

Dams and Ditches: Cultural Landscapes of Colonial Water Management in the Central Highlands of Victoria

Historic Environment 27(3):36-47 (2015)

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ABSTRACT

Gold miners captured and diverted large volumes of water to work their claims in the nineteenth century. This extensive manipulation of water sources, however, has not been widely researched or understood, despite the profound effect it had on the transformation of landscapes and waterways, its role in the commodification of water, and its influence on the development of colonial water law. The alluvial goldfields around Creswick in central Victoria, where extensive evidence of water management is preserved in the landscape today, provide an important case study of water use in alluvial mining. The Humbug Hill Sluicing Company was one of many groups in the district to engage in water engineering on a large scale, and the remains of their activities shed light on changes in the use and perception of water and the role of miners with Californian experience in developing water resources on the goldfields.

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INTRODUCTION

Dams, races, puddlers, sluices and other features related to water use are ubiquitous on the goldfields of south-eastern Australia, but they are generally encountered in isolation and neither their scale nor their significance is immediately evident. Closer study reveals not only

the spatial extent of water networks but also points to their broader significance for landscape change, the development of infrastructure, and shifts in the cultural value of water. Along with deforestation, water manipulation had a significant impact on the natural environment of goldfields districts, transforming and disrupting natural water flows and causing erosion, siltation and downstream flooding (Lawrence & Davies 2014; McGowan 2001). Such impacts were local in their immediate effect but widespread in occurrence, resulting in extensive physical changes to the landscape across the goldfields regions. In many cases the facilities constructed by mining interests became the basis of later municipal water supply schemes. More profoundly, the new attitudes to water fostered by mining laid the foundations for a cultural shift in the way that water was perceived. Miners increasingly viewed it as a commodity that could be owned, bought and sold, and the laws created to regulate their activity ultimately paved the way for legislation on large-scale irrigation and water control (Davies & Lawrence 2014a; Powell 1989: 50, 113).

Construction of extensive networks of races and dams created an alternative landscape of water movement that overlapped the original hydrological patterns. Water no longer simply flowed downstream, as ground and surface water through creeks and gullies. Instead, it was extracted and diverted sideways, channelled to flow on contours at right angles to the natural drainage. This process was repeated across goldfields of the colony, resulting in almost 4000 km of water races in use by 1868 (Smyth 1980: 547). Flowing water connected widely separated places, from the collecting dams high in the ranges through meandering networks of races and flumes to extraction and processing sites and finally to the deposits of sludge in the rivers downstream from the mines (Davies and Lawrence 2013a, Lawrence and Davies 2014). These landscapes of water management created by the miners expressed a range of legal, economic and social values that came to be associated with the control of water. During

the nineteenth century, the meaning of water shifted from being simply part of nature to an industrial commodity, before eventually emerging as a public good.

This paper extends a presentation at the Watermarks Conference in 2011 in which we explored the activities of the Humbug Hill Sluicing Company, which operated near Creswick in central Victoria from the late 1850s until around 1880. Extensive traces of the company's operations have survived and are listed on the Victorian Heritage Register. The archaeological remains of the group's activities provide a prism through which to examine the landscapes of water management created on the goldfields, and the ways in which water was extracted from the natural environment and transformed into a measured and traded commodity (Lawrence & Davies 2012). We begin by outlining the essential role of water in gold mining and then describe the operations of the Humbug Company and its manipulation of water sources across local landscapes. The company is then considered more broadly as one of many groups involved in the commodification of water on the goldfields, and it is argued that buying and selling large volumes of water became well established in Victoria during this period.

The operations of the Humbug Hill Sluicing Company represent only a small part of the many archaeological remains associated with water use that are well preserved in the Creswick Regional Park. The area is managed by Parks Victoria to preserve and enhance the natural and cultural features of the environment. Controlled burning in the forest in recent years has helped reveal surface features associated with water management. Cultural features include approximately 155 kilometres of water races, numerous dams and tailraces, and more than 450 hectares of land affected by ground and hydraulic sluicing. At least six alluvial mining companies operated in the area during the 1850s and 1860s, each of which

constructed substantial networks of dams and races (Davies & Lawrence 2012; Davies, Lawrence & Turnbull 2015). The activities of the Humbug Hill Company are best preserved in the 11 kilometres of water race and the remains of three large dams that survive in the area today. The physical evidence of their main sluicing area on the west side of Humbug Hill was largely obliterated in the 1960s by the excavation of a deep clay pit by Ballarat brick-maker James Selkirk, and operations further to the west in the Bald Hills area have been destroyed by subsequent farming and forestry activity. Historical references to the company during its early years of operation have been identified in reports by the district Mining Surveyor and in *Dicker's Mining Record*, as well as the *Creswick Advertiser* and *Ballarat Star* newspapers. Information on Creswick mining operations generally is also preserved in the E. J. Semmens Collection at the University of Melbourne Archives. The unevenness of historical sources, however, emphasises the importance of the archaeological remains in understanding the role of the company in creating a landscape of water management during this period.

MINING TECHNOLOGY AND WATER

Alluvial mining dominated work on the goldfields during the early years of the gold rush. Miners recovered flakes and nuggets eroded into streambeds using a variety of simple pans, cradles and sluice boxes, all of which required good flows of water. In drier areas puddling machines were used, consisting of a large ring-shaped trough in the ground filled with clay and water. Harrows drawn by a horse or steam engine mixed the clay into a sludge, which was released through a valve and left the gold to be recovered from the bottom of the trough. Ground sluicing was a more intensive way of working a claim and used larger quantities of water. Low-pressure water was conveyed by a race from a creek and diverted over the face or along the base of an auriferous deposit. Miners worked at the bottom to pick and shovel the

washdirt towards sluice boxes where the gold was trapped between riffles (Ritchie and Hooker 1997: 6-7; Smyth 1861: 106-08; Tracey 1997: 7-8).

Hydraulic sluicing was a dramatic intensification of this process, with a stream of water from a race channelled through a series of smaller and smaller pipes ending in a nozzle, or monitor. The high-pressure water was used to blast away the wall of a creek or gully and wash the deposit towards sluicing channels where the gold could settle. This technique, developed in California in the early 1850s, demanded even more water but increased the volume of soil that could be worked by a small group of miners (Hundley 2001: 77). It also took a heavy toll on natural landscapes, causing erosion on a massive scale and washing huge quantities of sludge into streams and rivers (Isenberg 2005: 39-47).

Water was also vital in deep lead and quartz mining, which dominated goldfields activity in the years following the early alluvial rushes. Deep leads were ancient watercourses buried far beneath the surface, while reefs were ore bodies containing gold and other minerals. Mining and processing such deposits was the province of large companies with access to money, equipment and expertise, rather than a few miners working together. Deep leads often accumulated water which had to be pumped out before the mine could be worked. Winders for hauling the ore and stamp batteries for crushing it were mostly driven by steam engines, which needed good supplies of clean water, while washing the ore through the batteries and pans used to separate the gold needed water as well. Water wheels also provided power for crushing mills in some areas of Victoria (Davies & Lawrence 2013b).

Miners built dams and water races at many Victorian goldfields to meet these needs. Races were simple earthen channels excavated by pick and shovel, usually about 1.5 metres wide

and up to one metre deep (Figure 1). Some were only a few hundred metres long, but others were 20 kilometres or more in length. The longest recorded mining water race in Victoria was built by the Pioneer Water Company at Yackandandah in the 1850s and extended for well over 100 kilometres (Lloyd 2006: 39). Races followed the contours of hills, winding in and out of gullies and falling at a very slight gradient to ensure the controlled, gentle flow of water. They were surveyed using simple lines-of-sight, water flow and a spirit level. Tunnels, flumes and inverted siphons were also used where necessary. Large races often required construction of a dam in a creek or gully to maintain the water supply, while smaller races relied on seasonal water flows. Dams were usually built of earth, rock and clay, with water flowing out through a by-wash at one side or through a pipe and valve at the base of the dam wall (Pearson & McGowan 2000: 152). Water drained from the diggings through tail-races and was often reused for mining further downstream.

FIGURE 1 NEAR HERE

Many of these races and dams are preserved on the goldfields of central Victoria. They represent an enduring archaeological landscape which reveals some of the ways miners tried to overcome the limits imposed by variable water supplies. Similar networks of water races have been recorded on the Lisle-Denison goldfields in north-eastern Tasmania (Coroneos 1993), the Shoalhaven River in New South Wales (McGowan 1997) and at Otago in New Zealand (Carpenter 2012; Ritchie 1981). Little work has yet been done to understand the meanings of these systems in Victoria, where the gold rush so profoundly transformed colonial society, although Colleen Bower's (2013) recent work on tin sluicing in south Gippsland is an important exception. Water engineering demanded a substantial investment of time and labour, with races and dams often taking months or even years to build at the cost

of thousands of pounds (Smyth 1980: 547-9). The Humbug Hill Sluicing Company was typical of many alluvial mining parties in this period, building a complex network of dams and races that represented an extensive cultural landscape of water diversion and management.

HUMBUG HILL SLUICING COMPANY

Gold was first discovered in the Creswick Creek area in September 1851, and alluvial mining at Humbug Hill began in 1854 (Flett 1970: 407-16; Graham 1987: 50, 176). Humbug Hill is located three kilometres south-east of Creswick, forming a low rise that separates Slaty Creek to the west from Lincoln Gully to the east, both of which flow northward into Creswick Creek nearby. The Humbug Hill Sluicing Company began operations in 1856, under the management of Irish-American John Boadle Bragg, with a claim on Little White Hill to the south of Creswick (*Creswick Advertiser* 10 August 1860: 4). Around 1857 the company began sluicing on the west side of Humbug Hill, but first they had to secure their water supply. Bragg's Dam was constructed on a tributary of Creswick Creek and connected to the workings at Humbug Hill via a race 11 kilometres in length (Figure 2). The dam held up to 20 million gallons (90 ML) of water, and cost the substantial sum of £1000 to build. In July 1859, the local mining surveyor, James Stevenson, noted that the company had recently washed 1500 cubic yards (1147 m³) of clay and soil, at the rate of 8½ cubic yards (6.5 m³) per man per day, for a yield of 245 ounces (6.94 kg) of gold. Water use was estimated at 300 gallons (1364 litres) per minute (Mining Surveyor 1859: 8).

Bragg's Dam is well preserved, although it has silted up and holds much less water now than it once did. The dam wall consists of a mound of clay up to 4.7 m high and more than 100 m in length. The race to Humbug Hill also remains in an excellent state of preservation, despite

disturbance in several small sections by road construction and logging. It is generally about one metre wide and up to 1.2 metres deep, curving around spurs and gullies with a gentle gradient of around 1.30 metres per kilometre. This was enough to ensure water flowed at about walking pace but not so steep as to scour out the channel. The race was dug by hand into clay and gravel subsoil, and silts from the flow of water helped to seal the channel and reduce leakage. A dam on Lincoln Gully provided a temporary storage for the flow of water along the race, as well as a means of sluicing the gully from all sides. In later years a section of the race was incorporated into the Creswick Municipal Water supply, while the reliable storage capacity of Bragg's Dam was vindicated more than a century later when it became the site of Cosgrave Reservoir in the 1970s.

FIGURE 2 NEAR HERE

As early as 1859, the company was alert to the potential for selling the water they controlled. Creswick sits on the northern fall of the Great Dividing Range and Bragg's Dam was ideally situated to capture rainfall runoff on the upper slopes. The company was eager to capitalise on the resources it had developed and began extending operations by establishing leases at Bald Hills and Long Point to the west, with the intention of using the water from Bragg's Dam to sluice large areas of auriferous ground along the route. The company constructed a water race to Long Point, 10 kilometres downstream on Creswick Creek (*Creswick Advertiser* 30 September 1859: 7), partly to supply their own new sluices but also to meet the desperate need for mining water experienced by others in the locality. By 1862 there were more than 30 companies working on deep leads in the immediate area, for whom water was 'a question of life and death' (*Creswick Advertiser* 21 January 1862: 3). While the municipal council commissioned surveys and pleaded for help from the colonial government, the

Humbug Company dug races and laid pipes to capture a market sorely in need of ample water supplies.

This operation to the west, and the implicit transition from making profits from mining to making profits from the sale of water, was a major source of friction within the group. In 1860, John Bragg, Thomas Lake, C.H. Lewis and Jacinto De Lima wanted to push ahead with the race but the four other partners preferred to focus the company's efforts on Humbug Hill itself. Work on the new race stalled for several months while sluicing continued, but arguments over water resulted in a fist-fight and the case ended up in the local Police Court and the Creswick Court of Mines. An application was made to dissolve the business in August 1860, which resulted in Bragg and his supporters buying out the others for £480 and the resumption of work towards Long Point (*Creswick Advertiser* 10 August 1860: 4).

Further problems soon arose. Bragg's Dam was badly damaged by heavy rain in September 1860 (*Creswick Advertiser* 28 September 1860: 3). In 1861 the partners were back in court on two occasions to defend their claim at the Bald Hills, when rival parties argued (unsuccessfully) that the Humbug Company was preventing other people from working the ground (*Creswick Advertiser* 14 May 1861: 2; 23 August 1861: 2). Money was also a problem. In June 1861 John Bragg issued a prospectus advertising shares in the Creswick Extension Sluicing Company, seeking capital of £2500 in 500 shares of £5 each (*Creswick Advertiser* 11 June 1861: 3). While a race had been cut seven miles (11 kilometres) west to the Bald Hills, more money was needed to build several elevated sections over creeks and gullies, including flumes over Nuggetty Gully, Cobbler's Gully and Diamond Gully.

The main barrier to completing the company's water system, however, was Slaty Creek, where the broad creek flats were more than 20 metres below the company's lowest operation on Humbug Hill. Almost half a mile of piping was needed to convey the water across at an adequate pressure. The company commissioned the Patent Bitumenized Pipe Company of Melbourne to lay 750 yards (686 metres) of eight-inch pipes across Slaty Creek. The pipeline was constructed as an inverted siphon carried partly on timber braces or trestles. The pipe began in a small header dam on the west side of Humbug Hill, about 114 feet (34 m) above the height of the creek. It descended into the valley and ascended to discharge water into the open race on the other side of the creek valley (Davies & Lawrence 2014b).

The pipes were made from paper sealed with bitumen, a new technology recently imported from Europe (*Sydney Morning Herald* 8 October 1861: 4). Bitumen pipes were cheaper and much lighter than iron pipes, and were used on the Victorian goldfields for fluming, draining and pumping (Dicker 1862: 16). Manufacture involved passing a roll of paper through a vat of molten bitumen, and then coiling the paper tightly around a cylinder to form a tube (*The Argus* 27 August 1860: 5). Pipes used by the Humbug Company featured flanged joints and a T-piece at the lowest point for blowing out any accumulated sediment. The pipes cost £650 to install, while the company's total outlay for building the dam and 22 km of races, along with substantial sections of fluming and tunnelling amounted to about £3000 (*Creswick Advertiser* 3 June 1862: 2; 12 September 1862: 2). The traverse of Slaty Creek was regarded as the greatest practical test the technology had had on any of the goldfields so far (*The Argus* 11 September 1862: 5).

Water was laid through the pipes and across the creek for the first time on Wednesday, 10 September 1862. The event caused great excitement, with the *Creswick Advertiser* reporting that:

The operation began at Humbug Hill at 4 p.m., and 35 minutes afterwards the water made its appearance on the White Hills, an intelligence which was transmitted through the firing of a gun and received with cheers at the starting point. A great many strangers were present on this interesting occasion and the whole company enjoyed themselves heartily to celebrate the event (*Creswick Advertiser* 12 September 1862: 2).

In the following days, however, there were reports that some of the lower level pipes had burst under the pressure of water (*Creswick Advertiser* 7 October 1862: 2). The bitumenised pipes were advertised as withstanding pressure of up to 400 lb. per square inch but repairs and replacements with thicker pipes in some sections were needed. In spite of these efforts, the 'paper and pitch' pipes do not appear to have been very successful, and by 1864 the company had replaced them with conventional iron piping (Dicker 1864: 180).

Over the following years the partners in the Humbug Hill Sluicing Company appear to have focused much of their effort, and derived most of their profits, from selling water to other mining parties and to the Creswick municipal council (*Ballarat Star* 10 November 1864: 4). The local mining surveyor noted that the company sold water at the rate of £2 10 shillings per sluice-head per week (Mining Surveyor 1871: 24). The water was often purchased by groups of Chinese miners who worked claims in Lincoln Gully and around the lower slopes of Humbug Hill. The energy which had characterised the company's early years, however, seems to have waned, probably in response to the death of the manager, John B. Bragg, in

1865. At this point the company largely disappears from the historical record, although there are indications that they continued operations for the next 15 years. By this stage, shallow alluvial mining in the hills south of Creswick was in decline, and the focus of production had shifted to the rich deep lead mines north of the town, which generated large profits in the following years (Bannear 1996). In 1880 the Humbug Hill Sluicing Company offered its races and other plant for sale to the municipal council, and thereafter most mining activity in the area was carried out by Chinese sluicers in the hills south towards Ballarat (Bradford 1902: 32; Taylor 1998: 74-93).

The Humbug Hill Sluicing Company represents an important early example of corporate alluvial gold mining in Victoria, with a strong emphasis on water management. The company held one of the most significant water privileges in the district and was very active in developing and trading its water resources. The partners were innovative, willing to apply new technologies in the form of bitumenised pipes to carry water for hundreds of metres over a nearby creek, and enterprising, conveying water through more than 20 kilometres of races around a number of watersheds. They were commercially astute, selling shares in the company and floating the Creswick Extension Sluicing Company in 1861 to raise money for expanding their operations, as well as litigious, often engaged in legal actions with other parties in the local Warden's Court, Police Court and the Creswick Court of Mines. The partners were also confident of success. When many others deserted the Victorian goldfields in 1861 to join the gold rush to New Zealand, the Humbug Hill Sluicing Company continued to develop and invest its resources in local mining operations. Their activities played a major role in transforming the natural environment of the area into a landscape of water management.

WATER AS COMMODITY ON THE GOLDFIELDS

Environmental historian Donald Worster described the process of commodifying water in the American West during the nineteenth century as a struggle between wealth, power and the use of technology to pursue environmental mastery. Water became, he argued, a resource to be bought and sold in the marketplace (Worster 1985: 88-90). A similar pattern of tradeable water rights emerged on the Otago goldfields in New Zealand in the 1860s and 1870s (Hearn 1994: 33-4). Before New Zealand, traces of this process had already begun to appear on the goldfields of Central Victoria, where mining parties such as the Humbug group also became water companies. Robert Brough Smyth, who served as Secretary of Mines in Victoria from 1860 to 1876, recorded cases where claimholders diverted water from one watershed to another and soon came to believe that:

he had an exclusive right to the enjoyment of the water over which he had had control for a long period, [and] he did not hesitate to sell it; and in this manner, by slow growth as it were, the claimholder was transformed into an owner of water (Smyth 1980: 398).

This quickly resulted in conflict between miners and the new 'water merchants' who held access to water races. The latter could, if they chose, decide which miners received water and who did not. It is not clear if the Humbug Hill Sluicing Company ever chose to favour one group over another but their control of miles of races and several large water storages placed them in a powerful position to control access to water and even modify natural flows in creeks and drainages.

FIGURE 3 NEAR HERE

Americans and those with experience of the Californian goldfields played a prominent role in the diversion of water to mining claims at Creswick and elsewhere in Victoria, and were at the forefront of commercialising water. The American brothers Benjamin and Charles Eaton, for example, developed substantial waterworks for mining on the Turon goldfield near Bathurst in New South Wales, before moving to Creswick Creek and purchasing Yankee Dam for £500 in 1857 (Potts & Potts 1974: 55). Several years later they built a much larger dam a short distance upstream, which was to become a prominent local landmark until destroyed by floods in 1933 (Figure 3; *Creswick Advertiser* 5 December 1933; Taylor 1998: 72). The brothers also obtained a Victorian patent for a mechanised sluice box in 1857 (Eaton & Eaton 1857). In 1853 Alpheus Boynton, recently arrived from Boston, rented out two Californian pumps to miners at Creswick at the rate of £1 an hour (Potts and Potts 1974: 88). In 1859, both John Bragg and Benjamin Eaton submitted ‘essays’ to the Creswick Municipality on providing a constant supply of water to the township, each proposing to use water from their own dams in return for a fee (Davies, Lawrence & Turnbull 2015). While both proposals were declined and the council chose to build a new reservoir with government funding, the willingness of both men to adapt their water enterprises to public benefit reveal something of the ‘ingenuity, enterprise, and energy’ so often observed among Americans on the Australian goldfields (Potts and Potts 1974: 220). Nearby at Ballarat, American miner John Kirk was responsible for constructing a large reservoir in 1857 which remains in use to this day (Bate 1978: 86; Nathan 2007: 14).

Water on the goldfields was diverted, measured and priced via a mechanism known as the ‘sluice-box’. This was a simple gauge consisting of an open-ended wooden box up to 12 feet (3.6 m) in length. It was placed in the head of a race and water flowed through the box and under a board or gauge inserted half way along, with a narrow gap at the bottom. Water

backed up behind the gauge to a specified, constant depth, typically five inches (127 mm). This was known as a ‘constant head’ and provided a rough calibration of water pressure and volume. Water flowing through the sluice-box at a constant rate for 24 hours constituted a ‘sluice-head’, which became a legally specified and widely accepted measure of water. The measurement of water via sluice-heads was also related to the mining technology employed. Ballarat mining by-laws in 1862, for example, specified the different fractions of sluice-heads that could be used for sluicing, puddling, pumping and crushing (Government of Victoria 1862: 132).

Calculations by engineers, however, showed that the amount of water delivered through sluice-boxes varied from place to place. In practice, the boxes varied in length, width and internal depth between Victoria’s seven mining districts. Robert Brough Smyth pointed out that miners at Ballarat received 211,500 gallons (0.96 ML) per day, while those at Ararat received 2.34 million gallons (10.6 ML), more than ten times as much (Smyth 1980: 405). British engineer Richard Sankey, who inspected progress on the Coliban Scheme of water supply to Bendigo in 1871, concluded in exasperation that he was ‘wholly at a loss to know what the term “sluice-head” may imply (Sankey 1871: 107). Miners’ ability to purchase adequate water also varied according to the presence of local storages, fluctuating demand, and variations in seasonal rainfall.

The legal framework within which miners diverted water from natural flows also came to recognise the measurement and pricing of water in the 1850s and 1860s (Davies and Lawrence 2014a). Miners extracted water through a variety of permits, privileges, rights, grants and licences, which evolved rapidly in response to demands from the miners themselves for legal security to water entitlements. The *Mining Statute* of 1865 (29 Vict. 291)

was a landmark in water laws on the Victorian goldfields. It provided licences for up to 15 years to construct water races on Crown land, and recognised that mining races and dams were articles of property that could be bought and sold. By the mid 1880s, miners held hundreds of water rights licences across the colony (Department of Mines 1884: 54-5). Victorian legal experience provided leadership in establishing water regulations which the other Australian colonies later followed (Pigram 2006: 44; Powell 1989: 37).

CONCLUSION

Historians and geographers have tended to focus on the creation of large-scale water infrastructure, including dam technology (Cole 2000), irrigation schemes (Blackburn 1999; Tyrrell 1999) and the development of metropolitan and regional water supplies (Dingle & Doyle 2003; Russell 2009). Mining water systems, on the other hand, were mostly small-scale interventions that cumulatively had a big impact. Gold miners diverted millions of gallons of water on a daily basis and flushed the resulting debris down the nearest creek, leading to major changes in stream flows and massive episodes of erosion and sedimentation. Miners deliberately created landscapes of water control on the goldfields, while almost inadvertently transforming the shape of hillsides, creeks, gullies and floodplains with the water and sludge they released.

The cultural landscapes of water management that emerged in this period were thus expressions not only of geology and mining technology, but also the process of coming to terms with the possibilities and limits of the natural world, as miners adapted traditional technologies of securing water in a new and unfamiliar environment (Lawrence & Davies 2013). The extensive networks of races and dams they created represented an artificial drainage pattern laid over the natural surface hydrology. The natural environment became an

increasingly modified, cultural environment as well, with the effort of collecting and distributing water ensuring that it became a cultural artefact to be valued, measured and priced (Strang 2004: 21-3). Gold mining commercialised water flows and provided legal recognition that it was a commodity to be extracted, used and returned to the natural environment. Mining water systems diverted water flows from one watershed to another, creating new hydrological landscapes that represented political authority, financial investment, technological control and command over nature.

ACKNOWLEDGEMENTS

We gratefully acknowledge support from the Australian Research Council and the Archaeology Program at La Trobe University in the preparation of this paper, along with the organisers and sponsors of the Watermarks conference. Jodi Turnbull has provided invaluable help with historical research and geo-mapping. Leon Bren and Kevin Tolhurst from the School of Forestry at the University of Melbourne have also offered us support and assistance. Staff at the University of Melbourne Archives have been extremely helpful in our searches of the E. J. Semmens Collection.

FIGURE CAPTIONS

Figure 1: Water race from Bragg's Dam to Humbug Hill (P. Davies).

Figure 2: Plan of water race constructed by Humbug Hill Sluicing Company, with the upper section now lost below Cosgrave Reservoir (P. Davies).

Figure 3: Section through Eaton's Dam, built in the early 1860s, showing stone slab facing and clay embankment on upstream side (P. Davies).

BIBLIOGRAPHY

Bannear, D. 1996, *Historic Mining Sites in the South-West Goldfield*, report to Heritage Victoria, Melbourne, and the Australian Heritage Commission, Canberra.

Bate, W. 1978, *Lucky City: The First Generation at Ballarat 1851-1901*, Melbourne University Press, Melbourne.

Blackburn, G. 1999, *Pioneering Irrigation in Australia to 1920*, Australian Scholarly Publishing, Melbourne.

Bower, C. 2013, *Water races and tin mines of the Toora District*, Collen Bower, Blackburn, Vic.

Bradford, W. 1902, *The Creswick Field and its Mining*, Department of Mines, Melbourne.

Carpenter, L. 2012, 'A 35-year endeavour: Bendigo's Rise and Shine sluicing syndicate', *Australasian Historical Archaeology*, vol. 30, pp. 4-13.

Cole, B. 2000, *Dam Technology in Australia 1850-1999*, Australian National Committee on Large Dams, Sydney.

Coroneos, C. 1993, *A poor man's diggings: An archaeological survey of the Lisle-Denison Goldfields, North-east Tasmania*, report to the Forestry Commission, Hobart and the Queen Victoria Museum & Art Gallery, Launceston

Davies, P. & Lawrence, S. 2012, 'Harvesting Water on a Victorian Colonial Goldfield', *Australasian Historical Archaeology*, vol. 29, pp. 24-32.

Davies, P. & Lawrence, S. 2013a, 'Flows of water on a nineteenth-century Australian goldfield', *Water History*, vol. 5, No. 3, pp. 331-47.

Davies, P. & Lawrence, S. 2013b, 'The Garfield Water Wheel: Hydraulic Power on the Victorian Goldfields. *Australasian Historical Archaeology*, vol. 31, pp. 25-32.

Davies, P. & Lawrence, S. 2014a, 'A mere thread of land: water races, gold mining and water law in colonial Victoria', *Journal of Australian Colonial History*, vol. 16, pp. 168-87.

Davies, P. & Lawrence, S. 2014b, 'Bitumen paper pipes and technology transfer on the Victorian goldfields', *Journal of Australasian Mining History*, vol. 12, pp. 45-58.

Davies, P., Lawrence, S. & Turnbull, J. 2015, *Water and Gold: Interpreting the Landscape of Creswick Creek*, Messmate Press, Melbourne.

Department of Mines 1885, *Mineral Statistics of Victoria for the Year 1884*, Parliament of Victoria, Melbourne.

Dicker, T. 1862, *Dicker's Mining Record and guide to the gold mines of Victoria*, February 1862, Thomas Dicker, Sandhurst, Victoria.

Dicker, T. 1864, *Dicker's Mining Record and guide to the gold mines of Victoria*, October 1864, Thomas Dicker, Sandhurst, Victoria.

Dingle, T. & Doyle, H. 2003, *Yan Yean: A history of Melbourne's early water supply*, Public Record Office Victoria, Melbourne.

Eaton, B.F. & Eaton, C.L. 1857, Specification for 'Patent for Improvements in Machinery for Puddling and Washing Earthy Matters so as to obtain Gold therefrom', Patent No.6, Colonial Secretary's Office, 13 March 1857 and 28 May 1857, manuscript held by State Library of Victoria, Melbourne.

Flett, J. 1970, *The History of Gold Discovery in Victoria*, The Hawthorn Press, Melbourne.

Government of Victoria 1862, *Acts of Parliament, Bye-laws, and Orders in Council, Relating to the Gold Fields*, Government Printer, Melbourne.

Graham, J.A. 1987, *Early Creswick*, Creswick Historical Museum, Creswick, Victoria.

Hearn, T.J. 1994, 'Miners and Irrigators: The Struggle for Water in Central Otago', *New Zealand Geographer*, vol. 50, no. 1, pp. 33-39.

Hundley, N. 2001, *The Great Thirst. Californians and Water: A History*, University of California Press, Berkeley.

Isenberg, A.C. 2005, *Mining California: An Ecological History*, Hill and Wang, New York.

Lawrence, S. & Davies, P. 2012, 'Learning about Landscape: Archaeology of Water Management in Colonial Victoria', *Australian Archaeology*, vol. 74, pp. 47-54.

Lawrence, S. & Davies, P. 2013, 'Landscape Learning in Colonial Australia: Technologies of Water Management on the Central Highlands Goldfields of Victoria', in Frankel, D., J.M. Webb & Lawrence, S. (eds), *Archaeology in Environment and Technology: Intersections and Transformations*, Routledge, New York.

Lawrence, S. & Davies, P. 2014, 'The Sludge Question: The Regulation of Mine Tailings in Nineteenth-Century Victoria', *Environment and History*, vol. 20, pp. 385-410.

Lloyd, B. 2006, *Gold in the North-East: A history of mining for gold in the old Beechworth Mining District of Victoria*, Histec Publications, Hampton East, Victoria.

McGowan, B. 1997, 'The typology and techniques of alluvial mining: the example of the Shoalhaven and Mongarlowe goldfields in southern New South Wales', *Australasian Historical Archaeology*, vol. 21, pp. 11-17.

McGowan, B. 2001, 'Mullock Heaps and Tailing Mounds: Environmental Effects of Alluvial Goldmining', in *Gold: Forgotten Histories and Lost Objects of Australia*, eds I. McCalman, A. Cook & A. Reeves, Cambridge University Press, Cambridge, pp. 85-100.

Mining Surveyor 1859, *Mining Surveyors Report (Creswick Division) July No. 3*, Mining Department, Melbourne.

Mining Surveyor 1871, 'Mining Surveyors Report for the quarter ending 30 Sept. 1871', *Papers Presented to Parliament (Victoria)* vol. 2, No. 103.

Nathan, E. 2007, *Lost Waters: A History of a Troubled Catchment*, Melbourne University Press, Melbourne.

Pearson, M. & McGowan, B. 2000, *Mining Heritage Places Assessment Manual*, Australian Heritage Commission, Canberra.

Pigram, J.J. 2006, *Australia's Water Resources: From Use to Management*, CSIRO Publishing, Melbourne.

Potts, E.D. & Potts, A. 1974, *Young America and Australian Gold: Americans and the Gold Rush of the 1850s*, University of Queensland Press, St. Lucia, Queensland.

Powell, J.M. 1989, *Watering the Garden State: Water, land and community in Victoria 1834-1988*, Allen & Unwin, Sydney.

Ritchie, N. 1981, 'Archaeological Interpretation of Alluvial Gold Tailing Sites, Central Otago, New Zealand', *New Zealand Journal of Archaeology*, vol. 3, pp. 51-69.

Ritchie, N. & Hooker, R. 1997, 'An archaeologist's guide to mining terminology', *Australasian Historical Archaeology*, vol. 15, pp. 3-29.

Russell, G. 2009, *Water for Gold! The Fight to Quench Central Victoria's Goldfields*, Australian Scholarly Publishing, Melbourne.

Sankey, R. 1871, 'Report on the Coliban and Geelong Schemes of Water Supply', *Papers Presented to Parliament (Victoria) 1871*, vol. 3, no. 48.

Smyth, R.B. 1861, 'Mining and Statistics of Gold', in *Catalogue of the Victorian Exhibition, 1861*, Government Printer, Melbourne, pp. 99-130.

Smyth, R.B. 1980 [1869], *The Gold Fields and Mineral Districts of Victoria*, facsimile edn, Queensberry Hill Press, Melbourne.

Strang, V. 2004, *The Meaning of Water*, Berg, Oxford.

Taylor, A. 1998, *A Forester's Log: The Story of John La Gerche and the Ballarat-Creswick State Forest 1882-1897*, Melbourne University Press, Melbourne.

Tracey M.M. 1997, 'No Water – No Gold: Hydrological technology in nineteenth century gold mining – an archaeological examination', in *The Australian Historical Mining Association Conference Proceedings 1996*, eds R. Kerr & M. M. Tracey, Home Planet Design and Publishing, Canberra, pp. 1-11.

Tyrrell, I.R. 1999, *True Gardens of the Gods: Californian-Australian Environmental Reform, 1860-1930*, University of California Press, Berkeley.

Worster, D. 1985 *Rivers of Empire: Water, Aridity, and the Growth of the American West*,
Pantheon Books, New York.

Revised after peer review