave openings.
- A sector of better-preserved stony terrain on the Mondilibi flows that may warrant field inspection is the stony ridge commencing ~1 km south of the hill and extending 600 metres south
- The gorge walls of Salt Creek are a possible site where cave entrances are displayed.
- Across the entire wind farm site, the area with a higher likelihood of cavities with surface access is the Mt Fyans lava flow 12 km north-east of Mondilibi, where these is evidence of a system of underground water conduits.

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APPENDIX 1

NEVILLE ROSENGREN RELEVANT QUALIFICATIONS AND EXPERIENCE

Director: Environmental GeoSurveys Pty Ltd
Honorary Associate: La Trobe University,Australia

QUALIFICATIONS:

Undergraduate: B. Comm. Dip Ed. (Melb.); Dip. Applied Geology (RMIT)
Postgraduate (M. A. Hons.) (Melb.) Thesis topic: Geomorphology of coastal dunes, East Gippsland). Ph.D. Research Thesis topic [in progress]: Coastal change in a volcanic and tectonic environments – Indonesia and New Zealand.

I am a specialist in landform studies involving assessment of landscape evolution, rates and processes of landform and selection of geoscience sites in a variety of environments. I am familiar with the geology and geomorphology of volcanic terrains in Victoria and elsewhere (active and ancient) and have undertaken a detailed inventory of eruption points in Victoria. I have prepared detailed field-based inventories of geoscience sites on volcanic terrains for several wind farm proponents in areas similar to the Mondilibi lavas.

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