WILLIAM GARNETT

A Little Book on Water Supply

CAMBRIDGE

A LITTLE BOOK
ON
WATER SUPPLY

BY

WILLIAM GARNETT, M.A., D.C.L.
Formerly Fellow of St John's College, Cambridge

CAMBRIDGE
AT THE UNIVERSITY PRESS
1922

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Published in the United States of America by Cambridge University Press, New York

Cambridge University Press is part of the University of Cambridge.

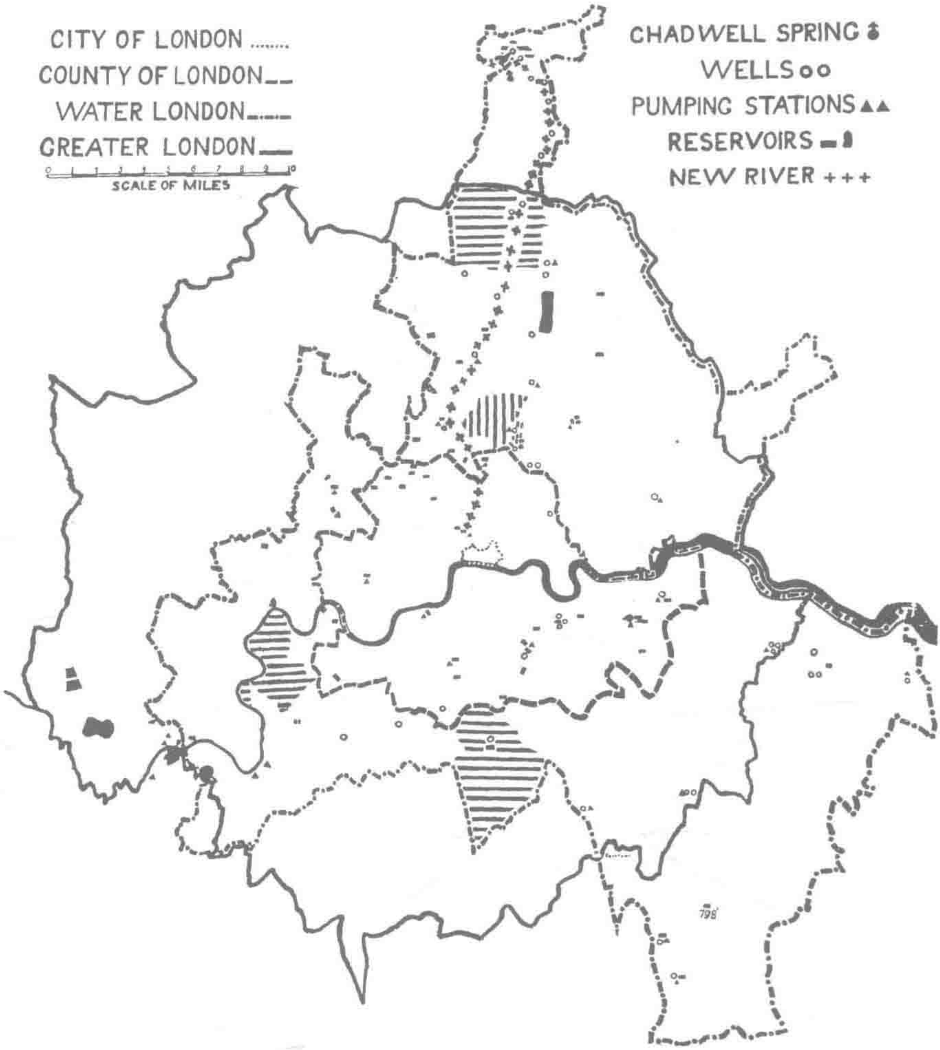
It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107650480

First published 1922
First paperback edition 2014

A catalogue record for this publication is available from the British Library

ISBN 978-1-107-65048-0 Paperback


CITY OF LONDON
COUNTY OF LONDON
WATER LONDON
GREATER LONDON
0 1 2 3 4 5 6 7 8 9 10
SCALE OF MILES
CHADWELL SPRING
WELLS
PUMPING STATIONS
RESERVOIRS
NEW RIVER
798

PREFACE

THIS little book when in manuscript was condemned by a very high authority on educational publications because it did not enable the reader "to prepare for any specific examination." Students whose sole object is to pass an examination are warned against devoting time to a book which is intended to give them only some general knowledge respecting the sources and mode of supply of one of the chief necessaries of life, that, in fact, which for all time has determined the localities which men have selected for residence, and at the same time to arouse an interest in a number of sciences which have an important bearing on everyday life.

Its origin was a quantity of information very carefully prepared by Mr G. P. Warner Terry, Barrister-at-Law, F.A.A., the Statistical Officer of the Metropolitan Water Board and Secretary of the Municipal Waterworks Association. This matter was sent by the Water Board in 1914 to the Education Committee of the London County Council together with a list of illustrative lantern slides belonging to the Board and available for lecture purposes. These slides were offered on loan to the Council for the use of any schools within its area. A commencement was made at the time by the present writer in the preparation of descriptive matter to be sent to the schools with the slides. The outbreak of war prevented any immediate action being taken on this proposal. The fear of injury to the water supply was illustrated by the action of the scout who called the attention of the special constabulary to a fisherman in the neighbourhood of a storage reservoir with a creel marked "POISSON." But while it was deemed undesirable during the war to publish information respecting London waterworks, the descriptive pamphlet gradually assumed the dimensions of a school reading-book; and it was thought that some account of public water supply would not only be serviceable to teachers and students in creating an interest in the proposed lectures, but would also be a useful addition to general education, especially in the new Part-Time Continuation Schools. Moreover there is a special need for a book on this subject in Training Colleges, and particularly in those Colleges which are attended by students of Domestic Economy and Hygiene. From the point of view of general education, water supply has a bearing on a great many school subjects and the teacher can use this little book as dealing with a central interest and affording a series of texts for lessons on the greater portion of the "Circle of the Sciences," including mensuration, mechanics, hydrostatics and hydraulics, surveying, geography, geology, heat and heat engines, chemistry, bacteriology, pathology and even electric distribution of power from the "white coal" of the mountains. Short accounts have been introduced of the water supply of Manchester, Glasgow, Liverpool, Birmingham, New York and the ancient city of Jerusalem; but London affords examples of nearly all the ordinary sources of supply except the upland sources, which have not yet been drawn upon for "Water London." For details of collection and distribution no other English city can afford such variety as the Metropolis, and the experience of the year 1921 suggests that the time is not far distant when an upland supply will be required by the Water Authority of London.

When the manuscript was nearly complete it was offered to the London County Council if the Education Committee desired to issue it as a Council publication; but the Council's representatives wisely distinguished between public water supply and a school-book descriptive thereof, holding that while the one should be in the hands of the Local Authority the other might safely be left to commercial enterprise. This decision accounts for the publication of the book in its present form.

The author makes no claim to originality. He has not discovered new sources of water supply or invented new methods of purification or distribution. He has simply attempted to present, in a form convenient for teachers and pupils, facts which are well known but not conveniently accessible, and he is unaware of any other school-book in which information of the same type is collected.

For most of the particulars respecting the recent Water Companies of London and the present Water Board, and its work, and for much of the early history of London's water supply the author is indebted to the Statistical Officer and other officers of the Metropolitan Water Board, especially the District Engineer and Mr H. W. Carmen of the Statistical Officer's Department. *The Springs, Streams and Spas of London* by Alfred Stanley Ford

has been freely consulted and some material has been taken from *Studies in Water Supply* by Sir Alex. Houston, the Water Examiner to the Board. The particulars of the artesian wells of London and the water gradients in the chalk were taken from the *Records of London Wells* by G. Barrow and L. J. Wills, published by the Geological Survey. The account of the making of the New River is partly taken from Smiles' *Lives of the Engineers*, while other matter has been derived from the article on "Water Supply" in the *Encyclopaedia Britannica* by the Engineer of the Liverpool Corporation and from other articles in the same encyclopaedia, and to the publishers of the encyclopaedia the author is indebted for some illustrations. The account of the ancient water supply of Jerusalem is taken from the work of Principal Sir George Adam Smith. The author's thanks are also due to the officers of the Manchester City Council for figures respecting the supply from Thirlmere and to Professor Hewlett, of King's College, London, for the illustrations of bacteria; to the Director of the Geological Survey of England and Wales, the Director of the Meteorological Office and the Controller of His Majesty's Stationery Office for permission to make extracts from State publications; and to Messrs Isler and Company for the use of blocks relating to deep well pumping.

The author also wishes to acknowledge his great indebtedness to the staff of the Cambridge University Press for their advice and suggestions and for the efficient manner in which they have dealt with his MS. and sketches.

The ornament on the title page is the old seal of the New River Company and indicates the ultimate source of all water supply. The legend is taken from the Vulgate of Amos iv. 7—ET PLUI SUPER UNAM CIVITATEM.

W. G.

December 29th, 1921

BIBLIOGRAPHY

The following are a few books among many which, in addition to those mentioned in the preface and text of this book, may well be consulted by teachers and others who desire further and more first-hand information on Water Supply.

The Several Memoirs of the Geological Survey on the Water Supply of the English Counties. (H. M. S. O.)

The Annual Reports of the Metropolitan Water Board. (P. S. King and Son.)

The Geology of Water Supply. H. B. Woodward. (Edward Arnold.)

The London Water Supply. R. Sisley. (The Scientific Press.)

The Water Supply of Towns. W. K. Burton. (Crosby, Lockwood and Son.)

Rainfall Reservoirs and Water Supply. Sir Alex. Binnie. (Constable.)

Conveyance and Distribution of Water for Water Supply. E. Wegmann. (Van Nostrand, New York, and Constable.)

Water Supply. W. P. Mason. (Chapman and Hall.)

The Examination of Water and Water Supplies. J. C. Thresh. (J. and A. Churchill.)

Well Boring. C. Isler. (Spon.)

History and Description of the Thirlmere Water Scheme. Sir J. J. Harwood. (Blacklock and Co., Manchester.)

The Thirtieth Annual Report of the Local Government Board—Supplement on Lead Poisoning and Water Supplies. (H. M. S. O.)

On the Structure of Moving Cyclones. J. Bjerknes. (Geofysiske Publikationer, Vol. I, No. 2. Grondahl and Sons, Kristiania.)

Meteorological Conditions for the Formation of Rain. J. Bjerknes and H. Solberg. (Geofysiske Publikationer, Vol. II, No. 3. Grondahl and Sons, Kristiania.)

CONTENTS

A LITTLE BOOK ON WATER SUPPLY

NATURE'S WATER SUPPLY

EVERYBODY knows that a good supply of sufficiently pure water is essential to life and that in towns water is required for a great many purposes besides drinking and washing. Apart from the water necessary for special manufacturing purposes something like 40 gallons a day have to be supplied for each person in large towns for domestic, trade and public purposes. This means that the amount of water which has to be supplied every year to the 117 square miles of the Administrative County of London is nearly seventy thousand million gallons. If a wall were built all round the square mile of the City of London to the height of St Paul's the tank so formed would not contain a year's supply of water for the Administrative County; and the Greater London which is supplied with water by the Metropolitan Water Board is very much larger than the Administrative County and covers an area of 559 square miles with a population of 6,930,000.

The great storehouse of water is the ocean, but sea water contains far too much common salt and other solids in solution to be fit for drinking, washing or use in boilers, and for the majority of people, including Londoners, the sea is a long way off. If you take a little sea water in a glass and leave it for a few days, the water will dry up and leave some white salt. The salt will taste like ordinary table salt but slightly bitter, because it contains some Epsom salts as well as common salt; but what has become of the water? It has passed into the air, leaving the salt behind. It has evaporated, or become vapour, but it is only pure water that has gone into the air. If we could get it back again it would be quite free from salt. The whole surface of the ocean is giving water to the air continually, just as the water escaped from the glass, but the amount of water which can remain as vapour in a cubic foot of air (or empty space) depends entirely on the temperature. The warmer the air the greater the amount of vapour, and if water is kept at the boiling-point it will blow away the air altogether and fill the whole space with steam. If air which contains as much vapour as it can is cooled the vapour condenses into tiny drops forming a cloud. If a jug containing very cold water is brought into a warm room full of people drops of water will presently be seen on the outside of the jug. This water has come out of the air. The vapour has been condensed on the cold jug. So when warm air from the surface of the sea is cooled by ascending to a great height, or by mixing with cold air, or by blowing against a cold mountain peak, the water vapour is condensed and a cloud or mist is formed. On a clear, warm day when a strong wind is blowing

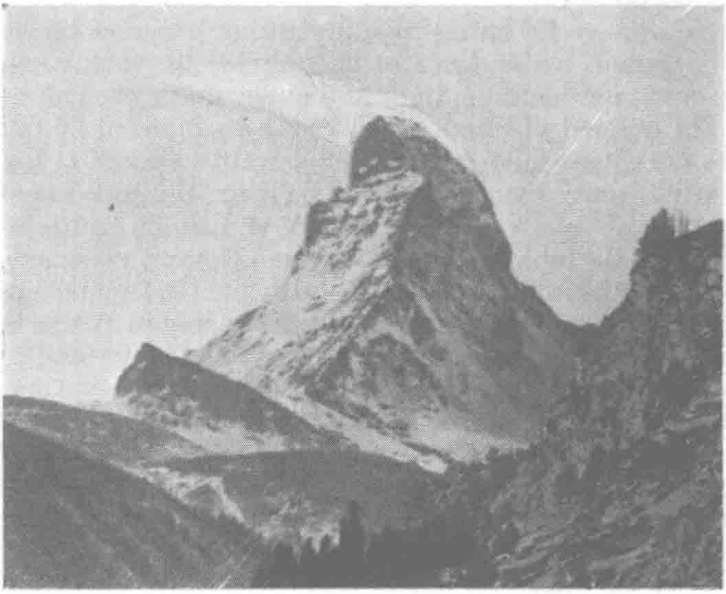


Fig. 1. Cervin (the Matterhorn) smoking his pipe.

from Italy against the very cold peak of the Matterhorn some of the moisture, carried with the wind is condensed, forming a beautiful white cloud in the sunshine. As the air passes away from the mountain and mingles with other air which has not been cooled against the snowy peak, while the sun shines on the cloud, it gets warm again and presently, perhaps half a mile away from the mountain, the cloud evaporates and the air becomes clear and the sky blue again. The result is that a cloud remains apparently stationary against the top of the mountain and extending for perhaps half a mile on the leeward side, never being blown away although the wind may be blowing very hard. Of course the cloud is really being carried with the wind, but fresh cloud is always being formed against the mountain and it evaporates as soon as it gets far enough away. The cloud is therefore always changing though it appears to be quite still. Fig. 1 shows the Matterhorn "smoking his pipe." The cloud is a good illustration of condensation and evaporation going on simultaneously in regions a little distance apart. The figure shows that it is formed on the Italian face of the mountain and blown over the rounded peak.

For those who have not studied evaporation and condensation in connection with lessons on heat the following are a few points worth noticing. For example, water will continue to evaporate until the space above it contains a certain amount of vapour which increases rapidly with the temperature and does not depend on the presence or absence of air in the space above the water, though the presence of air renders the evaporation much slower than it would be without the air. When the space contains all the vapour it can at the existing temperature it is said to be saturated. If the vapour in a saturated space is cooled it will condense into drops of water, forming cloud. If you wear spectacles and come into a warm room on a cold day from the open air your spectacles will become dim with dew. If two lots of air, one warmer than the other but both full of vapour, are mixed, the warm air is cooled and the cool air is warmed, but the whole space at the middle temperature cannot hold as much vapour as the two spaces, one hot and the other cold, because as the temperature increases the amount of vapour which any space can hold increases faster and faster. Consequently, if a cold wind and a warm wind, both full of vapour, mix, some of the vapour will be condensed and a cloud will be formed. As we ascend in the atmosphere in a balloon or by going up a hill or mountain the pressure gets less and less. If we carry with us a large bottle of air with a tube passing through the cork closed by a stop-tap and we open the tap when we have gone up a thousand feet or so some of the air will escape, because under the smaller pressure the air expands. As it expands it will get cooler because it does work in lifting the air outside the bottle. If the air is quite full of vapour the cooling will make some of the vapour condense and form a cloud in the bottle. The cooling of warm air as it ascends and expands in the atmospheric circulation is the principal cause of the formation of cloud.

When the little drops of water forming a cloud come together to make larger drops, rain is produced. As a raindrop falls through the cloud it keeps on picking up more and more little drops so that it becomes bigger and bigger as it falls. If the cloud is so cold that the water it contains is frozen snow is formed instead of rain. When the rain falls on the ground some of it generally finds its way into streams and rivers and in course of time again reaches the sea carrying with it some parts of the soil which it has dissolved. This completes the circuit. The sea water evaporates into the air, the air carries it away with the winds perhaps into higher latitudes where the climate is much colder or perhaps on to a cold mountain-side, or perhaps it is carried high up into the atmosphere with a rising current, or possibly it meets with a wind from a cold region; in all these cases some of the vapour is condensed into cloud and may fall as rain or snow and then it may return to the sea by streams and rivers. If the cloud falls as snow on high mountains it may help to make a glacier, or river of ice, and then it may be hundreds of years before it reaches the sea, with the very slow descent of the glacier into regions where the ice will melt; or it may fall on some ice-covered country like Greenland and slide slowly with a sheet of ice down to the sea and then break off into icebergs.

But not all the rain falling on the land makes its way directly to the sea. Very much depends on the kind of soil on which it falls and on the vegetation. Some of the rain will soak a little way into the ground or lie on the surface and evaporate again in course of time, just as it would evaporate from the sea, and so form cloud and rain again. Some will be sucked up by plants and trees and evaporate into the air from their leaves. Some will soak through the porous soil until it reaches clay or hard rock which is waterproof and it will then flow over the surface of the waterproof rock until it reaches some valley where it appears as a spring if it has originally fallen on high land, and then finds its way into a stream or river and so to the sea. Sometimes a porous rock like the Upper and Middle Chalk, the Greensand or the New Red Sandstone, will extend to a thickness of some hundreds of feet under the surface. The rain water will soak into this porous rock and flow out into some distant valley where the lower part is exposed, but if the porous soil extends below sea-level the water will remain in the soil until it is filled up to sea-level, and this water cannot escape unless the water in the rock is raised from wells by pumps or otherwise. We shall have a good deal to say presently about the great reservoir of water in the chalk extending to a depth of 500 or 600 feet or more under London.

Where, as in most of the Welsh mountains, there is only a thin layer of peaty soil lying on waterproof rock, like the slate of the Silurian formation, the rain which does not evaporate and is not absorbed by vegetation soon finds its way down the hillside close to the surface and flows into the rivers and lakes, perhaps a little stained with peat or containing a little acid from the fermentation of the peat, but otherwise almost pure, with hardly any lime or other mineral in solution. In the Thames valley the soil is, as a rule, much more porous than on the Welsh hills. This is true of the oolitic rocks in the upper valley of the Thames as well as of the chalk of the Chilterns and lower Thames valley. While some of the rain, especially after a heavy fall, finds its way to the river in streams along the surface, a good deal of the rain soaks into the soil and reaches the river, after flowing for a long way underground, rising in springs in the river-bed. This water will dissolve some portion of the soil through which it flows and reach the river with common salt and carbonate of lime (chalk) and other mineral substances in solution.

Sometimes a few feet of sandy clay, or brick earth, or clay interspersed with thin seams of sand lie just below the surface but rest on a hard waterproof clay like the London Clay or the boulder clay of the north of England. Rain water can soak into the sandy clay or seams of sand and flow slowly through them but it cannot penetrate the clay below. If a well is dug through the porous soil and a little way into the hard clay water will slowly flow into the well and fill up the watertight hole in the stiff clay. This is an example of a shallow well. Some of the rain falling on the Bagshot sands on Hampstead Heath used to find its way through seams of sand above the London Clay to a well in Well Walk. This was the origin of the Hampstead Pump Room. The water dissolved some iron from the sands in its course. Here and there on the lower parts of the Heath water may still be seen flowing from the sand seams in the drift clay having found its way through them from the Bagshot sands at the top. Water from shallow wells in a thickly populated neighbourhood is not safe for drinking, and most of the water which used to supply the Hampstead well now flows into the sewers through pipes constructed to drain the foundations of the houses.

When the whole soil of a district is porous for a considerable depth, say a few hundred feet, the rain water soaks in and saturates the porous soil up to a certain depth depending on the levels at which it can find its escape into some neighbouring valley, on the distance of the valley and the resistance offered by the rock to the flow of water. It is only with great difficulty that water can flow through sand or chalk, and consequently a mile or two away from the valley the water will stand at a level much above the outflow. If a well is sunk into this porous soil below the level at which the water stands water will collect in the well up to that level and can be drawn out by a bucket or pump. In this case the water is held in the well not because it is sunk into a waterproof stratum but because it is sunk below the level at which the water stands in the porous soil, through which it is constantly flowing. Examples of water levels (contours) in the chalk in the London area are given in the map, p. 64, and described on pp. 64 and 65.

RAIN, WELL, AND RIVER WATERS

If rain water be collected in a watch-glass in the country and allowed to evaporate it will dry up leaving scarcely any stain behind it. Pure rain water contains no solids in solution. Water flowing off the surface of slate hills will perhaps leave a little brown residue of peaty matter which will be nearly all destroyed if heated in air to redness. Water taken from a shallow well made in gravel or sandy clay will probably leave a little oxide of iron with some vegetable matter. If the water comes from a shallow well in chalk soil it will leave behind it a quantity of chalk but not nearly so much as the common salt left by the evaporation of the same quantity of sea water. If water from a chalk well is boiled it will become slightly milky and deposit a white sediment of chalk. This forms "fur" in kettles and incrusts steam boilers so that it sometimes has to be removed with a hammer and chisel. The reason why the chalk is thrown out of solution by boiling is that pure water can dissolve very little chalk. It is only when there is free carbonic acid in the water that the chalk is soluble. Soda water would dissolve a