THE

YILGARN RAILWAY WATER SERVICE,

WESTERN AUSTRALIA.

J. M. S. Woore, B.E.,

Stud. Inst. C.E.

(A Paper read before the Sydney University Engineering Society on 3rd November, 1898.)

THE YILGARN RAILWAY WATER SERVICE, WESTERN AUSTRALIA.

J. M. S. Woore, B.E.,

Stud. Inst. C.E.

As the country traversed by the Yilgarn Railway is destitute of permanent supplies of fresh water in sufficient quantity for railway purposes, a number of artificial reservoirs had to be constructed at various stations on the line, without which it would have been necessary either to haul water from the coastal districts in special trains, or to condense the salt water readily obtained by sinking in the lakes or river beds.

Although in very dry seasons it is necessary to haul a certain quantity of water in order to supplement the artificial supplies, this method cannot be entirely relied upon, as the cost would be prohibitive. The use of condensed water for railway purposes is also precluded by the cost.

After passing Northam, the country consists of a succession of sand plains, low hills, and occasionally rich clay flats, and is intersected with numerous dry watercourses, usually small, the large ones being salt. The average rainfall is 15·8 in. at Northam, and falls off at the rate of about 1 in. in every 23 miles eastward; the average at Southern Cross is 8·4 in. The rain is most continuous during the winter months, *i.e.* June and July, when the creeks usually run. In the summer there are very heavy thunderstorms, during which a large quantity of water falls in a short time, sometimes as much as 3 in. falling within an hour. It is necessary to design the reservoirs and works connected with them to suit these conditions of rainfall.

The geological formation eastward from Northam is principally granite, intersected by dykes of diorite and other rocks; towards Southern Cross, a slaty and schistose formation predominates containing numerous quartz reefs. The clay formed from decomposition of the granite makes excellent holding ground for the water in the reservoirs.

Scattered irregularly through the country, at distances varying from one to many miles, there are large mounds and platforms of bare granite rock, some of them measuring many acres in extent. These rocks form an important and peculiar feature in the general scheme of water supply, and are used to great advantage in conserving the rainfall; as they are practically impervious, all the water falling on their surfaces may easily be collected. A drain is formed around the base of the rock, and is connected with the main system of drains which discharge into the tank or reservoir. If the rock is large, and the amount of water to be carried off is great, when the drain passes over the bare rock, a dwarf masonry wall is built of rough granite slabs, about 9 in. thick and of the height necessary for the volume to be discharged These are firmly bedded in cement on the inclined surface of the rock, and form a gutter. Owing to the formation of parallel joints in the granite, stones of the required thickness may readily be procured, and thus only a small amount of dressing is necessary.

Each reservoir has an extended system of artificial drains, which greatly improve and enlarge the natural catchment area (when such exists), and are sometimes many miles in extent. Any isolated patches of rock in the catchment area are surrounded with small drains connected with the main channel. The principal drains stretch out on each side of the reservoir, and approximately follow the contours. Where they intersect natural watercourses, a small bank with puddle wall is formed on the down stream side to divert the flow into the drain. As the rain falls mostly in heavy showers, the larger drains were designed by Mr. W. H. Shields, the engineer, as storm-water channels, with a fall as steep as 3 in., or more frequently 6in., to the chain. Such a steep fall is quite admissible, since the drains run for so short a time that they do not become furrowed and cut up, as would happen if they were running continuously with the same fall. This plan has proved to be necessary in practice, and has been eminently successful. At the intersection of contour drains with creeks, and at the mouths of all watercourses discharging into the reservoirs, strainers are provided, which prevent rubbish from forming obstructions on being washed down into the tank. Silt pits are also provided at the mouths of drains to collect the sand and silt carried down by the water.

Leading into the contour channels there is a system of lateral drains, and these again are connected with a smaller system, and so on—thus forming a complete network over the catchment area. The main contour drains are traversed and pegged out before being cut, but the smaller ones are made to suit the natural formation of the ground, and surveyed and plotted afterwards.

The reservoirs connected with the Yilgarn Railway may be divided into two types, viz. :—

Type I.—Reservoirs formed by a straight dam thrown across a valley or depression.

Type II.—Reservoirs consisting of a rectangular excavation entirely, or partly, surrounded by a dam.

In Type II., the water is led into the reservoir by a pitched channel, elevated to the level of the top of the dam by an embankment, if the former entirely surrounds the excavation. Wrought-iron fluming has been constructed for this purpose on the Southern Cross–Coolgardie line, formed of $\frac{1}{8}$-inch wrought iron plates riveted together, bent to the arc of a circle, and stiffened with angles at the edges. The fluming is supported by light pile trestles placed about 8 feet apart; expansion joints are provided every 100 feet, the ends of the sections being overlapped and bolted together through slots, and covered on the outside with a strip of $\frac{1}{8}$-inch lead, secured to each section, and of sufficient width to allow for expansion and contraction.

The following is a list of the reservoirs already constructed on the Yilgarn Railway :—

NAME.	TYPE.	Miles from Fremantle.	Area of Catchment.	Capacity in Gallons.
Northam	I.	77	300	11,300,000
Cunderdin	II.	114	788	12,200,000
Tammin	I.	128	2060	94,000,000
Kellerberrin	II.	142	1182	3,800,000
Merredin	II.	178	1257	7,470,000
Burracoppin	II.	193	1175	8,700,000
Bodallin	II.	215	640	16,800,000
Parker's Road ...	II.	233	1377	7,080,000
Southern Cross—				
New Zealand Gully	II.	247	300	1,687,000
Parsonage ...	II.	247	218	643,000

WATER SERVICE AT TAMMIN.

The largest reservoir is situated about three miles from Tammin Siding on the southern side of the railway line, and is formed by a straight dam across the valley of a watercourse. This is a gravitation scheme, the difference between the lowest water line and the top of the elevated engine tank at the siding being 73 feet. The least hydraulic gradient has a slope of 1 in 221.

The catchment area consists for the most part of sandy loam overlying decomposed granite and clay at a depth of a few feet; there are also a number of patches of rock a few acres in extent scattered throughout the catchment.

Drains.

The largest contour drain is on the south-west side of the catchment, and runs approximately in a line with the dam. It is 203 chains in length, and 1 foot in average depth, with side slopes of 1 to 1. The width at the bottom is 10 feet at the mouth, and decreases to 2 feet at the source. This drain is cut with a fall of 3 inches to the chain, the slope being uniform except where it has been necessary to avoid patches of rock. The slope is usually varied to suit the ground; thus in sandy material it is steeper than where the soil consists of stiff clay, so that the water may run off without having time to percolate. Giant bamboos have been planted at the mouth of the south-western drain, and also at the places where it intersects natural watercourses; the bamboos, when grown, are intended to act as strainers.

The smaller contour drain is situated on the north-eastern side, and is about 70 chains in length; it is 6 feet wide at the bottom, at its mouth, which width decreases to 2 feet at its source. The fall of this watercourse is as steep as 6 inches to the chain, and it has proved to be very effective in draining the part of the catchment through which it passes. The smaller drains form a network extending over the catchment area, as shown on the plan of Parker's Road Tank.

Description of Drain, Etc.

The drain is 10 feet wide at the top, and 26 feet in maximum height, with the usual slopes of 3 to 1 and 2 to 1 on the water face and back respectively, and contains 40,000 cubic yards of filling. The water face is protected with a layer of broken stone 12 inches in thickness, and grass has been sown on the top and the back slope. The puddle wall, which is 4 feet wide at the top, is carried up to within 1 foot of the upper surface of the bank with a batter of 12 to 1, and contains 7940 cubic yards of puddled clay. The trench was taken down to a good clay foundation which forms the sub-soil of the reservoir.

The byewash is entirely in excavation, and is situated at the south-west end of the dam, the width being 100 feet. This width might seem excessive, but it must be borne in mind that heavy rainstorms are liable to occur, and owing to the rocky nature of the catchment, and the manner in which it is artificially drained, it is possible for a large body of water to find its way down to the reservoir in a very short time. There is a fall of 1 in 50 either way from the sill, which is 3 feet below the top of the dam. To maintain it at this level, two strips, each 10 feet wide, were pitched with granite set in cement. This is a necessary precaution, as the scour of the waste water would otherwise tend to lower the sill. The angle where the byewash passes round the end of the bank is also protected with granite pitching.

The footbridge and tower are of timber, the piles being locally-procured White Gum, which is the most suitable wood of large section to be found in the district, and the sawn scantlings of Jarrah. The tower consists of four piles, each 12 in. diameter, tenoned into 12 in. x 16 in. flattened logs as sills, and braced on three sides with a double system of 5 in. x 3 in. timber. On the side next the dam the lower system of bracing was omitted, to allow for movement of the adjustable suction pipe. The bridge has six 15-feet spans with piers formed of two 12-in. piles tenoned into 12 in. x 16 in. flattened logs, and strengthened with 8 in. x 4 in. walings, and 5 in. x 3 in. diagonal bracing in two lays. The stringers are 12 in. x 6 in. in size, and are bolted to the upper walings: 9 in. x 2 in. planking is spiked to the stringers, and there is a simple form of handrail on one side.

The following is a specification for timber, taken from the W.A. Government contract for Northam Reservoir:—

"All timber required for the work (unless otherwise specified) shall be hill-grown Jarrah, cut clear of heart wood.

"All timber shall be of the best quality of its kind, straight, sound throughout, free from shakes, piping, gum veins, or other imperfections, and must be cut of such size as will allow amply for shrinkage, and any timber which, at the completion of the work, is less than the specified dimensions, must be removed by the contractor at his own expense, and replaced by seasoned timber. All timber, unless otherwise specially permitted by the Engineer, in writing, must be ring-barked or felled during the season commencing with February and ending with May. The contractor must produce evidence satisfactory to the Engineer that the timber has been ring-barked or felled in the season mentioned.

"All timber (except any distinctly shown or specified to be round) shall be sawn or squared at least 6 months before date for completion of contract. Round timber shall be barked before use. All timber shall be wrought in the best style of ship carpentry."

Method of Drawing off Water.

The water is drawn off from Tammin Reservoir by means of a syphon which passes through the dam 3 ft. 6 in. below the level of the byewash and forms part of the cast-iron main. The pipe is surrounded with puddle where it passes through the bank, and is carried by a timber flume supported on the intersection of the bracing to the tower, where it terminates with an adjustable wrought-iron pipe. This movable length is connected with the main by a conical pivot joint of bronze; the end is provided with a clack-valve and rose, and is kept at a constant distance below the surface by means of a cylindrical pine float enclosed in a sheet-copper casing. There is an air valve at the highest point of the syphon, and a force pump is provided for starting the flow. The main is of 3 in. cast-iron S and F pipe, and is provided with automatic air valves, and with sluice valves where necessary. The valve well is situated at a distance of 120 feet from the toe of the bank, and measures 5 ft. x 3 ft. inside and 3 ft. in depth, and is lined with concrete 9 in. thick. In the well are placed a stop valve of the ordinary pattern and a water meter.

Construction of Dam.

The material for the dam was taken out within the 1012 ft. contour on the side remote from the byewash. A tram-line of 2 ft. gauge, with 12 lb. iron rails, was laid from the borrow pits and along the bank at the back of the puddle wall. The puddle, and also the muck for the outer half of the bank, was conveyed from the pits in trains of wrought iron side-tipping trucks, drawn by heavy draught horses. When a strip the length of the dam had been filled in to the required thickness, the rails and sleepers were shifted sideways and the operation repeated. For the inner half of the bank a number of heavy drays with broad tyres were employed in the work of filling. The continual passage of drays, trucks, horses, etc., served greatly to consolidate the layers of earthwork, the hard lumps in which were broken up by a number of men with old axes.

The method of preparing the puddle was as follows:—The clay was taken out, broken up, and thrown in a heap, on which a hose was continuously playing water. After standing some days, it was thrown forward towards the tram-line, loaded into the trucks, and conveyed to the trench, and, after being dumped in its place, it was watered again and rammed in. The puddle was thus handled three or four times, and thoroughly turned over and mixed during the process.

The works at Tammin were commenced about the beginning of February and finished by the end of August, 1897. This reservoir, together with those at Burracoppin and Bodallin, was constructed on the day labour system. The maximum number of men employed at Tammin was 160.

Other Reservoirs.

As an example of Type II., Burracoppin Reservoir may be taken. The catchment contains a large mass of granite rock measuring 75 acres in extent, and is improved by a number of artificial drains, those at the base of the rock being formed by stone walls, of which 21½ chains were 4 ft., and 37 chains 2 ft., in height.

The excavation measures 230 ft. x 100 ft. at bottom, with slopes of 2 to 1, and an average depth of 13 ft. 6 in. It is surrounded on three sides by a dam, the greatest height of which is about 15 feet. The puddle wall has the same top width and batter as that at Tammin; the foot-bridge, etc., is also of similar construction.

Bodallin.

The reservoir is of the same type as that at Burracoppin, and of about double the capacity. At this place good clay for puddle was obtained about 1 foot below the surface, at distances of 1 mile and ½ mile from the dam. The overlying soil having been removed, the clay was ploughed up with a heavy muck-plough, and thoroughly watered, after which it was re-ploughed, watered, and ploughed again, and the operation repeated until a thorough mixture was obtained, The puddle was then conveyed to the trench in drays, where it was tipped and rammed. By this method a great deal of labour in excavating and turning over was saved.

Cunderdin.

At Cunderdin it was thought expedient to enlarge the catchment by obtaining the drainage from about 40 acres of rock situated a short distance from the tank, but separated therefrom by a low ridge.

To accomplish this, a tunnel ½ mile in length was driven at a distance below the surface of about 30 ft. in the deepest part. The ground passed through consisted of several varieties of very hard granite, and ironstone conglomerate, also decomposed granite, and clay. About 22 chains were lined on the floor and sides with granite slabs 1 ft. thick, set in cement, the remainder of the length being unlined. The lined portion was constructed with a width of 4 ft., and height of about 5 ft., the roof being arched, but many of the unlined portions through granite were made 6 ft. wide by 8 ft. high, as it was found quicker to use double-handled hammers.

The tunnel is connected with the tank by an open cutting, and in a similar manner to the system of drains collecting the water from the rocks, and a wrought-iron strainer is provided at the upper mouth to prevent rubbish from being washed in.

This undertaking has proved to be very successful in practice, and several times during heavy rain the tunnel has run with a full section.

Cost of Construction.

The following are statements of cost for reservoirs at Tammin, Burracoppin, and Bodallin. It was originally intended to construct a 54,000,000 gallon reservoir at Tammin, but during the progress of the work, it was decided to add 3 ft. to the height of the dam (top width remaining the same) which increased the capacity to 94,000,000 gallons.

Cost of Construction of 94,000,000 Gallon Reservoir at Tammin.

	Dr. £	Dr. £	Cr. £	Cr. £
Authority for constructing 54,000,000 gallon Reservoir	...	11300	...	...
Labour and Accounts paid to 18th September, 1897 ...	...	...	12640	...
Outstanding Accounts, say ...	...	...	20	...
Depreciation on plant (not including horses) 10% on £1950	...	...	195	...
Supervision, say	...	...	80	12935
Material on hand at end of work	...	300	...	...
Plant.				
½ mile (about 10 tons) 12 lbs. iron rails, sleepers, and fastenings	80	...	...	...
16 Side Tip Trucks	192	...	...	...
16 Tip Drays	308	...	...	...
17 Heavy Draught Horses ...	485	...	...	...
Pipes, Tools, Etc.	1370	2435	...	...
Balance	...	...	...	1100
	...	£14035	...	£14035

COST OF CONSTRUCTION OF 8,700,000 GALLON RESERVOIR AT BURRACOPPIN.

	Dr. £	Dr. £	Cr. £	Cr. £
Authority for Constructing Reservoir	..	6000	...	...
Labour and Accounts paid to 18th September, 1897 ...	...	...	5390	...
Outstanding Accounts, say ...	...	.	230	...
Depreciation on Plant (not including horses), 10% on £480	...	...	48	...
Supervision, say	...	...	80	...
				5748
Material on hand at end of work	...	190	...	...
PLANT.				
11 Draught Horses	355	...	...	...
11 Tip Drays	208	...	...	...
Pipes, Tools, etc.	272	...	...	...
		835		
Balance	...	...	...	1277
		£7025		£7025

Cost of Construction of 16,800,000 Gallons at Bodallin.

	Dr. £	Dr. £	Cr. £	Cr. £
Authority for Constructing Reservoir	...	8300	...	...
Labour and Accounts paid to 18th September, 1897 ...	...	...	6554	...
Outstanding Accounts, say ...	...	...	330	...
Depreciation on Plant (not including horses), 10% on £482	..	...	48	
Supervision, say	...	...	80	... 7012
Material on hand at end of work	...	155	...	...
Plant.				
13 Draught Horses	429	...	...	...
14 Tip Drays	268	...	...	...
Pipes, Tools, etc.	213	... 910	...	...
Balance	...	...	...	2353
		£9365		£9365

Details of Cost of Muck Work at Tammin.

Embankment.	£	s.	d.
Total labour	2219	0	0
Explosives	256	0	0
Horses	169	0	0
Total	£2644	0	0

40,000 cubic yards, @ 1s. 4d. per yard.

Cutting Puddle Trench.	£	s.	d.
Total labour	205	0	0
Explosives	53	0	0
Total	£258	0	0

3900 cubic yards, @ 1s. 4d. per yard.

Puddling.	£	s.	d.
Total labour	1068	0	0
Horses	31	0	0
Total	£1099	0	0

7940 cubic yards, @ 2s. 9d. per yard.

The average cost per day of keeping one horse was estimated at 3s. 6d.

Scale of Wages.

Foreman	20s.	per day.
Timekeeper	12s.	,,
Blacksmith	12s.	,,
Carpenter	12s.	,,
Gangers	11s., 12s.	,,
Labourers	8s., 9s.	,,

The following table shows the comparative cost, etc., of some of the principal reservoirs on the Eastern Railway :—

Locality.	Contract or Day Labour.	Type	Time to Complete.	Distance from Station.	Distance from Fremantle.	Capacity in Gallons.	Gravitation or Pumping.	Cost in £	Cost per 1000 Gallons.
Spencer's Brook...	Contract	I.	9 m'ths	3 m. 20 chs.	71	28,000,000	Gravitation	6,620	4/9
Northam ...	,,	I.	9 ,,	2 m. 47 chs.	77	11,300,000	,,	7,220	12/9
Tammin ...	D'y L'b'r	I.	7 ,,	3 m. 3 chs.	129	94,000,000	,,	12,935	2/9
Burracoppin	,,	II.	6 ,,	1 m. 40 chs.	192	8,700,000	,,	5,748	13/11
Bodallin ...	,,	II.	7 ,,	4 m. 0 chs.	215	16,800,000	,,	7,012	8/4
Karalee ...	Contract	II.	12 ,,	1 m. 75 chs.	279	12,500,000	Pumping	15,380	£1/4/7
Boorabbin...	,,	II.	11 ,,	1 m. 0 chs.	307	1 968,700 2 4,847,000	,,	3,025 10,520	£2/6/7

It will be seen that, other conditions being similar, the cost increases rapidly as the capacity decreases.

The reservoirs at Northam, Spencer's Brook, Tammin, Burracoppin, and Bodallin, as well as improvements to the water service and Kellerberrin, Parker's Road, Merredin, Cunderdin, and New Zealand Gully, and numerous surveys of proposed catchments were ably carried out under the direction of Mr. W. H. Shields, B.Sc., the Assistant Engineer for the Yilgarn Railway Water Service, under whom the author was employed as Accountant and Engineering Assistant during the months May to September, 1897.

In conclusion, the Author takes the opportunity of expressing his thanks to Mr. James Thompson, B.E., Assoc. M. Inst. C.E., Engineer for Railway Construction, Perth, for the use of the accompanying plans, and also to Mr. W. H. Shields, B.Sc., for his assistance in preparing this paper.