Figure 3.8 Fissure type cave bes ide Bernard Rd South

3.4.4 Case Study 4 – Mining lease land

The block of land adjacent to Emerald Estate is currently controlled by a mining lease. Numerous small caves occur on this land and most are partially concealed due to a covering of grass (Figure 3.9).

Figure 3.9 Typical exposure of a discreet caves

This block of land is highly vegetated and contains caves with numerous openings. Figure 3.10 shows one of the eight entrances to Tuarts cave. These vertical openings are fissure type and are up to 5m in depth. As this land is adjacent to Emerald Estate, it may be hazardous if members of the community explore the land as no signs or barriers exist around caves.

Figure 3.10 One of the eight entrances to Tuarts Cave

3.5 GROUND SUBSIDENCE

When groundwater levels are high, the karst weathering process occurs at the base of caves - where limestone and groundwater interact. When calcium carbonate goes into solution, gradual subsidence occurs.

3.5.1 Case Study 1 – Cabaret Cave

The pillars at the entrance of Cabaret Cave exemplify gradual subsidence within this cave system. These pillars, made of limestone blocks, were human made and were joined to the base and roof of the cave. Over time, gradual subsidence has led to gaps forming between the roof of the cave and the top of the pillars (Figure 3.11).

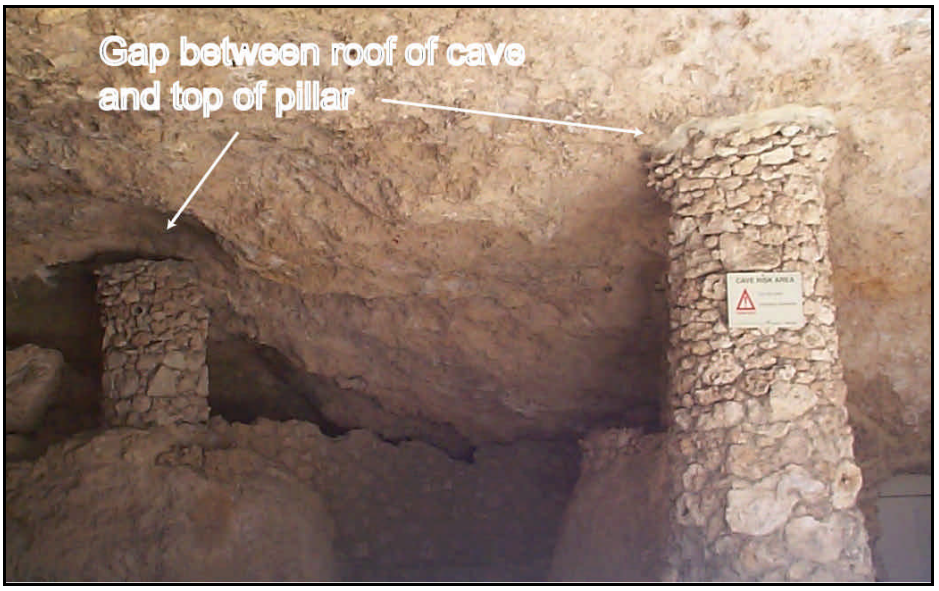

Figure 3.11 Pillars at Cabaret Cave. The left pillar has a gap between the roof of the cave and the top of the pillar. The pillar on the right does not have a gap as it has been filled in.

3.5.2 Case Study 2 - Rural land use

There are many hobby farms within Wanneroo and land use plays an important role in karst hazard prevention. Vegetated land holds soil together as well as increases soil structure. When the ground is bare, there is nothing holding the soil together and with increased rain or floods (natural or human made), the soil has a greater potential to be washed down a pre-existing cavity. This could lead to holes forming in the ground, similar to those described in Section 3.2. During parts of the year, the soil within the hobby farms is bare (Figure 3.12).

Figure 3.12 Un-vegetated land between plantings in hobby farms within Wanneroo

The holes that formed on the rural properties in Section 3.2 occurred due to an increase in water, concentrating on a small area of land. These case studies demonstrate that water should not be concentrated to one spot on karstic land. Figure 3.13 shows an inefficient sprinkler system off Bernard Rd South. The green grass shows that water is concentrated in these areas. With increased watering, subsidence may occur. However, this can only happen if is a pre-existing cavity is below.

Figure 3.13 Inefficient sprinkler system concentrating water within a small zone

Ground subsidence can cause structural damage to roads and houses. The tilting of fence posts as well as cracks along mortar joints and in pavements are indicators for ground subsidence (Figure 3.14).

Figure 3.14 Schematic diagram representing cracks in masonry and tilting fences due to ground subsidence.

3.6 INFRASTRUCTURE OVER KARST FEATURES

3.6.1 Building on pinnacles

The limestone within the Wanneroo area contains an abundance of pinnacles. When developing infrastructure it is important that these pinnacles are identified. With increased rain or erosion, the soil between the pinnacles can be removed causing a cavity. Figure 3.15 depicts how pinnacles are situated in the ground. The lines down the cutting are solution flutes which provide a method for transporting water and soil. Building over pinnacled ground, can cause structural damage from subsidence.

Figure 3.15 Most pinnacles in Wanneroo and below ground level. This photo depicts how pinnacle are situated in the ground with solution flutes running down the cutting.

3.6.2 Houses over caves

Within Emerald Estate, a house was built over a fissure type cave (Bastion, 2003). Although the surface of the cave was filled in, movement down the fissure may occur. If the caves structural integrity is reduced then structural damage to the house will possibly occur, similar to Figure 3.13. However, more damage may occur if the cave collapses as the structural foundations to the house will be removed.

3.6.3 Roads over caves

Caves represent zones of potential structural failure. Bastian (2003), revealed that the main road that runs through Emerald Estate passes over at least two caves. Both cave entrances have been covered up in the construction of the road. This is a hazard as monitoring the cave's stability cannot occur and structural failure cannot be predicted. The proposed road alignment of Alkimos Drive potentially covers approximately 5 caves (Bastian, 2003).

Figure 3.16 is a photo of a road collapse in Two Rocks. This site is on Holocene Limestone which is a lot more friable that the Pleistocene limestone within the karst belt. Nevertheless, it depicts the hazards associated with road collapse and potential social, economic and environmental disruption.

Figure 3.16 Road collapse in Holocene limestone at Two Rocks