

NOTES ON JERUSALEM WATER SUPPLY.

THE low level aqueduct and pipe line from springs near Solomon's Pools was the only outside source of water supply to Jerusalem from the time when the Herodian System fell into disuse till the 15th June, 1918. The completion of this partial restoration of the ancient system was commemorated by a thanksgiving ceremony on the Sultan's birthday, 27th November, 1901 (*Quarterly Statement*, 1902, p. 3). The quite inadequate addition to cistern storage and the Bir Eyub supplies which formerly supported the city, was hailed on that day as a great benefaction following upon many centuries of criminal neglect. Subsequent schemes for extending the system were proposed, but none of them had materialised up to December, 1917, when the British Army entered Jerusalem. Within little more than six months from that date, and only two months after the commencement of the work, the city experienced the first blessings of sweet water in abundance. The story of this remarkable work is here told in a technical report, which it has been thought advisable to publish in full. It puts on record the latest service to Jerusalem of the Royal Engineers, whose close connection with the Holy Land has lasted through peace and war for over half a century.

Plan
Ref. No.

(1) *Existing Supply on British Occupation.*—On the occupation of JERUSALEM by the British Forces in December of 1917, the Water Supply consisted of:—

- (a) Water conserved from the previous year's rains in A1/3
underground cisterns.
- (b) A small aqueduct and pipe line from POOLS OF
SOLOMON and URTAS, delivering water to JERU-
SALEM via BETHLEHEM.

(2) *Capacity and Quality of these Sources of Supply.*—There is estimated to be a total storage capacity in cisterns in JERUSALEM of 360,000,000 gallons, ranging from those of several million gallons capacity under the Mosque of Omar, to the small domestic cistern to be found under or near every house.

Owing to neglect in repairs and cleaning, most of those cisterns were either empty, or the water was quite unfit for drinking. They were mostly unprotected from mosquito breeding, and were thus a serious menace to health.

The POOLS OF SOLOMON—JERUSALEM piped supply had been maintained by the Turks, and delivery from the various springs an estimated total of 80,000 gallons per day, *i.e.*, 40,000 gallons drawn at BETHLEHEM and 40,000 gallons delivered at JERUSALEM. At the JERUSALEM end water was supplied to:—

- (a) BIRKET EL-SULTAN, an artificially dammed storage of foul water.
- (b) To the cistern storage in the HARAM ARIA (Mosque of Omar), which was comparatively clean.

The supply itself was pure, being drawn direct from the springs.

(3) *Reasons for Providing the New Supply.*—After the British Occupation, the Army consumed the whole of the piped supply for drinking water for the troops, and large quantities of the cistern storage for animals. The civilian population was watered entirely from cistern water of doubtful quality, and the reserves, which would otherwise have been accumulating, were getting rapidly depleted.

It was therefore evident that immediate steps had to be taken to ensure against a serious shortage during the Summer months.

The Chief Engineer, whose area included JERUSALEM, instructed his Field Engineers early in January to make immediate investigations for a new supply.

(4) *Preliminary Investigation for New Supply.*—The probable sources to be tapped were well known, as under the Turkish régime, scheme after scheme had been got out, only to die a natural death when it reached the stage of actual construction. A1/46

From North, East and West available supplies were ruled out owing to levels and the enormous pumping schemes consequently involved.

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UNCOVERING ANCIENT AQUEDUCT.



SCREWING PARTY. K. 11½.

From the South the nearest supplies were already tapped, viz.:—those at SOLOMON'S POOLS, and the next supply of any magnitude was situated in the WADI ARRUB, on the JERUSALEM—HEBRON Road, 22 kilometres from JERUSALEM.

In the WADI ARRUB water flowed from several what appeared to be spring heads, and ran down the valley in an open stream, the water being used principally to irrigate small patches of cultivation.

On investigation these so-called spring heads were found to be fed from a system of ancient underground aqueducts, dating back to before the Christian Era; the system finally leading to an ancient reservoir or Birket lower down the valley, 1,050 metres East of the main road.

In January, the yield of these springs was gauged at 14,000 G.P.H., and was considered capable of increase by careful cleaning.

On 14th of February, 1918, the preliminary investigations had been completed; a line of levels run from the ancient Birket to JERUSALEM, and a provisional scheme to deliver 250,000 gallons per day submitted to the Engineer-in-Chief on 18th February, 1918.

(5) *Topographical and Climatic Conditions. Population.*—JERUSALEM is 31.46 N. Latitude and 33° E. Longitude. Altitude above sea level for the purposes of the supply has been taken at:—

	feet.
JAFFA ROAD RESERVOIR	2,788
JAFFA GATE	2,618
FATHER RATISBONE'S SCHOOL	2,750
RAILWAY STATION	2,558
MOUNT OF OLIVES	2,748
BIRKET ARRUB (bottom of ancient Birket)	2,723
PUMPING STATION	2,732
KILO 19 RESERVOIR	3,083

Rainy season is from middle of November to middle of April, and average rainfall is 60 cm., ranging from 90 cm. maximum to 45 cm. minimum.

Summer temperature seldom exceeds 97° F.

The population is now estimated at 50,000.

(6) *Scheme as Finally Approved.*—The scheme as finally approved was as follows, and was governed chiefly by the machinery and piping available in the country:—

- (a) To develop and collect the water from the springs, and use the ancient aqueducts to convey the water to the ancient Birket, where 4,000,000 gallons storage could be accumulated.

This entailed the excavation, clearing, partly rebuilding and re-roofing of 1,100 metres of aqueduct, and considerable repairs to the old Birket.

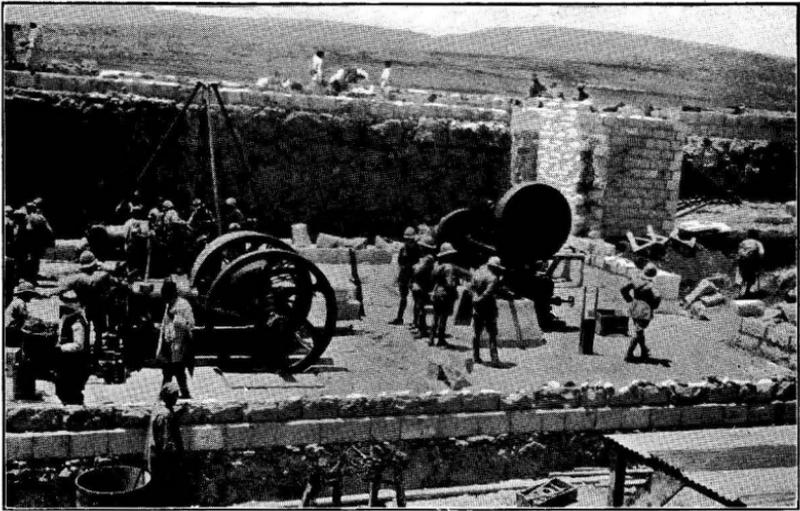
- (b) To erect a three-throw ram pump of a capacity of 15 to 20 thousand gallons per hour against a head of 410 feet, with two 66-H.P. Hornsby engines in a pumping station adjacent to the Birket, so arranged that water could be pumped direct from the aqueduct leading from the springs, or from the Birket storage as required. This latter provision was made so that, should the yield of the springs diminish during the dry season, all the output of the springs could be conserved in the Birket during the time that the pumps were not actually running, thus, not only having a 4,000,000 storage in reserve, but taking full advantage of the total yield of the sources of supply.

- (c) To lay a twin 6" rising main from the pumping station to a reservoir situated at Kilo 19, HEBRON ROAD, a distance of 3,320 metres with a difference of level of 351 feet.

A1/1

It was necessary to twin this main so as to shorten the hours of actual pumping to 12 to 16 hours a day. No larger diameter pipe was available.

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PUMPING STATION AT BIRKET EL-ARRUB.



WATER ARRIVES AT JERUSALEM, 18TH JUNE, 1918.

Plan
Ref. No.

- (d) To build a reservoir of a capacity of 300,000 gallons on the natural watershed about Kilo 19, HEBRON ROAD, in such a position that a natural gradient would be obtained, and water would be delivered to JERUSALEM entirely by gravity. This reservoir to be of masonry, and to be built of two equal compartments, and completely enclosed. A1/7
- (e) To lay a single 6" pipe from Kilo 19 Reservoir to a point in JERUSALEM situated for position and level to feed the distribution system in JERUSALEM by gravity. The length of the line is 20,350 metres.
- (d) To build a reservoir of 200,000 gallons capacity at LIFTA, JERUSALEM, at an altitude of 2,788 feet, or 295 feet below the level of the Kilo 19 Reservoir. This reservoir to be of the same type as the Kilo 19 Reservoir, and to be completely covered in.
- (g) To lay the nucleus of the distribution system in JERUSALEM, with a ring main capable of dealing with the maximum delivery of the gravity main in 12 hours. This system to include branches to all Army supply points and a certain number of civilian watering points in districts where there was likely to be a shortage during the summer months. The total length of Main on the original distribution system was 11,500 metres. A1/37

(7) *Carrying Out of the Work.*—Owing to severe weather and shortage of labour and transport, the work did not commence until 12/4/18 in JERUSALEM, and 15/4/18 at BIRKET ARRUB. Water was delivered in JERUSALEM on 18/6/18.

Referring to Appendix 2 :—

- (a) After careful reconnaissance the final line was set out, and profiles built or dug at 20 m. intervals.
- (b) The formation was 2 m. wide on top, slopes $1\frac{1}{2}$ to 1, and drainage culverts placed where necessary.

- (c) The laying of the distribution was difficult, owing to traffic and rock excavation, when it was not possible to use explosives.
- (d) The investigations and clearing of the old system of aqueduct had to be undertaken with great care. All the aqueducts are now partially cleared, but about one-third is still to excavate and recover. The reservoir was built in lime mortar. The suction pump enabled the pumping to commence before the ancient Birket was restored.
- (e) A considerable amount of rock excavation was done in the foundation of this reservoir. Stone was quarried on the site, and the masonry was built in 6 to 1 cement mortar.
- (f) Originally 5 tractors were estimated to do the work in 30 days, but owing to these having to travel over metalled roads, a further 7 machines were detailed.
- (g) In some cases 3 Kilos carry by E.L.C. was necessary, chiefly owing to the line following the WADI BIAR a considerable distance from the metalled road. Appendix 4.
- (h) The three-throw pump was requisitioned in Cairo. Certain structural alterations were necessary and were completed before delivery at the site. The 66-H.P. Engines were ex the original pumping station at MAZAR.
- (k) The washing out and coupling up was done in the usual manner.

(8) *Tests.*—The pump delivers 15,000 G.P.H., against a head of 400 feet. The reservoirs are satisfactory and no leaks occurred. The gravity main delivers 12,500 G.P.H. to JAFFA ROAD Reservoir, or 25 per cent. in excess of the calculated discharge.

The distribution system at every point is up to calculated discharge, and is being rapidly extended.

(9) *Finishing Off and Maintenance.*—Appendix 3 gives Appendix
the lines on which the final work is being done on the
pipe line. The reservoirs are now nearing final completion. 3.

(10) *Historical.*—The ancient works at BIRKET ARRUB
are supposed to date back to the time of Herod, 4 B.C.

At that time BIRKET ARRUB was part of the main
supply of JERUSALEM and fed the POOLS OF SOLOMON by
aqueduct. 5.

The aqueduct between BIRKET ARRUB and POOLS OF
SOLOMON is long since disused, and, in some places, has
entirely disappeared.

The present aqueduct between POOLS OF SOLOMON
and BETHLEHEM is still in use, but in a much modified
condition, being simply an earthenware pipe built into the
ruins of the once great aqueduct.

By the ruined aqueducts to be found in JERUSALEM, and
knowing the sources that were capable of being tapped to the
SOUTH, as much as a million gallons per day may at one time have
flowed into JERUSALEM by gravity.

(Signed) F. W. STEPHEN,
Major, R.E.

JERUSALEM,
20/7/18.

APPENDIX 1.

JERUSALEM WATER SUPPLY.

Notes on the Laying of the Line.

(1) The line will be marked with iron Kilo posts, numbering
from JERUSALEM Reservoir: $\frac{1}{2}$ Kilos will be marked with a red
painted L.W.E. post.

(2) Screwing parties will work from the $\frac{1}{2}$ Kilos, and sections
will be coupled up with Expansion Joints, so that each Expansion
Joint will come at the Kilo post.

(3) Scour Valves will be placed at all the "dips," and will consist of 6" Tee reducing to a 3" Valve. The valves will be turned downwards, and suitable pitched channels will be built under the valves.

(4) Air Valves, $\frac{1}{4}$ " piping tapped into the nearest socket, will be placed at each peak, and will afterwards be protected by locked chambers, as heretofore.

(5) Sluice Valves will be placed immediately adjacent to the Expansion Joints at Kilos 4, 8, 12 and 16.

(6) A Tee will be placed about Kilo $3\frac{1}{2}$ (exact position later). This Tee will have one Reflux Valve immediately North of it. The object of this is to have an emergency fire service for the Main Supply Depot.

(7) The line at Kilo 3 to Kilo $5\frac{1}{2}$, and Kilo $8\frac{1}{2}$ to Kilo $9\frac{1}{2}$ is subjected to a very high pressure—about 600 feet—and care should be taken in screwing the pipe at these points, and all pipes and fittings should be examined.

(8) Preliminary washing out will be done at Expansion Joints.

(9) The preliminary covering will be 1 foot deep, final covering 2 feet deep. Where banks and cuttings will permit, the pipe should be kept to one side, preferably the side farthest from the Bethlehem Road to allow of a foot patrol.

(10) The pipe is all American except $5\frac{1}{2}$ kilos, which is English. The English pipe will be laid where the pressure is lightest, viz., Kilo 15 to Kilo $20\frac{1}{2}$.

(11) Section herewith explains itself.

(Signed) F. W. STEPHEN,
Major, R.E.

Copies to:—

Capt. Inwood, R.E.

Lieut. Dixon, R.E.

Lieut. Dickie, E.L.C.

S. M. Davis, R.E.

DATES OF COMPLETION OF WORK NECESSARY FOR DELIVERY AND DISTRIBUTION IN JERUSALEM.

Date commenced.	WORK.	By	Officer in charge.	Date completed.	Remarks.
1/4/18 (A)	Setting out of main pipe-line and building of profiles.	Sappers and local labour.	Lt. Dixon, R.E.	15/4/18	
10/4/18 (B)	Formation of main pipe-line, building of culverts, etc., 23 $\frac{3}{4}$ kilos.	60th Coy., E.L.C. 97th Coy., E.L.C. Contractor.	Lt. Dickie, E.L.C., Kilo 0 to Kilo 15. Lt. Dixon, R.E., Kilo 15 to Kilo 23 $\frac{3}{4}$.	14/5/18	
15/4/18 (C)	Distribution system in JERUSALEM:— 2 $\frac{1}{2}$ kilos 6" Main. 2 $\frac{1}{2}$ kilos 4" Main. 6 $\frac{1}{2}$ kilos 3" Main.	E.L.C. and local labour.	S. M. Davies, R.E.	12/6/18	
15/4/18 (D)	Clearing and repairs to feeder aqueduct. First half of Kilo 19 Reservoir. Engine House and suction pump.	E.L.C. and local labour.	Lt. Dixon, R.E.	13/6/18	
15/5/18 (E)	First half of Jaffa Road Reservoir.	35th Coy., R.E., and local labour.	Lt. French, R.E.	14/6/18	
9/5/18 (F)	Tractor distribution of 6" pipes, 5,000 pipes, 750 tons.	12 Tractors 1006th M.T. Coy. A.S.C.	Capt. Inwood, R.E.	31/5/18	
14/5/18 (G)	Placing on formation, screwing and preliminary covering of 6" Mains.	60th Coy., E.L.C. 97th Coy., E.L.C.	Lt. Dickie, E.L.C., Kilo 0 to Kilo 15. Lt. Dixon, R.E., Kilo 15 to Kilo 23 $\frac{3}{4}$.	10/6/18	
15/5/18 (H)	Machinery—One Three-throw Pump and two 66-H.P. Hornsby Engines.	Sappers Det. 357th Coy., R.E.	Lt. Oakley, R.E.	13/6/18	
17/6/18 (I)	Washing out and coupling up.			18/6/18	Water in Jaffa Rd. Reservoir at 1845

APPENDIX 3.

JERUSALEM WATER SUPPLY.

Notes on Completion and Maintenance.

(1) *Covering*.—The final covering will be completed to a depth of 2 feet over pipe: 2 feet wide at top, and $1\frac{1}{2}$ to 1 slopes, stones pitched where necessary.

(2) *Anchorage*.—Anchorages built in masonry will be placed on all slopes over 1 in 10, two in each slope, viz. :—

Kilo $2\frac{1}{4}$ to $2\frac{1}{2}$, two.		Kilo $13\frac{1}{2}$ to $13\frac{3}{4}$, two.		Kilo $14\frac{1}{4}$ to $14\frac{1}{2}$, two.
„ $2\frac{1}{2}$ to $2\frac{3}{4}$, two.		„ $13\frac{3}{4}$ to $14\frac{1}{4}$, two.		„ $14\frac{1}{2}$ to $14\frac{3}{4}$, two.

Ten of these have been made in workshops on Order No. 9. Two others are indented by Order No. 22.

(3) *Road Crossings*.—All road crossings will be banked to 2 feet over pipe and ramped to 1 in 20 either side of pipe line, stone pitched where necessary.

(4) *Protection of Formation*.—Where natives are found to use the formation as a track, stone walls will be built over the covering at intervals as obstacles.

(5) *Drainage*.—Where the drainage is considered to be insufficient, such as between Kilo $1\frac{1}{2}$ and Kilo $2\frac{1}{2}$, additional culverts will be built before the rains.

(6) Kilo posts will be built in dry stone with number stone let in in face, indicating kilos and half-kilos.

(7) *Expansion Joint Chambers*.—With the exception of those in Rising Main, Kilo $20\frac{1}{2}$ to Kilo $23\frac{3}{4}$, these will be built in dry stone, roofed with flat stones of suitable size.

(8) *Scour Valve Chambers*.—When all Scour Valves are fixed they will be enclosed in locked chambers as shown in Drawings.

(9) *Air Valve and Line Valve Chambers*.—When fixed these will be built in vertical chambers with a standard 2 feet manhole cover and locked.

(10) *Kiloage of Valves, &c.*—Kiloage of all Valves and Expansion Joints to be measured and clearly indicated on the plan and section.

(11) *Repair and Patrol Stations*.—These will be established :—

- (1) At JERUSALEM.
- (2) „ SOLOMON'S POOLS.
- (3) „ BIRKET ARRUB RESERVOIR.

Repair sets to standard list—see Appendix A—will be kept at these stations. Patrols consisting of 1 E.L.C. pipe fitter, and 2 E.L.C. natives will traverse the section daily outwards before 1200 and backwards after 1200. They will carry keys of Valve Chambers, caulking tools and materials, spanners, picks and shovels.

(12) *Reports*.—Reports will be sent to Works Office as to “all clear” or otherwise each night from JERUSALEM and BIRKET ARRUB Stations, and within 24 hours from Centre Section.

Weekly reports of condition of line and list of Station Equipment to this Office on Wednesday evenings.

(Signed) F. W. STEPHEN,
Major, R.E.

Copies to:—

Capt. Inwood, R.E.
Lieut. Dixon, R.E.
Lieut. Dickie, E.L.C.
S. M. Davies, R.E.

APPENDIX “A.”

EQUIPMENT OF PATROL STATIONS.

	No.
Pipe Wrenches, 6"	5
Pipe Cutter's Wheels, 6"	2
Expansion Joints, complete with packing ...	2
Chisels, Hand, Flat	6
Chisels, Hand	6
Hammers, Hand	4
Caulking Tools	6
Spanners, Adjustable	4
Lead Wool	50 lbs.
Red Lead	50 „
Boiled Oil	2 gallons.
Picks	10
Shovels	10
Fasses	10
Baskets	20

Note:—One spare pipe, English or American, as case may be, to be placed at each Expansion Joint Chamber with threads greased and protected.

APPENDIX "B."

PERSONNEL OF PATROL STATISTICS.

SAPPERS, 3. E.L.C. PIPE-FITTERS, 3. E.L.C. LABOURERS
(minimum), 6.

APPENDIX "C."

PROCEDURE IN CASE OF A COMPLETE PULL-OUT OR
BURST PIPE.

- (1) Runner to be despatched to Kilo O Reservoir with report.
- (2) Line Valves both sides to be closed.
- (3) In case of:—(a) PULL-OUT.

Pipe socket to be cut off, or pipe cut close to socket,
and Expansion Joint fixed.

In case of:—(b) BURST PIPE TO BE REPLACED.

New pipe cut to give 3" clearance between pipe ends
and Expansion Joint fixed.

- (4) Open Line Valves.
- (5) Despatch runner to Kilo O Reservoir to report "all clear"
and return with message that supply has been resumed.

APPENDIX 4.

TRACTOR DISTRIBUTION.

Diameter.	1 Holt or Clayton Truck-extended drawbar.	2 good Bucks with brakes.	3 Pontoon wagons.	1 Holt or Clayton Truck with drawbars.
6"	50	40	36	30
4"	85	70	60	50
3"	120	90	75	70

Maximum trip 22 kilos out and 22 kilos Home.

E.L.C. DISTRIBUTION.

On formation (dry weather).

One man carried one 6" pipe 1 kilo per day.

6 men carry 6".

4 men carry 4".

3 men carry 3".

E.L.C. SCREWING.

Diameter.	E.L.C.		Tongs.	Pipes per day.
	Ostas.	Naffars.		
6"	2	15	5	35—40*
4"	2	10	4	40—50*
3"	2	8	4	50—60*

* According to condition and quality of pipes.

HYGIENE AND DISEASE IN PALESTINE IN MODERN AND IN BIBLICAL TIMES.¹

By DR. E. W. G. MASTERMAN.

(Concluded from *Q.S.*, 1918, p. 171.)

CHAPTER VIII.—*Diseases and Medicine in the New Testament.*

THE diseases in the New Testament need to be treated apart from those of the Old Testament, because the facts recorded about them are different. The information given is much more definite; medical terms used by well-known Greek writers occur, particularly in the works of St. Luke; it is disease of the individual rather than of the community which attracts notice; and, lastly, it is not so much

¹ As these articles will subsequently be reprinted in book form, and in order to make them as accurate and complete as possible, Dr. Masterman would welcome any suggestions or criticisms which readers may be willing to send him.