

(*Paper No. 2237.*)

## “Water-Supply in the Cape Colony.”

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### 1. GENERAL PHYSICAL FEATURES.

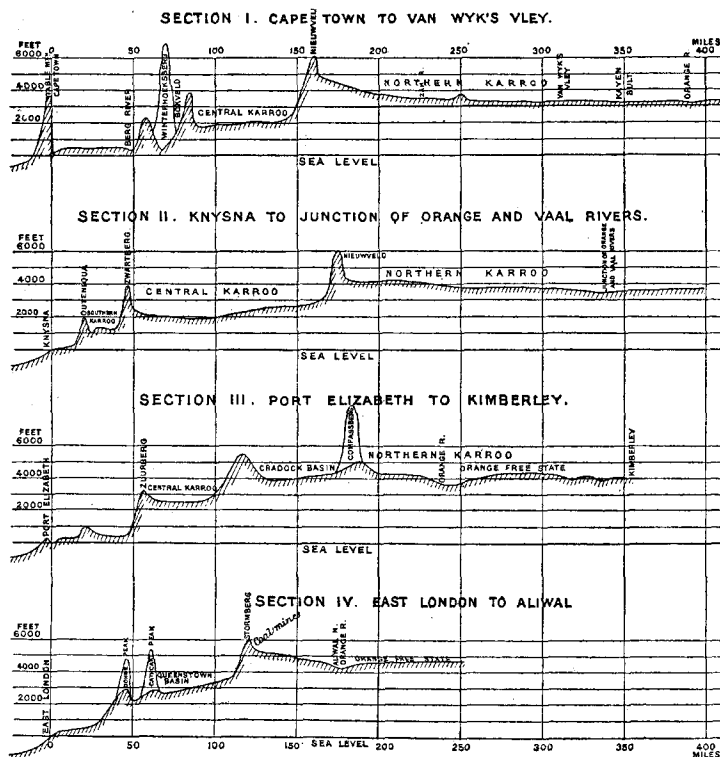
THE southern extremity of Africa has been likened to a saucer broken in half and turned upside down. That is to say, mountain ranges run more or less parallel to the coast, and enclose an interior somewhat lofty table-land of considerable extent.

Between the ocean and the first range, a width of perhaps 30 miles, the average elevation of the land is about 300 feet above sea-level. The first range, which is ordinarily visible from the sea, is very uneven, and some of its peaks are over 5,000 feet high, but they are generally much lower. This is the coast-range. The strip of country between the first and second ranges is narrow, seldom exceeding 30 miles in width, and being often much less. The height above sea-level of the various villages in this strip varies very much, but is probably about 1,000 feet. This is called the Southern Karroo. The second range is also somewhat irregular, and its peaks occasionally exceed 6,000 feet in height. It has different names in different parts, but the Zwartberg may be chosen to distinguish it. The strip between the second and third ranges is much wider than the Southern Karroo; it is mostly over 50 miles broad, has an average height of 2,000 feet above the sea, and may be called the Central Karroo. The third and last mountain range, called the Nieuwveldt range from the name it bears along a considerable part of its length, is a more regular chain, and its peaks are generally over 6,000 feet above sea-level. Further to the north is the Northern Karroo, a great basin, averaging perhaps 4,000 feet above sea-level, the eastern parts being over 5,000, and some of the western end scarcely 3,000, the drainage all running to the north-west.

The above description of three parallel ranges applies accurately only to the south-western and central portions of the Colony. In the extreme north-west the three ranges become mixed up

about the Kamiesberg and the copper mines. In the east the coast range runs into the sea at Port Elizabeth; the second range sinks and disappears near Grahams Town; while the third range splits into two about Graaff Reinet, the southern portion becoming the Amatola range, the northern the Stormberg, and including between them the two basins of Cradock and Queens

FIG. 1.



Town. The Stormberg is topographically the more true continuation of the Nieuwveldt, for it is the line of water parting, inasmuch as the Cradock and Queenstown basins drain to the southward. Those basins, however, have a greater likeness to the Northern Karroo than to the Central Karroo, and their height above the sea averages about 4,000 feet.

The Transkei is not included in this Paper, as it has scarcely

yet been fully explored, and there is little or no irrigation there. It is a country, watered by many permanent rivers and streams, where irrigation might be most usefully employed.

A notable feature in South Africa, and one which chiefly distinguishes it from Australia and from South America in the same latitude, is the great height above the sea of the interior basin. This is shown on the typical cross-sections Fig. 1. The average height of the whole Colony above sea-level is 3,000 feet. Hence the rivers have a rapid fall, exert considerable eroding power, and carry down immense quantities of silt. The strong winds and currents, as well as the surf, prevent, however, the formation of deltas on the coast by the products of this erosion.

A warm ocean-current (Mozambique) sweeps down the east coast, and a cold Antarctic current follows the west coast; these, as will be seen, have a very marked effect on the rainfall. The ocean is deep to the east and west, but on the south side of the Continent lies the L'Agulhas bank.

The coast and Zwartberg ranges consist of rocks at least as old as the Carboniferous series. Sandstone and quartzite form the principal rocks of both the above ranges, the Zwartberg having remarkably folded and contorted sandstones. The Nieuwveldt range consists of the comparatively recent but still very ancient Karroo formation, assigned to the Triassic Age; here layers of claystone and sandstone are horizontally stratified with occasional faults, but scarcely any foldings, though frequently intersected by dioritic dykes which alter the constituents of, but do not otherwise disturb the rocks near them. It is these horizontal strata that give the "table mountain" appearance to the country; that is, when a trap or other hard rock is the highest layer, the appearance is tabular; when the highest layer is soft, it weathers differently, and the appearance is that of a cone. Nevertheless, the celebrated Table Mountain at Cape Town is not of this formation, and its tabular appearance is more or less a geological accident, the formation to which it belongs not being remarkable elsewhere for horizontality.

Between the coast-range and the Zwartberg is a limestone outcrop, which is of considerable importance to the farmer. In this are the celebrated Cango Caves. As a rule, limestone is very scarce in the whole Colony. There are local deposits of recent limestone, or "kalk," or "drup," as it is called; but the principal other considerable deposit is the Campbell randt, in the extreme north.

A very remarkable and puzzling conglomerate occurs along the  
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whole southern outcrop of the Karroo strata. It has been called porphyry, trap, glacial conglomerate, and breccia! It is extremely hard and impervious.

There are scarcely any Tertiary formations; and, in fact, excepting some deposits near the South Coast, there is little later than the Triassic.

## II. RAINFALL.

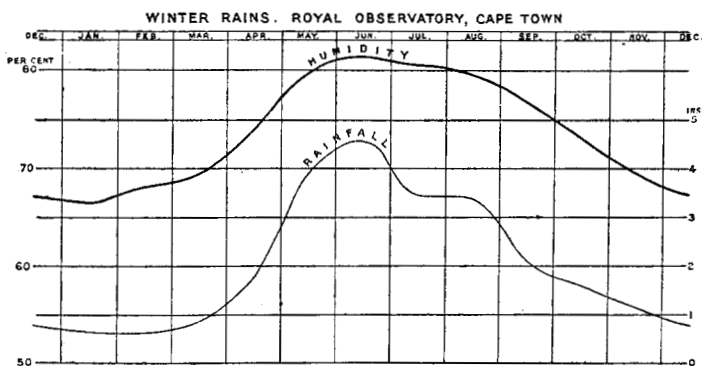
Eleven years ago, when the Author went out to South Africa, there was little trustworthy information about rainfall except the observations made at the Royal Observatory, near Cape Town. The climate immediately round Cape Town is very different from that of the rest of the Colony, and meteorological observations made at Cape Town are not applicable to other places. The Royal Engineers had, indeed, made some careful observations at Grahams Town, but only for five years, too short a time to give a trustworthy average. Private observers in various parts had kept registers, but only for a few years, and not always continuously, so that there were doubts how far they were fair examples. The Author induced the Cape Government to place a rain-gauge at each seat of magistracy in the country, and to make it a duty of the magistrate to supervise the rain-gauge and register. A yearly grant of £100 was obtained from Parliament, so that, after the magistrates had been supplied, gauges were lent to willing private observers. There are now about three hundred observed in the Colony. Plate 4 shows some of the results obtained.<sup>1</sup> The small Cape peninsula is subjected to a great variety of rainfall, some parts having as little as 20 inches per annum, whilst others have much more; for example, Bishops-court, under the eastern cliffs of Table Mountain, has a depth of 54 inches. Eleven years, giving as they do a complete sunspot cycle, will afford a fair estimate of average annual rainfall, but they by no means indicate that most important requirement for engineers, the fall of the three driest consecutive years.

Excepting the north-west, beyond Saldanha Bay, the whole coast strip has a fair rainfall, is watered by permanent rivers, and can do without artificial irrigation. The Southern Karroo has a small rainfall, not more than 10 or 11 inches, but is fairly well off for water from the numerous springs and streams that flow off the coast range and the Zwartberg. By the aid of this running water,

<sup>1</sup> For further information, see the Report of the Cape Meteorological Commission for 1886, at the end of which are reduced copies of monthly maps of rainfall exhibited by the Author at the Indian and Colonial Exhibitions.

farmers succeed in raising fine crops. The Central Karroo has a scanty rainfall, varying from 8 inches and under in the west to 15 inches and upwards in the east. The Northern Karroo has a small supply, the western part having 6 inches, the eastern 13 inches and upwards. Here the rivers are intermittent; in the west they often only run for a few days in each year, and sometimes a year occurs in which they do not run at all. As a rule, and excepting the extreme south-west corner, the rainfall increases from west to east, the north-west near the mouth of the Orange River being practically rainless, the mission station at Pella having only 2 inches per annum.<sup>1</sup> The extreme east of the Northern Karroo, on the other hand, has over 20 inches. The wettest parts are Table Mountain, Cape Town, and its slopes, 40 to 60 inches; the Knysna and Zitzikamma forests, 40 to 50 inches; and the southern slopes of the Amatolas, where 69 inches is the average of the last three years'

FIG. 2.



observations at the Katberg. Of course everywhere the mountains and mountain valleys have a better chance of rain than the more deeply lying plains. This is especially to be seen in the Central Karroo, in a low-lying area between Prince Albert and Beaufort West, where the average annual fall is but 6 inches.

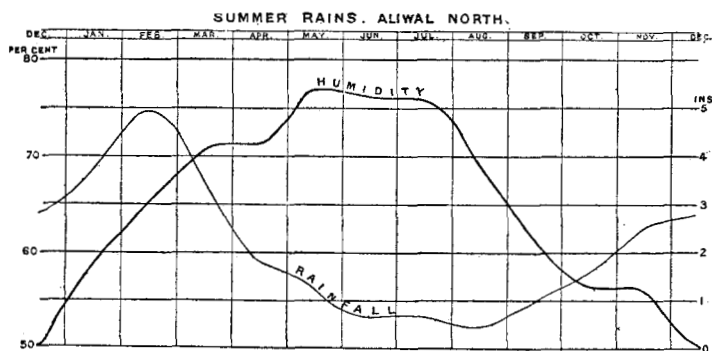
The west coast and south-west get rain in winter, and have a dry summer (Fig. 2); the south coast has rain more or less fairly distributed throughout the year. But the whole of the rest of the Colony, the centre, east, and north, have what is called summer rains; here March is generally the wettest month, but the more eastern stations get rain earlier than the central (Fig. 3). There

<sup>1</sup> In 1884 the fall at Pella was less than 1 inch,  $\frac{1}{2}$  inch falling in January,  $\frac{1}{10}$  inch in May, and  $\frac{1}{4}$  inch in November.

is a second maximum in many parts, especially in the south-east, in November; these early summer rains, when they occur, are most valuable for agriculture, as this is just the time that water is most wanted.

The east, centre, and north of the Colony get rain with the south-east wind, the indraught of the "trade," although many individual storms appear to come from west and north-west. This south-east wind, coming over the warm Mozambique current, is charged with moisture; it spares some to the coast lands, and then meeting a mountain range, is forced upwards, the air expands, and can no longer carry so much moisture in suspension; hence rain is abundantly deposited on the mountain slopes. In the intermediate valleys little rain falls, because the air, having descended from the mountain ridges, is again compressed, and can hold more moisture in suspension. The south-east wind is dry at Cape Town,

FIG. 3.



probably because it has not passed over such a warm portion of the current, and because it has not been raised vertically. It is well known that when the dry south-east wind blows strongly at the Cape peninsula, heavy rains may be expected in the Central and Northern Karroo.

The south-west district is subject to winter rains with the comparatively warm north-west anti-trade. The extreme north-west of the Colony is practically rainless, because the sea-breeze has passed over a cold sea-current, and has come to a warm land; it is thus not inclined to part with the little moisture it bears. At Port Nolloth there is little else but fog.

Even in the driest parts the rain, when it does fall, often descends very heavily; an inch frequently is registered in an hour; 4 inches once fell in two hours at Victoria West.

Snow is rare, except on the mountains of the south-west coast,

where there are winter rains, but the other high mountain ridges have generally some snow every winter.

It is curious to note that relative humidity and rainfall do not increase together except where there are winter rains. Although rain is very scarce at Aliwal North in winter, yet the relative humidity is then greatest, and although summer is the rainy season, yet it is relatively dry (Fig. 3).

It is a remark frequently made by travellers that the climate of South Africa is becoming drier. Springs which were once abundant are now weak, and rivers that formerly flowed almost constantly now seldom run. The hippopotamus used to be found in pools in the Kuruman River in Betchuana Land, which are now quite dry, except in an unusually wet season. Is this in consequence of less rain falling, or from some other cause? The observations made for forty-seven years at the Royal Observatory, and the scanty records elsewhere, give no support to the view that the general rainfall is materially decreasing. And it is a fact that nearly all travellers a hundred years ago speak of fearful droughts. Three causes have, however, most certainly lessened both the discharge of springs and the flow of permanent rivers, as well as the duration of floods in the intermittent rivers. These are, destruction of forests, burning of the grass or bush, and overstocking. Trees have been, and are, cut down in the most reckless manner; the wandering sheep-farmer goes on to Crown land and cuts down the trees so that his goats may feed on the leaves; the Kafir destroys thousands of saplings in the Kaffrarian forests to restore his easily and frequently burnt hut. The wood of most of these trees is very hard, especially the magnificent "Kameeldoorn," which is in consequence often burnt down instead of being chopped down. Large areas along the Hart River and elsewhere have been denuded of this tree to supply firewood for the machinery at the Diamond Fields. The veteran missionary, the Rev. R. Moffat, states that after the destruction of a grove of wild olives near Griqua Town, the springs of that village gave a considerably smaller discharge. Burning of the "veldt" is a common practice, and has been so for a long time past; indeed, the old Portuguese navigators noticed the bush-fires on the south coast as they sailed by. These fires are generally caused intentionally in order that young grass may spring up. It is probable that the pasture is in the end deteriorated by this practice, but it is certain that springs are lessened, for the high grass, and especially the reeds and thickets in the valleys, which form excellent temporary storage reservoirs, are destroyed; and from this cause

many perennial streams have become intermittent earlier on their course. Overstocking is perhaps as powerful a cause as any, not merely from the eating off of the grass and bush, but because the tramping of the animals' feet continually along the same paths causes tracks to be formed, along which surface-water runs after rain. These, by erosion, soon become small "canyons," often 30 feet deep and upwards, thus taking the surface-water away more rapidly, and underdraining the land to a considerable depth. The Boers scarcely make any attempts to stop this erosion, although in the early stages a few bushes and stones might prevent the mischief. Many of the river-channels have only been formed within the memory of man; for example, before the village of Fraserburg was founded, about 1851, the Zak River had no definite channel. To a certain extent water now runs off to the sea which under more favourable circumstances would be re-evaporated and fall again as rain. To go back, however, to previous geological epochs, then, doubtless, South Africa must at one time have enjoyed a heavier rainfall. Perhaps the coast-ranges were then less high and intercepted less moisture, and there is little doubt that portions of the coast have risen; for example, the lower valleys of the Zwartkops, Coega and Sunday's Rivers were once estuaries. Perhaps the sea-currents were different; before the L'Agulhas bank was deposited, or when it had not been raised so high, the Mozambique current may have curled round the Cape of Good Hope and gone north, displacing the present cold Antarctic current.

### III. DESTINATION OF THE RAINFALL.

1. *Evaporation*.—The only continuous observations of evaporation are those that have been kept up at the Author's request at the Van Staaden's River, the intake of the Port Elizabeth Waterworks. The monthly averages of five years are given in Appendix I. They vary from 5 inches and upwards in summer to 2 inches and less in winter. These results agree remarkably with the observations made at Melbourne, Australia. At Port Elizabeth the annual evaporation is 39·1 inches, at Melbourne 40·6 inches, and the distribution throughout the year is very similar at the two places. But the Van Staaden's gauge is too near the coast to give an accurate representation of average evaporation in South Africa. A much more instructive result has been afforded by the actual loss from the Van Wyk's Vley reservoir hereinafter described. Here there was a total loss in eleven months and seven days of 80 inches, varying from 10 inches in the summer months to 2 or

3 inches in winter. Some of this loss is due to percolation into the dry strata at the sides of the reservoir, but the Author estimates the loss due to evaporation, corrected so as to apply to the whole year, at 80 inches. Of course much depends on the wind, which is almost as important a factor in evaporation as the sun. However, 39 inches for the coast region, and 80 inches for the back country may be taken as the limits, the water-surface in both cases being moderately protected from the wind.

Besides the evaporation from the surface of water, there is the evaporation from the surface of the ground. In this way small amounts of rain disappear without running off or percolating. After a dry time probably more than  $\frac{1}{2}$  inch of rain would disappear in this way.

2. *Surface-Flow.*—The proportion that flows off the surface, as may be expected, is much less in dry South Africa than in England, where Dalton estimated it at 36 per cent. Almost the only continuous observations of surface-flow in South Africa are those made by Mr. W. B. Tripp, M. Inst. C.E.,<sup>1</sup> on the flow from the catchment area of the Buffalo River which supplies King William's Town.<sup>2</sup> The results given in Mr. Tripp's Paper show that only some 2 per cent. runs off after or during a drought, while after a previous rain the proportion running off may be as large as  $\frac{1}{10}$ . Mr. Tripp seems to favour a proportion of  $\frac{1}{4}$  to  $\frac{1}{2}$  as flowing off in an ordinary period of some length. As far as geological structure goes King William's Town is a fair specimen of South African country, but as it is in the extreme south-east it has a larger rainfall than the centre or west; hence the land is covered with grass, and considerable patches of forest are still to be found in the catchment area. Observations were made by Mr. E. J. Dunn, F.G.S., when in charge of boring operations near Aberdeen,<sup>2</sup> in the Central Karroo. These were made on the occasion of a heavy storm, when the rainfall on the plains was  $1\frac{1}{2}$  inch, and when in the mountains probably 3 inches fell, or an average of perhaps 2 inches over the drainage area. Mr. Dunn's river-gaugings go to show that half this quantity ran off. The surface-flow takes place with great rapidity, as there is a very considerable gradient, and there are no lakes to retain the water. The rivers in the north-west and central parts of the Colony, as has been said, only run for a few days in the year, and some years they do not run at all. When they stop they form a chain of

<sup>1</sup> Minutes of Proceedings Inst. C.E. vol. lxxxi. pp. 241–251.

<sup>2</sup> For the position of these and other places see Plate 4.

pools called sea-cow or hippopotamus holes, the water in which as a rule gradually becomes more and more brackish.

Both the Vaal and the Orange Rivers rise beyond the colonial boundaries in the well-watered Drakensberg, dividing Natal from Basuto Land and the Orange Free State, and yet the Orange River, which with its tributaries drains some 400,000 square miles, is occasionally closed or filled up with sand at its mouth; in 1851 it was closed for six weeks, so that not even the smallest boat could have got out.

3. *Underground Percolation.*—The amount of underground percolation can as a rule only be ascertained by deducting the evaporation and surface-flow from the rainfall. No experiments have been made. There is a considerable thickness of porous rocks in the Karroo strata, but they are very level; clay-slates, claystones and sandstones alternate, but there are seldom any intercalated beds of clay. There are no undulating strata with high-level outcrops to favour the formation of artesian springs. Springs generally occur either in the bed of a river, or at a dyke, or at a fault. Those in the bed of a river occur where the eroding river has cut its way down to a water-bearing stratum. Innumerable dykes intersect the Central and the Northern Karroo, and they cut up the subsoil into distinct underground catchment basins. These underground reservoirs overflow at the lowest point of the dyke on the lowest side of the basin. This intercepting dyke is often made visible on the surface by the line of trees which fringe it, and whose roots here get the water necessary for life. The Boers call these lines “aars,” or veins, and think, or used to think, that the water coursed along in the earth like blood in a man’s veins. Faults are also a frequent cause of springs; the Author has noticed some score of wells in the back country, and there are probably hundreds, sunk on the line of a fault. These wells are often open, and sometimes have an inclined way down to them, when the different strata on the two sides with the broken churned-up appearance may be noticed close to the line of fault. It is frequently remarked that the springs in the dry river-beds become weaker after a flood; if this be the case, it is probably owing to silt closing up the fissures in the rocks. After a time the sun’s heat cracks the silt, or perhaps the underground water is backed up sufficiently to be able to force its own way. A good fall of snow on the mountains is of great importance to the springs. In the years 1851, 1852 and 1853 snow lay on the Sneeuwberg and Winterhoek mountains from April in each year till August, and this so strengthened the springs that, as the

inhabitants put it, for the fifteen subsequent years no complaint of low springs was heard.

The springs of the Cape Town Table Mountain are exceptionally interesting, and so worthy of notice. Table Mountain is of horseshoe shape; the middle and highest parts look northward down upon Cape Town; the eastern wing overlooks the favourite suburbs of Rondebosch, Wynberg, &c.; the western wing, called the Twelve Apostles, faces the Atlantic, and the hollow part faces south. The outer edges are generally higher than the centre, so that the surface-drainage is to the centre, and finally to the south. The top layers are of sandstone of varying hardness; these rest on granite except at the north-east corner, where the granite is replaced by clay slate. The springs generally come out at, or a little below, the top of the granite. The strata dip to the southward, and this, combined with the horseshoe shape, causes a considerable part of the underground drainage to go away to the south, and to be lost in the sea. Under the Author's advice, a Company was formed, and an Act of Parliament obtained giving the necessary powers to bring both spring- and surface-water from the interior of the horseshoe to the suburban villages on the east, which as a rule are badly off for water. Owing mainly to financial depression, nothing further has yet been done. There is also a vast mass of *débris* at the foot of the eastern precipices, which acts as an underground reservoir, and helps to feed some very strong springs. The principal of these, the Albion Mills Spring, has a discharge of about 800,000 gallons daily. These springs are mostly private property, and, being at a low level, could not be available for village supply without pumping—an expensive item in South Africa.

Many of the up-country springs come out below a bed of surface limestone or travertin. Such is the case at Fraserburg, and at the Roman-Catholic mission station, at Pella. The water from the latter is decidedly brackish, but some plants, notably the pomegranate, thrive on it.

Hot springs occur in various parts of the Colony. They do not seem confined to any geological formation, but are found more or less in a belt running from north-east to south-west. They are much used by the Boers, as they were by the natives before them. The Boers come and camp round them, so as to enable the members of their families suffering from rheumatism, &c., to avail themselves of the warm water. The following is the temperature of three of the principal and hottest springs: Caledon, 111° Fahrenheit; Olifants River, Calitzdorp, 124°; Brand-Vley, Worcester, 160°.

## IV. NEED OF ARTIFICIAL IRRIGATION.

Between the coast-range and the sea in the south-west and centre, and between the Amatolas and the sea in Albany and Kaffraria, irrigation is not necessary for vines or corn, or some other crops, though it is advantageous for market-garden produce. In the Koeberg country immediately north of Cape Town, large quantities of cereals are grown without irrigation. So also in Olifants Hoek east of Port Elizabeth, Lower Albany, and Kaffraria south of the Amatola Mountains. Rust is, however, frequent, especially in the east. In other parts of the Colony crops have occasionally been grown, and especially in hilly regions, without artificially-applied water, but the experiment is so uncertain that it is seldom made except by natives.

The quantity of water required for a crop varies with the rainfall, the atmospheric humidity, the nature of the soil, the inclination of the ground, the kind of crop, and the weather while the water is being applied, so that no hard and fast rule can be laid down. Vines seldom want more than three waterings; wheat and oats want four, five, or even six, the general rule being once before ploughing, and three times after. Tobacco wants water once a fortnight. A watering may be considered as a layer from 2 to 3 inches deep, but in some parts, where flood-water is allowed to stand on the land, the amount is greater, and then the necessity for frequent irrigation is less. It is curious to note that in France the principal irrigated crop is grass, but in South Africa it is almost unheard of to irrigate grass.

## V. ARTIFICIAL WORKS BEFORE 1875.

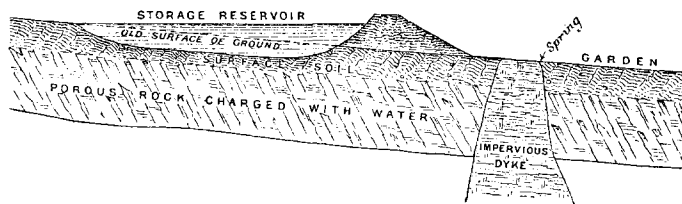
The Author has chosen 1875 as an epoch, because it was about this time that the impulse given to South Africa by the Diamond Fields began to be felt: public works were started with more confidence; attempts were made to legislate for water-supply, and because the office of Hydraulic Engineer to the Colony, to which the Author was appointed, was then constituted.

At the Cape the early permanent farms were mostly settlements below some natural spring, whose water was led out by a simple ditch to a garden. Such a garden varied in size with the discharge of, and the distance from, the spring, the loss by evaporation and percolation in the open ditch being considerable. Sons and sons-in-law established themselves close by, as long as the water sufficed, and the will of the somewhat autocratic head of the

family permitted. Hence many South African villages have arisen. When rain occurred in any part of the country, so as to leave temporary ponds in natural depressions, or to refill the sea-cow holes in the river-beds, then the farmers left their permanent settlements in the higher or less dry regions, and thronged down to the water, so that their stock might graze in a comparatively virgin region. There they stayed encamped till the water was exhausted, or had become too brackish to drink. This is still done in the north-west of the Colony, though on a lesser scale than formerly, farmers having, by aid of wells and surface-reservoirs (called dams), settled down in places that would have been regarded as hopeless some years ago.

Among the earliest works were wells, which were dug to a certain extent; and even the Bushmen had their drink-holes, the position of which they kept carefully secret. Wells are useful for stock, but they are seldom available for agriculture except on a

FIG. 4.



BOER METHOD OF STRENGTHENING A SPRING.

very small scale. Where the ground is favourable, trenches are often cut for long distances up to wells, so as to enable the water to flow by gravitation, but the loss in such a trench by evaporation is great. A favourite artificial work with a Boer who has a spring, or, as he calls it, a "fountain," is to make a reservoir to "strengthen the fountain." That is, supposing a spring comes out in the bed of a valley, the farmer makes a pond some 50 or 100 yards further up the valley, so that the soakage from the pond adds to the discharge of the fountain (Fig. 4). It would seem, at first sight, that it would be better to make the reservoir watertight, and to draw off the water by a sluice-valve in the ordinary way. But in some cases the Boer method may answer; as, for example, when there is a large mass of porous underground strata above the spring, shut in by a volcanic dyke. Here the "dam" water would percolate into and further charge the underground strata, and the extreme evaporation of a sub-aerial reservoir be avoided.

The farmers construct their dams by first ploughing the surface where the future reservoir is to be, and then by dragging the ploughed-up earth to its position in the bank with oxen and scrapers. A scraper is like a large wide shovel, only it is moved by chains attached to each side instead of by a handle. It is a good method of making small banks, as the bank has the benefit of the tramping of the oxen to consolidate it. As a rule, farmers make their dams much too steep, slopes of 1 to 1 being considered sufficient. A common design is as follows: Two dry-rubble walls, 20 feet apart, each perhaps 5 feet thick at the bottom, 20 feet high, and 2 feet thick at the top, the space between the walls being filled with clay without any punning. In fact, artificial consolidation is seldom attempted. The bush and turf on the original surface are seldom cleared off; there is no puddle-trench, and pipes are laid through the bank without any foundation. One dam, strange to say, has for years given its supply through a leak under the bank. The overflows are seldom large enough, hence the first high flood flows over the wall, and destroys the dam.

The gradients of most farm-canal are extremely irregular; they are seldom, if ever, laid out with the spirit-level, and the farmer digs on by a process of trial and error, letting the water "find its own level." This of course generally results in a great waste of head. Canals are seldom puddled; the Author on one occasion gauged a small canal in the Worcester Valley, and found that a flow of 4 cubic feet per second, near the point of entry, was reduced to less than 2 cubic feet in a length of rather over 1 mile; and at another place, a flow of 1 cubic foot per second was lost altogether in  $1\frac{1}{2}$  mile.

Before 1875, few artificial works of importance had been constructed. A tunnel made by the Rev. Mr. Philip, a missionary at Hankey, on the Gamtoos River, is worth notice. The River Gamtoos makes a bend round a promontory of conglomerate rock, and comes back to close upon its original position. By making a tunnel through the friable conglomerate, Mr. Philip was able to lead the water over nearly 1 square mile of land below. A further improvement was the use of a pipe under the river-bed, to carry some of the water to the opposite side of the river. Unfortunately, as has been so often the case in South Africa with missionary enterprise, the good work done in the time of early enthusiasm has been allowed to fall into neglect.

An earthwork reservoir had been made at Beaufort West, an important village in the Karroo. Owing to imperfect consolidation, the bank had given way, and, after some delay, was in 1875

in course of repair. Had this reservoir bank not failed from defective consolidation, it would certainly have failed through the overflow being too small. The overflow was originally some 3 feet wide. The Author, when he visited the place, strongly urged that it should be 150 feet wide. It was widened to 100 feet; the overflow water once ran 6 feet deep over this width, and it has since been further widened. The supply is given through siphon-pipes laid over the bank.

Grahams Town, the centre of the English settlers sent out in 1820, and for a considerable time the head-quarters of the military, possessed three storage-reservoirs in 1875, none of which were perfectly satisfactory, though doubtless an advance on the style of dams made by the farmer. One of these reservoirs, whose bank is a combination of masonry and earthwork, has masonry buttresses on the inside of the dam!

King William's Town had a water-supply contrived with some ingenuity. Water taken from the River Buffalo worked a turbine, which pumped a portion of the water to the higher parts of the town.

## VI. LEGISLATION.

In order to make it easier for farmers to improve their properties by artificial works, several Acts of Parliament of the Cape Legislature have been passed.

The first is the Water-passage Act of 1876, which gave farmers, who had a right to water from a stream, power to convey that water in a canal through the lands of proprietors on higher ground, such compensation being paid as arbitrators might grant. This has been availed of to a certain extent.

The second was the Irrigation Act, passed in 1877, which had two objects in view: (a) To facilitate the formation of associations for the purpose of irrigation; (b) To authorize Government to advance loans to farmers for the construction of waterworks, such loans to be repayable in twenty-four equal annual instalments of 8 per cent. This is equal to 6 per cent. in perpetuity, which was about the rate of interest on the best first mortgages. The loans were only to be granted after the designs had been approved by the Government Engineer. The first part of the Act was founded more or less on the English Land-drainage Act. As yet it has been a dead letter, co-operation of any sort being strange to the farmers. The second part of the Act has been availed of, though, owing to the Government urgently requiring money in other directions, it has been applied in an intermittent way. The South

African farmer or Boer, whether of Dutch or French extraction, is extremely suspicious of all Government interference or control. Indeed some farmers thought the Irrigation Act to be a dodge whereby the Government hoped to get their farms away from them. This suspiciousness is not merely because Government is in English hands, for it was much the same when the Netherlands Government possessed the Cape.

A third Act was passed in 1879 to extend the provisions of the Act of 1877 to municipalities, enabling them to borrow for works of household supply, and for the irrigation of town lots.

A fourth Act, called the "Irrigation Act Amendment Act," was passed in 1880. This enabled Government to advance one-fifth of a loan before the works were commenced, the original Act having only authorized Government to advance money as the work was done. It also made provision for the loan being paid off in less than twenty-four years if desired by the borrower.

Up to May, 1886, there had been one hundred and sixteen applications for loans from individuals or corporate bodies. Of these thirty-one had been granted, and nine were under consideration. The total sum of £53,524 had been advanced, in addition to a further sum which had been advanced under a more general Act, the Local Loans Act, to six local bodies, who originally applied under the Irrigation Act.

Further legislation is much needed for the purpose of defining water-rights. At present the rights of the various proprietors along a stream are in a very uncertain state, and some of the most intricate lawsuits are those dealing with disputes about water. Enterprise is in consequence hindered.

Some registration is urgently required of the amount of water that a riverside proprietor is entitled to take, so that any one who executes works by which waste is stopped may have a right to what he has saved. There is no proper measurement of water. Title-deeds give rights to so many inches of water, meaning as much as will go through so many holes each an inch in diameter, without any regard to the velocity of the water, or even as to usage in respect of the depth of the holes below the surface of the discharging-pond or conduit.

A Local Government Board is much needed. Town councils, as a rule, err on the side of caution, and refuse to carry out works of improved water-supply on account of the expense. The general object of a Local Government Board would be to compel town councils to give wholesome water for household purposes to the townfolk, and for this purpose to adopt suitable designs. As a

rule, the owners of village lots are satisfied if there is plenty of ditch-water for irrigation. This is aggravated by the fact that many houses in most villages are owned by absentee farmers, who come in occasionally to combine divine worship on Sunday with shopping on the previous Saturday afternoon.

## VII. WORKS CARRIED OUT BY THE GOVERNMENT.

1. *Van Wyk's Vley*.—The Cape Government has carried out one large work, Van Wyk's Vley, and a few smaller ones.

Van Wyk's Vley is in the north of the Colony; it is close to the edge of a waterless tract of country, the Kayen Bult, a southern prolongation of the Kalahari desert. Here a storage-reservoir has been made, by throwing an earthwork bank across the contracted portion of a river valley, and thereby giving an opportunity for the creation of a very large lake. The catchment-area is 460 square miles; the average annual rainfall is under 6 inches (Appendix II). In order to take advantage of an adjacent depression, or "col," in the watershed for an overflow, the bank was made somewhat higher, and the reservoir more capacious, than would have been justified by the amount likely to be caught. That is to say, it was cheaper to raise the bank than to cut down the overflow. The content is 35,000,000,000 gallons. As yet 4,000,000,000 gallons is the most that has stood in the reservoir at any one time, or 13 feet deep on the sluice. As may be seen, it will require over 5 inches running off the whole catchment-area to fill the reservoir, so that as long as the water is drawn off for irrigation, and unless several wet years occur in succession, it is probable that the reservoir will never be actually filled. As has been noticed before, the loss by evaporation from the soil is very considerable; a rainfall of  $\frac{1}{2}$  inch in twenty-four hours gives no increase to the water in the reservoir, unless it immediately follows a previous rain, or unless it falls with unusual rapidity. The bank is of earthwork, with puddle-trench and puddle-core, inside pitched slope 3 to 1, outside slope 2 to 1, greatest height of bank 34 feet. The top of the bank is 4 feet above the natural overflow already described. The supply-sluice is 27 feet below the overflow. There is a convenient bend in the valley just above the dam, so that the bank is not exposed to any considerable fetch of the waves. The pitching is 12-inch, laid on 18 inches of broken stone; this large quantity of broken stone was chiefly used to prevent the burrowing of crabs, a fruitful source of leakage and trouble to dams and canals in South Africa.

There is a parapet-wall 2 feet in height. The supply-pipes are laid in a masonry culvert sunk in the solid shale at one side of the valley. Exterior rings of masonry are built every 9 feet along the culvert, to bond the culvert into the rock. The culvert was available to carry off any flood-water that might accumulate during progress. A masonry tower gives access to the sluice-valves. After the pipes had been laid, the interior part of the culvert, from the tower to past the puddle-core, was plugged with Portland cement concrete, grooves having been left in the walls of the culvert, every 9 feet, to assist in forming a tight joint. Owing to the great distance inland, a cask of cement, which cost 15s. in Cape Town, had cost £4 when it got to Van Wyk's Vley.

Instead of putting selected material on each side of the puddle-core, the Author prefers to place the whole of it on the inside of the puddle, leaving the outer side of the puddle to be filled up with somewhat inferior material. Excepting the outer toe of such banks, which for some 6 feet high may conveniently be made of a pile of boulders, only an extremely small proportion of gravel or broken stone was allowed on the outer part, and none on the inner part. Of course the whole was brought up in thin layers, and well consolidated. The contractor having up till then only had experience of railway embankments, the duties of superintendence of Mr. J. E. Macnellan, the Resident Engineer, and of Mr. R. Taylor, the Inspector, were unusually arduous, especially as the work was frequently carried on both day and night.

The quantity of earthwork in the bank is over 80,000 cubic yards, the total cost, without land compensation, was £18,000.

During the first year, 1884, after the reservoir was finished, there was an available depth of over 4 feet, but no irrigation was undertaken, the survey of the irrigable allotments below the reservoir not having been made. This, as has already been noticed, enabled most valuable observations on actual evaporation to be made. Although the water sank below the level of the supply-pipe, yet the gauging was still practicable, as there is a large natural pool inside the dam below this level. Percolation was small, though no doubt when the reservoir catches more water there will be some loss from this cause, as some not very solid shales outcrop on the hillsides that enclose the basin. During the second year, 1885, with an available depth exceeding 5 feet, no land was let or sold by Government, but the bailiff, Mr. G. Alston, cultivated 20 acres experimentally, sowing almost every practicable kind of seed, and his success was great. In 1886, with an

available depth of 7 feet, some 500 acres were sown with excellent results, one of the tenants reported the wheat to be of unusually good quality, much of it 5 feet 6 inches high, and often with seventy to one hundred ears on a single root; he expected the crop would be 6,000 bushels. A much larger area would have been sown had it not been for the great depression prevailing, the farmers scarcely having money enough to buy seed-corn. In the beginning of the present year, 1887, the available depth was 13 feet. The total area of land connected with the Van Wyk's Vley reservoir is 100,000 acres, and of this 10,000 acres are of best quality and irrigable, while almost all the remainder is fair grazing land.

There is a considerable proportion of various salts in the shales of this part of the country. This is frequently seen in efflorescence at the surface, a phenomenon especially noticeable below the ponds or reservoirs made by the farmers. Some alarm was at first caused by newspaper paragraphs, stating that the water in Van Wyk's Vley would all be salt; these were disproved at the time by the fact that crops had been raised on adjacent farms by the aid of artificially stored water, and at several of them there was exactly similar efflorescence. A considerable area is to be left below the embankment unleased and unsold, to allow for possible deterioration by salts. At present no trouble has been experienced, the water having remained drinkable from January 1884 up to the end of the same year, although scarcely any appreciable addition was made by rainfall. Careful subsoil drainage, and judicious use of manure, are known to counteract the effects of the salt. Sheep's dung is a manure fairly plentiful in the Karroo.

Any percolation into the shales will become less and less as the bottom and sides get coated with the finely-divided Karroo silt thrown down by the water. There is, however, no fear that Van Wyk's Vley will ever silt up, as so many farm reservoirs have done. Very little mud is brought down, and, as has been stated, the available content is very large compared with the supply. The water-parting is close to the reservoir; it is not formed by high mountains, but is often scarcely perceptible. Few of the hills in the catchment-area are of any great height.

Cereals of all sorts are, and have been, very dear in the neighbourhood of Van Wyk's Vley. The sheep-farmers are often unable to keep horses or cows because they have no food for them. It is a great drawback, in case of stolen sheep, if a farmer has no horse in his stable ready to carry him in pursuit, but has to wait hours while the Hottentots are seeking the horse grazing some-

where in the "veldt." Hence the produce of an irrigation-farm should find ready sale in the neighbourhood.

2. *Brand Vley*.—A smaller reservoir, constructed by Government, is at Brand Vley, in somewhat the same latitude as Van Wyk's Vley, but further west. This reservoir holds 1,500,000,000 gallons, and cost only £670. It is fed from overflows of the Zak River by means of a small canal. The catchment-area of the Zak above this site is so great that there is no difficulty in filling the reservoir whenever the Zak River flows at all strongly, so long as the feeding-canal is in proper order. This is an earthwork bank founded on solid rock, and with two small puddle trenches sunk into the rock to cut off leakage along the rock-surface.

3. *Stolshoek* is a reservoir close to the village of Beaufort West, made to irrigate a proposed plantation. Here the wall is of rubble masonry in Portland cement mortar on a rock foundation. The height of wall above the foundation is 23 feet; the reservoir contains 65,000,000 gallons, and the drainage-area, which has been recently somewhat enlarged by catchwater drains, is 6 square miles. A depth of 1 inch of water running off would fill the reservoir. Though finished in 1883, it has not yet been more than half filled, owing to recent dry seasons combined with a specially absorbent catchment-area. There is a certain amount of percolation through the adjacent strata which will become less as the surface is covered with silt. There was some sweating through the wall, which is, however, becoming clogged with stalactite. There are 2,960 cubic yards of masonry in the work, and the cost was £8,500.

4. A small reservoir called *Wolvehoek* was constructed close to the village of Fraserburg in 1885 as a relief work for starving natives. Here the bank is of earth of the ordinary pattern, but with no puddle-core. The drainage-area is 3 square miles; the content is 18,500,000 gallons. The supply is by means of a siphon over the bank, and the cost has been £883.

5. *Keiskamma Canal*.—The Government constructed a small canal on the Keiskamma river, Kaffraria. This was done to redeem a promise made to a native tribe by previous governments. Unfortunately the tribe and its chief are so lazy that they will not maintain the canal, and it has fallen into disrepair. It is 8 miles long, and cost £4,000. The natives for whose benefit it was being made would not work on it at the then current rate of wages—2s. per day without rations—and other labourers had to be got from a distance.

6. *Campbell Springs*.—There is a remarkable line of cliffs in the north of the Colony formed by the escarpment of a limestone

formation, the strata of which dip some  $15^{\circ}$  or  $20^{\circ}$  away from the escarpment. In one of the ravines, scooped out by surface-drainage from this ridge, are the village sites of Upper and Lower Campbell. In this valley are thirteen different springs, which, together, give nearly 1,000,000 gallons daily. A great deal of this water has hitherto been wasted in evaporation; but in 1885 the Cape parliament voted £500 for the improvement of the channels leading from the springs to the irrigable land. This sum has been spent in cleaning the channels and lining them with masonry. The laws with regard to the illicit diamond traffic of Kimberley afforded a supply of convicts, some of whom were employed on this work, although small and straggling works are not suited to convict labour.

7. *Borings*.—On the Author's arrival in Cape Colony, he found that Crown lands were from time to time put up for lease or sale without any previous examination of their water-capabilities, and he urged that a preliminary inspection or survey should, whenever possible, be authorized, and, if necessary, borings be sunk to ascertain the level of subsoil water. Farmers in all parts said that they were anxious to investigate their properties by boring or otherwise, and, although boring without previous topographical and geological study is somewhat risky work, yet as the advantages of discovering water are so great that boring to a moderate depth seemed justifiable, the Author obtained permission from Government to import two sets of tools to bore to a depth of about 100 feet, and a foreman to take charge of them. As Government was not prepared at once to bore on Crown land, the loan of the tools was offered to private persons, who were merely to pay the wages of a foreman, and to find labourers and transport; but the farmers did not respond very briskly to the offer, although they are often victimised by speculative persons with boring tackle, who promise the most wonderful results. One such man used to state openly that there was always plenty of water under pressure to be found by boring deep enough! Another advertised in the newspaper that bore-holes were preferable to wells because the water rose so much higher in them. Borings were successfully made with the Government tackle along the Port Elizabeth and Graaff Reinet Railway, and, recently, borings have been started on Crown land in the Kayen Bult, already alluded to.

## VIII. IRRIGATION WORKS CARRIED OUT RECENTLY BY PRIVATE PERSONS.

It will scarcely be useful to do more than allude briefly to a few examples of irrigation works, as it is difficult to get any very accurate results from farmers, who seldom commit their experiences to writing.

Mr. Charles Rubidge has a fine pastoral farm north of Graaff Reinet. He had no spring or permanent water at the site where he wished to build a homestead, but by aid of storage-reservoirs he has now over one hundred orange-trees in full bearing, as well as irrigated crops, especially lucerne, which is found most excellent for ostriches.

Mr. S. McCune, in the Queens Town district, has been very successful with irrigation. He borrowed £500 from Government under the Irrigation Act, spent the money chiefly in leading out a small river, and he calculated that with the profits of three fair seasons he would be reimbursed for his whole expenditure. This is where he has led out water by gravitation: his experience with pumping will be alluded to further on. He employs Kafirs, and finds they work well "on the halves"—that is, he finds land and water; they find labour, and get half the proceeds.

The Oudtshoorn division is *par excellence* the irrigation country. In the Report of the Irrigation Commission much information of a somewhat startling kind is given. For example, a place called Nooitgedacht, where thirty-five years ago the proprietor was unable to raise bread for his own consumption, now, as the witness put it, supports two hundred and sixty-four souls, besides coloured people.

A good deal of irrigation, in a spasmodic way, has been done along the western feeders of the Hartebeeste, especially the Visch and the Zak, advantage being taken of occasional floods. Weirs are made in the beds of these rivers: they are generally of rubble, laid much too steeply; but occasionally, where a rock bottom is available, they are of masonry laid in lime mortar. Such works would be better carried out by a co-operative association, for it seldom happens that the site of the intake, the canal, and the irrigable land all fall on one man's property; and although the "right of passage" Act appears to remove obstacles, yet a quarrelsome or envious neighbour can still give much trouble.

In the olden time portions of Crown land were left along the high roads for the use of the public as "outspans," where the travelling oxen might graze. When the railways were finished,

some of these became of little use in consequence of the diversion of traffic to the railway. Government therefore placed German immigrants on these, and where there was a fair supply of water, the Germans raised fine crops of vegetables; but they were too poor and too much thwarted by neighbours to construct anything but the rudest weirs and canals. The success of the German immigrants settled near King William's Town, after the disbandment of the German legion in 1857 deserves passing mention, but there artificial irrigation is not essential.

Harrington is a site on the Vaal River, some 40 miles from Kimberley. Here a canal has been made from the Vaal, irrigating sixty or seventy allotments of 2 acres each. One cultivator sold on the Kimberley market between the 17th of October, 1883, and the 14th of January, 1884, the produce of a 2-acre lot for £780. No doubt this is an exceptional case.

Pumping is extensively used for watering stock in the back country, and in many places it is an absolute necessity; but for irrigation it is not so often employed, though in out-of-the-way places where there is little competition from more favoured districts, it answers well. The Author has recommended it on the lower Orange River at Wegdraai, where there is plenty of drift and other wood for fuel. The farmer is seldom supplied with the best kind of pump for his particular kind of work; he generally has an instrument strongly recommended by the importers traveller, and which is one they happen to have on hand. The great thing the farmer likes is simplicity, as mechanical assistance, when repairs are needed, is difficult to obtain. Hence, pulsometer pumps are frequently seen. Mr. McCune, before alluded to, has supplied to the Author the actual result of two years' irrigation by pumping, one year being good and the other indifferent (Appendix III). Of course the great difficulty is fuel. Mr. McCune is close to the coal-fields (Molteno, Cyfergat, and Indwe); but it is only in the north-east of the Colony that coal, in workable quantities has been found. Wood is everywhere scarce. "Mist," or naturally compressed sheeps-dung, is an excellent fuel. It is got from the "kraals" or yards where the sheep are shut up at night. It is cut out in square slabs, about a foot each way, and 3 or 4 inches thick: it is excellent fuel for brickmaking. Means of using the sun's rays for pumping should be found. Sun engines have been employed with success in Algeria, and the Author obtained a working model from Paris in the hope of inducing some farmer to make experiments on a larger scale. Subsequently a French firm took out a patent for a sun engine in Cape Colony.

Windmills have been used somewhat extensively for pumping, and several kinds, chiefly American, seem to work well. The Author endeavoured, on the occasion of an agricultural show at Willowmore in the Central Karroo, to arrange for a competition between the various kinds favoured by different importers. An interesting report on them was written by the Author's assistant, Mr. T. Stewart, Assoc. M. Inst. C.E., but the trials were not in any way final on account partly of failure of wind, partly because, in consequence of local difficulties, the machines did not all pump from the same depths, and also because the machines were not all fitted with the same kind of pumps.

Persons not acquainted with wool-washing would scarcely believe that it takes 20,000 gallons of water to wash a bale of wool, the bale weighing, before it is washed, 400 lbs. This is the quantity used at Uitenhage, near Port Elizabeth, where the principal wool-washing is done, and where, the water coming from the sandstones of the Zuurberg, is pure and "sweet." Those that get water from the brackish Karroo shales use still more. At Aliwal North the amount is 30,000 gallons; at Mr. Bradfield's, Dordrecht, over 40,000 gallons were used on a recent occasion; while at King William's Town, the quantity is even greater. On the other hand, warm water is apparently much more economical: the Cradock wool-washery, which has a spring of a temperature of 78° Fahrenheit, charged with sulphuretted hydrogen, uses, if the Author's informant is not mistaken, only 4,400 gallons per bale. Water being seldom abundant, any economy would be welcome to the wool-washer.

#### IX. TOWN WATER-SUPPLY.

Most villages and towns in South Africa require more water per head of population than towns in England, because a large quantity of water is required for irrigation. When a village in South Africa is laid out it is divided into wet "erven," and dry "erven," or lots commanded by the water furrow, and lots above the furrow. Only a few towns have pipes with water under pressure.

The water-supply of Port Elizabeth, the principal commercial port in South Africa, was carried out by the Author. It is very complete, and has already been described in a Paper read before this Institution.<sup>1</sup>

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<sup>1</sup> Minutes of Proceedings Inst. C.E. vol. lxxiv. p. 123.

The improved supply of King William's Town, of which Mr. W. B. Tripp, M.Inst. C.E., was Resident Engineer, consists of  $7\frac{1}{2}$  miles of 10-inch main, bringing water in to the highest parts of the town by gravitation, supplying 50 gallons per head per diem, and abolishing the turbine arrangement alluded to above (p. 269). The town, from motives of economy, and in opposition to the Author's advice, connected the new high-level supply with an old low-pressure service, and the Author believes that there is in consequence very considerable waste.

At East London (formerly called Panmure), a storage-reservoir has been made by throwing an earthen bank across a valley. This collects the rainfall of an area of 2 square miles, contains 97,000,000 gallons, has a masonry culvert in the solid rock at the side, and a cast-iron valve-tower at the foot of the inner slope.<sup>1</sup> The tower was fastened to a foundation to prevent its floating. There are 4 miles of main 5 inches in diameter, a covered service-reservoir, and partial distribution. (Appendix IV.)

At Queens Town there is a storage-reservoir with earthen banks of the usual pattern containing 80,000,000 gallons fed by a canal from a stream. There is no culvert, but a specially designed siphon. The chief points of interest about this siphon are: (a) an air-chamber fixed on the charging pipe, with a valve above and below it, in which air can collect, and from which air can be passed without stopping the discharge of the siphon; (b) the inlet valve is worked by a double set of rods acting in tension, one of which pulls to open it, the other pulls to shut it; (c) there is a tramway along which the pipes and valves of the inside leg of the siphon can be drawn up for examination. The relative dimensions of this and of other reservoirs is given in Appendix IV. This reservoir has several times been full to overflowing. Pipes are laid from it to and through the town. Had it not been for this reservoir all the trees in Queens Town would have perished in a recent drought, and during 1886 it was for some months the only source of supply of the town.

At Somerset East a pipe main has been laid from a river giving 1,000,000 gallons daily for irrigation and town supply.

At Graaff Reinet a concrete culvert bringing water from the Sunday's River has been substituted for a dirty and leaky open canal. The concrete was made of Portland cement  $1\frac{1}{4}$  cask to the cubic yard of concrete.

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<sup>1</sup> The Civil Commissioner reported very satisfactorily of this reservoir in December 1886: "Plenty of water after the late rains."

At Riversdale pipes have been laid from a river, and at Ceres an open aqueduct has been constructed.

At Cradock works are in progress under the direction of Mr. T. Stewart. They consist of 10 miles of main bringing 65,000 gallons per diem into Cradock from a spring, besides service-reservoir and distribution.

Besides the above, which were designed by and, excepting Cradock, carried out by the Author, works were carried out at Cape Town, Mossel Bay, Paarl, Grahams Town, George, and Kimberley, independently of the Author.

At Cape Town a large earthwork reservoir was made; the Town Council insisted on the engineer taking sole charge of this as well as of his regular work, and even then refused to follow his advice. The reservoir gave way and was reconstructed and lined with concrete by Mr. C. J. Wood, M.Inst. C.E., who went out from England on purpose.<sup>1</sup>

The Kimberley works are remarkable; they have already been noticed in the discussion on the Author's Paper on the Waterworks of Port Elizabeth.<sup>2</sup> Water is pumped from the Vaal a distance of 17 miles in 14-inch pipes, the total lift being some 500 feet. The chief novelty consists in the use of wrought-iron  $\frac{1}{4}$  inch thick for the pipes for the purpose of lessening the enormous cost of transport.

With regard to the price, the authorities of Port Elizabeth used to charge 17s. 6d. per 1,000 gallons for water from Shark's River, but since the Van Staaden's works have been finished they charge 5s.; Cape Town charges the shipping 4s.; and the Kimberley Company sells water for 12s. 6d. per 1,000 gallons.

## X. SPECIAL DRAWBACKS IN THE COLONY.

1. *No Perpetual Snow*.—Among the drawbacks to irrigation in the Cape Colony may be mentioned that none of the mountains are covered with perpetual snow. Therefore there is no constant supply to the rivers like there is to the Ganges and Jumna in India and to the Po in Italy. The snow, when it does fall and lie, is of great help, for it not only feeds the springs, but what melts and runs off the ground does so so slowly that it carries few earthly particles with it, and appears bright and transparent in the river-beds, and suitable for storage in reservoirs against the spring season.

<sup>1</sup> Minutes of Proceedings Inst. C.E. vol. lxxxix. p. 285.

<sup>2</sup> *Ibid.*, vol. lxxiv. p. 128.

2. *No Lakes*.—There are also no lakes. The nearest approach to lakes is the extraordinary “pan-veldt,” a belt of country which stretches from Bloemfontein nearly to Namaqua Land. To an observer in a balloon this strip would appear pitted with circular depressions, something like the surface of the moon seen through a telescope. These pans contain more or less water after rains; most of them are then quite fresh, and the “trekboers,” or farmers wandering away from their homes if they have any, are found encamped on their shores. After a while the water generally becomes too brackish for men to drink it, and, although the cattle hold on longer than human beings, unless rain falls the boer loads up his chattels on his wagons and travels away. This “pan-veldt” is a puzzle to geologists. Mr. E. J. Dunn attributes it to ice action, and a French mining engineer, Mr. A. Moulle, has recently<sup>1</sup> propounded the theory that the pans are volcanic chimneys, or throats in which the volcanic breccia has not come to the surface, but instead the upper part has been filled in by sand, silt and the other products of ordinary surface denudation. Thus the regular diamond mine, according to Mr. Moulle, is a volcanic throat in which the igneous rock has come to the surface and perhaps flowed over—the pan is a throat in which the igneous rock has stopped short of the surface. These pans are seldom so situated as to be of much use for irrigation.

3. *No Deltas*.—There are no deltas, properly so called; the coast is too much beaten by surf, and swept by currents for their formation. The nearest approach to deltas is made by the large alluvial deposits in the river valleys in those parts of their course where the otherwise steep gradient is temporarily flattened. These will be noticed presently.

4. *Scarcity of Timber*.—Another drawback is the great scarcity of timber. What timber there is is usually hard to work, and in most parts of the country it is cheaper to use imported timber in spite of heavy duties. Hence there is no chance to make cribwork weirs like those on the New England rivers, or timber “flumes” like those in California. Some of the timber is excellent, the sneezewood (*Pteroxylon Utile*) is one of the few timbers that withstands the “teredo,” but, owing to former neglect of the forests, it cannot now be got of regular shape or large scantling. It is, however, excellent for the piers, or props, to small aqueducts. Yellowwood (*Podocarpus Elongatus*) is suitable for “launders,” or shoots, but it must be cut at the right time, namely when the fruit

<sup>1</sup> Annales des Mines, 8<sup>e</sup> Série. Mémoires. Tome VII. 1885. p. 193.

is quite ripe. The Author would, however, as a rule, prefer wrought-iron for such works if intended to be of a permanent character. Olivewood is largely used up country for posts and other purposes.

5. *No Hydraulic Lime.*—No one seems as yet to have manufactured hydraulic lime in any quantity, or successfully. Here and there weirs and walls may be found built with mortar made of the lime of the country, in which the mortar has remained hard under water, but the few experiments made by the Author with local lime were not satisfactory, and until some manufactory is started, with proper scientific apparatus for chemical analysis, as well as arrangements for careful measurement and burning, it would not be safe to trust it. The cost of cement up country renders some works quite impracticable, the cost of a barrel of cement at Van Wyk's Vley has already been noticed. The Author has designed a large masonry dam for a very promising site, Booyesen's poort, near Graaff Reinet, the chances of financial success of which would be largely increased if trustworthy colonial lime with hydraulic properties could be obtained.

6. *Little Crown land.*—There is very little Crown land. Many parts of the country are eminently suited for irrigation, but the land is all in private hands, the farmers will not combine, and without parliamentary powers it is almost impossible to get land for a large work on reasonable terms.

7. *Cost of Transport.*—Transport has always been very costly; until the recent extension of railways all was done by ox-wagon. each wagon carrying 8,000 lbs. £10 a ton was not an unusual price for materials taken from one of the seaports to the northern border. There is much more climbing up and down mountain chains and pushing through gorges in South Africa than in South America, or in Australia. Even the North and Central Karroos that appear so flat have stony hills and valleys. Now that three trunk railways have been finished from the three principal ports to the frontier, as well as several branch lines constructed, ox-wagon transport will chiefly be required for feeding the railways. An indirect effect of so much ox-wagon transport was that the young farmers preferred the free and independent life of a "transport rider," to the less exciting work of a farm. Hence farming, and especially agriculture, was much neglected. Now that wagon transport is less required more land is being cultivated.

8. *Cost of Travelling.*—Travelling is also expensive; a two-wheeled Cape cart and pair of horses cannot be hired for less than 30s. per diem, including feed of horses and driver, and occasionally the

traveller has to pay 50s. After rainy weather, or if the roads are more than usually heavy, four horses are required, and the hire varies from 50s. to 70s. per diem.

9. *Quality of the Water.*—The up-country water is almost always somewhat brackish. In the sandstones and quartzites of the two coast ranges the water is mostly pure, and where there is pure water there is generally sour or coarse grass; where there is brackish water the grass, if there is any, is sweet and tender. The pure-water country is good for corn and wine, the brackish-water country for sheep<sup>1</sup> and ostriches. The analysis of Van Wyk's Vley water in January 1886, soon after it had received a considerable quantity of rain-water, gave 26 grains dissolved matter to the gallon. In 1884, after standing five months, the amount was 45 grains (Appendix II.) The water from Sunday's River supplying Graaff Reinet has 52 grains, the Aliwal North spring 93 grains, two samples from the river supplying Oudtshoorn village 44 and 84 grains, the old Port Elizabeth supply from Shark's River had 43 grains, while the present Van Staaen's water has only 7 grains. In order to make a comparison, it may be noted that the water supplied to London by the Companies drawing water from the Thames is said to contain 18 grains, while sea-water has 2,688 grains to the gallon.

Endeavours have been made by the railway department to get rid, by the Porter-Clarke process, of the carbonate of lime which, excepting common salt, is generally the principal component. Works have been in operation upwards of two years at Grootfontein in the Central Karroo, and the Author was informed by the locomotive superintendent that the cost was about 6d. per 1,000 gallons in addition to the cost of pumping; but it would be cheaper if done on a larger scale, and indeed he expected after a time to do it cheaper. The chief difficulty is to get lime, for the common white "kalk" of the Karroo is not suitable. Hard blue limestone has been obtained from Piquetberg on the coast belt.

Brackish water is generally very clear, perhaps on account of the alum salts which throw down the suspended mud, also because wild creatures do not trouble it.

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<sup>1</sup> Although the country where the water is brackish is good sheep country, yet the brackish water obtained from rivers and pools is not so good for sheep as the purer water from artificial reservoirs, brackish water making their bellies swell and their legs thin.

## XI. ADVANTAGES IN THE COLONY.

The advantageous places for waterworks are: (1) *alluvial valleys*, where the river-water is used immediately for irrigation; (2) *overfalls or rapids*, where power is available; (3) *reservoir sites*, where water can be stored before or after it has reached a river.

1. *Alluvial Valleys*.—Perhaps the most favourable sites for irrigation on a large scale are the many alluvial valleys, where the river now runs in a channel cut in materials which it had itself deposited ages ago. Such irrigation is at present carried out on a small scale in many places by means of a low weir and a canal, and in some cases aided by storage-reservoirs. In the west the rivers only run occasionally, and such irrigation corresponds in a small way to the flood-irrigation of the Indus. In the east the streams are more permanent.

One of the most remarkable valleys is the lower portion of the Clanwilliam Olifants. This river has two sets of feeders, the one permanent and the other temporary. The permanent feeders come from the Cedarbergen and other mountains of the coast and second ranges, which are reached by the winter rains. The intermittent feeders come from the western portion of the Central and Northern Karroo. In former times this river used to overflow its banks frequently, if not with some approach to regularity; but the farmers cut down the trees on the banks, and the river widened its own channel and ceased to overflow. The results of irrigation were very remarkable, and will be noticed further on. The Author has proposed, by throwing weirs across the lower part of the river, to reproduce the old floods. It is proposed not merely to irrigate land below the weir, but also, and more especially, to flood the land above by raising the water-level and throwing back the water over the banks. For this purpose it was intended to make the upper portion of the weir movable, so that the water could be let off when done with. More than 13 square miles are irrigable in this manner, besides about 7 square miles in detached positions. The financial success of the scheme would be considerably increased if the mouth of the river could, as the Author believes, be made accessible to the small craft that at present trade from Cape Town to adjacent anchorages; the proposal being to leave the main mouth and its bar entirely alone, but to improve a small channel between rocks, through which boats used at one time frequently to pass.

In the valleys of the Berg and the Breede Rivers much more might be done, though the lower parts of their course are in the

coast-belt, where irrigation is not absolutely necessary. Some of their tributary valleys, such as that of the Hex River, are energetically worked, but without much scientific skill, and therefore with much waste.

The Oudtshoorn Olifants differs from its Clanwilliam namesake in having no strong permanent feeders; in fact, it is an intermittent river like those further north. But there are magnificent alluvial flats on its banks, which are extensively, though somewhat rudely, irrigated by floods or from springs in the river-bed.

The Zak and the Visch Rivers have been noticed above. This part of the country has already attracted the attention of English capitalists, and attempts have been made to form companies to develop it. In the purchase of land, the selection of tenants, the designing of works, the dealing with neighbours, thorough local knowledge and experience of Karroo farming and Karroo difficulties are essential. It is estimated that 50 square miles can be watered in boer-fashion from the intermittent floods, but a still larger area could be brought under irrigation by judicious works.

The lower Sunday's River, between the Zuurberg range and the sea, affords some fine alluvial flats. A local company was got up to work some farms immediately below the range, and it has an excellent opportunity for leading out the Sunday's River, which, owing to feeders in the Zuurberg, is more constant here than where it crosses the Central Karroo, but so far it has done very little beyond repairing a badly laid out canal more than half a century old. Further down the same river, and close to the sea, are fine alluvial flats, the owner of one side of which was anxious to make a weir to keep out the tide, thus retaining a lake some 7 miles long, the water of which could be pumped up on to the land. The range of the tide is small, and the weir would not be very costly. The proprietors of the opposite bank would not, however, join in the enterprise.

There is a remarkable site for a great work on the Great Fish River, near the Cookhuis station of the railway between Port Elizabeth and Cradock. Here the Fish River makes a bend of about 20 miles, and returns below the bend to within 2 miles of where it was above the bend. During this circuit of 20 miles it falls 200 feet. A tunnel  $\frac{3}{4}$  mile long would bring the water through the neck at an elevation of nearly 200 feet above the river below. A further canal of some 7 miles in length would bring the water to some fine flats 33 square miles in extent, and intersected by the railway. The whole of the land is private property, and in consequence parliamentary powers are necessary

before work can be done. It has been objected to this scheme that the Fish River sometimes dries up; but the Zak and the Oudtshoorn Olifants only occasionally run, and yet on them profits from irrigation have been considerable. Another objection is that the Fish River carries a quantity of silt. This would no doubt be an objection if the object were to fill reservoirs, but as the water would go almost immediately on to the land the silt would act as manure. Mr. E. Young, M. Inst. C.E., who made the preliminary surveys for this work, experimented on the amount of silt held in suspension, and found that it varied from  $\frac{1}{11}$  of the volume of water in floods to  $\frac{1}{2,000}$  in the ordinary state. The silt was extremely fine, and took a long time to settle.

The Hart River in Griqualand West is a tributary of the Vaal, coming in from the north or Betchuana Land side. It runs through some alluvial plains almost parallel with the Vaal before joining it. The Vaal valley, on the other hand, is narrow, and has a steeper gradient than the Hart; and the Vaal is much more constant. It has been ascertained by survey that a canal could be made from the Vaal to the Hart valley, by placing the canal intake on Colonial territory just below the Transvaal boundary. A tunnel 5 miles in length will be required to get through the dividing ridge, and this seems a considerable length; but as the depth of the canal below the surface nowhere exceeds 50 feet, frequent shafts can be used. No borings have as yet been taken to ascertain the quality of the rock. Should the rock at any one place prove too hard several other lines are available. On the Hart side of the tunnel there will be about 20 miles of distributing canal. The Cape Ministry in office in 1882 proposed to Parliament a vote for detailed surveys, but Parliament referred the matter among others to a Commission, which however was dissolved without having considered this proposal. The Colonial Parliament during the session of 1886 granted to any company that would undertake this work an extent of some 66 square miles of Crown land. Of this area 30 square miles are suitable for irrigation. There is besides a large area of land belonging to private owners to whom the water would be very acceptable. An area of 200 square miles could be irrigated from the canal if there were water enough. Kimberley is about 30 miles off, and affords an excellent market for the produce of the Hart valley.

There are few alluvial flats along the course of the Orange River, its valley being generally narrow. Some twelve years ago, enthusiastic but inexperienced persons urged the Cape Govern-

ment to undertake large irrigation works on the Orange River, and it was one of the Author's not too pleasant tasks in South Africa to show the impracticability of such plans, and the insufficiency of the estimates. The Author has made himself acquainted with a great portion of the river valley, and he does not know any place where irrigation works on a large scale by means of gravitation would be financially advisable. The banks are seldom less than 30 feet high, and the fall in the river-bed is not often more than 3 feet per mile, hence a very long canal would generally be required to get out the water. Pumping-works may succeed at suitable sites. Water-wheels have been tried in places, but turbines are preferable, as they can be so much more easily protected against damage from floods, the extreme rise of flood being in many parts 50 feet.

2. *Waterfalls and Rapids as Power.*—Considering the steep gradient which most South African rivers possess, it is remarkable that so little has been done to utilize the fall as power, either to pump up water for irrigation, to grind corn or to wash wool. The great falls of the Orange at Aughrabies, in longitude  $21^{\circ}$  E., are perhaps too far off, in too barren a country, and too uncertain in their discharge for much to be done with them. But there are many lesser falls and rapids, of which the Douglas, on the Vaal River, just above its junction with the Orange, has been surveyed by the Author. Douglas is a new village site, and close to it there are rapids on the Vaal, giving an available fall of 17 feet in less than  $\frac{1}{2}$  mile, 12 feet being in  $\frac{1}{4}$  mile. The Author has estimated that a head-race and tail-race could be excavated, a turbine, pumps, and rising main fixed, and irrigation-canal executed, for £10,000. This would irrigate the village lots, and a considerable area of land beside.

The fall of the Breede River below Ceres is worthy of notice. Some little use is made of it by a wool-washery, the Waverley mills.

3. *Storage Reservoir Sites.*—In consequence of the large quantity of silt carried down by all South African rivers in flood, weirs made in a river-bed silt up level with their crest almost immediately; and hence storage-reservoirs must be placed either (a) very early on the course of the river, or (b) away from the main channel. The construction of a by-wash, to take the run of the river when it is very dirty or the reservoir is full, would generally be very costly, and in reality would come under the latter head (b), for the by-wash would practically become a new channel. Van Wyk's Vley is an excellent example of (a), the Queens Town

municipal reservoir of (b). Old lakes, whose overflow channels have seen their way deep enough to drain the lake, are generally good sites for reservoirs.

It is difficult at the present somewhat experimental stage of waterworks in South Africa to give any numerical relation between the catchment area of a reservoir and the capacity that can with reasonable hopes be given to it. Mr. Garwood Alston, Government surveyor, and bailiff at Van Wyk's Vley, says that, in the back country where the average rainfall is less than 6 inches, in order to irrigate an acre it is necessary to have a catchment area of 100 acres. This, he says, is a rule for small farm works, but in large works less than 100 acres would suffice, the relative evaporation from a large mass of water being less than from a small shallow pond. This rule is somewhat remarkable; for if a stratum 25 inches deep be taken as sufficient watering per annum for ordinary crops, and since in order to get this stratum of 25 inches to the land it may be necessary to store in the reservoir a quantity equal to a layer 50 inches deep over the irrigable land, then this law means that only  $\frac{1}{2}$  inch per annum can be expected off the catchment area.

The Author has proposed a plan by which reservoirs can be made on the main line of a river even though it may carry a considerable quantity of silt; namely by establishing a movable weir, like those in France, but with a different object. In France the main object of making the weir movable is to give a greater waterway in flood-time. In South Africa the object would be to give the flood free course during the early part of its discharge, and, when it was beginning to subside, and when, as is usual, the water becomes clearer, to draw up the shutters of the weir and retain a pond of water for any purpose that may be required. There are often long level reaches, at the bottom end of which such a weir might be suitably placed. Besides, every time the weir was lowered the rush of water would help to scour away the silt deposited since the last flood. The Author prepared designs for such a weir for a proprietor of a wool-washery, but it fell through, partly because the proprietor owned only one bank of the river, and had no security that the owner of the land on the opposite shore might not fix a pump and take away the water without payment.

4. *Fertility of the Soil.*—The great advantage of the Cape Colony is the fertility of the Karroo soil, which, when sufficiently irrigated, produces as abundantly as any of equal extent in any part of the world. For example, evidence was given before a Committee of the Cape Parliament that, after an inundation of

the Clanwilliam Olifants, a farmer sowed 7 bushels of wheat and reaped 900 bushels, and that next year the river overflowed again, and, though no fresh seed was sown, another 450 bushels was got from the same land, or nearly 200 for 1 in all. On the Zak and the Visch Rivers fifty- to seventy-fold is quite common; the ears of corn often measure from 6 to 9 inches in length, and one hundred stalks from one seed are occasionally obtained. From an acre of Karroo soil, sufficiently prepared and well watered, the farmer may expect to get 30 bushels of wheat, or 40 to 50 bushels of Indian corn, locally called "mealies."

5. *Labour*.—Although the farmers complain of the scarcity of labourers, yet contractors are always able to obtain them, and both skilled and unskilled labour is much cheaper than either in Australia or in the United States. Unskilled labour can occasionally be got as low as 2s. per day without rations; the Kafirs, and more especially the Zulus, are strong hard-working men, the Hottentots are inferior, the Malays, descendants of slaves brought by the old Dutch East-India Company from the East Indies, are excellent horsekeepers. The natives are fairly industrious, and, unlike those in America or Australia, take kindly to agriculture. The Author was told of a case in which a native had employed a white man to make an irrigation canal for him.

6. *Price of Land*.—The price of land depends largely, and beyond the coast range principally, on the water facilities. The value of an acre may vary from 6*d.* up to £100 or even more in special positions. Fabulous prices, such as £270, or even £680 have been given for an acre of tobacco land. It may be said that, as a rule, land with a full supply of water is worth £25 an acre. This is in the country, in a village it would of course be more. Such land can be let for £1 an acre. According to evidence given before the Irrigation Commission £20 to £30 per acre was cleared each year from some of the best land in Oudtshoorn. However, any well-informed person, waiting his opportunity, will have no difficulty in getting land fairly cheap.

## XII. CONCLUSION.

The Author's object in writing this Paper has been to put on record some of the results of eleven years' careful study of all parts of the Colony. Further details may be found in the Report of the Irrigation Commission, in the Author's annual reports to the Cape Government, and in the reports of the Meteorological Com-

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mission, copies of which he has from time to time presented to the Institution library.

The Colony has certainly the disadvantage of a very dry interior, but this interior has incomparable soil; and much more might be done by judiciously husbanding the scanty rainfall. South Africa has at present a monopoly of diamonds, of ostrich farming, and more or less of mohair (the wool of the Angora goat); more grapes can be grown from an acre of land, and more brandy made from a given weight of grapes than anywhere else; and if the farmers would only combine to stamp out the scab insect (*Brandziekte*) the Colony could hold its own in wool. There may be some gold in the Colony, there certainly is much in the Transvaal.

During the year 1886-7 there was a great increase of land under cultivation, so much so that farmers have complained that they could not sell their produce at remunerative prices. It may be hoped, therefore, that South Africa, which imported from 1874 to 1883 an average of 24,000 tons of wheat and flour per annum from South Australia, will soon grow enough cereals, at any rate for its own consumption, if not for export.

The Paper is illustrated by several maps and drawings, from which Plate 4 and the Figs. in the text have been reduced.

## APPENDIXES.

## APPENDIX I.

AVERAGE MONTHLY EVAPORATION and RAINFALL at the INTAKE of the PORT  
ELIZABETH WATERWORKS DURING the YEARS 1882 to 1886.

	Evaporation. Inches.	Rainfall. Inches.
January . . . . .	4·57	2·40
February . . . . .	5·05	1·65
March . . . . .	3·40	2·23
April . . . . .	1·79	2·86
May . . . . .	1·20	2·95
June . . . . .	1·81	1·33
July . . . . .	1·77	2·01
August . . . . .	1·94	2·38
September . . . . .	2·68	3·58
October . . . . .	4·11	2·37
November . . . . .	5·09	1·88
December . . . . .	5·65	1·85
	<u>39·06</u>	<u>27·49</u>

## APPENDIX II.

AVERAGE MONTHLY RAINFALL at VAN WYK'S VLEY DURING the YEARS 1882  
to 1886.

	Inches.
January . . . . .	0·88
February . . . . .	0·42
March . . . . .	0·82
April . . . . .	0·91
May . . . . .	0·39
June . . . . .	0·20
July . . . . .	0·00
August . . . . .	0·13
September . . . . .	0·72
October . . . . .	0·08
November . . . . .	0·96
December . . . . .	0·17
	<u>5·68</u>

### ANALYSIS of WATER in VAN WYK'S VLEY RESERVOIR.

	Feb. 1886. Grains per Gall.	Sept. 1884. Grains per Gall.
Silica . . . . .	1·12	0·05
Oxide of iron and alumina . . . .	0·97	1·33
Carbonate of lime . . . . .	6·60	10·50
Sulphate „ . . . . .	0·05	0·16
„ „ „ „ „ „ „ „ „ „ „ „ „ „	0·86	—
Carbonate „ . . . . .	1·30	2·03
Sulphate of soda . . . . .	4·42	8·52
Carbonate „ . . . . .	1·24	1·42
Common salt . . . . .	8·40	20·05
Saltpetre . . . . .	0·30	0·83
Organic substance . . . . .	1·05	0·41
Phosphoric oxide . . . . .	trace	trace
Total of soluble ingredients . .	26·31	45·30

### APPENDIX III.

## IRRIGATION by MEANS of STEAM PUMPING. ACTUAL RESULTS.

CASE 1.—An area of 26 acres put under irrigation by means of a Gwynne's centrifugal pump and an 8-HP. portable engine, vertical lift 27 feet, near Queens Town, South Africa, 1883.

*Daily expense during actual irrigation.*

	£	s.	d.
Firewood per day . . . . .	1	10	0
Wear and tear . . . . .	0	5	0
Working expenses . . . . .	0	12	0
Labourers leading water, two men at 2s..	0	4	0
	2	11	0

*Expenditure.*

	£	s.	d.
Eighteen days at £2 11s. . . . .	45	18	0
Rent of land—26 acres at 10s. . . . .	13	0	0
Ploughing, harrowing, reaping, threshing, cost of two } bags of seed wheat, eight bags of seed oats . . . }	31	10	0
<b>Total expenditure . . . . .</b>	<b>90</b>	<b>8</b>	<b>0</b>

*Receipts.*

	£	s.	d.
Eighty bags of wheat at 25s. . . . .	100	0	0
Oat hay . . . . .	105	11	0
	<hr/>		
	205	11	0

The balance, £115 3s., leaves ample margin for manure and for interest on the price of the engine and pump, besides an abundant profit.

CASE 2.—An area of 20 acres put under irrigation by means of a Gwynne's centrifugal pump and portable engine, vertical lift 27 feet, near Queens Town, South Africa, 1884.

*Daily expense during actual irrigation.*

	£	s.	d.
1,600 lbs. Colonial coal at 1s. 9d. per } 100 lbs. <sup>1</sup> . . . . . }	1	8	0
Wear and tear . . . . .	0	7	6
Man, oil, &c. . . . .	0	6	3
Two labourers leading water at 2s. . .	0	4	0
	<hr/>	<hr/>	<hr/>
	2	5	9

*Expenditure.*

	£	s.	d.
Four irrigations of seven days each—twenty-eight days } at £2 5s. 9d. . . . . }	64	1	0
loughing, harrowing, reaping, threshing, purchase of } four bags of seed . . . . . }	38	12	6
	<hr/>	<hr/>	<hr/>
	102	13	6

*Receipts.*

	£	s.	d.
Sale of ninety-two bags of wheat at 26s. 6d. . . . .	121	18	0
	<hr/>	<hr/>	<hr/>

The balance is thus very small.

It will be noticed that in 1883, 40 for 1 was reaped, while in 1884 only 23 for 1 was reaped, although more water was given. The year 1884 was exceptionally dry, and probably the farmer erred in not giving still more water. It is not stated whether any part of this 20 acres coincided with part of the 26 acres irrigated the previous year.

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<sup>1</sup> Colonial coal has since become cheaper, and is now 1s. 3d. per 100 lbs. at this farm.

## APPENDIX IV.

## STORAGE RESERVOIRS RECENTLY CONSTRUCTED in the CAPE COLONY.

Name.	Material of bank.	Catchment area. Square Miles.	Content. Million Gallons.	Cost. £.	Remarks.
<i>(i.) Under supervision of the Author.</i>					
Van Wyk's Vley.	Earthwork	460	35,000	18,000	{ Largest amount as yet in reservoir at any one time 4,000 million gallons.
Brand Vley . .	" { Fed from river	6	1,600	670	
Stolshoek . . .	Masonry	6	65	8,500	{ Including siphon, £65.
Wolvehoek . .	Earthwork	3	18	883	
East London . .	"	2	97	6,514	{ Not including iron valve tower.
Queens Town. .	" { Fed from river	80	16,045		{ Siphon and fixing, £468 extra.
<i>(ii.) Not under supervision of the Author.</i>					
Beaufort West .	Earthwork	60	572	14,000	{ Revenue £700 to £800.
Cape Town . . .	" { Fed from stream	50	100,000	circa.	
Distin's . . .	" { (?)	200	4,000		
Bradfield's (Dor-drecht). . .	"	70	300	600	{ Water used first for a wool-washery, then for irrigation.

