1925

KENYA

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C.O.
10386
5 MAR 25

From Dep. Gov. Denham — Conf 14

Date 4th Feb., 1925

For Circulation:—

Mr.

Mr.

Mr.

Asst. U.S. of S. Mr. Strachey

Perm. U.S. of S.

Parl. U.S. of S.

Secretary of State.

Report on Mombasa Water Works

Sends —.

Previous Paper

Gov. 57938/24

Answd – Conf 8 April 25

Subsequent Paper

D.A.G. 26228

MINUTES

In the general despatch about the local services, received last July, (Gov/31193/24) £100,000 was asked for for the Mombasa Water Supply. The enclosures to the present despatch take us up to August, when the recommendation was in favour of an expenditure of about £40,000 for treating the existing pipes.

In the Governor's telegram of December 10th (57938/24) it was stated that the replacement of the main was urgent, and consequently approval was given to £100,000 as a Loan service, and also to the work being begun immediately.

As a matter of fact we have only the reference to replacement in the December telegram to indicate that the £100,000 scheme is again proposed.(i.e. either "C" or "D" in the table supplied by the Director of Public Works,

representing

(334313) Wt. 17813/38 Gp. 140 50000 12-24 W & S Ltd.

representing expenditure of £92,000, or £107,500 as the case may be.)

I do not think we need go into this point, as, if one of the larger schemes is proposed, it will mean an increased supply of 1,100,000 as against 700,000 gallons a day, and, according to Major Rhodes, will last a longer time-15 years.

The whole story of these water works is not edifying, but the War certainly had something to do with the failure to execute the work promptly, and to instal the liming process, which would apparently have saved much of the corrosion of the steel pipes. As an example, however, of departmental construction, in view of the gradual growth of the capital expenditure on a scheme which in the end was unsatisfactory and incomplete, there is not much to be proud of in this matter.

Apart from the service to the town of Mombasa, the watering of shipping as being a means of attracting transport to the Colony is a matter of general advantage, and I think that it should be ruled that the loan charges on both the original cost, and the new expenditure, shall not be borne on the revenue of the water works ~~only~~ until a net revenue of £10,000 a year has been obtained, and that all net revenue up to that amount shall be set aside each year to ~~the~~ a Renewals Fund.

W.C.B. 24:3-25.

Approval for immediate proceeding with the work at an estimated cost of £100,000 was given on Gov 58251.

As proposed. C.S. 3-4-25

[illegible]

KENYA.

No. 14.

CONFIDENTIAL.

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GOVERNMENT HOUSE,
NAIROBI,
KENYA.

C O
10386
5 MAR 25

4th February, 1925.

Sir,

With reference to my Confidential telegram No.349 of the 10th December, relative to the urgency of immediately replacing the existing mains of the Mombasa Water Supply, and to your telegram of the 14th January, intimating that the inclusion of a sum of £100,000 for this purpose in the proposed Colonial Loan has your approval, I have the honour to transmit for your information copies of Reports upon the Mombasa Water Works, prepared by the Director of Public Works and the Chief Engineer, Uganda Railway, which were laid on the table of the Legislative Council in August last.

Cyp. 57938/25

Reports Cyp. 58251/25

I have the honour to be,

Sir,

Your most obedient, humble servant,

GOVERNOR.

THE RIGHT HONOURABLE
LIEUTENANT COLONEL
L. C. M. S. AMERY, P.C., M.P.,
SECRETARY OF STATE FOR THE COLONIES,
DOWNING STREET,
LONDON, S. W.

REPORTS

ON

MOMBASA WATER WORKS.

COPY.

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REPORT ON

MOMBASA WATER WORKS.

EARLY INVESTIGATION.

The first project for the supply of water to Mombasa Island was prepared by Col.Bagle R.E. in 1899, and was based on a reconnaissance by him of a stream called the Kitsamni at the north end of the Shimba Hills. The scheme, which was estimated to cost £.95,000, comprised the conveyance of 500,000 gallons of water per day to the Island. No action was taken at that time and in later years the stream was reported to have ceased to flow during a drought.

In 1909, the supply of water for Mombasa again became a pressing one, and after an examination of the Kitsamni in that year, a preliminary investigation of a scheme to supply Mombasa from the Mreri, a tributary of the Manolo, a river draining the western slopes of the Shimba Hills through Mombasa Gap, was made in 1910 by the Director of Public Works, and a report advocating the utilisation of that stream was submitted to Government on November 18th, 1910. The preliminary estimate annexed to the report placed the probable cost of the works for the delivery of 1,500,000 gallons per day at £.86,000. The report was examined by the Consulting Engineers to the Colonial Office, and the opinion was expressed that only 700,000 gallons per day should be provided at a cost of £.91,000.

Detailed investigation for the proposed works on the Mainland took place in 1911 with the result that the scheme was adopted in a modified form, and the expenditure of a sum of £.90,000 out of loan funds was sanctioned for the execution of the project.

In 1912, Government arranged for a report after examination of the project on site by Mr.H.J.Morton,M.I.C.E. of the firm of Messrs.Babtie, Shaw and Morton, M.M.I.C.E., Consulting Engineers, Glasgow. Mr.Morton's report was

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submitted in September, 1912. It contained many valuable suggestions, which were adopted. 58

Professor Simpson, an eminent sanitarian, reported to Government in 1913 while pipe laying was in progress. The chief feature of his report was the advocacy of redesign of the project so as to provide for the delivery of 1,100,000 gallons per day. His recommendation in this respect was not adopted by Government.

WORKS CARRIED OUT.

The country in which the works were to be carried out was hilly and involved; most of it was densely covered with forest and scrub and deeply dissected by gorges. It also proved to be very unhealthy for both Europeans and Africans.

The project, finally adopted after various alterations of the original intention, provided for headworks situated 705 feet above sea level at a point on the Kreri Stream some 4 miles south of Kwale Forest Station. From this intake a gravitation main 26½ miles in length was to convey the water to a Service Reservoir of 1,500,000 gallons capacity, situated 200 feet above sea level at Changamwe, from which the Distribution System emanated.

The first 8 miles of the Gravitation Main consisted of pipe of 12 inches in internal diameter and this portion was laid to a hydraulic gradient of .1704%. The remainder was of 10 inches internal diameter and consisted of 3½ miles at a hydraulic gradient of .530% to a break pressure tank situated at level 535, and 15 miles at a hydraulic gradient of .410%. The alignment, diameters and gradients were such that the main should have delivered 800,000 gallons

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per day at the Service Reservoir while the pipes were clean.

The pipes were of lapwelded steel, 3/16 inch thick with inserted joints. They were in lengths varying from 16 feet to 22 feet and were dipped in Smith's solution, wrapped in hessian, and again dipped by the makers.

The Distribution System consisted of pipes of similar type, varying in diameter from 16 inches downwards. A complete project was prepared to meet future requirements, but some of the branch mains were left for execution in subsequent years when demands justified their installation.

INITIAL CAPITAL EXPENDITURE.

In the middle of 1911, loan funds to the amount of £.90,000 bearing interest at 3½% and to be extinguished by a sinking fund of 1% were provided. The Distribution System was not investigated in detail until 1914. It was then found that the sum of £.14,200 which had been provisionally inserted in the early estimates for this division of the work would be inadequate and that a further sum of £.9600 would be necessary. It was furthermore decided, on representations from Professor Simpson, to provide a Service Reservoir of 1,500,000 gallons capacity instead of one of 750,000 gallons capacity, which had previously been regarded as likely to be adequate for some years. The sum of £.17,900 was therefore provided in the Estimates for 1915-16 bringing the total sanctioned expenditure at that time to £.107,900.

CONSTRUCTION.

Material from England began to arrive in June, 1913. Much preliminary work had already been

per day at the Service Reservoir while the pipes were clean.

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CONSTRUCTION.

Material from England began to arrive in June, 1913. Much preliminary work had already been

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done in connection with the clearing of forest; the construction of 17 miles of service road through hilly country intersected with water courses; the erection of a landing jetty, temporary buildings and camps; the excavation of the trench and the construction of aqueducts and bridges across the gorges.

The records show that, even before the war started, work was carried on under most trying conditions, chiefly on account of the difficulty of procuring adequate supplies of labour, the unhealthiness of the climate and transport troubles. There was much illness, and many deaths occurred amongst the native labourers, in spite of every effort to provide good accommodation and sanitary conditions. The Europeans constantly became incapacitated by illness. These causes frequently brought work practically to a standstill for long periods at a time. After the war started, the difficulties of procuring labour and obtaining stores were much accentuated.

Work was completed, with the exception of certain items, by the end of 1916. A limited supply, chiefly to meet military requirements, had already been led into Mombasa in March, 1915, partly by means of various temporary connecting pipes of small diameter pending the completion of the permanent works.

On January 30th, 1917, the completion report was submitted by the Director of Public Works to Government, but the installation of certain items of work, which it had not been found possible by that time to carry out, was foreshadowed. Amongst these were:-

(1) a permanent bridge across the Mwachi River,

(2) liming plant at the Head Works,

(3) a meter to provide an automatic record of the town's rate of consumption,

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(4) replacement of the temporary bridges on the service road by permanent structures, 61

(5) augmentation of the distribution system on the Island.

The actual expenditure on capital works up to the end of the year 1916 was £.103,060. Prices had been much enhanced after the war started, and the delay and consequent extra expense in procuring stores, labour and transport were much increased.

CAPITAL EXPENDITURE BETWEEN 1917-18 AND 1923 INCLUSIVE.

The capital expenditure incurred on Mombasa Water Works subsequent to the submission of the completion report up to the end of 1923 was £.14,562. bringing the total capital expenditure on the work to £.117,622. Details of this expenditure are given in Appendix I.

The necessity for most of the capital works executed in recent years had been foreseen from the days of the early investigations. Chiefly on account of various uncertainties and delays to be ascribed to the war and consequent high cost of material, many of them had not been executed previously. Others again are works which only become necessary as demands increase from year to year, such as extensions of the distribution system and new kiosks. It would not be economical to construct initially a distribution system to fulfil all future demands, thereby locking up initially unproductive capital and incurring unnecessary depreciation on the works.

The expenditure on account of flood damage was rendered essential by the destruction caused by the floods of May, 1922, when 19 inches of rain fell in 4 days, demolishing numerous bridges and sweeping away considerable lengths of the main and service road.

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The opportunity was taken of reconstructing the bridges in a permanent manner; the necessity for this work had already been foreseen in the completion report. Although temporary connections had been rapidly made after the floods ceased, much of the permanent work remained unfinished at the end of 1923, and the sum of £.4100 is being expended in 1924 on completing these works.

The construction of the bridge and aqueduct at Kwache Creek had been contemplated in the early investigation reports, but there was some diversity of opinion regarding the most economical type of structure to adopt and this caused delay in construction. The demolition of the second temporary structure during the floods of 1922 rendered it desirable to carry out the permanent work immediately.

The buildings constructed during this period consist of stores for material and accommodation for employees at the Head Works and Service Reservoir.

The other items in Appendix I are either self explanatory or individually so small that they do not seem to call for comment except the Liming Plant which will be referred to later.

ANNUAL EXPENDITURE AND REVENUE.

The balance sheets for the period January 1st, 1917, to December 31st, 1923, are shewn in Appendix II. In the compilation of these balance sheets, allowance has been made for all administration and overhead charges (whether provided specifically for this purpose in the Estimates or not) in order to shew the true financial position of the undertaking in a commercial sense. For this

(151)

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reason interest and sinking fund at the current rates on the capital expenditure provided out of general Revenue has been taken into account although this charge is not actually paid. However, no renewal fund has been inaugurated. 63

It will be seen that during the period from January 1st, 1917, to 31st March, 1920, the works were operated at a loss, and that it was only in 1922 that the undertaking entered on the producing stage taking previous losses into consideration.

It will also be observed that the old rate for interest plus sinking fund was £.4-10-0%; this was increased to £.6-12-0% in 1922 by reason of the repayment of the old loan out of the new one which could not be raised on such easy terms as the former.

The revenue and the operation and maintenance charges (excluding administration and overhead charges) between the years 1917-18 and 1923 inclusive were as follows:-

Year.	Revenue. £.	Operating and Maintenance. £.
1917-18	4,758	2,785
1918-19	6,684	2,214
1919-20	7,158	2,730
1920-21	13,506	4,573
1921 (9 mon.)	10,247	4,153
1922	14,648	6,131
1923	16,473	6,111

In 1923, it will be noted that the cost of operation and maintenance was 4% of the capital expenditure up to the end of that year, and the revenue 14% of that expenditure. Nevertheless, the gross profit during the year 1923 (taking losses and profits in previous years into account in accordance

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with the balance sheets) was only 5% of the total capital expenditure to the end of 1923.

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CONSUMPTION OF WATER.

The consumption of water during the early years of the operation of the Water Works is not known as the supply was not metered; it was used for military purposes to a considerable extent. The average consumption per day during recent years was approximately as follows:-

1920-21	
1921 (9 mos.)	244,000
1922	304,000
1923	360,000
1924 (mos.)	383,000

During 1923, the maximum consumption in any one day was 504,000 gallons. Heavy demands occur when shipping is supplied. There were 523 service connections in use at the close of 1923, 60 new ones having been made during the year.

WATER RATES.

The water rates were fixed by Government on the recommendations of a Committee which sat in June, 1916, under the chairmanship of the Hon. the Treasurer. It was decided that the rate for domestic purposes should be Rs.1.50 (Rs.1.25 for each 1000 gallons in excess of 30,000 gallons in one day) for public purposes Rs.1.25, and for shipping Rs.4.00 per thousand gallons, and that water should be sold at kiosks at the rate of 1 cent of a rupee per 4 gallon tin. On conversion the rupee has been regarded as equivalent to two shillings.

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QUALITY OF THE WATER.

Both prior to the commencement of construction and subsequently, a number of analyses of the Mreri water had been made. All analyses indicated a high degree of purity. They also showed that the water was an extremely soft one, and that it would be necessary to increase its temporary hardness; for it is well known that soft waters corrode iron and steel more rapidly than hard waters. Examination of specimens of the various soils through which the main would be laid was also made, to establish whether there would be likely to be solvent action of the metal from the outside or not. This examination indicated that there was not likely to be action, and in fact none has occurred.

Tests were carried out in 1911 with a small experimental filter of which one of the layers was coral limestone, and on the failure of this filter to give satisfactory results, filtration by means of one of the rapid processes was under consideration in 1912; for the Medical Department had recommended filtration, in view of a certain degree of opalescence due to the presence of finely divided matter in suspension.

Of the eleven analyses of the Mreri water carried out by the Director of Chemical Research in 1911, six shewed the temporary hardness as nil, and the remainder as a fraction of one on Clark's scale. The highest permanent hardness recorded in these analyses was 3.7, but five of them indicated that it was nil and the five others as below 2.0.

The matter was postponed for investigation by the Director of Public Works when on leave in

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England during 1913. The files indicate that various systems of filtration were then examined. 66
Several well known firms of filter-manufacturers were consulted and samples of the water, with which they were provided in England, were independently analysed by them. The low degree of temporary hardness was evident, and they all recommended lime treatment as part of the filtering process.

Filtration, as an essential requirement, appears to have been abandoned in 1914, and the correspondence indicates that it was then decided to instal independent liming plant. The particular type favoured was the Paterson Patent Osilameter, a well known apparatus for this purpose made by the Paterson Engineering Company Ltd. The matter seems to have been held in abeyance for some cause probably connected with the war, and it was not until the Director of Public Works again visited England in 1915 and 1916 that full details and the cost were obtained. Government sanction for the expenditure was applied for in 1916. Difficulties arose through the enhancement of prices by the war and restrictions on the export of material, so that it was not until 1919 that the Paterson Osilameter was received and installed. Lime was first introduced at the rate of 2 grains per gallon (1 in 35,000). This was afterwards increased to 4 grains per gallon (1 in 17,500) and in 1922 to 8 grains per gallon (1 in 8750).

CORROSION OF WATER MAINS.

In view of the fact that the Mombasa water mains have depreciated greatly by internal corrosion of the metal and the resulting incrustation of the surface of the pipe, it seems desirable to interpolate

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In view of the fact that the Mombasa water mains have depreciated greatly by internal corrosion of the metal and the resulting incrustation of the surface of the pipe, it seems desirable to interpolate

some notes on the subject of the corrosion of steel and iron pipes in order that the cause which has operated at Mombasa may be appreciated. It is common knowledge that iron and steel become corroded in the presence of water and oxygen. The action is more rapid when the water is very soft; for such waters carry traces of carbonic acid in solution.

Iron and steel water pipes are protected by various methods from solvent action, and so long as the protective coating precludes access of water and remains intact corrosion does not occur. When the protective coating becomes damaged so as to allow access of water - whether it be hard or soft - the metal starts to oxidise and becomes deposited in a hydrated form on the surface of the pipe. The most usual protection adopted for both cast iron and steel pipes during the last 30 or 40 years has been the application at high temperature of a solution in certain proportions of coal tar, tallow, quicklime, resin and coal naphtha known as Smith's Solution; but solutions of tar and asphalte, bitumen and maltha, bitumen and tar have also been used.

At the end of last century, steel pipes instead of cast iron began to come into fairly gener use in localities where transport was difficult and expensive and the liability of breakage of cast iron pipes was great on account of frequent handling and jolting before they were laid. The cost of construction was thereby decreased; for light steel pipes of small thickness were much cheaper to handle, transport and lay than heavy fragile cast iron pipes.

Even during the first decade of this century, cases were on record where damage to the protective coating had caused serious corrosion and

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perforation of steel pipes a few years after their 68
installation. One of the chief causes to which this damage was ascribed in tropical climates was the melting of the coating under solar heat and its subsequent cracking, when the pipes were left exposed for any considerable period prior to laying. Under these circumstances, a solution with a low melting or fluxion temperature tends to gravitate to the lowest part of the pipe, where it collects in a longitudinal strip between the ends. When the exposure is prolonged, loss by evaporation of the more volatile constituents occurs, and, probably helped by stresses induced by heating during the day and cooling at night, the coating becomes brittle; it cracks and assumes a pattern like that of a crocodile skin, which has been termed "alligatoring". The flow of the coating causes the portion of it adhering to the majority of the pipe to be much thinner than it should be; the cracking causes access of water to the metal.

The cause and prevention of corrosion in metal pipes have been the subject of much investigation, chiefly in America, and there is much literature on the subject. The particular form of internal corrosion which occurs in metal pipes carrying water is known as "pitting" owing to the corrosion being concentrated at small areas of the internal surface of the pipe from which the metal is gradually removed in solution, and after undergoing certain chemical changes is deposited as hydrated ferric oxide in a colloidal state as a cone (nodular incrustation) over the pit. The volume of the substance of the cone is some ten times the volume of the metal from which it is formed and when the spots where intensive corrosion has taken place are numerous individual cones coalesce with one another producing great reduction in the flow by increased friction and

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decrease of effective pipe diameter. As the pits increase in depth, up to the thickness of the pipe, perforation takes place, but it is probable that owing to solidification of the cones which are initially hollow and solidify by deposition of internal layers of ferric oxide, corrosion does not normally extend to a greater depth than ¼ inch. It is well known that once corrosion has started and ferric oxide has begun to form the corrosion proceeds, for a time at any rate, at a greater speed than on initiation if other factors are constant. It is now held by most investigators that the cause of this type of corrosion is an electro-chemical one accentuated, if the water contains carbon dioxide, by direct attack by carbonic acid on the metal and initial formation of ferrous carbonate. It may be said that, in outline, this theory is that corrosion is initiated at spots where there is a slight difference of potential between adjacent particles which may be either a particle of metal and a particle of millscale or two particles of metal of slightly different composition. A galvanic couple is set up and by electrolytic action in the presence of dissolved oxygen and free hydrogen ions, the electropositive particle of iron enters into solution as ferrous oxide and is deposited as ferric oxide on the cathode, which is either the fragment of millscale (magnetic oxide of iron) or the more electronegative of the two particles of metal. Once ferric oxide is formed the electro-chemical action is intensified, and it is in fact demonstrable that if a particle of rust is placed on a clean surface of iron immersed in water containing oxygen in solution corrosion will take place and a nodule will be formed at that spot.

The effects of corrosion on cast iron pipes

are not as serious as they are on steel pipes; for, although the rates of corrosion are not markedly different, actual perforation of cast iron pipes does not usually occur rapidly, on account of their thickness. Moreover the incrustation deposited on the pipes can be removed by scraping at intervals without serious damage to the pipes. This has to be done frequently to be effective, for, on account of the destruction of the protective coating, corrosion is rapid, and the coating cannot be replaced efficiently without dismantling the main.

Several methods for stopping corrosion after it has started have been proposed and tried. One of these aims at the elimination of dissolved oxygen by means of deaerators. Another consists of treatment of the water with excess of lime with the object of causing a protective deposition of carbonate of lime on the pipe. The former method is expensive, and it has not been proved that it can be effectively applied in practice. The latter method probably reduces corrosion, but does not stop it.

CAUSE OF THE CORROSION OF THE MOMBASA WATER MAINS.

It will be observed from the above remarks that Smith's Solution flows and perishes when exposed for a considerable time to solar heat in a tropical climate. The Mombasa water pipes were coated with Smith's Solution, wrapped with hessian, and recoated in accordance with the usual engineering practice of that period. As shown under the head of "CONSTRUCTION" above, work was at a standstill for considerable periods, and the pipes were lying exposed for many months after arrival before laying could be carried out. At intervals during recent years, occasional

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individual pipes have become so badly perforated that it was uneconomical to repair them further, and they have been replaced by new ones. These pipes showed a longitudinal strip where the solution had collected which had remained either unaffected by corrosion or only affected to a slight degree.

The cause of the rapid depreciation of the Mombasa Water Supply mains is ascribed to two principal causes, namely, (1) perishing of the protective coating prior to laying, and (2) failure to instal liming plant until four years after the use of the main had started. Both causes are primarily attributable to the war, but (2) would probably not have caused trouble if (1) had not occurred. It may also be regarded as certain that if the liming plant had been installed and operated from the commencement of the supply, corrosion would have taken place, though not so rapidly.

BEGINNING OF CORROSION OF MOMBASA WATER SUPPLY MAINS.

The files indicate that the first evidence of solvent action by the water on the metal of the pipes was noted in 1917, but it was not until the end of 1919 that the first perforations were recorded. The number of perforations which occurred up to the end of 1921 was 401; during 1922, 276 were recorded; in 1923 220 occurred; while during the first six months of 1924 the number repaired was 73. The total number up to June 30th, 1924, has, therefore, been 970.

These leaks have been closed in the usual manner with rubber insertion pads fixed by clamps. The perforations have occurred throughout the main, but the greatest intensity occurs in portions where the pressure is greatest. It will be observed that there was a reduction of the number of perforations in 1923

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and the first six months of 1924; this is to be ascribed to treatment with lime in excess and the resulting formation of a protective coating of carbonate of lime.

REMEDIAL ACTION.

In 1921 the matter was referred to the Crown Agents for the Colonies with a view to obtaining advice whether any more effective treatment than liming, such as decarbonation, should be adopted. A specimen of the corroded main was sent for examination. The subject was taken up with the makers of the pipes, but no treatment other than liming was recommended. Information regarding water works where decarbonation had been tried, apparently without success, was quoted.

During the summer of 1923, specimens of the corroded main were again sent to the Crown Agents, and meetings were held in London between the Director of Public Works, the Chief Engineer to the Crown Agents and the Consulting Chemists of the Colonial Office. The question of taking up the main, recoating and relaying it was carefully considered. The best protective coating to employ under the circumstances was the subject of much discussion and experiment by the Consulting Chemists and a firm of steel manufacturers who took the matter up. The desirability of dismantling the main and lining it with concrete was also examined. Visits were made by the Director of Public Works to certain steel and iron works in this connection, and correspondence was carried on with various Water Works Authorities who had adopted this method of protection.

When the Director of Public Works left for Kenya in October, 1923, investigation and correspondence were still in progress. The experiments which had been made were regarded as inconclusive, and decision had not been reached. It was decided that tests of

certain solutions should be made by their application to pipes at Mombasa and that pipes so treated should be fixed and left in the main for as long a period as possible to ascertain the effectiveness of the coatings. Further examination of the possibility of reconditioning the pipes by centrifugal application of a concrete lining or, alternatively, replacement of the existing main by a concrete-lined pipe was also considered necessary.

It may be remarked that corrosion of water mains has been the cause of serious concern to Water Works Authorities throughout the world. In recent years manufacturers have been adopting various solutions in place of Smith's Solution, such as bituminatic preparations, pure bitumen, anti-corrosive paints, etc. Several important Corporations in England are installing, for their new mains, pipes lined with concrete centrifugally applied by a patent process. Both steel and cast iron pipes can be treated in this manner, and there are strong arguments in favour of its affording the best known protection from internal corrosion.

After the return of the Director of Public Works to the Colony, further correspondence and investigation took place, and is being continued. The cost of applying cement concrete locally has been examined and specimen pipes lined with concrete in England are being sent for demonstration of the manner in which they stand handling and transport and for use in the main.

CERTAIN FACTORS AFFECTING DECISION.

Any recommendation regarding the best action to take to ensure in the future an adequate supply of water for Mombasa Township would be valueless unless

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it were based on consideration of the following factor

(1) The quantity of water procurable from available sources of supply during drought.

(2) The present consumption of Mombasa Township and probable increase.

(3) The availability of other sources of supply and supply to the portion of the Mainland adjacent to Mombasa Island.

QUANTITY OF WATER AVAILABLE.

The higher elevations of the Shimba Hills, i which the Mreri Valley is situated, are composed of a quartzo-felspathic grit known as the Shimba Grit, from its considerable development in the region south of Mombasa; it is the uppermost component of the Duruma Sandstone Series. The rock is capable of transmitting water through its substance as well as along its joint planes. Although this formation, and others of a similar nature underlying it, occur to the north of Mombasa, the streams of the Shimba Hills are the only ones which need be considered for the future supply of Mombasa until the demand is so great that artificial conservation of flood water has to be resorted to.

The principal perennial streams, of which th Mreri is the largest, discharge into the Manolo River on its right bank. The Manolo River discharges into Port Reitz. These streams are normal in that they increase in volume by increment from springs as they flow to lower levels. They are somewhat abnormal in that portions of their courses are underground; for the nature of the strata is such that subsurface channels are easily eroded, and works which impose a hydrostatic pressure at the surface may easily cause a surface stream to follow an underground course. It is probable also that surface flow is dependent to some

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extent on the degree to which subsurface channels are blocked or open from natural causes. This factor has to be taken into consideration when installing measuring weirs.

Since the year 1913, readings of measuring weirs have not been taken, and the weirs have fallen into disuse. During this year, these measuring weirs are being reestablished in new sites so that continuous records of surface flow throughout dry seasons can be obtained and recorded.

Further investigation is necessary during future dry seasons to determine with accuracy the amount of water which can be relied on from the various streams during droughts, but there is reason for believing that not less than 900,000 gallons per day will be available in the driest years from the three streams in the Mreri Valley (Mreri, Makombo and Madabara). It is probable that 1,500,000 gallons per day would be available except towards the close of exceptional droughts. When a supply, greater than that which is available by gravity to the present head works during droughts, is necessitated by the demands, pumping from the Manolo River to the Mreri Intake will be essential at such times as it may be required to augment the supply; for it is not desirable on engineering grounds to lower materially the present level of the head works on the Mreri River.

WATER DEMAND IN THE FUTURE.

The average daily consumption of water in Mombasa (inclusive of the island and the portion of the mainland between Changamwe and Magongas) during recent years is stated under the head "Consumption of Water". The extent to which the demand for water

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will increase in the future is a matter of conjecture. It may, however, safely be anticipated that it will increase yearly during the next decade when Kilindini Harbour Works are finished, Mombasa Township develops, and increased exports and imports cause a greater number of steamers to enter the port. It is to be remembered that a large steamer may require as much as 200,000 gallons to fill its tanks. Increasing demands will necessitate extensions of the distribution system at intervals. In this connection also the probability of the extension of the township to the mainland either in the Changamwe - Meritini area or Likoni or both during the next two decades has to be considered. It is thought probable that the average consumption will not have reached 700,000 gallons per day in 10 years time, though the maximum consumption in any one day may be double that amount. Nevertheless it must be admitted that it is extremely common to underestimate the rate of increase of demand for water of developing towns, and cases frequently arise where Water Works Authorities have to incur heavy capital expenditure on additional works soon after Water Works have been installed owing to this cause.

CAPACITY OF THE EXISTING MAIN.

When the pipes were clean, the existing main should have delivered not less than 800,000 gallons per day at the hydraulic gradients worked to. It is recorded that the capacity of the main on completion was tested to 700,000 gallons per day, but it is not stated what method was adopted for measuring the flow, and it is uncertain what degree of precision attaches to the measurement. Measurements during 1923 and 1924 indicate that the present capacity is only 510,000

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gallons per day. There is reason for believing that this low capacity is not entirely due to incrustation and that improvement can be effected at comparatively small expense. The matter is the subject of investigation at present.

PROPOSALS FOR RECONDITIONING OR REPLACING THE MAIN.

It is considered that replacement or reconditioning should be undertaken as soon as possible. Although the rate of corrosion has become considerably reduced by excess liming, it cannot be stopped by this process; and gradual reduction of the capacity of the main by incrustation and deposit of carbonate of lime will continue. The sooner the work is undertaken the greater will be the proportion of the old main that can be saved. Moreover it is the case that individual bursts of some consequence sometimes occur - there were six in 1923 - and while these are being repaired the supply of water has to be curtailed. Furthermore the replacement or reconditioning of the main might take as long as two years to finish after financial arrangements has been made for its execution. Various proposals for reconditioning and replacement which are under consideration are referred to in Appendix III. Of the seven proposals therein mentioned, A would be most suitable if a short future is provided for; C if a period of, say, 15 years is contemplated, and E if it is desired to make provision for, say, a period of 25 years.

Sd. H.L.Sikes.

DIRECTOR OF PUBLIC WORKS.

HH.

COPY.

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PUBLIC WORKS DEPARTMENT,
HEAD OFFICE,
NAIROBI, 31st July, 1924.
Ref.No.2387.

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The Hon'ble
The Ag.General Manager,
Uganda Railway, Nairobi.

Mombasa Water Works.

With reference to the decision of Government expressed at the last Session of Legislative Council that a full report on the Mombasa Water Works should be prepared by me in consultation with you and laid on the table at next Session of Council, I enclose herewith the draft of the report which I propose.

2. I shall be glad to dicuss the matter with you at 10.0 a.m. on August 6th, as arranged.

Sd. H.L.Sikes.
DIRECTOR OF PUBLIC WORKS.

Enclosure [illegible] D.P.W's No.2357 of 31.1.24 to Hon. C.S.
(thro' Hon. [illegible])

APPENDIX I.

MOMBASA WATER SUPPLY.

STATEMENT OF EXPENDITURE ON CAPITAL WORKS. 1911-12 TO 1923.

Services.	Expenditure during years 19-													Total
	11-12. £.	12-13. £.	13-14. £.	14-15. £.	15-16. £.	16-17. £.	17-18. £.	18-19. £.	19-20. £.	20-21. £.	-21 (9 mos.) £.	-22. £.	-23. £.	Total £.
1. Survey.	395	23	4	40	-	-	-	-	-	-	-	-	-	462
2. Buildings.	249	156	73	6	-	-	-	-	250	-	200	-	-	934
3. Tools & Plant.	273	441	1592	624	63	-	-	-	-	-	-	-	-	2993
4. Acquisition of land.	-	-	169	-	-	-	-	-	-	-	-	-	-	169
5. Telephone.	-	122	91	108	-	-	-	-	-	-	-	-	-	321
6. Headworks.	-	91	889	828	751	-	-	-	-	-	-	-	-	2559
7. Gravitation Main.	690	2562	37635	5758	405	-	-	-	-	-	150	-	-	47200
8. Transport.	-	1712	2371	1993	425	42	-	-	-	-	-	-	-	6543
9. Staff and Supervision.	569	1207	1801	2696	1277	-	-	-	-	-	-	-	-	7550
10. Service Reservoirs.	-	-	310	2472	6296	1603	-	-	-	-	-	-	-	10681
11. Distribution System.	-	-	-	5834	10981	1763	-	912	896	186	781	150	-	21503
12. Meters.	-	-	-	-	-	-	-	750	-	300	335	-	-	1385
13. Mwache Crossing.	-	-	-	-	-	-	-	-	-	495	-	-	3623	4118
14. Liming Plant.	-	-	-	-	-	-	-	-	800	-	-	-	-	800
15. Kiosks.	-	-	-	-	-	-	-	250	600	-	200	-	-	1050
16. Renewals necessitated by flood damage.	-	-	-	-	-	-	-	-	-	-	-	1547	1827	3374
17. Miscellaneous.	56	1552	2271	1846	445	7	-	-	230	-	80	-	-	6487
TOTAL.	2232	7866	47206	22205	20643	3415	-	1912	2776	981	1746	1697	5450	118129
Deduct Cr.	-	-	-	-	-	507	-	-	-	-	-	-	-	507
	2232	7866	47206	22205	20643	2908	-	1912	2776	981	1746	1697	5450	117622

APPENDIX II.

MOMBASA WATER SUPPLY.

SUMMARY OF BALANCE SHEETS FROM JANUARY 1ST, 1917, to DECEMBER 31ST, 1923.
(to nearest pound).

RECEIPTS. £.

Details.	1-1-17 to 31-3-18.	1-4-18 to 31-3-19.	1-4-19 to 31-3-20.	1-4-20 to 31-3-21.	1-4-21 to 31 12-21.	1922.	1923.	Total £.
Shipping.	565	1602	1368	3284	2627	4453	4524	184[illegible]
Uganda Railway.	2893	2283	2115	3762	2229	2488	2442	182[illegible]
House Connections.	719	1503	1842	3533	3030	4771	4934	201[illegible]
Government Offices.	85	60	137	166	238	364	474	15[illegible]
Kiosks.	201	1055	1473	2512	1979	2592	2813	125[illegible]
Military.	295	431	223	108	-	-	-	10[illegible]
Commercial & Industrial.	-	-	-	-	-	-	802	8[illegible]
Meter Rents.	-	-	-	116	144	269	484	10[illegible]
Totals.	4758	6684	7158	13506	10247	14937	16473	73763
Balance of Loss.	6715	250	423	-	-	-	-	-
£.	11473	6934	7581	13506	10247	14937	16473	73763

EXPENDITURE

Details.	1-1-17 to 31-3-18.	1-4-18 to 31-3-19.	1-4-19 to 31-3-20.	1-4-20 to 31 3-21.	9 mos. only. 1-4-21 to 31-12-21.	1922.	1923.	Total
Salaries and Allowances.								
Engineering and Head-quarters.	187	437	502	823	773	1229	1010	4961
Clerical and office boys.	201	198	410	410	370	379	705	2673
Sub-Overseers.	143	160	160	270	228	315	243	[illegible]519
General Maintenance.	1954	1069	1256	2350	2216	3170	3463	15500
Overhead charges not specifically appropriated under Mombasa Water Supply.	300	350	400	720	566	890	670	3896
(1) Interest and Sinking Fund on Imperial Loan of £.90,000.	(3) 8100	4050	4050	4050	3038	(4) 5940	5940	35168
(2) Ditto. on Capital provided ~~do~~ from Colony General Revenue. See below.	588	670	801	801	641	1347	1463	6311
	11473	6934	7581	9424	7832	13270	13514	70028
Balance of gross profit.	-	-	-	4082	2415	1667	2959	3735
	11473	6934	7581	13506	10247	14937	16473	73763
(1) Capital Account, Imperial Loan	90000	90000	90000	90000	90000	90000	90000	
(2) Capital Account for year concerned, provided from Colony General Revenue.	13060	14900	17800	17800	19000 (9 mos.)	20471	22172	

(3)
2 years interest for period 1-1-17 to 31-3-18
$3\frac{1}{2}$ plus 1% = $4\frac{1}{2}$%

(4)
Interest at £.6-12%.

APPENDIX III.

MOMBASA WATER SUPPLY.

Preliminary estimates for alternative schemes for reconditioning and replacement of the existing main.

		Estimated Cost.	Estimated cost of reconditioning old pipe.	Estimated value of reconditioned pipe.	Net Cost of scheme.	Capacity of main in gallons per day. G.p.d.
		£.	£.	£.	£.	
A.	Reconditioning Existing Main by application of ¼ concrete.	38650	-	-	38650	700,000
B.	Reconditioning Existing Main by cold application of preservative solution.	20325	-	-	20325	750,000
C.	Replacement of Existing Main by a 11¾ - 11"net diameter concrete lined steel main lining ¼" thick - allowing for use of present 12 inch pipe after reconditioning.	92000	4000 (10 inch pipe only).	18200 (10 inch pipe only).	77800	1,100,000
D.	Replacement as C making no use of present pipe.	107500	6000	28500	84750	1,100,000
E.	Replacement of Existing Main by a 14" - 12" net diameter concrete lined steel main, lining ¼" thick.	125000	6000	28500	102500	1,500,000
F.	Replacement as last by a 13" - 11" Spun Cast Iron main lined with concrete ¼" thick.	128000	6000	28500	105500	1,100,000
G.	Replacement as last by a 14¼" 12" net diameter main lined with concrete ¼" thick.	150000	6000	28500	127500	1,500,000

Ref:D.P.W's report dated 31st. July, 1924. (COPY)

11th. August, 1924.

The Hon'ble Colonial Secretary,
Colony and Protectorate of Kenya,
N a i r o b i.

MOMBASA WATER SUPPLY.

In accordance with your instructions I have gone carefully into the problem of the Mombasa Water Supply.

2. I have read the enclosed report from the Hon'ble Director of Public Works, and have discussed the matter fully with that officer, and who has very kindly placed all available information at my disposal. As a result of these investigations I have come to the following conclusions:-

(a) Inception of Scheme.

It is evident that before any work was actually commenced, the whole scheme was thoroughly worked out, both by local officers of the Public Works Department, and by an expert from home. All the present difficulties as regards corrosion were anticipated and foreseen, and the subject was exhaustively examined from every point of view by many chemists and experts, in addition to liming by the Medical Authorities. This requirement was, however, subsequently dropped.

(b) Execution of Work.

The actual execution of the scheme suffered from various causes, many of which were due to the war, some to the unhealthiness of the climate, and some to the delay in reaching a decision as to the best method of treating the water. As a result many of the pipes suffered, perhaps more than they otherwise would have done, from exposure to the sun. Moreover, the liming plant itself was not finally installed until 1919.

(c) Present condition of Pipe Line.

The present condition of the pipe line is clearly described by the Hon'ble Director of Public Works in his report. A considerable amount of permanent work has been carried out during the past two years, and I understand most of the temporary bridges will have been made permanent by the end of the present year. The condition of the actual pipe line gives cause for concern, and there is no doubt that some steps must be immediately taken to put matters right.

(d) Finance and Charges.

The figures given by the Hon'ble Director of Public Works shew that the whole concern has not been working at a profit, but that during the past two years or so the sale of water has considerably increased, and the supply is therefore beginning to shew signs of becoming a commercial success.

The Hon'ble Director of Public Works shews in Appendix II, a summary of Balance Sheets to December 31st.1923. It will be noticed that no allowance has

has been made for a Renewal Fund. For a work of this nature and size, at least £5,000/- per annum should be set aside for "Renewals". If this had been done from 1917 there would have been a reserve available at the end of 1923 of £35,000/-. Actually the sum available is only £3,735/-. It is evident, therefore, that there can be no reduction of charges for some time to come.

(e) Action to be Taken.

It is quite evident that the time has arrived when some definite action must be taken if the water supply for Mombasa is to be assured for the future. In the absence of a Renewal Fund, money must be found from the Colony's Revenue or from Loan.

The various possible schemes with their cost are shewn in Appendix III. These appear to have been carefully prepared and considered.

I am of the opinion that the present capacity of the pipe line should be sufficient for some considerable time, say, 10 to 15 years. Under the circumstances, therefore, I do not consider money should be found at the present moment to increase the capacity of the pipe line. Proposal "B" would, therefore, be the most satisfactory if the suggested method of re-conditioning were likely to prove successful. Owing to the present condition of the pipes, however, I do not consider this method as being possible owing to the pitting the pipes must be reinforced in some way. Proposal "A" fulfils this condition, and from all enquiries made gives every promise of being a success. I therefore recommend that £40,000/- should be definitely earmarked for carrying out this work.

Special plant of a more or less inexpensive nature would have to be provided, and probably the payment of a royalty for the use of the system to be employed would be necessary.

3. The Hon'ble Director of Public Works has already made many preliminary enquiries regarding the method to be adopted, and the evidence appears to shew that it will be successful.

4. If, however, this work is to be undertaken, it must be pushed on with vigour and without interruption, until completed, it is imperative, therefore, that funds must be forthcoming in a regular manner so that a suitable organisation can be installed for completing the whole amount.

Sd/- G. D. Rhodes,
AG. GENERAL MANAGER, U.RLY.

N.M.

Gen 10340/25 K.

8 April 1925

DRAFT.

Kenya

Gov.

C.

Sir

I have the honour to ack. the recd. of Sir Robert Coryndon's conf. despatch No. 14 of the 4th of February transmitting for my information copies of reports on the Mombasa Water Works approval was given by tel. on the 22nd of January for the immediate inception of the work.

~~2. I am aware that~~

2. In view of the great importance of ~~apart from~~ the service ~~it~~ not only to ~~[illegible]~~ the town of Mombasa, ~~the~~ but also to the country as a whole ~~watering of shipping as being~~ from the facilities which it gives ~~a means of attracting~~ for watering shipping, ~~and~~ I

MINUTE.

Mr. Fiddes 7.4

Mr. Bottomley 7.4

Mr.

Mr. Davis.

Sir G. Grindle.

Sir H. Read.

Sir J. Masterton Smith.

Mr. Ormsby Gore.

Duke of Devonshire.

I am informed with the sanction of
[illegible] to the Colony, to a
[illegible] it is of full efficiency, and I
[illegible] I
am of the opinion that the
same desirable [illegible]

loan charges on both the original
cost of the works and on the
new expenditure should not be
borne on the revenue of the
water works until a net revenue
of £10,000 a year has been obtained.
All net revenue up to that
amount should be set aside
each year to a Renewals Fund.

I have &c.

(for the Secretary of State)
(Signed) W. ORMSBY GORE.