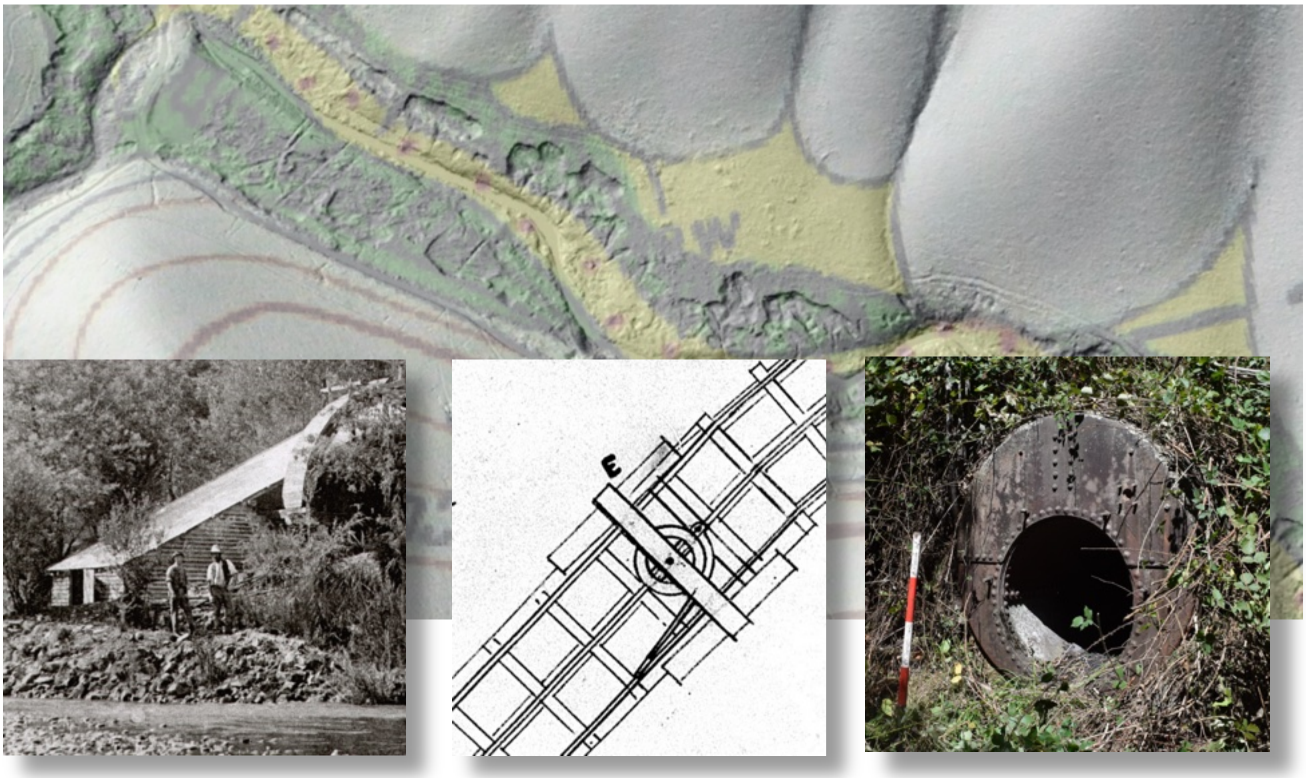
Buckland Valley State Forest LiDAR Project

A case study for the interpretation of a historic gold mining landscape



A report prepared for Heritage Victoria

September 2023.

Acknowledgement
We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honor Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

6th September 2023

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1. Introduction

The mountainous regions of Victoria's State Forests contain many historic archaeological sites. The types of places vary greatly and can include sites related to exploration and surveying, mining, timber and forestry, townships and settlements, agricultural and early recreational sites. Many of these places can lie beneath a thick cover of vegetation, largely hidden to traditional survey methods.

Light Detection and Ranging technology, or LiDAR, is now becoming a widely accepted tool in the remote sensing of historic archaeological sites. This spatially referenced, three-dimensional data is more regularly used for the identification and management of historic sites and landscapes.

The Buckland Valley State Forest, in Victoria's north east, contains a largely hidden historic goldfields landscape; a landscape that has not been seen in modern times. LiDAR is now revealing this important part of Victoria's heritage for the first time.

The goldfield's landscape of the Buckland Valley is located in steep and rugged mountain ranges, hidden beneath thick and at times impenetrable vegetation.

1.1. LiDAR

LIDAR is a remote sensing technology that uses light pulses or laser to measure distances between the earth from an aircraft. The light pulses scan a specific area, penetrating through vegetation and ground cover as points. The LiDAR derived topographic data forming a detailed ground surface model that is geo-referenced for spatial accuracy.

Once collected, the raw data is processed, digitally removing the upper vegetation layers (digital de-forestation) and defining the spatial characteristics of the ground below. With the vegetation layers removed, the shape and detail of the usually hidden ground surface is revealed. Forming an accurate three-dimensional surface model and revealing the historic archaeological landscape.

The remote sensing data of LiDAR instantly exposes what would have otherwise taken decades by more conventional on-ground surveying techniques. More readily allowing a detailed analysis of individual sites as well as broader historic landscape.

1.2. Purpose and Objectives

The purpose of this project was to examine the practicalities of using LiDAR data to interpret and analyse historic archaeological sites in forested mountainous regions of Victoria. The Buckland Valley historic mining landscape was used as a case study to analyse this data in conjunction with the historical record and field surveys on a range of mining site types, to positively identify, interpret and spatially reference case study sites, and verify remote sensing data with on-ground features. The project aims to provide a practical guide for the interpretation of historic mining features using LiDAR imagery. This in turn, can assist land managers, statutory authorities, field staff, archaeologist and cultural heritage specialists with adequate and accurate methods to be able to make informed decisions about the management these places.

1.3. Extent of Project Area

The survey area covers a significant portion of the historic Buckland Valley Goldfield, situated within the Buckland Valley State Forest. The survey area covered approximately 193 km^2.

The survey area does not represent the entire historic goldfield. Both historic alluvial and quartz reef workings and associated features lay outside the study area. The northern section of the Buckland River, all the way to its junction with the Ovens River at Porepunkah, was worked for gold. Numerous workings occur in this area, on both freehold, and crown land reserves. Other isolated quartz reef and alluvial mining areas lie to the east in the extensive catchment of Devil's Creek, and in the headwaters of Clear Creek.

The area selected was chosen for its range and concentration of historic features situated largely within the Buckland Valley State Forest reserve.

Airborne LiDAR technology was used to map topography and detect historic cultural features hidden beneath the forest canopy and understory vegetation. Providing a detailed aerial overview of much of the Buckland Valley goldfield landscape and its historic and archaeological sites and the surrounding landscape. The LiDAR survey was undertaken in January 2021. LiDAR imagery was taken at a high resolution of 24 points per square metre.

Figure 1.1: Locality Plan, Buckland Valley State Forest, North East Victoria.

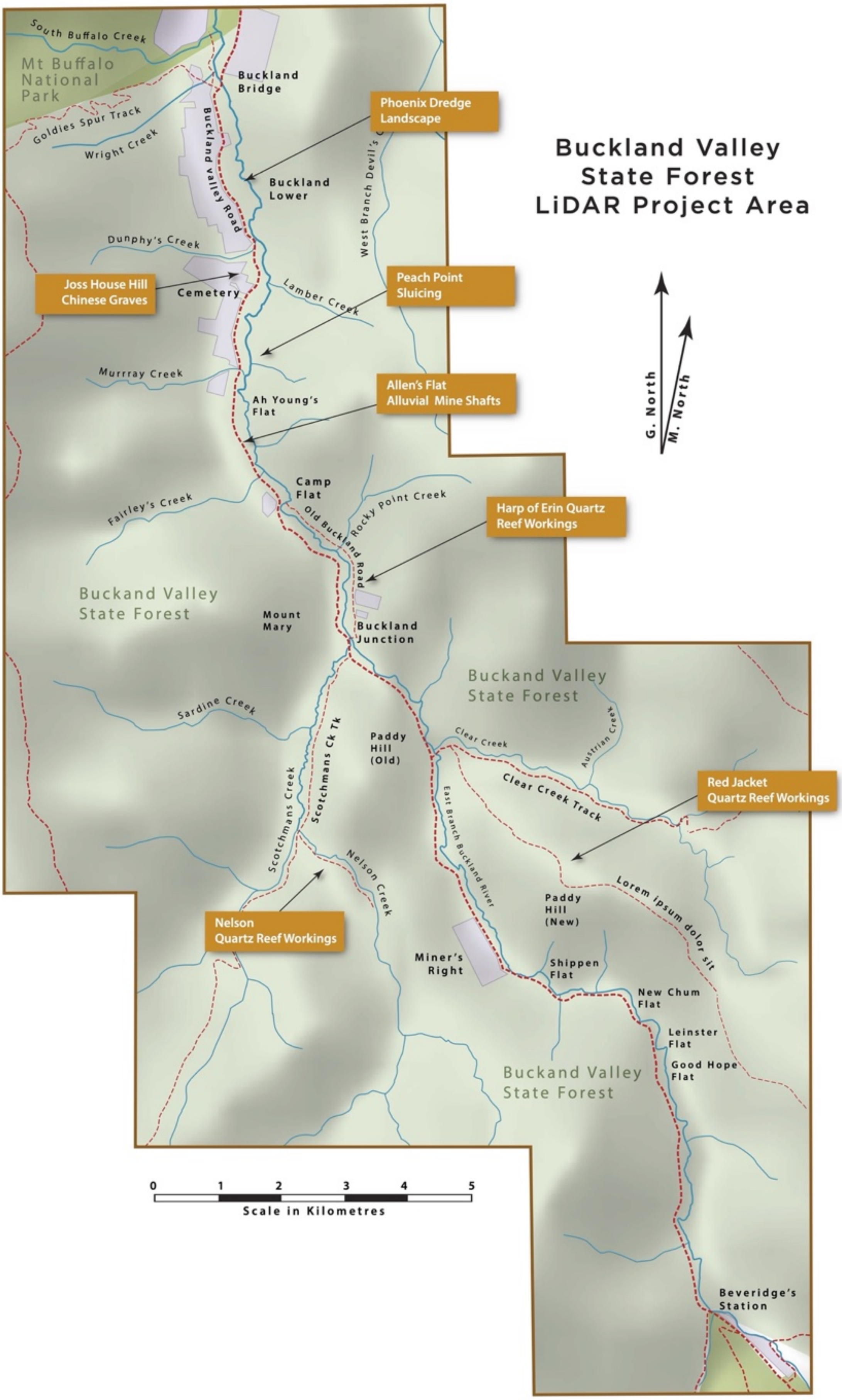


Figure 1.2: Extent of LiDAR survey area. Case Study sites shown in orange text boxes.

1.4. Methodology

This report was initiated with the understanding that the Buckland Valley State Forest contains a range of historic gold mining sites. A representative range of sites were selected and site cards prepared to 'ground-truth' LIDAR imagery with field survey. This field work was supported with a background study of the historic record for each site. This research included examining, contemporary historic records including: periodicals, government publications, newspaper reports, mining plans and maps. This built a reasonable understanding of the historic activity that occurred at each of the sites. Sites were then visited, using LiDAR imagery to determine extents of sites and interpret features within these areas.

1.5. Initial Analysis Findings

The Buckland Valley contains a range of features relating to the goldfield's history of the locality. The geospatial data of LiDAR clearly reflects the historic record, providing a detailed overview of the surface features of the Buckland goldfield landscape for the first time. The range of features and archaeological sites forming the goldfields' landscape include:

- **Alluvial Sluice Mining**; Surfacing, shallow bank and ground sluicing, low and high-pressure hydraulic sluicing, cobble and tailings landscapes, and exploratory and extractive mine shafts and tunnels. Associated occupation sites, including short and longer-term sites.

- **Bucket Dredging:** Tailings landscapes, heaps and corridors. Construction, repair and dismantling sites and associated remnant machinery components. Weir or levee wall infrastructure. Flying-fox and cable anchor locations. Ancillary water race and wood-fuel networks.

- **Quartz reef mining sites**: Includes surface costean prospects and extractive stopes and quarries, and adits. A range of stamp battery sites and remnant machinery. Associated sleigh, dray and bridle tracks and tramway networks. Mining camps and isolated buildings, including, dwellings and blacksmith workshops.

- **Water Race Networks**: Includes low level and high elevation races. Dams and reservoirs, flume and siphon sites.

- **Township sites:** Early rush settlement, government administration, commercial centres, both general European and Chinese. Includes a range of Individual building sites, such as dwellings, stores, shanties, church and temples, schools and blacksmiths.

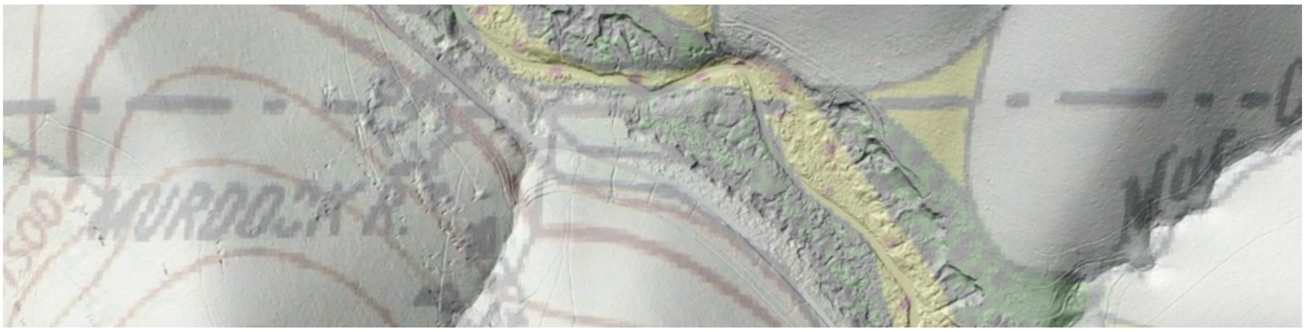
- **Burial Grounds**: Lone graves, burial grounds and cemetery.

1.6. Acknowledgements

The input from the Heritage Victoria project team was vital to the completion of this study report, and Helen Kiddell, Jacinta Bauer, Joanna Lyngcoln, Laura Campbell, and Jeremy Smith and their departmental colleagues Warren Maguire and Darren Green are thanked for their contributions. Heritage advisor, Gaye Sutherland made a significant contribution both in the field and in the background compilation of Site Cards. Jerem Leach (DELWP) was instrumental in compiling the initial project proposal.

Other significant contributions came from local residents, including the research of Fred Sargent. Rebecca Swift provided valuable additional word processing assistance.

Unless otherwise stated, all site plans, features surveys, historical overlays, photography and illustrations by author.



2. Case Studies - Feature Analysis & Interpretation

LIDAR imagery captures a 3-dimensional image, revealing above ground formations such as ruins and mining features in areas with low-visibility due to vegetation cover - features that would usually be hidden to traditional surveys, such as aerial photography and field surveys.

The key to the use of LiDAR is in the perception, comprehension, and interpretation of features. The ability to understand the various forms and shapes; as well as their contexts within the broader landscape. This generally comes from experience, largely obtained through on-ground field observations.

LiDAR imagery is best suited for the preliminary desktop planning assessment and targeting of sites within a specific geographic area. Any targets should be followed up with fieldwork inspections, to confirm and positively identify the initial interpretations.

Historical Record Overlays

The practical applications in the use of LiDAR in site identification and interpretation are many, particularly in conjunction with accurately surveyed historic maps and plans. In most instances georeferencing of historic plans and maps provides a fairly accurate representation of what is on (or below) the ground. Early survey techniques of 19th century were relatively accurate, particularly on a more detailed, smaller scale. Whilst broader scale surveys may require some tweaking to obtain reasonable spatial alignment.

Digital georeferencing and rectifying of historic maps and plans to align precisely with the LiDAR imagery converts old maps into real geographic information. This can greatly assist in the correct spatial alignment of historic archaeological sites.

The technique applied was to:

- Import historic maps into any suitable mapping or graphics-based software,
- Create layers of historic map, geospatial mapping and LiDAR imagery,
- Establish recognisable reference points; property and land boundaries, physical features such as roads and waterways,
- Match points to LiDAR imagery, increase or decrease transparency to overlay image to align both images.

From this process, of georeferencing specific historic features it is possible to measure any changes that have occurred in landscape. This technique is therefore a versatile tool for assessing the values and extents of the specific site.

Case Studies

The following case studies demonstrate a range of mining site types and various techniques that can be applied to maximise the understanding of our historic archaeological sites and landscapes. This in turn provides us with the information to make informed decisions about the management of a site.

2.1. Joss House Hill Chinese Burial Ground: *Overlays – Titles & Parish Plans*

The Buckland Goldfield attracted a culturally diverse population, including at one time a population of 2,000 Chinese miners. Evidence of their occupation and efforts is still present across the landscape of the valley. Features and archaeological sites include: water races, bank sluicing claims, mining camps, townships, huts sites and temple sites.

Joss House Hill was occupied by Chinese diggers from the earliest days of the goldfield. It was the site of the first house of worship of any denomination erected in the valley. In July 1857, only a few days after opening, it was destroyed in the Buckland Riot.

For many years a Chinese burial ground lay forgotten and overgrown. At some point a road was bulldozed through the site and the grave stones removed. It has since become an overgrown and unmaintained parcel of crown land.

The site was identified on an old parish plan by local historian and author Diann Talbot in the late 1990s.

Figure 2.1.1: Detailed parish title plan showing Chinese graves and other historic features. Image D. Talbot

The historic plan, identifies the burial ground and a number of nearby features, including reservoirs, 'Wards Race', gardens and old gold workings.

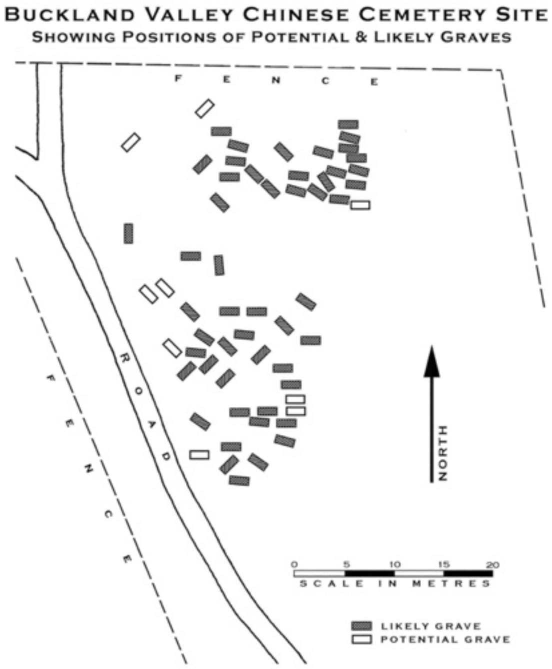


Figure 2.1.2: Stylised drawing of potential graves identified by GPR in 2004. A. Swift 2005.

In December 2004, a geophysical investigation was undertaken by La Trobe University, Melbourne and the University of Tasmania, Hobart. The survey was instigated by a community group and the Chinese Australian Family Historian of Victoria Inc.

Using ground penetrating radar, a cleared portion of the burial ground was surveyed. The project identified some 51 likely and 9 potential graves.[1]

Today, the majority of the site is still covered in heavy vegetation and is barely discernible.

An overlay of the historic plan onto the LiDAR imagery, spatially aligns many of the plans features with features still in existence today. At the site of the graves, the LiDAR shows partially disturbed ground, possibly by dozing and earthworks, with small mounds and uneven ground surfaces that may be an original goldfields era surface. The general area of the graves shows a contrast to the surrounding landforms and paddocks.

[1] A Chinese memorial was unveiled on the 1st July 2007 and dedicated to the Chinese who lost their lives and to those who lie buried in unmarked or unknown graves throughout the Buckland Valley. The granite stela was erected by the Chinese Australian Family Historian of Victoria Inc.

Figure 2.1.3: Parish plan, LiDAR overlay showing corresponding features and area of graves

2.2. Harp of Erin Quartz Reef Workings: *Site Extents & Boundaries*

The Harp of Erin quartz reef workings are situated below the Buckland Junction on the eastern side of the river. The reef was worked from the late 1860s, intermittently into the early 1900s. Over 20 adits (*horizontal tunnels*) were driven into the reef during this period. A network of dray and sleigh tracks were cut to convey the gold-bearing stone to a water-powered battery below the mine. One of the early discoverers of the mine, took over £20,000 worth of gold up until 1873. Stephen Paulussy then acquired the claim and held it into the early 1900s. A waterwheel powered battery was erected in 1885 to crush from the mine as well as undertake public crushings. The mine produced reasonable returns into the early 20th century. Paulussy died in 1909. In 1912 government geologist, J. Easton reported that Rowe and Wilson were driving a lower-level adit from near the river to the west. Little of their efforts is known.

The site today is located within mature eucalypt forest with a generally heavy understory of post 2019 bushfire regrowth and blackberry. Discerning features at the site is difficult due to this vegetation cover.

Figure 2.2.1: Southern lower mullock dump, east of Old Buckland Road, showing heavy understory vegetation.

Figure 2.2.2: Paulussy's battery, c1890s, possibly Stephen Paulussy at right. Harrietville Historical Society collection.

Paulussy's battery was comprised of a four-head stamp battery powered by an over-shot waterwheel. The supply of water for the wheel and mill was conveyed via a water race approximately 2 kilometres in length, sourced from the east branch of the Buckland River. The water race was excavated through previously sluiced workings. The race winds through cobble heaps and tail races. LiDAR imagery clearly shows the race for much of its length through this heavily worked landscape.

The site has a good historic record. It appears in the official government registers, mining reports and returns, as well as on historic maps. The site is also represented in contemporary newspapers.

The site is a good example for the benefits of LiDAR imagery in the determination of site extents.

LiDAR Site Feature Interpretation and Analysis:
The Harp of Erin workings contains a representative range of quartz mining workings and associated features, including: surface features and stopes, shafts, adits, costeans and associated mulllock dumps.[2] Ancillary features include, sleigh and dray tracks, battery site and associated water races and domestic huts or building sites.

[2] Site also has accessible underground workings which have potential for underground, digital mapping. Providing opportunities for three-dimensional underground and surface modelling.

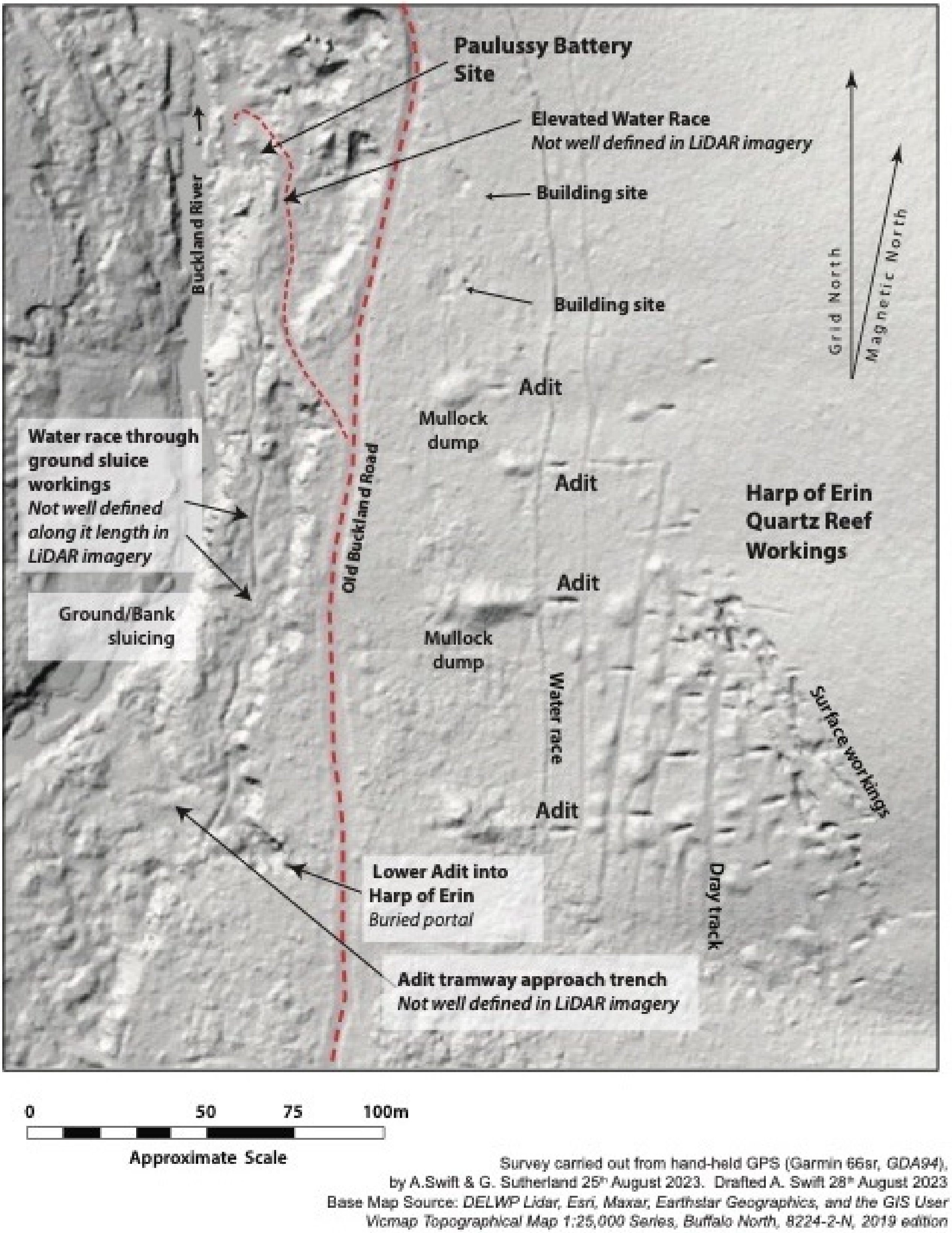


Figure 2.2.3: Harp of Erin, historic Feature LiDAR analysis.

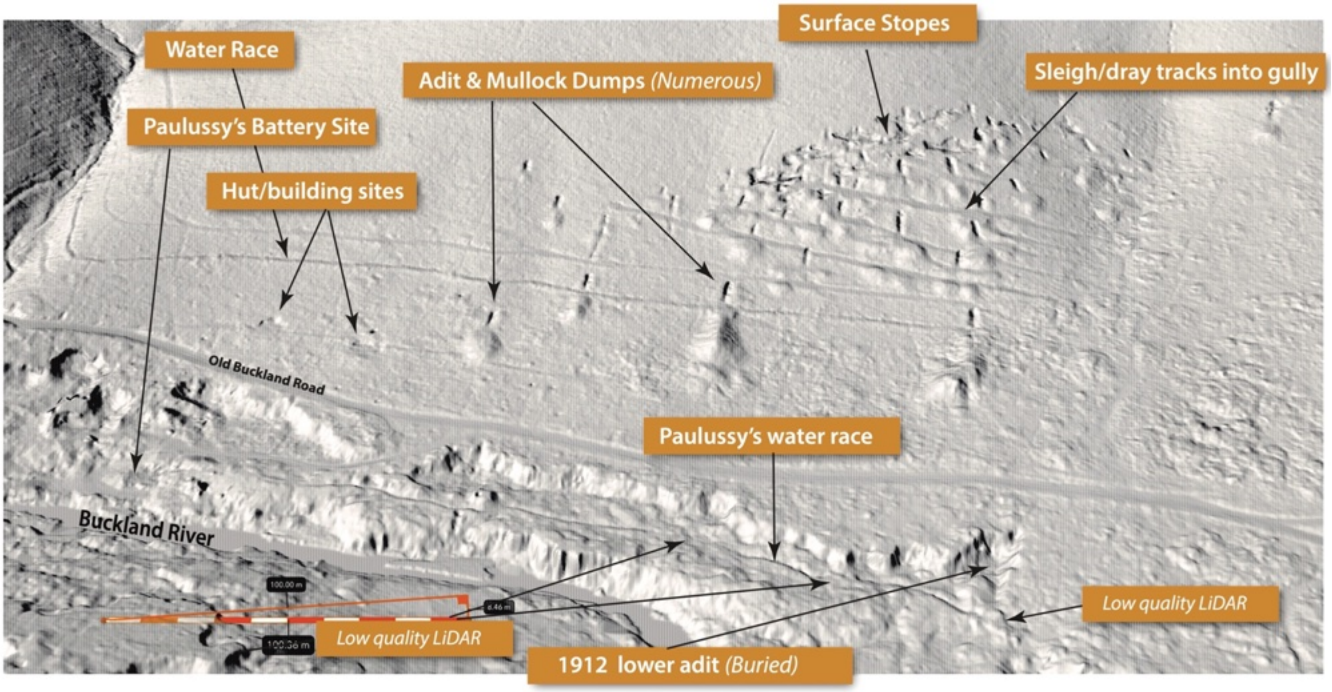


Figure 2.2.4: Oblique view looking east into the Harp of Erin Workings; providing a different visual perspective of the features in relationship to the topography of the locality.

The standard 'top-down' (*Figure 2.2.3*) view provides a good two-dimensional plan for the general interpretation of range and context of features, whilst the oblique or 'set-viewpoint' (*Figure 2.2.4*) better visualises the network values between features in context with the actual topography of the locality

Historic Geographic Position Correction
Occasionally historic maps can incorrectly show positions or locations of sites. In certain contexts, this can potentially lead to longer-term management issues. When overlaying historic maps and positioning sites onto modern-day GIS data-bases, traditional aerial imagery may not be suited to accurately confirming a sites location due to dense terrain. In this context LiDAR imagery can confirm or disprove the positions of historic sites.

LiDAR can be utilized to determine and update accurate positions of official historic surveying data. In this example, the official Mines Department records show the Harp of Erin workings indicated within Freehold Block No.6 at the Buckland Junction. An accurate overlay of the 1910 geological map on the LiDAR imagery clearly shows only limited prospecting activity within the north-west corner of this block, whilst the actual workings are located 200 metres to the north.

The benefits of accurately updating the positions of historic mine workings using available historic records and LiDAR are many. Some include:

- Updating the historic record, with the correct geographic placement of historic mine workings
- Accurately positioning extents of underground workings (*see also Red Jacket case study*), and any potential hazards or risk to public or private land management.

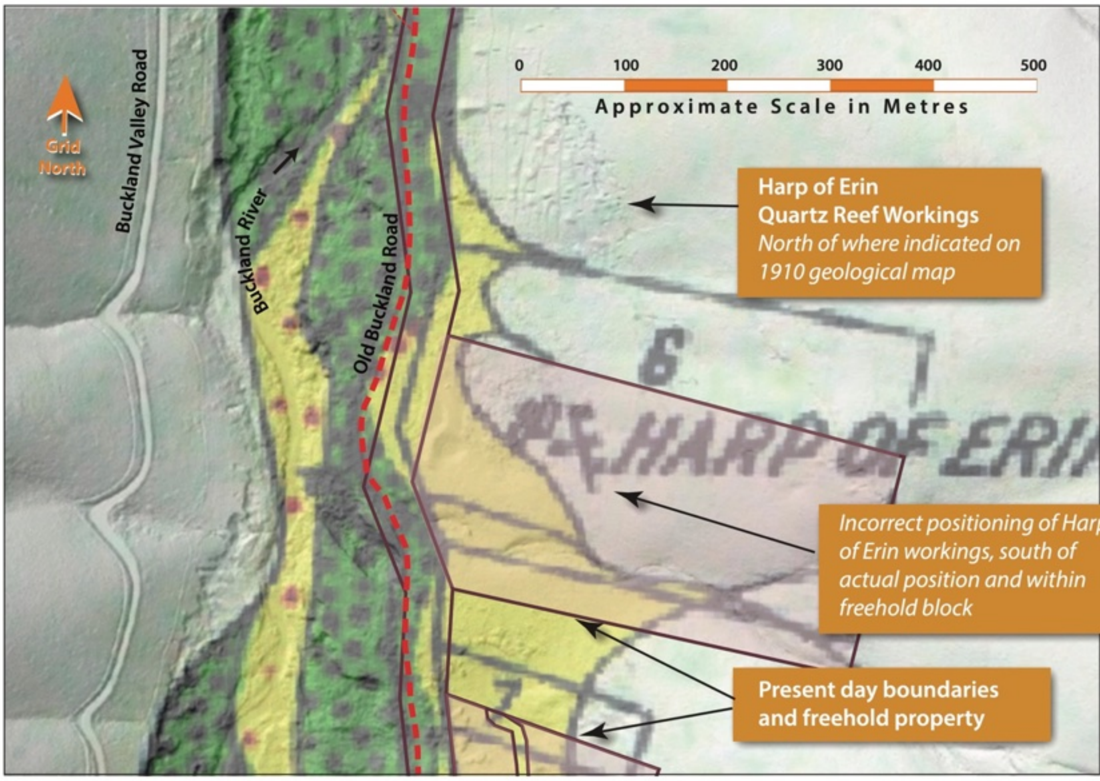


Figure 2.2.5: 1910 Geological Plan of the Buckland Goldfield overlay on LiDAR and referenced to present boundaries. Map source, Geological Survey of Victoria.

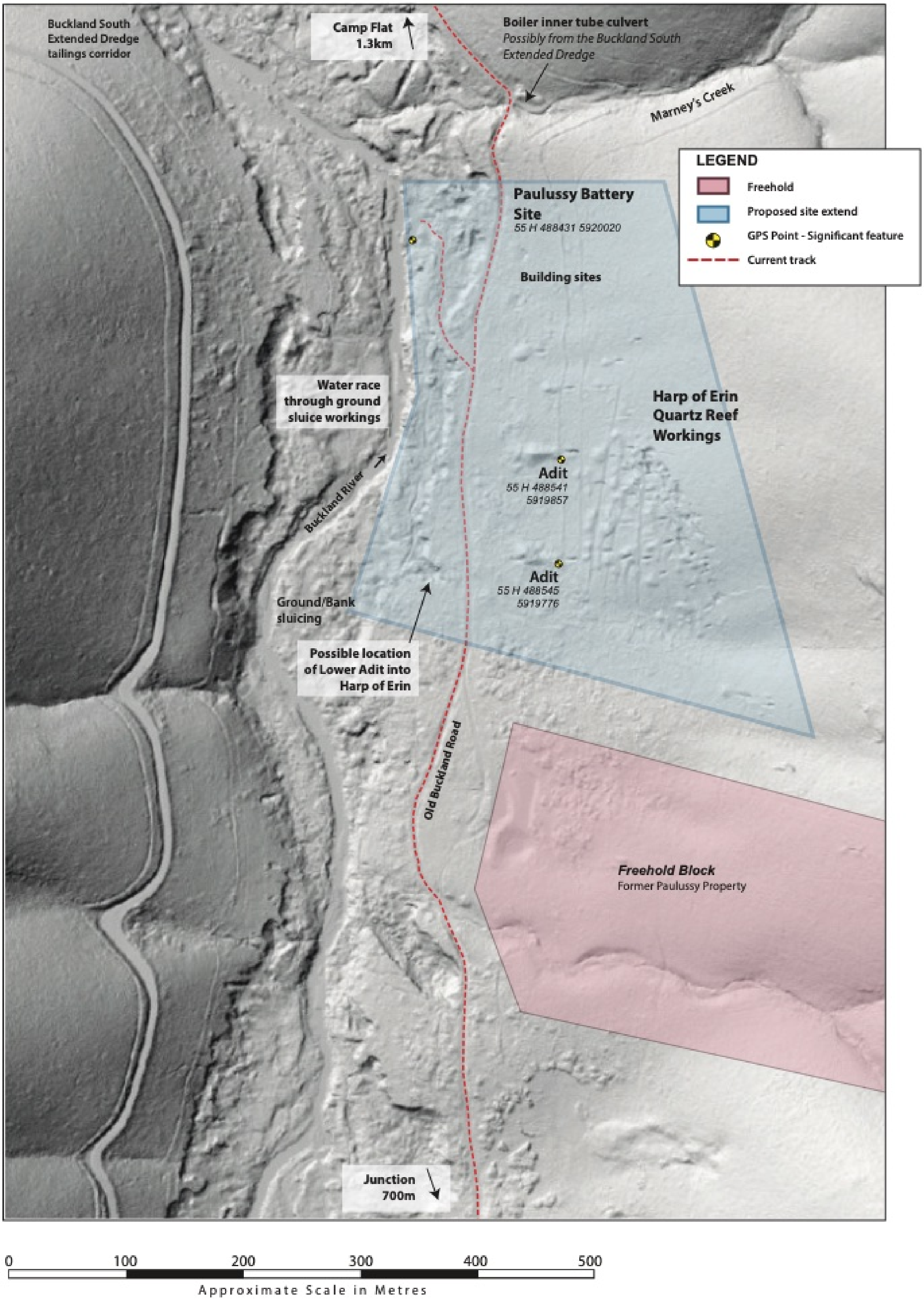
Site Extents

Determining the extent of a historic site is a key management principle, as it determines the boundaries within which all of the significant features of the site are contained.

A good understanding of the site is generally required, which is greatly assisted by a well-researched historic record. The use of LiDAR can then assist in determining this management boundary. A follow-up field inspection would be required to confirm the initial LiDAR interpretation in context with the historic record.

In the case of the Harp of Erin workings, the historic record indicated that a low-level adit was driven from river level in 1912. LiDAR greatly assisted in narrowing down 'likely' features and position of the tunnel, hidden amongst earlier alluvial ground sluicing workings. Despite the unclear resolution of LiDAR in this locality due to interference from vegetation, a steep bank amidst the workings was identified as a likely position. Field inspection located a tramway approach trench, bounded by parallel mounds of rough broken sandstone and quartz boulders, typically found in tunnel extraction; a stark contrast to the surrounding rounded, river-worn cobble heaps of the alluvial sluice workings. The adit portal was buried by a collapse of earth at the bank. However, the adit's position is clearly defined by on-ground features and its positioning on the LiDAR in relation to the upper, eastern workings.

The identification of this feature allowed for the western boundary of the Harp of Erin site extent to be extended to include this significant feature.



Survey carried out from hand-held GPS (Garmin 66sr, GDA94),
by A.Swift & G. Sutherland 6th July 2023. Drafted A. Swift 1st August 2023
Base Map Source: *DELWP Lidar, Esri, Maxar, Earthstar Geographics, and the GIS User*
Vicmap Topographical Map 1:25,000 Series, Buffalo North, 8224-2-N, 2019 edition

Not all historic features and mine workings areidentified on this plan.

Figure 2.2.6: Extent of Harp of Erin workings and Paulussy's battery site shown in blue shaded area. Site Extent is shown in relationship to adjoining features, such as freehold parcels and reserves, other historic workings and sites. Topographical context is also clearly shown by LiDAR.

Micro-topographical Detail

LIDAR may not always provide the detail required for interpretation. Thick vegetation cover or low-resolution imagery may not provide enough information required to understand and subsequently make appropriate management decisions for a site. More traditional survey methods may be required.

Paulussy's battery site is a significant aspect of the workings, providing a crushing facility for the extraction of gold from the ore of the Harp of Erin. The site is in a well-defined bedrock cutting on the bank of the Buckland River, currently covered in a thick understory of tea-tree. The site also has a well-defined elevated water race, 24 metres in length, 1.4 metres high and 2 metres wide, constructed with outer retaining walls of drystone cobble, with earth fill. This was the end section of a 2-kilometre-long water race that provided water for the overshot waterwheel and the mill. Neither of these features were defined well enough in the LiDAR to interpret the significance of the site.

Figure 2.2.7: Cobble-stone retained elevated water race that directly fed flume over waterwheel of Paulussy's battery (200mm divisions on pole)

Detail of the LiDAR (*Figure 2.2.8*) showing poor definition of features, making initial interpretation of imagery, without prior site knowledge, very challenging. Particularly when the broader setting is very busy with ill-defined shapes of the alluvial mining landscape.

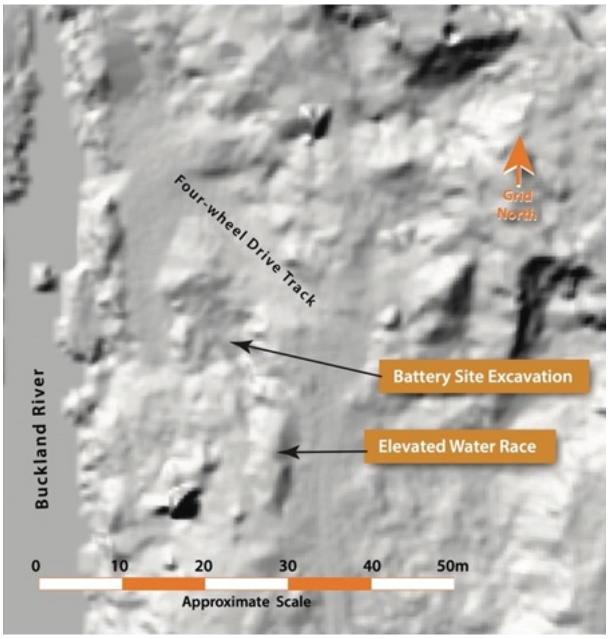


Figure 2.2.8: Poorly defined LiDAR imagery of Paulussy's battery site, barely discernible amidst the alluvial mining landscape.

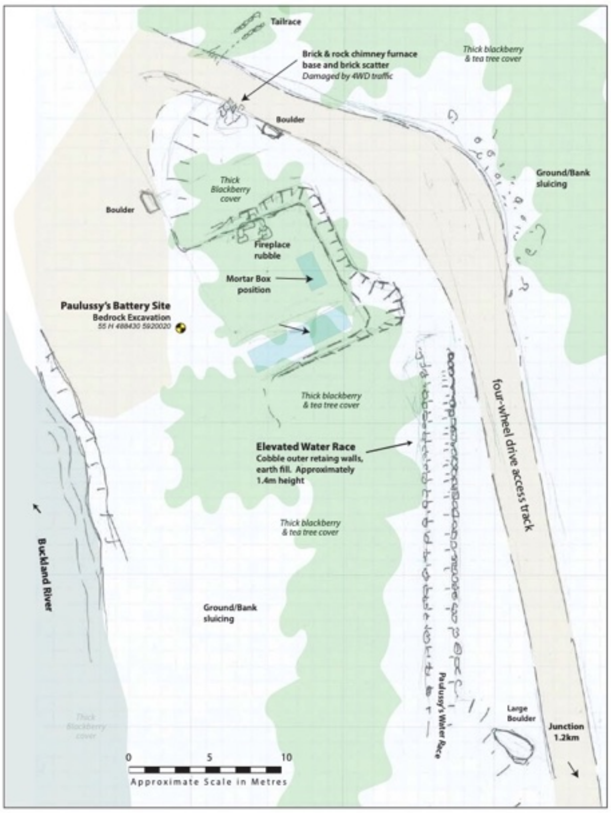


Figure 2.2.9: Paulussy's battery site. More traditional survey techniques, such as compass and tape, may be required when interpreting historic features, and determining significance. August 2023.

2.3. Nelson Reef Inclined Tramway: *Micro-Topography and Resolution*

The Nelson was one of the first gold-bearing quartz reefs to be discovered on the Buckland. The mine was initially worked from shafts located on a shallow spur. Ore was conveyed to the battery situated on the creek below via an inclined tramway. In January 1860, Robert Holden Stone, mining surveyor for the Buckland Mining Division, completed a detailed survey of the shafts, windlass and head of the tramway.

These detailed drawings align with features still on the ground today. LiDAR imagery assists in identifying the position of lost timber infrastructure and how it corresponds to present day features. Overlaid, the two images give an important glimpse into the positions and extent of this lost infrastructure.

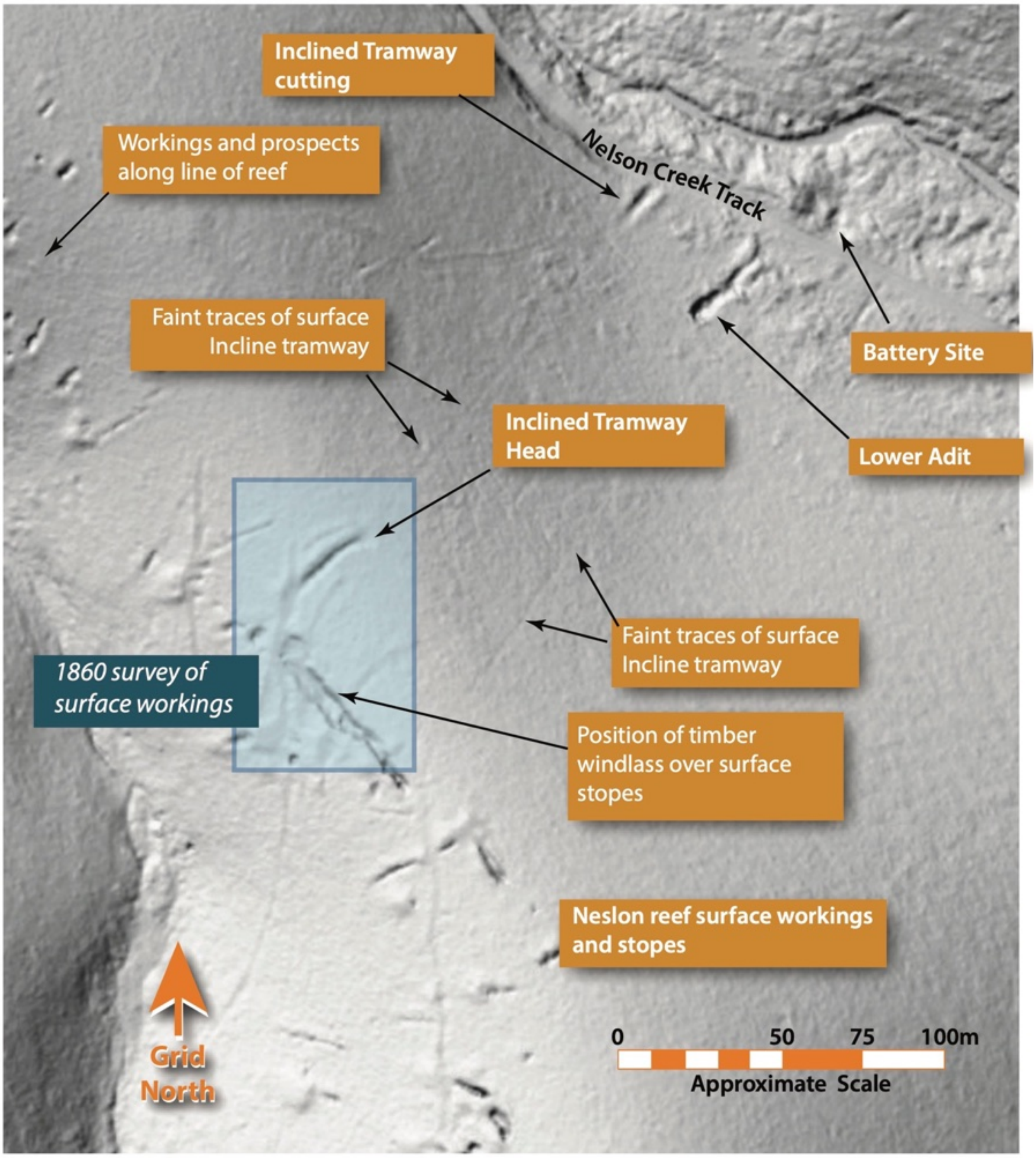


Figure 2.3.1: Interpretation of LiDAR features of the Nelson quartz reef surface workings. Position of 1860 drawing of infrastructure shown in blue.

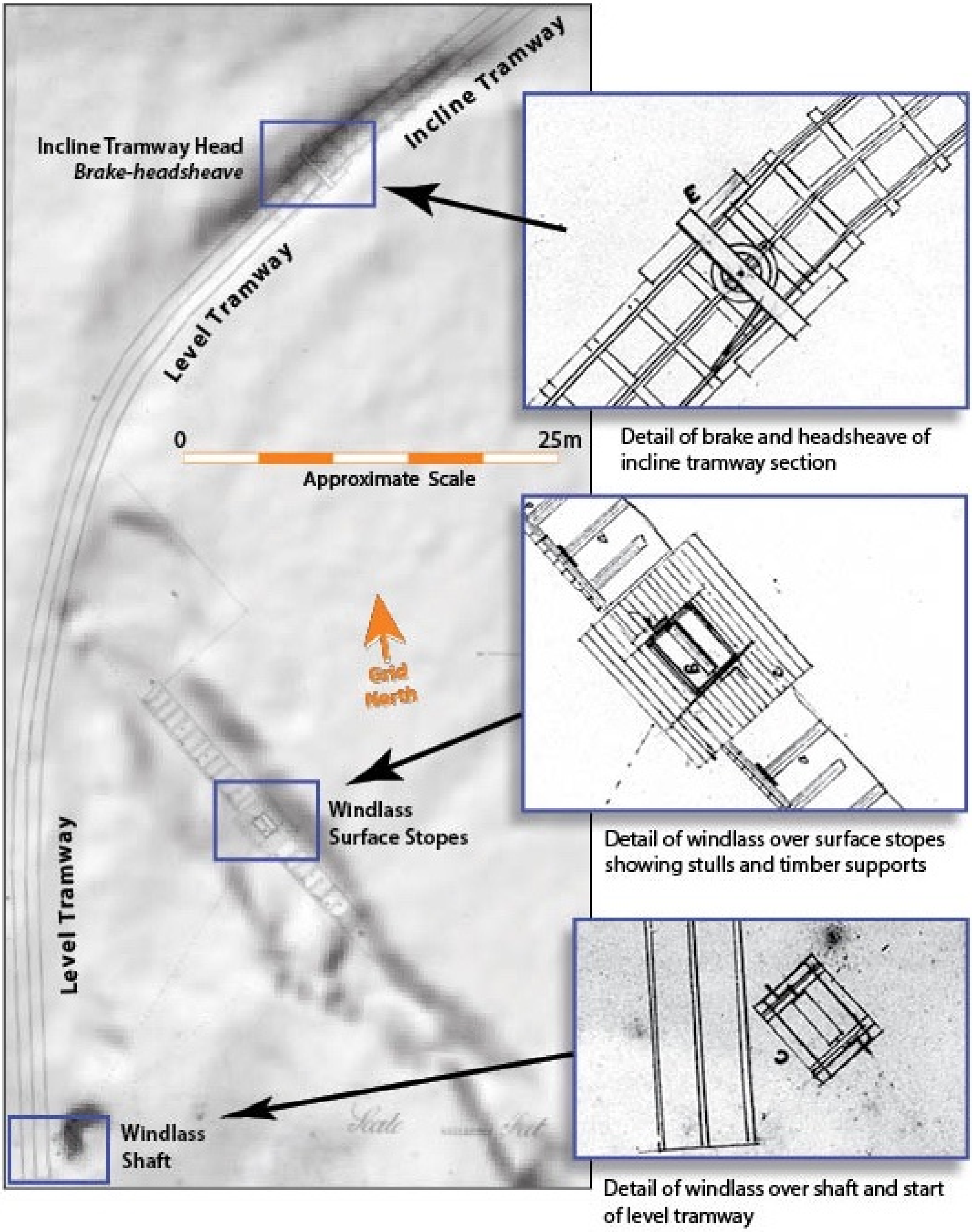


Figure 2.3.2: R.H. Stone's infrastructure drawings, specifically overlaid on LiDAR imagery of the surface features of the Nelson reef. This technique provides micro-topographic accuracy, specifically pin-pointing archaeological targets.

Figure 2.3.3: A typical mountain tramway, showing partially built on ground surface and partially into ground. Footprint would be similar to that of the Nelson Tramway. Big Gun incline tramway at Harrietville, c1903. Geological Survey of Victoria.

Such historic drawings provide specific geographic targets where important features where likely to have been positioned.

This method of geographic and historic based research can help specifically identify archaeological sites within an otherwise challenging landscape.

Three-Dimensional Infrastructure Modelling
Digitally overlaying lost infrastructure in a three-dimensional geographic setting provides many research opportunities to accurately reconstruct historic landscapes.

Accurately reconstructing lost infrastructure in extreme topographical settings can be a powerfully engaging tool in comprehending the significance of historic archaeological sites in the mountainous regions of Victoria.

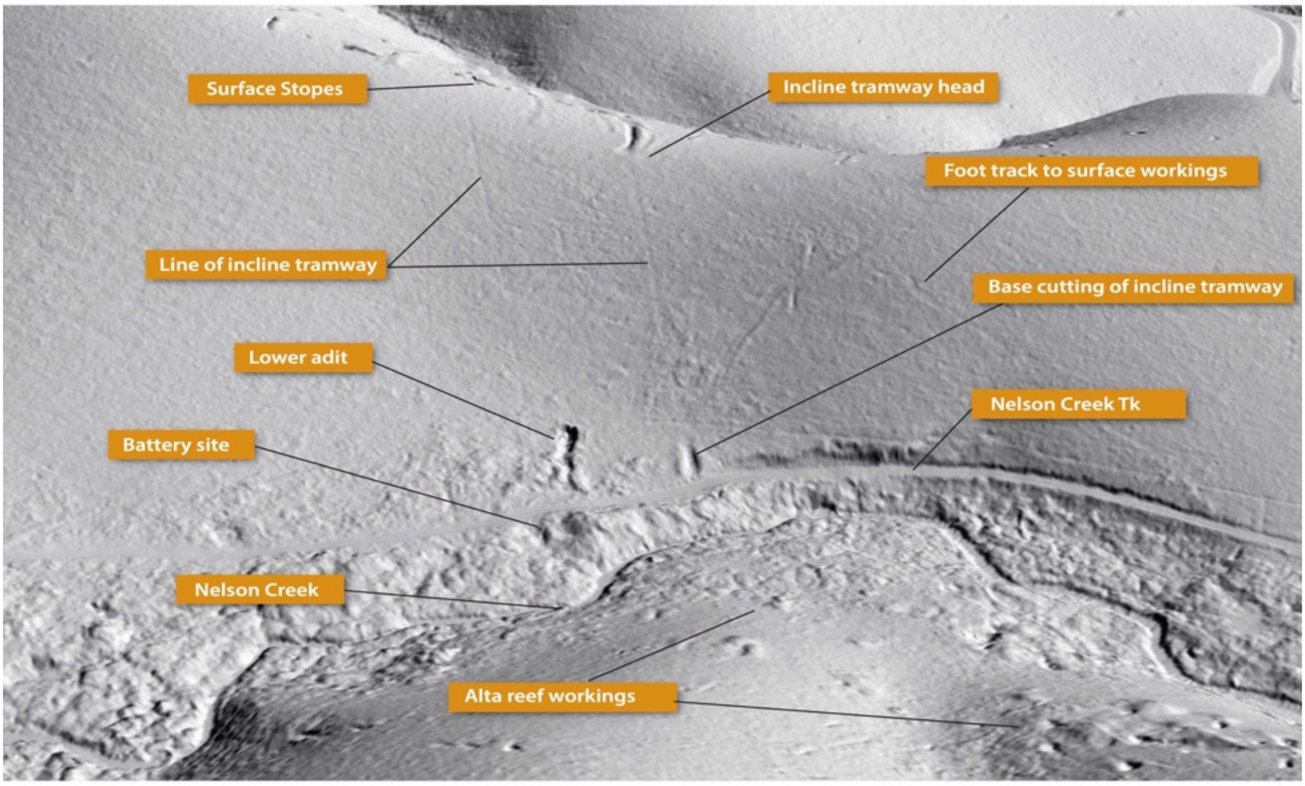


Figure 2.3.4: Oblique view looking south from the position of the Alta workings into the Nelson workings; providing a different visual perspective of the features in relationship to the topography of the locality. A digital reconstruction of lost timber infrastructure in this landscape would be a powerful and engaging tool in comprehending the significance of such sites and the remaining features.

Issues with algorithms and vegetation cover

During the late 19th century, a steam-powered stamp battery was erected between the Nelson lower adit and the creek. Remains of the mill still exist beneath a heavy cover of blackberry and wattle. The battery site excavation contains an in-situ Cornish boiler and associated features.

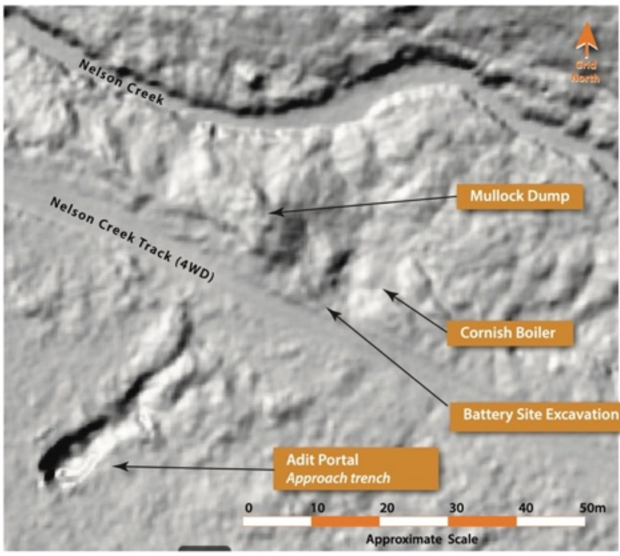


Figure 2.3.5: LiDAR image of the ill-defined features of the Nelson battery site.

LiDAR imagery has not necessarily successfully captured the form and structure of the site. This may be due to a number of factors.

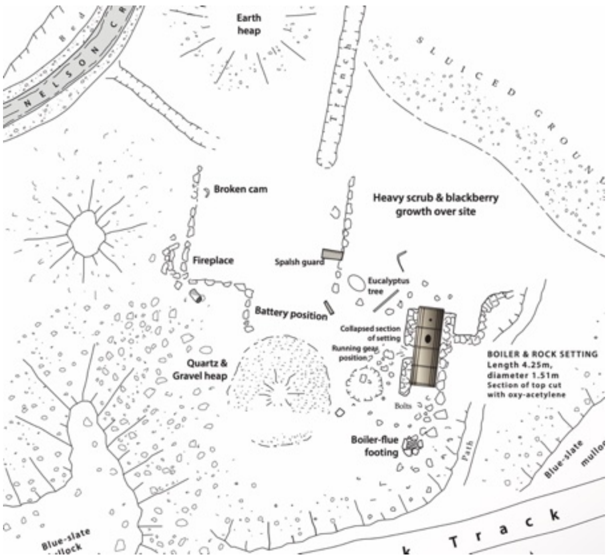


Figure 2.3.6: Detail from heritage feature survey of the Nelson battery site, showing features associated with the site. 2004.

Figure 2.3.7: Cornish boiler at the Nelson Battery site, May 2022.

Figure2.3.8: Nelson boiler after to 2006 bushfires, cleared of vegetation. January 2007.

Another factor may be in the processing of raw LiDAR data. Algorithms may be inadvertently removing shapes or form of a sharp, three-dimensional nature.

The heavy density of blackberry cover at battery site has deflected the penetration of LiDAR, not allowing for adequate data collection to define features.

2.4. Alluvial Mine Shafts: *Hidden Hazards*

Across Victoria many thousands of historic mine workings exist, each with its own associated risk.

LiDAR can be a valuable tool in identifying historic mine shaft hazards. In the Buckland goldfield, many hundreds of mine shafts were sunk throughout the valley over the principal decades of mining between 1853 and the early 20th century.

In understanding the features and contexts used in identifying mine shafts in LiDAR imagery and on the Buckland field, a basic understanding of their use is required.

Shafts, or vertical holes were sunk for a number of purposes, mostly for accessing and removal of gold-bearing material in the form of gravel or ore. Other shafts were sunk for facilitating drainage or ventilation.

Alluvial Shafts – Shallow Leads: The majority of shafts were sunk on alluvial gold deposits associated with ancient stream gravels, buried beneath later hill drift and eroded wash material. The shaft is usually sunk through softer clay or loam material until the buried river course is met. This generally only required the use of pick and shovel; sometimes harder rock deposits or cemented river conglomerate may have required the use of explosives. Alluvial shafts are usually identified by their proximity to water courses, and their associated extracted material (mullock) of water-worn pebbles, cobble, clay and gravel. The depth of the shaft is largely determined by the depth of the gold-bearing lead. On the Buckland, these types of shafts can vary from 1 metre to 15 metres in depth.

Prospecting shafts were sunk to test the extent and values of buried gravels, whilst mine shafts were used to extract and remove gold-bearing gravels; often these would have tunnels driven out from the bottom along the lead.

Round or rectangular shaped shafts: Often round shaped shafts are attributed to Chinese miners, whilst rectangular holes more to miners of European origin. This is certainly a generalisation and should not be considered to be a definitive fact. The shape of a shaft often relates to several varying factors, including, structural stability associated with the type of ground, type of haulage used, (such as windlass or hand-whip), and access, including ladder ways, rope or free-climbing.

Figure 2.4.1: 10 metre deep round alluvial mining shaft, Allen's Flat, Buckland. August 2023.

Quartz Reefing Shafts: On the surface, shafts were sunk to either test the values or extent of a quartz reef, or used to mine and extract a gold-bearing ore body. In the mountainous areas of the Buckland, both shafts, open stopes (quarries) and adits were used to extract the ore. Shafts were usually sunk in sedimentary bedrock, often requiring explosives. Shafts are found along the line of reef where it outcrops on the surface. These types of workings are generally defined by large scatterings of white quartz rock and rough, broken sandstones and slates. Shaft depths can vary significantly on a reef mining site from 2 metres to 35 metes, or even greater.

Figure 2.4.2: Obvious mullock dump associated with a 10 metre deep alluvial prospecting shaft at Allen's Flat, Buckland. August 2023.

Mullock Heaps: Most shafts, but certainly not all, are identified on the surface by features known as mullock heaps. This is the waste rock extracted from beneath the ground and cast immediately adjacent to the hole. The size of the mullock can be indicative of the depth of the shaft and/or the extent of underground workings. Mullock from alluvial shafts usually consist of clays, gravels and water-worn pebbles and cobble. Whist quartz reef shafts consist of mostly of rough broken sandstones, slates and quartz.

Not all shafts have mullock heaps. There are numerous reasons why a shaft may not have a mullock heap, including;

- All material was removed for processing and gold extraction.
- The shaft was partially back filled with its mullock, later to have slumped and subsided.
- The shaft may have been opened upward from beneath the ground from another entry point such as a tunnel or adit.

A shallow shaft without an identifiable surface feature, such as mullock dump, can potentially be of a greater 'unseen' risk than a deep shaft with an obvious mullock dump.

When it comes to identifying the locations of historic mine shafts there are many limitations. These can include;

- Poor records of locations.
- Large expanse of potentially mined ground where shafts may exist.
- Heavy vegetation cover in potential areas.
- Risk associated with on-ground surveys in poor conditions.
- General access.

LiDAR

The use of LiDAR imagery can greatly assist in any preliminary planning and fieldwork associated with future mineshaft safety assessment. Lidar imagery would greatly assist with;

- identification of type and range of potential hazard.
- Specifically pin-point and locate potential hazards (*particularly in areas of heavy vegetation cover*).
- Identifying risk from an Occupational, Health and Safety perspective prior to fieldwork inspections or work activities.

LiDAR imagery would significantly reduce the amount of preparatory work required before undertaking fieldwork assessment and surveys. Field work assessment would still be required to fully understand the nature of the risk and the priority, as well as any heritage values associated with the workings.[3]

Challenges

LiDAR imagery will not locate all mine shafts through the visual identification of features alone. It can however, assist in identifying likely areas through associated features and contexts.

Such feature context could include:

- Barren and apparently flat undisturbed ground adjacent to and in between ground sluicing paddocks or pits.
- Areas of mounds or potential mullock heaps in and adjacent to mine workings. Where individual holes may not show in LiDAR due to heavy vegetation cover.
- Areas showing quartz mining features, mullock heaps and adits. Where individual holes may not show in LiDAR due to heavy.

[3] Historic Mine Shaft Safety Project, Central Gippsland and Goulburn. Department of Environment, Land, Water & Planning, A. Swift, 2022

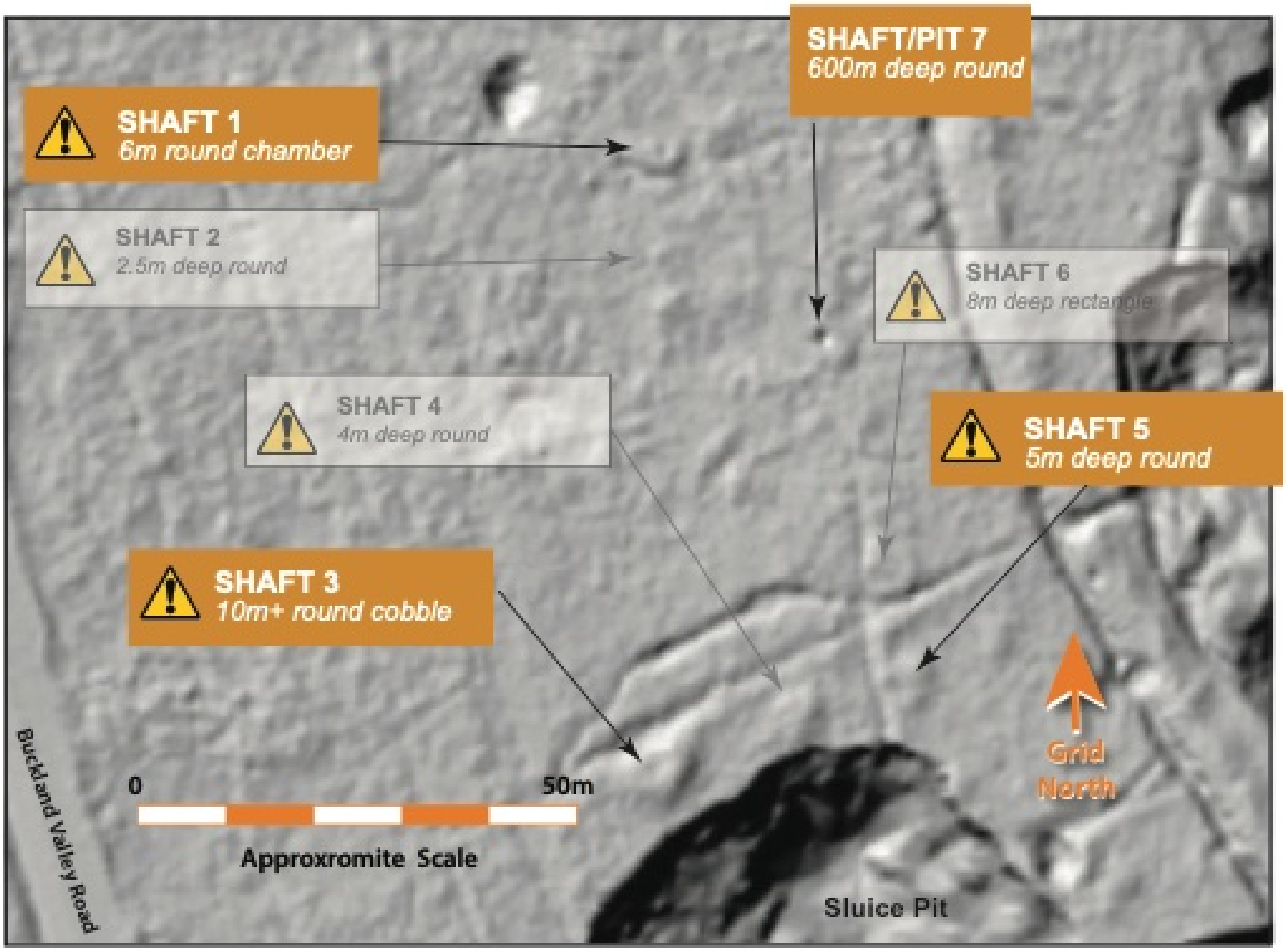


Figure 2.4.3: LiDAR feature analysis, selected mine shafts, Allen's Flat, August 2023.

Allen's Flat Shafts, LiDAR Analysis Case Study
The Buckland LiDAR project has identified some of the challenges associated with the spatial identification of mine shafts using LiDAR. The following case study outlines some of these benefits and challenges

Allen's Flat was one of the localities of the Buckland diggings, worked and occupied in late 1853. Many stores and miners' tents occupied the area which was adjacent to the richest river claims. In 1858 the flat saw a rush of Chinese miners, who were sinking shafts from 35 to 45 feet in wet ground. It was reported that a hundred shafts had been sunk in the area.[4]

A number of alluvial mining shafts are located on a large flat covered in heavy understory and ground cover of post 2019 bushfire regrowth. The shafts are associated with a stranded deep lead or ancient course of the Buckland River. The shafts were sunk to access, prospect and mine the gold-bearing gravels buried beneath the hill-drift. It is likely that these shafts were sunk during the late 1850s into the 1860s. They are possibly of Chinese origin.

The surface features of the shafts vary in type and appearance. The thickness of vegetation cover also varies greatly. A sample range of the shafts is analysed.

[4] Ovens & Murray Advertiser, 24th April 1858. Easton, John. *The Buckland River Alluvial and Quartz Mining Area.* Geological Survey of Victoria, Department of Mines, 1912. Unpublished.

Figure 2.4.4: SHAFT 1, showing thick vegetation cover, with some mullock and cobble apparent.

SHAFT 1: Is approximately 6 metres deep and opens up into a larger underground chamber. A thick cover of vegetation obscures these workings. This shaft appears to have been used to mine the buried alluvial gravel deposits. Trenches in the collar of this shaft suggests the use of a *hand whip*[5] The original shaft was likely to have been much deeper. The initial round nature of the shaft and the use of hand whips and the historic record suggest that it was of Chinese origin.

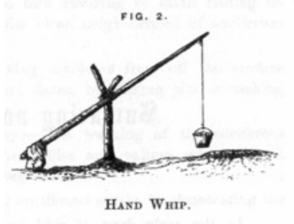
<u>*LiDAR Appearance - Poor*</u>: The opening of the shaft is difficult to discern. The mullock dump being only a slightly apparent feature, and the shape is not necessarily consistent with similar workings. The context of the feature would identify the site as a possible mine working.

Figure 2.4.5: SHAFT 3. Showing well-defined mullock dump of gravels and cobble.

SHAFT 3: Located approximately 6 metres north of a large hydraulic sluice pit. There is little vegetation cover on these workings. The shaft is situated on a large mullock dump consisting of large cobble rock of both blue slates and sandstones and quartz. This round shaft is approximately 10 metres deep and has a balance beam trench from a hand whip in the collar of the shaft. It is also immediately adjacent to a head race on its northern side. The initial round nature of the shaft and the use of a hand whip and the historic record suggest that it was of Chinese origin.

<u>*LiDAR Appearance - Good*</u>: The opening of the shaft is apparent, particularly in association with the shape of the mullock heap. The context in association with the sluicing pit is another good indicator that the feature is a shaft.

[5] One of the earliest means of raising material from a shaft or well was the *Hand Whip, Shadoof* or *Chinese Whip*. A long pole or balance beam, was centrally pivoted on a forked stick firmly set in the ground and as the miner pulled on a rope attached to one end of the pole, the bucket was raised out of the shaft. Chinese miners are 'generally' regarded as using this means of elevation as opposed to the traditional windlass.



I. Image from Brough-Smyth

Figure 2.4.6: SHAFT 5, showing shaft collar and eucalypt tree.

Shaft 5: Small amount of ground cover vegetation. The round shaft is approximately 4 metres deep. A large peppermint eucalypt tree is growing immediately adjacent to the collar of the shaft. It also has a balance beam trench from a hand-whip. The initial round nature of the shaft and the use of a hand whip and the historic record suggest that it was of Chinese origin.

LiDAR Appearance - Medium: The opening of the shaft is not apparent, the large tree deflecting LiDAR scanning. The appearance of the mullock dump is a good indicator, particularly in context with the sluice pit.

SHAFT/PIT 7: Situated out in a relatively open area with a light vegetation ground cover. The round hole is only 600mm deep, with a small mullock heap off to one side.

LiDAR Appearance - Good: The opening of the shaft is well defined, particularly in association with the shape of the mullock heap. The context in association with the sluicing pit is another good indicator that the feature is a shaft. However, the 'shaft' is barely much more than a shallow pit.

Summary

The use of LiDAR imagery is a valuable tool in identifying potential historic mine shafts, and associated hazards. There are however, many variables, including;

- Thickness of vegetation cover at time of LiDAR data acquisition.
- Raw data processing and algorithm analysis.
- Initial resolution or points capture per square metre.

The resolution of the Buckland LiDAR project was 24 points per square metre. This is considered a reasonably high resolution. Many mine shafts are clearly identified in the imagery; however, many are also poorly discernible, or not apparent at all.

Understanding the context in which shafts are 'likely' to occur is an important way to detect likely shaft locations.

2.5. Peach Point: Alluvial Mining, Ground, Bank & Hydraulic Sluicing

In the Buckland, as in many goldfields across Victoria, alluvial mining areas are difficult landscapes to understand and interpret.

Peach Point Hydraulic Sluicing Pit
It is very rare to find specific historical accounts of smaller alluvial mining claims. Little of the history of the Peach Point Hydraulic sluice area has been found.

Maguires Point to the south, was the location of the first rich gold discovery on the Buckland in mid 1853. Peach Point, a short distance to the north, would have been worked within weeks of the rush to the area.

In 1897, Messrs. W. and P. Robinson were working ground north of Murray's Creek, and quite possibly in the study area. When water was not available for working the face of their claim, the company held reservoirs which had sufficient water to process gravels extracted from the workings by tunnelling. It was reported that the claim had paid well for several years, and that there was still a lot of ground unworked. Recent rainfalls had allowed hydraulic sluicing to be resumed.[6]

Figure 2.5.1: Steep banks of the main hydraulic sluice pit, 2023.

Site Description
The large area extends for approximately 500 metres north of Murray's Creek and lies between the Buckland Valley Road and the Buckland River.

The area contains a range of historic features that relates to various periods and modes of alluvial sluice workings.

Figure 2.5.2: Part of the large cobble-field of the main hydraulic sluice pit.

Hydraulic Sluice Paddock, Central Peach Point: The largest feature of the site is a hydraulic (high-pressure) sluice paddock dating from the late 19th into the early 20th centuries. The face of the workings are defined by cliffs up to 15 metres in height. A vast cobble field contains large cobble dumps and tail races. Tail races drain into the Buckland River and are in places approximately 2.5 metres deep; cut into bedrock and retained by dry-stone cobble walls.

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[6] Ovens & Murray Advertiser, 24th July 1897.

Earlier alluvial workings – Peach Point South: An ancient course of the river has been worked on the western side of a high bedrock formation (Peach Point). This deposit has been worked by ground sluicing and tunneling. A deep tailrace, up to 10 metres in depth, has been excavated through the bedrock to facilitate drainage and working of the deposit. The high bedrock formation also has evidence of surfacing. It is possible these workings were undertaken at some point in the latter half of the 19th century.

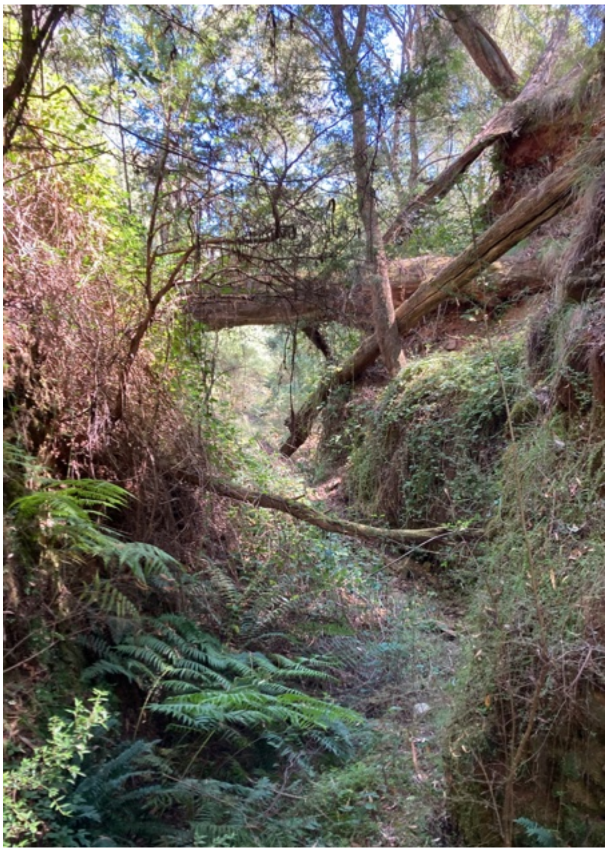


Figure 2.5.3: Deep tail race cut through bedrock, Peach Point south.

Earlier alluvial workings & reservoir – Peach Point North: Located immediately to the north of the main hydraulic sluicing pit is an open area of high ground partially situated on a high bedrock formation. The eastern and northern areas of this area have been mined by bank sluicing and/or low-pressure hydraulic sluicing. Above these workings, in an open paddock, is a square-walled reservoir or holding dam. It appears to have been manually constructed with earth walls up to 2 metes in height. It is likely that this feature was constructed in conjunction with a series of nearby water races and head races to work the claims below the dam. It is likely the dam, races and bank sluice workings date from the early years of the field.

Figure 2.5.4: Square earthen reservoir, Peach Point north.

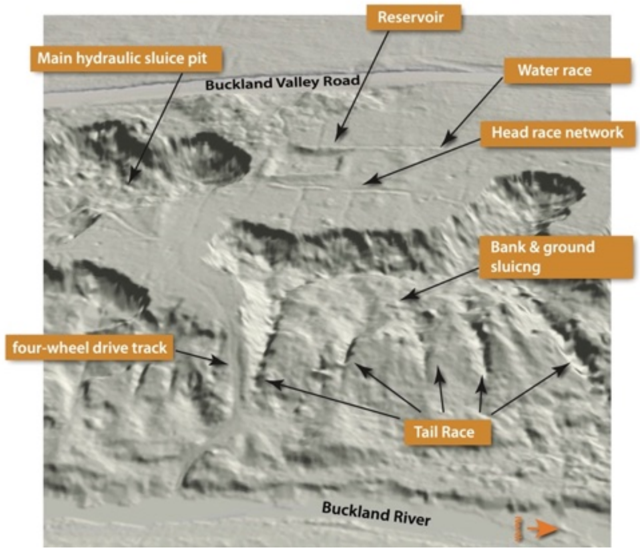


Figure: 2.5.5: Oblique view looking west showing early alluvial workings at Peach Point North.

Traditional Feature Surveys

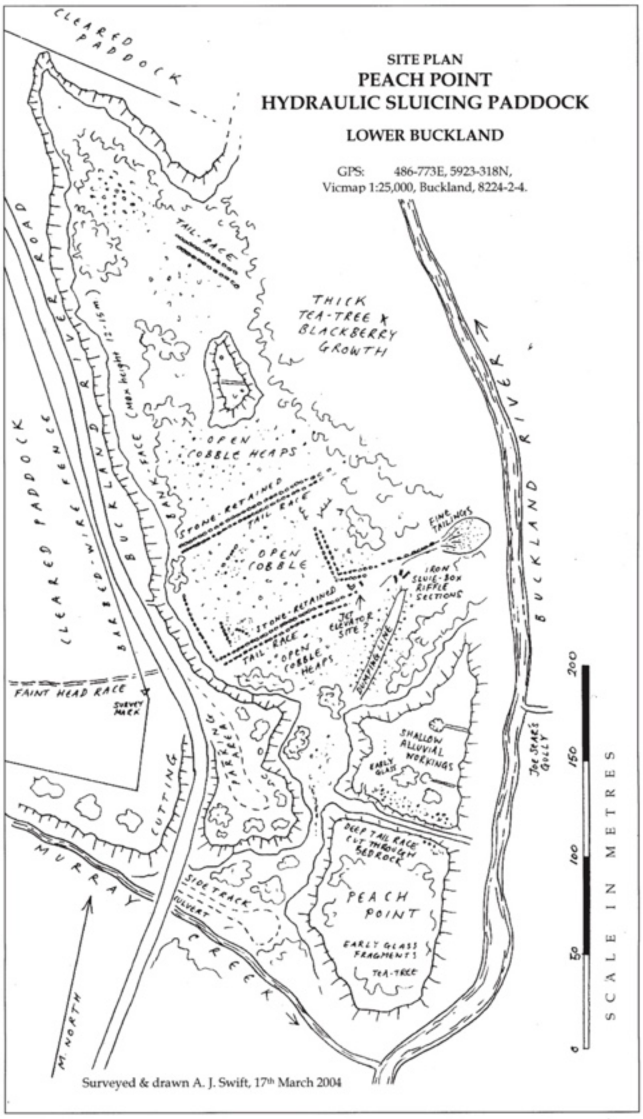


Figure 2.5.6: Peach Point, post-2003 bushfires survey. Department of Sustainability & Environment.

When assessing a site for its cultural heritage values, a feature survey is usually undertaken. This can be done using simple techniques such as compass and tape surveys. This allows for features to be recorded with some accuracy. Recording and identifying features within a mining landscape helps build a picture of what went on in these localities based upon surface features. This also allows for interpretation of the features in association with the historic record and to ultimately assess the significance of a place.

However, on broad and topographically diverse sites such as Peach Point traditional survey methods can be challenging and time consuming, both in recording and drafting. Georeferencing of features may also be inaccurate when the data is transferred on digital mapping platforms.

The Peach Point survey undertaken in 2004 identifies all of the principal historic features, however, the survey lacks detailed spatial information that would allow for an accurate representation of the site. The three-dimensional modelling offered by LiDAR imagery greatly enhances the understanding of larger more complex sites such as Peach Point.

LiDAR imagery can offer a much easier way to survey large and complex sites. The details of features recorded in the field using hand-held GPS units can be utilised at desktop to annotate the digital LiDAR set or a digital image. This saves considerable time compared to traditional surveys techniques, both in field recording and in post drafting. This method also doesn't necessarily require the compass and tape mapping or drafting skills.

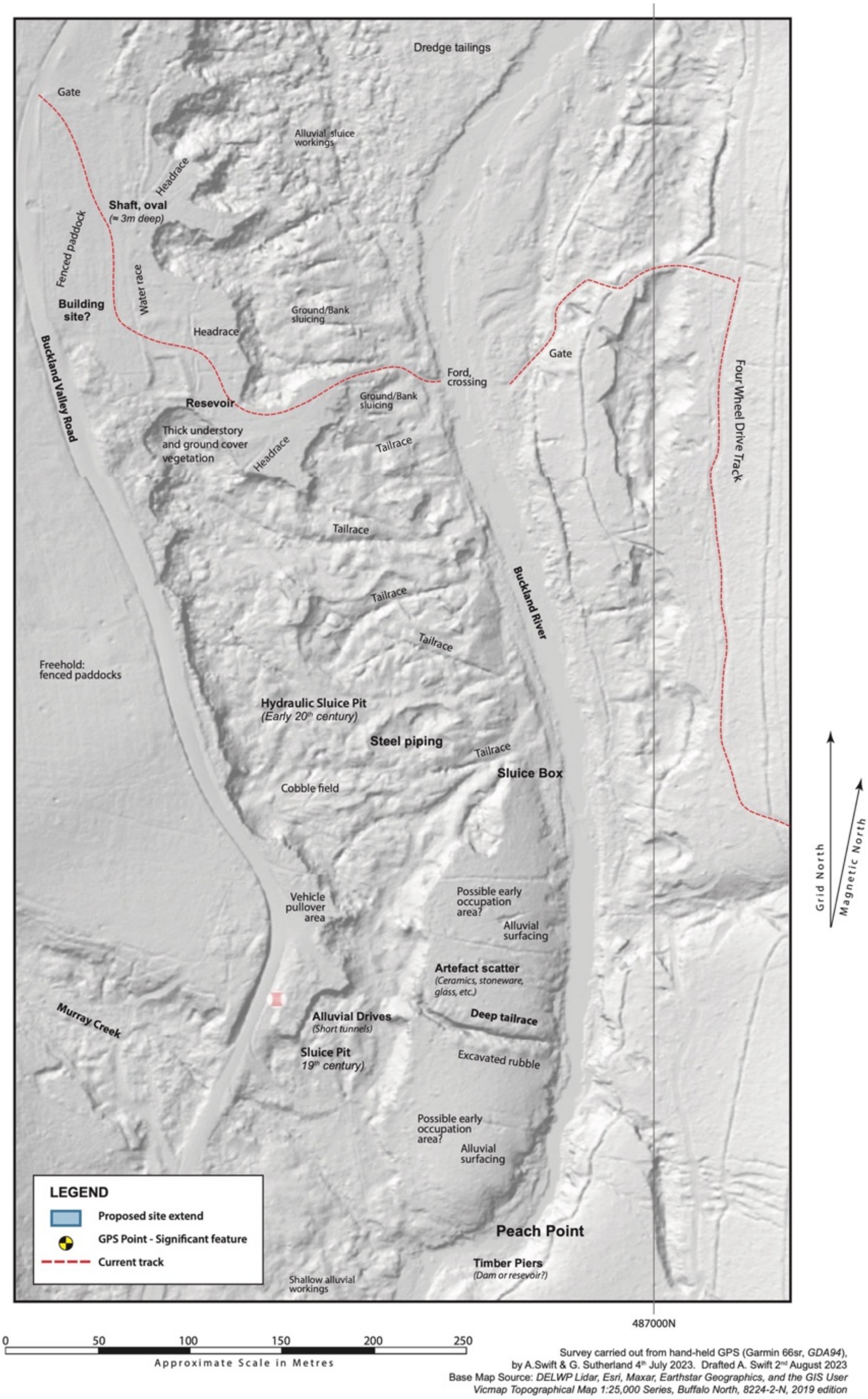


Figure 2.5.3: Interpretation of LiDAR features at Peach Point.

2.6. Phoenix Bucket Dredge: *Broad Landscape Interpretation*

Figure 2.6.1: Phoenix Dredge working the river flats immediately adjacent to the river, circa, 1907.
Bright & District Historical Society collection

The Upper Ovens Valley is one of the most heavily dredged areas in Victoria and Australia, with nearly 60 dredges operating between 1900 and 1955, producing more than half a million ounces of gold. Initially dredges re-worked previously sluiced ground in and adjacent to waterways. As this ground became worked-out, other river flats, marginally paying to earlier mining methods, could be profitably worked by dredging. Evidence of dredging across the landscape can take the form of large ponds and wetlands, tailings areas and mounds. Many of these features are now overgrown with native vegetation and weeds, or have been utilised for pine plantations or rehabilitated to varying degrees.

Much of the riparian landscape of the Upper Ovens Valley is a landscape of various alluvial mining types that took place over an eighty-year period, bucket dredging being amongst the most significant.[7] The Buckland Valley in particular contains many examples of alluvial mining types in the form of features and archaeological sites. Within the confined areas of the narrow valley floor, discerning and interpreting this mining landscape can be extremely challenging.

LiDAR is a valuable tool for understanding this complex landscape – a landscape containing many layers of mining activity. The features left in the wake of the Phoenix dredge offer many opportunities for the interpretation of a heavily mined area.

The Phoenix Dredge

The Phoenix Gold-Dredging Company launched its pontoons adjacent to the Buckland bridge in 1903. The dredge processed the flats in this locality, working to the west and south, crossing the Buckland Road, before continuing upstream in the bed of the river. In the first seven years of production to 1909, the average annual production was 1,542 ounces of gold. The dividend for this period was £17,138, illustrating the success of the company. Dredging operations continued under Sydney management until 1911, at which time dividends totalled £19,688. Diminishing returns of the dredge, under local management, saw the company pay £3,185 in dividends up to their closure in 1919. After working an area of 140 acres, the dredge was dismantled on the east side of the river near Dunphy's.[8]

[7] Alluvial mining commenced in late 1853 and continued almost continuously in the Buckland Valley up until the Great War. Alluvial mining continued on a diminishing scale into the mid 20th century.
[8] Government Gazette, New South Wales, December 1902, Talbot & Swift. P113. Lloyd, p173

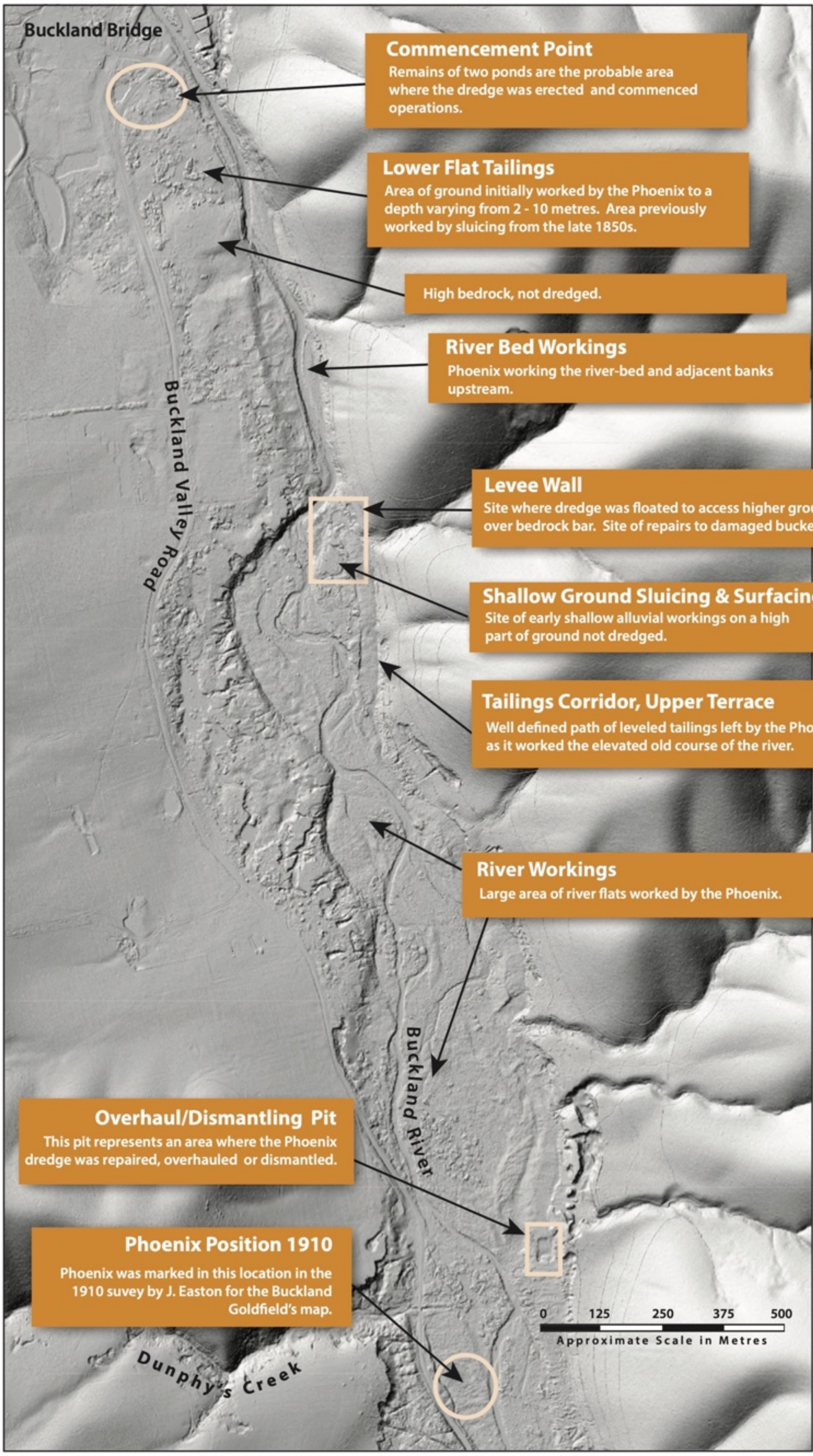


Figure 2.6.2: LiDAR feature interpretation of the Phoenix dredge mining landscape.

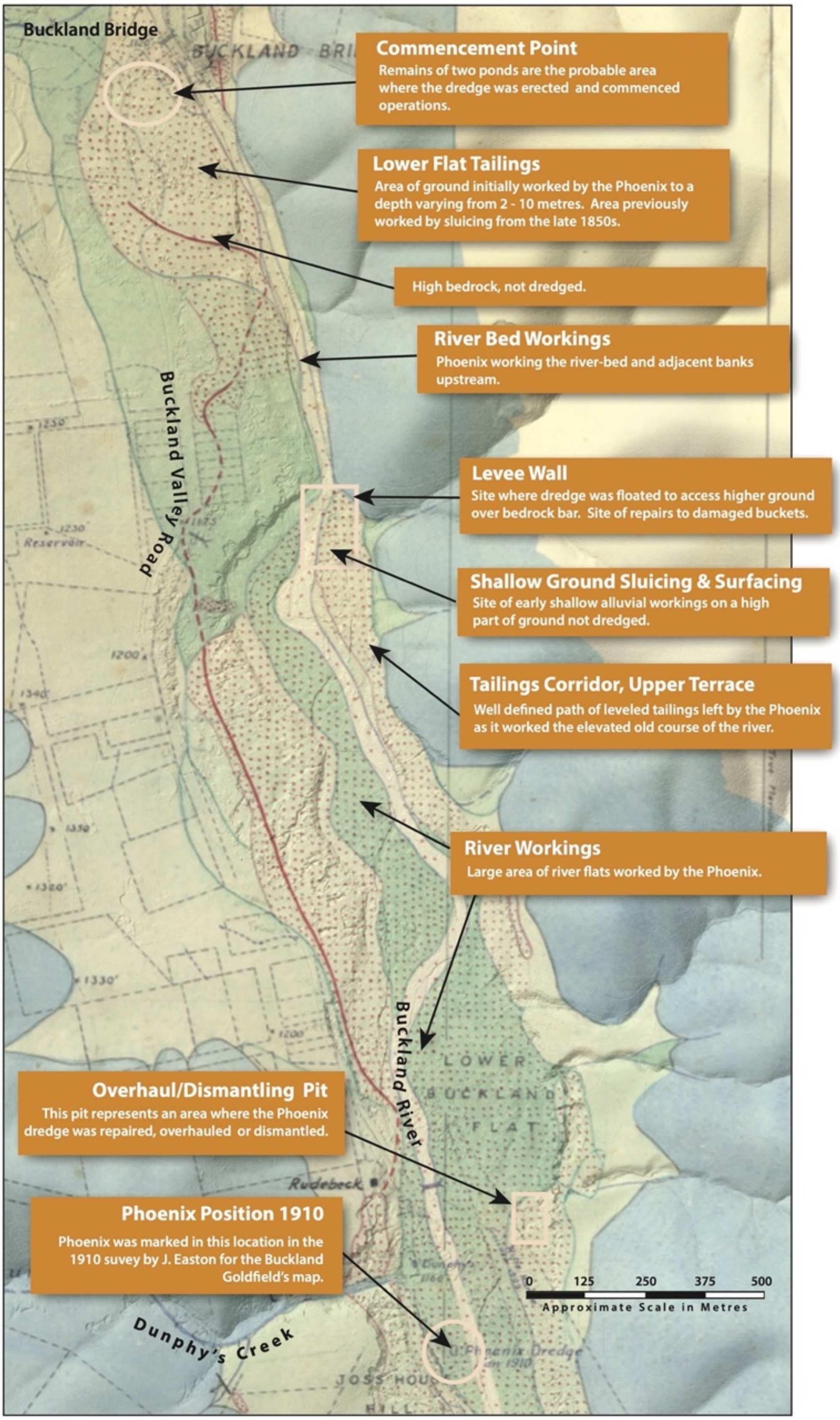


Figure 2.6.3: Easton's 1910 goldfield's map overlay with 70% transparency over LiDAR. This allows for reasonably accurate interpretation of features. Red dotted areas denote gold bearing alluvial gravels mined by sluicing or dredging.

The Phoenix Dredge Mining Landscape:
This landscape contains the near complete course of operations, from a 16-year period of a steam-powered bucket dredge between 1903 to 1919. Through a combination of historic record and images, examination of LIDAR imagery, and followed up with field surveys and inspection, a good understanding of the route and the operations of the dredge can be obtained.

The Phoenix is recorded as having operated upon 140 acres of ground[9], mostly river flats and adjacent banks. Within this varying landscape there are many features that reveal the operations and the range of topography operated upon:

Figure 2.6.4: Dredge pond adjacent to bridge area. Probable commencement point of the Phoenix bucket dredge. 2021

Commencement Pond: Located where the dredge pontoons launched and the super-structure erected. Although the exact position of the commencement pond is not certain, the two probable locations are indicated by shallow excavations that have been partially filled and altered, though are still largely discernible.

Lower Flat Tailings: Immediately adjacent to the bridge is an area of tailings left by the dredge. These tailings have largely been altered by the removal of tailings heaps as resource material for roadworks, etc. The shallower areas in this locality would have initially been sluiced for gold deposits overlaying the bedrock from the mid 1850s. The depth of bedrock at this location is difficult to discern, but could range from 2 to 10 metres. To the south, the bedrock rises, and it appears the area was not dredged.

River-bed Workings: From the lower flat the dredge worked its way upstream, principally working the river bed and it adjacent banks until meeting with the Levee Wall site.

Figure 2.6.5: Upper levee wall of the Phoenix dredge. Used to float the dredge, much like a canal-lock, to a higher elevated level to avoid a shallow bedrock formation.

Levee Wall: This feature facilitated the floating of the Phoenix to a higher level, over a bedrock bar onto an elevated, earlier course of the river. Damaged buckets show the impact of the dredge hitting the natural feature. The dredge would have undergone some repairs to the bucket-band in this location.

Figure 2.6.6: Dredge tailings from upper corridor, with light cover of understory vegetation.

Upper Terrace Workings: This path of the dredge is clearly discernible both on the LiDAR imagery and in the field.

[9] This historic figure reasonably accurately corresponds to the area measured on the LiDAR imagery.

River-bed and bank workings: The historic photographic record shows the dredge operating on large open river flats with many acres of tailings in its wake. The course of the dredge away from the eastern most upper terrace workings, against the eastern range, is not yet clear.[10] From the LiDAR, the dredge appears to have worked its way back downstream at some point, maybe diverting the river course, then perhaps worked its way back up along the original river bed and adjacent, low-lying banks. Much of this ground is likely to have been worked in the earlier days of the field, possibly by the Chinese miners living in the adjacent Macao camp.

Wood-Fuel Network: On the eastern range, above Phoenix workings is a network of water races that supplied water for a range of alluvial mining types and claims over many decades. Some of these races were abandoned at the time of the dredge operations. It appears as though sections of water race ditches were filled to facilitate the cartage of wood-fuel timber, via horse-drawn carts to feed the boiler of the dredge.

Water Race: Additional water may have been supplied to the dredge operations via one of these water races. This may have been used for maintaining pondage levels whilst operating on the upper terrace workings and/or for the removal of tailings.

Figure 2.6.7: Stone retained water race in Lamber's Creek above dredge workings. 2022.

[10] Determining the specific geographic areas worked by any one dredge can be a challenging research project. Use of contemporary photography, goldfield maps, LiDAR imagery, lease plans and field inspections are principal resources. A more thorough research project into bucket dredging would help give more definitive answers to the many questions that research into this topic presents.

Maintenance/Dismantling Pit: This site is probably the position where the dredge underwent a significant overhaul. The position of the excavated rectangular shaped pit, outlining the probable footprint of the dredge pontons. Adjoining the pit is associated sundry metal-work and 25mm diameter wire-rope, suggesting a repair or even dismantling site.

Significance

In conjunction with the historic record, traditional field survey and assessments, the LiDAR imagery significantly informs the assessment and interpretation of heritage values of the mining landscape.

Interpretation of the LiDAR features, clearly shows the near complete timeline of events of the Phoenix dredge; from its initial construction and launch in 1903, thorough to potentially the final dismantling site in 1919. The landscape contains a variety of bucket dredge mining features in a broad area of re-growth forest. These features demonstrate high technological significance, particularly demonstrated by the levee wall, as well as high archaeological potential in sites such as the overhaul or dismantling pit.

2.7. Red Jacket Quartz Reef Workings: *Overlays - Underground Plans*

The Red Jacket reef was discovered in 1867 in Clear Creek. The mine was worked by expensive adit levels with ore transported to a steam-powered battery on the creek flat below via a series of tramways. The recorded production for the first five years was 7,496 ounces of gold from 5,645 tons of ore.

In 1875, a third, lower-level tunnel reached the reef. The stone appears to have been poor and nothing is recorded on the mine for the rest of the decade.

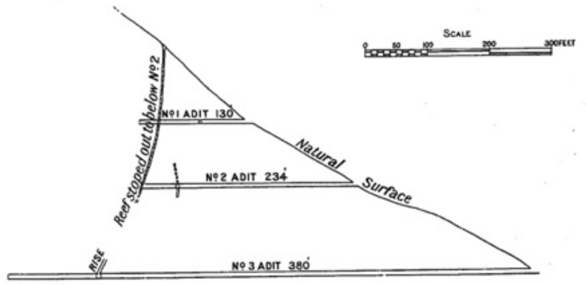


Figure 2.7.1: Red Jacket, mine plan section showing main adit levels. Easton, 1912, Geological Survey of Victoria.

In 1899, after years of numerous parties fruitlessly attempting to re-work the mine, a payable reef was discovered in the No. 2 adit level. The first crushing of 3 tons produced 26 ounces of gold. Work continued making small yet profitable crushings up until 1904. This period produced 526 ounces from 305 ½ tons of stone.

Figure 2.7.2: No.3 Level mullock, Red Jacket. B. Jones, 2007.

The Red Jacket was taken up in 1936 and was still working in 1939 when the battery and buildings were destroyed by the Black Friday bushfires. The mine then appears to have been abandoned.[11]

The surface features of the Red Jacket include;

- Three main adit levels and associated mullock dumps
- Surface workings
- Tramway and track network
- Battery sites
- Associated buildings, miners' huts and blacksmith sites

LiDAR shows many of these features, providing a clear understanding as to the extent of the sites features on the surface. However, in quartz reef mining, the majority of work occurred beneath the ground surface.

Understanding the extent of hidden underground workings and their context with the surface features of a site is generally not always possible. Undertaking subterranean feature surveys offers many occupational health and safety issues and is generally out of the question.

When available, historic underground plans of mine workings offer important contextual information to surface features.

[11] *Talbot, D. & Swift, A, The Buckland Valley Goldfield, 2004.*
Kaufman, R & Swift, A, Historic Mining Sites Survey, Buckland Valley, Bushfire Recovery Program, Parks Victoria, Dept. Sustainability & Environment. July 2004.

Underground Mine Plan Overlays

Overlaying of historic underground mine plans can be a useful tool in understanding the extents and scale of historic mining activity. This can provide important context when evaluating and assessing the cultural significance of a particular site or landscape.[12]

An overlay of a historic underground mine plan and surface LiDAR features can help interpret or identify on-ground features. They can also give a good practical understanding of the actual scale and extent of subterranean workings.

This application can have many benefits, in particular when locating potential historic mine hazards and associated surface features.

Figure 2.7.3: No.3 adit level portal. -B. Jones 2007.

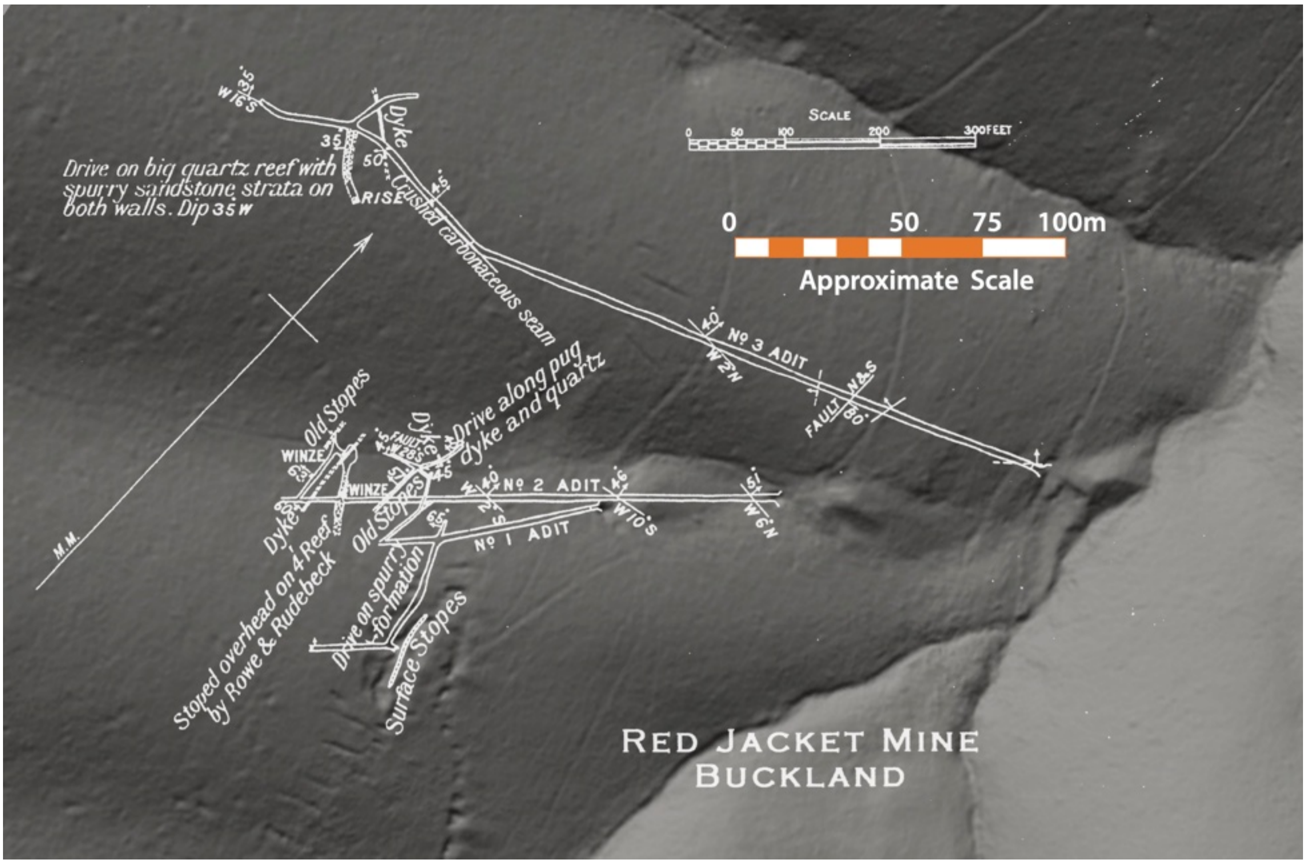
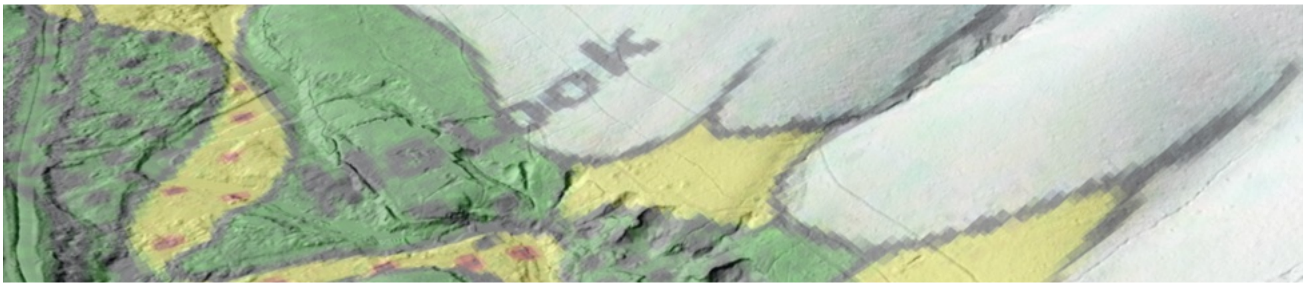


Figure 2.7.4: Red Jacket mine plans, overlay on LiDAR. Easton, 1912, Geological Survey of Victoria.

[12] The next step would be to undertake underground three-dimensional LiDAR mapping of accessible workings, providing a useful tool in understanding the history of a site.



3. Summary

The benefits of LiDAR to understanding our historic landscapes are many. More specifically, there are many advantages for land management agencies to better understand and manage our historic places.

3.1. General Heritage Management Applications and Opportunities

LiDAR has many potential cultural heritage management benefits and opportunities. Some of which may include:

- Preliminary desktop assessments of potential heritage values and archaeological sites within a specific geographic area.
- Specific targeting of unknown or potential historic and archaeological sites.
- Overcoming accessibility limitations, particularly with thick vegetation cover, such as blackberries, or heavy bushfire regrowth is an issue.
- Cultural Heritage Management - LiDAR can effectively assist government and industry to manage historical/archaeological sites and natural environments.
- Providing base data for assessing and measuring future impacts (*such as extreme climate events, including bushfires and flooding*) to heritage sites by comparison to before and after data.
- Site Presentation - LiDAR imagery brings a new level of accessibility and understanding to otherwise remote or inaccessible places to a new (*Public*) audience.
- Cultural Heritage Significance: LiDAR Imagery can provide a broader understanding and interpretation of the historic landscape. Providing a greater context between individual sites and broader historic landscape. Giving a greater understanding of the significance of a site.
- Assist in determining impacts to original ground surfaces and extent of ground disturbance to inform Aboriginal cultural heritage management processes.

Heritage Management Strategies

Prioritization of future heritage works, including,

- Priorities for heritage surveys and assessments
- Conservation, preservation or mitigation works
- Presentation and interpretation opportunities
- Priorities for public protection works, i.e. fencing of mine shafts.

Assessment of significance of heritage and archaeological sites.

The use of LiDAR imagery will assist greatly with the assessment of the cultural significance of historic and archaeological sites.

- Understanding type of site
- Characteristics
- Extent of site
- Assisting with the comparative analysis of similar/adjoining sites

Site Monitoring

LiDAR could greatly assist the periodical monitoring of vulnerable historic landscapes, significant site, or in areas more prone to extreme climatic events; such as sites along major waterways or in bushfire effected steep mountainous landscapes.

Digital Record
It can be taken for granted that historical archaeological places in our forest will be there indefinitely. However, natural disasters, such as bushfires and post-bushfire erosion events have caused many sites to be destroyed. Digital three-dimensional LiDAR models of historic landscapes in our crown land reserves are an important record. It will be increasingly important to have a digital record of these important landscapes into the future, to create a high-resolution baseline record of significant historic areas. Areas of subsequent extreme natural events can ultimately be rescanned to measure against the original data and quantify, evaluate and understand impacts on our historic archaeological landscapes.

Other Benefits of LiDAR
Outside the historic archaeological field, LiDAR has many possibilities and benefits.

- **Bushfire Management** - identifying historic bushfire management activity, such as previous earthworks associated with bushfire management activities, such as planed burns, fire-breaks and containment works.
- **Risk Management and Assessment -** Assistance with the identification of hidden hazards associated with legacy historic mine workings including mine shafts, steep banks, quarries and surface stopes.
- **Historic Land Use -**Identification of areas of historic land use and extents of ground disturbance.
- **Outside Heritage** - Data sets can be used to study forest ecology, hydrology and geology. There are also many unknown future applications.

LiDAR Capturing Opportunities:
Ideal or optimum times for acquiring LiDAR data in mountainous regions of Victoria would be during the winter months, when vegetation cover is generally lighter and penetration through understory would be reasonably greater. Acquiring of LiDAR, immediately after bushfire events and before any heavy rainfall events would be of a maximum benefit for a high-quality data-set.

3.2. LiDAR use in the Field
There are numerous ways in which LiDAR data can be used in the field to accurately target predetermined features. Georeferenced LiDAR imagery can be used in much the same way a handheld GPS unit. Georeferenced PDF maps or other mapping software are readily available. Public access to high resolution LiDAR imagery of Victoria at this time is very limited.

3.3. Research Opportunities
Analysis of LiDAR data in conjunction with the historic record, provides many opportunities to expand our knowledge of the many mountainous historic archaeological sites across Victoria.

- Potential to discover new sites to add to the record as well as gain a better understanding of known sites.
- Broader Analysis of the mountain goldfields and their remnant features.
- Production of a detailed district goldfields maps, highlighting key historical locations.

3.4. Limitations
Despite the many benefits of LiDAR, there are some minor limitations that should be considered.

- **Digital Noise**: Subtle historic and archaeological features may not necessarily appear in LiDAR imagery, whilst some features could be misinterpreted where areas of image have a lot of digital noise. Final assessments of archaeological and historic sites should ultimately be determined through field survey and ground-truthing.

- **Resolution**: The processing of the data and the its resolution can greatly influence the subsequent analysis of historic features. Initial algorithms and analysis can inadvertently remove sharp angular structures, such as historic chimneys and walls. This can lead to confusion, or even the overlooking of important historic sites. This highlights the importance of ground truthing where sharp angular features occur in the LiDAR set.

3.5. Responsibilities

The LiDAR data that captures the footprint of archaeological sites has many positive applications. It can, however, reveal what has been unintentionally protected and hidden by heavy vegetation for many years. The inappropriate use of this data, could potentially lead to sites being targeted by treasure hunters, ultimately damaging or destroying heritage values. Any actively promoted public access to LiDAR imagery should consider some form of management protection strategy of historic places. Such as;

- Promotion of the importance of these places to the local and broader community.
- Monitoring of vulnerable historical archaeological sites.
- Awareness of land management responsibilities in regard to the *Heritage Act 2017*.

Appendix 1. Mining Feature Types - Identification Guide

The identification of archaeological mining features and types in LiDAR imagery can be readily gained with a basic understanding of the features' form or signature, its particular construction and use, and its context with other features. Along with a little field experience the identification of individual features and the interpretation of a site's context with adjacent features and topography is relatively straight forward.

The basic features identified in the Buckland LiDAR project can be identified in following general categories;

Alluvial Mining Features

Shallow Ground Surfacing or Sluicing

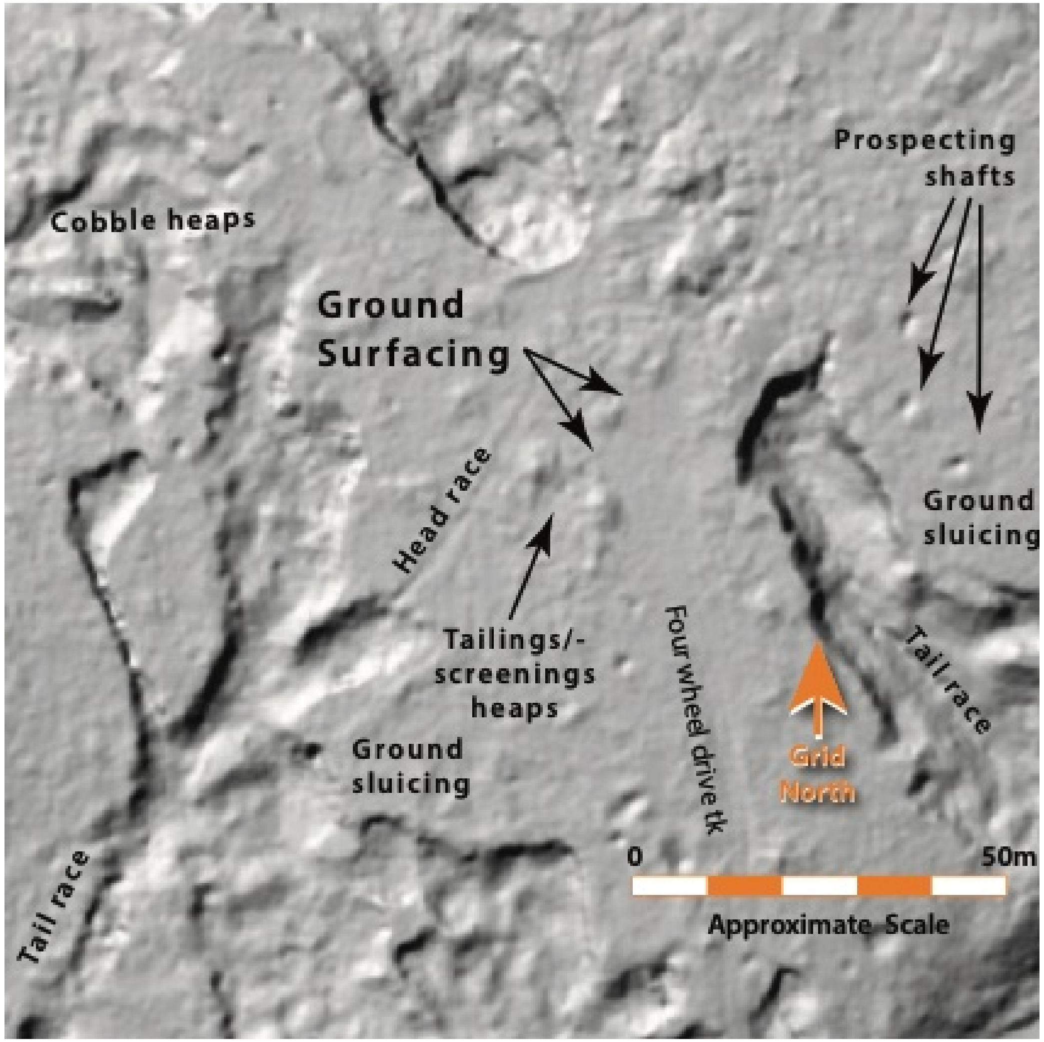
Description: Use of low-pressure water via ditches, head races, or water races, to break down and remove overburden and auriferous gravels. This method also utilised manual labour to break down surface material and rake or barrow to sluice boxes or cradles for gold extraction.

Physical Characteristics: Generally, ground surface is stripped back to expose bedrock. Surface deposits were originally the result of old stream courses or flooding. Small mounds of screenings or washed gravels where tub and cradles, or temporary sluice boxes may have been used. Some surfacing deposits were directly eroding from quartz reefs. These types of workings were usually worked with smaller parties or individuals.

Associated Archaeological Features: Often found adjacent to deeper ground sluicing sites. Water races, head races & tailraces, associated occupation sites. tailings and screenings.

General Topographic & Geological Context: Sloping undulating hillsides, often adjacent to waterways and shallow ground sluiced areas. Working of old/ancient stream courses generally buried by very shallow post drift or overburden.

Image: Anderson's Flat at Clear Creek junction with Buckland River.



Ground Sluicing Pit or Paddock

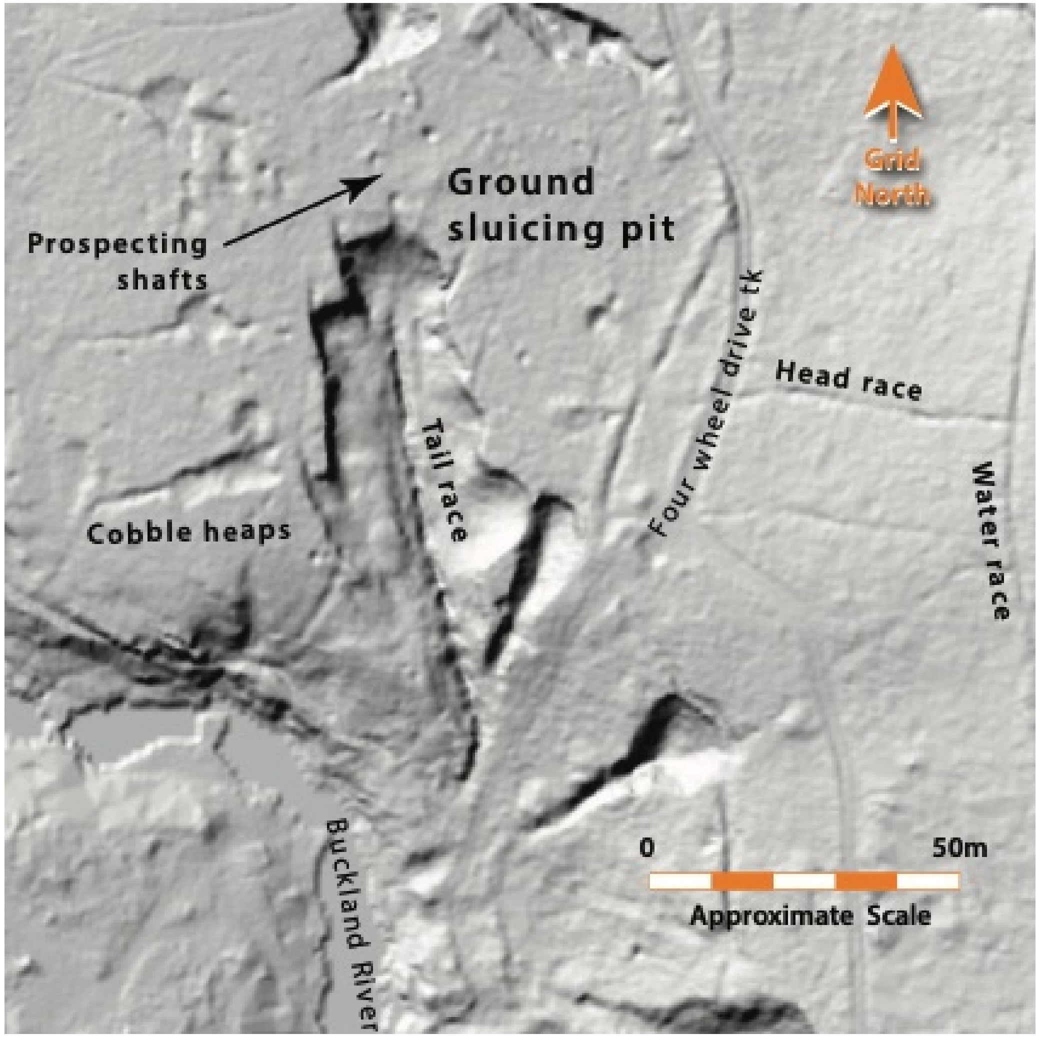
Description: Use of low-pressure water via shallow ditches, head races and/or water races. Directly run over bank to break down and remove overburden and auriferous gravels. Sometimes low pressure, canvas hoses were used in early claims. Gold recovery in sluice boxes often located in tail race cuttings. Often referred to as '*Bank Sluicing Claims*'. Generally worked by smaller parties of individuals or small companies.

Physical Characteristics: Generally shallower pits than hydraulic sluicing pits with steep earth banks. Large tailings mounds and cobble heaps formed around tail races.

Associated Archaeological Features: Water races, head races & tailraces, tailings and cobble heaps, associated occupation sites and mine buildings.

General Topographic & Geological Context: Sloping undulating hillsides, often adjacent to waterways. Working of old/ancient stream courses generally buried by post drift or overburden.

Image: Ma Looks Flat, on eastern side of Buckland River. Smaller sluicing pit with cobble heaps. Main drainage tail race running in a southerly direction.



Hydraulic (High-pressure) Sluicing Pit or Paddock

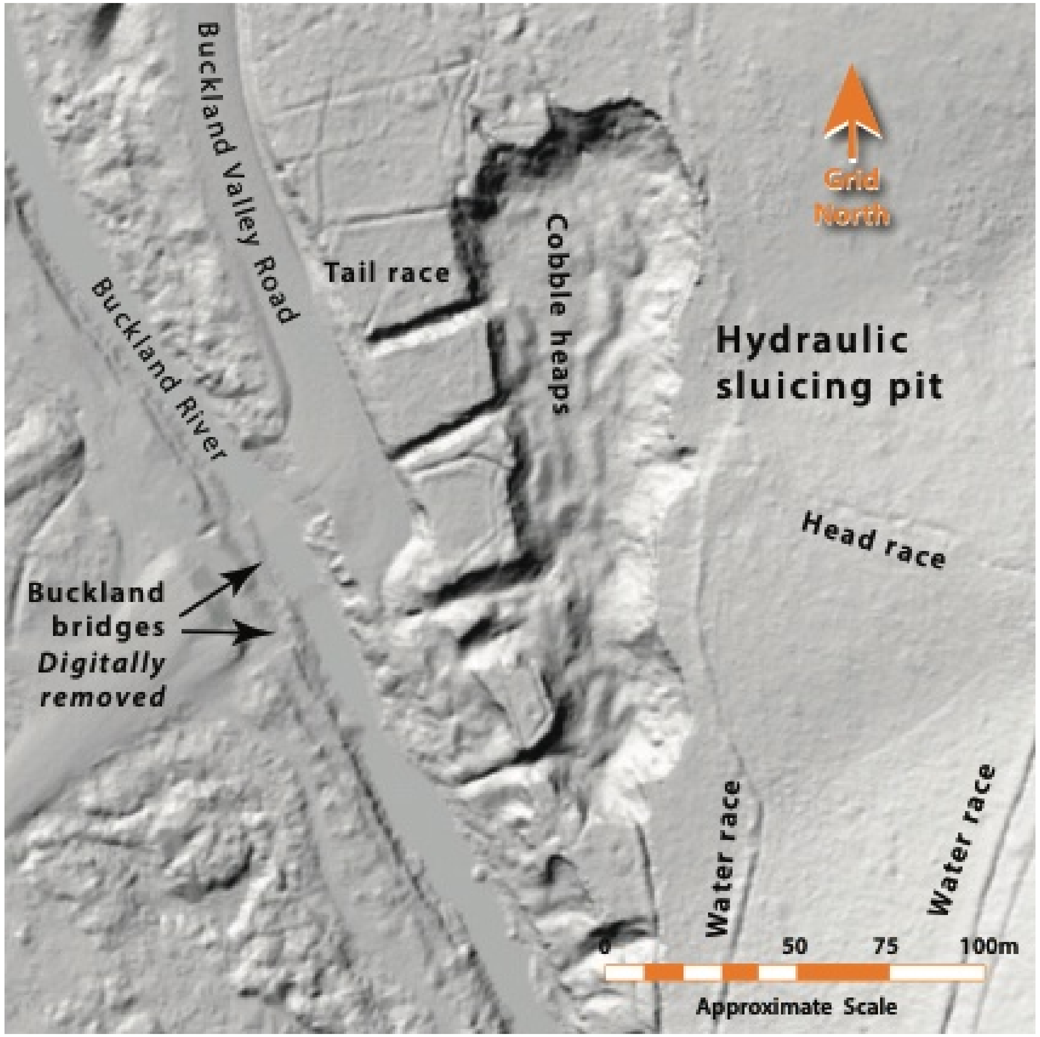
Description: Use of high-pressure water via steel pipes or similar from water races to breakdown and remover overburden and auriferous gravels. Gold recovery in sluice boxes often located in tail race cuttings. Technology came into use from the early 1880s on the Victorian goldfields. Generally, more capital heavy and worked by small or large companies.

Physical Characteristics: Larger and generally deeper pits with steep earth banks. Large tailings mounds and cobble heaps formed around tail races or elevator sump.

Associated Archaeological Features: High elevation water races, head races & tailraces, associated occupation sites and mine buildings.

General Topographic & Geological Context: Sloping undulating hillsides, often adjacent to waterways. Working of old/ancient stream courses generally buried by post drift or overburden.

Image: Immediately east of Buckland Bridge. Large sluicing pit with cobble heaps. Drainage tail races on western side of pit.



Alluvial Shaft Round/rectangular

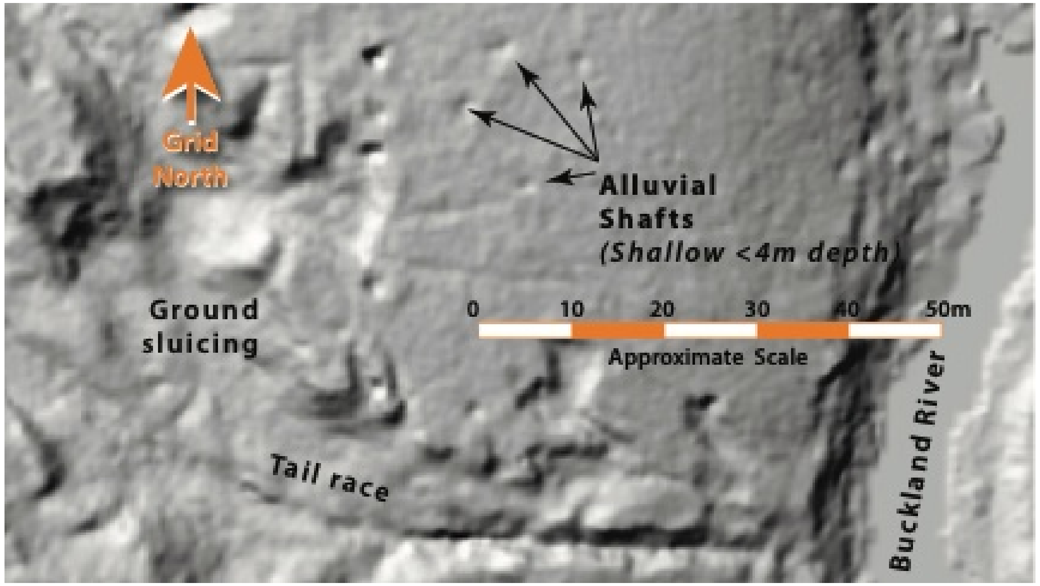
Description: Sinking of shafts to test depths and values of buried gravels, usually preparatory to mining by sluicing. Sometimes shafts were also used to extract or mine gravels. Large mullock dumps can indicate extent of underground mine workings and the amount of barren or waste rock required to be removed before reaching auriferous gravels. Worked by individuals, small parties and companies.

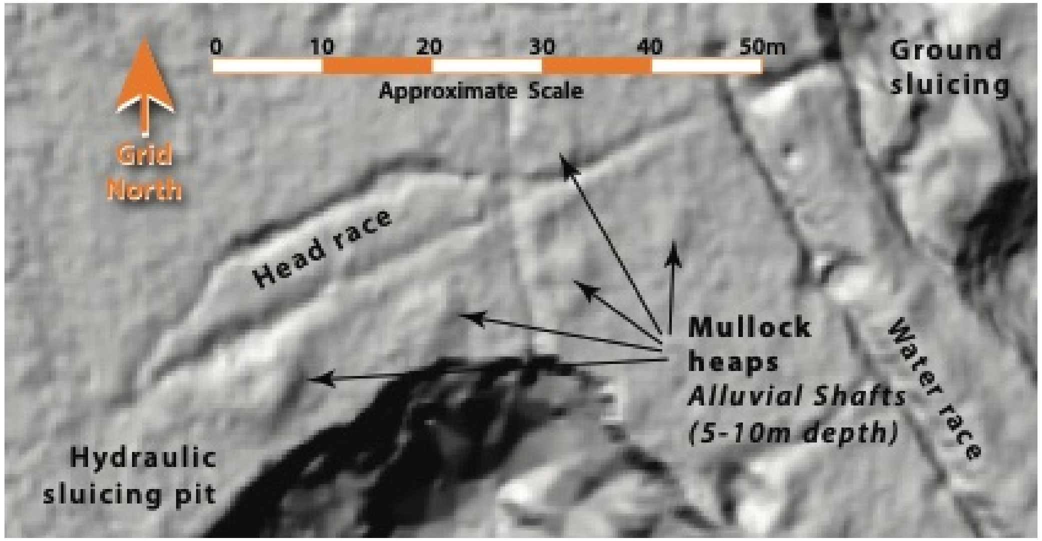
Physical Characteristics: Sometimes identified by mullock dumps, other times not. Rehabilitated shafts may have been filled with mullock, but still continue to subside, with little evidence apparent on surface. Types of mullock heaps or dumps may indicate method of haulage such as hand-whip, windlass, horse-whip or whim. Usually the mullock helps identify the position of the shaft, sometime the hole is a small black dot.

Associated Archaeological Features: Adjacent to ground or hydraulic sluicing pits. Sometimes occupation sites nearby.

General Topographic & Geological Context: Often adjacent to waterways on river flats or adjacent hillsides. Working of old/ancient stream courses generally buried by post drift or overburden.

Image: Allen's Flat, adjacent to large hydraulic sluicing pit.





Alluvial Drive, Adit or Tunnel

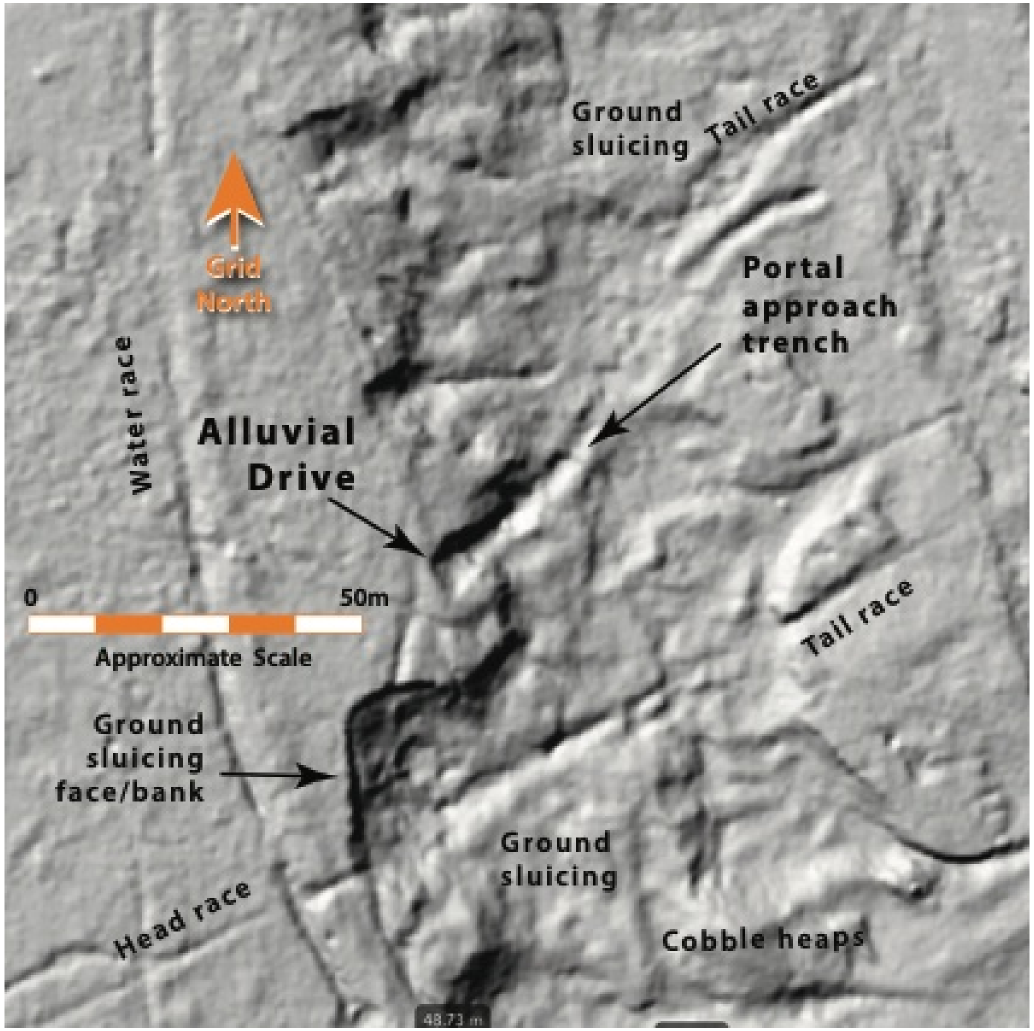
Description: A horizontal tunnel driven beneath over burden, (sometimes through bedrock) to access ancient buried auriferous gravels, that were usually too deep to access by sluicing. In some instances, can pre-date the introduction of hydraulic sluicing technology.

Physical Characteristics: Often in sluiced areas where gravels have been too difficult to access by sluicing. Tunnel portals can be found in sluiced banks. Often a portal approach trench is evident. Sometime a mullock dump or dumping line of broken slates or gravels is evident when drive has been driven through bedrock. Often difficult to discern amidst 'busy' sluice tailings.

Associated Archaeological Features: Mullock dumps, blacksmith site, processing or sluicing area. Sometimes occupation sites nearby.

General Topographic & Geological Context: Often adjacent to waterways on river flats or adjacent hillsides. Working of old/ancient stream courses generally buried by post drift or overburden.

Image: Allen's Flat, banks/ground sluicing workings.



Bucket Dredging

Dredge Tailings Areas & Corridors

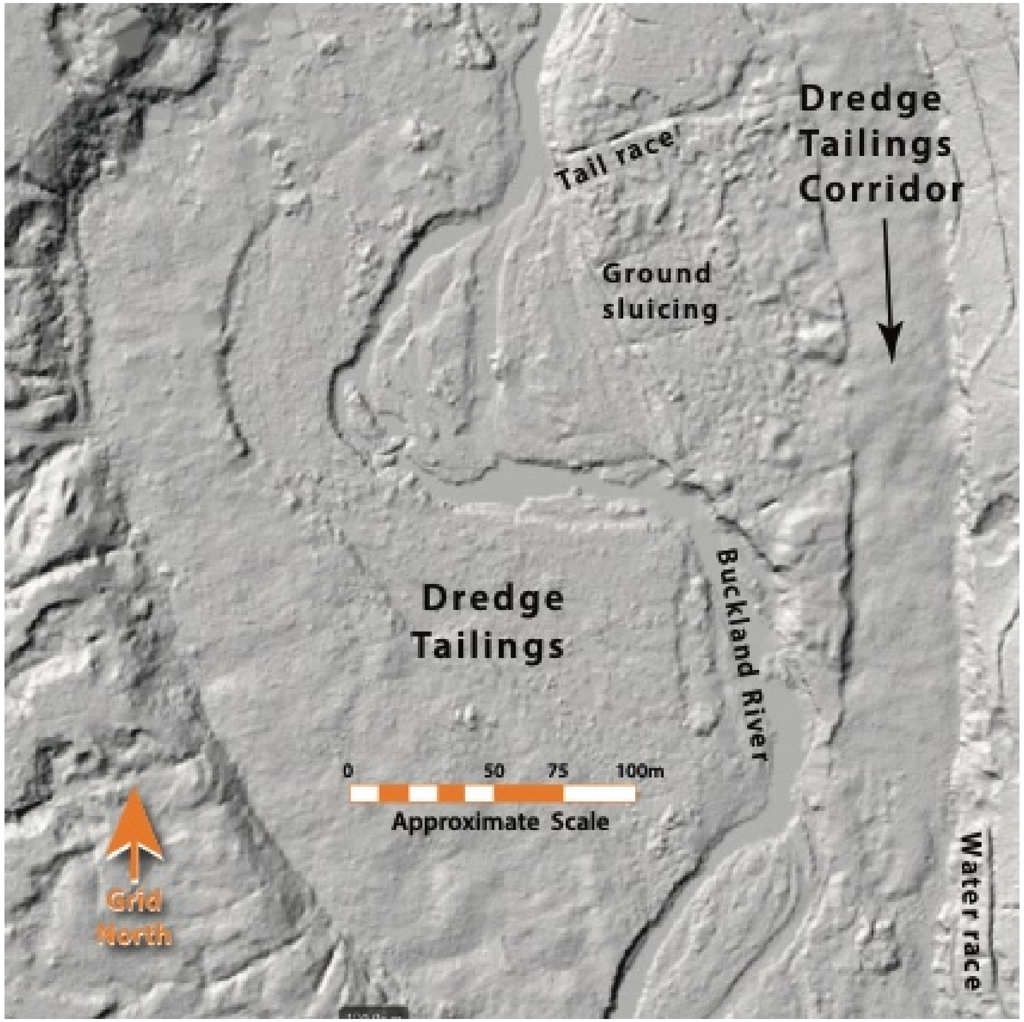
Description: The path through which a bucket dredge has passed. Working gravels towards the front and leaving a trail of screened and washed gravels in its wake. Often graded to regular sizes depending upon method of 'stacking' used by dredge.

Physical Characteristics: Generally flat level area. On-ground washed gravels, sometimes screened or graded to regular sizes.

Associated Archaeological Features: Water races, tailings heaps, dredge ponds or holes, repair sites and discarded components such as wire rope or cable and damaged dredge buckets.

General Topographic & Geological Context
Often in previously sluiced landscapes. In or adjacent to waterways or on broader open alluvial river plains.

Image: Lower Buckland, site of Phoenix bucket dredge operations, circa 1903. Left of image shows broad sluiced flats directly adjacent to river. Far right show dredge corridor through previously sluiced areas against side of hill.



Dredge Levee Wall

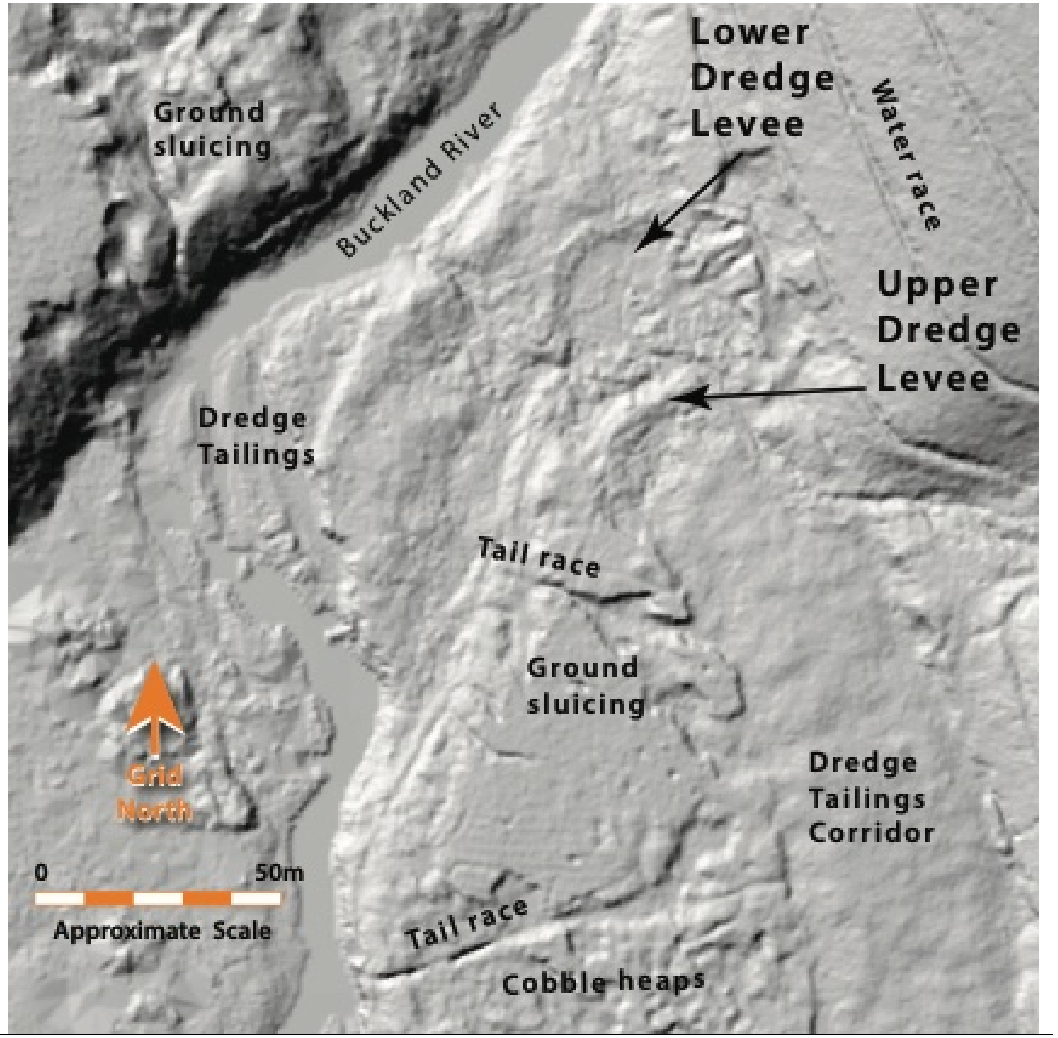
Description: Location where a dredge was floated to gain height to navigate obstacles such as shallow bedrock bar. Similar to a shipping lock.

Physical Characteristics: Earth or rock mounded walls, situated amongst dredge tailings corridor. Often found in narrower valleys.

Associated Archaeological Features: Water races, tailings heaps, dredge ponds or holes, repair sites and discarded components such as wire rope or cable and damaged dredge buckets.

General Topographic & Geological Context
Often in previously sluiced landscapes. Adjacent to waterways or on broader open alluvial river plains. Often found in narrow valleys.

Image: Lower Buckland, site of Phoenix bucket dredge operations, circa 1903. Location where dredge shifted operation from the bed of the river to the eastern river flats against the hill. Area previously worked by shallow sluicing operations.



Dredge Overhaul Site

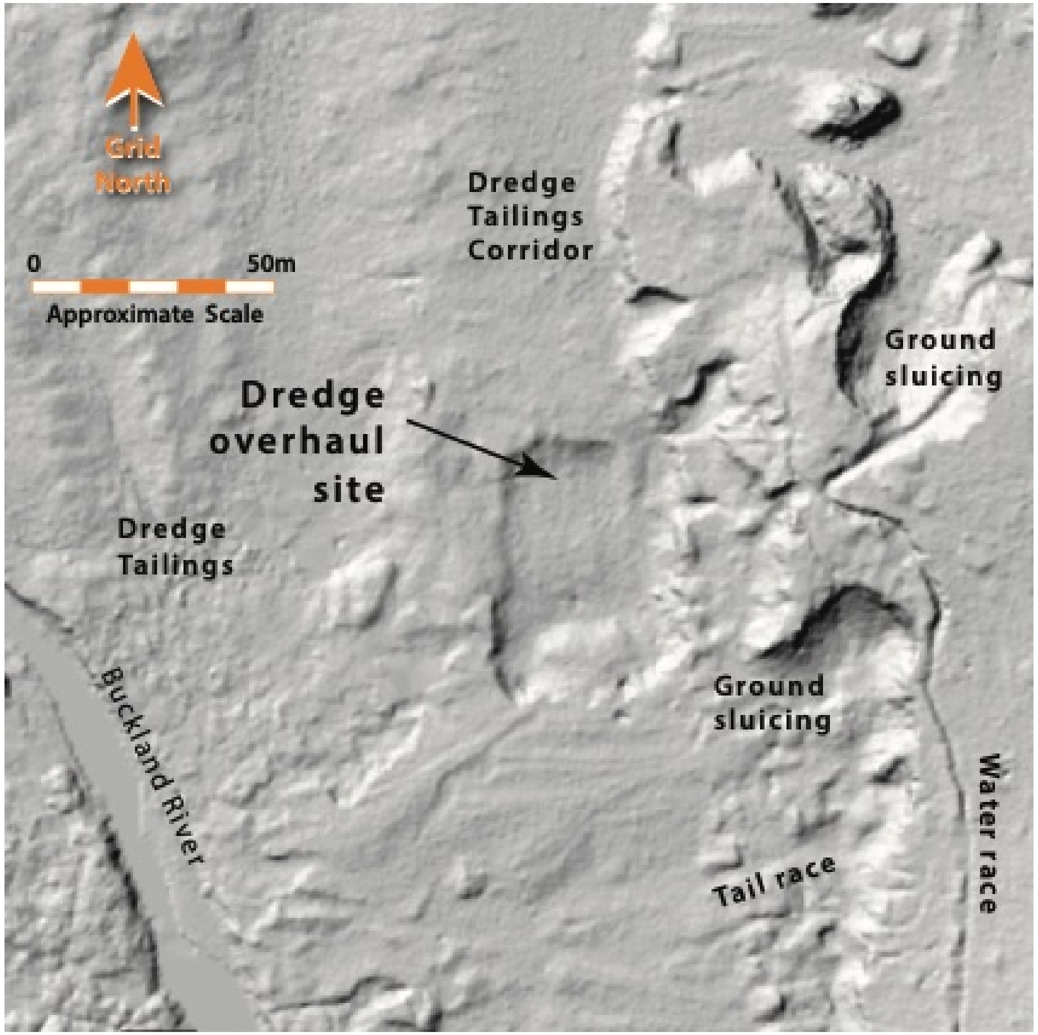
Description: Location where a dredge was dry-docked or moored to facilitate maintenance to its pontoons or superstructure, or to be dismantled.

Physical Characteristics: Defined rectangular shape or outline of dredge where moored.

Associated Archaeological Features: Water races, tailings heaps, dredge ponds or holes, repair sites and discarded components such as wire rope or cable and damaged dredge machinery components. May also be a dray road present along which components were transported.

General Topographic & Geological Context
Often in previously sluiced landscapes. Adjacent to waterways or on broader open alluvial river plains.

Image: Lower Buckland, site of Phoenix bucket dredge operations, circa 1903. Location where dredge may have been overhauled or possibly dismantled.



Quartz Reef (Hard-rock) Mining

Stopes & Surface Workings

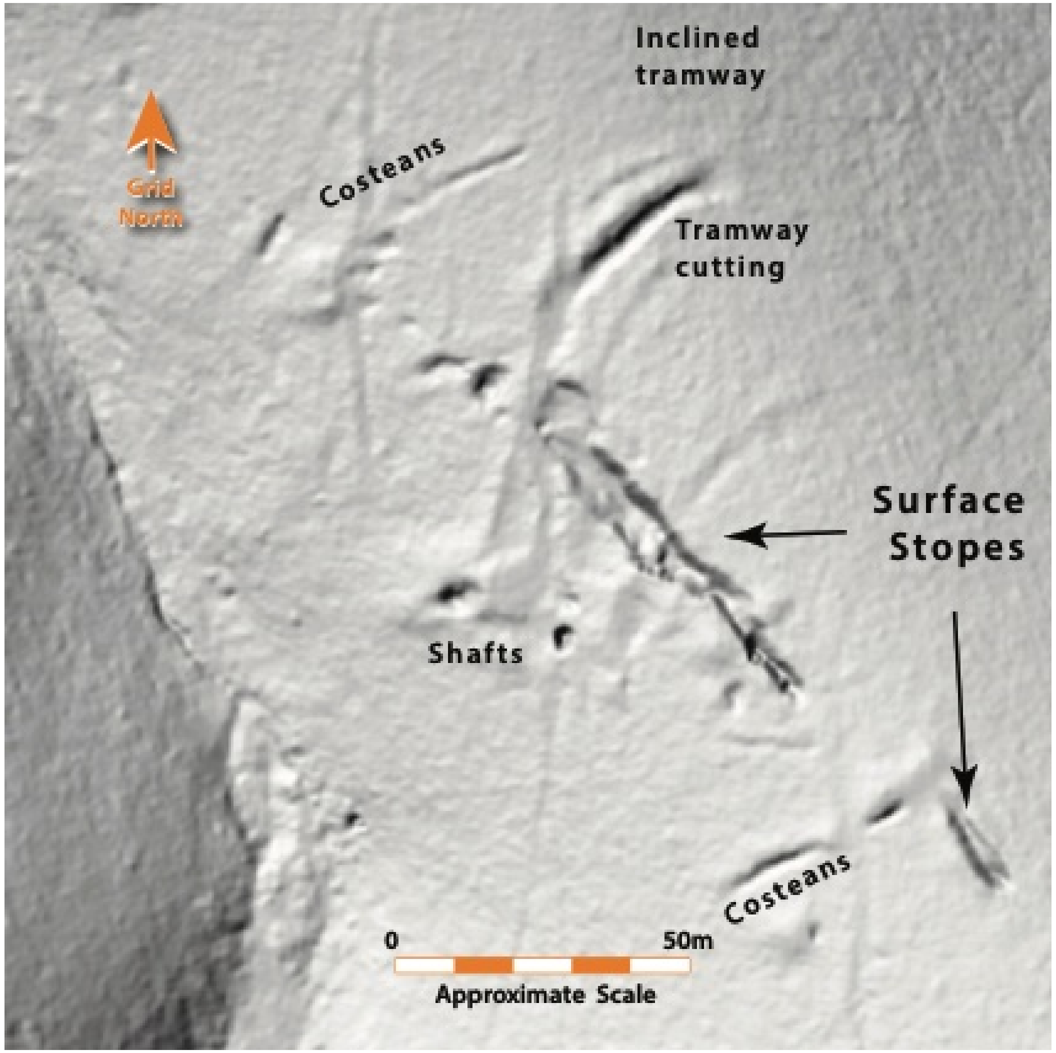
Description: Location where gold-bearing reef or shoot outcropped on the surface of the ground. Site of initial prospecting and working of reef usually by open quarrying and sinking of shafts.

Physical Characteristics: Open, often steep sided pits, and/or shafts. Depending on size of reef and payable nature of stone could vary greatly in width, length and depth. Mullock dumps usually located on downhill side depending upon method of ore extraction.

Associated Archaeological Features/Networks: Quarries, pits, costeans, trenches, shafts, adits and associated mullock dumps, quartz paddocks and transfer sites. Infrastructure such as haulage sites, tramways, blacksmiths and workshop sites, occupation areas and associated mining camps. Quartz processing and crushing sites. Access tracks and water races.

General Topographic & Geological Context: Located in a diverse range of topographical settings; from the tops or ranges and in the beds or streams and rivers.

Image: Nelson Reef surface workings on the west branch of the Buckland. Open stope and shafts.



Adits & Mullock Dumps

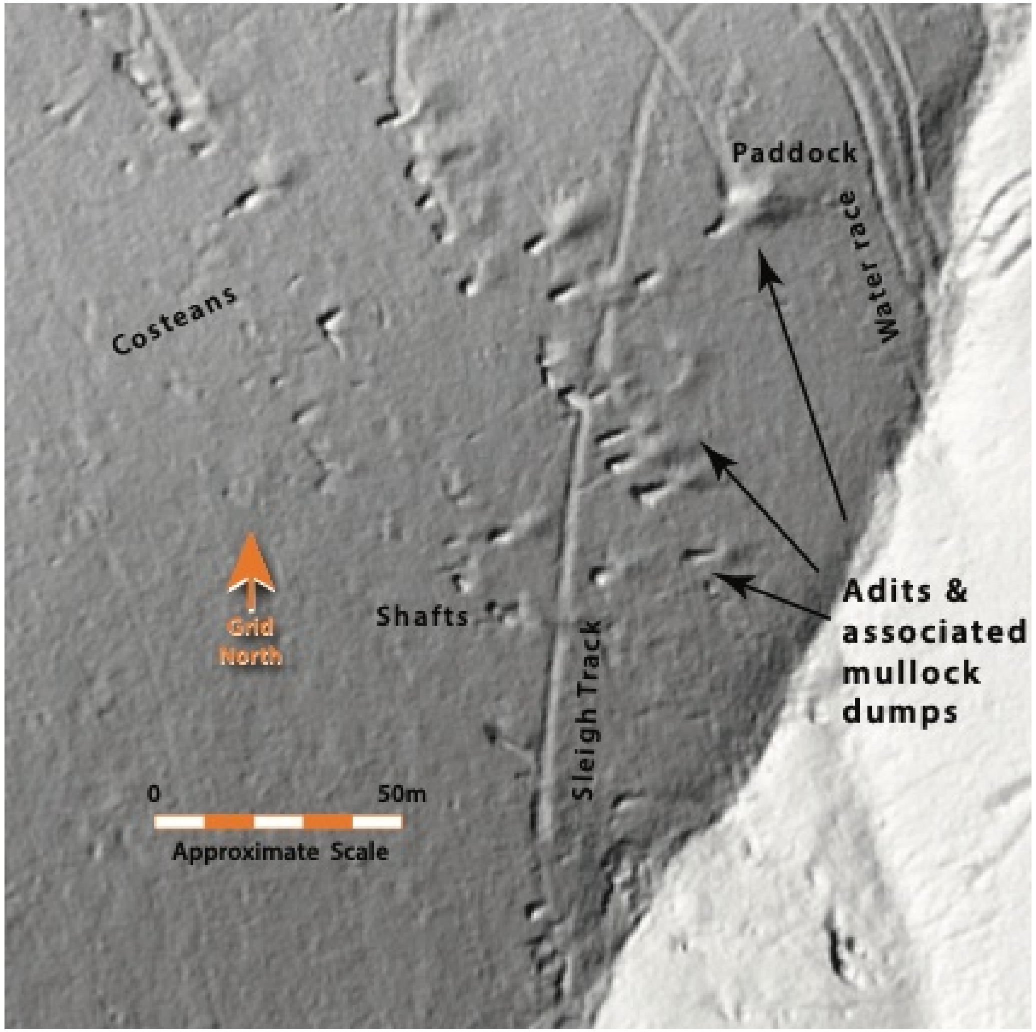
Description: A horizontal tunnel driven from the surface to access a gold-bearing shoot or reef at a greater depth than the surface workings. The waste rock from the tunnelling process is dumped outside the adit portal, usually via a small tramline.

Physical Characteristics: Adit portal is often indicated by a small dark point. An access approach trench is also often apparent. The mullock can be in the form of single or multiple dumping lines, formed by the positions of tramways.

Associated Archaeological Features/Networks: Quarries, pits costeans/trenches, shafts, additional adits levels and associated mullock dumps, quartz paddocks and transfer sites. Infrastructure such as haulage sites, tramways, blacksmiths and workshop sites, occupation areas and associated mining camps. Quartz processing and crushing sites. Access tracks and water races.

General Topographic & Geological Context: Located in a diverse range of topographical settings; from the tops of ranges and in the beds or streams and rivers.

Image: Murdock reef workings, showing a series of adits, mullock dumps and connecting sleigh tracks shafts.



Quartz Paddock & Transfer Areas

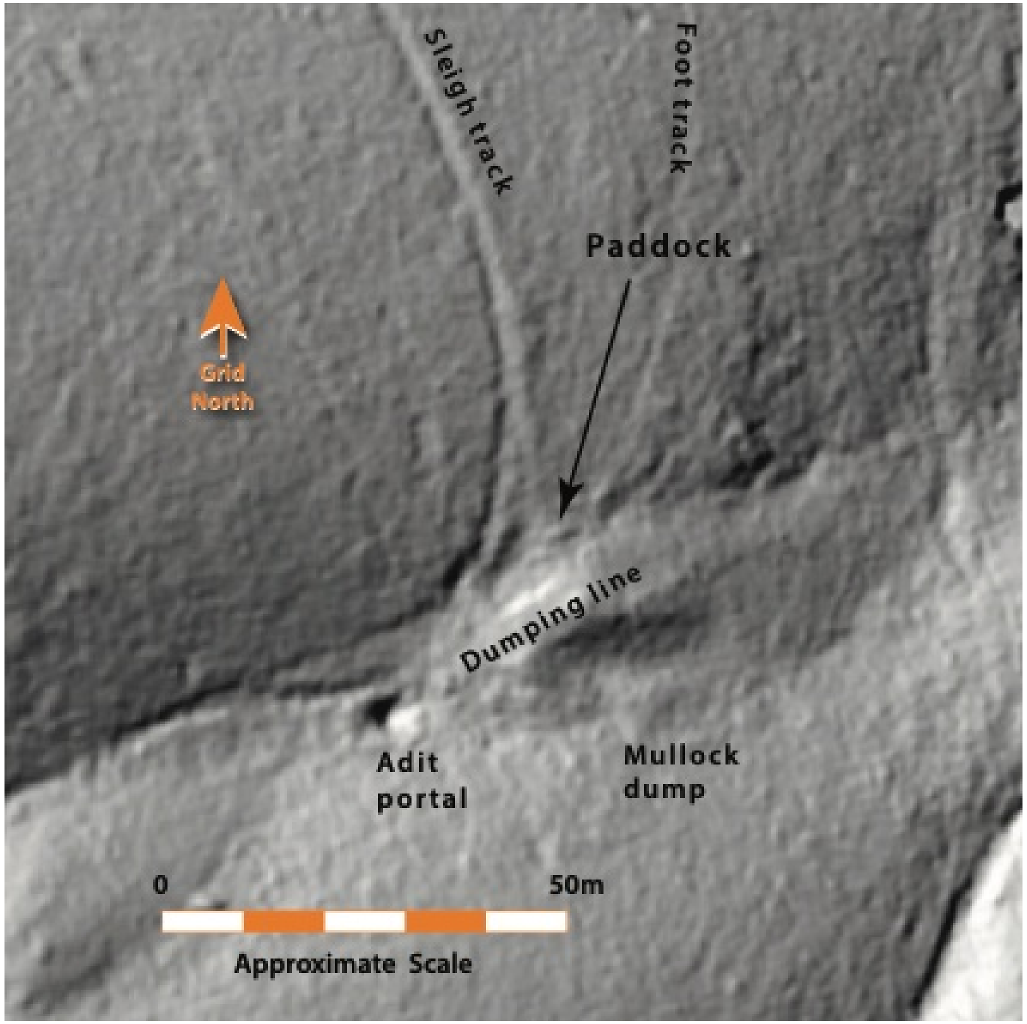
Description: A location, usually outside an adit portal and formed by part of a mullock dump. Location where gold-bearing quartz, or ore, was stored or 'paddocked' until it was transported to be crushed. This feature usually represents a mine that has had some reasonable level of gold production.

Physical Characteristics: A dark area outside an adit and forming part of a mullock dump. The paddock will be connected by a dray or sleigh track for transportation to a mill for crushing.

Associated Archaeological Features/Networks: Quarries' pits costeans/trenches, shafts, additional adits levels and associated mullock dumps, quartz paddocks and transfer sites. Infrastructure such as haulage sites, tramways, blacksmiths and workshop sites, occupation areas and associated mining camps. Quartz processing and crushing sites. Access tracks and water races.

General Topographic & Geological Context: Located in a diverse range of topographical settings; from the tops of ranges and in the beds or streams and rivers.

Image: Red Jacket reef, No.2 level adit. Rock lined paddock with sleigh track leading away from feature.



Quartz Mill Battery Sites Pelton-wheel - Powered

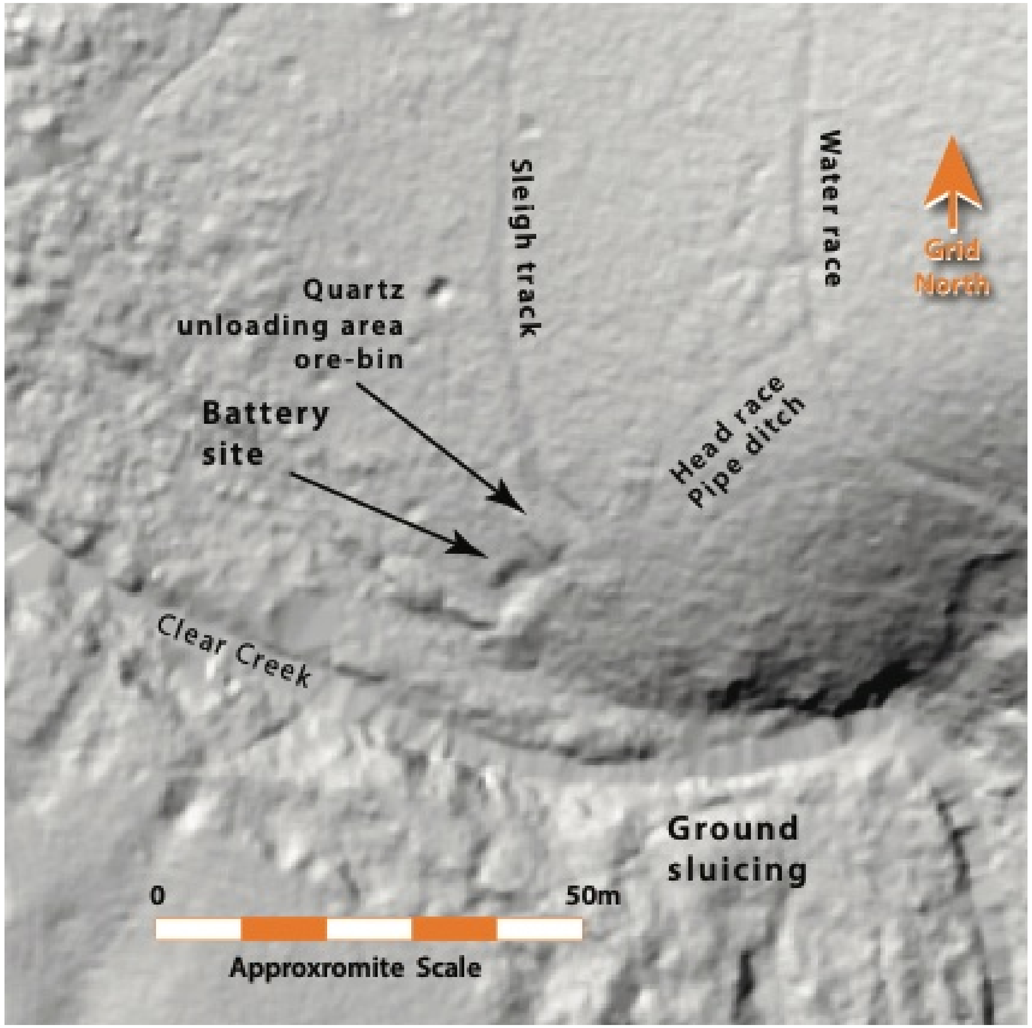
Description: A location where ore was crushed to extract gold. Primary method of crushing was the stamp battery, secondary processes may have occurred in the form of Chilean mills, etc. Gold recovery usually included amalgamation tables. Motive power varied on the Buckland. From the late 1880s, Pelton, turbine wheels were used. High pressure water, directed into steel pipes from a high elevation water race, was directed onto a small diameter wheel with cups or paddles providing power to operate machinery.

Physical Characteristics: Usually a benched pad with a quartz unloading area above, sometimes with an intermediate level being the site of an ore-storage bin. Building connected to workings via tramways or sleigh or dray tracks. Mortar box positions are often indicated by bedlog pits, sometimes still with tie-down bolts in situ. Pelton wheel driven batteries have a high elevation water race above the site.

Associated Archaeological Features/Networks: Tramways, dray and sleigh tracks, water races. Outbuildings and occupation sites. Sand heaps, cyanide works, quartz holding paddocks, additional recovery plants, smelting and refractory furnaces, blacksmith hearths.

General Topographic & Geological Context: Usually located within close access to good supplies of water.

Image: Red, white & Blue battery site on Clear Creek. High level water race above connected by faint trench being the site of the main feed pipe. Dray/sleigh track from mine bringing stone to above site.



Quartz Mill Battery Sites - Waterwheel Powered

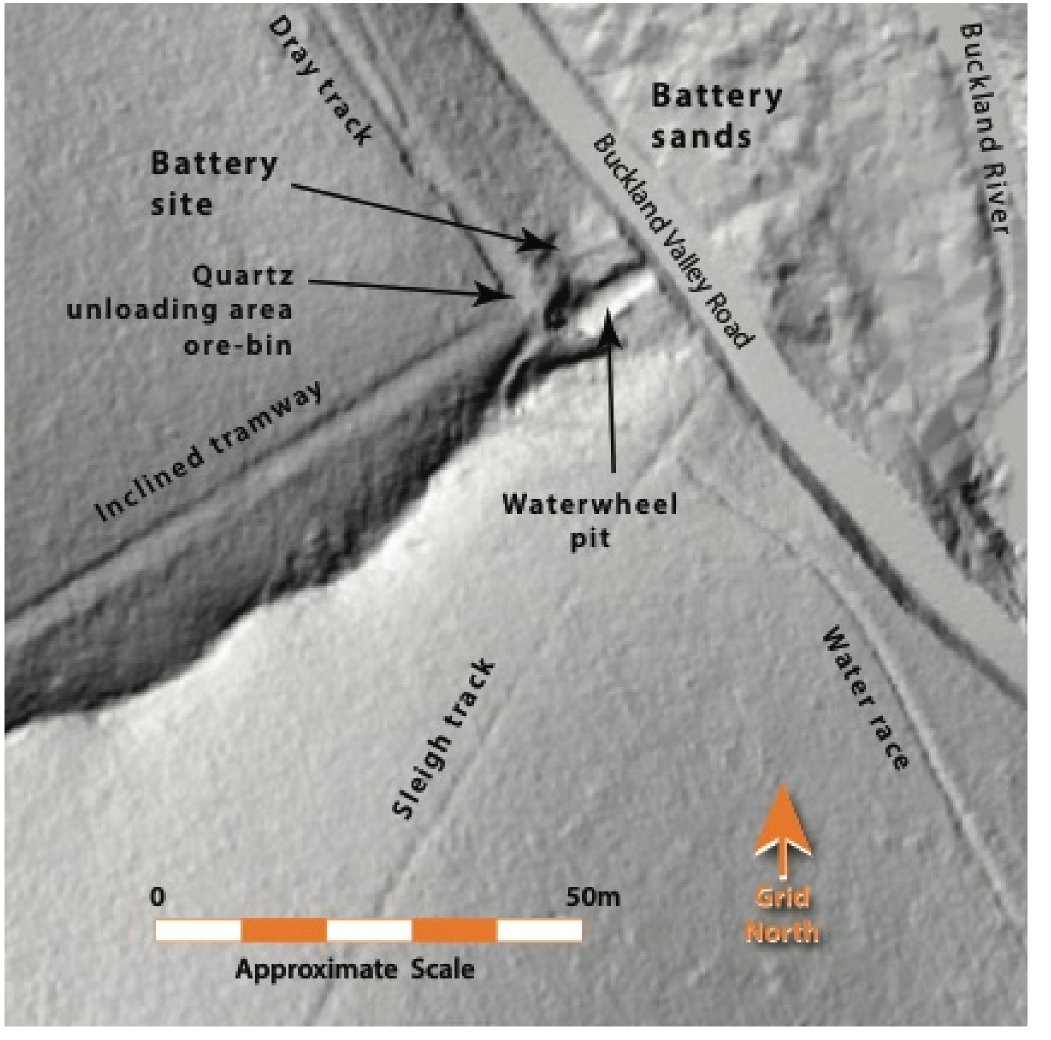
Description: A location where ore was crushed to extract gold. Primary method of crushing was the stamp battery, secondary processes may have occurred in the form of Chilean mills, etc. Gold recovery usually included amalgamation tables. Motive power varied on the Buckland. Waterwheels were a common means of motive power for quartz crushing facilities. The larger the wheel, the greater the horsepower.

Physical Characteristics: Usually a benched pad with a quartz unloading area above, sometimes with an intermediate level being the site of an ore-storage bin. Building connected to working via tramways or sleigh or dray tracks. Mortar box positions are often indicated by bedlog pits, sometimes still with tie-down bolts in situ. The site of the waterwheel is marked by a deep trench or pit adjacent and parallel to the battery building site.

Associated Archaeological Features/Networks: Tramways, dray and sleigh tracks, water races. Outbuildings and occupation sites. Sand heaps, cyanide works, quartz holding paddocks, additional recovery plants, smelting and refractory furnaces, blacksmith hearths.

General Topographic & Geological Context: Usually located within close access to good supplies of water.

Image: Leinster battery site, large waterwheel pit to the south with water race leading into above pit from south. Incline tramway and dray track leading to above site. Mortar box/battery position adjoining waterwheel pit to north



Quartz Mill Battery Sites - Steam Powered

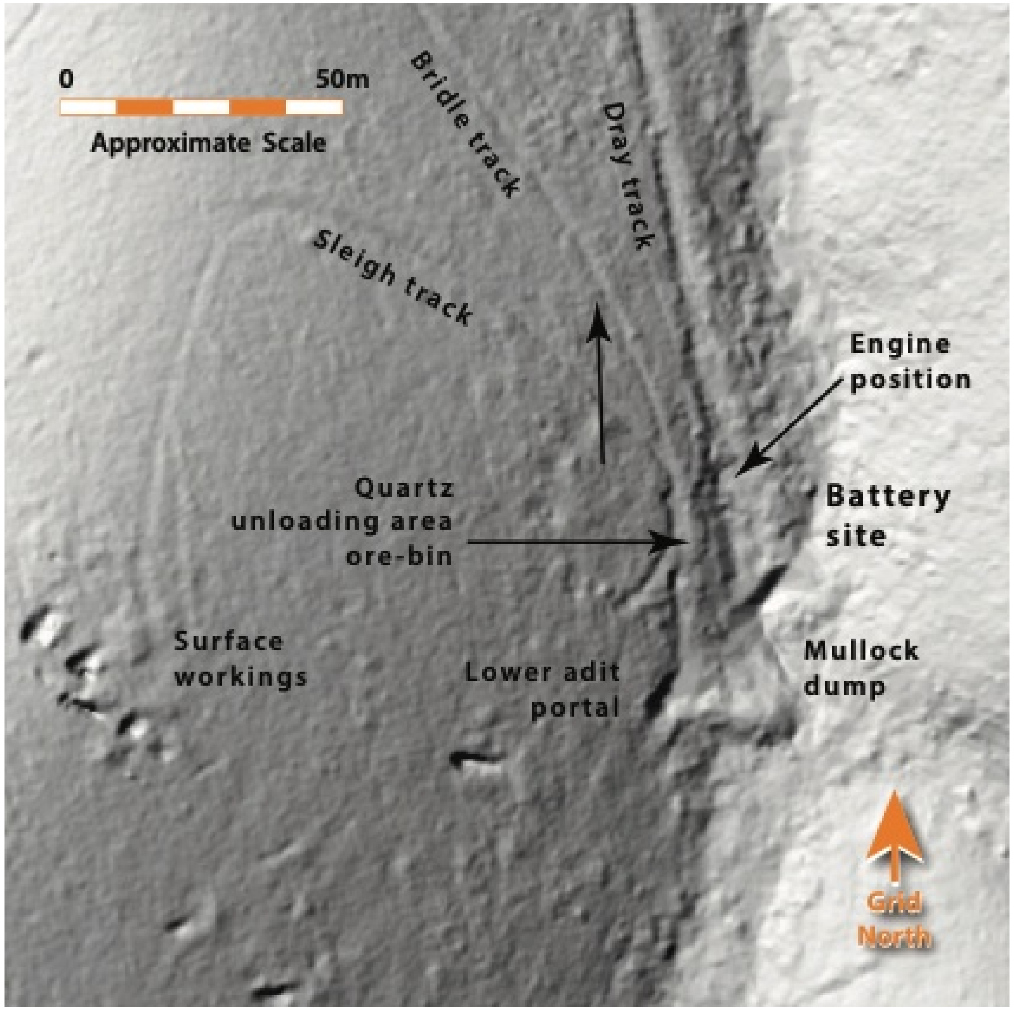
Description: A location where ore was crushed to extract gold. Primary method of crushing was the stamp battery, secondary processes may have occurred in the form of Chilean mills, etc. Gold recovery usually included amalgamation tables. Motive power varied on the Buckland. Steam powered plants could have utilised free-standing portable engines, or larger Cornish type boilers in stone settings. Usually used in areas with less reliable water supplies, and not suitable for reliable waterwheel use.

Physical Characteristics: Usually a benched pad with a quartz unloading area above, sometimes with an intermediate level being the site of an ore-storage bin. Building connected to working via tramways or sleight or dray tracks. Sites of steam powered plants are less distinctive in LiDAR imagery, unlike waterwheel sites with distinctive pits or trenches, boiler or engine positions can be far more subtle. It is usually the context in relation to workings and road networks that can assist in identifying battery sites of this type.

Associated Archaeological Features/Networks: Tramways, dray and sleight tracks, water races. Outbuildings and occupation sites. Sand heaps, cyanide works, quartz holding paddocks, additional recovery plants, smelting and refractory furnaces blacksmith hearths,

General Topographic & Geological Context: Usually located within close access to reasonable supplies of water.

Image: Queen Jubilee battery site. Only features identifying it as a battery site is the large benching north of the lower adit. The network of tracks that radiate out above the abandoned benching area provides additional evidence of the use of this area as a quartz crushing location.



General Ancillary Features/Infrastructure

Water Races & Ditches

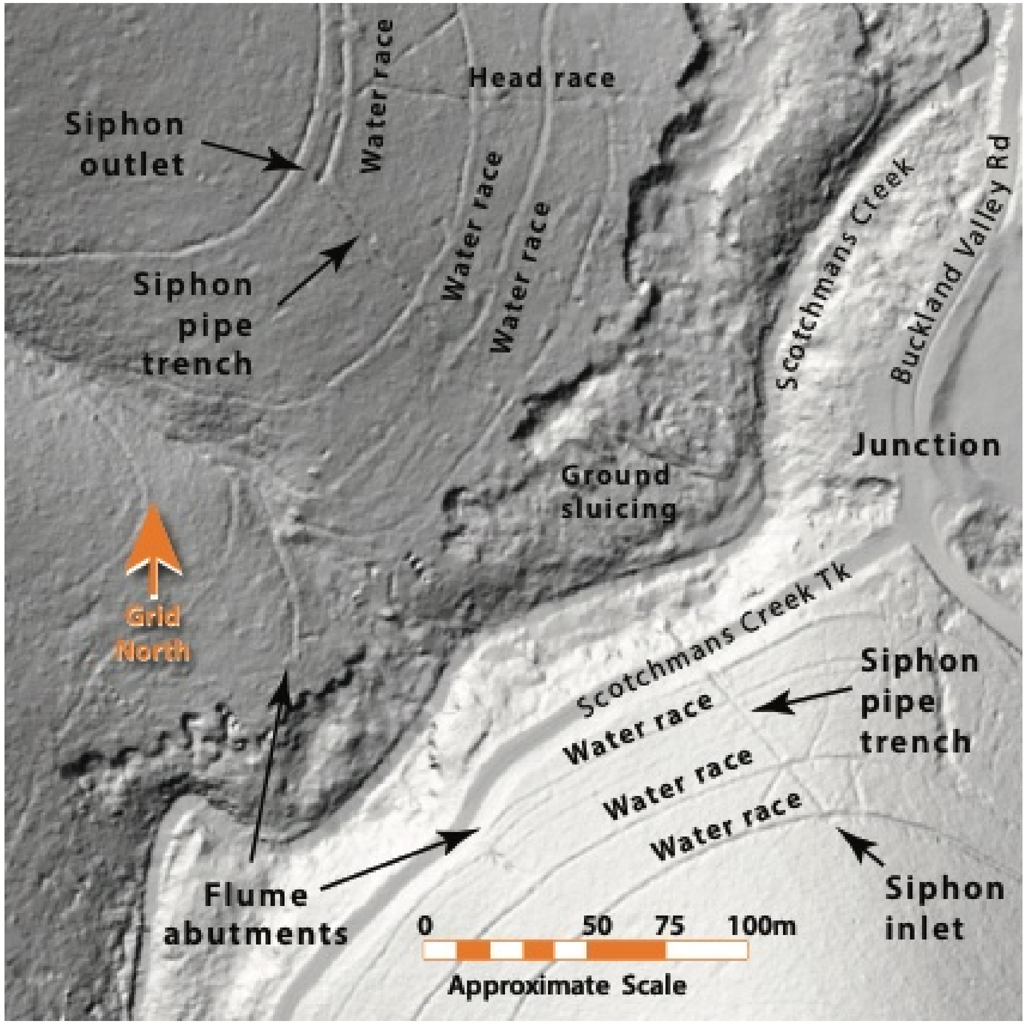
Description: A channel excavated along with a slight drop in elevation for the conveyance of water to a quartz reef mining or alluvial claim. Constructed along the contours of hillsides. Water is taken from streams and/or dams/reservoirs. In the Buckland they are usually constructed of earth, sometimes retained by rock walling.

Physical Characteristics: A distinctive ditch cut along a contour. Sometimes the ditch is heavily filled with silt and debris. Retaining wall construction varies depending upon characteristic of the associated excavated ground. Generally earthy loams, which don't require lining. In steeper rocky country walls are stone retained and sometimes clay or earth lined. Sometimes timber or steel lining was also used to prevent leakage.

Associated Archaeological Features/Networks: Dams, weirs or reservoirs, flume and siphon sites and abutments.

General Topographic & Geological Context: Usually located within hilly country and associated with streams and catchments.

Image: Buckland Junction, water races in vicinity of the west Branch or Scotchman's (Scotch Bill's) Creek. Several flumes and a siphon were constructed across this creek.



Head Race

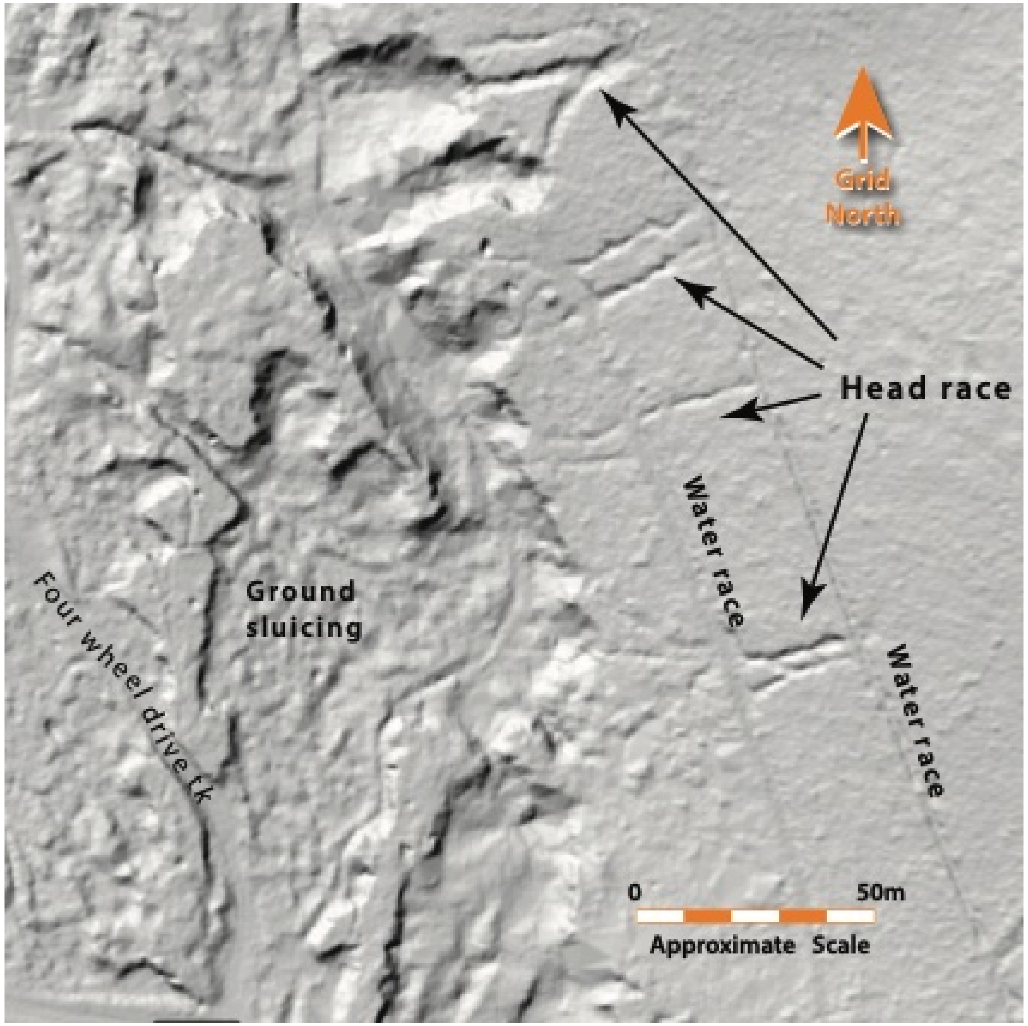
Description: A channel between a water race and an alluvial mining claim, quartz reef machinery, waterwheel sites or horticultural garden area or domestic residence.

Physical Characteristics: A sometimes shallow ditch cut into the wall of a water race. Head race usually runs perpendicularly to race, heading to required site.

Associated Archaeological Features/Networks: Dams, weirs or reservoirs, flume and siphon sites and abutments, alluvial claims, machinery and wheel sites, gardens and domestic sites.

General Topographic & Geological Context: Usually located within hilly country and associated with streams and catchments.

Image: Camp Flat water races.



Tail Race

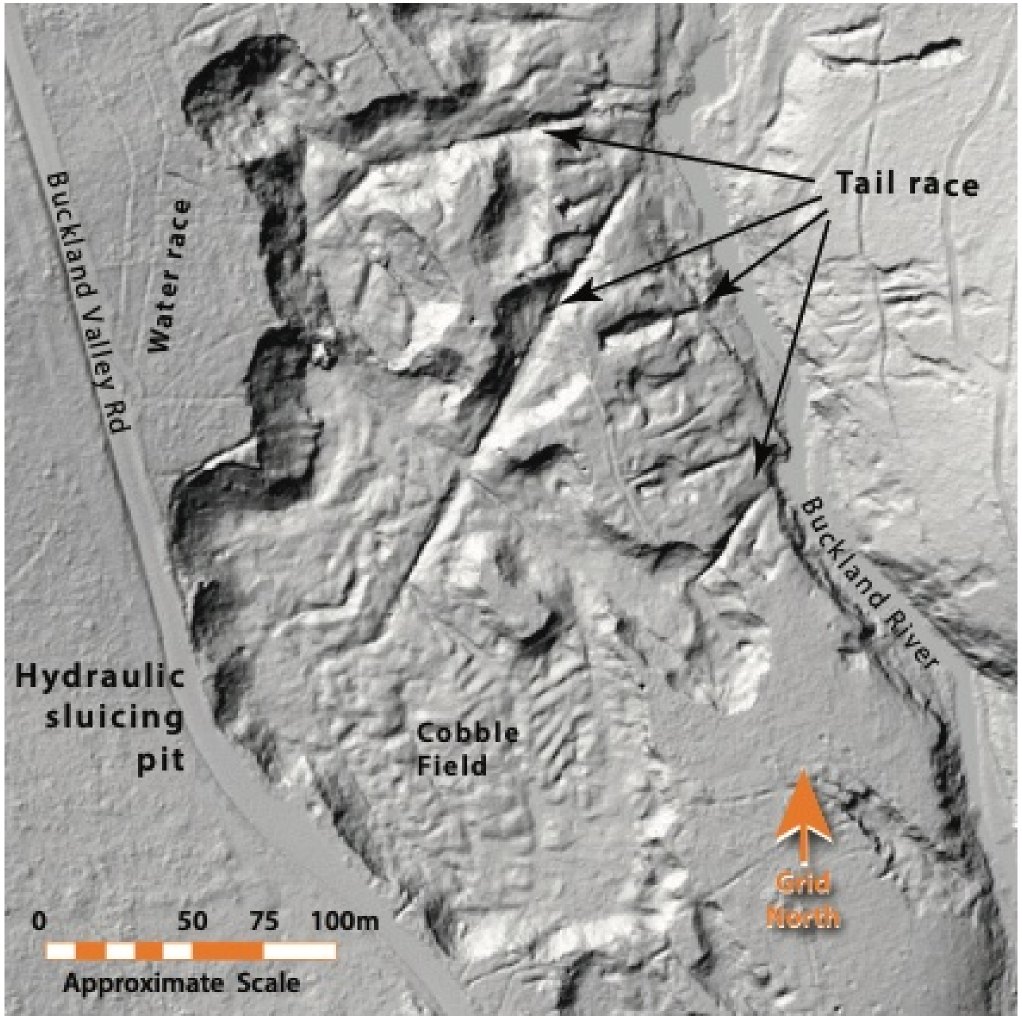
Description: A channel cut within or from an alluvial sluicing claim to facilitate the drainage of tailings and water from the workings. Tail races would often be used for sluice box, gold recovery positions. Tail races were sometime associated with waterwheel pit drainage as well as aspects of tailings associated with quartz milling sites.

Physical Characteristics: A ditch cut into the bottom most part of a claim. Sometimes excavated into bedrock or stone retained.

Associated Archaeological Features/Networks: Alluvial sluicing claims, water races.

General Topographic & Geological Context: Usually located within hilly country and associated with sluicing claims adjacent to streams.

Image: Allen's Flat hydraulic sluicing paddock. Long water races associated with extensive claim. Draining directly into Buckland River



Foot Track

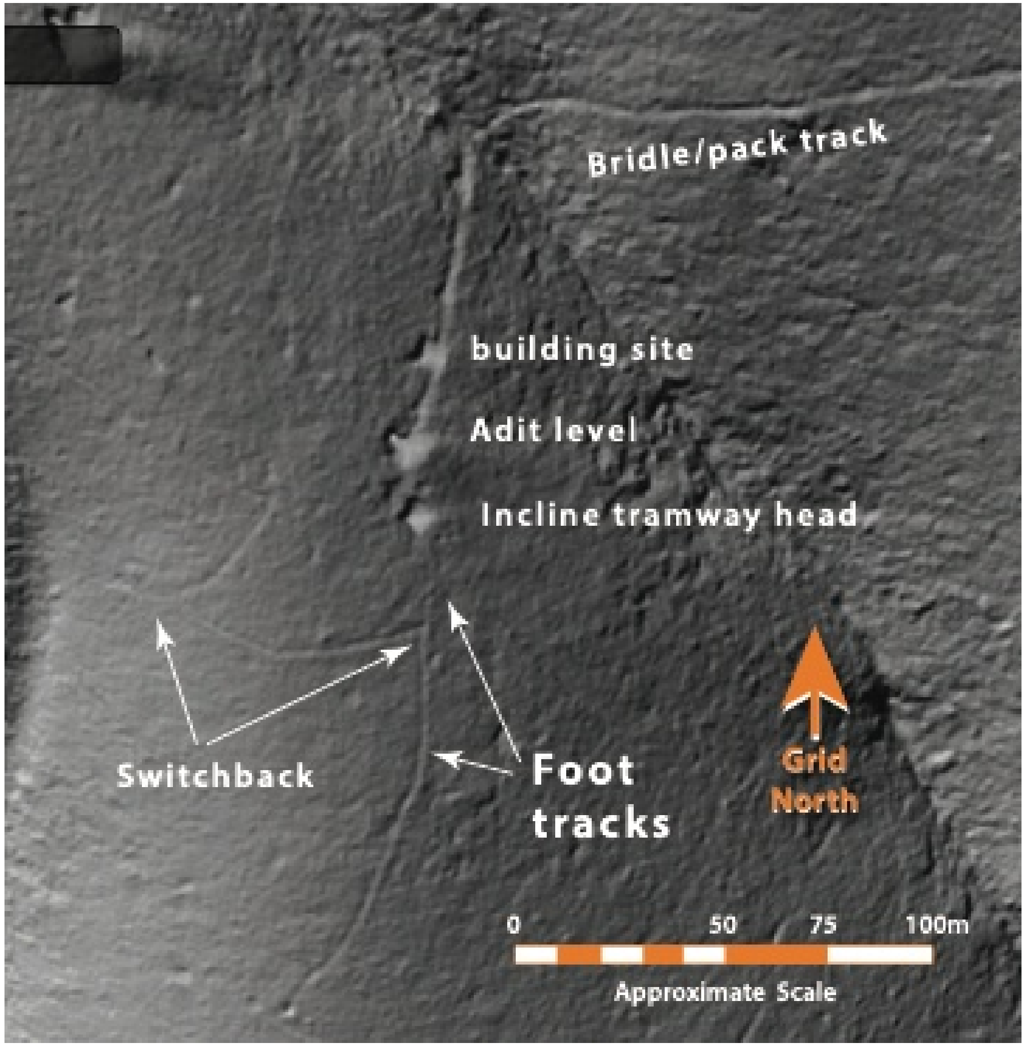
Description: A narrow track approximately 600mm in width cut by hand to facilitate the passage of pedestrians.

Physical Characteristics: Depth of excavation dependent largely on steepness of topography and grade of track. Sometimes stone retained on upper and lower sides. Usually prone to erosion. Very subtle features in forested landscapes.

Associated Archaeological Features/Networks: Mine workings, building sites, etc.

Image: Fairley's Creek quartz reef workings. Faint foot track to workings from creek, traversing steep hillside. Several switch backs are apparent.

Features like this are difficult to discern in steep forested landscapes.

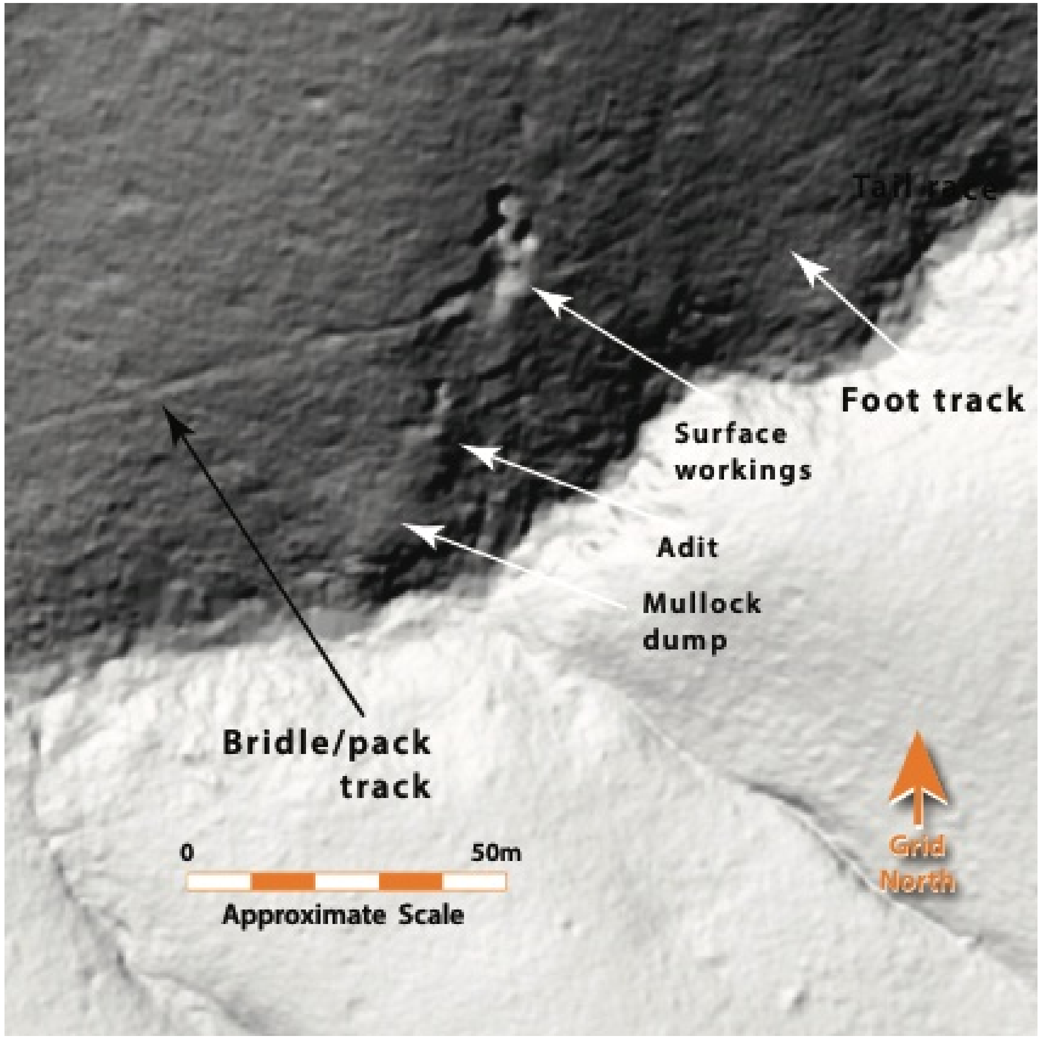


Bridle Track

Description: A narrow track approximately 1.2 m in width cut by hand to facilitate the passage of pedestrians and horses. Sometimes cut as official government sponsored facilities. Often used for the packing of small parcels of stone for crushing to be carted by horse teams.

Physical Characteristics: Depth of excavation dependent largely on steepness of topography and grade of track. Sometimes stone retained on upper and lower sides. Usually prone to erosion. Usually more defined, can also be cut as steep grades.

Image: Red, White & Blue quartz reef workings, Clear Creek. Bridle track accessing upper reef workings.



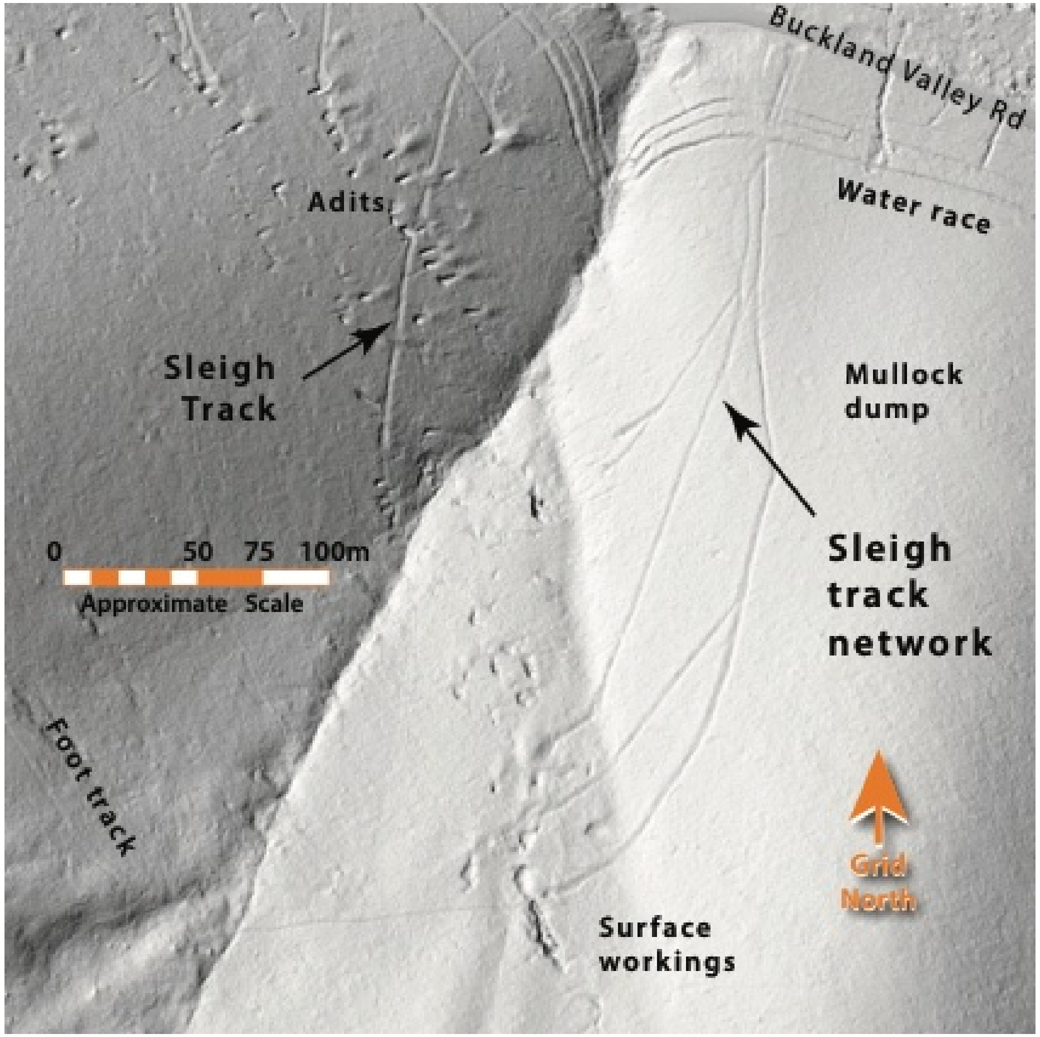
Sleigh Track

Description: A wide track approximately 2.4 m in width cut by hand to facilitate the sleighing of quartz ore on timber sleds from the mine workings to the crushing facility.

Physical Characteristics: Depth of excavation dependent largely on steepness of topography and grade of track. Sometimes stone retained on upper and lower sides. Usually defined, can also be cut as steep grades. Often found on spur lines. Sometimes mistaken as bulldozer lines.

Associated Archaeological Features/Networks: Quartz reef workings, including adits, shafts and battery sites.

Image: Murdoch quartz reef workings showing sleigh track traversing hillside down to main Buckland Road.

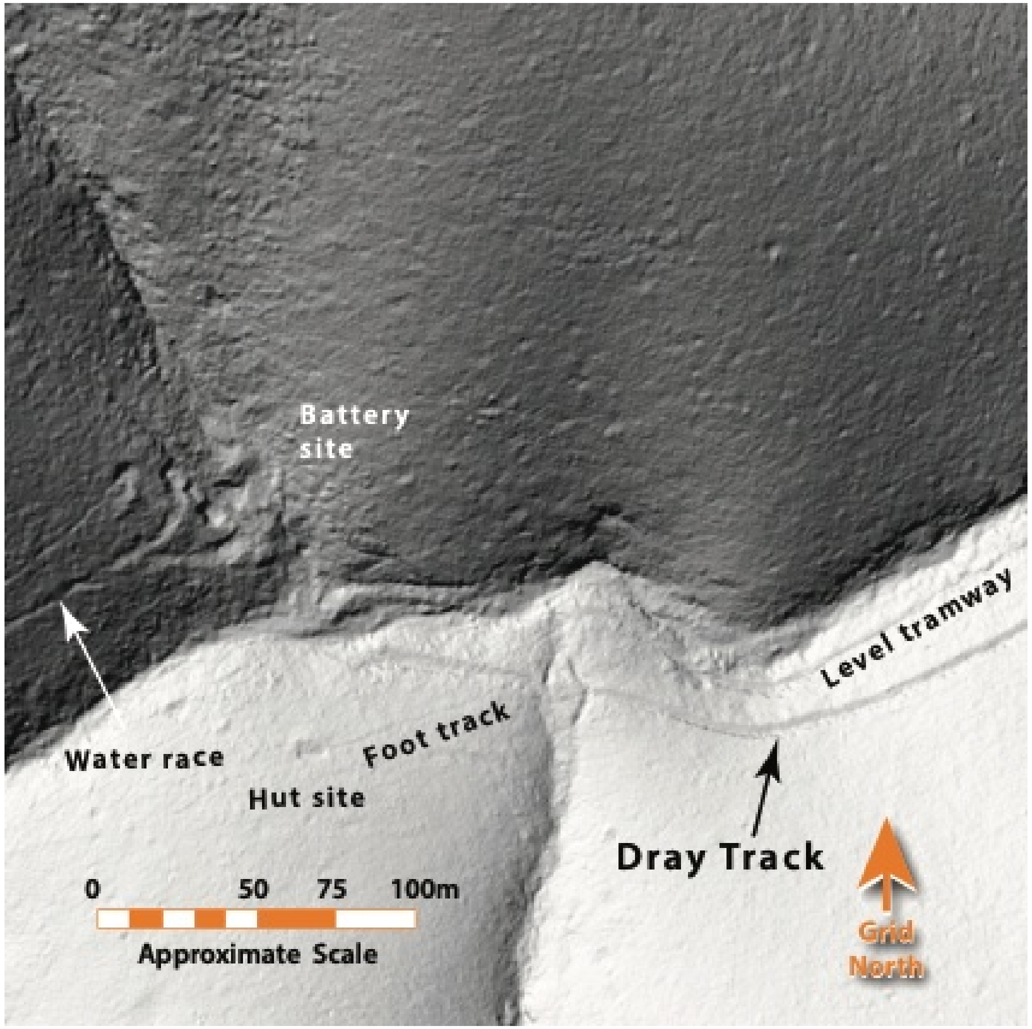


Dray Track or Road

Description: A wide and generally level track approximately 2.4 metres in width specifically cut by hand for the passage of horse drawn vehicles, usually of a more robust nature.

Physical Characteristics: Depth of excavation dependent largely on steepness of topography and grade of track. Often stone retained in places on upper and lower sides. Usually well defined, cut on gentle grades.

Image: Fairley's Creek dray road, cut between the Buckland Road and the mine workings. Immediately below the road is a narrower level tramway.

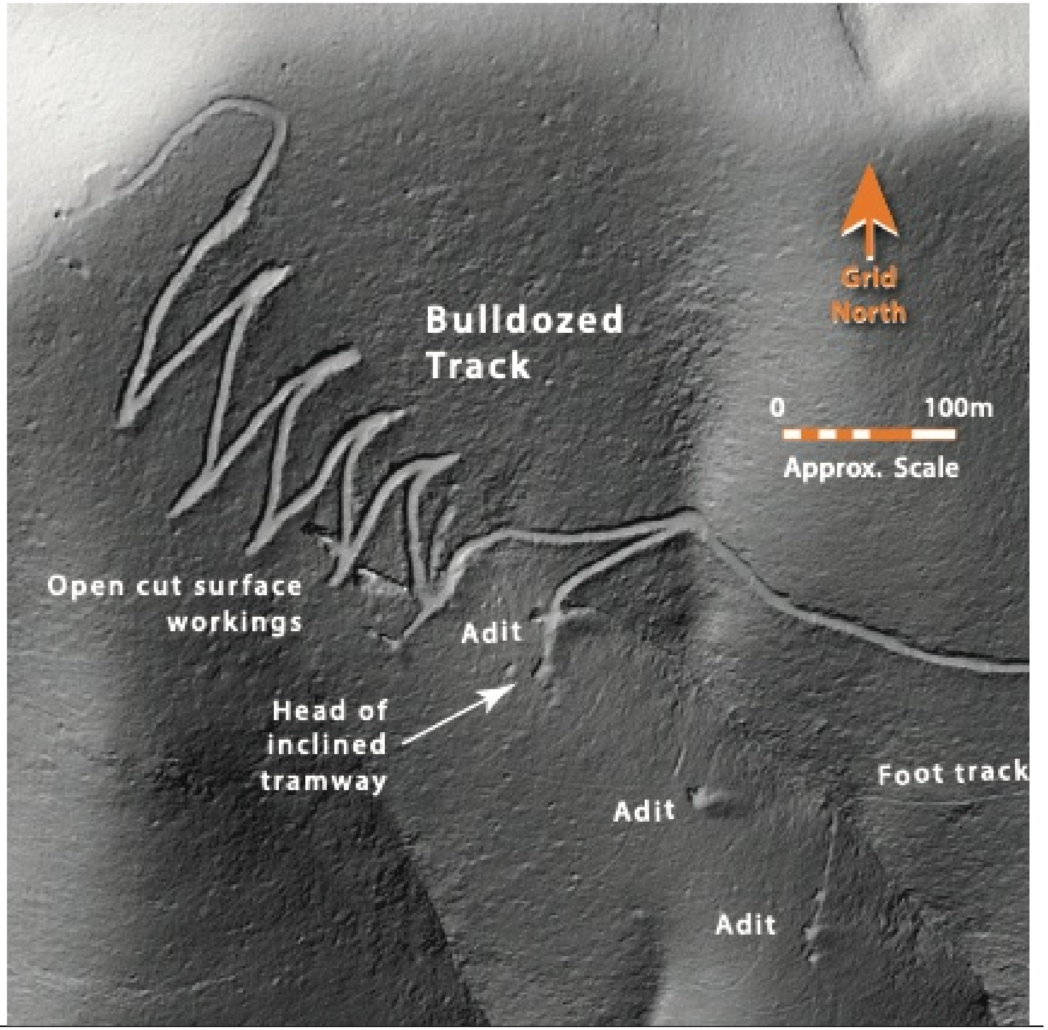


Mechanical (Bulldozed) Track

Description: A wide track approximately 2.4 - 3 metres in width cut by mechanical means by varying sized bulldozers. Usually used in bushfire prevention or in mining exploration.

Physical Characteristics: Depth of cut dependent largely on steepness of topography and grade of track. Often blade spill is found on lower side of track. Push-up mounds are also prevalent on switch-back or direction changes, or associated with water-run off.

Image: Fairley's Creek mine exploration track for drilling program c2000's. Faint foot track, circa 1890s, can be made out in bottom left hand corner



Associated Features

Building Hut sites

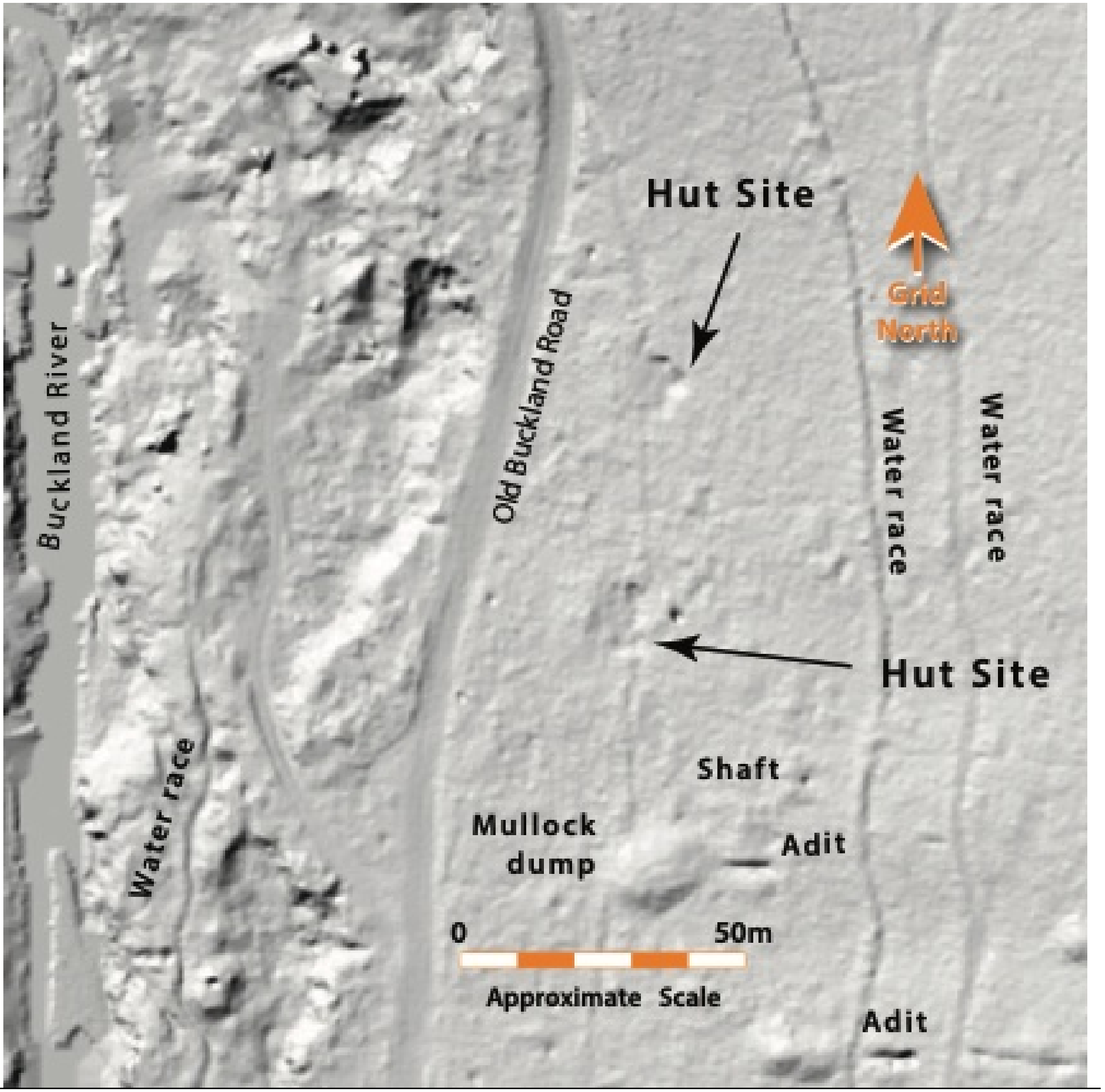
Description: A small benching often with an associated earth and rubble mound from a fireplace or chimney.

Physical Characteristics: Hut sites are lesser defined in LiDAR imagery. Usually rectangular in shape in steeper topography due to benching.

Associated Archaeological Features/Networks: Numerous, mine workings and tracks, domestic refuse/artefacts.

General Topographic & Geological Context: obvious building sites are generally more visible in steeper country where the excavation into the hillside is greater.

Image: Harp of Erin workings, Upper Buckland.



Bridge Abutment Sites

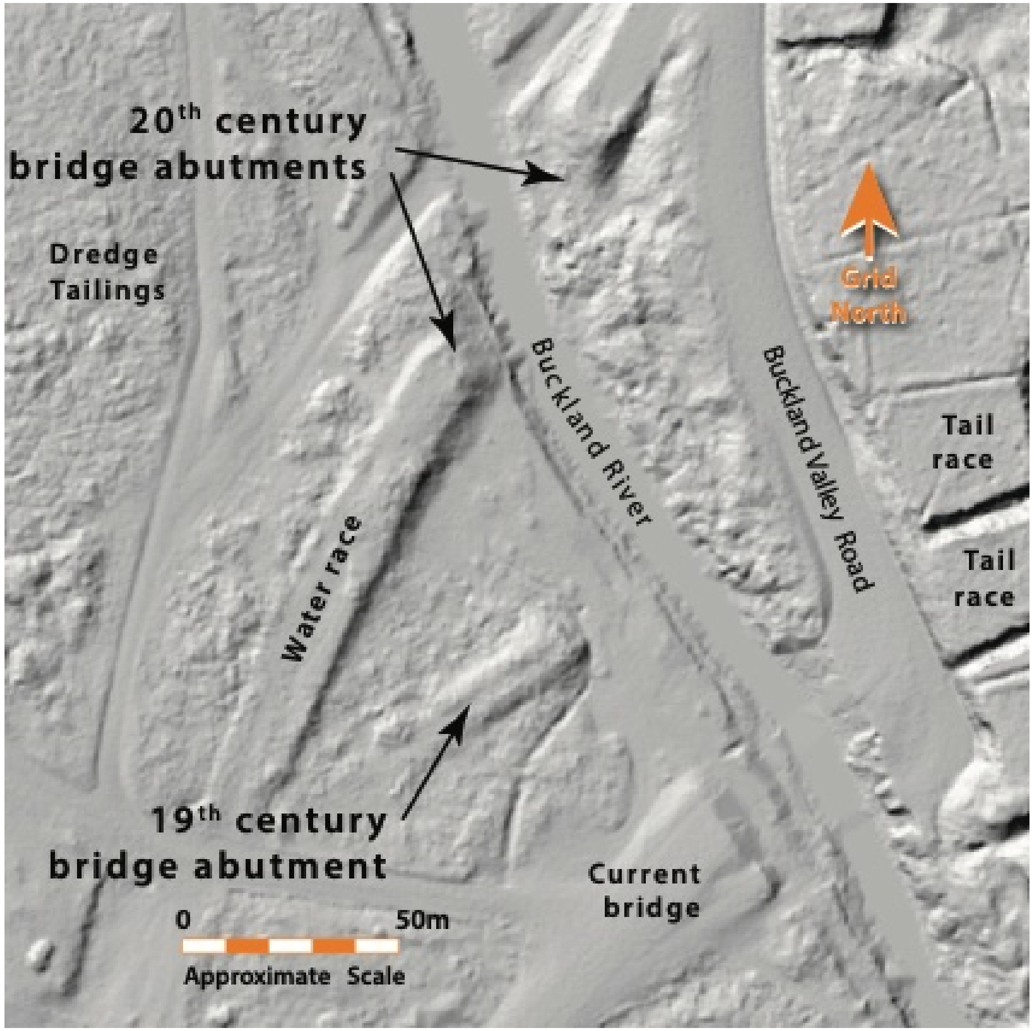
Description: The former site of usually timber bridge.

Physical Characteristics: Often opposing raised earth mounds, sometimes stone-retained. Sometimes timber piers can still be found in streams.

Associated Archaeological Features/Networks: Larger sized tracks or roads.

General Topographic & Geological Context: Associated with stream or gully crossings.

Image: Buckland Bridge. (*LiDAR algorithms have removed current bridge superstructure.)*



Appendix 2. – Brief History, Buckland Valley Goldfield

The Buckland Valley Goldfield.

Post Contact

The tranquillity of the Taungurung Country, in vicinity of the Buckland Valley was first disturbed by Europeans during the late 1830s, early 1840s, when squatters began to move into the district from the north. John Buckland was associated with the Bowheedgee (Barwidgee) Run in 1840, which included the Port Punka or Little Portland Run (Porepunkah). Thomas Buckland took up the Buckland Run (later Wandillgong run) in 1844. The river was named after one of these squatting run holders.

Goldfield's Era

Henry Pardoe and his party of six men are generally credited with the discovery of gold in the Buckland River in the winter of 1853. They were said to have obtained over 360oz of gold within a few days from the Maguire's Point area. By mid-December the daily increasing population was estimated at 3,000 with as many as 6,000 by the end of January 1854. This represented half the population of the Ovens (Beechworth) mining district.

Gold was initially worked in the banks and beds of the streams with pan and cradle, though within a very short time the topography of the valley was utilised with the introduction of the water-race and sluice-box. This method of mining quickly dominated the field for its efficient and labour-saving means of gold extraction.

Figure A2.1: Buckland Camp 1862. A detailed and probably accurate representation of the Camp some 8 to 9 years after its original formation. Eugene Von Guerard. Sketches in Victoria 1862. State Library (Mitchell) New South Wales.

Initially basic canvas and rudimentary dwellings, stores and shanties were spread out along the valley in close proximity to the diggings. Within a short time, the permanent nature of the gold deposits and workings saw the general centralisation of population and commercial business areas. The Camp (Camp Flat/Twelve-Mile) was the first main mining camp, containing many mixed businesses and dwellings. The location was also the first government administration centre for the district; including a police camp, lock-up and petty sessions court. The Junction was the Buckland's main 'upper' settlement, and was a turn-off point for workings up the west and east branches of the Buckland River. The Lower Buckland had two main business centres - the first at Dunphy's Creek, referred to as Lower Buckland, and another centre down toward the Buckland Bridge known as Lower Flat, or Buckland Lower.

During the hot summer of 1854, disease swept through the digging's population, and "Colonial Fever" or typhoid killed a significant proportion of the population. The locality was referred to as '*The Valley of the Shadow of Death*', with estimated deaths of over 1000 from disease. The surviving population deserted for other fields, eventually to return in lesser numbers.

Figure A2.2: 1857 Buckland Riot.

Chinese began arriving on the field in mid 1856. By 1857 the population in the Buckland Valley was about 500 Europeans and 2,000 Chinese miners. A growing resentment towards the Chinese population heightened in the winter of 1857, with the opening of a temple on Joss House Hill, and the taking up of alluvial ground above the Junction. An anti-Chinese meeting at Tanswell's Hotel on 4th July ignited ill-feelings by some of the Euro-Americans. At the conclusion of the meeting, a group made for the new Chinese camp at Louden's Flat intending to expel all Chinese from the valley. The angry mob of Europeans grew as they successively robbed and beat the Chinese as they were driven down the valley. A scene of devastation was left in their path - smouldering tent frames, torn, trampled and scattered possessions. Officially, three Chinese died in the aftermath of the riot, though there were stories of others killed and bodies disposed of before the police arrived. With the promise of government protection, the Chinese gradually returned to the Buckland, becoming a strong portion of the goldfield's population.

Figure A2.3: Fairley's Creek miners, c1890s. Percy Croft collection. Rose Chandler.

In 1858 a "*quartzmania*" had taken hold of the European population. The Alta and Nelson were the first quartz reefs to be profitably exploited. The mines were also the first to have quartz crushing machinery erected on the Upper Ovens fields. During the early decades of mining, local and Melbourne-based companies were formed to exploit the reefs. Gold-bearing quartz reefs were discovered throughout the Valley, with the Junction, Clear Creek, Fairley's Creek, Miner's Right and Leinster all important quartz reef mining localities.

Figure A2.4: John Bishop hydraulic Sluicing, early 20th century. E.R. Weston collection. D. Weston.

Towards the end of the 19th Century, large-scale hydraulic sluicing was introduced to the field. The use of high-pressure water, through steel pipes and cannons, enabled efficient working of ground that may not otherwise have been readily worked. The introduction of this new technology created a small boom on the Buckland. It also had one of the most significant environmental impacts.

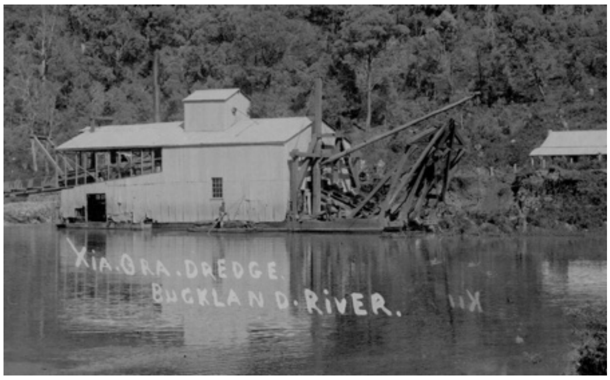


Figure A2.5: Kia Ora Bucket dredge, Lower Buckland, c1905. Bright & District Historical Society collection.

During the late 1890s bucket dredging technology was introduced to Australia from New Zealand. This mode of mining made the Upper Ovens mining district one of the largest gold producers in the State. Bucket-dredges were introduced to the Buckland Valley in the early 1900s with eight dredges operating in the upper valley up until 1919. The dredges also contributed significantly to the legacy of environmental impacts of the area.[13]

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[13] Brough Smyth, R, The Goldfields and Mineral Districts of Victoria. 1869, Republished Queensbury Hill Press, 1980.
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Appendix 3. Buckland Mining Types

A brief and general summary of alluvial mining types is outlined here. These descriptions can assist greatly when it comes to understanding and interpreting this type of landscape.

Alluvial Mining

Figure A3.1: River claim, using a Californian pump to drain workings.

River, Creek or Stream Claims

Those confined mostly to the bed of the river and its immediate banks. These areas were the lowest point along the valley and were usually where the richest deposits of gold occurred. Little evidence of this type of early mining exist today due to subsequent dredging and flood events.

Surfacing

Use of low-pressure water via shallow ditches, head races and water races, directly run over ground surface to break down and remove shallow overburden and auriferous gravels. This method also required manual labour to break down surface material and rake or barrow wash to sluice boxes or cradles for gold extraction. The occurrence of shallow auriferous deposits usually originated from ancient courses of streams, or gold shed from adjacent reefs.

Bank, Terrace of Ground Sluicing Claims

These workings are found at various elevations up to 50 or 60 feet above the present river level. These deposits were remnants of much older river courses, left behind as the stream shifted course and cut a deeper channel. The washdirt along these old river courses was later covered by a non-auriferous (not gold bearing) earth deposit or overburden; which in the Buckland consisted of a red surface loam or hill drift, covering the wash to a varying depth. The problems often associated with bank claims were the depth of the overburden, which had to be removed to gain access, and the availability of water to work these deposits. The advantage of these workings was that they were usually at sufficient elevation for the tailings and water to be readily 'drained' from the workings via tail races.

The term "Bank sluicing" generally referred to claims above the river level where water was directed down the banks from shallow races or channels and used to assist the breaking down of the over burden and gold bearing wash. This type of mining could be used in conjunction with ground and box sluicing techniques.[14]

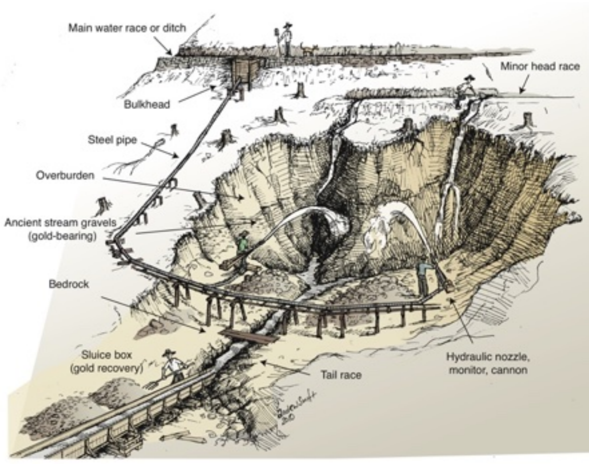


Figure A3.2: Stylised diagram of high-pressure hydraulic sluicing claim.

Hydraulic Sluicing

Hydraulic mining was first introduced on the Buckland in 1858. The volume of ground that could be worked by this means was greatly increased the bank and ground sluicing methods. One of the main reasons for the continuing success of the field was the advancement of such mining technology.[15]

Hydraulic mining involved directing a jet of water against the earth to break it down. The conditions for hydraulic mining were limited to access to adequate supplies of water at a suitable elevation; the topography of the field was ideal for such operations. The earliest hydraulic mining used flexible canvas hose supplied with water from a race at sufficient elevation above the claim. Substantial water pressure when released from a nozzle would cut into the earth at which it was directed. The technique involved undercutting a face or cliff as high as 60 feet. Mr. R. Holden Stone, the Mining Surveyor and Registrar for the Buckland division reported that the greatest number of

[14] Talbot & Swift p. 180-182
[15] Ovens & Murray Advertiser, 21 August 1866.

hydraulic hoses employed at one time in the early 1860s was 24

Figure A3.3: High-pressure hydraulic sluicing on the Lower Buckland. Geological Survey of Victoria.

High-pressure Hydraulic Sluicing

Introduced onto the Buckland from the 1880s, this mode of mining was generally on a much larger scale and more technologically advanced scale than earlier hydraulic mining. A greater supply of water was fed into steel pipe at a sufficient elevation above the workings to create a high-pressure jet of water directed from a steel nozzle, often referred to as a gun, monitor or cannon.

Generally used in low-lying areas, where tail races were not sufficient to drain tailings, a hydraulic jet elevator was employed. It was a device that lifted gravels by a venturi effect. Material broken down by the nozzle, was lifted by force into sluice boxes for washing. A number of elevators were known to be employed in the lower Buckland, with sites still existing within the Mt Buffalo National Park and on freehold property.

Bucket Dredging

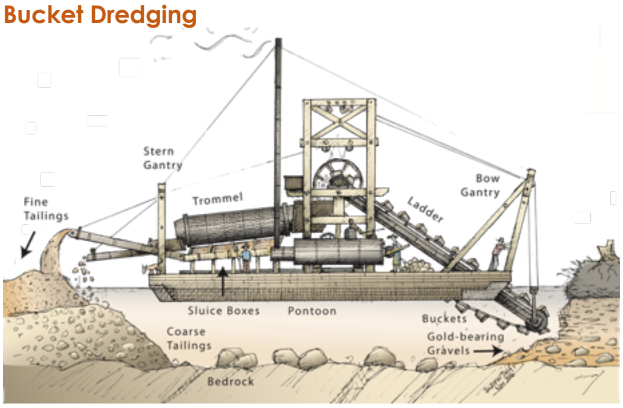


Figure A3.4: Stylised diagram showing type of operation and impacts of a steam-powered bucket dredge.

The bucket dredge was a self-contained factory which floated on a pond, processing the gold-bearing gravels it scooped from beneath. Constructed on a timber pontoon, the main component of the bucket dredge was a continuous chain of as many as 60 buckets. The buckets revolved around a large iron ladder which would be raised or lowered to depths up to 60 feet, excavating and elevating the gravels where directed. The ladder was fixed or pivoted at its upper end, whilst wire ropes and pulleys mounted over a gantry at the front of the dredge, would raise or lower the ladder via a winch. Heavy tumbler wheels located at each end of the ladder gave motion to the bucket chain. The excavated gravel was elevated to the top-end of the ladder where large rocks were removed over a grate or revolving trammel, discharging it overboard at the rear of the dredge. The finer material was washed through sluice boxes or other similar gold saving appliances. The entire dredge was maneuvered by a series of cables and winches attached to anchor points on adjacent banks. The dredge created its own pond as it moved forward, filling the hole at its stern.

Tail Races

A substantial cost to any alluvial claim, was the drainage and removal of tailings. In some localities deep channels or 'tail races' had to be cut through high points in the ground to facilitate adequate fall for the water and tailings to be washed away. Tail races would be directly discharged into the streams and river, adding to the muddy soup that already existed.

Water Races

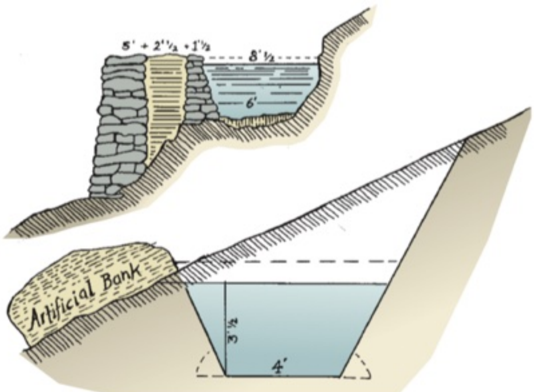


FIG 104.
DITCHES AND FLUMES

Figure A3.5: Ordinary mode of water race construction. Gold, Its Occurrence and Extractions, A.G. Lock, 1882, p960.

A water race was essential to work most claims. It was basically an artificial channel, ditch or aqueduct used for conveying water from a stream or reservoir to a claim. Races were cut through earth and often solid rock and followed a contour of a hill with a gradual fall to the required destination. The fall when constructing a race was critical; too steep a fall the race would be eroded away, too little and the water wouldn't convey. In many instances where a saving of distances could be gained a flume would be constructed across a gully or stream. The water was conveyed in timber roughs or boxes which were supported by a timber trestle.

The construction of races and their associated infrastructure was of great capital outlay to a party and much confidence in a claim would be needed for investing in such infrastructure.

Water rights were granted to claimholders to divert water from a spring or stream. A measure of water, or "sluice head", would be allocated to the holder of a water right under the mining by-laws. The measure of a sluice head varied from field to field and at times was the cause of some heated arguments.

In 1857 the combined length of water races on the Buckland was said to be one hundred miles, varying in size from three to ten sluice streams. The average cost of construction of these races was about £300 per mile, and in some cases the races cost three times this amount.

Quartz Reef Mining

Quartz Reef Mining

Sometimes referred to as '**hard rock**' mining. Quartz reefing was the extraction of a quartz orebody, contained within the solid bedrock. Generally, in the Buckland the reefs are like 'sheets' of quartz, commonly from a few centimetres to 2 metres in thickness, and steeply-dipping. The gold usually occurs as fine particles distributed throughout the quartz matrix, in isolated areas known as '**shoots**'.

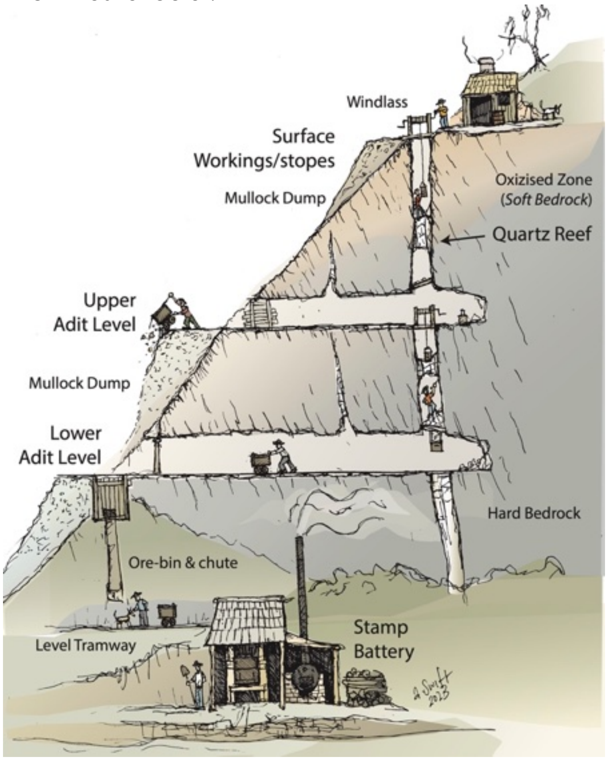


Figure A3.6: Stylised diagram of a quartz reef mining claim on a fissure lode.

Reefs were often discovered outcropping on the ground surface. Samples were taken and crushed in a mortar and pestle, sometimes referred to as a **dolly pot**. If any potential gold value was indicated the reef would be quarried, or open cut. As the reef continued underfoot, **shafts** would be sunk on the gold-bearing lode. If the nature of the geology and topography allowed, **adits**, or horizontal tunnels would be driven into hillsides to intersect the reef at greater depths. Once the gold was extracted it was often conveyed to the surface. It was then transported to a quartz mill or battery for crushing.

Stamp Battery

The stamp battery or gravity stamp is essentially a large mortar and pestle that pulverized the gold-bearing quartz into fine particles from which gold could be freed. The gold-bearing ore or quartz was fed into the rear of the battery, into a large iron box known as the **mortar-box**. The **stems** or **stamps**, (*varying in number; 4-head battery, 5-head, 10-head battery, etc.*) acting like pestles are lifted by a 'S' shaped **cam** on a revolving **cam-shaft.** Falling onto the stone the stem pulverizes it between a large **shoe**-clad **head** on the end of the stem and an iron **die** in the base of the mortar box. Water is added into the box causing a slurry of fine and coarse material. Fine metal **screens** at the front of the mortar-box regulate the size of the discharged material. This fine sand then passes over **copper-plate** or **amalgamating tables** in front of the mortar box. Coated with a thin layer of mercury, or quicksilver, the lighter sands and mineral pass over the top of these tables whilst the heavier gold gets trapped or 'amalgamates' with the mercury.

In the Buckland, various modes of motive power drive the plant. These included;

Waterwheels: Usually constructed with a central iron or steel hub, timber spokes radiated out to an outer perimeter of paddles or buckets. These were filled by a constant overhead flow of water via a timber flume and water race. These were generally referred to as overshot waterwheels. For stamp batteries on the Buckland these wheels could vary in diameter from 12 feet to 30 feet in diameter.

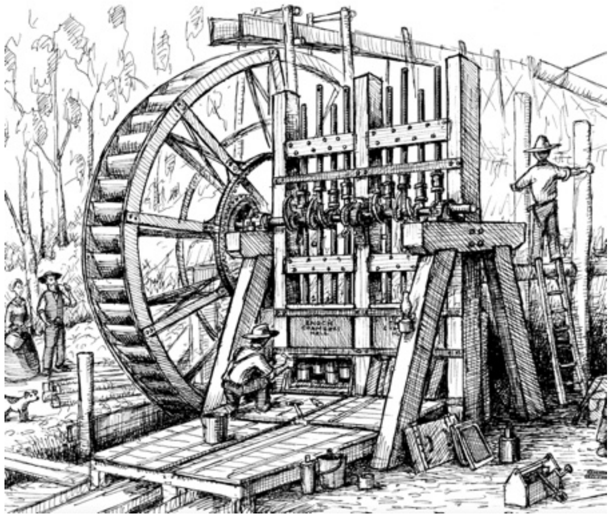
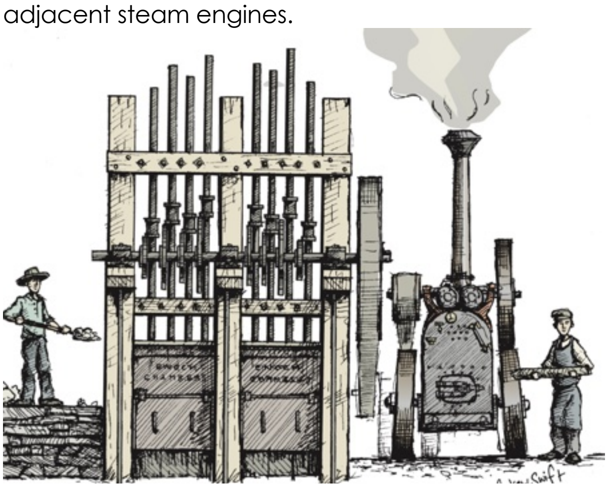


Figure A3.7: Gladstone waterwheel powered battery, Nelson Creek, Upper Buckland.

Steam Power: Several types of steam power stamp batteries operated in the Buckland. These consisted of smaller portable steam engines, usually with transportable wheels which were removed once in place. Or, large Cornish type boilers housed within stone settings and connected to adjacent steam engines.



A3.8: Portable steam powered battery.

Pelton Wheel: Significantly smaller than a traditional waterwheel, a Pelton turbine is a type of hydro or impulse turbine where a jet of water is directed into specially curved cups or buckets on the outer diameter of the wheel.

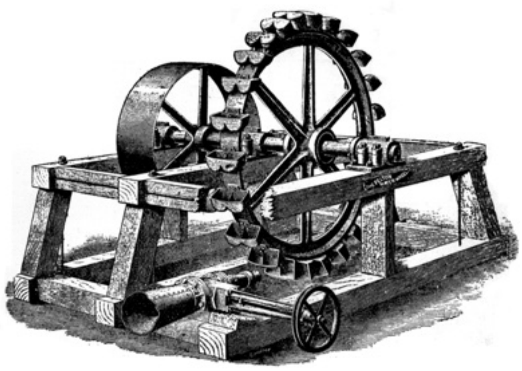


Figure A3.9: Pelton wheel. Pg144. The ABC of Mining. A handbook for prospectors. C. A. Bramble. Rand, McNally & Company, Publishers. Circa 1890s

Appendix 4. Principal References.

The documents and references used in this document are numerous. The principal references include the following:

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