Arterial drainage works, water supply, and sewage drainage works, executed at Windsor, between the years 1867 and 1873 / by William Menzies.

ARTERIAL DRAINAGE WORKS, WATER SUPPLY, AND SEWAGE DRAINAGE WORKS,

EXECUTED AT WINDSOR, BETWEEN THE YEARS 1867 AND 1873.

BY WILLIAM MENZIES, MEMBER.

Read at the Ordinary General Meeting of the INSTITUTION OF SURVEYORS, *April 21st*, 1873.

THE works which I propose to describe in the following Paper are all situated on that portion of the river Thames which lies between the Windsor and Eton Bridge and the Staines Bridge. The whole distance is 7¼ miles. The fall, per mile, of the natural bed of the river, is 2 ft. The average width of the river is about 200 ft.; the depth varies from about 4 ft. 6 in., immediately below Old Windsor and Bell Weir Locks, to 10 and 12 ft. at Ankerwycke; and the average flow per day at its lowest summer level is about 200,000,000 gallons.

Before 1867 there was a difference of 10 ft. between its lowest summer level and its highest flood level.

The Crown lands extend along the right bank of the river from Windsor Bridge to Old Windsor Lock.

Geologically, the whole of the district from Windsor to Staines Bridge is usually spoken of as the London clay; but, over it, there lie everywhere surface beds of Thames drift, gravel, silt, and alluvial deposit. Between Windsor

Bridge and Old Windsor Lock the bed of drift gravel under the alluvial deposit varies in depth from 10 to 30 ft., and extends half a mile inland from the river. It is full of water at the level of the river, and this underground bed of water travels, in a line parallel to the river, at the rate of about half a mile a day.

Up to the year 1866, the regulation of this portion of the river was vested in the Commissioners of the Upper Districts of the Thames; but, in that year, it was transferred to the Conservators of the Thames, who had, previously, the charge of the river from its mouth up to the town of Staines.

I propose to divide my description of the works which have been carried out since 1867, into the three following heads :—

First. The Arterial treatment of the River by Locks, Weirs, and Tumbling Bays.

Second. The Water Works for the Supply of Windsor Great Park.

Third. The Sewage Drainage Works of Windsor Castle, and other Crown Buildings.

I.

The Arterial Drainage Works.

In the portion of the river under description, there are three locks and weirs placed across the stream, viz. :

The Bell Lock and Weir, near Egham; Old Windsor Lock and Weir; and Romney Lock and Weir, opposite Eton.

On taking possession of these structures in 1866, the Conservators found them in a most dilapidated condition,

and in constant danger of being swept away by a flood. The bed of the river itself was filled with mounds of gravel, greatly obstructing its flow. The summer level could not be maintained at its proper height, while the floods in winter overflowed the banks, and did serious damage. All the regulating works have now been reconstructed in the most permanent manner, and on the best known principles.

It is unnecessary to describe them all in detail; and I propose to take Old Windsor Lock and Weir as a specimen. These two works regulate the river opposite the Home Park. The general surface of the Home Park itself, varied from 6 to 7 ft. above the surface of the ordinary summer level of the river, as it was in 1866; and the underground bed of water, previously referred to, is always at about the same level as the river.

It appeared desirable that this bed of underground water should be raised in summer rather than depressed, both for the benefit of the pasturage and for the maintenance, in vigour and health, of the splendid trees which cover the Home Park. It had always been observed that in dry summers when the level of the river sank low the pasturage burned up, and also that the old trees, which are principally elms and limes, changed colour and lost their leaves early, under similar circumstances. It was at first proposed, in order to remedy the evils arising from floods in that locality, that Old Windsor Lock and Weir should be wholly removed and the river allowed to sink fully 3 ft. in level. Besides many other serious disadvantages that would have arisen from adopting such a course, I have no doubt but that most of the old trees, and especially the elms, which are exceedingly susceptible of any change in this respect, would have died, if the water, to which they had been so long accustomed, and which, besides, is moving and not stagnant, had been withdrawn

from the roots by lowering the level of the subsoil water. It formed also a material element in considering the beauty of the Home Park, that there should be a full river in summer, and lowering its level would have made it invisible from many portions of the Royal Domain, in which it forms so important a feature.

Five feet from the surface may be taken as the average depth at which it was decided to maintain this underground water on both sides of the river, although, of course, absolute uniformity is impossible.

In considering this part of the question, the laborious investigations, so very ably conducted by Dr. BUCHANAN, under Dr. SIMON, of the Medical Department of the Privy Council, were not lost sight of. It appeared from Dr. BUCHANAN'S Papers that great benefit had resulted to the general public health of special districts from lowering the level of the subsoil water. But it should be noted that where this improvement has arisen, the subsoil water appears to have been within 1 or 2 ft. of the surface. It was not apparent, on the other hand, that there was any risk of danger from dampness where this level was maintained at 5 ft. from the surface or thereabouts. Further, if the permanent level of the river in this reach had been raised higher than was proposed, the tail water of the water-wheels at Romney and Eton would have been shut back upon them, and serious questions of damages would have arisen. The interests of the navigation, also, demanded the maintenance, if possible, of the same level. It was equally essential, however, to relieve the river, by every possible means, of floods in the winter time. These various considerations led to the decision to rebuild Old Windsor Lock on its old site, and for the passage of flood waters a self-acting tumbling bay, 60 ft. wide, was constructed, immediately adjoining (see General Plan), and at such a level

that, whenever the river rises 1 ft. 3 in. above the fixed summer level, the flood waters shall pass down the river. It was also decided to rebuild Old Windsor Weir, with a large tumbling bay attached; and the plan will show the method pursued in its reconstruction, which is now almost completed.

The water-ways of the old weir which previously existed at this point, gave a total area, when the sluices were raised, of 555 ft. for the river to pass through, while the new water-ways will give 647 ft. for a similar purpose, and the discharge will be of a more efficient character, because the sill of the new weir is 18 in. lower than that of the former weir. It will also be observed, on examining the plan, that the machinery to be employed will ensure the hatches being removed much more promptly than was possible under the old system.

The two islands in the river immediately above the weir were taken into the hands of the Crown; and all the overhanging trees and bushes, and the eel bucks which obstructed the river, have been removed.

The bed of the river, for the whole way opposite to the Home Park, has been dredged to an uniform depth of about 5 ft., and the gravel thus removed has been used in constructing the other works.

These are the arrangements made for passing flood waters off as rapidly as possible, while the maintenance of the summer level, at a point 1 ft. higher than formerly, has been effected by the construction of the sluices and hatches for impounding the water to the height desired, a result which could never have been accomplished with the Old Weir.

In addition to the advantages previously referred to, which it is anticipated will arise from raising this summer level, increased power will be given to the turbine at Old

Windsor Lock, described in a subsequent part of this Paper.

I may here mention that the permanent summer level or "High Water mark," as it is technically called, of any reach of the river is indicated by a mark, fixed at all locks or weirs, at which level, the Conservancy endeavour, by regulating the sluices, to maintain the river for the benefit of the land-owners on the banks, the millers on the side streams, the navigation, and, in fact, all concerned.

The expenses of these works were as follows:—

	£	*s.*	*d.*
Bell Lock, Weir, and Tumbling Bays .	6,008	13	10
Old Windsor Lock and Weir (not yet quite finished)	3,500	0	0
(Of which the Crown paid £1,500.)			
Old Windsor Tumbling Bay . .	591	18	11
(Which the Crown paid in full)			
Romney Lock, Weir, and Tumbling Bays	6,529	7	2
(Of which the Crown paid £2,500)			

The cost of dredging the river is not reckoned separately, as this was included in the other works. The clearing away of the eel bucks and trees cost about £50, and was paid by the Crown. The works were commenced in 1867, and are now almost completed.

Although the whole of the works were not finished in January 1872, the floods, which then prevailed, gave an opportunity of observing how the river acted under its changed condition, and of comparing it with that of February 1869, of which I had a correct record, and which was the last flood before the alterations, at Old Windsor.

In inquiring into the rainfall, which produces a flood, it is, obviously, impossible to reason with minute accuracy.

Much depends upon the time of the year, and the previous state of the country as to saturation, and over a large basin like that of the Thames, the rainfall of two different periods is never identical throughout the district, so that only general conclusions can be drawn.

On this point I gladly availed myself of the assistance of the Rev. J. CLUTTERBUCK, of Long Wittenham, near Abingdon, one of the Thames Conservators, who has bestowed much attention on these subjects for many years. He most kindly gave me the following statement as the result of his registers and observations. He states that the height of floods does not appear to depend so much upon the aggregate rainfall over an extended period, as upon the extent to which the ground has been previously saturated at the moment when a heavy rainfall takes place within a short space of time.

It is obvious that the period over which a heavy fall of the kind takes place must not be too short, or there is a presumption that it is merely local, and does not extend over a whole district, such as the Thames Valley. Probably, from 3 to 6 days may be taken as a pretty accurate period to judge by for the final fall that produces a flood.

Applying these principles to the flood of 1869, Mr. CLUTTERBUCK informed me that from December 22nd, 1868, to January 28th, 1869, there fell, during the 37 days, about $3\frac{1}{2}''$ of rain, which saturated the ground, but did not produce a flood. A considerable quantity of rain continued to fall,—quite sufficient to keep up this state of saturation,—till the 8th of February, 1869, from which day to the 12th there fell 1·650 inches.

The greater portion of this fell on 2 days; but as the rain was continuous, it should, as previously explained, be taken as falling in 5 days, thus giving an average of ·332″ per day.

The flood was at its highest point on the 15th of that month, when, as Mr. CLUTTERBUCK informed me, there were 5 ft. 5 in. of water above High Water mark at Clifton Weir, immediately adjoining his residence.

He stated further, that from the 2nd January, 1872, to the 9th (*i.e.* in 8 days), there fell 2·07 inches of rain, which quite saturated the soil, and between the last-mentioned day and the 23rd of the same month there fell sufficient to maintain this condition. From the 23rd to the 26th, extending over 4 days, there fell 1·490 in., or an average per day of ·372 in., which produced the flood of the 27th of that month. The flood at Clifton Weir on that day was again 5 ft. 4½ in. above High Water mark, or within ½ in. of the same height as in February 1869.

From these statements, it appears that although the land did not receive so much previous rain in 1872, as in 1869, to bring it up to the saturation point, before a flood came, it fell in a shorter time in 1872, and more immediately before the rain which produced the flood, and also that the quantities falling on the final days were nearly the same in both years.

Considering, further, that the flood attained to very nearly the same height at Clifton Weir in 1872 as in 1869, we may presume that the two floods were nearly the same; and if I can show that opposite Windsor Home Park in 1872 there was a great improvement upon the flood of 1869, I hope you will consider the matter as well proved as the case admits of.

During the flood of January 1872, I measured the current in the New Cut leading to the tumbling bay at Old Windsor, which used to be dead water, blocked back upon the Home Park, and I found that in the centre of the stream it was flowing at the rate of 4 miles per hour, and that the tumbling bay at the lock was discharging water

3 ft. 7 in. deep. Mr. LEACH, the engineer to the Thames Conservancy, measured this at the height of the flood, and from the inclination at the bottom and other data, informed me that the water thus discharged, which would otherwise have been pent up, was about 150,000,000 cubic feet in the 24 hours; a result which was equivalent to that which would have been effected by lowering the river 15 in. at Albert Bridge, immediately above the weir.

The map attached shows, by one line, the extent of the flood of 1869, and, by another line, the limits of the flood of January 1872. There was, in reality, a difference of about 1 ft. 6 in. in vertical height between the two floods on the Home Park.

Mr. CHAMBERLAIN, the late Mayor of Windsor, in a letter, which I received from him in the early part of last year, after describing the inconveniences to which he was previously subjected by the floods, says, with reference to the improvements effected in the locks and in the bed of the river, that he was "astonished to find after a long succession of wet weeks how slowly the river rose at Windsor Bridge, and to see that it never on any day covered the 'Cobbler.'" He adds that "since the rain has ceased, it is equally remarkable how soon the river has gone back into its bounds. These things are matter of common remark among my neighbours, and are very gratifying to all who are interested in the Thames."

Dr. GOODFORD, the Provost of Eton, has also written, bearing his "testimony to the great advantage derived from the lately constructed works."

I hope these statements will show that the level of the river can now be maintained higher, by at least 1 foot, than its previous summer level, and that the floods are reduced by 1 ft. 6 in., so that the varying levels of the river, instead of being 10 ft., are now 7 ft. 6 in.; and that

the benefits which have arisen therefrom, in a country so flat as that on the banks of the Thames, are great. Other consequent advantages will appear in the subsequent part of this Paper.

The whole of these works were designed and executed by Mr. Leach, the careful and able engineer to the Thames Conservancy. That Board had no power to tax any riparian owners for such works; but on the plans being submitted to and approved by those acting for the Crown, contributions were voluntarily given, to the amount which I have stated.

I may here add that, having, I trust, proved the benefit that has arisen by a comparison of the details of these two floods, I have thought it unnecessary to investigate, in a similar manner, the flood of December 1872; but may state that, in so far as I have done so, the conclusions arrived at have been of the same character.

One effect that has arisen from the lowering of the flood level of the river may here be mentioned, as I consider it of importance.

Hitherto, the building of all houses on the sides of rivers liable to flood has been regulated by the height to which these rivers rise; and there being no law to interfere with these matters, dwellings, generally occupied by the lower classes, have been built as far within the flood line as it was possible with any decency to go. From this cause we have had occasionally, after the flood waters subside, great outbreaks of epidemic disease, which could clearly be traced to the bad situation of such houses. Inspecting medical officers were then sent amongst them; and we have received from them, and from the house-owners themselves, strong recommendations to sweep away all obstructions in the river which appear to cause these floods; quite forgetting the benefits conferred by these structural works in other

respects; and how very open a question it is, whether the river would not flood to the same extent as it now does, even if the supposed obstructions were removed, and the stream allowed to take its course, and follow its natural tendency to cut deep holes in one place, and pile up heaps of gravel and earth in others.

I observe already that the lowered level of the Thames in the district under description, will be made immediately available by new houses being built within the new water-line; and in a few years hence, when all that has now been done will probably be forgotten, we shall, in all likelihood, have the same complaints renewed, and the old remedy suggested, and so the process will be unending.

It is a matter well worthy of the attention of the newly-appointed Health Officers in each county, to endeavour to prevent such a state of matters arising, or at any rate to fix the responsibility of their actions upon those who raise the difficulty, as any one who has ever had to consider the question practically in all its bearings, well knows the heavy expenses that will arise, and the amount of care, labour, and thought, he must give to the subject before he ventures to recommend the alteration of either the summer or winter level of such a river as the Thames, where it flows through a district covered with houses inhabited by the wealthier classes, and where all interests concerned are of so much value.

II.

Windsor Great Park Water Works.

The soil of the greater portion of Windsor Great Park is strong clay, and the private dwellings of the official staff, the large hunting establishments, and the workshops had

for many years laboured under serious difficulties for want of water.

The number of inhabitants to be supplied was about 250, and of horses 150, and there was no provision made previously in case of fires; a fact of great importance, as the Crown never insures any buildings.

There were also about 300 acres of land in the immediate neighbourhood, belonging to the Crown, which would be available for building if water could be supplied. These difficulties culminated in the dry years of 1869 and 1870, and it was resolved to have a system which would, if possible, embrace the whole. The ponds in the park could not be resorted to with safety, as they were only surface water, and liable to contamination, and an artesian well was too hazardous an experiment to be attempted.

After much consideration, it was decided to obtain the supply wanted, near the side of the Thames, although the distance of the source would be 3 or 4 miles from the centre of the district to be supplied.

It was, at first, proposed to attempt to reach the chalk near the river, for water; but it was found that the chalk was 100 ft. deep, and that the water would not rise higher than 30 ft. from the surface. It appeared preferable therefore to trust to the deep bed of gravel at the side of the river, and a well being sunk near Old Windsor Lock a supply of first-class water, which promises to be unfailing, was obtained. This enters, principally, from the side of the well away from the river; it being found on examination that the subsoil water was all travelling towards the main stream. Thus greater purity is ensured than if it had been filtered from the river direct.

The quantity required for the Crown buildings, including the Indian Civil Engineering College at Cooper's Hill,

Englefield Green, was 18,000 gallons per day. 18,000 gallons were reserved for the future requirements of the building land referred to, and advantage was taken of the opportunity of disposing of a portion of the additional water to houses on the borders of the Park close to the pipes; from which some return was obtained in aid of the expenses. The highest cistern is 274 ft. above the level of the river, and the length of pipes laid down nearly 12 miles. Arrangements are made at all the principal houses for a large supply in case of fire.

To secure motive power for raising the water, the improved state of the river, previously described, rendered it practicable and reliable to use the fall at Old Windsor Lock to turn a water-wheel. This fall was 3 ft. 8 in. in the ordinary state of the river, and the new arrangements of the weirs, both above and below this lock, secured the possibility of keeping the two reaches of the river rising and falling in parallel lines, so that the fall at the lock itself continues about the same. Motive power of this class also gave the great advantage of continuous supply, and obviated the necessity of building any water tower in the Park.

Messrs. Easton & Anderson, therefore, designed a turbine for the purpose, which acts, as compared with an undershot wheel, with but slight diminution of power in all states of the river, and has, during the last winter, kept on working with 8 ft. 6 in. of tail water upon it.

The plan attached shows the general arrangements of the turbine house and culverts leading to and from the wheel. Much difficulty was experienced in getting in the lower portion of the culvert shown in the drawing. Although the ground was sheet piled, and two 14-horse power engines were employed in keeping the cutting of 50 yds. in length free from water, the bottom, which consisted of river silt and

running sand, passed the water through so rapidly that no concrete could be laid, the lime being immediately washed out.

At the suggestion of Mr. Leach, a large quantity of old linseed bags was obtained, and filled with rough gravel and Burham cement, in the proportion of two of the former to one of the latter, and when the concrete was half set, but still, to a certain degree, compressible inside the bags, they were forced down into the sand and water among the piles, till they would go no further, and in 24 hours, being under water all the time, they were set in a solid mass, and the brickwork of the culvert was then founded upon them.

An auxiliary steam engine of 8-horse power was put in the turbine house to raise the water in case of any accident to the water-wheel. The turbine itself is of 12-horse power; the additional strength being wanted for a purpose to be subsequently explained.

The works were commenced in May 1871, and finished by Christmas of the same year, and the whole has worked with great regularity hitherto.

The total cost was £8,529 8*s.* 1*d.* One man is expected with slight occasional assistance to manage the whole of this and the Castle drainage works, at a cost of about £100 a year, and the saving of labour alone, for the pumping and carting of water in Windsor Park, is fully £250 or £300 a year.

This total cost includes a sum of £1,000 paid to the Thames Conservators as a contribution towards the rebuilding of Old Windsor Weir.

The rents already realized, and value of the water in reserve, and the increased value of the building land, will, in time, pay a good interest on the outlay.

III.

Sewage, Drainage, and Utilization Works of Windsor Castle, and other Crown Buildings in the Home Park.

When the Conservators took possession of the upper portion of the river in 1866, notices were immediately served by them under their Act, directing the Crown to remove all foul drainage from the Thames. The foul drainage of the Castle and Royal Mews flowed direct into the river by a special drain. That from Frogmore and many of the buildings, flowed into the Windsor sewer. That from the Shaw Farm and Dairy Farm, was received into a mixed system of tanks and cesspools.

All the rain-water from the roofs and yards, and much subsoil, and other water passed into the same outlets as the foul drainage, so that the difficulties to be overcome were not slight.

Serious consideration was given for 2 or 3 years by all concerned, both as to the best system of drainage to be followed, and the safest and most efficient method of treatment to be adopted at the outlet. At last it was decided, both on sanitary and economical grounds, to follow the recommendation of the Report on the Drainage of the Towns in the Thames Valley, by Colonel Ewart, C.B., R.E., specially appointed by the Home Secretary in 1868 to inquire into the subject. The principles laid down in that paper may be briefly stated as follows. To discharge all rain-water, by the shortest channels, into the nearest outlet leading direct to the river, and to convey all foul drainage by a special system of sealed pipes, carefully ventilated, to land prepared for the purpose and purify it by

irrigation. These principles, it will be remembered, engaged for a long time the attention of the Members of this Institute, and were debated with much earnestness. At length Mr. JOHN CLUTTON, as President, summed up the discussion on the 24th January, 1870, in favour of the conclusions adopted for the works now being described.

I was instructed, early in 1871, to prepare plans and estimates on this system, and was fortunate enough to secure an able and energetic colleague in Captain GUN of the Royal Engineers, who has been associated with me in the whole of the last-mentioned work.

The essential points laid down for our guidance were—

1st. That all impurities should be continuously and promptly removed in all weathers from the Crown buildings, and as shortly as possible incorporated with the natural soil when prepared for their reception.

2nd. That there should be no overflow of any kind into the river at any time, except in the case of a breakdown of all the machinery provided.

3rd. That the whole of the foul drainage should be removed to such a distance that there could be no question as to the safety of the process, or likelihood of substantial complaint being raised by any one residing in the neighbourhood of the irrigated land.

It was at once decided, both for sanitary and administrative reasons, that the whole of the Crown buildings should for the future have an entirely distinct and separate system of drainage from that of the Town of Windsor.

The population of all the buildings under consideration was about 1,000, and the number of horses and cattle to be provided for, about 500.

The water supply was about 150,000 gallons a day, which was more than sufficient, and as the overflow, after every

purpose, including flushing, had been served, poured down the foul drains where it was of no benefit, we recommended that it should be cut off with the view of utilizing it by turning it into the lake at Frogmore, which always sinks in level during dry weather.

The plans and estimates being finally approved, we received instructions to commence in October 1871; but little could be done beyond making general preparations during the winter.

In April 1872, an equalizing reservoir to hold 20,000 gallons was built where shown at Old Windsor.

The bottom of the reservoir is fully 15 ft. below the surface, and as the gravel in which it is built is in communication with the river, in flood time when the tank is empty, which it will be every day, there will be a heavy pressure upon its bottom and sides. It was, therefore, built in compartments, and presents arches in all directions. In this reservoir is an iron strainer, situated immediately at the point where the foul drain enters, which intercepts anything that might interfere with the pumps, and the whole of the remainder is lifted by the pumping machinery provided.

A new foul drain was then laid up towards the Home Park, 1 ft. 6 in. in diameter, with 3 ft. fall to the mile, and on entering the Home Park, branches were taken from this in all directions to the different buildings, and a junction effected with the Castle foul drain near the Royal Kennels. Ventilating shafts were built along the line up to the surface where practicable, and carried up the trees where near the roads.

Between the middle of July and the middle of October a new set of rain-water drains was laid in, all over the Castle and the other buildings, and the water conducted to the river. Where the rain-water pipes had formerly acted

as ventilators they were disconnected, and new special ventilators were put in, reaching over the tops of the battlements far above all windows.

The overflow from all the cisterns was intercepted and conducted, in the meantime, into the clean-water drains, and as the quantity appears to be about 30,000 gallons a day, it will in all probability, be conducted to Frogmore Lake, by which means, it is believed, that long-standing difficulty will be overcome.

The whole of the foul drainage, with its proper and regulated amount of flushing water, is conducted to the reservoir near Old Windsor, and is raised over the bridge (which was rebuilt to receive the pipe) by two engines of 3-horse power each, and two sets of pumps. These engines were constructed by Messrs. Easton & Anderson in such a form that they can be worked either by compressed air or by steam; a boiler being placed in the engine house for the purpose.

To supply this compressed air, the turbine wheel at the water works previously described, acts upon a piston and cylinder, which forces the air into a pipe, 2 in. in diameter and 425 yds. long, leading up to the sewage pumping station, and great economy is thus obtained, as coals will not be required except in special cases.

A self-acting float in the sewage reservoir stops the air engines when the tank is empty, and a safety valve at the turbine house then blows off and, at the same time, stops the whole compressing machinery, while the pumping of the water for the Great Park goes on as usual.

The maximum amount, which we calculated the sewage pumps would ever be called upon to lift, would be 200,000 gallons a day of 24 hours.

This was estimated on the supposition that the whole of the 150,000 gallons, as previously stated, of the water supply

used at the Crown buildings came down the foul drains; that there was a heavy rainfall on the dung and manure pits and yards at the Royal farms, which drain into the system, and that there was a quantity of subsoil water which would pass into the main drain when it was submerged in flood time, notwithstanding all the precautions we could take to exclude it.

Each set of pumps at the sewage reservoir was, therefore, planned to throw 10,000 gallons an hour, whether worked by steam or compressed air; but, in a case of emergency, double the quantity could be lifted by putting steam to work on one set of pumps and air on the other; or the boiler alone, at the same place, is sufficiently powerful to drive both sets of pumps for the greater part of the day, when working at 50 lbs. pressure to the inch.

For the utilization of the sewage, about 18 acres were purchased where shown, and embanked to keep out floods. Here again the lowering of the flood level of the river came to our assistance, and although the water will pass to some extent, in flood time, through below the bank, we have ascertained that quite 5 acres of the inclosed land which would previously have been at such times all but submerged, are now fully 2 ft. above the highest flood level.

About 15 acres of land are laid out for irrigation. The main feeder or carrier is covered over and laid along the line of the river, and the sub-channels are laid off from this. Before the sewage is passed on to the land, it will all have to pass through a tank, where it may be deodorized by some process; the nature of which is not yet definitely settled.

The width of the ridges is 66 ft. from furrow to furrow, and the fall from ridge to furrow is 6 in.

I think, probably, this slope is rather too slight, but it is easily remedied, as is now being done, by ploughing the furrows up towards the centre before the land is sown down.

The fall along the ridge is 1 in. to the chain which is little more than sufficient to overcome friction, and thus the irrigating water disperses itself along the line with but little necessity for stops or other arrangements.

The whole has been levelled as accurately as possible, and I cannot but call attention to the great cost of doing so—fully £80 per acre. The contour and shape presented no very special features; but this expense is a costly process in any manner; more especially when it is attempted to save the surface soil to be placed again uppermost. The expense of levelling, without which I believe sewage irrigation would be a failure, is a very important element in considering the advisability or necessity of adopting that process. The feeders along the ridges are laid in half-round iron, which is less liable to be broken than stoneware pipes when moved out of the way for ploughing. The remainder of the land has been used for roads and planting.

The land selected for irrigation consists of an alluvial soil, of 2 or 3 ft. deep, resting on Thames drift gravel, and the whole liquid will pass down through it.

It was ascertained before commencing the works that the subsoil water of this land was passing, although very slowly, in a direct line to the old bed of the river, distant 330 yds.; so that in addition to the purifying effect of the vegetation to be grown upon the land, there will be the whole of that extent of deep gravel beds between the sewage and the river.

The distance of the land irrigated from the nearest farmhouse is 385 yds., and from the nearest private residence fully 450 yds.

The land will, probably, be let, and part has now been sown down with Italian rye-grass.

The purely technical details of these drainage works will be found very fully and lucidly stated by Captain Gun, in the Professional Papers of the Royal Engineers for 1873.

Mr. Wm. Ripley, of Bracknell, acted as local superintendent in laying out the land and putting in the main drains; Mr. Simmonds, of Windsor, had charge of the alterations of the Castle and other buildings, and the whole was done without employing any general contractor.

The progress of the works was somewhat affected, and the cost increased, by the prevalence of strikes and the rise in prices in 1872, when the principal portion was in hand; but the total outlay, as nearly as it can be apportioned, will be as follows:—

	£	s.	d.
Purchase of Land, Rights of Way, Compensation to Tenants, &c. .	2,003	14	0
Contribution to Thames Conservancy for Rebuilding Weir and Bridge .	800	0	0
Separation of Rainfall from Sewage at Windsor Castle, Frogmore, &c. .	3,404	4	8
Construction of Main Drain and Branches	4,492	4	11
Construction of Reservoir and Buildings at Old Windsor . . .	1,258	1	4
Pumping Machinery, including Proportional Expense of Turbine and Buildings at Old Windsor Lock .	3,302	14	7
Embanking and Laying out Land for Irrigation, Making Roads and Planting	1,686	16	1
Preliminary Expenses, Preparing of Plans, Expenses of Supervision, Travelling, and Petty Expenses .	1,171	12	11
Total . . .	£18,119	8	6

The total cost of the Works reported upon in this Paper has been £41,808 16*s.* 6*d.*, of which the Thames Conservators have paid £12,028 1*s.*, and the Crown £29,780 15*s.* 6*d.*

PLAN

to accompany Mr. Menzies paper on

THE ARTERIAL DRAINAGE WORKS

WATER SUPPLY

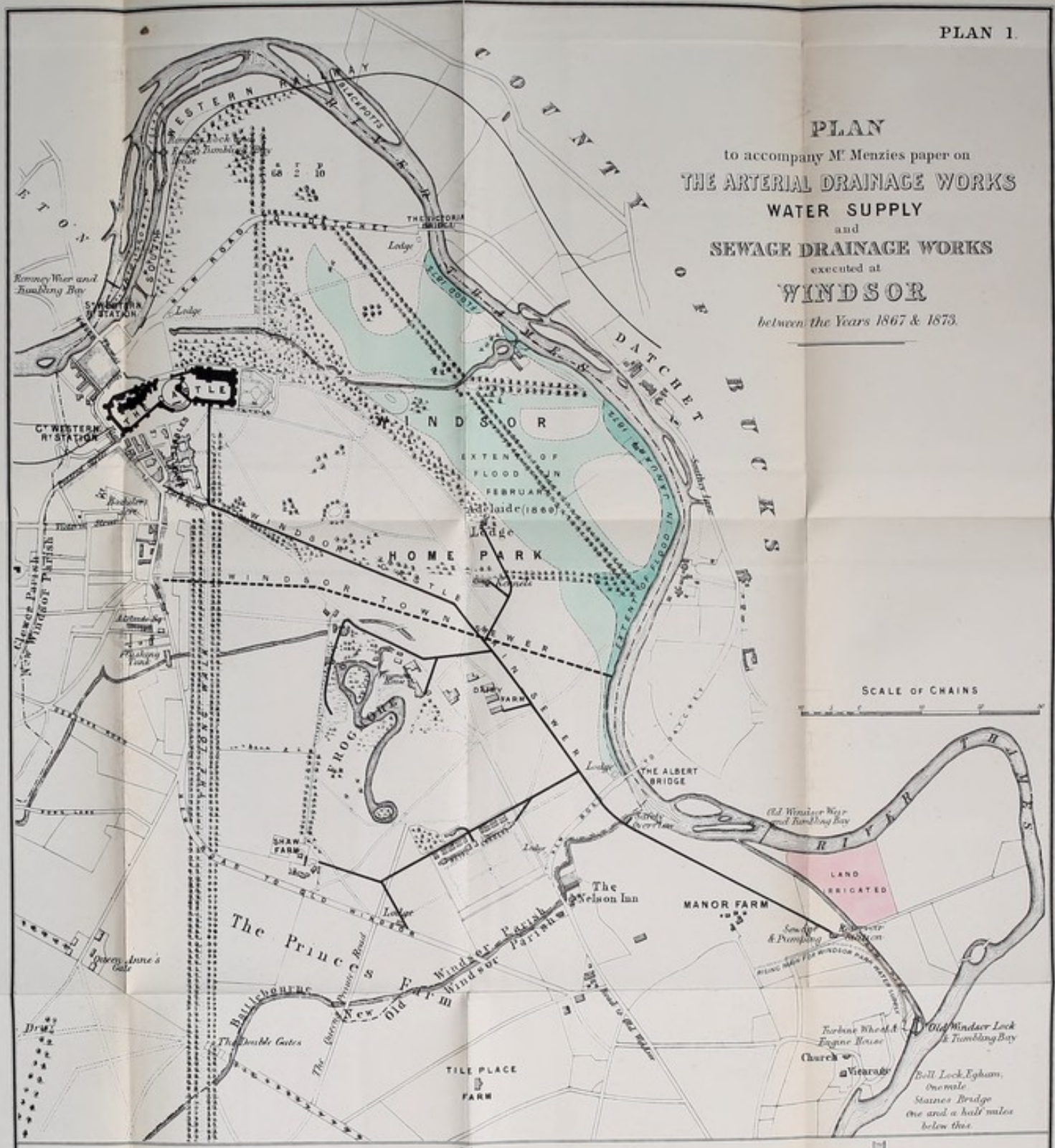
and

SEWAGE DRAINAGE WORKS

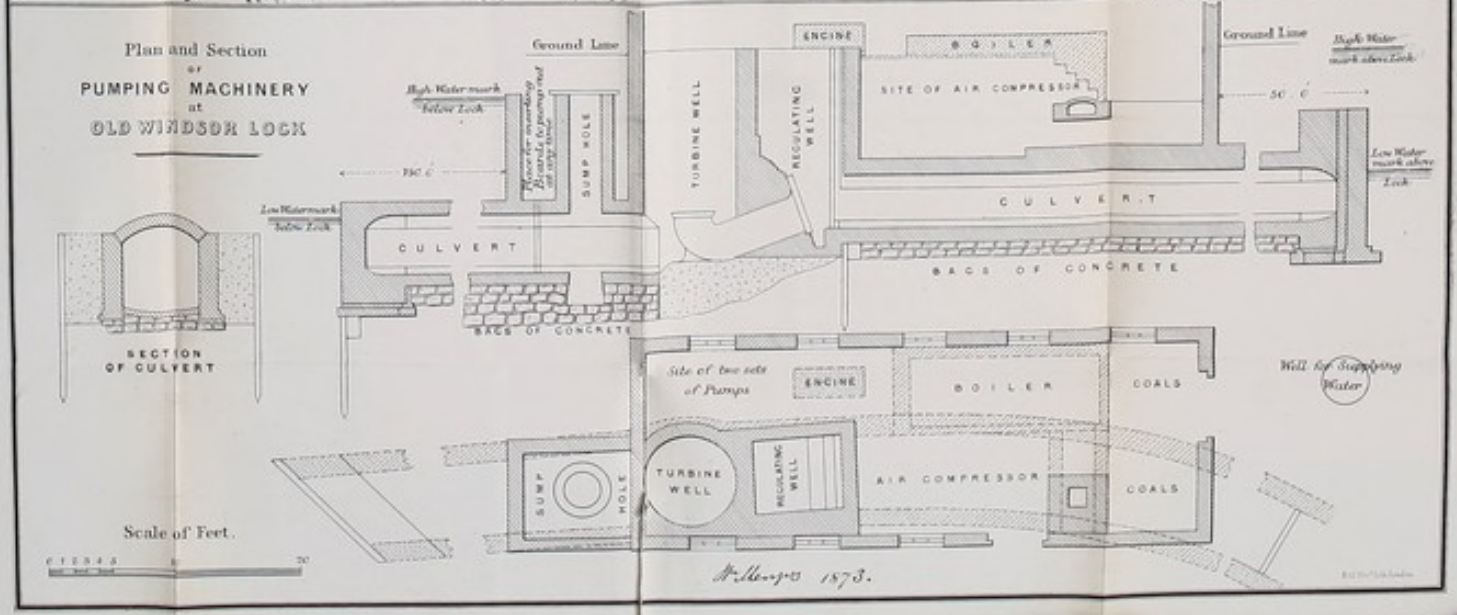
executed at

WINDSOR

between the Years 1867 & 1873.

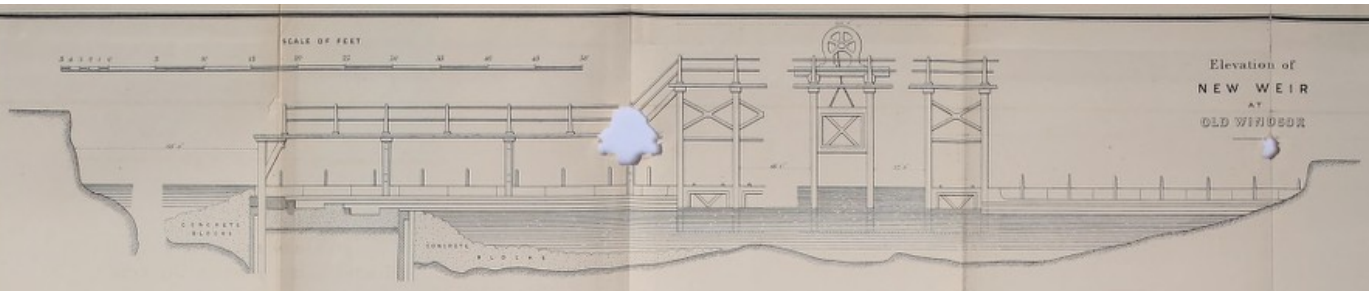


Plan and Section
of
PUMPING MACHINERY
at
OLD WINDSOR LOCK



Mr. Menzies 1873.

PLAN 2



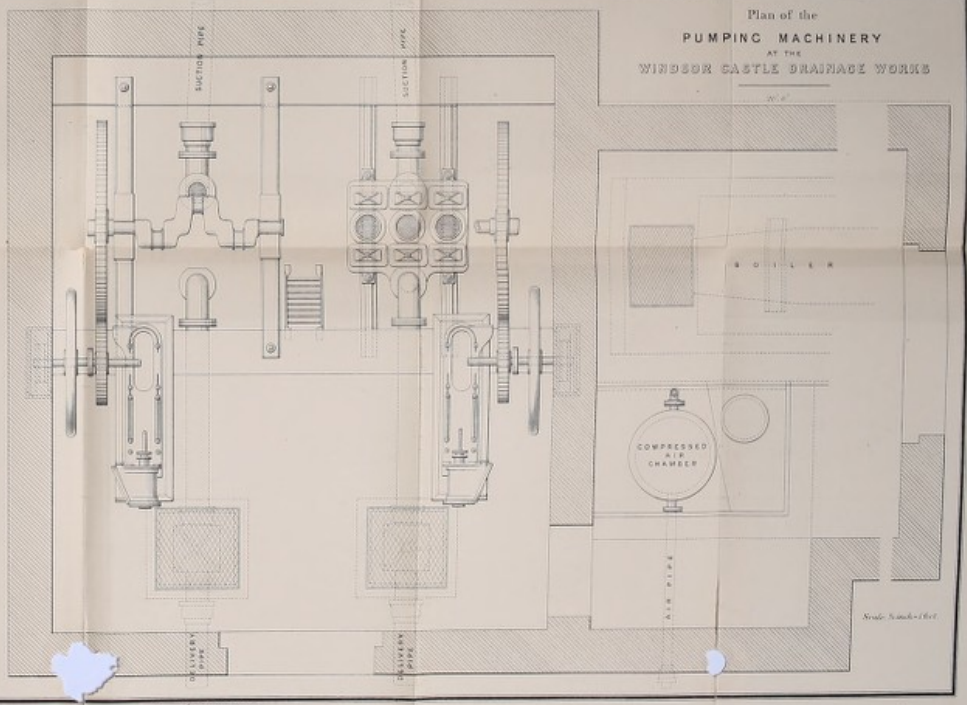
Elevation of
NEW WEIR
AT
OLD WINDSOR

PLAN
to accompany Mr. Menzies paper on
THE ARTERIAL DRAINAGE WORKS
WATER SUPPLY
AND
SEWAGE DRAINAGE WORKS
executed at
WINDSOR
between the Years 1867 & 1873

PLAN OF RIVER THAMES SHOWING
SITE OF THE NEW WEIR

SCALE FOR PLAN OF RIVER

Billings 1873.



Plan of the
PUMPING MACHINERY
AT THE
WINDSOR CASTLE DRAINAGE WORKS

HILL BROT LITH LONDON E.C.