

**TECHNICAL REPORT
ON
RESERVOIR SITE INVESTIGATION
EAST HAMPSHIRE. 1977-78**

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Following the submission of a document entitled "Brief Preliminary Report and Proposals" in April 1975 Mander, Raikes and Marshall were instructed by the Authority to carry out site investigations on ten potential reservoir sites in the Test and Itchen valleys, Hampshire.

The Engineering Report, November 1976, described the results of the investigations, which excluded one of the original sites (Site 4) and included another five (1, 2, B, C and D). After the submission of this report, additional investigation work was carried out on Site C and a short Engineering Report was written on the proposals for Sites B and C in May 1977.

In 1977 the Authority requested Mander, Raikes and Marshall to look at five additional sites in East Hampshire. This Engineering Report describes the results of the investigations carried out in connection with these sites. It presents the technical and economic problems connected with developing each site and suggests the site or sites which should be retained for possible development.

2.0 TERMS OF REFERENCE

At a meeting between the Southern Water Authority and Mander, Raikes and Marshall on 8th February 1977 the Authority extended the Consultant's brief to include a further five reservoir sites in the Havant area. The original terms of reference are reproduced in full in the earlier Engineering Report (November 1976) on the Test and Itchen sites and need only be briefly summarized as follows:-

A report prepared in 1965 by Herbert Lapworth Partners identified a number of potential reservoir sites, largely based on the occurrence, at shallow depth, of "London Clay", though this Report was of a preliminary nature and was not based on a scrutiny of the mechanical properties of the London Clay deposits on any of the sites.

In the course of a re-appraisal, by the Southern Water Authority engineers, of the sites mentioned in the 1965 Lapworth Report, it was recognised that the general geological term "London Clay" did not necessarily imply material suitable either as impermeable fill material or as an acceptably water-tight foundation and bed material. Therefore, having selected the most promising sites identified in the 1965 Report, the Authority decided that each of these sites should be investigated with a view to deciding which of these could be relinquished as unsuitable and which were the more promising sites for possible future development. This investigation was to form part of an overall study of sources of supply and storage, as well as future demands.

3.0 GENERAL PROBLEMS AND POSSIBLE SOLUTIONS

3.1 Location of Sites

The location of these sites is shown in Figure 1.

3.2 Preliminary Appraisal

In general this Report looks at the potential for reservoir development of each of the sites, outlines the problems and identifies the likely preferred solutions. Each site is subject to a range of constraints several of which are outside the scope of this Report and any of which could prove to be of over-riding significance. Therefore it should be borne in mind - as it has been when carrying out the studies - that the final choice of sites is unlikely to be based only on the engineering considerations assessed here, though these are perhaps the easiest to quantify.

As with the Itchen and Test work, desk studies were carried out at the outset in order to establish the likely most economic method of developing each of the sites. These studies looked at various capacities for each of the sites and from consideration of the respective ratios of storage volume to fill volume, as well as the actual storage capacities of which each site was capable, it was decided to look in more detail at one solution for Sites 15, 19 and 20, three solutions for Site 17 and two solutions for Site 18.

3.3 Locating the Boreholes

These preferred solutions were then drawn up on more detailed plans and the quantities checked. A preliminary assessment of the ground conditions was made in order to check that there was no reason to re-locate any of the dams or bunds. Boreholes were then put down to investigate the strata so that the tentative layouts could be worked up and costed in more detail.

3.4 Further Study at Design Stage

This Report does not attempt to cover every possible reservoir configuration that could be constructed on each and every site. Rather, it puts forward a range of possibilities which can be drawn on in the light of other related studies and later policy decisions. Since this Report is essentially of a comparative nature, there would of course remain at any selected site the need for further fieldwork before final detailed proposals for construction of a reservoir could take place. This applies to all sites, but is of special application to one of the favoured ones, namely Site 18.

4.0 ORGANISATION AND MANAGEMENT

4.1 Overall Programme

The Engineering studies have been carried as part of the wide-ranging Hampshire Reservoir Investigation.

4.2 Co-ordination

The co-ordination of the whole investigation has been carried out by Mr. C.J. Cotton and Mr. R.B. Armstrong of the Authority headquarters staff. The Consultants have reported on the progress of the work at a total of three quarterly meetings. At these, the significance of the results to date and the courses of action to deal with the remaining problems have been thoroughly discussed and agreed. The co-ordination of all fieldwork has been carried out by Mr. D. Giles.

4.3 Scope of Consultants' Work

The Consultants have been responsible for drawing up contract documents for Contract 3, obtaining tenders from an agreed list of six contractors, vetting the successful tenders and for administering the Contract and overall supervision of the fieldwork, specifying and checking on the laboratory tests. Most of this work was controlled by Mr. I.J. King.

The Consultants have also been responsible for desk studies to evaluate the capacity and shape of the proposed reservoirs and work up the schemes so that an economic comparison of developing the various sites could be made. The bulk of this work was controlled by Mr. J.R. Grimshaw.

Apart from engineering studies on reservoir types which forms the essence of this investigation, the Consultants have arranged for certain other subsidiary work to be carried out as necessary such as the contouring of 1:2500 plans by B.K.S. Surveys Limited.

4.4 Specialist Advisers

In accordance with Section 6.2.d in the "Initial Report and Proposals" submitted to the Authority in April 1975, the services of two external specialist advisers were engaged to assist in the study.

Dr. A.B. Hawkins, University of Bristol, has been kept in close touch with the site investigation work at all stages, including co-operation with Mr. I.J. King of Mander, Raikes and Marshall in the detailed description of samples examined in the laboratory and the geological interpretation of the data obtained.

Professor J.K.T.L. Nash, Professor of Civil Engineering, Kings College, University of London has also been consulted on some of the engineering aspects; and by arrangement with Professor Nash, his colleague Professor R.E. Gibson has advised on certain problems to do with pore pressure build-up and dissipation in fill materials.

The study of future storage requirements and possible modes of operation, as well as other related studies, is being handled by the Authority. This Report has in certain respects been based therefore on certain assumptions as to the outcome of other work still in progress.

5.0 SITE INVESTIGATION

The Site Investigation work is reported in full in Appendix I at the end of this Report. The following is a summary of the objectives and the work done.

In discussion with the Authority's officers, a list of approved contractors was drawn up and these were asked to tender for the site investigation contract. Tenders were invited on 14th June 1977 and the completed tenders were opened on 8th July 1977. The lowest tenderer, Foundation Engineering Limited was awarded the Contract on 26th July 1977. Work commenced on Site 15 on 13th September 1977; the fieldwork was completed on 17th November 1977; and completion of the laboratory work is imminent at the time of writing this Report. The original Tender Sum was £31,882.50 and to date accounts have only been submitted for £13,008.90. The laboratory testing has taken longer than anticipated, mainly owing to the long times needed to saturate triaxial samples.

6.0 DESK STUDIES

6.1 Lapworth and Other Sites

The reservoir sites under investigation and covered in this Report were selected by the Authority from amongst those recommended for further study in the 1965 Report by Herbert Lapworth Partners. The object of the present study was to look at each of these selected sites more critically to determine the feasibility and likely relative advantages of constructing a reservoir on each. It was not within the scope of this study to check that any of these sites will necessarily be the best available in the area, although this may well be the case.

The position of the Authority at the outset was that it may review the remaining Lapworth Sites if none of the selected sites proved to be feasible.

6.2 Storage Capacity

The initial desk studies were carried out using 1:10,000 scale contoured plans. Various reservoir configurations were considered and for each of these configurations the storage capacity and the ratio of capacity to embankment fill were calculated. This ratio is useful as a primary indicator of economic development and within one site, where the cost of works other than actual embankment construction is reasonably constant, it provides a good comparative guide for a first choice between various possible schemes.

In discussions with the Authority it was agreed to base the preferred solution on each site on a reservoir with a storage capacity of 6 million m³. However, this was not always feasible and so the layout with the highest storage/fill ratio was adopted as the preferred solution.

These preferred solutions were then studied in 1:2500 plans which had been contoured using aerial photography by B.K.S. Surveys Limited. From these studies a summary of quantities for preferred solutions at 1:2500 scale, Table 1 was drawn up.

Subsequent to the site investigation these solutions have been worked up in more detail and this work is presented in Section 7.

6.3 Hydrology

With the exception of imports from Gaiter's Mill on the River Itchen, the area's demand is met by supplies from a number of boreholes sunk in the Upper Chalk. The pattern of their flow together with that of demand is shown on Figure 2, where it can be seen that any increase in demand can only be met by the introduction of new sources.

With groundwater resources in the area fully extended there is no choice but to turn either to further imports from the River Itchen or to surface reservoir storage of winter surpluses.

Figure 3 compares the effect of increasing imports to 115Ml/d with providing surface storage of 6Mm³. The figure of 115Ml/d is taken as within the practical capacity (135Ml/d) of the existing 40 ins diameter pipeline from Gaiter's Mill allowing for some boosting at Fir Cottage if necessary. 6Mm³ is a target capacity for some of the potential sites. Importing from Gaiter's Mill results in meeting a peak demand of 292Ml/d, whilst the 6Mm³ of storage only meets 260Ml/d compared with the upper bound of the projected demand of 298Ml/d.

TABLE 1

Table Comparing the Ratio of Water Storage
to Embankment Fill for Sites 15, 17, 18, 19 and 20

<u>Name of Site</u>	<u>Number of Site</u>	<u>Ratio</u>
West Walk	15	7.5
Boarhunt	17(1)	2.9
Boarhunt	17(2)	8.0
Boarhunt	17(3)	5.3
Havant Thicket	18(1)	12.2
Havant Thicket	18(2)	8.0
Southleigh Forest	19	6.2
Southleigh ^{farm} Forest	20	4.2

It should be noted that no measures are required to augment the Itchen flows to enable it to support the abstraction up to 115Ml/d since sufficient augmentation is already necessary to meet the minimum residual flows of the river to carry the Chickenhall effluents.

Provided there are no great distribution cost differentials resulting from the Itchen imports being delivered to Hoads Hill, and reservoir resources come to some other part of the system, then it is likely that Itchen imports will be more economic and feasible options. If this is so, then one of the eastern reservoir sites (18, 19 and 20) would be the better choice to provide a balanced supply to meet possible future expansion beyond and above that covered by the 115Ml/d from Gaiter's Mill.

115 Ml/d.

This eventual network, together with the associated pipelines and works included in the costing of each site, is shown on Figure 4, together with an arrangement of the other sites studied.

6.4 Landscaping

The Landscape Consultant visited Site 18 to photograph the site in the summer whilst leaves were still on the trees in case the Authority wanted landscaping studies to be carried out during the winter.

7.0 SOLUTIONS

The plan layouts and cross-sections considered for estimating purposes in the light of the soils data are now considered in relation to each site in turn.

7.1 General

With the exception of Site 20, and to a lesser extent Site 18, the soil conditions were found to be sufficiently similar for a standardised typical cross-section to be taken for comparative purposes. This applies to both foundation conditions and to the likely characteristics of fill materials. The exception in the case of Site 20 is the presence of granular material which should provide sufficient fill material to constitute a significant part of the outer shoulders of the embankment on either side of the dam, where its far greater shear strength and freedom from construction pore pressure problems enable significantly steeper slopes to be used. In the case of Site 18, the doubts about the foundation shear strength parameters which can be safely used in design have made it advisable to flatten the slopes slightly for estimating purposes, whilst the presence of the permeable basal beds traversing the axis of the dam have necessitated provision for special cut-off measures and a locally modified cross-section, though elsewhere in the embankment the cross-section would be basically similar to that used in the other sites, with the modification to the slope angles mentioned above.

The typical section for the proposed dams is shown in Figure 5 which is the proposal for Site 15. This typical section consists of a homogenous clay embankment with a 1 in 3 downstream slope and 1 in 4 upstream slope. The high natural moisture content of this material compared with its plastic limit and its optimum moisture contents means

that if the material is allowed to pick up any more moisture during construction (as an overconsolidated deposit tends to do) there may be problems in placing and compacting it as fill. The pore water pressures induced in the clay due to construction will be very high and due to the nature of the deposits these will take a very long time to dissipate. These high pore pressures could lead to stability problems immediately after construction. In order to accelerate the consolidation of the London Clay and thus to reduce the construction pore water pressures, granular drainage layers have been included in the cross-section of the dam. (These will also have the benefit of providing small zones with slightly higher shear strength, although the overall effect of this on the stability of any shear surface will be small). Owing to the absence of a suitable material in Hampshire, this drainage material will probably be sea aggregate. The use of chalk is not recommended as it is likely to degrade down to a putty chalk which would then not be sufficiently permeable to fulfill its desired function. Each of the typical cross-sections will have a shallow cut-off extending into the natural ground to control any seepage in the interface between fill and foundation material.

To avoid erosion, the upstream slope would require a protective layer of some kind, and the downstream slopes in all cases would be topsoiled and grassed.

The effective shear strength parameters determined in the laboratory for selected samples from each site show a certain degree of variation from one site to another. However, examination of the samples has shown that the nature of materials from each formation does not vary greatly from site to site.

Over the whole study area, variations in the fundamental shear strength parameters of the clays seem to depend primarily on two factors, namely the preconsolidation load

in the geological history of the sample (c.f. Rowe's report which demonstrated a systematic relationship between shear strength and height above basal beds which is, very broadly speaking, a measure of preconsolidation load, at least on a single site, in this case Site 18); and secondly the particle size distribution of the specimen. An empirical relationship established for a dam in Nigeria by J.D. Humphreys proved, interestingly enough, to work tolerably well for the Hampshire clays. (These parameters will, of course, be modified in the case of samples which have undergone deformation, local or regional, in their history, as discussed in the Appendix).

Thus, there was no systematic or intrinsic relationship between shear strength and purely geographical location of the sites, so it has been possible to establish and use a common set of parameters for all the East Hampshire sites (noting, nevertheless, presumably because of the marginal geological differences between this study area and the Test and Itchen area, these values are appreciably lower than the latter area).

On the basis of all the available data, including the occurrence of slickensides within certain samples the shear strength parameters selected for the purpose of this study, for both fill and foundation materials, are:

$$C' = 0 \text{ and } \phi' = 18^{\circ}$$

The slickensided shear planes are not in themselves a cause for concern as these are in general only small discrete planes representing local movement in the past rather than large scale regional or systematic movement. Appendix I records the drained shear box tests on a sample from Site 18 giving a "peak" ϕ' of 16° and a "residual" value of 10° , suggesting that the relatively low values of ϕ' from other samples are probably peak strengths and not indicative of earlier disturbance. It is believed investigations recently in connection with the A3(M) have

generally revealed a value of ϕ' for the London Clay of 18° , though confirmation of this information is still awaited. This grey or brown-grey clay can exhibit high undrained shear strengths but these can be misleading; it is the effective or drained shear strength parameters which govern the stability of embankment dams, coupled with an assessment of the pore water pressures, and to this extent test data from nearby road construction works, which are usually expressed in "undrained" terms, are likely to be of limited applicability only.

7.2 Site 15

The proposed cross-section and plan of the embankment is shown in Figure 5. This section is the typical one used, with the exceptions already noted, for the East Hampshire sites. The general ground conditions are outlined in Appendix I. If this site were to be developed, a more detailed study would be required to ensure that there would be no leakage from the reservoir basin through the basal beds of the London Clay into adjacent lower lying areas. Moreover, whilst seepage might not be a problem, the presence of the basal beds under the dam could lead to uplift pressures affecting stability, so that it may be necessary to reduce the slopes or to install a system of relief wells and underdrainage to control these uplift pressures.

If it were decided to consider this site in more detail, it would be necessary to put down a series of trenches on the northern side of the valley under the projected dam foundation to ensure that there were no existing large shear surfaces affecting the strength of the foundation. The southern side of the valley would need to be investigated with boreholes to determine whether there were any sand bands requiring cut-offs to prevent leakage from the reservoir basin. The potential borrow area would need to be investigated in more detail to determine the variability of potential fill material and hence the likely proportion of waste.

7.3 Site 17

Three different sections have been studied for this site and these are shown in plan and section in Figures 6, 7 and 8.

These solutions all incorporate a common embankment cross-section and all that varies is its position and top water level and consequently the storage capacity. The river diversion cut would also vary in position from one solution to another. The ground conditions across the whole site are detailed in Appendix I.

Where the embankments cross the main valley of the River Wallington, the cut-offs will need to be carried down and keyed into the underlying impermeable London Clay to prevent any seepage through the alluvial gravels. The vertical and lateral extent of these deposits could be assessed using a hand auger at the design stage. At the same time, and probably by the same means, the extent of the peat found only in Borehole 2 should be further investigated. Whilst the silty clay containing the peat would be liable to consolidate considerably, with controlled loading the majority of the settlement is likely to occur quickly, so that provided that peat is present only in local pockets it may not be necessary to remove it, which would otherwise involve the cost of removing the overlying deposits.

The basal beds of the London Clay are thought to outcrop just outside any of the proposed reservoir basins, so that even if their permeability were greater than that recorded in Borehole 3, they probably do not constitute a potential source of direct leakage. Before preparing the final designs, it would be necessary to check on the outcrop and permeability of the basal beds in order to confirm that they do not in fact represent a leakage risk.

For solutions 2 and 3, impermeable cut-offs would need to be constructed under much of the embankment north of the River Wallington. These would have to penetrate the silty and sandy Bagshot Beds into a more impermeable layer in the London Clay. This could probably be achieved effectively and economically by means of a slurry trench, i.e. a trench from which the spoil is mixed with bentonite and clay and then replaced in the form of a slurry backfill. This is carried out on a more or less continuous process and can prove relatively cheap and efficient.

At the detailed design stage, it would also be necessary to put down trenches at the junction of the London Clay and Bagshot Beds to determine with more precision the location of the impermeable layer to which the cut-off would require to be taken down, although owing to the manner in which deposits were laid down any particular horizon may not have a distinct planar boundary.

There is a small artesian pressure in the London Clay in the northern valley, across which an embankment is incorporated in Solution 3. This is relevant to the stability of the embankment. Measures taken to offset this effect might include the use in part of the embankment of the Bagshot Beds excavated for the stream diversion; relief wells as well as the usual underdrainage system; or a combination of these.

The sideslopes of the stream and river diversions have been provisionally taken as 1 in 4, with a 10m berm between the toe of the embankment and the top of the cut, for stability reasons. Using the same effective shear strength parameters as elsewhere, namely $C' = 0$ and $\phi' = 18^\circ$, the cut slope would have a factor of safety of about 1.3. It may be possible in places to use steeper slopes, but this would require to be verified by supplementary investigation.

The slopes would of course require protection from erosion below the maximum possible level of flows, and the same protective works should be designed so as to accommodate any groundwater outflows at the face.

7.4 Site 18 ~~HAVANT~~ THICKET

Two different solutions have been studied for this site and these are shown in plan and cross section on Figures 9 and 10. These solutions incorporate a common general dam cross-section, but with shallower slopes than those used on the other sites, for the reasons detailed in Appendix I.

The typical cross-section used is substantially different from that tentatively proposed by Professor Rowe in his own Report on the 1962 study, though this difference does not in fact reflect any substantial measure of disagreement between the interpretation of the data in this Report and the interpretation arrived at by Professor Rowe. In effect, Professor Rowe's cross-section sets out to meet two of the particular features of this site to which attention is drawn in Appendix I, namely (1) the basal beds traversing the dam axis, with the attendant cut-off and uplift pressure problems; and (2) the evidence that foundation shear strength may tend in places to be lower than on the other East Hampshire sites (though it has yet to be established whether this evidence is of sufficiently general or systematic validity to have an appreciable influence on the safe working values of shear strength used in a full design calculation). Rowe's section overcomes the first problem by carrying the central clay core of the dam out to the upstream toe of the embankment, as a horizontal layer at foundation level, and thence presumably as a continuous blanket over the whole extent of the outcrop of the basal beds across the reservoir basin. His suggested solution to the shear strength problem (providing also a relief of any residual uplift pressures which penetrate the cut-off) is the installation of a number of vertical sand drains over

virtually the whole of the embankment foundation. This latter is, of course, a perfectly viable engineering solution (it was used extensively in the case of Empingham Dam) as a method of assisting the process of consolidation under the load of the new embankment, i.e. enhancing the shear strength of the foundation beneath the dam itself (though not, of course, outside the immediate foundation area, even though certain critical shear surfaces of any appreciable depth would extend at least some way from the toe of the affected slope).

The simplified cross-section used in this Report, with substantially flatter slopes than those incorporated in Rowe's solution and without the extensive use of sand drains, has been selected for the main part of the embankment (excluding only the section directly affected by the basal beds) mainly because, for the comparative purposes of this study of all five East Hampshire sites, it is appreciably simpler and more susceptible to subsequent adjustment, in direct comparison with the other sites, in the light of supplementary data acquired later on - whether such data may relate to soil mechanics problems or water resources strategy; another reason for preferring the section shown is that the doubts about the significance of isolated low shear strength test results are at present very far from becoming an established design limitation (discussions with Professor Nash on this aspect have been reassuring); whilst the cut-off problem presented by the basal beds crossing the dam axis is very localised indeed, and it is considered that the peculiar needs of the cut-off problem in this section - i.e. knitting the upstream blanket with which the basal beds outcrop are sealed into the essential impermeable core of the embankment - do not constitute a valid reason for a radical departure in cross-section over the whole length of the embankment, from those used in the comparative study of the other sites. The eventual choice between Rowe's solution to the foundation problem (if it be established that there is one) and the solution illustrated here, based instead

upon flatter slopes - or some combination of the two - would ultimately depend upon more detailed data to be obtained in the eventual design stage, followed by an up to date cost comparison between the two approaches. Thus, the difference between Rowe's solution and the one included here is not one of interpretation, but is to some extent conditioned by the different objectives of the 1962 study, which related to one site in isolation, and the 1977 study, which is essentially one of comparison between several sites.

At the time of writing of this Report a few additional shear strength tests, designed to investigate further the foundation shear strengths on this site - and in particular the "residual" values of ϕ' - have not yet been received and it is proposed to carry out a further stability analysis by computer when all the available data have been assembled. This would be the subject of a supplementary report in the event that the results cast any serious doubt upon the assumptions made in presenting the solutions for this site.

As to the selection of fill materials, tests carried out in the study, supported by those reported by Professor Rowe, indicate that although the compaction characteristics of the potential fill materials vary a good deal across the site, the dry densities at optimum moisture content are generally higher for the Reading Beds than for the London Clay. Preference would therefore be given to the Reading Clay in preference to the London Clay, though this detail again might need to be reassessed in relation to haulage distance from the selected borrow area. To a limited extent, the coarser basal beds of the London Clay might serve a useful purpose in the outer shoulders of the dam, or in drainage layers, provided of course that they can be exploited in such a manner as not to prejudice the cut-off measures adopted in the final design.

Following on from the preceding sentence, it is worth noting that an alternative solution to the cut-off problem might of course be concentrated grouting, to an appreciable depth, into the basal beds. It is not possible to say without further study, not thought to be justified within the scope of the present work, which of these two alternative methods of cut-off might prove eventually to be the cheaper and more effective solution. In the "blanket" solution it would almost certainly be necessary to provide drainage measures of some kind beneath the clay blanket, across the dam foundation and into a collecting drain downstream, as a second-line insurance against any remaining tendency for artesian pressures to develop, notwithstanding the blanket itself; and by the same token such measures would have to be completed before the whole cut-off system comprising the blanket and the dam core was completed, in order to prevent its upward penetration by an uplift head which might otherwise exceed the static load of the blanket itself. This is not, however, a major cost consideration - it is simply one of the factors to be taken into account when choosing the method to be adopted.

On the other hand, a cut-off wholly dependent upon grouting is a notoriously difficult item to cost accurately in advance, whilst further study would in any case be required in order to fix, with reasonable confidence, the necessary extent of the grout "plug" in order to be sure of reducing seepage losses to an acceptable minimum, since the basal beds have to be assumed to extend along the shallow dip plane more or less indefinitely; so that it would be a matter of deciding, by means of flow nets based on supplementary permeability tests on the stratum itself, what minimum length of seepage path would be required beyond the limit of the grouting. By analogy with deep cut-offs on semi-infinite permeable foundations, studied elsewhere, the length of this minimum seepage path might prove to be considerable.

The estimated cost of the "blanket" solution may be given with rather more confidence than any estimate for grouting, so the figure included, £300,000, may fairly safely be regarded as an upper limit; thus the selection of grouted cut-off instead would not materially affect the relative rating of this site.

The alternative layout shown as solution 18(2), although appreciably inferior in terms of direct cost/benefit, was suggested in discussion with the Authority at an early progress meeting, on grounds of superior land use and on environmental considerations. From the point of view of soil data and engineering considerations, there is no significant difference between the two alternatives and a choice between the two is left for further discussion in the Overall Engineering Report on the East Hampshire, Test and Itchen sites, which is being presented simultaneously with this Report. Within the context of the present Report the only difference worthy of mention is that the first solution - the original one considered by Edgar Morton and put forward by the Authority at the commencement of this study - would involve a somewhat greater length of exposed basal beds within the reservoir basin, and hence a correspondingly higher cost for the blanket cut-off. In purely economic terms, this difference is of course more than offset by the substantially more attractive ratio of cost to capacity for this solution.

7.5 Site 19

The proposed cross-section and plan for this solution are shown on Figure 11. The slopes used for the embankment are the typical ones referred to in Section 7.1. The general ground conditions encountered are outlined in Appendix I.

The major problem with this site would be one of potential seepage through the basal beds. Whilst it would be possible along the north eastern embankment to construct a cut-off down to the impermeable Reading Beds below, seepage would still occur under the southern embankment. This would need to be prevented by means of a grout curtain through the basal beds and into the underlying Reading Beds. The remarks about grouting in the preceding Section, Site 18, are also relevant here. However, as the outcrop of basal beds within the reservoir basin occurs only along the north eastern edge of the site, it may be more economical to form an impermeable seal over the outcrop, as proposed for Site 18. From the investigation, the western edge of the outcrop may coincide with the upstream toe of the embankment. In this case, the embankment fill could be extended out in the form of a blanket over the basal beds, this detail being similar to that described in Section 7.4 Site 18, where the basal beds run under the upstream toe of the dam.

The Plateau Gravel which occurs in the south west corner of the site would need to be removed under part of the embankment, so as to permit the effective cut-off into the impermeable London Clay below.

If this site were to be developed, trenches should be dug along the upstream toe of the north eastern embankment in order to ensure that no additional work would be required within the reservoir basin. If the basal beds extend further south westwards, it would be necessary to excavate the top 3m or so and replace this material with an effectively impermeable clay.

The material from Borehole 10 in the proposed borrow area has a high natural moisture content compared with Plastic Limit and optimum moisture content. Further tests would be required to confirm that material from this area

could in fact be used for construction, or whether it would be necessary to relocate the borrow area.

7.6 Site 20

The proposed cross-section and plan for this solution are shown on Figure 12. The ground conditions are detailed in Appendix I.

Owing to the topography of the site, a fully bunded solution is the only one possible.

This is the only site where any appreciable quantity of gravel has been encountered, sufficient to be considered for use as a main fill material. The presence of this well-graded gravel, containing about 20% of fines, should enable steeper slopes to be used for the embankment profile. A clayey silt or sand occurs below the gravel, and this could be used as an intermediate fill between the outer gravel zone and the inner clayey core, as indicated in Figure 12. The selection of fill materials, as between the core and the intermediate zone, might be a matter of on-the-spot decisions by the site supervisory staff.

The precise quantities of gravel and intermediate zone materials available are difficult to assess on the basis of the information gained in the study, owing to the variability of the strata between boreholes. Therefore, the supplementary investigation preceding the design stage, should this site be developed, would require to incorporate a survey of potential fill materials, for which purpose trial pits would probably be the most effective means.

Borehole 3, in the middle of the Site, revealed neither gravel nor any substantial depth of material suitable for the intermediate zone referred to above.

However, the limited laboratory test data on the underlying London Clay obtained from samples from this site indicate that it may have a somewhat higher sand content than on other sites and may be suitable for the intermediate zone, though this requires checking.

8.0 ESTIMATE OF COSTS

8.1 Summary Table

The quantities and estimates for the various proposals are listed in Table 2 overleaf. This is broken down into component elements for convenience in examining the detailed make up of each total.

8.2 Estimates

The estimates have been based on those used in the Engineering Report on the Southampton Area. They relate to costs current in November 1976, so that the resultant summary total can be compared with those in that earlier report.

8.3 Summary

The overall estimated costs and the cost per unit volume stored are as follows:-

<u>Site No.</u>	<u>£-Total Cost</u>	<u>£-Cost/m³ Stored</u>
15	2,075,000	0.60
17(1)	4,342,000	1.12
17(2)	1,658,000	0.87
17(3)	3,100,000	0.73
18(1)	3,177,000	0.36 - 1
18(2)	3,256,000	0.53 - 2
19	1,948,000	0.70
20	6,546,000	0.55 - 3

The original arrangement on Site 18(1) with a total storage of 8.8 Million m³ is the most economical in terms of cost per unit volume. The smaller sites such as 15 are penalized to some extent by pipeline and pumping costs which are just as great as those required for the larger sites. Site 18(1) and 18(2) costs would increase by about 20% if the additional pumpsets as Bedhampton and mains to Farlington were to be included in this first cost.

9.0 CONCLUSIONS AND RECOMMENDATIONS

The 1977/78 East Hampshire Reservoir Site Investigation covered 8 possible solutions on a total of 5 different sites. These sites had already been identified in a previous Report. No work was done in looking for further additional sites.

The overall conclusions of the study bear out the previous work of the Portsmouth Water Company in confirming their assessment of the preference for Site 18. There are nevertheless certain problems concerning the foundations - applicable to a certain extent to all or most of the East Hampshire sites but applying rather more strongly to Site 18 - which would require special attention before final design decisions could be made. Some account has been taken of these in evaluating this site in comparison with the others, though the basis of comparison, in terms of parameters some of which are not quantifiable, is a matter of subjective judgement.

It is suggested that Site 18 should be preferred by the Authority for retention for possible future reservoir use, and that Site 20 should be maintained as a standby site until the use of 18 is confirmed. The remaining Sites 15, 17 and 19 can be abandoned for reservoir use as and when required.

It cannot be too strongly emphasized that the cost estimates are given for comparative purposes only, and costs considered to be common to all sites, within reasonable estimating accuracy, are excluded.

10 ACKNOWLEDGEMENTS AND REFERENCES

10.1 Acknowledgements

We wish to thank the following for the assistance and co-operation in the carrying out of this investigation:-

Southern Water Authority - Directorate of Resource Planning.

Portsmouth Water Company

All landowners and tenants concerned.

Southern Electricity Board.

Post Office.

Southern Gas Board.

Forestry Commission.

Ready Mix Concrete.

Institute of Geological Sciences.

Department of Transport, South Eastern Road Construction Unit;
Hampshire County Sub-Unit.

Dr. A.B. Hawkins Geological matters

Professor J.K.T.L. Nash Soil Mechanics matters

Professor R.E. Gibson Pore pressure problems

Ms. Janie Thomas Landscaping

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Mr. J.R. Grimshaw

For most of the period occupied by this study and the earlier one of the Test and Ichen Sites, the Project Engineer was Mr. J.R. Grimshaw and by far the greater part of the strategic appreciation of the studies as well as the basic design concepts developed were his responsibility and very largely the results of his own work. In the latter part of 1977 Mr. Grimshaw decided to leave Mander, Raikes and Marshall in order to take

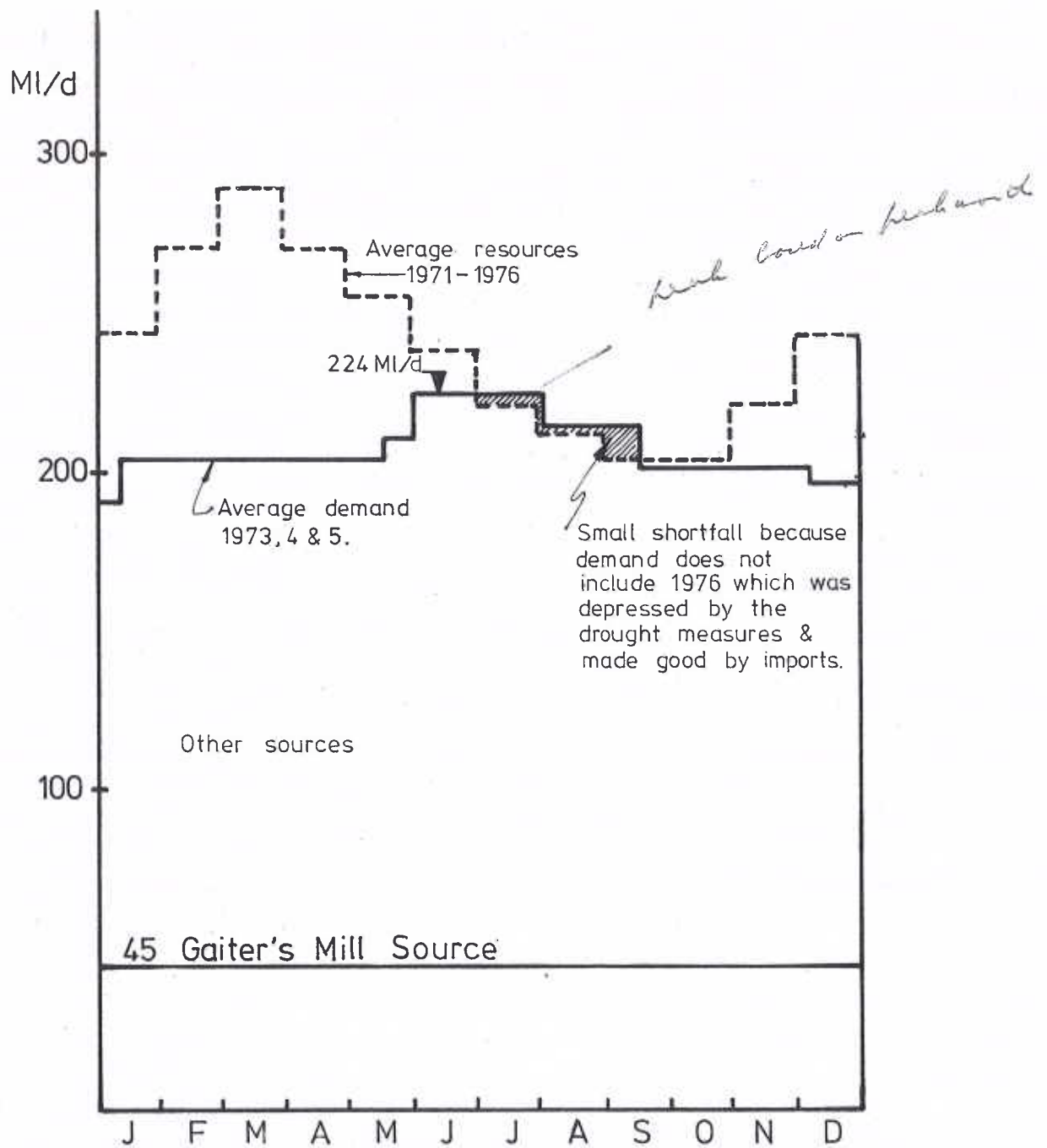
a leading part in the development of a new practice, but undertook to assist in the completion of the two reports then in hand, namely the present one and the February 1978 General Report covering this and the November 1976 reports. Grateful acknowledgement is made of his earlier work whilst in the employment of the Consultants and the vital role he has continued to play since his departure in the preparation of the two reports, without which it is difficult to see how they could have been completed in their present form or by the date required. We have pleasure in wishing him every success in his new practice.

10.2 References

A Regional Engineering Geological Study of the London Clay in the London and Hampshire Basins - Burnett A.D. and Fookes P.G., 1974, Quarterly Journal of Engineering Geology, Vol.7, pp. 257-295

Some empirical relationships between drained friction angles, mechanical analyses and Atterberg Limits of natural soils at Kainji Dam, Nigeria - Humphreys J.D., 1975, Geotechnique 25, No.3, pp. 581-585.

PRESENT POSITION IN PORTSMOUTH WATER COMPANY (HAMPSHIRE) AREA



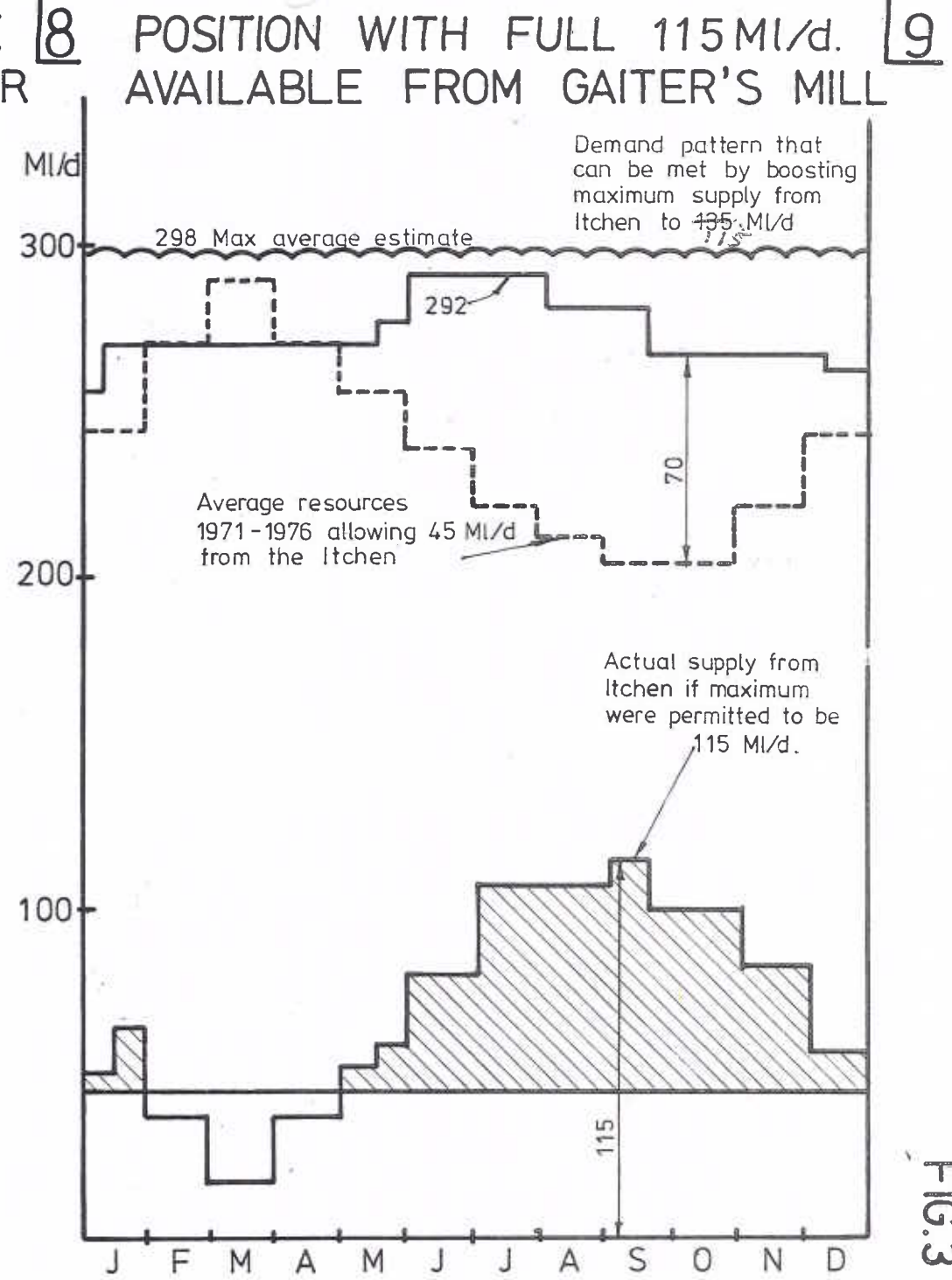
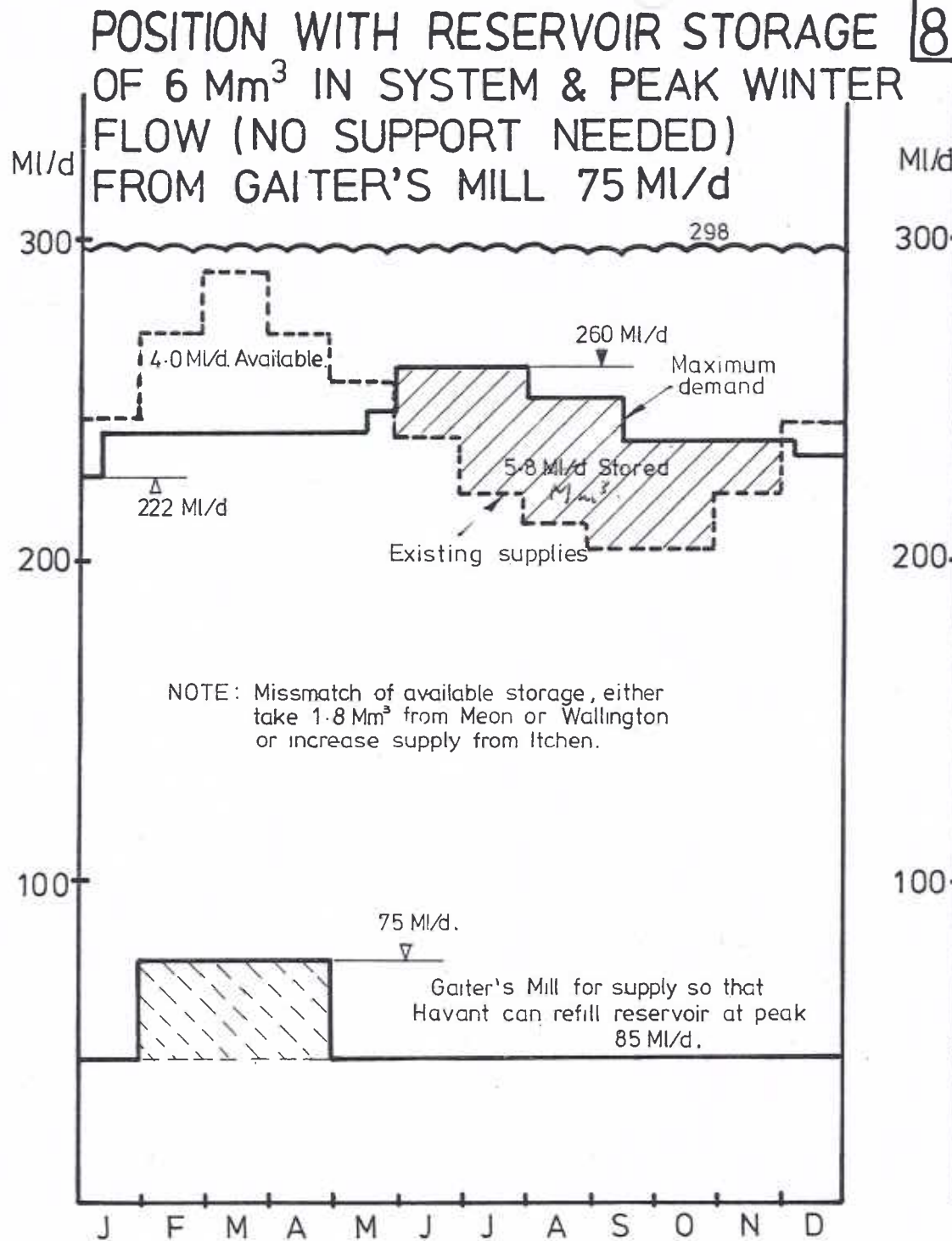


FIG.3

FIG. 4

PLAN SHOWING ARRANGEMENT OF RESERVOIRS WITHIN THE EXISTING SUPPLY SYSTEM SHOWN SIMPLIFIED AND SCHEMATICALLY. RELIABLE YIELDS SHOWN IN ML/D.

FIG. 4

PLAN SHOWING ARRANGEMENT OF RESERVOIRS WITHIN THE EXISTING SUPPLY SYSTEM SHOWN SIMPLIFIED AND SCHEMATICALLY. RELIABLE YIELDS SHOWN IN ML/D.

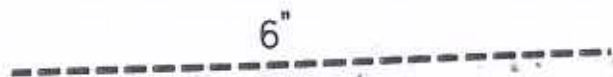
PLANS OF RESERVOIR PROPOSALS 1:5000

KEY TO SERVICES

Note - Services are shown as either existing or proposed routes.
Diversions are not shown.



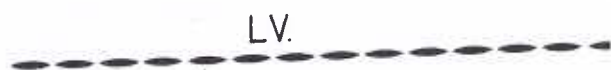
SEWER (with diameter)



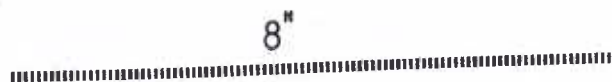
WATER MAIN (with diameter)



11 kV. POWER LINE



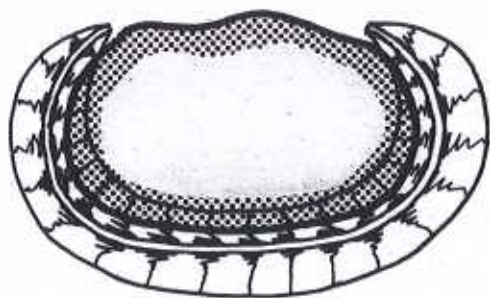
LOW VOLTAGE POWER LINE



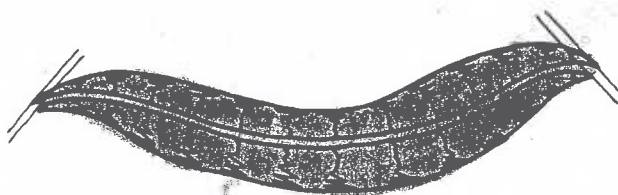
GAS MAIN (with diameter)



PROPOSED SEWER



RESERVOIR AREA



RIVER DIVERSION

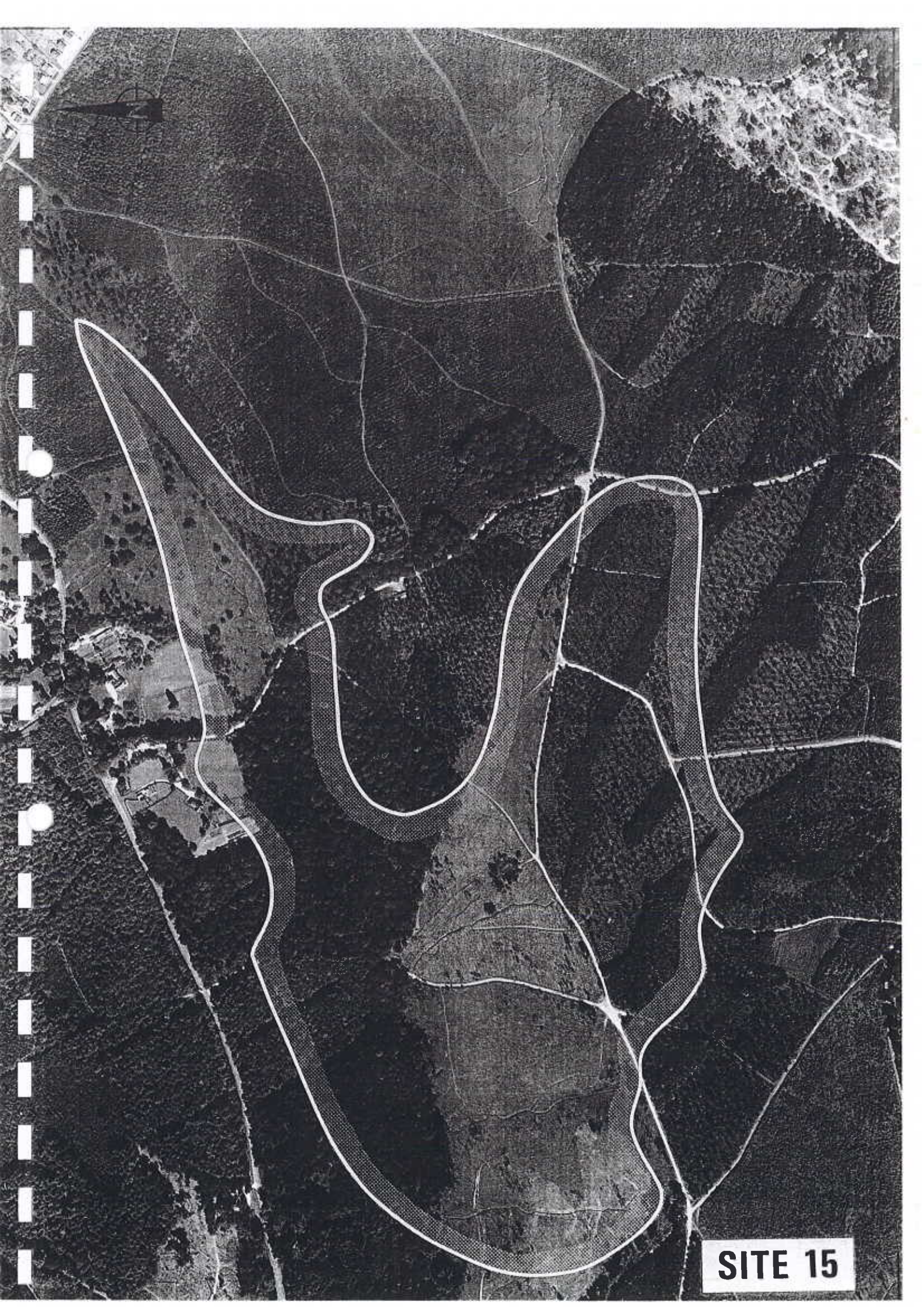


WATER CONTROL

The aerial views are reproduced from photographs taken by B.K.S Surveys Limited for Hampshire County Council 1971.

The Scale of the photographs is approximately similar to that of the plans shown in Figs 5 - 12, - 1:5000.

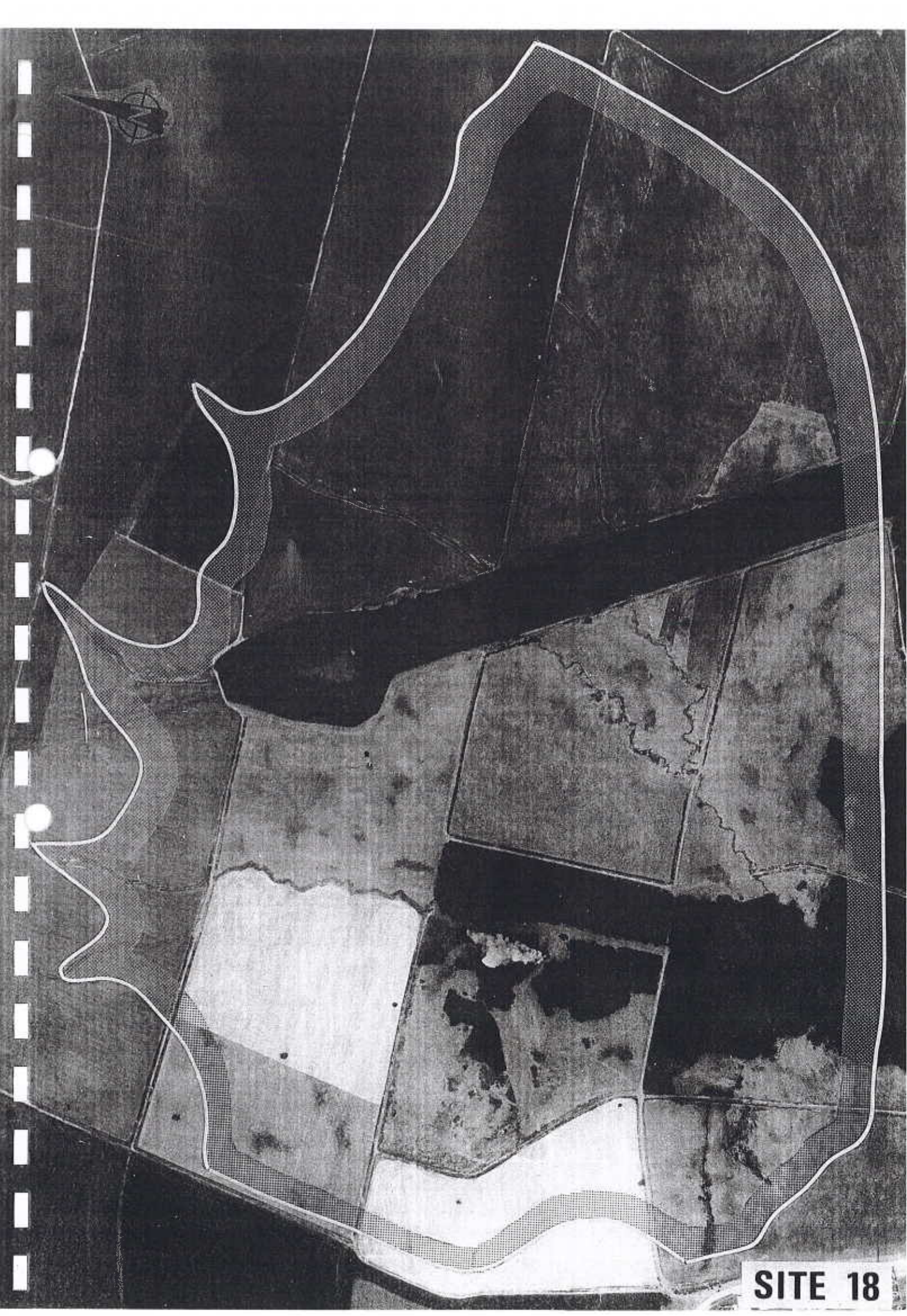
The white line depicts the approximate line of the Top Water Level of the completed reservoir.



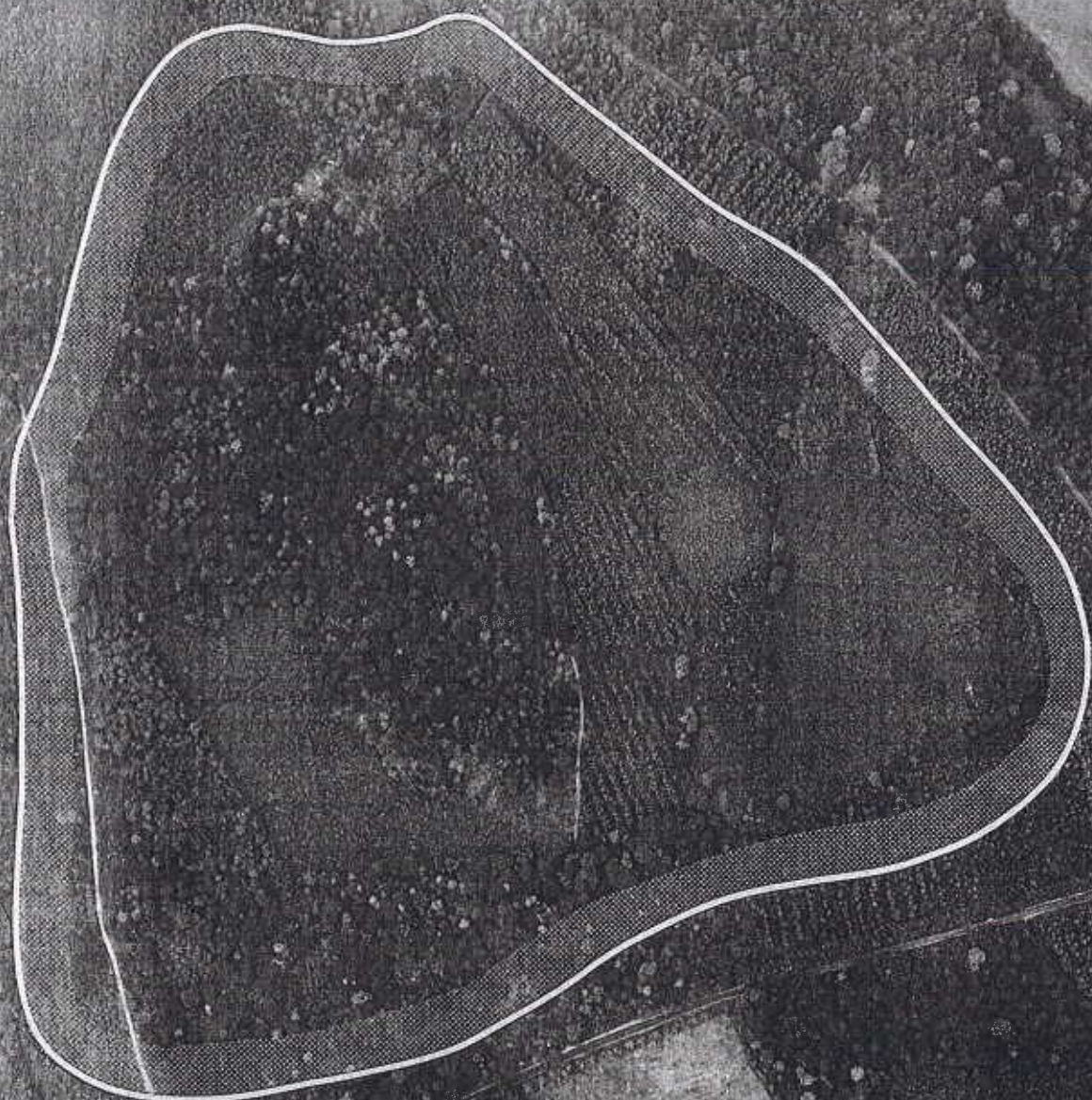
SITE 15



SITE 17



SITE 18



SITE 19



SITE 20

APPENDIX I

Site Investigations and Laboratory Tests



Visit to borehole on Site 19 - 4th November, 1977

From left to right.

I.J. King (MRM), R.B. Armstrong (S.W.A), J. Humphreys (MRM)
C.J. Cotton (S.W.A), D.M. Giles (S.W.A.), P. Arnall (F.E.)
and J. King - (P.W.C.) obscured by rig.

APPENDIX I

TO

TECHNICAL REPORT

ON

RESERVOIR SITE INVESTIGATION

EAST HAMPSHIRE

1977-78

APPENDIX I

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APPENDIX I

SITE INVESTIGATIONS AND LABORATORY TESTS

I.1.0 EXISTING INFORMATION

I.1.1 Geological Records

The geology of these five sites is indicated on the Institute of Geological Sciences 1:63,360 Sheet Number 316; Fareham.

The map indicates that the relevant solid deposits are Tertiary Strata of Eocene age, consisting of a variety of sediment types from marine to fluvial. At present the Hampshire Basin is being re-surveyed by the Institute of Geological Sciences who are attempting to make some recategorisation of the deposits. At present, however, it is necessary to use the established categories and boundaries which may subsequently need modification. The lithology of the individual formations can be summarised as follows:

Bagshot Beds:	Sands with impersistent layers of over-consolidated fissured clay, some gravel and cobbles becoming more abundant towards the top.
London Clay:	Over-consolidated fissured clay, silts and silty sand with occasional segregation nodules or bands of calcareous mudstone or argillaceous limestone.
Reading Beds:	Over-consolidated fissured clays and silty sands with bands of concretionary ironstone and beds of pebbles and gravel.

The London Clay in the Hampshire Basin was deposited in near-shore or estuarine conditions, in contrast to the open marine situation of the London Basin. Lithologically therefore, it is more diverse and in some instances it is indistinguishable from the adjoining formations on the basis of lithology alone.

Drift deposits are present on four of the five sites. These deposits consist of River and Valley Gravel, Plateau Gravel, Brickearth and possibly Coombe Deposits.

I.1.2 Site Investigation Report for Site 18

An investigation was carried out for the Portsmouth Water Company on Site 18 in 1962, by Pre-Piling Surveys Limited. A report on the feasibility of this Site was written by Edgar Morton and Partner in 1962; and Professor Rowe wrote a supplementary report on the soil parameters to use in the design.

I.1.3 Site Investigation for the A3 (M)

Investigations have been carried out for the South Eastern Road Construction Unit (Hampshire Sub-Unit) in connection with the A3(M) and borehole information in the London Clay and Reading Beds have been made available to the Consultants. The road is at present under construction and a visit was made to the site to discuss some of the construction problems with the Materials Engineer from the Sub-Unit.

I.1.4 Site Investigation Report for A27(M)

Investigations were carried out for the South Eastern Road Construction Unit (Hampshire Sub-Unit) in connection with the proposed A27(M) in the Warblington area. This proposed road would pass beside the embankment on Site 20 and was

one of the criteria used in positioning the embankment.
The borehole information in this area from the road
investigation was made available to the Consultants.

I.2.0 SITE INVESTIGATIONS

I.2.1 Objectives

From a study of the potential reservoir capacities and the existing ground profiles, it was decided that the best solution on four of the five sites would constitute an embankment dam, whilst for the remaining site (Site 20) a fully bunded reservoir would be required.

The site investigations were designed to provide the following information:-

- (i) thickness of any drift deposits beneath the dams, to assess the quality and quantity of material which would need to be excavated and run to spoil;
- (ii) general nature of the solid deposits, to determine their suitability as fill materials, the optimum method of excavation and the feasibility of forming cut-offs where necessary;
- (iii) permeability of the solid deposits, to assess leakage, the depths of any cut-offs required and the groundwater flow pattern on draw-down;
- (iv) groundwater levels and chemistry;
- (v) shear strength parameters for calculations of stability of embankments and foundations.

I.2.2 Field Work

Cable tool percussive boring was selected as the primary method of ground investigation and proved to be an entirely satisfactory and appropriate method.

Within the Tertiary strata, continuous undisturbed samples were taken, i.e. at intervals of about 0.5m. Where the strata were very sandy it was not possible to obtain undisturbed samples. Occasionally, hard bands of mudstone or argillaceous limestone were encountered but these did not necessitate the use of rotary drilling equipment.

Where appropriate in-situ permeability tests were carried out in the boreholes. In the Tertiary strata such tests were only considered worthwhile in zones of relatively high permeability. Emphasis was placed on the recording of groundwater during boring operations. A number of piezometers were also installed and the readings taken to date are presented in Table 8.

I.2.3 Laboratory Work

As a matter of routine, all bulk and small disturbed samples and the ends of undisturbed samples were examined by the site investigation Contractor, so as to enable the borehole records to be compiled. The Contractor also prepared descriptions of any samples used in the laboratory tests, including undisturbed samples. In addition, a number of undisturbed samples of Tertiary strata were extruded and split for detailed examination by the Consultants.

Selected disturbed and undisturbed samples were subjected to standard laboratory tests for moisture content, particle size distribution and Atterberg Limits. These tests were aimed at providing a means of correlating the results of other tests, i.e. for compaction properties, shear strength and permeability, as well as checking sample descriptions based on visual examination.

The compaction tests were standard, except that an assessment of the consistency of the compacted soils was

made using a hand penetrometer.

The shear strength tests comprise the following:-

- (i) consolidated undrained triaxial tests on 38mm diameter undisturbed and remoulded samples of Tertiary strata;
- (ii) drained triaxial tests on 38mm diameter undisturbed samples of Tertiary strata;
- (iii) consolidated undrained triaxial tests on 100mm diameter undisturbed samples of Tertiary strata;
- (iv) undrained triaxial tests on 38mm diameter undisturbed samples of Tertiary strata;
- (v) drained shear box tests on 62mm by 62mm undisturbed samples of Tertiary strata.

In the permeability tests, selected 102mm diameter samples were set up in the triaxial apparatus and consolidated under a pressure equivalent to overburden pressure. They were saturated before a direct measurement of a vertical permeability was made by passing a flow of water through the sample under a small differential head. No attempt was made to measure the horizontal permeability of non-homogeneous soils, as it would only have been possible to test 38mm specimens, obtained at right angles to the axis of the 102mm undisturbed samples. Such specimens would generally have been too small in relation to the macro-structure of the soil and would also have suffered excessive disturbance.

No consolidation tests were considered necessary on the Tertiary strata. One test was carried out on an alluvial peat.

Chemical analysis of groundwater samples were carried out in the Southern Water Authority's laboratory at Winchester.

I.2.4 Results

Foundation Engineering Limited will be producing a factual report containing the following information:-

- (i) Borehole Records;
- (ii) Borehole Location Plans;
- (iii) Results of in-situ Tests;
- (iv) Results of Laboratory Tests.

Detailed descriptions of some of the undisturbed samples, prepared by the consultants, are presented in Section I.4 of this Appendix.

Some care is needed in interpreting the geological descriptions of the Tertiary strata. Generally, the descriptions given in the borehole records are compatible with those given in Section I.4, but some differences of detail are evident. In many cases these can be attributed to variations between the samples used for logging by the respective personnel and the necessity of grouping together thinly bedded or laminated materials under a single stratum description. Disturbed samples or the ends of undisturbed samples do not give as good an impression of the structure of the strata as split undisturbed 102mm samples and this leads to silty sand with thin clay bands being described, for example, as silty sand. The Consultant's description of some of the samples as very weak mudstone is not at variance with the stiff fissured silty clay recorded on the borehole records, this being a difference in terminology only. The

current trend is to call any stratum with a clear structure a very weak rock, rather than describing its constituent components; although the method described in the current Code of Practice is the latter method.

The results of the chemical analyses of groundwater samples are presented in Table 9.

I.3.0 INTERPRETATION OF GROUND CONDITIONS.

I.3.1 General

Before considering in detail the ground conditions on individual sites, the relevant characteristics of each of the main geological soil types, as disclosed by the investigation, are discussed as follows: -

I.3.1.1 Drift

As the drift encountered varies from site to site, this will be described under each site heading;

I.3.1.2 Tertiary Strata

The investigation has emphasised the variability inherent in the lithology of the Tertiary strata.

In areas where the presence of Bagshot Sands is indicated by, or maybe inferred from, the Geological Sheet, the strata consist of fairly uniform fine to medium sand with a relatively small clay or silt content.

The lithology of the London Clay is known to be very variable and whilst essentially a silty clay, it consists in places of silt and sand bands. The clay content of this formation in the five sites seems to be higher than in the sites investigated in the Southampton area. A bed of coarser material is found at the base of the London Clay and will be referred to in subsequent sections as the basal beds; being coarser, these beds are more permeable and are significant when considering potential seepage from reservoir basins. The London Clay is known to have been deposited in such a manner that lateral facies changes will occur as well as vertical changes. The only distinct pattern to emerge from this investigation was the occurrence of the basal beds

at the base of the London Clay immediately overlying the Reading Beds.

The Reading Beds were found to be clay rich and to have a more uniform lithology than the London Clay.

The junction of any of these deposits is sometimes interdigitated, thus making it difficult to draw the boundary between one formation and another with any certainty.

The clays of the London Clay and the Reading Beds are usually stiff to very stiff and are frequently fissured. In general the fissures are closed, but they show occasional evidence of water seepage and occasional evidence of movement (in the form of smooth, shiny, sometimes lineated surfaces). This movement is thought to have occurred on a small very local scale, thus it is unlikely to have any major effect on embankment stability. However, the presence of these surfaces should be noted and may require further investigation, as discussed elsewhere in this Report. The strata sometimes contain carbonaceous material, occasionally replaced to some degree by iron pyrites. The London Clay contains shells and shell fragments, sometimes present in distinct bands, as well as occasional mudstone and lime stone bands or nodules.

The schematic geological sections presented for each site are an attempt to correlate the various geological formations and present a very brief description of the strata encountered in some of the boreholes. Not all the boreholes are shown on the sections, as only the more relevant sections are presented in this Report. As the strata on these sites seem to be more amenable to this lithological division than those encountered in the previous investigation in west Hampshire, this method of presentation has been selected in preference to the method used in the Engineering Report of November 1976, on the previous study.

The results of all the laboratory tests carried out are presented in Tables 1 to 5: a separate Table being given for each site.

The compaction tests, compared with the natural moisture contents, indicate that, for much of the Tertiary strata, care will have to be taken in excavating, transporting, placing and compacting the material as fill. As in many cases the strata possess natural moisture content in excess of optimum, an increase in moisture content will soften the material and make it difficult to handle and achieve the required dry density in the embankment. As most of the potential fill materials lie beneath the groundwater table during their excavation, there will be a tendency for an increase in moisture content to occur as water entering the excavation becomes mixed with, or absorbed by the soils

In the laboratory direct measurements of vertical permeability have yielded values given in Table 6. They span a fairly wide range, from less than 10^{-9} m/sec to 10^{-6} m/sec. In-situ measurements were selectively carried out in relatively permeable zones and gave values towards and above the upper end of this range (Table 7). The field permeability measurements give a good impression of the horizontal permeability of the strata and they may also reflect the influence of seepage along discontinuities (i.e. fissures etc.) within the strata. In the case of in-situ tests, siltation and clogging of the strata in the boreholes together with sometimes unreliable definitions of the equilibrium water level present difficulties in performing as well as interpreting the tests. The laboratory permeability gives a measure of the vertical permeability of the strata and is thus significantly affected by any small bands of clay which may be present in the sample. When considering potential seepage from a reservoir basin in these strata, as the dip of the strata is very gentle the more significant permeability is the horizontal permeability. Some of the

laboratory permeability tests ordered were cancelled because on extrusion of the samples clay bands were observed which would have distorted the results. The Contractor's report will provide descriptions of the samples which were tested and those on which it was decided not to proceed with the test.

The shear strength test results are summarised in Tables 1 to 5 and their relevance to the solutions proposed are detailed in Section 7 of this Report. The shear strength parameters quoted in the tables are peak values for the materials involved. Initially it was thought that the value ϕ' for the London Clay was related to the height of the sample above the basal beds - an interpretation of part of Professor Rowe's 1962 report. When the present results were plotted on a similar basis, however, it was seen that no such relationship was evident.

In studying the results more closely there was found to be a tentative empirical relationship between the plasticity index of a sample and the value of ϕ' recorded for the same sample. There was a slightly better agreement between ϕ' and a parameter "j" which reflects certain characteristics of the grading of the sample. This parameter has been used elsewhere and although no scientific basis for its validity can be claimed, it is quoted here as a matter of possible interest for the enthusiast:-

$$j = a + 2 \left(\frac{b-a}{\sqrt{a}} \right)$$

where a represents the percentage smaller than 0.002mm

b represents the percentage smaller than 0.02mm

I.3.1.3. Groundwater

Groundwater levels recorded during the investigation are indicated in the schematic geological sections, Figures 1 to 5. These levels comprise those recorded during normal drilling operations in sufficiently permeable

strata, during in-situ permeability tests and in piezometers installed on completion of drilling. Where no groundwater level is given this does not usually indicate the absence of groundwater, but rather the absence of a good record of its location. Where possible, the elevation of the stratum in which the measurement of groundwater level was made is also indicated. The piezometer readings are presented in Table 8.

Data from the chemical analyses of groundwater samples are presented in Table 9.

I.3.2 Individual Sites

I.3.2.1 Site 15

The borehole locations together with schematic geological sections are shown in Fig.I.1. The site lies within a wooded valley and is underlain by London Clay except for the extreme north east where Reading Beds were encountered near the surface. The beds dip very gently south south west. The Reading Beds were only encountered at depth in Borehole 3. Gravel terraces are shown on the 1:63360 geological map but none were encountered during the investigation. As these gravel terraces lie on the London Clay, even if they have high permeability, there should be no significant seepage from the reservoir due to these deposits. As the dip of the beds is southwards and any leakage through the coarser bands has a very long path to travel, any leakage from northwards to the Meon valley is likely to be prevented by clay horizons.

The London Clay and the Reading Beds are generally very clay rich although silty sand bands were encountered in Boreholes 5, 8, 9 and 3. These sand bands are thought to be local and lateral variations in the general grey silty clay except for Borehole 3 where they are considered to be the basal beds of the London Clay. The basal beds of the London Clay are known to be more sandy and permeable. A falling head permeability test at 33.0m in Borehole 3 gave a permeability

for the sand of 3×10^{-3} m/sec whilst tests at 27.5m and 37.0m gave permeability in the order of 10^{-6} m/sec. Thus, the more permeable zone may be quite thin.

If the permeability is assessed from the grading curve at 32.0m using Hazen's formula the permeability would be expected to be in the order of 10^{-2} to 10^{-4} m/sec. This is in good agreement with the measured value.

A schematic section drawn down approximately along the general line of the valley shows the slight apparent dip of the beds down the valley. The geological map suggests that the London Clay is formed into a syncline, thus any seepage path would be very long. The piezometer on Borehole 3, sealed into the sand band, indicates a groundwater table of 3.7m below ground surface. This means that the sand band is already saturated to this level.

When the reservoir is filled if the outcrop of these basal beds within the reservoir has the same permeability as the deposits in Borehole 3 water will seep into these beds and uplift pressure will be exerted on the dam. This uplift pressure will be present under rapid draw-down conditions and precautions should be taken to counteract the effect of these pressures on the stability of the dam. This could be done by means of a relief well system.

The terrain and vegetation were such that it was not possible to place a borehole half way down to the southern abutment. Assuming that boreholes 1, 3 and 5 give a representative indication of the geology, it is likely that 15 per cent of the dam length will be a sandy material. Where this is the case it will be necessary to carry out a cut-off down to the silty clay. The northern abutment slope is 1 in 10 and it is possible that movement has occurred within the slope. In sample 45 from borehole 4, smooth shiny lineated surfaces were observed which probably indicate geological stress effects within the London Clay.

I.3.2.2 Site 17

The borehole locations, together with schematic geological sections, are shown in Figure I.2. The site comprises mainly pasture and arable land and is underlain mainly by London Clay, with Reading Beds outcropping in the south west of the site and Bagshot Sand overlying the London Clay on the higher land to the north. The strata dip gently north east across the site. The geological sheet shows river gravel in the area to the north of Borehole 6. Alluvial gravel deposits were found in the boreholes along the valley floor, numbers 1, 2 and 6; while in Borehole 2 a silty clay containing peat was found overlying the gravel.

This gravel and peat represent former river accumulations and are unlikely to constitute a permeable zone through which a cut-off would have to be constructed. As the peat shows up only in the one borehole, it may well be only a pocket of limited extent, in which case it may do no harm if left in place; whilst it might be expected to consolidate considerably, such consolidation would take place rapidly and thus, if it is indeed a local pocket only, there may be no problem in terms of settlement under the embankment. However, this assumption would have to be checked at the design stage by means of supplementary boreholes. Should the peat prove more extensive than has been assumed, then it may require removal or special treatment, representing an additional cost item not included in this Report.

The 1:2500 plan for the site shows Gravelhole Copse on the northern side of the river on the line of the western dam; as this lies above the present river level, it is probably terrace deposit.

London Clay in the area is generally clay rich and will thus provide a sufficiently impermeable base for the reservoir. The basal beds of the London Clay were coarser and the field permeability tests indicated that this band has a permeability of about 10^{-6} m/sec. The Bagshot Sands

are a mixture of sandy silt and silty sand, sometimes with a little clay; however, in-situ permeability tests indicate that these deposits have a permeability in the order of 10^{-7} to 10^{-8} m/sec. These values indicate that it may not be necessary to provide a deep cut-off, both in view of the low values of permeability and also because any potential seepage path would be relatively long, so that losses would be likely to be very small. To prevent any leakage into the Bagshot Sands, it would be advisable to form a permeable cut-off down to the London Clay underneath the dam. One method of achieving this would be to remove the silty sand, mixing in a small quantity of bentonite and clay and replacing the slurry in the excavated trench. This method is not new and has been successfully used elsewhere.

The piezometer in Borehole 9 indicated that there is a slight artesian head in this area and this would need to be taken into consideration when considering the stability of the northern dam. This artesian pressure will tend to increase when the reservoir is filled, so relief wells would probably be required.

Smooth, shiny lineated surfaces were observed in sample 33 from Borehole 4 (at 11.0m) and the remarks made under Site 15 would also apply here.

I.3.2.2 Site 18

The borehole location, together with schematic geological sections, are shown in Figure I.3.

Previous Studies

A good deal of data for this site was already available in the report of a feasibility study carried out in 1962 by Edgar Morton and Partner, with a report by Professor Rowe on laboratory tests on samples obtained in the course of that study. This earlier work included 20 boreholes which provided a good cover to the development then envisaged (referred to in the present Report as 18(1)). In the 1977 study, it was therefore decided that the supplementary field work required could be limited to a further 4 boreholes only, the objectives being: (a) to investigate conditions in the extreme northern part of the site; (b) to obtain additional information relating to the highest part of the proposed dam; (c) to investigate conditions relevant to an alternative layout - referred to as 18(2) - which was considered worth investigating on the grounds of possible improved environmental aspects; and (d) to obtain some correlation between the previously obtained data and the results of the new investigation, not only on Site 18 but on the other East Hampshire sites also - a mutual calibration of data description and evaluation.

Correlation between Previous and New Data

The data from the new boreholes were in good agreement with the earlier results, with London Clay overlying Reading Beds, separated by the more permeable basal beds about 2.4m thick, all dipping at about $1\frac{1}{2}^{\circ}$ as given by Edgar Morton.

Basal Beds

The basal beds contain water which was found to exhibit artesian pressure in the lower part of the valley. A piezometer

was installed in an attempt to record the maximum value of the artesian head, but as this rose above the top of the standpipe its value can not be given with any confidence. These beds outcrop across the reservoir basin traversing the line of the dam (this applies to each of the two alignments considered) and also outcrop outside the reservoir basin in the valley to the east, some 1500m from the reservoir, though with a head difference of probably 10-13m over this distance any hydraulic gradient over this latter potential leakage path would of course be small. Nevertheless, the traversing of the dam axis by the outcrop gives rise to a cut-off problem, discussed in the appropriate section of this Report.

Potential Fill Materials

As with all the other site materials studied, the moisture content of the in-situ clays, both London Clay and Reading Clay, tends to be higher than the optimum for compaction, and tends generally to be rather higher than the Plastic Limits by perhaps 2 or 3 percent, which places it near the limit for acceptable fill material, though its use is certainly feasible given some attention to the most appropriate choice of construction plant and proper control over construction methods so as to avoid any unnecessary increase in moisture content during construction.

Rowe's report on laboratory testing gives some interesting comments on the respective properties of the two formations, Reading and London Clays, as well as a suggested relationship between shear strength parameters of the London Clay and its height above the basal beds. However, the results of the 1977 work so far received suggest that a better correlation exists with the constituent components of samples regardless of depth. Again, as with all the East Hampshire sites, the clays tend to exhibit somewhat lower shear strength

I.3.2.4 Site 19

The borehole locations, together with schematic geological sections, are shown on Figure I.4. This site, which is at present wooded, lies near the brow of a gentle rise. The London Clay/Reading Beds interface crosses the north east corner of the site and Plateau Gravel is indicated on the geological map in the vicinity of Borehole 1.

The boreholes confirmed the presence of these deposits and sections across the site confirmed the south south west dip of the beds. The London Clay was found to be predominantly silty clay with coarser deposits forming the basal beds encountered at 1.7m in Borehole 3. The in-situ permeability of this zone was found to be 10^{-6} m/sec and as it may outcrop within the reservoir basin it is a potential source of seepage, especially as it appears, from the geological map, to outcrop also at lower elevations north of Westbourne.

The whole of the eastern part of the dam will be founded on basal beds of the London Clay which are generally silty sand, so it may be necessary to install a cut-off down to the more impermeable silty clay below these beds. This cut-off would be generally some 7m in depth.

Smooth, shiny, lineated surfaces were observed in several samples from this Site, so shear strengths of the clayey beds will probably be nearer those recorded on other sites. The samples on which the triaxial tests were performed had a significant sand content, which explains why the shear strength parameters are higher than those recorded for other sites.

I.3.2.5 Site 20

The borehole locations, together with the schematic geological cross-sections are shown on Figure I.5. This site comprises low lying flat arable land. The boreholes confirmed the presence of London Clay beneath the Drift

characteristics than in the case of the Test and Itchen sites.

Foundations

The preceding remarks about shear strength apply particularly to the in-situ properties, and more so at this site, perhaps, than the others. Rowe had already commented on the low measured values of the shear strength parameter ϕ' , with laboratory "peak" values as low as 15° . A value of 16° was obtained from a shear box test carried out as part of the recent study and other values from triaxial tests ranged from 18° to 20° .

A few slickensides were discovered in certain of the clay samples examined in the laboratory in company with Dr. Hawkins (samples 13 and 48 from Borehole No.3) and from discussions with engineers involved with the motorway construction nearby and other sources, there are reasons for believing that the in-situ clays contain some zones - each probably very limited indeed in extent, though this would need confirmation - which have undergone a certain shear deformation in the past, so that their shear strengths may locally lie somewhere between the laboratory "peak" and "residual" condition.

In discussion of this problem with Professor Nash and Dr. Hawkins, it was concluded that the available evidence is insufficient to give any good grounds for assuming that such zones, or small patches, of sheared or partially sheared clays would occur with sufficient frequency, or in a sufficiently systematic orientation, seriously to reduce the overall shear strength available to withstand slippage, even on a preferred potential shear surface in the foundation of a continuous embankment dam; while a slip failure in an embankment forming part of the motorway earthworks nearby involved embankment slopes of $2\frac{1}{2}$ to 1, appreciably steeper than those contemplated for a dam at this site. Nevertheless a rather more conservative approach to the preliminary design used for estimating purposes seems appropriate here than for the other sites in the group studied.

Deposits. These consist of Brickearth and Coombe Deposits. These are typical periglacial deposits; the Brickearth having accumulated during cold dry spells, while the Coombe deposits were accumulated during cold wet periods. As a result, the dominantly windblown clays, silts and sands of the Brickearth interdigitate in places with the gravelly soliflucted Coombe Deposits. The underlying London Clay is thought to dip slightly northwards, though no determination of the dip angle was possible from the boreholes.

The London Clay is generally a very clayey silt or silty clay. Some of the samples examined, however, were rather sandy and this could mean that locally a deeper cut-off might be required. This coarser material could be incorporated in an intermediate zone in the dam cross-section, next to a central core comprising the impermeable silty clay.

The early appraisal of this Site, based on the ratio of fill volume to storage capacity, indicated that this was unlikely to be one of the preferred sites, though other factors have subsequently resulted in its being uprated. As the priorities for laboratory testing were largely based on the preliminary appraisal, the data now available from the tests ordered on samples from this Site are somewhat on the sparse side.

Any sandy zones at depth, such as that encountered at 21m in Borehole 2 and having an in-situ permeability of about 10^{-5} m/sec are unlikely to cause any cut-off problems as long as the reservoir bed is rendered impermeable during construction, so as to prevent seepage penetrating to the underlying coarser zones. The only shear strength parameter determined for this site was obtained on a sample containing some sand, which would explain the high resulting value. As with the other sites, some supplementary sampling & testing would be required for design purposes in the event of this site being developed; in the meantime, it is considered reasonably safe to use parameters based on data

from the other sites when contemplating the shear strength of the clay zone in the embankment cross-section considered.

Smooth, shiny, lineated shear surfaces were noticed in some samples and earlier remarks in this Appendix would apply here also.

The more granular material appears to occur in sufficient quantities to be incorporated in the embankment as a discrete zone in the outer shoulders, enabling steeper upstream and downstream slopes to be used than on the other sites. It would however have to be verified as part of the confirmatory work preceding the final design, that the required quantities do in fact occur in sufficiently well-defined zones to provide the requisite quantities assumed in preparing the cost estimates; and that the foundation shear strengths are uniformly adequate to support the higher shear stresses imposed on the foundation by these steeper slopes.

Earlier remarks in this Report about the moisture contents of the London Clay apply equally here.

SAMPLE DESCRIPTIONS

Unless otherwise stated, samples are 102mm diameter undisturbed samples.

Site 15 Borehole 1 No.9 (2.60m)

Stiff brown mottled orange brown silty CLAY with occasional sub-rounded fine gravel in upper half. Some thin (1mm) rootlets and grey clay along certain horizons.

Site 15 Borehole 1 No.17 (5.20m)

Very weak, medium brown, highly to completely weathered slightly micaceous MUDSTONE with extremely closely spaced discontinuities. Occasional shell fragments and one thin (2mm) brown silty band.

Site 15 Borehole 2 No.13 (4.10m)

Very weak, medium brown, highly to completely weathered slightly silty MUDSTONE with extremely closely spaced discontinuities and occasional gypsum crystals. Some grey gley along certain discontinuities.

Site 15 Borehole 2 Nos.17 and 21 (5.30m & 6.50m)

Very weak, medium brown, highly weathered slightly silty MUDSTONE with extremely to closely spaced discontinuities and occasional gypsum crystals and shells. Bands (up to 3mm) of light brown silty fine sand. Additional occasional isolated lenses of silty fine sand. Sample 21 has more of a mudstone structure.

Site 15 Borehole 2 Nos. 29 and 25 (8.90m & 10.70m)

Very weak, grey highly to completely weathered silty MUDSTONE with extremely to closely spaced discontinuities and occasional shell fragments. Sample 29 contains irregular lenses (2) of light brown silt. Sample No.35 siltier.

Site 15 Borehole 3 No.13 (4.40m)

Stiff to very stiff mottled orange brown/medium brown slightly silty CLAY with occasional small gypsum crystals and a small amount of gley.

Site 15 Borehole 3 No.17 (5.70m)

Very weak, grey completely weathered slightly silty MUDSTONE with extremely closely spaced discontinuities with occasional shells and rare gypsum crystals and carbonaceous lenses. One (1-3mm) light grey fine sandy silt band at an angle of 45 degrees.

Site 15 Borehole 3 Nos.9 and 41 (9.45m & 13.45m)

Very weak, grey, completely to highly weathered slightly silty MUDSTONE with extremely closely spaced discontinuities with rare shells and gypsum crystals. One calcereous claystone concretion 75 x 20mm at 100mm from top in 29. At top of sample 41 carbonaceous branch, sample 41 becomes silty rather than slightly silty.

Site 15 Borehole 3 No.51 (17.70m)

Very weak, grey, slightly weathered MUDSTONE with very closely to closely spaced discontinuities and very occasional light brown silty dust (this is rare in volume) and rare fine gypsum crystals.

Site 15 Borehole 3 No.61 (20.85m)

Compact very silty fine SAND with some (up to 12mm) thick mudstone bands and thin lenses of mudstone.

Site 15 Borehole 3 No.65 (22.35m)

Very weak grey moderately to highly weathered silty MUDSTONE with silty sand bands and lenses. Occasional glauconite specks in silty sand and very rare haematite, rare fine subrounded gravel.

Site 15 Borehole 3 No.77 (25.55m)

Stiff to very stiff, brown light blue grey, red mottled clayey SILT.

Site 15 Borehole 3 No.83 (27.80m)

Loose brown occasionally grey at top silty fine to medium SAND with some silt. In upper 50mm is silty clay with some sand and rare fine angular gravel.

Site 15 Borehole 3 Nos. 89 and 95 (29.85m & 32.36m)

Loose mottled various browns and greys, slightly silty fine to medium sand. Medium towards base of sample 95 the rest being fine sand. Base of sample 95 grey medium SAND.

Site 15 Borehole 3 No.100 (Bulk) (36.00m)

Brown grey slightly silty fine, medium, coarse SAND.

Site 15 Borehole 3 No.102 (37.80m)

Stiff to very stiff, light and dark grey, mottled brown, in places clayey, SILT with much sand.

Site 15 Borehole 3 No.106 (38.85m)

Stiff to very stiff, dark brown/red brown mottled, occasionally light grey, occasional light grey specks, very silty CLAY and rare gypsum crystals.

Site 15 Borehole 4 No.7 (3.00m)

Firm to stiff mottled brown/grey brown sandy clayey SILT.

Site 15 Borehole 4 No.11 (4.30m)

Very weak, light to medium brown, slightly mottled, highly to completely weathered silty MUDSTONE with occasional shells. 100mm band in middle, moderately calcereous and breaking naturally into material with closely spaced discontinuities.

Site 15 Borehole 4 No.15 (5.65m)

Firm to stiff (variable) dark grey very clayey SILT with occasional shells and cobbled-size fragments of argillaceous limestone at top for 100mm.

Site 15 Borehole 4 No.45 (15.30m)

Very weak grey moderately to highly weathered silty MUDSTONE with closely spaced discontinuities and occasional shells. Some shiny slickensided surfaces.

Site 15 Borehole 4 No.63 (21.15m)

Very weak grey moderately weathered silty MUDSTONE with moderately closely spaced discontinuities. Occasional shell fragments and gypsum crystals.

Site 15 Borehole 5 No.7 (2.60m)

Stiff brown, grey brown mottled orange brown silty CLAY at base about 50mm of weakly cemented calcereous siltstone.

Site 15 Borehole 5 No.14 (Jar) (5.20m)

Light brown slightly silty fine SAND with fine gravel-sized clay lumps.

Site 15 Borehole 5 No.17 (6.05m)

Loose to compact, brown mottled brown grey sandy SILT with a little clay and occasional shell fragments.

Site 15 Borehole 5 No.27 (9.35m)

Firm to stiff dark grey slightly sandy slightly clayey to clayey SILT. Sub-angular medium gravel-sized fragments in pockets in top 100mm. Material brown around gravel (also wetter and softer), and occasional fine gypsum crystals in lower part.

Site 15 Borehole 6 No.3 (1.10m)

Top 125mm: Soft to firm mottled light brown and light grey silty CLAY with some sub-rounded fine to medium gravel.

5mm: of highly organic material.

Bottom of sample: Firm thinly laminated grey/orange brown mottled clayey SILT and silty fine SAND laminae (predominantly silt, 80% plus silt).

Site 15 Borehole 6 No.11 (3.50m)

Stiff red light grey occasional orange brown mottled slightly silty CLAY.

Site 15 Borehole 6 No.17 (5.30m)

Very stiff red, orange brown, light blue grey mottled clayey SILT.

Site 15 Borehole 7 No.5 (1.70m)

Firm to stiff orange brown, brown grey silty CLAY with a little grey and occasional carbonaceous lenses and rootlet holes.

Site 15 Borehole 7 No.15 (4.70m)

Stiff dark grey slightly silty CLAY with occasional shells.

Site 15 Borehole 8 No.19 (5.90m)

Loose light brown/orange brown slightly silty fine SAND.

Site 15 Borehole 9 No.11 (3.50m)

Very weak brown grey/brown moderately to highly weathered silty MUDSTONE with very closely spaced discontinuities and occasional shells and small gypsum crystals.

Site 15 Borehole 9 No.21 (6.50m)

Loose grey slightly silty fine SAND.

Site 15 Borehole 9 No.31 (9.60m)

Very stiff grey clayey fine slightly sandy SILT with some bands of fine sandy silt with occasional shells.

Site 15 Borehole 10 No.13 (3.90m)

Very weak grey brown highly to completely weathered silty MUDSTONE, extremely to very closely spaced discontinuities, with some gypsum crystals, with some grey gleying on discontinuities and occasional fine roots (very localised) (a lot of gypsum).

Site 15 Borehole 10 No.23 (7.15m)

Very weak brown grey moderately to highly weathered silty MUDSTONE with closely spaced discontinuities. Occasional fine sandy silt partings and occasional gypsum crystals.

Site 15 Borehole 10 No.31 (9.75m)

Very weak grey moderately to highly weathered slightly silty MUDSTONE with closely spaced discontinuities, occasional shell fragments and occasional small gypsum crystals, occasional thin (less than 5mm) lenses or bands of silty fine sand.

Site 17 Borehole 1 No.5 (1.70m)

Stiff brown silty CLAY with rootlets holes up to 2mm, with some grey gleying predominantly beside roots but general as well. Occasional small gypsum crystals.

Site 17 Borehole 1 No.15 (4.70m)

Stiff to very stiff grey fine very sandy SILT with a very small trace of clay. Occasional shells.

Site 17 Borehole 1 No.29 (8.90m)

Stiff to very stiff grey fine sandy slightly clayey SILT. Some lenses and occasional bands of silty fine sand. Occasional shells.

Site 17 Borehole 1 No.35 (10.70m)

Stiff to very stiff grey fine sandy SILT slightly clayey becoming sandier with depth (almost some structure).

Site 17 Borehole 1 No.61 (18.50m)

Very weak grey highly weathered clayey SILTSTONE with extremely to closely spaced discontinuities. Occasional shells. Occasional very small gypsum crystals at bottom lens-band of silty fine sand material (up to 8mm) in lower 75mm.

Site 17 Borehole 1 No.77 (23.30m)

Very weak grey moderately to highly weathered clayey SILTSTONE with extremely to closely spaced discontinuities. Occasional very small gypsum crystals.

Site 17 Borehole 2 No.17 (6.10m)

Stiff to very stiff dark grey slightly silty CLAY with occasional shells.

Site 17 Borehole 2 No.29 (9.65m)

Very weak grey highly to completely weathered silty MUDSTONE with extremely to very closely spaced discontinuities. Rare discontinuities slightly shiny.

Site 17 Borehole 2 No.45 (14.90m)

Very weak grey highly weathered silty MUDSTONE very closely spaced discontinuities. Occasional very thin silty fine sand lenses. Occasional shells with a fine gravel-sized pyrite nodule.

Site 17 Borehole 2 No.63 (20.80m)

Top: Loose brown occasionally light grey silty fine SAND, beneath which is a brown occasionally light blue grey very sandy SILT with a trace of clay. Occasional fine rootlets.

Site 17 Borehole 2 No.69 (22.90m)

Laminated to very thinly bedded clayey SILT and silty fine SAND. Clayey silt proportion 25% becomes fine to medium sand in last 80mm.

Site 17 Borehole 2 No.79 (26.20m)

Irregular laminated to thinly bedded silty fine SAND to clayey silt. Silty fine sand about 80%.

Site 17 Borehole 2 No.85 (28.20m)

Loose (to compact) grey silty fine SAND with some bands up to 10mm and lenses of clayey silt. The bands have an apparent dip about 20-25 degrees with rare traces of carbon; 90% sandy in upper half, 50% sandy in lower half.

Site 17 Borehole 3 No.5 (1.70m)

Loose fine to coarse subrounded to subangular GRAVEL (chert) with some red brown clayey sandy silt matrix.

Site 17 Borehole 3 No.9 (2.90m)

Stiff to very stiff mottled light buff occasionally grey silty CLAY with occasional subrounded fine gravel (appears carbonaceous).

Site 17 Borehole 3 No.15 (14.70m)

Very stiff mottled medium grey/green grey silty CLAY.

Site 17 Borehole 3 No.23 (7.10m)

Top 100mm: Stiff to very stiff variable brown/yellow brown/grey/black compact slightly silty SAND becoming clayey sandy SILT with occasional small carbonaceous material.
Bottom: Stiff to very stiff very dark grey clayey very sandy SILT with silty fine sand small lenses which tend to form an incontinuous band 10mm wide, with a little carbonaceous material around calcite crystals.

Site 17 Borehole 3 No.31 (Jar) (11.00m)

Grey silty fine SAND.

Site 17 Borehole 3 No.38 (14.50m)

Stiff to very stiff (compact) mid to dark grey interbedded clayey SILT/fine sandy SILT, beds 3mm to 15mm. Distinct semi-horizontal band. Occasional rounded medium gravel fragment of sandstone.

Site 17 Borehole 3 No.40 (Jar) 15.50m)

Greys, from light to dark, thinly laminated almost interbedded very sandy SILT, silty fine SAND and clayey SILT.

Site 17 Borehole 4 No.9 (2.90m)

Very stiff, medium brown very clayey SILT with some dark brown rootlets, gleying along rootlet tracks, discontinuous very thin (3mm) silty horizon in middle of sample.

Site 17 Borehole 4 No.27 (8.95m)

Very stiff dark grey fissured SILT and CLAY with very closely to closely spaced discontinuities with some iron staining.
At bottom: thin 15mm claystone horizon, probably concretion rather than bands, with a little iron staining on surface.

Site 17 Borehole 4 No.33 (16.10m)

Very stiff dark grey fissured at top silty CLAY becoming slightly silty CLAY towards base.
Bottom 100mm: Contains numerous small shear planes.

Site 17 Borehole 5 No.2 (Jar) (1.00m)

Mid brown with lots of grey gleying silty CLAY with occasional carbonaceous fragments with one piece of sandy angular fine gravel.

Site 17 Borehole 5 No.7 (2.35m)

Very stiff medium brown mottled mid grey clayey SILT with occasional small white silt pockets and very thin bands of silt, with occasional dark brown rootlets.
At base: Chert subrounded medium to coarse gravel.

Site 17 Borehole 5 No.13 (4.30m)

Stiff to very stiff medium brown mottled yellow brown, with grey gleying, clayey SILT with occasional broken shell fragments.
Changes 50mm from bottom to very stiff dark grey clayey SILT, with thin silty lenses in bottom 25mm.

Site 17 Borehole 5 No.15 (4.95m)

Stiff to very stiff dark grey occasional brown grey fissured clayey SILT with silty fine sand lenses and almost discontinuous bands, with occasional shells and carbonaceous material.

Site 17 Borehole 6 No.16 (6.00m)

Compact dark grey very silty fine SAND becoming more sandy towards base occasionally light grey, with medium weathered claystone horizon/nodule at base.

Site 17 Borehole 6 No.24 (8.60m)

Top 50mm: Stiff dark grey laminated fine sandy SILT.
Middle 100mm: Loose dark grey silty SAND.
Lower 230mm: Stiff dark grey fine sandy SILT with occasional lenses of fine sand.

Site 17 Borehole 6 No.36 (12.50m)

Very stiff dark grey clayey sandy SILT with some silty fine sand lenses and bands up to 6mm thick. Sandier bands tend to be dark grey.

Site 17 Borehole 6 No.40 (13.80m)

Very stiff dark grey friable compact slightly clayey sandy SILT with light grey sandy lenses and discontinuous horizon up to 10mm thick, towards base iron stained closely spaced discontinuities.

Site 17 Borehole 6 No.48 (16.40m)

Very stiff dark grey clayey SILT with occasional light grey silty fine sand lenses and discontinuous bands. Occasional shell fragments and weakly developed closely spaced discontinuities.

Site 17 Borehole 7 No.10 (3.20m)

Loose medium brown to orange brown silty fine SAND with occasional carbonaceous lenses.

Site 17 Borehole 7 No.14 (4.40m)

Top 250mm: Loose grey with yellowish brown mottling silty fine SAND with occasional clayey zones and occasional medium to coarse subangular pyrites nodules.
Bottom 125mm: Very dark grey firm very silty CLAY with some fine sandy silt horizons up to 2mm thick.

Site 17 Borehole 7 No.24 (7.40m)

Loose grey with some light grey/orange brown silty SAND slightly clayey at top, at base slightly silty sand.

Site 17 Borehole 7 No.34 (10.40m)

Loose light grey silty SAND with some dark grey clayey silt horizons, with a trace of carbon.

Site 17 Borehole 7 No.42 (12.80m)

Stiff to very stiff dark grey silty CLAY with occasional carbonaceous material partly replaced by pyrite. Some iron staining along discontinuities.

Site 17 Borehole 8 No.5 (1.70m)

Firm brown orange mottled light orange grey slightly sandy very clayey SILT with occasional subrounded to subangular chert gravel and one carbonaceous horizon (20 mm thick, 100mm from top).

Site 17 Borehole 8 No.11 (3.50m)

Loose generally greyish fine to medium subangular to subrounded chert GRAVEL in a silty sand matrix.

Site 17 Borehole 8 No.15 (4.70m)

Loose white fine to medium chert GRAVEL in an orange brown/green grey silty fine sand matrix becoming silty SAND with gravel at base.

Site 17 Borehole 8 No.17 (Jar) (5.30m)

Assorted medium to coarse angular to rounded chert GRAVEL with a little fine gravel.

Site 17 Borehole 8 No.22 (6.80m)

Loose to compact grey silty fine SAND with occasional clayey silt lenses.

Site 17 Borehole 8 No.25 (Jar) (8.00m)

Grey silty fine SAND.

Site 17 Borehole 9 No.5 (2.30m)

Firm grey clayey SILT with diffuse iron staining along very closely spaced poorly defined fissures, occasional roots up to 4mm and medium gravel size iron pyrites fragments with occasional light grey silty fine sandy horizons up to 3mm thick.

Site 17 Borehole 9 No.32 (10.70m)

Stiff to very stiff dark grey sandy clayey SILT with some light grey silty fine sand lenses and discontinuous bands.

Site 17 Borehole 9 No.44 (14.30m)

Very stiff dark grey slightly sandy very clayey SILT with occasional light grey silty fine sand lenses, carbonaceous lenses, occasional shells, occasional limestone medium gravel.

Site 17 Borehole 9 No.58 (18.50m)

Very stiff dark grey slightly sandy very clayey SILT with occasional light grey very thin sandy silt lenses.

Site 17 Borehole 10 No.7 (2.30m)

Only 40mm of sample: Loose orange brown occasionally light grey and dark brown slightly silty SAND with occasional subrounded fine chert gravel fragments.

Site 17 Borehole 10 No.10 (Bulk) (4.25m)

Orange brown silty fine SAND with a trace of clay, occasional organic matter with rare subrounded fine gravel.

Site 17 Borehole 10 No.11 (4.50m)

Loose, various buffs, light orange brown silty fine SAND with occasional subrounded carbonaceous pockets up to 2.5mm, some of which has been dissolved in upper half.

Site 17 Borehole 10 No.17 (6.35m)

Mid brown light grey silty fine SAND, slightly clayey at base.

Site 17 Borehole 10 No.25 (8.90m)

Compact dark grey very silty fine SAND with some very thin (less than 3mm) clayey silt bands.

Site 18 Borehole 1 No.5 (1.50m)

Top: Brown clayey SILT with some fine rootlets and occasional angular to subangular fine chert gravel size fragments.

Bottom: Firm to stiff grey/red/occasional brown silty CLAY with occasional fine gravel fragments of limestone.

Site 18 Borehole 1 No.13 (4.10m)

Very stiff red/pink/grey mottled silty CLAY with dark red fine gravel concretions of iron (haematite) rich silty clay at base.

Site 18 Borehole 1 No.19 (6.05m)

Very stiff dark red/grey mottled silty CLAY with specks of fine gravel red haematite.

Site 18 Borehole 1 No.23 (7.35m)

Top: Very stiff dark red/grey/brown/pink mottled silty CLAY.

Middle 120mm: Fine sandy clayey SILT.

Bottom 75mm: as top.

Site 18 Borehole 3 No.3 (1.10m)

Top 150m: Black rounded medium to coarse GRAVEL small COBBLES of chert in a dark brown clayey silt matrix with little assorted subangular fine gravel.

Bottom: Loose brown/grey silty fine SAND with a 10mm silty clay band and occasional medium gravel chert.

Site 18 Borehole 3 No.13 (4.10m)

Very stiff pink/mauve/light grey/dark red silty CLAY occasionally brown, with a shiny slickensided shear surface at 25°. Mauve all down one side, occasionally almost fine gravel haematite down other side towards top probably other smooth shiny surfaces of various angles in mauve clay.

Site 18 Borehole 3 No.24 (7.70m)

Very stiff dark red/brown/light grey mottled occasionally mauve silty CLAY.

Site 18 Borehole 3 No.48 (14.90m)

Very stiff dark grey silty CLAY becoming lighter grey towards base.

200mm down: 50mm band with red specks pockets of red hermatitic colouring and from 0 - 200mm down a series of shiny slickensided surfaces of varying orientation and dip.

Site 18 Borehole 3 No.67 (21.90m)

Very stiff grey/dark red mottled occasionally dark brown silty CLAY.

Site 18 Borehole 4 No.5 (1.70m)

Very stiff medium brown mottled silty CLAY with extremely to very closely spaced discontinuities (fissures), with prominent sand-sized gypsum crystals and occasional fine rootlets, with grey gleying along root tracks.

Site 18 Borehole 4 No.9 (2.90m)

As above, very small amount of gypsum.

Site 18 Borehole 4 No.27 (8.30m)

Very stiff dark grey clayey SILT occasional mica flakes with some light grey silty fine sand lenses and one sub-angular medium gravel size fragment of pyrite.

Site 18 Borehole 4 No.35 (10.70m)

Very stiff dark grey very fine sandy SILT with occasional very thin (2mm) clayey bands, occasional light grey fine sand lenses.

Site 18 Borehole 4 No.42 (Jar) (13.10m)

Dark grey silty CLAY with fine to medium rounded chert gravel with occasional shells.

Site 18 Borehole 4 No.43 (13.10m)

Firm dark grey clayey SILT with 20mm thick shelly silty sand (glaucinitic) and at base 50mm of medium grey silty fine SAND.

Site 18 Borehole 4 No.49 (14.90m)

Very stiff dark red/light grey/mauve/dark brown mottled silty CLAY, a lot of haematitic material.

Site 18 Borehole 4 No.63 (19.20m)

Very stiff dark red/mauve/light grey mottled silty CLAY one fine angular chert gravel.

Site 18 Borehole 4 No.83 (25.20m)

Very stiff mid brown occasionally light grey mottled very occasionally dark red very silty CLAY.

Site 18 Borehole 4 No.103 (31.20m)

Very stiff dark red/light grey mottled occasional dark brown very silty CLAY.

Site 19 Borehole 1 No.6 (2.70m)

Firm dark and medium brown clayey SILT and CLAY with occasional yellow silty bands up to 3mm thick with some fine rootlets with gleying and rare carbonaceous specks.

Site 19 Borehole 1 No.7 (Jar) 3.30m)

Medium brown very sandy SILT or very silty fine SAND with one subrounded medium gravel pebble of very weathered limestone.

Site 19 Borehole 1 No.10 (3.90m)

Top 100mm: Firm dark grey very clayey SILT with occasional shells and one 1mm silty fine sand band.

70mm: Loose grey silty fine SAND with semi-horizontal colour banding.

Base 140mm: As top with no sand band and some iron staining along rare discontinuities.

Site 19 Borehole 1 No.18 (6.30m)

Compact (stiff to very stiff) dark grey slightly clayey fissured SILT with occasional shells and a little dark brown iron staining along discontinuities and occasional fine sandy silt bands.

Site 19 Borehole 2 No.3 (1.10m)

Firm medium brown with much light grey gleying, slightly sandy silty CLAY with roots and a silty fine sand band at about 10°.

Site 19 Borehole 2 No.15 (4.70m)

Very stiff dark grey, occasional stained dark brown, fissured clayey SILT with occasional shells, rare slightly sandy silt lenses and occasional bands.

Site 19 Borehole 2 No.25 (7.70m)

Very stiff dark grey, very occasional stained dark brown, fissured clayey SILT with occasional fine sandy silty horizons (at about 5°) and occasional shell fragments.

Site 19 Borehole 3 No.15 (4.70m)

Very stiff dark grey/orange brown fissured silty CLAY, very closely spaced fissures, with some gypsum crystals, with some dark brown iron staining along fine sand silt horizons borings and bands.

Site 19 Borehole 3 No.23 (7.10m)

Very stiff dark grey silty CLAY and clayey SILT, closely fissured with one fragment of pyrites, occasional shells.

Site 19 Borehole 3 No.37 (Jar) (11.30m)

Grey silty fine SAND.

Site 19 Borehole 3 No.46 (14.30m)

Very stiff dark mauve/dark red/predominantly grey silty CLAY, with some dark red haematitic material, occasionally gravel sized but friable.

Site 19 Borehole No.72 (22.70m)

Very stiff dark red/grey mottled silty CLAY with a trace of carbonaceous material.

Site 19 Borehole 4 No.7 (2.30m)

Brown grey, iron stained along fissures, clayey SILT with occasional silty fine sand bands up to 1mm thick with very closely spaced iron stained discontinuities.

Site 19 Borehole 4 No.15 (4.70m)

Loose, light and dark grey horizontal colour banded, silty fine SAND with dark grey sandy clayey silt bands up to 15mm mainly in bottom 60mm.

Site 19 Borehole 4 No.23 (7.10m)

Very stiff light grey dark red occasionally mauve with some dark brown at top, silty CLAY, feels slightly gritty due to presence of hermatite.

Site 19 Borehole 4 No.45 (13.70m)

Very stiff light grey red mottled slightly silty CLAY.

Site 19 Borehole 4 No.63 (19.10m)

Very stiff dark brown very dark grey with occasional red mottling silty CLAY with both continuous lineated shear surfaces shiny and abundant shiny smooth discontinuous shear surfaces.

Site 19 Borehole 5 No.7 (2.30m)

Loose brown silty fine SAND with a trace of clay and occasional discontinuous laminae of light brown silty clay and a trace of dark carbonaceous matter.

Site 19 Borehole 5 No.20 (6.50m)

Very stiff light grey mottled red silty CLAY with both continuous lineated shiny smooth shear surfaces and some small shiny smooth discontinuous shear surfaces.

Site 19 Borehole 5 No.32 (10.10m)

Very stiff brown with some light grey mottling silty slightly sandy CLAY (feels coarse).

Site 19 Borehole 5 No.38 (11.90m)

Compact light grey occasional brown mottling silty fine SAND with occasional small hollows resulting from dissolving of carbonaceous material.

Site 19 Borehole 6 No.3 (0.85m)

Loose orange brown silty to very silty fine SAND.

Site 19 Borehole 6 No.22 (Jar) (7.30m)

Dark grey occasional orange brown interbedded clayey sandy SILT and clayey SILT with occasional dark brown organic matter.

Site 19 Borehole 6 No.25 (8.00m)

Very stiff mauve/light grey silty CLAY with occasional dark brown rootlets both horizontally and vertically, light red at top.

Site 19 Borehole 7 No.9 (2.80m)

Loose to compact (bordering compact) brown very occasionally grey silty fine SAND with some discontinuous silty clay laminae up to 3mm thick.

Site 19 Borehole 7 No.12 (Jar) (4.05m)

Grey slightly clayey silty fine SAND.

Site 19 Borehole 7 No.17 (5.40m)

Very stiff dark grey occasional red mottling slightly silty to silty CLAY with many continuous and discontinuous smooth shiny, in part lineated, shear surfaces with a random orientation.

Site 19 Borehole 7 No.25 (8.00m)

Very stiff light grey mottled bright red silty very slightly sandy CLAY.

Site 19 Borehole 8 No.7 (2.30m)

Stiff to very stiff dark brown clayey SILT with a few slightly sandy discontinuous laminae, occasional grey gleying and one dark brown rootlet.

Site 19 Borehole 8 No.11 (3.50m)

Stiff dark grey clayey slightly sandy SILT occasionally laminated with very thin laminations of silty fine sand, occasional flakes of mica, becoming more sandy with depth dark brown iron staining at base.

Site 19 Borehole 8 No.19 (5.90m)

Very stiff dark grey very sandy clayey SILT with more clay towards top, very closely fissured at top with occasional light grey loose subrounded gravel.

Site 19 Borehole 8 No.25 (7.70m)

Loose to compact dark grey slightly clayey fine sandy SILT with occasional white worm tubes and shells, occasional silty clay and fine sand bands up to 10mm wide.

Site 19 Borehole 9 No.7 (2.30m)

Very stiff dark brown light grey mottled silty CLAY with some weakly defined very closely spaced fissuring, on some fissure faces smooth particularly shiny surfaces probably indicative of small lateral movement, occasional calcereous shells.

Top 50mm and bottom 75mm: Light orange brown clayey SILT with a little carbonaceous matter only in the top.

Site 19 Borehole 9 No.17 (5.30m)

Top 70mm: Very stiff dark brown silty CLAY with closely spaced fissures with grey gleying along fissures.

60mm: Weak to moderate weak argillaceous limestone, no obvious indication of significant water passage.

Bottom 75mm: Very stiff dark brown silty CLAY with a trace of fine sand, with very closely spaced fissuring.

Site 19 Borehole 10 No.7 (2.30m)

Very stiff dark brown light grey mottled silty CLAY with some weakly defined very closely spaced fissuring, on some fissure faces smooth particularly shiny surfaces probably indicative of small lateral movement, occasional calcereous shells.

Top 50mm and bottom 75mm: light orange brown clayey SILT, with a little carbonaceous matter only in the top.

Site 19 Borehole 9 No.17 (5.30m)

Top 70mm: Very stiff dark brown silty CLAY with closely spaced fissures with grey gleying along fissures.

60mm: Weak to moderate weak argillaceous limestone, no obvious indication of significant water passage.

Bottom 75mm: Very stiff dark brown silty CLAY with a trace of fine sand, with very closely spaced fissuring.

Site 19 Borehole 10 No.7 (2.30m)

Firm to stiff medium brown mottled light grey with a little gleying silty CLAY with weakly developed very closely spaced fissuring, with occasional fine sandy silt bands (2mm) and some concertionary calcereous nodules up to about 4mm, occasional shell fragments, occasional carbonaceous fragments.

Site 19 Borehole 10 No.9 (2.90m)

Firm medium brown silty CLAY with extremely closely spaced fissuring, some gleying on fissure surfaces and with some light grey fine sand bands up to 8mm thick.

Site 19 Borehole 10 No.13 (4.10m)

Firm to stiff medium brown silty CLAY with very closely spaced fissures, some gleying along fissure surfaces, occasional fine sandy silt horizons up to 2mm thick and occasional shells.

Site 19 Borehole 10 No.17 (5.30m)

Stiff to very stiff dark brown very silty CLAY with very closely spaced fissures sometimes gleyed occasional fine sandy silt laminae up to 2mm, occasional shells and occasional silt inclusions.

Site 19 Borehole 10 No.21 (6.50m)

Very weak dark slightly brown grey highly to completely weathered silty MUDSTONE with very closely spaced discontinuities, some of which are iron stained and have a weak shine usually vertically orientated fine sandy silt bands up to 2mm thick.

Site 19 Borehole 10 No.27 (8.30m)

Very stiff dark grey very silty CLAY/very clayey SILT with closely spaced fissures, occasional weakly developed shiny surfaces, occasional silty horizons (up to 2mm).

Site 19 Borehole 10 No.34 (10.70m)

Very stiff dark grey slightly clayey SILT with closely spaced fissures, some of which have weakly to well developed shiny unlineated surfaces with occasional weakly cemented pockets.

Site 20 Borehole 1 No.3 (Bulk) (3.00m)

Subangular occasionally subrounded fine and coarse mainly chert GRAVEL with one small cobble with some sand sized fragments, slightly chalky, in a dark brown clayey silt matrix.

Site 20 Borehole 1 No.9 (Bulk) (4.00m)

White and grey subangular coarse sand to coarse chert GRAVEL in a dark brown clayey silt matrix. Matrix 20 to 30%.

Site 20 Borehole 1 No.14 (5.80m)

Compact grey silty fine SAND occasional shells slightly clayey towards base occasionally glauconitic.

Site 20 Borehole 1 No.20 (7.75m)

Compact grey very sandy SILT (sand mainly fine) with a few light grey fine sandy bands, small pockets of concertionary limestone and 10mm (discontinuous) band of limestone at base.

Site 20 Borehole 1 No.25 (9.50m)

Very compact (very stiff) dark grey micaceous slightly clayey SILT with occasional shells.

Site 20 Borehole 1 No.29 (10.85m)

Compact dark grey very silty micaceous fine SAND with occasional concertionary limestone (up to 10mm).

Site 20 Borehole 1 No.37 (13.45m)

Very compact dark grey sandy micaceous SILT with one thin (10mm) light grey fine sandy horizon and occasional worm tubes.

Site 20 Borehole 1 No.41 (Bulk) (15.30m)

(Compact) dark grey clayey slightly sandy micaceous SILT with some medium to coarse gravel sized fragments of limestone with a trace of shells and with occasional fine sandy horizons.

Site 20 Borehole 1 No.50 (18.00m)

Very stiff dark grey clayey slightly sandy SILT with closely spaced fissures and some pockets of light grey fine sand and occasional shells.

Site 20 Borehole 2 No.9 (3.35m)

Compact brown mainly light grey brown silty fine SAND with occasional lenses of silty clay (up to 4mm) occasional shells, occasional semi-spherical hollows (up to 3mm).

Site 20 Borehole 2 No.11 (4.00m)

Loose grey occasional orange brown silty fine SAND with some silty clay bands (up to 3mm thick) with occasional shells.

Site 20 Borehole 2 No.18 (6.30m)

Very stiff dark grey brown very clayey SILT, with medium gravel sized pyrites fragments, with closely spaced fissures, occasional dark brown black carbonaceous material, some poorly developed smooth shiny unlineated surfaces on some of the fissures.

Site 20 Borehole 2 No.22 (7.65m)

As above, slightly micaceous, no pyrites.

Site 20 Borehole 2 No.45 (15.85m)

As Site 20/2/18, slightly micaceous, occasional discontinuities smooth shiny very weakly lineated.

Site 20 Borehole 2 No.59 (Jar) (20.45m)

Grey clayey silty fine SAND with occasional clayey silt lenses.

Site 20 Borehole 2 No.67 (23.65m)

Compact grey fine sandy SILT, with a trace of clay, with occasional shells.

Site 20 Borehole 2 No.81 (28.30m)

As Site 20/2/67 and light grey pockets of fine silty sand.

Site 20 Borehole 3 No.3 (1.10m)

Top 50mm: Friable dark brown clayey SILT with some subangular fine to coarse chert gravel and occasional subrounded assorted gravel.

Middle 275mm: Firm to stiff buff brown silty CLAY with some variable mainly subangular fine to coarse chert gravel, with some dark brown ferruginous/carbonaceous fine gravel pockets.

Site 20 Borehole 3 No.7 (2.30m)

Generally subangular fine to medium GRAVEL with some coarse chert gravel with a brown silty clay matrix.

Site 20 Borehole 3 No.9 (Bulk) (2.90m)

(Moist soft) brown silty CLAY and generally white subangular coarse SAND to medium GRAVEL, generally of chert, occasional shells, occasional black carbonaceous material with a trace of chalk. (generally a putty chalk).

Site 20 Borehole 3 No.16 (5.30m)

Stiff to very stiff dark grey silty (possibly slightly silty) CLAY with very closely spaced fissures with occasional dark brown iron staining along fissures at top and bottom of sample, with occasional shells, trace of light brown fine sand very thin (1mm) band at top and bottom (very small) slightly micaceous.

Site 20 Borehole 4 No.7 (Bulk) (2.00m)

(Very stiff) dark brown mottled medium grey silty CLAY with some coarse silty pockets greys probably extensive gleying, with occasional dark brown organic matter.

Site 20 Borehole 4 No.14 (4.60m)

Compact (very stiff) dark grey sandy slightly micaceous SILT, with occasional very thin (up to 2mm) silty clay bands with occasional shells, and occasional pockets of light grey silty fine sand and one very thin (3mm) band of light grey silty fine sand across middle of sample, rare dark brown iron staining along very closely spaced fissures.

Site 20 Borehole 4 No.32 (10.45m)

Very stiff (compact) dark grey clayey, in places slightly clayey, slightly micaceous SILT with very closely spaced fissuring, with occasional shells with rare dark brown iron staining along fissures (generally fissures tightly closed) with occasional (5) very thin (up to 3mm) fine sand continuous horizons and occasional fine sandy pockets.

Site 20 Borehole 4 No.64 (20.85m)

Very stiff (compact) dark grey very silty CLAY with very closely spaced fissures, occasional dark brown staining down discontinuities, with occasional dark brown organic material some of which has been dissolved to leave 1mm small bores with occasional shells, with occasional continuous light grey horizons up to 2mm thick, occasional slightly shiny smooth slightly lineated surfaces along a few randomly orientated fissures.

Site 20 Borehole 4 No.82 (26.70m)

Generally stiff dark grey silty CLAY with very closely spaced fissures down which some of the clay has been reduced to soft by water imgration, with occasional shells, with some shiny smooth lineated surfaces, along some of the fissure surfaces.

Site 20 Borehole 6 No.6 (2.10m)

Top 30mm: soft to firm brown silty CLAY with some subrounded fine and medium greval.

Middle 130mm: Loose light orange brown slightly clayey silty fine SAND.

Bottom 80mm: Loose dark grey slightly brown sandy slightly clayey SILT; sand mainly fine.

Site 20 Borehole 6 No.12 (4.40m)

Very stiff dark grey slightly clayey slightly sandy SILT with very closely spaced fissures, occasional brown staining along fissures, with occasional shells towards base, with many light grey fine sandy horizons, some thin (up to 5mm) continuous pockets.

Top 10mm: soft dark brown/grey intermingled silty slightly sandy CLAY with some subangular to subrounded fine and medium gravel.

Site 20 Borehole 6 No.30 (10.25m)

Very stiff dark grey very clayey SILT, in places micaceous and slightly sandy with very closely spaced fissures, some of which are stained slightly brown and occasionally with shiny smooth lineated and unlineated surfaces, with occasional light grey fine sandy continuous horizons (up to 3mm) and pockets.

Site 20 Borehole 6 No.54 (18.05m)

Very stiff dark grey silty CLAY with very closely spaced fissures and rare shiny smooth possibly lineated surfaces generally on vertical fissures, occasional slightly brown colouring along fissures.

Site 20 Borehole 6 No.87 (28.50m)

Very stiff dark grey very silty CLAY with very closely spaced fissures and occasional shiny smooth and possibly lineated surfaces on fissures, occasional light grey fine sandy horizons and occasional pockets.

TABLE I.1
EAST HAMPSHIRE - SUMMARY OF LABORATORY TESTS - SITE NUMBER 15

BOREHOLE	SAMPLE	Depth m	Nat mc %	LL %	PL %	PI %	SHEAR STRENGTH			COMPACTION				GRADING			
							Test Type	C' kN/m2	ϕ °	Cu kN/m2	Opt mc %	MaxYd Mg/m3	Nat-opt mc % - PL %	CLAY %	SILT %	SAND %	GRAVEL %
15/1	7	1.95	27	66	26	40							1	51	47	2	
15/1	13	3.9	29	65	28	37							1	51	48	1	
15/2	5/7	2.0	26, 27	76	22	54					22	1.5	4.5	66	32		
15/2	11	3.5	28	77	22	55	RemCU	10	19				6	54	42		
15/2	23/25	7.1/7.7	24, 26	61	19	42					20	1.58	4	57	42		
15/3	5	1.8	24	68	25	43	CU	35	20				-1	55	45		
15/3	19	6.35	27	70	26	44	CU	16	21				1	58	42		
15/3	85	28.45	20	30	14	16							6	16	22	52	
15/3	98	34.00														60	
15/3	104	38.20	13	36	14	22							-1	34	48	18	40
15/4	9	3.65	25	60	22	38	CU	25	26				3	37	55	8	
15/4	19	6.95	25	53	19	34							6	35	63		
15/5	5	1.95	25	70	24	46							1	70	30		
15/5	19	6.70	25	42	17	25							8	18	60	20	
15/6	7	2.30	24	44	18	26							6	41	40	17	
15/7	7	2.30	30	60	26	34							4				
15/8	11	3.50	25	70	21	49							4				
15/8	21	6.50	23	NP	NP	NP								6	24	70	
15/9	19	5.90	24	NP	NP	NP								13	19	68	
15/9	29	9.00	20	45	23	22							-3	29	55	16	
15/10	11	3.20	26	76	23	53							3	63.5	36.5		

TABLE I.2
EAST HAMPSHIRE - SUMMARY OF LABORATORY TESTS - SITE NUMBER 17

BOREHOLE	SAMPLE	Depth m	Nat mc %	LL %	PL %	PI %	SHEAR STRENGTH			COMPACTION				GRADING				
							Test Type	C' kN/m2	ϕ °	Cu kN/m2	Opt mc %	Max γ_d Mg/m3	Nat-opt mc %	Nat mc - PL %	CLAY %	SILT %	SAND %	GRAVEL %
17/1	7	2.3	34	74	26	48								8	35	65		
17/1	13	4.1	25	43	22	21								3	2	51	47	
17/1	25	7.7	25	45	24	21								1	4	71	25	
17/2	5	2.05																
17/2	7	2.7		NP	NP	NP											23	77
17/2	9	3.35															13	87
17/2	13	4.8	28	82	28	54	CU	2	23					0	50	47		
17/2	59	19.5	18	32	16	16								2	13	47	40	
17/3	3	1.1	22	36	12	24								2	24	48	24	
17/3	13	4.1	18	64	25	39	CU	24	18					-7	44	50		
17/3	21	6.5	13	35	15	20	CD	21	28					-2	36	21	43	
17/3	29	10.0	23	NP	NP	NP											100	
17/3	34	12.5	19	36	14	22								5	33	62		
17/4	5	1.6	26	58	20	38								6	48	48		
17/4	13	4.2	27	61	22	39	CD	40	23					5	52	45		
17/4	23	7.45	27	71	23	48								4	40	60		
17/4	29	9.6	27	76	23	53								4	67	33		
17/5	5	1.7	25	59	34	25				22	1.58	3		-9	48	48		
17/5	9	3.0	29	67	30	37								-1	43	50	7	
17/5	11	3.65	30	60	23	37				20	1.52	7		7	42	50	8	
17/5	17	5.6	26	65	21	44				22	1.58	4		5	32	58	10	
17/6	4	1.6													2	13	29	56
17/6	12	4.7	24	65	22	43	CU	15	31					2	40	58		
17/6	20	7.3	23	46	19	27								4	27	50	23	
17/6	32	11.2	24	56	20	36								4	27	67		
17/7	8	2.6	27	39	29	10								-2	7	33	57	
17/7	18	5.6	27	43	27	16								0	6	37	51	
17/7	28	8.6	22	32	24	8								-2	3	23	74	
17/7	36	11.0	18	NP	NP	NP									4	16	80	
17/8	3	1.1	20	39	15	24								5	20	45	30	
17/8	7	2.3	18	41	10	31								8	26	44	26	
17/8	11	3.5	15	NP	NP	NP											75	25
17/9	3	1.7	26	62	21	41								5	23	50	27	
17/9	9	3.5	24	57	22	35	CU	0	31					2	22	65	13	
17/9	23	7.7	22	43	23	20								1	15	73		
17/10	5	2.25	28	42	24	18								4	23	38	39	

TABLE I.3
EAST HAMPSHIRE - SUMMARY OF LABORATORY TESTS - SITE NUMBER 18

BOREHOLE	SAMPLE	Depth m	Nat mc %	LL %	PL %	PI %	SHEAR STRENGTH				COMPACTION				GRADING			
							Test Type	C' kN/m2	ϕ °	Cu kN/m2	Opt mc %	MaxYd Mg/m3	Nat-opt mc %	Nat mc - PL %	CLAY %	SILT %	SAND %	GRAVE %
18/1	3	0.85	30	60	23	37								7	52	43		
18/1	7	2.15	23	66	23	43					21.5	1.65	1.5	0	61	35		
18/1	17	5.40	20	61	22	39					22.5	1.64	-2.5	-2	61	35		
18/2	7	2.15	16	48	16	32								0	41	57		
18/2	19	6.05	16	45	15	30					16	1.79	0	1	28	64		
18/2	27	8.75	16	32	12	20					13	1.84	3	4	23	50	27	
18/3	9	2.9	15	46	17	29	RemCU	12	18					2	55	40		
18/3	11	3.5	18	48	19	29	CU	11	18					-1	61	34		
18/3	15	4.7																
18/3	17	5.3	15	55	15	40								0	30	65		
18/3	32	10.1	16	54	18	36					17	1.76	-1	-2	40	58		
18/4	3	1.1	30	86	28	58								2				
18/4	7	2.3	30	72	27	45	CU	18	20					3	60	38		
18/4	11	3.5	33	98	31	67								2	65	31		
18/4	15	4.7	27	79	26	53								1	45	47		
18/4	17	5.3	28	71	25	46	DS	55	16					3	53	45		
18/4	25	7.7	26	63	19	44								7				
18/4	31	9.5	25	71	21	50								4	55	43		
18/4	39	11.9	27	NP	NP	NP								.	5	37	58	
18/4	51	15.6	16	46	16	30								0	49	42		

TABLE I.4

EAST HAMPSHIRE - SUMMARY OF LABORATORY TESTS - SITE NUMBER 19

BOREHOLE	SAMPLE	Depth m	Nat mc %	LL %	PL %	PI %	SHEAR STRENGTH			COMPACTION				GRADING				
							Test Type	C' kN/m2	ϕ °	Cu kN/m2	Opt mc %	Max/d Mg/m3	Nat-opt mc %	Nat mc - PL %	CLAY %	SILT %	SAND %	GRAVE %
19/1	1	0.75																
19/1	4	2.1	22	51	20	31				93				2	26	60		
19/1	8	3.3	22	47	21	26								1	28	62		
19/1	12	4.5	24	53	23	30								1	21	64		
19/2	7	2.3	31	64	29	35								2	42	51		
19/3	5	1.7	24	78	25	53								1	53	37		
19/3	9	2.9	30	76	27	49								3				
19/3	13	4.1	28	65	19	46	CU	15	29					9	43	42	15	
19/3	17	5.3	30	83	27	56								3	44	49	7	
19/3	35	10.7	28	35	23	12								5	14	49	37	
19/4	5	1.7	28	51	22	29									30	30	40	
19/4	11	3.5	19	36	18	18								1	24	19	57	
19/4	19	5.9	21	37	19	18								2	21	54	25	
19/4	25	7.7	18	59	25	34								7	58	39		
19/5	5	1.7	30	NP	NP	NP									12	40	48	
19/5	11	3.5	18	52	17	35								1	58	42		
19/5	16	5.3	20	54	12	42								8				
19/6	5	1.5	27	43	25	18	CU	2	33					2	24	38	26	
19/6	13	4.1	21	53	19	35								3				
19/7	7	2.15	26	26	25	1								1	2	16	82	
19/7	13	4.10	18	35	18	17								0	35	64		
19/7	21	6.70	18	60	18	42								0	51	38	11	
19/8	7	2.3	28	65	21	44					22	1.55	6	7	48	44	8	
19/10	5	1.7	27	64	27	37					22	1.587	5	0	55	41		
19/10	11	3.5	27	64	22	42								5	46	50	4	
19/10	15	4.7	31	64	22	42					22	1.526	9	9	48	50		
19/10	23	7.1	27	67	23	44					20	1.548	7	4	57	41		

TABLE I.5

EAST HAMPSHIRE - SUMMARY OF LABORATORY TESTS - SITE NUMBER 20

BOREHOLE	SAMPLE	Depth m	Nat mc %	LL %	PL %	PI %	SHEAR STRENGTH			COMPACTION				GRADING				
							Test Type	C' kN/m2	ϕ °	Cu kN/m2	Opt mc %	Max γ_d Mg/m3	Nat-opt mc %	Nat mc - PL %	CLAY %	SILT %	SAND %	GRAVE %
20/1	5	2.0													7	10	11	65
20/1	7	3.0	(17)				RemCUM	0	42		16	1.8			10	4	19	67
20/1	12	5.15	25	30	22	8	CUM	18	28				3		38	49	13	
20/2	5	1.75	(13)				RemCUM	0	35		12	1.86			6	15	15	65
20/2	16	5.6	25	72	23	49							2		53	44	3	
20/4	8	2.65	33	74	25	49							8		65	31		
20/4	12	3.95	21	44	18	26							3		10	53	33	
20/6	6	2.1	26	48	18	30							8		27	63		
20/6	14	5.05	21	55	17	38							4		25	65		

TABLE I.6

SUMMARY OF LABORATORY PERMEABILITY TESTS ON TERTIARY STRATA

Borehole Number	Sample Number	Depth m	LL %	PL %	PI %	Grading		Vertical Permeability (m/sec)
						Clay %	Silt %	
15/3	85	28.45	30	14	16	16	22	0.7×10^{-9}
15/5	19	6.7	42	17	25	18	60	7×10^{-9}
15/6	7	2.3	44	18	26	41	40	0.2×10^{-9}
15/8	21	6.5	NP	NP	NP	6	24	2×10^{-7}
17/3	29	10.0	NP	NP	NP	0	0	1×10^{-6}
17/7	8	2.6	39	29	10	7	33	3×10^{-8}
17/7	18	5.6	43	27	16	6	37	2×10^{-8}
17/7	28	8.6	32	24	8	3	23	0.2×10^{-9}
17/8	11	3.5	NP	NP	NP	0	0	2×10^{-7}
17/10	5	2.25	42	24	18	23	38	2×10^{-8}
19/3	35	10.7	35	23	12	14	49	8×10^{-8}

TABLE I.7

SUMMARY OF IN-SITU PERMEABILITY TESTS IN TERTIARY STRATA

Borehole Number	Approx. Depth (m)	Type of Test	Permeability (m/sec)	Stratum Description (abstracted from Borehole Record)
15/3	27.45	Falling Head	2×10^{-7}	Clayey coarse silt with fine sand
	32.96	Falling Head	3×10^{-3}	Sand
	37.0	Rising Head	8×10^{-6}	} Sand
		Falling Head	4×10^{-6}	
17/2	23.5	Rising Head	1×10^{-6}	Silty sand
17/3	9.7	Falling Head	9×10^{-7}	Silty fine sand
17/10	4.35	Falling Head	7×10^{-7}	Silty sand
19/3	12.5	Rising Head	2×10^{-6}	Very silty fine sand
20/2	21.0	Rising Head	2×10^{-5}	Very silty fine sand becoming clayey

EAST HAMPSHIRE

[illegible]