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SECTION X

GROUNDWATER PROBLEMS.

SUB-SECTION X a

GENERAL GROUNDWATER INVESTIGATIONS

X a 4

SOME RECORDED OBSERVATIONS OF GROUND WATER LEVELS RELATED TO ADJACENT TIDAL MOVEMENTS

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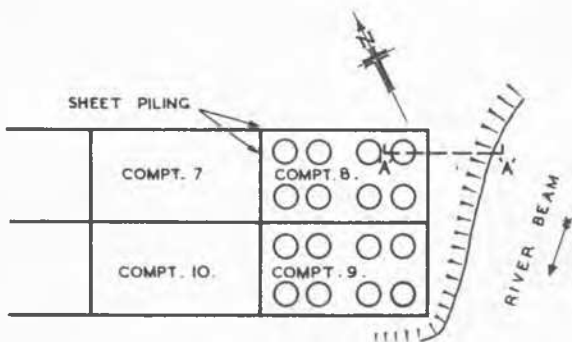
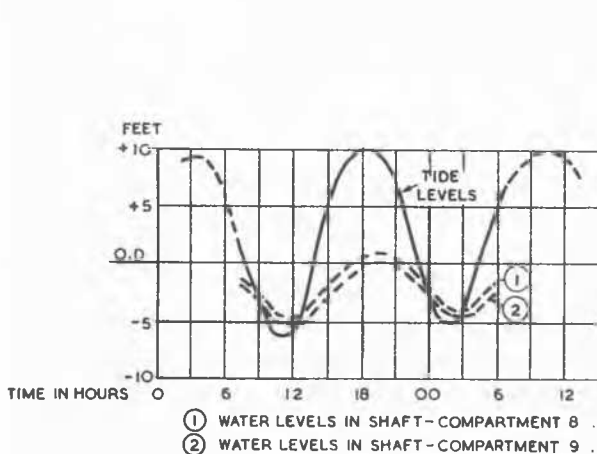
This paper gives several examples of ground-water levels obtained by the Author during execution of works or during Site Investigations in England, close to tidal waters. The results are plotted relating the ground water movements to the rise and fall of the tides on a time basis.

Most of the results are recorded over quite short periods of time as they were not research observations but part of the normal procedure of obtaining information which might be important to the problem in hand. In some cases records were only taken during working

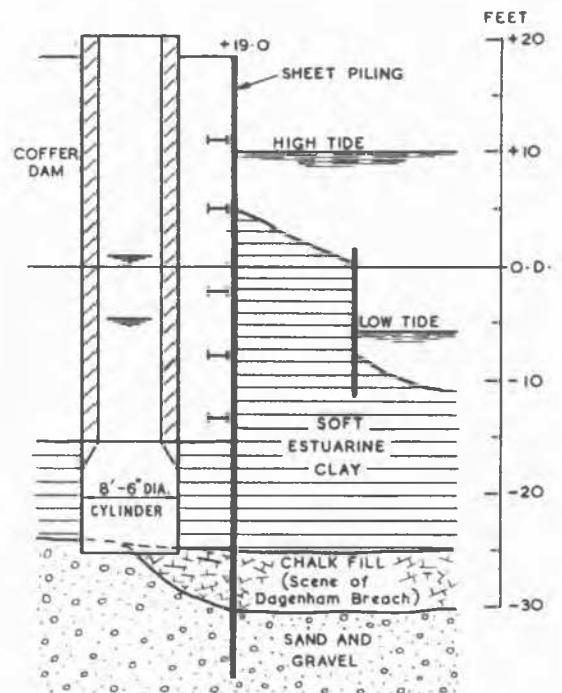
hours when men were available.

The method of obtaining ground water levels in boreholes was as follows:

Boreholes were of a minimum diameter of six inches. Lengths of two inch diameter pipe, perforated for about three feet at the lower end, were set inside the borehole, with the perforations opposite the appropriate stratum. The space between the perforated pipe and the ground was filled with a graded filter gravel as the lining tube was withdrawn. The remaining space above and below the perforated length was filled with puddled clay. Ground



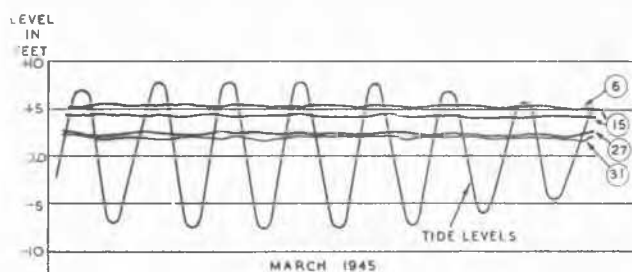
PLAN.



DIAGRAMMATIC SECTION A-A'.

GROUND WATER VARIATIONS
INSIDE COFFER DAM — DAGENHAM.

FIG. 1



GROUND WATER LEVELS
COMPARED WITH TIDE RANGE
— PORTSMOUTH HARBOUR

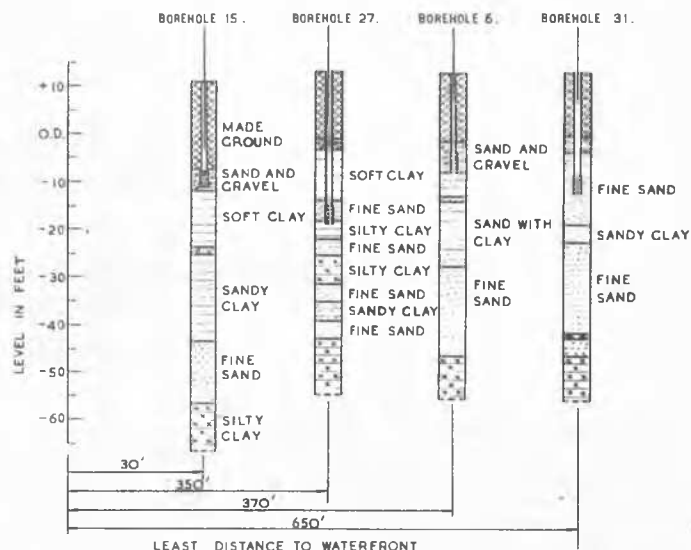
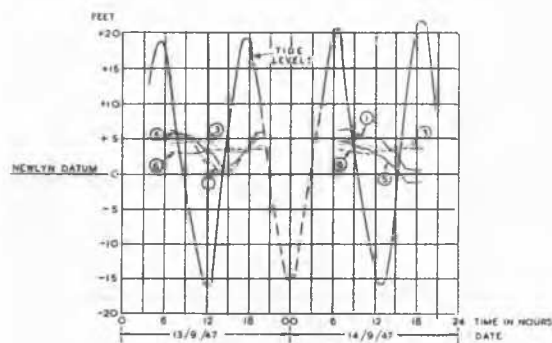
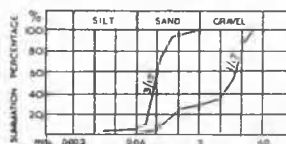


FIG. 2



WATER LEVELS ① AND ⑤ IN GRAVELS
WATER LEVELS ③ AND ⑥ IN SANDS



VARIATIONS IN ARTESIAN HEAD
IN SEVERN ESTUARY

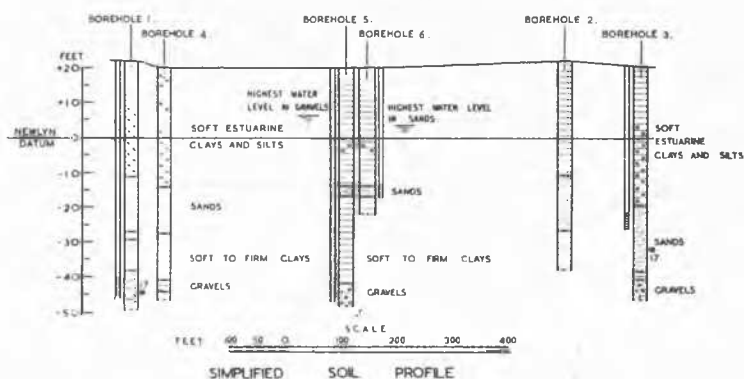
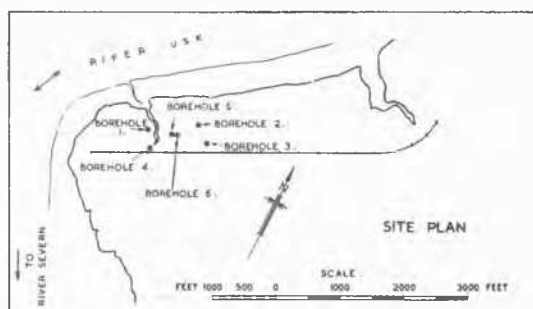


FIG. 3

water levels were then recorded by sounding inside the two inch tube.

Figure 1 shows a short recording of the rise and fall of water inside a flooded coffer dam. The section shows the tide rising and falling on one side of the steel piling and it can be seen that the Thames Sands and Gravel are continuous under the sheet piling except for the chalk filling encountered, and which proved to be the filling dumped by Vermuyden in 1621 to close a famous breach in the Thames Bank.

Fig. 2. shows the Tide range inside Portsmouth Harbour. The movements of Ground Water in four boreholes at varying distances from the free water in the Harbour are shown and also the various strata in which observation tubes were set.

Fig. 3 shows the result of observations beside the River Usk where it runs into the River Severn. Here the tidal range is very great. A bed 16 feet thick of fine sand occurs under a covering of 30 feet of soft estuarine clay and contains water under artesian pressure. Below the sand is a bed of coarse gravel with varying quantities of sand and separated from the upper sand by a bed of soft to firm clay. The ground conditions change in the centre of the site and the beds of sand and of gravel seem to connect. The sizing curves of the materials are given and the relation of boreholes to the river. The ground water rises and falls with the tide after a lag of a few hours, but it should be noted that the movement of the water in the sand is very slight, while that in the gravel beneath varies by

VARIATIONS IN GROUND WATER LEVELS
COMPARED WITH TIDE LEVELS,
BUGSBY'S REACH — RIVER THAMES

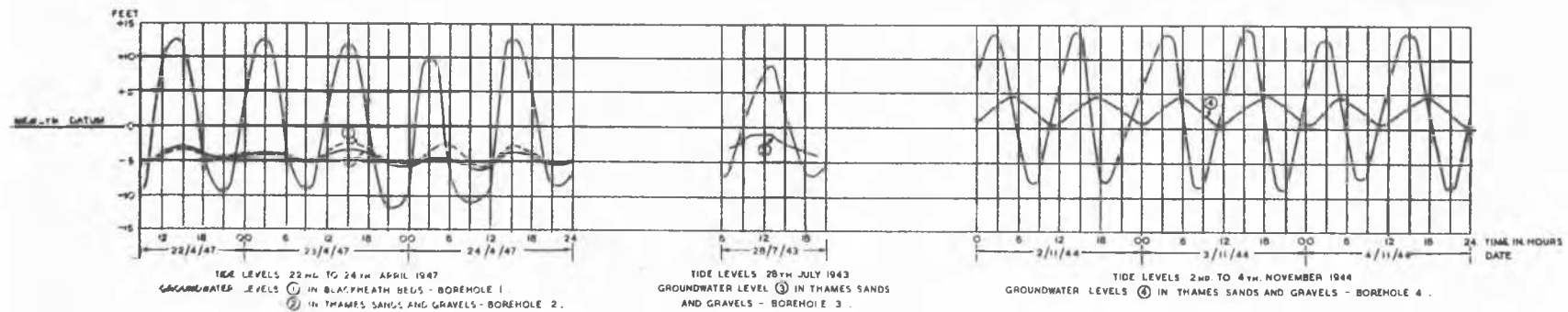
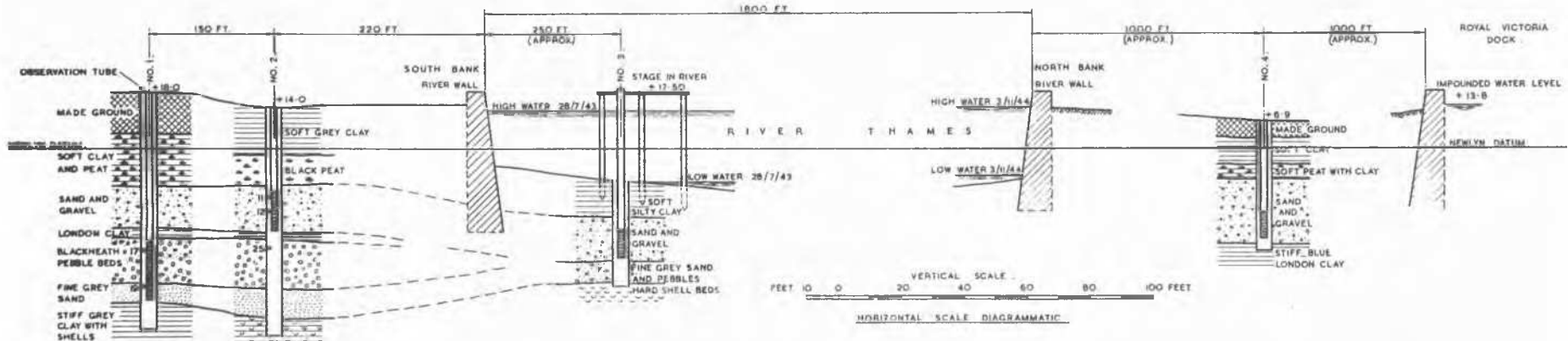
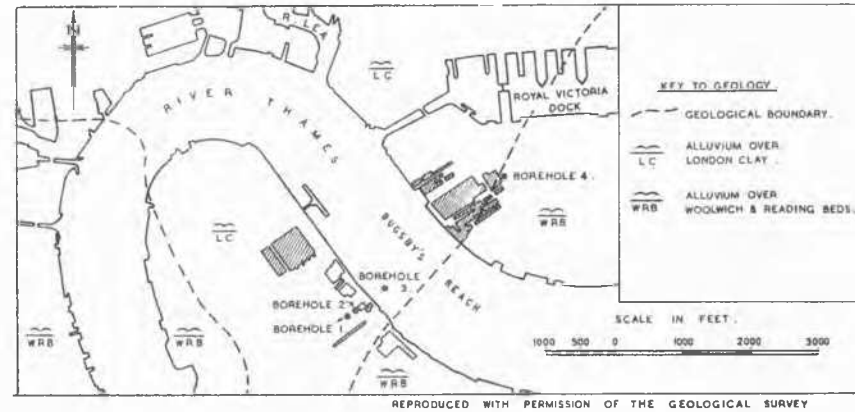
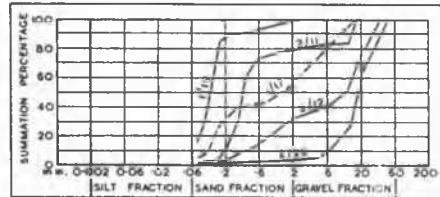


FIG. 4

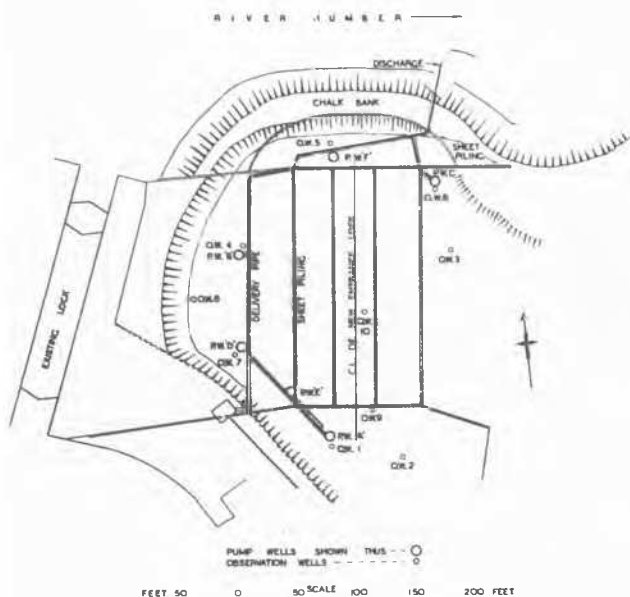


FIG. 4. VARIATION IN ARTESIAN HEAD DURING GROUND WATER LOWERING WITH DEEP WELLS GRIMSBY

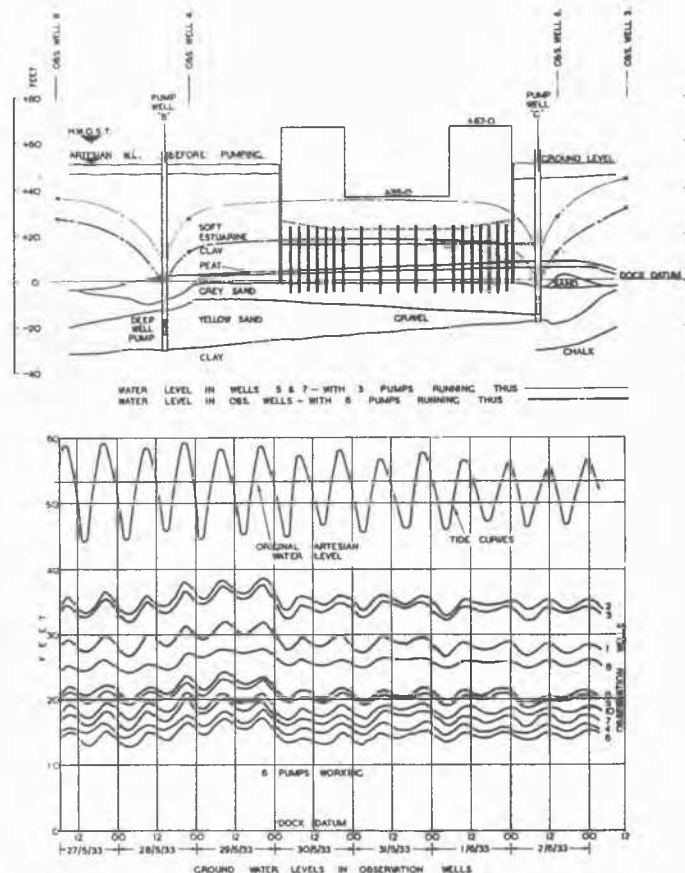


FIG. 5

several feet, probably due the difference in permeability of the two strata.

Fig. 4. is a combination of observations on three different sites which chanced to fall in a straight line across the River Thames below Blackwall Point. These are shown as longitudinal section on a foreshortened horizontal scale.

On the left are two boreholes about three hundred feet inland from the South bank. These pass through the usual estuarine clays into Thames Sand and gravel. An observation tube was inserted in this stratum in one borehole (No. 2). Then a very thin seam of stiff London Clay was encountered and below that the very varied strata shown. These consist of the Blackheath Beds which vary laterally as well as vertically in various arrangements of black spherical pebbles of assorted sizes with sometimes negligible amounts of sand, and at others with sand very plentiful. The sizing Curves show this as it can be seen that some samples are much coarser and others finer than the Thames Gravels above them. In Borehole No. 1 the observation tube was set in the Blackheath Beds.

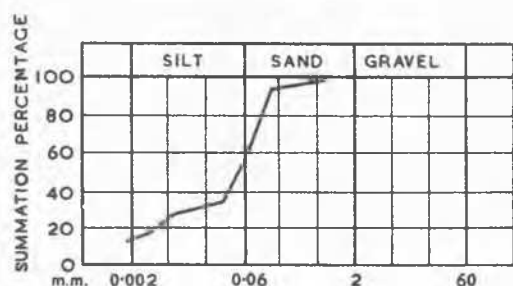
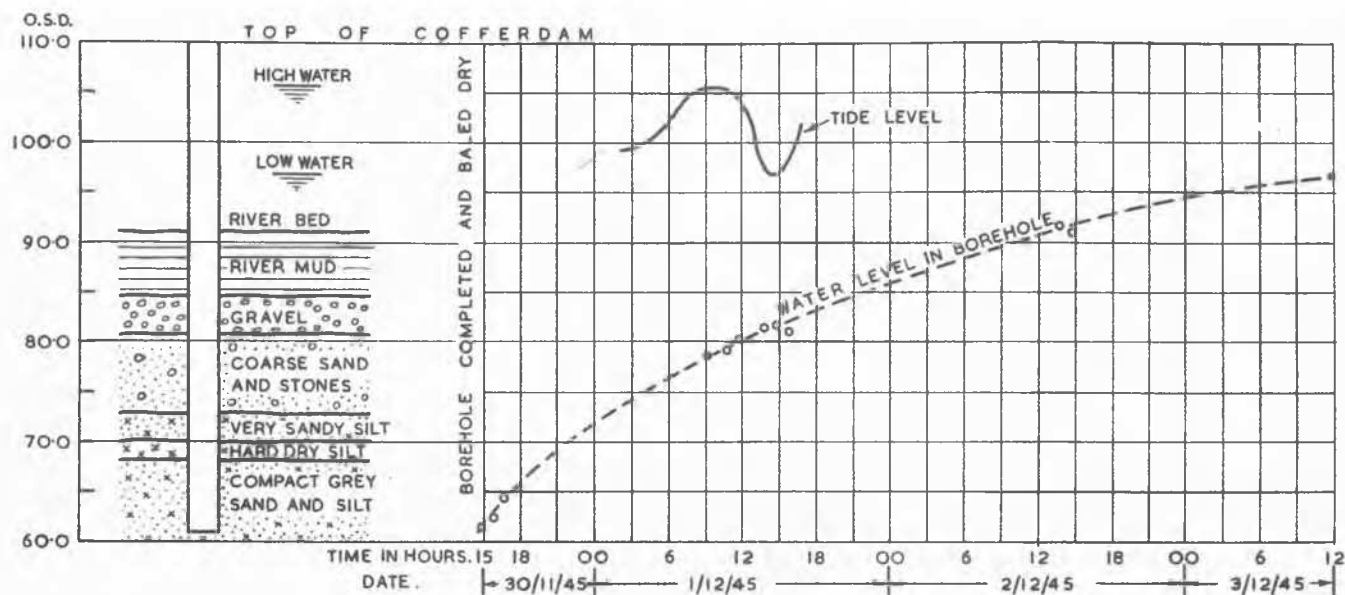
The Woolwich and Reading beds are below.

The Blackheath beds are under Artesian pressure as are the Thames Gravels. It can be seen that the Water in the ground rises and falls a few feet and that the movement in the Blackheath beds is greater than the gravels above, and this again is probably due to the greater permeability of this ground. The amount of water which would have to be pumped from the Blackheath beds is difficult to estimate owing to the variations in composition laterally as well as vertically and also depends on the variations of the surrounding strata.

In the centre of the Section is Borehole No. 3. This was carried out from a timber jetty in the river and passed through estuarine soft clays and Thames Gravels. The London Clay in this distance had petered out and the Woolwich and Reading beds were encountered. A two inch tube was set in the Thames Gravels and the remaining part of the borehole filled with Puddle Clay. It should be noted particularly that although this borehole was two hundred and fifty feet from the shore and actually in the River, the water level in the gravels only varied slightly from Newlyn Datum.

Borehole No. 4 was on the north bank of the River about three hundred yards from the bank. Here the London Clay is again met with, and the Thames gravels lie between it and the Estuarine clays above. The fluctuation of the ground water with the tides is of the same order as before, but the mean level is slightly higher. This may be due to the fact that the Thames Gravels cover a very wide area and the water table may be higher in the position of this borehole as it is about the same distance from the Victoria Docks where water is impounded at about 15.00 N.D.

Fig. 5. shows water levels recorded during a deep-well ground water lowering contract on which the Author was engaged in 1932 at Grimsby on the estuary of the River Humber. A plan and section of the work is shown and also the water levels in the observation wells while the ground water was lowered by 38 feet, below its artesian level. This case is particularly interesting as it shows the influence of the tidal movement although the permeable beds over the working site are covered with a thick impermeable bed. Data was not available as to whether the sand beds outcropped in the bed



RATE OF RECOVERY OF
WATER LEVEL THROUGH
BOTTOM OF SIX INCH
BORING TUBE IN SILT

FIG. 6

of the estuary or whether this fluctuation of the lowered water was due to the change of pressure above it.

Fig. 6. shows a borehole in the River Itchen in Southampton Water and the strata through which it passes. In this case the lining tube had entered a bed of fine sand and been bailed dry in the course of "shelling-out". The diagram shows the rate of recovery of the water level entering the bottom of the tube. The curve of recovery was parabolic over three days and also the rate of recovery varied with the tide. A sizing curve is given.

Fig. 7. shows a cross section through the wall of a Graving dock in the Port of London and the strata around it. In order to relieve hydrostatic pressure, pipes had been left in the walls where shown and protected by tidal flaps. Atrial borehole was sunk where shown and equipped with a filter tube. The figure shows water levels in the ground during periods when the dock was full and empty and are reproduced through the courtesy of the Chief Engineer of the Port of London Authority. It will be seen that the weep holes reduce the water level in the ground locally and that the ground water level recovers during the period that the dock is full. Sizing curves of the strata are given.

COMPRESSED AIR PRESSURES IN TIDAL WATER.

Fig. 8 shows the variations in air pressure used when driving a tunnel from a stage in

the River Thames towards the shore in the same ground as figure 1. It will be seen that the pressure required was less than the theoretical pressure needed to balance the head of water and that the pressure fluctuation was less nearer the shore. It is usually found when tunnelling in the Thames gravels, that the pressure adjusts itself to the rise and fall of the tide. As the tide rises so the loss of air through the permeable ground is reduced and the pressure builds up in the tunnel without special adjustment by the compressor driver. Where elaborate methods of recording the tides for the benefit of the compressor driver have been adopted they have generally proved unnecessary.

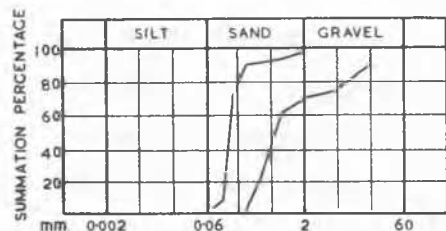
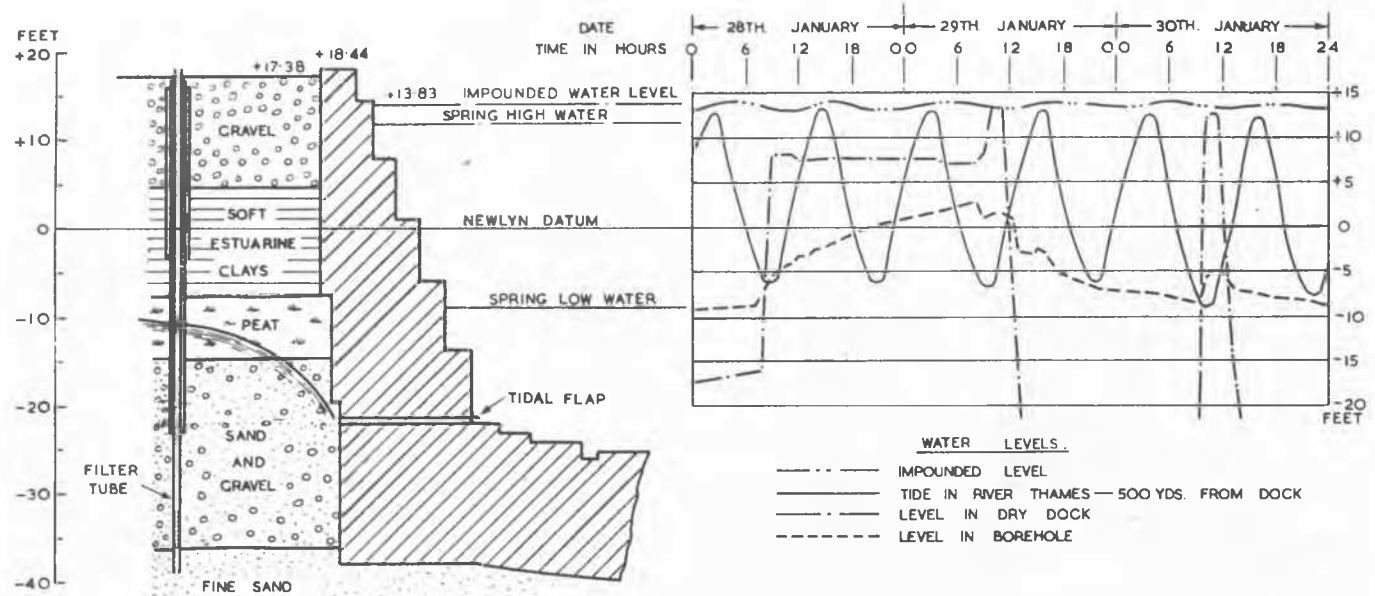
Fig. 9. shows an approximate rise and fall of tide at Battersea and the maximum and minimum air pressures which were used.

CONCLUSIONS.

These observations are set out as a record and without any theoretical deductions. Much more numerous boreholes and studies covering a much wider area would be needed to elucidate all the influences at work.

When work occurs close to tidal waters, it has been noticed by the Author that many persons anticipate that great inflows will be met with and that water levels would be at high tide level.

Many practising engineers do not realise that where work has to be carried out in water



VARIATIONS IN GROUNDWATER
OUTSIDE GRAVING DOCK

FIG. 7

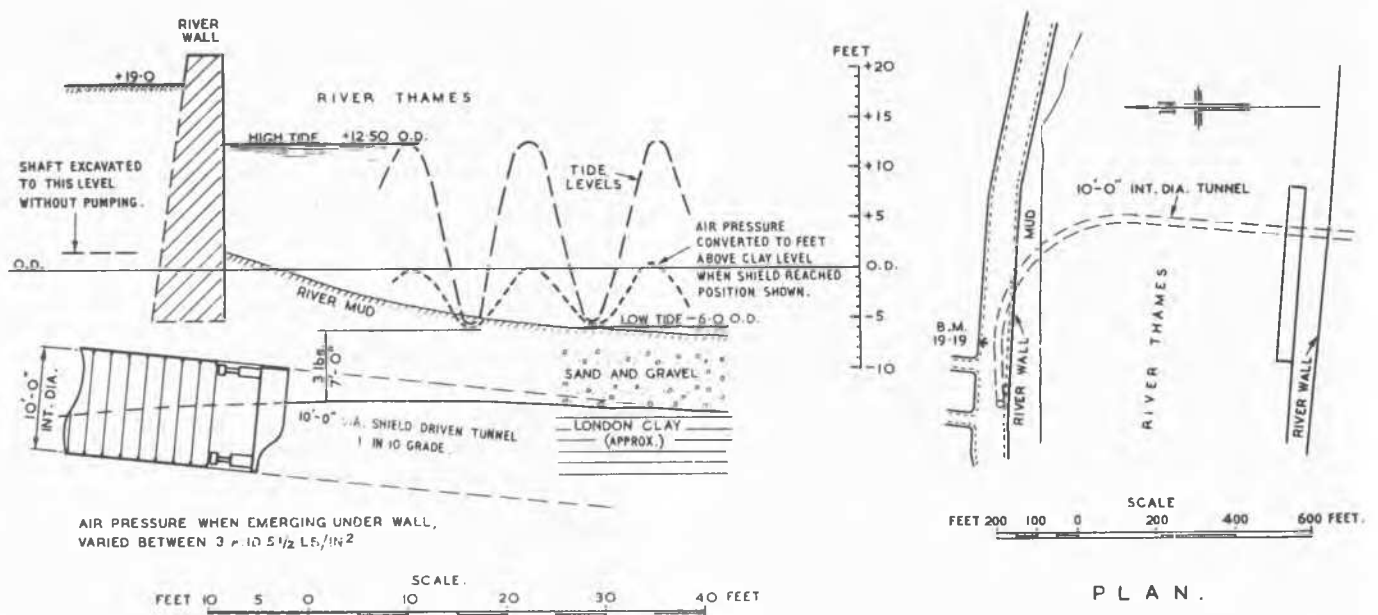


FIG. 9

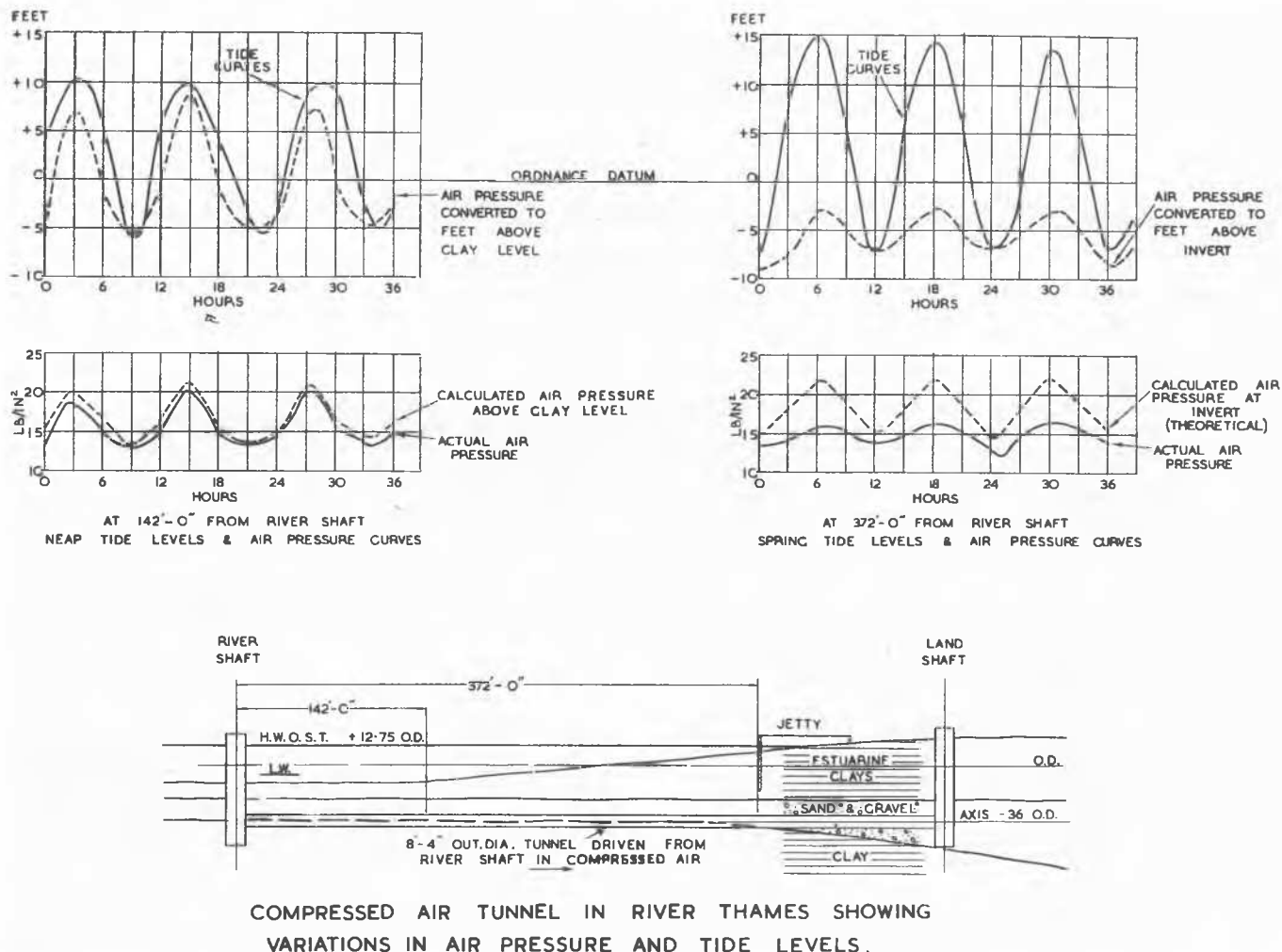


FIG. 8

bearing strata, whether artesian or not, the problem of dealing with this water is scarcely affected by the presence or absence of tidal waters or even non tidal rivers and lakes.

The problem depends upon the permeabilities and relative arrangement of the strata to be met with, the rate at which they will allow water to move through them and the head created which causes the water to flow. The building of railways in Berlin across the River Spree by cut and cover methods is an example. Cofferdams were filled with sand of the same permeability as the ground and the water lowered by means of filter wells and the work was quite unaffected by the existence of free water surrounding the site.

In site investigations the need for proper recording of ground water levels by the method described should be more widely adopted and the making of sizing analyses carried out.

When taking samples of permeable ground, care is necessary to ensure that the fine materials are recovered as well as the coarse in each stratum, as the ten per cent grain size is the fact which controls the characteristics of each stratum.

The problem of obtaining true undisturbed samples of non cohesive materials has not yet been solved in a manner suitable for routine commercial site investigations, where the client begrudges expenditure, and laborious or intricate methods would be difficult to adopt.

However desirable it is that site investigations should be thorough and carried out with scientific care, the fact remains that a majority of every day work will remain on a competitive and commercial basis.

Good service can be done by this conference in educating those initiating such investigations, so that they may avoid the folly of begrudging necessary preliminary expenditure.