

1929

Kenya

No. 15634

SUBJECT

C0533/387

Water Investigations

(Mr Bulby Thompson's report)

Previous

15402/28

Subsequent

*S/R.A.
(Rly. Questions)
20436/29 Uganda*

Major, Dutton. a/c. 30th. Feb. 29.

Requests ~~any~~ any information regarding transfer of the water boring machinery and whether any operations for water boring had been provided in this year's Estimates.

DESIGNED UNDER STATUTE

Off. reply to
dt. Allen
4/3
at all

HA 2

L. Major Dutton a/c
(No. 1 and)

16 MAR 1929

3. Crown Agents. 22 July 1929.
Towards account of expenses incurred by
Mr. Baby Thompson on his visit to Kenya.

4. A. BEEBY THOMPSON. (S.O). 15 July, 1929.
Enquires as to presenting his report as a general
East African Report or only Kenya & Uganda;
encls. copy report on T.T.

Mr. Allen

No. 3

we cannot, I think, question
Mr Thompson's claim, and Kenya have
agreed to pay his out-of-pocket
expenses. (See No. 2 a X/5402/28)
I. Feb. 3 and authorize payment
of claim for Kenya funds. And
send copy of No. 3 with vouchers,
and reply to OAG (P. info) reference
No. 8 a X/5402/28

No. 4

If Mr Thompson's report is as

he says, of general African interest,
it should clearly be made available
for all African Govts, but the cost
of publication must be considered.
I understand that this is a
matter on which the Col. Devt. C.H.C.
might help and that it would
not be too petty a matter to put
before them if they were ~~not~~
willing to defray the cost, I
don't think Kenya could really
grumble at having had to pay
the original expenses themselves
it is only a small sum in
all (£231) and they have
already had several private
reports for this money.

Mr Boyd might be asked
whether it would be worth
putting this up to the C.D.C.
No is possible in any event be
asked but if it is proposed
to put the matter before the
C.D.C. Mr Thompson can be
informed of the position.

(The Cliffs)

he says, of general African interest,
 it should clearly be made available
 for all African Govts, but the cost
 of publication must be considered.
 (understand that this is a
 matter on which the Col. Dev. Ctte.
 might help and that it would
 not be too petty a matter to put
 before them if they were ~~not~~
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 already had several private
 reports for this money.
 Mr Boyd might be asked
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 putting this up to the C.D.C.
 No committee in any event be
 asked but if it is proposed
 to put the matter before the
 C.D.C. Mr Thompson can be
 informed of the position

(Mr Cliffe)

24th 29

No. 3. Draft to C.A. herewith. Take L.F.
 action as suggested by Mr. Cliffe.

Ed 1

No. 4. I don't think this is a matter to
 submit to the Colonial Development Committee. Also
 in spite of the fact that Mr. Beety Thompson refers
 to his report as of interest to "most of our African
 possessions", I think we can limit ^{it} ~~itself~~ to East
 Africa and not drag in West Africa.

I submit draft reply for conson. If it is
 approved Mr Boyd should see later.

W. Miller
 6/8/29

Copy sent to Mr Boyd

Mr Boyd

Answers it w. Mr Miller to pass
 through you now.

I agree.

W. Miller
 7.8.29

Ed Boyd

8/8/29

See on
 20-4 on 6.77
 register

Ed 16
 at once

19.8.29

5 To Mr Beety Thompson (No. 5 and) 12 August 29

6 To C.A. (No. 5 and) 14 AUG 1929

7 To Gov. 634. Specimen 3 & 6. 19 AUG 1929

Ed. See 15/11/29 (C.W.D. Report, 1928) as to
 result of water boring operations.

One copy in X.B.A.

The two copies of the Report addressed to the Governor of Kenya by Messrs Beby Thompson and Partners on the Water Problems of the Colony.

1) Crown Agents (S-07) 16 Dec 29

Muffled

After all the discussion in No. 4 it seems that Kenya have authorized the printing of Mr Beby Thompson's Report in their own name.

We shall doubtless receive the Gov's orders in due course.

In the meanwhile 7 pp shall circulate to the C.A. & W.A. Deps.

and I also to Downing Office to see whether rough copies for the C.A.'s records shall be sent to other Govts.

If this is done & the other Govts wish to be supplied with any appreciable number of additional copies, & perhaps another printing could be arranged.

Though the Report is to the Kenya Govt, I do not think we should have to consult them before sending complimentary copies to other Govts.

If this is agreed Uganda at any rate should have one.

Chris Cliffe

20.12.29

(Mr Beby Thompson thought it would be of general opinion interest)

I cannot imagine that this will be necessary I don't know the land here - not Kenya
1892

8. Crown Agents. 9th. Dec 29.

One copy in
I.B.A.

The two copies of the Report addressed to
the Governor of Kenya by Messrs. ~~by~~ Thompson and
partners on the Water Problems of the Colony.

Crown Agents (S.O.) 16th Dec 29

Mr Allen

After all the discussion on No. 4
it seems that Kenya have authorized
the printing of Mr. Baily Thompson's
Report on their own.

We shall doubtless receive
the G.O. orders in due course.

As the memorandum of 7 pp. shall
circulate to the G.O. & S.O. & S.P.
and I also to Downing Office,
to see whether single copies for
the C.A.'s receive shall be
sent to other G.O.'s. If this is
done & the other G.O.'s wish to
be supplied with any appreciable
number of additional copies, &
perhaps another printing could be
arranged.

Though the Report is to be
Kenya Govt. I do not think we
should have to circulate them
except sending complimentary copies
to other G.O.'s. If this is rejected,
Uganda at any rate should have
one.

Chas Cliffe

16 Dec 29

Mr Baily Thompson thought
it would be of general
interest

I cannot imagine
that this will be
necessary & that
Kenya Govt. has
half - not Kenya
Govt

9a

I put up a short note of what
are the important features of the report
for the various offices
? available as proposed but
distribution is rather to be limited
& think I've come to my own place -

See also
1832
Sub File 11

W. G. Cliffe

Mr Allen
6/1/30

all Parburton
6.1.30

One copy will be enough for
each place. I hope that one can also
be found for the Geological Society

J. W. M. Allen
6.1.30

We have been investigating water in N. Nigeria
& the N.T. of the Gold Coast but with very negative
results.

Nigeria should have 3 copies - one for Lagos one for
Kaduna & one for the Geological Dept. The Gold Coast
also should have 3, 3. Lagos & Fombia 1 each.

18.12.29
6.1.30

6 copy, 1 copy to each of the 5 C.A. f. 1. 1/1/30

6.1.30
7/1/30
J. W. M. Allen

10 To C.A. (4 Annand) 17 Jan 1930
11 To Gov. Kenya 92. (1/1/30 8 without intro & 10) - 1/1-2.0 JAN 1930

10

Enquires whether there is any objection to a copy of the Report being supplied to the Editor of "East Africa" for re-

Mr Parkinson.

We are sending a copy to the entirely unofficial body - the Geological Society - & I don't think there would be any objection in sending Mr Tolson a copy for his personal use. but I have my doubts whether this is a document which ~~should~~ ^{could} properly be removed by "East Africa" - certainly not before Kenya has received its own copies.

But they want copy in Dec. See No. C

all P

? Say a copy ~~can~~ may be sent to Mr Tolson, but that he should be told that it is not desired that it should be removed.

C.A. Cliffe

26.1.30

I am afraid X will not do, it will be little giving a cat a drink & kicking it not to drink it!

I think we had better let us in M.P.

all P

27.1.30

at once

Let to Gov. Kenya. gen. 25 Jan. 30.

No objection to copies being supplied to "East Africa" - desirable that facilities should be afforded to local papers, which cannot be done pending receipt of copies from C.A.'s.

Mr Parkinson.

I understand from the C.A. that the 150 copies were sent by the Museum & from the B.I. that the Museum received them on January 17th. It is odd that they had not been received in Nairobi before N.I. was sent on the 29th, but they must surely arrive there within the next few days.

Therefore it would be safe enough now to let "East Africa" have a copy for review and the C.A. may be so informed.

Let inf. go by disp. ref 14
explaining...

C.A. Cliffe

31.1.30

all P

31.1.30

at once

PRINTED UNDER STATUTE

To C.A. (22 Annual) Jan. 4 FEB 1930

16 To - Gov. Kenya 11th - 1st Approved - 4 FEB 1930

DESTROYED UNDER STATUTE

States copies now received.

? *W. J.*
W. J.
W. J.
W. J.
W. J.
W. J.

18. Magadi Soda Company. 15th. March 30.

Enquires whether they may be supplied with two or three copies of the report for perusal and files.

W. J. *W. J.*
W. J.
W. J.
W. J.

DESTROYED UNDER STATUTE

To Magadi Soda Co. (18 Annand)
(w/2 c's incl in No 8)

24 MAR 1930

29. Magadi Soda Company. 25th. March 30.

Ack. of No. 19.

Mr. Ashworth,
? put by pl.

W. Needham,
26-3-30.

W. J.
W. J.
W. J.
W. J.

17.

Gov. Tel. 37. 6th. Feb. 30.

DESTROYED UNDER STATUTE

States copies now received.

? busy ✓
⑧ Eastman
22/2
at once

18.

Magadi Soda Company. 15th. March 30.

Enquires whether they may be supplied with two or three copies of the report for perusal and files.

HT Bennett
at once
22.3.30
at once

DESTROYED UNDER STATUTE

To Magadi Soda Co. (18 Annual)
(w/ 2 c's incl in No 8)

24 MAR 1930

25.

Magadi Soda Company. 25th. March 30.

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Mr. Ashworth,
? Put by pl.

W. Needham.
26-3-30.

W. Ashworth
26/3/30
at once

TELEPHONE: VICTORIA 4444.
TELEGRAMS: SODAQADI, LONDON.

RECEIVED
12 MAR 1930
COL. OFFICE

MAGADI, KENYA COLONY.
KILINDINI

The Magadi Soda Company Limited.

DIRECTORS:
MR. COL. LEED WELCHETS, F.C.S., B.Sc., F.R.S. (Chairman)
J. BRUNNINGSON (deputy chairman)
SIR E. H. ALLEN, C.B.E.
MR. H. V. MITCHELL
MR. FLITERS
MR. H. MARRIOTT
MR. W. W. W. W.
MR. COL. G. P. POLLITT, D.S.O.
MR. P. SAUNDERS

Imperial Chemical House
Millbank
London S.W.1

OUR REFERENCE

YOUR REFERENCE

15th March 1930.

The Secretary of State for the Colonies,
Colonial Office,
London, S.W.1.

Sir,

We have noticed in the Press recently references to a report on Kenya Water Supplies by Messrs. A. Beeby Thompson & Partners. On approaching them for copies they have informed us that a number of these reports were handed to you and that they have no further copies available for distribution.

We are therefore taking the liberty of approaching you and asking whether you would be good enough to let us have, say, two or three copies of this report for our perusal and files.

We remain,

Sir,

Your obedient servants,
FOR THE MAGADI SODA COMPANY, LTD.

J. B. Talbot
ASSISTANT SECRETARY

mswd 24 MAR 1930

C.O.

Mr. Clegg 311.30

Mr. [Signature]

Mr.

Mr. Rottonley.

Sir J. Shackburgh.

Sir G. Grindle.

Presd. U.S. of S.

Presd. U.S. of S.

Secretary of State.

X/3354/30

Kenya

16

S+R

16 February 1930

DRAFT.

Kenya, No. 11st

General Clegg

Sir,

I have to refer to your telegram No. 31 of the 19th January & to inform you that the C.A. for the C. have been authorized to supply the Editor of East Africa with a copy of W.A. Beeby Thompsons Report on Kenya Water Problems for review ~~in~~ in East paper.

2. It is understood that 150 copies of the

2040

was conveyed by the
S.S. Mohan, which
arrived at Bombay
on the 17th January,
and it was therefore
assumed that ~~the~~
copies would be available
for distribution to the
local newspapers within
a few days after the
despatch of your letter
under reference.

(Signed) PASSFIELD.

was conveyed by the
S.S. "Madras" which
arrived at Bombay
on the 17th January,
and it was therefore
assumed that ~~the~~
copies would be available
for distribution of to the
local newspapers within
a few days after the
despatch of your letter
under reference.

(Signed) CASSFIELD.

RECEIVED
30 JAN 1930
COL. OFFICE

8

14

TELEGRAM from the Governor of Kenya to the Secretary of State for the Colonies.

Dated 29th January, 1930.

(Received Colonial Office 4.50 p.m. 29th January, 1930)

(No. 13)

No. 31.

29th January. Your telegram of 25th January
No objection to copies of Beeby Thompson Report being
supplied to East Africa but desirable that facilities
should be afforded local papers. This cannot be done
pending receipt from the Crown Agents of 150 copies
which despatch notified us 5th December.

(see No. 8)

Amund - 1147 - 4 FEB 1930

O/Misc.220.

RECEIVED
24 JAN 1950
COL. OFFICE

12

9

East African Department,
COLONIAL OFFICE.

We have been asked by the Editor of "East Africa" for a review copy of Mr. A. Beeby Thompson's Report on Water Problems in Kenya, and we shall be glad to know whether there is any objection to a copy being supplied to him for review in his periodical.

Approved - *Frederick* 14 FEB 1950

2. As you are aware this Report was printed for the use of the Government of Kenya, and it is not usual for such Reports to be sent to the press before publication.

3. The Editor has informed us that his attention was drawn to the Report by Mr. Beeby Thompson himself.

W. A. Birchall
"O" Department,
Crown Agents,
23.1.50.

C. O.

Mr. Cliffe 13.130

Mr. Allen 14

Mr.

Mr. Bottomley

Sir J. Shackburgh

Sir G. Grenfell

Paras. U.S. of S.

Paras. U.S. of S.

Secretary of State

10
X 13624/29
4624A
LGA-DA

D. D.
16

17 January 1930

DRAFT.

Comm Agents

Gentlemen

Copy Case No. 72-20 JAN 1930 11

(9) I am in reply to refer to your letter No. Z/E 29/1/30

of the 9th December 1929 regarding the Report on Water Problems in Kenya

submitted by Messrs. A. C. G. Thompson & Partners, &

to request that you will distribute complimentary copies of the Report as follows -

Five copies each to the Chief Secretary, Nigeria & the Colonial Secretary, Jamaica.

(9) (11 copies incl)
1/15/30
1/15/30

One copy sent to -

The Chief Secretary, Uganda
Tanganyika Territory
Nyasaland Prov
Northern Rhodesia

The Secretary to the Govt., Swaziland

The Colonial Secretary, Sierra Leone
Gambia

The High Commissioner for South Africa

The Secretary, Geological Society of London
(Burlington House, W.1)

H. T. ALLEN

One Copy each to -

The Chief Secretary, Uganda

Tanganyika Territory

Nyasaland Protectorate

Northern Rhodesia

The Secretary to the Govt., Swaziland

The Colonial Secretary, Sierra Leone

Gambia

The High Commissioner for South Africa

The Secretary, Geological Society of London
(Burlington House, etc.)

Signed: H. T. ALLEN

9a
11

Notes on Report of Kenya Water Problems by
Messrs. A. Beeby Thompson and partners.

Page 1. It is considered that the difficulties arising from scarcity of water cannot be remedied for many seasons, and that in the case of the Northern Frontier Province startling results may follow an organised programme of subsoil water development. It is also affirmed that in the developing of subsoil water by drilling lies the main hope of promoting the agricultural and pastoral progress of the Colony, as opportunities for impounding water are very rare, and the cost of such projects is exceedingly high, and local in its effect.

Page 9. The Rift Valley in particular offers almost unlimited scope for detailed investigation.

Page 14. As regards the Magadi area, the conditions warrant drilling in the first parallel valley between the rifts on the east side of the lake and close to the railway. A bore-hole in the middle of Lake Magadi would certainly disclose data of the greatest scientific interest, and possibly fresh water might be found below the mineralised zone, but drilling should only be conducted under skilled advice.

Page 15. Tube wells could be driven in sandy patches to be found on the shores of Lakes Victoria Nyanza and Albert with a certainty of tapping ~~and~~ an abundance of good filtered and clear water. As regards Lake Naivasha, the geological conditions justify the belief that successful tube wells could be driven which would ensure an ample supply of water.

Page 16. Many of the swamps fringing the great fresh water lakes and running inland are well worth prospecting for subsoil water.

Pages 17 and 18. Northern Frontier Province.

At both Wajir and Eil Wak, the water supplies could be improved beyond recognition by simple works, and in the Lorian swamp region the geological conditions appear to favour the presence of subsoil waters of good quality over a wide belt of country. Along the Dana River separating Kenya and Abyssinia, a series of water stations could be established under most pleasing conditions. Possibly a methodical exploration of the lake beds would result in the location of better quality waters. A special report on water prospects in the Northern Frontier Province will be found at pages 37-45 of the report.

Page 20. A number of water courses were seen which could be developed by drive tube wells.

Page 23. No hesitation is felt in asserting that boreholes are likely to afford the best, safest and cheapest solution of the water supply of most districts where moderate quantities are needed. Where quantities in excess of, say, 50,000 gallons a day are requisitioned, the question of some other source of supply should be considered.

The report also deals fully with the technical aspects of the problem, and it may be

noted

12
noted that on page 30 they refer to the "Star", a machine of American origin, as being the most popular portable percussion rig, and one which has far out-sold all other types. (This is the type which has already been acquired by the Kenya Government).

X. 875. 26 A

W. H. C.
4/1/30

139
4, MILLBANK,

WESTMINSTER,

LONDON, S.W. 1

(VICTORIA 7750)

16th December, 1929.

Dear Mr. Cliffe,

With reference to your recent conversation on the telephone with Mr. Spiller regarding Mr. Beeby Thompson's report of the 5th September on Kenya Water problems, I attach a copy of correspondence, from which you will see that the Government of Kenya authorised the printing of 200 copies, after having been advised of the approximate cost.

Yours sincerely,



C. A. E. Cliffe, Esq.,
Colonial Office,
S. W. 1.

E/291/13.

COPY.

A. Beeby Thompson & Partners.

18 St. Switains Lane,

London. E.C.4.

9th September 1929.

The Crown Agents for the Colonies,

4 Millbank, S.W.1.

Gentlemen,

The Kenya Water Report is now ready, but as it is desired to introduce reproductions of many photographs to illustrate features, it would appear desirable to have it printed. The cost of 100 ~~copies~~ copies with 50 illustrations would, we understand, be about £100. If unwilling to authorise printing, will you kindly wire Kenya asking if they agree to procedure and to state number of copies desired.

Yours faithfully,

(Sgd.) A. Beeby Thompson & Partners.

TELEGRAM FROM THE CROWN AGENTS TO THE COLONIAL SECRETARY,
KENYA.

Telegram dated 11th September 1929.

"Beeby Thompson recommends that report on Water Supply now ready should be printed cost of 100 copies with 50 illustrations about £100 do you concur if so how many copies shall we order".

REPLY.

TELEGRAM FROM COLONIAL SECRETARY, KENYA TO CROWN AGENTS.

Dated 17th September 1929.

"Referring to your telegram of 11th September Martin telegraphed to by Private Secretary that 200 copies of Beeby Thompson's Report were required"

ALL COMMUNICATIONS
TO BE ADDRESSED TO THE
CROWN AGENTS FOR THE COLONIES.
THE FOLLOWING REFERENCE AND THE
DATE OF THIS LETTER BEING QUOTED.



8 16

4, MILLBANK,
WESTMINSTER,
LONDON, S.W.1.

E/R 291/13

TELEGRAMS: CROWN, LONDON.
TELEPHONE: 7730 VICTORIA.

RECEIVED
13 DEC 1929
COL. OFFICE

9th December, 1929.

Sir,

I have the honour to transmit herewith, for the information of the Secretary of State and for the service of the Colonial Office, two copies of the report addressed to the Governor of Kenya by Messrs. A. Beeby Thompson & Partners, on the Water Problems of the Colony.

2. Six copies of the report have been forwarded to the Colonial Government by this week's mail, and 150 further copies are in course of shipment.

3. There remain approximately 30 copies in this Office available for distribution as required.

I have the honour to be,

Sir,

Your obedient servant,

W.A. Wickham

for Crown Agents.

The Under Secretary of State,
Colonial Office.

Copy des - Gov Kenya 72 - 20 JAN 1930
2/5 mcl Lt Inyandi Soda Co 24 MAR 1930

Answered 17 JAN 1930

15634/1929 Kenya

617

Mr. Allen

Mr.

Mr.

Mr. Ecclesley.

Sir E. Harding.

Sir J. Shuckburgh

Sir G. Grindle.

Sir C. Davis.

Sir S. Wilson.

Mr. Ormsby-Gore.

Lord Loth.

Mr. Amery.

Downing Street,

14 August, 1929.

C.
R 12/16
D 16/16

Gentlemen,

I am, etc., to ack. the receipt of your letter of the 22nd of July, Z/E 321/71, and to inform you that he approves of your paying to Messrs Beeby Thompson and Partners, the sum of £231., being the expenses incurred by their Senior Partner in connection with his recent visit to Kenya.

I am, &c.

(Sd) U.C.C.P.

DRAFT.

THE U.A. FOR THE COLS.

24/5
 Copy No. 639
 11 AUG 1929

Copy No. 3 & encls. and
 this to DAG L.F.
 Ref. No. B of 15402/28

15634/1929 Kenya

5.18

Mr. Allen 6/8

Mr. Parkinson 7/8

Mr. S. H. 8/8/29

Mr. Bottomley

Sir E. Harding

Sir J. Shuckburgh

Sir G. Grenfell

Sir C. D. ...

Sir E. ...

Mr. ...

Mr. ...

Mr. ...

For Sir Samuel Wilson's signature.

Downing Street,

12 August, 1929.

DRAFT. 6/8
15 minutes

A. BEEBY THOMPSON, ESQ.

M.I. Mech. E. 32

re-acknowledged
with work &
visitors, and
put it aside to
deal with
the Department

Dear Sir,

I must apologise very
much for not having written to
you before ~~to~~ to answer
heavy pressure of other work.

were found it impossible to reply
earlier to your letter of the 15th
of July regarding your recent visit

to East Africa: but since I
get back I have been

As in your opinion the main
report which you have prepared will be
of general interest to the East African
Colonies, I see no objection to your

making ~~it~~ it be in a comprehensive
form, and when we get it, we can

consider the question of its reproduc-
tion and of the division of the cost
of printing among the territories
concerned.

In the circumstances if
If you are any other

Copy the ...
...
(2/8/29)

near here I should naturally

~~seems hardly necessary to trouble you~~

~~like to see you very much.~~

~~to come round and see me.~~

I have had a note made of your
wish to have an opportunity, if possible,
of assisting the Colonial Development
Committee in considering schemes where
water is a first necessity.

Signed, A. Wilson.

near here I should naturally
~~seem hardly necessary to trouble you~~
like to see you very much.
~~to come round and see me.~~

I have had a note made of your
wish to have an opportunity, if possible,
of assisting the Colonial Development
Committee in considering schemes where
water is a first necessity.

*Yours truly,
A. Wilson*

19
4

TELEGRAMS: "ANTROLOGIC, GARRON, LONDON"

PRINTED IN GREAT BRITAIN
BY THE COLONIAL OFFICE
LONDON

A. DEEY THOMPSON & PARTNERS

1, BECKETT ROAD, LONDON, E.C. 1
ROBERT HALL, 10, ADELPHI, LONDON, W.C. 2
LONDON & NEWCASTLE, ENGLAND

18, ST SWITHIN'S LANE,

LONDON, E. C. 4.

CONSULTING ENGINEERS

PETROLEUM MINING
GEOLOGICAL SURVEYS
WATER SUPPLIES
PETROLEUM REFINING

AMX/MLC

RECEIVED
-2 AUG 1929
COL. OFFICE

1929 July 1929

Sir Samuel Wilson, K.C.M.G.,
Under-Secretary of State for the Colonies,
Colonial Office,
WHITEHALL, S.W.1.

Recd. 12 Aug 1929

Dear Sir Samuel,

I arrived home last Monday after visits to Mozambique, Rhodesia and South Africa, and on the voyage home from the Cape I was kept busy with a Kenya-Uganda Report I promised to write. As I am a little undecided as to the best way of presenting my Report, I should much like your advice if you could spare a few minutes one day. So many of the recommendations made apply almost equally to most of our African possessions that it would appear an advantage for all to be incorporated in one general Report which could be printed and illustrated with reproductions of some of the many interesting photos I have taken. On the other hand, the visit was made in the interest of Kenya which undertook to reimburse any expenditure incurred beyond the Sudan.

My visit to Uganda was a subsequent development arising from an invitation by the Governor, and I eventually spent a month there investigating various water problems as well as the Lake Albert oil situation. As Uganda is under no obligation to share expenses, Kenya might object to a joint Report,

Sir Samuel Wilson K.C.M.G.

-2-

15/4/29

Although I have valued all questions of transfer the trip in my anxiety to obtain first-hand information on the spot and be better able to advise the Crown Agents. I certainly did not anticipate an absence of six months, but once on the ground I willingly extended what help I could and felt disinclined to leave until I had investigated the more difficult problems submitted to me.

I have prepared a fairly long and comprehensive Report in addition to the many minor Reports on local problems handed to the two Governments whilst out there. All in the Colonies seem agreed that agricultural progress depends largely on water, and from the content of my Reports which will reach the Colonial Office in due course, you will be able to judge what can be done with a moderate expenditure if the work is rightly directed.

I enclose herewith copy of a Report which I have today sent to the Crown Agents for transmission to Tanganyika dealing with water problems in that country. As the new Government is considering development schemes for the Colonies, the Reports I have in preparation may prove helpful. In any case, I should much like an opportunity, if that is possible, of assisting some of the Committees being formed, I understand, for considering Colonial Settlement schemes where water is a first necessity.

Yours sincerely,

A. Bealy Thompson.

When action taken on the para will be good & will be reported in the R. G. Service.

Recd on 29/5/29 T.T.

Enc.

KENYA
WATER PROBLEMS

A. BEEBY THOMPSON & PARTNERS

APPENDICES :
NORTH FRONTIER PROVINCE
LAKE SOLAI DISTRICT

LONDON :
Printed by WILLIAM BROWN & Co. Limited,
1, Bury Court, E.C. 3.
1926

LIST OF ILLUSTRATIONS.

- Fig 1. Map of East Africa.
- 2 A-View on the Athi River (traversing Tufts in the Plains).
- 3 Typical Scenery in low-lying Tuff Country (where fair amount of water during rains).
- 4 Typical View of Plains between Rifts in Rift Valley (rocks are glassy lavas).
- 5 Typical Rift Valley Scenery (between N'gong Hills and Magadi Soda Lake).
- 6 Long straight Rift in Lapilla Beds south of the Momenbu Volcano, near Nakuru.
- 7 Swallow Hole Lake Solai District.
- 8 Swallow Hole N'dalal Plain, Solai.
- 9 Swallow Hole Kaperikes Valley, Solai.
10. Magadi Soda Lake
11. Typical Cotton Soil Scenery (with growth of grass although dry belt. N.F. Province).
12. Cotton Soil Plains near the Lorian Swamps.
13. Sheep Watering in river course where shallow malodorous water found at few feet in sands between outcropping crystalline rocks, N.F. Province.
14. Native Wells in dry river course, Muddo Gashi (where water table is deep).
15. Watering Sheep in sandy river course (where sands thin and underlain by granitic rocks).
16. Native Well in gneisses on edge of dry river course at Garba Tulla.
17. A typical Ant Hill in Northern Frontier Province where crystalline rocks prevail.
18. Native Water Well in river course at Muddo Gashi (showing the difficulty of getting sustained supply of water due to intruding sand).
19. Typical Scrub country Northern Frontier Province (scarcely any foliage in dry season, and no shade).
20. Deep Native Wells in crystalline rocks at Buna, near Moyale (water raised by chain of natives in well).

LIST OF ILLUSTRATIONS—*cont.*

- Fig. 21. Typical Scenery near Isiola (decomposed Basalts and Tuffs).
.. 22. The Water Holes of Wajir (Limestone Belt and water highly mineralised).
.. 23. Chain of Natives Raising Water from crooked well at Eil Wak (17 men and women employed on steps in well to hand giraffe-like vessels up and down).
.. 24. Bailing a Water Hole at Eil Wak (one of the very few straight holes where large herds of camels are watered daily).
.. 45. The Lake at Wajir.
.. 26. River Dana, Frontier of Ethiopia, near Ramu (deep water obtainable as river bed sand and gravel).
.. 47. Watering at excavated Tanks in Cotton Soil.
.. 28. Water Tank of 5,000 tons capacity excavated in Cotton Soil.
.. 29. Impounded Water Reservoir in the Machakos (gneiss country).
.. 30. Duplex Steam Pump in well.
.. 31. Centrifugal Pump in well.
.. 32. Single Acting Bore-hole Pump and Surface Gear.
.. 33. Double Acting Bore Pump and Surface Gear.
.. 34. Steam Drilling Rig (steam power).
.. 35. Steam Drilling Rig (oil engine driven).

5th September, 1929.

KENYA WATER PROBLEMS.

His Excellency,
SIR EDWARD GRIGG, K.C.M.G.,
GOVERNMENT HOUSE,
NAIROBI.

SIR,

We have pleasure in presenting the attached Report based on the recent visit of our senior partner who desires to take this opportunity of acknowledging with gratitude the willing assistance afforded and social courtesies extended to him by the many officials with whom it was his pleasure to be placed in contact during the many safaris undertaken.

The gravity of the water situation was repeatedly brought home very forcibly during journeys to the more poorly watered districts, and on many occasions the distress caused to men and animals by the scarcity of water was witnessed. That this state of affairs can be remedied in many regions is certain, and in the case of the Northern Frontier Province startling results may follow an organised programme of subsoil water development.

No hesitation is felt in affirming that in the developing of subsoil water by drilling lies the main hope of promoting the agricultural and pastoral progress of the Colony, as opportunities for impounding water are very rare, and the cost of such projects is exceedingly high and local in its effect.

During a visit of some eight weeks' duration in Kenya, in addition to a further five weeks' journeys in Uganda, a fair idea was obtained of the water difficulties of the country. Most attention was naturally directed to those areas where the water scarcity was more acute, but such wide strips of territory are characterised by similar topographical and geological conditions that almost identical problems are reproduced and the same remedies are applicable. A map is incorporated showing the

2
routes followed when away from the railways, along which latter system various trips were made with Officials and the installations in use examined. See Fig. 1.

During the many excursions made, the writer met with nothing but courteous attention from Officials of the Government who spared no pains to make the safaris comfortable and interesting and to ensure the full extent of the difficulties being understood.

Referring specifically to the railways, and more generally to regions remote from the line, it was apparent, firstly, that surface supplies thought to be permanent are not so; secondly, that demands for water are increasing due to the natural increase of traffic and the larger settlements connected with developments. As regards the total or partial failure of supplies deemed to be permanent, it may not always be possible to find an acceptable explanation; some failures have been sudden and due to earth tremors which have deflected surface flows into new channels below ground but more often troubles have probably resulted from causes connected with rainfall vagaries or more likely to greater uses nearer the source of supply. The progress of agriculture and general settlement on the land leads to striking changes in the distribution of precipitated rain; ploughing of soil, drainage of land, destruction of forests or clearing of scrub, all lead to greater use of water for crops or to quicker run-off, and so reduce the period of flow of springs. Increased population and modern sanitary provision also operate in depleting sources of supply at one time ample for local requirements. Apart, therefore, from disturbing fluctuations of rainfall, both as regards amount and incidence, it is certain that less and less reliance should be placed on surface supplies of modest dimensions.

Until recently water supplies have been almost entirely confined to the collection of surface water from rivers, streams or springs, and it is the natural procedure in new countries to utilise obvious and visible sources in preference to exploring unknown and uncertain aquifers calling often for expert geological knowledge and mechanical appliances which are not available. Nevertheless, there are very obvious objections to this course, as rivers and streams are subject to sudden and frequent changes in their levels, volumes and character of the water. During heavy rains many water courses become seething masses of mud, and water may carry clay or sand in suspension for long periods during and after rains causing trouble

3
to the pumps, unless sedimentation and filtration chambers are provided. On account of the desire to avoid the above difficulties, the use of subsoil water is advocated whenever circumstances admit. There are naturally at times obvious supplies from springs which it would be folly to neglect, but very distant sources of supply are open to the objection of possible damage to pipes along the lines of their routes. When a piped supply follows the railway, there are fewer objections to long distance transmission as the system comes under the immediate observation of the officials, but, generally speaking, it will be found cheaper and more convenient to have a number of water stations with independent supplies than to place reliance upon a single source for a long stretch of line.

The development and use of subsoil water calls for material changes in the type of plant for water extraction, and these matters are discussed elsewhere. Not everywhere can underground water be obtained in useful quantities, so that any work undertaken must be done with discretion and under advice. The customary means of reaching subsoil waters are by means of Drive tube wells, shafts or headings or boreholes where the water is deep. More detailed reference to this subject will be found on pages 19 to 24.

GEOLOGICAL FEATURES—The geological conditions of Kenya can scarcely be regarded as favourable for water supplies, but in this respect they differ little from so many other parts of Africa where the geological features call for exceptional handling. Sceptics are numerous enough to discourage activities where the prospects cannot be clearly defined, for amongst Waterworks Engineers there is a strong disinclination to probe into the earth after the unknown, if visible supplies of water can be collected and stored. Impounding water is, however, far too costly a procedure for most young Colonies with limited funds for disposal, especially as there are so many objections and difficulties connected with the storage of water in tropical countries. Much more extended development results from a wide distribution of small water units than from a concentration in some region bounded by the limits of a reservoir. The earth itself constitutes by far the best container for water which as a rule undergoes purification in its descent and travel through rocks where it is preserved from pollution and evaporation losses until abstracted for use. Crystalline rocks which cover the bulk of Kenya are not good water yielding beds, for neither the volcanic, metamorphic, nor igneous types are themselves porous and permeable, but fortunately they are sufficiently fissured and

decomposed at many points to cause them to admit and to hold water, and in this way to behave much as permeable sedimentary rocks. Only by a courageous policy of exploratory drilling can the water resources of such country be disclosed, but wherever undertaken with energy and determination, success has rewarded all efforts. A proportion of failures must be anticipated and the cost of such is a legitimate charge on the successful works undertaken for the benefit of the community at large.

Except for a strip of country along the Indian Ocean and along the Jubaland frontier district where sedimentaries of supposed Jurassic age outcrop, the bulk of the country is covered with volcanic, metamorphic or igneous rocks. Patches of Tertiary or newer beds occur here and there, and in some districts ancient lake deposits occur, but the characteristic type is crystalline.

Obviously some types of rock offer better prospects for water than others, but regardless of the type of rock, some locations are more favourable than others. No one denies the unsuitability of crystalline rocks for the reception and storage of water, but supporters of a drilling policy in such rocks have always maintained that decomposed, crushed or faulted beds not only lead to the formation of porous zones, but also permit the entry of water. Provided some kind of underground circulation is established, salts derived from the decomposition of the rocks are leached out and carried away, forming space for the storage of more water.

Some idea of the large amount of salts leached from crystalline rocks is shown by the enormous deposits of laterite (murrum) or kankar (efflorescent lime) formed on the surface. These deposits are found covering nearly all kinds of crystalline rocks where the requisite conditions of temperature and rainfall occur. Under certain favourable conditions these efflorescence beds yield water in commercially useful quantities.

By whatever means water gains access to the earth, there is abundant evidence that not only is such the case, but that sufficient space occurs in the hardest rocks to give enduring supplies. However, as might be expected, there is no consistency of results even in rocks of the same general character. Water gaining access circulates in a complicated network of joint cracks, fissures, cleavage and foliation planes and crush zones about which the native rock has usually suffered changes

of some kind favouring the formation of pore space where previously only water of crystallization or capillary water was present. Very naturally such conditions preclude trustworthy estimations of depths, yields and qualities of water, but acquaintance with work in many countries enables those with experience to form a fair idea of what may be expected under different conditions.

The Archaean complex of highly metamorphosed rocks are generally so much distorted that they outcrop or approach the surface at a steep angle. During the process of crushing or disturbance, lines of weakness developed which afforded opportunities for atmospheric agencies to operate and set up a process of decomposition. Precipitated waters rendered active by solution of oxygen and carbon dioxide from the air attack the less stable minerals composing the rocks causing their disintegration. The depth to which these agencies operate depends upon many circumstances, but as a rule the conditions favourable for water accumulation in useful amounts fade at depth and with them the chance of finding water. Major fault planes may at times yield water at great depth, but the search for these few and far separated lines of weakness would be far too precarious a work to attempt by drilling. Generally speaking, it is unprofitable to prospect for water in crystalline rocks at depths in excess of 500 feet except of course where for some reason a high point is selected near a deep depression which is equivalent to assuming the land surface at the lowest point.

GRANITES AND GNEISSES.—Granitic and gneissic rocks readily decompose on exposure to atmospheric agencies. Those in massive form better resist attack than those prominently foliated where seams of isolated, concentrated minerals cause differential decomposition and expose the harder layers to destructive agencies. Fortunately the massive granite rarely escapes fracturing, and a roughly rectangular system of joint planes breaks the homogeneity of the mass and permits access of active rain water. Sometimes granites are pierced by intrusive veins or dykes of more basic material which assist disintegration and promote lines of weakness which facilitate the process of destruction. The picturesque tors found in granite country are the result of combined agencies following the jointing which is such an almost universal feature.

Once below the regional water table of the district any crack or fissure will yield water, the quantity depending upon the size and extent of the fissure system which, however, usually

communicates with a complex series of joint planes. As a rule granites yield a good quality of water, but if circulation is poor and the rocks are fed by water draining salt pans or areas where desiccation causes salty efflorescences on the surface, the quality may be poor. In such cases improved results may be obtained by drilling in the rock at a distance from any water-course where the first rains would dissolve and carry away the surface incrustations, which would otherwise find access to absorptive outcropping rocks. Amidst these surroundings it is often found that the water at different depths will differ in saline contents, as also will the quality of water in nearby wells. A single disappointment should not, therefore, discourage further tests where the circumstances and possibilities are perfectly clear.

The extent to which water does gain admission to hard granitic but jointed rocks is seen by the presence of springs near the boulder-strewn base of granite tors many months after rains have ceased. Water admitted at higher points gradually percolates along cracks until a convenient escape is found at some low point on the hill side.

Gneisses vary so much in character that it is difficult to generalise. The foliation may be almost indistinguishable or the mineral components may lie in clearly defined bands which give the appearance of a sedimentary rock. Nearly always standing with the cleavage planes at a steep angle they present very favourable opportunities for the operation of disintegration agencies and for water admission. As with granite, intrusive veins may assist the process of destruction by differential disintegration. Rarely do bores sunk into these rocks fail to yield water when entered in regions of moderate rainfall or near where surface flows occur. Sometimes a sluggish circulation may lead to highly mineralised water due to the solution of salts derived from the decomposition of the rock minerals, but the frequency of springs in valleys carved out of these beds is itself proof of their value, as water receivers and retainers. The best prospects are presented where the gneisses are inclined at a sufficiently steep angle to admit readily water passing over the surface, yet not too steep to cause the drill to continue for long distances without cutting the foliation planes and crossing a succession of probable water sources.

VOLCANIC ROCKS—Next in importance are the volcanic rocks which cover vast areas in Kenya and Uganda around the great mountain peaks and in the Rift Valley and elsewhere.

26

Away from the main centres of past volcanic activity where everything in sight and to great depths consists of lava flows, the sheets of lava have followed the irregularities of an old topography in the Archean rocks, and consequently present a new class of conditions. Most of the volcanic rocks are basic or ultra-basic in character and do not disintegrate into sands like the granites or quartzites. Their decomposition is more often accompanied by the formation in the valleys of clays and silts where papyrus swamps are a familiar sight.

Certain types of volcanic rock are very vesicular and readily weather; others are of a very resistant nature and are quite impervious to water. The hard, waterless type certainly predominates in most districts, but a situation of some gravity is relieved by their sporadic distribution and limited thickness at each flow, resulting thereby in the formation of land surfaces which have weathered and formed porous layers. Land movements, earthquakes, and temperature variations have also caused the cracking of the banded rocks enabling water to gain admission to the series so that it can circulate in the porous layers. Possibly beds of ash, scoria and lapilli separate some of the harder lavas and constitute reservoirs for water. The lava flows distant from the volcanoes are generally horizontally bedded or nearly so, and when deeply eroded into modern valleys the issuing springs denote the extent to which the beds receive and yield up water.

Vast areas are covered with basaltic type lavas which decompose more readily than most varieties, particularly the very vesicular classes. Other regions are marked by a covering of white or grey tufts which, although very porous, are not permeable and will not yield up the contained water which is mainly capillary. Nevertheless, these tufts do give water often quite freely, due doubtless to the presence of interlaminated ash beds or decomposed and pitted old land surfaces along which water can travel. At times the tufts, though generally horizontal, have been subjected to considerable flexuring since deposition, and in a deep 90 ft. railway section near Equator springs are to be seen issuing from porous ash layers in the otherwise fine grained material. See Figs. 2 and 3.

ARCHÆAN ROCK.—The Archean complex of metamorphic rocks is the one remaining uncertain type calling for consideration. Unlike the others they are true detrital rocks of sedimentary origin which are distorted and inflected into complicated structures. During subjection to great pressures the

rocks have undergone such startling changes that the original character is totally obliterated. Quartzites and siliceous beds supersede all others in importance, but slaty shales are common in some districts. The very hardness of these rocks, as a result of transformation by chemical actions and pressure has led to heavy fracturing, faulting and slickensiding by means of which opportunities are afforded for water to gain access and circulate in their midst. Almost everywhere where opportunities exist for water to cross their upturned exposed edges there are reasonable chances of striking water below the regional zone of saturation. There is evidence that such cracks and crevices existed at earlier periods in the numerous veinlets of calcite, gypsum, earthy or silicious matter which are to be seen running through the rocks at all angles. The same class of fractures is reproduced in the rocks as at present inflected, and in time when these are submerged in turn and covered with other sediments, the present cavities and channels would be filled with mineral substances.

A note of warning might be sounded concerning the danger of assuming that ridges of outcropping granites and quartzites are representative of rocks over intervening areas. Wide strips of country between ridges are covered with alluvium, soil or swamps, and it may be that these unexplored basins owe their origin to the occurrence of other and softer types of rock than those exposed on the ridges. This is certainly the case in the Sudan where somewhat similar conditions prevail.

The above description can only be considered as a sketchy account of the rocks which are expected to yield water. Sufficient drilling has been undertaken in Kenya to demonstrate that water can be obtained from rocks of the type described, but extensive and widespread tests in the Union of South Africa give an abundance of confirmatory evidence. Much the same type of geology characterises a great deal of South Africa, where the large proportion of successful bores has led to drilling demands far in excess of existing facilities. Some varieties of rocks respond less freely to development than others, and strata of a particular character may be barren, or nearly so, at one place, yet highly prolific in water at another where they have been subjected to different tectonic influences.

RIFT VALLEY PROBLEMS.—As might be expected, unusual and special water problems arise from purely local peculiarities, in fact, some of the Kenya and Uganda water

problems present almost unique features which will only be properly understood when boreholes have been sunk. The Rift Valley, in particular, offers almost unlimited scope for detailed investigation, as along this great belt of faulted country the flow of ground water is influenced by a whole series of unusual and obscure conditions only imperfectly understood. The very nature of the forces causing the rifts is in dispute, some supporting a compression theory in opposition to the generally accepted tension explanation. Approach to the bottom of the valley is characterised by the passage of successive faults until the floor is reached where a line of lakes exhibiting a variety of peculiarities marks its lowest point. At each rift a vertical escarpment faces the valley, and behind this the rocks dip away causing the formation of valleys between each scarp. These intervening valleys are often covered to an undisclosed depth with sedimentary deposits, mainly tuffs and diatomite, but sometimes sands and gravels, and the value of these as sources of water supply has yet to be demonstrated. Whether these represent the relics of one or more vast lakes which covered the valley, or whether a series of independent lakes stretched along the valley as at present, is not yet clear, but the latter seems the most likely event. Abundant proof is forthcoming to show that some of the present lakes like Nakuru, Naivasha and Elmenteita covered infinitely larger areas than at present, even within the period when man inhabited the earth. See Figs. 4 and 5.

Although the rainfall is low over most of the Rift Valley, certain parts receive considerable volumes of water at certain seasons from the neighbouring hills like the Aberdares, yet all disappears in porous valley deposits soon after reaching the plains. This water naturally courses underground, following channels of least resistance to lower points, and no very satisfactory explanation of its movements has been evolved. A few boreholes sunk near the volcanoes in the Rift Valley have yielded hot or boiling water, apparently the result of meteoric waters meeting with deep-seated volcanic dust or scoria which has not yet cooled. Near the volcanoes of Longonot and Menenlai there are extensive deposits of lapilli, which not only readily absorb water, but promote its rapid underground circulation. Where these beds are very thick admitted water may reach great depths and escape unused and unseen to the lakes. In this connection a succession of earth fissures which have recently developed between the eastern lip of Menenlai and Lake Nakuru are worth describing. Following the direction of the Rift Valley roughly N.S. a series of long parallel cracks have appeared which have caused lively concern for the safety of the railway and public

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road which they cross. The major fissure is 20 to 30 ft. wide at places, and the surface has collapsed about 30 ft., leaving nearly vertical sides. Other parallel fissures have appeared, and they are generally attributed to the movement of streams of water which continually erode a deeper course beneath the surface. This may be so, although it is strange that the removal of so much material should have escaped notice at Lake Nakuru into which the water passes. The cracks are probably related to rift faulting, but the interest of such phenomena lies in the direct evidence afforded of obscure subsoil water movements in the Rift Valley area. See Fig. 6.

Judging by what was seen in the series of long parallel plains and valleys lying between the successive rifts, and from information collected, the prospects of finding subsoil water are considered to be favourable. A single bore sunk between two upper scarps near the N'gong hills is yielding an excellent supply of water at 450 ft. from the volcanic rocks, and should the lake deposits in the lower rifts fail to give water, there are always good chances in the zone of contact with the volcanics or in their upper brecciated or decomposed surface. The nature of the beds and the general absence of water courses in these valleys leads one to conclude that a considerable quantity of water finds its way into the ground and works its way by devious routes to lower levels. Until some bores have been sunk in these valleys, no very reliable advice can be tendered as to the best sites for drilling. With the vertical scarp of volcanic rocks always facing the valley, and that on the opposite side inclining generally at a moderate angle, it is difficult to say where the deepest point in these plains will be struck, but probably near the vertical cliff. The influence of the fault itself as a medium of escape for water at great depths is unknown and much debated, but the fact that lakes have filled these valleys possibly at a date when lower lakes existed, supports the belief that these fault planes are clogged and do not drain off the valleys.

A detailed investigation of some of the plains and valleys between rifts above and west of Lake Solai led to some interesting discoveries bearing on their water problems. Several unusually dry plains were the object of careful study, and it was found that the bulk of the not inconsiderable quantity of water which reached these plains escaped underground in swallow holes, dozens of which were found dotted about the plains. The natives said that following rains the rush of water entering these holes could be heard from a long distance, and there were certainly ample manifestations that much silt-laden water

escaped in this way at times. The swallow holes follow no general direction, nor conform to any systematic arrangement, and are not therefore likely to be connected with faulting, but they afford positive proof that porous beds exist at depth, and that much water gains admission thereto during rains. The exposed valley deposits are whitish, well-laminated tufts, but on the edges of Lake Solai more sandy types of lake sediments were seen. Unless, therefore, deep-seated faults in the volcanic strata carry away the water, methodical search for water in the district is bound to prove successful. Lake Solai had in fact dried up in May, 1929, except for a few pools of water at several low points; elsewhere it was an expanse of green grass on which herds of zebra and buck and other animals grazed undisturbed. See Figs. 7 to 9.

Ancient volcanic tufts and horizontally bedded sediments could be traced to the lowest point of the lake bed, so that bores are almost certain to yield supplies of good water in the lake basin.

The Rift Valley lakes present a whole mass of problems awaiting a satisfactory explanation. Contrary to popular opinion, most of the lakes are very shallow, and their levels are subject to considerable fluctuations. Doubtless an explanation of the reduction of lake levels from the high stage marked by ancient sediments is due to the breakage of barriers which once enclosed the water, and is not attributable to rainfall changes. Present topography would certainly not admit of the impounding of such vast bodies of water as existed in the past, but besides this there are reasons to suspect the loss of much water underground. Concerning the waters which flow northwards and feed the Nile, the level of Lake Victoria Nyanza, the largest of the African lakes, with an area of 27,000 square miles, is controlled by the outflow at the Ripon Falls at Jinga, evaporation, and run-off from a well-watered area round the lake, and it receives none of the water from the high mountains of Central Africa. Lake Albert on the contrary is skirted on the Belgian Congo side with mountainous country, and is fed by the Samliki river which receives the main drainage of the Rowenzori snow-capped range, and it is probably the chief feeder of the white Nile waters. There is evidence to show that the waters of Lake Albert once stood hundreds of feet higher than their present level, as lake deposits are found round the foot of Rowenzori, and the eastern lake sides where also the cliffs show a distinct line marking an ancient shore. The reversed flow of some rivers in Uganda traced out by the Geological Department of Uganda further illustrates the extent of movements which modified the drainage of Central Africa.

Referring specifically to the eastern Rift Valley which comprises an enormous catchment area besides receiving the drainage of considerable adjoining areas of moderate rainfall, it seems impossible to believe that the evaporation from the present lakes accounts for all the water which escapes surface losses in the rainy seasons.

Streams of importance flowing from the Aberdare Mountains and other ranges lose their water rapidly during their passage to the valley, and strange disappearances or appearances are said to be observed in water courses after earthquake shocks. There seems reasonable grounds for believing that much water finds its way into porous beds of the volcanic rocks which exclusively constitute Rift Valley structures below the lake deposits, and this water may travel for hundreds of miles in the nearly horizontal formations without meeting any obstacle which would force it to the surface. The wide differences in the saline contents of the waters of the various lakes leads one to regard these as more or less isolated units influenced rather by local hydrological conditions than by widespread and general rainfall. Most of the waters are characterised by high soda contents, but the concentration of some lakes is much higher than others. Thus Nakuru and Elementeita are too saline for potable purposes. Naivaisha contains nearly fresh water, whilst Lake Magadi contains a solid mass of crystallised sodium carbonate. Although Lake Natron in Tanganyika receives the whole flow of the river Uaso Nyiro, it is a concentrated mass of salts due to intense evaporation in widespread swamps near the lake. See Fig. 10.

Hot mineralised springs of perennial flow are found occasionally near the great faults, and these supplement run-off or the ephemeral streams which gain access to the lakes. Only the springs at Magadi were personally visited, but these are exceptionally large. Those issuing at Lake level near the north end of the lake with a temperature of about 95° F. give 750,000 gallons a day, but at the south end of the lake the flow is several million gallons a day; the temperature at the points of egress being 140° F. As soda predominates in all waters which have traversed the volcanic rocks, and soda-producing minerals are present in so many of the lavas, one is more disposed to attribute the soda contents of water to the volcanic series than to any basement rocks. The writer strongly inclines to the view that the saline contents of lake waters is more likely due to leaching of salts from volcanic rocks by meteoric waters than to salts derived from deep-seated plutonic rocks.

Conditions do not seem to preclude the possibility that the lake beds are more or less insulated by silty deposits and that much water finds a passage below the lakes along porous seams in the volcanic rocks, and any waters traversing deep-seated beds might be of good quality due to its passage along less decomposed rocks than surface waters. The steep gradient southwards of the eastern Rift Valley would induce a steady flow of any subsoil water in that direction. The deep picturesque gorge that once led the overflow waters from Lake Naivaisha no longer carries surface waters, and caves near the lake exit suggest underground conditions of some interest and perplexity. Considerable water may still flow in deep underground channels below the present gorge.

No deep bores have been sunk in or near the Rift Valley lakes, but information of much value would result from such tests. Below the Magadi Soda deposit, some 16 ft. deep, a clay is said to occur, and this may constitute an insulating medium between the soda deposit and water-bearing beds beneath. Sodium carbonate deposits cover an area of about 30 square miles, say 20,000 acres, but this does not represent the whole area of the lake depression into which the springs and rain-water flow. Under the hot arid conditions prevailing in the vicinity of the lake only 2,000 ft. above sea level, evaporation would easily dispose of the total involved. The first impression that the springs are the cause of the deposits is rather countered by the fact that 40 per cent. of the salts in solution are sodium chloride, whereas in the lake product this salt is nearly non-existent. The masses of chert deposited on the volcanic rocks bordering the lake, and as layers or slabs on some of the dry lake beds near the soda mass may have resulted from diatoms of which there is abundant evidence in the diatomites in the valley sediments.

No data concerning the temperature, rate of flow and saline contents at different periods of the year were obtainable, but the vital importance of these for attempting to connect the springs with meteoric waters is obvious.

Magadi is at present supplied with drinking water by a pipe line leading from the Ngong Hills near Nairobi, and some concern has been occasioned by the gradual fall of yield of the springs and the increasing needs for water at the Soda works. The question of developing a local supply naturally arises, but there are nowhere surface springs or native wells which would afford a clue to guide its search. About 20 miles to the southwest the river Uaso Nyiro which flows into Lake Natron in

Referring specifically to the eastern Rift Valley which comprises an enormous catchment area besides receiving the drainage of considerable adjoining areas of moderate rainfall, it seems impossible to believe that the evaporation from the present lakes accounts for all the water which escapes surface losses in the rainy seasons.

Streams of importance flowing from the Aberdare Mountains and other ranges lose their water rapidly during their passage to the valley, and strange disappearances or appearances are said to be observed in water courses after earthquake shocks. There seems reasonable grounds for believing that much water finds its way into porous beds of the volcanic rocks which exclusively constitute Rift Valley structures below the lake deposits, and this water may travel for hundreds of miles in the nearly horizontal formations without meeting any obstacle which would force it to the surface. The wide differences in the saline contents of the waters of the various lakes leads one to regard these as more or less isolated units influenced rather by local hydrological conditions than by widespread and general rainfall. Most of the waters are characterised by high soda contents, but the concentration of some lakes is much higher than others. Thus Nakuru and Elmenteita are too saline for potable purposes. Naivaisha contains nearly fresh water, whilst Lake Magadi contains a solid mass of crystallised sodium carbonate. Although Lake Natron in Tanganyika receives the whole flow of the river Usuo Nyiro, it is a concentrated mass of salts due to intense evaporation in widespread swamps near the lake. See Fig. 10.

Hot mineralised springs of perennial flow are found occasionally near the great faults, and these supplement run-off or the ephemeral streams which gain access to the lakes. Only the springs at Magadi were personally visited, but these are exceptionally large. Those issuing at Lake level near the north end of the lake with a temperature of about 95° F. give 750,000 gallons a day, but at the south end of the lake the flow is several million gallons a day; the temperature at the points of egress being 140° F. As soda predominates in all waters which have traversed the volcanic rocks, and soda-producing minerals are present in so many of the lavas, one is more disposed to attribute the soda contents of water to the volcanic series than to any basement rocks. The writer strongly inclines to the view that the saline contents of lake waters is more likely due to leaching of salts from volcanic rocks by meteoric waters than to salts derived from deep-seated plutonic rocks.

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Tanganyika would certainly satisfy all Magadi's needs for the whole year, but it involves a pump station in rather wild and inaccessible country where buffalo and other game abound. A wide flood plain must of necessity render access at times quite difficult, and during the single visit made a violent dust storm was experienced equalling in intensity those of the Sahara. A more accessible source of supply is preferred, and the conditions certainly warrant drilling in the first parallel valley between the rifts on the east of the lake and close to the railway. The 30,000 gallons per hour spring of mineralised yet clear water near the Soda works fulfils all the requirements of the factory for process work, but the sweet water is needed for potable, domestic and boiler purposes as well as for improving the amenities of the camp where scarcely a tree or shrub breaks the bareness of the desert-like, wind-swept township.

As already mentioned, the Rift Valley conditions are very unusual, if not unique, and there are reasons for believing that much water travels underground totally protected from evaporation influences. Constant circulation of such water along porous beds, which have escaped the decomposition to which the surface and shallow rocks are subjected, could result in water of good quality lying below that of a mineralised character. A borehole in the middle of Lake Magadi would certainly disclose data of the greatest scientific interest, as salts of a different nature may be struck, but below the mineralised zone fresh water might be obtained and conceivably under a head. In any case drilling should only be conducted under skilled advice, and somewhat elaborate measures should be taken to isolate upper mineralised waters and to control any artesian flow by valves and suitable appliances.

Should the above-named sites fail to give successful results, locations in other and higher valleys might be tested near the pipe line into which any water found could be pumped. Needless to add, the discovery of water in these valleys and plains would be of considerable importance in improving the lot of natives whose cattle graze the region only when surface rain water is available.

LAKE BEDS AND BEACHES. Whilst dealing with the subject of the Central African lakes, the value of the beach deposits as sources of good water might appropriately receive attention. Some of the lake beds are muddy silts of little service as sources of water supply, but in many there are sandy beaches or strips where currents have sorted and deposited sandy material. Such sandy patches are to be found on the

shores of the fresh-water lakes Victoria Nyanza and Albert, where tube wells could be driven with the certainty of tapping an abundance of good filtered and clear water. Entebbe well illustrates the potentialities in this direction where certain bays are filled with a coarse, silver-sand of nearly pure quartz grains admirably suited for drive tube wells. Instead of drawing the lake water, which is always turbid with suspended organic and inorganic matter, and liable to pollution from the shore even when collected some distance away, naturally-filtered supplies should be taken from tube wells deeply set in the beach sands and gravels. By grouping and coupling to a common suction pipe almost any quantity of water can be abstracted in this way.

Lake Naivaisha presents a somewhat different problem, for here a series of sand and gravels, silts and clays compose the lake bottom, and the variations of lake level, which cause the water's edge to advance and recede long distances over its flat bed, give those using its waters constant trouble. During the last four years the lake level has fallen 14 ft., but this, it is believed, is only one of those periodical changes which have been witnessed before, and is attributed to deficiency of rainfall. The geological conditions certainly justify the belief that successful tube wells could be driven round the edge of the lake at locations which would ensure an ample supply of water at all periods in the unflooded belt and at a depth which would admit a suction pump drawing water at any time. When at Naivaisha the difficulties of Mr. McCrae's installation were described, and suggestions were made on the lines described above to effect a remedy. Here the constant recession of the lake edge has enforced the excavation of a long channel to the sump at the pumps, but in-running sand and silt leads to incessant attention and stoppages, and the pumps must suffer from the indrawn gritty matter. In this case some 30,000 gallons per hour are needed when the mill is working, and a brief stoppage for water results in serious losses.

A well sunk to 30 ft. at the Naivaisha Hotel by the proprietor was examined at the request of the owner, who said the water, though plentiful, emitted an odour. Apparently his well drew water from lake sediments in which embedded organic matter has caused the evolution of a little sulphuretted hydrogen. An analysis was recommended, but probably the water is perfectly wholesome and quite devoid of objectionable bacteria. The town of Naivaisha has considered schemes for piping water from the hills to the east, but the cost was beyond their means.

and the project had to be shelved. A simpler expedient would be to drill a few wells within the township and lift the water with pumps, as the cost would be very low and the water would probably be bacteriologically pure if taken well below the upper zone of saturation.

SWAMPS.—Many of the swamps fringing the great fresh-water lakes and running inland are well worth prospecting for subsoil water where the surface flow is precarious or too objectionable for the purposes required. Beneath a mass of organic slimes or silts there may be deposits of sand or gravel, or perhaps lateritic beds which would yield consistent supplies of clear, purified water. When making the foundations for the railway viaduct over the arm of Lake Salisbury near Soroti, thick deposits of water-bearing pisolitic laterite were struck below the muddy swamp deposits.

A very common feature of Central African scenery is the papyrus swamp which extends along flat valleys at all altitudes up to 7,000 ft. or more, and in many cases they would probably repay exploration with a drill. Even if no sandy sediments were struck, the upper decomposed surface of the enclosing crystalline or Archaean rocks might yield useful supplies of water quite free from the impurities which pollute the surface and shallow sources.

In several cases the alluvial deposits had been pierced and the basement gneisses uncovered in native excavations, and in each case the exposed rocks were so decomposed that they could be loosened with the point of a pick. A little water ran into the shaft between the alluvial clays and the rock surface, but the rock itself was saturated with water which oozed slowly into the shaft.

COTTON SOIL PLAINS.—Along some of the wide alluvial and cotton soil plains of the Northern Frontier Province, Turkana, Karamoja, lying within regions of low rainfall, the whole local precipitation can be readily absorbed by the upper few metres of dry material, and no water can possibly find its way into the underlying crystalline or other rocks. Unless, therefore, water can gain admission at some distant point and a gradient causes travel in the direction of the general regional drainage, it cannot reach the underlying rocks, which may, nevertheless, be sufficiently porous to admit and store water. See Figs. 11 and 12.

NORTHERN FRONTIER PROVINCE.—The Northern Frontier Province of Kenya has been the subject of a separate Report following a reconnaissance covering some 1,600 miles at

the driest period of the year just before the advent of the spring rains. Except for widely-separated water holes and a few dry but sandy river courses in which the falling water table is followed by deeper and deeper excavations in the sandy beds, there are no regular watering centres. For some time after the rains surface water collected in depressions or impounded in irregularities of the ground enables herds of cattle and flocks of sheep or goats to graze on the grass which is plentifully distributed about the scrub country as well as on the extensive cotton soil plains. Much of the distress occasioned by the scarcity of water could be dissipated by developing new water centres and improving the existing ones. At both Wajir and Eil Wak the water supplies could be improved beyond recognition by simple works outlined in the Report; in the Lorian swamp region the geological conditions appear to favour the presence of subsoil waters of good quality over a wide belt of country. See Figs. 14 to 25.

Unusual interest attaches to these schemes, as in this region are to be found extensive plains overgrown with rank grass which now supports an abundance of game wherever a little water can be found. In some of the sandy water courses, which only carry surface water during rains, permanent works could be installed to replace the improvised shafts made by the natives each season. The process of watering herds of thirsty cattle by abstraction of water from crude excavations in the river gravels and sands is a slow and tedious process, as the loose sands run into holes nearly as fast as the water is removed and necessitate the double operation of clearing sand and raising water.

At the Daua river which separates Kenya and Abyssinia, no water was to be found, somewhat to our consternation, near Ramu. As reliance was rather placed on this river bed for replenishing stocks for drinking, washing and for the car radiators, considerable privation was only averted by rigid economy for some days. Here there is a glaring example of the neglect of some obvious and perennial supply of good quality water due to lack of technical knowledge. Along this frontier river a series of water stations could be established under most pleasing conditions, as the sloping valley sides are overgrown with a mass of large trees and dome palms, giving a welcome shade and relief in this province of intense heat, less than 1,000 ft. above sea level. See Fig. 26.

The Northern Frontier Province represents a large percentage of the total area of Kenya, yet so small and poor is the population that no form of taxation has so far been levied on

the tribes. Most of the area traversed was far from unattractive, and although parched and devoid of leaf, extensive forests of thorn bush and scrub and long plains of dry grass showed that the soil was fertile and the rain sufficient to nurture and sustain a heavy growth of vegetation capable of supporting considerable herds and flocks of animals. In addition to the group of gneissic rocks with overlying volcanic lavas in places, there is an important development of sedimentaries of supposed Jurassic age, and large belts of limestones believed to represent the bed or beds of inland lakes which covered a large area. Very little is known concerning the extent and depth of these limestones, as they are horizontally bedded and have never been prospected with a drill. They have been penetrated to a depth of about 70 ft. at Eil Wak, where the water table is low. On the other hand, sections of the Jurassic rocks are exposed on ridge of hills where it is seen that sandstones predominate.

Both the Jurassic sandstones and the lake limestones are likely to give water at selected points where topography favours an overground flow in excess of the meagre rainfall of the province. Elsewhere the surface soils might absorb the whole rainfall so that no water would reach underlying beds. The limestone series often appear to be gypseous in character, and the waters are mainly objectionable to drink due to salts in solution. Possibly a methodical exploration of the lake beds would result in the location of better quality waters at certain depths or in circumscribed localities.

Unquestionably the construction of modern watering centres would lead to an influx of Somalis from the neighbouring States of Abyssinia and Jubaland, and the strategic distribution of water stations would not merely facilitate the work of the District Officers when collecting taxes, but diminish the sufferings and inconvenience due to over-grazing near congested water holes. So long as the watering of animals can only be undertaken at a few places, it is impossible to keep the cattle in good condition or to prevent the spread of disease. Miles around the known water holes every blade of grass has been devoured, and animals have to endure long dusty tramps before water or in turn grazing is reached.

DRIVE TUBE WELLS.—Water courses carrying perennial supplies can be cheaply and effectively tapped for water by driving tube wells where the river bed contains a moderately thick deposit of fairly coarse sand or gravels. Unless there are

4 to 5 ft. of sand always saturated with water, their use is not to be recommended, but where coarse sand or gravels fill a water course to a considerable depth, no more satisfactory method of tapping supplies can be suggested, and for cheapness or speed of completion no other process compares. Provided sandy water courses carry perennial water in useful quantities either above or below surface level, they can be rapidly developed by drive tube wells. A preliminary survey of such river beds can be expeditiously made by driving tubes at intervals across the bed of the stream, preferably at some contracted point where scour is likely to have carved a deeper channel at some former period. Most of the existing valleys have suffered from the consequences of a rainfall far in excess of the normal or recent, and there is usually some deep point where underground water flows when it fails elsewhere. Such deep spots also frequently contain coarser and, therefore, more permeable sediments than elsewhere where the current has not been so strong.

Not all water courses present the necessary conditions for success. Those having a bed of boulders in a torrential stream cannot be so handled; nor can useful supplies be obtained where fine silts or clays have been deposited in slowly moving water. Generally there is a succession of silts, sands of various grades and gravels representing different periods of rainfall and flow, and these provide ideal conditions for drive tube well work. Under ordinary conditions the screens can be set at points which ensure the abstraction of a clear filtered water often bacteriologically pure. Tubes driven to a suitable stratum well below the water table of the valley and preferably to bed rock will yield a water quite unaffected by overground flow or surface pollution. When a single tube will not supply needs, several should be coupled together and the suction of the pump should be connected with the grouped tubes.

A drive tube well consists of a perforated screened or unscreened steel-pointed drive pipe with upper screwed socketed joint to which additional lengths can be added as they are driven by a monkey or otherwise to the requisite depth. They vary from 1½ in. to 2 in. diameter usually, and can only be used in unconsolidated or loosely compacted strata which suffer compression during the process of driving, and thus provide space for the passage of the tubing. If struck within 10 or 15 ft. from the surface good supplies of water can be obtained by simply attaching a suction pump to the surface pipe. Many little, but very essential, technical matters require careful atten-

tion to secure uniform success, so that although an apparently simple affair, skilled operation is generally necessary except in the simplest of cases.

The productive capacity of tube wells depends upon their diameter and the permeability of the water-bearing bed. For technical reasons tubes in excess of 2 in. diameters are not generally advised, and those of that size will yield from 500 to 2,000 gallons per hour, according to the coarseness or thickness of the aquifer in which the screened point is set. Where heavy surface flows may occur and tree trunks or boulders may be carried which would destroy unprotected surface works, the tubes should be connected below the surface, and the main suction pipe should be led in a trench to one side of the flow channel. The same advice applies to those cases where the water table may fall considerably with the seasons. In no case should the suction be in excess of 15 ft. at the worst period and preferably always within 5 to 10 ft. of the level of the main suction main.

One of the manifest advantages of tube wells is the ability for working in water. Where, as sometimes happens, the beds of river courses can be opened in the dry season, other methods described in the next section are possible.

A number of water courses were seen which could be developed by drive tube wells. The works at Malawa station for the supply of Tororo furnish a typical example for investigation. Near the station a stream flows in a sandy bed over granite country. Just below a waterfall water is drawn by steam pumps from the stream and put into settlement and filtration chambers before passing into a 6-in. pipe line some 7 miles to Tororo. The stream bed contains coarse quartz sand into which a stick was easily thrust to a depth of about 2 ft. 6 in. During rains the water is very turbid, and colloidal matter gives trouble in the filtration chambers. The waterfall has probably caused at this point a deeply scoured channel in the granitic rocks, and a few tube wells driven into these sands should ensure a plentiful supply of clear filtered water at all seasons, thereby avoiding the use of filtration and sedimentation chambers.

For installations of this kind we do not advise large pumps working for a few hours daily. A much better plan is to use smaller pumps and run them for a longer period so that at no time is an excessive drain made on the tube wells. Capital charges are thereby reduced whilst running labour costs are not materially increased.

Water courses traversing granite country or territory where acid crystalline rocks prevail usually have sandy beds suitable for drive tube well work, except where the gradient of the valleys is steep and the sediments are not in consequence sufficiently thick to give satisfactory results. Such courses should, however, be examined for stretches where the fall is gentler, or the width contracted, in such a way as to have caused deeper erosion and subsequently thicker depositions of detritus. At Myanga, some miles from Malawa where water is taken for station use from a stream, conditions appear promising for tube well work. Here a pump draws water from a flowing stream evidently subject to violent floods of turbid water, as was seen by flood lines of debris on the steep sides. The banks consist of crumbling granite which is decomposing into a quartz sand and kaolin, the latter gets washed away, leaving an excellent quartz sand into which a stick was pushed several feet. Almost certainly drive tube wells could be set here to ensure clear water at all times.

Less favourable prospects may be expected at the Athi pump station where the river crosses tufts and basic rocks more likely to produce impermeable silts. A test might, however, be made as ancient floods might have scoured out and later filled channels with coarser sediments. For working instructions on driving tube well see "Emergency Water Supplies."

SHAFTS, TRENCHING OR HEADINGS.—Clear water designed to escape the influences of surface flows and forms of pollution may often be obtained by sinking shafts in or near river beds, or carrying trenches or headings along their course. Shaft sinking is always a difficult matter in unconsolidated sediments liable to movement, and once water is reached only very expensive arrangements will usually enable work to be continued much deeper. Shafts generally fail at some period, unless carried much deeper than the water table during construction, and in loose strata incessant expenditure is frequently occasioned by the need for cleaning out in-running sand. This trouble can sometimes be overcome by sinking a shaft in hard material near the water course and driving a heading outwards into or below the bed of the stream. Percolating water so obtained is usually clear and free from pollution, but what is much cheaper and more satisfactory is to open up the stream bed at low water after testing the character of the bed by probing with tube wells or otherwise and depositing along the trench, perforated, screened or open-jointed pipes to which a pump suction pipe can be attached or the outflow led to a sump or into a main. By

* "Emergency Water Supplies" by A. HAZEL TAYLORSON. Crosby Lockwood & Sons, 1924.

controlling the outflow, the submerged piping can be kept always flooded and in a state to yield clear filtered water. When covering the perforated sector gravels and sand should be nicely packed to ensure a good filtering medium. The first flood usually compacts the sediments and completes the work.

Works of the above nature are only possible when the water table does not fall very low at the worst season, and when 6 to 10 ft. only are involved pumping can be avoided by trenching far enough down stream to carry away the water that issues from the trench.

IMPOUNDING WATER.—Although there are so many objections to the storage of water in tropical countries, there may be occasions when it affords the only feasible method of opening up a district. The shallow dew pond type of village pool relies upon a well-puddled mass of mud and straw which plugs the interstices of permeable strata to prevent percolation losses. Puddling is usually effected by animals which wade into the water to drink, so that the African and Indian village ponds become masses of polluted liquid where the natives perform their ablutions, wash their clothes and quench their thirst. They are commonly fed by the run-off of badly fouled ground and constitute a menace to health which should be avoided. Within the dry belts the water is only infrequently refreshed by rain and the evaporation reaches half-an-inch a day, equal to 30 tons, say 11,000 gallons per acre-day; a very serious loss in shallow retainers.

Reservoirs designed to store water in dry river courses are invariably expensive to construct and are liable to damage during storms as well as diminution of size by bad silting. Those in South Africa have caused much trouble, and we have witnessed many failures elsewhere. Evaporation losses are a serious matter and may imperil the usefulness of a scheme where no additional supplies are added for many months.

Recent experiments in the Sudan under our direction have shown that valuable supplies of water can be collected and stored in deep excavations in cotton soil. Once the cotton soil is saturated it is practically impermeable, and the seepage losses are negligible. Contrary to expectations the water has remained fresh and clear after storage for six months and longer during which period the measured evaporation was half-an-inch daily. The sustained purity of the water is attributed to the aeration resulting from wind and wave action, as no algae developed, nor did weeds grow. The rectangular excavations of 3,000

cubic metres (say 1,000,000 gallons) capacity were protected by a fence, and water was drawn by the natives and placed into circular mud troughs near the tanks instead of permitting animals to enter and foul the water. Suitably constructed in depressed areas where a surface flow of water can be directed during rains, whilst providing for the by-passing of storm water and silt, tanks so constructed have suffered little damage or silting in face of ordinary tropical storm conditions.

Several illustrations are attached of tanks constructed in the Bhutana, Sudan where large numbers of camels and cattle were daily watered for eight months after the cessation of rain. The completed tanks, 10 ft. deep, cost between 18.0d. and 28. per ton of capacity, and a little expense in annual repairs should keep them in good condition. Even allowing for evaporation, it will be noticed that if the water were valued to repay the cost in one year the price would not be higher than that charged to shipping at many ports in dry countries like Egypt, Sudan and Aden, where the price is 2s. 6d. up to 10s. per ton. See Figs. 27 and 28. A view is also shown of an impounded water reservoir in the Machakos. See Fig. 29.

BOREHOLES.—No hesitation is felt in asserting that boreholes are likely to afford the best, safest and cheapest solution of the water supply of most districts where moderate quantities are needed. Where quantities in excess of say 50,000 gallons a day are requisitioned, the question of some other source of supply should be considered.

The following very pertinent remarks prefix a water paper by Dr. du Toit, late Geologist to the Irrigation Department of the Union of South Africa, on South African work:—

“Although such does not appear to have secured adequate recognition, the occupancy of the vast spaces of South Africa and their Settlements has been made possible principally through the agency of the boring machine. I firmly believe that more has been achieved towards the general development of the country from the comparatively few thousands of pounds spent annually upon State boring than from all the millions expended upon large diversion storage schemes.”

At times the conditions may justify the belief that boreholes will yield over 2,000 gallons per hour, but the geological conditions of the country do not favour expectations much in excess of 1,000 gallons per hour. Within limits bores can be

drilled in groups, but too much multiplicity of bores entails expense and trouble outweighing advantages. It would be dangerous to assume that water can be obtained anywhere by drilling, but experience has shown that there are few types of rock, even the most unfavourable, which will not yield economically useful supplies of water if the location is carefully chosen. Admittedly it is sometimes a mere question of hit and miss, but usually there are surface clues which cause a geologist to give preference to certain sites.

Speaking generally, the hazards of drilling are greater in areas where igneous and metamorphic rocks occur than in regions where the rocks are sedimentary. Plutonic rocks like granite cover vast areas in some districts, whilst in other regions volcanic lavas or ashes alone are in evidence and they reach a thickness which makes them the main source of ground water. Each of these types of strata introduce their own problems, the general nature of which is understood. Several general principles should be kept in view when arranging a water scheme.

Firstly, the bore site should not be subordinated to surface requirements where an obvious site is suggested.

Secondly, sites should be selected where water is expected at the shallowest depth, as this involves less cost on drilling, especially if erratic results necessitate several wells or several trials before success is achieved.

Thirdly, sufficiency of supply should be ensured by the drilling of enough bores to constitute a reserve and allow of a rest or intermittent pumping.

Referring to the second point, it will be gathered that the regional water table is likely to be at about the same depth for some considerable distance, so that the vertical lift would be the same to any particular tank. The determining factor may be the pipe friction in the surface line to the tank. Not only does a shallow bore cost less and take less time than a deep bore, but it necessitates less plant below surface, always an advantage.

As regards the extent of the reserve it is advisable to provide for any service; experience has shown that it is better to give bores occasional periods of rest rather than continue uninterrupted pumping. The rate of pumping should be adjusted to suit the well after ample tests, so that the level of water is

not depressed below some agreed amount, which ensures the submersion of the pump barrel at all times. It is generally better to meet fluctuating demands by hours of pumping rather than by speed of operating pumps; one equipped bore should always be held in reserve at important watering centres.

Contrary to popular notions, there is usually no advantage in drilling deeply into rocks of the prevailing types for useful supplies of water; indeed, in crystalline rocks the prospects of success diminish with depth below some point to which decomposition and cracks extend. Beyond 500 ft. it is rarely advisable to drill into the rocks of tropical Africa, and if water is not found within 250 ft. a new site should be chosen under most circumstances. Beyond the zone of decomposition and surface cracks, circulation of admitted water is so impeded that dissolved salts are not flushed away, but cause mineralised waters. Native water holes are rarely carried beyond 100 ft., partly owing to the dangers and difficulties of working at this depth and partly on account of the physical energy required to lift useful quantities of water that distance by hand measures. Boreholes have the advantage over shafts by permitting the hole to be continued without inconvenience long after the water table has been struck. This is always advisable to provide against oscillations of the water table with seasons and years and to establish a head when the level is depressed.

EQUIPMENT OF BOREHOLES.—The type of installation for a borehole must be guided by circumstances. As a deep well pump can be operated at any depth within the limits of any schemes under consideration with almost equal ease, the water table plays little part in the design of plant if that type is used. Railway work presents special features which do not apply so forcibly to other installations, and somewhat modified classes of plant are in consequence adopted. Reliability comes first, as a shortage of water at a recognised station throws into confusion arrangements for watering traffic over long distances. Quality as applied to mineral contents in solution is important, when water is wanted for boilers as well as domestic purposes, but as regards the type of power, factors which influence other schemes removed from a railway need not influence a choice. One of the reasons for preferring borehole water is the freedom from suspended matter in the water liable to cause damage to pumps and trouble in the boilers. Even if borehole water contains minerals in solution, they are at least constant in quality and character so that simple remedies can be applied, if necessary. Stream or impounded waters, on the other hand,

are subject to sudden and frequent changes, and suspended inorganic or organic matter may lead to objectionable priming even if the water is soft.

Water can be raised from boreholes by the following methods, each of which has its particular advantage for special purposes:

- | | |
|-----------------|--|
| From surface | (a) Deep well plunger lift and force pump. |
| | (b) Vertical centrifugals. |
| | (c) Air-lift. |
| By use of shaft | (d) Horizontal centrifugals. |
| | (e) Plunger pumps. |

Obviously no hard and fast rule can be made for fixing the type of pump for particular duties, but some general rules for guidance may be laid down based on experience elsewhere.

Where the water level is deep, say in excess of 100 ft. from the surface, and the water is clear, a borehole pump usually best meets the case. Borehole centrifugals and air-lifts are not well suited to cases where the water level fluctuates with seasons or with the rate of pumping, as their efficiency falls if the conditions for which they were designed vary. Vertical centrifugals are open to the objection that they call for high speeds most usefully transmitted by an electrical drive, and their withdrawal for inspection or repairs is a lengthy operation. They are largely used for free yielding, low-lift boreholes of large capacity when cheap electrical energy is available.

Air-lift is an inefficient mechanical process usually confined in practice to employment where some unusual occurrence renders the use of pumps unsatisfactory. Such cases arise when corrosive or turbid water has to be raised, or where the noise or vibration caused by pumps in motion might prove a nuisance. In the absence of electrical power, it may prove an advantage to instal the power plant some distance from the borehole when air constitutes a convenient medium of transmission. The chief objection to air-lift lies in the restricted limits of water level under which it will function at even low efficiency. Firstly, a 50 per cent. submergence is essential for proper aeration and consequently effective operation, and secondly, compressors are more expensive than pumps and require more attention. It will also be appreciated that the necessary static and working levels to give the proper submergence cannot always be obtained, and that only by a fairly lengthy pumping test can the working level of water in a borehole at some fixed rate of abstraction be ascertained. Unless one or other of the above-named conditions

are present, the employment of air-lift is not recommended, particularly as it is usually essential to raise the water a further distance on reaching the surface.

Perhaps it would be well to emphasise that in any given well the starting and working air pressures are determined by submergence, and that any excess pressure beyond that due to submergence of the air-pipe plus that necessary to overcome friction of the air leads to defective results. Water rises merely as the result of lightening with air, and any excess beyond that necessary to aerate the column causes ejector action and spoils the working.

Railways carrying fuel for steam generation generally favour steam plants for their water installations, and the simple and fool-proof character of this class of machinery encourages its use whenever circumstances permit. If, therefore, the strata are compact and the water level of a bore rises to within say 50 ft. of the surface and suffers no abnormal depression on pumping, a popular plan is to sink a masonry lined shaft to near the highest water table and provide foundations for the installation of a duplex steam pump to which steam could be led from the surface. Amongst the advantages pertaining to this method may be mentioned the flexibility in pumping rates within the capacity of the bore to suit requirements and the ease with which the pumps can be replaced. This type of pump can be purchased almost anywhere, and Railway Companies usually have many in stock for use in constructional and other works. All working parts are in sight, easily accessible, and no skill is required for running. (See Fig. 30.)

Some engineers favour the use of plain horizontal centrifugal pumps for use in shafts mainly on the score of cheapness. Their employment calls for the use of countershafts and belting liable to give trouble unless a self-contained steam turbine unit is placed in the shaft above the borehole. Provided steam power is used to give flexibility of speed, there are no objections to this course if it is favoured for some reason. The fact that the discharge of centrifugals running at a fixed speed falls as the water level is depressed certainly suits some classes of bores when an undue lowering of the water level causes trouble in the hole. (See Fig. 30A.)

Next in usefulness for railway work is the deep well pump which can be driven by steam, oil engine or windmill. The vertical direct-acting, steam-driven type of pump has found

some favour on certain railway systems, and it is a thoroughly sound and satisfactory piece of mechanism. The only objection to its use lies in the higher cost of erection, insertion and withdrawal, besides its somewhat high initial cost. We are inclined to advise in preference the much simpler engine-driven geared frame and crank device which involves a minimum of time to instal or repair, and in most makes provides for the balancing of the pump rods. These pumping frames can be belt or chain driven from any kind of power unit and are very cheap. (See Figs. 31 and 31A.)

Single or double-acting deep well pumps can be obtained for use in 6-in. to 12-in. bores. When the capacity of the hole does not far exceed 1,000 gallons per hour, there is no need to complicate matters with a double-acting pump, but for quantities in excess it is an advantage to employ the latter type in small diameter bores. Pumps of 2,500 gallons per hour capacity can be conveniently employed in 6-in. or 8-in. boreholes. Another feature which makes submerged pumps popular is that they are always primed ready for use, whereas a pump above water often needs priming before it will start.

The attached sketches illustrate the types of installations recommended and described, and the tabular statement shows the relative cost of plants to do the same duty. See Page 60.

APPROXIMATE RELATIVE COSTS OF PUMPING PLANT.

	WELLS WITH SHAFT AT TOP		BOREHOLES, SAY 400' 0" DEEP		
	HORIZONTAL CASEPIPE PUMP AND OIL ENGINE	DUPLEX STEAM PUMP & BOILER	SINGLE ACTING BORE HOLE PUMP HEAD AND OIL ENGINE	DOUBLE ACTING BORE HOLE PUMP HEAD GEAR AND OIL ENGINE	AIR LIFT WITH COMPRESSOR AND OIL ENGINE.
Size of Pump	14"	0 4 1/2" x 6"	4"	3 1/2"	2" Bore Main Air Pipe 1"
Capacity in G. per Hr	3,600	3,000	2,760	3,000	2,500
Approximate actual H.P. required	5		12	12	25
Cost of Pump	£22	£46	£280	£265	£300
Cost of Engine	£64		£96	£96	£400
Cost of Boiler		£248			
TOTAL COST	£86	£296	£376	£361	£700

Mention might appropriately be made of the value of a shaft for collecting water in cases where the yield of a bore is sluggish and long hours of pumping at a slow rate are a disadvantage. By sinking a shaft well below the static level of water in the borehole, a storage can be created from which water can be pumped at a high rate at intervals. Instead of carrying the shaft deep it is sometimes preferable to drive headings below the lowest water level with the same object in view. Naturally the yield of the bore at various depths of depression should be ascertained by trial before deciding upon the storage needful to give convenient periods for pumping.

DRILLING PROBLEMS.

DRILLING MACHINERY—Obviously no single type of drilling machinery would equally well deal with all the many kinds of strata into which it may be necessary to drill for water in Central and East Africa. There may at times be justification for the purchase of more than one type of plant, but this should be avoided wherever possible as duplicity of types involves a multiplicity of spares, tools and perhaps operators. Efforts should be directed to the selection of a standard form of rig which is likely to give the best all-round results. Considerations of intentions, diameter of bore, yields available or desired, depth and kinds of strata combine to influence one in the choice of plant, but experience in various Colonies and Dependencies has served to emphasise the importance of avoiding the temptation of cheapness and light weight when ordering drilling plant, for when seasons of great heat or excessive rains, as in the Tropics, are liable to impede normal operations, it is essential that work should be speeded up to the maximum limit. In most industrial pursuits standing charges form such a considerable proportion of the total costs that except under very extreme conditions all else should be subordinated to speed.

A portable type of machine has so many advantages over one requiring dismantling and reassembling at each bore that it warrants first consideration, and preference has been given to this class in most countries, but portability is a wide term and latitude in its meaning must be observed. Thus weight and bulk may be reduced by mounting the engine on a separate truck, and the machine itself may be lightened by the removal of a few heavy parts. Where good roads and railways give easy access to regions being developed, the whole drill with its

power may be carried on a single wheeled frame, sometimes self-propelling, but more often arranged for pulling by means of draft animals or tractors.

Whatever type of rig is ordered the form of motive power can be decided to suit circumstances. Steam is recommended where fuel and water are available, as the steam engine is the simplest form of power for unskilled people to handle and it allows of wide variations of speed so necessary for meeting changeable conditions. An increasing disposition to use internal combustion engines for use in remote districts is now manifested, and greater reliability and simplicity of oil engines has mollified some of the earlier objections to their employment. If ample power is provided and the engines are left ungoverned so that they can be regulated by a control at the front of the machine, a fair variation of speed can be arranged to meet different situations and operations. (See Figs. 32 and 33.)

By far the most popular portable percussion rig on the market is the "Star," a machine of American origin which has far outsold all other types, nor is this popularity unmerited, as no other rig on the market fulfils demands so comprehensively. It is made in a variety of sizes for different depths, but the 1,000 ft. nominal size has been found in practice to suit best the ordinary water-drilling operations. The world-wide distribution of "Star" rigs simplifies the search for experienced operators accustomed to a particular type of drill, for the rate of progress with a drill is largely dependent upon the experience of drillers on a particular rig. The machine incorporates a number of features developed as the result of long and wide-spread experience, and it does not preclude the addition of further changes designed to suit peculiar local conditions. Amongst the changes made to meet special demands is a "Calf Wheel" to operate raising blocks without the necessity of uncoiling the drilling cable from the main drum, also the mast may be heightened and strengthened for the use of longer strings of tools.

Local arrangements are often made for driving the machine with an engine mounted on a separate frame and truck for the sake of portability.

The drilling rig only comprises the mechanism for operating tools which perform the act of drilling, and it is upon the selection of these latter that so much depends to ensure maximum rates of progress. Much has been accomplished in recent years in the way of improving both the design and quality

of instruments made for piercing rocks of various kinds, with the result that although percussion tools are really unsuitable for both very hard and very soft rocks, tools have been produced which will cope with either. Improved quality of steels and alloys and modified designs of bits are enabling harder and harder rocks to succumb quicker to attack by percussion tools, and even the disposition for bits to depart from the vertical when drilling in steeply-inclined laminated strata has been thwarted, to a considerable extent, by specially designed tools.

Unconsolidated sediments can be best handled with the aid of rotary flush tools with fish tail or disc bits: but the process calls for heavy demands on water to ensure a regular circulation to flush away the "cuttings." Such strata are so rare in the part of Africa under review that they call for no serious thought, and such insignificant alluvial deposits as are found can be quite well negotiated with an ordinary percussion rig. On the other hand, diamond or chilled shot *core* drills can best deal with the hard rocks so often met with, but this type of drill is open to the grave objection of large water requirements for circulation in addition to difficulties in piercing fissured or decomposed zones in which water is usually sought.

There may be cases where a combination outfit would accelerate progress to a marked degree, but a critical analysis of results in South Africa has led to the unqualified conviction that with suitable tools and plant it is an unnecessary refinement. Full concurrence is felt with this view as a result of experience elsewhere. With a suitable assortment of tools there are few crystalline or other hard rocks with which the modern percussion system will not deal.

Speaking with greater precision it may be said that the following quantities of water and fuel represent the needs for average wells using different methods:—

	Water per Hour Gallons	Fuel per Hour
Percussion portable rig with steam power	60 to 80	50 lbs. good quality coal.
Percussion portable rig with oil (kerosene) engine	20 to 30	15 lbs., say 2 gals. kerosene per hour.
Rotary flush core drill, steam or oil engine drive	50 to 300	About same as percussion rig, as pumps worked as well as rig.

Generally water for drilling is a more serious question than fuel and other items of expenditure, and it is often the determining factor in the selection of the kind of power to employ. On percussion rigs the make-up water needs may be greatly reduced by attention to little details such as recovering most of that used for drilling by dumping the bailings in a tub or tank, also by condensing the exhaust of the steam engine in long strings of piping or by the use of an aero-condenser. In this connection the losses of water sustained by the use of a steam jet in the chimney for maintaining pressure in the boiler should not be overlooked. A boiler should be provided with sufficient heating surface to give an ample supply of steam with the fuel available without the need of artificial blast. This frequent defect might be overcome by having a longer smoke stack and by so placing the boiler that a draught may be directed into the ash pan by deflection of the prevailing wind.

The transport of three to five tons of water daily may prove a serious item of expense when carriage is by car, camel or other animals for a distance over rough country, and this amount may easily be increased several-fold in the case of rotary drills losing water in broken ground. It is mainly the question of water that has led to the introduction of oil engines in place of steam engines, notwithstanding the objections already enumerated.

There may be occasions when a very light portable rig might be justified, but the whole tendency is towards increased weight which means quicker and more efficient drilling. A hand boring plant is practically useless for hard rocks, as besides a speed measured in only inches a day, the rods and tools are constantly being broken by vibration following crystallization of the metal.

The subject of staff is not one to be treated lightly, as drilling is a highly specialised art only acquired by many years of practice. It is not so much a question of drilling a hole as the ability to avoid difficulties and recover tools lost through accident. Drillers are left largely to their own devices away from control or direction, and it is difficult to bring home to operators charges of carelessness, neglect, laziness, &c., when things go wrong. Operators should, therefore, be selected with care, and it is just here that difficulties have to be faced, as the demands are far in excess of those available, except in America, where very high rates of pay are earned by qualified men. It is useless providing good plant for the use of inefficient operators,

and the popular yet erroneous impression that suitable men can be got at any time from South Africa should be dissipated. The Union Government is itself much perturbed by the difficulty of procuring good drillers, and having just decided upon a much larger drilling policy, they have recognised this deficiency and have started a system of training suitable youths. British drillers with the necessary qualifications can be found occasionally, but trustworthy and proved operators are not to be got at short notice. Home drilling experience in the British Isles does not adequately fit a man for Colonial work of the class being discussed, as help is always at hand in the event of trouble, and it is rarely necessary to improvise or economise in details which are of the first magnitude when distant from help.

Provision should be made in each Colony to have one or two youths with mechanical knowledge always in training, and where possible also natives of superior intellect should be selected with the same object in view.

Drillers usually command a higher rate of pay than other artisans, partly because good ones are scarce, but mainly because they have to live generally in remote localities away from their homes and families which have to be supported. A scale of about £50 monthly to include living expenses has come to be regarded as a suitable remuneration for skilled operators in foreign countries, but they are usually furnished with free quarters and camping outfit and often water, fuel and light. Travelling expenses incurred on official journeys are refunded. Men of marked superiority deserve and rightfully command a much higher rate of pay, but payments beyond the established rate should preferably be given in some form of bonus dependent upon results, instead of establishing a high rate which might cause dissatisfaction amongst others of less merit. Generosity in the matter of leave is usually well repaid by improved efficiency where men work in distant and oft-times unhealthy localities where nutritious food cannot be obtained and white society is non-existent.

The question of how many constitute a drilling crew arouses most contentious views. Some drillers will surround themselves with 12 to 15 men, others are equally content with 4 or 5 assistants. There is certainly no need for the larger-numbered crew about a rig however inefficient they may be, and in the Union of South Africa 4 or 5 are considered ample. Usually a superabundance of labour is a hindrance rather than a help, as without occupation they chatter and become neglectful

of their duties. The drilling crew usually includes a blacksmith for dressing tools and a fireman or engine-driver, with some mechanical knowledge. A labour time sheet is usually kept by the driller, and one man displaying abilities beyond the ordinary is generally nominated head man and taught to operate the drill in the temporary absence of the skilled operator.

A supervisor is commonly appointed if a number of rigs have to be maintained in operation, as the manifold duties involved in keeping rigs supplied with all needs becomes quite onerous. Delays for materials which may have to be transported hundreds of miles are very demoralising to the staff besides costly, and no arrangements should be omitted designed to keep the rig working the whole time. In South Africa the working days per rig year average 200, and the cost is £1,200 a year, say £6 per working day, when fuel, water and transport are provided by the farmers and the rest by the Government.

Naturally little more than an approximate cost for bores can be given where so many variables are involved. A general figure of £150 per working rig month may be used for estimating the running costs of outfits under normal conditions where transport, fuel and water needs can be met without great difficulty, excluding casing and overhead charges. Allowing for removals of rig and other delays, it is likely that £100 a month or £1,200 per year will cover costs. If an average footage of 8 ft. per working day is taken over 200 working days, this equals 1,600 ft. per rig year, say seven to eight wells per year between 200 and 230 ft. deep. Bores are, therefore, likely to cost around £160 each, about 15/- per foot, excluding any standing charges. It will be understood that transport to some remote districts might cost the equivalent of several boreholes and keep a rig from effective use for a month or more. In order to compensate for such contingencies, it is an advantage to have one or two spare rigs so that the drilling staff would not be engaged on unprofitable work during long non-productive intervals.

The average cost of 11,989 bores in the Union of South Africa representing a footage of 1,715,802 ft. has been almost exactly £120, the average yield per day per bore being 15,000 gallons. In Southern Rhodesia, where the number of rigs operating in 1928 were increased to 13, some 33,000 ft. had been drilled in five years at a cost of about 30/6 per foot. The aggregate yield was 2,400,000 gallons a day and the bores averaged 120 ft. deep, of which 60 per cent. gave useful supplies of water.

In conclusion, we should like to emphasize the value of drilling as a cheap means of opening up new countries where water is a prime necessity. Every year the value of subsoil water is more generally appreciated, especially in tropical and sub-tropical countries where surface supplies so often fail after long periods without rain and the quality suffers deterioration through exposure and pollution. Drilling affords a cheap and easy means of exploring for and developing ground water supplies, and the increasing use of the power drill in all parts of the world clearly proves that satisfaction is derived from its use.

A. BEEBY THOMPSON & PARTNERS.

REPORT ON WATER PROSPECTS
OF THE
NORTHERN FRONTIER PROVINCE, KENYA.

(Figures 3, 11, 12 and 13 to 26).

The following notes are based upon a hurried reconnaissance of the Northern Frontier Province of Kenya in March, 1929, when some 1500 miles were covered by car. The routes followed were along the few cleared roads accessible to cars, and there was no time for departures from the beaten track owing to the near approach of the rains. Furnished with the reports of Dr. Parkinson and the notes of Mr. Noaks one was able to follow the deductions drawn from nearly equally rapid surveys of the country made by those observers. An absence of contour maps and levels rendered detailed observations of little use, but such observations as could be made were often facilitated by the absence of dense undergrowth and a scarcity of foliage on the trees following the long drought.

Generally speaking, the main topographical and geological features were readily discernible. Changes of soil and surface configuration were commonly reflected by vegetation. Stunted growth and leafless plants in well-drained ground contrasted strongly with the green, fresh and more virile developments in depressions or where water was held by strata of certain types over a longer period. Although unacquainted with the names of plants and shrubs it was soon noticed what types predominated under different conditions. This gave some assistance in tracing drainage lines where optical illusions as to elevations and an absence of erosion channels would otherwise have led one astray.

Although an absence of surface run-off was evidenced by the infrequency over long distances of rivers or watercourses, the fact that some run-off occurs is clearly indicated by the sinuous belts of green vegetation which meander about the country and can often be traced for miles from a commanding position. With a rainfall averaging less than ten inches a year the run-off would be very small except during heavy downpours, even then a few feet of suitable soil would greedily absorb the whole amount which escaped evaporation were the run-off spread over a sufficient interval of time to ensure penetration.

Surface relief presents no striking feature over large areas where wide, ill-defined ridges separate depressions in some of which latter sedimentary beds have been deposited or volcanic lavas have flowed. The Lorian Swamp is certainly a feature of significance and may provide a clue to the elucidation of the problems connected with the limestone deposits of Wajir and Eil Wak. There is certainly good reason to suspect that this series is of sedimentary origin and not an abnormal development of Kankar (lime efflorescence) as suggested by some writers. The fossils alone would disavow the latter origin, and in addition it appears to occur beds of different ages and types which would not be the case if resulting from the leaching of salts from certain kinds of rocks. The Wajir limestones certainly overlap the gneissic rocks towards the Lorian Swamp and along the Moyale Road, for in both cases the last limestone outcrops are followed by granitic sands, quartz breccias and crystalline fragments.

Nothing was seen to suggest a connection between the Wajir and Eil Wak limestones, which were probably deposited in basins of older rocks and cover an irregular area. Limestones again appear near Ramu on the Daua river, which marks the Abyssinian frontier, and here appearances tend to show that they overlie the Jurassic (?) sedimentary group, ridges of which seem to break the continuity of the limestone series. These might not be related to the Wajir group, but their appearance is significant. Without levels, the limits of any lake could not be defined, but even given accurate levels it might still be difficult to appraise the extent of denudation since their deposition, or to ascertain the extent of any land level changes. No evidence was found which would indicate that sandstones were interbedded with the limestones, yet the wide strips of ferruginous coarse sands overlying the limestones round Wajir and elsewhere suggested a local origin rather than transport by water or wind on scrub-overgrown country. Into such a lake large quantities of sand must have been swept from the outcropping crystalline rocks which everywhere weather into coarse sands, but such might have been mainly confined to channels of restricted dimensions. Perhaps ill-luck led to the failure to notice the sandy limestones mentioned in some reports.

Neglecting the purely academic side of the problem and dealing with economics it is certain that many of the rocks of the district are suitable for the reception and storage of water. The limestones have attracted main attention as they are porous, fractured and broken up by solution channels. When exposed on the surface they seem to be extensively creviced, and below or near the depth of saturation the beds may often be cavernous in character, and yield very copious supplies if penetrated. At Wajir the water table is within 8 to 10 ft. of the surface in the pronounced depressions where the wells are located, and the fenced-in, reserved, low-lying area would probably expose water if cleared of silt and filth which has washed into the basin. The wells appear to yield freely in this district, and the rate of extraction was estimated at about 400 to 500 gallons per hour per well by hand measures; a rate of extraction said to be continued often day and night. Some half-mile away water still filled a basin in the limestone to a depth of several feet, although used for watering animals since the last rains. This was thought to be surface drainage, but it seems more probable that this depression reaches below the present water level and is fed by inflow from the limestones. On the edge of this pool, some 100 yards in diameter, large crevices in the limestones can be seen and these could hardly fail to admit water if the beds below were unsaturated. A few shallow shafts on the edge of the pool would definitely settle the question. (See Figs. 22 and 25.)

Doubtless it is the shallow depth of the water table said to fall rarely much below present level, that has made Wajir so popular as a water centre. At Eil Wak, where no such depression is obvious, water has to be raised some 80 (?) ft. from crooked wells which admit only of primitive and laborious methods of extraction. Although it might be unsafe to assume that water would be found everywhere in the limestone belt, it is almost certain that water could be obtained over very wide areas, especially at depressed points where exposed to heavier surface flows and longer contact than elsewhere. The rarity of defined drainage channels suggests ready absorption, and a profuse vegetation is indicative of the retention of capillary water. One objection to the limestone water is its high salinity, perhaps 2,000 to 3,000 parts per million of dissolved solids. No ill-effects were experienced by members of the expedi-

tion from its use, but it is very hard, and that of Eil Wak and of certain Wajir wells very objectionable to the palate. Hitherto only top water has been taken, and it may be that porous seams of calcareous beds at certain depths may yield better qualities of water. An exploration for deeper water is certainly justified, as although the cattle and natives readily drink the water it is likely that all would benefit from less mineralised supplies. As the limestone series is horizontally bedded only a very limited section is exposed, but on the sides of wells may be seen clearly defined bedding planes and beds of irregular hardness and porosity.

Although there is presumptive evidence of the wide occurrence of limestone with excellent prospects for water, a very little excavation would definitely prove their limits. It might be that the continuity of the limestone series is broken at intervals with outcrops of gneissic rocks which are the source of the prevailing red quartz sands, but if so their limits could be determined by very little pitting or quite shallow drilling.

The limestone area worthy of serious attention can be roughly delineated on the south of Wajir from a point on the Meru-Wajir road near where the side road to Moyale branches off; on the Moyale road from a point somewhere beyond the Waghalla wells before the quartz fragments are met with on the road; along the Eil Wak road to beyond Eil Wak until near where the sandstones appear. Also an ill-defined belt near the Daua river on the Eil Wak-Ramu road, where the limestones are very obtrusively exposed on the surface and seriously obstruct transport by their rugged exposed edges.

The acid gneissic rocks, often mingled with basic types, are exposed in many parts of the N.E. Province. Their presence is usually manifested on the surface by coarse quartz sands and rock fragments. These crystalline rocks are first met with soon after branching off from the Meru road to the Wajir road; then after a long strip of country they appear again as a ridge rising above the plains and continue almost without apparent interruption until some miles from Wajir. At Garba Tulla a group of granitic hills is a feature of the landscape, and a deep khor has been cut into the crystalline rocks. (See Fig. 16.)

For many miles a clearly defined khor lined with dome palms follows a course roughly parallel to the road, and at various points water is obtained from wells or surface pools for watering cattle, sheep and camels. At Banani an outcrop of granitic rocks forms a bold and picturesque feature around where the country is much cut up with khors draining into the main watercourse. Kankar (calcareous) deposits were seen in the banks of the stream near here overlying the crystalline rocks. Another long strip of crystalline rocks is reached about 25 miles out from Wajir on the Moyale road, and depressions are made apparent by the periodical appearance of more luxuriant vegetation of types that do not thrive in dry parts. At several places true gravels were seen on the surface, suggestive of concealed ancient watercourses, and now and again ferruginous lateritic gravels gave the road a hard surface. As Buna is approached the plains are broken by hill ranges of evidently gneissic rocks, and at Buna itself water is being drawn from deep wells in crystalline rocks with nearly vertical foliation planes striking roughly north-south. Although the hills were not visited, the weathering was typical of both acid and basic rocks, and in the wells area both types of rock were noticed above which a small deposit of kankar had formed. Until about 10 miles from Buna the country is thickly covered with scrub and thorn, but this is followed by

40
a wide grassy plain of unusually soft and fine material which causes the road to be badly cut up and produces clouds of dust, causing much discomfort. Our box car, indeed, gave up here, and we had to complete the journey to Buna with one car and return in the evening. Eventually we had to return alone to Wajir the next day and send a lorry out to drag in the damaged car to Wajir. (See Figs. 13, 14 and 15.)

Along this belt of crystalline rocks water is likely to be found at certain points. Judging by surface debris and outcrops acid rocks predominate, and these generally decompose more freely than many basic types and produce a better receptacle for water. The Buna wells are located between two hill ranges, and are alleged to yield water at all seasons. The run-off from the neighbouring hill ranges would ensure a greater and longer wetting of the rocks than elsewhere, and in consequence lead to further percolation. (See Fig. 20.)

In arid regions well sites are preferably located in depressions where the equivalent of far more than the average rainfall of the district must flow. Percolation is largely a function of time, and the higher the percolation the greater the degree of decomposition of the rocks, and consequently the better the prospects of finding water in crystalline rocks. In the absence of surface outcrops there must always be some degree of uncertainty as to results; for as subsoil water follows a somewhat intricate system of crevices, joint cracks and cleavage planes, the actual output of individual wells may vary considerably, especially as the type of vertically foliated rocks may differ widely within short distances. A zone of saturation (water table) usually exists in most places, and if the rocks are piecemeal below this depth any fissure system is likely to act as a feeder to a borehole.

It is only rarely that sufficient methodical work is undertaken within a circumscribed area to determine the full effects of purely local circumstances. Close observations were made of a series of bores drilled at El Obeid, Khordofan, Sudan, with a view to providing that station with water. Although ten wells were drilled within a narrow radius in mica schists with pegmatite inclusions no bore failed to yield at some depth, everyone gave different yields and qualities of water, the settled yield varying from 120 to 1,000 gallons per hour, and the solids in solution from 500 to 1,750 parts per million. One or more failures should not, consequently, be taken to condemn a region, and further sites should be selected at right angles to the strike of foliation and not along the strike where, similar conditions might be anticipated; that is usually east and west rather than north and south.

A third series of deposits covering considerable areas in some parts are the volcanic eruptive group. White tufts and highly vesicular basaltic lava cover a belt of country stretching from Meru in a northerly and north-eastern direction. On the Wajir road they are only seen along the first plains bordering the crystalline masses flanking the Jomben range. The tufts are not extensively developed, but the basaltic lavas cover a wide strip of plain and extend over the hills around Meru. Towards Isola basaltic lavas cover vast areas around the crystalline masses which rise out of the plains. Only at one or two spots were white tufts noted on the road between Meru and Isola.

The decomposed basaltic lavas and tufts should furnish good supplies of water when struck at a level which would ensure the water table being reached within a hundred or two feet. On high ground they may so effectively drain

41
the ground by sub-soil flow that unless covered by a thick deposit of heavy soil the land is stony and nearly barren. Around Meru the basaltic masses have formed thick deposits of rich fertile soil on which flourishes all kinds of produce, aided by a good rainfall.

There appears therefore good prospects of striking sub-soil water at moderate depths on the plains where basalt is exposed along the Wajir and Isola roads. The lavas exposed on the surface beyond the Kiama crater are highly vesicular and have the appearance of readily absorbing rainfall.

The sandstone group offers further possibilities for water in the belt of country between Eil Wak and Ramu. A watershed of sandstone is crossed by the road some miles north of Eil Wak, and for many miles northwards scarps of sandstone are visible to the east of the road. The strata appear to be horizontally bedded, probably over a wide belt of territory in the neighbourhood. Bores sunk into this series of rocks at low points are sure to yield water at moderate depth. A few odd fragments picked up showed interbedded layers of gypsum, but this did not appear to be a general characteristic. Where subsoil water circulates the beds are likely to yield a water of good quality. D. C. Reece stated that a long ridge of high country extends to the north-west of Eil Wak, admirably suited for pastoral occupation, and this would appear a useful direction in which to prosecute research for water.

Finally, the alluvial deposits of the district are likely to prove useful sources of water supply in some places. All the khors near the crystalline rocks have floors of clean, coarse, unconsolidated sands and gravels capable of storing 20 to 30 per cent. of their volume of water. At many places animals were being watered from holes scooped in the sand, and where the deposit of sand was small there was often a surface flow. At Muddo Gashi shafts were carried to a depth of about 12 ft. in coarse sands and gravels, and ample water was obtained to water large herds of animals. Time did not admit of any detailed examination of these khors, but from glimpses at various points it is apparent that the beds of the khors vary greatly in character according to the gradient, and along some long stretches of crystalline rocks are exposed with little covering. At other places there are long strips of deep sands and gravels carrying water at some depth. The alluvial deposits of the khor at Muddo Gashi consisted of coarse sands and gravels capable of giving good yields of water to the depths seen, and water oozed from the beds freely when the level was lowered by raising in skins from a sump. (See Figs. 14 and 18.)

Perhaps the most interesting deposits of this nature are in the neighbourhood of the Daso Nyiro, where a wide swampy belt of sands follows a broad grassy, black, cotton-soil plain of great fertility. The extent and nature of the beds of this Lorian swamp area will never be known till tested by the drill, but considering the wide belt of crystalline rocks drained and the great quantity of sands which must be carried into this swamp by the various khors there must be considerable thicknesses of sandy material, at least, in parts. It may be that sandy beds underlie the cotton-soil plain to the south, in which case valuable use might be made of this rich piece of land, not only capable of supporting cattle, but also growing almost anything in years when the annual rainfall is sufficient. Thirty inches or upwards in the Sudan on such land ensures good crops of maize and allied grain. The other source of useful development is the Daus river where at no great cost perennial supplies of water might be secured at many points and at little cost. No wells were

42
found at Ramu as we hoped to find, due probably to the great depth of the water table and the difficulty of keeping open a deep sump in running sands. (See Figs. 11 and 12.)

The foregoing remarks are designed to give the reason for considering there are reasonable prospects of developing useful supplies of water in the Northern Frontier Province. Present conditions are indeed deplorable, far worse than in most backward countries. Not only is water scarce and often bad in quality, but the primitive methods used entail a maximum of labour and hardship on men and animals. Beyond the perennial streams which cross the plains near the Kiuna river in the fly belt the watering arrangements are very bad and call for some Government action, especially as no great expense would be involved in improving matters. The paucity of water centres involves at well centres a congestion of animals which produces filthy surroundings and dangerous conditions. In the natural anxiety to minimise the height to which water is lifted, wells are made at the most depressed points, so that all animal refuse is washed into them during rains, and during the process of watering much filth is carried back to the wells by spilt water. Even in the khor beds the shallow sands at some spots where water was close to the surface stank badly, and at Wajir abandoned wells were visited half filled with camel dung in a state of oblation with escaping gas. As the porous limestones readily permit circulation of water the conditions are such as to impede the supply of the district.

The simplest expedients designed to safeguard pollution are often neglected by the Native element. A number of abandoned wells have filled with drift dirt and filth instead of being filled up with soil if not wanted. At Eil Wak and Bina, where the water is deep, 60 to 80 ft. perhaps, it is lifted by the laborious and slow process of handing leather vessels up by relays of men and women stationed on supports at intervals in crooked wells. Fourteen to seventeen men and women are employed in a narrow badly ventilated shaft, passing up and down the filled and empty vessels to the time of a song. At the surface hundreds of thirsty and impatient animals awaited their turn for a drink so tediously drawn. (See Fig. 23.)

The choked wells may be due to unskilled construction or more likely to the falling up of some fissure or crevice leading to the water. At Eil Wak many scrub-overgrown surface depressions were noticed, probably representing the sites of former wells now abandoned through some cause.

The P.C. very rightly urges the development of more well centres rather than encouraging the concentration of animals at certain existing stations. Congestion at a few points leads to great delays in watering and much unnecessary suffering of animals besides resulting in the total extinction of grazing for miles around the water holes. Exactly the same evil is being remedied in the Sudan by an extension of water points in grazing territory. If, therefore, good water is located at many spots the problem of extraction at each centre becomes simplified. Generally the water table will be lower than 20 to 30 ft. and may often reach 100 ft., which latter is about the maximum that experience has shown Natives will draw water by hand except in dire necessity. If heavy animals have to be watered mechanical means of extraction are justified for wells in excess of 50 ft., as the process of hand recovery becomes very slow indeed. At a place like Wajir the well tops could be redesigned to ensure some measure of safety from the surface pollution, but it would probably be preferable to raise water mechanically and lead it away in pipes to watering places outside the immediate vicinity of the wells themselves.

43
If custom has established a sentimental inclination for certain centres of antiquity like Wajir and Eil Wak it might be politic to encourage their use on a moderate scale, and let the Natives see what can be done for their benefit by installing model plants and noting their effects. The most satisfactory plan would be to test certain wells for capacity with a pump, and if they yielded the needful supply finish them off in good style or sink new wells near and raise water by windmills, with perhaps the reserve of a power plant. It would be a simple matter to test the Wajir wells where the water table is high, but at Eil Wak it might be preferable to sink a new vertical shaft or bore near an existing well and connect the two with a tunnel. A deep well pump could then be installed and operated by a power plant or windmill. Water could be conveyed by a pipe to troughs located some distance from the well.

Bores sunk in crystalline rocks are unlikely to be large individual producers of water, and if the depth is in excess of 100 ft. windmills could in any case not raise large quantities, so that if moderately large well centres are to be established under those conditions several bores would be necessary. One bore at least should be fitted with an emergency power plant for use in the event of the wind falling for long periods. A tank will take care of the daily fluctuations due to wind changes. In the Sudan the sinking of three bores at each place has long been advocated and answer admirably, and as transport of plant is the main expense of drilling the cost of several wells does not greatly increase the cost of one installation.

Some of the river courses could probably be cheaply and quickly developed with drive tube wells instead of going to the expense of drilling, and the same might apply to sandy belts in the Lorian Swamp area where the dry season zone of saturation is within 20 to 25 ft. from the surface. If the sands persist at depth or are interbedded with gravel or coarse sand, large quantities of water might be struck under a sub-artesian head at depths up to 30 or 40 ft. An experiment would be cheap and quick, and a few tests would quickly determine the feasibility of the proposal.

Water would certainly be obtained in the Daua and Lugga river courses at selected points. In the former case the water table may at times be deeper than 20 to 30 ft., that is beyond the limits of a suction pump, in which case it would be necessary to sink a shaft to a depth where a lift and force pump could be placed within workable reach of the water. In all cases the tubes should be driven well below the water table in order to ensure a head on the screens and submergence at all times, otherwise constant troubles are experienced with in-running sands. Where water is found in the valley alluvials at depths exceeding a few feet there is always trouble in keeping an open hole using to the sand running in. This difficulty was specially noticed at Muddo Gashi, where the water was drawn from loose running sands and gravels at about 10 to 12 ft., and in-running sand had to be constantly scooped up. Under native methods every flood destroys the work of a previous year, and some kind of permanent works would probably prove very beneficial where the water is deep. (See Fig. 13.)

Obviously, the use of mechanical devices for the extraction of water is to be discouraged where simple native methods can be adopted, but in many cases where shallow water is available by merely scooping out the sand it might be preferable to sink a shaft on the edge of the khor where clear water could be drawn by hand instead of using dirty and infested water, doubtless

the cause of hook worm and other abdominal troubles. A large diameter masonry-lined well with terraces around above ground level would at least prevent pollution by direct return of surface filth, whilst providing means for a number of Natives to water simultaneously instead of only one or two as at present. Efforts should be made to induce the Natives to place their troughs and receptacles some little distance from the well, from which the water could be carried or led in masonry-lined gutters. It was, however, seen that at many places animals were watered in portable elongated wooden vessels or in troughs cut out of the solid rock, rather indicative of some attention to cleanliness, yet they failed to take adequate precautions to avoid dirt returning to the wells.

From the context of this report it will be seen that the prospects of finding sub-soil water in the Northern Frontier Province are regarded as distinctly hopeful. As a potential field for partial developments the Province offers considerable scope. Large areas of ungrazed land were exposed at the very end of the dry season, and the conditions closely resemble those characteristic vast areas of the Sudan where schemes of water development are in progress. Considerable areas are made accessible for grazing during and after the rains by the simple expedient of collecting water in puddled depressions, but this only affords temporary relief and the Natives are continually forced to concentrate near water holes where the supply never quite fails. Doubtless the Agricultural Department may have ideas as to the best areas for directing energies, but, on the other hand, strategic questions may sway decisions as they do in the Sudan. The few main roads are likely to be the scenes of initial activity, and some effort will surely be made to space the wells at convenient distances apart to facilitate movements of animals about the country.

Conversations with the Provincial Officials led to the feeling that some discontent was felt by the Natives at repeated failures to fulfil promises, and if as a preliminary to imposing taxation it is desired to give practical proof of the Government intentions to improve their lot it might be preferable to start by making a useful display at a place like Eil Wak, where any model scheme would be seen by many and its usefulness appreciated to the full. A project of development outwards from such centres as Wajir and Eil Wak, where water is procurable in abundance would appear a useful way of attacking the Northern Frontier problem.

The question of revenue and prevention of waste will certainly exercise the minds of officials here as it has done in the Sudan. So highly prized is water in the Sudan that no difficulty is found in obtaining payment for water in addition to the collection of the usual herd taxes. On the other hand, the Government has always disliked the idea of charging for water in addition to imposing taxes, yet the policy has continued owing to the certainty of excessive waste if the tribes were given free water. Collection of charges, about halfpenny per four-gallon tin, by native clerks is always liable to abuses, but certain checks are imposed by various means which reduce the evil. When only indirect payment is charged for water, as by herd taxes, it seems very desirable to arrange the plants in such a way that although water is available in abundance it cannot be obtained without a certain amount of physical effort, for example, by bailing out of a subterranean tank rather than by merely opening a valve or cock which is invariably broken in a short time or left running.

The question of utilising the Abyssinian raid indemnity for water supply schemes is apparently much debated at present, and the natural disinclination of deflecting direct relief from sufferers might be met, it is suggested, by using the capital sums for common water projects and reserving a certain proportion of the revenue collected as a herd tax or otherwise for the compensation of dependents or sufferers if found. Interest or redemption charges on capital might be waived under such circumstances, and the schemes might be subject only to running costs and upkeep.

The Government control of model water stations is a fixed policy in the Sudan, and in Kenya popular resorts are likely to facilitate tax collection from those attempting to evade payment.

Although windmills are advocated it is never safe to depend entirely upon wind at important water centres where reliance is placed on supplies at all periods of the year; consequently the question of power is sure to arise. Throughout the N.E. Province food is so plentiful that steam plants would appear to meet circumstances best. Steam affords the safest, easiest, most fool-proof source of power known, and power-driven pumps should certainly be run by steam engines.

I would here like to emphasise the fact that windmills are not mere toys, a prey to the vagaries of climate as is often stated. Against tendered advice windmills have been erected at a number of places in the Sudan, where subjected to severe gales and storms, and they have for years weathered the very trying conditions and given practically no trouble or required any attention. The English made mill has given complete satisfaction, and if slightly more expensive than some of foreign make the extra expense seems justified. They are made self-oiling and self-governing so that gales do not cause damage.

Some reluctance is felt in submitting definite proposals regarding a scheme of development, as purely domestic circumstances must necessarily dictate policy. A show of interest in native affairs would certainly result from attention to Eil Wak and Wajir, and a few experiments with tube wells at the points indicated would be inexpensive and useful for future guidance. A deeper well should be sunk at Wajir to test lower strata, and at Eil Wak a bore should be sunk to prove the value and thickness of the limestone. Doubtless views will be held as to the best course of following up a programme of drilling, whether by working southwards from the Abyssinian frontier to attract pastoralists from that direction or working northwards from some spot like the Lorian Swamp region, or even further south to tempt a population northwards. Probably it is unknown to what extent the Natives are likely to abandon their nomadic habits and settle their families if permanent water is found at many points. There has been a tendency in the Sudan to create permanent villages at new water centres, and in one case a group of villages spring up and schools were opened following the discovery of water, where before there was nothing but a few Natives dependent upon water stored in Baobab trees in the dry season.

A few dozen tube wells should be ordered with say three driving sets to test promising localities. The number of drilling rigs would naturally have to be fixed by the funds placed at disposal for any development along or near the few main trade routes extending northwards.

April, 1920.

(Signed) A. BERRY THOMPSON

REPORT ON LAKE SOLAI DISTRICT.

(Figures 7, 8 and 9.)

The present report is based on a fairly comprehensive examination of the Solai district where scarcity of water in several plains to the west of Lake Solai has caused the Kamasia herdsmen and the authorities serious concern. The investigation was made in company with Mr. E. G. Stone, Provincial Commissioner, and Mr. Jones, Public Works officer, and later the expedition was joined by Mr. Oldfield, District Commissioner. A camp was pitched at the foot of the vertical western scarp of Lake Solai on 17th May, and from here excursions were made on foot as movements by car were quite impossible. The lake into which a number of streams flow from the eastern escarpment of the Rift Valley was found to be practically dry, only a few pools at distant intervals being seen. Over the whole basin a growth of green grass had spread, on which zebra, gazelle and ostriches were feeding.

The first upland plain, Kapertek, was reached by a pass over a low point on the scarp to the west which is generally about 500 ft. higher than the Solai valley floor. As is usual, once over the scarp the ground slopes down again so that the plain itself is much lower than the scarp top. This plain varies in width, but has a flat floor with slight slopes from the edge of the volcanic rocks, and a gentle fall northwards in which direction the main drainage runs. A number of herdsmen joined us and readily answered questions and guided us to localities of interest in response to our queries. They displayed intelligence in their replies and showed a general willingness to impart information. Over a more or less desiccated plain patches of short grass and bunches of thorn bush were scattered, but nowhere was a stretch of grass found. The sloping ground from the volcanic rocks of the ridges was almost devoid of vegetation, but here and there where rain water had collected along slight depressions there was a certain amount of vegetable growth. Over the dry parched ground there were signs of surface flow, and the travel of the water could be traced by scour lines and fringes of debris carried by the moving water. Shallow pools of water had collected at a few points as a result of recent rains, and numbers of cattle were grazing upon the little grass available and also watering at the pools.

No regular watercourses carrying off the surface drainage could be seen, and on questioning the native herdsmen, they affirmed that the water ran into holes on the plain during rains and disappeared. We were then taken to several swallow holes where the signs verified their statement, and later other and more obvious places were noticed which made it clear that much water found its way underground. At a few places water had been held up and ponded in depressions, whilst at others it had evidently soaked away after collecting. One or two primitively excavated ponds were seen where water had accumulated, and at one place an excavation protected by a thorn fence was shown to us where water was stored and was being reserved exclusively for drinking. This supply was said to furnish their needs for two months after rains, and showed that the people appreciated good clean water.

By far the most interesting discovery was the presence of white banded soils, quite different to the volcanic rocks exposed on the scarp ridges, indicating the occurrence of lake deposits which accounted for the light-coloured nature

of the soil. One excavation entirely in tufts was holding water satisfactorily, and at many places there was evidently little more than a veneer of soil, as material expelled by burrowing animals was mainly composed of tufts. Subsequent investigations in this valley led to the discovery of a large number of swallow holes, and also to the presence of at least one watercourse on the western side where a strip of gravels was traced. This particular dry course was due to the rush of water during storms down a confined subsidiary valley caused by a low spur of volcanic rocks.

The second and higher parallel valley to the west, N'dalai, is narrower than that just described, but otherwise presents much the same general appearance, but, if anything, is more desiccated than the lower as the photographs will show. Here also lake deposits were found between the two ridges of volcanic rocks which form its sides. On the west a high vertical cliff rises sheer out of the plain, whilst on the east side the volcanic rocks slope at a moderate angle to the plain. Along the N'dalai valley the swallow holes are numerous and much more perfectly developed. The general run off is northwards on a low gradient and in the plain itself there were clear indications that water had collected during rains when there was a surface flow. A very distinct water-course can be traced along this plain notwithstanding the presence of numerous large swallow holes, which appeared to follow no obvious arrangement.

Quite a number of typical swallow holes were examined in detail and photographed. They varied in size at the surface from more or less circular pits, some 10 to 20 ft diameter, to elongated depressions, perhaps 50 ft long and 10 to 15 ft wide. All were overgrown with scrub and bush, and at a depth of between 6 and 12 ft, one or more holes could be found between 1 and 2 ft diameter where water had descended. Evidence of the rush of water was found in the confused collection of grass, twigs, leaves, &c., around and about the mouth of the actual orifice, as well as in the pit. In some cases the water must have run away as fast as it entered the pit. In other instances the deposit of mud on the scrub and vegetation showed that the pit had filled and even overflowed, so that the rate of outflow did not keep pace with the inflow of water. Natives confirmed this fact on interrogation, but they also affirmed that the inrush was so fierce in some cases that the gurgling of the water could be heard for a considerable distance. (See Figs. 7, 8 and 9).

Although the plain was traversed for several miles and many swallow holes minutely inspected, they appeared to follow no general plan or direction, but seemed to occur more or less sporadically wherever irregularities of the surface favoured a concentration of water during rains. Fortunately one large pit was found exposing an excellent section of the valley sediments, and they were seen to consist of well-laminated lake deposits of white or grey tufts with perhaps diatoms. At another spot an excavation for drinking water over 6 ft deep was carried into the same beds, as the spoil heap alongside proved, yet the water did not leak, and we were told that the supply would last for two months after rain. Several cases were noticed where water was lying in pools within a few yards of swallow holes, thus clearly showing that unless some moderately deep porous zone is reached the beds do not readily absorb water, at least when plastered up with mud.

One naturally sought for some artificial cause for the entrance of water into the ground, either accidental or intentional, but beyond a few obsidian

chips there was no evidence of past occupation here, nor were there signs of old spoil heaps. There is thus no reason to suspect that these swallow holes are the relics of man's handiwork in search of water as was at first suspected. If the water table is not very deep, it is just possible that animals may have burrowed sufficiently deep in search of water to initiate work which Nature later developed. At several places a distinct watercourse marked by green foliage and a depression abruptly terminated where water found its way into a swallow hole, the natural dam beyond failing to hold up water as would otherwise have been the case.

Another interesting discovery was the junction of the horizontal white tuft deposits with the volcanic rocks on the western side of the valley below the fault scarp, a white line showing its exact position.

One day was spent exploring still higher valleys between two volcanic ridges, where always the eastern edge of the ridge was represented by a vertical cliff hundreds of feet high. The narrow plains separating the ridges above N'dalai were too small and barren to be of any economic value, but even here beautifully developed swallow holes were found along a line which may easily have corresponded with the fault in the volcanic rocks. Only silt deposits were observed in these high plains which had a steep fall northwards and would discharge any water into the northern end of the N'dalai valley.

From a high beacon point marking the boundary of the reserve and alienated lands a fine view was unfolded of the whole series of parallel valleys between successive ridges, and the barrenness of the Native reserve was especially noticeable. The difference between the two areas was so marked that it supported the contention that the Native lands were over-grazed or otherwise neglected and suggested the need for skilled advice, especially as drainage was largely northward into the Native reserve rather than southward into alienated lands.

Both the Kaperikei and N'dalai plains, as also the Solai, have lake deposits, but their depth is unknown and can only be ascertained by drilling. These beds are not generally disturbed, fractured or faulted, and if water does gain admission one would hardly expect a considerable vertical fall, but rather entrance into some permeable stratum near the line of saturation. (All the tufts are porous, but mere porosity would not lead to an absorption of water at the rate it enters swallow holes. Only rarely does water find unobstructed escape in subterranean channels of size, and such would not be expected in the lake deposits or on the floor of the volcanic rocks in these valleys.)

No information could be collected regarding sub-soil water as no shafts or wells had been sunk by the Natives. Where the run-off is concentrated due to topographical features, healthy green clusters of acacias give the impression that the roots may reach a zone of saturation, and naturally this feature attracted attention. Unless the water is assumed to be lost in deep fault fissures, the sub-soil drainage must find its way along these upland valleys; for there are no signs of percolation through the volcanic ridges into the lower valleys.

Several courses of action suggest themselves for ameliorating or mitigating the present miserable situation. Only the remote but, nevertheless, possible contingency that water finds its way into deep fault fissures in the

volcanic rocks would prevent water being reached at some accessible depth in the two upland plains, Kaperikei and N'dalal. The first-named plain is probably not more than 200 to 300 ft. above the Solai Lake, and the second is not much higher, although high sharp ridges of volcanic rocks separate the various plains. Under the worst conditions the depth to water should not exceed 500 ft., well within the limits of a drilling machine, as the regional zone of saturation should not exceed this figure, although no levels were taken to prove this. It would seem an unnecessarily pessimistic attitude to assume without supporting evidence that some peculiar hydrological conditions prevail, although the eventuality in this country of strange phenomena should not be entirely disregarded. A more likely probability is that surface water finds its way into fairly shallow porous beds in the lake deposits, as where seen in sections elsewhere, at Nakuru and Naivaisha highly porous sandy beds were observed interbedded with the tufts.

When discussing this subject with Mr. Leakey and his geological associate at his camp near Nakuru, the opinion was expressed that all these upland lake deposits had a water table, and that the discharge did not exhaust the beds in the intervals between rainy seasons. If this proves a correct diagnosis of conditions and the lake deposits are moderately thick, useful supplies of water may be tapped at quite moderate depths, say within 100 or 150 ft. from the surface. The lake deposits appear to be horizontal, and the gradient of the plains northwards is certainly insufficient to induce an excessive rate of flow. In the event of the lake deposits not being very thick, it might be necessary to drill into the decomposed or brecciated surface of the volcanic rocks which may form a valuable reservoir for water.

Although there is little to guide one in the choice of drilling sites, and a regional water table may exist, initial operations might be concentrated where most water is likely to enter the ground. As the surface and sub-soil drainage is northward, bores should preferably be sited in the same direction and particularly where any contraction of the valley concentrates the flow. A favourable location in the Kaperikei valley would be near the north end where any surface flow would pass and be supplemented by an eastern flow from a spur which deflects the discharge from a large catchment into the valley. Locations should be near the centre of the plain, or if anything nearer the western side than the eastern owing to the vertical nature of the cliffs on the latter side.

Another useful location for a test is along the watercourse extending to the area submerged by water at the time of the visit, near the track which leads from Kaperikei to N'dalal over the low ridge. Here were found on the surface the only gravel beds noticed in the district, a fact which had not escaped the notice of the Natives who said water was usually found associated with pebbles. At both of these sites groups of thorn trees with luxuriant foliage gave proof of a heavier watering than elsewhere.

On the N'dalal plain a position is suggested on the edge of the watercourse at the northern part somewhere near the large tree situated in the small plantation to which water is being conducted by trenches during rain-falls. The valley narrows here, swallow holes occur and the vegetation is fresh and green. Probably it matters little where a bore is made provided it is kept well away from the eastern side where the volcanic rocks slant gently under the valley sediments.

This opportunity is taken to emphasize the extraordinary difficulties the Natives must suffer in these upland valleys. Whereas the Solai valley is cloaked in a rich mantle of long healthy grass, apparently almost untouched by cattle, the two upland plains are nearly barren wastes which can only afford a precarious food for the many cattle grazing there. The cause warrants investigation by the Agricultural Department, but appearances led me to suspect over-grazing as all new growth is eaten as soon as it appears and no natural local re-seeding is possible. The soil, except for humus, resembles that of the Solai valley, so cannot take the full blame. Desiccation may be largely attributed to the general absence of vegetation, as devoid of the protection afforded by grass any soil is loosened by movements of cattle and is then in a fit state to be carried away by winds, which are sure to be strong in these long narrow valleys at times. Many sand devils (whirlwinds) were, indeed, seen and felt during the visit, and clouds of loosened earth were being carried upwards and away, whereas on the grass-protected Solai valley no such attrition of soil was taking place.

A contributory cause for desiccation is, doubtless, the heavy loss of water in swallow holes, and this could certainly be largely prevented by the simple expedient of filling up the holes, or perhaps better still encircling each with a surround of earth which would prevent the water gaining access and running underground at too great a depth to provide moisture for plant life. Water would then spread over the surface, soak the earth and assist the growth of vegetation.

Should the absence of seeding be one of the causes for the barren condition of the land, a few areas might be enclosed with a fence where grass could be planted and allowed to seed. Winds would then spread the seed and help matters.

Acute distress must be occasioned to cattle driven as far as the Molo river for water, a journey occupying the best part of two days along barren lands, separated by a succession of nearly vertical scarps over which a goat might hesitate to climb in hot weather. Certainly the passage over these scarps was no light task for members of the party in moderately cool weather, judging by our fatigued condition on return to camp.

If the Kamaxia are to continue to occupy these plains without access to the Solai valley, some official action is much overdue, and even if drilling failed to give the anticipated results, two other alternative courses are open; namely, impounding surface water or sinking bores or shafts in the Solai valley and granting suitable access thereto. The pass on Col. Lean's property alone furnishes easy access to the valley as it crosses a very low point on the scarp near where water could be found.

Impounding water would not be an impossible task, although presenting the usual objections to exposing water to surface influences and evaporation. Satisfactory silt could doubtless be found with a little search quite suitable for mudding up excavations in the lake deposits. The somewhat extensive sheets of water exposed many days after rain prove that impermeable materials are to be found in the valley. Unless made deep, the value of such reservoirs is usually nullified by evaporation losses, even if access by animals is prevented and water only taken out in vessels.

Water is almost sure to be found in the Solai valley at no great depth, and if a convenient track could not be provided for the movement of cattle, no great expense would be incurred in pumping water over the ridge into the Kaperiko valley.

The best way of dealing with any sub-soil water discovered would depend upon depth from surface quantities available and needed. A windmill with an engine in reserve might best suit conditions if the water is not too deep, but if a supply is found within 100 ft. shafts would probably prove the best solution and let the Natives draw water with their own vessels in their own way. The comparatively soft lake sediments should prove easy material in which to drill, but unless some better way of approach is found it would be necessary to use a hand rig or small power plant, as everything would need man-handling after crossing the Solai valley. A water supply for the work could be developed at Lake Solai.

The subject of this report has been discussed with the Director of Public Works whose advice and help are gratefully acknowledged. Thanks are also due to Mr. Stone for the time and trouble taken in ensuring all available information being collected and everything of interest seen.

(Signed) A. BEEBY THOMPSON

25th May, 1929.

ILLUSTRATIONS REFERRED TO
IN REPORTS.

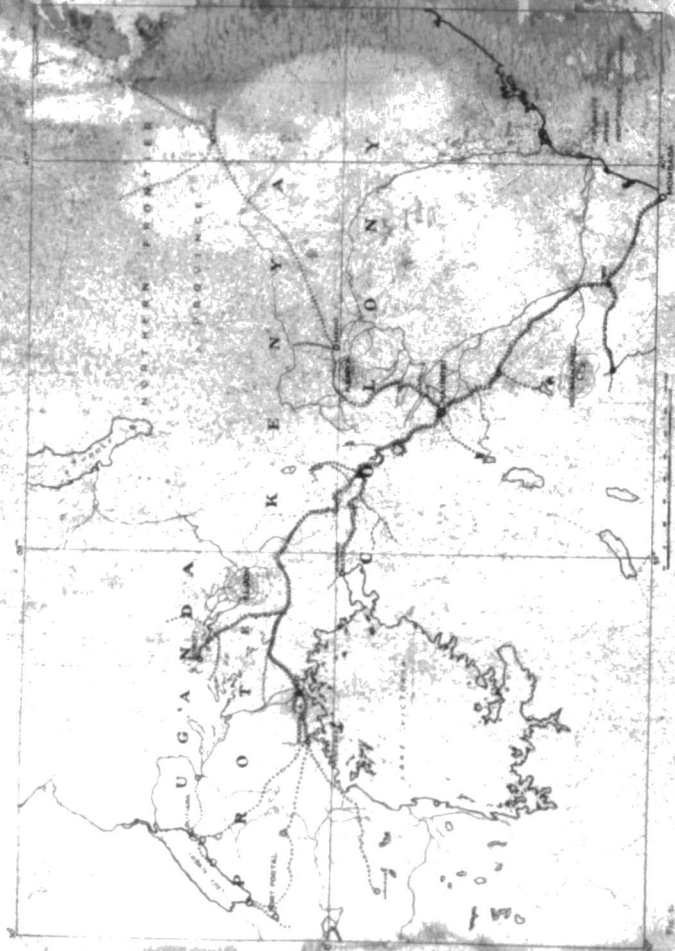


Fig. 4. A view of the Alor River through forest in the PLAINS.



Fig. 5. Tropical forest in the Alor River basin, near the mouth of the Alor River.



Fig. 1. The plain between the Rye Valley and the Rye Valley.



Fig. 2. The plain between the Rye Valley and the Rye Valley.



Fig. 3. Low streamer ridge in the Rye Valley, near the Rye Valley.



Fig. 4. Low streamer ridge in the Rye Valley, near the Rye Valley.



WILLOW HOLE, THERMAL PLAIN, SOBAL



Fig. 6. SWISS HOLE, HAPENHO VALLEY, SOBAL



MAKANI SOBAL AREA



Fig. 21. Thermal, COFFEE SOIL, SOBAL. Rich growth of grass although very hot. X. G. P. P. P. P.



Fig. 10. Dotted line, FLAME near the LARVAE SWAMP.



Fig. 11. Sheep watering in River Country, where shallow watercourses water fields at 200 feet in sandy
between watercourses (see below page 100). S. V. P. P. P. P. P.



Fig. 12. Native Watering Day River Country, Sheep Grazing.
(Water water level is high).



Fig. 13. Watering sheep in River Country.
(Water water level and water level of the river is high).

62



Fig. 12. Native woman in traditional dress of the river valley at Garra, Kenya.



Fig. 13. A woman and child in traditional dress of the river valley at Garra, Kenya.

63



Fig. 14. Native women in traditional dress of the river valley at Garra, Kenya, showing the difficulty of getting water in the valley of the river.



Fig. 15. A woman and child in traditional dress of the river valley at Garra, Kenya, showing the difficulty of getting water in the valley of the river.



04. 1937. WATER-IRRIGATION SYSTEM AT BOKA, NEAR SUVAH (PARTIALLY BY DIGGING OF CISTERNS).



05. 1937. OPENING OF A WELL AT SUVAH.



06. 1937. THE WATER RIDGES AT MAJID (LIMBANGA) AND THE WATER RIDGES AT SUVAH.



07. 1937. VIEW OF NATURAL SPRING WATER FROM COMMON WELL AT SUVAH. THE RIDGES AND RIDGES APPLIED TO THIS IN WHICH HAND OF THE RIDGES UP AND DOWN.



Fig. 26. *Wardha & Wardha, at the War.*
The way to the straight line from the bank of Canada are watered daily.



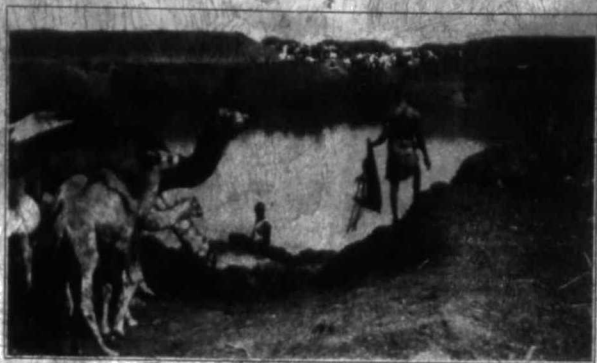
Fig. 27. *The Lake of Wardha.*



Fig. 28. *Wardha, Wardha on the river, with the boat, they are in the water and the river.*



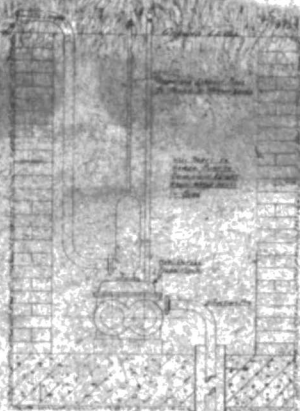
Fig. 29. *Wardha at the pond, they are in the water.*



WELL IN THE SANDS OF THE DESERT IN THE MOUNTAINS

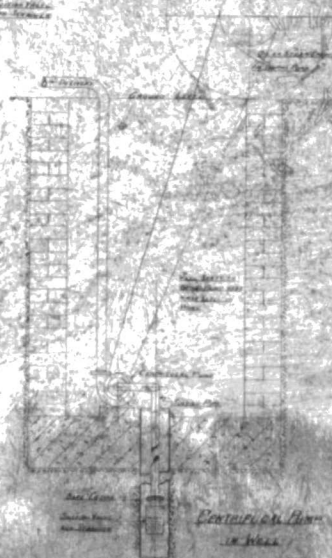


DESERT LANDSCAPE IN THE MOUNTAINS



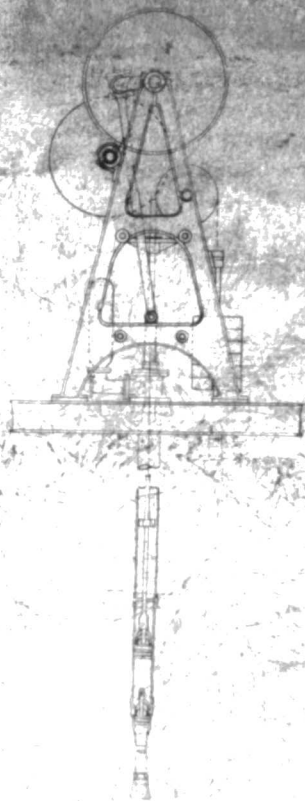
Dug Well

Fig. 25

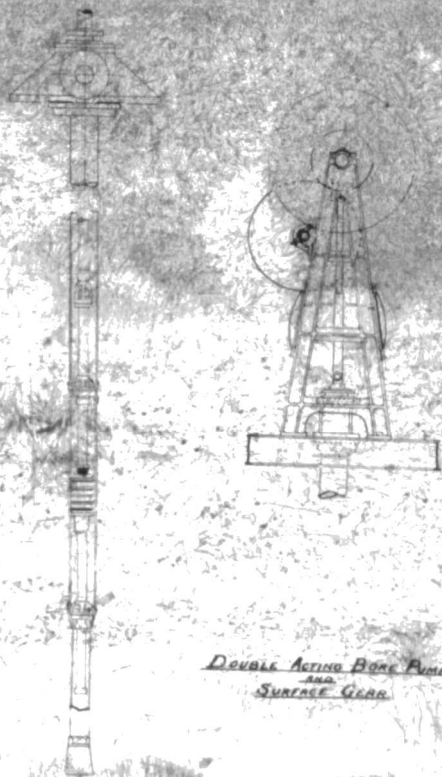


Cemented Well

Fig. 26



SINGLE ACTING BORE HOLE PUMP
 AND
SURFACE GEAR



DOUBLE ACTING BORE PUMP
 AND
SURFACE GEAR

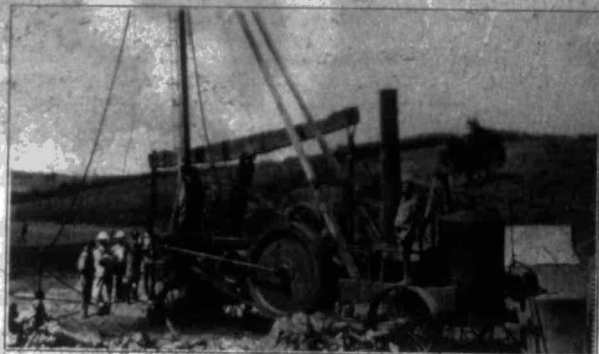


FIG. 25. — LIFTING THE STEAM POWER.

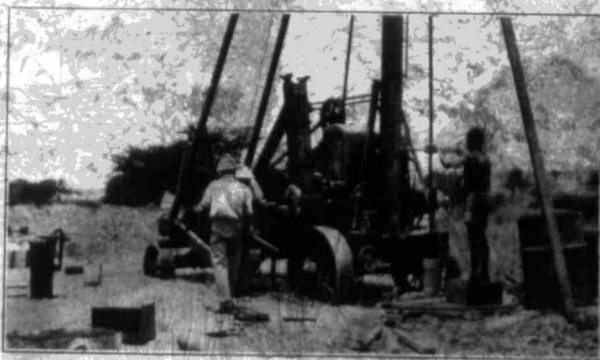


FIG. 26. — LIFTING THE STEAM POWER.

359



ALL COMMUNICATIONS
TO BE ADDRESSED TO THE
CROWN AGENTS FOR THE COLONIES
THE FOLLOWING REFERENCE AND THE
DATE OF THIS LETTER BEING QUOTED

4, MILLBANK,
WESTMINSTER,
LONDON, S.W.1.

3/E. 321/71 RECEIVED
24 JUL 1929
COL. OFFICE

TELEGRAMS: CROWN LONDON
TELEPHONE: 7730 VICTORIA

22nd July, 1929.

Sir,

I have the honour to transmit the enclosed copy of a letter from Messrs. A. Beeby, Thompson & Partners submitting an account amounting to £231. 0. 0. for expenses incurred by their senior partner in connection with his recent visit to Kenya.

We understand that the arrangements for this visit were made by the Colonial Office and we accordingly await the formal authority of the Secretary of State before paying.

I have the honour to be,

Sir,

Your obedient servant,

W. H. Wickham

for Crown Agents.

14 AUG 1929
Copy Ser. 639
11 AUG 1929

FROM MESSRS. A. BEEBY, THOMPSON & PARTNERS TO CROWN AGENTS.

18 St. Swithin's Lane,

London, E.C.4.

18th July, 1929.

Gentlemen,

To enclose herewith Account of expenses incurred in connection with the Kenya visit and not met by the Kenya Government. It was thought that certain charges could be more conveniently included in Mr. A. Beeby Thompson's account than pass through routine channels locally. A number of reports dealing with pressing questions were handed in during the visit but it is proposed to submit a general report covering these and other questions when the data has been suitably collected. No charges are made for certain expenses in Uganda and Tanganyika, as no arrangements were made for such. A number of reports were submitted to the Authorities in Uganda on various problems and a report has been forwarded to Tanganyika.

2. Mr. A. Beeby Thompson left Khartoum for Uganda on February 9th and departed from Tanganyika on June 3rd.

3. As he returned via South Africa he has charged a lump sum of £120 to cover the fares and expenses between East Africa and London and treated the other expenses as personal.

4. The following reports were submitted locally:-

- (1) North West Frontier Province, Kenya.
- (2) Railways - on schemes at many points on Kenya-Uganda system.
- (3) Lake Solai district, Kenya.
- (4) Nairobi Municipal Council Scheme to augment water supply quickly.
- (5) Lake Albert Oil prospects.
- (6) Scheme for water developments, Uganda,

and a report has been sent in to the Governor, Tanganyika, on Tanganyika water problems.

5. In addition the papers relating to a number of water prospects in Kenya and Uganda were scrutinised and discussed on the ground, including the Entebbe, Kampala, Nairobi and Mombasa water supplies.

Yours faithfully,

(sgd.) A. Beeby Thompson & Partners.

COPY.

S/E. 321/71.

A. Bebb Thompson & Partners.

18 St. Swinfin's Lane,
London, E. C. 4.

18th July, 1929.

The Crown Agents for the Colonies,
4 Millbank, S.W.1.

IN ACCOUNT WITH A. BEBBY THOMPSON & PARTNERS

1929.

Expenses incurred in connection with Kenya visit.

Fares and expenses Khartoum to Nairobi	£41.0.0.
Expenses incurred in connection with North Frontier Safari not met by Government	30.0.0.
Hotel and travelling expenses in Kenya and sundry charges for cars not met by Government	40.0.0.
Fares and expenses Mombasa - London	120.0.0.

£231.0.0.

115
Jo
Mr. Allen

Mr.

Mr.

Mr. Bottomley.

Sir B. Harding.

Sir J. Shackleton.

Sir G. Grindie.

Sir C. Davis.

Sir S. Wilson.

Mr. Grassby-Cox.

Lord Lovat.

Mr. Amery.

Downing Street,

62 2
16 March, 1929.



Dear Dutton,

I am sorry that there has been some delay in answering your letter of the 20th February regarding the enquiry by Mr. Noakes whether we had any news about the transfer of the water boring machinery and whether any operations for water boring in the Northern Frontier Province had been provided for in the Kenya Estimates for 1929.

As regards the distribution of the water boring plant, our latest information was that given by Mr. Noakes himself when he called at the Colonial Office on the 16th of February, and we do not appear to have any information as to the transfer of any of the machines to the Northern Frontier Province.

DRAFT.

MAJOR E. A. T. DUTTON

C/o Eastern African
Dependencies Trade and
Information Office.

The draft Estimates for 1926

provided the sum of £13,050 for the Water Boring Branch, and that was increased by the Select Committee to £15,823.

This increase was in part due to the creation of an appointment of Water

Boring Inspector, and the increase of the establishment of the Branch by five additional Drill

Foremen (two for nine months and two for six months) and two additional

Assistant Drill Foremen. Sanction for

this expenditure was covered by the

general approval which has now been

given for the expenditure provided in

the Estimates.

The Select Committee also recommended that four more drills should be bought if the money becomes available, but there is no indication either in the Report of the Committee or other papers as to where the existing drills are at the moment being employed, or where any additional drills that may

^{as} required would be employed.

63
END

Yours sincerely

P.S. Since dectober this
Mr. Moore has called here &
Enclom the list of this

(Signed) W. T. BLEN