Flows of Water on a 19th-century Australian Goldfield

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Water History, 5(3):331-347 (2013)

Water acquired a range of meanings and values as it flowed through the goldfields of central Victoria in 19th-century Australia. Miners arrived from around the world with ideals and expectations of water and climate that could not always be accommodated in the drier environmental conditions they encountered. Alluvial mining required abundant water to wash gold from the earth, but natural supplies were often inadequate. Miners responded to water scarcity by building dams and extensive networks of channels, or races, to capture and divert water to their mining claims. As competition for water increased, the natural flows in creeks and gullies were soon overlaid with industrial, political, legal, economic and social values as well.

Many scholars have noted the diversity of social and historical meanings embodied in water, including the increasing commoditization of water flows during the 19th century (e.g. Harris 2010; Hundley 2001; Pisani 1996; Powell 1991). Expansion of European settlement around the world placed new demands on water resources for agriculture, mining, industry and town supply. Intensifying engagements with Indigenous peoples and environments demanded new responses to how water should be stored and distributed (Strang 2008:124), which often resulted in disempowerment, poverty and depletion of natural resources (Ward 1997). Dams, reservoirs and canals created new hydrologies that represented political authority, financial power, technological control and command over nature (Worster 1985).

In this paper we use the flow of water as a metaphor to explore different aspects of water use, management and value in 19th-century Victoria. Our focus on the Creswick alluvial goldfield offers a prism through which to identify the multiple and overlapping meanings of water in a region of unreliable rainfall and highly variable surface flows, and how these contributed to new understandings of water in colonial Australia. Miners from Britain, Germany, Italy, the United States, China, the Philippines and many other countries arrived to participate in one of the great gold rushes of the 19th-century world, and their responses to cycles of dry, drought and flood conditions created a physical legacy of water management that can still be read in the landscape today. In historical terms, water shifted from being part of nature to an industrial resource, before emerging as a public good (Powell 1989). As the driest inhabited continent, water in Australia has always been a crucial factor in human survival. The transformation of colonial society during the gold rush, however, drove vital changes in water management on this new frontier of European settlement.

International experiences had important implications for water values on the goldfields. Water in Britain, for example, was extracted in increasing volumes during the 18th and 19th century for industrial and irrigation purposes, and became entangled in a variety of social, legal and environmental disputes (Getzler 2004:204-252). The effort of collecting and transporting water ensured that ‘water carriers’, and the technology they created, were imbued with meaning and value, and that water itself became a cultural artefact (Strang 2004:21-23). In the United States, the rise of hydraulic mining and irrigated agriculture in the dry western states during the 19th century saw great contest over water policy between free enterprise and state intervention, and the export of water engineering expertise to various semiarid environments including Australia (Pisani 1984; Teisch 2011). In the same period,

thousands of Chinese migrants came to Australia from the lush south-eastern provinces of Guangdong and Fujian, many arriving with experience of traditional small-scale irrigated farming. As well as mining, Chinese migrants also established successful market gardens on the Australian goldfields, and gradually learned to use water in ways that were intensive, stable and highly productive (Frost 2002; Stanin 2004). The responses of immigrants to water and climate thus contributed to the diverse meanings associated with water use and diversion in 19th-century Victoria.

While the importance of both gold and water in Australia has long been acknowledged by historians, the relationship between these two elements has often been neglected. Water histories have generally focused on large-scale infrastructure, including dam technology (Cole 2000), irrigation systems (Powell 1989, 1991; Blackburn 1999; Tyrrell 1999), urban sanitation (Beasley 1988; Dingle and Rasmussen 1991) and the development of metropolitan and regional supplies (Hammerton 1986; Dingle and Doyle 2003; Russell 2009), often placing these developments within an international context (Powell 1997). Rivers have also been subject to ecological and sociological analysis (e.g. Seddon 1994; Sinclair 2001; Strang 2009; O'Gorman 2012), while others have explored the symbolism of water on the semiarid margins between agriculture and pastoralism (Meinig 1963; Williams 1975; Sheldrick 2005; Cathcart 2009; Ballinger 2012). Geographer Denis Cosgrove (1990:4) has observed, however, that most interventions in water flows have historically been 'local, small-scale and unrecorded'. One of our primary aims has been to understand the complex localism and economic individualism that characterised water manipulation in colonial Victoria, involving water systems at a scale below that of major infrastructure but which nevertheless had important consequences for the layering of values on water flows. The networks built by gold miners to secure water supplies thus had importance well beyond the simple dams and muddy ditches they constructed, as they adapted traditional technologies to the challenge of securing water in a new and unfamiliar environment and demonstrated the possibilities and limits of natural water flows.

We begin by outlining the historical and physical sources relating to the Creswick alluvial goldfield, and then review the importance of water to miners, and the infrastructure they created to transfer water from where it was available to where it was needed. As the vagaries of climate, rainfall and water supplies in the region became better understood, colonial governments drew on British and American legal precedents to create water laws within the context of mining legislation. Water thus became a commodity that was measured and traded, extracted from its natural course and given a commercial value. Mining parties, including those established by groups of immigrant Americans and Chinese, built and controlled substantial water infrastructure, and their activities reveal the new meanings that water was acquiring in this period.

Sources and approaches

Reconstructing the historical development of water diversions on the Creswick goldfield in the 19th century has drawn on a range of historical, mapping and archaeological resources. Unlike the Californian goldrush, government authority was established quickly on the major Victorian goldfields in the early 1850s. Wardens, commissioners, police and other officials created rules to regulate mining activity, which generated extensive correspondence and reports, while politicians and bureaucrats investigated miners' conduct via Royal Commissions and parliamentary inquiries. The result was a substantial, if often patchily preserved body of contemporary documents from which details about water permits, licenses

and surveys can sometimes be gleaned. In addition, local newspapers were established quickly on the goldfields, and these frequently reported disputes over water use.

Extensive archaeological remains of dams, races and other features are also preserved on the Creswick goldfield (Davies et al. 2011; Lawrence and Davies 2012). In many cases these are recorded on modern orienteering maps, which are invaluable for locating and verifying traces of water networks. We have incorporated evidence of these features into MapInfo GIS software to analyse a range of spatial relationships, including the position of dams and races in relation to local hydrology, geology, mining claims and historical land ownership. Field surveys have also benefited from the use of an iPad, which combines digital historical and modern map layers with MapInfo-generated spatial data. This greatly enhances the ability to locate and interpret relationships between features on the ground in this complex landscape of water management.

Water and gold in Victoria

Payable gold was first discovered in Victoria in 1851, only 16 years after permanent European settlement began in the mid 1830s. The impact of the subsequent gold rush was swift and dramatic, with the population of Victoria increasing from 77,000 people in 1851 to 540,000 just ten years later (Bate 1988:8). Victorian miners produced more than 25 million ounces (709 tonnes) of gold in this period, about one-third of total world output (Serle 1977:390-392). Agriculture expanded rapidly to feed the new immigrants, while factories and foundries were established to make the equipment and machinery needed by the mining industry. Gold deposits stimulated the formation of new banks, while the miners' need for houses and clothing boosted the building and textile trades, and the wider development of metropolitan centres (Butlin 1976; Bate 1978). Mining also had dramatic impacts on the natural environment, with forests ravaged to produce timber and fuel, and hillsides and creek beds torn up in the search for gold (McGowan 2001).

Major gold deposits were found in central districts on the northern side of the Great Dividing Range, characterised by a drier rainfall pattern than areas to the south (Lee 1982). The region has a Mediterranean-type climate, with highly variable rainfall arriving mostly in winter and spring (June to October), and generally hot and dry summers. There is also significant variation in annual rainfall in the region, along with a high rate of surface evaporation and irregular groundwater supplies (Figure 1). These conditions placed a premium on rainfall and natural flows in creeks and rivers.

In the first years of the gold rush most mining focused on shallow alluvial deposits, which involved working the surface soil layers or digging shafts up to 10 metres deep. Miners initially used a variety of pans, rockers and cradles to wash gold from the earth. These basic technologies were cheap and simple, but large quantities of water were needed and the recovery of gold was inefficient. Puddling machines were also used in drier areas, consisting of a large circular trough dug in the ground and filled with clay and water. One or two horses were used to drag harrows around the trough and reduce the mix to a sludge, which was then released through a valve and the gold was collected from the bottom. The peak of this method occurred in Bendigo in 1856, when 3000 puddling machines provided work for around 10,000 men (Smyth 1980 [1869]:93; Russell 2009:46). The sludge flows created by this technique, however, filled waterholes in creeks and caused rapid siltation and damaging floods (Royal Commission 1859).

Ground sluicing was a more intensive method of mining alluvial deposits. A stream of water was conveyed by a race to the claim area and used to wash the topsoil and washdirt into a channel or sluice. Stones were removed with a pitchfork and the water was drained away in a tail-race, leaving the gold to be recovered from the bottom of the sluice. A variation of this method was to direct the water over a working face which was typically 20 to 30 feet (6 to 10 m) high, with miners standing at the base to pick and rake the washdirt towards the sluice channel (Tracey 1997). This technique was widely used, but it could be very dangerous. Working faces sometimes fell in slabs, bringing down tons of clay and rock onto the miners below. At Humbug Hill near Creswick, at least seven miners were killed by earth falls during the 1860s and 1870s (Chin and Scott 2010).

In later years, hydraulic sluicing was also employed, a method first developed in California (Hundley 2001:77). A stream of water from a race was channelled into a series of progressively smaller pipes which ended in a nozzle or 'monitor'. The high-pressure jet of water was used to blast away the wall of a creek or gully and wash the deposit towards sluicing channels in which the gold could settle (Smyth 1980 [1869]:144-145). The final phase of alluvial mining was dredging, which developed late in the 19th century from technology developed in New Zealand and California. A dredge consisted of large floating pontoons which supported machinery for excavating river and stream beds and banks, washing the gold from the gravel and re-depositing the tailings. Bucket dredges obliterated former alluvial operations and created new landscape features including dredge ponds and large tailings mounds (Pearson and McGowan 2000:163). The technology peaked in 1908, when more than 100,000 ounces of gold were produced (Birrell 1998:136).

Alluvial mining thus required large volumes of flowing water to break down auriferous deposits and recover the gold. Frequently, however, dry conditions meant that mining came to a standstill until rain returned to replenish creeks and springs. Bendigo, for example, was well known as a 'winter diggings', where alluvial mining was generally limited to winter and spring (Russell 2005:115). Miners responded by constructing elaborate networks of races and dams to convey water to their mining claims. Races were excavated or raised channels, usually about one metre wide and up to one metre deep. Some were tens of kilometres long while others were only a few hundred metres in length (Figure 2). Most represented a substantial investment in money and labour, and often took months or even years to construct. Races followed the contours of hills, winding in and out of gullies, with tunnels and flumes also used where necessary. Dams of earth, clay and stone were often built to provide a head of water, although small races relied on seasonal water flows. The scale of races constructed on the Victorian goldfields is evident from the work of Robert Brough Smyth, who served as Secretary of Mines in the 1860s and 1870s. Collating the reports of local Mining Surveyors, he calculated that 2434 miles (3916 km) of water races were in use in Victoria's principal mining districts in 1868, a figure that does not include the many small-scale water systems created for watering farms, market gardens and local townships, and which reflects a period before the large-scale advent of water-intensive hydraulic sluicing (Smyth 1980 [1869]:547).

Water laws

The heavy demands on water supplies created by the gold rush gradually resulted in laws to regulate access. Colonial authorities in Victoria drew on English notions of 'prior use' and riparian rights, as well as American appropriation law, in a model now known as the 'California doctrine' (Pisani 1996; Kanazawa 1998; Harris 2010). In Britain, laws had emerged over the centuries that recognised property rights in flowing water attached to

possession of waterside land, a doctrine known as 'riparian access'. This principle held that land owners along the banks of rivers and streams had the right to use the water for domestic and stock purposes, but were unable to deprive others of its benefits (Getzler 2004:43-45). While English common law rules regarding water had been applied in Australia since 1788 (Stoeckel et al. 2012:17), the riparian approach was difficult to apply on the Victorian goldfields, as most mining took place on Crown (public) land where the legal control of water was uncertain.

The doctrine of water appropriation, however, had also emerged in Britain during this period, as the growing need for water to fill canals and drive thousands of textile mills created conflict between competing users. The notion of 'prior use' was based on the idea that first usage created a title to the water flow, but this was still limited to landowners adjacent to watercourses (Blackstone 1979 [1766]:18; Getzler 2004:175-177). Prior appropriation was taken up in the dry mining states of the American West with the discovery of gold in California in 1848. Courts encouraged the diversion and productive use of water, based on the idea that the first person who came to a stream and claimed its water acquired a vested right to the water, making it a form of personal property. This right to appropriate water, however, was unrelated to the ownership of land and resulted in a highly commercialised attitude to water supplies (Worster 1985:89-91; Pisani 1996:23). Elements of the California doctrine were soon applied in the Victorian context, including the extraction of water for mining purposes by non-landowners, water trading, seniority of water rights, and the forfeiture of unused water (Davies and Lawrence in press).

The custom of prior appropriation was effectively introduced in Victoria in the early 1850s, when miners asked local goldfields commissioners for permission to construct water races and to be given priority in diverting water from a stream. In the chaos of the early gold rush, these first permits were vague and failed to define the extent of water privileges and their connection with any area of land. Many of the permits changed hands, however, and large sums of money, sometimes several thousand pounds, were exchanged in the belief that the permits gave good legal title to the water rights taken out (Report 1860-1861:1-2; Smyth 1980 [1869]:398). Conflict emerged when permit holders diverted water they were authorized to use into separate drainage areas, but governments at the time were poorly equipped to regulate the situation (Powell 1989:50).

Laws began to catch up with the reality of mining and water diversion in 1857, when the *Goldfields Amendment Act* (section 3) entitled miners to build races and dams for mining purposes on Crown land. In spite of this, lack of cooperation between competing miners often resulted in wasteful diversion methods, with individuals and groups taking water where they could. Races were often cut parallel and close together, which was a waste of time and labour, and multiplied water lost through seepage and evaporation. Claims for water sometimes exceeded the available natural flows, while permits were lost and it became difficult to prove what rights they conferred (Report 1867:9). Tension also arose among miners claiming first, second and subsequent water rights, a process which reflected the prior appropriation model used in the United States, with district by-laws in Victoria granting earlier occupants a superior right to available water (Parliament of Victoria 1862:224). In addition, conflict emerged over water used in different mining technologies, with ground sluicing applying water directly to mining deposits, while quartz miners used races to drive waterwheels and crushing batteries (Royal Commission 1862-1863:359-360).

Further legislation in 1862 created water-rights licences, where reservoirs and races could be held for up to 15 years. This required preparation of formal plans to mark out the route of the race, and a charge of 10 shillings per annum for every 1 million gallons of water drawn from a reservoir. These regulations were consolidated in the *Mining Statute* of 1865, which spelt out the privileges and circumstances of water rights in detail, including rents for the use of races and dams, and penalties for stealing or polluting water. Government authorities issued licences for the private construction and maintenance of water storages for mining purposes, while retaining notional ownership of the water as a resource.

Legislation relating to water diversion on the goldfields was thus well established by the mid 1860s, with the principal of public ownership of water helping to protect the rights of mining parties over monopoly practices by individuals (Powell 1989:40). Water laws drew on overseas experience, as well as English and American legal models, while adapting rules and regulations to the unique conditions of the Victorian goldfields. In the 1880s, new legislation for irrigation effectively nationalized State ownership of Victoria's surface water, creating rights of access for private supply while abolishing previously recognized riparian rights in order to assert State management (Powell 1989:113-14).

Commercial flows

One of the consequences of uncertain water rights in Victoria during the early gold rush was the emergence of 'water merchants'. When miners diverted water to work their claim, and then used the water elsewhere, sometimes in a different watershed, some came to believe that they

> 'had an exclusive right to the enjoyment of the water over which [they] had had control for a long period, [and] did not hesitate to sell it; and in this manner...the claimholder was transformed into an owner of water.' (Smyth 1980 [1869]:398)

This quickly resulted in conflict between miners and the new merchants who had access to water races. The latter could, if they chose, decide which miners received water and who did not. Miners tried to thwart them by cutting and diverting the water channels, leading to disputes and extensive litigation. The rights of permit holders gained added legitimacy when they were transferred from one miner to another. When a miner moved between claims he would take 'his' water with him and then sell the water when he moved out of the district. Part shares in water permits could also be purchased and traded, and often changed hands for large amounts of money (Royal Commission 1862-1863:339).

Water thus became a commodity whose flow was measured, bought and sold. The amount of water that could be diverted for mining purposes, however, soon came to be regulated by district by-laws under parliamentary sanction. The scale of water rights varied according to the mining method in use and the number of men, horses or machines employed (Parliament of Victoria 1862:132). In addition, a minimum volume of water had to remain in creek or river beds, to ensure that at least some water was available for farmers downstream and other users (Department of Mines 1874:254). Volumes were measured by 'sluice-heads', which referred to a specific quantity of water passing through a 'sluice-box'. The latter was an open timber box, typically 12 feet long, 12 inches wide and up to 12 inches deep. A wooden partition divided the box while leaving a small gap at the base under which the water could flow. The opening across the bottom was usually between one and three inches, and this determined the volume of a sluice-head, calculated by the flow over 24 hours.

By 1868 the seven mining districts of Victoria had specified the size and flow rate of sluice-heads in local by-laws. This gave rise to anomalies in the delivery of water volumes. Up to 2.3 million gallons (10.5 ML), for example, were available per sluice-head each day in the Ararat district, while almost 1.9 million gallons (8.6 ML) could be diverted at Maryborough, but only 211,500 gallons (0.96 ML) at Ballarat (Smyth 1980 [1869]:405). The cost of such water, if provided by a water merchant or company, also varied substantially from place to place. On the Creswick goldfield, the average cost of water for 'general sluicing' was around one third of a penny for 1000 gallons (Report 1871:45). In other words, miners in the district generally paid about £3 per sluice-head per week (Mining Surveyor 1871:24).

Creswick alluvial goldfield

Creswick is located in central Victoria, 100 km north-west of Melbourne on the inland side of the Great Dividing Range. Gold was first discovered in the area in September 1851, and by 1856 the local population peaked with around 8700 people (Sherard 1856:1-3). The miners initially worked shallow deposits of clay and gravel to recover flakes and nuggets of gold, with ground sluicing and puddling being the main techniques employed. Surface deposits began to be worked out by the 1860s, however, and the focus of mining at Creswick shifted to the deep leads and quartz reefs north of the town. By the 1880s only a few hundred people remained in the forested ranges south of Creswick, and the area was gradually incorporated in the Ballarat-Creswick State Forest (Taylor 1998). Extensive remains of gold working and water management are preserved in the State Forest today.

Watercourses on the Creswick goldfield generally rise in the hills south-east of the township, starting at around 600 metres above sea level and flowing into Creswick Creek. Tributaries include Adekate (or Atticott) Creek, Ashwells Gully, Lincoln Gully and Slaty Creek, all of which were associated with extensive water race systems and sluicing. Long-term average rainfall at Creswick is around 720 mm per annum, but this obscures substantial variability from year to year. Major droughts in the area were recorded in 1865-66, 1876, 1881 and 1888, while flood years included 1863 and 1870.

Hills and gullies to the south-east of the town featured shallow deposits of gold-bearing clays and gravels that were well suited to ground sluicing, but substantial volumes of water were needed to work these claims. By the late 1850s a number of mining parties, including several with American experience, had formed to develop the water resources of the area. The activities of these groups, and the archaeological remains of the water infrastructure they created, casts light on the different values that water acquired in the early years of the gold rush.

Creswick water companies

The first generation of mining and water managers on the Creswick alluvial goldfield included a number of Americans and others with experience of the Californian goldfields. Parties of Chinese miners also played an important role (see below). Americans were widely admired in Australia for their entrepreneurial spirit, and their willingness to build substantial water infrastructure in mining region (Potts and Potts 1974:52-62). In November 1854, for example, the *Ballarat Star* newspaper urged 'energetic Americans' to provide Creswick with water for sluicing (Ballarat Star 11 Nov. 1854:2, 1 Jan. 1855:2). A number of parties took up the challenge, including James William Robertson, the brothers Charles and Benjamin Eaton, and John Boadle Bragg.

James William Robertson was a pioneer of water harvesting on the Creswick alluvial goldfield. Born in New Brunswick in Canada in 1823, he went first to California and then migrated to Australia in the early 1850s. He worked on the Turon goldfield near Bathurst in New South Wales before arriving in Creswick around 1855. In a series of letters he wrote to his father, he described the various sluicing activities and water races in which he was involved and the mining interests he developed (Wynn 1979). Lengthy sections of his race network are preserved on the goldfield today. In 1861 Robertson sold his shares in water races and left for the Otago gold rush in New Zealand, where he achieved success in business and politics before his death in 1876 (Scholefield 1940:246-247).

Benjamin Franklin Eaton and Charles Lafayette Eaton began their gold mining career in Australia in 1853 on the Turon goldfield in New South Wales, where they may have encountered James Robertson. The brothers' origins in the United States are obscure, although they arrived from California with some experience of ground sluicing, and Charles Eaton claimed familiarity with the Mississippi and its tributaries (Ballarat Star 4 August 1858:2; Select Committee 1858:772; Potts and Potts 1974:55). After initial success their fortunes declined and they took themselves off to Creswick in Victoria around 1855. They soon became active participants on the goldfield, paying £500 for a dam and water race on Creswick Creek that had been constructed three years earlier, and employing 50 men to work a large claim (Ballarat Star 14 Nov. 1857:2).

In 1862 the brothers began building a large new dam further upstream. It was completed two years later, with a capacity of 15 million gallons (68 ML), and its remains are today among the best preserved and most striking archaeological features on the Creswick goldfield (Figure 3). The dam is unusual for having been constructed with a substantial stone facing and a clay embankment on the upstream (water) side. The dam wall is approximately 70 metres long, eight metres wide at the base and generally 4-5 metres in height. The top of the dam wall is 1.5 metres wide and was originally secured with a frame of heavy timbers (Ballarat Star 2 July 1862:4). The masonry on the air face consists of large schist slabs and a steeply sloping buttress in the central section, which may have been an economy measure to avoid the cost of building a full embankment on the downstream side.

Water flowed from the dam along a water race that extended two miles (3.4 km) downstream along the south side of Creswick Creek to Portuguese Flat. The race was used jointly by the Eatons and another miner, John Roycraft, until the late 1860s, after which Roycraft and his son appear to have taken control of the dam and race and renewed the water licence until the early 1900s. By this stage Eatons Dam had become a popular site for picnics, bird watching, shooting parties and fishing, while the larger 'Government Lake' a short distance downstream was also a popular site for recreation (Graham 1987:124; Taylor 1998:29, 72). The area which had begun as a focus of water supply and alluvial mining in the 1850s thus became an important focus of social activity and recreation among Creswick residents as well. In 1933, however, heavy rain brought floods that breached the dam wall and destroyed the reservoir (Creswick Advertiser 5 Dec. 1933:2).

The Humbug Hill Sluicing Company began operation in 1856 under the management of Irish-American John Boadle Bragg. The multi-national party included Domingo Francisco, a Philippine sailor, and Jacinto De Lima, a Portuguese migrant from the Azores. Bragg himself worked as a tanner in New Orleans before arriving in Australia in 1853 at the age of 32. The eight partners in the group developed one of the most substantial water interests on the Creswick goldfield at the time, with extensive evidence preserved today of dams, water races

and areas of ground sluicing (Figure 4). The company was an early and active presence in the area, constantly negotiating and competing with other mining groups to establish and defend the water system the partners developed.

By 1859 the company had completed construction of a large dam at a cost of £1000, which could hold 15 to 20 million gallons (68 to 91 ML) of water (Creswick Advertiser 3 June 1862:2). Originally, the dam wall was 'substantially built of wood' (Creswick Advertiser 4 Nov. 1859:4), but this was later replaced with clay. A race extended six miles (9.6 km) from the dam to Humbug Hill where the group was engaged in ground sluicing. While this solved the immediate problem of water supply, the gold yield was modest, and plans were soon developed to divert the water further to the west to supply other miners who desperately needed more reliable supplies. The focus of the company thus began to shift from gold mining to the delivery and sale of water.

The main obstacle to extending the group's water system, however, was Slaty Creek, where the broad creek flats were well below the level of the company's works on Humbug Hill. A distance of eight hundred yards (730 m) had to be spanned to convey water across by gravity at sufficient pressure. While the use of a wooden flume was feasible, the partners decided to use a new technology, in the form of 'patent bitumenized' pipes, laid in an inverted siphon across the creek (Ballarat Star 12 Sept. 1862:2). The pipes, made from paper sealed with bitumen, were cheaper and much lighter than iron pipes, and were sometimes used on the 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 pipes were supported in iron-braced wooden boxes, with the entire outlay for the company amounting to £3000 (Creswick Advertiser 12 Sept. 1862:2).

With this connection made, the Humbug Hill Sluicing Company had succeeded in delivering water from its reservoir a total distance of 14 miles (22.5 km), from Adekate Creek in the east to the Bald Hills in the west. In addition to piping, the race network had required 800 metres of fluming and 240 metres of tunnelling (Creswick Advertiser 12 Sept. 1862:2). The bitumen pipes, however, tended to leak and even burst under pressure, and by 1864 the company had replaced the 'paper and pitch' pipes with more conventional iron pipes (Creswick Advertiser 5 Sept 1864:2). Following the death of John Bragg in 1865, much of the energy that had characterised the company's early years began to wane, although sluicing and water sales continued to generate modest profits. Water was often purchased by groups of Chinese miners, while the Creswick town supply was also bolstered by use of the Humbug dam and race. The company's assets were finally sold to the Creswick municipal council in 1880.

Americans were thus at the forefront of water management in the Creswick region, developing and commoditizing the available water resources. The Eaton brothers, for example, not only built substantial dams and races, but also provided employment for large numbers of men, thereby creating opportunities for self improvement and modest prosperity via their alluvial mining claims. Another American, Alpheus Boynton, arrived from Boston in 1853 and promptly rented out two California pumps to miners at the hefty rate of £1 an hour (Potts and Potts 1974:88). Nearby at Ballarat, American John Kirk headed a party of miners who built a 17-acre dam for sluicing in 1857. The dam proved so reliable that it was purchased five years later by the municipal council to provide a permanent water supply for Ballarat (Bate 1978:86; Nathan 2007:14).

Chinese miners at Creswick were also skilled at manipulating water supplies. The population of Chinese in the area peaked at around 1250 in 1861, with most coming from villages in Guangdong Province in south-eastern China (Chin et al. 2009:77-79). While the majority worked at alluvial mining, others were employed as merchants, butchers, market gardeners, hawkers, farm labourers and timber cutters. As finds of surface gold dwindled in the 1860s, many Chinese men left the Creswick area to pursue mining opportunities in Queensland, the Northern Territory and New Zealand.

The Chinese were adept water managers, not only for mining but also for market gardening. They owned races, leased races, sold water to European miners and were often employed to cut and repair races and dams at Creswick. A prominent Chinese miner and storekeeper in the town was Ah Fee, also known as Wai Jung Chin. In 1862 he employed a party of 70 Chinese men to sluice 1.4 million feet (32 acres) of abandoned mining claims (Creswick Advertiser 24 June 1862:2). He also appeared frequently in court over the years in relation to mining and water disputes, as both complainant and defendant (Chin et al. 2009:101-130). In 1880 he arranged with the local council to lease surplus water from Bragg's dam for no charge, in return for keeping the race clean and in good repair. Prior to his death in 1883 at the age of 65, he contributed a substantial sum to the construction of the See Yup Temple in Melbourne, demonstrating his piety, the success he had achieved on the colonial goldfields, and his links to the broader Chinese community (Chin et al. 2009:37).

Municipal water supply

There was a great deal of debate in the early 1860s about the best means of providing a water supply to the residents of Creswick. Numerous proposals, revisions, complaints and petitions were received by Council members, before a supply was secured in 1864 from the Bullarook reservoir, located 11 km south-east of the town. The process was complicated by the competing interests of miners, farmers, sawmillers and others, as each tried to protect their interests and, if possible, benefit from the establishment of a water supply. Development of a water scheme was also closely associated with the pre-existing entitlements of alluvial mining parties, several of which the Council later incorporated into the town supply.

As the town developed in the 1850s, the provision of domestic water was initially an *ad hoc* affair that depended on wells, rain barrels and old mining shafts, with water drawn from creeks often fouled with sludge and debris from mining operations. Between 1859 and 1864, however, a reservoir was constructed and pipes, races and flumes were laid to bring the water to a standpipe in town. The system worked well for the next few years, and there was often surplus water available for the Council to lease to miners. This created tensions, however, when it was realized that miners, including parties of Chinese, were receiving hundreds of thousands of gallons of mining water for the cost of a few pounds, while domestic users needed a horse, cart and barrel to secure a modest supply.

Water shortages in the 1870s prompted further discussion about supplementing the water supply. By this stage alluvial mining was in decline, and the old water rights of miners offered an obvious and reliable solution. In 1879 and 1880, the Council purchased the dams and races belonging to the Humbug Hill Sluicing Company, the Russell family and the St. George's Sluicing Company, creating a more complex but secure water system. The value of water had changed from an essentially industrial commodity to a resource that was managed and distributed for public benefit.

Conclusion

While much of the scholarly debate around the development of water infrastructure relates to the role of government authorities, our analysis has revealed that smaller scale interventions by gold mining parties and individuals could also have a substantial impact. In the case of colonial Victoria, miners were very often the first to explore and take advantage of local water sources, and maintain control at the local level. Their management of water sources resulted directly in the creation water laws, by-laws and regulations. They demonstrated that adequate water supplies were often available if sufficient time and effort was made to understand seasonal variability and hydrological landscapes. This showed the way for farmers, pastoralists, local government authorities and others in the following years, who secured water for a wide range of purposes.

The networks of races excavated by miners on the Creswick alluvial goldfield created an artificial water system that altered and cross-cut natural flows in creeks and gullies. Water was removed from its natural course and made to flow along the side of hills through channels, pipes, flumes and tunnels. Our research to date has identified the remains of more than 160 km of water races on the Creswick alluvial goldfield, and at least 27 dams of various sizes. This extensive infrastructure ensured that claims could be worked profitably for longer, and expanded opportunities for alluvial mining to other parties. Water thus rapidly emerged as a powerful economic and industrial force on the goldfields, creating employment for hundreds of men in the construction of dams and races, and work for the hundreds of miners who used the water on their claims. It also generated profits for those companies capable of capturing, storing and diverting water to where it was needed.

The social value of water was expressed through its role in human relationships, and contributed to the community's sense of place and belonging. Access to water was contested by miners, pleaded for by town dwellers, and in later years enjoyed as a focus of recreation. Miners generally worked in small parties, using their limited capital to build, extend and secure their water infrastructure. In the early years of the gold rush, access to water provided an independence for small alluvial miners that would be lost in the following decades as capital-intensive deep-lead mining took over.

Mining parties did not act in isolation. Individuals and groups interacted and negotiated constantly, jostling for mining claims and access to water. Conflicts and grievance were frequent and sometimes violent, and disputes often ended up in the local Police Court or Court of Mines. Hostility was frequently directed at Chinese miners who were alleged to steal water and foul streams and water holes with sludge and mining debris, while the Creswick municipal council debated for years about the best way to supply the town with water. Water flow was thus an intensely social phenomenon, as arguments about its diversion, control and pollution were played out in the local newspapers and court system.

The value and unpredictability of water was recognised from the beginning of European settlement in Australia in the late 18th century (Grove 2005), but the goldrush of the 1850s brought a dramatic new intensity to water use. This in turn resulted in new ways of seeing, valuing and managing water, as rights of access were clarified in law, exchanged between miners, and argued in the courts. Natural flows of water were thus overlaid with a range of industrial, political, legal and commercial values as well. Water was captured and diverted, measured and traded, disputed and polluted in a complex exchange of responses that led to increasing knowledge and understanding of this most precious of natural resources.

Acknowledgements
We are grateful to the Archaeology Program at La Trobe University and the Australian Research Council for support of our project, 'Cultural Landscapes of Colonial Water Management in Victoria's Central Highlands'. Jodi Turnbull has conducted much of the primary archival research and is responsible for GIS-mapping. We also acknowledge the assistance of the following institutions and individuals for their advice and assistance: Heather Bice (Ballarat), Don Henderson (Hepburn Shire Council), Kevin Tolhurst (University of Melbourne), State Library of Victoria, Victorian Archives Centre (Ballarat and Melbourne) and Katie Wood (University of Melbourne Archives).

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Figures

Fig. 1 Variation in annual rainfall recorded at the large mining towns of Ballarat (average 683 mm) and Bendigo (average 549 mm) in central Victoria, from 1858 to 1889 (Bureau of Meteorology 2011)

Fig. 2 Map showing water races on the Creswick goldfield associated with the Humbug Hill Sluicing Company, Charles and Benjamin Eaton, and James William Robertson

Fig. 3 Profile of Eatons' dam wall, facing north, with scale in 50 cm increments (Davies 2011)

Fig. 4 Water race near Humbug Hill, Creswick, Victoria (Davies 2011)