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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Road Research Laboratory

REPORT ON THE FACTORS INVOLVED IN PROVIDING A ROAD SYSTEM IN RURAL AREAS OF THE FALKLAND ISLANDS

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SUMMARY

Life on the farms in the Falkland Islands, whilst similar in many respects to that in any sparsely populated rural area, is more isolated than most due to the lack of a system of roads linking the various settlements. In recent years increasing interest has been shown in the provision of a road system. At the request of the Governor the writer visited the islands from the 30th March to the 6th May, 1963 to examine and report on the problems involved in providing such a road system. During the visit he travelled extensively in the two main islands, East and West Falkland. The main conclusions and recommendations are as follows:

(i) The real interest of the people of the Falkland Islands in local travel is demonstrated by the fact that, although there are few roads, there are about 800 mechanically propelled vehicles including motorcycles in a population of 2200 people, i.e. about one vehicle to every three persons, a proportion similar to that in the U.S.A.

(ii) At present outside Stanley there are only some 10 miles of constructed road. For the rest vehicles travel across the countryside beating out tracks that converge on defined river crossings and on gates in fences. Travelling over the country is most uncomfortable and during the worst weather journeys are undertaken only in case of necessity.

(iii) In the conditions obtaining, the minimum standard for a constructed road would involve a gravel running surface 10 ft wide and with passing places at intervals. Roads constructed to such a standard would be adequate for the traffic likely to develop.

(iv) To provide a network of such roads connecting the main settlements on East and West Falkland some 400 miles of road would be needed.

(v) Between the existing conditions and the gravel roads recommended there is no suitable intermediate type of road or track, because the peaty conditions on the Falkland Islands prevent the evolution of roads from beaten tracks.

(vi) Road cross-sections for the main types of terrain are recommended, and the prime importance of good drainage from both the road surface and the immediate environs of the roadway is emphasized.

(vii) Standards of road alignment and for the design of bridges and culverts are suggested.

(viii) The main sources of road surfacing materials would be decomposing rock supplemented by deposits of beach and alluvial sands and gravels, sandy clays, and creep gravels.

(ix) The construction of the proposed road system would need to be carried out by contract with the contractor obtaining his labour force, of about 30-40 men, from outside the islands.

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(x) A road maintenance organisation would be required to keep the roads in suitable condition to carry traffic and to preserve the value of the capital invested. This organisation should be part of the existing Public Works Department. This would involve the recruitment of labour from outside the islands.

(xi) The cost of constructing this road system is difficult to estimate, but it is suggested that it would amount to between £1.6 and £2 million. The recurrent annual cost of maintenance would be expected to be between £20 and £30 thousand.

REPORT ON THE FACTORS INVOLVED IN PROVIDING A ROAD SYSTEM IN RURAL AREAS OF THE FALKLAND ISLANDS

Introduction

1. Life on the farms in the Falkland Islands, whilst similar in many respects to that in any sparsely populated rural area, is more isolated than most due to the lack of a system of roads interconnecting the various settlements. In recent years increasing interest has been shown in the provision of a road system. At the request of the Governor, the writer visited the islands early in 1963 to examine and report on the problems involved in providing such a road system.

2. The problems involved in creating a road system fall into three broad categories as follows:-

(a) The outlining of the road system required and the priorities to be attached to the various roads in the system.

(b) The standards to which the roads should be constructed.

(c) The ways and means of constructing and maintaining a road system and the likely cost of the forms of construction and maintenance recommended.

Itinerary

3. The writer arrived in Stanley on the 30th March, 1963, and spent the first week there with occasional short trips into the adjacent camp.* He then proceeded by air to West Falkland visiting the settlements at Chartres, Fox Bay East, Fox Bay West, Roy Cove and Hill Cove travelling overland between these settlements. Returning by sea to East Falkland he visited the settlements at Port San Carlos, San Carlos, Darwin, North Arm, Fitzroy and Bluff Cove again travelling over the camp in all instances with the exception of the first when the journey was made by motor boat. The remainder of his stay in the Falkland Islands was mainly spent in Stanley in discussions and the preparation of this report but also included a two day trip by Land Rover to Teal Inlet and Douglas Station. The writer departed on the 6th May, 1963.

The road system required

The need for roads

4. At the present time travel in mechanically propelled vehicles between settlements on the Falkland Islands is over the camp in four wheeled drive vehicles or motor cycles. In general there are no defined roadways and tracks wander across the countryside avoiding the more boggy areas and converging on well established bridges, fords and gates. Traffic tends to "follow the leader" and ultimately bunches through in the weaker peaty areas (Plate I). The next traveller avoiding this bog hole finds a new route and the process is repeated. Some clay roads have been made in the camp but these are in the areas where travelling conditions are relatively good. These roads suffer from poor drainage and lack of maintenance and many long stretches have been abandoned (Plate II).

/5. Travelling

*In the Falkland Islands the countryside outside Stanley is referred to as the camp from the Spanish word 'campo'.(1)

5. Travelling over the camp is most uncomfortable in comparison with normal travel in a motor car. Some measure of the difficulty experienced can be gleaned from the low average speed of travel. Even in summer time when travelling conditions are at their best average speeds rarely exceed 10 mile/h even for the most experienced camp drivers. Travelling conditions at other times of the year are not as good and the danger of becoming bogged increases until in winter only the hardiest travellers venture forth and then only in case of necessity.

6. All the settlements on the islands are situated on the coast and at present all the farm produce, consisting in the main of wool and hides, and provisions and materials are transported by sea. An air service using two Beaver seaplanes provides a passenger service and medical attention although the high wind speeds prevalent reduce the amount of flying possible.

7. Thus the main object of providing a road system in the Falkland Islands is to provide means whereby people can move easily between the various settlements. Roads would, therefore, be an amenity rather than a necessity but such amenities are common place nowadays in other countries and have become part and parcel of every day life. In addition by providing easy access at all times they help to allay people's fears of isolation e.g. fear that medical attention would not be available in emergency.

8. The desire to travel in the people of the Falkland Islands is illustrated by the data in Tables I, II and III which give details of the distribution of population and mechanically propelled vehicles including motor cycles on the islands. The number of vehicles per head of population about 1 vehicle to every 3 persons is very high being similar to that found in the U.S.A.(2) The gross national product in relation to the population is also similar indicating that car ownership is related principally to the wealth of the community. This is somewhat surprising in this instance considering the absence of a road system in the Falkland Islands.

Proposed road system

9. The Falkland Islands consist of two main islands, East Falkland and West Falkland and a number of small islands. Stanley the centre of government and commerce is situated in the north east of East Falkland. None of the smaller islands has more than one main settlement and so communications between them and other main settlements must depend as it does now, on travel by air or sea. The locations of the main settlements on East Falkland and West Falkland are shown in Fig. 1. The islands are sparsely populated about 1 person to every 2 sq. miles and all that could reasonably be expected from a system of roads is the linking together of the main settlements.

10. On East Falkland, Stanley provides the focal point of the road system. The disposition of the farm settlements and east-west mountain range favours the adoption of a loop road running from Stanley via Fitzroy to Darwin crossing the mountains to the west of Bodie Peak and returning to Stanley via Douglas Station, Teal Inlet and Estancia. This would involve the construction of 138 miles of road and the reconstruction of 10 miles of existing road near Stanley. Branches to connect in the remaining main settlements would involve the construction of a further 99 miles of road.

11. On West Falkland a road running from Fox Bay East, where the government services for the island are located, to Hill Cove would provide the spine of the road system. With short branches to Fox Bay West and Chartres it would involve the construction of 54 miles of road and interconnect four settlements. Additional branch roads to connect in the other three main settlements would necessitate the construction of 93 miles of road.

/12. Further

12. Further details of the proposed road system are given in Table IV and the layout is shown in Fig. 1. The main consideration in assessing the priorities to be attached to any length of road was that the maximum number of people should have access to the road system as quickly as possible. In addition existing travelling conditions over the camp between the different settlements and the minimising of unnecessary movement of construction equipment were kept in mind.

Additional effects of a road system

13. The introduction of a road system might result in the principal products on the islands, wool and hides, being transported by road to Stanley on East Falkland and to a single port on West Falkland. The total amount of wool and hides produced is about 2200 tons per annum and the present cost of transporting these by sea to Stanley is about £20,000. Although the cost of transport by road to the producer might be half the present cost by sea a ship would still have to collect wool from the smaller islands. Since the ship is not fully utilised even at present it is unlikely that any real benefit would accrue to the colony since this service would have to be maintained.

14. Other side effects, although of no great economic effect, would have considerable social value. The movement of goods from Stanley to the camp could be more regular and frequent, and with an outlet to Stanley people in the camp might find it worthwhile to supply butter, eggs and vegetables regularly to Stanley. Where settlements are close together children could be sent by car to school and so the amount of schooling they received would be increased. Medical services would be surer; it might be possible to dispense with the services of one of the three doctors on East Falkland. The air service to all the settlements on East Falkland and to all but one settlement in West Falkland would be unnecessary and its efforts could be concentrated on inter-island traffic. Postal deliveries on these two islands would be facilitated and could be more frequent. The road system would provide a most welcome outlet for the townspeople of Stanley. Weekend afternoon motoring would be possible and fishing or shooting expeditions into the camp would be easy.

15. With the increase in traffic and the higher speeds that would result from providing public roads it is likely that the number and severity of accidents will increase. The increase in mileage of rural public road from 10 to about 400, will involve the police in extra duties and a considerable extension of the application of road and road traffic ordinances.

Standards of road construction

The expected traffic

16. At present there are about 800 mechanically propelled vehicles including motor cycles on the Falkland Islands equally divided between Stanley and the camp (Table II). These vehicles are not used extensively and mileages of the order of 2000 per annum are common. Increases in travel are to be expected on the introduction of a road system. However it is considered probable that the larger proportion of this increase would result from increased usage of vehicles. It does not appear likely that the total number of vehicles on the islands would increase greatly although the improved conditions of travel might cause an increase in the number of cars at the expense of four wheeled drive vehicles and motor cycles. In any event there are only 1600 persons over the age of 15 years[3] and this places an upper limit on the number of vehicles that could possibly be in use at any time. As the road system outlined above comprises a total of 394 miles of road the picture even in the most extreme circumstances must be one of generally light traffic intensities.

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The type of road required

17. The traffic conditions outlined above only justify roads with a gravel surfacing. Roads of this type are widely used and in sparsely populated regions, e.g. Northern Rhodesia where they form at least 95 per cent of the road system.(2) Even in the U.S.A. 25 per cent of the road network is in this category.

18. A 10 ft running surface with passing places located at $\frac{1}{8}$–$\frac{1}{4}$ miles intervals or closer if required by inadequate sight distance would easily accommodate the expected traffic intensities on all but exceptional occasions e.g. the Stanley races. Even then delays are not likely to be serious as the traffic flow would be predominantly in one direction.

19. Between the existing camp conditions and the gravel road recommended there is no intermediate type of road or track suitable to the Falkland Islands since the peaty conditions prevent the evolution of roads from beaten tracks.

20. At present all the larger rivers and streams have been bridged or can be forded and it is the general difficulty of the terrain rather than conditions at isolated points which causes travel to be such a continuously uncomfortable experience. In the more peaty and difficult areas, e.g. Stanley to Estancia, the filling up of bog holes and soft spots would virtually result in the construction of a road piecemeal between these points.

21. Maintenance of the approaches to the larger bridges and fords and the relocation at intervals of the smaller bridges and gateways would improve conditions at these points (Plates III and IV). The cutting down of the knobby brows on rough areas with a rotovator without biting too deeply into the peat and destroying the supporting power of the root mattress provides a relatively smoother ride for a time but concentrates traffic and new tracks are required at regular intervals if the improvement in travelling conditions is to be maintained. All these operations help to ensure that movement from point to point is more certain but they cannot make general travelling conditions much more comfortable since they only ameliorate conditions on such small portions of the distances to be covered.

The road cross-section

22. Good drainage of rainwater from the running surface of the road and the vicinity of the roadway are the prime considerations governing the layout of the road cross-section. On gravel roads the efficient draining of the road surface is accomplished by using a steep camber of about 1 in 24 and regular maintenance is essential to eliminate longitudinal ruts and potholes.(4) In addition the slopes of verges and other drainage arrangements must be such that the water is conveyed away quickly from the vicinity of the roadway. However gradients should not be excessive otherwise erosion may result.

23. The adaption of these principles to conditions in the Falkland Islands requires consideration of the two different types of terrain in the islands:-

(a) the plains and gently rolling areas

(b) the mountainous areas.

24. The former areas, situated on the less durable rocks consist in general of a relatively shallow layer of peat overlying clay. Deep areas of peat are not very common and are mainly confined to the vicinity of streams. In the mountainous areas where the impermeable nature of the quartzite and sandstone rocks hampers drainage the peat cover is generally thicker and boggy areas are very common.

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25. The type of cross-section suitable for areas where the peat cover is not generally greater than 1-1½ ft are shown in Fig. 2. The dimensions of the cross-section are such that the fill material required for the roadway is obtained from the side drains the dimensions of which are suited to the dimensions of the construction and maintenance plant. These ditches will adequately deal with the low precipitation rates normal in Falkland Islands (see Table V).

26. Water collected in the side drains is discharged clear of the road by turnouts as shown in Fig. 3 when the road and ground slope in the same direction. In sidelong ground the water collected in the uphill drain is discharged into culverts or natural drains and conveyed across the road to discharge on the downhill side.

27. Peat is always a difficult material on which to construct roads and it is best removed and replaced by more suitable materials.(5) Where this is ruled out for economic reasons and the peaty area cannot be avoided economically then it is common practice to lay a mattress of brushwood, heather or gorse over the peat and construct the road on this. In the Falklands there are few bushes or trees but the upper layers of the peat consist of a mass of intertwined roots. This forms a natural mattress over the humified peat which is capable of supporting quite heavy loads as is shown by the amount of traffic traversing these areas at present. The supporting power of this natural mattress should not be destroyed and it is recommended that the road structure be founded on it where the peat layer is over 3 ft deep. The road would then consist of a low embankment founded at existing ground level. The minimum depth of fill material required over the peat would be 2 ft(6) and a suitable cross-section is shown in Fig. 3. Side drains should be set well clear of the road embankment as shown to keep the root mattress intact near the roadway.

28. Water collected must again be discharged downhill clear of the road and it is particularly important that culverts especially pipe culverts crossing the road are not founded on peat. All peat under culverts should be removed and be replaced with suitable material preferably sand. The cross-sections shown in Figs. 2 and 4 can be adapted to suit individual circumstances but it is essential to bear in mind at all stages that the efficient disposal of rainwater is most necessary if the road is to perform satisfactorily in service. The decision whether to excavate the peat or form an embankment would be mainly decided on economic considerations but the inferior performance of roads founded on peat should be given due weight in marginal cases.

29. Two lengths of the existing roads near Stanley have been included in the proposed road system (Table IV). They consist of "rock rubble" founded on the clay soil below the peat layers. Their shape and the drainage from them is generally poor while the large size of stone used in their construction precludes mechanical maintenance (Plate V). In this area the peat layer is usually deep and rather than construct new roads it would be better to make use of the existing construction, providing a layer of suitable surfacing material and improving the drainage arrangements.

Geometric standards

30. Standards of both vertical and horizontal alignment on roads vary little from place to place(7) and only those aspects dependent on local circumstances need be considered here.

31. Considering the light traffic conditions expected and the distances between settlements in the Falkland Islands, drivers are likely to travel at high speeds. Over most areas where the ground surface is flat or gently undulating, roads with horizontal and vertical alignment appropriate to speeds of at least 50 mile/h are both desirable and practicable. In mountainous areas the minimum design speed may have to be reduced to 30 m.p.h. These

/speeds

speeds are minimum values and should be increased in all circumstances where such increases will not involve extra construction costs.

32. Sight distances both horizontal and vertical are of prime importance from a safety point of view. The minimum sight distances provided should be either the spacing between passing places plus twice the comfortable stopping distance at the chosen design speed measured between points 3 ft 9 in. the road surface or the comfortable stopping distance measured between points 3 ft 9 in. and 1 ft 0 in. above the road surface. 3 ft 9 in. is the average eye level of the driver and 1 ft 0 in. allows for the contingency of sheep and lambs straying on to the road.

33. A gradient of 1 in 25 should ordinarily be regarded as the maximum desirable. However in difficult circumstances steeper gradients up to 1 in 15 would be acceptable for short stretches of road. Steeper gradients on gravel roads are likely to lead to erosion of the road surface and result in increased maintenance costs. (Plate VI).

Road structures

34. Bridges and culverts. The heaviest lorry at present in the Falkland Islands weighs a total of 11 tons when fully loaded. Items of road maintenance and construction equipment likely to be used on road works on the islands could weigh up to about 15 tons. Bridges and culverts should be designed to carry these loads and a design live loading equal to half the HA loading specified in B.S. 153:1954[8] would be suitable. This recommendation assumes that steps will be taken to limit the size and carrying capacity of commercial vehicles which can be imported into the Falkland Islands. Bridges should be at least 10 ft wide between kerbs. Kerbs at least 12 in. high surmounted by tubular parapets are desirable.

35. The proposed road from Stanley to Fitzroy would cross Port Fitzroy on the existing bridge (Plate VII) there. This bridge, Fitzroy Bridge, has a timber deck and longitudinal beams supported on concrete piles. No construction records are available but the piles appear to be generally in a good condition. It is suggested that a detailed survey including loading tests on a few representative pile tests should be carried out to assess the carrying capacity of the pile substructure. If this proves adequate, which is a reasonable possibility, then the superstructure could be reconstructed to carry the required loads. If the substructure were inadequate then consideration could be given to a number of alternatives:-

(i) Constructing a 5 mile length of road to circumvent Port Fitzroy.

(ii) Constructing a new bridge at the present site

or (iii) Placing a load restriction on the existing bridge and making the heavier loads travel to the southern parts of East Falkland by the longer route via Teal Inlet and Douglas Station.

36. The location of the roads was influenced by the desirability of reducing the number of large bridges to a minimum. Thus the road from Darwin to Douglas Station crosses the San Carlos river in its upper reaches although this results in a small increase in the length of road required.

37. Paved fords ("Irish Bridges") could be used as an alternative to bridges at some of the larger river crossings e.g. the Malo. On the smaller streams especially those with relatively high banks meandering through deep peat deposits this alternative would not lead to any great initial economy. This form of river crossing is more difficult to maintain than a bridge and travel during periods of flood is not possible.

38. The rainfall data in Table V enables an estimate to be made of the flood volumes which will only occur infrequently. Considering the other

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uncertain factors involved a simple expression relating run-off to the catchment area could be used.[9] For conditions in the Falkland Islands calculation indicates that $Q = 200 A^{2}/3$ where Q is the run-off in cusecs and A the catchment area in square miles would give a reasonable estimate of the flood intensities to be considered. However, it would be necessary to obtain as much local information as possible on the flood levels which have occurred at the intended bridge sites.

39. **Cattle Grids.** All the areas traversed by the proposed roads are sheep farms and cattle grids (paso libre) or gates will be required at all fences. The opening and closing of gates is an irksome business and impedes movement while farmers should not be burdened with the task of closing gates after delinquent travellers. Cattle grids 10 ft wide with side gates to permit the passage of stock are recommended. A layout similar to that already in use on the road from Stanley to Moody Valley would be suitable.

Constructing the road system

40. Construction materials. Eighteen typical samples of the soils and decomposing rock on the two main islands have been examined in the Laboratory. Details are given in Tables VI and VII and Figs. V(a) and (b) and the results agree with the visual assessments made in the field.

41. Selection criteria used for surfacing materials for gravel roads vary from country to country[4][10] reflecting differences in local climate conditions and the available sources of material. In simple terms a gravel must possess sufficient cohesion to resist displacement and abrasion, the development of corrugations and excessive dusting in the dry season and at the same time be sufficiently granular to support traffic in the wet season without becoming slippery. Additionally it should not contain very large particles which would render maintenance by motor grader and the obtaining of a smooth riding surface difficult.

42. To satisfy these requirements gravels and soils to be used in road surfacings should be well graded and the plasticity of their fines i.e. the fraction of the materials passing the B.S. No. 36 sieve should lie within certain limits. In general the maximum size of particle should not exceed 2 in. and suitable grading limits are given in Table VIII. For conditions in the Falkland Islands it is considered that the plasticity index of the fines should lie between 5 and 20 per cent with preference being given to materials in the lower part of this range.

43. In the Falkland Islands decomposing rock would provide the most useful source of surfacing material (Plate VIII). Outcrops of this type of material are widely scattered on the two main islands. Extensive occurrences were seen on the sea cliffs formed in the Lafonian Tillite, Bluff Cove Beds, and the Choiseul Sound and Brenton Loch Beds[11] and to a lesser extent in the low lying coastal areas occupied by the Fox Bay, Port Stanley and Port Philomel Beds. In the more mountainous areas occurrences were less evident but a deposit of decomposing quartzite and a creep gravel were located (Sample Nos. 2148 and 2149). In addition the cohesionless gravels and sands in beach and alluvial deposits would provide a useful source of material which could be mixed with excessively clayey decomposing rock materials or the sandier clay soils to produce an acceptable surfacing.

44. To make best use of the local materials available for use as road surfacings the particle-size distribution and plasticity index of the fines[4] of representative samples from suitable located deposits should be determined to assess their compliance with the requirements set out above. Evaluation of decomposing rock materials is complicated by the fact that their gradings are mainly determined by the methods of winning used. With these materials the main considerations are that they should be weak enough to break down to a suitable grading under rolling and that the fines produced

/comply

comply with the plasticity requirements. The latter can be assessed by carrying out the aggregate impact test[4] on prepared samples of ½ in. to ⅝ in. material and determining the plasticity of the fines produced. Linear shrinkage tests would also be a useful check on the plasticity index determinations especially on the more silty and organic materials where the determination of the liquid and plastic limits is difficult.

45. The winning of these natural materials is easily and quickly carried out with mechanical excavators. Material in excess of 2 in. can be removed at the pit or a grid roller used to break down the larger lumps of decomposing rock during the compaction of the surfacing layer. During construction a detailed record should be kept of the source of surfacing material used on each length of road. This would enable the more suitable materials in service to be easily located and provide useful information on the materials most suited to the environment of the Falkland Islands.

46. All the soils examined could be used as fill materials. Where possible preference should be given to the less clayey soils since they are easier to handle and compact. All fill materials should be deposited in 6 to 9 in. loose layers, watered if necessary and compacted with rollers.

47. Concrete is the most suitable material to use in bridges and culverts as it requires the minimum of maintenance. Culverts and the smaller bridges could well be constructed of precast standard elements and concrete pipes. At present crushed stone and beach sand are used as concrete aggregate in Stanley as there are no gravel deposits in the vicinity. Although the beach sand (Sample No. 2147) contains some sodium chloride reinforced concrete fence posts made using it have performed well in service. However, there is some risk involved and if prestressed concrete was used it would be a wise precaution to wash the sand prior to use.

48. Outcrops of durable stone abound in the remaining areas of the main islands and there would be no difficulty in procuring suitable aggregate anywhere. Some of the gravel deposits in rivers might form suitable and cheaper sources of coarse aggregate. The suitability and the proportioning of the various concrete mixes should be based on the grading of the various aggregate and the strength of the concrete. Routine crushing tests should be carried out to ensure that the concrete being produced is up to specification.

49. Road construction. Labour on the Falkland Islands is in extremely short supply and there is no unemployment. A large proportion of labour on the farms is at present recruited in the United Kingdom so that the labour required to construct the road system must of necessity come from outside the colony.

50. There is no local experience of large civil engineering works and contractors in the accepted sense do not exist. The Public Works Department is equipped and staffed only to provide local services in Stanley. Its limited resources in manpower, often of indifferent quality, are stretched to capacity to carry out routine tasks, minor construction projects and peat cutting.

51. The construction of a road system in these circumstances could best be undertaken by an outside contractor who would supply all the men, equipment and experience required. A road system of the size suggested might be likely to attract a contractor interested in work overseas provided the annual expenditure on the project was at least of the order of £100 to £200 thousand per annum. About 30-40 men would be needed but the exact number would depend to a great extent on the rate of construction required. Proper supervision of contract work is absolutely essential and it would be necessary that a resident engineer be appointed to undertake this. In addition he would also be responsible for the preparation of the detailed road alignment plans and other detailed contract drawings. The number of subordinates he would require would depend mainly on the contractor's construction programme.

/Construction

Construction costs

52. Road construction costs vary quite a lot from country to country and there is little costing information available in the colony. However consideration of local conditions and what cost data there are available in the Falkland Islands with those elsewhere make it possible to give an estimate of the order of magnitude of the cost of constructing the road system.

53. The average cost elsewhere of roads with a cross-section as shown in Fig. 2 would be about £2000 per mile in the level country while on peat using the cross-section in Fig. 3 the cost would be about £3000 per mile.(2) Bridges are not included in these figures. As the terrain becomes more difficult and earthworks increase costs will rise and might be increased to twice the above figures in mountainous conditions so that the average cost per mile over a road system would be about £3000 per mile.

54. The meagre costing data available in the Falkland Islands indicate that construction costs are well above the average elsewhere. This is to be expected where labour is expensive and difficult to obtain and where all manufactured items, petrol and diesel oil must be imported since freight charges make up a large proportion of the cost of many items e.g. cement costs £20 per ton. Additionally since building roads would be a once only operation a contractor's overheads would be higher than normal. In these circumstances it is likely that the average cost per mile of the road system would be somewhere in the region of £4000 to £5000 per mile, putting the total cost of constructing the road system between £1½ and 2 million. These costs would be similar to those currently obtained on road works in New Zealand.(12)

Road maintenance

55. Continual maintenance of the road system is essential to keep it in good condition and prevent it becoming a wasting asset. About 15-20 men using mechanical equipment would be continously occupied carrying out routine day to day maintenance and the regravelling necessary every few years. Since there are no reserves of labour on the islands imported labour will be required either to do this road maintenance or to replace labour drawn from the farms.

56. Maintenance work is invariably carried out by the authority responsible for roads and in the Falkland Islands the road maintenance organisation should be attached to the existing Public Works Department.

Road maintenance costs

57. The average cost of properly maintaining lightly trafficked gravel roads in other countries is about £50 per mile per annum. Bearing in mind the local factors already discussed when considering construction costs, that the labour force will have to be provided with housing, and as there are two islands that some of the larger items of plant will have to be duplicated on account of their bulkiness it is likely that the figure would be higher. The annual maintenance expenditure consequent on the construction of a road system is therefore likely to be somewhere between £20,000 and £30,000. This figure includes items which at present are classed as capital items. However since road maintenance plant has a relatively short life it would be more realistic to create a plant replacement fund so that money would be available when required for the purchase of new equipment.

/Wayleaves

Wayleaves and rights to materials

58. Most of the country to be traversed by the proposed road system is freehold land. Since the construction and maintenance would be undertaken by the government it is recommended that the land on which the road is located should be acquired. A strip of land about 40 yards wide should be obtained so that if farmers decide to fence along the road there would be sufficient land available for the movement of flocks of sheep. In addition the maintenance authority should be given statutory rights to obtain road construction materials from outside the road reservation.

Conclusions and Recommendations

See Summary.

/TABLE I

PLATE I. Landrover bogged down.

PLATE II. Poor drainage and lack of maintenance on Fitzroy-Darwin track.

PLATE III. Conditions resulting from the concentration of traffic at a small bridge.

PLATE IV. Conditions resulting from the concentration of traffic at a gateway.

PLATE V. The existing "rock rubble" road from Stanley to Pony Pass.

PLATE VI. Erosion on the Fitzroy-Darwin track.

PLATE VII. Fitzroy Bridge.

PLATE VIII. Decomposing rock and clay cliff near Fitzroy Bridge.

TABLE I

Distribution of Population in Falkland Islands*

Stanley	1074
Remainder of East Falkland	548
West Falkland	358
Other Islands	151 (?)
Shipping	41
Total	2172

*Data supplied by Statistics Section, Secretariat, Stanley and also reference (3)

N.B. There is some lack of consistency between Tables I, II and III but the data there are the best available and the discrepancies do not alter the overall picture.

TABLE II

Motor vehicles registered in Falkland Islands April 1963*

Vehicle type	Stanley	Elsewhere	Total
Vans and lorries	81	16	97
Private cars	122	20	142
Landrovers and jeeps	97	130	227
Tractors	15	75	90
Motor cycles	102	198	300
All vehicles	417	439	856

31 of these vehicles are known to be no longer in use.

*Data supplied by Police Department, Stanley.

/TABLE III

TABLE III

Population and number of vehicles on the main settlements on East Falkland and West Falkland*

Location	Farm owner	Main settlements	Number of people on farm	Number of vehicles on farm
East Falkland	San Carlos Sheep Farming Co. Ltd.	San Carlos	40	12
	Pitaluga Bros.	Salvador	24	13
	Falkland Islands Co. Ltd.	Darwin and Goose Green	172	57
	do.	North Arm	68	29
	do.	Fitzroy and Green Patch	55	20
	Smith Bros.	Johnsons Harbour	16	8
	Mrs F.O. Yonge	Bluff Cove	11	5
	Estate T. Robson	Port Louis North	20	6
	The Douglas Station Co. Ltd.	Douglas Station	40	12
	Port San Carlos Co. Ltd.	Port San Carlos	56	10
	Teal Inlet Ltd.	Teal Inlet	36	19
	Estate H.T. Pitaluga	Rincon Grande	10	9
West Falkland	J.L. Waldron Ltd.	Port Howard	82	17
	Holmested Blake and Co. Ltd.	Hill Cove	63	19
	Falkland Islands Co. Ltd.	Port Stephens	45	13
	do.	Fox Bay West	24	16
	Packe Bros and Co. Ltd.	Fox Bay East	62	24
	Luxton and Anson Ltd.	Chartres	46	21
	Bertrand and Felton Ltd.	Roy Cove	36	16

* Data supplied by Statistics Section Secretariat, Stanley, and Farm Managers.

/TABLE IV

TABLE IV

Proposed Road System

Island	Location of road	Length to be constructed	Priority	Remarks
East Falkland	Stanley-Fitzroy	16	1 (a)	5 miles existing road to be reconstructed
	Fitzroy-Darwin	38	1 (b)	
	Darwin-Douglas Station	43	1 (c)	
	Douglas Station-Teal Inlet	13	1 (d)	
	Teal Inlet-Stanley	28	1 (e)	5 miles existing road to be reconstructed
	Branch roads to:-			
	San Carlos	7	2 (a)	
	Port San Carlos	13	2 (b)	
	Johnsons Harbour via Green Patch and Port Louis (North)	20	2 (c)	
	Rincon Grande	9	2 (d)	
	Salvador	16	2 (e)	
	North Arm via Goose Green	34	2 (f)	
West Falkland	Fox Bay East - Hill Cove	48 39	1 (a)	
	Branch roads to:-			
	Fox Bay West	3 4	1 (b)	
	Chartres	3 ✓	1 (c)	
	Port Stephens	48 40	2 (a)	
	Port Howard	34 30	2 (b)	
	Roy Cove	11 10	2 (c)	
		124		

/TABLE V

TABLE V

The frequency and duration of heavy rainfall at Stanley 1951-60*

Period (hours)	Rainfall amount (millimetres)				
	10	15	20	25	30
1	6	3	-	-	-
2	22	4	-	-	-
3	37	9	-	-	-
4	59	15	1	-	-
5	67	25	4	-	-
6	73	33	6	1	-

Note: On 31st December 1951, 10 mm rain fell in 13 minutes and 15 mm in 22 minutes. Such intensity is unusual.

* Data supplied by the Meteorological Service, Stanley.

/TABLE VI

TABLE VI

Details of Decomposing rock samples from the Falkland Islands

Sample reference number	Location	Description	Geological Formation(11)
2131*	Teal River West on track to Chartres opposite the Sand Pond Gate.	Decomposing shale intermingled with peaty material.	Port Stanley and Port Philomel Beds.
2133*	Fitzroy-Darwin track on March Ridge opposite west end of Long Pond.	Decomposing shale.	Black Rock Slates.
2134	Low cliff on south side of Port Fitzroy near Fitzroy Bridge.	Decomposing tillite - muddy sandstone with angular pebble includions.	Lafonian Tillite.
2136	Low cliff on north side of Bluff Cove opposite settlement.	Decomposing banded sandstone.	Bluff Cove Beds.
2137	Low cliff on north side of North Basin.	Decomposing siltstone and shale.	Bluff Cove Beds.
2140	Low cliff at head of Port Harriet.	Decomposing tillite - muddy sandstone with angular pebble inclusions.	Lafonian Tillite.
2145	Left bank of Estancia Brook near outlet.	Decomposing shale.	Port Stanley and Port Philomel Beds.
2148*	Low cliff on south side of Stanley Harbour between the outlets of Moody Brook and Felton Stream.	Decomposing quartzite.	Port Stanley Beds.

*These samples have also been included in Table VII

/TABLE VII

TABLE VII

Details of typical soil samples from the Falkland Islands

Sample Reference Number	Location	Description	Casagrande Classification(4)
2128	Left bank of Murrell River below Murrell River Bridge	Sandy clay	CL
2129	Left bank of Murrell River at Murrell River Bridge	Alluvial sand	SU
2130	Roycove camp at fence between bailey bridge and Authur Pass	Clay	CH
2131*	Teal River West on track to Chartres opposite Sand Pond Gate	Decomposing shale intermingled with peaty material	GW
2132	Fitzroy-Darwin track opposite Swan Inlet House	Clay	CH
2133*	Fitzroy-Darwin track on March Ridge opposite the west end of Long Pond	Decomposing shale	GW-GM
2135	Low cliff on south side of Port Fitzroy near Fitzroy Bridge	Sandy clay	CI
2138	South side of Mullet Creek	Clay	CH
2139	Left bank near outlet of Mullet Creek stream	Alluvial sand	SW
2141	Raised spit at east side of the Canache	Sand	SU
2147	Surf Bay	Beach sand	SU
2148*	Low cliff on south side of Stanley Harbour between the outlets of Moody Brook and Felton Stream	Decomposing quartzite	SU
2149	Bank adjacent to crushers at P.W.D. Quarry Moody Valley	Creep soil consisting of quartzite fragments and clay	GC

*These samples have also been included in Table VI

/TABLE VIII

TABLE VIII

Proposed limits of particle-size for gravel surfacings

B.S. sieve size	Nominal maximum size			
	1½ in.	¾ in.	⅜ in.	3/16 in.
1½ in.	100	-	-	-
¾ in.	80–100	100		
⅜ in.	55- 80	80–100	100	-
3/16 in.	40- 70	55- 80	80–100	100
No. 7	30- 60	45- 70	50- 80	80–100
No. 25	25- 50	25- 50	30- 55	30- 60
No. 72	20- 40	20- 40	20- 40	20- 45
No. 200	10- 25	10- 25	10- 25	10- 25

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REFERENCES

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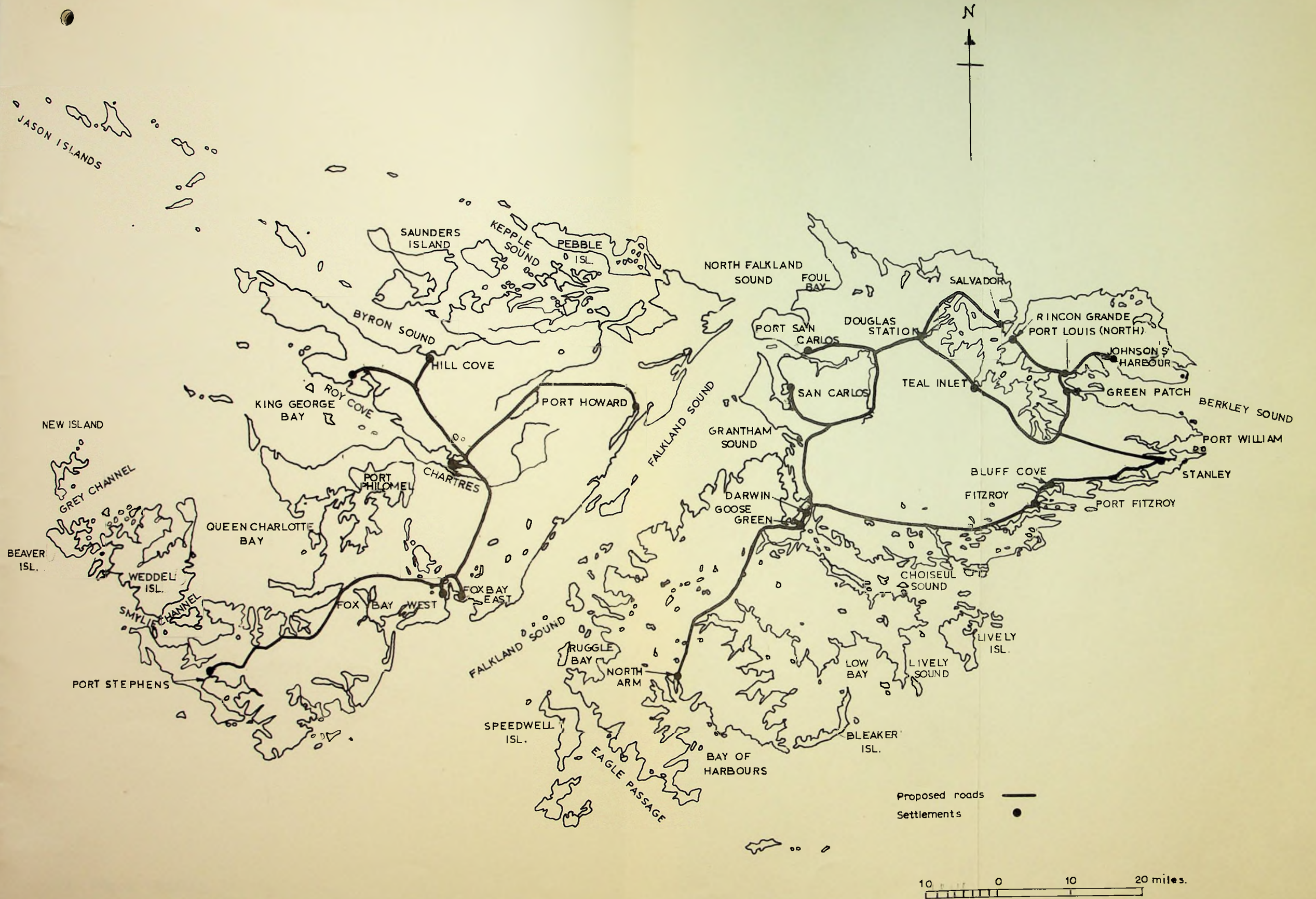
JD.



THE FALKLAND ISLANDS

Fig. 1. LAYOUT OF THE PROPOSED ROAD SYSTEM

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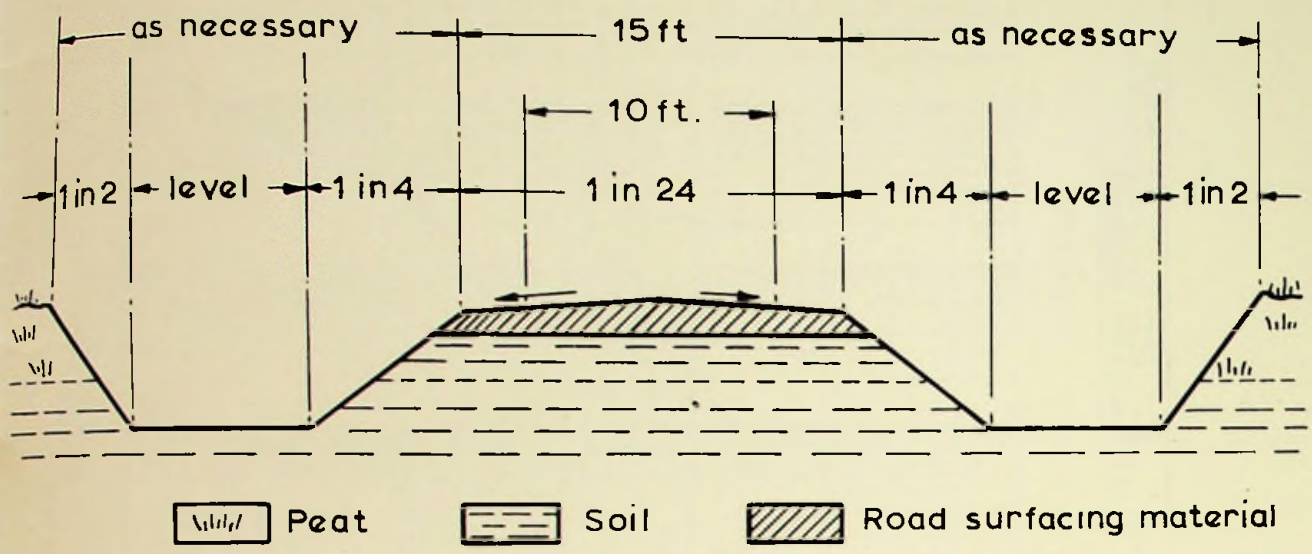


Fig. 2. CROSS SECTION FOR ROAD WHERE THE PEAT LAYER IS NOT GENERALLY GREATER THAN 1 to 1½ ft.

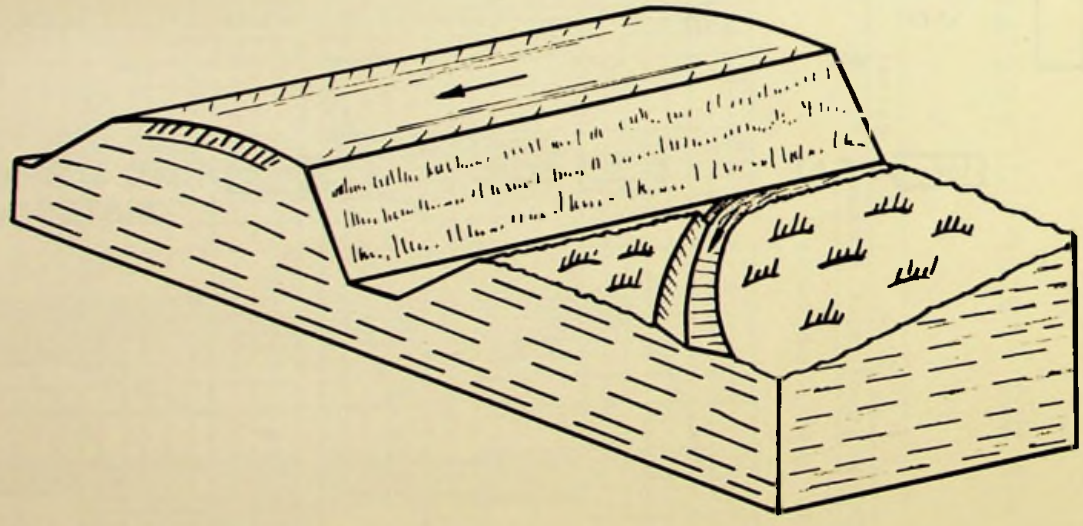


Fig. 3 BLOCK DIAGRAM SHOWING ARRANGEMENT OF TURNOUT FROM SIDE DRAIN

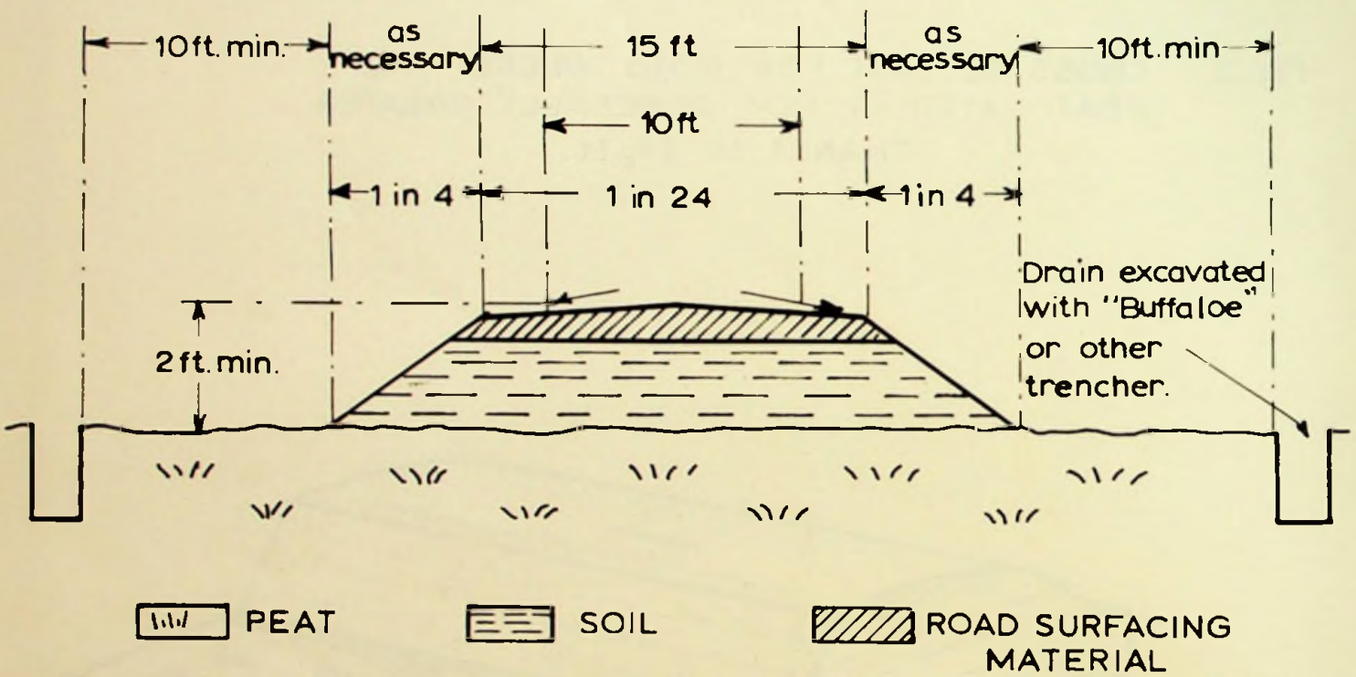
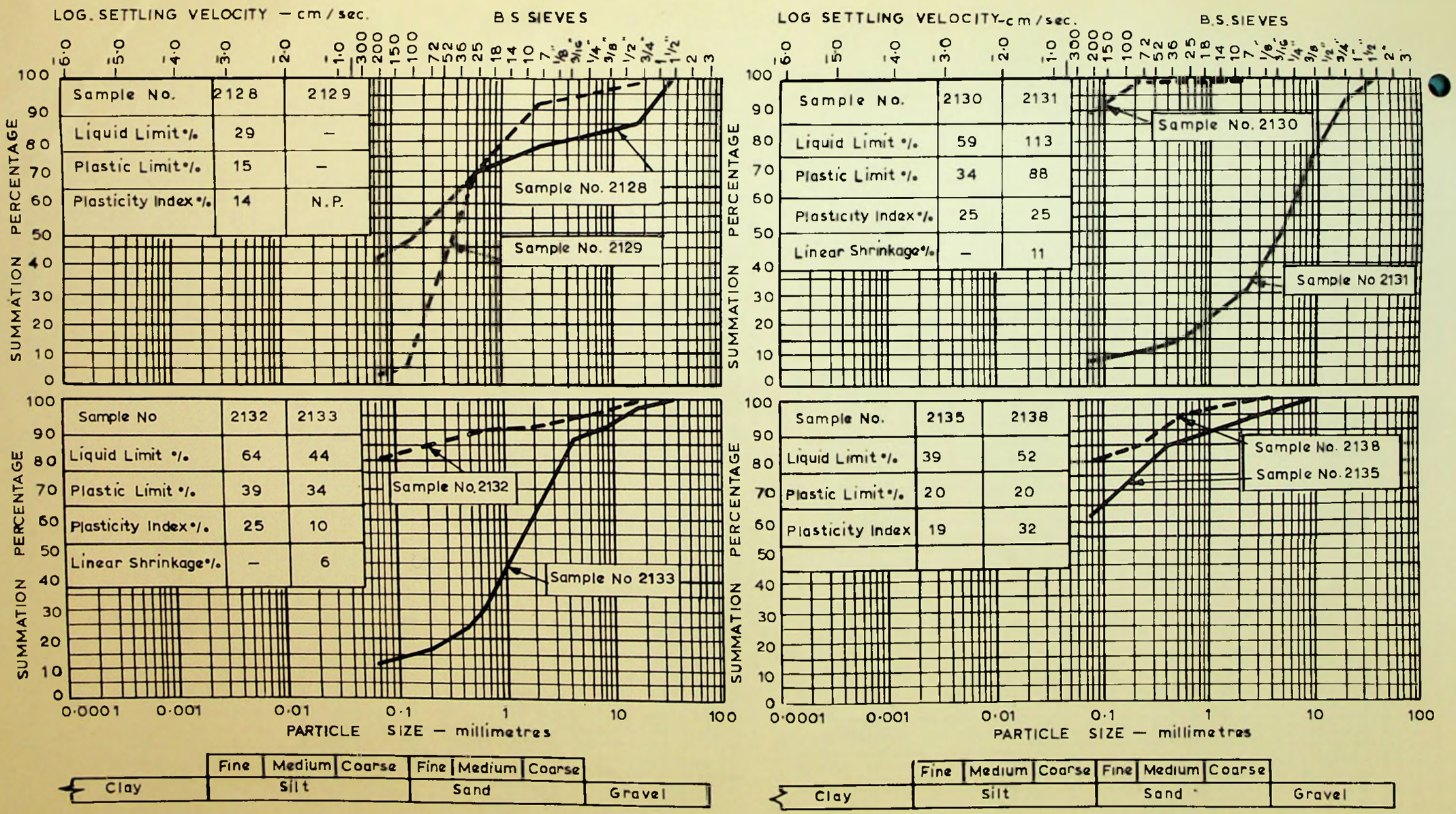


Fig. 4. CROSS SECTION FOR ROAD WHERE THE PEAT LAYER IS GENERALLY GREATER THAN 3ft.



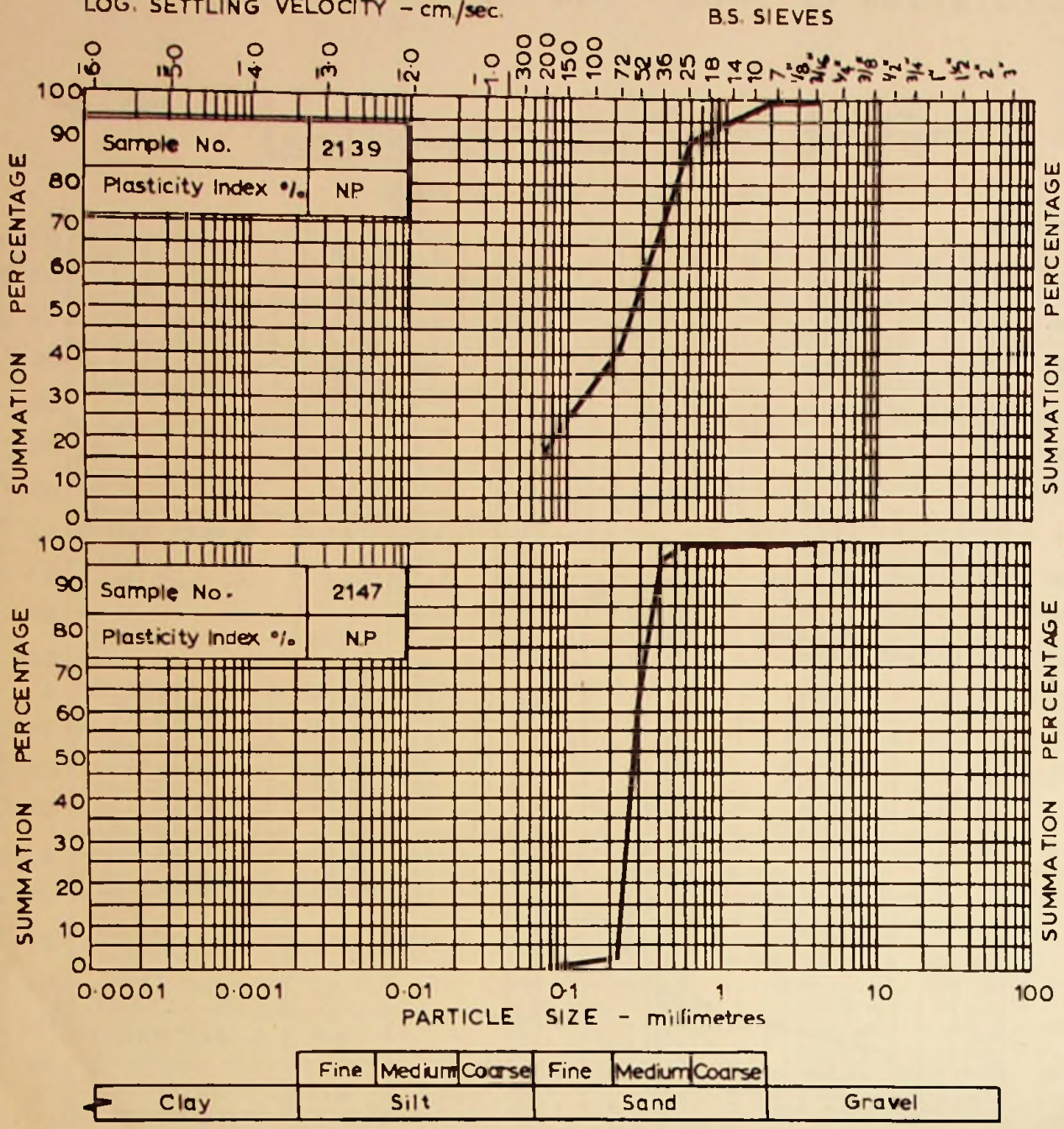
Sample No.	2128	2129
Liquid Limit %	29	—
Plastic Limit %	15	—
Plasticity Index %	14	N.P.

Sample No.	2130	2131
Liquid Limit %	59	113
Plastic Limit %	34	88
Plasticity Index %	25	25
Linear Shrinkage %	—	11

Sample No	2132	2133
Liquid Limit %	64	44
Plastic Limit %	39	34
Plasticity Index %	25	10
Linear Shrinkage %	—	6

Sample No.	2135	2138
Liquid Limit %	39	52
Plastic Limit %	20	20
Plasticity Index	19	32

Fig. 5(a) SOIL CLASSIFICATION DATA



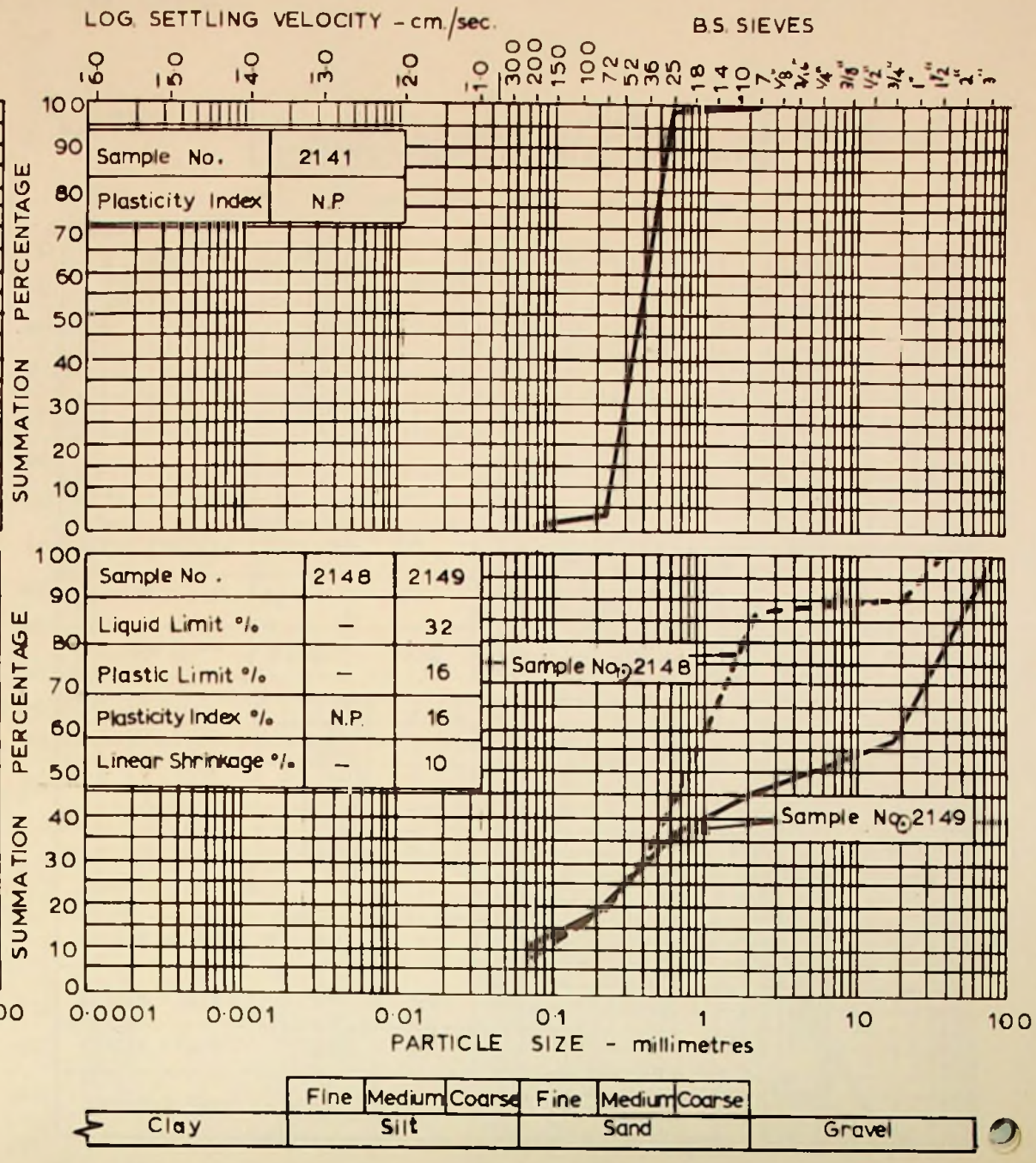


Fig. 5. (b). SOIL CLASSIFICATION DATA (continued).