Water-Powered Flourmills in Nineteenth-Century Tasmania

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The author, a consultant in archaeology and heritage management, presents a physical survey of the production technology and processes preserved at five of nineteenth-century water-powered flourmills in Tasmania. These mills were included in data collected for comparative analyses of nineteenth-century watermills in Britain and Australia for a recently completed Ph.D. in historical archaeology at the University of New England, Armidale N.S.W. The aim of the research was to construct a model for technology transfer between the two countries in the nineteenth century. The results of the research have been published previously in this journal.

This paper presents the results of field surveys carried out on the material remains of five nineteenth-century watermills in Tasmania (Fig. 1). These surveys represent part of the database for research undertaken by the author for a Doctorate in the Department of Archaeology and Palaeoanthropology at the University of New England, Armidale, from 1991 to 1995. The aim, rationale, methodology and results of the research have been previously published in this journal.

Briefly, the aim of the research was to answer the question, 'Can we construct a model for the transfer and adaptation of industrial technology from Britain to Australia in the nineteenth century'? In order to answer this question, published research on international technology-transfer was used to identify and define the most important economic, environmental, industrial, human and cultural factors influencing the process. These factors were then used as starting points for a comparison of two countries, Australia and Britain, between which a given technology, that of watermills, was transferred. From this comparison it was possible to hypothesise about how the technology should have been adapted as a result of its transfer. These hypotheses were tested by a comparison of the physical remains of watermill technology preserved in the West Midlands of England, Tasmania and the New England Tablelands of New South Wales. From this, a generalised model for the transfer and adaptation of industrial technology into nineteenth-century Australia was put forward.[1] This emphasised production inputs and physical resource endowments in the recipient country as the most influential selection pressures, and defines the relationships of these with other factors, including the presence of skilled operators and supportive industries for the technology in the recipient country and the cultural makeup of both the donor and recipient countries.

Fig. 1: Location of watermills studied in Tasmania. All are flourmills, and range in date of construction from the 1820s to the 1850s.

There is a general lack of published research on nineteenth-century Australian watermills.[2] Further, no previously published research on watermills in Australia contains a detailed description of how the technology worked. Finally, only a handful of the many hundreds of watermills built throughout Australia in the nineteenth century preserve their technology and production processes for study, and the continued preservation of still less of these is assured. With this in mind, this paper contains a detailed description of the technology of five water-powered flourmills in Tasmania, set in a contextual discussion of the history of that industry in nineteenth-century Tasmania and Australia.

This sample of Tasmanian watermills represents only one part of the spectrum of conditions into which the technology was introduced in nineteenth-century Australia, however. A more complete picture will be given by comparison of this sample of mills with a discussion of the history and technology of a second sample of nineteenth-century water-powered flourmills from the New England Tablelands of New South Wales.[3] Viewed in conjunction, the two samples present a wider range of technological responses to a wider range of adaptive pressures. Both these samples form the database upon which the general model for transfer of the technology from Britain to Australia was formulated.[4]

WATERMILLS IN NINETEENTH-CENTURY TASMANIA

The climate of Tasmania (known as Van Diemen's land until 1853) lived up to the expectations of the British colonists in being more akin to that of Britain than the climate of any other Australian colony. Burn, writing in 1840–1841, states:

> The rivers of Van Diemen's Land which take their rise in the great Western tier of mountains, have always had an ample volume of water, even in the driest summer, such for instance as the Sorrel, Thames, Plenty, Styx, Russel's Falls, Jones, Broad River etc., which flow from Lakes Sinclair, Echo, Clarence, and the nineteen Lagoons, are alike fortunate in a never-failing ample stream — a circumstance which not only renders the operations of the miller continuous, but enables many of the landholders to irrigate their meadows.[5]

This naturally led to a heavy reliance on watermills to power early industry in Tasmania. The first of these clustered around the initial settlements at Hobart and Launceston.

Robert Nash, who had constructed the first watermill in the Australian colonies on Norfolk Island in 1795, is reputed to have been the first to take advantage of the favourable climate. After the forced closure of his mill on Norfolk Island due to relocation of the settlement to Hobart, he was recompensed in 1814 with land to build another mill in the second colony.[6] It is probable that a flourmill equipped with an overshot[7] water wheel and supplied with water by a weir and race from the Hobart Rivulet, in operation by 1816, was this second mill of Nash's.[8] By January of 1818, Nash had sold this mill, known as the 'Old Mill', to Arnold Fisk.[9]

Hobart's second water-powered flourmill, the 'Waterloo Mill', built by Fisk, was also in operation by 1818.[10] Also in this year, after requests for machinery to be sent from England as early as 1805, a government-owned water-powered flourmill, built and operated under the supervision of the convict Edward Yates, was opened.[11] Both these mills were equipped with overshot wheels supplied with water from weirs erected in the Hobart Rivulet. From the 1820s, the Government Mill was leased to private entrepreneurs.[12] In 1826 it was described as,

> ... a brick stuccoed building 80 by 35 feet at the basement and four storeys high. In the east end are six good apartments occupied by the miller, and in the other are machinery for two pair stones.[13]

After a short period as Government Miller, Yates opened his own water-powered flourmill in 1820, in partnership with James Tedder.[14] This was also powered by an overshot wheel, fed by a race from the Hobart Rivulet. This was followed by William Rayner's 'Sorell' Mill in 1822, which was powered by two overshot wheels.[15]

The name of Peter Degraves was prominent among these early watermill ventures on the Hobart Rivulet. In addition to a sawmill, which was powered by a conventional 22 foot diameter overshot wheel, he had erected a flourmill powered by a Fourneyron turbine by 1836.[16] This must have been among the first uses of the new turbine technology outside France, where it had been pioneered in 1827.[17] Degraves had erected a second water-powered flourmill on the Rivulet by the 1840s.[18]

Thus, there were no fewer than seven flourmills powered by the waters of the Hobart Rivulet operating by the early 1840s. The Rivulet also powered sawmills operated by Peter Degraves from 1825 and Thomas Stace from 1827.[19] Further north, the first watermill was erected in the Launceston area by James Brumby and Edward Yates in 1821–1822.[20] This was located on the North Esk River.

At times the supply of water tapped by water-powered mills could become an oversupply. Sibbald and Ferguson's Cataract Gorge Flourmill, located on the South Esk River, near Launceston, was washed away by floods soon after it was built in 1833.[21] The navigability of Tasmania's larger rivers nevertheless encouraged the siting of mills on them for ease of access to trade and supply routes. Guillan and Symes' flourmill on the Supply River, near Launceston, and John Terry's flourmill on the Derwent River at New Norfolk near Hobart, both built in the 1820s, were well situated in this respect.[22]

The first watermill to be constructed in the interior of Tasmania was built at Baghdad, northwest of Hobart, in 1822.[23] Other early watermills in the interior included those built on 'Thorpe' and 'Nant' Estates in 1823 and 1824–1825 respectively (see below). By 1861 there were up to 50 water-powered flourmills in use throughout the colony (Table 1). Fourteen of these still remained in use by 1900.

Table 1

YEAR	Water	Water & Wind	Animal	Steam	Unspecified
1834	9			1	21
1840	37	14		3	1
1845	26	2		12	30
1850	46	1		11	4
1855	45	9	2	23	1
1860	42	7	2	19	
1865	45	9	3	21	
1870	45	7	7	27	
1875	36	5	5	22	
1880	33	3	3	23	
1885	26	1	1	23	
1890	24	1	1	20	
1895	20			13	
1900	14			16	

Table 1: Statistics for the use of water-power in the Tasmanian flourmilling industry throughout the nineteenth century. Numbers of steam-powered flourmills are added for comparison (Institute of Engineers 1988).

Table 2

STATE	Flourmills	Sawmills	Mining	Textiles	TOTAL
N.S.W	45	21	194	2	262
V.D.L	50	9		2	62
VIC.	18	10	443		471
S.A.	6				6
W.A.	11	4			15
QLD.		1	25		26
TOTAL	130	45	662	5	852

Table 2: Comparison of water-power use in Tasmania with that in other nineteenth-century Australian colonies (Colonial Statistical Registers, Returns and Blue Books).

A summary of patterns in watermill use in all of the Australian colonies in the nineteenth century is presented in Table 2. These figures show the maximum number of watermills recorded in operation in the Colonial Statistics of each colony at any point during the nineteenth century. Reference to Table 1 shows that throughout much of the nineteenth century, particularly the latter part, the actual number of watermills in operation in any one colony was much lower than this maximum figure. Also, these maxima did not all occur at the same time in all colonies, but at various times throughout the nineteenth century. Finally, the figures quoted in the Colonial Statistics sometimes do not agree with data available from other, more reliable, historical sources, such as newspapers, so that the figures in Table 2 should be seen only as a guide to the importance and role of water-power in the nineteenth-century Australian economy.

Figure 2 shows the relative distribution of the maximum number of nineteenth-century watermills by colony. Given the relative suitability of the climate of each colony for the use of water-power, the distribution is as expected, with the bulk of the mills recorded in the more suitable climates, such as Tasmania, New South Wales and Victoria. However, given that it has the most suitable climate of all, the figure for Tasmania appears to be quite low. This anomaly may be explained by the fact that water-powered sawmills and water wheels used in mining, of which there were many in use in nineteenth-century Tasmania, were not recorded in the Colonial Statistics for that colony, as they were in New South Wales and Victoria, perhaps due to the ephemeral nature of these industries.[24]

The relative distribution of the maximum number of watermills by industry is shown in Figure 3. This shows that water-power was most important numerically in the mining industry, followed by the flourmilling and sawmilling industries. This is a much more restricted range of industries than those in

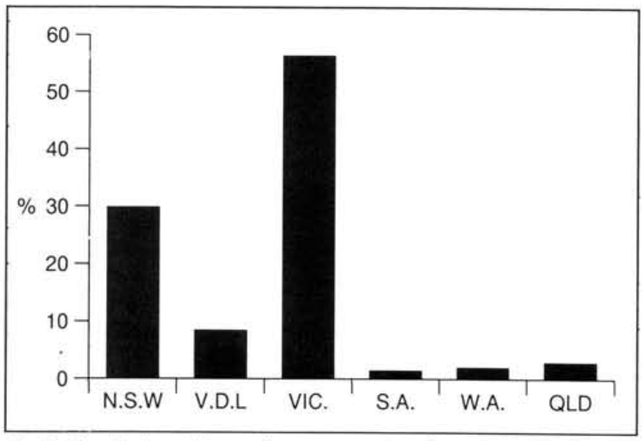

Fig. 2: Distribution of the maximum proportion of water-powered mills at any time during the nineteenth century, by colony.

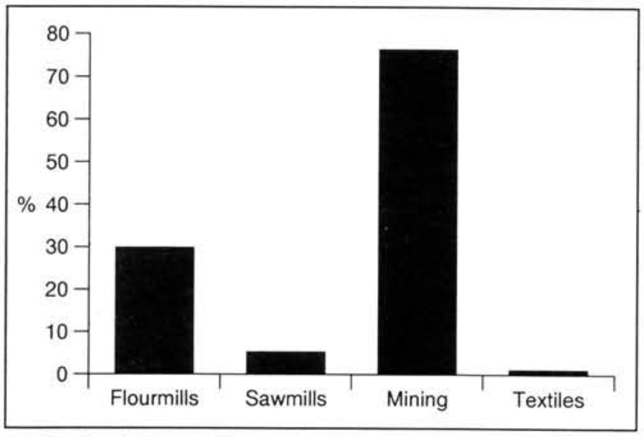

Fig. 3: The relative distribution of the maximum proportion of water-powered mills at any time during the nineteenth-century, by industry.

which water-power was used in nineteenth-century Britain and can be seen to reflect the colonial nature of the nineteenth-century Australian economy, geared to mainly primary and extractive industries, rather than manufacturing.[25] It should be noted that the relationship of the figures for the mining industry with those for the other industries, particularly the flourmilling industry, may give an inflated picture of its relative importance. The mining industry was only a major user of water-power for a relatively short time in the mid-to-late nineteenth century in Victoria, Tasmania and New South Wales. For most of the nineteenth century and in all of the colonies, the flourmilling industry was in fact the largest user of water-power.

Finally, in assessing the economic importance of water-power in Tasmania, it is also necessary to examine the extent of its use in relation to alternative power sources such as animal, wind and steam power. Unfortunately, due to the vagaries of nineteenth-century record-keeping, the flourmilling industry is the only industry where the data is complete enough to allow a comparison (Table 1). The figures are indicative of the fact that the very long and expensive transport links to Britain would naturally have initially favoured the use of watermills over alternatives such as steam technology, at least in those parts of the continent suitable for their use, as the former could be largely constructed in the colonies, while the latter would have had to be transported from Britain.

WATERMILLS IN THE TASMANIAN FLOURMILLING INDUSTRY

While watermills powered a wide variety of industries in the nineteenth century, including flourmills, sawmills, mining machinery of various descriptions and textile mills, flourmilling was, of necessity, the first major industry in all of the Australian colonies and, for a long time, the only industry. It remained one of the most important industries throughout the nineteenth century in most colonies.

According to Linge, the Hawkesbury area of New South Wales was the main source of colonial grain by the beginning of the nineteenth century.[26] However, Linge states that during the years 1841–1843, 1847 and 1849, the area sown to wheat in Tasmania exceeded that in New South Wales.[27] From 1839 through to 1850, 42 per cent of the total Tasmanian wheat crop was exported (25 per cent as grain and 17 per cent as flour), 80 per cent of this through the port of Launceston to destinations such as New Zealand, the United States and even Britain.[28] With the settlement of new colonies in Queensland, Western Australia, Victoria and South Australia in the late 1830s and early 1840s, new markets for flour from Tasmania were created, with grain also being sent from these colonies to be ground there.

However, it did not take the newer colonies long to develop self-sufficiency in flourmilling capacity. By 1843 South Australia had a small export capacity of its own; a sign of things to come.[29] The role of the largest producer of grain and exporter of flour shifted from Tasmania to South Australia during the late nineteenth century, at least until agricultural expansion in that colony overreached environmental constraints in the early 1880s, precipitating a marked decline in production.[30] Victoria, which had previously been a flour importer, also became self-sufficient by the 1860s.[31] Queensland remained a large-scale importer until the 1870s.[32] Such moves towards self-sufficiency by the late nineteenth century produced a slump in the external demand for flour from Tasmania, whose flourmilling industry languished after 1875.[33]

While these trends in flour production, export and import would necessarily have influenced the numbers of mills constructed in each colony over time, it is important to remember that the expense and difficulty of overland transport would have encouraged the construction of numerous small mills, serving local markets only, in all of the colonies.[34] With the coming of the railways and the growth of large population centres towards the end of the nineteenth century, this trend reversed towards a major reduction in the number of flourmills, an increase in the scale and mechanisation of operations in those remaining and a concentration of these in large population centres, as noted by Jones and Jones in their survey of Victorian flourmills throughout the history of that state.[35]

Linge asserts that these geographic trends may be broken down into a number of phases.[36] The first of these comprises the flourmills erected by or with the assistance of colonial Governments, to ensure the rapid self-sufficiency of the colony. Mills such as the Government Mill in Hobart fall into this category. The second phase was the construction of small flourmills by settlers to make their estates more self-sufficient as they moved into previously unsettled areas. Mills such as Thorpe and Nant Mills fall into this category. The third phase was the emergence of purely commercial enterprises. Large-scale flourmills such as the Yates and Tedder Mill in Hobart characterise this phase. The fourth phase was the development and location of establishments which more clearly reflected the growth of larger settlements. This phase is reflected in the decline of all types of small-scale rural flourmills and the emergence of large flour factories to supply urban markets. This decline of the small-scale rural mill is seen in the examples discussed in more detail below. At least in Tasmania, these phases were not strictly sequential, however. All of Linge's first three phases were present by the 1820s.

SURVIVING WATERMILLS IN TASMANIA

It is into this historical context for water-power use in flourmilling in Tasmania and the rest of the Australian colonies that the five watermills described below fit. Along with Anderson's Mill at Smeaton in Victoria, Bridgewater Mill in South Australia, Yallingup Sawmill in Western Australia and Gala, Mayfield and Strathmore Mills in Tasmania, they are among the few known to have water wheels and/or machinery surviving or restored sufficiently to allow a detailed study of their technology and manufacturing processes.[37] With the exception of Yallingup Sawmill, all are flourmills. The bias towards flourmills is a result of two factors. Firstly, as we have seen, flourmilling was one of the earliest and most important colonial industries. Accordingly, most watermills in the nineteenth-century were flourmills. Secondly, mills in rural locations have a far greater chance of survival and preservation from the forces of demolition and redevelopment than those in larger population centres.

Connorville Mill

The water-powered flourmill on 'Connorville' Estate, near Cressy in central Tasmania, was built in the early 1860s. A study of the Valuation Rolls for the estate indicates that the Rockford Mill, on the St Paul's River, was added to the property of the estate between 1850 and 1858. It ceased to exist after 1866, so it is likely that this mill was demolished and the machinery used in the erection of the mill at Connorville.[38] The mill is still part of a large pastoral and agricultural estate founded by the O'Connor family, settlers from Ireland.

Orders and prices, scribbled on the inside of the front door of the mill by the millers, ranging in date from 1885 to 1956, indicate that the mill remained active until well into this century, with the water wheel remaining the sole source of power. Due to its prolonged use-life, only minor restoration work has been required in recent years on the water wheel and some of the machinery inside the mill to preserve it in working order. For the most part, the mill remains as it was constructed, preserving intact the technological integrity of a nineteenth-century, colonial, water-powered flourmill. It remains an integral part of a large complex of preserved early nineteenth-century farm buildings, all classified by the National Trust, comprising 'Connorville' Estate, which is still a working property.

The water-supply for the mill (see Table 3 for details) comprises a small earth dam, which creates a pond on Pisa Creek, a tributary of the Lake River. At one end of the dam, a lever-operated, wooden sluicegate set in a spillway admits water to a headrace, constructed as an unlined earth channel. Close to the mill, a wooden sluicegate with a rack-and-pinion control allows overflow back to the creek via a short concrete race. A second sluicegate admits water to another short concrete race, which feeds a turbine for electricity generation, housed in a small shed on the stream bank.

The main headrace continues directly onto the wheel, located inside a wheelhouse attached to the mill. At the wheel, a final rack-and-pinion-operated, wooden sluicegate admits water onto the wheel at the nine o'clock position.[39] The sandstone breastwork in which the wheel is housed is curved to fit the wheel to improve the water retaining efficiency of the buckets, and is equipped with a ventilation shaft to act as a valve, preventing water backing up in the tailrace and impeding the rotation of the wheel.

The breastshot water wheel (Fig. 4) (see Table 3 for details) is built around an iron axle. Two sets of eight wooden arms are set into iron hubs, or 'spiders', carried on the axle. The arms support two iron rims, known as 'shrouds', each bolted together in eight sections. These, in turn, support 40 wooden buckets, with wooden 'sole' boards forming the interior surface of the wheel. The wooden parts of the wheel are constructed of Tasmanian King Billy pine.

The inner end of the water wheel axle carries a gear known as a 'pit' wheel (Fig. 5) (see Table 3 for details). The teeth of this mesh with a smaller, iron pinion wheel 2 feet in diameter, carried on a first motion shaft. The inner end of this carries a second large pit wheel identical to the first, driving another pinion wheel identical to the first, carried on a second motion shaft, providing a second step up in the gearing ratio and resultant rotational speed of the mill machinery. The second motion shaft carries two iron pulleys for belt drives to a chaff cutter, sawmill and lathe machinery, located in a shed adjoining the mill.

Inside the mill proper, the second motion shaft carries a third pulley for a belt drive to a layshaft located on the first floor of the mill, providing power for machinery located on both the first and second floors of the mill. The inner end of the second motion shaft carries an iron gear wheel with bevelled teeth, which mesh with the wooden teeth of a second gear wheel. This is attached to a vertical shaft, or 'spindle', which carries the upper of the two millstones, known as a 'runner' stone, on the first floor of the mill. The lower 'bedstone' remained stationary. The lower end of the stone spindle rests in a screw-adjusted bearing, allowing the gap between the millstones to be adjusted; a process known as 'tentering'.

The single pair of millstones on the first floor is housed in a vat called a 'tun' and fed grain via a funnel, equipped with a vibrating feeder, or 'shoe', at its base, and mounted on a wooden frame, known as a 'horse', on top of the tun. The

Table 3

	Connorville	Thorpe	Nant	Riversdale	Millbrook
WATER SUPPLY					
dam/weir length by height (feet)	100 x 6	15 x 6	25 x 2	–	–
Headrace length (approx. yards)	450	500	450	1 650	1 250
Headrace width by depth (feet)	6 x 3	10 x 3	8 x 4	7 x 2	5 x 3
WATER WHEEL					
Construction Materials	Wood & Iron	Wood & Iron	Iron	Wood	Wood & Iron
Diameter by width (feet)	16 x 4	7 x 7	12 x 4	15.5 x 2	10 x 5
GEARING					
Pit Wheel (diameter, in feet)	Iron, 8	Iron, 5	Iron & Wood, 5	Wood & Iron, 5'6"	Iron & Wood, 6
Wallower (diameter, in feet)	–	Iron, 2	Iron, 1'6"	Iron, 1	–
Spur Wheel (diameter, in feet)	–	Wood & Iron, 6	Iron, 6	Iron, 5	–
Crown Wheel (diameter, in feet)	–	Iron, 3	Iron, 4	–	–

Table 3: Details of the water supply systems, water wheels, and gearing for the five mills studied

Note: Dimensions given in imperial to preserve their historical meaning. For conversion to metric one foot = 30.5 cm and one yard = 0.914 m

Fig. 4: Breastshot water wheel supplying power to Connorville Mill. Water is admitted into the buckets of the wheel through the sluicegate at right foreground. Range pole divisions are 50 centimetres (Photo W. Pearson, July 1993).

funnel is in turn fed via a sack chute from a bin on the second floor of the mill. Also located on the first floor is a grain-cleaning machine, or 'smutter' used to remove impurities from the grain prior to grinding. This is fed grain from the second floor via a wooden chute and powered by a belt drive from a layshaft ('c' in Fig. 5). It bears the inscription:

EUREKA SMUT & SEPARATING MACHINE
MANUFACTURED BY HOWES, BABCOCK & CO. N.Y.
PATENTED MAR. 16 1858
REISSUED MAR. 5 1872
PATENTED FEB. 23 1864
PATENTED IN GREAT BRITAIN JULY 23 1872

This indicates that the machine was most likely imported from the United States, sometime after 1872. Imported machines from this company also served flourmills in Victoria. A 'Howes & Babcock' grain-cleaning machine installed at Clark's Mill, Benalla, was said to be capable of cleaning 40 to 60 bushells of grain per hour.[40]

The first-floor layshaft also powers a large flour-sifting machine, or 'bolter', located on this floor of the mill. This is a large, cylindrical, revolving sieve which separated the ground flour into various grades of fineness, each bagged from separate chutes on the ground floor. The machine bears the inscription:

W.H. KNIGHT, LAUNCESTON

indicating that it was of local manufacture. Leavitt states that W.H. Knight was in the business of manufacturing and supplying milling machinery at Launceston from 1859 to the 1870s.[41] Knight had originally arrived in Tasmania in 1854 to install machinery brought from England for Grubb and Tyson's sawmill, near Launceston. He is also known to have installed the Leffel turbine at the Waverly Woollen Mills, also near Launceston. The frame, or 'hurst' supporting the gearing on the ground floor of Connorville Mill also bears his inscription, suggesting his firm may have been responsible for the reconstruction of the Rockford mill at its Connorville site, sometime in the late 1850s or early 1860s.

A pulley on the end of the first-floor layshaft also powers a belt-driven sack-hoist located on the second floor of the mill. The mill is also equipped with a grain elevator powered by a belt from a second layshaft on the second floor ('d' in Fig. 5).

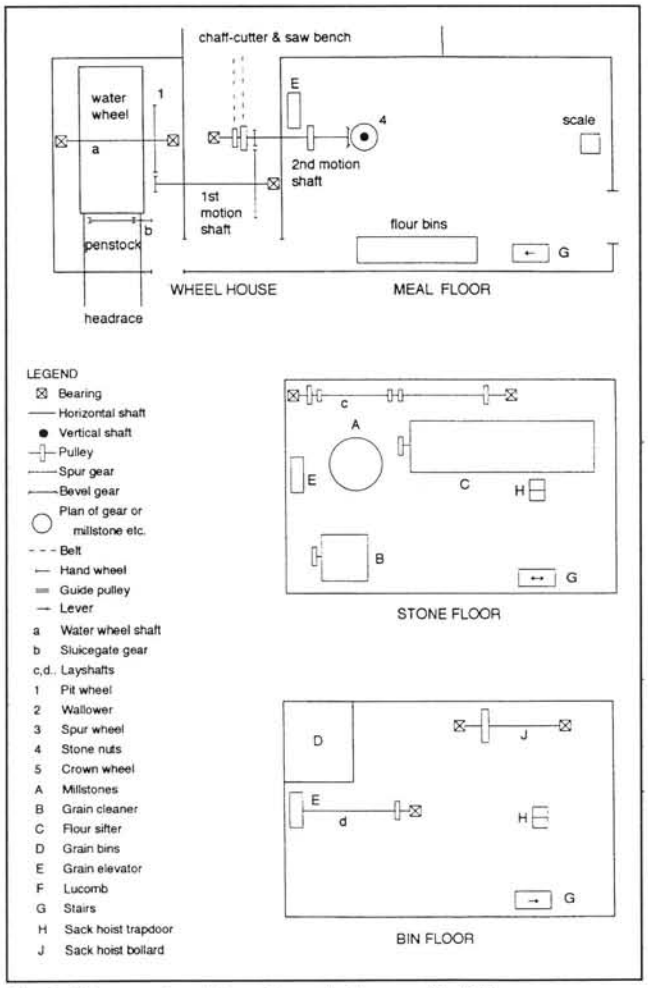

Fig. 5: Diagram of machinery layout in Connorville Mill.

The grain is poured into a hopper on the ground floor, from where an enclosed conveyor belt of buckets raises it and deposits it into the single grain storage bin located on the second floor. This bin alternately feeds the smut machine or millstones below. The mill building comprises three floors: the ground, or 'meal', floor housing the gearing for the millstones, the first, or 'stone', floor housing the millstones and auxiliary grain and flour-processing machinery, and the second, or 'bin', floor housing the sack-hoist, grain storage bin and further grain storage space. This arrangement allowed for milling processes to be gravity fed, and was a common arrangement in nineteenth-century flourmills.[42] The mill is built of brick with a gabled, corrugated iron roof, replacing original wooden shingles. Two weatherboard miller's cottages also form part of the complex of farm buildings at 'Connorville'.

Thorpe Mill

Thorpe Mill was built by Thomas Axford in 1823 as part of his large pastoral and agricultural estate, 'Thorpe', at Bothwell in central Tasmania. Axford had arrived in Tasmania in 1822 from Berkshire, England.[43] As the mill was one of the earliest in the district, and indeed in Tasmania, it would have been built not only to ensure the self-sufficiency of 'Thorpe' Estate but also to supply the surrounding district. The multiple uses to which the water wheel was put attest to the vital role of the mill in ensuring the self-sufficiency of the isolated farming settlement. The race supplying the mill with water also supplied a complex system of field irrigation channels, in what must have been one of the earliest such enterprises in the Australian colonies, attesting to the willingness of Axford to adapt and experiment; a trait further testified to by aspects of the mill design. These adaptive experiments did not always result in the most efficient design, however.

The history of the mill was troubled.[44] An early shortage of skilled millers in Tasmania forced Axford to rely on convict labour to run the mill until the 1840s, after which time professional millers were employed. Axford himself was murdered by bushrangers in 1865. An advertisement in the Colonial Times in the year 1836 advising customers that he had '... finished his new mill ...' suggests a major refit of the mill by Axford at that time.[45] This refit was accompanied by the cutting of a channel from Lake Crescent to the Clyde River, in partnership with William Roadknight, to ensure a more reliable water supply to Thorpe Mill, and to Roadknight's mill at Hamilton, further downstream. During the mid-late nineteenth century the mill passed through a succession of lessees, continuing to produce flour until at least 1897, when competition from steam roller-mills in larger centres forced its closure.[46] The water wheel continued to power chaff-cutting machinery for the farm until the wooden axle broke in 1916.

Restoration of the mill to working order was undertaken by the present owners of 'Thorpe' Station during the 1970s and is described in detail by Bignell.[47] Original parts, materials and techniques were used wherever possible to ensure a sympathetic reconstruction and to preserve the nineteenth-century technological integrity of the mill. The work included rebuilding part of the millpond dam, cleaning out the head and tailraces, fitting a new wheel axle and wooden parts to the wheel, cleaning and refitting gearing throughout the mill, redressing the millstones and replacing the roof shingles and some flooring and windows. The restored mill is classified by the National Trust.

The source of water for the mill is the Clyde River, augmented by Lake Crescent. By 1836 the Clyde supported three mills, including Thorpe Mill, Nant Mill and Roadknight's Hamilton Mill. Later, a canal was also dug so that the Lake Crescent supply could be augmented by Lake Sorell. In 1857 the Clyde Water Trust was formally set up to oversee the supply of water to the mills and associated irrigation schemes on both 'Thorpe' and 'Nant' Estates. This Trust is one of the few remaining under private control today.

To supply Thorpe Mill with water, the River Clyde is dammed above the mill to form a millpond. The main dam is constructed of two dressed sandstone walls, flanking a concrete spillway (Table 3). This is equipped with a frame into which wooden hatches could be dropped to dam the flow.

A headrace carries water from the millpond to the mill. This is constructed in the form of an earth channel built up on each side with levee banks (Table 3), and is equipped with an eel trap to supply the mill-owner with an extra source of income. Close to the mill, a large wooden sluicegate supplies the field irrigation system with water. The headrace supplies a wooden chute, or 'penstock', above the wheel inside the mill, from which water is admitted to the wheel at the 12 o'clock position through a final sluicegate operated by a lever inside the mill. A long tailrace returns the water to the river downstream.

The siting of the mill in relation to its water supply is unusual in that the headrace is much shorter than the tailrace, a reversal of normal practice in designing water supplies to watermills situated on relatively flat ground. Because the tailrace had to be dug below ground level at the mill to allow the water to flow away after turning the wheel, it had to be constructed almost one mile long before it reached the level of the river into which it discharged. The normal and more efficient practice was to construct the headrace longer than the tailrace, as this only had to be deep enough to convey water to the mill. Only a short, deeper tailrace would then be required to return the water to the river. Thus Thorpe Mill is unusual in that it is located closer to the inlet end of the water-supply system than the outlet end, which was less efficient in terms of cost and ease of construction.

The overshot water wheel is located entirely below ground level in a stone-lined well underneath the mill building (Table 3). It is constructed around a solid wood axle 16 inches in diameter and 18 feet long. Iron rings strengthen the ends, which carry iron gudgeon pins on which the axle rotates in journal bearings. The major iron parts of the wheel comprise two spiders, each carrying five wooden arms, which support the wooden shrouds of the wheel. Each spider is cast in one piece and held in place on the axle by wooden wedges. The wooden shrouds are constructed in five sections and bolted together with iron ties. A third wooden rim in the centre of the wheel is not supported by arms from the axle, but is held in place by long bolts across the width of the wheel. The shrouds have 15 wooden buckets mortised between them, with wooden sole boards. The wooden parts of the wheel are all constructed of Tasmanian pine. The design of this wheel is unusual, in that it is as wide as it is high. The extra width maximises the carrying capacity of the buckets, to suit it to a site with a limited fall but a good flow of water.

Also carried on the water wheel axle is a pit wheel (Fig. 6) (see Table 3 for details of gearing). The bevelled teeth of this wheel mesh with those of a 'wallower' gear, carried on a thin, iron vertical shaft. Above the wallower, this shaft carries a large gear called a 'spur' wheel. This drives two small iron pinion wheels, which in turn drive two iron gears called 'stone nuts' attached to the millstone spindles. The two intermediate pinion wheels may be raised or lowered on their shafts by means of wooden wedges, enabling the drive to the millstones to be engaged or disengaged as required by the miller. The lower ends of the millstone spindles rest on screw-adjusted horizontal bearers known as 'bridgetrees', allowing for the tentering of the millstones. Only one pair of millstones and stone nut remain. This arrangement of pit wheel, wallower, spur wheel and stone nut gears was common in nineteenth-century water-powered flourmills, and was known as a two-stage, underdrive system, as it involved two steps up in gearing and rotational speed of the machinery.[48] The intermediate pinion wheels between the spur wheel and stone nuts at Thorpe Mill represent a departure from the standard two-stage, underdrive system, and suggest that the original spur wheel may have been replaced by one of smaller diameter, possibly during the 1836 refit of the mill.

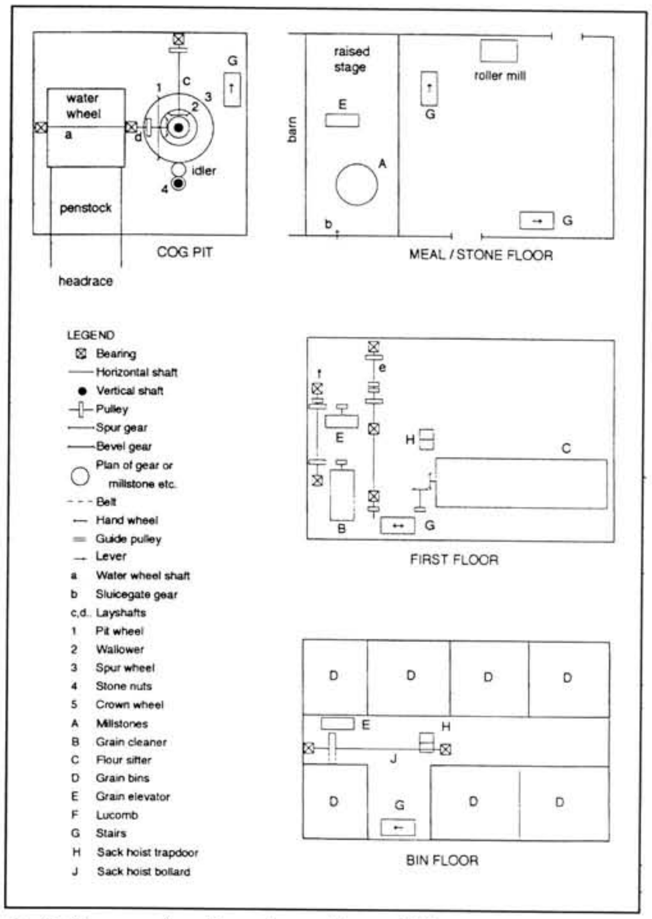

Fig. 6: Diagram of machinery layout, Thorpe Mill.

There were originally two pairs of French Burr millstones (a type of stone imported only from France) in the mill, the runners of which were balanced on the upper ends of the spindles by a ball-and-socket joint known as a 'rynd'. The stones are fed grain from horse-mounted hoppers, which discharge onto vibrating shoes and thence into the eyes of the runner stones. The millstones are mounted on the upper level of the split-level meal floor of the mill, to allow sufficient space for the water wheel, gearing pit and flour bagging chutes to be located below them. Above the spur wheel, the vertical shaft also carries a gear known as a 'crown' wheel. This drives two small, bevelled, iron pinion wheels attached to two separate layshafts. The first of these ('c' in Fig. 6) carries a belt drive to a layshaft ('e' in Fig. 6), on the first floor of the mill, while the second shaft ('d' in Fig. 6) powers a belt-operated sack-hoist located on the bin floor of the mill. Large, hexagonal centre holes in the spur wheel and crown wheel, blocked in with wooden wedges, indicate that the thin, iron vertical shaft replaced an earlier, wooden vertical shaft, probably at the time of the 1836 refit.

The layshaft on the first floor of the mill ('e' in Fig. 6) carries pulleys for belt drives to a large flour bolter located on this floor, and a second layshaft ('f' in Fig. 6), carries pulleys for a belt drive to a grain cleaner also on this floor. This bears the inscription:

THOMAS TYSON

MELBOURNE

SOLE AGENT FOR AUST.

indicating an overseas origin. The second layshaft also powers a grain elevator to transport grain from the meal floor of the mill to storage bins occupying most of the bin floor. The bin floor also contains a hopper feed to the grain cleaner on the floor below, and the sack hoist bollard. The mill comprises three floors in addition to the underground wheel and gearing pit. The split-level meal floor contains the millstones on the upper of its two levels, the stone floor contains the grain-cleaning and flour-sifting machinery and the bin floor contains the sack hoist and grain storage bins. This arrangement represents a departure from the standard nineteenth-century three-floor flourmill layout, due to having to site the water wheel below ground level.

Thorpe Mill is built of locally-made brick on dressed sandstone foundations, and has a gabled, tile roof. Traces of an adjoining miller's cottage can be seen in the brickwork of the mill. The adjoining single storey wing of the mill structure served as a barn and chaff-cutting shed.

Nant Mill

'Nant' Estate, near Bothwell in central Tasmania was established by Edward Nicholas in the 1820s. The first flourmill built to serve the property had been constructed by 1825, soon after that on neighbouring 'Thorpe'.[49] No trace of this mill, built of locally-made brick, now survives, save for a brick barn which was attached to the mill and which continues to serve the present mill.

The mill now occupying the site was constructed in 1857, according to a date stone set in one of the masonry walls. Orders and prices scrawled on the inside walls of the mill date to 1884, indicating the mill was still at work at this time. The Returns of Mills and Manufactories indicate that the mill operated until at least 1897.[50]

After commercial operations ceased at the mill, the water wheel continued to play an important role as a major source of power for the operation of the property, powering a saw bench and, from the 1930s, a pump to supply water to 'Nant' house. Also, as with nearby Thorpe Mill, the headrace supplied an extensive system of field irrigation channels, in use from the 1820s. The continued use of the wheel at the mill until well into the twentieth century has contributed to the preservation of the mill and its largely intact machinery.

The mill is supplied with water by the same hydro-engineering scheme which supplies Thorpe Mill, operated under the auspices of the Clyde Water Trust. To provide water to Nant Mill, a low concrete weir across the Clyde River diverts water into a headrace (Table 3). The headrace is formed by an earth channel flanked on both sides by levee banks and feeds numerous small irrigation channels along its length. A pond is formed at the mill by a stone-built dam 3 feet high and approximately 60 feet long. This incorporates a spillway overflow. An overflow race leaves the headrace above the millpond to join the pond overflow below the mill. A wooden sluicegate, with a rack-and-pinion control operated by a wheel inside the mill, admits water from the pond onto the water wheel at the nine o'clock position. After turning the wheel, the water joins the pond overflow to form a tailrace, which rejoins the river downstream.

The breastshot wheel is mounted inside the mill, half below ground level, in a stone breastwork built to fit the curve of the wheel. It is built around a solid iron shaft of 5 inches in diameter, rotating in journal bearings. Two iron hubs are locked in place on the shaft with iron keys. To these are bolted two sets of eight flat iron arms, in turn bolted to two sets of eight shroud sections, also bolted together. These carry 32 curved iron buckets, with iron sole plates. An inscription on the wheel reads:

R. KENNEDY & SONS, HOBART

identifying a local foundry as the manufacturer of the wheel. As this firm did not commence operation until 1883, this wheel must have replaced an earlier wheel at the mill.[51]

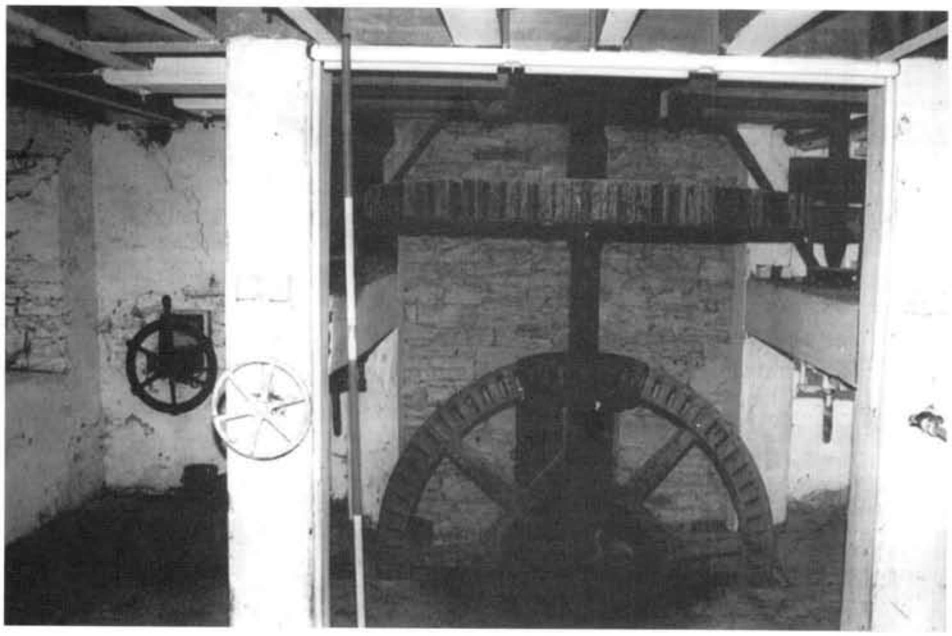

Fig. 7: Two-stage, underdrive gearing, Nant Mill. The screw jacks to engage the stone nuts, and bridgetrees for tentering the millstones can also be seen. The hand wheel at left operates the sluicegate admitting water to the wheel (Photo W. Pearson, July 1993).

The outer end of the water wheel axle carries a cam attached to an iron shaft. This provides an oscillating motion to a water pump. The inner end of the wheel axle carries a pit wheel (Fig. 7), which meshes with a wallower on an iron vertical shaft. This carries a spur wheel, which meshes with two stone nuts, in a conventional two-stage underdrive gearing arrangement (see Table 3 for details of gearing). The stone nuts may be disengaged from the spur wheel by being raised on their spindles by means of screw jacks, thus disengaging the runner stones on the upper ends of the spindles from the drive. The lower ends of the spindles rest on screw-adjusted bridgetrees, providing the tentering mechanism for the millstones.

While the runner stones and millstone furniture are now missing from the mill, they would probably have been fed grain via wooden hoppers mounted on horses on top of circular wooden tuns, as was the case in most nineteenth-century flourmills.[52] A rotating odd-shaped piece of iron, called a 'damsel', fixed to the top of the stone spindle agitated the wooden shoe feeding the grain into the central hole, or 'eye', of the runner stone. The hoppers were fed by wooden chutes from bins on the floor above.

Above the millstones on the stone floor, the vertical shaft carries a crown wheel with bevelled wooden teeth on its underside (Fig. 8). This drives two iron pinion wheels attached to layshafts. One of these layshafts ('c' in Fig. 8), carries a wooden pulley for a belt drive to a flour-sifting machine, only the cylindrical reel of which remains in the mill. The other layshaft is now missing, but wall brackets indicate that it also carried a pulley for a belt drive to another machine located on the stone floor.

The vertical shaft continues through to the bin floor of the mill, where it carries a small, iron, bevel gear, which meshes with another attached to the bollard of a sack hoist. The hoist is engaged remotely from the ground floor by means of a rope and pulley system, which lowers the end of the bollard carrying the gear wheel onto the gear on the vertical shaft.

The mill comprises a standard nineteenth-century three-floor arrangement and is built of undressed sandstone with a gabled, shingle roof. A single-storey, two-room wing provided accommodation for the miller. The mill abuts a brick barn contemporary in date with the first mill on the site, to which access is gained at the stone floor level of the mill. Adjoining the barn is a row of cottages built in the same style of

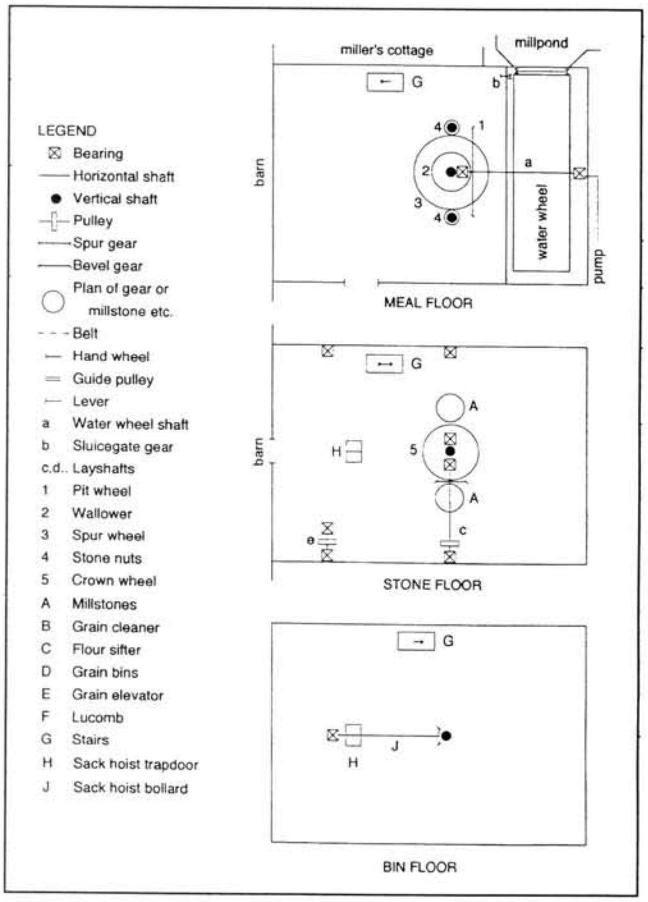

Fig. 8: Diagram of machinery layout, Nant Mill.

stonework as the mill. This whole complex forms part of a larger collection of preserved early-to-mid nineteenth-century farm buildings, which are classified by the National Trust and remain in use as part of 'Nant' Estate.

Riversdale Mill

The water-powered flourmill on 'Riversdale' Station, near Swansea on the east coast of Tasmania, was built between 1838–1844 by a Scots millwright, John Amos, for the property owner George Meredith, who came from Wales.[53] Amos also constructed the nearby Gala Mill, now derelict but still standing, to an almost identical design as the Riversdale Mill, in 1842. The small size of these mills, and concomitant small scale of operations, indicate that they were designed and built largely to serve the needs of the 'Riversdale' and 'Gala' estates, and the immediate area, a duty which Riversdale Mill fulfilled until at least 1887–1890. From 1858, Riversdale Mill was leased as a commercial venture by the miller William Gibson, later of Gibson's Flourmills in Hobart. However, as with so many other small-scale rural flourmills, this mill also eventually succumbed to the forces of centralisation of the industry and technological change.

After it ceased to function, some of the machinery from the mill was transferred to a steam flourmill operating in Swansea. The mill itself remained essentially intact until the early 1990s when approximately one third of the building was destroyed by a tree fall. The mill has now been completely restored as a tourist attraction.

Water was supplied to the mill from the Wye River, tapped at a point over one mile distant from the mill. All traces of any dam or weir in the river, which would have served to regulate the level of the river and divert water into the headrace to the mill, have long since been removed by floods. However, the remains of a shallow earth channel serving the mill as a headrace can still be traced for a distance of nearly one mile (Table 3). Close to the mill the water-supply goes underground into a ceramic pipe. From this, water entered the wheel at the 10 o'clock position. After turning the wheel, the water flowed through an underground drain for a short distance, and then into an open tailrace, thence to rejoin the river.

The high breastshot water wheel is housed inside the mill, and situated almost entirely below ground level in a stone breastwork built to fit the curve of the wheel. It is built around a square-section, wooden axle, measuring 2 by 2 feet, comprising four smaller, square-section beams held together at the ends by iron rings (Table 3). At each end of the axle an iron gudgeon rests in depressions in wooden bearing blocks. Two sets of four wooden clasp-arms, measuring 3 inches by 6 inches, held in place on the axle by wooden wedges and mortised into each other at their crossing points, support wooden shrouds made up of sections of uneven length, bolted together. The shrouds have wooden buckets mortised into them, with wooden sole boards. The wheel is strengthened by iron bolts across its width. Tasmanian pine has been used for construction of the wheel.

The inner end of the water wheel axle drives a conventional two-stage, underdrive gearing system (Table 3). The pit wheel is again of clasp-arm construction, with original wooden teeth replaced by segmented iron castings (Fig. 9). This is held in place on the axle by wooden wedges, and also by iron braces. The vertical shaft is of wooden construction. The spur wheel is held on the vertical shaft by wooden wedges, a difficult task, as its centre hole is square rather than round, indicating possible recycling of this gear wheel from another mill. The spur wheel drives two iron stone nuts, with wooden teeth. These may be disengaged by being raised on their spindles by means of wooden wedges. The lower ends of the spindles rest on screw-adjusted bridgetrees, providing the tentering mechanism for the runner stones carried on the upper ends of the spindles. The mill originally contained two pairs of millstones of local quartzite. The single remaining pair of stones is housed in a wooden tun, which supports a wooden, horse-mounted hopper equipped with a damsel-agitated shoe, to feed the grain into the millstones. The original 2 feet square hopper has been enlarged at some point in time by the superimposition of a larger 4 feet square hopper, to allow larger volumes of grain to be processed automatically.

The runner stone of the second pair of millstones has been removed at some stage, and a vertical shaft of iron attached to

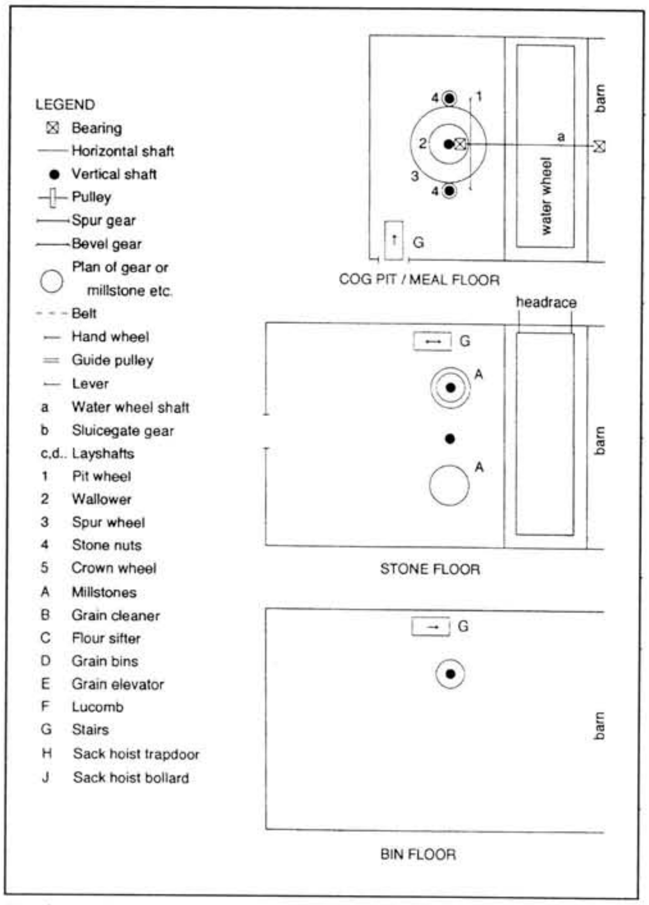

Fig. 9: Machinery layout diagram, Riversdale Mill.

the top of the spindle. This carries two horizontal, wooden pulleys, one on the stone floor of the mill, and one on the bin floor. That on the stone floor carried a belt drive to some item of machinery now absent from the mill. This was most likely a flour-sifting or grain-cleaning machine, added at a later date than the initial construction of the mill to improve the quality of the product. This machine was an improvement considered important enough to sacrifice a pair of millstones to provide it with power. The pulley on the bin floor of the mill carried a belt drive which most likely provided power to a sack-hoist. The addition of this would have improved the capability of the mill to handle bulk quantities of grain.

The mill building comprises two storeys in addition to a cog pit, or cellar, containing the water wheel and gearing. The stone floor contains the millstones, and space for auxiliary grain or flour-processing machinery, while the bin floor comprises grain storage space and a power-take-off for additional grain or flour-handling machinery and/or a sack-hoist. By housing the gearing below ground level in a cog-pit, only two floors needed to be built above ground level; the stone and bin floors. The building is of brick construction on a stone rubble base. It has a gabled, shingle roof. The demolished section of the mill comprised a barn. A wooden, lean-to stock shed is also attached to the rear of the mill. The mill is listed on the Register of the National Estate and, with Gala Mill, displays unique features among the few surviving water-powered flourmills in Australia, including the almost exclusive use of wood and the clasp-arm method of construction for the water wheel and some of the gearing.

Millbrook Mill

Millbrook Mill, near Ouse in central Tasmania was built on the property of Walter Bethune in 1835.[54] Although located on a property, the mill was close enough to Ouse, a regional rural centre, to have served a more extensive market throughout the district. Bethune retained ownership of the mill until the 1860s. It is not known when milling ceased at the mill, but by the mid-twentieth century the flourmill gearing had been dismantled and replaced with that for an irrigation and water-supply pump, powered by the water wheel, in which capacity it continued to operate until the 1960s. The wheel suffered damage to its buckets soon after, and it and the mill have since been allowed to run down. Nevertheless, the extended use-life of the wheel has contributed to an excellent state of preservation of the mill and much of its machinery. With the exception of the gearing removed to make way for the installation of the water pump, the wheel remains intact. Some internal stabilisation work to the fabric of the building has also necessitated the removal of the millstones and the hurst frame. The dismantled parts are stored in the mill.

The nearby River Ouse provided the water to power the mill. The headrace leaves the river at a point approximately three quarters of a mile from the mill, where a series of rapids create a natural weir and pond. No evidence of a constructed dam or weir is visible at the site, although this may have been erased by floods. A wooden rack and pinion-operated sluicegate admits water directly from the river into a headrace formed by an earth channel and levee banks (Table 3). An overflow race of similar construction leaves the headrace close to the mill, diverting excess water around the mill to rejoin the tailrace immediately below the mill. A wooden sluicegate operated by a lever inside the mill admits water to the wheel at the nine o'clock position.

The breastshot wheel is situated outside the mill, half below ground level in a sandstone breastwork built to fit the curve of the wheel (Table 3). It is constructed around an iron axle 5 inches in diameter, turned down at the ends to form gudgeons on which it rotates in journal bearings. Two iron hubs, held in place on the axle by iron keys, have two sets of eight flat iron arms bolted to them. These, in turn, carry two iron shrouds, each bolted together in eight sections. The shrouds carry mortises for 40 wooden buckets, with wooden sole boards. The wheel hubs bear the inscription:

FORD & PYE, HOBART TOWN

indicating a local manufacture for the wheel.

Inside the mill, the water wheel axle originally carried a pit wheel, now dismantled but still at the mill (see Table 3 for details of gearing). A circular iron hub carried eight flat iron arms bolted to it, each cast with a section of the bevelled wheel, which was fitted with wooden teeth, to reduce the friction of iron teeth meshing with iron. Along with the rest of the gearing, and the wooden hurst frame which supported it, this was dismantled in the 1930s when the pump gear was installed and now rests outside the mill. As a result, the methods of disengaging the drive to the stones, and of tentering the millstones are not now evident.

The millstones, also removed to outside the mill, comprise one pair of French Burr stones and one pair of locally-manufactured quartzite stones. These were housed in wooden tuns and fed grain via wooden horse-mounted hoppers equipped with damsel-agitated shoes. These in turn were fed by wooden chutes from grain bins on the bin floor of the mill. The mill also contains a rare, complete set of steel picks, or 'bills', interchangeable in a wooden handle, used for hand-dressing the grinding surface of the millstones, by cutting patterns of shallow grooves into them.

The horizontal layshaft ('c' in Fig. 10), carried a pulley for a belt drive to a second layshaft ('d' in Fig. 10), located on the stone floor of the mill. This carried pulleys for belt drives to three large flour-sifting machines located on this floor; one with a wire reel, one with a cloth reel and one with rotating brushes inside a cloth reel. The latter two sifting machines bear

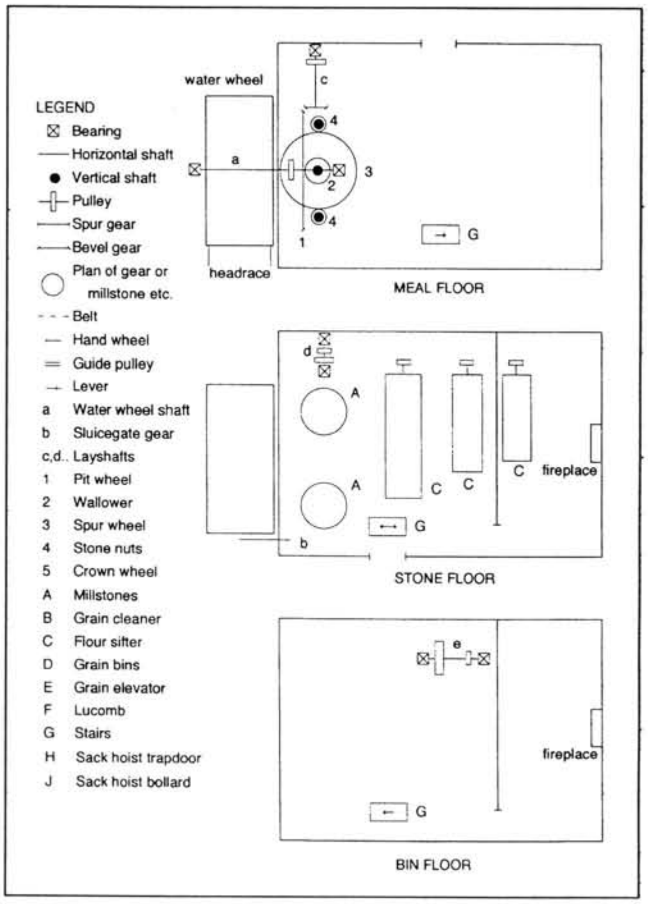

Fig. 10: Diagram of machinery layout, Millbrook Mill.

inscriptions attesting to their manufacture by the firm of 'O.C. Schumacher' based in Adelaide from 1882, and Melbourne from 1887.[55] Supplying flourmills in Victoria, South Australia, Western Australia and Tasmania, Schumacher was an agent for many overseas firms, including: Leffel and Co. (U.S.A.), and E. R. and F. Turner Ltd, England, as well as manufacturing milling machinery to his own patents. At least two of the sifting machines at Millbrook Mill were therefore installed during or after the 1880s.

The second layshaft ('d' in Fig. 10), on the first floor of the mill also carries a belt drive to a third layshaft ('e' in Fig. 10), on the bin floor of the mill. This, in turn, carried a pulley for a belt drive to a sack-hoist. Unfortunately, the hoist mechanism has been dismantled to allow repairs to the roof of the mill. However, the remaining parts stored in the mill permit the conjecture that it was of the belt-driven type. Parts for a grain elevator, also supplied by O. C. Schumacher, but never actually installed, are stored on this floor of the mill.

The mill is of the conventional three-floor arrangement and is built of dressed sandstone with a hipped roof. This was originally of wooden shingle, but has since been replaced with corrugated iron. A two-room miller's office and quarters are contained inside the mill on the second floor.

CONCLUSION

Collectively, this group of five watermills is significant for a number of reasons. Aspects of their technology tell us a great deal about economic conditions in the industry they served in nineteenth-century Tasmania. Their small scale of production indicates that many mills were built to serve local markets only. The extensive use of auxiliary grain and flour processing and handling machinery may have been a result of several factors: a shortage of labour to do these jobs, the types of grain grown, and the quality of product demanded by the consumer.

The dates when the mills ceased operating all coincide with a late nineteenth-century trend towards the demise of small-scale country flourmills in favour of large-scale, urban-based operations making use of technological innovations such as steel rollers in place of millstones, producing whiter flour. This geographic concentration favoured the use of steam over water-power.

Aspects of the water-power technology of the mills surveyed are informative on the suitability of the Tasmanian environment for watermill technology. The formation of the Clyde Water Trust to supply water to three mills spread over a large geographic area, including Thorpe and Nant Mills, indicates the high degree to which the favourable climate of the colony rendered capital investment in water-power viable. This is the only known privately-owned system of its type in Australia.

Other aspects of the design and construction of these mills are informative about the development of early Tasmanian industry. While the construction of some of the earlier mills in the sample, such as Thorpe Mill and Riversdale Mill, relied heavily on local materials, such as the local species of pine, for water wheels and gearing, some iron parts for watermill machinery were nevertheless available. The first iron foundry capable of casting items of mill machinery, such as gearing, was in operation in Hobart by 1822.[56] By 1834, colonial foundries were capable of casting all iron parts for mills, including water wheels up to 40 feet, 6 inches in diameter.[57] Local supply could not entirely meet demand, however, and mill-owners still found it necessary to import iron mill parts from Britain in 1830, and to re-use machinery as late as the 1860s, as with the Rockford Mill machinery used in the construction of Connorville Mill.[58] Evidence of the replacement of some wooden parts of gearing with iron parts at Thorpe Mill from as early as the late 1830s shows the gradual improvement in the availability of iron parts for mills. By the 1880s when the foundry of R. Kennedy and Sons, Hobart, cast the wheel for Nant Mill, locally-cast iron mill parts would have been in widespread supply.

This group of mills also indicates the importance of imported flourmilling technology, such as millstones, grain-cleaning, flour-sifting and grain and flour handling machinery, from overseas sources such as France, Britain, and the United States, for the development of the local industry. Along with the machinery for mills, the importation of skilled millwrights from Britain, men such as John Amos and Edward Yates, also remained crucial for the construction and maintenance of colonial watermills, especially during the early nineteenth-century. The mills built by these millwrights in Tasmania are also instructive on the international transfer of nineteenth-century innovation in watermill technology. The early nineteenth century was a time of rapid development in watermill technology, from traditional techniques and materials, such as wooden, clasp-arm, undershot and overshot wheels and simple, wooden drive mechanisms, to extensive use of breastshot wheels of advanced design, incorporating extensive use of iron for wheels and gearing.[59] British millwrights coming to the colonies from industrial centres would have been familiar with the new technology, while those originating from country districts would have been more likely to have continued the use of traditional techniques. Use of traditional, techniques by the Scots millwright, John Amos, is seen at Riversdale Mill, for example, while the work of English millwright, W. H. Knight, at Connorville draws more heavily from nineteenth-century advances in watermill technology.

These five mills are perhaps most significant in being able to demonstrate a now-defunct technology, that of the application of the power of water to the flourmilling industry. In this, they are almost unique in Australia. Beyond this, these mills form a tangible link to the pivotal role of water power in the formative stage of Tasmania's industrial economy. More than any other source of motive power, water was relied upon throughout much of the nineteenth-century for most industrial activity in Tasmania. The wheel has come full circle, with Tasmania's reliance on hydro-electric power in the twentieth century.

ACKNOWLEDGEMENTS

The content and presentation of this paper has benefited greatly from a reading by fellow molinologist, Keith Preston. However, any errors of fact or omissions remain the responsibility of the author.

NOTES

1 See Pearson 1996.

2 See Pearson 1996 for a detailed discussion of previously published research on nineteenth-century Australian watermills.

3 Pearson in prep.

4 Pearson 1996.

5 Burn 1840–1841:140.

6 *Historic Records of Australia* (HRA) Series III, vol. iv:33.

7 An overshot wheel receives water at its apex, and generates power by the weight of the water descending in its buckets. These can be of two types: 'overshot' wheels revolve in the same direction as the flow of water entering the wheel, and 'pitchback' wheels revolve in the opposite direction. These types of wheels are about 75 per cent efficient as power generators. A 'breastshot' wheel is powered by a fall of water amounting to less than the diameter of the wheel. That is, the water enters the wheel at some point between its apex and base. Again, power is generated by the weight of the water descending in the buckets of the wheel. This wheel type is approximately 65 per cent efficient as a power generator. An 'undershot' wheel receives water at its base and generates power through the impact of the flow on its paddles. This type of wheel is about 30 per cent efficient. A detailed discussion of the relative efficiencies of the different types of water wheels as power generators is contained in Reynolds (1983).

8 *Hobart Town Gazette* 20 March, 1816.

9 *Hobart Town Gazette* 3 January, 1818.

10 *Hobart Town Gazette* 3 January, 1817.

11 HRA Series III, vol. i:343; *Hobart Town Gazette* 3 May, 1818.

12 See for example *Hobart Town Courier* 12 July, 1828.

13 *Correspondence of the Colonial Secretary's Office* (CSO) 1/107/2597.

14 *Hobart Town Gazette* 2 September, 1820.

15 *Hobart Town Gazette* 23 November, 1822.

16 *Hobart Town Courier* 13 May, 1836.

17 Reynolds 1983:339.

18 *Hobart Town Gazette* 24 July, 1844.

19 Ross 1831:91.

20 *Hobart Town Gazette* 26 October, 1822.

21 Morris-Nunn and Tassell 1982:25.

22 Dallas 1959:85; Hartwell 1954:148; Linge 1979:122.

23 *Hobart Town Gazette* 23 November, 1822.

24 Dallas 1959.

25 Reynolds 1983.

26 Linge 1979:47.

27 Linge 1979:122.
28 Hartwell 1954:148; Linge 1979:127–129.
29 Linge 1979:143.
30 Davis 1988:21, 25; Harrison 1979:23, 45.
31 Linge 1979:320.
32 Rafferty 1988:6.
33 Linge 1979:654.
34 Connah 1988:129–30.
35 Jones and Jones 1990:xxii. See also Jack 1983:28.
36 Linge 1979:82–110.
37 Department of Conservation and Environment 1990; Department of Environment 1980; Connah 1988; Preston pers. comm.
38 Preston pers. comm.
39 O'clock positions on water wheels are noted with the recorder standing on the power-take-off side of the wheel.
40 *Benalla Standard* 17 January, 1879.
41 Leavitt n.d.:33.
42 Jones 1969.
43 Bignell 1988:83.
44 Bignell 1988:83.
45 *Colonial Times* 8 March 1836.
46 Institute of Engineers 1988.
47 Bignell 1988.
48 Jones 1969.
49 *Hobart Town Gazette* 24 June 1825.
50 Institute of Engineers 1988.
51 Macfie 1985.
52 Jones 1969.
53 Glamorgan History Society n.d.
54 *Hobart Town Courier* 30 January 1835.
55 Jones and Jones 1990:354.
56 *Hobart Town Gazette* 30 March 1822.
57 *Hobart Town Courier* 19 December 1834.
58 *Hobart Town Courier* 21 August 1830.
59 Reynolds 1983.

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